Title

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ABSTRACT

San Pablo Creek drains 42 square miles, debouching into the San Pablo Bay in Richmond, California. In 1919, East Bay Municipal Utility District built a dam in the mid-watershed. The Dam rarely releases water, so the reach downstream (lower San Pablo Creek) has a distinct hydrology driven by runoff from the unregulated, lower, 11.2 square-mile drainage area. Perhaps because flooding is infrequent, and because land-use policies and management have not historically considered low-order channels and their riparian habitat, regulating agencies have spent little time collecting baseline information on the creek. This study seeks to gather such baseline information. The specific questions this study addresses are: 1) What are the key ecological and geomorphic transition zones along the Lower San Pablo Creek? 2) What are the geomorphic, hydrologic, and vegetation characteristics in each of these zones? and 3) What are the discharge estimates for cross-sections in each of these zones?

The results of our study indicate that there are five distinct zones along lower San Pablo Creek: the Upper Alluvial Valley, the Lower Alluvial Valley, the Upper Alluvial Fan, the Wildcat-San Pablo Creeks Alluvial Fan, and the Tidal Flats zones. Results from discharge estimates indicate a wide variance of discharge rates between Rantz, Haltiner, and Wannanen-Crippen methods. A high dominance of non-native vegetation and significant incision in the upper cross-sections indicates potential for future restoration efforts.

INTRODUCTION

Background

Little baseline data exists for lower San Pablo Creek, which is located in the eastern portion of the San Francisco Bay area (Figure 1). The entire San Pablo Creek watershed drains 42 square miles, including portions of Orinda, El Sobrante, Richmond, and San Pablo. In 1919, the People's Water Company [now known as the East Bay Municipal Utility District (EBMUD)] constructed a dam on San Pablo Creek. The reach downstream of the Dam, lower San Pablo Creek, is largely disconnected from the upper watershed because water is rarely released from San Pablo Reservoir (B. Gardner, EBMUD, personal communication, 2004). This area includes 11.2 square miles of the watershed and 9.2 creek miles.

Despite the fact that the creek is dammed, it is primarily open and unchannelized from dam to mouth, except for a 1,200 foot stretch below the I-80 culvert. The land use adjacent to the creek varies from semi-urbanized to urbanized. At its upper extent, the creek is contained by Kennedy Grove

Regional Park. From there through the unincorporated town of El Sobrante, residential and commercial property abuts the floodplain, though much of the surrounding ridges are free from dense development. In the City of San Pablo, the creek enters a much more urbanized landscape, with retail buildings, schools and homes built in the floodplain as well as the rest of the watershed. For the last two miles above the creek's mouth, it enters an industrial area, with large (150-300 feet) buffers along the channel's edge.

Lower San Pablo Creek rarely experiences flows that exceed bank capacity. Historical records recount that the largest, recent flood event occurred in 1958, when the creek overflowed onto the streets in the City of San Pablo (J. Austin, local resident, personal communication, 2002). Currently, EBMUD, operator of the San Pablo Dam, releases water only to avoid flooding hazards. And in the past decade, EBMUD has only released water during the wet season, such as the week-long release that occurred on February 25, 2004 after a peak storm. (B. Gardner, EBMUD, personal communication, April 2004). Despite these facts, a recent study—conducted to assess flooding hazards for neighboring houses—concluded that many houses along the creek were in fact in a flood-risk zone (National Flood Insurance Program, 2004). Because the flood insurance study only used aerial photographs to identify flood risk zones, we are interested in using additional field-derived data to generate flooding potential calculations, so as to compare them with the national assessment.

Perhaps because of its low flooding incidences, and because land-use policies and management have not historically considered low-order channels and their riparian habitat (Beschta and Platts 1986) regulating agencies have spent little time collecting baseline information on the creek. However, because in recent years, recreation, aesthetics, habitat and water quality have been increasingly recognized as important (Beschta and Platts 1986), we sought to deepen the understanding of San Pablo Creek's natural processes, in order to begin outlining restoration potential.

Our study objectives were two-fold: 1) Classify the creek channel into distinct zones, based on geomorphic and hydrologic context, 2) Survey channel morphology and vegetation at a representative cross-section for each zone, 3) Assess the creek's peak discharge at each cross-section, and 4) Evaluate the creek's potential for flooding.

METHODS

Transitional Zones

We began this study by identifying geomorphic and vegetation transitions along Lower San Pablo Creek. To determine this, we walked portions of the creek from Kennedy Grove Regional Park (its upper extent) to the mouth of the creek (adjacent to the West Contra Costa County Sanitary Landfill) – a 9.2-mile stretch. We recorded changes in bank elevation, bedrock, substrate, and vegetation. We also obtained information on the hydrology of the lower watershed from Contra Costa County and the San Pablo Watershed Neighbors Education and Restoration Society (SPAWNERS), a grassroots environmental group. Based on the sum of this information, we categorized the creek into distinct "zones", which we define heretofore as reaches of the creek where there are significant differences in channel morphology and hydrologic inputs.

Cross Sections and Baseline Data

Assisted by Sarah Pearce, a geomorphologist from the San Francisco Estuary Institute, we surveyed one cross-section at a representative area for each zone identified. The cross-section surveys took place at 6380 Hillside Drive in El Sobrante, 4191 Appian Way in El Sobrante, Kennedy Plaza Park in San Pablo, Third Street and Parr Boulevards in North Richmond, and adjacent to the West Contra Costa Sanitary Landfill.

We conducted the Hillside Drive cross-section just behind the house, parallel to a small trail that leads down to the creek. A solitary California bay tree (*Umbellularia californica*) by the trail marked the end of the cross-section on the left bank. The cross-section at Appian Way was located behind the El Sobrante Library. The cross section began on the right bank, at the large bay tree, roughly 20 feet west of the street, and continued down into the channel along a straight line from the tree to the opposite bank, ending at the third stripe of the Oliver's parking lot. We surveyed the creek at Kennedy Plaza, 80 feet west of the covered park. Our cross-section started on the right bank, 15 feet upslope of an inset terrace, where there is a mound of concrete. The cross-section ended on the opposite bank, passing between a bay tree and a box elder tree. At Third Street, our cross section began on the left bank, at the gravel driveway, 20 feet in from the fence. The cross-section continued downslope, roughly 35 feet out from the Third Street bridge. Our cross-section at the West Contra Costa Sanitary Landfill began 115 feet downstream from the Richmond Parkway bridge.

Surveys for each site consisted of area sketch maps, cross-section surveys and descriptions, slope calculations, elevation of survey site using a Global Positioning System (GPS) and verification on a USGS 7.5 minute topographical map for the Richmond quadrangle, water depths at the thalweg, and velocity estimates. We determined velocity using the orange-peel method, which involves calculating the amount of time that it takes for an orange peel to travel a given distance along the channel's reach.

Michele Lee, former Recording Secretary for the East Bay Chapter of the California Native Plant Society and LSA Associates, Inc. Botanist, guided the vegetation estimates along the cross-section. We estimated relative cover for each bank separately for a distance of 20 feet on both sides of the cross-section, representing an area 40 feet in width, and varying in length (depending on the given cross-section). We visually estimated total relative canopy cover for the primary overstory, secondary overstory, and understory. We defined overstory as trees or shrubs that were greater than or equal to 15 feet in height. The secondary overstory consisted of trees and shrubs less than 15 feet tall. The understory consisted of herbaceous vegetation. For each of the three strata, we recorded the relative cover of individual plant species. The estimated cover did not include overlapping cover, but was a rough estimate of the relative contribution of each species to the total canopy cover. We recorded cover estimates as percentages that were rounded to the nearest 5 percent or less than 5 percent. We recorded the locations and the approximate size of invasive exotic plants on aerial photographs.

We used the survey data to develop a cross-section diagram for each reach. We used the dominant overstory species to determine the plant community associated with each zone, according to the *List of Terrestrial Natural Communities Recognized by the California Natural Diversity Database* (California Department of Fish and Game, 2003). We defined the vegetation communities based on the dominant overstory in accordance to California Native Plant Society (CNPS) protocol (California Native Plant Society, 2003).

Discharge and Flood Frequency Analysis

Using a Geographic Information System (GIS), we determined the drainage basin area for the entire study area and each of the zones. Using this information, we calculated the unit runoff (cubic feet per second/square mile) for different magnitude flows and the peak runoff amounts for each stream segment.

We used Rantz's method (1971) to calculate discharge for the 5, 10, 25 and 50-year recurrence intervals. Here, Discharge $Q = KA^a P^b$, where K is a constant, A is the drainage area (square miles), a is a constant, P is the average annual precipitation, and b is a constant. We compared the Rantz method to the Waananen and Crippen method (1977) for the 5, 10, 25, 50 and 100-year recurrence intervals. Here, Discharge $Q = KA^a P^b H^c$, where H is the altitude index at points 10% and 85% of the distance along the stream from each cross-section to the mouth of the creek. We used Haltiner's method to calculate discharge for the 100-year recurrence interval, where $Q = (0.5 - 1.0)$ (drainage area in acres).

Using the Manning's equation we calculated both velocity and discharge at each of our five cross-sections. Here, $v=(c(s^{0.5} R^{0.67})/n$, where v is velocity, c is a constant coefficient, s is the energy slope, R is the hydraulic radius, and n is a calculated roughness coefficient. We calculated velocity and discharge for both maximum channel capacity and current channel capacity. Using our field-derived velocities (orange-peel method) we back-calculated Manning's n, to verify our results.

RESULTS

Transitional Zones

Based on hydrologic records and field-observed geomorphology, we identified five distinct reaches along Lower San Pablo Creek (Figure 3): the Upper Alluvial Valley, the Lower Alluvial Valley, the Upper Alluvial Fan, the Wildcat-San Pablo Creeks Alluvial Fan, and the Tidal Flats.

Upper Alluvial Valley

The *Upper Alluvial Valley* (drainage area 2.43 square miles) extends from Kennedy Grove Regional Park to the confluence of Castro Creek, a tributary draining 0.061 square miles. Sobrante and San Pablo Ridges mark the northern and southern extent of this area. The principle source of water is run off from three ephemeral tributaries. The active floodplain is narrow, but the greater floodplain is very wide and most likely remnant of pre-dam flows.

The Upper Alluvial Valley cross section (Figure 4) had a wide floodplain with small terraces on the right upper bank and lower left bank. It also had a forced bar (depositional area) in the center of the active channel. Elevations here ranged from approximately 185 to 197 feet (Table A).

At the Upper Alluvial Fan site, northern black walnut (*Juglans californica. var hindsii*) was the dominant overstory species, representing 60% of the cover on the right bank. Coast live oak (*Quercus agrifolia*) comprised approximately 10% of the total canopy cover. Other species that were 5% or less of the total canopy cover included California buckeye (*Aesculus californica*), non-native fruit tree (*Prunus sp.*), California sycamore (*Platanus racemosa*), California bay, and willow (*Salix sp.*). In the understory, English ivy (*Hedera helix*) covered 90% of the right bank and 5% of the left bank. On the left bank, the dominant overstory species (40%) was California bay. We classified this zone as Mixed Riparian Forest and Woodland (62.900.00) (Table F).

Lower Alluvial Valley

The second zone, the *Lower Alluvial Valley*, stretches from the confluence of Castro and San Pablo Creeks to the I-80 culvert, and drains an area of 7.84 square miles. Three perennial tributaries drain to San Pablo Creek in this area. Therefore, the active channel was wider here than the Upper Alluvial Valley. The creek in this area was incised 25 feet. The Lower Alluvial Valley cross section (Figure 5) had two terraces (one high, one low) on the right bank and a single middle terrace on the left slope. This creek reach also had a stable in-channel lateral bar. The elevation ranged from approximately 83 to 109 feet (Table B).

In the Lower Alluvial Valley, different species dominated each bank. On the right bank, the dominant overstory species was northern California black walnut (15%). Other species included California bay and buckeye. On the left bank, box elder (*Acer negundo* var. *californicum*) was the dominant overstory species (35%). Other trees, each with less than 5% cover, included California bay, California buckeye, blue elderberry (*Sambucus mexicana*), California sycamore, and willow (*Salix sp.*). English ivy comprised 90% of the understory ground cover. We classified this zone as Mixed Riparian Forest and Woodland (61.900.00) (Table G).

Upper Alluvial Fan

The *Upper Alluvial Fan* stretches from the bottom of the I-80 culvert to the railroad tracks near Giant Way, in the City of San Pablo. This zone's drainage area is 8.99 square miles. Similar to the Lower Alluvial Valley site, this area was incised by 20 feet. The Upper Alluvial Fan cross-section (Figure 6) had a high terrace on the right bank and a mini-inset terrace and an upper terrace on the left bank. Elevations ranged here from 42 to 56 feet (Table C).

At the Upper Alluvial Fan site, box elder was the dominant overstory species on the right bank (20%). Red willow (S*alix laevigata)* was the dominant overstory species (10%) on the left bank. Additional tree species included California bay, California buckeye, blue elderberry, and red willow (*Salix laevigata*). English ivy comprised 90% of the understory ground cover on the left bank. We classified this zone as Mixed Riparian Forest and Woodland (61.900.00) (Table H). .

Wildcat-San Pablo Creek Alluvial Fan

The *Wildcat-San Pablo Creek Alluvial Fan* is the area where, historically, Wildcat and San Pablo creeks shared an alluvial fan (San Francisco Estuary Institute, 2001). This zone stretches from the railroad tracks in San Pablo to the area between Third Street and the Richmond Parkway in North Richmond, and has a drainage area of 9.66 square miles. This zone was characterized by a wide, flat floodplain with a narrow, active stream channel (Figure 7). Incision was moderate at 10 feet. This stretch of the creek ranged in elevation from approximately 5 to 20 feet (Table D).

At the Wildcat-San Pablo Creeks Alluvial Fan site, arroyo willow (*Salix lasiolepis*) dominated the right bank and no trees were present on the left bank. English ivy covered 30% of the right bank. We also found red willow in this area. Therefore, we classified this area as two different zones: Central Coast Arroyo Willow Riparian (61.201.01) or Arroyo Willow Riparian Forests and Woodlands (61.201.00) (Table I).

Tidal Zone

The last zone was the *Tidal Zone*, stretching from Third Street/Richmond Parkway to the mouth of the creek. This area is adjacent to the West Contra Costa Sanitary Landfill. The drainage area here is 11.12 square miles. This zone was distinguishable by the presence of pickleweed (*Salicornia virginica*) and alkali bulrush (*Scirpus robustus*) both salt-thriving species. Like the Wildcat-San Pablo Creeks Alluvial Fan, this area had a wide, flat floodplain spanning almost 250 feet (Figure 8). Elevation ranged from 5 to 20 feet (Table E).

There were no trees at the Tidal Flats, and therefore there was no dominant overstory species. Rather, the landscape was covered by fennel (*Foeniculum vulgare*), marsh gumplant, (*Grindelia stricta var. angustifolia*), pickleweed (*Salicornica virginica*), and alkali bulrush (*Scirpus robustus*). Therefore, we classified this section as a modification of the Alkali Bulrush (*Scirpus maritimus*)/Pickleweed (Salicornica spp.) (52.112.01).

Discharge and Recurrence Intervals: Rantz, Waananen and Crippen, Haltiner

The Rantz method produced varying results at each cross-section site. Specifically, for the Upper Alluvial Valley, the discharge estimates for the 5, 10, 25 and 50-year recurrence intervals were 221, 332, 482 and 765 cubic feet per second (cfs), respectively (Table 1). For the Lower Alluvial Valley, the discharge estimates for the 5, 10, 25 and 50-year recurrence intervals were 652, 977, 1404 and 2063 (cfs), respectively (Table 1). For the Upper Alluvial Fan, the discharge estimates for the 5, 10, 25 and 50-year recurrence intervals were 740, 1108, 1590 and 2316 (cfs), respectively (Table 1). For the Wildcat San Pablo Fan, the discharge estimates for the 5, 10, 25 and 50-year recurrence intervals were 791, 1184, 1698 and 2462 (cfs), respectively (Table 1). For the Tidal Flats, the discharge estimates for the 5, 10, 25 and 50-year recurrence intervals were 901, 1349, 1931 and 2773 (cfs), respectively (Table 1). For detailed information by cross-section, see Appendix Tables J-N.

The Wannanen and Crippen method produced different results at each cross-section site. For the Upper Alluvial Valley, the discharge estimates were 5, 15, 43, 85, 155 (cfs) for the 5, 10, 25, 50 and 100-year recurrence intervals, respectively (Table 1). For the Lower Alluvial Valley, the discharge estimates were 25, 68, 178, 329, 557 (cfs) for the 5, 10, 25, 50 and 100-year recurrence intervals, respectively. For the Upper Alluvial Fan, the discharge estimates were 36, 96, 237, 426, 703 (cfs) for the 5, 10, 25, 50 and 100-year recurrence intervals, respectively. For the Wildcat San Pablo Fan, the discharge estimates were 67, 159, 358, 603, 941 (cfs) for the 5, 10, 25, 50 and 100-year recurrence intervals, respectively (Table M). For the Tidal Flats, the discharge estimates were 114, 250, 523, 843, 1260 (cfs) for the 5, 10, 25, 50 and 100-year recurrence intervals, respectively. All results are summarized in Table 1. For details by cross-section, see Appendix, Tables 0-S.

Discharge results were much higher for the Haltiner method (estimated for the 100-year interval, only). Specifically, for the Upper Alluvial Valley, discharge ranged from 778 to 1555 (cfs), as the coefficient variable varied from 0.5-1.0, respectively (Table 1). For the Lower Alluvial Valley, discharge ranged from 2509 to 5017 (cfs), as the coefficient variable varies from 0.5-1.0, respectively. For the Upper Alluvial Fan, discharge ranged from 2877 to 5754 (cfs), as the coefficient variable varied from 0.5-1.0, respectively. For the Wildcat San Pablo Fan, discharge ranged from 3091 to 6182 (cfs), as the coefficient variable varied from 0.5-1.0, respectively. For the Tidal Flats, discharge ranged from 3559 to 7117 (cfs), with the coefficient variable varying from 0.5-1, respectively.

A summary of the variables for each cross-section and method is included in the Appendix Tables T-X.

Discharge: Manning's Equation

Using the Manning's equation, the capacity of the channel at high flows, from Upper Alluvial Valley to Tidal Flat, were 3,450, 7251, 1,485, 6,420, and 4,154 cfs respectively (Table 2). Detailed calculations are included in the Appendix in Tables Y-CC.

DISCUSSION

Channel Morphology

In 1977, Schumm described a model for streams by breaking a watershed into three zones. Zone 1 is the upper zone and the area of sediment generation. Zone 2 is the middle zone or area of sediment transport. Zone 3 is the lower zone and the area of sediment deposition. In the San Pablo Creek Watershed, the Upper and Lower Alluvial Valley zones are the main source of sediment, coming from erosion off of the surrounding ridges. The Upper Alluvial Fan is most likely the zone of transport. The zone of "transport" in an urbanized system might be a misnomer, since channel erosion in this reach may be a major sediment sources as well (Haltiner, 2004). The depositional zone is the Wildcat-San Pablo Creeks Fan and Tidal Flats, nearest to the stream's mouth.

Issues associated with the sediment generation zone that can be witnessed in the lower San Pablo Creek Watershed include active erosion and incision (Haltiner, 2004). In urbanized watersheds there are more impermeable surfaces, which results in a greater amount of water draining into storm drains and the creek system, rather than percolating through the soil. The sediment transport zone can also experience channel incision in response to the increased stream flows and reduced channel instability (Haltiner, 2004).

The presence of the dam can also help explain the incision. Normally, stream characteristics such as drainage density and channel profiles develop from the interaction of runoff and sediment transport (Beschta and Platts 1986). In streams below dams, the sediment that is normally transported downstream is trapped behind the dam. Without this sediment load, the stream below the dam begins to erode its own channel as a consequence, a phenomenon known as “hungry water” (Kondolf, 2004).

Incision decreases in the Wildcat-San Pablo Creek’s zone and ceases completely by the Tidal Flats toward the channel’s mouth, because these are the depositional zones (Schumm, 1977). Below the railroad tracks in North Richmond, the active channel was approximately 7 feet deep, much shallower than the Lower Alluvial Valley and Upper Alluvial Fan cross sections. At this point, the channel also widened. These lower stretches of the creek do not have a built-upon floodplain. Here, the channel-floodplain is more of a unit (Kondolf and Keller 1991), and we conclude that this is beneficial for the stream’s morphology, because over time the channel may be freer to shift across the floodplain.

Channel incision is a feedback process: as each episode of channel enlargement occurs, higher flows (that had previously overtopped the channel banks and spread across the floodplain) are now concentrated entirely in the channel, further accelerating the incision process (Haltiner, 2004).

Vegetation

The vegetation zones along the San Pablo Creek Watershed do not directly correlate with the geomorphic zones in this study. Soil, microclimate, geology type, canopy cover, groundwater table, and invasive vegetation all influence the presence of vegetation communities in the watershed. Therefore it is understandable that discrete vegetation differences would not be present in highly discrete zones.

Non-Native Vegetation

Some of the most dominant vegetation types were not native the watershed. This is true of the northern California black walnut (CDFG, 2004). Though native to California, this tree was introduced to the East Bay and has become naturalized. Because of this fact, we could not classify plant communities in the watershed as northern California black walnut community, according to the California Department of Fish and Game.

The fact that English ivy dominated most of the groundcover in the Upper and Lower Alluvial Valleys, as well as the Upper and Lower Alluvial fans can be explained by its highly invasive nature. This plant competes with native plant species, displacing habitat for wildlife. It also climbs and strangles trees, often killing them in the process. Future revegetation and riparian restoration efforts should include the removal of this non-native ivy and replacement with locally appropriate species.

Discharge and Recurrence Intervals: Rantz, Waananen and Crippen, Haltiner

As would be expected, for all three methods, the discharge increases as we move downstream, down to the tidal flats, for the 5, 10, 25, 50 and 100-year intervals.

Despite this similarity, there is a significant difference in the estimates for each of these methods. Discrepancies in discharge results between the Rantz, Wannenen-Crippen and Haltiner methods can be explained, in part, by considering the background of each of these equations. Rantz developed his method based on creeks and rivers with drainage basins greater than 5 sq mi (Rantz, 1971). Therefore, though it might not be an appropriate model for the Upper Alluvial Valley cross-section, with a drainage area of 2.43 sq mi, the model could work for the other cross-sections. The Waananen and Crippen method separates the state of California into six hydrologic regions and uses regression equations generated for each region to determine peak runoff for a known drainage area and storm recurrence interval. The equations were developed using peak-discharge statistics with 10 or more years of record from 705 gaged locations in California through 1975. Because the regression equation for this region includes parameters for a wide range of watershed types, the peak discharge predicted by this method for a small watershed like San Pablo Creek may be inappropriate. Also, none of these methods take urbanization into consideration as a variable. We reviewed a restoration plan for Kennedy Plaza (the location of the Upper Alluvial Fan cross-section) that was developed by the Urban Creeks Council. This firm relies on the Rantz method to calculate peak flows (Urban Creeks Council, 2002). Some environmental consulting firms now rely on the Army Corps of Engineer’s Hydrologic Engineering Center (HEC) model, which might be used to better predict the capacities of each of these cross-sections (D. Shaw, personal communication, November, 2004).

Discharge: Manning

Results from the Manning's equation can be used to analyze 100-year flood predictions at each cross section. According to Waananen-Crippen and Haltiner methods, at all five cross-sections, but the Upper Alluvial Fan, the channel could contain flows greater than the 100-year flood prediction without topping the banks. The Upper Alluvial Fan could contain a 100-year flood according to Waananen-Crippen, but not the Haltiner estimate.

Our results parallel results of the National Flood Insurance Program' Flood Insurance Rate Map (2004). Specifically, this map highlights the Upper Alluvial Fan as the area that is in the 100-year flood zone. That the Upper Alluvial Fan could be more prone to flooding is confirmed by recent flooding episodes, when the creek topped the banks for a few hours this year at Rumrill Boulevard (K. Samkien, City of San Pablo, personal communication, December 2004).

CONCLUSIONS

Based on the aforementioned results, we can conclude that there are five key zones along San Pablo Creek, each of which varies in terms of geomorphic and vegetation characteristics.

Despite discrepancies in our discharge and flow estimates, when compared to the City of San Pablo's flooding estimates, we find that the Upper Alluvial Fan may, indeed, be in the 100-year flood zone, depending on which flood calculation method is employed.

Future studies may wish to reconcile the discrepancies between the difference discharge estimates. Specifically, a future study could provide for the installation of a stream gage on San Pablo Creek, in the current area of risk. This would provide for the development of a real-time rating curve, which could make predicting floods extremely accurate. The Urban Creeks Council, in partnership with

Balance Hydraulics, is preparing to install a stream gage on Wildcat Creek, the stream nearest San Pablo Creek. Future studies could also correlate San Pablo Creek flows to Wildcat Creek. Current Wildcat Creek flow records only span 32 years.

Riparian vegetation adjacent to small streams can control many biologically important channel characteristics, and hence engineering approaches must take into account the important role of vegetation. Thus, future management and restoration efforts should consider our vegetation results.

The identification of potential restoration sites should only occur with a thorough survey of the channel's baseline conditions. Though this study provided some useful insights into the lower San Pablo Creek Watershed as a whole, future studies of specific stream reaches could help fill other scientific gaps – necessary steps for effective watershed management and restoration.

REFERENCES

Beschta, R.L and Platts, W. 1986. Morphological Features of Small Streams: Significance and Function. Water Resources Bulletin. 22 (3), 369-379.

California Department of Fish and Game (CDFG). 2004. Rarefind. California Natural Diversity Database. Version 3.0.5, November 3, 2003. Updated November 2, 2004. California Department of Fish and Game, Wildlife Habitat Data Analysis Branch, Sacramento, California.

California Native Plant Society (CNPS). 2003. California Native Plant Society – Vegetation Rapid Assessment Protocol. http://www.cnps.org/vegetation/rapid_assessment_protocol.pdf.

Chow, V.T. 1959. Open channel hydraulics. McGraw-Hill Book Co., New York.

California Department of Fish and Game (CDFG). 2003. List of California Terrestrial Natural Communities Recognized by the California Natural Diversity Database. September 2003 edition. Department of Fish and Game, Wildlife and Habitat Data Analysis Branch, The Vegetation Classification and Mapping Program. http://www.dfg.ca.gov/whdab/pdfs/natcomlist.pdf.

Gregory, K.J. 1987. River Channels. Human Activity and Environmental Processes, 207-235. John Wiley and Sons, Ltd, Chichester.

Haltiner, J. and Beeman, C. 2004. Restoring Floodplain and Channel Functions to Incised and Leveed Stream Systems. Proceedings given by Philip Williams & Associates, Corte Madera, CA.

Kondolf, G.M. 2004. Presentation to Landscape Architecture Students at University of California at Berkeley, October 2004.

Kondolf, G. Matthias and E.A. Keller. Management of Urbanizing Watersheds. California Watersheds at the Urban Interface: Proceedings of the Third Biennial Watershed Conference. Berkeley, CA: California Resources Center, University of California, Report No 75. April, 1991, 27-40.

National Flood Insurance Program. 2004. San Pablo Flood Map Index. http://www.ci.san-pablo.ca.us/main/documents/floodmaps/index.htm.

Rantz, A. 1971. Suggested criteria for hydrologic design of stormwater drainage facilities in the San Francisco Bay region, California. USDI, USGS, Menlo Park, California.

San Francisco Estuary Institute. 2001. http://www.sfei.org/watersheds/wildcatreport/wildcatindex.html

Shumm, S.A., 1977. The Fluvial System. Wiley-Interscience, New York, New York.

Tompkins, Mark. 2004. Landscape Architecture 227 Lecture, University of California at Berkeley.

Urban Creeks Council.2002. San Pablo Creek at Kennedy Plaza Park Bank Restoration.

Waananen and Crippen, 1979. Flood frequency relations.

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