

**ECOLOGICAL, GEOMORPHIC, AND LAND USE HISTORY OF
THE CARNEROS CREEK WATERSHED:
A COMPONENT OF THE WATERSHED MANAGEMENT PLAN FOR
THE CARNEROS CREEK WATERSHED, NAPA COUNTY,
CALIFORNIA**



**PREPARED FOR
STEWARDSHIP SUPPORT AND WATERSHED ASSESSMENT IN THE NAPA
RIVER WATERSHED: A CALFED PROJECT**

**CALFED CONTRACT NO. 4600001703
NAPA COUNTY RESOURCE CONSERVATION DISTRICT**

BY

**Robin Grossinger
Chuck Striplen
Elise Brewster
Lester McKee**

December 2003: Rev. February 2004



Robin Grossinger, Chuck Striplen, and Lester McKee: San Francisco Estuary Institute
Elise Brewster: Brewster Design Arts

This report should be cited as:

Grossinger, R., C. Striplen, E. Brewster, and L. McKee, 2004. Ecological, Geomorphic, and Land Use History of Carneros Creek Watershed: A component of the watershed management plan for the Carneros Creek watershed, Napa County, California. A Technical Report of the Regional Watershed Program, SFEI Contribution 70, San Francisco Estuary Institute, Oakland CA. 48 pp.

Table of Contents

Executive Summary	4
Acknowledgements	6
Introduction	7
Methods.....	9
Results and Discussion	12
I: Cultural Context	12
II: Land Use	16
III: Landscape Changes.....	30
Management Implications.....	42
References	45

List of Tables and Figures

Table 1: Pre-contact population estimates for Napa Valley.....	13
Table 2. Historical data on North Bay grazing (Mexican period)	21
Table 3. Lower Carneros Creek Watershed Changes 1940-1993	27
Figure 1. Map of the Carneros Creek watershed.....	8
Figure 2. Annual rainfall at Napa State Hospital (1850-2002)	11
Figure 3. Ten-year average annual rainfall for Napa, Sonoma, and St. Helena (1850-2002).	11
Figure 4. USCS Topographic Sheet #T777	15
Figure 5. Carneros Creek crossings circa 1844	19
Figure 6. Land use and major vegetation types (ca. 1940).....	24
Figure 7. Land use and major vegetation types (1993)	25
Figure 8. 1902 US Geological Survey.....	29
Figure 9. Time-series views of lower Carneros: 1844 and 1858	32
Figure 10. Time-series views of lower Carneros: 1942 and 1999	33
Figure 11. Expansion of riparian canopy along Carneros Creek.....	39
Figure 12. Change in stand density and canopy cover, 1940-1993.....	41
Figure 13. Timing and intensity of major land management activities.	42

EXECUTIVE SUMMARY

During 2002-2003, the San Francisco Estuary Institute, with the assistance of the Napa County Resource Conservation District, carried out a study of the historical ecology of the Carneros Creek Watershed. The resulting technical report is one of seven produced to inform the development of a watershed management plan through a participatory process that includes the community, natural resource agencies, and scientists.

To assess historical land use and associated changes within the watershed, we used a multifaceted approach to collect and synthesize a diverse range of information. This process included collecting numerous historical documents from the 19th and early 20th centuries, analyzing historical maps and aerial photography, interviewing local residents, and assessing field conditions with other project team members. Interpretations were analyzed in the context of the findings of the other technical teams through project team meetings.

The Carneros Creek watershed has been shaped by a unique and intensive history during the past 200 years and before. Descriptions in the earliest European accounts of the watershed provide direct evidence of indigenous management of the watershed through the use of fire. Following Spanish conquest, Carneros Creek was characterized by a land use history that diverges from other parts of the region, with relatively early, high intensity grazing during the Mexican Rancho era and persistent ranching activity through the 20th century. Several inherent geographic and physical characteristics of the watershed have helped reduce population growth and the maintenance of ecological resources. These include relatively limited groundwater resources; a naturally narrow, single-thread channel; and Carneros' particular geographic position away from the major fertile valleys of the North Bay, and bordered by the vast Napa-Sonoma marshlands.

Direct major alterations to the stream channel, such as straightening and the removal of side channels, have been relatively limited. As a result, the channel network plan form has not been as dramatically altered as in most other local streams. The Carneros Creek watershed has maintained a relatively high level of ecological resources through historical times and displays significant potential for restoration and enhancement of stream, valley, and hillside habitats.

This Historical Ecology report presents a number of specific implications for future management of the watershed; these are listed below. The report also provides a detailed summary of land use history and historical information resources, which are intended to provide a basis for answering subsequent questions about the watershed history.

1. Carneros Creek was noted as a good spot for steelhead fishing in the 19th century, but was also probably never an exceptional steelhead stream because it is naturally "flashy" and seasonally dry. However, the massive modifications experienced by most rivers and streams in the region have probably increased Carneros' value relative to other Bay Area and Napa Valley streams. While most migration routes through the Bay require difficult passage through agricultural or urban areas with associated contaminants and flood control channels, or past the Delta water supply pumps (Leidy pers. comm.), anadromous fish approaching Carneros Creek from the Bay have a direct route from the Napa River marshlands to the creek mouth. Once in the creek, fish encounter relatively few major road or railroad crossings and no major dams. As a result, Carneros Creek may have particular long-term importance as a viable steelhead stream.
2. Historical evidence indicates that Carneros Creek did not have a substantially broader riparian corridor prior to European land use. Also, unlike many other local streams (e.g. Soda Creek (Pearce et al. 2002)), Carneros has not experienced the loss of low-gradient meanders or overflow channels. As a result, the current system is not compromised by the loss of major channel/riparian components. Restoration should focus on watershed processes responsible for the maintenance and improvement of existing channel and riparian canopy.

3. Carneros naturally maintained a well-defined, relatively incised channel across the valley floor into tidal waters. This historical characteristic is in contrast to other small streams for which connecting ditches or flood control channels had to be constructed, often resulting in persistent sediment deposition problems requiring regular dredging (SFEI 2001).
4. While the stream appears to have been relatively incised according to mid-19th century mapping, additional incision may have taken place and could be assessed by field comparison to historical data, dating of exposed tree roots, and other field indicators.
5. There is evidence that pool habitat in the lower reaches, which is currently of poor quality, was substantially better in the past. Summer stream flow, while naturally limited and intermittent during historical times, does appear to have decreased in recent decades. Groundwater levels in the lower watershed have been reported to be quite susceptible to diminishment by pumping, which would likely reduce stream base flow and pool persistence.
6. Riparian habitat in the lower watershed has been extremely dynamic. This indicates that the tree canopy can respond rapidly in response to favorable conditions. However, there is also strong indication of potential loss of riparian trees in the near future, which could have significant detrimental effects to creek shading and aesthetic value [see *Channel Geomorphology* and *Fish Habitat Assessment* reports.
7. Grazing pressure in the watershed was severe by the mid-19th century, such that impacts to sediment dynamics are likely by the time of the 1862 floods, which could have mobilized large amounts of sediment. While no specific effects could be identified at this time, a high level of grazing activity was documented, which may have present-day effects. Intensive ranching on the Alexander property prior to 1993 is also probably still having downstream effects. Assessment of current in-stream sediment problems should attempt to distinguish between sources caused (and potentially solved) by current activities and those triggered by management in previous eras.
8. Substantial parts of the watershed have been subject to over a century of agriculture and associated plowing, vegetation removal, and other practices which could also be responsible for sediment production. Obvious downstream effects were not found in this study, but as in the case of grazing, may nevertheless be present and should be considered as analysis and management of the watershed continues.
9. General extent and stand density of chaparral and woodlands appears to have increased in the upper watershed, likely due to reduced fire frequency. This change in vegetation may pose a threat for larger fires in the future. Besides the obvious cultural impacts, significant fire, particularly in late summer before substantial rains, could cause large delivery of sediment to the stream.
10. Native management activity in all likelihood had a significant influence upon the composition, distribution, abundance, and productivity of most habitats in the watershed for a very long period of time. Some aspects of native management practices may be useful tools for the future. For example, despite extensive changes remnants of native grassland still exist in the watershed (Graves pers. comm.), constituting a valuable local resource. Restoration and expansion of these native grasslands, potentially with the use of fire, could provide benefits to soil structure, stream flow, and local ecology that could be explored through further research. Trial projects to test management approaches and ecological results could be initiated and would have significance to grasslands management research in the greater region.

ACKNOWLEDGMENTS

We would like in particular to acknowledge the watershed residents who generously contributed their time and expertise about the history of the land and the people, flora, and fauna that it has supported over the last several hundred years: Al and Mavis Fournier, Al Giovannoni, David Graves, Lee Hudson, Carl Larsen, Ira and Shirley Lee, Betty Mukerji, and Mary Pettis. The impressive knowledge of local residents is one of the valuable resources of the Carneros Creek watershed.

This focused study of the landscape history of one subwatershed of the Napa River basin was made possible by the work of the basin-wide Napa River Watershed Historical Ecology Project (NRWHEP). The NRWHEP, established in 1999 by San Francisco Estuary Institute and the Friends of the Napa River (FONR), provided a foundation of historical resources and analysis, which was built upon and expanded in this project. Special thanks to Chris Malan and Shari Gardner of FONR for their tireless efforts to develop these valuable resources for understanding the ecological history of the region, and the NRWHEP sponsors: the Mead Foundation, the Mennen Environmental Foundation, and the Napa Valley Vintners Association.

We would like to thank Mike Champion of the Napa County Resource Conservation District for his research efforts on behalf of the project, particularly through interviews with local residents and archival newspaper research. Numerous other individuals have provided valuable knowledge and insights to the research presented here, including Jake Ruygt, Phill Blake, Ellie Insley, Michael Napolitano, Stephen Rae, Parry Mead, Laurel Collins, and Garrett Buckland. Arthur Dawson contributed helpful review comments.

We would also like to thank our colleagues at SFEI, and the other members of the CALFED funded *Stewardship Support and Watershed Assessment in the Napa River Watershed* project for their many contributions: Sarah Pearce, Josh Collins, Leigh Sharp, Jonathan Koehler, Lara Hadhazy, Eileen Weppner, Matt O'Connor, Bob Zlomke, Kathleen Edson, and Blaine Jones.

The analysis of 1940s aerial photography was made possible by Phill Blake of the Natural Resources Conservation Service, who provided the imagery, and Thomas Burns of GIS Mapping and Analysis (agismap1@maine.rr.com), who created the georectified photomosaic. Jeff Kennedy, Mike McCoy, and Jim Thorne of the Information Center for the Environment at UC Davis generously facilitated our use of the new Napa Vegetation Map developed by UCD, CNPS, the Land Trust of Napa County, and others.

Special thanks also to the many individuals who have maintained these valuable resources over the years, and helped us find them at the local archives, including The Bancroft Library, the UC Berkeley Earth Sciences and Map Library, the Napa Historical Society, the UCB Water Resources Archive, and the CA State Library.

This project was funded by the CALFED Bay-Delta Watershed Program awarded to the Napa County RCD and its partners through Agreement No. 4600001703.

INTRODUCTION

The watershed of Carneros Creek occupies a relatively small, fault-bounded valley in the southwest portion of the greater Napa Valley (Figure 1). An active tectonic geology, seasonal rainfall, mild winters, and warm dry summers influence vegetation and topography which in turn provide an aesthetically beautiful backdrop to a number of world-class vineyards in a peaceful rural setting. The residents of the watershed value the lifestyle provided by this setting but also recognize the inherent pressures on the watershed associated with human population and intensive land management. In 2001, the Carneros Creek Stewardship, an apolitical, non-advocacy group, was formed to promote and help coordinate a variety of activities including groundwater monitoring, tours, education, watershed assessment and restoration. Their goals are to:

1. Assess the physical features of the watershed on an on-going basis;
2. Provide education about the watershed;
3. Protect and restore natural resources, including native fish and wildlife species;
4. Protect and enhance the economic and human resources;
5. Create a sustainable, enduring watershed stewardship.

Quality, defensible science is an important precursor to sound environmental management and restoration decisions. Once the community has constructed a set of management questions, sound science protocol is applied within a framework of continual community involvement to develop appropriate watershed management plans. The assumption is often made that a single science methodology can be used to answer all of a group's management questions. However, the best way to apply environmental science methodologies is to use a variety of protocols that have overlap in the scope of information that they provide. In this way, any conflicting conclusions that are derived from each isolated protocol are reconciled during the planning process, increasing the chance of a solution being developed.

The technical teams carried out the following types of empirical data collection and/or review of existing information:

1. Historical ecology,
2. Flora and fauna,
3. Channel geomorphology,
4. Hillslope geomorphology/sediment budget,
5. Fish habitat assessment,
6. Water quality,
7. Water budget.

This technical report describes the methods, results and conclusions derived from the *Historical Ecology* and *Flora and Fauna* components, and is part of the larger study outlined above. (The other project technical reports are referenced in this report by the above names.) This report will be integrated with the other listed technical reports, in close consultation with the Carneros Creek Stewardship, to create a management plan for the local community.

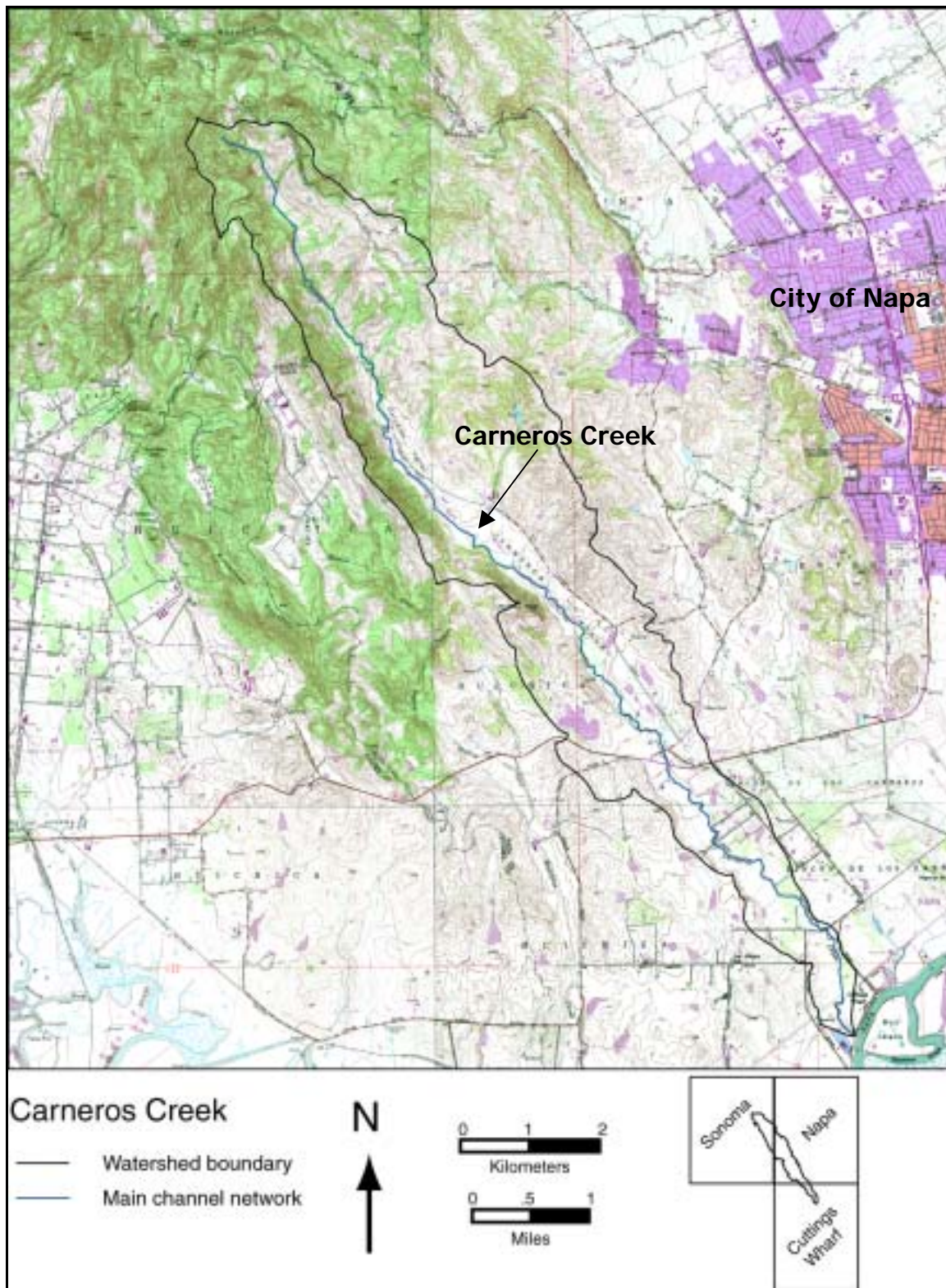


Figure 1. Map of the Carneros Creek watershed.

METHODS

We used a multifaceted approach to build a strong historical dataset and analyze key questions about historical land use and landscape change in the Carneros Creek watershed. Key components to this approach, described in Grossinger (2001), include the following.

Use of different types of historical data. Since each historical data source provides only a selective view of environmental conditions, overlapping materials of different scale and purpose are required to create a relatively unbiased picture (Collins et al. 2002). Historical geomorphic or ecological assessments are commonly limited to either 1940s era aerial photography, standard local histories, or historical USGS quadrangles, producing findings which are largely shaped by the choice of data source. This study provides a more realistic picture of baseline watershed condition by incorporating information from many other sources, including official survey data of the General Land Office and U.S. Surveyor General, Mexican land Grant materials, extensive historical maps and texts, and land use history interviews with local residents.

Assessment of pre-American impacts. There is a tendency to overlook the role of Spanish/Mexican and Native land uses in shaping the present-day environment, probably because this analysis requires the use of a different suite of historical documents and associated analysis. The research performed here incorporates a reconstruction of Mexican land use practices and timing, and uses archeological and ethnographic information to assess the effects of the periods prior to American settlement.

Historical documents are tested for accuracy, rather than assumed to be correct. Key interpretations of a given historical map feature, for example, are based upon intercalibration with contemporary sources, understanding of landscape processes, and knowledge of the technical strengths and limitations of the map type, its author, and intended use.

Determination of the actual land use history of the watershed, rather than assumption of generalized regional land use patterns. This element turns out to be particularly important for this project since not only is the sequence and timing of land uses in Napa Valley substantially different from most of the Bay Area, but also Carneros' history differs from that of other sub-watersheds of the Napa River watershed. To minimize the problem of basing interpretation of trends or change on just one historical data point, information from different decades was developed along with a supporting history of human settlement and cultural change.

One of the goals of the Historical Ecology component was to develop an information base of that would provide a useful foundation for subsequent projects by the Carneros Creek Stewardship group. As stewardship efforts are considered and implemented over the coming years, a diverse range of further questions about historical changes to the watershed will most likely arise. As a result, we attempt in this report to both analyze key current concerns and provide a baseline historical perspective on the native, Spanish, and American history, and associated landscape changes, to inform future discussions.

Historical Data Collection

Archival research was carried out at numerous institutions. Some of the most important areas of archival research were the records of the Mexican Land Grant Cases and other historical accounts, at Bancroft Library; historical texts, newspaper archives, and early photographs, at the Napa Historical Society and Sharpsteen Museum; archeological and ethnographic records, from the Northwest Information Center at Sonoma State University; General Land Office Township and Range data, from the BLM in Sacramento; United States Coast Survey maps, from the California State Lands Commission, the National Ocean Survey (Rockville, MD), and National Archives II (College Park, MD). Several other archives provided fewer, but important, sources. We also acquired a number of useful historical texts from used bookstores with relatively small expense and delay through *abebooks.com* and *amazon.com*.

It was possible to acquire the quantity of historical data required for this analysis because of the extensive historical archive developed by the ongoing Napa River Watershed Historical Ecology Project. Assistance was also provided by Mike Champion of the Napa RCD and by Arthur Dawson of the Sonoma Valley Historical Ecology Project, a joint effort of Sonoma Ecology Center and SFEI.

Interviews

Because the Carneros Creek watershed includes a number of longtime residents who have been actively involved in managing and observing the land as part of farming and ranching activities, interviews about 20th century land use and landscape changes were particularly important. Many of these were coordinated through presentations at the meetings of the Carneros Creek Stewardship Group. Interactions were facilitated by Leigh Sharp and interviews were carried out by Elise Brewster and Mike Champion, as well as through discussions with residents in the field by Sarah Pearce of the geomorphology team.

Land Use Mapping 1940-1993

To provide a more detailed picture of land use changes within the watershed during the 20th century, we mapped general habitat types and land uses for the watershed using georectified, grayscale photomosaics. For a recent view, we used the 1993 Digital Orthophoto Quadrangles of the USGS (<http://wgsc.wr.usgs.gov/doq/>). We used the 1993 dataset because (1) it is the most recent georectified and mosaicked aerial imagery currently available for the region and (2) it is the base imagery being used by UC Davis ICE for their development of present-day vegetation maps of Napa County, allowing coordination of mapping for change analysis (Thorne et al. [in press]).

For the earliest possible historical comparison, we created a digital photomosaic using 82 high-resolution photographs provided by Phill Blake of the NRCS. These images from 1940 and 1942 (and a single photograph from 1953) represent the earliest available set of direct overhead imagery for the Napa River watershed. We focused mapping on the lower watershed -- from Scott's Canyon to the junction with Napa River -- where land use changes were most significant. Initial assessment indicated that changes in the upper watershed between Grassland/Range and Scrubland/Woodland, while noteworthy, would be relatively difficult to distinguish by mapping (because of the narrowness of features and limitations in the horizontal accuracy of the earlier imagery) and would be better illustrated through qualitative visual examples.

Mapping agricultural types circa 1940.

Mapping units were determined based upon (1) discussions with members of the other technical teams about which habitat or land use distinctions would have significant influence on the production of sediment and runoff, and (2) assessment of habitat/land use distinctions which were technically possible given available information. Some units were easily distinguished, such as the regularly-spaced, large "dot" pattern of *Deciduous Fruit, Nuts, and Olives* (Orchard) and the water surfaces of *Reservoir*. Vineyards were also relatively easy to determine because of their visible rows and the numerous examples available in the present-day imagery.

Greater uncertainty is associated with the distinction between the *Hay, Grain, and Miscellaneous Agriculture* and *Grassland/Range* units, which did not exhibit clear markers from above. To calibrate the imagery, we used other historical sources to identify crops at specific sites near the time of the earlier photographs. For instance, the site of the Spreckels Ranch south of the town of Napa provided the example of several hundred acres of hay and grain around 1940 (Weber 2001: 16, 281). Similarly, the UC/USDA map of "Farming Areas" circa 1930 (Crawford and Hurd 1935) shows general crop patterns that correspond with areas visible on the 1940 photography.

Where we could not distinguish grazing vs. general agriculture solely based upon photographic information, we utilized information about general land use of soil types. Some general assumptions were used in these cases to supplement visual information. For example, at this time fertile valley soils were rarely used for grazing and other soils were used almost exclusively for grazing (Carpenter and Cosby 1938). Uncertainty is greater in the case of these distinctions. The certainty of classification is recorded in the feature attribute tables of the GIS coverage. Horizontal accuracy of the circa 1940 coverage is limited by the challenges of historical photographic georectification. Horizontal error in this coverage can be as much as 50-80 m but is more typically <20 m.

Historical Rainfall Record

Cultural land management activities and watershed conditions evolve in the context of changing climatic conditions. To assess climatic variability during the historical period, we used a recent analysis of historical annual rainfall records for the North Bay and San Francisco by McKee and Grossinger (unpublished manuscript). This analysis uses correlation to early San Francisco rainfall records developed by Jan Null (pers. comm.; <http://ggweather.com>) to extend North Bay data back to 1850 (Figures 2, 3).

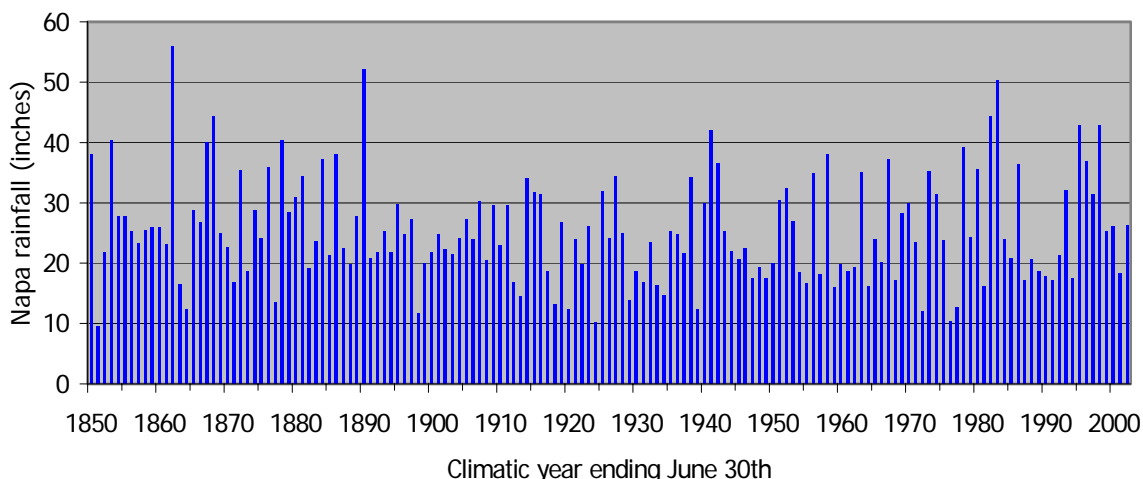


Figure 2. Annual rainfall at Napa State Hospital for the period water year 1850 to water year 2002. Data are from local measurements subsequent to 1908, with earlier values calculated from San Francisco data ($r^2=0.82$).

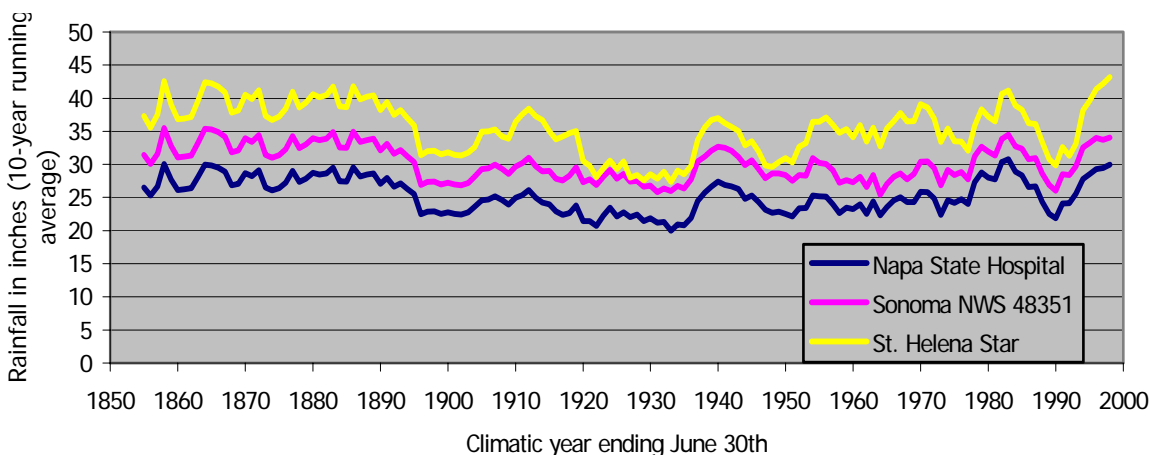


Figure 3. Ten-year running average annual rainfall at Napa compared to Sonoma and St. Helena for the period WY 1850 to WY 2002.

RESULTS AND DISCUSSION

The following three sections describe the findings of the Historical Ecology component of the Carneros Creek Watershed Assessment. First, transformations in human settlement since European contact are described in **Cultural Context**. The **Land Use** section then details the types, duration and intensity, and potential effects of different land uses practiced by people within the watershed over that time. Actual physical changes in watershed resources and processes during historical times, as evidenced by historical and modern data, are described in the third section, **Landscape Changes**.

I: CULTURAL CONTEXT

An important step in developing a landscape and land management history for Carneros Creek is to understand the origins and numbers of people that inhabited the land and how human populations changed through time. Newcomers to the Napa Valley often brought with them tools, experience, and land management practices from other places that with time were adapted to deal with local conditions. Understanding these dynamics is a critical component to documenting and understanding changes in the landscape.

Indigenous peoples

At the time of European contact, the Napa Valley comprised a complex mosaic of different linguistic and cultural groups, including peoples who had inhabited the Bay Area for at least 3-4,000 years (Heizer 1953, Milliken 1978). At least three distinct languages were spoken along the Napa River. The people of the upper Napa Valley spoke Wappo, an isolated and likely very old language whose range extended northward to approximately the Russian River. The Patwin language was spoken below the present-day town of Napa, and east into the Suisun and Central Valley. The area around Mare Island was likely occupied by Costanoan-speaking (Ohlone) people who occupied both sides of Carquinez Straits (Milliken 1995).

Establishing the pre-contact geographic territories of tribal groups and locations of villages is a challenging endeavor, however, because of the rapid cultural changes that accompanied Spanish expansion into the North Bay. Substantial information is, in fact, available in the form of Spanish and early American accounts, archeological data, and, in particular, the analysis of mission registers. The delineation of territories based on data from this period is complicated by the rapid loss of life in local villages, the wholesale movement of groups to the missions, or to more rural areas to escape missionization, and the formation of new Indian settlements as work camps for Spanish and American industries. Milliken (1978) assesses these data for the Napa Valley and describes three major tribes or villages, and their relative locations: the Canijolmano, in the vicinity of present-day St. Helena; the Caymus, in the Yountville area; and the Napa, along the lower reaches of Napa River below the present town of Napa. In addition, the Carquin occupied the lowest part of the River near Mare Island.

Despite substantial archeological documentation of the region, published accounts do not identify a major permanent village in the vicinity of Carneros Creek. This may reflect the absence of substantial perennial surface waters in comparison to the reliable source of Napa River, along which the three major villages identified by Milliken are found. However, the watershed was clearly inhabited and used by indigenous peoples, as indicated by local archeological sites and Altimira's account of native fire management (Altimira [1823] 1861). For example, Heizer's (1953) summary archeological report of Napa County reports "habitation sites" with scattered obsidian flakes along the Creek near the locations of the Las Amigas and Old Sonoma road crossings.

Evidence for the Napa Valley as a whole suggests that at least several thousand people inhabited the region at the time of European contact and delete that for centuries before. Exact estimates range widely, as shown in Table 1.

Table 1: Pre-contact population estimates for Napa Valley.

Author/Year	Estimate	Region
Menefee 1873	2,000	Suscol to Oakville
Rev. Orange Clark (n.d.)	8,000	Napa Valley
Cook 1956	4500	Napa Valley
Milliken 1978	3,000-4200	Napa Valley
Beard 1979	1650	Valley above town of Napa

Spanish contact

Southern Mexico fell under Spanish rule by about 1520. Over the next 250 years, however, the combination of intimidating tribes in northern Mexico, the physical barriers of deserts and mountains, and the lack of apparent gold in California prevented Spanish expansion northward. As a result, California Indian culture continued to flourish with little or no impacts from the transformations to the south until the late 1760s. Spanish presence in the Bay Area is thus notable both for its relative brevity yet high impact.

The northern part of San Francisco Bay experienced an additional delay, due to the natural barriers of Carquinez Straits and the Golden Gate (Milliken 1978). While missions, pueblos, or presidios were established in San Francisco, the Peninsula, the East Bay, and the South Bay during the late 1700s, tribes in the North Bay were still intact by 1810 (Milliken 1995). With a weakening Spanish government and resistance of tribes in the North Bay, nearly a half-century passed between the founding of the San Francisco Mission (1776) and the Sonoma Mission (1823). One effect of the persistence of indigenous culture in the North Bay was the adoption of native, rather than Spanish, names for most significant places (e.g. Marin, Napa, Sonoma, Petaluma, Suisun).

However, the isolation of the North Bay from the Spanish colonial presence in the rest of the Bay Area was probably not quite as extreme as has often been reported. Father Altimira's expedition to determine a site for the Sonoma Mission is generally considered the first documented European exploration of the North Bay (Weber 1998), and George Yount is famed as "the first white man to set foot" in Napa Valley (Carpenter and Cosby 1938). However, Smilie (1975) and Milliken (1978) provide evidence of a number of previously undocumented Spanish excursions into the North Bay prior to Altimira's expedition of 1823. These contacts were recorded in the Mission San Francisco de Assis ("Mission Dolores") *Libro de Bautismos*, along with entries for new baptisms of Napa Indians. In addition, Smith and Elliott (1878: 2) describe a Spanish fort that was reportedly established in 1776 "a short distance northwest of Napa;" however, we have found no other confirming sources.

Changes following Spanish contact

While impacts to Napa Valley tribes have generally been considered to follow the establishment of the Sonoma Mission in 1823, examination of mission records shows that many of the effects came earlier. Spanish recruitment of North Bay peoples for work in the construction of Mission Dolores, and other settlements, resulted in the abandonment of the village near the present-day city of Napa by 1815. By 1824, the entire Valley south of Yountville had been essentially depopulated (Milliken 1978: 2.38-39). Even earlier impacts may have occurred: Milliken's analysis of demographic data (1978: 2.32, 2.35) suggests that the village near Napa may have been ravaged by the epidemic (type unknown) at San Francisco de Assis in 1795, nearly 30 years before the establishment of a Mission in Sonoma. Still unfamiliar with the manner in which communicable diseases spread, Napa Indians working at Mission in San Francisco likely carried the disease home with them on visits, or in an effort to flee the epidemic, rapidly infecting their entire community and anyone they met along the way.

Subsistence-based Indian land management techniques, which had likely played a major role in determining the character of the Napa landscape for generations, were thus in flux by the early 19th century. However, Indian habitation, and even management of the land was not easily halted. Despite

intensive recruitment to missions and several decades of exposure to disease, Indians were reported to be carrying out a controlled burn in the hills of Huichica or Carneros in 1823 (Altimira [1823] 1861). After the demise of the missions, Indians returned from San Francisco, San Jose, and Sonoma to Napa Valley and, despite large losses, survived the smallpox epidemic of 1838-39 (Heizer 1953) to the extent that Menefee describes perhaps 2,000 or more Indians in rancherias established on the Mexican land grant ranchos in 1843 (Menefee 1873).

Pejorative accounts of Napa Indians by Menefee, the author of Napa's first history, and others are common (e.g. "they encumbered the sidewalks, lounging or sleeping in the sun, half clad and squalid pictures of humanity in its lowest state of degradation" (Menefee 1873, describing Napa City before 1856)). These established a demonstratively negative conception of the local native peoples in the popular imagination (Beard 1979). Yet other, less well-cited accounts create a different picture of cultural resilience and continuity well into the American period. For example, an old-timer attested to seeing 3,000 Indians passing along the ancient trail from Napa Valley through Wooden Valley to Gordon Valley to attend a traditional dance in 1853 (Davis n.d.: 10). A large dance house was built just northwest of where the Yount Bridge crosses Napa River in 1866 (Davis n.d.: 11), re-establishing the traditional Wappo dance site at Yountville (Driver 1936: 85). However, by the early 20th century, censuses reported fewer than 100 Wappo (Calkins 1993). Yet many tribal members survived by moving north to Alexander Valley and Clear Lake, with groups existing through to the present in the form of, for example, the Mishewal-Wappo Tribal Council (Calkins 1993).

Mission and Ranchero Periods

Mission San Francisco de Solano (the "Sonoma Mission") was established in 1823, the final and northernmost of the California missions. The Sonoma Mission grew over the next 10 years, recruiting Indians from the local tribes, and developing agricultural fields and ranchos. These activities constitute the first direct, non-indigenous management activity in the Carneros area.

In 1833, the Mexican government initiated secularization of the missions. The prosperous Mission lands of California were legally intended for the Christianized Indians, but secularization effectively transferred land to Spanish and Mexican settlers over the following decade. Concern over the establishment of Russian bases at the ports of Bodega and Ross (Lightfoot 1991, 1997) led Sonoma to become the Mexican military headquarters for the North Bay and hastened divestment of land to settlers, mostly Mexican, to occupy the northern frontier of Mexico.

As a result, during the 1830s the Mission Rancho in Napa Valley began to be split up, and Rancho Rincon de los Carneros, extending northeast from Carneros Creek to the Napa River, was granted to Nicolas Higuera around this time. Higuera also received Rancho Entre Napa, contiguous to the north along the creek. Rancho Caymus, from Yountville to just past Rutherford, was granted in the same year to George Yount. In the next year, Antonio Ortega, the Administrator of Mission San Francisco Solano, was given permission to develop a rancho in the large area extending roughly from Napa to Yountville. This area, which extended to Carneros Creek, above Higuera's grant, was later granted to Salvador Vallejo (Smilie 1975).

Transition to American ownership

From the late 1830s into the American period, the Carneros Creek watershed was managed by just three individuals. Jacob Leese owned the lands extending west from the creek, Rancho Huichica. On the east side of the stream, the land was divided at Old Sonoma Road, with Higuera owning the relatively small lowland area downstream to the baylands and east to Napa River (Entre Napa and Rincon de los Carneros). Vallejo controlled the west side of the watershed upstream from Old Sonoma Road and extending east across much of Napa Valley to Yountville (Rancho Napa). In the 1850s, these large land grants began to be sold off as smaller parcels, leading to more diverse land ownership and management through the next 150 years. Landholders in the second half of the 19th century included many of those for whom local landmarks are now named, such as Boone "Fly," "Stanly," and "Duhig." A map of the lower watershed circa 1858 is presented in Figure 4.

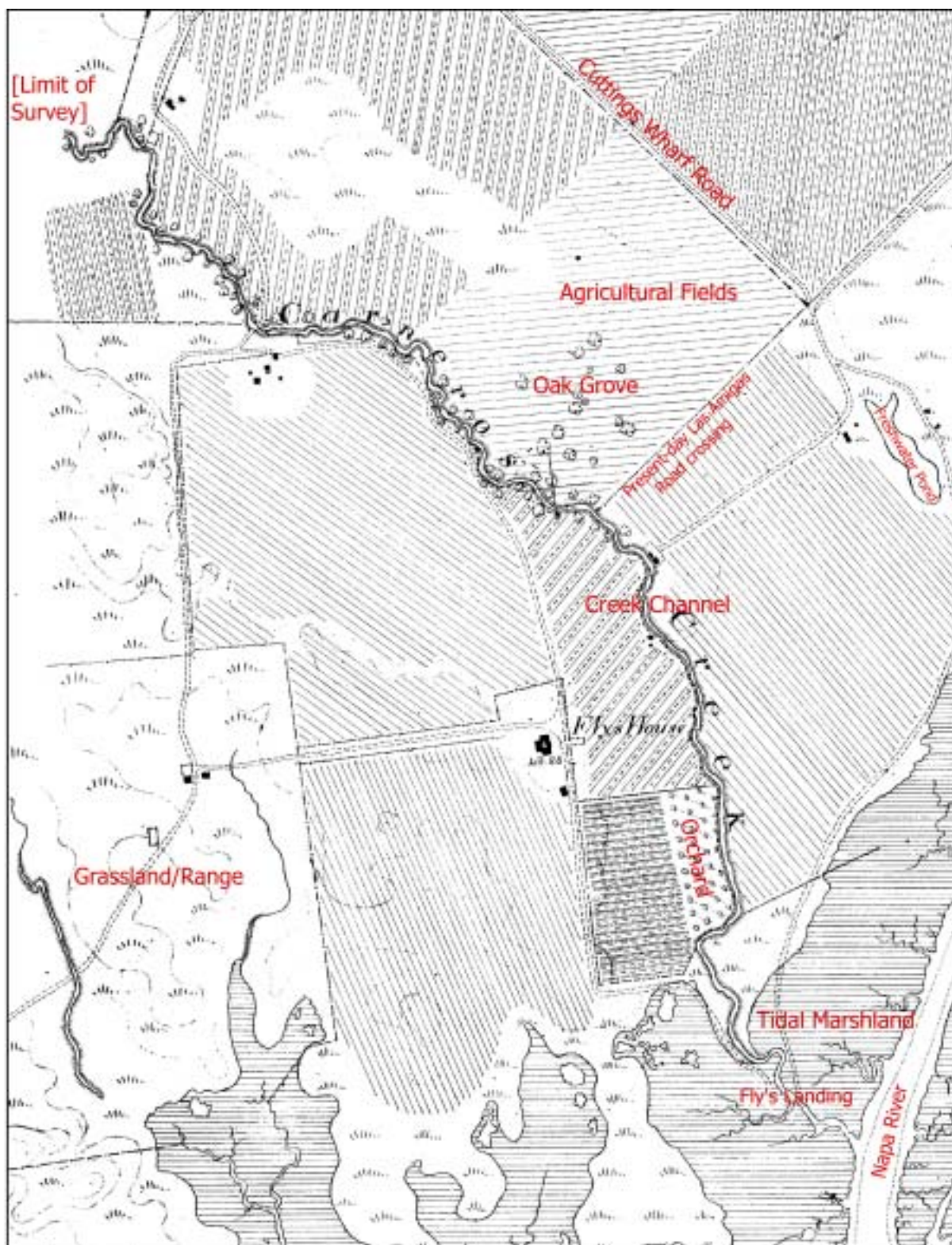


Figure 4. USCS Topographic Sheet #T777 shows Carneros Creek passing through agricultural lands as it approaches the Napa River marshlands in 1858. The indicated fence line marks the approximate location of the present-day Las Amigas Road crossing.

II: LAND USE

This section describes the land use history of Carneros Creek watershed, divided into major categories of activity.

Aboriginal Subsistence and Resource Management

Given the population density and duration of human presence documented earlier, it is likely that controlled burns and other means of native management played a role in modifying the Carneros Creek watershed prior to the Spanish and American eras. There is a growing recognition in the environmental sciences that the role of indigenous peoples in shaping the California ecosystem has been traditionally overlooked (Lewis 1973; Blackburn and Anderson 1993). Indigenous use of fire to modify grasslands, shrublands, riparian zones, forested areas, and even wetlands has been documented among tribes throughout North America (Lewis 1973; Stewart 2002) and clearly had the ability to alter vegetation cover at the landscape scale (Anderson 2002). Other techniques such as coppicing, aeration through tilling, transplantation, and selective harvesting were also likely employed to shape the character and extent of local vegetation types (Calkins 1994; Mathewson 1998).

Plants used for basketry, cordage, snares, nets, and traps, weapons, clothing, structures, food, and ceremonial items were managed with fire for specific quality, quantity, length, texture, and nutrient content (Blackburn and Anderson 1993; Mathewson 1998). In an analysis of Sierra tribes, Blackburn and Anderson (1993) estimated that more than 75% of plant-based items were made from just the epicormic branches or adventitious shoots – new growth which can be spurred by fire. In terms of influence over resources at a landscape scale, the successional trajectory of many systems was likely tightly controlled to maintain the productivity of specific resources over vast acreages. For example, Kunkel (1962) estimated that an average Central California “tribelet”, consisting of some 850 people, would be dependent upon a territory of no less than 150 mi².

The cultural disruption of missionization on indigenous culture in the Bay Area has resulted in native subsistence practices being less well-documented here than in many other parts of California. The use of fire in the region was nevertheless noted repeatedly by early European visitors in many parts of the Bay Area (e.g. Mayfield 1978; Stewart 2002). Deliberate setting of fires is actually fairly well-documented in the Napa region and specifically in the Carneros/Huichica area. In 1823, on the expedition to site the eventual Sonoma Mission, Father Altimira reported midsummer (June 28) Indian burning in the hills between Sonoma and Napa, probably in Huichica or Carneros. Translations of this event vary:

“We...proceeded in a north-easterly direction by a chain of hills. Although the grass had been burnt by the Indians of the neighborhood . . .” (Altimira [1823] 1861: 61)

“We went thus to northeast by one range of hills (which without delay were to be burned by the Indians whom we encountered) . . .” (Smilie 1975: 8)

Further evidence indicates that Indian burning in the Napa region was regular and purposeful, and well known to European settlers. Ethnographer Harold Driver (1936), who interviewed tribal elders in the 1930s, reported that the Wappo called the month of June “burn-the-valley moon,” corroborating Altimira’s observation. The 1836 treaty between Lieutenant Vallejo and the neighboring tribes, noteworthy as possibly the first formal treaty between the Spanish and California Indians, included the specification “...[T]hat they should not burn the fields (Smilie 1975: 61).”

Indian burning practices in the vicinity clearly continued at least through to the time of the treaty, although there may have been a gap prior to secularization, when Mission membership was highest. In addition to the effects of the treaty, the decimation of North Bay tribes by the smallpox epidemic of 1838, killing an estimated 60,000 to 70,000 Indians in the Mexican *Frontera del Norte* (Tays 1937), and the diversion of the Mission lands designated for the Indians to the Mexican land grants, probably caused native-directed fire management in the Carneros area to cease by the late 1830s.

Although Vallejo was clearly not an advocate of prescriptive burns, there is some evidence that vegetation management through fire continued, at least in places, in the region during the 19th and early 20th centuries. A noted accident in summer 1896, when Father White burned down the St. Francis Solano Church in Sonoma while “burning off dry grass” (Smilie 1975: 119) records the local use of small, low-intensity fires to keep vegetation low. Hunters on the McCormick Ranch (parts of the Sulphur Creek watershed and Sugar Loaf Ridge State Park) regularly burned the underbrush to keep the hillsides open for hunting as late as the 1950s (Perry pers. comm.). This effective perpetuation of the native practice through cultural change is documented in other parts of the country to enhance hunting, maintenance of agricultural fields, and livestock forage improvement (e.g. Cronon 1984; Wilkerson 2001).

The regular use of fire by native peoples in Carneros probably was largely responsible for maintaining the open grassland mosaic, which drew the European ranching-based communities to the area (as observed by researchers in other parts of the West, e.g. Stewart 2002). Repeated, “cultural burning” also would have reduced the incidence of larger, catastrophic fires, which can mobilize massive amounts of sediment.

In recent years, researchers have studied the effects of fire on diverse landscape functions, from sediment supply and drainage density to channel morphology and vegetation succession (Allen-Diaz and Jackson 2000; Allen-Diaz, Jackson, and Fehmi 1998; Collins and Ketcham 2001; O'Dea et al. 2003; George et al. 2002). However most studies have been conducted in systems that have undergone many decades of fire suppression, where fires can be far hotter, larger, and have very different ecological effects than earlier fires. Few, if any studies have had the opportunity to study systems in which “cultural” burning has persisted uninterrupted, therefore a true understanding of “indigenous fire” and its role in shaping the landscape must be inferred from historical accounts and assembly of relevant academic investigations. As a practical tool, however, the use of fire to restore and manage such rangelands has undergone somewhat of a renaissance as scores of researchers and land managers realized that fire can reduce undesirable species while enhancing desirable taxa (Belsky 1992).

The grasslands of the Carneros watershed are now predominately exotic, Mediterranean annuals, which are tolerant of grazing and drought, and produce large amounts of residual dry matter (RDM), or mulch, which can suppress the growth of native grasses (Hervey 1949; Bartolome 1987 & 1989). In pre-European times, the native species that would have predominated retained a much higher root-shoot ratio, storing significantly greater carbon and nitrogen in the soil and creating a very different hydrologic character and responding to fire quite differently (Hild et al. 2001; Mapfumo et al. 2002).

As is common in areas with intensive cultural effects from Spanish missions, there are few specific, published records of native management of the Carneros Creek watershed. However, based upon local information about the extent of native settlement, and information from other areas, it would be prudent to assume that this activity took place and had significant influence over the composition, distribution, abundance, and productivity of most habitats in the watershed for a very long period of time. Some aspects of native management practices may be useful tools for the future. For example, despite extensive changes substantial remnants of native grassland still exist in the Carneros Creek watershed (Graves pers. comm.). Restoration and expansion of native grasslands, potentially with the use of fire, could provide some of the benefits to soil, water, and ecology described above.

Grazing

Grazing of hoofed animals can increase sediment and surface water runoff in a watershed by changing the vegetation cover and the properties of the soil. These changes take place by altering soil characteristics such as porosity and permeability, soil fauna, root depth and strength, and rain droplet interception and impact. However, most grasses are adapted to herbivory, hence the low placement of their apical meristems (centers of growth), among other traits (Hild et al. 2001). Many studies have demonstrated that careful application of grazing can be beneficial in restoring and maintaining native, perennial grasslands (e.g. Belsky 1992). During periods of drought however, the carrying capacity of

rangeland systems can sometimes be exceeded, leading to overgrazing, exposure of bare soils, and loss of desirable forage species. It is also possible that early grazing activities on native ecosystems simultaneously adjusting to other changes (e.g. invasive species, reduction of fire) can result in particularly significant, long-term system effects. Understanding historical grazing practices is an important part of piecing together human influences on sediment and water production and change through time (e.g. SFEI 2001).

Introduction of Ranching to the North Bay and Carneros Creek Watershed

In the fall of 1823, as the new Sonoma Mission was being established, livestock were brought from other Bay Area missions to start the Sonoma herds (Smilie 1975: 19). The year 1823-1824 is thus the beginning point for Spanish grazing practices and the introduction of non-native grazing mammals in the North Bay. (The Russian settlement further north at Fort Ross, which was established in 1812, was presumably the first introduction of cattle north of Carquinez Straits.) Native grazing mammals were plentiful at this time as well, as illustrated by the French traveler Duhaut-Cilly on his visit to the Mission in 1827: "the hills of this part of California, and the plains they leave between them, support an immense quantity of deer of prodigious strength and size" (Duhaut-Cilly [1827] 1999). Native grazers were hunted intensively, partly to reduce competition with domestic animals: "The many herds of large elk that roamed the nearby valleys were used for meat and manteca (butterfat) as well as tallow and hides, in these earlier years, to allow the domestic cattle to increase and also to clear the pasturage of wild animals (Smilie 1975: 26)."

By the end of 1823, the Sonoma Mission reported 180 head of cattle and 1100 sheep. At this point, herds were contained in the vicinity of the mission, but in 1824 ranches were established further into Sonoma Valley and to the east in Suisun Valley (the Santa Eulalia Rancho). The Mission ranchos extended further out into the adjacent valley and foothill grazing lands during 1825 and by 1827 ranchos were established in Napa Valley and the Huichica area, initiating managed grazing practices in the Carneros Creek watershed. Mexican period grazing data is summarized in Table 2.

After a temporary high point and subsequent decrease in the first years, perhaps because substantial numbers of cows were killed for food, herds operated by the Mission increased steadily. In 1831, it was reported that the herds had become large enough that older animals were regularly removed to manage herd size (Smilie 1975: 20-35).

Sheep in "Carneros"

Several sources specify that the Carneros area was used as grazing land for the Mission sheep herds, Napa Valley for cattle, and the areas nearest to the Mission -- Huichica and Sonoma Valley -- reserved for horses (Milliken 1978). That the initial European use of Carneros was as sheep pasture is reaffirmed by the name itself, alternately translated as "ram", "mutton", and "sheep". Land grant testimony (Vallejo 1842: 57-58; De la Riva 1854: 30) identifies a sheep corral at a ford on Carneros Creek, which served as an important landmark -- Corral del Paso de Abajo.



Figure 5. Carneros Creek crossings circa 1844, in the vicinity of present-day Old Sonoma Road. Courtesy the Bancroft Library.

Numbers of sheep reported by the Mission increased dramatically when ranchos were established in Napa, Huichica, and likely Carneros, and ranged between 3,500 and 7,114 during 1827-1834. Many of these animals would have been kept in Carneros, suggesting a fairly high density. Herds would have been concentrated in the vicinity of the corral, as sheep require substantial husbandry (because of their susceptibility to scouring and parasites, and general maintenance such as nail clipping and shearing), likely upstream and downstream of the corral in the area historically described as “Carneros.” The watershed thus probably experienced substantial grazing by sheep during this period, as well as direct, higher-intensity effects where the corral was adjacent to the creek (near old Sonoma Road).

Unutilized period and transition to cattle

Within several years of secularization in 1834, grazing density increased substantially, as the Mission Ranchos were sectioned off into smaller grants and herds were managed locally. However, this did not necessarily take place immediately. For a brief period before the distribution of the massive Mexican land grants, management of the landscape was relatively diverse and distributed. Indians released from the Mission were allotted small plots of land and their own herds of cattle and sheep (Smilie 1975: 62), while other Mission officials, the Mission itself, and Vallejo all maintained herds.

Some areas, including parts of Carneros, apparently went unutilized during this period. For example, we

know that cattle and/or sheep were already using the Napa Valley and Carneros area during the Mission period, but when Ortega received permission to use the former Mission lands in Napa adjoining Carneros, he brought cattle from Sonoma (Smilie 1975: 63). Ortega also testified in the Land Case hearings for Entre Napa that in 1836 these lands (the eastern side of lower Carneros Creek) were presently “not occupied by the natives of the Pueblo nor by the stock or cattle under my charge, for the former have their rancho established in common and the latter the place of Soscol [sic] in the straits of Carquinez, where they trouble no one with their location” (Ortega 1836: 40-41). By 1838 or 1839, however, Higuera had a high density of cattle on his land (2,000 head/8,200 acres) and Leese brought in “four or five hundred cattle” soon after his first occupation of Huichica in 1839 (Vallejo 1852: 6).

With the establishment of the land grant ranchos, the number of cattle in the area increased dramatically. While the entire Sonoma Mission lands contained about 6,000 head in 1834, Higuera had 2,000 and Salvador Vallejo 5,000-6,000 head of cattle on their relatively small properties by the end of the decade:

In 1838 and 1839 the prominent ranches or cattle farms about the bay of San Francisco and in the vicinity were as follows: . . . The rancho of Don Salvador Vallejo was located in Napa Valley, and contained from 5,000 or 6,000 cattle and about 2,000 horses; adjoining him on the east was Nicolas Higuera, with about 2,000 cattle and 1,000 horses; to the south of the latter Cayetano Juarez, with a few hundred cattle and horses; adjoining him on the south was the Nacional Rancho Suscol in charge of General Vallejo. This was reserved by the Mexican government for the purpose of supplying the troops of the department of California with cattle and horses. It contained 5,000 head of cattle, and two or three thousand horses . . . (Davis 1929: 31-32).

By the mid-1840s, the herds had grown even more dramatically, with the Nacional Rancho Soscol increasing from 5,000 to 14,000 head in about five years. Davis notes the massive size of Vallejo's herds at this time, not even including the additional animals owned by Juarez, Higuera, and other neighboring ranchers:

The Nacional rancho at Soscol had about 14,000 head of cattle, and a large number of horses. These cattle used to stray to a long distance along the margin of Suisun Bay. This rancho was under the control of General Vallejo from the time he founded the military headquarters at Sonoma. He was virtually the owner of all the cattle on the north side of San Francisco Bay, which were originally reputed to be Mission or government property, but eventually he became the acknowledged proprietor of all these animals. Including Petaluma, Temblec and another rancho, the total of cattle on all these estates reached the enormous number of 50,000 head. This made the General the largest cattle owner in early California.” (Davis 1929: 138)

Cattle were carefully counted “as they went out of the corral, before the number became too great on a hacienda” (Davis 1929, p. 138), indicating concern about overstocking and the attainment of a “maximum” stocking rate. It should be noted that the Spanish cattle were physically different from later American breeds, with smaller size (Bancroft [1890] 1970: 53-55) and impacts presumably correspondingly less. However, in almost all cases the ranchos also included substantial numbers of sheep and other animals not counted in stocking estimates.

Estimates of grazing density

The highly detailed annual reports (“*informes*”) of Mission accounts, which effectively summarize regional land use during this period, are not matched by subsequent datasets. At the same time, the corresponding land area is not well-defined. Information for subsequent years of the Spanish period is derived from Vallejo's inventory following the assumption of military control over Sonoma, visitors' accounts, and other sources, including testimony from the land grant hearings. Little or no data is available to describe grazing density during the years immediately following secularization, but an

accounting of herd size associated with each rancho near the end of the 1830s and the mid-1840s is provided by William Davis. Davis was a merchant, trading in hides and tallow during this time period, so he is speaking from personal experience and professional expertise (see Davis 1929: 71, 80).

Table 2. Historical data on North Bay grazing during the Mexican period.

Year	Rancho	Cattle	Sheep/Goats	Horses/Mules	Est. Area (acres)	Calculated Density (acres per cow)	Source
1823	Mission Sonoma (immediate vicinity)	180	1100	61			1, p. 20
1824	MS Ranchos (Sonoma Valley + Sta Eulalia?)	1100	4000	446			1, p. 22
1825	MS Ranchos	800	2000	515			1, p. 23
1826	"	582	1439	511			1, p. 26
1827	"	1200	3500	550			1, p. 29
1828	"	1400	4000	531			1, p. 30
1829	"	1500	5000	529			1, p. 32
1830	"	2000	4000	729			1, p. 34
1831	"	2500	5000	729 (?)			1, p. 35
1832	"	3500	6000	913			1, p. 38
1833	"	4849	7114	1066			1, p. 45
1833	"	8000	4000	700			2, p. 76
1834	"	6000	6000	2000			3, p. 51
1838/39	Salvador Vallejo (Rancho Napa)	5000-6000	-	2000	21,917 (incl. hills)	3.7--4.4	4, pp. 31-32
"	Higuera (Entre Napa + Rincon de Los Carn.)	2000	-	1000	8269	4.1	4, pp. 31-32
"	Juarez (Rancho Tulucay)	"a few hundred"	-	"a few hundred"	8866		4, pp. 31-32
"	Nacional Rancho Suscol	5000	-	2000-3000	~50,000*	10	4, pp. 31-32
1844	unspecified Vallejo land		4000				5, p. 84
~1845	Nacional Rancho Suscol	14,000	-	"a large number"	~50,000*	3.6	4, p. 138
"	all of General Vallejo's lands at this time	50,000	--	--	120,000-200,000	2.4--4	4, p. 138

Sources:

1. Smilie 1975 (Mission Informes); 2. Duffot de Mofras 1844 (in Smilie 1975, p. 76; based upon a visit in 1841); 3. Smilie 1975 (Vallejo Inventory); 4. Davis 1929; 5. Smilie 1975 (Vallejo Letters).

* Claim rejected so boundaries were not officially determined

To estimate the land area corresponding to these herd sizes requires an understanding of land use and ownership patterns of the time. During the Mission period, occupation of the surrounding lands increased over time, with indefinite boundaries, so it is difficult to assign appropriate acreage values. During the Ranchero period, boundaries were more precisely defined once recognized European settlers occupied all borders of a given site. There appears to have been general agreement on the intended boundaries of most of the North Bay land grants, often utilizing streams or village sites as evident boundaries. The total area (acreage) of these grants, as later confirmed by the American government, probably approximates the area under direct impact by the settlers during Mexican times; this was the legal intention of the Land Act of 1851. Some of the land grants incorporate areas that were wooded at the time and thus would have been less accessible for grazing. Alternatively, the ranchos bordering the tidal marshlands may have utilized parts of that habitat, but most of this area would have been inaccessible because of large sloughs. Given these uncertainties, and the fact that there were no fences during this time, corresponding acreages must be considered rough estimates, but calculated densities are probably conservative.

General Vallejo's "estates" described in the mid 1840s included at least Rancho Petaluma (confirmed as 66,622 acres (Beck and Haase 1978)), which probably included "Temblec", an Indian village in the vicinity, as a part of the rancho, and Nacional Rancho Suscol. The claim for Rancho Suscol was rejected, but its area as shown in a map by Smilie (1975: 139) is approximately 50,000 acres. It is unclear whether Davis included Salvador Vallejo's Rancho Napa (~22,000 acres) within this account, but most of the other area around the North Bay was the well-defined property of other rancheros at this time (e.g. Higuera, Juarez, Leese, Yount, etc.). Based upon these data and assumptions, General Vallejo's 50,000 cattle were spread over as little as 120,000-150,000 acres. Even if one includes all of the ranchos in

Napa and Sonoma Valleys, a high-end estimate would be 200,000 acres, still indicating an unusually high density of one cow per 3-4 acres. Descriptions of grazing in Sonoma County during the drought a couple of decades later suggests that high grazing densities were not uncommon in the mid-19th century: "The Russian River and Sulphur Creek [Sonoma County] country, once noted for its excellent grazing, has of late years been so overstocked and 'et out', that the cattle in that region are now dying of sheer property (Napa County Recorder 1861)." Another local newspaper described the Sonoma hills as "literally covered with immense herds of cattle at all seasons" (Sonoma County Democrat 1857).

Grazing in the American Period

Agriculture displaced grazing in the lower watershed relatively quickly following the assumption of American control of the region, with the drought of the early 1860s (see Figure 3) and fencing legislation in the latter part of the decade contributing to the decline of the vast livestock operations (Carpenter and Cosby 1938; Verardo and Verardo 1986: 32). By 1858, the United States Coast Survey map shows agricultural fields dominating the lowest part of the watershed. However, grazing areas are still indicated to the north, above South Avenue at this time (the map ends before Old Sonoma Road) and, in fact, ranching has persisted in the middle and upper part of Carneros through to the present day.

This trend is in contrast to much of the rest of the Napa region, where relatively little area was dedicated to livestock by the late 19th century. In 1880, for example, only 10,000 cattle were reported in the entire county, just four decades after Higuera had an estimated 2,000 head on his small rancho on Carneros Creek.

Ranching nevertheless continued throughout the watershed. We identified substantial rangeland in 1940s aerial photography (see Figure 6) and discussed this history with local residents. Ira and Shirley Lee, who have lived in Carneros since 1966, described five working dairies in the region back then, as well as difficulties finding enough water for the cows. Betty Mukerji remembers the land all around her, on the east side of the lower creek, as being orchards, but there were "cattle on the other side of Carneros" such as the Stornetta Dairies (Campbell 2000). In the middle watershed, at the Alexander property, a cattle feedlot operated for many decades along the creek (Pettis pers. comm.). At the time of its closing in 1993, the ranch had 5,000 head of cattle (Hudson pers. comm.). The cows were not fenced off from the channel and all channel vegetation was absent (Hudson pers. comm.).

Euroamerican ranching reached the Carneros Creek watershed by the late 1820s. By 1840, grazing density was high enough to potentially cause significant impacts to sediment and surface water runoff, more than a century and a half ago. For example, similar grazing densities in Wildcat Creek were shown to change rates of sediment production (SFEI 2001). Recent impacts from the now-terminated feedlot operation may have been even more severe.

Introduction of Agriculture

The introduction of agriculture can dramatically change vegetation cover, with ramifications for sediment production and hydrologic processes (Whitney 1996). In contrast to grazing, growing crops involves varying amount of tilling, cultivation, and soil aeration. The styles of land surface change can vary substantially depending of the types of soil parent material, crops grown, the management of ground vegetation, vegetation for wind and sun protection, and use of water. In modern times, the use of chemical fertilizers and pesticides can be an important additional impact of agricultural practices.

Early establishment

The Sonoma Mission established fields in the 1820s to sustain the population of missionaries and military personnel, and to encourage Indian attendance. The Mission agricultural fields were considered quite productive by 1826. In that year, the fields produced 2,627 fanegas (~4,000 bushels) of grains, including wheat, barley, beans, peas, corn, and garbanzos from the "extensive irrigated fields south of the Mission," which were nevertheless probably limited to several hundred acres in size (Adams 1946, Bancroft [1886] 1963: 344).

As a result, European agricultural practices were probably not introduced into the Carneros watershed until the late 1830s. Leese (Vallejo 1852: 6) and Higuera (De la Rosa 1853: 18) are reported to have established some crops on their lands, in addition to their ranching operations, as grant terms stipulated the establishment of some agriculture. One of these first agricultural fields in the Carneros watershed is shown in Figure 5. The extent of agriculture was quite limited prior to 1850, though, as illustrated in Figure 5 and attested to by Duhig's description of Rancho Huichica in 1853, when "he walked for hours through wild oats reaching to his shoulders as he followed Huichica Creek through the valley." At this time, "wild hay was actually free for the cutting and hauling (Duhig 1990: 2)."

European-style agriculture then expanded relatively rapidly in Carneros, with the arrival of settlers like Duhig. With the development of hay and grain fields, substantial parts of the lower watershed were plowed with horse-drawn moldboard plows by the 1850s (Duhig 1990: 4). By 1858, the United States Coast Survey map shows cropland almost continuously along both sides of the lower 1.5 miles along the creek (USCS 1858). Interestingly, the adjacent areas outside the watershed to the north and south are shown simply as grassland, which was likely grazed. At this time a relatively small percentage of the other lowlands adjacent to the Napa marshlands in general had been developed for agriculture. In comparison to other areas along Napa River below the town of Napa, Carneros appears to have been cultivated relatively early.

The crops shown in 1858 along the lower part of the creek are probably wheat or other grains. Wheat in particular dominated agricultural production in Napa Valley in the 1850s: "in 1857 the farmers of Napa Valley devoted their efforts almost exclusively to the production of wheat. As the yield was large and the prices obtained for their crops big, they were as a rule well rewarded for their efforts . . . The work of harvesting as it was conducted in those days required the labor of many hands which were recruited from every possible place, including the Indians." (Carpenter and Cosby 1938: 7).

Lee Hudson, who talked extensively to longtime resident Walter Carvelli in the mid-1990s, reports that ranchers would plant hay on small, flat areas scattered among the steeper hillslopes, bundle the hay in place, and bring cattle to the bales in winter, perhaps back into the 19th century (Hudson pers. comm.). The open areas of the middle and upper watershed thus would have consisted of a mosaic with uncultivated grassland on the slopes and plowed hayfields on the flats.

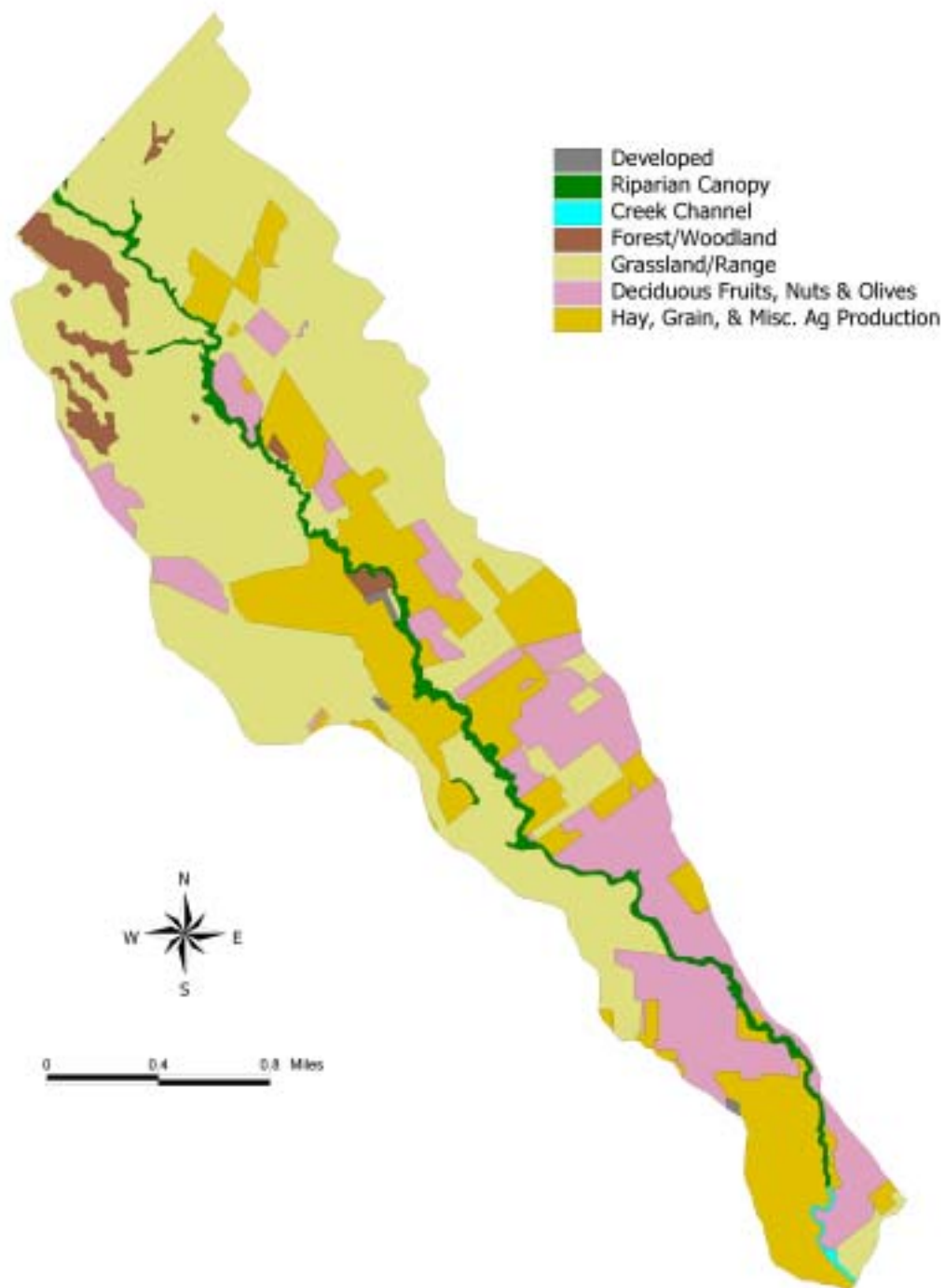


Figure 6. Land use and major vegetation types in lower Carneros Creek Watershed circa 1940, based upon interpretation of aerial photography and other sources.

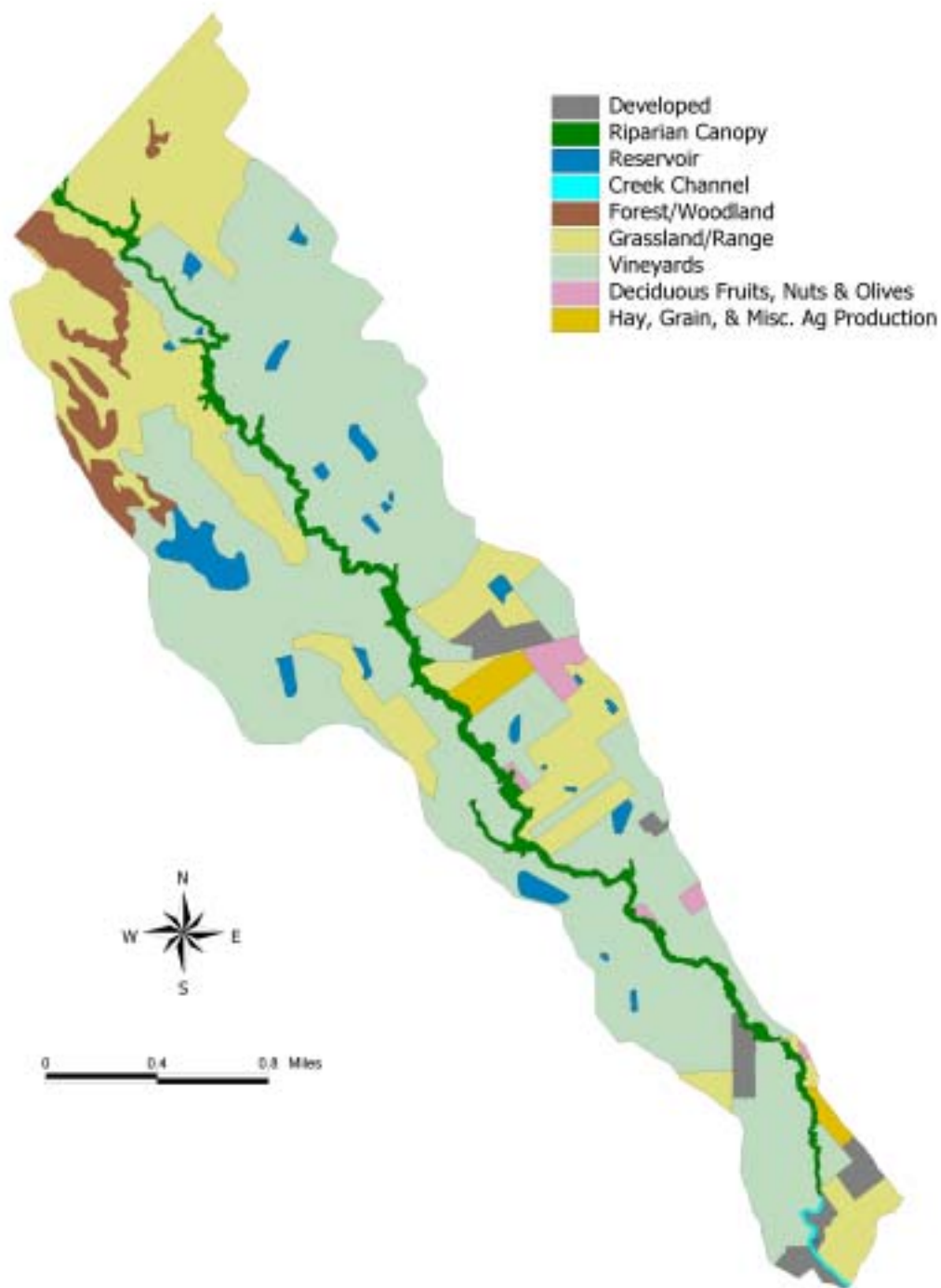


Figure 7. Land use and major vegetation types in lower Carneros Creek Watershed circa 1993, based upon interpretation of aerial photography and other sources. Grasslands/Range polygons adapted from those developed by UC Davis (Thorne et al. [in press]).

Development of orchards and vineyards

Only a single forty-acre orchard is shown near the marshland on Fly's land in 1858. The ascendancy of grain appears to have continued longer in the Carneros-Huichica area than in the deeper soils of the Napa Valley (Duhig 1990), where the "end of the great grain-growing activities" occurred by the 1870s (Carpenter and Cosby 1938). By the 1870s, a few vineyards were introduced in Huichica and presumably in Carneros as well. In fact, the Winter vineyard on neighboring Huichica Creek was described as the largest in the county in 1872, although it may have been no larger than 100 acres (Heintz 1985). The root louse *phylloxera* severely damaged this and most other plantings of vineyards in Napa by the 1890s (Carpenter and Cosby 1938, Heintz 1985, Duhig 1990).

As a result, land was replanted in orchards, particularly prunes. Duhig's father and neighbors planted apricots beginning in about 1915, with award-winning results, making the Carneros area the largest producer of apricots in Napa County. Cherries and pears were also planted heavily in the Carneros area in the early decades of last century, because prunes were not quite as successful in Carneros as they were in the Napa Valley, where they became the dominant crop. Duhig explains that "the soil here was not suitable for the large prunes which brought the top prices" (Duhig 1990: 11-12). Particularly away from the immediate vicinity of the creek, pasture, hay and grain continued to be significant activities down towards the Bay into the 1970s. A study for water supply in the "Carneros Area" (defined roughly by Huichica Creek, Old Sonoma Road, and Horseshoe Bend) reported 4,000 of 7,000 acres used for pasture, hay and grain in 1976 (Hamilton 1976). Vineyards accounted for just 1,700 acres by this time, with the remainder in "orchard or other uses."

The development of orchards on the east side of lower Carneros in the 20th century, and the persistence of both ranching and hay and grain cultivation are shown in aerial photography taken circa 1940. A map produced from photo analysis of these images showing land use in the lower part of the watershed circa 1940 is shown in Figure 6. The middle and upper watershed (not mapped for the reasons described in *Methods*) at this time was dedicated primarily to ranching, with areas of local cultivation and hay production for cattle.

Personal recollections of longtime local residents confirm and detail these aerial observations. Al Giovannoni, born in 1914, remembers the pear orchard that was the downstream extent of agriculture shown in the 1940 photography (Figure 9). Mavis and Al Fournier, who arrived in the region in 1919 and 1946, respectively, recollect prune trees, with fruit sold at 10 cents per box. Betty Mukerji describes cherries, pear, apples, and prunes, noting that "the market went out about [19] 75/76." At this time the buyers in Suisun stopped taking pears from Napa, leading Betty, the last pear grower in the area, to take out her trees (Mukerji pers. comm.).

Recent changes

Beginning primarily in the 1970s, another major shift occurred, with vineyards returning to the Carneros area. As depicted in the map of landuse circa 1993 (Figure 7), and summarized in Table 3, nearly all of the orchards, hay and grain, and rangeland in the lower watershed has been replaced with grapes (Campbell 2000). Just a few smaller areas are uncultivated grassland, used for grazing purposes, or are in other types of agricultural production as of 1993. Associated with this change in agricultural production is a general shift from dry farming (Carpenter and Cosby 1938: 5) to irrigation of crops.

Table 3. Lower* Carneros Creek Watershed Changes 1940-1993.

Land use or habitat type	ca. 1940 (acres)	1993 (acres)	% change
Developed	5	65	+1,200%
Vineyards	0	1450	--
Reservoir	0	71	--
Hay, Grain, & Misc. Ag Production	532	29	-95%
Deciduous Fruits, Nuts & Olives	449	29	-94%
Grassland/Range	1374	693	-50%
Riparian Canopy/Riverwash	88	113	+28%
Open Creek Channel	5	4	-20%
Forest, Woodland, Chaparral	76	77	+1%
Total	2,529	2,531	

Note: Based on GIS analysis of 1940/42 and 1993 aerial photography, consultation with local residents, archival references, and limited "ground-truthing."

*Below Scotts Canyon to the junction with Napa River.

Other land use changes 1940-1993

During the past half-century, several other significant changes in land use can be observed. One of the most notable changes has been the increase in surface storage of water. In the lower watershed, as shown in Figures 6 and 7, approximately 25 reservoirs or storage/stock ponds were created by 1993, where there were none in 1940. This may have had a substantial influence on the persistence of flow and pools in the mainstem of Carneros, especially if these reservoirs were built in subwatersheds that yielded more persistent or even perennial flow. The area of substantially developed areas (defined as > 50% commercial/residential, minimum size one acre) also increased notably during this time period. In comparison to many other flat areas in the vicinity of Napa, residential/commercial development has been quite limited due to agricultural zoning and preservation efforts by local citizens, such as "Keep Carneros Green" in the 1970s.

Channel crossings and other uses

Land use and land management changes in the vicinity of the creek channel have a greater chance of changing sediment and water production and influencing riparian vegetation. Stream crossings can provide a virtually unimpeded flow of both sediment and water to the creek. Early railroad and other crossings are often undersized for peak flood flows, causing debris jams, backwater effects, and flooding, with associated impacts to the channel (Collins and Ketcham 2001).

People have traversed Carneros Creek in the general location of the Old Sonoma Road crossing for centuries. Based upon interviews with surviving Indians and early settlers, D.T. Davis (n.d.: 2) described the trail down the west side of Napa Valley (which was less popular than the east side trail roughly corresponding to the Silverado Trail) as continuing "down west of Yountville by the Veterans' Home to the mouth of Dry Creek, then through the rolling hills across Redwood Creek and on across Carneros and Huichica Valleys to Sonoma." The trail appears to correspond with Old Sonoma Road, and the *Camino Real de Sonoma a Napa*, as it was called under Spanish and Mexican rule. There were at least three fords across the creek during this time (e.g. *Paso de Abajo*), which are depicted by the Huichica Diseño (Figure 5).

In 1862, Boone Fly, whose house happens to be shown in the 1858 U.S. Coast Survey map (Figure 4), was granted the right to construct a wharf on the west side of Napa River, presumably at the base of Carneros Creek where it provides a clear channel through the marshlands to the river (Soderholm n.d.: 11).

Carneros was among the last Bay Area streams to receive a railroad crossing and is currently among the relatively few complete watersheds without one. While railroads circumnavigated the Bay and extended to the top of Napa and Sonoma valleys by 1888, the section crossing Carneros was not opened until 1905 (Soderholm n.d.: 14, River, Harbor, and Canal Dredging and Land Co. 1887). This occurred because the track from Vallejo to Calistoga naturally stayed on the east side of the Napa River tidal marshlands and the branch from Santa Rosa to Vallejo crossed the Napa River a mile below Carneros at the Buchli Station (Figure 9). The section between Buchli and West Napa, when finally built by the San Francisco and Napa Railroad Company, provided direct service from Calistoga to Tiburon (with ferry service to San Francisco). However, passenger service from Calistoga to Buchli Station was discontinued in 1911 and, when freight operations were halted in 1938, the short-lived section between Buchli and Napa was abandoned and removed (Soderholm n.d.). Its remnants can be seen in the 1940s photography (see Figure 10).

Carneros Creek continues to have relatively few crossings (current maps show just seven road crossings of the main channel or one crossing per 1.3 miles of stream), and has no engineered flood control channel.

Water Use

While a complete analysis of changes in water use and resources is beyond the scope of this project, some information providing historical perspective on these issues was found. Available water has always been limited in the Huichica-Carneros area, with few natural springs and seasonal creeks. Wells dug by hand in the mid 19th century were shallow (20-40 feet) and tended to go dry in the summer. Deeper wells made using mechanical drilling equipment replaced the dug wells by the late 19th century (Duhig 1990: 24-25).

Assessments of groundwater resources in the Napa Valley have been completed at several intervals during the 20th century. Examining the whole of Napa Valley, Kunkel and Upson (1960: 78) found no significant change since 1918 by comparing water levels in 82 wells circa 1949 with earlier water levels. Similarly, DWR (1995: 12) found that in general, "long-term groundwater levels in most of the valley have remained unchanged."

Several local areas have been consistently described as having different groundwater characteristics than the rest of the valley, however, including Carneros. The "Milliken-Sarco-Tulucay Creeks Area" and the "Suscol Area" both appear to be isolated groundwater systems, which experienced substantial downward decline and low current groundwater level. Decline between 1918 and 1949 in the Milliken area is reported in the range of 30 feet or less, with the reduction of many year-round wells to seasonal wells (Kunkel and Upson 1960: 51). Kunkel and Upson reported that water levels in the Suscol area were "originally at, or slightly above, the land surface" (p. 51) but declined, considerably due to heavy pumping between 1920 and 1937; recent measurements indicate a water level about 60 feet below ground surface (DWR 1995: 13).

Unlike these areas, the Carneros area south of the Sonoma highway is not described by Kunkel and Upson as experiencing unusual diminishment; but it is noted as having unusually small pumping yield, generally five gpm or less: "The yields of some wells in this area are inadequate for minimum household needs, and some families must haul water during the summer and fall for drinking and washing. For example, static levels before pumping are in many places at or near the land surface, but after only a few hundred gallons is pumped the water level may be 70 or 80 feet below the land surface, and 24 hours may be required to recover to 20 feet below the surface (p. 29)." Groundwater here is more sensitive to overdraft than it is in most of the Napa Valley.

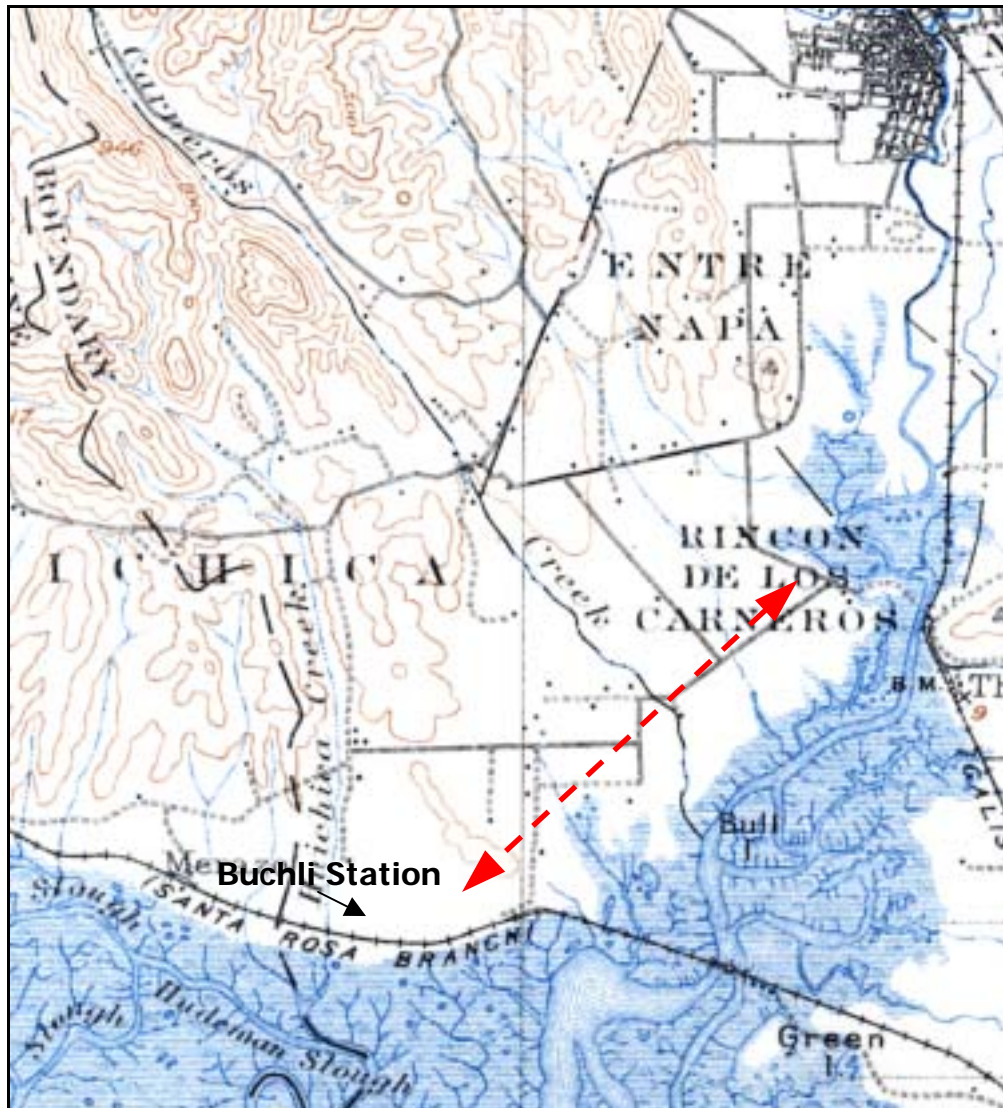


Figure 8. 1902 US Geological Survey shows the gap in railroad connections (red dashed arrow) in the vicinity of Carneros. The location of Buchli Station, which is shown in some maps but not this one, is indicated. Courtesy UC Berkeley Earth Sciences and Map Library.

III: LANDSCAPE CHANGES

In this section we document specific changes in the geomorphic and ecological characteristics of the watershed that have taken place during the historical period described in the previous sections. We present evidence for observed changes in terrestrial vegetation, channel condition, and riparian habitat, and discuss the implications for present-day watershed function. Topics are addressed in the form of pertinent questions developed through conversations with local residents and project team members, and based upon previous experiences in other watersheds.

Channel Plan Form

Changes in channel plan form include channel redirection, filling, culverting, and loss of side channel or “backwater” features associated with the floodplain. These kinds of alterations can influence a range of critical fluvial characteristics, including channel gradient, base/peak flows, and riparian and in-stream habitat. On the valley floor and open plain, creeks can be directed along completely new routes, creating new channel geometry and slope, which can affect the channel both upstream and downstream (Pearce et al. 2002). Documenting these changes is fundamental to understanding current trajectories in stream function.

Has the Creek Channel Been Straightened or Redirected?

Comparison of the present-day channel route with the earliest historical documents indicates that, at this scale, Carneros Creek has experienced very little redirection, straightening, or meander loss on the alluvial plain since the mid 19th century (Figures 9 and 10). U.S. Cadastral Engineer Joy (1921: 550-53) notes the lack of change between 1858 and 1921 during his resurvey of lower parts of the stream, reporting that “there are no indications of change in the position of the creek during the years that have elapsed since the survey, also the retracements conform very closely to the meanderings of the creek at this time.” It appears that some small meanders may have been removed, but this could also be due to natural causes. Significant straightening has occurred only in the short tidal reach.

Channel Connectivity

Has the channel's connectivity to the mainstem of Napa River changed?

Recent findings of the NRWEP suggest that prior to European settlement many of the tributaries to Napa River did not maintain continuous channels across the valley floor. These streams did not directly connect to the mainstem until the creation of ditches in the late 19th or 20th century. In the case of Carneros Creek, however, evidence suggests that the creek was able to maintain a clearly defined channel across its alluvial plain during historical times. While creeks such as Tulucay are shown by the USCS (1858) ending before reaching Napa River, Carneros is shown with a clear, incised channel. The Huichica Diseño (O'Farrell 1844) shows the channel extending into marshlands, which is notable since diseños of the region often distinguish between streams that reached the Bay and those that didn't.

The lower reach of the stream does exhibit some sections with somewhat unusually straight form, raising the question *Did ditching occur prior to 1858?* While this would be fairly early for major ditching in the region, clear evidence of smaller scale ditching does exist in the vicinity (USCS 1858). However, the lowest reach above the marshlands is very sinuous, contradicting the ditching hypothesis, and contains a well-defined natural levee as it enters the marsh, indicating a sustained presence at that site. Furthermore, the use of a stream without a clear channel as a land grant boundary generally results in substantial testimony to determine the appropriate boundary in the land grant confirmation hearings (e.g. Land Grant Case 100 ND, in Alameda County), which we did not find in the relevant case records.

How did the channel enter tidal waters?

The Carneros Creek channel happens to enter the Napa River baylands at a point where the river is quite close to land and appears to have naturally intersected a tidal marsh slough, thus providing a direct connection between the river and the creek. In contrast, many other Bay Area creeks of similar size to Carneros ended in broad tidal marshlands with no connecting slough, creating a less direct fluvial-tidal

connection for anadromous fish. Since 1858, Napa River has eroded its western bank some 40-50 feet in the section where Carneros enters and some tens of acres of tidal marshlands have been filled to make dry land. The vicinity of Carneros was apparently never diked, remaining tidal while vast areas to the north, south, and east were all diked by 1914. Sequential historical maps indicate that filling of the marsh at Carneros Creek occurred between 1933 and 1948 (Carpenter and Cosby [1933] 1938; USGS [1948] 1949). Despite this filling, reduction of the tidal prism in the creek's tidal reach, which could potentially cause channel downsizing, was probably not significant since there were only a few small sloughs tributary to this section (see Figure 4).

Channel Depth and Width

Changes to the channel cross-section influence its suitability as fish habitat through changes in sediment storage and production. They can also alter the intersection of the channel thalweg with groundwater, affecting riparian vegetation and the persistence of pools and perennial flow. Information about historical channel geometry can be challenging to find but invaluable for understanding trends of aggradation or incision.

Has the channel incised and/or broadened significantly during historical times?

Distinctive hatch marks on the USCS (1858; Figure 4) depiction of Carneros Creek, indicating steepness alongside the creek, suggests that the creek was already incised to some degree near the time of European contact. Since that time, incision does not appear to have been massive but may be substantial in places. Evidence supporting little or no incision during the past century includes the bridge at Old Sonoma Road, built in 1896, which has not been undercut over the subsequent period, and the 1921 survey by Joy crossing the creek along the 4N/5N Township and Range line about 1,500 feet below the Bay View Road crossing. Joy's field notes record "banks 10 ft. high, 50 lks wide (1921: 517-20)." The recorded width of 33 feet (100 links=1 chain= 66 feet) is comparable to that shown by the 1858 USCS map (~20-40ft in this section) and present-day aerial photography, although the site has not yet been reoccupied.

Recollections of local residents over the past 50 years indicate that the banks below old Sonoma Road were steep then as well as now, and that incision, if present, has not been dramatic enough to notice over this time. However, a cursory examination of the lowest channel reaches found many large trees with exposed roots well above channel depth and substantial bank erosion. Widening of the channel appeared to be taking place, which could explain the observed expansion in width of riparian canopy in some places along the creek.

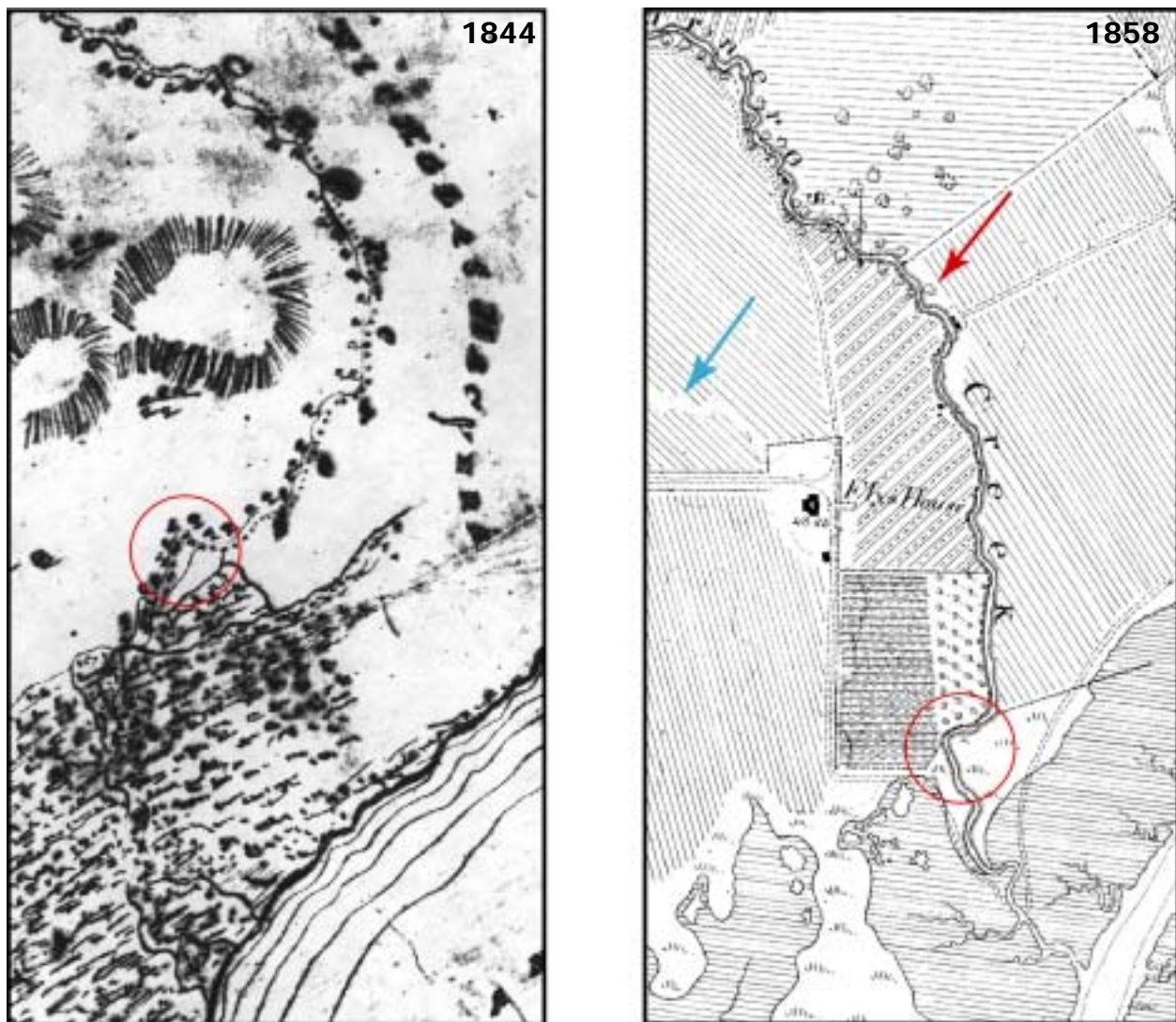


Figure 9. Time-series views of the lower reach of Carneros Creek: 1844 and 1858. The diseño produced in 1844 to support Jacob Leese's application for the Huichica land grant shows Carneros Creek as the proposed grant's eastern boundary. The sketch shows a continuous corridor of trees along the entire creek, but may not be very spatially precise. In contrast, the 1858 United States Coast Survey map, produced by plane table survey methods at 1:10,000 scale, shows the lowest section of the creek as unwooded, beginning at the point marked with the red arrow. (The fence line just above the red arrow marks the approximate current location of Los Amigos Road.) Similarity in the depiction of the meanders at the bottom of the creek between the two maps is circled in red; similarity in channel plan form between 1858 and 1999 can be seen by comparison with Figure 10. The route of a former channel, marked by a break in crop pattern, is indicated by the blue arrow.

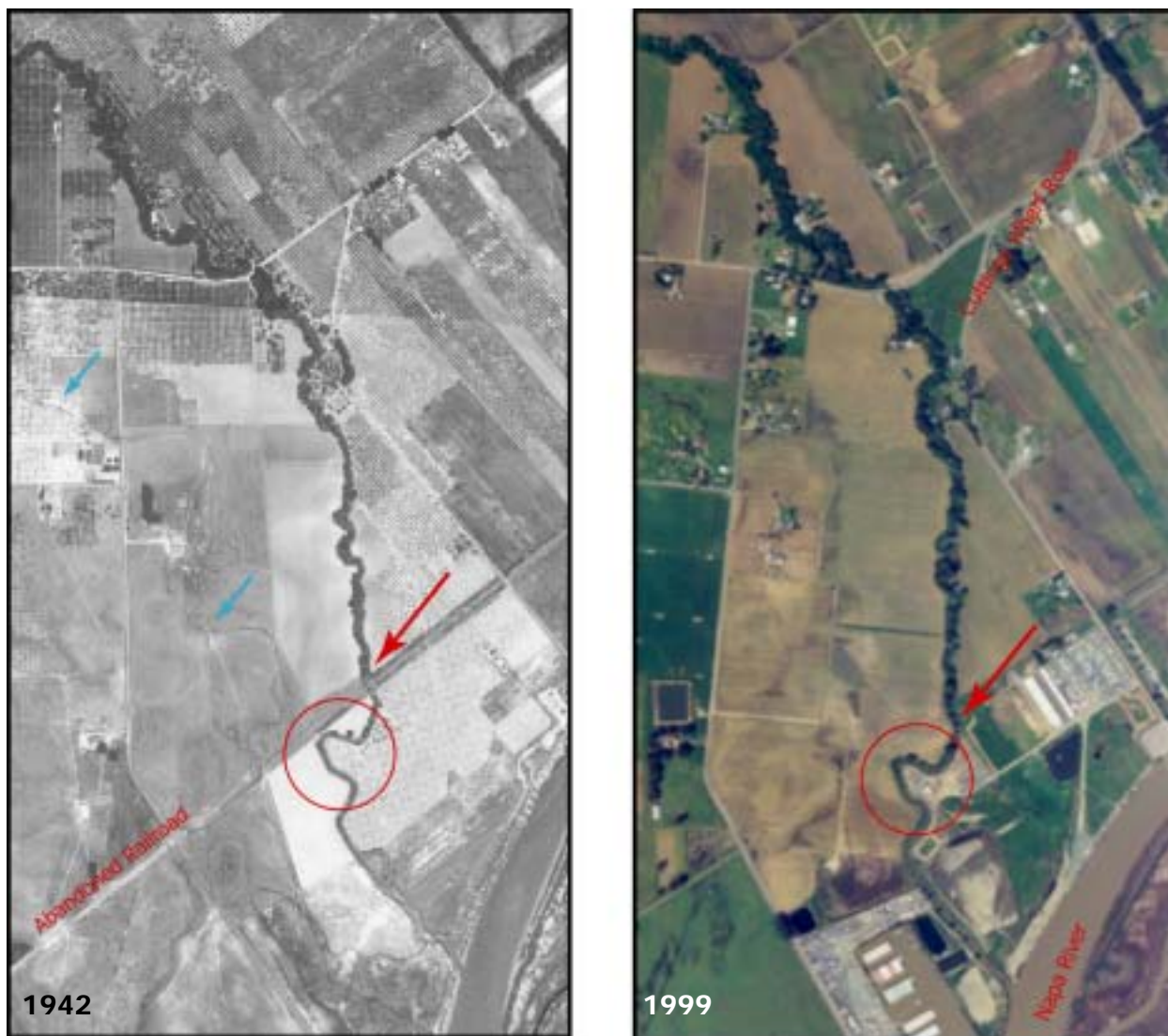


Figure 10. Time-series views of the lower reach of Carneros Creek: 1942 and 1999. By 1942, the riparian tree canopy has extended downstream approximately 4,000 feet, to the crossing of the recently abandoned railroad (red arrows). By 1999, tree canopy has extended slightly further, filling in the now almost undetectable location of the former railroad. Comparison of channel meanders (circled in red) with the 1858 map suggests the development of a larger meander, perhaps in response to the construction of the railroad trestle in the intervening period. The still-moist route of a former channel, marked by channel shapes and darker areas, is indicated by the blue arrows.

Flow

Have flow characteristics changed?

The terms perennial and seasonal can be problematic in a region with such highly variable annual rainfall (Figures 2 and 3). While the diversion of water for modern land uses has inevitably altered the flow on many streams, the common supposition that presently seasonal creeks were perennial in earlier historical times is not always correct. (See, for example, the discussion of Soda Creek, known in Spanish times as *Arroyo Seco* [= Dry Creek], in Newland et al. 2002.)

Evidence suggests that Carneros Creek did not maintain perennial, above ground flow during historical times, and that flow was historically negligible or intermittent in the summer. However, there is evidence that, in the past several decades, the amount of intermittent flow and persistent pools has decreased.

The first detailed, recorded description of the North Bay happens to have included a fairly detailed description of flow in what is in all likelihood Carneros Creek. Observing the creek in midsummer 1823 (June 28) near Old Sonoma Road, Altimira describes a stream with little, but some, flow and pools likely suitable for steelhead.

Presently we arrived at an *arroyo* which was said to be the entrance to *Napa*. This measures very little flowing current, of not much abundance are their waters, but we observed by measuring some places there are small permanent ponds with clear, sweet, abundant and pleasing water, sufficient to water some cattle. (Altimira, *in* Smilie 1975:8)

This description suggests that water could have been limited to pools by the end of summer. Similarly, local residents living along the lower reaches of the creek over the past half-century describe a seasonal creek, noting that the stream “didn’t run year-round” and that “every year it dries up”. However, a number of residents independently described a diminution in the extent of pools and seasonal flow, reporting that “it ran more” and “used to visibly run . . . enough to get over the rocks when I came here” (Fournier, Lee, Mukerji pers. comm.).

In the upper watershed, sections which were “bone dry” have been perennially wet since the 1999 earthquake (Hudson pers. comm.), indicating the importance of local faulting and seismic effects.

Flora and Fauna

What were the ecological characteristics of the alluvial plain at the time of European contact?

While the Napa Valley supported substantial areas of valley oak savanna at the time of European contact, conditions in the vicinity of lower Carneros Creek were ideal for open, unwooded grassland with seasonal wetlands. Observers from Grandfather Duhig (Duhig 1890) to U.S. Commissioner Bartlett (Bartlett 1852) and U.S. Deputy Surveyor Dyer (1862: 33) described the lowlands bordering the Napa marshlands below Suscol as open, without trees except for along the creeks. Joy (1921: 651-654/ 91-94), surveying the lower watershed below Old Sonoma Road, notes “soil adobe and clay loam, first-rate . . . no timber.” One exception to this picture was a grove of trees, perhaps willows, just east of the creek and above the Las Amigas Road crossing (USCS 1858; Figure 10). That this is probably not a remnant of harvested riparian or valley floor woodland is indicated by historical quotes affirming the unsuitability of riparian trees and valley oaks for firewood and lumber (see Riparian Habitat Section).

The soils in this area, bordering the Napa River marshlands to the north and south of Carneros Creek (as well as on the other side of Napa River) are shallow, underlain by a claypan which restricts subdrainage and plant root development. The *Soil Survey of the Napa Area, California* produced by USDA/UCB in the 1930s describes the dominant soil in this area, “San Ysidro loam, dark-colored phase,” as “subject to appreciable seepage from higher land” and “often boggy following heavy rains.” The soil’s heavy texture restricts drainage and provides little moisture in the summer, limiting its value for deep-rooted crops. Prior to agriculture, these characteristics created seasonal wetlands and made this soil generally

unsuitable for the valley oak savanna common in the deeper soils of the valley. (Subdrainage is also restricted, although to a lesser degree, in the soils occupying the floodplain of Carneros Creek below Henry Road, a zone about 1,000-2,000 feet wide merging into San Ysidro, Bale clay loam and Sutter loam (Carpenter and Cosby 1938: 31, 40, 51, 54).)

These open grasslands would have supported Western burrowing owls, now a California species of special concern (Duhig 1990). The numerous present-day trees in Carneros Valley, from the eucalyptus planted by Stanly (Duhig 1990) to the yard trees and remaining orchards, are thus a dramatic change from earlier conditions. The grassland cover, seasonal ponding, and absence of roosting sites for raptors made the native grasslands adjacent to Carneros and the Bay's edge ideal habitat for waterfowl:

"There were literally millions of ducks and other waterfowl inhabiting the ten or so miles of marsh, clear to San Pablo Bay, many of them nesting in the grassy upland. My father told of running through the fields when he was a boy, about 1868-1875 in April and May and having to be careful not to step on any of the myriad of baby ducks and geese rising from their feeding grounds in such numbers they would darken the sun." (Duhig 1990: 3)

In the vicinity of Carneros, Altimira observed native grazing animals in this habitat, reporting "two or three hundred head of female elk" and noting that the area also contained an abundance of antelope and deer (Altimira *in* Smilie 1975:8).

Substantial impacts to the grasslands may have already taken place by this time, as well, as non-native grass species rapidly replaced native species in the wake of Mexican ranching, or even prior to Spanish arrival (Mensing and Byrne 1999). As a result, the "wild oats" encountered by Duhig in the 1850s and assumed by many chroniclers to be illustrative of native Napa (e.g. Menefee 1878) were the product of changes in the previous few decades. King (1967: 96) is one of the few local historians to identify this early transformation.

How have populations of salmonids changed during historical times?

Specific documentation of salmonids in Carneros Creek dates to the mid-19th century. Local resident Menefee (1873: 36), describing his experiences over the past several decades, reports that:

"In early spring, during the spawning season, salmon of large size, are often caught on these streams [west side of Napa Valley], many miles from tide water. The writer has caught several that weighed from 7 to 10 ½ pounds, in the Carneros, five miles from its mouth, where the water was not a foot deep. Many are stranded upon the shoals when the water falls, upon the cessation of the rains."

While the author refers to "salmon", their size indicates that they are most likely steelhead (J. Koehler, pers. comm.). Interestingly, Menefee's fishing site is located just below Henry Road crossing in the same mid-watershed reach that provides the best steelhead habitat today (*Fish Habitat Assessment* report). This would suggest that this reach's high quality relative to other reaches is due substantially to natural causes (e.g. geology, base flow) rather than degradation of the rest of the creek. Menefee also describes similar flashy, seasonal water conditions to today, when limited high flows may hinder outmigration.

Altimira's 1823 description of "clear, sweet . . . pleasing" (presumably cool) pools on the lower creek in late June, however, does also suggest good quality habitat in the lower reaches. Accordingly, local residents recall seeing steelhead commonly in pools of the lower watershed in the 1960s (Mukerji pers. comm.; Fournier pers. comm.) despite the fact that rapid surveys by California Department of Fish and Game in 1958 and 1976 did not find any steelhead there (see *Geomorphology Report* for details). More

recently, pool habitat in the lower watershed appears to be diminished (see Flow section above) and residents of the lower watershed have observed a decrease in steelhead populations.

Riparian Habitat

Channel side vegetation, or riparian habitat, is an important aspect of the fluvial system, protecting banks from erosion, potentially providing shaded summer rearing habitat for fish, and substantially determining its aesthetic character. Riparian habitat can be affected by changes in general environmental conditions, such as channel incision, reduction in groundwater level, saltwater intrusion, climate change, as well as direct impacts from logging, clearing, grazing and other land uses. Because of these potential impacts, and because riparian trees grow relatively quickly, the current extent of riparian canopy can be greater or lesser than in previous eras. Understanding these trends may help identify the long-term processes determining the future of riparian trees along the creek.

In Carneros, fieldwork by the *Fish* and *Channel Geomorphology* teams in this study revealed that many of the riparian trees along the lower parts of the Creek are substantially undercut and in jeopardy of falling into the creek in the near future. This observation raises questions about the future viability of riparian trees along the lower reaches. One part of the answer to this question is determining whether the presence of trees at this site constitutes a relatively recent development or continuous long-term occupation.

Observations by the NRWEP in other parts of the Napa River watershed have identified stream reaches that have shown substantial increase in riparian habitat during the 20th century. Some reaches with few or no riparian trees circa 1940 have developed substantial canopies in the decades since that time (see *Sulphur Creek Historical Ecology* report). In some cases, both in the Napa Valley and in other Bay Area watersheds, this change over the past 60 years represents a reestablishment of historically-present habitat which had been removed by earlier land use (e.g. the alluvial plain section of Wildcat Creek 1900-2000, SFEI 2001: 24). At other sites the extension of riparian canopy appears to be an ecological response to a change in hydrological conditions (e.g. the downstream extension of riparian trees in the tidal reach of Wildcat Creek in response to reduced tidal prism 1850-1900, SFEI 2001: 22). Historical data from other parts of the Bay Area indicates that some of the smaller streams, of size similar to Carneros, did not support continuous riparian tree canopies across the lower alluvial plain at the time of European contact.

A related concern in Napa, and other areas assessing goals for stream restoration, is determining the historical width, and subsequent loss, of riparian canopy. In many parts of the United States, broad riparian tree canopies along low-gradient river systems have been reduced to narrow corridors with trees restricted to the area immediately alongside the stream as a result of clearing, channelization, and/or incision. Bay Area streams generally appear historically to have had narrow riparian corridors, however.

Has the linear (alongside the stream) extent of riparian canopy changed during historical times?

There are at least two complementary approaches to assessing historical changes in riparian tree canopy. The development chronology of existing riparian canopy can be analyzed by measuring the age of individual trees by tree coring methods. This approach only works where trees are currently present. Historical archival data can bracket periods of change and identify features no longer present. In this project, historical archival analysis was performed to provide a framework for potential future tree coring efforts, which could be useful to test the interpretations generated.

Several useful historical data sources were found to address this question. Comparison of recent and 1940 aerial photography shows that the current (1999 photography) downstream spatial extent of riparian corridor is similar to that of 1940, with a slight extension downstream into the area previously occupied by the San Francisco and Napa Railroad crossing (Figure 10). The 1940/1993 similarity is striking in comparison to neighboring Huichica Creek, which exhibits major changes during the same

period, with only sparse riparian trees in its lower reaches in 1940 but a nearly continuous corridor by 1993. (This aerial perspective resolves only changes in habitat area; other kinds of changes, such as in species composition or habitat quality which might have taken place will require more eyewitness accounts than we currently have.)

The 1858 United States Coast Survey map (USCS 1858) of the Napa marshlands, which depicts the lower two miles of Carneros Creek, however, shows substantial differences in the lowest reach of the creek. This highly detailed map shows individual trees consistently along the creek downstream to a fence line corresponding to the present-day Las Amigas Road crossing. No trees are shown along the 4,000 foot section below this point to the junction with Napa River.

While the accuracy of historical (and modern) maps is always a concern, this map was produced by an agency renowned for its accuracy, with the work carried out by David Kerr, a surveyor whose work around the estuary during the 1850s has been shown to be particularly detailed and precise (Grossinger 1995; Grossinger and Collins, in prep.). Comparisons of similar patterns of tree symbols on these maps in other locations indicate that the symbols accurately correspond to individual trees. On a largely flat landscape, trees adjacent to the Bay would have been carefully identified as landmarks for coastal navigation. It is unlikely that this distinction between wooded and non-wooded sections of the stream is an error.

A calibration of the map is provided by the final confirmation survey for Rancho Entre Napa, which was carried out in or around 1880. The locations of the two large live oak trees used as survey corners correspond closely to trees shown by the Coast Survey map. The confirmation survey also reports the diameter of these trees as 36 inches and 60 inches, respectively, indicating trees that are probably at least 100 years and potentially several centuries old.

An earlier map, a *diseño* (literally a “sketch” of desired land produced for the Mexican government (Beck and Haase 1978)) commissioned by Jacob Leese as part of his request for the Huichica land grant provides an earlier, and different, picture of this setting (O’Farrell 1844). Most notably, in contrast to the Coast Survey map produced just 16 years later, the *Diseño de Rancho Huichica* shows a continuous line of trees along Carneros Creek from the hills to the tidal marshlands (Figure 9).

There is reason to consider the potential accuracy of the *diseño*, particularly since Carneros Creek forms the eastern boundary of the proposed grant and would be among the most carefully recorded parts of the map. However, the difference in original scale between these two maps is significant. The 1858 USCS map, and other Coast Surveys of this era, were produced at the unusually resolute scale of 1:10,000. The original Huichica *Diseño*, extending from Sonoma Creek to Carneros Creek, is approximately 11 by 14 inches with a scale of about 1: 50,000 (scale shown on map is “quarto mil varas”, corresponding to a 2.56” scale bar [2.56”/11,200 feet~ 1/50,000]). This means that the reach in question, which covers five inches in the USCS view, comprises less than one inch in the *diseño*. Given that the survey was completed in one day in the winter, with difficulty noted navigating the swampy grasslands of the lower plain (Vallejo 1842: 41-44), it is likely that distinctions of this size, while perhaps locally significant, would not have been recorded in this map.

Based upon this evidence, the present riparian vegetation below the Cuttings Wharf Road/ Bay View Avenue crossing appears to have developed since the mid-19th century. Preliminary field investigation to test this hypothesis found that there are a number of large (>2.5’ dbh) trees along the creek in this reach (mostly Bay laurel), but none obviously older than 140 years, given potentially rapid growth in advantageous riparian conditions. (For example, as part of the NWHEP component to map remnant historical valley oak savanna in Napa Valley, an individual valley oak 1m in diameter growing under riparian conditions, was found to be only 57 years old (Rae, pers. comm.; Ruygt, pers. comm.).) Measurement of tree ages by coring methods in this reach and others would help establish the development chronology of the present day riparian habitat.

There are several potential explanations for the observed downstream extension of riparian tree canopy between 1858 and 1940. It is possible that the corridor in this section was clearcut by Fly and other local landowners. However, early chroniclers repeatedly describe local riparian trees as not particularly useful for timber or firewood, as illustrated in an 1857 description of Napa River through Rancho Caymus: "On the banks of the creek and of the slough there is an abundance of timber of an inferior quality for all purposes of fuel" (Thompson 1857: 489/37). In this first decade of American settlement and agriculture, removal of this narrow section to extend grain fields such a small amount is possible, but unlikely.

It is also possible that the dryer, lower reaches of the stream were more susceptible to impacts from the intensive grazing during the prior two decades. A substantial flooding event before 1858 could, potentially in combination with grazing impacts, have wiped out trees from the lower reach, as was observed on Huichica Creek in 1997. (Blake pers. comm.). It may also be possible that early residents clearcut the riparian trees in order to prevent flooding. The winter of 1852-53 is among the 10 wettest winters in Napa since 1850 (McKee and Grossinger unpub. manuscript), resulting in "the first memorable flood of record" in Napa, which was strong enough to, for example, float away "Thomas Cordua's hay press" (Dillon n.d.: 22).

In these cases, the downstream extension would represent a reestablishment of historical conditions. Coring of several trees in this reach and additional historical data would help clarify this question.

Has the width of riparian canopy changed during historical times?

As appears to be the case on most Bay Area streams, riparian trees along Carneros do not appear to have formed a significantly broader zone of riparian trees during historical times. We have found no evidence that broad areas alongside the stream were cleared of riparian forest to make way for grazing or agriculture. Instead, the historical sources for Carneros illustrate a narrow row of trees along the mainstem, with slightly wider clusters of trees in some places, whether shown as individual trees by the Coast Survey or as a general "ribbon" of trees along the stream in the Huichica Diseño (Figure 9)

In fact, many of the tributaries show substantial expansion of riparian tree stands between 1940 and the present day. This general trend was observed throughout the watershed, with both the development of new riparian canopy along tributary reaches with almost no vegetation circa 1940, and the expansion of canopy existing in 1940 (Figure 11). While the degree of expansion was not measured directly, in many cases it clearly represents a dramatic increase over the past 60 years.

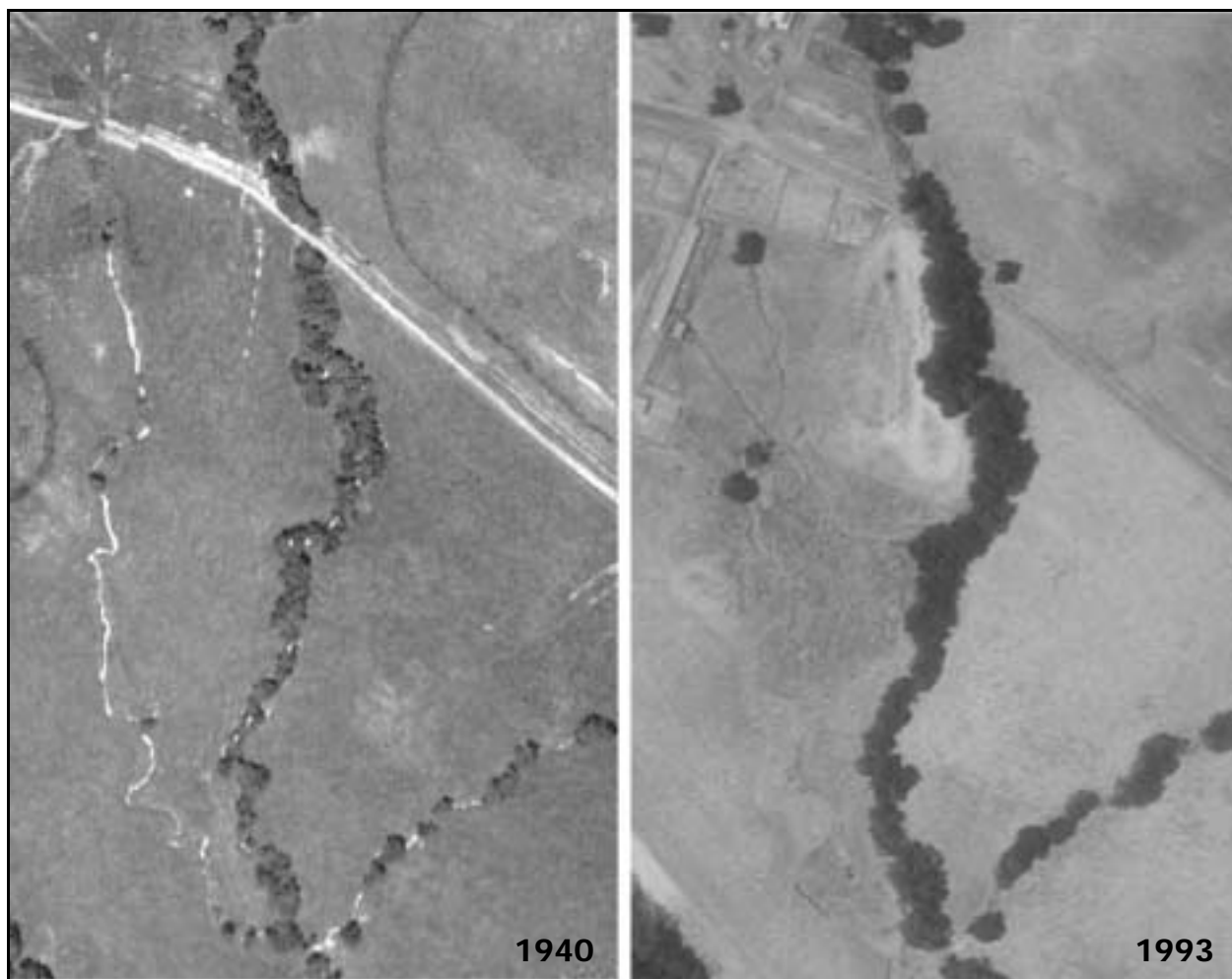


Figure 11. Expansion of riparian canopy along Carneros Creek and tributary near the Henry Road Crossing between 1940 and 1993. Also note change in the left tributary.

Hillside Vegetation

The effects of vegetation changes on the supply of sediment and water to a stream, which are described in earlier sections, are a particular concern in the hilly or mountainous portions of the watershed, which tend to contain most of the watershed area. Historical changes in the upper watershed, which is generally recorded in less detail by early documents than creeks and wetlands, are addressed in this section.

In the earliest available description of the Carneros hills, Altimira ([1823] 1861:61) is impressed by the openness of the woodlands: "Although the grass had been burnt by the Indians of the neighborhood, it could easily be perceived that it was convenient grazing land for cattle, sheep, horses, etc., distributing them suitably; for besides the hills having good pasturage, there are also sufficient springs, showing to be permanent, not omitting the remark that they are free from dense woods, which favor the straying of cattle."

This description of North Bay hillsides, even slopes facing generally east or north, as grass-covered during this era is not unusual. For example, Duhaut-Cilly ([1827] 1999: 134) describes the Marin hills (roughly Tiburon to San Rafael) from the perspective of the Bay as his ship approaches the Sonoma mission, noting limited woody vegetation: "The coast that we were skirting is formed of mountains of moderate height, covered with grass that was rather parched at the time. In the ravines we could see clumps of oaks." (Interestingly, the timing of his mid-summer description (August 4) provides a piece of evidence contrary to assumptions that the grass was always greener during Indian summers. However, it is also possible that the description of dry grasslands already reflects invasion by non-native species, or an unusually dry year.)

Within fifteen years, the land use practice that was most likely responsible for this condition -- native use of fire as a management tool -- had ceased. The replacement of fire with intensive grazing would have tended to continue to maintain open grasslands against the potential expansion of scrubland and woodland, preventing broad invasion of grasslands (McBride 1969). This would have been particularly true when the watershed was grazed by sheep during Mission times, as sheep more aggressively browse on brush and low trees than cattle (Duhig 1990: 38).

Despite regular fires, evidence suggests that some woodlands were present near the time of contact, but that chaparral was more common. Surveys of the upper watershed in the 1860s describe rolling hills with "chamisal brush" and "scattered timber," including "live and black oak, few madronas" (Pierce 1867: 95-96). Woodcutting in these hills was probably significant. For example, 19th century surveyors in upper Carneros noted logging, indicating frustration that "woodchoppers had no respect for bearing trees" (DeWoodie 1890: 93/2). Local residents report government-sponsored programs to poison and remove trees to increase rangeland (Graves pers. comm.; Hudson pers. comm.).

Visual comparison of numerous places in the middle and upper watershed in 1940 and 1993 aerial photography indicates general expansion of woody vegetation into grasslands (Figure 12). Numerous qualitative observations suggest that scrubland/woodland patches increased slightly but consistently in size between 1940 and 1993. Some areas exhibit more dramatic changes in extent, and in some cases this expansion is a probably a revegetation of woodlands cleared earlier. The 1940 image in Figure 12 shows some unnaturally straight woodland edges in the center, which have since expanded outwards.

Additionally, an increase in stand density is apparent within areas of chaparral or woodland existing in 1940 (Figure 12). Areas of scattered brushland have filled in and areas of open woodland or savannah between adjacent woodland patches have in many cases merged to become continuous stands. Within patches of scrubland or woodland the absence of fire has not been counterbalanced by grazing (McBride 1969). These observations indicate that substantial changes in the composition of hillside vegetation communities are currently taking place. This observation, and similar findings in the Sulphur Creek watershed, appear to confirm local resident and ethnobotanical researcher K.K. Burtis, who described "overgrown chaparral covering the Napa Valley hills" resulting from the cessation of indigenous fire management (Calkins 1994: 10).

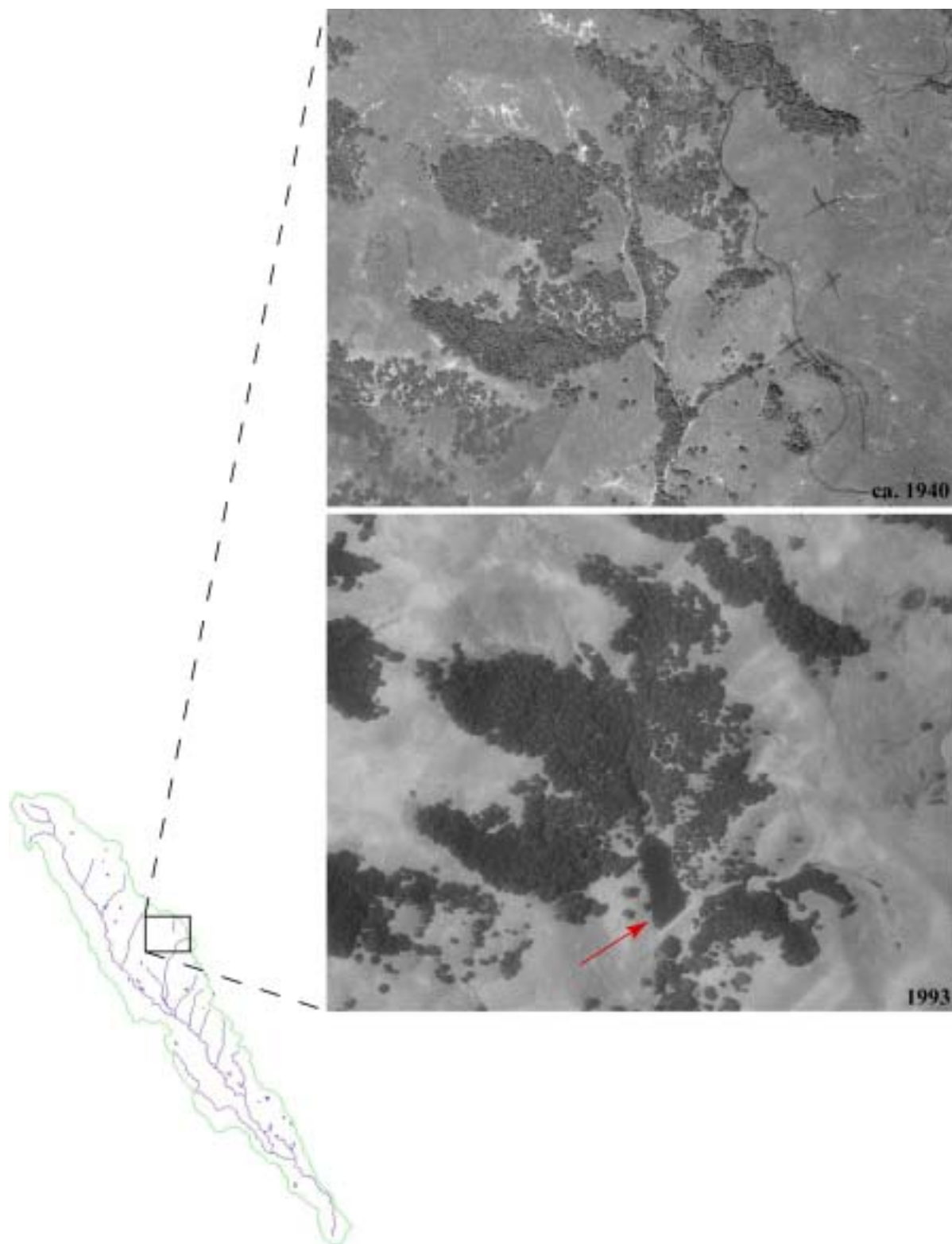


Figure 12. Change in stand density and extent of canopy cover, 1940-1993, is apparent in much of the mid- and upper reaches of Carneros Creek Watershed. Also note the new reservoir present in the lower (1993, red arrow) photo.

MANAGEMENT IMPLICATIONS

This report summarizes the sequence of major land uses within the Carneros Creek watershed over the past two centuries, with the identification of major shifts in land management practice. Land management has changed dramatically a number of times during this period, with one of the major shifts occurring in the past two decades. Current conditions reflect a series of impacts from these distinct activities and eras, which are summarized in Figure 13.

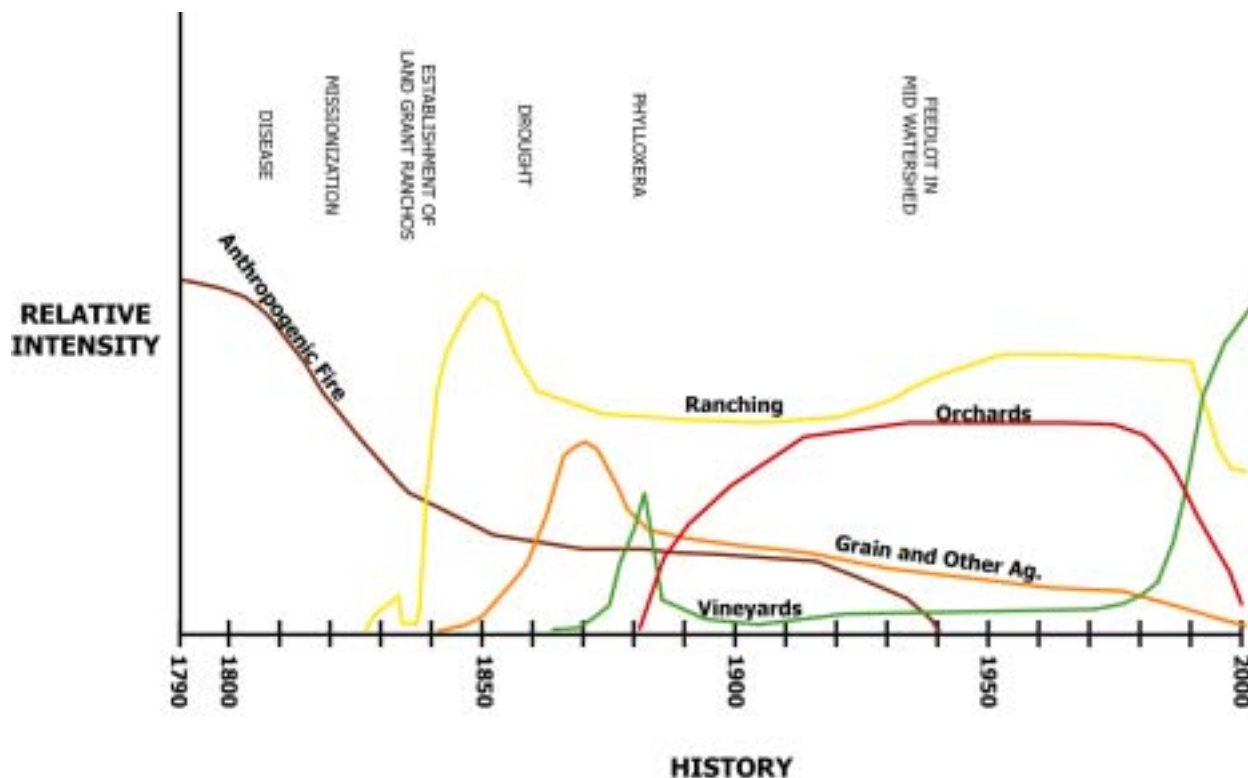


Figure 13. Generalized timeline showing the relative timing and intensity of major land management activities in the Carneros Creek watershed over the past two centuries. Relative intensities are not necessarily comparable across categories.

Implications for the management of the watershed are listed below.

1. Carneros Creek was noted as a good spot for steelhead fishing in the 19th century, but was also probably never an exceptional steelhead stream because it is naturally “flashy” and seasonally dry. However, the massive modifications experienced by most rivers and streams in the region have probably increased Carneros’ value relative to other Bay Area and Napa Valley streams. While most migration routes through the Bay require difficult passage through agricultural or urban areas with associated contaminants and flood control channels, or past the Delta water supply pumps (Leidy pers. comm.), anadromous fish approaching Carneros Creek from the Bay have a direct route from the Napa River marshlands to the creek mouth. Once in the creek, fish encounter relatively few major road or railroad crossings and no major dams. As a result,

Carneros Creek may have particular long-term importance as a viable steelhead stream.

2. Historical evidence indicates that Carneros Creek did not have a substantially broader riparian corridor prior to European land use. Also, unlike many other local streams (e.g. Soda Creek (Pearce et al. 2002), Carneros has not experienced the loss of low-gradient meanders or overflow channels. As a result, the current system is not compromised by the loss of major channel/riparian components. Restoration should focus on watershed processes responsible for the maintenance and improvement of existing channel and riparian canopy.
3. Carneros naturally maintained a well-defined, relatively incised channel across the valley floor into tidal waters. This historical characteristic is in contrast to other small streams for which connecting ditches or flood control channels had to be constructed, often resulting in persistent sediment deposition problems requiring regular dredging (SFEI 2001).
4. While the stream appears to have been relatively incised according to mid-19th century mapping, additional incision may have taken place and could be assessed by field comparison to historical data, dating of exposed tree roots, and other field indicators.
5. There is some early historical and more recent evidence that pool habitat in the lower reaches, which is currently of poor quality, was substantially better in the past. Summer stream flow, while naturally limited and intermittent during historical times, does appear to have decreased in recent decades. Groundwater levels in the lower watershed have been reported to be quite susceptible to diminishment by pumping, which would likely reduce stream base flow and pool persistence.
6. Riparian habitat in the lower watershed has been extremely dynamic. This indicates that the tree canopy can respond rapidly in response to favorable conditions. However, there is also strong indication of potential loss of riparian trees in the near future, which could have significant detrimental effects to creek shading and aesthetic value [see *Channel Geomorphology* and *Fish and Macroinvertebrates* reports.
7. Grazing pressure in the watershed was severe by the mid-19th century, such that impacts to sediment dynamics are likely by the time of the 1862 floods, which could have mobilized large amounts of sediment. While no specific effects could be identified at this time, a high level of grazing activity was documented, which may have present day effects. Intensive ranching on the Alexander property prior to 1993 is also probably still having downstream effects. Assessment of current in-stream sediment problems should attempt to distinguish between sources caused (and potentially solved) by current activities and those triggered by management in previous eras.
8. Substantial parts of the watershed have been subject to over a century of agriculture and associated plowing, vegetation removal, and other practices which could also be responsible for sediment production. Obvious downstream effects were not found in this study, but as in the case of grazing, may nevertheless be present and should be considered as analysis and management of the watershed continues.
9. General extent and stand density of chaparral and woodlands appears to have increased in the upper watershed, likely due to reduced fire frequency. This change in vegetation may pose a threat for larger fires in the future. Besides the obvious cultural impacts, significant fire, particularly in late summer before substantial rains, could cause large delivery of sediment to the stream.
10. Native management activity in all likelihood had a significant influence upon the composition, distribution, abundance, and productivity of most habitats in the watershed for a very long period

of time. Some aspects of native management practices may be useful tools for the future. For example, despite extensive changes remnants of native grassland still exist in the watershed (Graves pers. comm.), constituting a valuable local resource. Restoration and expansion of these native grasslands, potentially with the use of fire, could provide benefits to soil structure, stream flow, and local ecology that could be explored through further research. Trial projects to test management approaches and ecological results could be initiated and would have significance to grasslands management research in the greater region.

REFERENCES

- Adams, F., 1946. The Historical Background of California Agriculture. University of California Press, Berkeley, CA.
- Allen-Diaz, B. and R.D. Jackson, 2000. Grazing effects on spring ecosystem vegetation of California's hardwood rangelands. *Journal of Range Management* 53:215-220.
- Allen-Diaz, B., R.D. Jackson, and J.S. Fehmi, 1998. Detecting channel morphology change in California's hardwood rangeland spring ecosystems. *Journal of Range Management* 51:514-518.
- Altimira, J., [1823] 1861. Journal of a Mission Founding Expedition North of San Francisco in 1823. Pages 58-62, 115-119, *in*: Hutchings' Illustrated California Magazine, July 1860-June 1861. Hutchings and Rosenfeld, San Francisco, California.
- Anderson, M.K., 2002. An Ecological Critique. Pages 37-64, *in*: Steward, O.C. *Forgotten Fires: Native Americans and the Transient Wilderness*. University of Oklahoma Press, Norman, Oklahoma. 364 p.
- Bancroft, H.H., [1886] 1963. The Works of Hubert Howe Bancroft, Volume XVIII: History of California Volume I 1542-1800. Wallace Heberd Publishing, Santa Barbara, California. 744 p.
- Bancroft, H.H., [1890] 1970. The Works of Hubert Howe Bancroft, Volume XXIV: History of California Volume VII 1860-1890. Wallace Heberd Publishing, Santa Barbara, California. 826 p.
- Bartlett, J.R. [1854] 1965. Personal Narrative of Explorations and Incidents in Texas, New Mexico, California, Sonora, and Chihuahua, connected with The United States and Mexican Boundary Commission, during the years 1850, '51, '52, and '53. Vol II. The Rio Grande Press, Inc. Chicago, IL.
- Bartolome, J.W., 1989. Ecological history of the California Mediterranean-type landscape *in* Landscape Ecology: Study of Mediterranean Grazed Ecosystems, W.J. Clawson ed. Proceedings of the Man and the Biosphere Symposium XVI International Grasslands Congress, Nice, France – October 7-8, 1989.
- Bartolome, J.W., 1987. California grassland and oak savannah. *Rangelands* 9: 122-125.
- Beard, Y.S., 1979. The Wappo: A Report. Malki Museum Press, Morongo Indian Reservation, Banning, California. 88 p.
- Beck, W.A., and Haase, Y.D., 1974. Historical Atlas of California. University of Oklahoma Press, Norman, Oklahoma. 202 p.
- Belsky, J.A., 1992. Effects of grazing, competition, disturbance, and fire on species composition and diversity in grassland communities. *Journal of Vegetation Science* 3: 187-200.
- Blackburn, T.C., and M.K. Anderson (eds.), 1993. *Before the Wilderness: Native Californians as Environmental Managers*. Ballena Press, Menlo Park, California.
- Calkins, V., 1993. The Wappo: Facing the Future. Pages 1 and 3, *The Weekly Calistogan*, September 16, 1993.
- Calkins, V., 1994. *The Wappo People*. Pileated Press, Santa Rosa, CA.
- Campbell, Eileen, 2000. *Carneros: Travels Along the Napa--Sonoma Edge*. Carneros Quality Alliance, Vineburg, CA.
- Carpenter, E.J., and Cosby, S.W., 1938. Soil Survey of the Napa Area, California. United States Department of Agriculture, Bureau of Chemistry and Soils. Series 1933, no. 13. 76 p.
- Collins, B.D, D.R. Montgomery, and A.J. Sheikh. 2002. Reconstructing the Historical Riverine Landscape of the Puget Lowland. Chapter 4 in: D.R. Montgomery, S.M. Bolton, D.B. Booth, and L. Wall (eds.) Restoration of Puget Sound Rivers. University of Washington Press, Seattle, WA. Pp. 79-128.
- Collins, L.M. and B. Ketcham, 2001. Fluvial Geomorphology Response of a Northern California Coastal Stream following Wildfire, Point Reyes National Seashore.
- Crawford, L.A. and E.B. Hurd, 1935. Type of Farming Areas North Central Coast Area 1930. California State Planning Board, National Resources Committee and the Giannini Foundation of Agricultural Economics, University of California.
- Cronon, W., 1984. *Changes in the Land: Indians, Colonists and the Ecology of New England*. Hill and Wang, New York, NY. 241 p.
- River, Harbor and Canal Dredging and Land Company, 1887. Map of 19,400 Acres of Land Belonging to River, Harbor and Canal Dredging and Land Company. H.S. Crocker and Company, San Francisco, CA.
- Davis, D.T., n.d. *Indian Trails of Napa County*. 24 p.
- Davis, W.H., 1929. *Seventy-five Years in California*. Published by John Howell, San Francisco, CA.

- Dillon, Richard H., n.d. Building Eden, Chapter 1. Napa Historical Society.
- De la Riva, R. G. 1854. Testimony in the Land Case "Part of Los Carneros Grant, Edward Wilson Claimant, 365 ND " District Court of the United States for the Northern District of California. [Obtained from The Bancroft Library]
- De la Rosa, J. 1853. Testimony in the Land Case "Part of Los Carneros Grant, Edward Wilson Claimant, 365 ND " District Court of the United States for the Northern District of California. [Obtained from The Bancroft Library]
- Department of Water Resources, 1995. Historical Ground Water Levels in the Napa Valley. State of California, The Resources Agency, Sacramento, CA.
- DeWoody, T.J., 1890. Transcript of the Field Notes of A Resurvey of the Part of "Napa Rancho" Confirmed to O.H. Frank. (Township No.6 North, Range No. 5 West (Mount Diablo Meridian). U.S. Dept. of the Interior, Bureau of Land Management, Vol. G1.
- Dillon, R.H. n.d. Building Eden (unpubl. manuscript). Napa Historical Society. Chapter 1.
- Driver, H.E., 1936. Wappo Ethnography. University of California Publications in American Archaeology and Ethnology, v 36, no. 3: 179-220. University of California Press, Berkeley, California.
- Duhaut-Cilly, A., [1827] 1999. A Voyage to California, the Sandwich Islands, and Around the World in the Years 1826-1829. Fruge, A., and Harlow, N. (eds.). University of California Press, Berkeley, California. 245 p.
- Duhig, S.M., 1990. Huichica: Recollections of Stewart M. Duhig. Viola Duhig, Napa County CA. 99 p.
- Dyer, E.H. 1862. Transcript of the Field Notes of the Re-Survey of the Exterior Boundaries of Tp. 4, N. R. 2, W.; Tp. 4, N. R. 4, W.; Tp. 3, N. R. 3, W.; Tp. 3, N. R. 4, W. U.S. Dept. of the Interior, Bureau of Land Management, Vol. R178.
- George, M.R., R.E. Larsen, N.K. McDougald, K.W. Tate, J.D. Gerlach, Jr., and K.O. Fulgham, 2002. Influence of grazing on channel morphology of intermittent streams. *Journal of Range Management* 55: 551-557.
- Grossinger, R. and J. Collins (in preparation). Geomorphic Accuracy of the First Coast Survey of the San Francisco Bay, 1850-60.
- Grossinger, R. 1995. *Historical Evidence of Freshwater Effects on the Plan Form of Tidal Marshlands in the Golden Gate Estuary*. Masters Thesis, University of California at Santa Cruz. 130 pp.
- Grossinger, R. 2001. Documenting Local Landscape Change: The Bay Area Historical Ecology Project. In Egan, D. and E. Howell, eds., *The Historical Ecology Handbook: A Restorationist's Guide to Reference Ecosystems*. Island Press, Washington, D.C.
- Hamilton, H.D. 1976. Carneros Area Agricultural Water Supply Study (Draft). Napa County Flood and Water Conservation District, Napa, CA.
- Heintz, W. F. 1985. Talcoa: A brief history of the ranch, vineyards and winery in the Carneros region of Napa Valley.
- Heizer, R.F., 1953. The Archaeology of the Napa Region. *Anthropological Records*, v. 12, no. 6: 225-314.
- Hervey, D., 1949. Reaction of a California annual-plant community to fire. *Journal of Range Management* 2: 116-121.
- Hild, A.L., M.G. Karl, M.R. Haferkamp, and R.K. Heitschmidt, 2001. Drought and Grazing III: Root dynamics and germinable seed bank. *Journal of Range Management* 54: 292-298.
- Joy, F.E., 1921. Field Notes of the Survey and Resurvey of a Portion of the N., and the S. Bdy . . . of Tp. 4, N. R. 4, W . . . U.S. Dept. of the Interior, Bureau of Land Management, Vol. R468.
- King, Norton L., 1967. Napa County: An Historical Overview. Office of Napa County Superintendent of Schools.
- Kunkel, F. and J.E. Upson, 1960. Geology and Ground Water in Napa and Sonoma Valleys Napa and Sonoma Counties California. Geological Survey Water-Supply Paper 1495. United States Printing Office, Washington, D.C.
- Kunkel, P., 1962. Yokuts and Pomo Political Institutions: A Comparative Analysis. Unpublished PhD dissertation, University of California, Los Angeles.
- Lewis, Henry T. 1973. Patterns of Indian Burning in California: Ecology and Ethnohistory. Ramona: Ballena Press.

- Lightfoot, K.G., 1997. The Archaeology and Ethnohistory of Fort Ross, California (edited with Thomas Wake and Ann Schiff). Volume 2, The Native Alaskan Neighborhood: A Multiethnic Community at Colony Ross. Contributions of the University of California Archaeological Research Facility No. 55.
- Lightfoot, K.G., 1991. The Archaeology and Ethnohistory of Fort Ross, California (edited with Thomas Wake and Ann Schiff). Volume 1. Introduction. Contributions of the University of California Archaeological Research Facility No. 49.
- Mapfumo E., M.A. Naeth, V.S. Baron, A.C. Dick and D. S. Chanasyk, 2002. Grazing impacts on litter and roots: perennial versus annual grasses. *Journal of Range Management* 55:16-22.
- Mathewson, M. S., 1998. The Living Web: Contemporary Expressions of California Indian Basketry. Dissertation. University of California, Berkeley.
- Mayfield, D.W. 1978. Ecology of the Pre-Spanish San Francisco Bay Area [Master's Thesis]. San Francisco State University, San Francisco, CA.
- McBride, J.R. 1969. Plant Succession in the Berkeley Hills [Dissertation]. University of California, Berkeley, CA.
- McKee and Grossinger, unpublished manuscript. Estimation of historical annual rainfall in the townships of Napa, Sonoma, and Saint Helena (1850-2002). 8 p.
- Menefee, C.A., [1873] 1993. Sketchbook of Napa, Sonoma, Lake and Mendocino. James D. Stevenson (publisher), Fairfield, CA.
- Mensing, S. and R. Byrne, 1999. Invasion of Mediterranean Weeds into California Before 1769. *Fremontia* 27:3
- Milliken, R., 1995. A Time of Little Choice: The disintegration of tribal culture in the San Francisco Bay Area 1769-1810. Ballena Press Anthropological Papers No. 43, Menlo Park, California. 364 p.
- Milliken, R., 1978. Ethno-history of the Lower Napa Valley. Section 2.1, *in*: Report of Archaeological Excavations at the River Glen Site (CA-NAP-261), Napa County California. Prepared by Archaeological Consulting and Research Services, Inc. for the United States Army Corps of Engineers, San Francisco District.
- Napa County Recorder, December 14, 1861. Stock Dying from Poverty. Gathered from the Napa County Historical Society.
- O'Dea, M.E. and D.P. Guertin, 2003. Prescribed fire effects on erosion parameters in a perennial grassland. *Journal of Range Management* 56: 27-32.
- O'Farrell, J., 1844. Diseño Rancho de Huichica. Map D-11 in the Land Case "Huichica, Jacob P. Leese, Claimant, 50 ND." [Literal attribution on map: "Jaspar Farral Agremensor y Arquitecto San Rafael"; Obtained from The Bancroft Library]
- Ortega, A. 1836. Testimony in the Land Case "Part of Los Carneros Grant, Edward Wilson Claimant, 365 ND " District Court of the United States for the Northern District of California. [Obtained from The Bancroft Library]
- Pierce, W.A., 1867. Transcript of the Field Notes of A Survey of the Subdivision Lines of Township No.6 North, Range No. 5 West (Mount Diablo Meridian). U.S. Dept. of the Interior, Bureau of Land Management, Vol. R178.
- Pearce, S., M. O'Connor, R. Grossinger, and L. McKee, 2002. Napa River Sediment TMDL Baseline Study: Geomorphic processes and habitat form and function in Soda Creek. San Francisco Estuary Institute.
- SFEI, 2001. Wildcat Creek Watershed: A Scientific Study of Physical Processes and Land Use Effects. Oakland, CA. <http://www.sfei.org/watersheds/wildcatreport/wildcatindex.html>
- Smilie, R.S., 1975. The Sonoma Mission: San Francisco Solano De Sonoma. Valley Publishers, Fresno, California. 149 p.
- Smith & Elliott, 1887. Illustrations of Napa County, California with Historical Sketch. Oakland, CA.
- Soderholm, E.P., n.d. 20,000 Years of Transportation to the Napa Valley. Napa County Historical Society, Napa, California. 18 p.
- Sonoma County Democrat Nov. 22, 1857. [Provided by Arthur Dawson.]
- Stewart, O.C., 2002. Forgotten Fires: Native Americans and the Transient Wilderness. University of Oklahoma Press, Norman, Oklahoma. 364 p.
- Tays, G., 1937. Mariano Guadalupe Vallejo and Sonoma - A Biography and a History. *California Historical Society Quarterly* 16: 99-121, 216-254, 348-372.

- Thompson, A.W., 1857. Field Notes of the Final Survey of the Rancho Caymus, George C. Yount, confirmee. Tp. 6, N. R. 5, W. U.S. Dept. of the Interior, Bureau of Land Management, Vol. 63.
- Thorne, J.H., J.A. Kennedy, J.F. Quinn, M. McCoy, T. Keeler-Wolf, and J. Menke, [in press]. A New Vegetation Map Of Napa County Using The Manual Of California Vegetation Classification And Its Comparison To Other Digital Vegetation Maps. Information Center for the Environment. University of California, Davis. (Submitted to Journal Madroño, 6/9/03)
- Trulio, L.A., 2000. Western Burrowing Owl. Pages 362-365, *in*: P.R. Olofson (ed.). Baylands Ecosystem Species and Community Profiles: Life histories and environmental requirements of key plants, fish and wildlife. Prepared by the San Francisco Bay Area Wetlands Ecosystem Goals Project. San Francisco Bay Regional Water Quality Control Board, Oakland, California.
- United States Coast Survey (USCS), 1858. Napa Creek and Napa City California, Plane Table Sheet XXXII, Register No. T777.
- USGS, 1949. Cuttings Wharf Calif. 15' Quadrangle Topographic Map, 1:24,000. United States Geological Survey, Denver, Colorado.
- USGS, 1916. Mare Island Calif. 15' Quadrangle Topographic Map, 1:62,500. United States Geological Survey.
- Vallejo, M. G. 1852. Testimony in the Land Case "Huichica, Jacob P. Leese, Claimant, 50 ND " District Court of the United States for the Northern District of California. [Obtained from The Bancroft Library]
- Vallejo, S. 1842. Testimony in the Land Case "Part of Los Carneros Grant, Edward Wilson Claimant, 365 ND " District Court of the United States for the Northern District of California. [Obtained from The Bancroft Library]
- Verardo, D., and Verardo, J.D., 1986. Napa Valley: From golden fields to purple harvest. Windsor Publications, Inc., Northridge, California. 160 p.
- Weber, L., 1998. Old Napa Valley: The History to 1900. Wine Ventures Publishing, St. Helena, California. 277 p.
- Weber, L., 2001. Roots of the Present: Napa Valley 1900 to 1950. Wine Ventures Publishing, St. Helena, California. 316 p.
- Whitney, G.G., 1996. From Coastal Wilderness to Fruited Plain: A History of Environmental Change in Temperate North America from 1500 to the Present. Cambridge University Press, Cambridge, UK. 451 p.
- Wilkerson, T.F., Jr., 2001. Jacks Fork River Watershed Inventory and Assessment. Missouri Department of Conservation. West Plains, Missouri
<http://www.conservation.state.mo.us/fish/watershed/jacksfork/landuse/160lutxt.htm>

Personal Communication

Phill Blake (Natural Resources Conservation Service)
 Al and Mavis Fournier
 David Graves
 Lee Hudson
 Jonathan Koehler (Napa County Resource Conservation District)
 Ira and Shirley Lee
 Robert Leidy (U.S. EPA)
 Betty Mukerji
 Jan Null (Golden Gate Weather Services)
 Jim Perry
 Mary Pettis
 Jake Ruygt (Napa Botanical Survey Services)