Post Project Evaluation of Miller Creek (Marin, CA) Restoration: Vegetation Survival

FINAL DRAFT

by Jantrue Ting with Caitilin Pope-Daum

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Prof. Matt Kondolf

University of California, Berkeley

ABSTRACT

We evaluated the survival of planted riparian vegetation within a restored reach of Miller Creek in Marin County, CA, and analyzed survey results to identify factors affecting tree survival. We surveyed three plots approximately 100 feet square within the restored reach. Of the three plots surveyed, the most downstream plot has the highest plant survival rates. The survival rates of tree species in the three plots, from upstream to downstream, were 35%, 43%, and 88%, respectively. Despite early irrigation, many of the trees planted in the two upstream plots have died, but both plots are slowly developing vegetative complexity, with volunteer shrubs filling in gaps and providing protection for new tree saplings. Our analysis of tree species survival by plant elevation, aspect, susceptibility to inundation, and soil types, indicated three likely important factors: location along the creek, aspect, and local geology and soil conditions. In future stream restoration projects, it may be cost-efficient to study the area's soils, underlying geology, and seasonal water table elevations to maximize plant survival rates. Alternately, a planting strategy that mimics natural succession would require more planning but might be more effective.

INTRODUCTION

Miller Creek, located in central Marin County, California, starts on Big Rock Ridge and runs for about nine miles east through Las Galinas Valley into the San Pablo Bay (Figure 1). Its watershed, roughly four square miles, consists of forested and grazed lands in its upper reaches, residential developments through its middle reaches, and agricultural uses on the alluvial plain. The restoration project area, which is located approximately two miles from the headwaters, is in a seasonal reach of the stream. The creek was restored in 1990 in conjunction with the development of Lucas Valley Estates, a housing development adjacent to the creek. Historic land use patterns such as cattle grazing had significantly altered the creek's morphology: increased runoff from compacted soils and damaged native hillside vegetation, as well as trampled riparian vegetation, had resulted in a deeply incised and widened creek and tributaries (Vandivere 1985). Recent urbanization of the middle reaches of the watershed had similar net effects. Increased impervious surfaces have decreased infiltration and contributed to larger, flashier runoff flows that have exacerbated incision and erosion. The restoration project aimed to protect the new housing development from further channel widening by stabilizing creek and tributary banks and to restore riparian habitat through grading and planting vegetation (Vandivere 1985).

In 2003, UC Berkeley students Caitilin Pope-Daum and Wan-Chih Yin conducted a post-project evaluation of the restoration project. Their comparison of surveyed cross-sections and designed sections showed that the project had stabilized the channel, as the two were nearly identical (Pope-Daum and Yin 2003). However, they found evidence that some of the vegetation had not survived in upstream locations. While some die-off is to be expected in any restoration project, one would not expect to see large, dead trees more than a decade after planting.[1] Furthermore, riparian vegetation in downstream portions of the project were dense and the creek well-shaded. They concluded that while the project had been successful in stabilizing creek banks, it had not fully met the goal of restoring riparian habitat.

This project seeks to both methodically evaluate the survival of riparian vegetation within the restored reach and examine possible factors affecting tree survival.

[1] Notes on the planting plans indicate that the designers anticipated 50 percent of the willows to survive and 75 percent of the trees to survive (Guzzardo 1989b, L-1).

METHODS

Vegetation Mapping

We conducted vegetation surveys of three plots along the creek on April 4, 2004. Each plot measured approximately 100 feet (ft) square. Two of the plots correspond to sections surveyed by Pope-Daum and Yin (sections 46 and 38 in their report and in project documents), while the third is further downstream from their project area (Figure 2). Due to heavy vegetation and the lack of a nearby benchmark, we did not take a cross-section at the third plot. Instead, we used the original design grading plan from 1989 to draw a section and assumed this to be fairly accurate because Pope-Daum and Yin found only minor changes between the designed and surveyed sections (Guzzardo and Associates, 1989c). For each plot, we mapped vegetation by stretching a tape straight, in roughly the direction of the creek for 100 ft. We mapped the locations of trees, shrubs, and other features such as ground cover and grade changes by stretching another tape perpendicular to the first. For trees, we measured approximate heights and trunk diameter in inches (in) at breast height (dbh) – a standard measurement of trunks four and a half feet above the uphill ground surface. For shrubs, we only recorded heights. We looked for evidence of deer grazing, such as eaten leaves and branches, or a shrubby stature of trees, and for indicators of planting, such as wire cages and irrigation hoses. For ground cover, we marked where changes occurred, such as from sand to gravel to grass. We also recorded areas with sand deposits and the height of high water marks to determine an active floodplain. Finally, we recorded abrupt grade changes in order to correlate the maps with the previously recorded cross-sections (Pope-Daum and Yin 2003) and to determine the extent of flooding.

Using the cross section locations, the location of large trees, and bends in the creek, we determined approximately where our plots were on the original design planting plans. We visually compared our vegetation maps with the design planting plans to determine whether or not planted vegetation survived (Guzzardo and Associates 1989a, b).

Vegetation Survival Analysis

We then analyzed vegetation survival for four possible correlations: plant elevation, aspect, geology and soils, and susceptibility to inundation (i.e. whether or not the plant is in the active floodplain). We analyzed the data by tabulating the number of planned trees and surviving trees by species and factor, and looked for correlations between survival and the four factors.

Elevation – By comparing our vegetation maps with area cross-sections, we determined the approximate elevations of the plants in each plot. The sections for plot 1 and 2 were taken from Pope-Daum and Yin's sections for station 46 and 38, respectively (2003), and the section for plot 3 was drawn from the original grading plan for station 18 (Guzzardo and Associates 1989c). We looked at elevation because we noticed that downstream locations looked healthier than upstream locations, and some species seemed to do better closer to the thalweg.

Aspect – We used our vegetation maps to determine which bank the plant was on, and the context map shows that the left bank is south-facing. Plants on the south-facing slope face more stress in the summer than those on the north-facing slope because of more sun exposure. In general, south-facing slopes in Mediterranean climates are characterized by annual grasses and shrubs, while north-facing slopes are characterized by forests.

Susceptibility to Inundation – In order to determine this year's active floodplain, we compared our survey maps with area cross-sections (Pope-Daum Yin 2003, Guzzardo and Associates 1989c). We determined the location of the active floodplain by using the location of sand and silt deposits and the heights of high water marks. Plants within the active floodplain need to be flood-tolerant, while those outside need to be able to withstand longer drought periods and drier soils.

Geology and Soils – We used a U.S. Geologic Survey (USGS) geologic map for the San Francisco Bay Area and a U.S. Department of Agriculture (USDA) Soil Conservation Service (SCS) soils map for Marin County to determine the underlying geology and soils of the three plots (Blake et. al. 2000; Kashiwagi 1985). The geology and soils of the plots could be important because of the differences in water table levels of different geologic bases and the different drainage rates and water holding capacities of different soil types.

RESULTS AND DISCUSSION

Vegetation Mapping

Figures 3 to 5 show the three plots, looking downstream. Figures 6 to 11 compare the three vegetation maps to the original design planting plans from 1990. Although we found a few dead trees (some as tall as 15 ft), the majority of vegetation that did not survive had washed away. Many of the trees planted in the two upstream plots have not survived, while most in the downstream plot have.

Table 1 shows the common and scientific names, number of each plant species found and/or planted, and the survival rate of each species in each plot. Because planting plans are only general guidelines for planting, and no as-built drawings are available, this analysis is prone to error, especially for shrubs species, which seem to have been substituted for one another during planting.

Figure 12 compares overall survival rates of the three plots, by bank side. Note that the right bank of plot 3 was not shown in the planting plans, and was not included in the analysis. We noticed two trends. First, survival rate is correlated with plot. The downstream plot has the highest overall survival rate, the middle plot has a medium survival rate, and the upstream plot has the lowest survival rate. It is important to note that Pope-Daum and Yin observed perennial stream flow downstream of the study area and intermittent flow upstream in the dry fall season (2003). Second, more trees on the right bank survived in the upstream plot, while survival rates were about even in the middle plot. Of course, the analysis in this report is qualitative; the small number of individual trees in our survey means that any conclusions that we draw are statistically insignificant.

Plot 1: Upstream

Plot 1 is our most upstream plot. It corresponds to station 46 in the original restoration project plans and in Pope-Daum and Yin's report. As shown in Figure 3, the left bank has fewer trees and shrubs than the right. Figures 6 and 7 show the original planting plan and our vegetation survey for this plot. In general, more of the trees and shrubs planted on the right bank have survived (Figure 12). The creek channel is relatively free of vegetation, except for a small gravel bar that has formed in the middle of the channel and is slowly being covered with young willows and horsetails. Deer grazing has stunted the growth of many of the trees and shrubs in this plot.

<u>Left Bank</u> – In general, the trees planted on the left bank have not survived (Figures 6 and 7). Native annual grasses and forbs such as purple needle grass cover the left bank up to the mature bays and oaks at the top of the bank outside of the restored area. Medium-sized volunteer coyote brush (3 ft to 5 ft tall) dot the bank. The trees that have survived are generally small and shrubby, due to deer grazing and/or other unfavorable conditions. High on the bank, a small live oak (4 in dbh) has survived, and has spread a few oak seedlings around it. Further downstream,

and lower on the bank, two alders have survived but appear unhealthy, tangled in their wire cages with their main stems truncated (Figure 13).

Right Bank – For the most part, the plantings on the right bank have been more successful than those on the left (Figures 6 and 7). Annual grasses and forbs, as well as a few alders, toyons, and coyote brush characterize the upstream part of the right bank. The alders on this bank are healthier and larger than those found on the left bank (Figure 14). The downstream portion has denser vegetation, with tall coyote brush (6 ft to 9 ft) and willow (up to 30 ft). While most of the plantings have survived, the bays, snowberries, and numerous California blackberries planted in this section have not survived. Additionally, deer have grazed on the lone live oak, rendering it small (1.5 in dbh) and shrubby. Though the planting plan does not show any elderberry, we found a heavily grazed elderberry "protected" by a wire cage in approximately the location of the planned snowberries. It is possible that elderberries were planted instead of snowberries. Also, we found willow in the downstream section instead of in their planned location in the upstream half of the plot.

Plot 2: Middle

Plot 2 is our middle plot. It corresponds to station 38 in the original restoration project plans and in Pope-Daum and Yin's report. Figures 8 and 9 show the original planting plan and vegetation survey for this plot. As in the first plot, the left bank is more open and grassy, with occasional shrubs, while the right bank has more trees and shrubs (Figure 4). Deer have grazed on the plants in this section, especially on the oaks. Heavy sand deposits cover the grasses and forbs on both banks.

Left Bank – On the left bank, two stands of willows of approximately the same age (both are 5 to 6 ft tall) frame the creek bed. These were probably planted, but they are not shown in this particular site on the planting plan. However, a similar clumped pattern was planned (and planted) upstream from this site. Behind the willows, the floodplain is covered with annual grasses and forbs, and dotted with coyote bush of different ages. Two clumps of Himalayan blackberry have established themselves, but none of the California blackberry planted have survived. All of the alders and ash planted in this section have died (Figure 15). The ash have washed away, but the two alders (10 and 15 ft tall) appear to have survived until recently. Two alders further upstream from the plot have also fared poorly. Further up on the bank, outside of the floodplain, two buckeyes have survived and are healthy (both 10 ft tall).

Right Bank – Vegetation on the right bank varies greatly with elevation. Within the floodplain, native annual grasses and forbs dominate, with occasional coyote brush and elderberry. Outside of the floodplain, we observed a mixture of trees and larger shrubs. In the downstream portion, planted live oaks, alder, and ash thrive. These trees are interspersed with volunteer coyote brush and elderberry (Figure 16). We also found an empty wire cage right at the edge of the floodplain, but could not determine from the planting plan what might have been planted. In the middle portion, elderberry planted higher up on the bank (likely substituted for the coffeeberry on the plan) have thrived, while two lower on the bank have died. Smaller, shrubby oaks and coyote brush that have been grazed on by deer dominate the upstream portion. Of these, only the valley oak is on the plan; the rest are likely seedlings that have been sheltered by the coyote brush (most are under a foot tall).

Plot 3: Downstream

Plot 3 is our downstream plot. It corresponds to station 18 in the original restoration project plans. Figures 10 and 11 show the original planting plan and vegetation survey for this plot. Compared to the other two plots and the designers' anticipated success rates, the restoration planting in this plot was effective (Figure 5). Unfortunately, the planting plans only show the left bank (Figure 10). On the plan, the right bank was planned to be riprapped and seeded with grasses. Currently, the right bank supports a fair number of seedlings and young trees, including live oak, valley oak, buckeye, and ash. Newer wire cages suggest that the valley oak (all 18 in tall) were recently planted. The creek bed is lined on both sides by large, dense willows. In contrast to the two upstream sites, the creek is narrower and more shaded in this reach. The planned check dam (riprap) is visible at the bend in the creek created by the gravel bar and willows. Our analysis only considers the left bank, as the right bank was not designed or planted until recently.

Left Bank – On the left bank, all of the trees (except one ash) and most of the shrubs have survived (Figure 11). However, like the alder on the left banks of plots 1 and 2, the alder in this plot has few leaves and dry branches (Figure 17). Willows dominate the creekside, while grasses and forbs cover the rest of the floodplain and higher banks. The downstream portion of the higher bank is characterized by an oak and ash canopy, and a coffeeberry, toyon, coyote brush (volunteer), and raspberry (volunteer) understory. The shrubs provide cover for the oak, willow, buckeye, and ash seedlings.

Vegetation Survival Analysis

Table 2 details habitat characteristics and needs of the different species observed in the project. With these habitat characteristics in mind, we examined the four variables – geology and soil, bank and aspect, susceptibility of inundation, and elevation – for correlations with survival rates. Due to the lack of consistency between the planting plan and vegetation surveys for shrub species, we decided to focus on the survival rates of trees only for this part of the analysis. We found that while many shrubs that had wire cages around them or growing in straight rows, indicating that they had been planted, they were not shown on the planting plans. Therefore, it was difficult to discern which shrubs on the planting plan had actually been planted.

Elevation

Figures 18 to 20 show the three schematic cross sections in relation to their plots. The sections for plots 1 and 2 are from Pope-Daum and Yin's study (2003). The section for plot 3 is drawn from the original grading plan (Guzzardo 1989c). None are entirely precise because the channel is always changing, but they are sufficient for our purposes. Table 3 and Figure 21 show the results of our elevation analysis. Table 3 includes only those trees planted, and whether or not they survived. There did not seem to be any strong correlation with elevation, except that trees seemed to either survive or die at a particular location. For almost all of the elevations, the survival rate of a species was either 0 or 100 percent. Figure 21 shows tree survival with elevation and height above the thalweg. It shows all individuals to give a sense of where certain species grow, both within plots and between plots. The planting schemes for the three plots look similar, in terms of trees and their height above the thalweg. Alders were planted lower in the floodplain, while oaks were planted higher. However, while almost all of the trees in the third plot survived, many of those in the upper two plots, even those planted low in the floodplain, did not. This could be due to a lower water table in the upstream section of the creek, or another unknown factor. Trees tended to survive or die in clumps, which indicates that local factors play a large role in survival. In order to determine the height of the water table, more studies would need to be done. Downstream of the study plots, the stream is perennial, while upstream areas have intermittent flow, suggesting that the summer water table might be higher downstream. Piezometers installed at different locations, and monitored throughout the dry season, would show if this is the case.

Aspect

We hypothesized that the trees planted on the left bank might be more vulnerable to sun exposure and stress in the summer because they are south-facing (Figure 1). In Mediterranean climates such as the Bay Area's, south-facing slopes are generally covered in annual grasses and shrubs, while north-facing slopes are more forested. Table 4 shows the survival rates of each tree species by aspect/bank side. Figure 12 also shows variation in overall survival rates by bank side.

In our three plots, most of the trees planted on the right bank had higher rates of survival than those planted on the left. All three alder planted on the right bank have survived and are healthy, while of the four planted on the left bank, only one has survived and is not healthy. Ash have slightly higher rates of survival on the right bank than left (1 of 2 compared to 2 of 6). Both of the two ash that survived on the left bank were in plot 3, where they were shaded by willows. None of the valley oaks or bays planted on the left bank survived, while 67 and 33 percent, respectively, of those planted on the right bank did. All were shrubby due to deer grazing. All of these species can tolerate seasonal flooding and need moist soils (Uchytil 1989, Owston 1990, Howard 1992a, Howard 1992b).

Of the six tree species planted, coast live oak were the only species that had higher survival rates on the left bank than the right. All 5 coast live oak planted on the left bank survived, while only 3 of the 5 planted on the right bank did. It should be noted, however, that 4 of these are in plot 3, where they were shaded by fast-growing willows and also out of the floodplain. Coast live oak generally are less tolerant of extreme conditions than other oaks – they cannot tolerate either frequent flooding nor drought (Steinberg and Howard 2002).

Finally, no bays were planted on the left bank so no comparison can be made. The planting plans do not show the two small bays that we observed on the right bank.

Susceptibility to Inundation

Figures 18 to 20 show the three plots and schematic cross-sections. For each site, we mapped an "active floodplain" area based on topography and observed high water marks. We suspect that these high water marks were left from a recent storm (February 25, 2004). Weather data show 3.51 inches of rain fell that day in nearby San Rafael (Accuweather.com 2004). Data did not show the event's duration, but we remembered the storm lasted for less than

12 hours. Comparing this rainfall with a rainfall frequency map of Northern California, we concluded that it was not a huge event, ranging between a 2- and 5-year storm event (NOAA 1973).[2] We hypothesized that riparian trees adapted to seasonal flooding may not have survived if planted outside of the active floodplain, and that other less flood-tolerant species may not have survived if they were planted within the floodplain. Table 5 tests this hypothesis.

We did not find a strong correlation between tree survival and location within or outside of the active floodplain. However, because the designers generally planted species either all within or all outside of the active floodplain, we could not make many comparisons.

Geology and Soil

A USGS geologic map shows that the area is underlain by a quaternary alluvium consisting of sands, gravels, silts, and clays (Blake et.al. 2000). Because the entire area is underlain by the same geology, we conclude that geology, as shown in the coarse-scaled (1:67,500) published map, is not a reason for the differences in survival rates. However, we observed rock outcroppings in the area that suggest that the geology may be more complicated than it appears on the published map. Additionally, the creek has incised approximately 20 feet in the past century (Vandivere 1985). It is possible that the surveyed data on the published map is no longer valid. Further exploration of the underlying geology may reveal important local characteristics that explain the differing survival rates.

A USDA/SCS soils map of the area shows that the soil in plots 1 and 3 are characterized by the Blucher-Cole complex (Figure 22, Kashiwagi 1985). Plot 2 lies just on the border between soils of the Tocaloma-Saurin association (to the north) and soils of the Blucher-Cole complex (to the south). Within the Blucher-Cole complex, Blucher silt loam dominates the drainageways while Cole clay loam is found on basin rims and in depressional areas. Plots 1 and 3 likely consist mostly of Blucher soils, which are "deep and somewhat poorly drained" (Kashiwagi 1985). Plot 2 likely consists of a combination of Blucher and Tocaloma soils, which are found in the drainageways within the Tocaloma-Saurin association. In contrast to the Blucher soil, the Tocaloma soil is well drained. Table 6 shows the different characteristics of Blucher and Tocaloma soils. Because the Tocaloma soils drain faster and have a lower water-holding capacity, there is a possibility that the areas with lower survival rates of

[2] A 2-year 24-hour event is 3.5 inches of rain; a 5-year 6-hour storm is 2.0 inches (NOAA 1973).

riparian species are underlain by the Tocaloma soils. While the coarse scale of the published soils map (1:24,000) warrants caution against making any definitive conclusions, we conducted a preliminary assessment assuming that the left bank of plot 2 consists of Tocaloma soils and the other areas consist of Blucher soils. We did not notice any differences in soil types while in the field, but we also did not specifically look at soils.

A preliminary assessment using these assumptions showed that the buckeyes and alders that died may have been planted in the wrong soil types (Table 7). None of the buckeyes planted in the Blucher soils survived, while 2 of the 3 planted in the Tocaloma soils did. This makes sense, since buckeyes are generally intolerant of summer water, and grow on drier slopes (Howard 1992a). The alders had the opposite response: all of those planted in the Blucher soils survived, while none in the Tocaloma did. This also makes sense, as alders generally grow in poorly drained sands and clays, and are restricted to the flooding zone (Uchytil 1989). For all other tree species, however, we could not draw any general conclusions because too few were planted in the Tocaloma soil. Only one ash was planted in the Tocaloma soil, and it died. Seven were planted in Blucher soils, and less than half survived. Finally, no oaks or bays were planted in the Tocaloma soil.

Again, because the soils map is at a coarse scale, we cannot make conclusive statements concerning soils and survival rates. Our assumption about the location of the two soil types may or may not be correct. As with the geology data, a more detailed field soil survey might provide more insight into the different survival rates.

Survival by Species

This section looks at the survival rate by species. We found that some trees that died were planted in unsuitable areas.

Aesculus californica – Three of the five buckeye planted did not survive. One was planted within the floodplain, while the other two were not. The two that survived were planted higher on the bank, where buckeyes are generally found.

Alnus rhombifolia – White alder are known to be flood-tolerant plants. They thrive in poorly drained sands and clays, and are generally restricted to the flooding zone around streams (Uchytil 1989a). However, some of the alders planted higher on the bank survived while some planted lower did not. Most were planted within the floodplain, but the one just outside of the floodplain, among coyote brush and poison oak in plot 1 is quite healthy. Nearby willow at the same elevation indicate that the soil is moist in the area (Uchytil 1989b). Strangely, two of the three alders planted on the left bank of plot 2 grew to approximately 10 and 15 ft high (4 in and 6 in dbh, respectively) before dying (Figure 15). One possible explanation for their death would be that they are in well-drained Tocaloma soils (Figure 22); however, this does not explain why they only recently died. It is unlikely that they had been irrigated for much longer than a couple of years; a long drought may have killed them.

Fraxinus latifolia – Most of the ash planted above 180 ft did not survive. The one exception was one on the right bank of plot 2 relatively high on the bank. The only ash planted within the floodplain (left bank of plot 2) did not survive. However, the left bank of plot 2 may be underlain by Tocaloma soils, which are well-drained highly permeable soils with a low water-holding capacity. Oregon ash generally grow on seasonal floodplains, in poorly drained, silty clays or sands (Owston 1990). Two of the ash that have thrived were planted outside of the floodplain (plot 3), but are in a moist environment, as indicated by the nearby willow. The two planted in plot 1, neither of which survived, were highly exposed to the southern sun and high on the bank.

Quercus agrifolia – Only two of the ten coast live oak planted did not survive. Most have developed a shrubby character, probably in reaction to heavy deer grazing. Most, including the two that did not survive, were planted high on the banks well outside the floodplain. The two that did not survive were planted in an area above the floodplain but dominated by willow, suggesting moist soils and perhaps inundation. While coast live oak are known to be more susceptible to drought than other California oaks, they also cannot tolerate frequent inundation (Steinberg and Howard 2002).

Quercus lobata **–** The three valley oak on the right bank of plot 3 were all recently planted saplings, protected by new, unrusted wire cages. The only surviving valley oak of the four planted in plots 1 and 2 is 1 ft tall, and has been heavily grazed on by deer. The three that did not survive were planted lower on the banks, one even within the floodplain. Generally, valley oak are tolerant of infrequent inundation, and also resistant to short-term drought, suggesting that they are adaptable to many conditions within the creek banks (Howard 1992a). The two that did not survive in plot 1 were on the left bank, where it is open and exposed, and likely too dry in the summer months.

Umbellularia californica **–** None of the bays planted survived. All were planted on the right bank of plot 1. One was planted within the floodplain, and the others just outside. From their water and soil needs, it is unclear why these bays died. In general, they are tolerant of flooding and clay soils (Howard 1992b).

CONCLUSION

Of the three plots surveyed, the downstream plot has been the most successful in terms of survival rates and in the creation of complex riparian and in-stream habitat. The other two plots are dominated more by shrubs and grasses than trees, but are slowly developing complexity, as tree seedlings grow under the protection of the shrubs and small trees. In general, riparian tree species did not do well on the left banks of plots 1 and 2, where they were more exposed to the summer sun than those on the right banks or in plot 3.

There seem to be three factors that determine vegetation survival. First, there is a basic macro-level condition that we do not yet understand but which results in markedly different vegetation patterns in the upstream and downstream of plot 3. Pope-Daum and Yin's observation of perennial flow in downstream areas and intermittent flow in upstream areas may be influenced by a condition such as water table levels (2003). Second, aspect, which is significant in Mediterranean climates, plays a role in plant survival. Finally, local conditions such as soils and geology, which we likewise understand poorly, are also important. Additionally, other factors such as deer grazing affect the survival and health of trees and plants, but we did not attempt to investigate these. It is beyond the scope of this study to explain how these factors interact with one another, or which is the most important determinant of plant survival.

In future stream restoration projects, it may be cost-efficient to study the area's soils and underlying geology to maximize plant survival rates. Alternately, a planting strategy that mimics natural succession would require more planning but might be more effective. For example, fast-growing or hardy plants, such as willows and coyote brush, could be planted first; once established, they would protect more susceptible seedlings from sun exposure and deer grazing.

Table 1. Plant Species Planted and Observed, by Plot

Common Name	Scientific Name	Plot 1			Plot 2			Plot 3 (Left Bank)		
		# Planted	# in 2004	Survival Rate %	# Planted	# in 2004	Survival Rate %	# Planted	# in 2004	Survival Rate %
Trees										
California Buckeye	*Aesculus californica*	2	0	0	3	2	66			
White Alder	*Alnus rhombifolia*	3	4	100	3	1*	0	1	1	100
Oregon Ash	*Fraxinus latifolia*	2	0	0	3	1	33	3	2	67
Coast Live Oak	*Quercus agrifolia*	4	2	50	2	6+*	100	4	4	100
Valley Oak	*Quercus lobata*	2	0	0	3	1	100			
California Bay	*Umbellularia californica*	4	0	0		2*				
Overall		***17***	***6***	***35***	***14***	***6***	***43***	***8***	***7***	***88***
Shrubs										
Coyote Brush	*Baccharis sp.*	6	12*	67		25+			2+	
Toyon	*Heteromeles arbutifolia*	5	2	40				2	2	100
Snowberry	*Symphoricarpos rivularis*	6?	0?	0?						
Coffeeberry	*Rhamnus californica*				6?	0?	0?	14	10	71
Red Currant	*Ribes rubrum*		+							
Rose	*Rosa sp.*		1							
Himalayan Blackberry	*Rubus armeniacus*		1			2				
California Blackberry	*Rubus vitifolius*	12	0	0	3	0	0			
Willow	*Salix sp.*	7	7+		0?	+		3	7+	100
Elderberry	*Sambucus sp.*		1		0?	6				
Poison Oak	*Toxicodendron diversilobum*		+			+			+	
Overall		***30***	***13***	***43***	***3***	***0***	***0***	***19***	***15***	***79***

* Not found where planted
+ many – not counted
? questionable whether or not planted

Table 2. Habitat Characteristics of Plant Species

Species	Site Characteristics	Soils	Water Needs
Aesculus californica[1]	on dry slopes, in canyons, and along waterways	sandy, sandy-loam, or gravelly-loam soils	intolerant of summer water
Alnus rhombifolia[2]	on streams that run all year; restricted to the flooding zone; infrequent farther away from streams	poorly drained sands and clays	needs a constant water supply
Fraxinus latifolia[3]	follows streams and swamps; characteristic in seasonally flooded habitats; also found in higher elevations; semi-tolerant of shade	poorly drained, moist bottom land with deep soil rich in humus; silty clay loams and clays; sandy soils or moist, rocky, gravelly soils	drought and flood resistant
Quercus agrifolia[4]	seedlings need shade (especially under shrubs), where herbivory protection and water availability are higher; also found on rocky outcrops	sandy loam; tolerates a range from silts and clays to weathered granite; tolerates serpentine soils	more susceptible to drought than other California oaks; does not tolerate frequent inundation
Quercus lobata[5]	floodplains and valley floors	silty loam, clayey loam, and sandy clay loam; tolerant of poorly drained soil and wet seeps	sensitive to over-watering but tolerant of infrequent inundation; resistant to short-term drought but dependent on water-table access; best growth when water tables are about 33 feet below the surface
Ubellularia californica[6]	best on mesic sites such as deep well-drained alluvial benches, valley bottoms subject to occasional inundation, well-watered coastal slopes, or along foothill streams	loam, sandy-loam, or clay soils; pH ranges from 5.7 to 7.4	needs well-watered or moist soils; tolerant of flooding
Baccharis pilularis[7]	actively eroding or alluviating areas such as gravel bars; facilitates establishment of other coastal sage species; shade-intolerant	range of soil types but best adapted to medium- to coarse-textured soils	wet springs maximize early root growth; tolerant of dry conditions
Heteromeles arbutifolia[8]	mesic chaparral and foothill woodlands; tolerates semidry, rocky slopes within foothills, mountains, and canyon bottoms	dry and well drained soils; tolerates somewhat saline soils	moderate water use requirements; maximum water stress declines well before the onset of fall rains
Rhamnus californica[9]	wide ecological amplitude: dry flats, moist slopes, ravines, and rocky ridges; tolerant of full sun to moderate shade		
Salix spp.[10]	floodplains, creek banks; tolerates full sun, part sun	sands	tolerates seasonal flooding
Sambucus cerulea[11]	forest openings, ravines in drier habitats and in riparian zones; shade intolerant	good on loam/sandy loam soils, fair to good on sand, fair to poor on clay or gravel, and poor on dense clay; grows poorly on saline, sodic soils; optimum soil depth is 20+ in	

Adapted from:

1. Howard, Janet L. 1992. Aesculus californica. In: Fire Effects Information System, [Online]. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fire Sciences Laboratory. http://www.fs.fed.us/database/feis/ [2004, April 9].
2. Uchytil 1989a.
3. Owston 1990.
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5. Howard 1992a.
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8. McMurray, Nancy E. 1990. Heteromeles arbutifolia. In: Fire Effects Information System, [Online]. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fire Sciences Laboratory. http://www.fs.fed.us/database/feis/ [2004, April 9].
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Table 3. Tree Species Survival by Elevation

Tree Species	Elevation	Number Planted	Number Survived	Survival Rate	Condition
Aesculus californica (California Buckeye)	205	2	0	0	
	198	2	2	100	Good
	192	1	0	0	
Alnus rhombifolia (White Alder)	201	3	3	100	Good
	192	2	0	0	
	191	1	0	0	
	177	1	1	100	Poor
Fraxinus latifolia (Oregon Ash)	205	2	0	0	
	202	1	1	100	Good
	195	1	0	0	
	192	1	0	0	
	182	1	0	0	
	180	2	2	100	Good
Quercus agrifolia (Coast Live Oak)	212	3	1	33	Poor
	205	1	1	100	Good
	199	1	1	100	Poor
	197	1	1	100	Good
	179	2	2	100	Good
	178	2	2	100	Good
Quercus lobata (Valley Oak)	205	2	0	0	
	200	1	1	100	Poor
	194	2	0	0	
Umbellularia californica (California Bay)	209	1	0	0	
	204	2	0	0	
	201	1	0	0	
	198	0	2*		

* not on design planting plans

Table 4. Tree Species Survival by Aspect

Tree Species	Aspect	Number Planted	Number Survived	Survival Rate	Condition
Aesculus californica (California Buckeye)	South	5	2	40	Good
	North	0	0		
Alnus rhombifolia (White Alder)	South	4	1	25	Poor
	North	3	3	100	Good
Fraxinus latifolia (Oregon Ash)	South	6	2	33	Good
	North	2	1	50	Good
Quercus agrifolia (Coast Live Oak)	South	5	5	100	Good
	North	5	3	60	Poor
Quercus lobata (Valley Oak)	South	2	0	0	
	North	6	4	67	Poor
Umbellularia californica (California Bay)	South	0	0		
	North	4	2*	0	

* not on design planting plans

Table 5. Tree Species Survival by Susceptibility of Inundation

Tree Species	Within Floodplain?	Number Planted	Number Survived	Survival Rate	Condition
Aesculus californica (California Buckeye)	Yes	1	0	0	
	No	4	2	50	Good
Alnus rhombifolia (White Alder)	Yes	7	4	57	Poor-Good
	No	0	0		
Fraxinus latifolia (Oregon Ash)	Yes	1	0	0	
	No	7	3	43	Good
Quercus agrifolia (Coast Live Oak)	Yes	0	0		
	No	10	8	80	Poor-Good
Quercus lobata (Valley Oak)	Yes	2	0	0	
	No	3	1	33	Poor
Umbellularia californica (California Bay)	Yes	1	0	0	
	No	3	2*	0	

* not on design planting plans

Table 6. Characteristics of Blucher and Tocaloma Soils

Characteristic	Blucher	Tocaloma
Soil Profile	0 - 7” silt loam 7 - 23” loam/silt loam 23 - 60”+ silty clay loam/clay loam	0 - 19” loam 19 - 39” very gravelly loam 39 - 59”+ bedrock
Drainage	Poor	Good
Permeability	Moderate to 23” (slow below)	Moderately rapid
Available water capacity	High to very high	Low
Effective rooting depth	Limited by seasonal high water table (3.5 to 5 ft from December to April)	20 - 40”
Runoff	Slow	Rapid
Erosion hazard	Low	High
Native plant community	Native annual grasses and forbs	Hardwoods (e.g. bays and live oak)

Source: Kashiwagi 1985.

Table 7. Tree Species Survival by Soil Type

Tree Species	Soil Type	Number Planted	Number Survived	Survival Rate	Condition
Aesculus californica (California Buckeye)	Blucher	2	0	0	
	Tocaloma	3	2	67	Good
Alnus rhombifolia (White Alder)	Blucher	4	4	100	Poor-Good
	Tocaloma	3	0	0	
Fraxinus latifolia (Oregon Ash)	Blucher	7	3	43	Good
	Tocaloma	1	0	0	
Quercus agrifolia (Coast Live Oak)	Blucher	10	8	80	Poor-Good
	Tocaloma	0	0		
Quercus lobata (Valley Oak)	Blucher	5	1	20	Poor
	Tocaloma	0	0		
Umbellularia californica (California Bay)	Blucher	4	0	0	
	Tocaloma	0	2*		

* not on design planting plans

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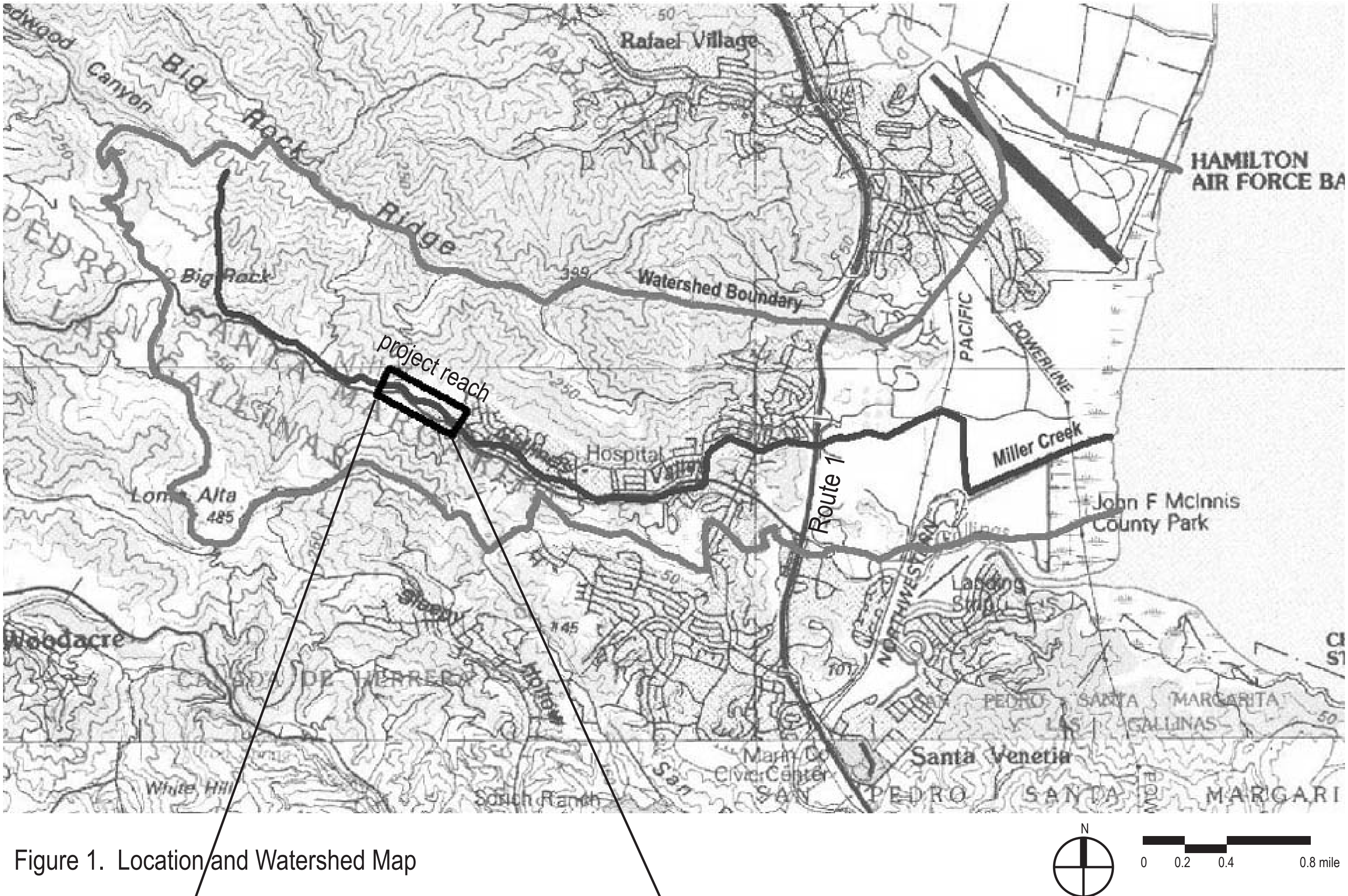


Figure 1. Location and Watershed Map

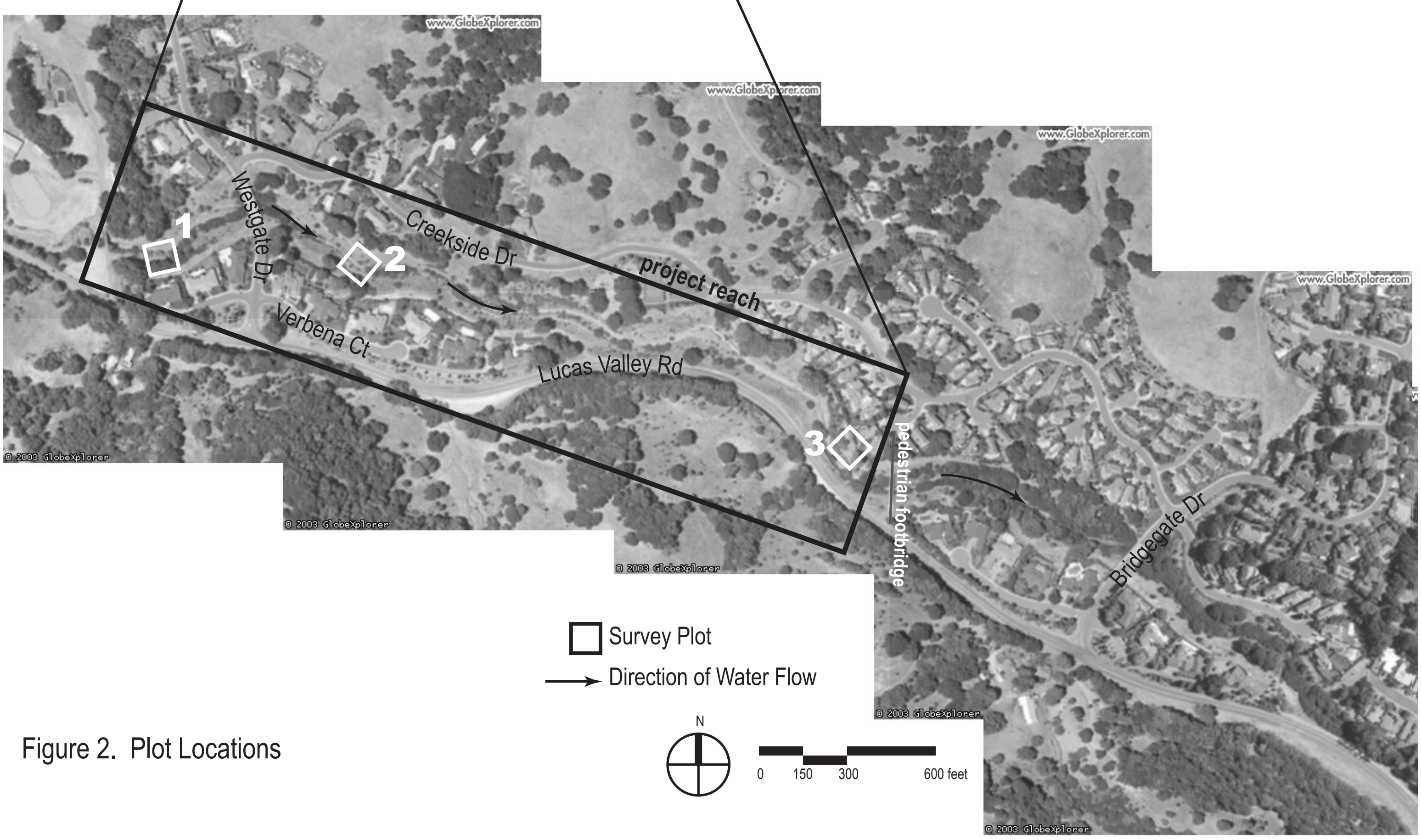


Figure 2. Plot Locations

Figure 3. Plot 1 looking downstream
Source: Photo by authors, April 4, 2004.

Figure 4. Plot 2 looking downstream
Source: Photo by authors, April 4, 2004.

Figure 5. Plot 3 looking downstream
Source: Photo by authors, April 4, 2004.

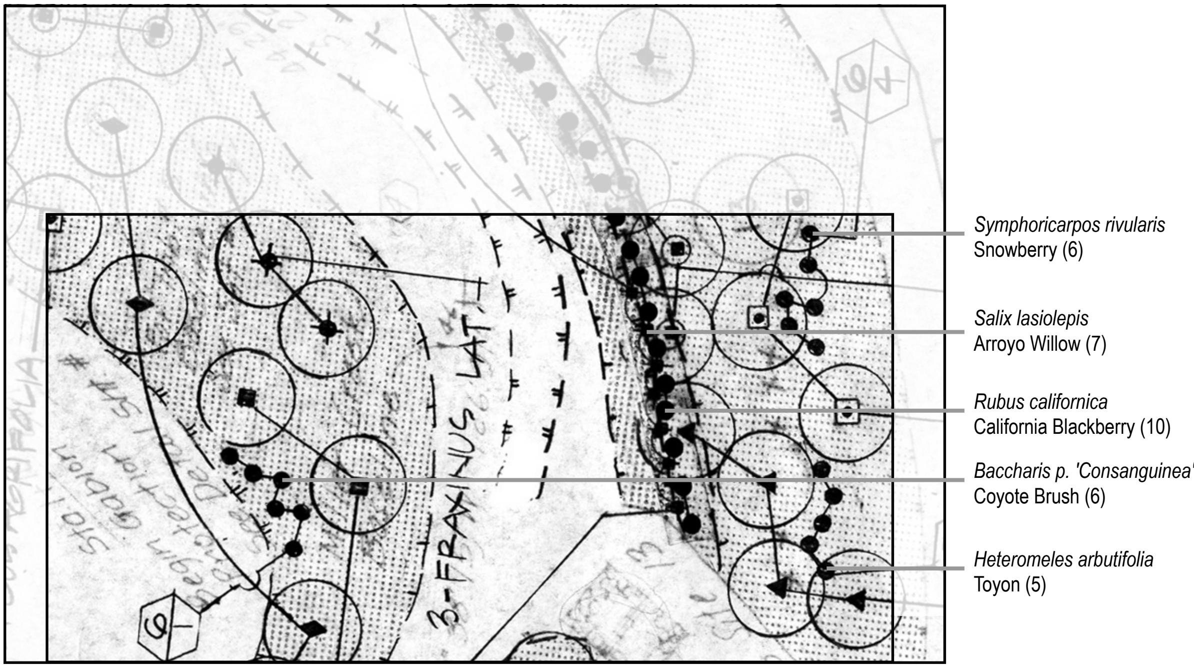


Figure 6. Planting Plan Plot 1
Source: Guzzardo 1989b, L-2

approx. scale
0 10 20 40 feet

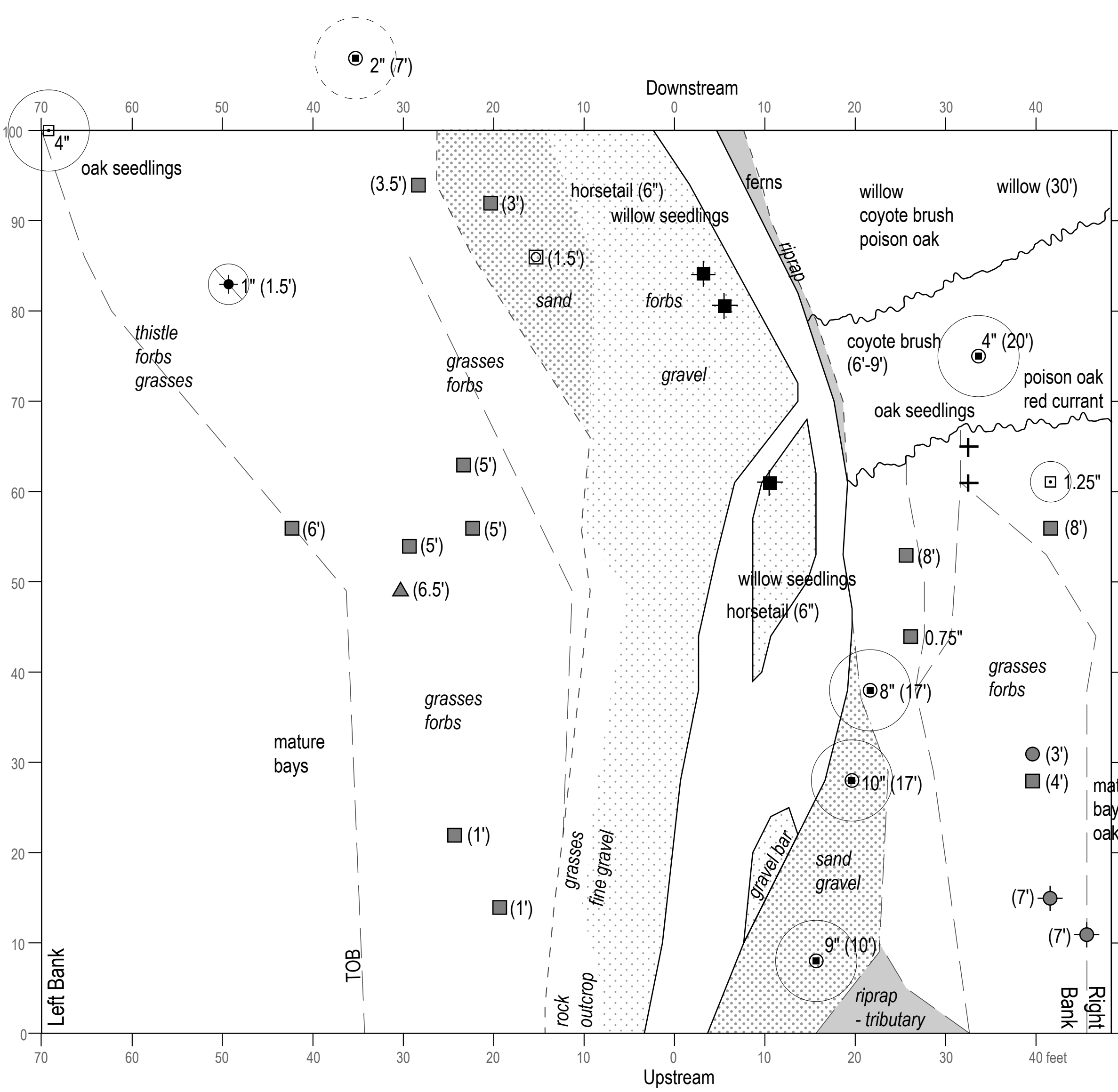
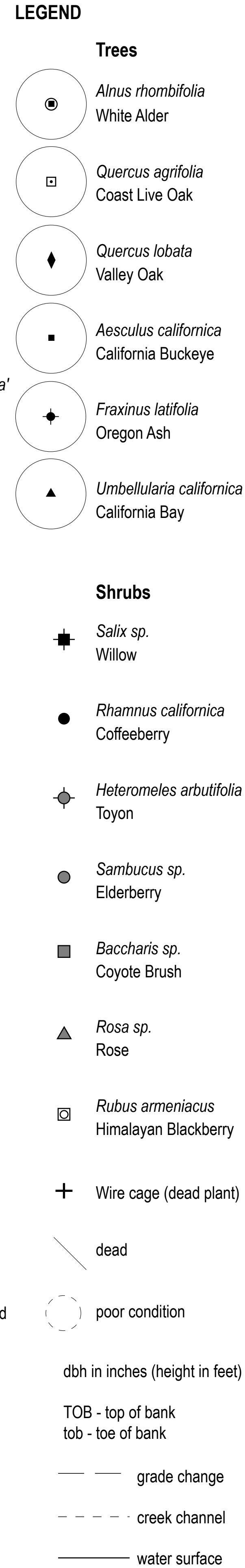


Figure 7. Existing Vegetation Plot 1



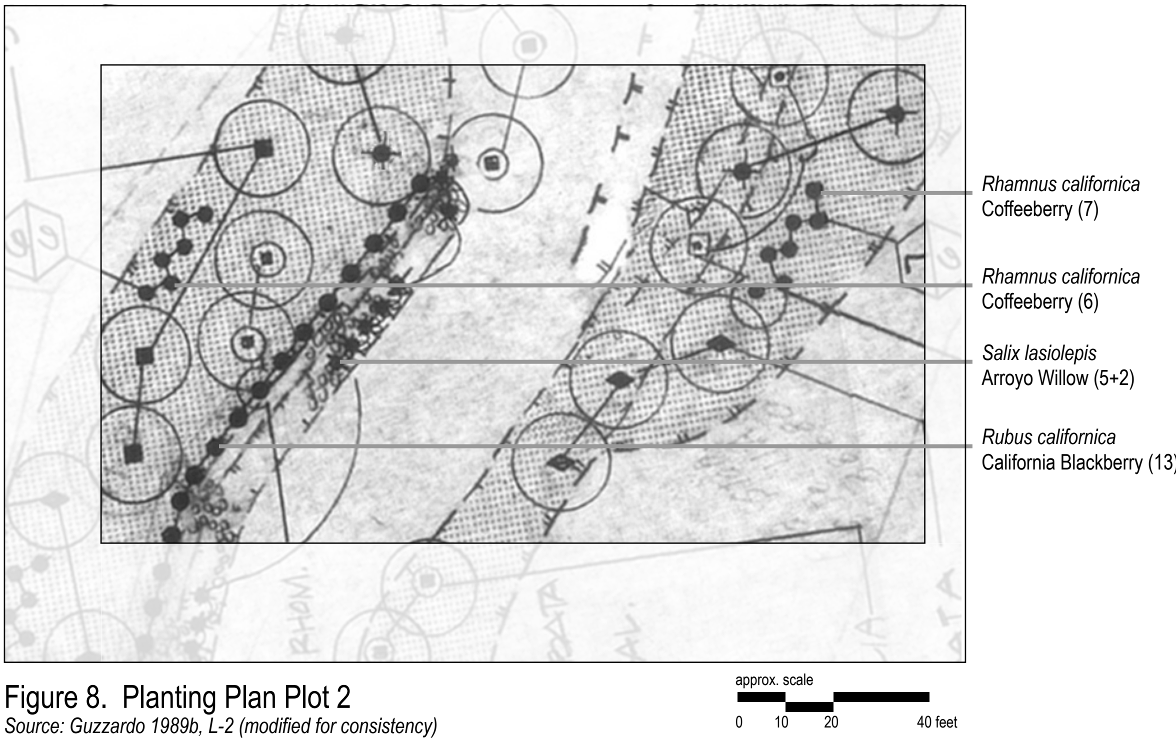
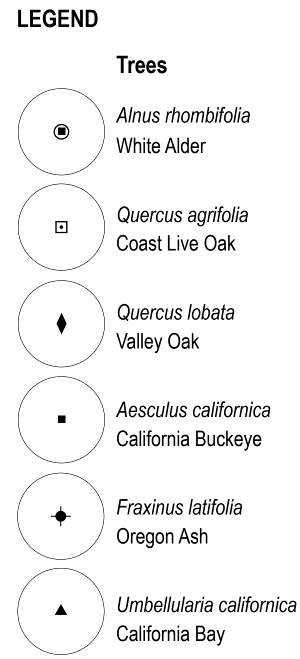


Figure 8. Planting Plan Plot 2

Source: Guzzardo 1989b, L-2 (modified for consistency)



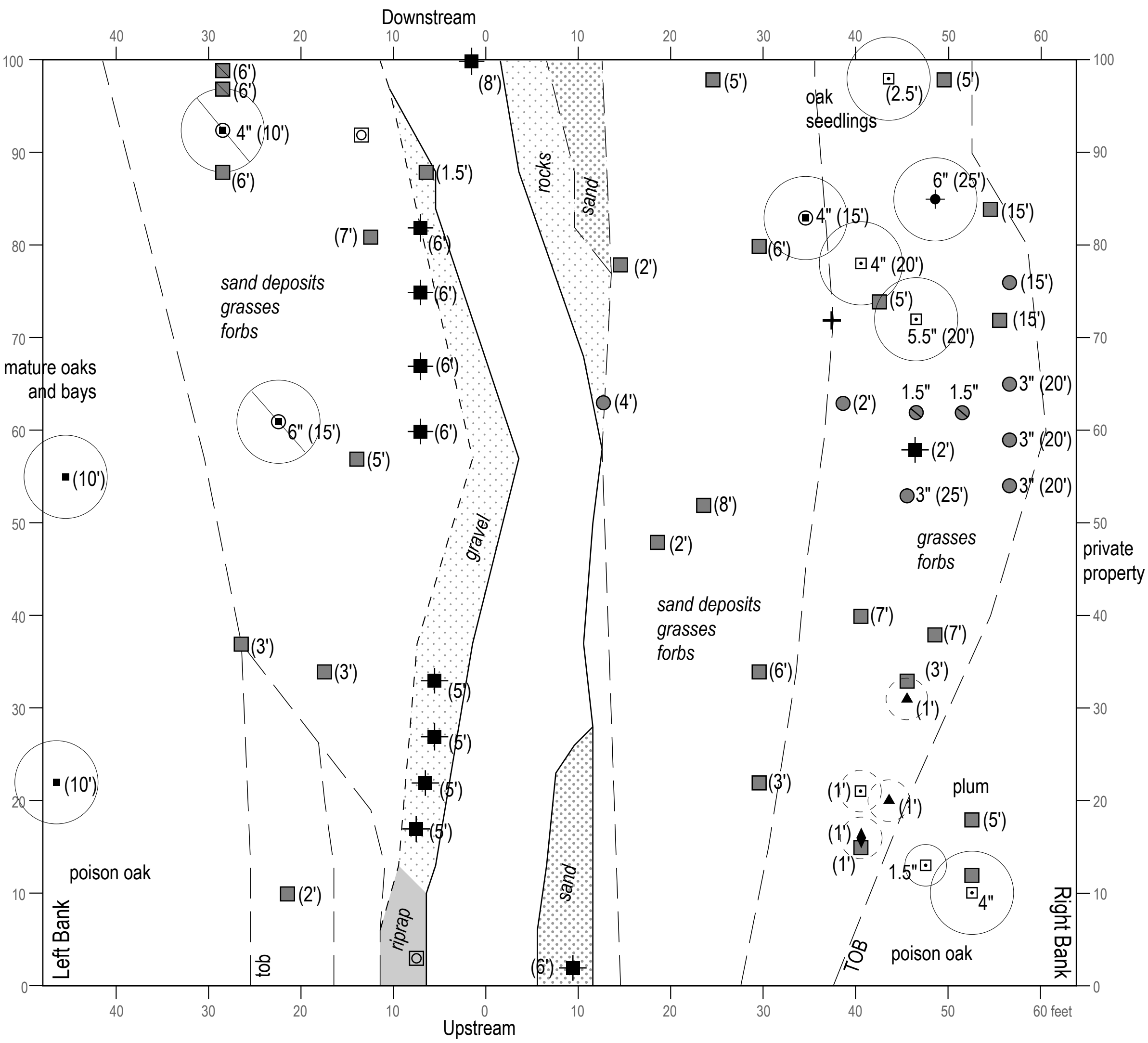
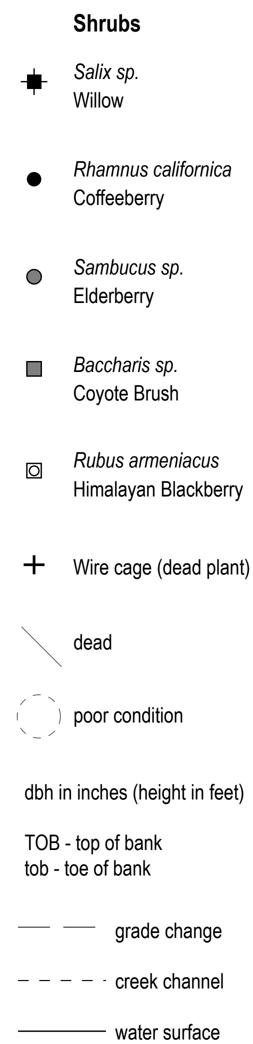


Figure 9. Existing Vegetation Plot 2



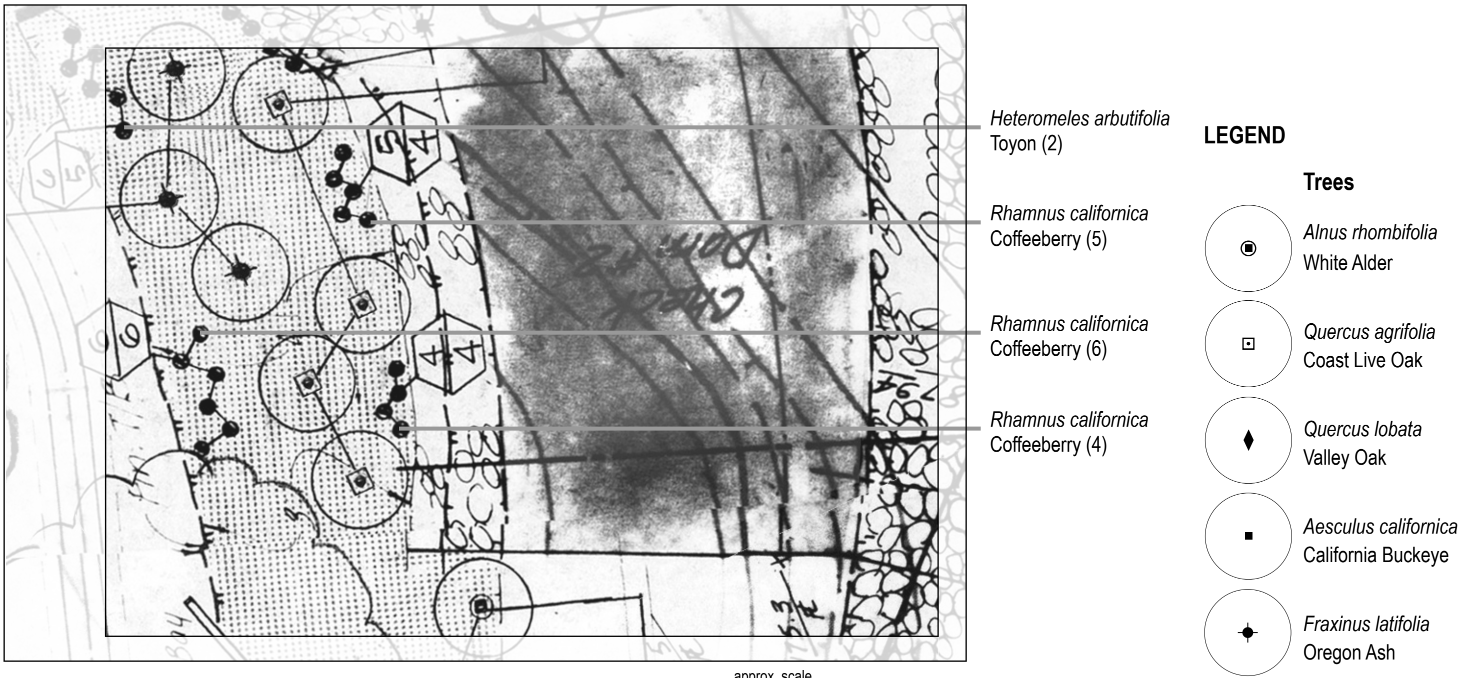


Figure 10. Planting Plan Plot 3
Source: Guzzardo 1989a, L-2 (modified for consistency)

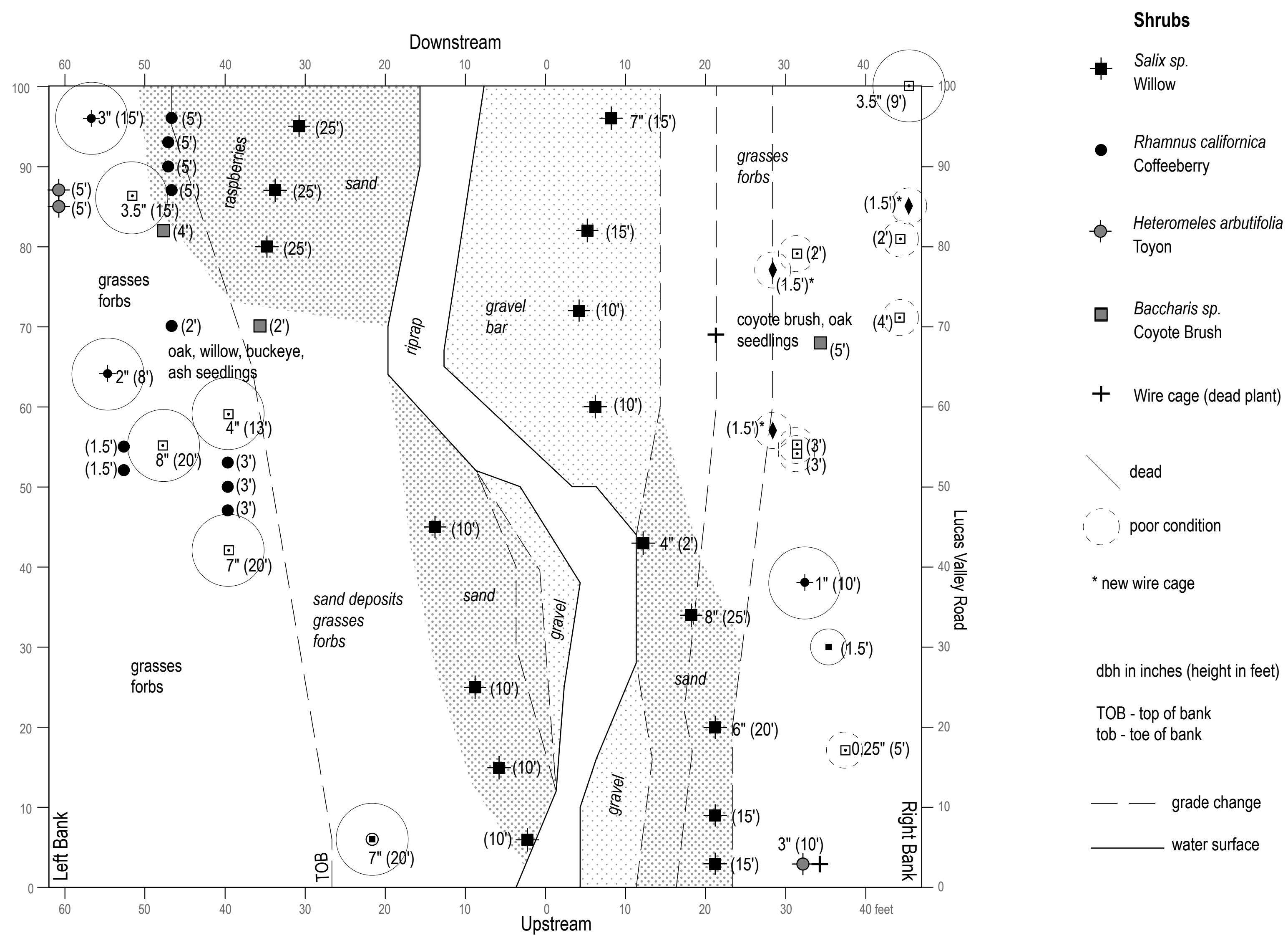
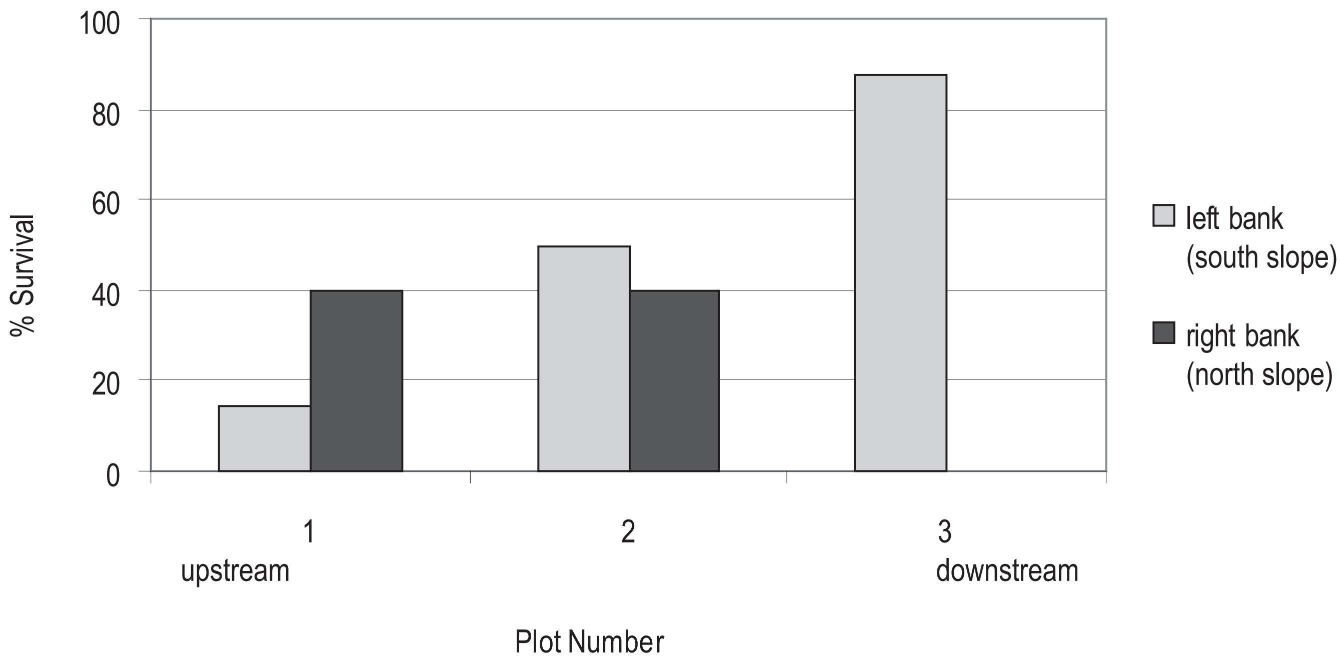


Figure 11. Existing Vegetation Plot 3



plot	left bank total planted	total survived	%survival	right bank total planted	total survived	%survival
1	7	1	14	10	4	40
2	4	2	50	10	4	40
3	8	7	88			

Figure 12. Survival rate by bank and position along stream

Figure 13. Two alders on the left bank downstream of plot 1, with mature bays in the background.
Source: Photo by authors, April 4, 2004.

Figure 14. Two alders on the right bank of plot 1.
Source: Photo by authors, April 4, 2004.

Figure 15. Dead alder on the left bank of plot 2
Source: Photo by authors, April 4, 2004.

Figure 16. Alder on the right bank of plot 2 with coyote brush in foreground
Source: Photo by authors, April 4, 2004.

Figure 17. Alder on the left bank of plot 3 with willow in the background
Source: Photo by authors, April 4, 2004.

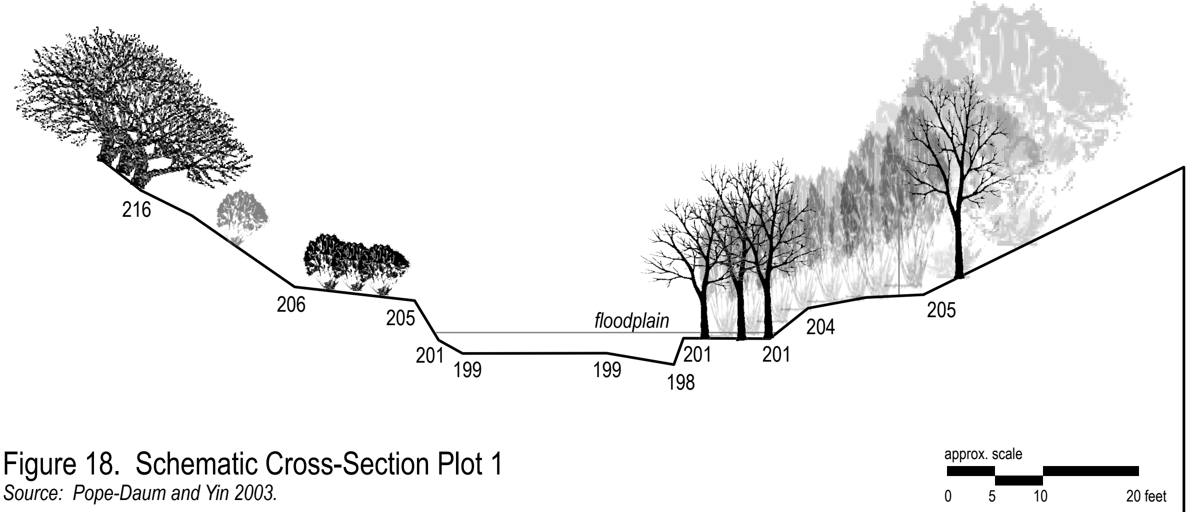
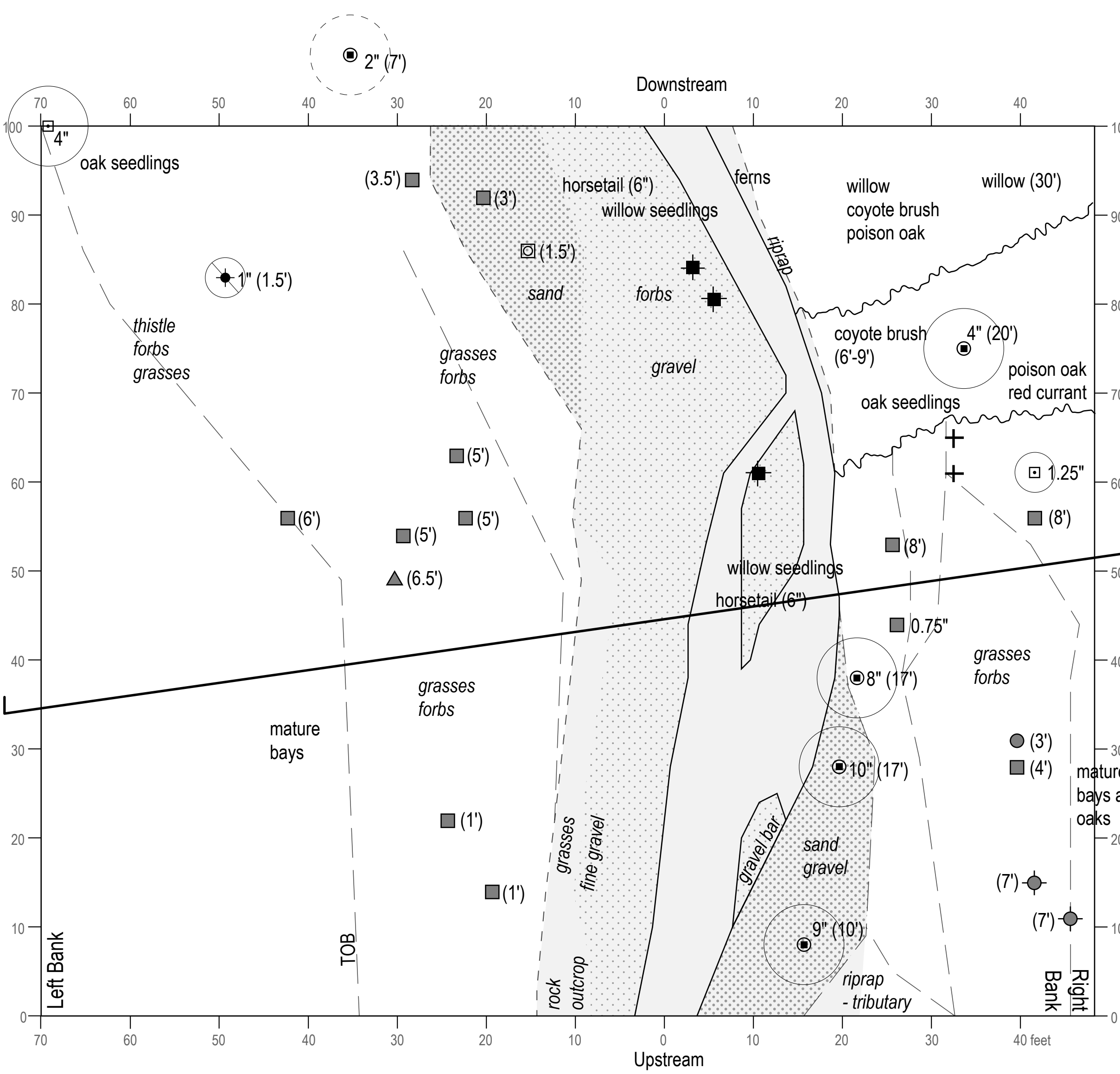
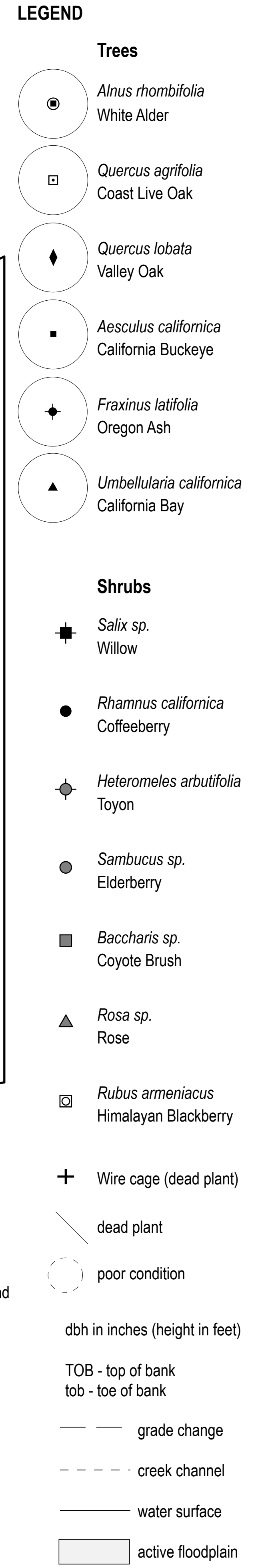


Figure 18. Schematic Cross-Section Plot 1
Source: Pope-Daum and Yin 2003.



Existing Vegetation Plot 1



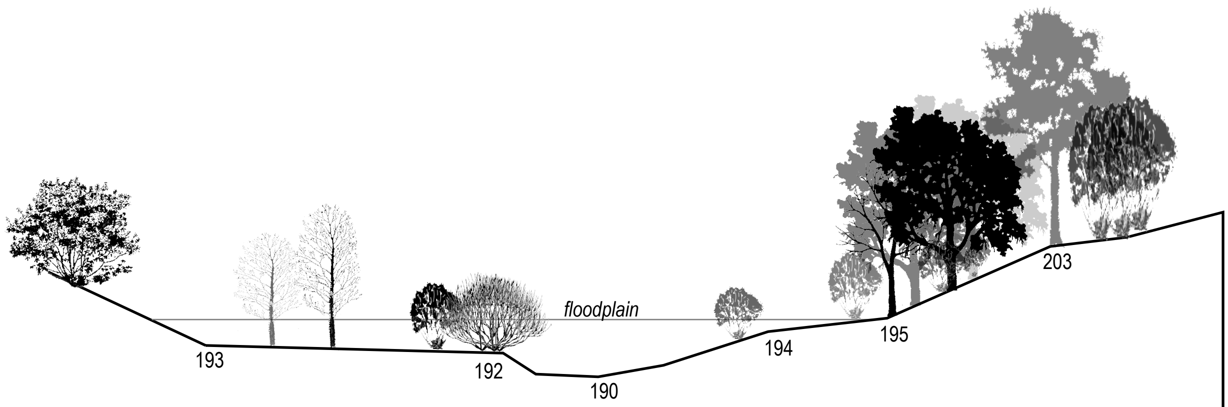
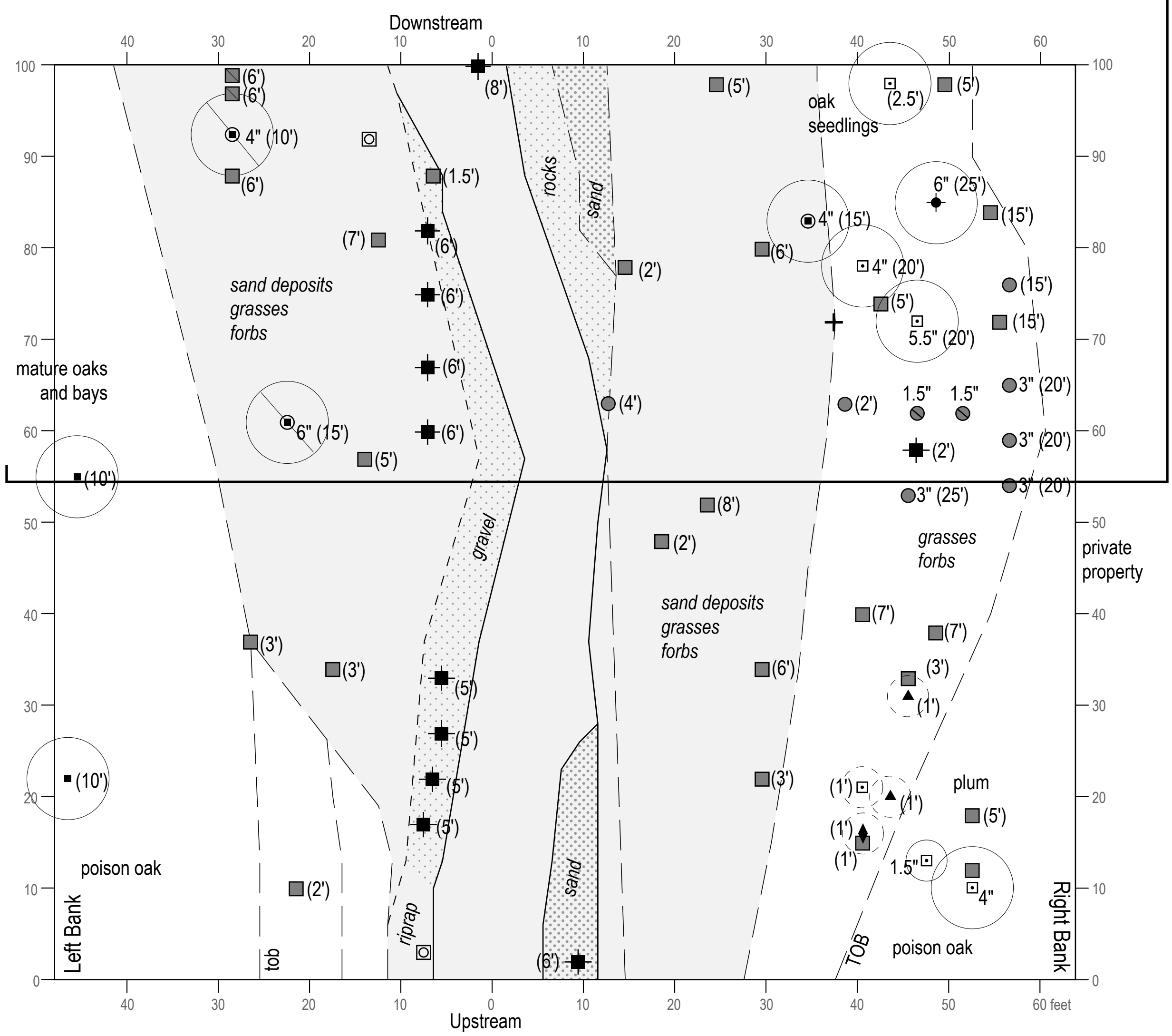
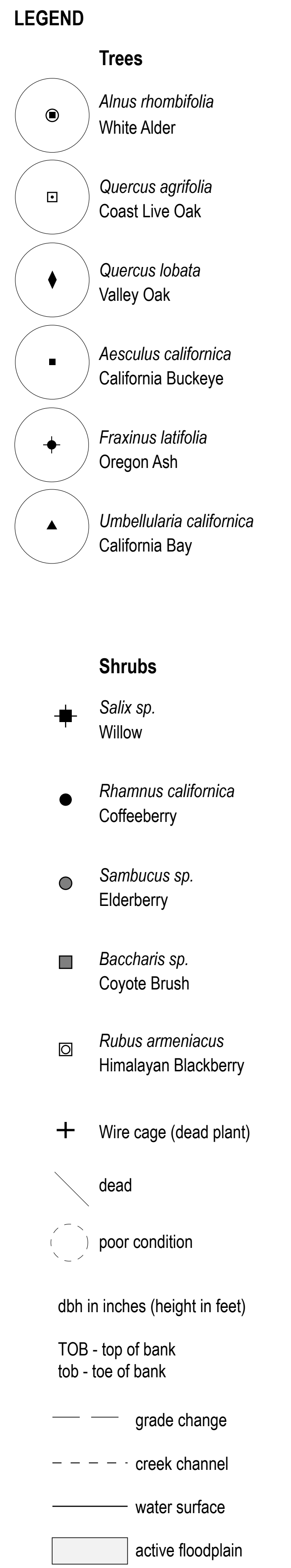


Figure 19. Schematic Cross-Section Plot 2
Source: Pope-Daum and Yin 2003.

approx. scale
0 5 10 20 feet



Existing Vegetation Plot 2



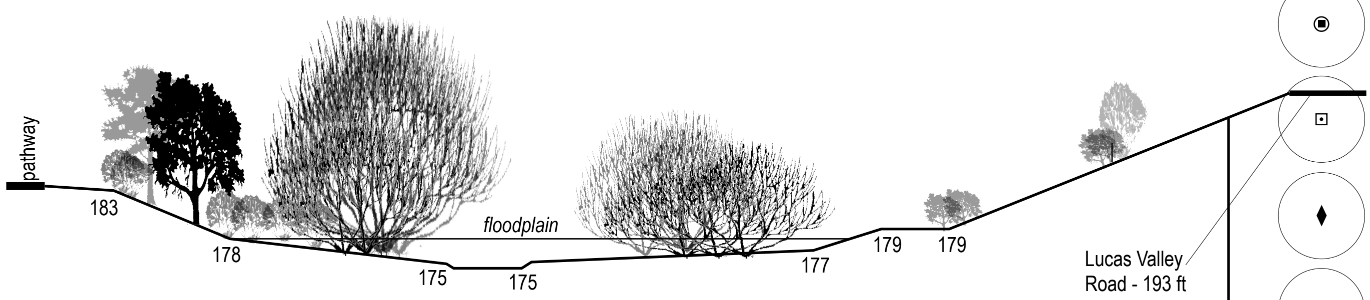


Figure 20. Schematic Cross-Section Plot 3
Source: Interpretation of Guzzardo 1989a, L-2

LEGEND

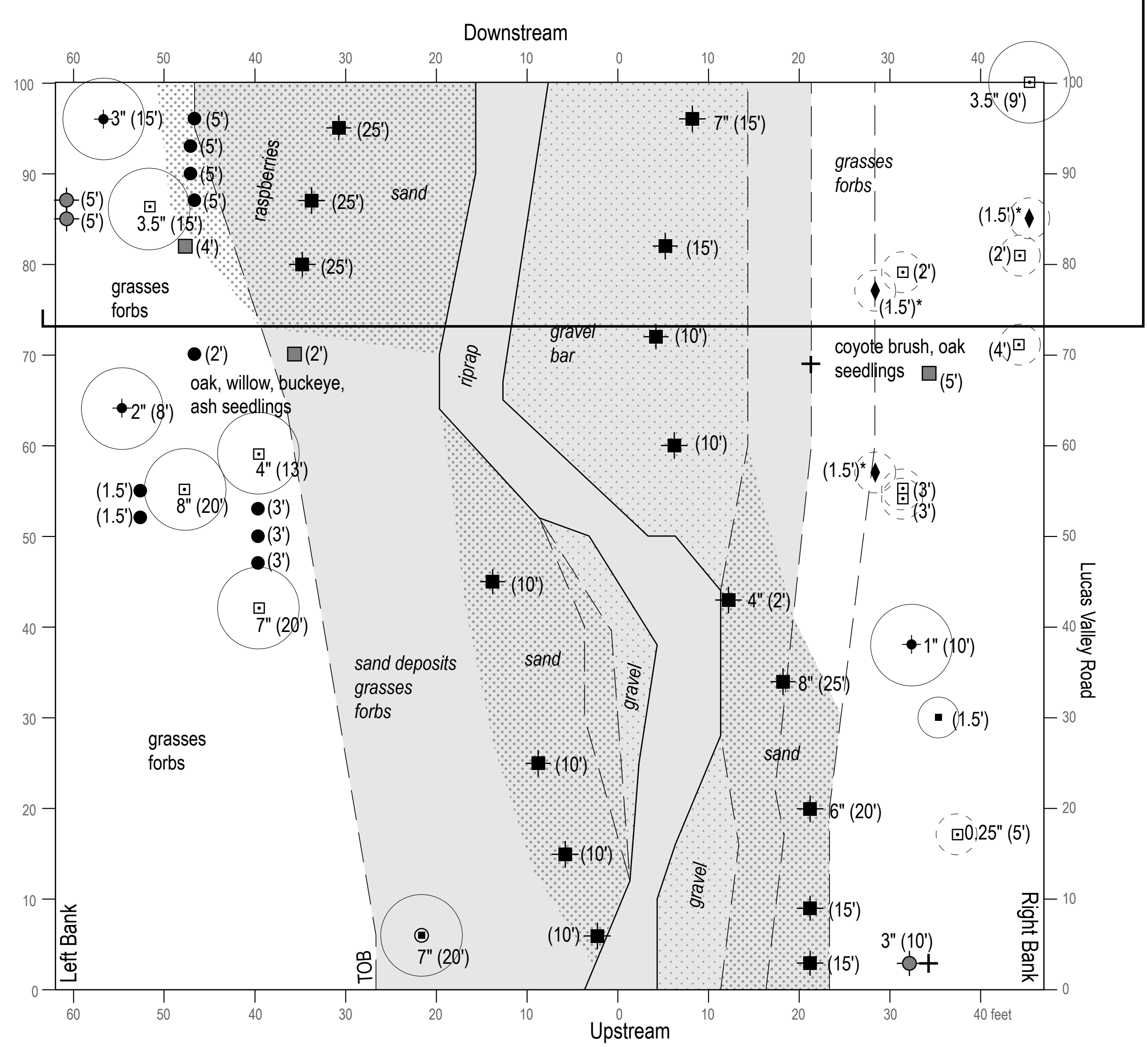
Trees

Alnus rhombifolia White Alder
Quercus agrifolia Coast Live Oak
Quercus lobata Valley Oak
Aesculus californica California Buckeye
Fraxinus latifolia Oregon Ash

Shrubs

Salix sp. Willow
Rhamnus californica Coffeeberry
Heteromeles arbutifolia Toyon
Baccharis sp. Coyote Brush

Wire cage (dead plant)
dead
poor condition
* new wire cage
dbh in inches (height in feet)
TOB - top of bank
tob - toe of bank
grade change
water surface
active floodplain



Existing Vegetation Plot 3

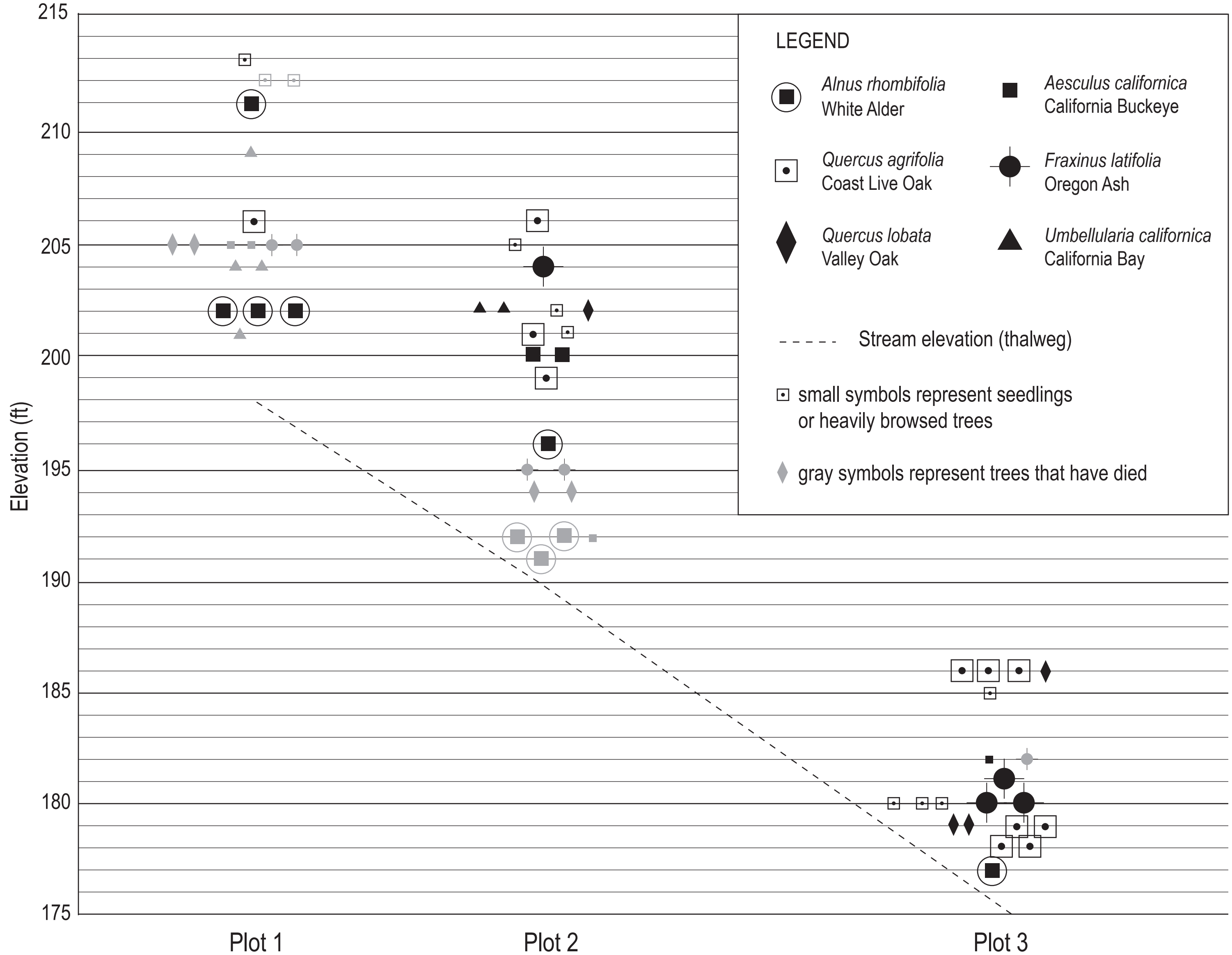


Figure 21. Tree Species Location by Elevation

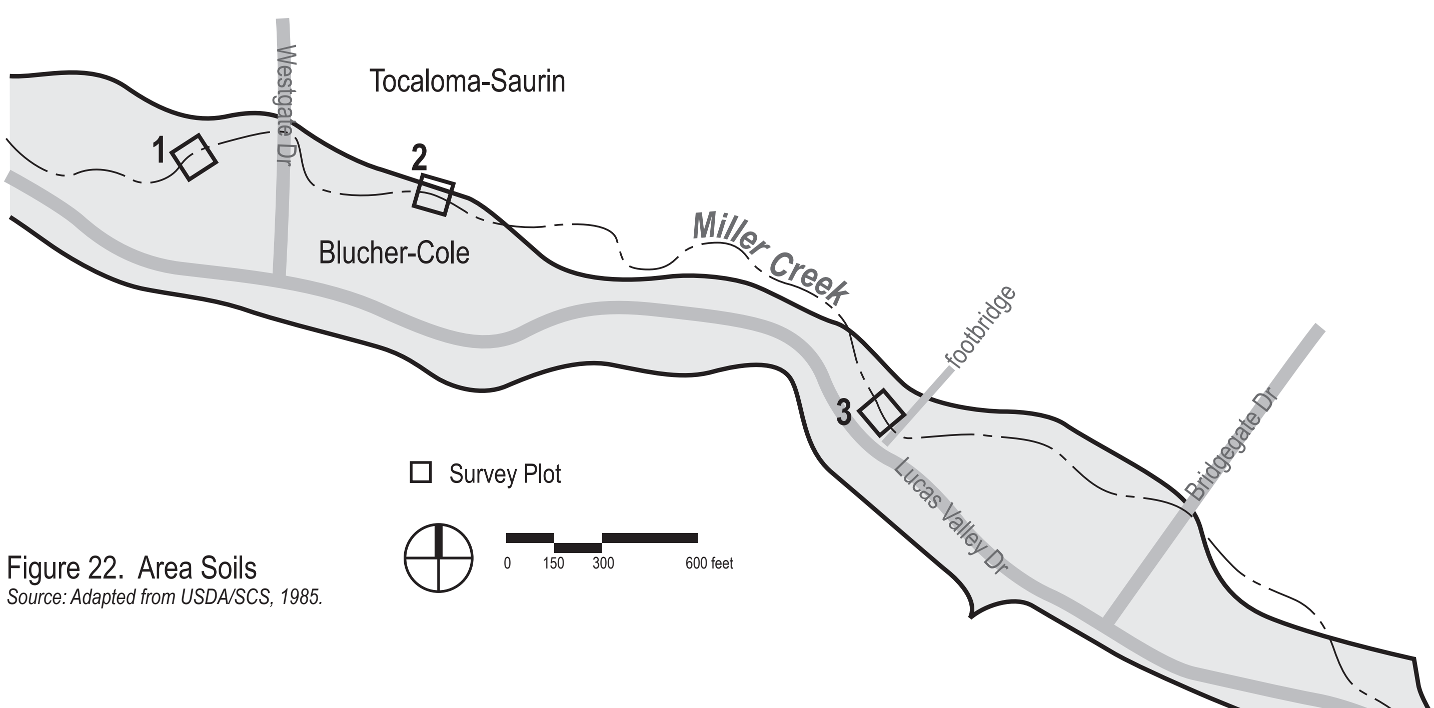


Figure 22. Area Soils

Source: Adapted from USDA/SCS, 1985.