Title

Sausal Creek Restoration at Dimond Park: Vegetation and Geomorphology Post-Project Appraisal

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Final Draft: Sausal Creek Restoration at Dimond Park: Vegetation and Geomorphology Post-Project Appraisal

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Abstract

We conducted a post-project appraisal in November 2022 to evaluate the restoration's performance using the goals outlined in the *Sausal Creek Restoration at Dimond Park Monitoring Plan* (Restoration Design Group, Inc. (RDG) 2017): restore native riparian habitat and improve channel stability. We performed vegetation surveys along the three transects (T1, T2, T3) initially defined by RDG and conducted a geomorphic survey along T3. We determined that the restoration project performed well in establishing native riparian habitat as we measured overall >90% canopy cover, which surpasses the percent cover criteria of 75% after five years of project implementation. Furthermore, we observed relatively high shrub survival rates of 138% at T1 and 173% at T2 and a limited shrub survival rate of 35% at T3. Despite meeting overall percent cover and survival rate criteria, we observed a decrease in native flora diversity, potentially due to excessive overstory shading from willows and invasive species outcompeting native plant species. Therefore, we recommend strategic thinning of willows, continued removal of invasive species, and additional replanting of native species. We compared the November 2022 channel geometry to previous years (pre-project, design, 2017, 2019, and 2021) and determined that the channel banks are stable (i.e., have experienced less than one foot of erosion). We also modeled the new channel geometry's ability to convey a 10-year and 50-year storm event. Our model (HEC-RAS and the National Weather Service Normal Depth Calculator) results indicated that the channel would contain a 10-year event but not a 50-year event.

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1. Introduction

1.1. Background

Urban streams, typically occupying low-lying points of watersheds, are highly susceptible to impacts from urbanized catchments and the combined effects of climate change and anthropogenic behaviors (Bernhardt & Palmer 2007). Urban streams commonly suffer from "urban stream syndrome," or the consistent hydrological degradation observed in urban streams characterized by flashier hydrograph, increased nutrient and pollutant concentrations, altered channel stability, and reduced biotic richness (Walsh et al. 2005).

1.1.1. Site History

Sausal Creek is one of the main creeks in Oakland, California, spanning 3.1 miles long and draining a 4.15 square-mile basin (Friends of Sausal Creek 2022). Since the beginning of the last century, anthropogenic behaviors have altered channel morphology within the Sausal Creek Watershed, and the expansion of urbanization has caused increased flood flows and bank erosion (Owens-Viani 1998). Although the Works Progress Administration (WPA) placed temporary controls on bank erosion during the 1930s, the lack of further maintenance finally led to bank failures (Owens-Viani 1998). In 1995, when the creek overtopped its banks during a heavy storm, the public realized the state of the watershed's degradation. The government started to develop a flood-prevention strategy, which finally catalyzed the restoration in the upper reach of Sausal Creek in Dimond Canyon upstream of El Centro Avenue (Grantham & Tollefson 2006).

In 2001, the City of Oakland, California Coastal Conservancy, and Alameda County Flood Control District funded and implemented a project designed by Waterways Restoration Institute (WRI) and Wolfe Maison and Associates (WMA). Map 1 shows the general area of

Sausal Creek and outlines the Dimond Canyon project reach in red. Objectives of this early project included channel profile restoration, flood prevention, sediment transport re-establishment, channel bank stabilization, native riparian plant species restoration, and general aquatic habitat improvement (WRI & WMA 2000). Specifically, this project aimed to remove the failed structures installed in the 1930s. UC Berkeley students performed lateral post-project appraisals for the restoration efforts in the upstream reach in Dimond Canyon sequentially in 2003 and 2005.

In December 2005, a large storm event with peak discharges in the 10- to 25-year recurrence interval range caused flood damages and significant bank loss in Dimond Park (downstream of the Dimond Canyon restoration project and Wellington Street). To address bank stability issues within the Dimond Park reach, the City of Oakland submitted a grant application in 2007, initiating the Sausal Creek Restoration Project at Dimond Park ("Project") (City of Oakland 2007). Map 1 distinguishes the Dimond Canyon restoration project (upstream of El Centro Avenue) and the Project (downstream of Wellington Street). Map 2 outlines the Project reach for Dimond Park. Additionally, RDG (2012) developed a Hydrologic Engineering Center's River Analysis System (HEC-RAS) model to evaluate the proposed project's ability to "contain the Alameda County Flood Control District's estimated 25-year recurrence interval storm event, and provide stability during storms up to the 10- to 25-year recurrence interval storm events." However, RDG chose to evaluate the project's ability to contain the Alameda County Flood Control District's estimated 50-year storm event instead to be conservative (RDG 2010).

1.1.2. Most Recent Restoration Efforts

The City of Oakland Watershed Improvement Program completed the Project in 2016. The stated purpose of the restoration project from the *Sausal Creek Restoration at Dimond Park*

Monitoring Plan ("Monitoring Plan") was to "expand the creek corridor to improve channel stability, increase riparian habitat, and enhance conditions for extant landlocked rainbow trout" (RDG 2017). To achieve these goals, the City of Oakland removed approximately 180 linear feet (ft) of the existing culvert, daylighting the creek, and restored about 600 linear ft of channel downstream of the daylighted portion. To restore bank loss and damages resulting from incision, the City of Oakland conducted grading to increase the width-to-depth ratio, which promotes vegetation growth on the banks to help stabilize them. The City of Oakland also placed root wads and large woody debris into the left bank to provide fish habitat, installed riprap along the toe of the right bank for stabilization, and reconstructed the channel bed to establish pool and riffle sequences.

1.1.3. Monitoring Efforts

RDG has conducted vegetation and geomorphic monitoring for the Project from 2017-2021 in accordance with the Monitoring Plan (RDG 2017). The Monitoring Plan required RDG to quantify tree and shrub survival, and vegetation cover to evaluate the Project's execution in meeting performance measures as required by the Project's California Department of Fish and Wildlife Streambed Alteration Agreement. The Monitoring Plan also required RDG to perform a geomorphic survey every other year to quantify aggradation and incision of the channel bed, and erosion of the banks through a thalweg survey (profile) and three cross sections. Map 2 outlines the locations of the three cross sections.

1.2. Problem Statement

In this paper, we aim to determine the changes in Sausal Creek in Dimond Park since its restoration in 2016 based on vegetation and channel morphology. With these goals, we evaluated the creek's ability to maintain healthy, native vegetation and whether the Project has improved the flood conveyance and short-term bank stability in the channel.

2. Methods

2.1. Document Collection

Rich Walkling, the CFO and restoration planner at RDG, shared five core documents that informed our survey methods. These documents include the *Sausal Creek Restoration Project at Dimond Canyon: California River Parkways Grant Application* (City of Oakland 2007), *Final Review Hydraulic Memorandum* (RDG 2012), *Plans for the Sausal Creek Restoration Project in Dimond Park* (City of Oakland 2017), *2017 Cross Sections* (Walkling 2022), and the *Sausal Creek Restoration at Dimond Park Year Five (2021) Monitoring Results* (RDG 2021).

2.2. Survey Methods

2.2.1. Vegetation

We surveyed vegetation cross-sections using the line-transect method mentioned in the *Sausal Creek Restoration at Dimond Park Year Five (2021) Monitoring Report* and compared our results to baseline results in the report (RDG 2021). We located existing vegetation transects using site maps and photos from the *2017 Cross Sections* (Walkling 2017). Then, we used nylon tape to connect the previously marked starts on the left bank to the rebar markers on the right bank. Finally, we measured about 10 ft on each side of the tape (in total, 20 ft wide) to outline our survey area. Within the three transects, we identified plants using the "Picture This" mobile phone application.

We tallied the native shrub species and determined the shrub survival rate by dividing the 2022 total shrub count by the 2017 total shrub count (RDG 2021).

2.2.2. Geomorphology

We surveyed the geometry of one cross section–station 1+40 on construction Plans (City of Oakland 2015) and T3 on the Monitoring Report (RDG 2021)–using a level, tripod, rod, and tape measure. We chose this cross section because it was one of the transects that RDG has monitored over time and was where RDG determined there would be flooding along the Project's reach (RDG 2012). We started surveying along the transect at a location 7 ft to the right (looking downstream) of where the pre-project survey began. We then compared the cross section data to the pre-project, design, 2017, 2019, and 2021 T3 cross section to identify significant changes in creek geomorphology.

We performed a pebble count using a gravelometer according to the Wolman method (Wolman 1954) to determine the creek bed's grain size distribution. Then, we estimated a manning's roughness coefficient of 0.088 from Chow (1959) based on the observed vegetation type and density (Photos 7 & 8), and the median grain size from our pebble count results. The coefficient was between the normal and maximum value for "Channels not maintained, weeds and brush uncut" that have "clean bottom, brush on sides, during highest flow stage" within the "excavated channel" section (Chow 1959). We input the cross section horizontal distance and elevation measurements into HEC-RAS to create a geometry file for the cross section, which we uploaded into the National Weather Service Normal Depth Calculator; this calculator solves for normal depth using Manning's equation for open channel flow.

We used the National Weather Service Normal Depth Calculator to determine the water surface elevation for a 10-year storm (789.7 cubic feet per second (cfs)) and a 50-year storm (2037 cfs) at T3. We used the same flow rates from RDG's 2012 hydraulic analysis to ensure our model results would only reflect changes in channel conditions (geometry and roughness). We also used the same channel slope of 0.019 ft/ft from RDG's 2012 hydraulic analysis since we did not measure the channel slope.

We performed a sensitivity analysis for the 50-year storm to see how the roughness coefficient (n) affected the calculated water surface elevation. We compared our flood analysis results for n = 0.088 to the results RDG modeled for pre-project and design conditions (RDG 2012).

2.3. Performance Measures

Through visual observations and surveying the cross sections and vegetation, we evaluated the creek's performance in meeting the bank stability and riparian habitat health targets outlined in the "Output and Indicators Table" from the Monitoring Plan. The target for bank stability was no excessive erosion or deposition, which RDG defined as incision or aggradation exceeding 1 ft. The targets for riparian habitat health were 80% survival at the end of five years, 70% cover after three years, and 75% coverage after five years (RDG 2017).

3. Results

3.1. Vegetation Survey

Table 1 shows vegetation results in shrub survival as a count of native species and total percent survival from 2017 (Year 1) post-project completion. Table 1 also includes 2017-2021 total shrub survival data from a previous monitoring report (RDG 2021) to provide comparison baselines. Table 2 shows estimations of canopy cover measured within the three transects.

In T1, we identified 22 native shrub species resulting in a 138% survival rate compared to the Year 1 total count of 16 native shrub species. In T2, we identified 19 native shrubs resulting in a 173% survival rate compared to the Year 1 total count of 11 native shrub species. In T3, we identified seven native shrubs resulting in a 35% survival rate compared to the Year 1 total count of 20 native shrubs.

Vegetation (canopy) cover was >95% for T1, >95% for T2, and 90% for T3. The canopy cover consists mostly of willows and white alders, which dominate the streamside zone and overstory of the creek. Vegetation cover within the three transects is consistent throughout the entire reach by visual inspection.

T1 has limited invasive/non-native species. In T2, the right bank is overgrown with English ivy (90% cover of the understory). In T3, English ivy has started to grow on the left bank (<5 % cover of understory). Although not quantified, we also identified the presence of the non-native species: Himalayan blackberry (*Rubus armeniacus*), glossy privet (*Ligustrum lucidum*), Chinese boxthorn (*Lycium chinense*), common cotoneaster (*Cotoneaster integerrimus*), English Ivy (*Hedera helix*), Silver Wattle (*Acacia dealbata*), White Leadtree (*Leucaena leucocephala*), wild strawberry (*Fragaria vesca*), and Chinese firethorne (*Pyracantha fortuneana*).

3.2. Geomorphology

3.2.1. Cross Section

The left and right banks at T3 have little to no change in elevation from the design, 2017, and 2019 surveys, with a maximum change of about -0.25 ft. However, the main channel bed elevation decreased by about 1 ft since 2017, and predominantly impacted the left toe. The 2021 cross section indicated about 2 ft of erosion on the left bank, which we did not observe in our 2022 survey (Figure 1).

3.2.2. Main Channel Grain Size Distribution

The channel bed's median grain size (d_{50}) was 16 millimeters (Figure 2), which indicates that the channel contains mostly medium to coarse gravel (Wolman 1954). We also observed cobbles in the channel (Photos 7 & 8).

3.2.3. Flood Conveyance

Our National Weather Service Normal Depth Calculator results for our input cross section, flow rates, and roughness coefficient indicate that the restored channel has a lower velocity (5.57 feet per second (fps)) than the designed channel (6.8 fps), resulting in a water depth increase of 1.28 ft for the 10-year storm event (Table 3).

Our calculated results also indicate that the restored channel has a higher velocity (7.24 fps) than the designed channel (6.84 fps) but a lower velocity than the pre-restoration channel (9.07 fps), and a lower maximum water depth (10.57 ft) than the pre-restoration channel (11.97 ft) for the 50-year storm event (Table 3).

At T3, the changes in channel geometry since construction did not result in flooding over the left or right banks during the 10-year storm event (Figure 3) but did result in overtopping over the right bank during the 50-year event (Figure 4). Based on our sensitivity analysis for the 50-year event (Figure 5), overtopping over the right bank occurs when $n > 0.078$. Beyond the right bank, adjacent to the survey area, we observed a metal fence (the survey ended at a rebar monument against the fence) and beyond the fence is a level townhouse backyard.

4. Discussion

4.1. Vegetation

4.1.1. Shrub Survival

The creek exceeds the performance criteria of 80% survival concerning native shrub species within the Project area. Year 1 monitoring by RDG established a baseline for planted shrubs within the vegetation transects (see Table B4 for extracted Shrub Survival by Species table from the Monitoring Report (RDG 2021)). Ninebark is the most common shrub, accounting for 55% (12/22), 63% (12/19), and 57% (4/7) of total native shrub count in T1, T2, and T3, respectively.

Notably, in our November 2022 survey, overall shrub survival rates are lower in T3 compared to T1 and T2. We hypothesize that more foot traffic and shading from redwood trees caused lower shrub survival rates in T3. We must conduct more thorough research to determine conclusive reasons for this difference.

In the *Sausal Creek Restoration at Dimond Park Year Five (2021) Monitoring Results* (RDG 2021), RDG identified ninebark and coyote brush populations thriving. We observed that ninebark overall continues to thrive and has averaged 302% survival compared to 2021 (Year 5). Other species are not as compatible with the conditions. There has been a decline in snowberry and pink-flowered currant, averaging 8% and 83% survival compared to Year 5. Overall, the creek exceeds total shrub survival rate criteria; however, in terms of native flora diversity, ninebark dominates.

4.1.2. Canopy Cover

Vegetation (canopy) cover exceeds the required performance criteria of 75% cover after five years (RDG 2017) at T1, T2, and T3. Willows largely contributed to the vegetation (canopy) cover (Photos 11-16).

We found willows thriving in the creek (not quantified). The vigorous growth of willows shaded areas from sunlight, potentially creating observable adverse effects on the survival of shrubs nearby (Photo 1). The impacts of canopy shade on understory plants are complicated and depend upon the shading tolerance of different species (Valladares et al. 2016).

4.1.3. Invasive and Non-Native Species

T1 has limited invasive and non-native species. In T2, the right bank is overgrown with invasive English ivy (~90% understory cover). In T3, English ivy has started to grow on the left bank (<5% understory cover). English ivy tolerates shaded conditions, thriving beneath the willows at the T2 right bank, and outcompetes native plants (Photo 2). Invasive species within the area favor likely shaded conditions more than planted native species, resulting in decreased native flora diversity. We propose continual maintenance of invasive species to reduce competition between native and invasive species, promoting the health and establishment of native species.

4.2. Geomorphology

4.2.1. Cross Section

The left bank (predominantly made up of fine soils) has not eroded between 2016 and 2022. This could be a result of the increased vegetation stabilizing the slopes (Table 1, Photo 16), decreased estimated flow velocity (Table 3), the design's increase in width-to-depth ratio (City of Oakland 2015), and lack of large storm events. The 2021 survey indicated erosion on the left bank that grew to a maximum of 2 ft near the left toe. The 2021 survey did not measure past the right toe due to an obstructed line of sight (R. Walkling, Restoration Design Group, personal communication, November 2022). The 2022 result's consistency with the 2016, 2017, and 2019 cross sections indicate that the 2021 survey may have had measurement errors; for example, they took measurements at a slightly offset transect location. Although RDG measured the cross section in December 2021, which was after a large storm in October 2021, the National Weather Service Normal Depth Calculator results show a low flow velocity for a peak flow up to 2307 cfs; therefore, it is unlikely that the flow eroded 2 ft off of the bank, which was then perfectly restored within a year.

While previous monitoring did not measure the creek's right bank, the rebar monument from the original cross-section was clear, so we included the right bank in our measurements. The right bank did not significantly change from the pre-project conditions, which indicates that the right bank is stable or flows may not have caused a high water level since 2016. The right bank primarily consisted of willows, leafy debris, fine sediment, and boulders (Photo 15). Overall, both banks have not eroded since the Project's completion in 2016, so the Project performed well in enhancing slope stability.

The channel bed changed the most over time. The bed incised about 1 ft since 2017 and predominantly impacted the left toe. Decreased sediment supply and increased runoff could have caused this incision. Sediment supply most likely decreased due to increased bank stability and vegetation growth. Runoff most likely increased due to development within the watershed, which increases impervious surfaces (decreases infiltration). T3 also occurs at the tail end of a riffle, and scouring behind boulders in the bed could have contributed to the elevation decreasing at the transect.

4.2.2. Flood Conveyance

Since construction, the increase in vegetation growth and density increased channel roughness, which slowed the channel velocity. According to our estimated results, changes in channel geometry allow the cross section to convey the Q_{10} with a slightly lower water surface elevation (~0.2 ft) than in 2017 but at a larger maximum depth of 6.47 ft compared to 5.19 ft (Table 3), possibly due to the 1-ft incision in the channel bed. According to our estimated results, changes in channel geometry and the increase in channel roughness could cause water levels to overtop the right bank during the Q_{50}.

The differences between our results and RDGs are mainly due to the differences in Manning’s n (the roughness coefficient) caused by the increased vegetation since the Project’s design. In Manning's Equation, which HEC-RAS and the National Weather Service Normal Depth Calculator use, velocity is inversely related to Manning’s n—as the coefficient increases, the flow velocity decreases. RDG used n = 0.068 in their HEC-RAS model for T3, which caused overtopping with the proposed channel geometry during the 50-year event. Although we chose an n = 0.088 for the restored channel, values of n > 0.078 would cause overtopping in the restored channel (Figure 5). The flow reduction in our results would increase if we lowered n towards 0.068. To best approximate n, we recommend future monitoring efforts measure the flow velocity field and water depth at T3 during a storm event to solve for n.

For the Q_{50}, RDG concluded that although the flow overtopped the right bank, it was most likely contained just outside of the survey limit (RDG 2012). We recommend that future monitoring efforts also further investigate flooding in this area since we did not analyze how or if the overtopped flow would be contained or redirected away from the adjacent properties beyond our survey limits. This investigation could include interviewing the adjacent property owner and visually inspecting cross sections immediately downstream of T3 to see if there are low points that will redirect the overtopped flow.

5. Conclusion

We found that the restoration project met the required performance criteria of 70% cover after three years and 75% cover after five years. The vegetation transects exceed 75% canopy cover and are representative of the entire reach by visual confirmation. The restoration project performed well in establishing native riparian habitat; however, excessive shading caused by willows and redwood trees and competition from invasive English ivy correlated with decreased native flora diversity (as seen with ninebark being the dominant species). To ensure the reach's continued performance, we suggest strategic thinning of willows, removing invasive species, and increasing the planting of native species.

The restoration project also performed well in maintaining and enhancing slope stability. The cross section at T3 showed almost no erosion on the left and right banks since the Project's construction. The increased vegetation on the slopes has helped with bank stability and decreased channel flow velocity during 10- and 50-year storm events compared to pre-project conditions by increasing channel roughness.

Overall, our analysis concludes that the project meets the goals for increased riparian vegetation and improved channel stability with insignificant changes in flooding conditions since the Project's design, despite the increase in channel roughness.

References

Bernhardt, E. S., & Palmer, M. A. (2007). Restoring streams in an urbanizing world. *Freshwater biology*, *52*(4), 738-751.

Chow, V. T. (1959). Open-channel hydraulics. Caldwell. In: New Jersey, USA: The Blackburn Press.

City of Oakland, & Watershed Improvement Program. (2007). Sausal Creek Restoration Project at Dimond Canyon: California River Parkways Grant Application.

City of Oakland, & Department of Engineering and Construction. (2015). Plans for the Sausal Creek Restoration Project in Dimond Park. City Project NO. C395912.

Friends of Sausal Creek. (2022). About the Watershed. https://www.sausalcreek.org/about-the-watershed

Grantham, T., & Tollefson, K. (2006). Monitoring channel change at the Sausal Creek Restoration Project, Oakland, California.

Owens-Viani, L. (1998). *The Sausal Creek Watershed: a cultural and natural history*. Aquatic Outreach Institute.

Restoration Design Group, Inc. (RDG). (2012). Sausal Creek Restoration Project in Dimond Park Final Review Hydraulic Memorandum.

RDG. (2021). Sausal Creek Restoration at Dimond Park Year Five (2021) Monitoring Results.

USGS Western Ecological Research Center SFBE. (2012). Vegetation Transects and Survey Plot Standard Operating Procedures. https://www.researchgate.net/profile/Maria-Kozlova-2/post/Transects-for-a-vegetation-survey/attachment/59d630ad79197b807798e87d/AS%3A362700891803648%401463486039235/download/USGS-WERC-Vegetation-Transects-and-Survey-Plot-SOP.pdf

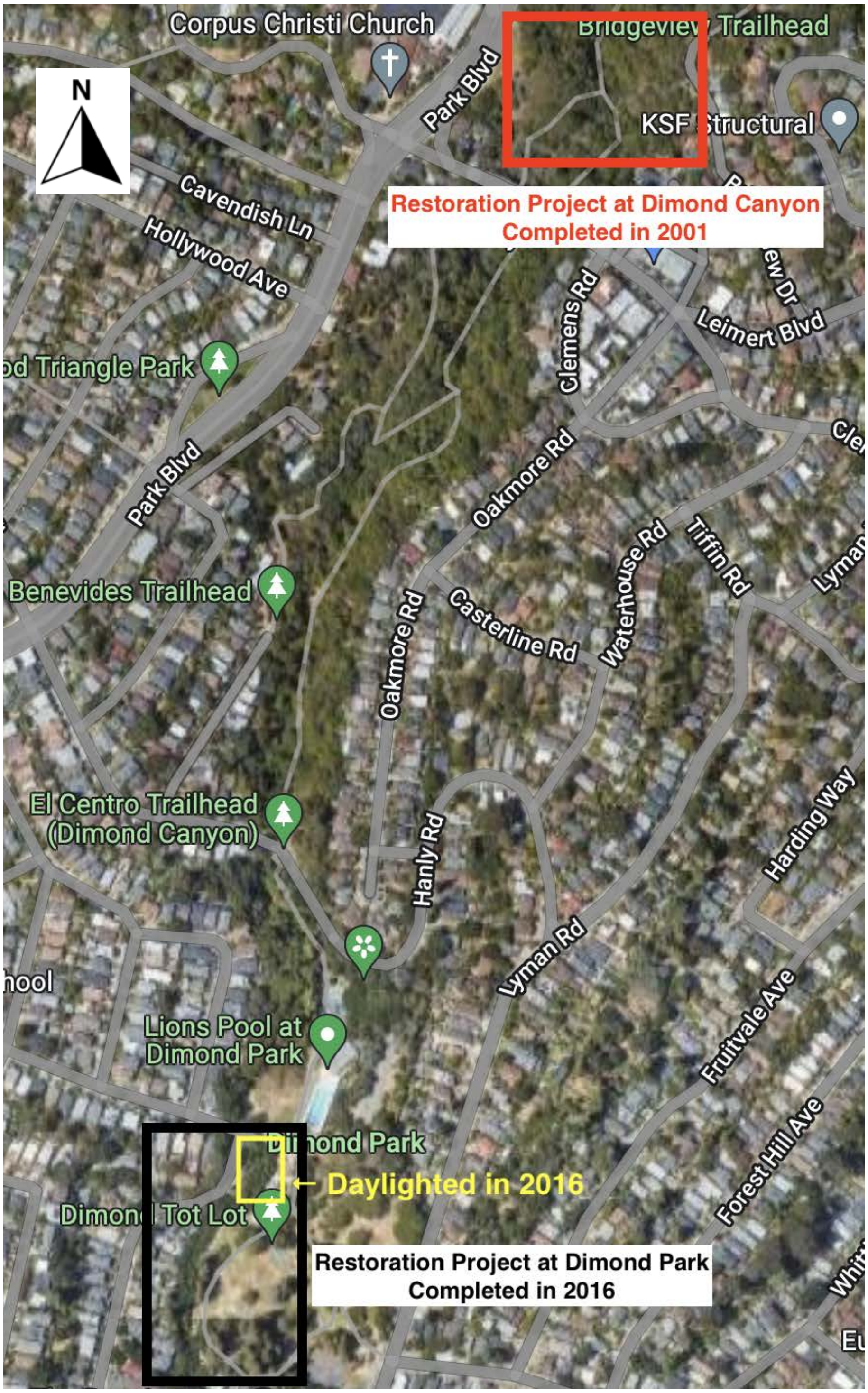
Valladares, F., Laanisto, L., Niinemets, Ü., & Zavala, M. A. (2016). Shedding light on shade: ecological perspectives of understorey plant life. *Plant Ecology & Diversity*, *9*(3), 237-251.

Walsh, C. J., Roy, A. H., Feminella, J. W., Cottingham, P. D., Groffman, P. M., & Morgan, R. P. (2005). The urban stream syndrome: current knowledge and the search for a cure. *Journal of the North American Benthological Society*, *24*(3), 706-723.

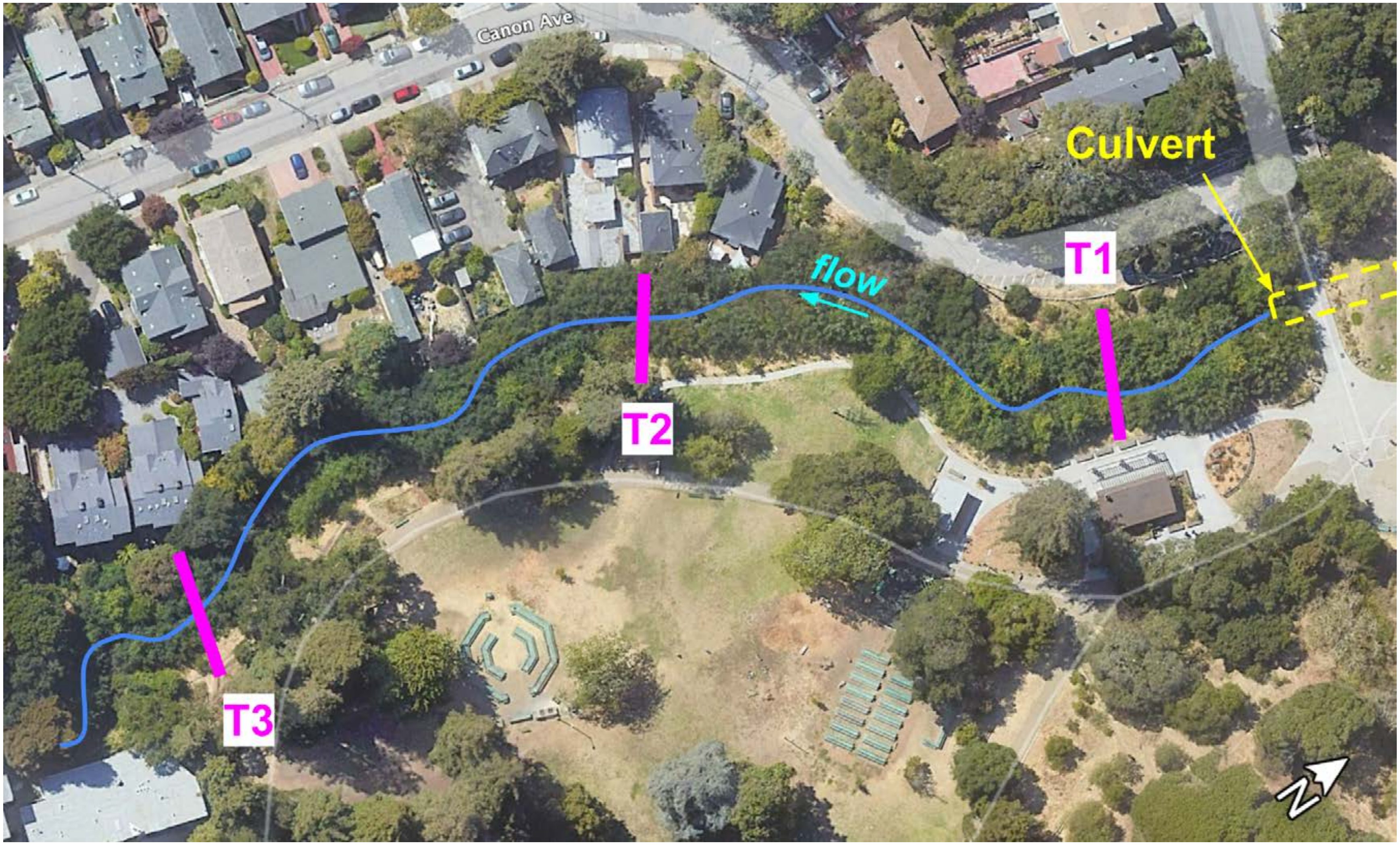
Waterway Restoration Institute, & Wolfe Mainson Associates, Inc. (2000). Sausal Creek Restoration in Dimond Park.

Wolman, M. G. (1954). A method of sampling coarse river‐bed material. *EOS, Transactions American Geophysical Union*, *35*(6), 951-956.

Maps



Map 1. Map depicting the overall Sausal Creek Area. The red box indicates the location of the 2001 restoration project completed in Dimond Canyon. The black box outlines the general area of the 2016 restoration project in Dimond Park.



Map 2. Site map depicting the 2016 restoration project reach at Dimond Park (Refer to the black square in **Map 1**). The magenta lines indicate the transects (T1, T2, T3) initially defined by RDG and used for our vegetation and cross-section surveys. The yellow dashed box outlines an existing culvert that feeds the project reach.

Tables

Table 1. Shrub count by species and overall survival within sample transects from Year 1 (2022 condition). 2017-2022 Total Counts extracted from the Year 5 Monitoring Plan (RDG, 2021).

Species	Transect 1	Transect 2	Transect 3
California Sagebrush *Artemisia californica*	0	0	0
Coyote Brush *Baccharis pilularis*	3	1	3
Jim Brush *Ceanothus oliganthus var. sorediatus*	1	0	0
California Hazelnut *Corylus cornuta var. californica*	0	0	0
Coast Silk-Tassel *Garrya elliptica*	0	0	0
Ocean Spray *Holodiscus dicolor*	0	1	0
Twinberry Honeysuckle *Lonicera involucrata*	0	0	0
Sticky Monkey-Flower *Mimulus aurantiacus*	1	0	0
Ninebark *Physocarpus capitatus*	12	12	4
Coffeeberry *Rhamnus californica ssp. californica*	3	0	0
California Gooseberry *Ribes californicum var. Californicum*	0	2	0
Pink-Flowered Currant *Ribes sanguineum var. glutinosum*	0	2	1
California Rose *Rosa californica*	0	0	0
Blue Elderberry *Sambucus mexicana*	0	2	0
Snowberry *Symphoricarpos albus var. laevigatus*	0	0	1
California Blackberry *Rubus ursinus*	1	0	0
Red Osier Dogwood *Cornus sericea*	5	0	1
2017 Year 1 Total Count	16	11	20
2018 Year 2 Total Count	20	9	8
2019 Year 3 Total Count	18	9	9
2020 Year 4 Total Count	25	11	14
2021 Year 5 Total Count	22	12	16
2022 Year 6 Total Count	**22**	**19**	**7**
% Survival from Year 1	138%	173%	35%

Table 2. Percent canopy cover in vegetation transects.

Transect 1	Transect 2	Transect 3
>95%	>95%	90%

Table 3. Flood analysis on T3 for 10- and 50-year peak flow (gray cells indicate input values).

	Q_{10}		Q_{50}		
Parameter	**Design (2016)**	**2022**	**Pre-Project**	**Design (2016)**	**2022**
Flow Rate (cfs)	789.7	789.7	2307	2307	2307
Channel Slope (ft/ft)	0.019	0.019	0.019	0.019	0.019
Manning's n	0.068	0.088	0.068	0.068	0.088
Water Surface Elevation (ft)	183.19	183.4	188.21	188.5	187.5
Average Velocity (ft/s)	6.8	5.57	9.07	6.84	7.24
Flow Area (ft^2)	116.21	141.7	254.46	337.09	318.8
Froude No.	0.64	0.49	0.65	0.50	0.52
Maximum Water Depth (ft)	5.19	6.47	11.97	10.5	10.57

Figures

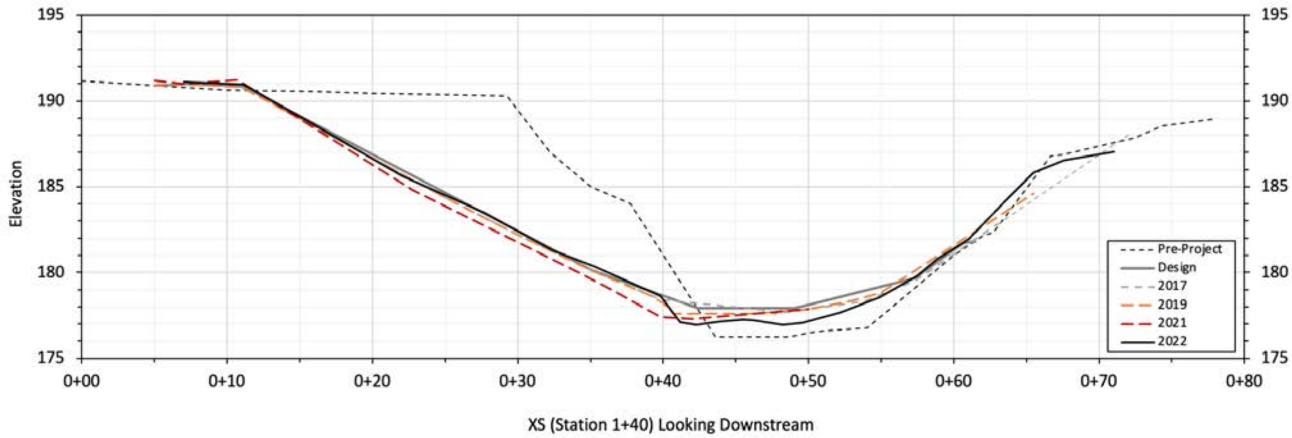


Figure 1. T3 cross-section looking downstream over time

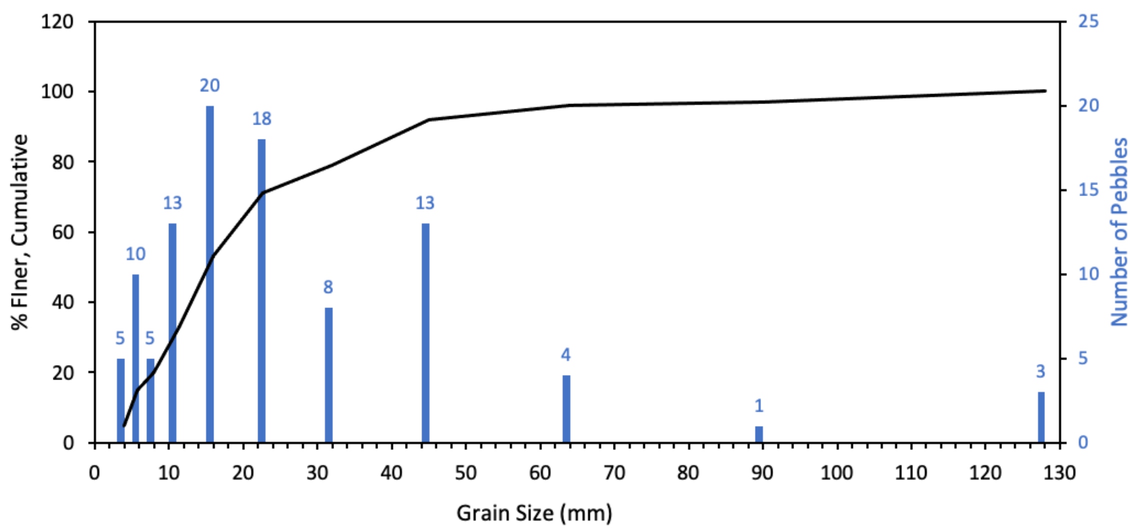


Figure 2. Pebble count grain size distribution and cumulative distribution at T3

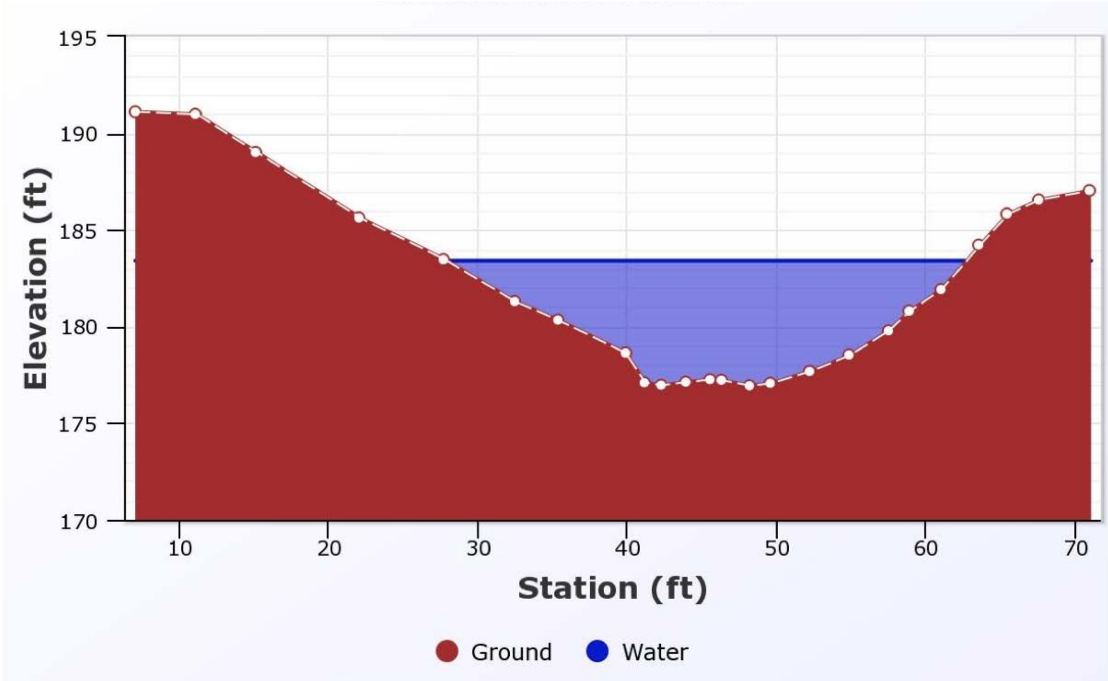


Figure 3. Water surface elevation for peak flow during a 10-year flood at T3 under surveyed conditions completed in November 2022

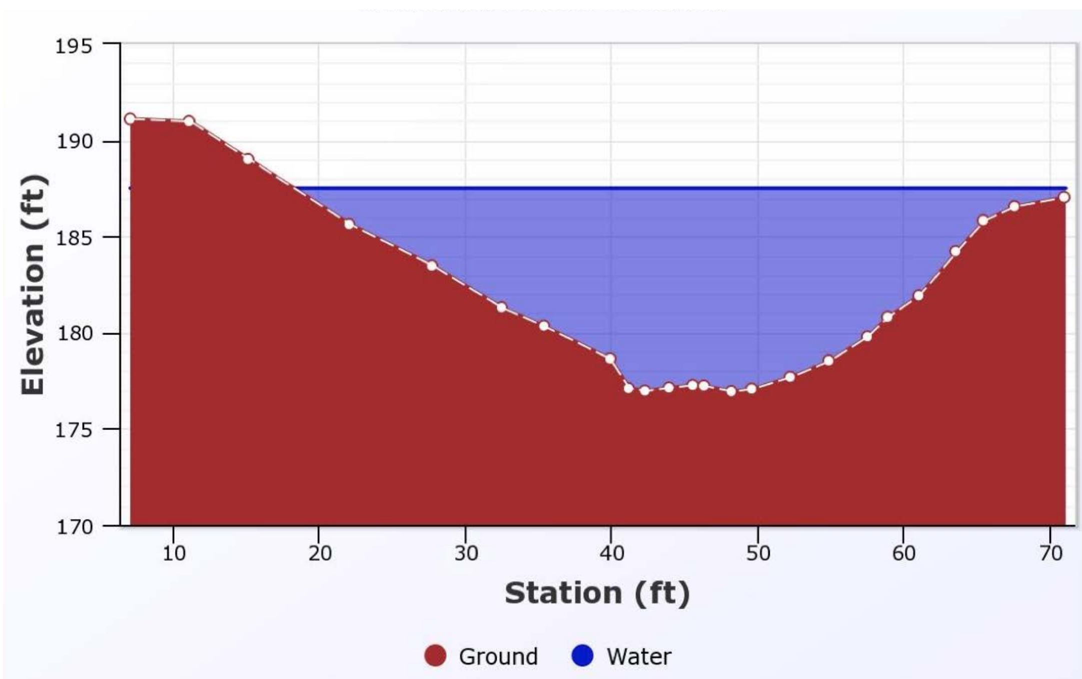


Figure 4. Water surface elevation for peak flow during a 50-year flood at T3 under surveyed conditions completed in November 2022

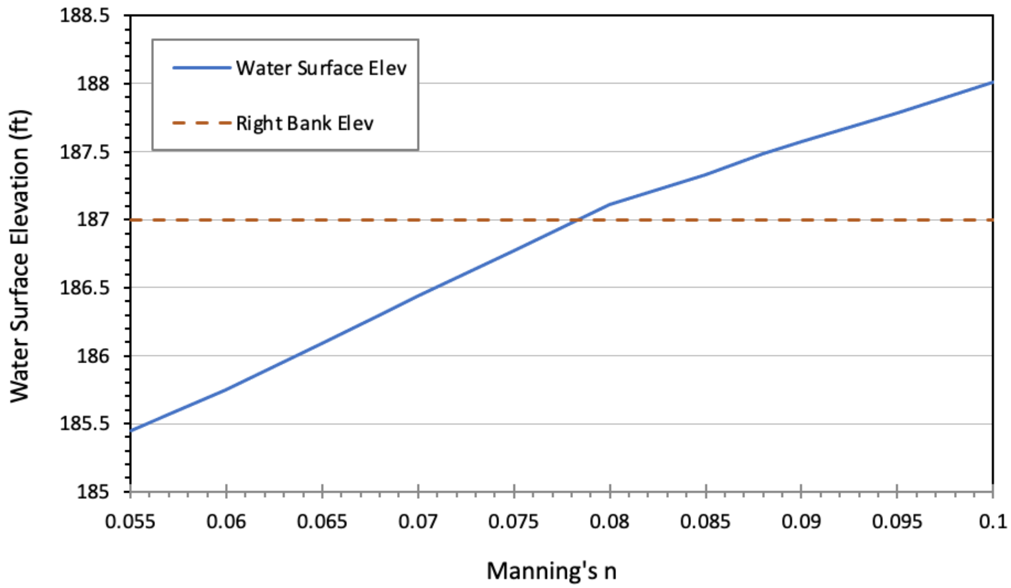


Figure 5. Water surface elevation sensitivity analysis based on changing Manning's n for peak flow during a 50-year flood at T3 under surveyed conditions completed in November 2022

Appendix A: Site Photographs

Photo 1. Impacts of willows on surrounding shrubs at T1 right bank.

Photo 2. Coexistence of willow and ivy at T2 right bank.

Photo 3. T1 looking upstream (N)

Photo 4. T1 looking downstream (SSW)

Photo 5. T2 looking upstream (NNE)

Photo 6. T2 looking downstream (SSE)

Photo 7. T3 looking upstream (NNE)

Photo 8. T3 looking downstream (SE)

Photo 9. Right bank looking upstream (left bank in Figures 1, 2, 4, 5, and 6) while surveying at T3. Instrument is at second TP position.

Photo 10. T3 survey starting point. 2022 T3 measurements began at the rod location shown. Measurements taken in the past began at the rebar (not shown) to the right of the log intersection.

Photo 11. T1 facing right bank (W)

Photo 12. T1 facing left bank (E)

Photo 13. T2 facing right bank (W)

Photo 14. T2 facing left bank (E)

Photo 15. T3 facing right bank (SW)

Photo 16. T3 facing left bank (NE)

Appendix B: Additional Tables and Figures

Table B1. T3 cross section measurements and calculations organized by horizontal distance from the left bank. Gray cells are raw data, and different shades of gray correspond to a single instrument location (we moved the instrument twice) to capture the entire cross-section.

Shot #	Horizontal Distance (m)	Reading (m)	Adjusted Reading (m)	Horizontal Distance (ft)	Elevation (ft)
0 (BM)	0	0.15	0.15	00+07.0	191.1
1	1.26	0.19	0.19	00+11.1	191.0
2	2.48	0.79	0.79	00+15.1	189.0
3	4.59	1.82	1.82	00+22.1	185.6
4	6.32	2.48	2.48	00+27.7	183.5
5	7.75	3.14	3.14	00+32.4	181.3
6	8.63	3.43	3.43	00+35.3	180.3
7 (TP)	10.01	3.95	3.95	00+39.8	178.6
7 (TP)	10.01	1.09	3.95	00+39.8	178.6
8	10.41	1.56	4.42	00+41.2	177.1
9	10.76	1.6	4.46	00+42.3	177.0
10	11.24	1.55	4.41	00+43.9	177.1
11	11.74	1.51	4.37	00+45.5	177.3
12	11.96	1.52	4.38	00+46.2	177.2
13	12.57	1.61	4.47	00+48.2	176.9
14	12.98	1.57	4.43	00+49.6	177.1
15	13.78	1.38	4.24	00+52.2	177.7
18**	14.60	2.87	3.98	00+54.9	178.5
17**	15.38	2.49	3.6	00+57.5	179.8
16 (TP)	15.81	0.43	3.29	00+58.9	180.8
16 (TP)	15.81	2.18	3.29	00+58.9	180.8
19	16.46	1.84	2.95	00+61.0	181.9
20	17.25	1.14	2.25	00+63.6	184.2
21	17.82	0.65	1.76	00+65.5	185.8
22	18.46	0.43	1.54	00+67.6	186.5
23	19.51	0.28	1.39	00+71.0	187.0

Table B2. Pebble count data from T3 (gray cells indicate raw data).

Pebble Diameter Size Range (mm)	# of Pebbles	% Finer
< 4	5	5
4 - 5.7	10	15
5.7 - 8	5	20
8 - 11.3	13	33
11.3 - 16	20	53
16 - 22.6	18	71
22.6 - 32	8	79
32 - 45	13	92
45 - 64	4	96
64 - 90	1	97
90 - 128	3	100

Table B4. 50-year event water surface sensitivity to Manning's n at T3

Mannings n	Water Surface Elevation (ft)
0.055	185.45
0.06	185.75
0.065	186.09
0.068	186.3
0.07	186.44
0.075	186.77
0.08	187.11
0.085	187.33
0.088	187.48
0.09	187.57
0.095	187.78
0.1	188.01

Table B4. Shrub survival by species within sampled transects (2020) condition. Extracted from *Sausal Creek Restoration at Dimond Park (2021) Monitoring Results* (RDG, 2021).

Species	Transect 1	Transect 2	Transect 3
California Sagebrush *Artemisia californica*	0	0	0
Coyote Brush *Baccharis pilularis*	5	3	2
Jim Brush *Ceanothus oliganthus var. sorediatus*	2	0	0
California Hazelnut *Corylus cornuta var. californica*	1	0	2
Coast Silk-Tassel *Garrya elliptica*	0	0	0
Ocean Spray *Holodiscus dicolor*	0	1	0
Twinberry Honeysuckle *Lonicera involucrata*	1	0	0
Sticky Monkey-Flower *Mimulus aurantiacus*	1	0	0
Ninebark *Physocarpus capitatus*	2	5	6
Coffeeberry *Rhamnus californica ssp. californica*	4	0	0
California Gooseberry *Ribes californicum var. Californicum*	0	0	0
Pink-Flowered Currant *Ribes sanguineum var. glutinosum*	4	1	2
California Rose *Rosa californica*	0	0	1
Blue Elderberry *Sambucus mexicana*	0	1	0
Snowberry *Symphoricarpos albus var. laevigatus*	2	1	4
2017 Year 1 Total Count	16	11	20
2018 Year 2 Total Count	20	9	8
2019 Year 3 Total Count	18	9	9
2020 Year 4 Total Count	25	11	14
2021 Year 5 Total Count	22	12	16
% Survival from Year 1	138%	109%	85%

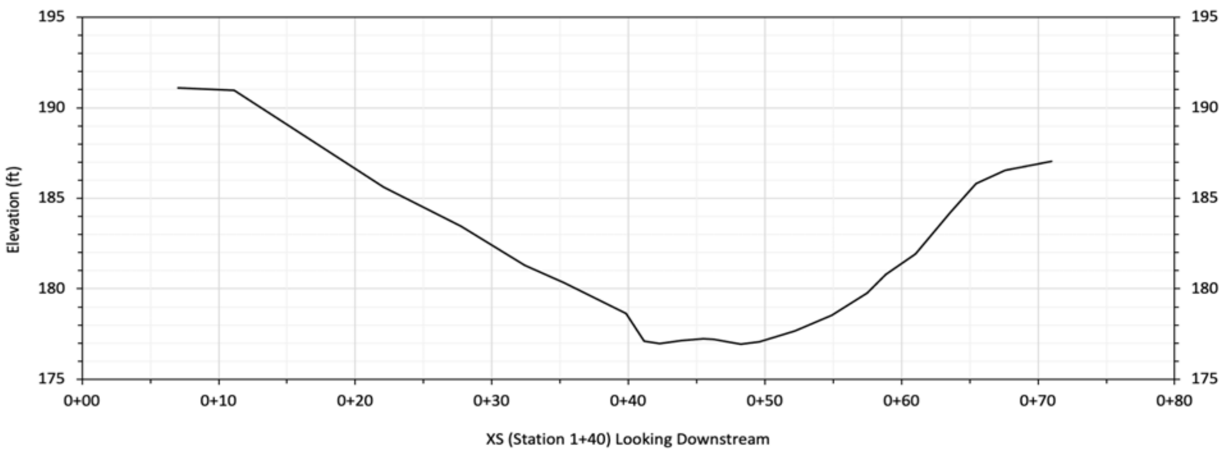


Figure B1. T3 cross-section looking downstream.

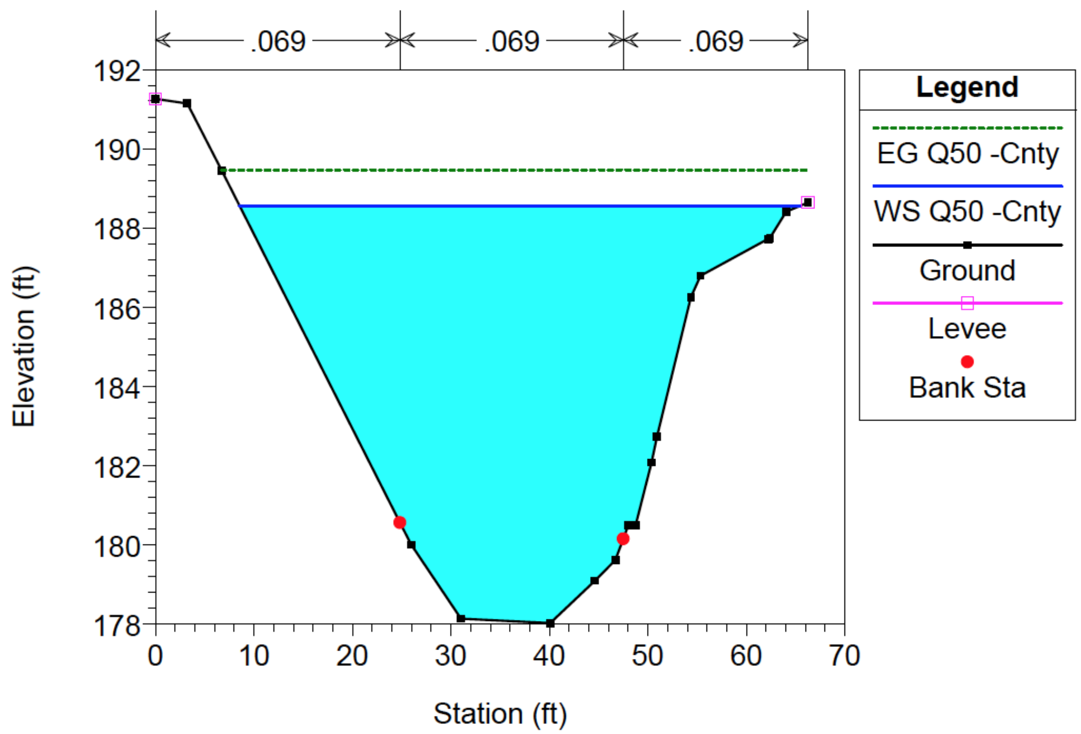


Figure B2. Water surface elevation for peak flow during a 50-year flood at station 1+25 in 2012 HEC-RAS analysis (RDG 2012)

Appendix C: Sausal Creek Timeline

1900	Sausal Creek functioned to move sediment.
1923	Due to the demand for automobiles, cities culverted the creek and put them underground. As a result, Sausal Creek lost its identity as a landscape.
1930-1950	Works Progress Administration attempted to “control” the creek by implementing cement structures.
1985	Heavy storms resulted in bank overflow, which catalyzed following restoration projects.
2000	WRI and WMA designed “Sausal Creek Restoration in Dimond Park” (upstream of El Centro Avenue), which the City of Oakland implemented in 2001.
2003	Post-project appraisal by previous Berkeley students for Dimond Canyon.
2005	Post-project appraisal by previous Berkeley students for Dimond Canyon. A 10- to 25-year storm event in December caused erosion in Dimond Park (downstream of Wellington Street).
2007	Grant application for restoration in Dimond Park, downstream of Wellington Street.
2016	Completion of the Sausal Creek Restoration Project in Dimond Park.
2016-Today	RDG monitors Sausal Creek conditions. Year 5 Monitoring Report published by RDG.