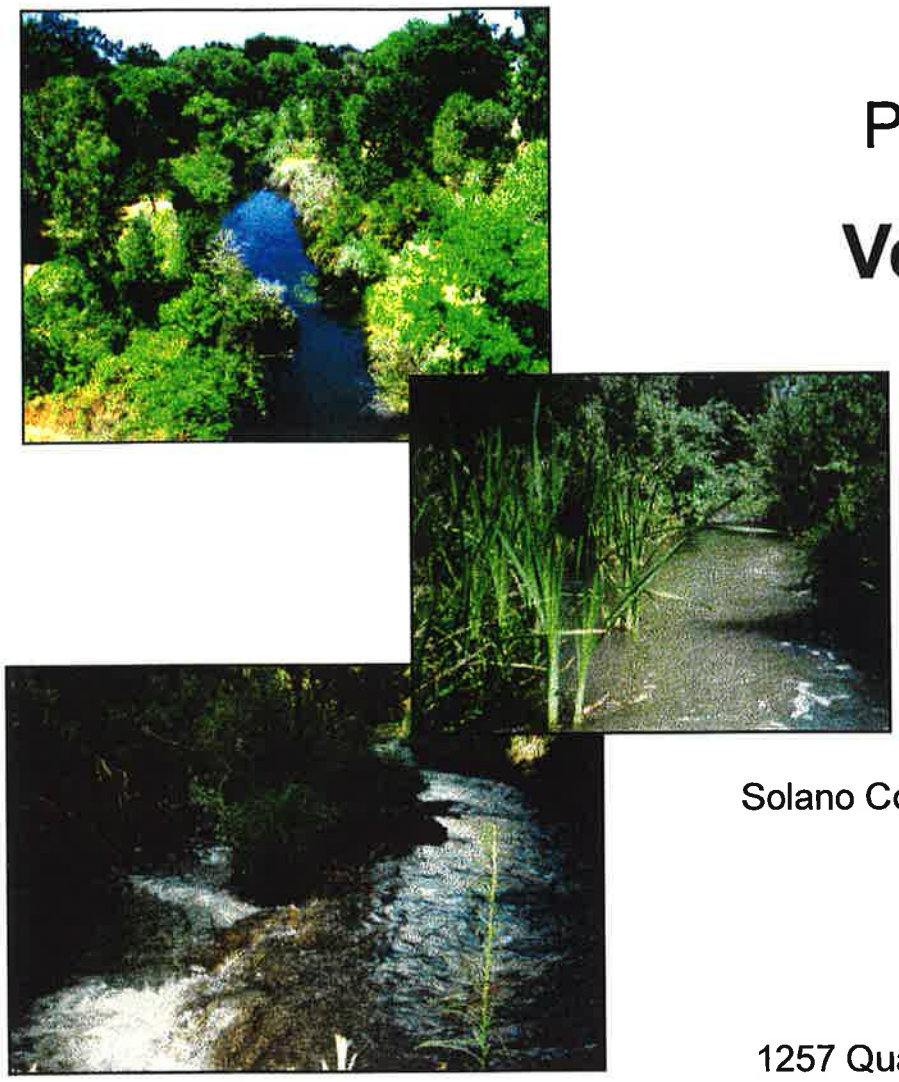

Putah Creek **Riparian Vegetation** Summary

June 1997

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Putah Creek Vegetation Summary

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Appendix I:	Aerial photographs of portions of Putah Creek
Appendix II:	Summary of riparian vegetation monitoring sites
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Putah Creek Riparian Vegetation Summary

Between 1990 and 1995 HortScience, Inc. monitored the riparian vegetation along Putah Creek to evaluate the effects of drought, and specifically, dry-year water release schedule, on the trees and shrubs. This report provides a summary of the studies and monitoring conducted during that period (Table 1). Work included:

- August-November 1990 study of vegetation development and soil moisture status
- April-July 1991 study of vegetation development and soil moisture status
- June 1992 vegetation monitoring
- May and September 1993 vegetation monitoring
- August 1994 vegetation monitoring
- June and October 1995 vegetation monitoring

HISTORICAL BACKGROUND

Prior to construction of the Monticello and Solano Diversion dams, Putah Creek carried large volumes of water in the winter and flow diminished dramatically in the summer. In most summer, the creek was dry at Davis. Since records were kept in 1906, annual flows have varied twenty-fold from year to year, from a high of over 1,000,000 acre feet to a low of 25,000 acre feet. The banks were flooded during heavy rains. The effects of high flows were to scour the creek channel, reduce the beaver population and deposit alluvium along the flood plain and terraces. During low rainfall years, creek flow decreased. In lower reaches, a series of intermittent pools remained, fed in part by groundwater seepage.

Vegetation along Putah Creek was composed of a wide riparian forest from the Coast Range to the Davis sinks prior to settlement through Mexican land grants. It has been estimated that the forest between Winters and the Sinks covered 22,000-65,000 acres[1]. The flood plain supported a diverse community of upper, mid-range and lower canopy. The riparian zone was flanked by valley oak savannahs, which were occasionally flooded.

The creek, especially the portion from Winters to the Putah Sinks, has undergone extensive modification in the last century, primarily to clear agricultural land, decrease flooding and improve water storage and ground water recharge. The first major change occurred in 1871-72 when the South Fork of Putah Creek was dredged to divert water away from Davisville for flood protection (Table 2, Fig. 1). In 1938, the Winters diversion dam was built to improve ground water recharge (following a dramatic drop in the water table in that area during the late 1920's to 1930's).

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[1] U.S. Dept. of the Interior Fish and Wildlife Service. 1993. Reconnaissance planning report: Fish and wildlife resource management options for Lower Putah Creek, California. Ecological Services Field Office, 2800 Cottage Way, Room #-1803, Sacramento CA 95825-1846. 128 pp.

Table 1: Putah Creek Studies and Monitoring Performed by HortScience, Inc.

Time	Tasks performed
August-November 1990	Mapped and measured vegetation in 8 transects between I-505 and Old Davis Rd. Investigated and described soil characteristics in 7 soil pit excavations. Measured foliar temperature, soils moisture and plant appearance biweekly in 5 transects. Collected increment cores from mature trees to measure historical pattern of tree growth. Prepared Putah Creek Riparian Vegetation Study Report, April 1991.
April-July 1991	Measured soil moisture and plant appearance biweekly in four transects. Prepared Putah Creek Riparian Vegetation Study Report, August 1991.
June 1992	Inspected riparian vegetation at I-505, Stevenson Bridge, Pedrick Rd., Old Davis Rd. and Mace Blvd., noting appearance, regeneration, water in creek.
May 1993	Surveyed Putah Creek by canoe, from the diversion dam to Pedrick Rd.
September 1993	Inspected riparian vegetation along creek from fishing access point, I-505, Stevenson Bridge, Pedrick Rd., Old Davis Rd. and Mace Blvd., noting appearance, regeneration, water in creek. Surveyed Putah Creek by canoe, from Pedrick Rd. to Mace Blvd.
August 1994	Inspected riparian vegetation along creek from I-505, Stevenson Bridge, Pedrick Rd., UC Davis, Old Davis Rd. and Mace Blvd., noting appearance, regeneration, water in creek.
June 1995	Inspected riparian vegetation along creek from I-505, Stevenson Bridge, Pedrick Rd., UC Davis, Old Davis Rd. and Mace Blvd., noting appearance, regeneration, water in creek.
October 1995	Surveyed Putah Creek by canoe, from the diversion dam to I-505.

Table 2 : Time Line of Activities on Putah Creek

Activity	Impact on Creek
Pre-settlement	
THE NATURAL PATTERN OF CREEK FLOW WAS HEAVY IN WINTER AND LOW IN SUMMER	Winter flooding events scoured creek clean, removed beaver dams, deposited alluvial soils along borders, and fed tributaries and secondary channels. Native Americans were forced from villages adjacent to the creek during high floods. In summer, there was reduced flow in the channel; isolated pools formed in some areas; the channel was dry in others.
FORESTS ALONG CREEK CHANNEL AND TRIBUTARIES; MAY HAVE BEEN 3 MILES WIDE AT POINTS.	Species included oak, willow, alder and cottonwood. Riparian forest from Winters to Putah Sinks may have been 22,000 acres.
1840-1880	
FIRST SPANISH LAND GRANTS GOLD RUSH, RAILROAD DEPOT COMPLETED, TOWN OF DAVISVILLE ESTABLISHED AND SETTLEMENT OF AREA	Settlement and conversion of land to agriculture begun.
1871-1872	
SOUTH FORK OF PUTAH CREEK DREDGED; IMPROVEMENTS CONTINUE ON A SPORADIC BASIS FOR 100 YEARS	Water diverted from North Fork approximately 1 mile west of present day I-80 overpass. Construction of the South Forst stimulated channel downcuttting, which proceeded in an upstream direction. Overbank flow and deposition of alluvium was reduced. Flooding still occured at Davisville, although only in years of very high water.
early 1900's	
USE OF WELL-WATER FOR IRRIGATION BECOMES COMMON	In 1912, there were 720 wells; by 1955, 1450 wells. Water table in Putah Creek - Dixon area dropped 20' in the 1920s and early 1930s; level briefly rose in the late 1930's and early 1940's, then began to decline. By the late 1950's ground water levels declined to all time lows.

Table 2 : Time Line of Activities on Putah Creek

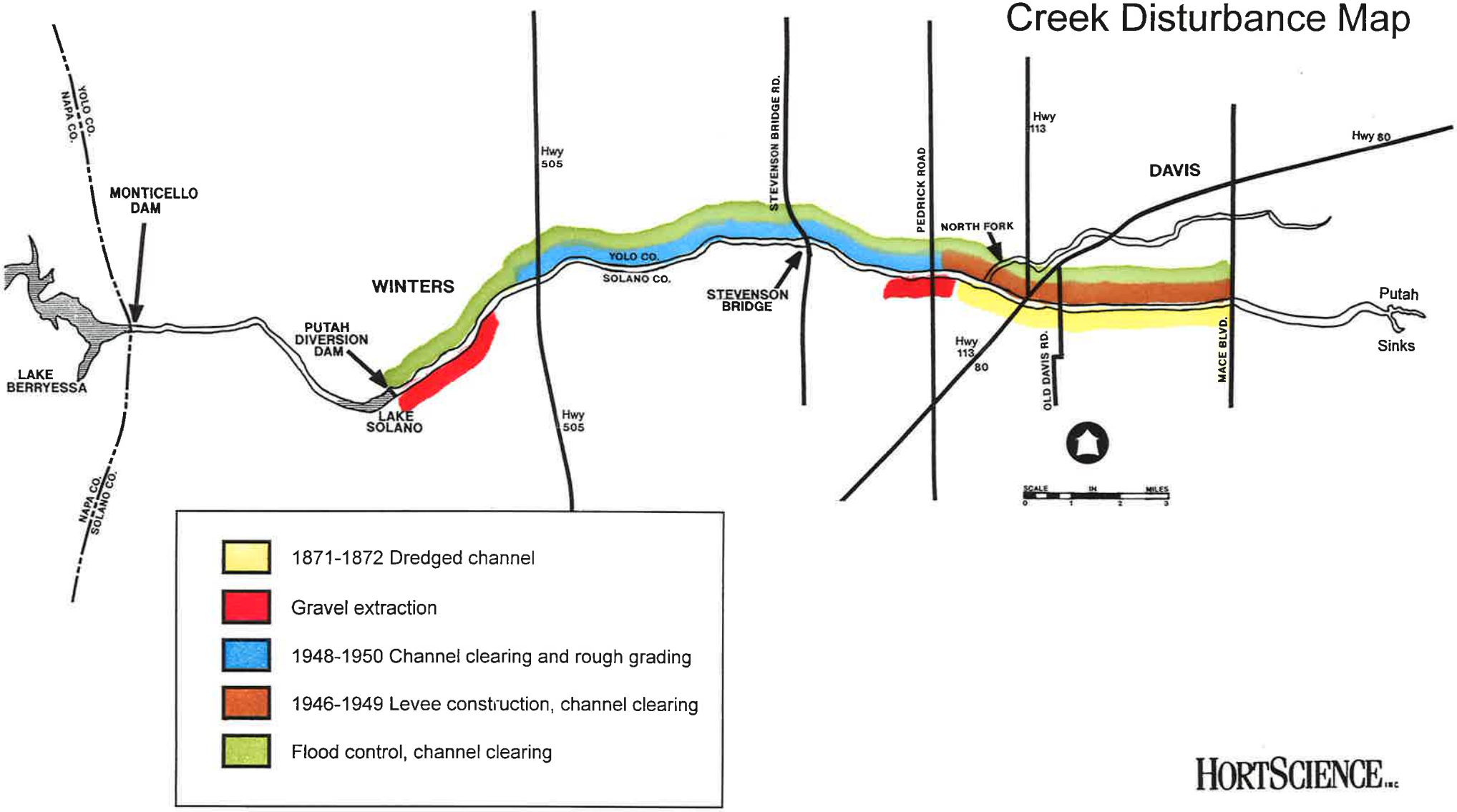
Activity	Impact on Creek
1940s	
CORPS OF ENGINEERS ALTERS CREEK TO INCREASE CAPACITY TO CONTAIN A 100-YEAR FLOOD EVENT	Most of bank-to-bank vegetation was removed by bulldozing from Winters to the Yolo by-pass. Channel was excavated to a trapezoidal profile.
CORPS OF ENGINEERS CONSTRUCTS LEVEES FROM DAVIS INTO SACRAMENTO COUNTY	Material extracted from creekbed was used for levee construction. Levees prevented Putah Creek from meandering and limited rejuvenation of riparian vegetation. South Fork greatly enlarged. North Fork isolated from natural flow.
GRAVEL EXTRACTED FROM CREEK BED NEAR DIVERSION DAM AND PEDRICK RD.	Left spoils of fine particles, deepened channel. Altered the natural conformation of the creek and associated vegetation. (Extraction discontinued near Diversion Dam in late 1960's; at Pedrick Rd. in late 1970's.)
1953-1957	
CONSTRUCTION OF MONTICELLO AND SOLANO DIVERSION DAMS	Natural flow within creek blocked during construction. Following construction, water was released to Lower Putah Creek when there was measurable flow into Lake Berryessa.
CLEARING OF CHANNEL VEGETATION OCCURS ON A REGULAR BASIS	Both large and small diameter trees were removed; soil surface was stripped clean.
1970	
WATER RELEASES OCCUR ACCORDING TO FIXED MONTHLY SCHEDULE RATHER THAN AS "LIVE STREAM", AND ADJUSTED TO REFLECT NORMAL AND DRY YEARS	Water might not continually flow through to the Yolo by-pass, especially during dry years when annual flow into Lake Berryessa was less than 150,000 acre feet.
1975	
CORPS OF ENGINEERS REEVALUATES CHANNEL CLEARANCE POLICY	Vegetation permitted on levee slopes to within 15' of toe; trees larger than 3" in diameter removed at regular intervals using chainsaws and handtools.

Table 2 : Time Line of Activities on Putah Creek

Activity	Impact on Creek
1984	
VEGETATION CLEARING CONTINUED	Selective channel clearing occurred east and west of Old Davis Rd., I-80 and railroad overpass.
1987-1992	
CALIFORNIA EXPERIENCES A DROUGHT	Summer creek flows did not reach Davis.
1995-1996	
ABOVE NORMAL RAINFALL	Water released according to normal schedule.

Putah Creek **Riparian Vegetation** Summary

Creek Disturbance Map



HORTSCIENCE INC.

The construction of Monticello Dam was completed in 1957. Prior to construction of the dam, water rarely reached Davis during the summer. Over the period 1916-1951, the creek was dry in the summer at Winters in 15 of the 35 years. After the dam was constructed, however, winter runoff was retained in Lake Berryessa, and released throughout the summer, so that flow was maintained through to Davis.

Summer flows in Putah Creek are supplied by groundwater inflow, irrigation return flow and water releases from Berryessa. Because of reduced inflow and water releases during the drought, increased percolation losses and increased riparian pumping, water in the creek began to recede from Davis during the summer of 1990. By the end of August the creek was dry in the reach from Pedrick Rd. to the Yolo bypass except for localized areas receiving water from agricultural irrigation return flow, water releases from the UCD fishery research facility, storm drain outlets, and effluent from the waste water treatment plant. During September, however, an additional 1400 acre feet of water was released over a two-week period. Those releases resulted in temporary water flow in the creek to within one-half mile of I-80.

Not only has water flow through the creek been altered and manipulated over the past century, but maintenance of the creek for flood control has had significant impact on vegetation. In the 1950's the Army Corps of Engineers cleared all vegetation in the creek from the Winters bridge to I-80 while converting the creek to a flood control channel.

Following construction of the dam in 1957, mass vegetation removal within the creek occurred regularly through 1975. In 1975 clearing requirements were reduced to allow vegetation to develop on the channel slopes and within 15' of the toe of slope. Under the new policy, trees greater than 3" in diameter in the channel invert (floodplain) were to be removed every 5 years. Plant removal was performed with chainsaws and hand tools, rather than with bulldozers. Aerial photographs of the creek taken in 1952, 1957 and 1973 illustrate the sparseness of vegetation in some areas due to vegetation clearing (Appendix 1).

Development of agriculture along the creek and creek modifications over the last century have reduced the size of the riparian forest to a narrow band concentrated within the creek channel. Jones and Stokes (1992) estimated that 120-200 acres of riparian forest are currently present, with a stand width of 400-1,000 feet. When compared to aerial photographs from the 1950's, however, it is clear that vegetation density in the 1990's has increased in many places along the creek.

In summary, Putah Creek has experienced continuing and large-scale changes over the last 100 years:

- The extent of the riparian forest has been reduced to a narrow corridor along the creek.
- The channel has been deepened and lateral movement reduced.

- Vegetation has been removed repeatedly for flood control.
- The natural pattern of streambed scour and clearing away of vegetation by peak flows that create opportunities for seedling establishment by many riparian species has been reduced.
- The system has become more stable in terms of volume of water and channel conformation, enhancing establishment of oaks, black walnut, ash and boxelder.

DESCRIPTION OF STUDIES

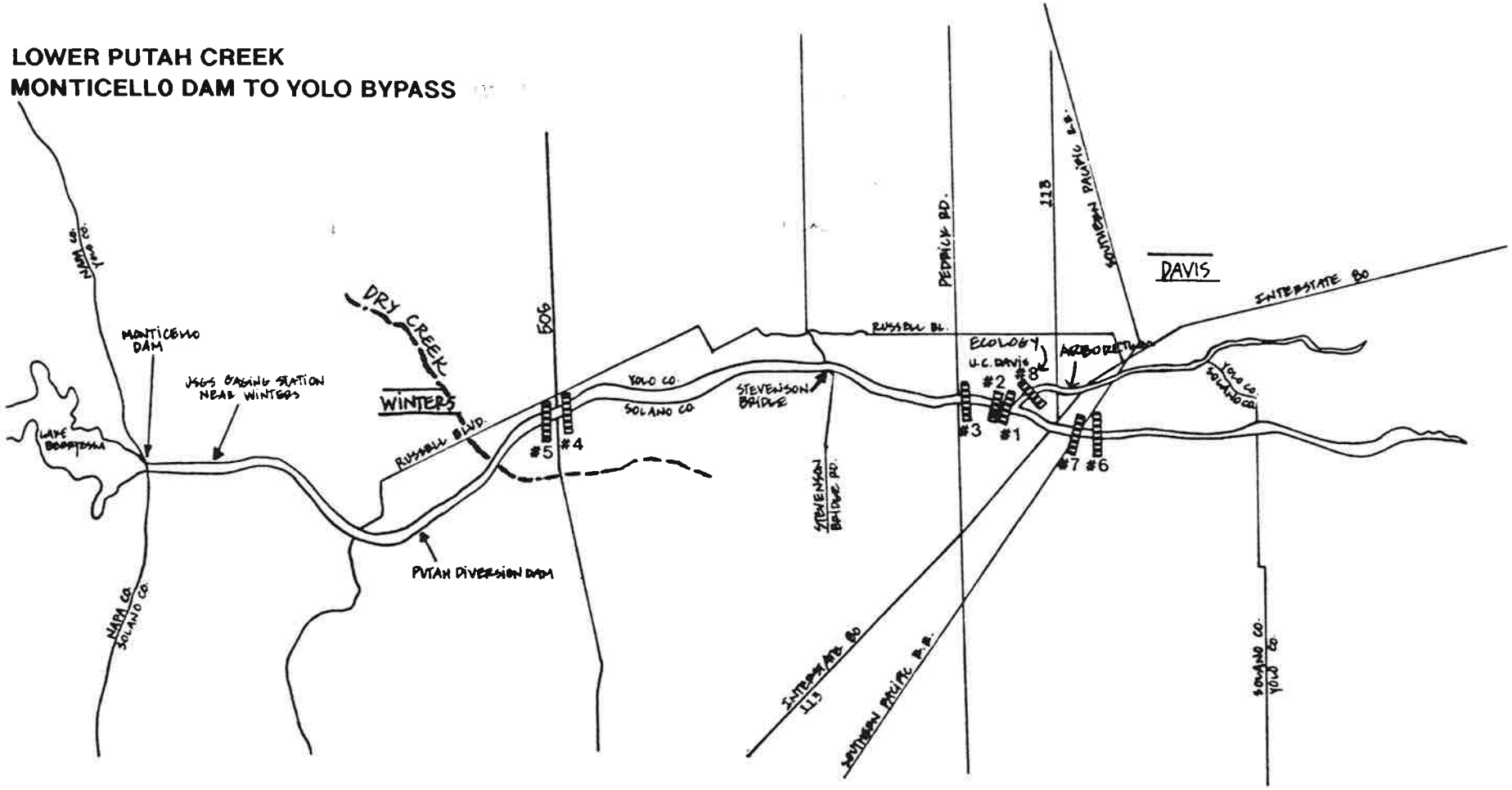
1990 Studies

During the late summer and fall of 1990 HortScience, Inc. evaluated the effects of dry-year water release schedules on the woody vegetation adjacent to the creek. The purposes of the studies were to monitor the water stress of the trees, estimate what would happen to them assuming the drought continued another year and the dry-year release schedule were continued, and to evaluate what benefits would be achieved if an additional 3000 cubic feet of water were released during the winter. The results of that study were described in the report *Putah Creek Riparian Vegetation Study*, April 1991, HortScience, Inc. A summary of that report is provided below.

Project Design

Initial site reconnaissance revealed that the area of Putah Creek that was most affected by low water flow was the reach from Pedrick Road to Mace Blvd., through the University of California property. Sampling sites were therefore concentrated in that area. The I-505 overpass area was chosen for comparison because water remained in the creek in that location and the vegetation types were similar to those on University property. The vegetation near Lake Solano was too different in composition to allow comparison with the eastern reach of the creek.

Eight 100-ft. wide transects were selected for study (Fig. 2). The woody vegetation within each transect was mapped and measured. In five of the transects, biweekly measurements were taken of foliar temperature using an infrared thermometer, soil moisture via gypsum blocks placed in the soil, and plant appearance using a visual rating system. In addition to periodic sampling, increment cores were collected from mature trees for comparison of growth to past rainfall and creek flow patterns. Soil characteristics were investigated and described in seven soil pit excavations.



Putah Creek **Riparian Vegetation** Study

Fig. 2 TRANSECT LOCATIONS MAP

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Results of 1990 Study

Vegetation Distribution

Woody vegetation in each of the eight transects was identified and mapped. Twelve woody plant species were encountered in the eight transects, four exotic species and eight indigenous species (Table 2). Trunk diameters of each tree were classified by size. The following observations were made:

- There were no clear differences in vegetation character (species, size, health) among the transects 1-7, at least none that could be distinguished from creek topography.
- There was a marked difference in vegetation within transects. Sandbar willows were located only on creek banks (location C), cottonwoods on the floodplain (location B), oaks and walnuts on the levee banks and slopes (location A) (Fig. 3).
- Although twelve species of woody plants were encountered, over 85% of population was composed of five species: valley oak, Oregon ash, boxelder, eucalyptus and California black walnut.
- The dominant large trees were valley oak and cottonwood.
- Regeneration of valley oak on the slopes and floodplains was excellent. Cottonwood was not regenerating; only one tree under 6" diameter was found.

It was clear from large number of seedlings that, given the existing conditions and management, oak, Oregon ash, eucalyptus and walnut have better chances for establishment and growth than the cottonwoods and tree willows. Vegetation composition was undoubtedly influenced greatly by floodplain clearing programs. Under the current policy dictated by the U.S. Army Corps of Engineers, the willows and cottonwoods which develop along the creek would be removed when tree diameter exceeds 3".

Water Stress Monitoring

Water stress was evaluated in several ways:

- Visual evaluations of appearance
- Foliar temperature
- Infrared photographs
- Soil moisture measurements

In general the valley oaks and black walnuts maintained full canopies throughout the study period. Evaluations of the cottonwoods was confounded by infestation with an insect that caused premature leaf drop.

Fig. 3: Typical riparian zones in a transect of Putah Creek.

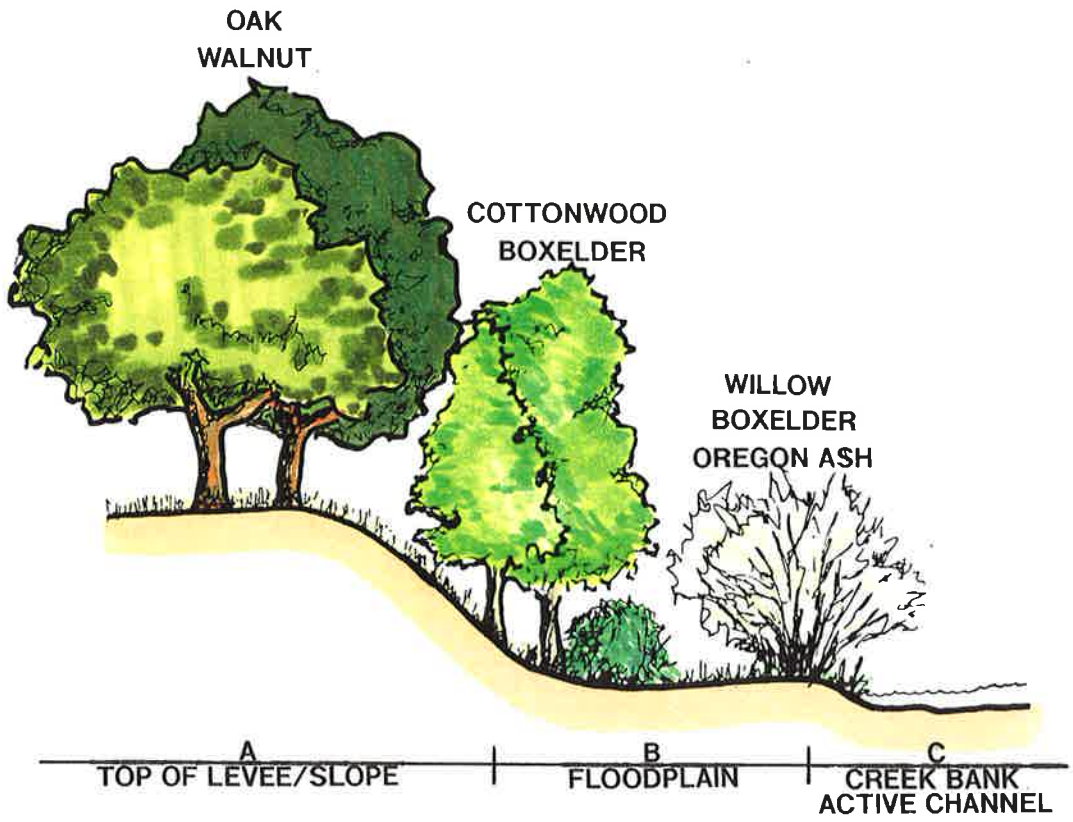


Table 3: Size class disribution and frequency of occurrence of trees in eight transects along Putah Creek

Species	No. of Transects[1]	Trunk size class (inches) 0-1	1-6	6-18	18+	Total
Valley oak	7	>90	38	19	4	>151
Oregon ash	5	>46	42	3	0	>91
Boxelder	6	31	55	3	0	88
Eucalyptus	6	>39	16	4	0	>59
Black walnut	6	20	11	10	3	44
Red willow	7	10	11	10	2	33
Cottonwood	4	0	1	12	5	18
Gooding's willow	2	2	7	3	0	12
Almond	3	0	5	1	0	6
Arroyo willow	1	0	0	1	0	1
Tree-of-heaven	1	1	0	0	0	1
	--	239	186	66	14	>505

The sandbar willow were highly variable in their appearance. In several areas plants on the creek banks close to water appeared water stressed. On the other hand, in some locations plants on the banks were fully foliated with no dieback. In transect #7 both conditions existed on opposite sides of the creek. The plants with full canopies were receiving water from agricultural runoff, not from the creek. Following release of additional water in September, sandbar willow in areas receiving water re-sprouted. Re-sprout was greatest in the gravel bar in transect 3.

Soils and Soil Moisture

Soils were examined in four transects (#3, 4, 5, 7) by digging pits with a backhoe to depth ranging from 5-7'. From I-505 overpass to Old Davis Rd. the soils were found to be tight, fine-grained soils of fan terrace materials. The one exception was the gravelly sand in the sandbar east of Pedrick Rd. (transect 3).

To evaluate soil moisture characteristics, 19 gypsum blocks placed in the rootzone of plants in 5 transects. The gypsum block readings indicated the following:

- Soil moisture declined through the sampling period in the floodplain and levee slope soils (locations A and B).
- Soil moisture did not increase in locations A and B following water releases in September.

The soil excavation pits showed that where the stream channel runs through the fine-grained sediments, very little lateral movement of water takes place. The monitoring results of the soil moisture blocks further substantiated this lack of lateral flow. Where streamside vegetation is found growing in these soils, the plants (especially the trees) must develop roots in the moist portions of the profile.

Historical Pattern of Tree Growth

Tree rings provide a historical record of growth. Annual increase in trunk diameter is related to climatic factors affecting growth, such as water supply and seasonal temperature. Samples were collected from trees to help establish a history of tree growth along Putah Creek, and to evaluate the effect of rainfall and creek flow on growth. Tree ring data for oaks on the upper banks (location A) did reveal some interesting trends:

- There were no differences in growth among transects 3, 4, 5 and 7 along the creek. However, growth patterns of oaks on the north fork of the creek (transect 8, UCD Ecology Reserve and Arboretum) were different than along the active creek.
- Ring increment (growth) of oaks was reduced during previous periods of drought; during years of normal rainfall, growth increased.

- A comparison of tree ring development vs. rainfall and creek flow for trees along Putah Creek indicated that variation in ring increment was more closely related to annual precipitation than creek flow. This would be expected from the soils information indicating lack of lateral movement of water from the creek into the terrace or levee soils (locations A and B).

The area has experienced other periods of drought: 1911-1913, 1928-1934 and 1976-1977. While growth was less during the drought years, the trees did survive. In years of more normal rainfall, ring increment increased. The peak in the tree ring indices for oaks in location A in the late 1930's, early 1940's correlated with high rainfall during that time. 1939 was a dry year and the mean ring index dropped. The same pattern is expected to occur during future droughts: reduction in growth during the low rainfall years, with recovery when rainfall increases.

1991 Study

This series of observations was undertaken to examine plant development and soil moisture during the early part of the growing season. We assumed that soil moisture was high at the end of winter and early spring (especially given the heavy rainfall of March). In the absence of substantial over-bank flow, trees in the floodplain and top of levee locations must rely on the soil moisture obtained from winter rains.

Project design

Four of the transects established in 1990 were used in this study: #3, 4, 5, and 7 (Figure 2). Gypsum blocks were installed across each transect as part of the 1990 study. Blocks were placed in creek bank, floodplain and top of levee locations. Measurements of soil moisture were collected on a biweekly basis from early April through early July. Visual observations of plant development were made at each soil moisture sampling date.

Results

Soil moisture

As seen in 1990, there were large differences in soil moisture status within individual transects. Through the study period, soils directly adjacent to the creek bank remained moist, while soil moisture in top of levee locations decreased.

Soils began to dry in the top of levee approximately 7 weeks (end of May) after installation of gypsum blocks. The pattern of drying continued until the observations were terminated, in early July. By that point, soils in the top of levee area were very dry (below the ability of the gypsum block to measure soil moisture accurately). The only exception to this pattern was found in Transect #4, where soils began to dry later in the study.

Observations of soil moisture in 1991 were similar to those seen in 1990 for the top of levee and creek bank locations; the former were dry while the latter remained moist (Figure 4). This result confirmed our conclusion from the 1990 study that water flow in the channel during the growing season is not a significant contributor to soil moisture along the top of levee location.

Plant development

At the time the 1991 study began, new shoots of most trees were just beginning to emerge and elongate. Cottonwood and willow were in full flower.

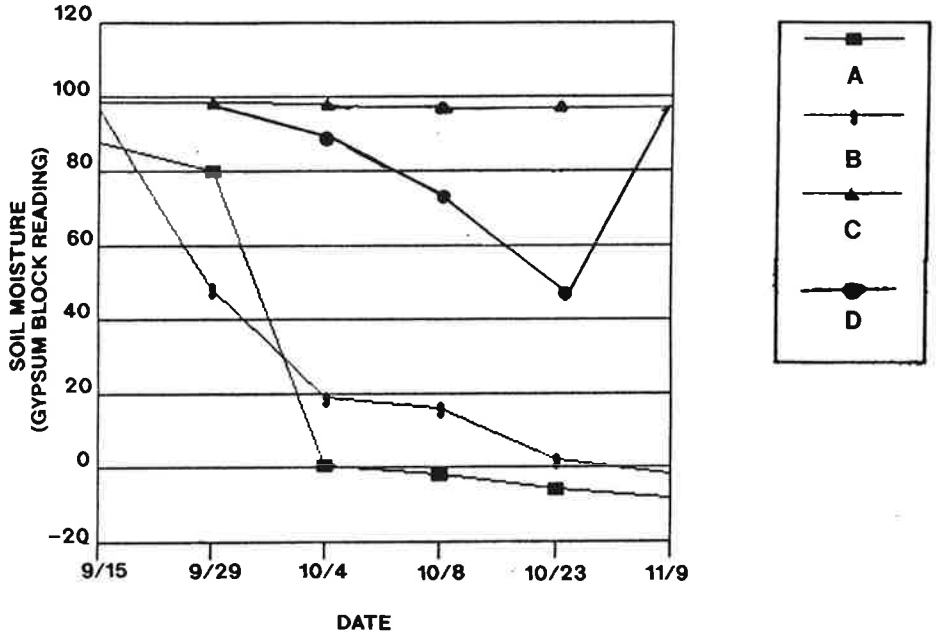
No significant changes in plant growth occurred during the 3-month period of observation. Development appeared to proceed normally. Even in early July, there was no evidence of any water stress at any transect or location within transect. Trees were fully foliated and there were no wilting symptoms.

Conclusions from 1990 and 1991 studies

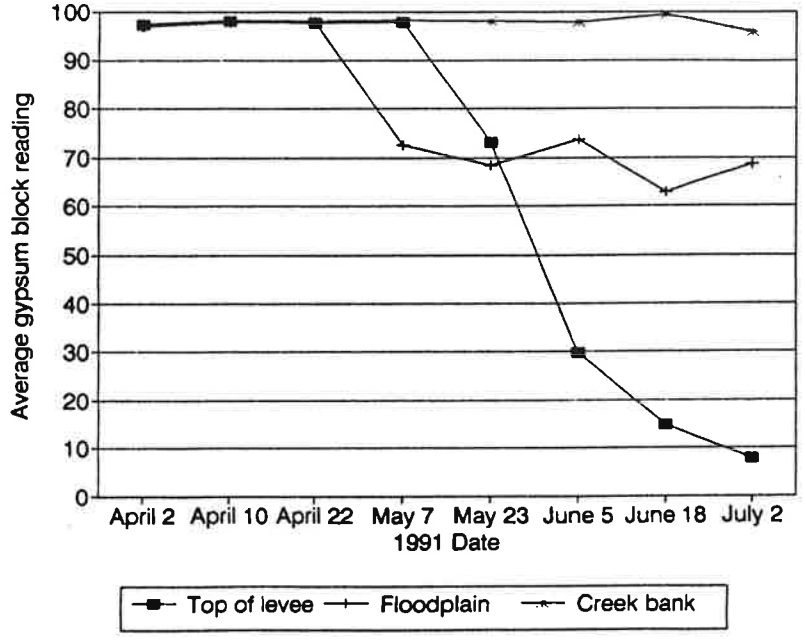
- Little water stress developed in the trees (oaks, cottonwoods, Oregon ash, tree willows) along the creek during the sampling period, regardless of distance from the creek, or presence or absence of water in the creek.
- The soil at the top of the levee was wetted during the winter, then became drier through the spring and summer. The resultant plant water stress was within the range of tolerance for the existing tree species.
- Clearly, much of the sandbar willow, the major shrub along the creek banks, experienced defoliation and twig dieback. However, poor plant appearance was not related to the presence or absence of surface water in the creek. Some willows that appeared lush and green where adjacent to water, while others appeared drought stressed.
- Soil moisture declined through the sampling period except in soils immediately adjacent to the water. Additional water releases in September did not affect soil moisture except immediately adjacent to the creek.
- Based on the soil characteristics examined, lateral movement of water from the creek into the floodplain and levee soils is restricted by soil type. In artificially constructed reaches of the creek, lateral movement is no more than two to three feet. In gravelly areas, there may be more movement. In no case examined did water enter the levee soils.
- Given the soil conditions within the area studied, one would not expect that dry-time releases of water would significantly aid vegetation outside the immediate channel of the actively flowing creek unless there was over-bank flow.
- The increment core data indicate that the oaks on the tops of the banks have undergone past periods of drought, to which they responded with reduced growth that improved when normal rainfall resumed.

Fig. 4: Soil moisture readings from gypsum blocks installed in the rootzone in locations A (top of levee or levee slope), B (floodplain or bankful channel) and C (creek bank by active channel). Each point is an average of the soil moisture readings for that location. D is data from a single gypsum block near the active channel, where the water receded during October, and rose in November.

1990 Study



1991 Study



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- The increment core data indicate that the oaks on the tops of the banks have undergone past periods of drought, to which they responded with reduced growth that improved when normal rainfall resumed.
- Comparison of tree ring development vs. environmental variables indicates that variation in ring increment was more closely related to annual precipitation than creek flow.

Vegetation monitoring

Annual vegetation surveys at the access areas along the lower reach of Putah Creek were undertaken in 1992-1995 (Table 1). Compiled comments of the appearance of the vegetation, regeneration and creek water flows are provided in Table 4. Our major observations were:

- Water was flowing in the active channel in all monitoring locations, except for Mace Blvd. in August 1994, which was on a "dry year" release schedule. Condition of the sandbar willow was variable 1992-1994. Some plants showed dieback even though water was present in the active channel.
- Healthy seedlings and saplings were noted in all locations, including valley oak, Oregon ash, boxelder and California black walnut and willow. No cottonwood seedlings were encountered.
- Heavy flows in winter 1994-spring 1995 overflowed the active channel banks and moved considerable debris. Vegetation establishment and growth of all species in all monitoring locations was enhanced.

Table 4 : Compiled Comments from Vegetation Surveys

Location	June 1992	September 1993	August 1994	June 1995
I-505	Water level to edge of bank. At east end of transect area, standing water in secondary channel.	Channel full; secondary channel pooled with water, drying.	Water in main channel to edge of bank; water present in secondary channel to east.	Channel full, as well as secondary channel. Water came over banks, flooding flood plain. Water still present in tire ruts under bridge.
	Vegetation green and vigorous; alder in excellent condition.	Oaks and walnuts on slope (south bank) in good condition; oaks had second flush of growth.	Major species appear in good condition.	Major species appeared in good condition. Single cottonwood continued to die back. 2nd cottonwood uprooted in direction of stream flow. Much debris. Many ash seedlings on flood plain. Many oak seedlings on south bank.
	No dieback in sandbar willow	Sandbar willow variable; some clumps thin with dieback; others with normal foliage.	Sandbar willow variable, some with tip dieback.	A few dead sandbar willow west of bridge; dieback in sandbar along edge of channel east of bridge. Red willow, valley oak and Calif. black walnut sapling emerged through dead sandbar. Many willows pushed over by stream flow.
Stevenson Bridge	Water in channel to edge of bank.		Water running over riffle under bridge.	Water running very fast.
	Cottonwood saplings green, with good elongation.		Many young valley oak seedlings, Calif. black walnut and cottonwood saplings.	Cottonwood, valley oak and Calif. black walnut all full, green, no chlorosis.
	No dieback in sandbar willow.		Mature cottonwoods with yellowing foliage.	Lots of sandbar willow regeneration

Table 4 : Compiled Comments from Vegetation Surveys

Location	June 1992	September 1993	August 1994	June 1995
Pedrick Rd.	Lots of water in channel, although receding.	Channel and adjacent pools full.	Channel full with water flowing slowly.	Lots of water. Secondary channel to south completely full.
	Dieback in old cottonwood and eucalyptus trees from previous years. Younger trees of same species appear vigorous. Beaver took down some pole-sized cottonwoods.	Oaks on flood plain look very good with second flush of growth. Some oaks and walnuts near road with twig dieback. Lots of green foliage near channel and pools; path on bar overgrown.	Vegetation very lush, especially near active channel. Many cottonwoods with yellowing foliage.	Vegetation very green and lush. Cottonwoods on south bank are healthy but crowns appear thin.
	Sandbar willow suffered dieback; resprouting along stem with good regrowth.	Sandbar willow on bar variable; some with dieback, others excellent.	Sandbar willow in good condition.	Willows on both banks look very healthy.
Old Davis Rd.			Water flowing in channel; agricultural runoff on south side of bank.	Upper flood plain at railroad bridge was dry and brown.
		Cottonwoods on south bank well-foliaged, save for one dead tree.	Mature cottonwoods variable; some with full crowns, some with dieback. Between railroad bridge and Old Davis Rd., good development of eucalyptus grove. Ash saplings developing on north side of bank. Early fall color on boxelder.	Several large dead cottonwoods to west of transect on south bank. Other cottonwood, boxelder appear healthy. East of Old David Rd. stems of cottonwood and willow piled against large willow and boxelder on north bank.
	Sandbar willow suffered dieback from previous years, with good regrowth. Willow continues to colonize north bank area, with very few trees of other species (primarily eucalyptus).	Path to channel overgrown with sandbar willow; vigorous and dense; some plants with twig dieback. West of transect, sandbar becomes thinner with bronze foliage.	Sandbar willow looks good. Some have dying/drying foliage and dieback of older branches.	At railroad bridge sandbar willow appears to be colonizing more of bank; very thick and lush. On south bank, much regeneration of sandbar and ash near edge of bank. East of Old Davis Rd, good regeneration of willow.

Table 4 : Compiled Comments from Vegetation Surveys

Location	June 1992	September 1993	August 1994	June 1995
Mace Blvd.	Main channel becomes very narrow.		No water in channel obvious from bridge (looking west). Water impounded just west of Mace Blvd. Appears to be flowing from east to west - agricultural run-off.	Channel completely full.
	Many young valley oaks on south bank terrace. Large valley oaks on north bank. Lots of beaver activity on north bank, attacking red willow primarily. Sandbar willows line channel.	Overall area looks very good. Trees appear full. Oak regeneration to west continuing very well.	Valley oak seedlings and saplings look great. Calif. black walnuts on north bank look good. Boxelder in early fall color. Some standing dead red willow next to vigorous trees. Sandbar willow dying back from tip; lower foliage good.	Young valley oak look great. Appeared to be several new recruits, at least 10 new seedlings. Lots of debris along south bank. Boxelder and Calif. black walnut appear lush. Channel west at bridge completed overtopped by willow and several emergent ash saplings. Sandbar willow lush.

STUDY SUMMARY

The results and observations from HortScience's studies of Putah Creek 1990-1995 are compiled and synthesized in two ways. First, each of the monitored creek areas are described (Appendix II). Second, each of the major tree species comprising the riparian vegetation are discusses (Appendix III).

In the pre-settlement past, Putah Creek functioned like many stream systems in California. Flows were seasonal, dependent upon precipitation which occurred almost entirely during winter months. During periods of heavy rainfall, the creek would overflow its banks, creating a broad floodplain of bars, secondary channels and natural levees. High flow scoured the channel bottom, removing soil that was deposited downstream. Through time, a complex geological base of gravel deposits intermixed with layers of fine soils developed. In some areas, water flowed laterally along the interface of distinct soil types. During summer months flow was minimal, if not absent. Throughout the system, small pools interspersed with dry channel beds occurred.

The pre-settlement woody vegetation reflected this hydrologic and geologic base. A mosaic of different types of trees and shrubs developed and changed as stream channels moved and soil profiles were altered. The pre-settlement forest has been described as a broad-band of vegetation on either side of the creek. Along the creek banks, where new sand and gravel bars were created by rushing flows and water was available through the growing season, willows and alder seeds germinated and were recruited into the existing forest structure. On the broad floodplain, where surface flow was seasonal but water table was shallow, species such as sycamore and cottonwood were found. On sites where the water table dropped to a greater degree, valley oak and Calif. black walnut were present.

This mosaic of tree species did not develop at random. Rather, the riparian forest present in the pre-settlement era was the result of the combined effects of timing, pattern and intensity of creek flows, and the pattern of scour and soil deposition as well as the availability of seed. The woody vegetation, its age, species composition and structure, changed over time due to periodic flood and drought.

Settlement of the area changed this system. Over the last 100 years, the naturally wide-spreading creek system has been confined to a single channel. Increasing agriculture cleared riparian vegetation. Construction of the dams eliminated most of the scour and deposition that occurred annually. The course of the creek through Davis was changed by the dredging of the South Fork. Gravel mining and other working altered the natural soil conditions. Clearing for

flood control and related reasons disturbed the existing forest. The introduction of non-native species, both woody and herbaceous, brought new plants with which native species must compete. By the early 1950s, just prior to construction of the Solano Project, there was limited vegetation along the existing creek alignment. While some areas had extensive tree cover, others were devoid of forest.

Based upon our observations, the riparian forest of the 1990s reflects the existing environment of the Creek, just as the pre-settlement forest did. During our reconnaissance of the Creek by canoe, we observed that where the existing creek is wide and aspects of the natural patterns of flow and soil movement occur, the woody vegetation is more complex and reminiscent of pre-settlement. Where the creek is confined to a narrow channel, defined by artificial levees, subjected to extensive soil alteration and located adjacent to intensive agriculture, the woody vegetation is unlike anything seen in pre-settlement times.

Over time, the historic patterns of species distribution have changed as new trees and large shrubs have been able to successfully establish, reproduce and be recruited into the forest. As the active channel has been confined to a narrow band within artificial levees, valley oak, Calif. black walnut and ash have begun to colonize levees and floodplain areas. Willows are confined to the narrow band along the active channel where adequate soil moisture is supplied throughout the year. Cottonwood does not appear to be recruited actively into the existing forest, apparently due to a lack of suitable soil substrate and seasonal change in the water table.

Activity by beaver also changes the distribution of water in the creek, and therefore influences vegetation. As dams are built, the creek backs up, creating pools where summer water may be present. Over the course of several years, woody species such as sandbar willow, which have an obligate requirement for seasonal water, may flourish. However, in very wet winters, heavy flows may destroy beaver dams. One result is that the channel flows more freely and eliminates the small pools. Vegetation in and around these pools declines due to lack of water and may be replaced by other, more drought-tolerant species. We observed this situation in several locations along the creek during our 1995 canoe reconnaissance.

Given the existing structure of the soils and channel of the Putah Creek system, there is every reason to believe that the woody vegetation will continue to evolve and change in foreseeable future. There is, however, no reason to believe that increasing flow during the summer months will restore the pre-settlement conditions or vegetation. Indeed, in our view the most significant threats to native woody species comes not from water flow in the channel but from competition by

exotic species such as eucalyptus and giant reed and the lack of a seed resource for native plants.

While we cannot restore the pre-settlement riparian forest, we can strive to maintain the quality of that forest in terms of its dominance by native species. To that end, management practices that actively reduce the extent of exotics and/or foster that growth and recruitment of native species are desirable goals. However, it remains uncertain where management of flow, either seasonal pattern or intensity, will differentially support native species to the detriment of exotics. It may be more appropriate to intervene more directly by removing exotics and replanting of natives than to attempt to manipulate their growth and development in an indirect manner.

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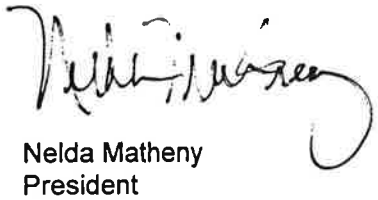
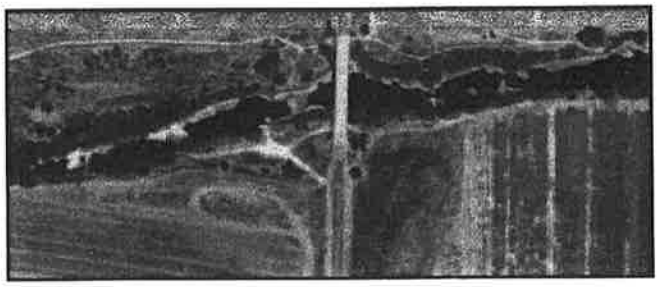


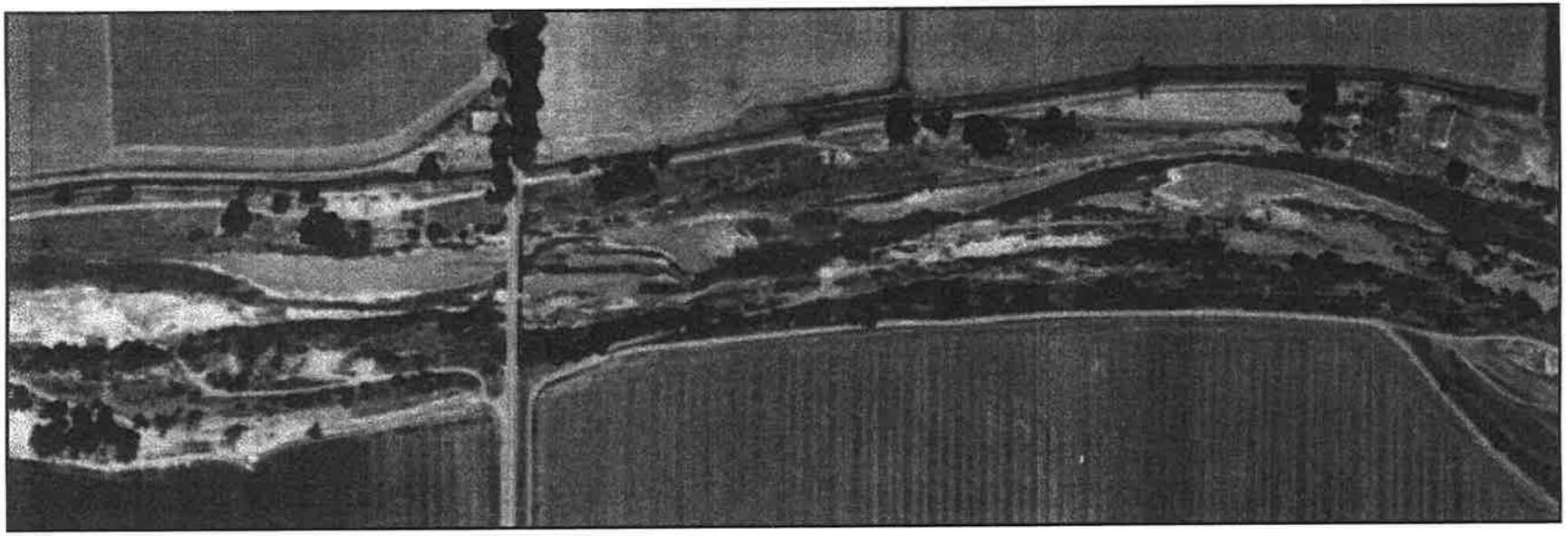
Nelda Matheny
President

Putah Creek **Riparian Vegetation** Summary

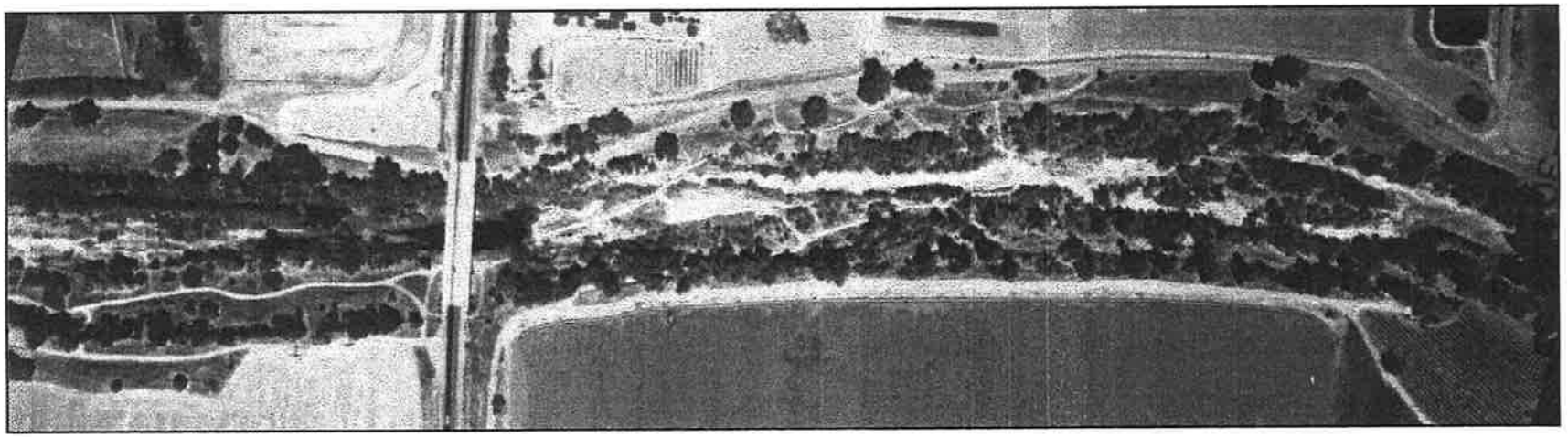
Appendix I
Aerial Photographs of Putah Creek



Aerial Views of Putah Creek at Pedrick Road

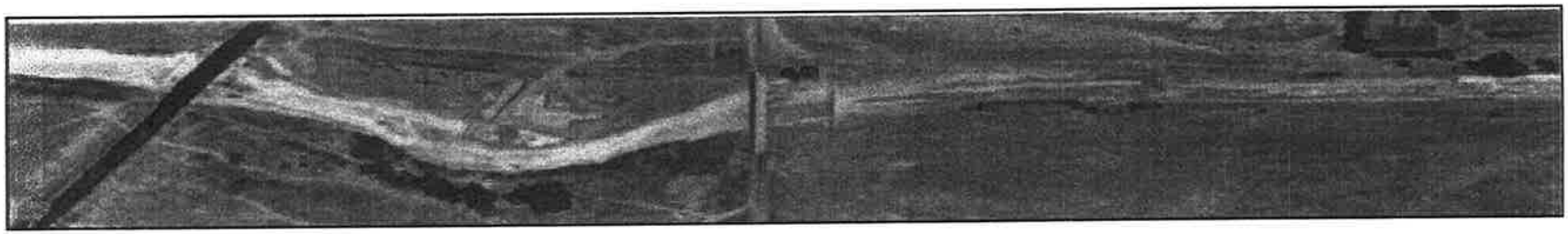


August 23, 1957

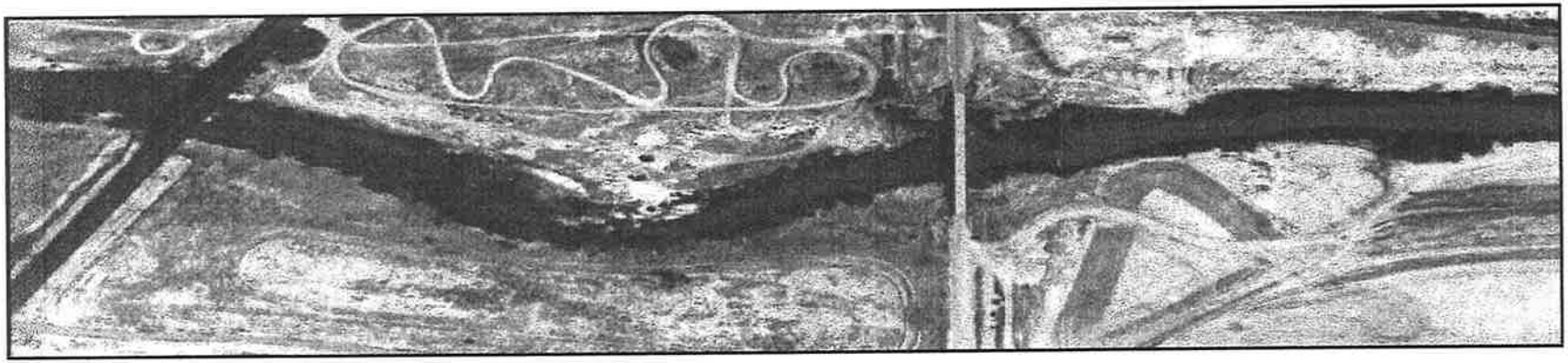


August 30, 1990

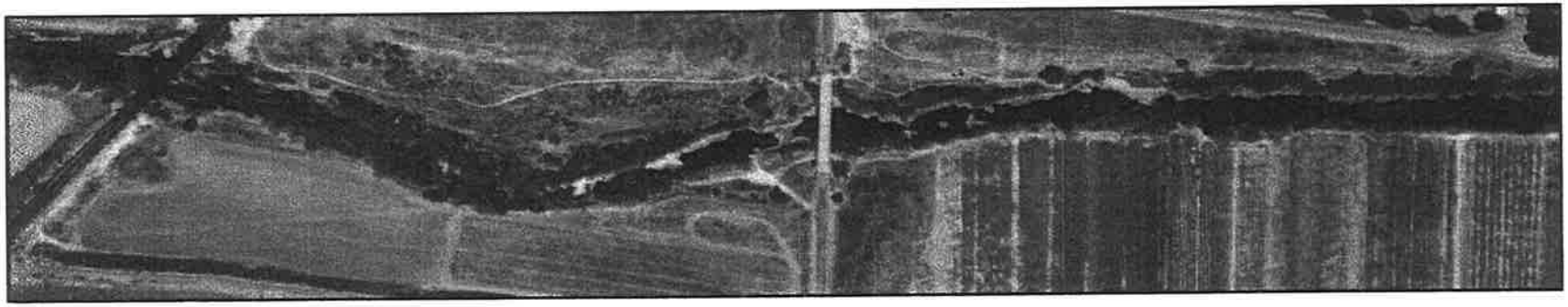
Aerial Views of Putah Creek at Old Davis Road



August 8, 1952



July 11, 1973



August 80, 1990

Aerial Views of Putah Creek at Mace Blvd.

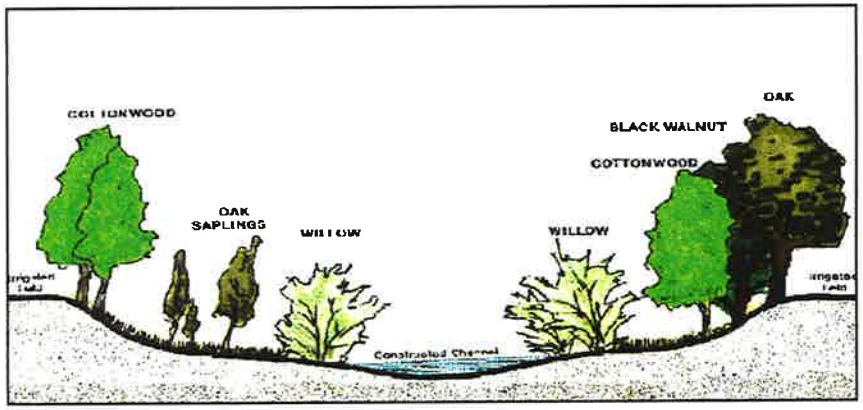
August 8, 1952

August 30, 1990

Putah Creek **Riparian Vegetation** Summary

Appendix II ***Summary of Riparian Vegetation Monitoring Sites***

Riparian Vegetation Summary
I-505 Overpass



- Water was present in the channel throughout the study period.
- In 1991 tests, soil moisture at the top of levee and the floodplain declined rapidly beginning in May. Soil moisture in the creek bank remained high.
- Good regeneration of oak, California black walnut and ash.
- Many willows pushed over and debris collected in high water in 1995. Red willow, valley oak, California black walnut emerged through dead sandbar willow areas.
- Sandbar willow condition was variable throughout study.

▲Valley oak (left) and Calif. black walnut (right) appeared healthy at the top of levee where soil moisture became dry in early summer. Infrared photographs indicated the trees were not stressed (Aug. 1990).

▲ Regeneration of valley oak, willow and ash (Sept. 1995)

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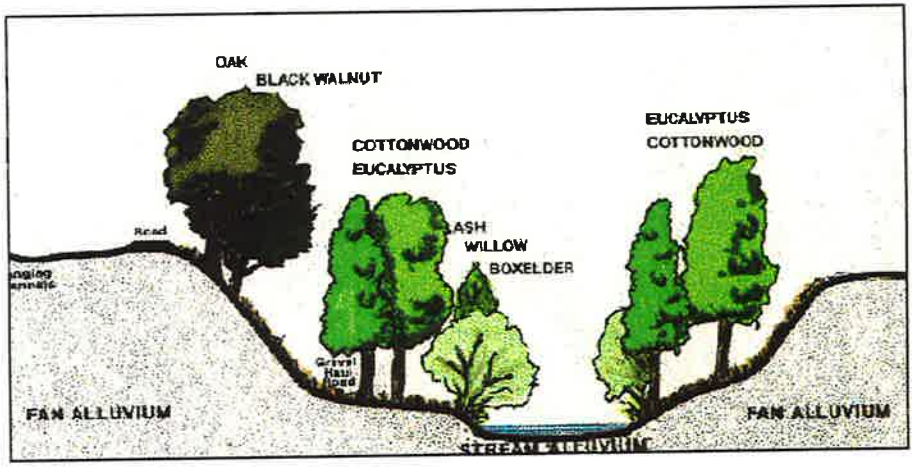
Riparian Vegetation Summary
Stevenson Bridge

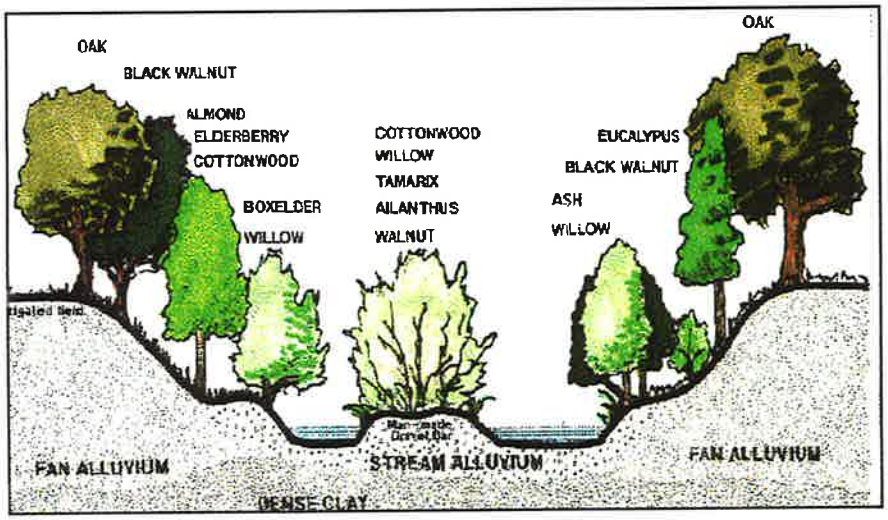


- Vegetation predominately riparian scrub-shrub and riparian forest.
- Eucalyptus well established.
- Cottonwoods, oaks and eucalyptus in good condition throughout study.
- Water in channel throughout study period.
- Many young California black walnut and cottonwood saplings, valley oak seedlings.

View from Stevenson Bridge, August 1990

View from Stevenson Bridge, August 1994

Riparian Vegetation Summary
Pedrick Road

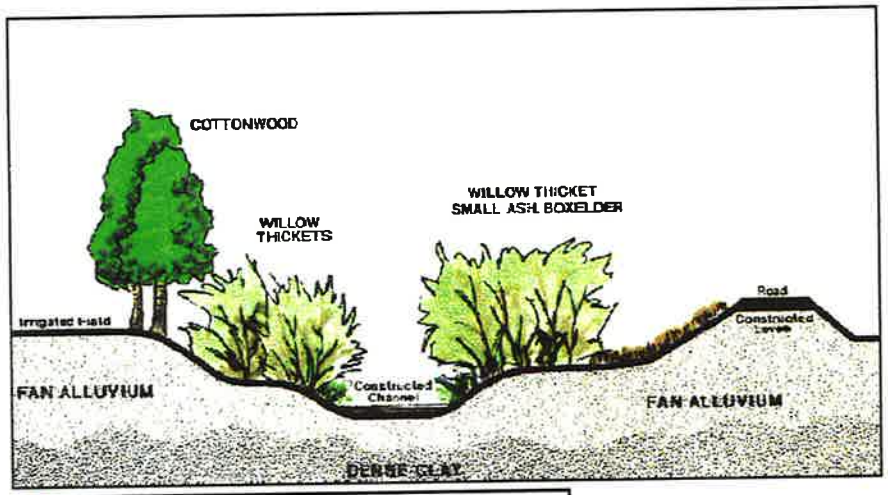


- Area of gravel extraction and vegetation disruption from early 1940's until 1970's.
- Sandbar willow on bars defoliated and died back during 1990-1992; recovered 1993-1995.
- Cottonwoods, oaks and walnuts in good condition throughout study.
- Eucalyptus and tamarix well established.
- Channel dry in 1990, 1991; full in 1992-1995.
- Beaver activity in 1992 destroyed several pole-sized cottonwoods.
- Riparian shrub-scrub on gravel bars and in a narrow band along the creek bank.

Sandbar willow on gravel bar, August 1990

View from Pedrick Rd., Sept. 1994

Riparian Vegetation Analysis
Old Davis Road



◀Healthy cottonwoods and sandbar willow were supported by water from agricultural runoff (August 1990). Willow not recieving runoff (right) showed drought symptoms even though the creek held water.

◀Infrared photograph showing water-stressed sandbar willow (green color on right) and non-stressed plants (red color on left) receiving agricultural runoff (August 1990).

- Channel was created in early 1870's to protect Davisville from flooding. Vegetation was removed, the channel deepened and levees constructed in 1940's.
- Channel is in fine-grained fan terrace soils with essentially no lateral movement of water from the channel through the banks.
- Creek was dry in summers 1990-91 during "dry year" water release cycle.
- Sandbar willow defoliated during summer 1990-91, and recovered in 1992-93
- Narrow band of riparian shrub-scrub supported by creek. Agricultural fields apparently support adjacent trees and shrubs.

August 1994

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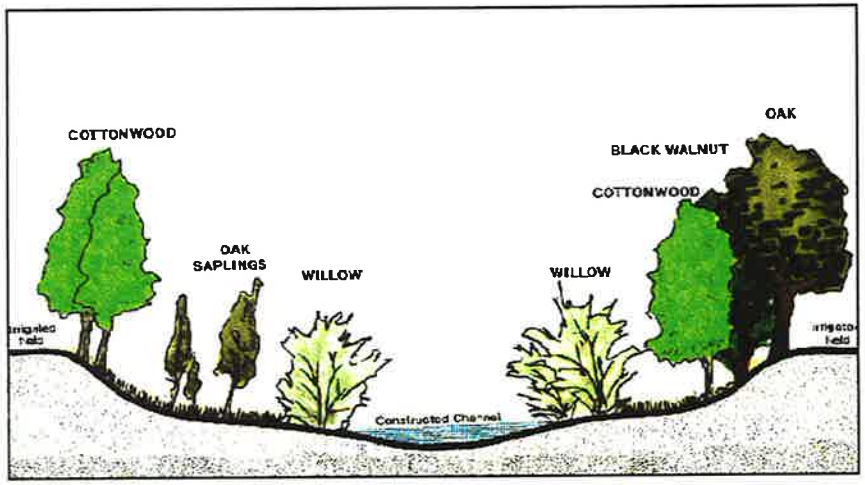
Riparian Vegetation Summary
Mace Blvd.



- Channel was created in early 1870's to protect Davisville from flooding. Vegetation was removed, the channel deepened and levees constructed in 1940's.
- Channel is in fine-grained fan terrace soils with essentially no lateral movement of water from the channel through the banks.
- Excellent valley oak and ash regeneration.
- Creek was dry in summers of 1990, 1991 and 1994 during "dry year" release schcycle.
- Many young California black walnut and cottonwood saplings, valley oak seedlings.
- Extensive beaver activity on red willow in 1993.
- Trees remained in good condition; some sandbar willow dieback in 1994, with recovery in 1995.

▲July 1993

August 1994▶

▲Extensive regeneration of valley oaks in flood plain (Sept. 1995)

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Putah Creek **Riparian Vegetation** Summary

Appendix III
Summary of Riparian Vegetation Tree Species

Riparian Vegetation | Boxelder *(Acer negundo)*

Description:	Broad, open-crowned, deciduous tree, 20-50' tall, often with several trunks. Leaves with three leaflets, coarsely toothed.
Habitat type:	Riparian forest and riparian shrub-scrub
Location:	Primarily along creek banks; occasionally on floodplain.
Indicator category:	Facultative wetland; usually occurs in wetlands, but occasionally in uplands.
Drought response:	No symptoms of water stress were observed during the study period. Infrared gun readings of boxelder in four transects showed no stress in September-October 1990. Typical drought response would be leaf desiccation, early fall coloration and defoliation.

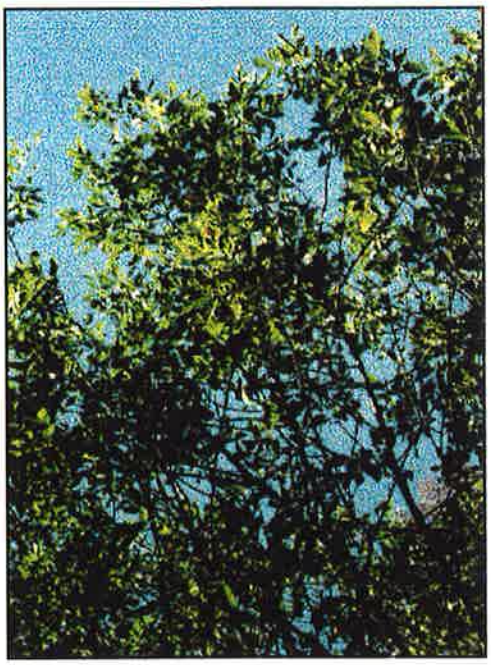
▶Young boxelder tree east of I-505 near active channel.

Water requirements:	Requires moist soil.
Regeneration:	Natural regeneration is by seed. Young trees were noted in 5 of 8 transects, and was greatest at the railroad crossing near Old Davis Rd. (transect 7) where there were 88 trees less than 6" in diameter). Boxelder can be planted as cuttings, container-grown plants and seeds.
Size class and frequency of occurrence:	Boxelder was present in 6 of 8 100'-wide transects studied. It represented 17% of the tree population.

Trunk diameter	*Number of trees*
0-1"	31
1-6"	55
6-18"	3
18+"	0
Total	88

◀Mature boxelder beginning to show fall color.

Riparian Vegetation | Oregon ash *Fraxinus latifolia*



Description:	Deciduous tree 30-75' tall. Leaves 6-12" long, with 5-7 leaflets. Male and female flowers are on separate trees.
Habitat type:	Riparian forest and riparian shrub-scrub
Location:	Primarily along creek banks; occasionally on floodplain.
Indicator category:	Facultative wetland; usually occurs in wetlands, but occasionally in uplands.
Drought response:	Ash showed development of some late season (end of Sept., early Oct.) leaf desiccation and defoliation in 1990. Water stress was confirmed by infrared gun readings of ash at Pedrick Rd. (transect 3). Trees appeared healthy 1992-1995.

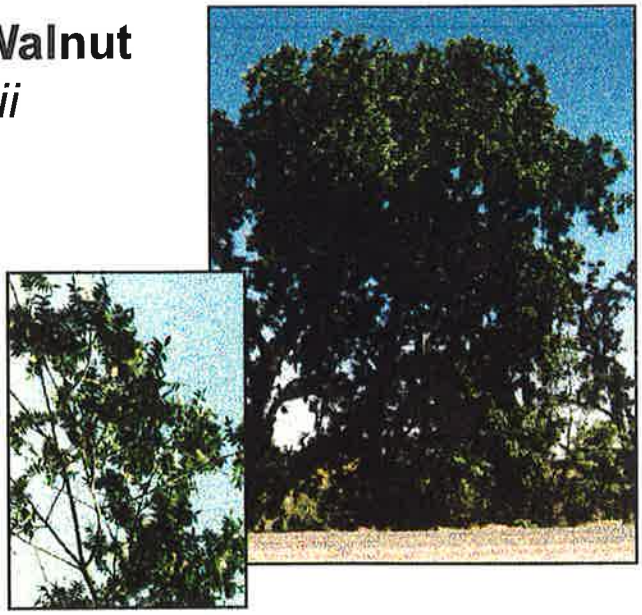
◀Ash with healthy foliage (transect 4, Sept. 1990).

◀Ash exhibiting drought symptoms of leaf necrosis and defoliation (transect 3, Sept. 1990).

Water requirements:	Requires moist soil. Tolerates periods of inundation in the winter.
Regeneration:	Natural regeneration is by seed. Young trees were noted in 4 of 8 transects in 1990, and were greatest east of I-505 (transect 4) where there were more than 43 trees less than 6" in diameter. Many seedlings were present at Mace Blvd. in 1995. Ash can be planted as bare root and container-grown plants .
Size class and frequency of occurrence:	Oregon ash was present in 5 of 8 100'-wide transects studied. It represented 18% of the tree population.

Trunk diameter	*Number of trees*
0-1"	>46
1-6"	42
6-18"	3
18+"	0
Total	91

Riparian Vegetation | Calif. Black Walnut *Juglans hindsii*



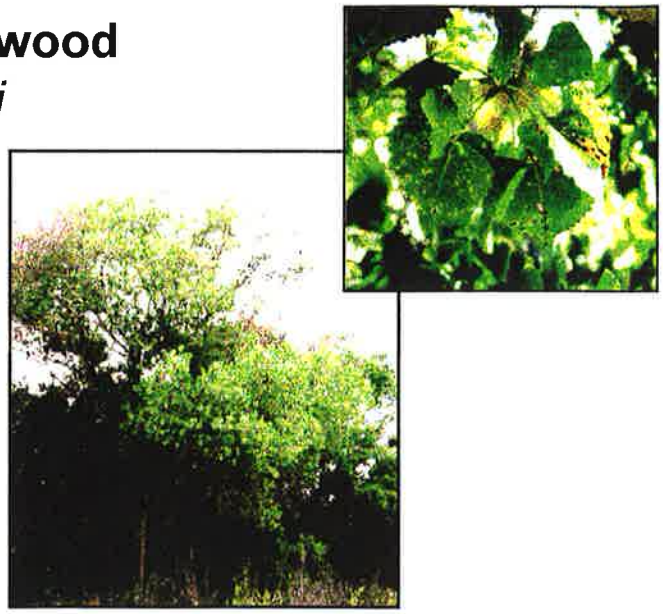
Description:	Deciduous tree, 30-60' tall, usually with a single trunk and broad crown. Leaves composed of 15-19 leaflets, each 3-5" long.
Habitat type:	Riparian forest and oak woodland.
Location:	On floodplain, levees, upper terraces and near creek banks.
Indicator category:	Facultative; equally likely to occur in wetlands or uplands.
Drought response:	Infrared gun readings of walnuts showed development of late season (October 1990) water stress. Plant appearance remained normal. Infrared photos taken at the top of the levee at I-505 revealed no stress (August 1990). Trees appeared healthy 1991-1995.

◀Young walnut on creek bank, 2' from water, showing water stress symptoms (Sept. 1990).

Water requirements:	Must be able to reach ground water when mature. Aerated zone above water table necessary. Soil moisture readings in 1990-1991 indicated that the soil (2.5' depth) in the levees and flood plains where walnuts occurred began drying in May, and continued through the summer.
Regeneration:	Natural regeneration of Calif. black walnut has been occurring, although to a lesser extent than oak, ash or boxelder. 77% of the walnuts encountered in transects were less than 6" in diameter. Walnuts can be planted as seed or from containers.
Size class and frequency of occurrence:	Calif. black walnut was present in 6 of 8 100'-wide transects studied. It represented 9% of the tree population.

Trunk diameter	*Number of trees*
0-1"	20
1-6"	11
6-18"	10
18+"	3
Total	44

Riparian Vegetation | Fremont Cottonwood *Populus fremontii*



Description:	Fast growing, deciduous tree, 40-60' tall, usually with a single trunk. Leaves are triangular-shaped, 2-4" wide, glossy, turning yellow in fall.
Habitat type:	Riparian forest and riparian shrub-scrub.
Location:	On floodplain and near creek banks; on levees where supplemental water available (e.g irrigated agriculture).
Indicator category:	Facultative wetland; usually in wetland, but occasionally in upland where watertable is high.
Drought response:	Infrared gun readings of did not show development of late season (October 1990) water stress. Plant appearance remained normal, except for leaf damage by insect and related defoliation. Some dieback in cottonwoods present at Pedrick Rd. in 1992, with recovery in subsequent years. Yellow foliage or thin crowns were noted in mature cottonwoods at Pedrick Rd. 1992, 1994, and 1995.

▲Mature cottonwoods at the railroad crossing near Old Davis Rd. receiving water from adjacent irrigated field (April 1991).

Water requirements:	Consistent soil moisture required. Growth is proportional to availability of water.
Regeneration:	Regeneration occurs primarily by seed. Seedling germination and establishment requires sandy seed bed and adequately moist soil throughout the establishment period. Natural regeneration of cottonwood has been less than other tree species. Only one tree less than 6" in diameter was inventoried in the 8 sample transects in 1990. Seedlings and saplings were noted at Stevenson Bridge in 1992. Cottonwoods can be planted as containers or cuttings.
Size class and frequency of occurrence:	Cottonwood was present in 4 of 8 100'-wide transects studied. It represented 4% of the tree population.

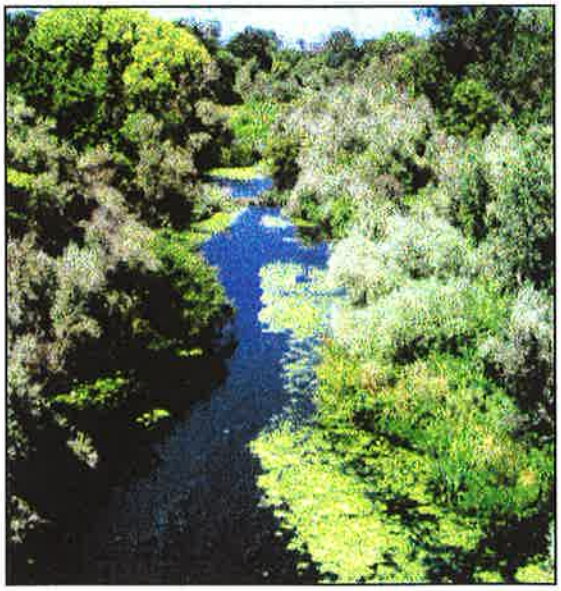
Trunk diameter	*Number of trees*
0-1"	0
1-6"	1
6-18"	12
18+"	5
Total	18

Riparian Vegetation | Sandbar Willow *Salix hindsiana*

Description:	Erect shrub with grey furrowed bark, 6 to 12' tall, leaves narrow, linear, covered by grey silky hair.
Habitat type:	Riparian shrub-scrub.
Location:	Along active channel.
Indicator category:	Facultative wetland; usually occurs in wetlands, but occasionally in uplands.
Water requirements:	Frequent inundation.

▲Sandbar willow at the railroad crossing near Old Davis Rd. (Summer 1991).

Drought response:	Defoliation and dieback was common in 1990-1991, with recovery in 1992-1995. Development of symptoms throughout study period was variable, and not always linked to presence or absence of water in channel.
Regeneration	Regeneration occurs through both vegetative and sexual means. Sexual regeneration requires a sandy seed bed and adequately moist soil throughout the establishment period. Vegetative reproduction occurs yearly as individual stems die, and new stems generate from the base. Flooding events that scour the creek channel, break off and carry away dead and weak stems and replenish soil moisture favor regeneration.



▲Sandbar willow along the active channel at Pedrick Rd. (Sept. 1994)