FINAL DRAFT

An Assessment of Stream Flow and Habitat Quality for Steelhead Trout in San Pablo Creek, Contra Costa County

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May, 2004

ABSTRACT
The San Pablo Creek Watershed is a large and geographically diverse stream located East of the San Francisco Bay. San Pablo Creek historically provided habitat for an abundant population of steelhead trout, a federally listed threatened species. However, in 1919, the East Bay Municipal Utility District (EBMUD) constructed a dam and reservoir on San Pablo Creek. Since the 1950's, residents and regulators have observed a decline in the abundance of anadromous fish. Our study assesses San Pablo Creek's current viability for anadromous fish, by examining the input of water from perennial tributaries of San Pablo Creek and the mainstem's habitat characteristics. By analyzing flow patterns and features including pool-riffle sequences and embeddedness, we determined that San Pablo Creek provides adequate rearing habitat for steelhead trout, but limited spawning habitat.

INTRODUCTION

Background

The San Pablo Creek Watershed is located East of San Francisco Bay (Figure 1). The creek drains 42 square miles, from its headwaters in Orinda, to the semi-urbanized town of El Sobrante, to the heavily urbanized lands of San Pablo and Richmond near the creek's mouth. Since construction of the San Pablo Dam in 1919, instream flows have been significantly reduced. In addition, accumulation of fine sediment has occurred in the lower channel because it is no longer flushed downstream by floods. This is a key concern in the El Sobrante Valley, where steep slopes are prone to mass wasting and landslides, thereby increasing the amount of sediment to San Pablo Creek.

East Bay Municipal Utility District (EBMUD), operator of the dam, releases water only to avoid a flooding hazard, such as a week-long release starting on February 25, 2004 after the peak storm this year. In the past decade, they have only released water during the wet season (B. Gardner, EBMUD, personal communication, April 2004). Even with the installation of the dam, an abundance of steelhead still inhabited the stream through the 1950's (Needham et al., 1959). After this period, residents and regulators observed a decline in the population (Leidy et al., 2003).

Steelhead trout have an adaptable range and biology. They are anadromous, meaning they migrate at various times in the life cycle between freshwater streams and the ocean. They begin life as eggs laid in clear, cool streams. Young steelhead, or fingerlings, spend up to four years in freshwater, growing seven to ten inches. Juveniles, the non-reproducing, non-adult fish, eventually move downstream and undergo drastic physiological changes that metamorphose them from freshwater to saltwater fish – they are then referred to as smolts. They spend one to three years in the sea, and can be netted up to 3,000 miles away from shore. Steelhead usually return to the stream where they hatched, "navigating via a chemical map etched in the brain" (DiSelvelstro, 1997).

According to McCain et al. (1990), the life stages of steelhead require various habitat features (Figure 2). Newly hatched fry require edge water in the spring, pocket water, back water pools, and secondary channel pools during the fall and winter. In the summer, virtually all habitat features are necessary. Smolts older than a year old prefer lateral scour pools and runs in the spring, as well as pocket water, backwater pools, and secondary channel pools in the summer, fall, and winter. Adults lay eggs in mid-channel pools, lateral scour pools, and secondary channel pools in the winter and spring. The Department of Fish and Game define these features in their Habitat Restoration Stream Manual (California Department of Fish and Game, 1998). Edgewater is a quiet, shallow area found along the margins of the stream, most typically associated with riffles. Pocket water is a combination of swift flowing stream with large obstructions, creating eddies or scours holes (pockets) behind these obstructions. Secondary channel pools are formed outside of the wetted channel; they typically dry up during the summer. Backwater pools are found along stream margins, and are formed by nearby obstructions. A lateral scour pool is formed by flow hitting a partial channel obstruction, such as large woody debris. A run is a swiftly flowing reach with little surface agitation and no major flow obstruction. A mid-channel pool is a large pool formed by scour, which encompasses more than 60 percent of a wetted channel (Figure 2) (California Department of Fish and Game, 1998).

Problem Statement

San Pablo Creek is part of the Central Coast of California Evolutionarily Significant Unit (ESU). An ESU is a population or group of populations of salmonids that 1) is substantially reproductively isolated from other populations and 2) contributes substantially to the evolutionary legacy of the biological species (National Oceanic and Atmospheric Administration, 2004). The Central Coast ESU is federally listed as threatened (National Oceanic and Atmospheric Administration Fisheries, 1998). The California Department of Fish and Game identifies “freshwater habitat loss and degradation as the primary cause of salmonid decline mostly due to excessive diversion of stream flows, blocked access to historical spawning and rearing habitats, and chronic watershed perturbations" (McEwan, 1996). Salmonids like steelhead trout survive in streams that are fairly cool (less than 22°C maximum), well oxygenated, with low levels of embeddedness (the degree of which large substrate particles are covered in fine sediment) (California Department of Fish and Game, 1998).

Dams cause deposition of sediment upstream, trapping 100 percent of coarse bedload. Below reservoirs large enough to reduce floods, the channel bed can aggrade and accumulate more fines because sediment delivered from tributaries and other sources is no longer transported downstream. Siltation can "plug" gravels used by steelhead for spawning, depriving incubating eggs of oxygen, and filling pools used by juveniles and adults for feeding, resting, and cover. In addition, the presence of water is critical to sustaining pools through the dry season. A combination of siltation and lack of water can be deadly to anadromous fish.

Needham et al. (1959) reported that steelhead were abundant as late as the 1950s, long after construction of the dam. The last recorded sighting of a large steelhead population was during a 1958 flood onto Road 20 in the City of San Pablo (J. Austin, City of San Pablo, personal communication, April 2002). The Environmental Protection Agency has conducted fish surveys in San Pablo Creek since then, most recently locating a steelhead trout in the creek in 1999 (Leidy et al., 2003). Our primary objective in this study was to determine if San Pablo Creek below the dam has viable steelhead habitat in its current state, based on flow and habitat characteristics. We also sought to determine why steelhead have declined since the 1950's, decades after the construction of San Pablo Dam.

METHODS

Flow Assessment

Flow plays an essential role in determining habitat suitability. Therefore, we began our assessment by installing stream gages on three perennial tributaries to San Pablo Creek below the dam: Appian Creek, Wilkie Creek, and Castro Creek (Figure 3). During the spring of 2004, we monitored the gage height and collected associated measurements of velocity, width of water, and depth of water every two weeks. We trained local volunteers how to take similar measurements to supplement our data.

Assisted by Sarah Pearce, Geomorphologist with the San Francisco Estuary Institute, we surveyed cross sections on these tributaries to help determine the flows associated with the high water marks (HWM) observed in the field, indicators of the season's biggest storm (February 25, 2004). Surveys at each site included area sketch maps, cross-section surveys and station descriptions, bed characterization, stream gage levels, velocity measurements (by orange peel method), slope calculations (high water mark and base level), and water depths at the thalweg, the deepest part of the channel (Figures 4 and 5).

Appian Creek

We surveyed Appian Creek just off of Appian Way in El Sobrante, adjacent to the El Sobrante Boys and Girls Club (Figure 4). Our flow calculations for this site involved the estimation of the Manning coefficient ('n') using Chow's *Open Channel Hydraulics'* table and our field observations (Table 1) (Chow, 1959). We based the calculation of the Manning coefficient on observations of silt and earthen dirt bed, minor, irregular channel form, gradual channel variations, negligible-minor obstructions, little vegetation, and a minor level of meandering. We determined the HWM as a visible trash line, which was consistent over two hundred feet.

Wilkie Creek:

Our field survey for Wilkie Creek took place near the intersection of Santa Rita Road and May Road, near DeAnza High School in Richmond, California (Figure 4). We based the calculation of the Manning coefficient on a silt dirt bed, slightly irregular channel form, gradual channel variations, minor obstructions, limited encroaching vegetation, and a minor level of meandering. For the HWM, we sighted flattened, dead grasses and woody debris. We also received additional information from a neighbor with property adjacent to the creek, who informed us that the water level reached the level of a footpath during the February 25th storm.

Castro Creek

We surveyed Castro Creek at the intersection of Hillside Drive and Castro Ranch Road in El Sobrante, California (Figure 5). We calculated the Manning's n based on a silt bed, irregular channel form and variations, large amount of obstructions, encroaching vegetation, and a medium level of meandering. The only visible piece of trash that we could find at Castro Creek was a white cloth at an outfall, which we used as the HWM.

For each tributary, we used the Manning Equation ($V = 1.49/n (R^{2/3}) (S^{1/2})$) for our high water marks observed in the field to further link the last storm event on the tributaries and San Pablo Creek. We also derived rating curves that correlated stream gage height to discharge.

Using the Contra Costa Watershed Atlas and a USGS topographical quadrangle map for the San Pablo watershed area, we determined the drainage basin areas for all three tributaries, San Pablo Creek (below the dam), and Wildcat Creek (as a reference). This enabled us to calculate the unit runoff [cubic feet per second/square mile (cfs/mi sq)] for different magnitude flows as well as the peak runoff amounts for each stream. We also used the Rantz (1971) and the Waananen and Crippen (1977) methods to determine the peak runoff flows given different drainage areas, precipitation, and elevation (Appendix A).

Correlation to Wildcat Creek

To set a reference and baseline for peak flow and unit runoff of the tributaries, we referred to the nearest stream with United States Geological Survey (USGS) surface water data – Wildcat Creek. We surveyed a cross section at Wildcat Creek in Davis Park to derive the flow for the peak storm flow of 2004 (Figure 5). Our observed HWM consisted of debris with piled sticks 6 feet above the creek bed on the left and right banks.

The USGS website provides real-time data for most watercourses in California, so we obtained the raw data for Wildcat Creek for the Vale Road gage in San Pablo, California. Using the data, we plotted a Flood Frequency Curve based on annual peak values for the entire period of record, 1965-1997 and derived the return interval for each annual peak flow (Figure 6). Given the discontinued gage records (they stopped in 1997), we applied the Manning Equation to find the 2004 peak flow. From there, we correlated Appian, Wilkie, and Castro Creeks' peak flows.

Habitat Surveys

Fish counts, pool-riffle habitat, diversity, and occurrence

On April 3rd, 2004, Rob Leidy, Fisheries Biologist with the Environmental Protection Agency, assisted us in surveying for presence of fish, pool types, pool-riffle sequences, and embeddedness. We chose four sites along the mainstem of San Pablo Creek below the dam: Third Street and Parr Boulevard in North Richmond, California (Site 1), El Portal Drive in San Pablo, California (Site 2), Via Verdi in El Sobrante, California (Site 3), and La Honda at D'Avilla Road in El Sobrante (Site 4). The objective was to electro-shock, collect, and identify various fish specimens at all sites and assess the relative habitat quality. We chose Site 1 because it is near the mouth of the creek. We chose Site 2, the location of the culvert below I-80, to observe impediments to fish passage. Rob Leidy suggested that we survey Sites 3 and Site 4, identified in previous studies as adequate habitat for steelhead (Leidy, 1999).

We had intended to conduct pebble counts for the reaches on which we surveyed, but high levels of embeddedness precluded us for doing so. Instead, we conducted an ocular observation of embeddedness at the sites where we found fish. We conducted the same visual surveys at Appian and Wilkie Creeks in order to provide reference points.

Water Quality

We compiled over a year of data (September 2002 to December 2003) on temperature and dissolved oxygen from the San Pablo Watershed Neighbors Education and Restoration Society (SPAWNERS) to assess water quality.

Barriers

Using the Contra Costa County Watershed Atlas, we identified potential migrational barriers in the form of underground culverts. We walked the length of the culvert at Site 2 to assess potential barriers to fish passage.

RESULTS

Flow Analysis

Appian Creek

Based on velocity calculations using the orange peel method and area derived from width and depth of water at Appian Creek, discharge values measured in the field ranged from 0.25cfs on April 2, 2004, to 8.9cfs on March 25, 2004. A summary of stream gage height, area, velocity, and discharge at this station is located in Table 2.

Our corresponding roughness coefficient using the Manning Equation and Chow's Table was 0.049 (Figure 7). Using the cross-sectional measurements from the HWMs, we found an area of 34.03sq ft and a velocity of 1.88ft/s. The HWM-based flow calculations using the Manning Equation indicated a flow of 63.87cfs, with a unit runoff of 80.85 cfs/sq mi. This ratio gives a flow of about 900 cfs, which corresponds on the Wildcat Creek Flood Frequency Curve as a flood with a 4.6 year return interval (Table 3).

Wilkie Creek

Discharge measured in the field, using the orange-peel method this season, ranged from 0.34 cfs on April 17 to 17cfs on March 25. A summary of stream gage height, area, velocity, and discharge at this station is located in Table 2.

For Wilkie Creek, we found a roughness coefficient of 0.058 (Figure 7). The HWM was 5 ft above the thalweg for a total area of 39.5 sq ft and a velocity of 3.23 f/s. These HWMs indicated a flow of 126 cfs, with a unit runoff of 217.24 cfs/sq mi. That same ratio applied to Wildcat Creek corresponds to the 50-year flood (Table 3).

Castro Creek

Flow values ranged from 0.45 cfs on April 17 to 11.5 cfs on March 25. These results are summarized in Table 2.

Our result was a roughness coefficient value of 0.096 (Figure 8). The area corresponding to our HWM came to 59.13 ft, with a velocity of 5.53 ft/s. These HWMs corresponded to a flow of 326 cfs, and a unit runoff index of 534 cfs/sq mi. That same ratio applied to Wildcat Creek gives us a flow beyond the estimate of the 100-year flood (Table 3).

The rating curves for Appian, Wilkie, and Castro Creeks are included as Figures 9, 10, and 11.

Correlation of Field Surveys to Wildcat Creek

The nearest gaged station, Wildcat Creek, enabled us to correlate the HWMs to the return intervals (calculated from the annual peak flows). Analysis is limited to the 34-years of record for Wildcat Creek. We estimated the roughness coefficient as 0.055 based on the channel characteristics observed in the field and applying them to Chow's Table of roughness coefficient values. With the use of the Manning Equation, these points correspond to an area of 91.2 ft and a velocity of 3.77 ft/s, leading to a value for flow of 343.82 cfs. Using the Flood Frequency Curve, we found that this flood had a return interval of 1.65 years and a 60 percent chance of occurring in any given year (Figure 8). We then compared these values with other Bay Area Watersheds, including Alameda Creek, Arroyo Valle, and the Guadalupe River. The return interval for the year's peak storm (February 25) on other streams ranged from 1.2 to 2.0 years, very close to the value we derived for Wildcat Creek (Appendix B).

Habitat Surveys

Fish counts, pool-riffle habitat, diversity, and occurrence

The results of our fish counts are included in Figure 12. We only found fish at Site 1 and Site 4, although we checked for fish habitat at all four sites (Figures 13-16). Only Site 4 had an anadromous fish - a Sacramento sucker (*Catostomus occidentalis*).

We characterized Site 1 by analyzing the presence pools and riffles. The site had a mid-channel pool that was 199 feet long and 15 foot wide, below which was a low-gradient riffle (45.5-foot long and 12.8 feet wide). Below the riffle was a deeper plunge pool(65-feet long and 38-feet wide). This plunge pool was followed by another mid-channel pool (283-feet long and 22.8-feet wide (Figure 17). Using these numbers we found the percentage of habitat by occurrence was 7.7 percent riffle and 92.3 percent pools.

At Site 4, we found a long plunge pool (30-feet long and 16-feet wide) formed by the presence of large woody debris. Downstream of this pool was a low-gradient riffle (34-feet long and 8 feet wide).

Following the riffle, we surveyed a long lateral scour pool (79-foot long and 13 feet wide) (Figure 17). This site also contained areas of pocket water. We calculated the percentage of habitat by occurrence here as 23.8 percent riffle and 76.2 percent pool.

Embeddedness

At Site 1, we found an embeddedness factor of 40 percent with 100 percent fine-grained bed material (Figure 18).

At Site 4, we found gravel of appropriate size for spawning habitat. However, the embeddedness factor was 50-80 percent, and fine-grained bed sediment totaled 60 percent.

At Appian Creek, embeddedness totaled 70 percent with 30 percent fines at our cross section survey site. At Wilkie Creek, we found an embeddedness factor of 10-20 percent with 20 percent fine-grained bed material.

Water Quality

According to SPAWNERS' monitoring records, San Pablo Creek's temperature peaked at 18°C in August and September 2002 and dipped at 11°C in January through March, 2003. The temperature reached 14°C during the first month of the spawning season, December, but dropped below 13°C soon after (Figure 19). San Pablo Creek's dissolved oxygen level varied from a low of 5.3 mg/l in September 2002 to a high of 10.6 mg/l in December of 2003. Most months of data collection clustered around a neutral level of 7 mg/l (Figure 20).

Barriers

San Pablo Creek flows primarily above ground, only culverted under the I-80 freeway near the border of San Pablo and El Sobrante. This culvert is split into three sections with lengths ranging from 440 to 673 feet each (Figure 14). With the assistance of Rob Leidy, we walked the length of the culvert, observed the culvert's slope, width and height, and concluded that the culvert would be passable by an anadromous fish.

DISCUSSION

Flow analysis

Monitoring of the stream gages on the three tributaries will continue through the dry season to validate the existing curve and add data points. Monitoring flows in the lower watershed will help determine the baseline of flow to the mainstem, which can assist us in determining if San Pablo Creek has a deficit of water.

To date, the three tributaries provide a minimum of 1.04 cfs. According to Contra Costa County records, San Pablo Creek's mean daily flow is 32 cfs for the entire watershed (Contra Costa County Community Development, 2003). However, there is no existing data for low flows for comparison.

Peak flows for 2004 varied dramatically between the Manning's, Waananen and Crippen, and Rantz methods. One explanation is that Rantz developed his method based on creeks and rivers with drainage basins greater than 5 sq mi (Rantz, 1971). The San Pablo Creek tributaries have drainage areas less than 1 sq mi each.

Habitat Surveys

Fish count

During our survey of fish, we caught and identified one Sacramento sucker (*Catostomus occidentalis*) above the I-80 culvert on San Pablo Creek. This fish is potamodromous, meaning that it migrates from large bodies of water to streams for spawning. Therefore, this fish could have possibly navigated from San Pablo Bay up through San Pablo Creek, through the existing I-80 culver, proving this stream modification is passable. The sucker favors similar spawning habitat as steelhead, i.e. a mixture of sand, gravel, and/or cobbles. The presence of this fish in San Pablo Creek could be an indicator of habitat quality for steelhead.

Pool-riffle type, diversity, and occurrence

The lower reach of San Pablo Creek at North Richmond, Site 1, contained two mid-channel pools. According to McCain et al. (1990), these pools represent critical habitat during the spawning period for steelhead. The El Sobrante station, Site 4, contained plunge pools and lateral scour pools, appropriate for smolts a year or older. They both had a combination of pools and riffles with pools exceeding 75 percent of the total occurrence. The proportion of channel area composed of riffles and pools is a useful index of habitat quality, and a stream with approximately 50 percent pools is generally considered to possess good habitat attributes. Under most conditions, however, the proportion of pool area typically varies from 30 to 70 percent total stream area (Ruggles 1966, Platts et al. 1983). This tells us that there is a surplus of pool habitat, but possibly not enough riffle habitat available. Riffles increase oxygen availability that may help salmonids cope with the stress of high water temperatures during summer low flow conditions (Higgins, 1994).

Embeddedness

Our ocular assessment of embeddeness indicates a high level of fine sediment (an average of 65 percent for the mainstem). Sediment may be accumulating from landslides and construction sites in the El Sobrante Valley. On our second survey day, April 3, 2004, silt had already started to settle on the gravels, only one week past a storm. So, though the gravel sizes were appropriate for spawning, the embeddedness of the gravels would prevent viable spawning.

According to Eleanor Lloynd, long-term El Sobrante resident, development in the El Sobrante Valley boomed in 1955-1956. During this period, development occurred along the mainstem of San Pablo Creek as well as along Castro Creek and an intermittent tributary (E. Lloynd, Town of El Sobrante, personal communication, 2004). With limited regulation for controlling sediment on construction sites, it is highly probable that current sedimentation condition is a product of increased development in the area, which continues to date. On our April 3 visit to the watershed, we observed construction of condominiums near Sites 3 and 4.

Water Quality

Water temperature plays an integral role in spawning habitat; steelhead eggs hatch in thirty days when the temperature is optimally below 13°C. Water temperature above 21°C can be lethal to adults (California Department of Fish and Game, 1998). In August and September, temperature of the main steam peaked at 18°C, below the critical temperature for steelhead.

When dissolved oxygen levels sink below 5-6 mg/l, impacts may begin, although rainbow trout are known to survive conditions as low as 1.5-2.0 mg/l (Leidy, 2004, personal communication). Even if the lack of oxygen does not kill an organism, it is likely to make it more susceptible to other environmental stresses. San Pablo Creek dipped as low as 5.3 mg/l in September, 2002. This data is limited by sampling design, as dissolved oxygen levels vary by time of day and associated temperature. To thoroughly determine San Pablo Creek's water quality, we would want to measure for dissolved oxygen and temperature several times per day.

Conclusions

The stream gage component of the project will continue beyond the scope of this term paper to determine summer base flows from the tributaries to San Pablo Creek, the primary sources of surface water during the summer months. We will consider installing another gage on San Pablo Creek, below the confluences of the three tributaries, to determine if there are other sources of water contributing to mainstem flow. We should also consider installing a stream gage in the upper watershed above the San Pablo Reservoir to determine stream discharge above the dam. We can compare our results to nearby streams with gage data known to have anadromous fish (such as Pinole and Wildcat Creeks).

The habitat surveys of San Pablo Creek's mainstem show that rearing habitat is plentiful in this watershed, specifically in the form of pool diversity, presence of riffles, water temperature and dissolved oxygen content. However, habitat quality assessments should be repeated during the summer seasons to determine if pools persist through the dry season. We should conduct these assessments during the spawning season as well to determine if habitat is available for all life stages of steelhead trout. In reality, the entire length of the lower mainstem should be surveyed (11-miles total) for the presence of habitat types and their relative quality levels.

Our measurements show levels of fine sediment in the bed far exceed the tolerance limits for steelhead trout spawning and rearing. The construction of the dam, while reducing the supply of sediment to the lower watershed, also limits transport flows. A more thorough analysis of percent embeddedness throughout the mainstem should be conducted. Sources of sediment should be identified and classified as mass wasting, surface erosion, stream bank erosion, or construction erosion. Where possible, these sources should be remedied, possibly through bank stabilization or Best Management Practices (BMP). BMP's are structural and nonstructural practices proven effective in soil erosion control and management of surface runoff. For example, construction sites could be required to keep sediment on site with the use of sediment traps or incorporate the revegetation of bare slopes as a component of the development (Appendix D).

Steelhead fish need enough flows to be attracted to natal streams and to continue upstream passage, as well as adequate flows for migration from the creek to the bay (Leidy, 2004, personal communication). They also require gravels appropriate for spawning. San Pablo Dam directly limits discharge to the lower watershed and indirectly prevents the replenishment of adequate spawning gravels from upstream sources. Since the removal of the dam is unlikely, EBMUD should consider releasing water during the summer months to maintain quality flows for fish habitat. Options for improving spawning habitat include stocking gravels below the reservoir in conjunction with limiting the amount of fine sediment from construction sites.

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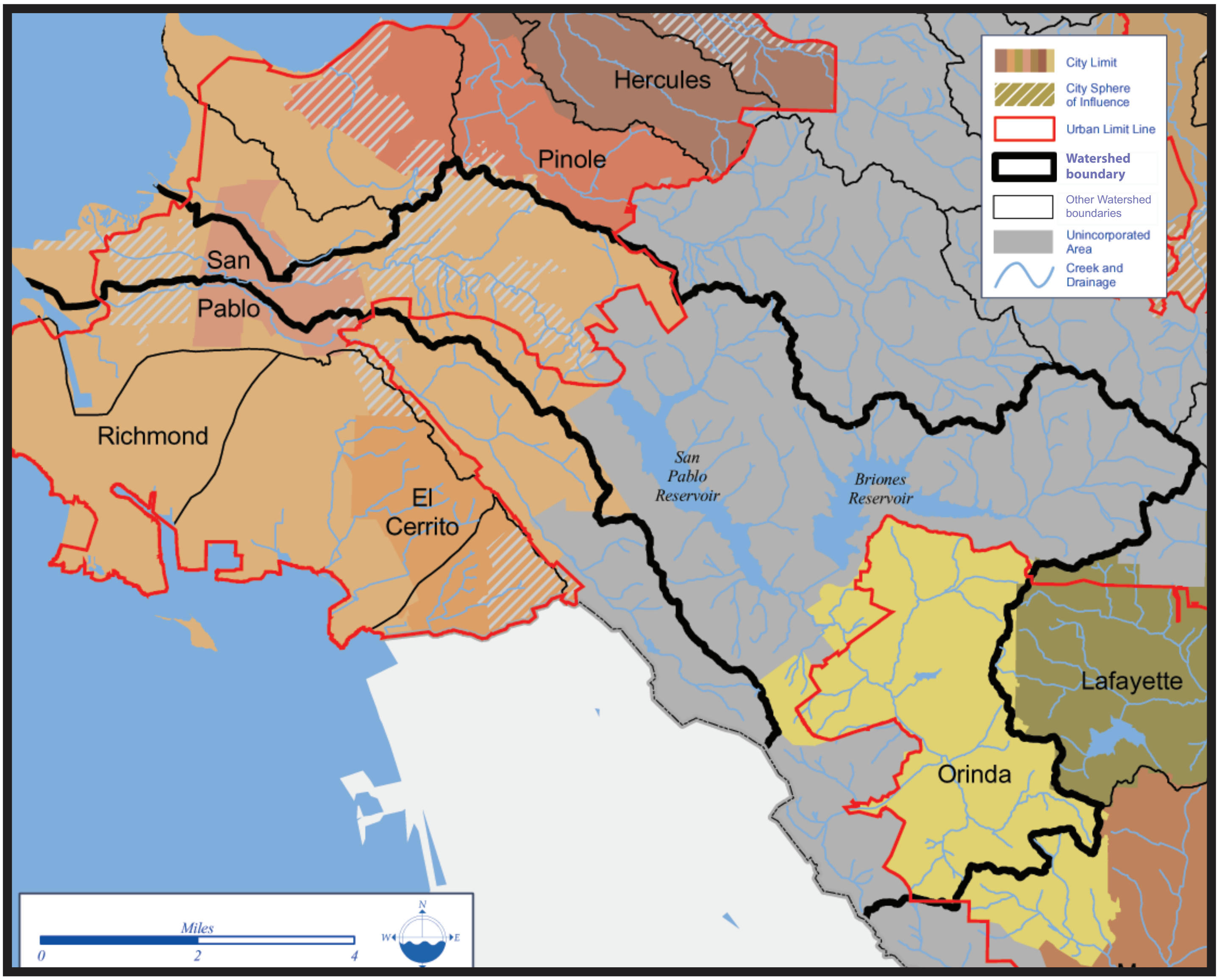
The authors of this paper would like to thank Rob Leidy, Sarah Pearce, and Dave Shaw for their assistance.

FIGURE 1 : LOCATION MAP
SAN PABLO CREEK WATERSHED



Source: Contra Costa County

Figure: 2 Steelhead Trout Habitat Needs

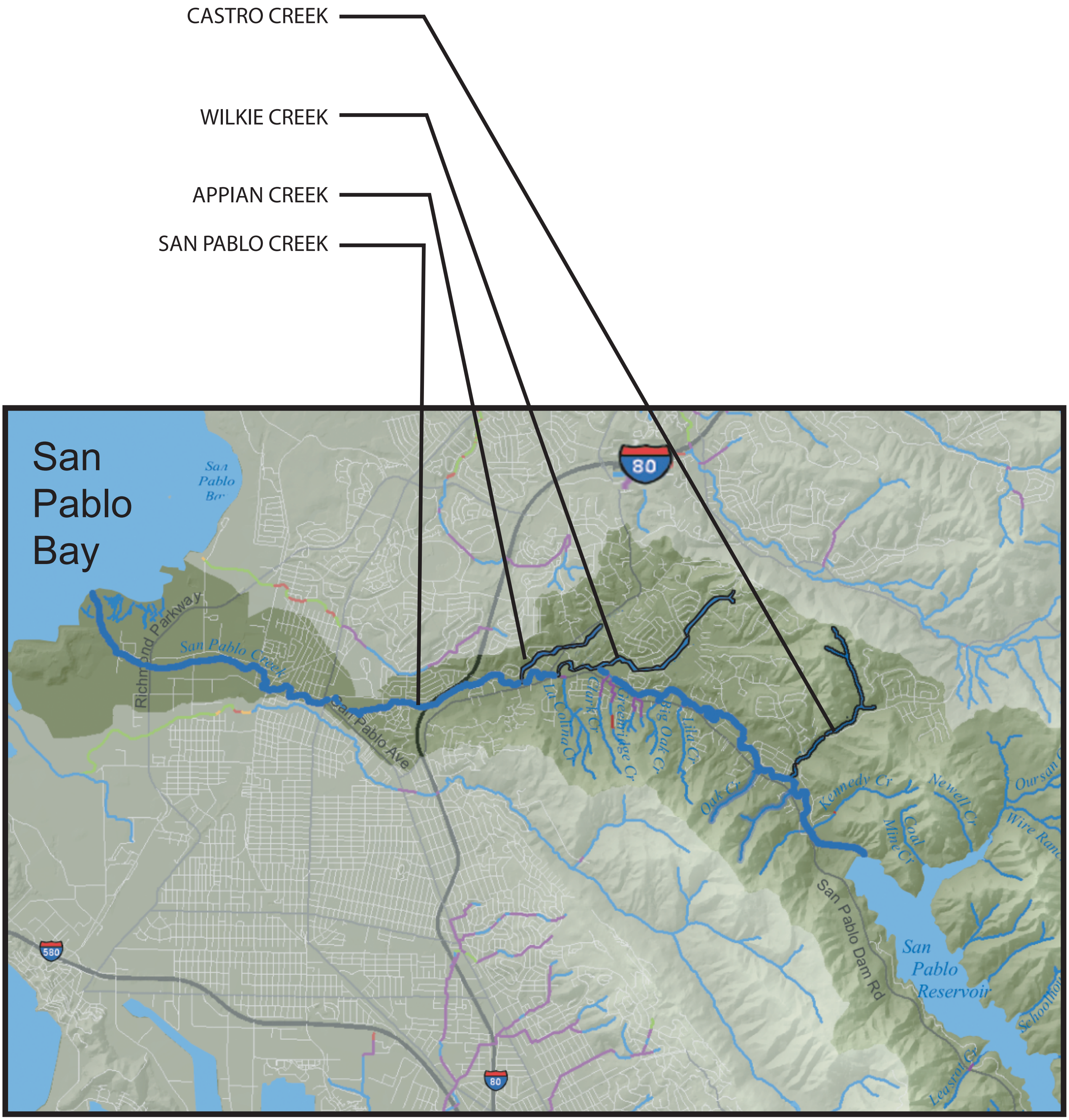
	Spring	*Summer*	*Fall*	*Winter*
Steelhead 0+ Rearing	Edgewater	All habitat types	Pocket water, backwater pools, secondary channel pools	Pocket water, backwater pools, scour pools
Steelhead 1+ Rearing	Lateral scour pools, runs	Pocket water, lateral scour pools	Pocket water, back water pools, secondary channel pools	Pocket water, back water pools, secondary channel pools
Spawning	Mid-channel pools, lateral scour pools, pocket water		Mid channel pools, lateral scour pools, pocket water	Mid channel pools, lateral scour pools, pocket water

Definitions:

- **Edgewater** is a quiet, shallow area found along the margins of the stream, most typically associated with riffles.
- **Backwater pools** are found along stream margins, and are formed by nearby obstructions.
- A **lateral scour pool** is formed by flow hitting a partial channel obstruction, such as large woody debris.
- **Pocket water** is a combination of swift flowing stream sections with large obstructions, creating eddies or scours holes (pockets) behind these obstructions.
- **Secondary channel pools** are formed outside of the wetted channel; they typically dry up during the summer.
- A **run** is a swiftly flowing reach with little surface agitation and no major flow obstruction.

Adapted from McCain et al. 1990. *Summary of Habitat Types and Measured Parameters.* http://www.dfg.ca.gov/nafwb/pubs/manual3.pdf

FIGURE 3 : CREEK MAP
SAN PABLO CREEK WATERSHED



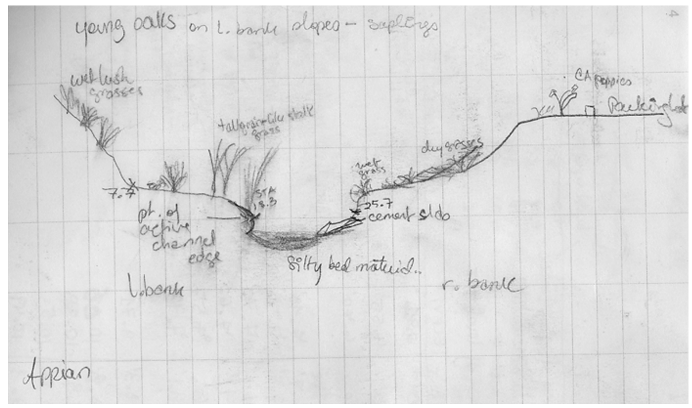
Souce: Contra Costa County

Figure 4: Cross-section Survey Sites: Flow Measurements

Appian Creek

Cross-section survey site

Site area during rainfall

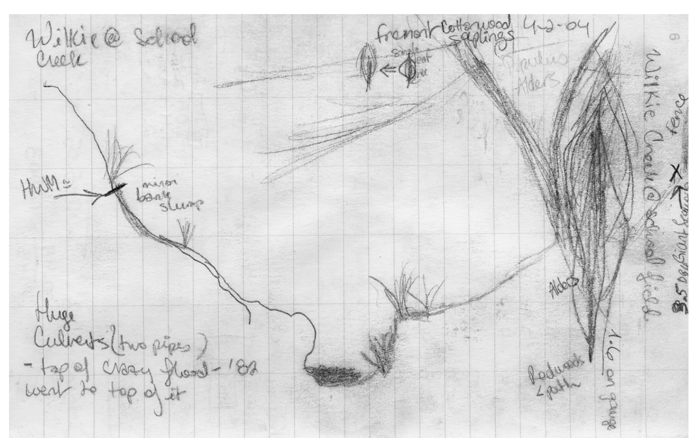


Cross-section field sketch

Wilkie Creek

Cross-section survey site

Left-bank culvert



Cross-section field sketch

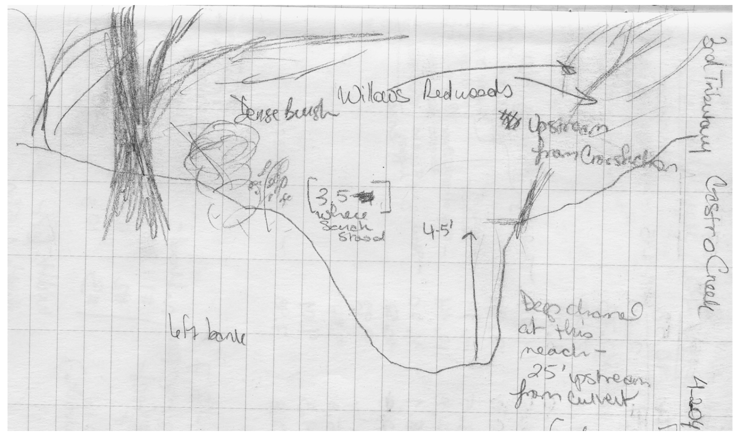
Figure 5

Cross-sectional Survey Sites: Flow Measurements

Castro Creek

Cross-section Survey Site

Lorraine and Sarah hold up the culvert leading to 8-ft cement steps

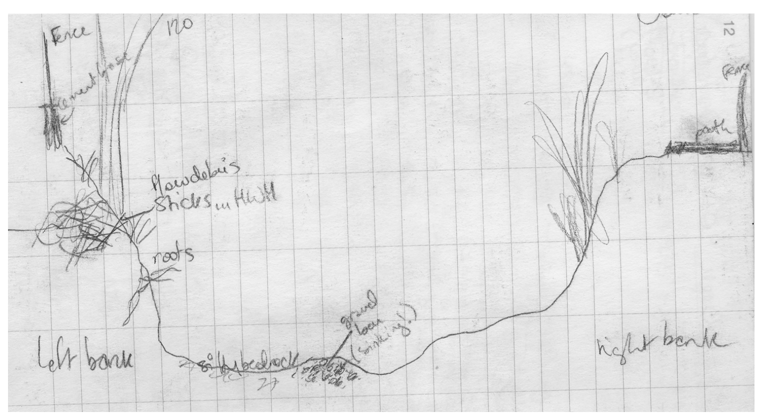


Cross-section field sketch

Wildcat Creek

Cross-section Survey Site

High Water Mark



Photos and sketches from April 2, 2004 field survey

Cross-section field sketch

Figure 6: Wildcat Creek Flood Frequency Curve

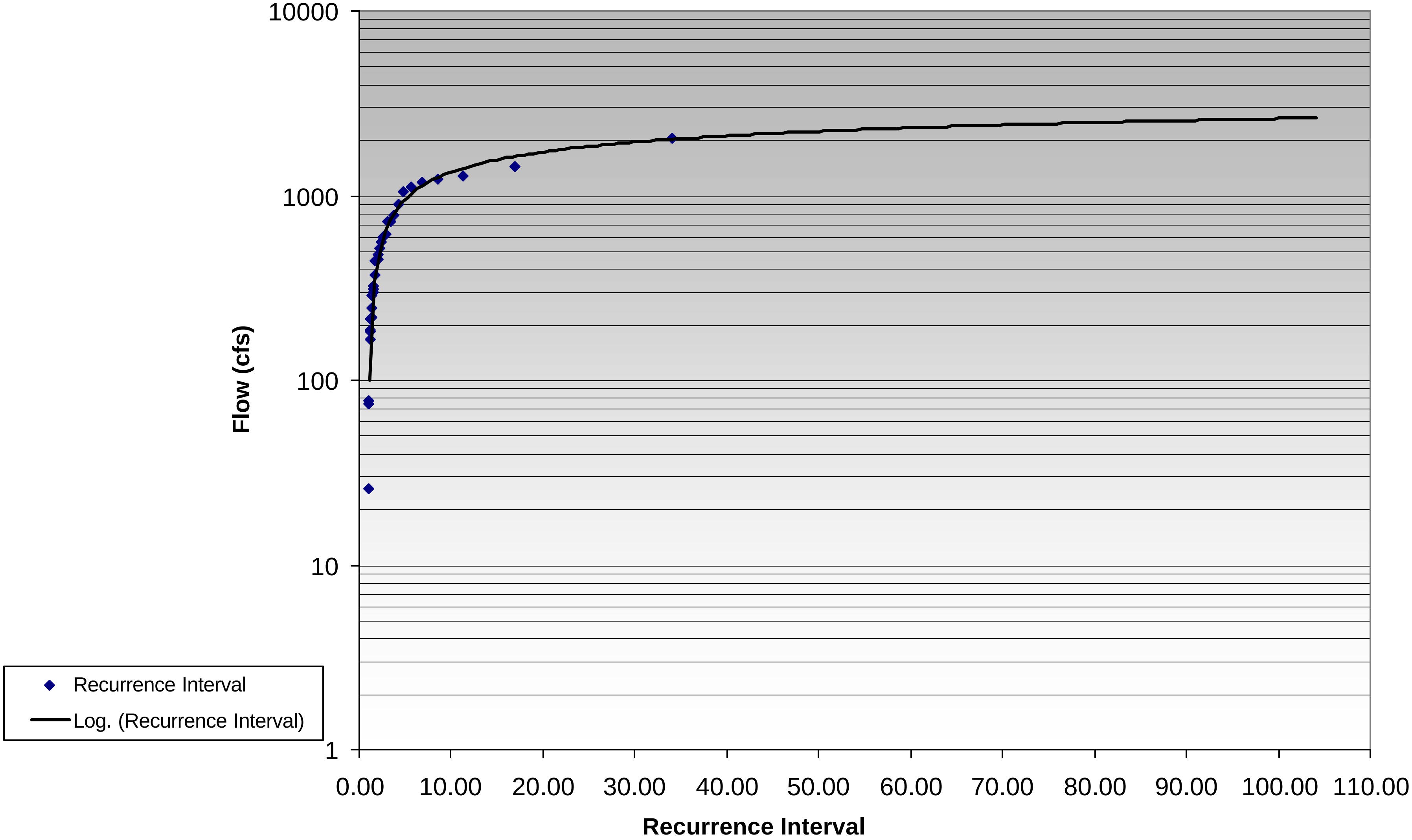
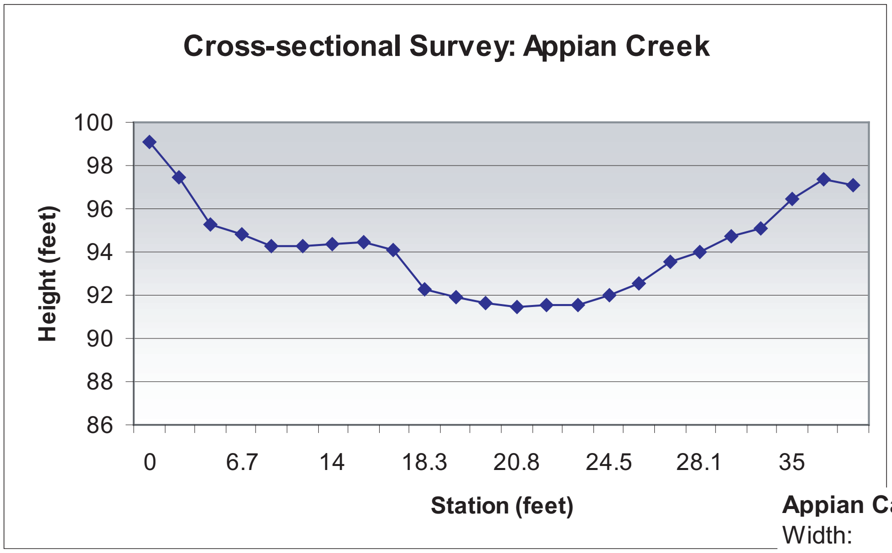


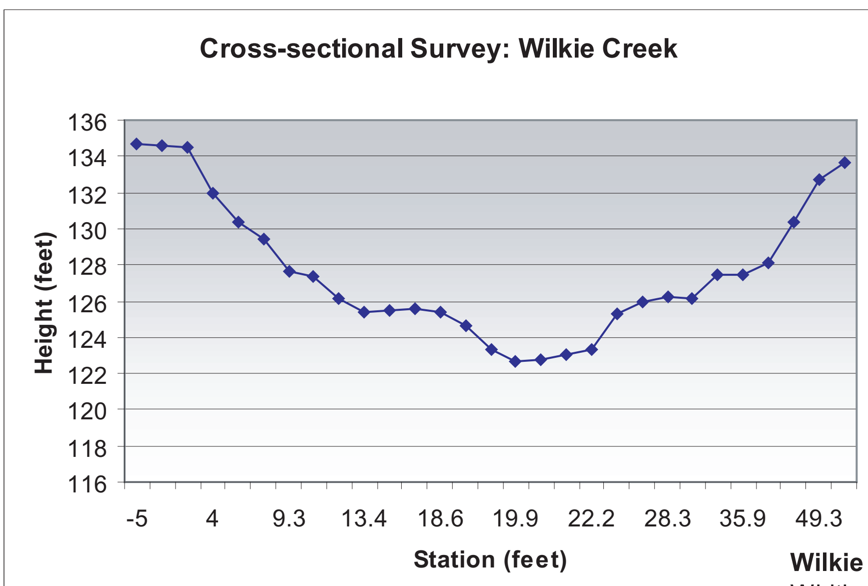
Figure 7

Cross-section Sites: Flow Measurements using the Manning Equation



Appian Calculation for 2004 HWM based on cross-sectional data

Width:	25.7-18	7.7 (off grid from cross-section)		
Depth:	94.75-91.51	3.25 feet		
Area:	1.5*6 (for left	34.025	S=0.003	
Wetted Perimeter:		28.5		
R:		1.19	n:	0.04888
			n0:	0.02
V:	1.49*1.12*.054/0.048		n1:	0.005
V:	1.88f/s		n2:	0.004
For Last Probable storm event:			n3:	0.008
Q:	**63.87cfs**		n4:	0.01
			m5:	1.04

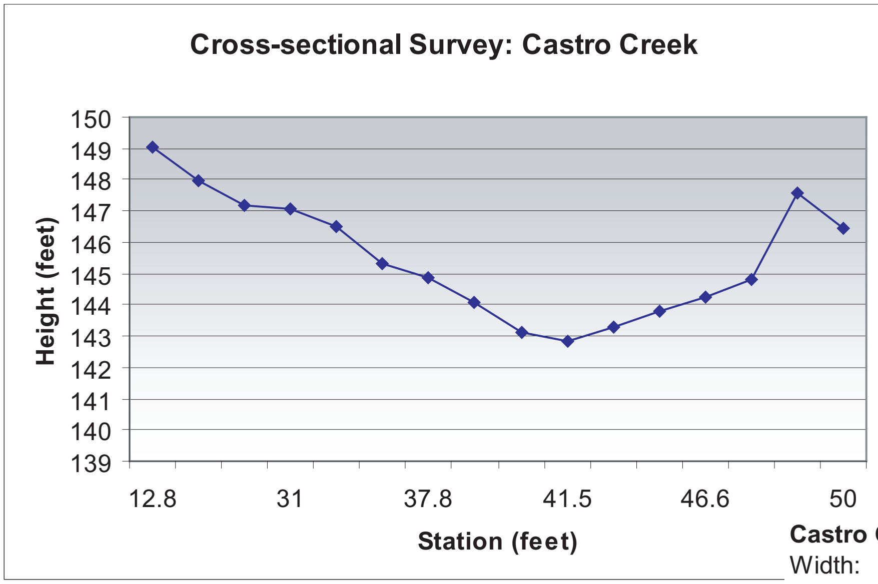


Wilkie Calculation for 2004 HWM based on cross-sectional data

Width:	28.3-15.6	8.7 (off grid from cross-section)		
Depth:	127.3-122.	4.54		
Area:	1.5*6 (for le	39.498	S=0.01	
Wetted Perimeter:		28		
R:		1.41	n:	0.05778
			n0:	0.02
V:	1.49*1.26*.1/0.058		n1:	0.008
V:	3.23f/s		n2:	0.004
For Last Probable storm event:			n3:	0.01
Q:	**126cfs**		n4:	0.012
			m5:	1.07

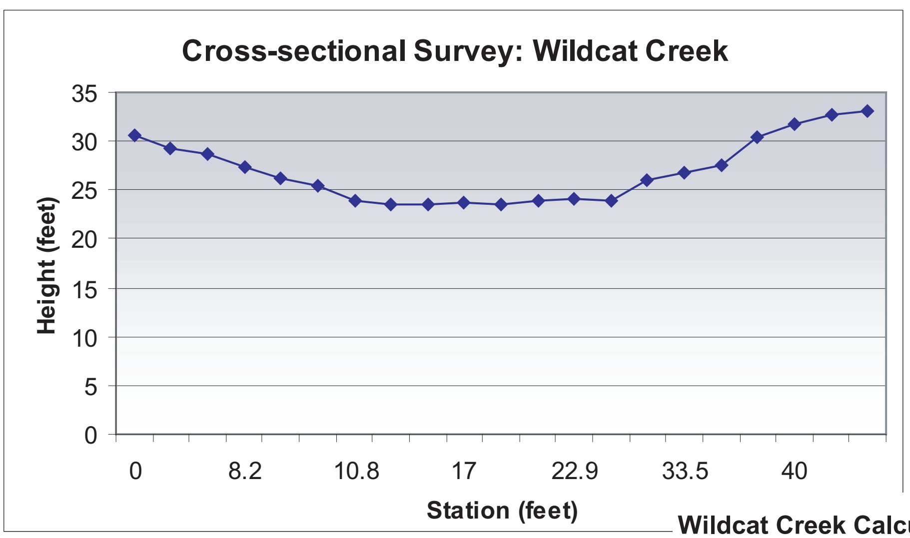
Figure 8

Cross-section Sites: Flow Measurements using the Manning Equation



Castro Calculation for 2004 HWM based on cross-sectional data

Width:	12.5 (off grid from cross-section)		
Depth:	4.73		
Area:	59.125	S=0.04	
Wetted Pe	25		
R:	2.365	n:	0.09592
		n0:	0.02
V:	1.49*1.78*.2/0.096	n1:	0.01
V:	5.53ft/s	n2:	0.007
For Last Probable storm event:		n3:	0.03
Q:	326.0cfs	n4:	0.021
		m5:	1.09



Wildcat Creek Calculation for 2004 HWM based on cross-sectional data

Width (34.5-11.7):	22.8 (off grid from cross-section)		
Depth:	4 feet		
Area:	91.2	S=13.82-13.42/100	
		Slope:	0.004
Wetted Perimeter:	28		
R:	3.26	n:	0.055
		n0:	0.022
V:	1.49*2.21*.063/0.055	n1:	0.004
V:	3.77f/s	n2:	0.005
For Last Probable storm event:		n3:	0.012
Q:	**343.82cfs**	n4:	0.01
RI: 1.65 years		m5:	1.04

probability of occurring any given year is 60%

Figure 9: Appian Creek Rating Curve

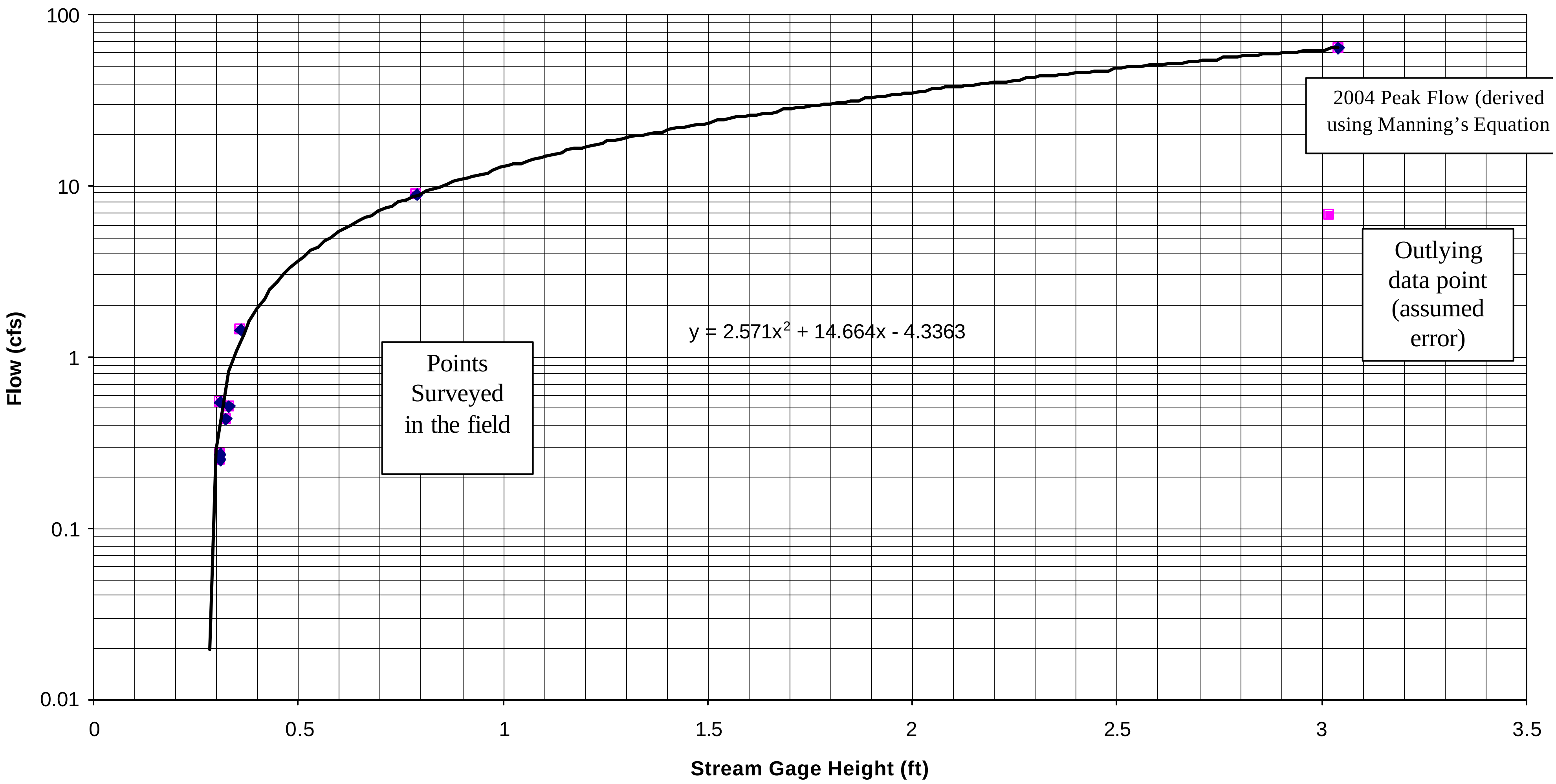


Figure 10: Wilkie Creek Rating Curve

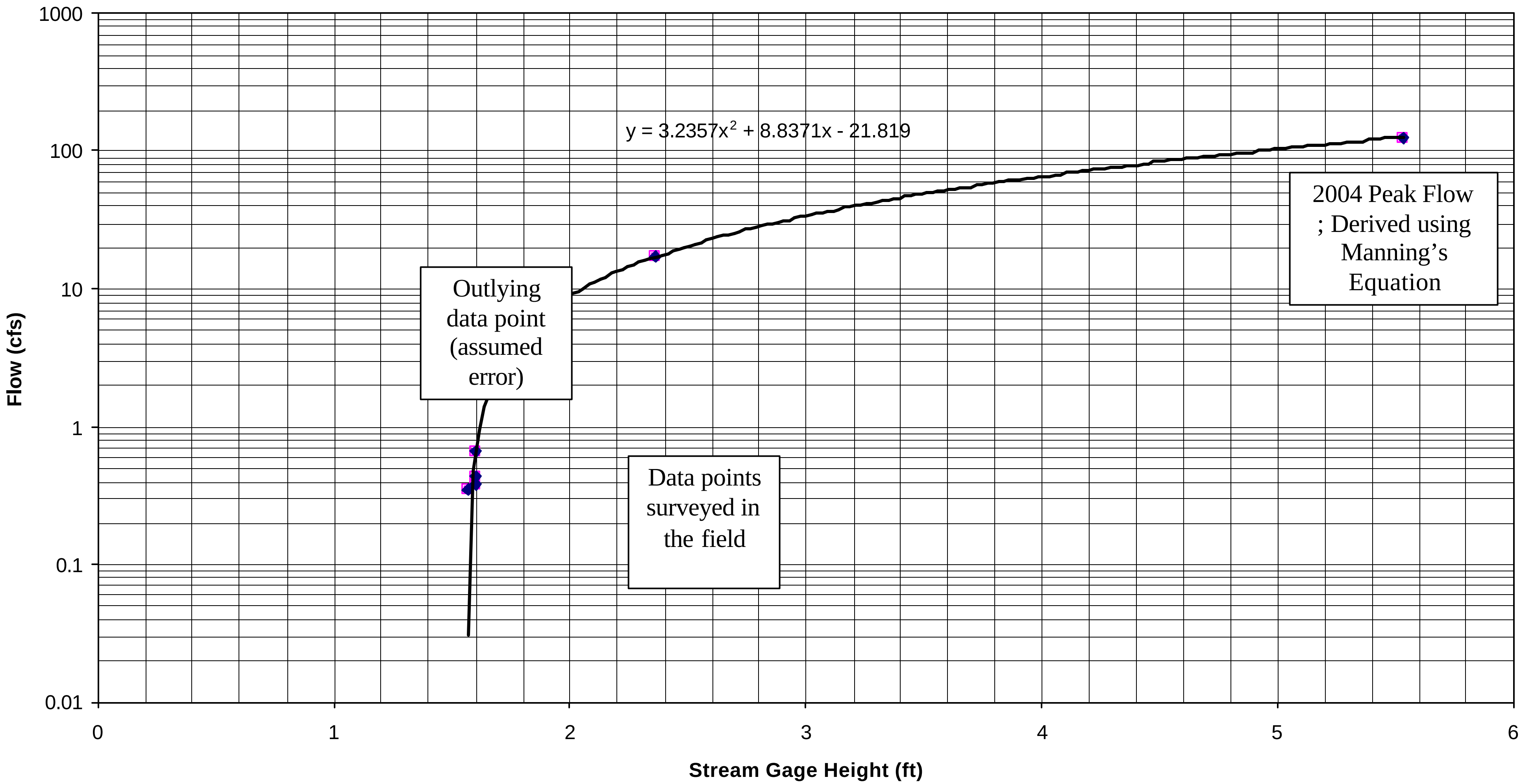


Figure 11: Castro Creek Rating Curve

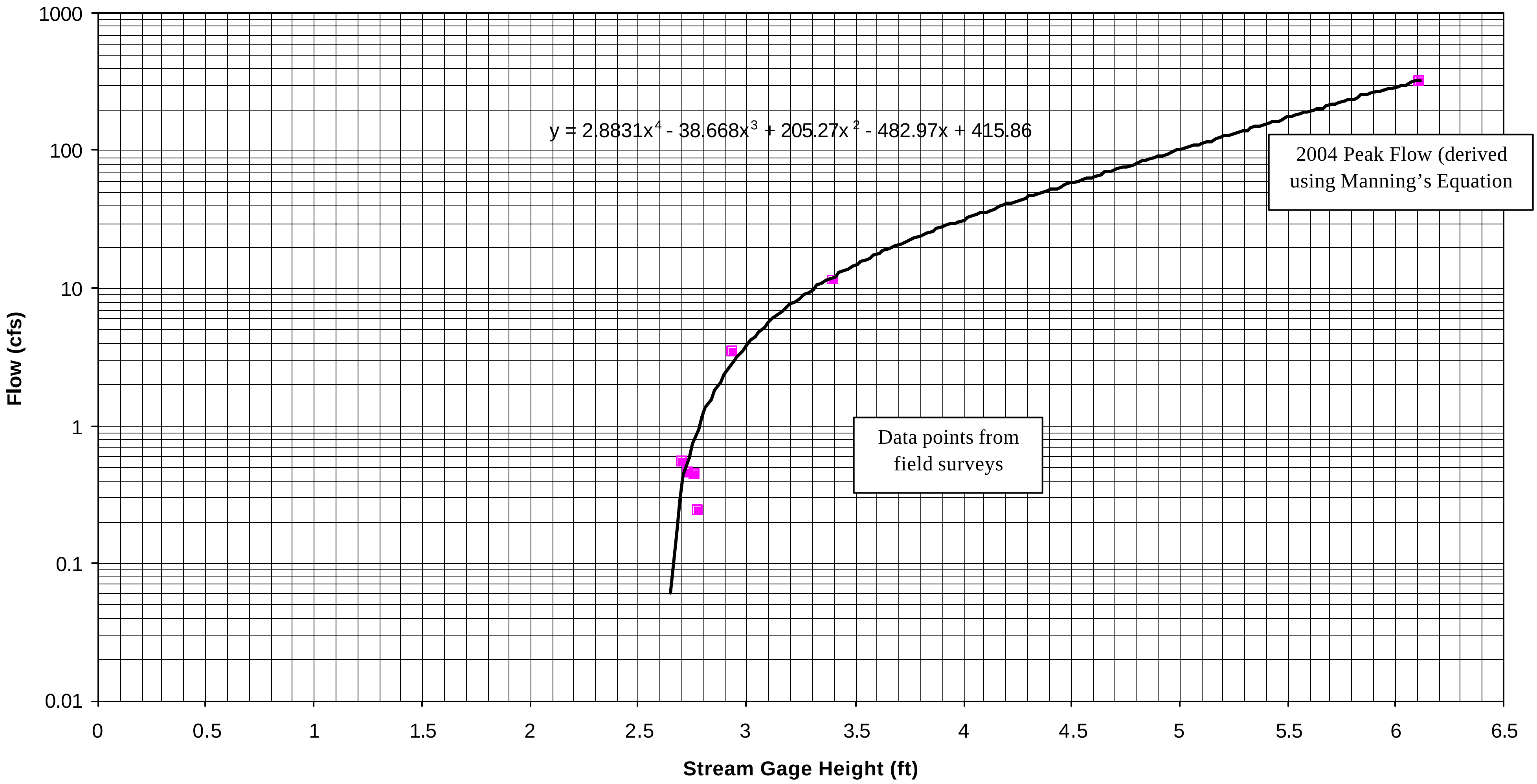


Figure 12

Habitat Field Evaluation: Catching Fish

Rob Leidy from the EPA with the electro-shock box: this equipment provides the voltage needed to shock fish for two seconds, just enough time to net, bucket, and measure them.

Rob, Shannah, and Elizabeth (from the Watershed Project) at work.

The Sacramento sucker, our big catch of the day.

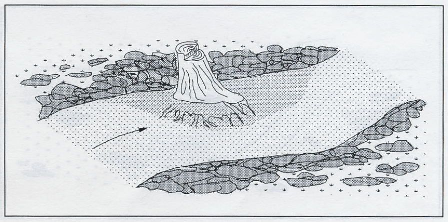
San Pablo between Parr and Third	**San Pablo at EBMUD Treatment Station**
Prickly Scalpin (Cotus asper)	Sacramento sucker
135mm	240mm
109mm	
100mm	Stickleback
80mm	6 found, range of 25-45mm
California Roach (endemic minnow)	
78mm	
62mm	
Stickleback	
55mm	
52mm	
50mm	
49mm	
48mm	
45mm	
45mm	
45mm	
45mm	

Figure 13

San Pablo Creek Sites: Fish Habitat Assessment

Site 1: San Pablo Creek
between Parr and Third St.

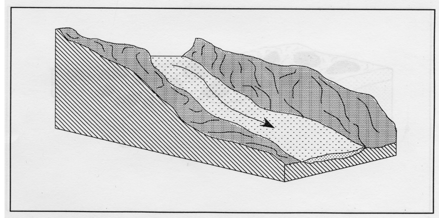
LATERAL SCOUR POOL - ROOT WAD ENHANCED (LSR) [5.3] {11}



Formed by flow impinging against a partial channel obstruction consisting of a root wad. The associated scour is generally confined to < 60% of the wetted channel width.

Lateral scour occurs beneath the vegetation along the left-bank, with exposed roots from willows and cottonwoods.

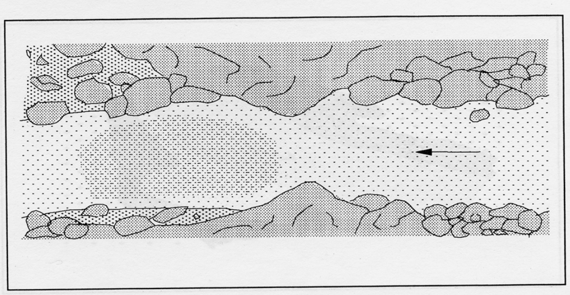
BEDROCK SHEET (BRS) [2.2] {24}



A thin sheet of water flowing over a smooth bedrock surface. Gradients are highly variable.

The site has an upstream bedrock sheet which can obstruct fish passage at high flows.

MID-CHANNEL POOL (MCP) [4.2] {17}



Large pools formed by mid-channel scour. The scour hole encompasses more than 60% of the wetted channel. Water velocity is slow, and the substrate is highly variable.

*Habitat Type Descriptions from California Salmonid Stream Habitat Restoration Manual, State of California Resources Agency Department of Fish and Game. January 1998.

The site is composed mainly of a mid-channel pool.

Figure 14

San Pablo Creek Sites: Fish Habitat Assessment

Site 2: San Pablo Creek at Interstate 80

This site was assessed as the single largest obstruction to fish passage along San Pablo Creek. The I-80 culvert is 200 feet long and bends, though its gradient is low enough for the fish to swim upstream (Rob Leidy, EPA).

Just downslope from the highway, we found a large leak -possibly an EBMUD waterpipe- draining into the San Pablo creek below.

Figure 15

San Pablo Creek Sites: Fish Habitat Assessment

Site 3: San Pablo Creek at Via Verde

This site has an extremely silty bed and many pools and riffles, but has formerly been surveyed for fish habitat. After an initial ocular assessment, we decided not to pursue fish counting in this area., as it was an unlikely spawning habitat.

Site 4: San Pablo Creek between D'Avilla and La Honda (EBMUD Treatment Plant)

Stairs lead down from the EBMUD treatment plant to the creek.

Thick vegetation borders the creek at the site.

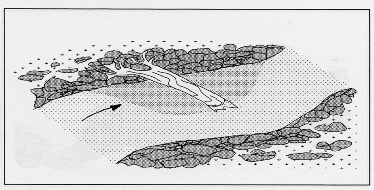
Figure 16

San Pablo Creek Sites: Fish Habitat Assessment

Site 4: San Pablo Creek between D'Avilla and La Honda (EBMUD Treatment Plant)

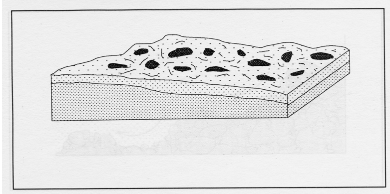
This site has low-gradient riffles in combination with plunge pools.

LATERAL SCOUR POOL - LOG ENHANCED (LSL) [5.2] {10}



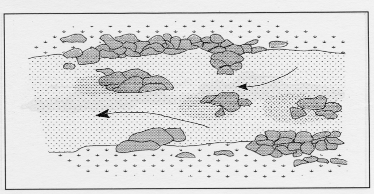
Formed by flow impinging against a partial channel obstruction consisting of large woody debris. The associated scour is generally confined to < 60% of the wetted channel width.

LOW-GRADIENT RIFFLE (LGR) [1.1] {1}



Shallow reaches with swiftly flowing, turbulent water with some partially exposed substrate. Gradient < 4%, substrate is usually cobble dominated.

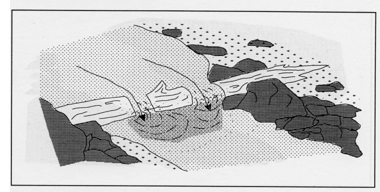
POCKET WATER (POW) [3.1] {21}



A section of swift-flowing stream containing numerous boulders or other large obstructions which create eddies or scour holes (pockets) behind the obstructions.

Lateral scour pools enhanced by logs and woody debris are characteristic of this site, as are sections of pocket water eddies and scour holes.

PLUNGE POOL (PLP) [5.6] {9}

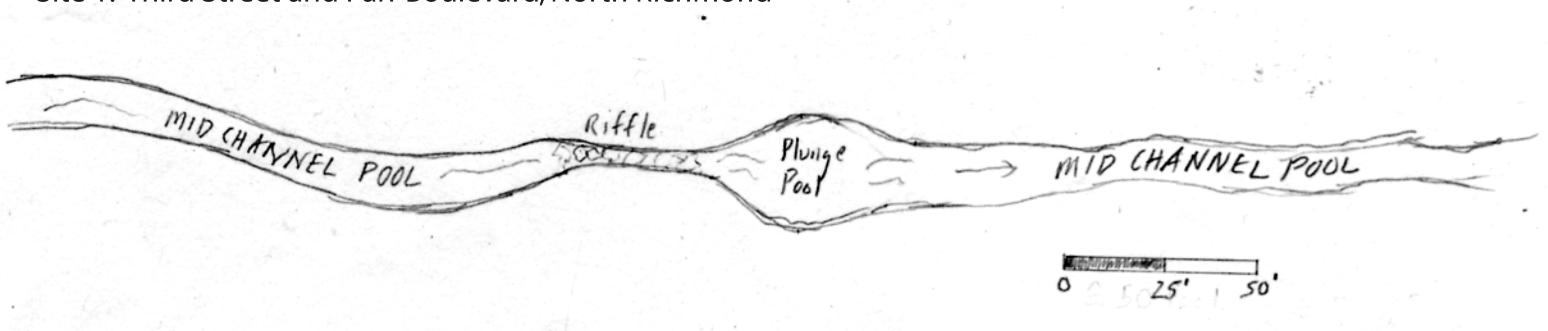


Found where the stream passes over a complete or nearly complete channel obstruction and drops steeply into the streambed below, scouring out a depression; often large and deep. Substrate size is highly variable.

*Habitat Type Descriptions from California Salmonid Stream Habitat Restoration Manual, State of California Resources Agency Department of Fish and Game. January 1998.

Figure 17: Pool Riffle Sequence Sketches

Site 1: Third Street and Parr Boulevard, North Richmond



Site 4: D'Avilla and La Honda Roads, El Sobrante

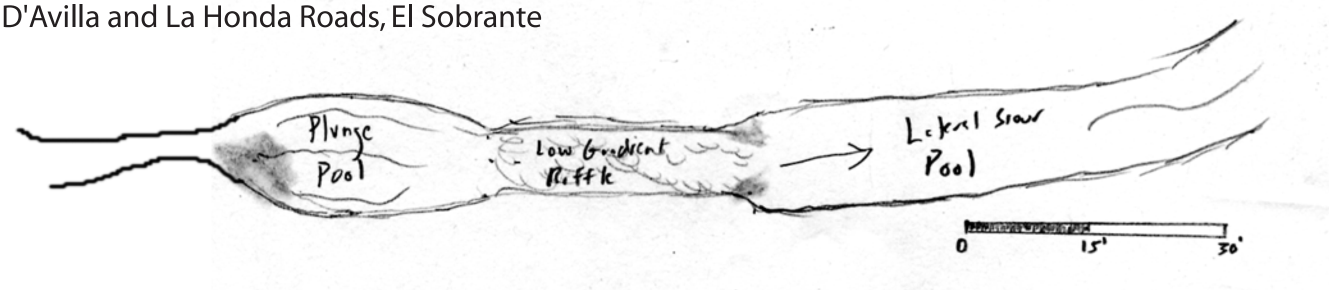
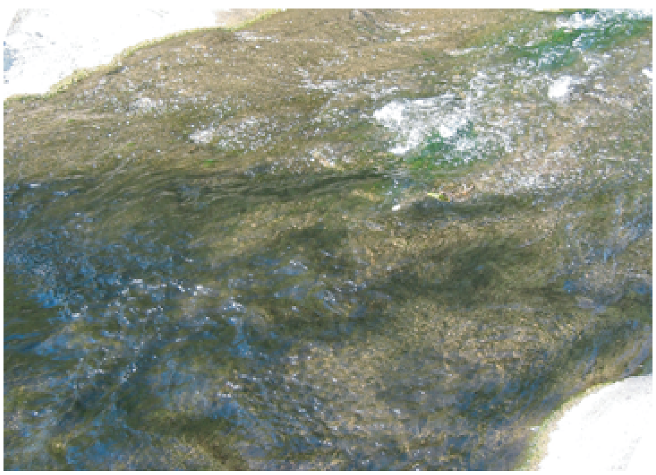


Figure 18

Creekbed Characteristic and Sediment Analysis of Sites

Appian Creek
*70% embeddedness, 30%fines

Wilkie Creek
*10-20% embeddedness, 20% fines



Site 1

San Pablo Creek at Parr and Third Street

*40% embeddedness,
100% fines

*100% Bedrock upstream
from surveyed pools and riffles
sites

Site 4

San Pablo Creek at EBMUD Plant

*50%-80% embeddedness,
60% fines

Figure 19 - San Pablo Creek Water Temperature

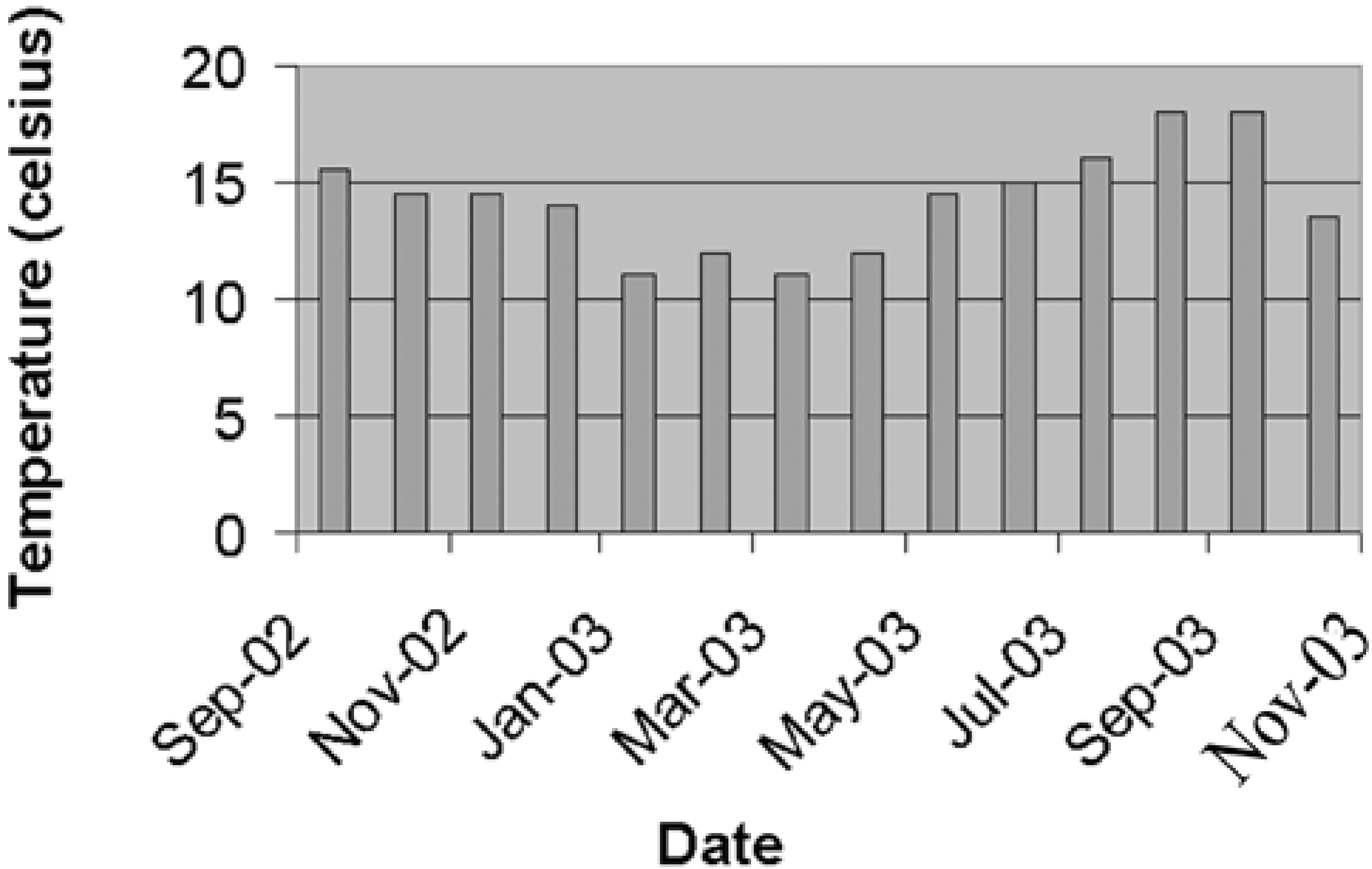


Figure 20- San Pablo Creek Dissolved Oxygen Levels

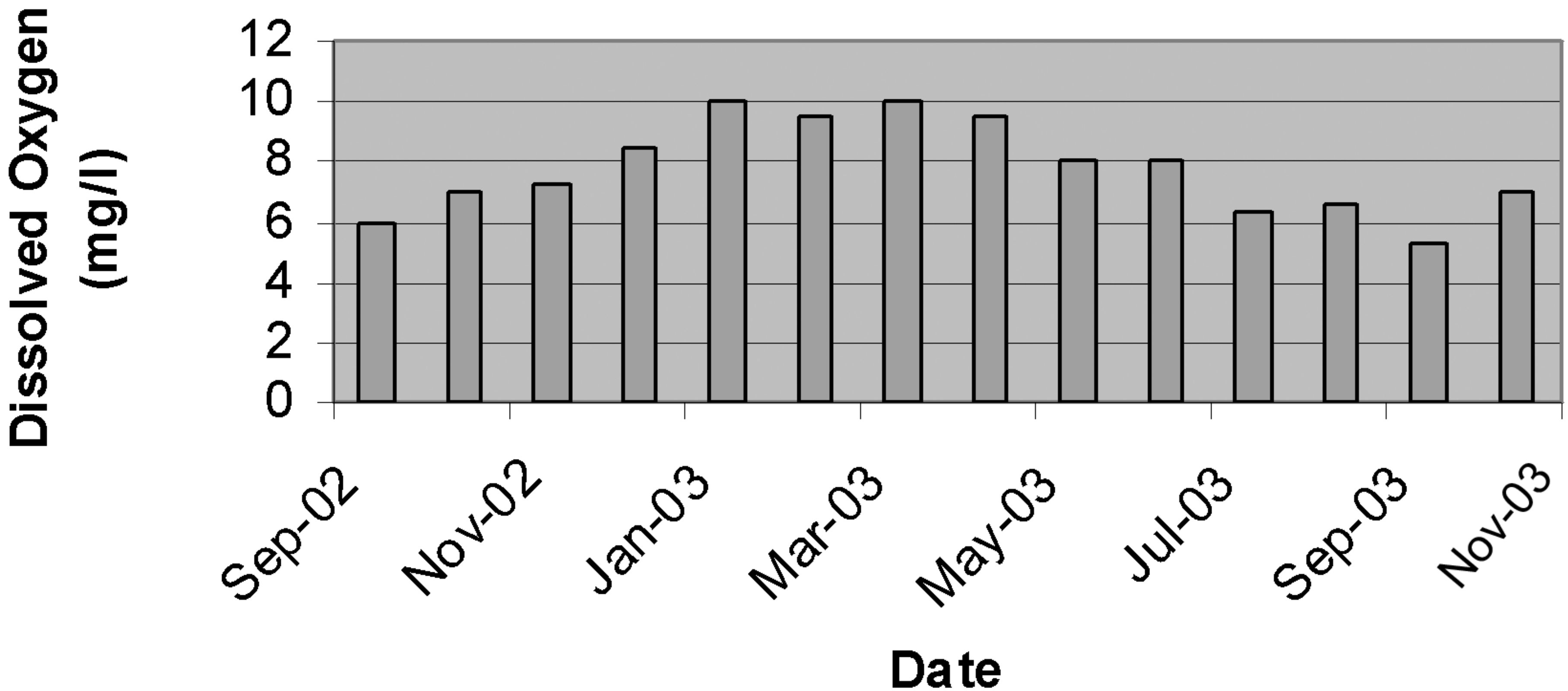


Table 1: Chow's Roughness Coefficient Values

TABLE 5-5. VALUES FOR THE COMPUTATION OF THE ROUGHNESS COEFFICIEN… BY EQ. (5-12)

Channel conditions			Values
Material involved	Earth	n_0	0.020
	Rock cut		0.025
	Fine gravel		0.024
	Coarse gravel		0.028
Degree of irregularity	Smooth	n_1	0.000
	Minor		0.005
	Moderate		0.010
	Severe		0.020
Variations of channel cross section	Gradual	n_2	0.000
	Alternating occasionally		0.005
	Alternating frequently		0.010–0.015
Relative effect of obstructions	Negligible	n_3	0.000
	Minor		0.010–0.015
	Appreciable		0.020–0.030
	Severe		0.040–0.060
Vegetation	Low	n_4	0.005–0.010
	Medium		0.010–0.025
	High		0.025–0.050
	Very high		0.050–0.100
Degree of meandering	Minor	m_5	1.000
	Appreciable		1.150
	Severe		1.300

Source: Chow, V.T. 1959. *Open Channel Hydraulics*. McGraw-Hill Company, New York.

Table 2: San Pablo Creek Tributaries Stream Flow Monitoring

Date	Average Distance	Average Rate (seconds)	Velocity	Velocity *0.8 (feet/ second)	Average Water Width (feet)	Average Water Depth	Area	Flow (cfs)	Stream Gage Height (feet)
Appian Creek									
2/29	20.00	35.00	0.57	0.46	3.56	0.89	3.18	1.45	0.36
3/15	25.00	82.67	0.30	0.24	3.56	0.59	2.11	0.51	0.33
3/25	25.00	11.33	2.21	1.76	4.61	1.10	5.06	8.93	0.79
3/26	25.00	36.67	0.68	0.55	3.22	3.83	12.35	6.74	3.02
3/29	25.00	84.67	0.30	0.24	3.42	0.54	1.85	0.44	0.32
4/2	18.00	30.67	0.59	0.47	2.13	0.25	0.53	0.25	0.31
4/10	8.50	13.00	0.65	0.52	3.13	0.33	1.04	0.55	0.31
4/17	4.70	5.49	0.86	0.68	3.15	0.29	0.92	0.27	0.31
Peak								64.00	3.04
Wilkie Creek									
3/19	33.00	68.67	0.48	0.38	5.17	1.60	8.25	*3.17*	1.59
3/26	63.00	29.33	2.15	1.72	*1.71*	0.13	0.23	*0.39*	1.60
3/25	25.00	9.67	2.59	2.07	5.17	1.60	8.25	*17.07*	2.36
4/2	55.40	22.00	2.52	2.01	1.80	0.18	0.33	*0.66*	1.60
4/10	44.00	19.33	2.28	1.82	1.50	0.16	0.24	*0.43*	1.60
4/17	24.00	7.47	3.21	2.57	1.40	0.10	0.14	*0.35*	1.57
Peak								*126.00*	5.53
Castro Creek									
2/29	20.00	8.67	2.31	1.85	3.75	0.50	1.88	3.46	2.94
3/25	72.33	27.67	2.61	2.09	12.00	0.46	5.50	11.50	3.40
3/26	72.33	52.70	1.37	1.10	1.71	0.13	0.22	0.24	2.78
4/2	17.00	10.67	1.59	1.28	3.50	0.13	0.44	0.56	2.70
4/10	72.33	50.00	1.45	1.16	3.55	0.11	0.39	0.45	2.76
4/17	33.00	16.49	2.00	1.60	3.90	0.07	0.29	0.46	2.73
Peak								326.00	6.11

Tributary Drainage Area	Basin Area (sq mi)	(acres)	Creek Length (mi)	
Appian	0.79	505.05	1.7	
Wilkie	0.58	370.18	2.17	
Castro	0.61	390.27	1.89	
San Pablo*	19.83	12691	11	*based on averages (3) on two different maps (one topo, one smaller watershe*
Wildcat Creek	10.7	6848	13.43	

***Calculations correspond to the area downstream from the San Pablo Dam (our area of focus)**

Table 3: Comparison of Peak Flow Values

Creek Name	**Method Used to Calculate Peak Runoff Values**			
	Rantz*	**Waananen and Crippen**	**HWM with Manning Equation**	**HWM Flow Recurrence Interval Based on Wildcat Creek Unit Runoff Index**
Appian	Q2=31.05cfs Q10=117.78cfs *Rantz Method doesn't incorporate calculation of Q100	Q2=164.30cfs Q10=308.93cfs Q100=468.97cfs	63.87cfs	4.6 years
Wilkie	Q2=24.38cfs Q10=90.27cfs	Q2=69.65cfs Q10=128.07cfs Q100=300.99cfs	126cfs	50 years
Castro	Q2=26.54cfs Q10=96.03cfs	Q2=57.58cfs Q10=151.69cfs Q100=292.70cfs	326cfs	100+ years