OBSERVATIONAL STUDY OF SYCAMORE REGENERATION

at two sites in Santa Clara County after the 2016-2017 Water Year

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Prepared for
Santa Clara Valley Water District

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Report is available on SFEI's website at www.sfei.org/projects/saw

COVER CREDITS

Photo of sycamore seedling, Pacheco Creek (Amy Richey, SFEI, 2017).

PURPOSE OF THIS MEMO

This memo serves as an update to the Sycamore Alluvial Woodland Habitat Mapping and Regeneration Study (Beagle et al. 2017), and describes changes seen at the two study sites, Upper Coyote Creek and Pacheco Creek, between fall 2015 and fall 2017. We were tasked with augmenting tree core data as reported in 2017 by adding additional trees to further investigate the relationship between sycamore establishment and geomorphic position, which partially serves as a proxy for the role flood processes play in improving the suitability of conditions for sycamore seedling establishment and growth. Coincidentally, major flooding during water year 2016-2017 provided us with an exciting opportunity to observe sycamore regeneration at these two study sites. This memo reports on tree coring results; documents and maps sycamore seedlings and other observed regeneration strategies of sycamores during 2018 related to geomorphic change at the two study sites; proposes natural and anthropogenic drivers of sycamore regeneration; and outlines next steps for further investigation.

SYCAMORE TREE NEAR UPPER COYOTE CREEK

TREE CORES

For this study, we expanded our sampling of sycamore tree cores by coring four additional trees. SFEI staff used an increment borer to core selected trees at the two sites. Single-stemmed trees within a geomorphic position that could be added to the prior dataset were selected (Figure 1). Extracted cores were stored within paper tubes while in the field. In the lab, tree cores were glued onto wooden mounts and sanded, then analyzed with a compound microscope. Tree rings were counted from each core and a best estimate of rings was made to associate an age with the tree. The complete list of all trees cored at Coyote and Pacheco Creeks is included in Table 1 below, with new trees highlighted in green.

Table 1. Tree Coring at Upper Coyote and Pacheco Creeks 2015-2017. Four additional trees were cored in 2017, bringing the total cores to 12. Four trees had heart rot, making tree age analysis impossible. Cores analyzed in 2017 are highlighted in green.

Site	Tree ID	Length of core (cm)	Number of Rings	DBH (m)	Error (+/- years)	% Error	Heart Rot	Complete Core	Estimated year established
Pacheco	103	9.9	18	n.d.	3	17	no	yes	1998
Pacheco	93	14.3	13	n.d.	5	38	no	yes	2003
Pacheco	43	17.2	20	n.d.	3	15	no	yes	1996
Pacheco	9	11.1	19	0.20	4	21	no	yes	1998
Pacheco	92	25.6	65	1.70	12	18	no	yes	1952
Coyote	65	12.1	35	0.84	4	11	yes	no	na
Coyote	41*	12.6	32	0.71	6	19	yes	no	na
Coyote	41*	14.9	42	0.71	5	12	yes	no	na
Coyote	9	18.2	67	0.55	6	9	no	yes	na
Coyote	27	44.7	99	0.76	15	15	no	yes	1917
Coyote	55	8.8	33	0.25	3	9	yes	no	na
Coyote	77	19.9	54	0.48	9	17	no	yes	1963
Coyote	58	19.1	47	0.29	4	9	no	yes	1970

*two cores were taken for tree 41, and both had heart rot

CORING SYCAMORE TREES, PACHECO CREEK

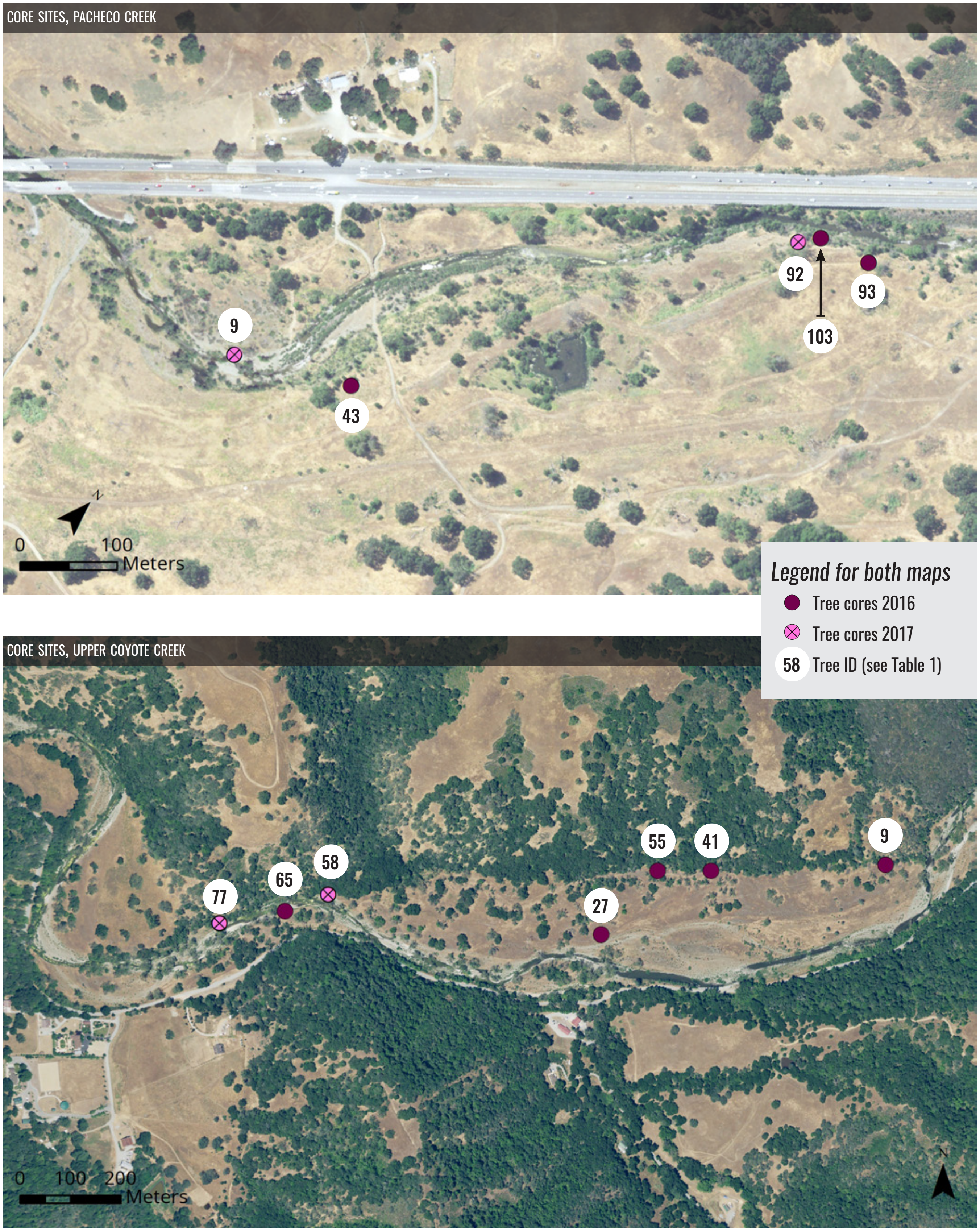


Figure 1. Site maps with location of tree cores on each creek. These maps show the location of 2016 cores (dark red) and 2017 cores (pink) on Pacheco and Upper Coyote creeks. The number next to the tree core symbol corresponds to the Tree ID (see Table 1).

HYDROLOGIC YEAR 2016-2017

Based on significant hydrologic events in water year 2016-2017, study sites at Pacheco Creek and Upper Coyote Creek experienced flows sizeable enough to provide noticeable geomorphic changes at each site. Changes were particularly of note at Pacheco.

Pacheco Creek

Pacheco Creek experienced its largest flood year on record since 1998, experiencing two >10 year events (Figure 2). As a result of the hydrologic activity, major geomorphic change was observed on site (Figure 3). These events scoured new floodplain areas, depositing coarse cobble and establishing what looked like an active channel in a previous grassy area. Similarly, side channels were activated or initiated, and new surfaces near and around the channel were scoured, forming new bars. The force of these events also damaged an in-channel road crossing and knocked down several trees.

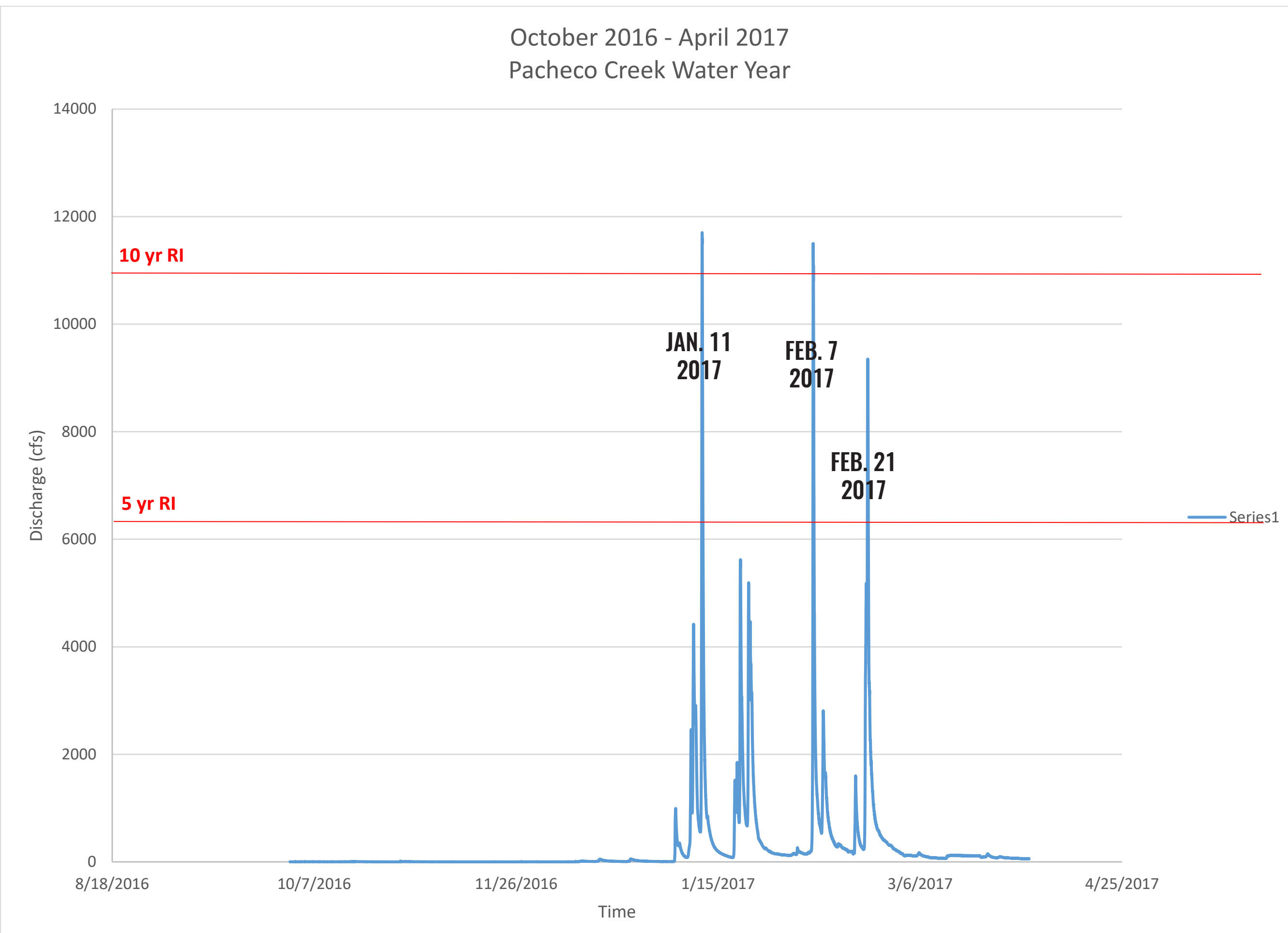
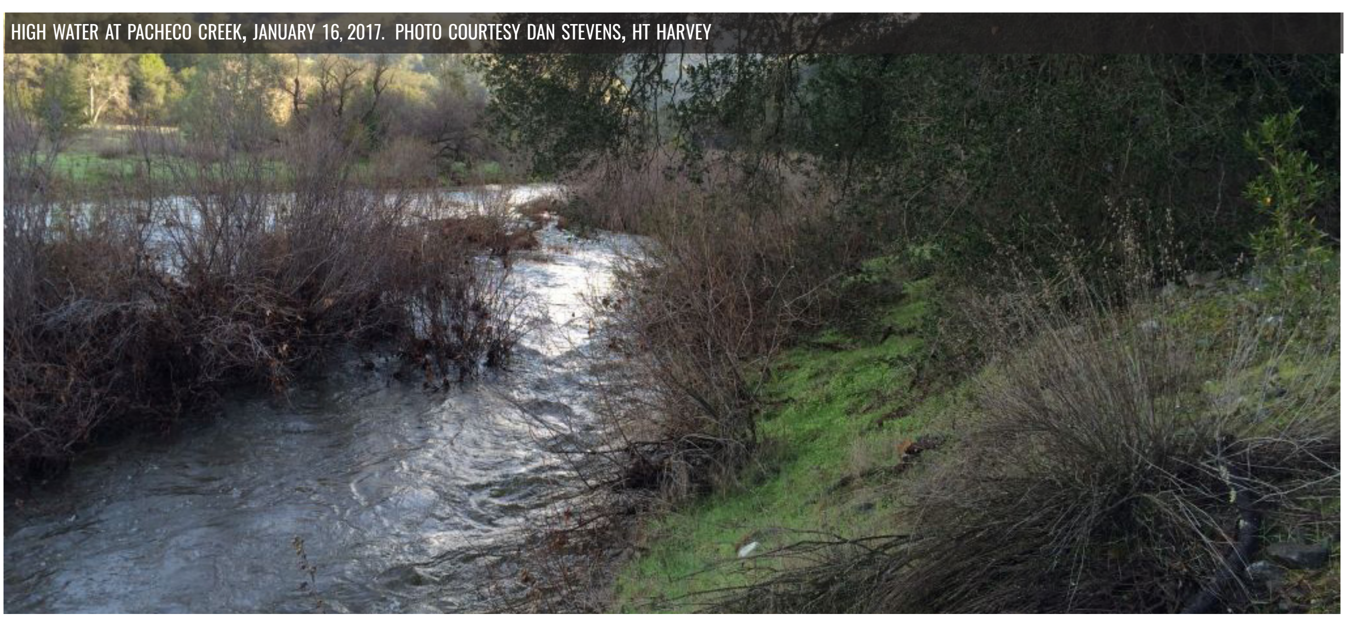


Figure 2. Hydrograph of flood events at Pacheco Creek from water year 2016-2017.

Figure 3. Geomorphic changes at Pacheco Creek. Pale areas indicate unvegetated cobbles and sediments. Note larger area of sediments reworked by flood flows during the 2016-2017 storms (B).



Upper Coyote Creek

Upper Coyote Creek also experienced significant hydrologic events in the 2016-2017 water year, including an approximately 25-year event for this system and two >5-yr events (Beagle et al. 2017, Figure 4). These events lead to noticeable geomorphic changes: secondary channels were activated, depositing coarse sediment, and new medial bars were scoured (Figure 5). However, very few trees were downed, and a major historical side channel was not activated.

To estimate the flood discharges, stage height and extent of wetted areas of these particular floods, we used the Riparian Zone Estimator Tool's Hydrologic Connectivity Module (RipZET, SFEI 2015) to construct a modeled rating curve and calculate the average flow depth and width associated with the flood-year recurrence interval. This model then estimates a relationship between flood stage and discharge, which can be plotted onto our LiDAR-derived cross-sections at Pacheco and Coyote. (More details about application of this tool to sycamore alluvial woodlands can be found in Beagle et al. 2017, and further detail on RipZET can be found in SFEI 2015). Using a combination of this RipZET modelling and field observation of existing sycamores, including tree coring, led to the development of the draft hypothesis that at least a 10-25 year event was required to sufficiently alter conditions to promote sycamore seedling regeneration (Beagle et al. 2017). Further, with new tree coring efforts, we estimate three trees along a similarly previously-scoured terrace were all dated back to 1998, a previous high discharge event (>10 yr recurrence interval). Considering

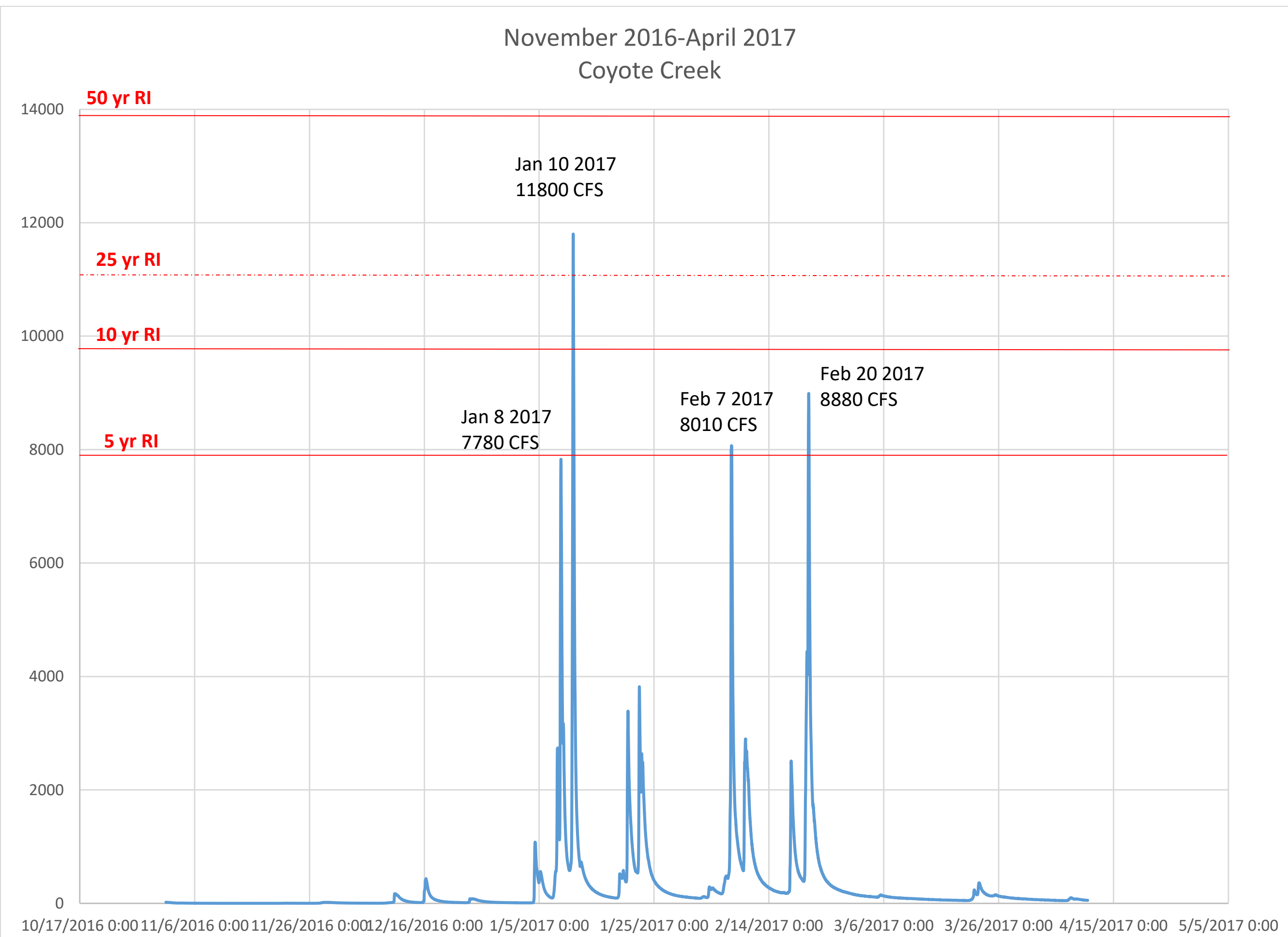


Figure 4. Hydrograph of flood events at Upper Coyote Creek from Water Year 2016-2017.

prior analysis from Beagle et al. 2017 as well as these more recent field observations, the implications of the changes seen in hydrologic year 2016-2016 suggest that conditions following the major flood events were appropriate to potentially catalyze a seedling regeneration event in the newly scoured areas. Natural hydrographs alone might not guarantee healthy regeneration, but we believe flooding is necessary.

We speculate that the interval between regenerative conditions for sycamores in the past has been decadal in length, and tied to 'threshold' flood magnitudes in which floods sort fresh substrate, with subsequent drawdown conditions that are wet enough to sustain growth of new seedlings. We wondered whether the 2016-2017 storms crossed this regenerative threshold.

Figure 5. Geomorphic changes at Upper Coyote Creek. Pale areas indicate unvegetated cobbles and sediments. Note larger area of sediments reworked by flood flows during the 2016-2017 storms (B).

REGENERATION OBSERVATIONS

SFEI staff visited both sites in November 2017 in order to observe whether the previous year's storms had in fact precipitated channel reworking and increased regeneration as hypothesized.

Pacheco Creek Sycamore Regeneration Observations

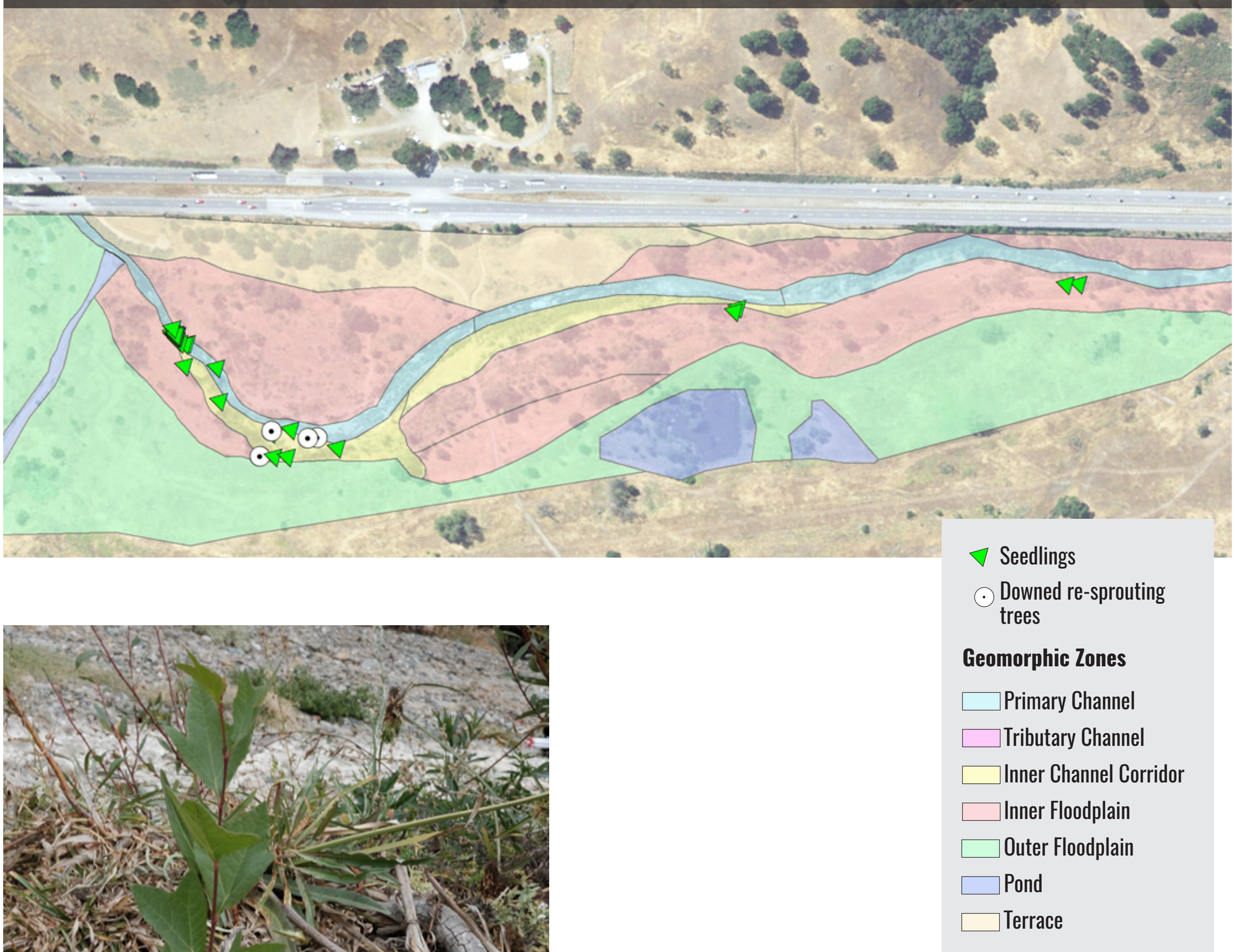
The study site at Pacheco Creek is located approximately three miles downstream of Pacheco Reservoir on North Fork Pacheco Creek, and drains approximately 435km^2. California State Highway 152 is adjacent to the study area, and the site is actively grazed. We observed sycamore regeneration in two categories at this site, both vegetative and by seed.

VEGETATIVE RESPROUTING FROM DOWNED TREES • Several trees along the active channel had been knocked over in the downstream direction and partially buried. These downed trees then sent multiple, large shoots upward from the prone trunks, similar to the growth strategies of other disturbance-adapted floodplain species such as bays (Umbellularia spp.) and willows (Salix spp.). This appears to be an additional resprouting strategy different than vegetative resprouting from ground level trunks observed during non-flood years (see Beagle et al. 2017).

DOWNED TREE AT PACHECO CREEK IS SENDING MULTIPLE, LARGE SHOOTS UPWARD FROM THE PRONE TRUNK.

SEEDLING RECRUITMENT • Sycamores reproduce sexually as well as asexually. Successful sexual reproduction by seed is thought to be controlled by the presence of suitable substrate, access to baseflow or groundwater, and seed production and dispersal (Bock and Bock 1989). During field observations on November 8, 2017, we mapped seedlings in 28 locations at Pacheco. We observed these seedlings within the geomorphic locations described below.

SEEDLINGS AND DOWNED, RE-SPROUTING TREES WITH GEOMORPHIC ZONES AT PACHECO CREEK




SYCAMORE SEEDLING AT PACHECO CREEK

POINT BARS • Seedlings were observed growing on freshly sorted point bars, in locations that were protected from high velocities on downstream ends of point bars, or in backwater areas of upstream ends of point bars.

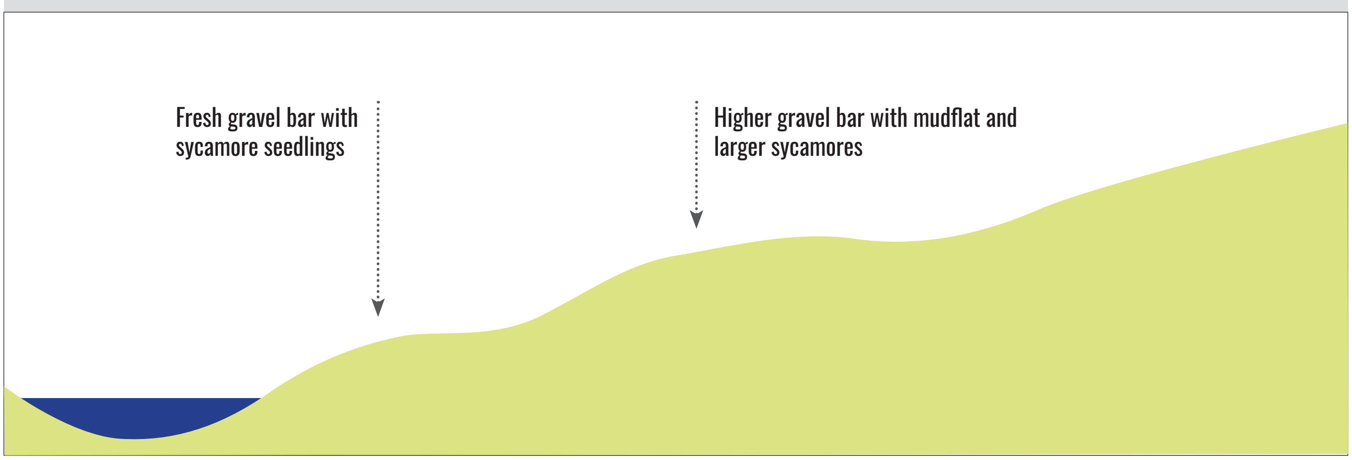
SYCAMORE SEEDLING ON FRESHLY SORTED CHANNEL BAR, PACHECO CREEK

NEW LATERAL-CHANNEL BARS •

Seedlings were observed in areas on new lateral-channel bars. In particular, they were observed in fresh cobble gravel bars about one foot above low flow, and situated such that groundwater access was still available. These bars were typically flat or of low grade, and tended to be on the inner bend of the river (though not always). When gravel bar grain size was fine or embedded, we did not see regeneration.

Seedlings were associated with young mulefat *(Baccharis salicifolia),* flat sedge *(Cyperus eragrostis)*, as well as water smartweed *(Polygonum sp)*. Bars with seedlings were in areas where no sign of grazing was observed. We observed sapling sycamores (1.5 -2m high) on bars of slightly higher evlevations that may have established in smaller events (see diagram below).

(left) Sycamore seedling among mulefat seedlings on freshly sorted gravel bar at Pacheco. (below) Idealized cross section of elevatons where sycamores were observed.




SYCAMORES OBSERVED NEAR LAKE FEATURES AT PACHECO CREEK

***SIDE CHANNEL OXBOW LAKE FEATURES* •** We also observed several saplings three to four feet tall, most likely one to three years old, located along a side channel which has become a series of small oxbow "lakes" or isolated pools. These saplings were located in a similar position as the new seedlings, in protected or lower-velocity sides of channels in flood stage.

(left) Off-Channel pool with fringe of mulefat seedlings. Young sycamores were found on bar where the person is.

***PERSISTENT BAR FORMATIONS* •** We observed a bar along the stream that had persisted through the most recent flooding event and that may have formed in another large event. This higher elevation bar has become vegetated with a several similar-sized sycamores in a patch of mature, 1.5 m high mulefat. These sycamores are estimated to be 20 years old based on tree coring. Though the age of the mature mulefat was only an estimate, we speculate that these mulefat and sycamores may have established together around the time the fresh gravel bar was formed. The last "threshold" event (1998) may have scoured this bar alongside the channel, beginning the cycle of succession.

It is not known what relationship the mulefat seedlings could have with the sycamore seedlings; perhaps the mulefat is protecting, or it could be competing with the sycamore seedlings. We did not find new sycamore seedlings in stands of older mulefat.


SYCAMORE ESTIMATED TO BE ABOUT 20 YEARS OLD WITHIN MATURE MULEFAT AT PACHECO CREEK

Upper Coyote Creek Sycamore Regeneration Observations

Upper Coyote Creek has experienced fewer anthropogenic disturbances than Pacheco Creek. Located near the headwaters of Coyote Creek, this area of Upper Coyote is upstream of two major dams and drains approximately 271 km^2 of steep, rugged terrain in protected park lands. Trespass grazing and wildlife use occur at this site. We observed very little regeneration at this site (see map, page 13).

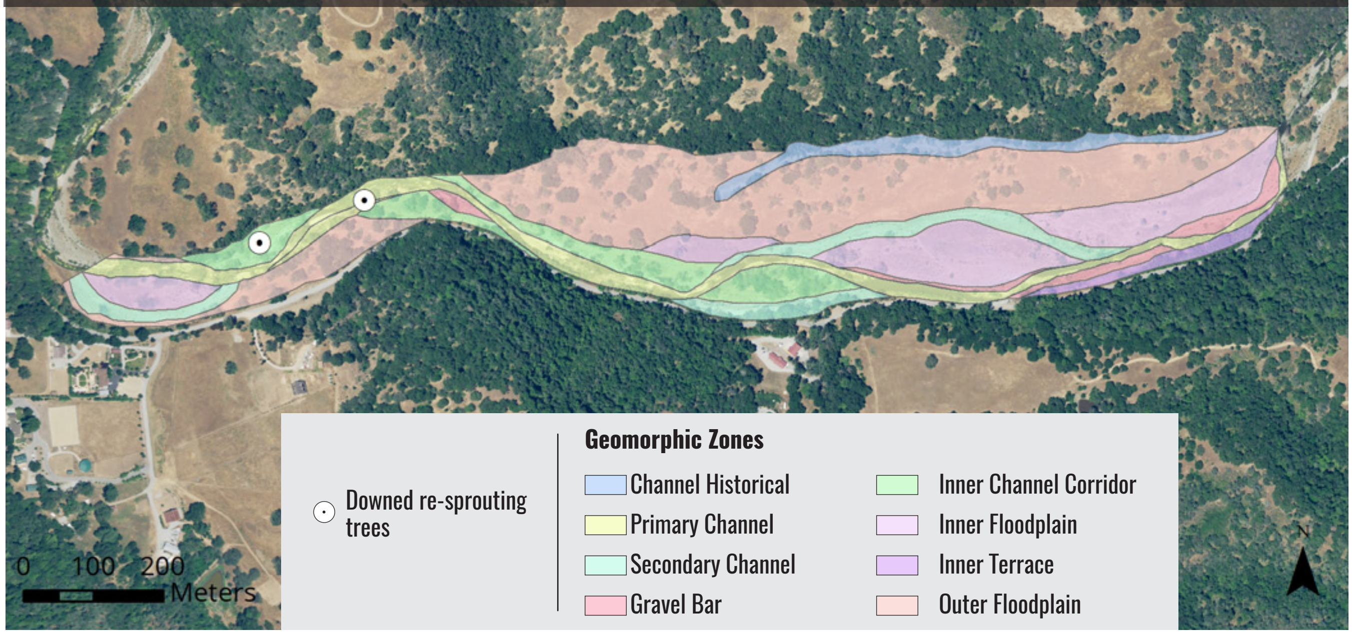
STAND OF MUELFAT SEEDLINGS WITH NO SYCAMORE RECRUITMENT AT COYOTE CREEK

SEEDLING RECRUITMENT • No seedlings were observed in any of the geomorphic zones at the site. Many freshly scoured bars with seemingly new mulefat seedlings were observed (photo), but in the geomorphic locations that we found seedlings at Pacheco, we found none at Coyote.

DOWNED, RE-SPROUTING TREE AT COYOTE CREEK

VEGETATIVE RESPROUTING FROM DOWNED TREES • At Upper Coyote Creek, we observed only two examples of sycamore branches knocked down, buried, with several new branches growing from the downed branch (see map, page 13).

DOWNED, RE-SPROUTING TREES WITH GEOMORPHIC ZONES AT UPPER COYOTE CREEK



GENERAL OBSERVATIONS AND WORKING HYPOTHESES

Cohorts

One potential pattern observed at both sites was groups of trees of the same size / age class within linear galleries. We speculate that these 'cohorts' of trees may have established during the same period under hydrologic conditions favorable to sycamore establishment and persistence. Correlating tree age with hydrological history could reveal patterns of regenerative flooding thresholds needed for sycamore establishment (Figure 6).

At Coyote Creek, we observed two possible cohorts. One cohort of old, large trees was concentrated in the main channel and may have established during large floods in the late teens and early 1920s. Another cohort was concentrated along the historical channel, and may date to the series of large floods in the mid-1950s. Major floods during these times may have deposited sediments and caused the channel to avulse into a new course, creating new substrate for several seedlings to establish. Continued access to flood or groundwater above baseflow water levels would have allowed these cohorts to persist.

We found a potential cohort of similar-aged sycamores at Pacheco of about 20 years old, which may date to the large flood event of 1998. These sycamore trees were growing in and among a stand of mature mulefat along the main channel (note that we do not have a good understanding of growth patterns / sizes of mulfat in relation to their age). The Coyote Creek site has mulefat of comparable size, but with no sycamore cohort - only one young sycamore was observed among the "mature" mulefat.

Given the 2016-2017 water year, it is possible that the seedlings observed with new mulefat on new bars at Pacheco in November 2017 have the potential to survive and form a new cohort. Much remains unknown about the history of both sites, but gathering evidence and observations of whether a cohort forms after a threshold flood year is important in understanding patterns and capacity in sycamore regeneration.

Though large flood events took place at the Coyote Creek site as well, It is possible that Coyote experienced change less conducive overall to promoting sycamore seedling regeneration, or other factors may be significantly affecting regeneration at the site.

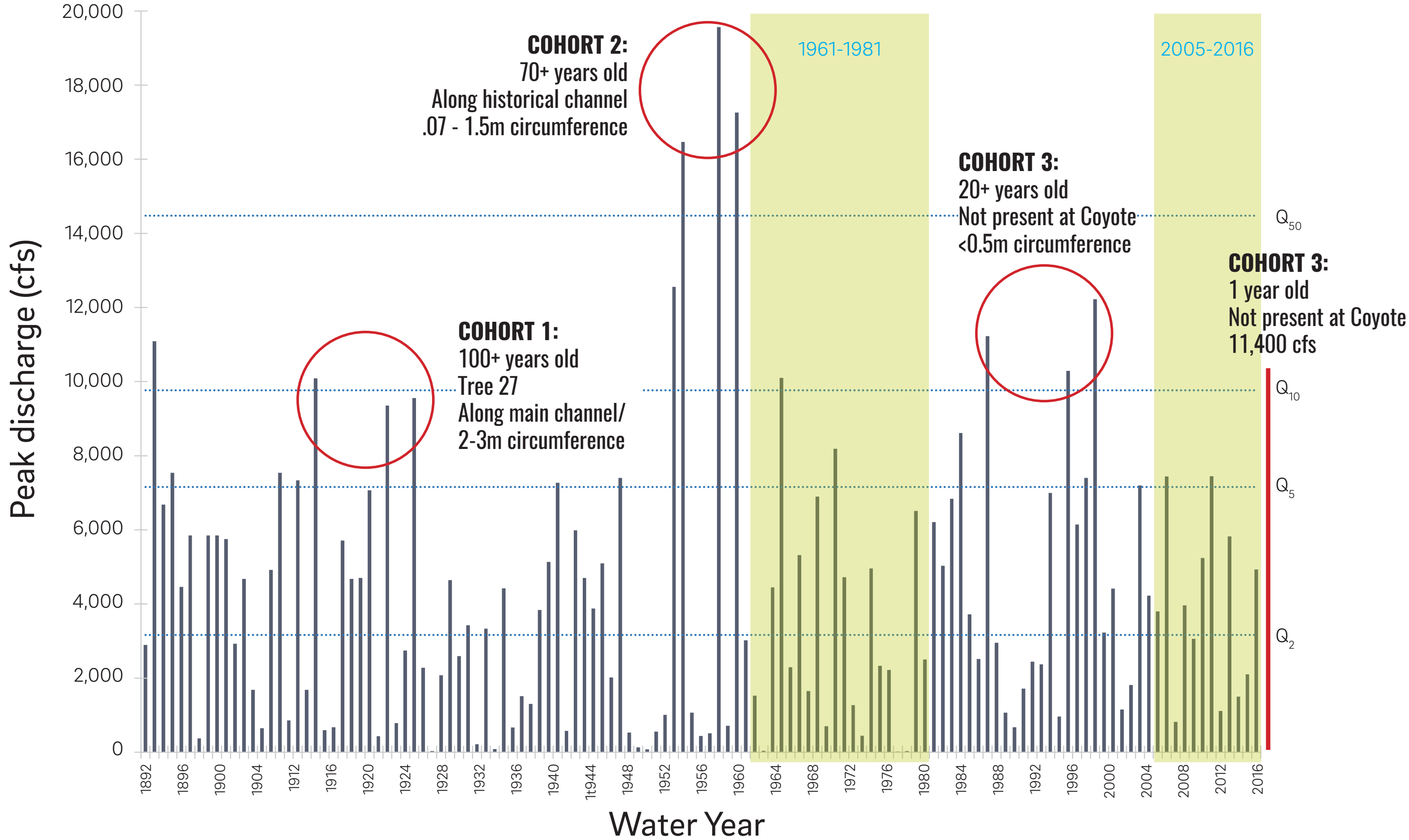


Figure 6 above shows the peak discharge from 1892-2017 from Coyote Creek at the Gilroy Gage, with missing data calculated from a regression from the Alameda Creek at Niles gage. Circles indicate major flood periods in the 1920s, 1950s, 1990s, and the 2017 event. Cohorts of sycamores observed at Coyote and Pacheco coincide with these flood events.

LINE OF CA. 1950 COHORT AT UPPER COYOTE CREEK

Distance to Baseflow and Groundwater

Many other factors may influence sycamore regeneration at these sites, including local access to groundwater. Local gradients or depth to groundwater may be impacting capacity for seedling regeneration on or near freshly sorted bars. We did not see regeneration on steep channel banks, even if species associated with sycamore seedlings elsewhere such as mulefat and *Cyperus* sp. were found on the steeper banks. We also didn't see as many seedlings far away from the active channel. It is possible that the sycamore seedlings we observed were establishing within a certain range of groundwater depths / elevation relative to the thalweg.

Many of the bars at Upper Coyote were steep sided, and the pool formations adjacent to them were deep (over 2 meters) and empty of water. It is possible that the gradient of the bars is too steep, or the difference in elevation between groundwater and the top of the bars is too great, to support healthy sycamore regeneration in these locations.

It may be useful to know the depths to groundwater of the varying geomorphic units, as depth to groundwater may be a limiting factor to seedling establishment and survival. Longitudinal variability of groundwater elevation may also be a factor, as the creek exits the canyon and widens out through the small valley, groundwater levels may drop, potentially affecting patterns of regeneration. It would be useful to survey downstream reaches for regeneration in areas suspected to have higher groundwater.

DEEP, EMPTY POOL FORMATION AT UPPER COYOTE CREEK

Anthropogenic and other drivers which could influence seedling survival

The regeneration patterns described above were surprising given the more "natural" flow regime at Upper Coyote Creek. We had assumed that Coyote would have supported more seedlings, and more vegetative regrowth after a water year like 2016-2017 than we observed. Some proposed hypotheses might help explain limiting factors for regeneration of sycamores at both sites. In general, successful regeneration by seed requires the right conditions at distinct phases: seed production, seed dispersal, seed germination, and seedling survival (Jones et al. 1994). One of these phases could be disrupted at Coyote.

Grazing and Browsing. More intensive grazing pressure might be limiting sycamore seedling survival at Coyote. Evidence of grazed vegetation was present throughout the site, including on mulefat, cottonwood, and young sycamore leaves (Figure 7). A browse line was observed at the more downstream end of the site. We also observed much deer scat and cow dung.

Drought and Regulated Flows. Seed production may be impacted by latent climate conditions; that is, it is possible that flows of requisite magnitude are still needed after a year of high flow to support seed production from sycamores. For instance, Pacheco did not experience "drought" conditions on site because continual releases from the upstream dam maintained more wetted conditions. Such a regime could potentially aid seedling survival or even seed production.

POTENTIAL BROWSE LINE AT DOWNSTREAM END OF UPPER COYOTE SITE. BROWSE LINES WERE NOT OBSERVED ELSEWHERE AT THE SITE.

Figure 7. (above) Grazed *Carex sp*. at Upper Coyote Creek. (below) Browsed sycamore seedlings at Pacheco Creek. November 15, 2017.

NEXT STEPS

Revisiting sites and protecting seedlings. Re-visiting the site in 2018 would be an appropriate next step, to assess seedling survival. Fencing should perhaps be considered to protect some seedlings to protect against grazing pressure and test the importance of grazing as a driver of disturbance on site.

Examining other sites. Examining re-growth patterns this year in other systems with sycamore alluvial woodland. Expanding sites and data points is of prime interest to understand this system more holistically, given the current study's small sample size and idiosyncrasies of the existing sites. Other potential study sites include at Sycamore Grove Park near Livermore, Sunol Regional Wilderness, and Garin-Dry Creek in Hayward.

Test seed viability. Seed success at Upper Coyote Creek is poor for reasons unknown. One possibility is that seeds produced at Upper Coyote Creek are not viable. This could be tested with a germination study (see Bock and Bock 1989).

Test depth-to-groundwater at Coyote. Testing groundwater levels at Coyote in strategic locations can help determine context and drivers of seedling success. In one study (Bock and Bock 1989), reproductive success from sycamore seeds has been observed in areas where seeds are kept in moist soil conditions for a period, and protected from uprooting by large floods. Groundwater tests could help answer this question.

LARGE SYCAMORE AT UPPER COYOTE CREEK

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APPENDIX A. LOG OF OBSERVATIONS AT PACHECO

Record	Growth Form	Geomorphic Position, Location	# of seedlings
1	resprout	Upstream side of low mid-channel bar	0
2	resprout	Upstream side of low mid-channel bar	0
3	seedling	Downstream side of low mid-channel bar	1
4	resprout	Upstream side of bar	0
5	resprout	Part of large pile (log jam) just downstream of Record 2	0
6	resprout	Upstream side of bar	0
7	seedling	5 ft above low flow on gravel bar; upstream of Record 6	1
8	seedling	Top of bar	1
9	seedling	Lower bar	1
10	seedling	Lower bar	1
11	seedling	Lower bar	1
12	seedling	Lower bar	1
13	seedling	Lower bar	1
14	seedling	Bankfull edge 2-3 feel above thalweg	1
15	seedling	Bankfull edge	1
16	seedling	Bankfull edge	2
17	seedling	Bankfull edge	2
18	seedling	Bankfull edge	1
19	seedling	Bankfull edge	1
20	seedling	Bankfull edge	1
21	seedling	Bankfull edge	1
22	seedling	Bankfull edge	1
23	seedling	Bankfull edge	1
24	seedling	Mid-channel bar. 1 m above thalweg, near scour pool	4
25	seedling	Bankfull edge on a bar	3
26	seedling	Shallow backwater back water pool area, swill	1
27	sapling	Backwater pool	1
28	seedling	1.5 foot up from thalweg on an in-channel bar	1
29	seedling	Gravel bar	1
30	seedling	Gravel bar	1
31	sapling	Steep bank, on silty surface at cut edge of bank	0
32	seedling	Gravel bar (higher)	3
		TOTAL SEEDLINGS OBSERVED	**35**