Napa River Flow Enhancement Study

An assessment of streamflow conservation opportunities in selected reaches of the Napa River watershed

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on behalf of
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In this new century ideals share equal space only if they are lucky with hard global reality; meanwhile, the valley's fate is being fixed in the long weave of ambition and desire, wealth and restraint, vines and the wildness of chosen places.

James Conaway
Napa, The Story of an American Eden

Introduction

The Napa River watershed is home to world-class wineries and the San Francisco Bay's most abundant steelhead trout run. While both grape production and the human population have soared in the past decades, particularly since the 1950s, the valley continues to offer high quality stream habitats founded on cold water and areas of riparian canopy. In the following, we present the results of our recent study assessing the various drainages of the Napa system and describing a plan for conserving streamflow in several ecologically critical, interconnected stream reaches.

Our approach for this project is derived from other similar efforts recently conducted or ongoing in California coastal basins, many of which support extensive agricultural operations. These areas share many characteristics with the Napa River: presence of salmon and steelhead, pressure to divert water during the extended dry season, and collections of landowners, involved agency staff and non-governmental organization members interested in simultaneously maintaining economic and natural prosperity. The shared experience of these streamflow conservation efforts suggests that reliable information regarding a number of key topics is essential to develop appropriate projects that can be readily funded and permitted.

This report first provides **background** information about fisheries and other related topics that provide the framework for the remainder of the discussion, which divides into four basic sections. The section on **area of interest** includes the rationale for selecting our focus reaches and a brief synopsis of land use and land ownership. In the **water use and timing** section, we characterize available data on streamflow and diversion, as well as habitat related information. We next address various elements of **streamflow improvement projects** that will advance the goal of protecting both habitats and water supplies in the selected Napa River watershed areas into the future. Finally, we offer **conclusions and recommendations** intended to create a road map for next steps to carry a long-term effort in the Napa into its next phase.

Fishery and Related Issues Background

Fishery

The Napa River is the second largest watershed tributary to the San Francisco Estuary and offers by far the most extensive steelhead habitat resources (Becker *et al*. 2007). Historical estimates of the annual steelhead run in the Napa River vary from a low of about 600 individuals to highs in the range of 6,000-8000 (Anderson 1969; USFWS 1968). Run sizes are extremely difficult to measure or estimate, and vary considerably inter-annually. Nevertheless, a few hundred steelhead are believed to spawn in the Napa system during an "average" year.

The decline of steelhead abundance in the Napa River system was studied in a limiting factors analysis (LFA), which found that temperature and lack of dry season flow "appear to severely limit juvenile steelhead growth during summer months." The study also identified fish passage barriers and relatively low amounts of large woody debris as decreasing both habitat availability

and habitat quality in tributaries to the Napa River. In the mainstem Napa, "pervasive channel incision and habitat simplification have greatly reduced the quantity of habitat for...early juvenile rearing (riffle margins, side channels and sloughs)..." (Stillwater 2002, p. vii). While various efforts are underway to remove or modify passage barriers, and to directly enhance instream habitat, fewer projects affecting dry season flow have been implemented, leading to the current study.[1]

In previous analyses, we and other investigators identified the portions of the Napa River system with the most extensive aquatic habitat resources. In decreasing order of availability, our study indicated that Dry, Redwood, Carneros, Sulphur, Tulucay, Napa, Ritchie, Milliken and York and Suscol creeks topped the list of most important potential contributors to the Napa River watershed steelhead fishery. Another "anchor" habitat analysis cited Dry Creek as the highest priority habitat in the Napa system, followed by a tier including Carneros, Redwood, Sulphur and Ritchie creeks (Dewberrry 2003). A third tier consisted of Jericho, Mill, Dutch Henry and Milliken creeks.[2]

For this study, we reviewed a conceptual model of the steelhead fishery of the Napa River system with several colleagues familiar with the local geography and habitat resources. This model includes several key features:

- spawning and high-growth rate rearing habitat concentrated in a limited number of Napa River tributaries (cited above)
- opportunities for juvenile fish to move away from drying reaches in late spring and summer to more favorable habitat areas
- habitat refugia in tributary and mainstem reaches allowing for oversummering of age 0+ steelhead (aka, young of the year)

We confirmed that this model is consistent with fish trapping and observation data gathered to date as well as with observed habitat conditions, especially regarding flows.

Related Issues

In the Napa River watershed, as in much of coastal California, the natural hydrologic regime of the streams (even "unimpaired," or without diversions) may pose unforgiving conditions on native aquatic species. The Mediterranean climate typically offers cool, rainy winters with regular high-flow events and warm, dry summers in which base flows in streams gradually diminish. Many creeks reach intermittence during the dry season, sometimes leaving only isolated pools that may be fed by seeps, springs or groundwater contacts (Deitch *et al.* 2009, Deitch and Kondolf 2012).

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[1] The LFA recommends: "[Conduct] studies to assess how...water use activities influence stream habitat quantity and quality..." and "...reduce unnecessary or inefficient water use and thus increase summer baseflow..."

[2] Dewberrry (2003) used two years of juvenile steelhead surveys for the prioritization while Becker *et al.* analyzed all available observations.

Juvenile steelhead trout emerge from redds in winter or spring, and spend between one and three years in streams before migrating to the ocean (Moyle 2002). The successful completion of the steelhead life history thus depends on the existence of cool water habitats in which juveniles can over-summer. In watersheds where human water uses occur upstream of such habitats, it is critically important to manage water resources in such a manner as to protect the environmental values of the downstream reaches.

Water resources of the Napa River watershed are thoroughly utilized. For example, the State Water Resources Control Board ("State Board") has declared the Napa River to be fully appropriated for the entire river upstream of Trancas Street crossing (in Napa) between May 15 and October 31. Also, diversion of water for frost protection is overseen by a State Department of Water Resources Watermaster, who is charged with allotting water resources for grape growers to maintain existing beneficial uses (especially important during periods of low availability). Despite this extensive utilization of water during the dry season, our results below indicate that the supply of rainfall and Napa River system streamflow in winter is generally sufficient to meet ecological needs and human needs over the course of the year. Water can be obtained in winter and stored in reservoirs in a manner that minimizes habitat impacts and can provide a more ecologically compatible means of meeting agricultural and other water needs.

Though many factors make developing new storage reservoirs challenging (including the cost of pond construction, environmental review, and possibly modifying water rights), they sometimes offer the only practicable way to enhance existing flow regimes and achieve goals for summer streamflow for steelhead and other aquatic species. Our experience suggests that creating or expanding water storage requires extensive planning. First, analysis needs to be conducted to determine that there is indeed enough water in project watersheds on an annual scale such that the amount needed for human uses represents an adequately small proportion. Additional analysis characterizes the dynamics of streamflow in subject basins in order to characterize the impacts of modifying diversion methods and timing. Finally, legal, engineering, and environmental analyses lead to designing projects that both satisfy regulators and are compatible with existing land uses and conservation requirements.

Area of Interest

Our experience in coastal California watersheds suggests that developing successful streamflow enhancement projects must account for two key considerations: matching geographic scope and available resources, and identifying areas where local landowners either will benefit operationally from water storage or are particularly interested in restoring stream habitat. We therefore sought to focus our study on an area where a pilot streamflow enhancement program might meaningfully affect habitat by virtue of its location and size, and the potential for collaboration with its landowners. We reviewed several candidate focus areas with others knowledgeable about steelhead habitat and landowner considerations in the Napa River watershed and solicited their professional opinions.

While important habitat resources exist throughout the Napa watershed (including the Carneros, Redwood and Dry Creek basins), we selected Ritchie, Mill, York and Sulphur Creeks (Figure 1) as a set of high-value contributors to the Napa River fishery meriting further evaluation for streamflow enhancement opportunities. Our selection was influenced by anecdotal accounts of collaboration potential, western position along the valley's north-south axis (important due to rainfall quantities and potential downstream extent of flow enhancement benefit), and condition of proximate mainstem habitat. In summary, a program to protect and increase dry season flow in these creeks and in the Napa River reach immediately downstream appears to offer high potential for producing large juvenile outmigrants (*i.e*., smolts) that may return as the steelhead run in subsequent years. Brief summaries of the characteristics of the selected basins and the mainstem Napa River reach are provided below.

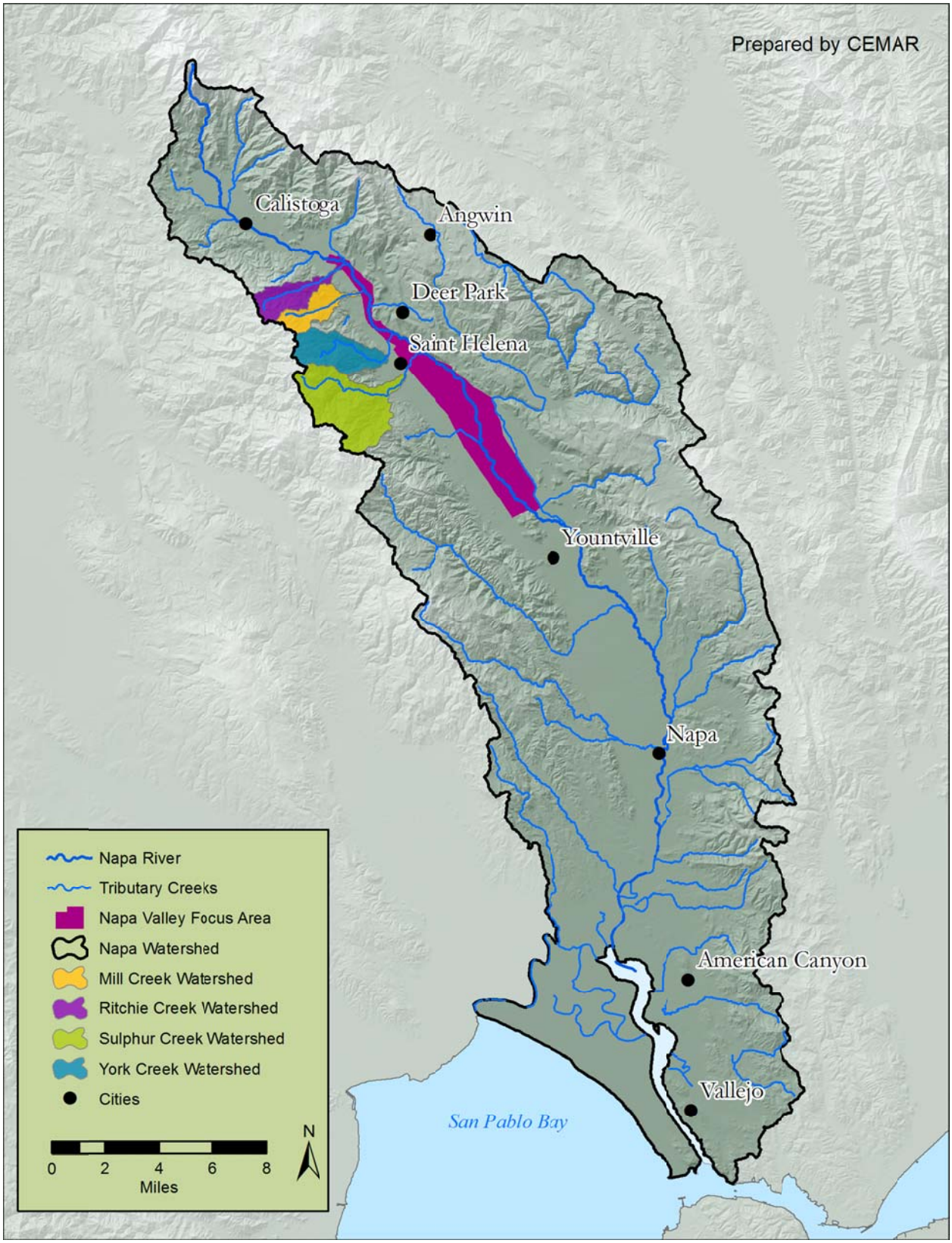

Figure 1. Locations of project watersheds and the focus reach of the Napa River.

Ritchie Creek

Ritchie Creek drains 4.8 square miles and contains some 3.2 miles of blue line stream.[3] The majority land use is park, as the basin is home to Bothe Napa State Park. Some vineyards are located in the upper portion of the Ritchie Creek basin, and the reach between the Highway 29 crossing of the creek and the Napa River is bordered by agricultural uses.

Riparian condition along lower Ritchie Creek appears to have improved since the middle of the last century (Grossinger 2012). Aerial photographs indicate low canopy density along other portions of the creek, however, suggesting a future rehabilitation target. Upper Ritchie Creek, by contrast, was measured to have cover of about 80 percent, satisfying the criterion for "good" condition for salmonid streams (Koehler 2002).

A road crossing of Ritchie Creek in Bothe Napa State Park was analyzed for fish passage in 2006, which concluded, "...the crossing still appears to block a proportion of adult steelhead as well as blocking resident trout and all juvenile salmonids" (Love 2006). Conceptual designs for a free-spanning bridge at the site were developed in 2008 under a grant from the California State Coastal Conservancy (Winzler & Kelly 2008). To date, funding has not been found to implement the project, which would allow access to about two miles of upstream habitat.

Another, less severe, fish passage barrier is presented by the Highway 29 crossing of Ritchie Creek. Plans also have been developed (in cooperation with CalTrans) to modify this feature to improve fish passage conditions, but funds are not yet in place to implement the project (Marcus pers. comm.). A third, partial barrier is created by a dirt road crossing higher in the watershed.

A 2011 habitat survey found that Ritchie Creek provided high quality steelhead habitat, including suitable flows and summer water temperatures. Some areas were recommended for revegetation, and pool enhancement was suggested to increase the shelter ratings for the creek (NRCD and PCI 2012).

Mill Creek

Mill Creek consists of 3.2 stream miles draining 1.75 square miles. Surveys in 2001 and 2002 found high and medium juvenile steelhead densities in several reaches, consistent with previous survey results (FONR 2001, 2002).

In a 2011 habitat survey, Mill Creek was found to have mean canopy density of 87 percent, indicating "good" cover (NRCD and PCI 2012). Water temperatures during July and August also were suitable for steelhead, and the creek offered suitable spawning substrate. Overall, the survey found high quality habitat, though pool frequency and depth was somewhat deficient

[3] USGS Calistoga 7.5 minute quadrangle.

and would benefit from enhancement. Three fish passage barriers were deemed to be partial (rather than total) barriers, worth attention but not highest priority for restoration.

York Creek

The York Creek basin is 6.0 square miles and the creek consists of 7.2 miles of blueline stream. The upper watershed has forest and vineyard uses, while the lower basin has residential areas.

According to the City of St. Helena staff, the city's water supply system formerly included facilities on York Creek, including a lower and an upper reservoir (Robinson pers. comm.). Though water rights records (for water right S017092, held by St. Helena Water Enterprise) indicate that the diversion from York Creek has been removed, a reservoir on a York Creek tributary supplied 63 acre-ft for beneficial use in 2011.

In the 2001 and 2002 juvenile steelhead surveys, several York Creek reaches were found to have high and medium densities (FONR 2001, 2002). A 2003 stream inventory report called the creek "one of the most significant steelhead streams in the Napa Basin" (NRCD 2005). Water temperatures were said to be favorable for most of the year, due in part to very high riparian canopy densities (*i.e.*, high degree of shading) and sustained flow. Some portions of the lower creek had low levels of bank vegetation, as well as unfavorable channel modifications.

Sulphur Creek

The Sulphur Creek watershed is approximately 9.3 square miles feeding channel length (in Sulphur and Heath Canyon creeks) of about 12.7 miles. The lower watershed is dominated by residential and other development and vineyards, while the upper watershed is largely undeveloped. Substantial gravel mining activities occurred in the lower portions of Sulphur Creek since 1910 and earlier (NRCD *et al.* 2004).

The Sulphur Creek basin "contains some of the best year-round coldwater habitat within the Napa River basin" (NRCD *et al.* 2004). Canopy cover in the middle and upper reaches of Sulphur and Heath Canyon creeks is very high. The watershed also offers perennial flow, cool water temperatures, and suitable spawning conditions. Deep pools are important for oversummering in drying portions of the creeks.

Napa River Central Reach

The portion of the Napa River of interest in this study stretches 13.5 miles from the Ritchie Creek confluence downstream to the Yountville Hills, upstream of the Conn Creek confluence (Figure 1). A 2004 stream inventory in the central Napa River found that steelhead in this reach were in low densities and were age 1+ and 2+ (consistent with the conceptual model described above). Summer stream temperatures ranged from 64 °F to 78 °F which was cited as a factor limiting the rearing potential of the reach (NRCD 2005). The report concluded, "Flow persistence and riparian shading, or lack thereof were the two most likely factors contributing

to elevated summertime temperatures" (NRCD 2005, p. 78). Another important finding regarded pools in the reach which "...do not provide sufficient complexity for hiding and holding."

Water Use and Timing

In the Napa River valley, 90 percent of the average annual rainfall (recorded at a rainfall gauge at Oakville, operating from 1950 to 2013) occurs between November and April, while less than 5 percent of the average annual rainfall falls between June and September (Figure 2). Streamflow follows a similar pattern, with less than 5 percent of the average annual discharge typically occurring between June and September. Streamflow gradually recedes during spring, diminishing to very low (or no) flow by late summer. Many tributaries become intermittent during the summer dry season, with hydrologic disconnection between wetted areas (such as residual pools) and between headwater reaches and the mainstem Napa River.

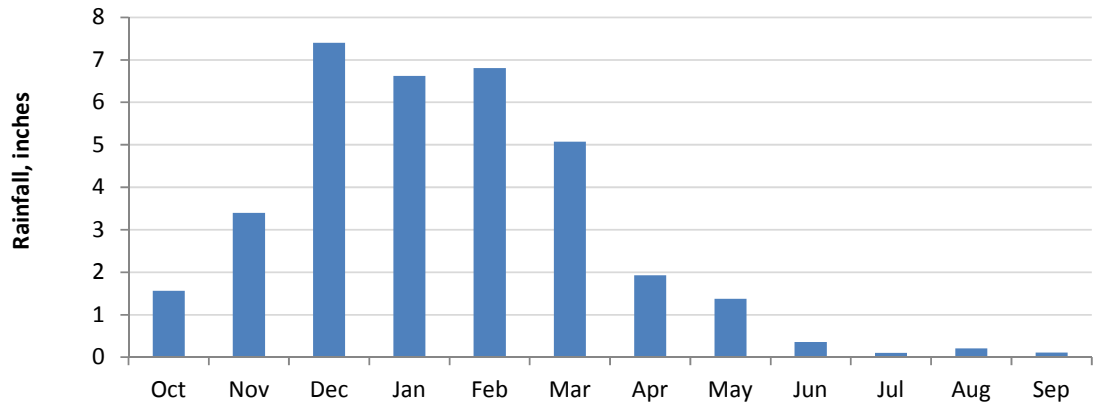

Figure 2. Average monthly rainfall recorded at Oakville, CA.

The region's extended dry season necessitates irrigation for most agricultural production, though crops such as wine grapes require less water per acre than many other crops grown in California (ranging from 0.25 to 0.67 acre-feet per acre (Smith *et al*. 2004)). Agricultural water needs commonly are met through small-scale instream diversions and groundwater extraction, often involving storage in small reservoirs. The underlying geology of much of the Napa Valley is categorized as Franciscan assemblage, which is well-documented as providing poor water yields (*e.g.,* Kleinfelder 2004).

In the Napa River and its tributaries, diversions pose the greatest threat to sustaining a stable summer flow regime. Direct diversions from streams or groundwater pumping from the adjacent shallow aquifer in spring and summer can appreciably reduce streamflow and the amount and quality of instream habitat available for over-summering salmonids.

Water Availability and Water Need

Streamflow enhancement projects are designed based on the concept that re-operating diversions can lead to increased summer base flow while also maintaining environmental flows in winter. Of the many California coastal watersheds CEMAR has evaluated, most have relatively small water need compared to total annual availability (*e.g.*, TU and CEMAR 2012, 2013). Nevertheless, water use regularly conflicts with ecological flow needs because the greatest need occurs when the natural availability of water is lowest. A preliminary hydrologic evaluation can help to determine whether there indeed is sufficient water available on an annual scale to meet human water needs with minimal ecological impacts.

This preliminary hydrologic evaluation compares rainfall, discharge, and human water need on an annual scale. Rainfall and discharge define water availability in a watershed: rainfall provides the overall input of water into a watershed, and discharge describes the portion that reaches streams. Rainfall is typically evaluated as average (or "normal") annual rainfall, which depicts conditions that occur most typically (our interest in long-term project resilience means that we often consider rainfall for "dry" type water years in subsequent evaluations). Rainfall can be captured off rooftops or collected directly in ponds, and it provides recharge of groundwater during winter. Discharge is the cumulative amount of streamflow from the watershed. Watershed discharge at an annual scale is an important component in this framework because it characterizes the amount of water available for stream ecosystem processes and is the source of water for people who divert directly from streams. Discharge also integrates several watershed processes such as evapotranspiration and groundwater recharge that affect the fraction of rainfall that becomes converted to streamflow through the year.

Human water need within the watershed comprises the total volume of water used in agricultural, domestic, and industrial applications during the year. The approach we use to estimate water use is described in further detail below. For regulatory applications, the State Board and Department of Fish and Wildlife (DFW) generally find that cumulative diversions of more than 10 percent of total annual discharge may pose a threat to aquatic habitats. While water need *in summer* regularly exceeds summer discharge, properly timed diversion and storage during the rainy season typically allows stream systems to support cumulative annual demand of less than 10 percent of *total annual* streamflow.

Rainfall

To calculate rainfall in the focus area, we used a spatially distributed data set developed through the Parameter-elevation Regressions on Independent Slopes Model (PRISM), a precipitation model developed by researchers at Oregon State University (considered the state-of-the-art in precipitation modeling in the western United States; available at www.prism.oregonstate.edu/). The rainfall data set was converted into a shapefile and used in

a Geographic Information System (GIS) to depict rainfall patterns over large areas and to perform calculations. Applying these tools, we estimated average annual rainfall in the Napa River watershed upstream of its tidal zone (Figure 3). Based on these data, average rainfall is 35 inches annually.

As is common in north-south trending valleys of the region, rainfall in the Napa river watershed is highest on the western side of the basin, lowest in the valley floor, and between the extremes on the eastern valley side. The results of the PRISM model run show that average annual rainfall on the steep western side of the watershed falls quickly in the west to east direction from 40-50 inches to 30-35 inches in the valley floor. The model shows average rainfall as varying between 30 inches toward the eastern side of the valley floor and 40-45 inches on the eastern slope.

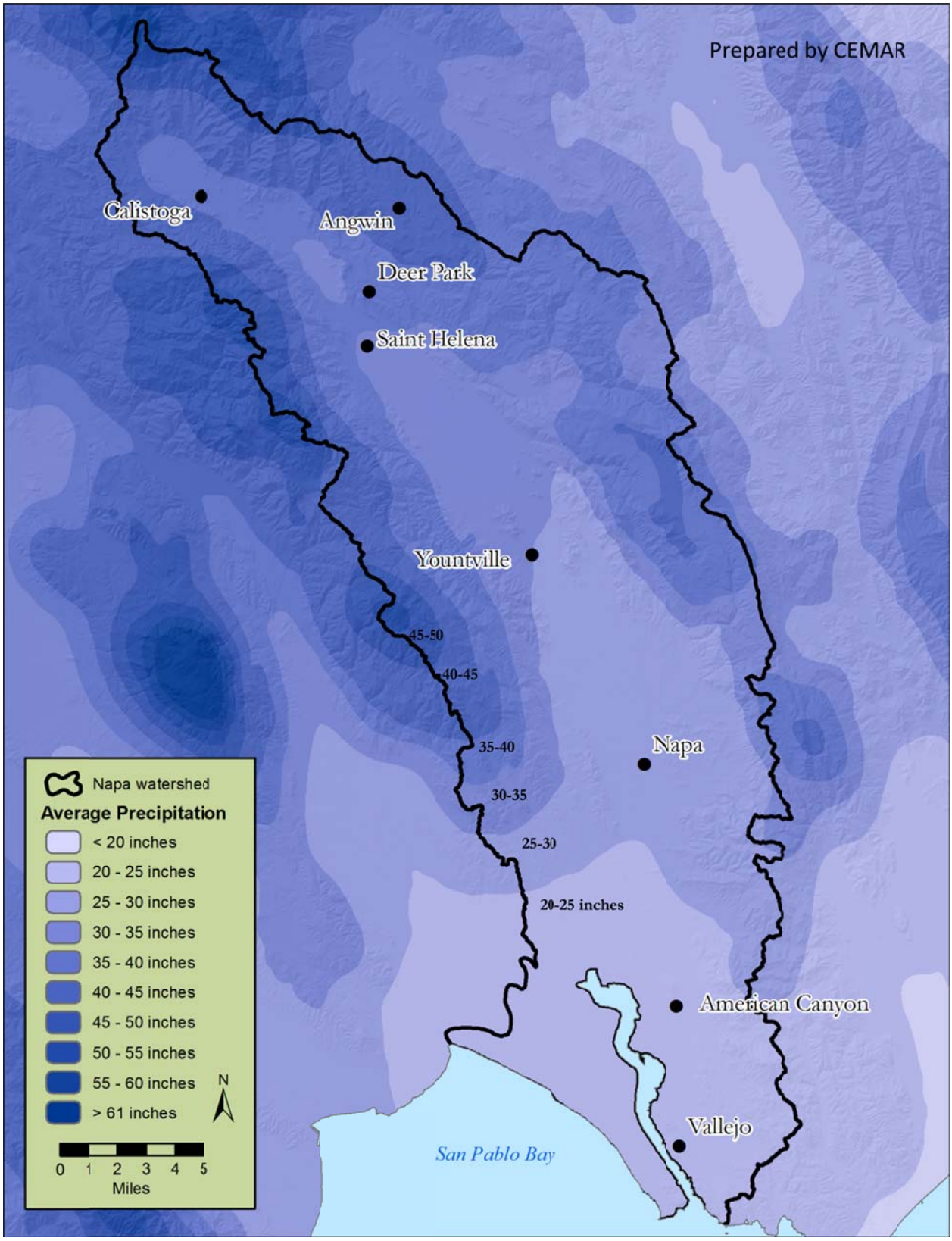

Figure 3. Average annual rainfall over the Napa River watershed.

Long-term rainfall data help characterize inter-annual variability over the range of conditions that occur in the study area.[4] A rainfall gauge in Oakville (between Napa and St. Helena) has operated from 1950 to the present. Gauge data show that the average annual rainfall at Oakville is about 34 inches (median = 32 in.). A frequency distribution of the data (Figure 4) shows that 26 inches or more of rainfall occurs in 75 percent of the years in the period of record (*i.e.*, the lower quartile). The amount of rainfall at Oakville is more than 18 inches in 90 percent of years.

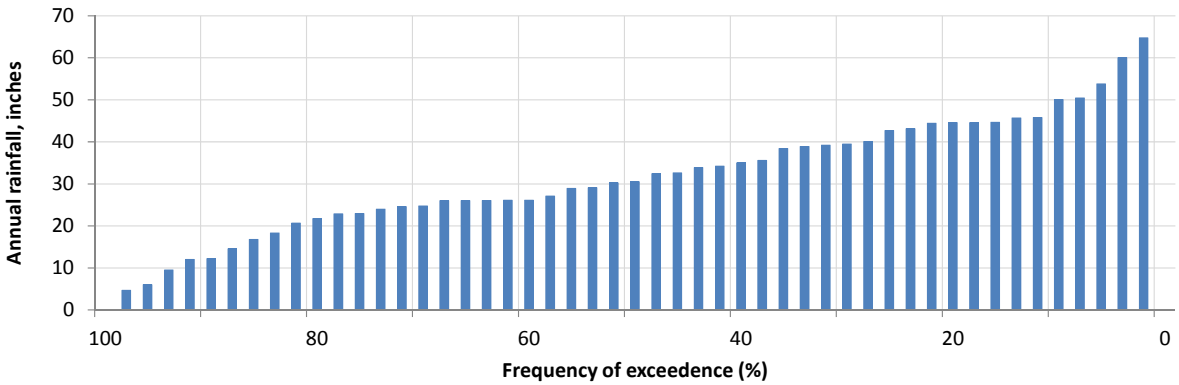

Figure 4. Distribution and frequency of exceedence of annual rainfall, recorded at Oakville, CA.

Streamflow

We modeled discharge for each of our project basins (Ritchie, Mill, York and Sulphur creeks) using a simple drainage basin area-ratio transfer based on historical streamflow records measured at nearby streamflow gauges. In the Napa watershed, Dry Creek is the Napa tributary closest to our project streams that was gauged historically by the US Geological Survey (USGS) (Figure 5)[5]. Data from this gauge was used for all of the discharge estimates described in this report.

[4] The analysis presented will be useful in establishing diversion conditions for various water year types when future streamflow enhancement projects may be developed.
[5] The Dry Creek gauge was located in the mountains above the Napa Valley.

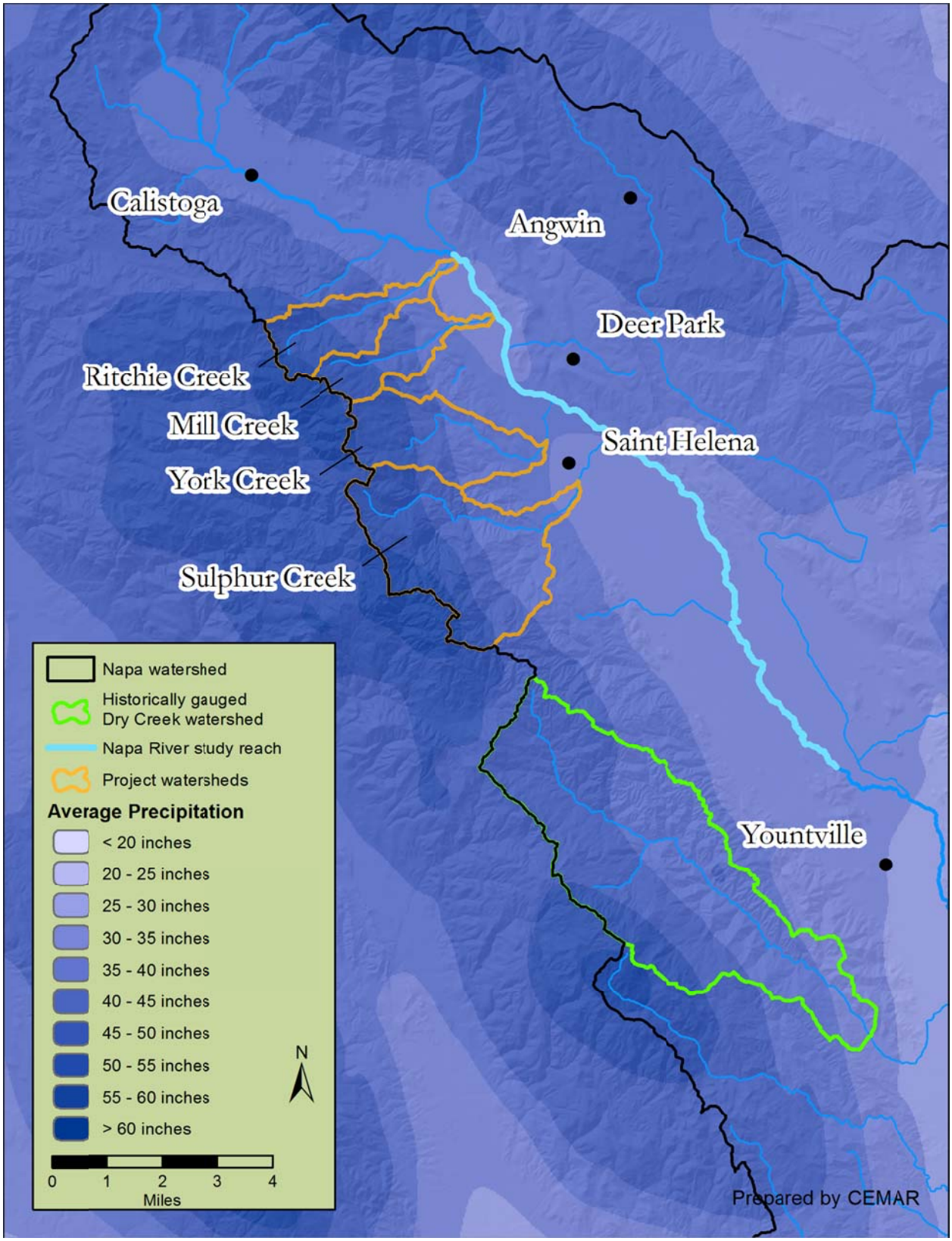

Figure 5. Project streams and watersheds, and nearby streams historically gauged by USGS and their watersheds.

The scaling method entails multiplying discharge recorded at the historical USGS streamflow gauge according to a ratio of catchment area and then by a ratio of average annual rainfall (based on PRISM data) in that watershed to average annual rainfall above the USGS streamflow gauge:

$$Q_{project\ wshd} = Q_{gauged\ wshd} \left(\frac{Area_{project\ wshd}}{Area_{gauged\ wshd}}\right) \left(\frac{Annual\ ppt_{\ project\ wshd}}{Annual\ ppt_{gauged\ wshd}}\right) \quad (1)$$

In Equation 1, the terms $Q_{\text{project wshd}}$, $\text{Area}_{\text{project wshd}}$, and $\text{Annual ppt}_{\text{project wshd}}$ refer to discharge, upstream watershed area, and average annual precipitation of the study basins; the terms $Q_{\text{gauged wshd}}$, $\text{Area}_{\text{gauged wshd}}$, and $\text{Annual ppt}_{\text{gauged wshd}}$ refer to discharge, upstream watershed area, and average annual precipitation upstream of a historically gauged watersheds (*i.e.*, Dry Creek). This equation appears in Appendix B of the State Board's North Coast Instream Flows Policy (SWRCB 2010).

This method for modeling streamflow was chosen because of its clarity and simplicity to calculate using GIS, as well as for its regulatory application: the State Board, which regulates surface water rights, advises water right applicants in this region to scale streamflow using this approach to determine if sufficient flow exists to allow a new water right (SWRCB 2010). Further, an evaluation by the USGS (Mann *et al.* 2004) found that the basin area ratio transfer method generally performed better than rainfall-based methods of estimating streamflow in this region. The resulting streamflow information is summarized in Table 1.

Table 1. Basin and hydrology characteristics, Dry Sulphur, York, Mill and Ritchie creeks, Napa River watershed, Napa County, California.

Stream	Wshd area, acres	Average annual rainfall, inches	Average annual rainfall volume, ac-ft	Average annual discharge volume, ac-ft
Dry	11,100	40.9	37,800	14,200 (measured, 1951-1966)
Sulphur[6]	4,940	42.8	17,600	6.480 (estimated)
York	2,530	40.4	8,500	3,130 (estimated)
Mill	1,420	39.5	4,660	1,720 (estimated)
Ritchie	1,560	43.5	5,670	2,080 (estimated)

[6] For this analysis, we considered the portion of the Sulphur Creek watershed upstream of St. Helena.

Beyond the regulatory applications such as the one described here, streamflow data are useful for many other components of streamflow restoration projects. The USGS has operated 11 streamflow gauges in the Napa watershed over various time periods, but only two of these are still in operation today (both located on the Napa River, near St. Helena and near Napa). In addition, the Napa County Flood Control and Water Conservation District's (NCFCWCD) website has available recent data from several other streamflow gauges operated in the county. As part of the current project, we assembled and reviewed gauge data for the Napa River and for streams on the western side of the Napa Valley (*i.e.*, study streams or streams proximate to study streams) including Browns Valley, Dry, Garnett, Napa, Redwood, Sulfur, and York creeks. More than a ten years of data are available for the majority of these west-side tributary gauges, beginning in water year 2001 (Table 2).

Table 2. Streamflow gauges in selected portions of the Napa River watershed, and related information.

Gauge location	Source	Watershed area, mi^2	Period of record (years operated)	Data quality
Napa River at Calistoga	USGS	21.9	1975 – 1983 (8)	Good
Sulphur Creek near St. Helena	USGS	4.5	1966 – 1967 (1.5)	Good
Napa River near St. Helena	USGS	79	1929 – 2013 (72)	Good
Conn Creek near Oakville	USGS	55.4	1929 – 1975 (35)	Good
Napa River near Napa	USGS	218	1929 – 2013 (58)	Good
Dry Creek near Napa	USGS	17.4	1951 – 1966 (15)	Good
Dry Creek near Yountville	USGS	18.7	1940 – 1941 (1)	Good
Milliken Creek near Napa	USGS	17.3	1970 – 1983 (13)	Good
Redwood Creek near Napa	USGS	9.8	1958 – 1973 (15)	Good
Napa Creek at Napa	USGS	14.9	1970 – 1983 (13)	Good
Tulucay Creek at Napa	USGS	12.6	1971 – 2002 (13)	Good
Napa River at Dunaweal Ln	NCFCWCD	30.5	2009 – 2013 (5)	Fair
Napa River at Lincoln Ave	NCFCWCD	265.2	2000 – 2013 (13)	Poor
Napa River at Lodi Ln	NCFCWCD	64.6	2000 – 2013 (13)	Fair
Napa River at Yountville Cross Rd	NCFCWCD	108.8	2000 – 2013 (13)	Fair/Poor
Browns Valley Creek at McCormick	NCFCWCD	3.5	2007 – 2013 (7)	Poor
Dry Creek at Hwy 29	NCFCWCD	23.5	2000 – 2013 (13)	Fair
Garnett Creek at Greenwood Ave	NCFCWCD	7.4	2000 – 2013 (13)	Poor
Napa Creek at Hwy 29	NCFCWCD	15.3	2000 – 2013 (13)	Poor
Redwood Creek at Forest Dr	NCFCWCD	10	2000 – 2013 (13)	Fair/Poor
Redwood Creek at Mt Veeder Rd	NCFCWCD	8.8	2000 – 2013 (13)	Poor
Sulphur Creek at White Sulphur Spring Rd	NCFCWCD	4.5	2000 – 2013 (13)	Poor
York Creek at Hwy 29	NCFCWCD	3.89	2008 – 2010 (2)	Poor

We found that the quality of stage (*i.e.*, water height) data available through the NCFCWCD varied considerably. For some sites, portions of the record showed characteristics of varying peak and base flow water levels in winter and gradual recession to base flow in summer that are characteristic of the regional flow regime (*e.g.*, Figure 6). These patterns suggested the gauge was operating correctly and we described the data quality as “Fair” in Table 2. However, many of the stage values exhibited large fluctuations on a daily scale that we considered unlikely to represent the streams’ water levels. In these instances, where the gauge did not appear to be operating correctly we described the data quality as “Poor” in Table 2. Ultimately, we decided not to use "fair" or "poor" data to characterize streamflow at these sites, as estimates based on inaccurate stage data would be unreliable.[7]

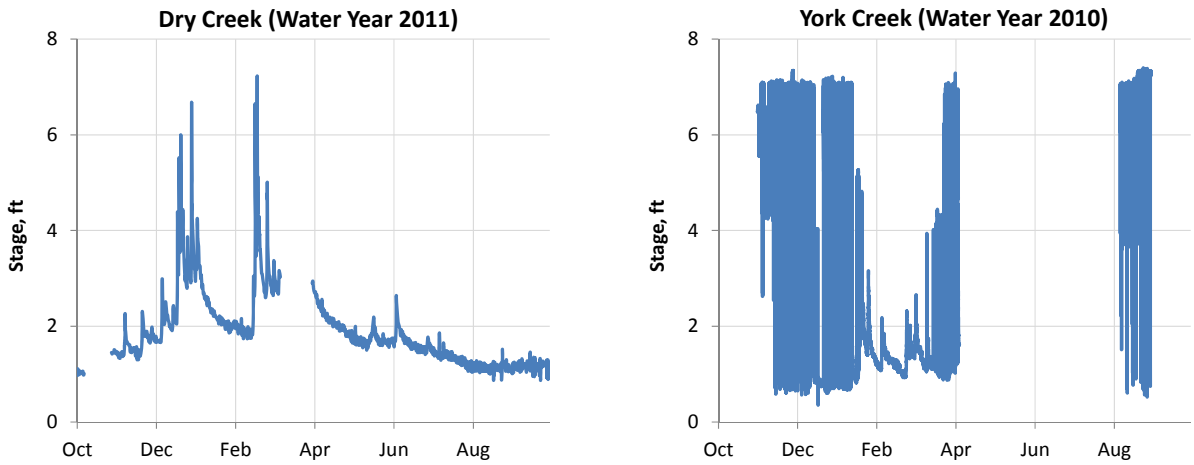

Figure 6. Stage graphs showing fair and poor data from Napa River tributaries.

Human Water Needs

Irrigated agriculture is the most visible form of water use in the Napa watershed, but the many rural residences and wineries in the region also contribute to water need. Domestic needs typically include requirements for landscaping and household use, and wineries use water for barrel and equipment cleaning and for dish washing in tasting rooms. Water needs at locations such as summer camps and parks can include campground showers and park restrooms.

The current study focused on potential streamflow enhancement related to agricultural, industrial and rural residential water use, consistent with our ongoing work in other coastal California watersheds. We compiled related datasets (such as winery locations and agricultural fields) from the Napa County GIS Data Catalog, and hand-digitized additional pertinent information (such as building structure locations) using aerial imagery in ArcMap to construct a model of the human development footprint in each watershed (Figure 7). We reviewed all data

[7] We contacted NCFCWCD staff and shared our observations. The District shared our concerns regarding data reliability and noted that steps are being taken to repair or replace equipment, and to address maintenance, data management, and communications protocols in the future.

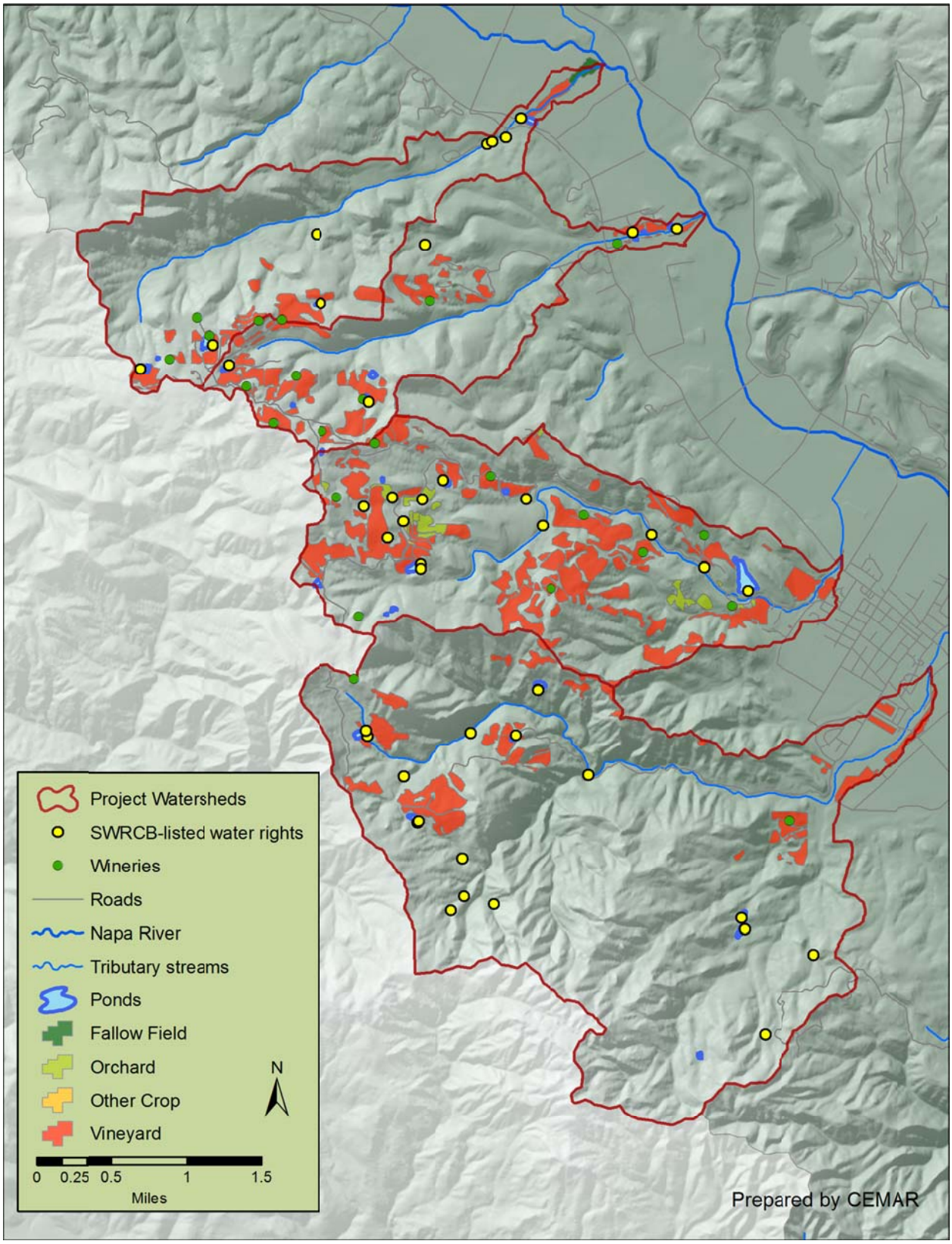

Figure 7. Human footprint in project watersheds, used to estimate water need.

acquired from Napa County for quality where necessary, we used Google Earth aerial images and Street View (within Google Maps) to verify the type and size of agricultural land uses. We estimated the number of households in each watershed by GIS digitizing building structures as points from aerial imagery, and then designating each structure as residence, garage/storage building, industrial building, agricultural facility, water tank, or unknown/other structure.

The information gathered, along with standardized water use estimates, guided our assessment of human water needs in the study area:

- *Agricultural.* We used digitized agricultural coverage to estimate the total acreage of land as vineyards in each project watershed, and then calculated total agricultural water need based on regional per-area estimates of water use. For example, vineyard irrigation in coastal Northern California typically requires approximately 0.6 acre-feet of water annually (Smith *et al.* 2004). Since our approach is based on average use rates, and many vineyards producing premium wines typically use water at lower rates (especially for fully established vines), our estimates should be considered conservative. For olive orchards, we used per area water use rates derived by researchers at the University of California Davis (*i.e.*, 2 ft of water per acre).[8]
- *Industrial (wineries).* We used existing data sets to create an estimate of wine production water use in terms of gallons of water per acre of grapes. Winery water needs were calculated only for those vineyards that appeared to be affiliated (based on proximity) with wineries in project watersheds. Our approach assumes that wine production is limited to grapes grown near the winery, and may underestimate total winery water use. However, our estimates of wine production correspond well with figures provided by the wineries themselves (on their web sites). We relied on various sources to estimate that wineries require approximately 2,750 gallons of water to make wine from an acre of grapes (*i.e.*, 0.008 acre-ft of water per acre of vineyards).[9]
- *Residential.* Based on our work in a subregion of coastal northern California, we estimated rural residential water use at 708 gallons of water per day (TU and CEMAR 2012). This rate was applied to the number of households within each watershed to estimate the annual water need for residents.

Ritchie Creek

We estimated the amount of human water need for the Ritchie Creek watershed (and the other study areas) based on the water use rate factors described above. Ritchie Creek has approximately 113 acres of vineyards, requiring 68 acre-feet of water annually for irrigation (Table 3). Five wineries are located within the watershed, with varying amounts of production. Based on individual winery production estimates, the total annual water used by Ritchie Creek watershed wineries is 0.5 acre-feet. We estimate that six rural residents live in the Ritchie Creek

[8] Based on deficit irrigation estimates described by Goldhamer (1999).

[9] An economic impact report of Napa County's wine and vineyards indicated that a total of 19,961,500 gallons of wine were produced from Napa appellation grapes in 2011, from a total of 43,580 acres of land as vineyards (Stonebridge Research Group 2011). The Napa appellation thus produces, on average, 460 gallons of wine per acre of vineyards. UCD researchers estimate that, on average, 6 gallons of water are used to make 1 gallon of wine (Oberholster 2011).

watershed. The total amount of water needed for these residences is approximately 4.7 acre-feet per year. For the purposes of this study, we did not include Bothe-Napa Valley State Park (also located in the Ritchie Creek watershed) water use in our analysis because park visitation and water use is estimated to be low. The total estimated human water need for the Ritchie Creek watershed is 73.7 acre-feet per year.

Table 3. Water need calculation factors and water needs in project watersheds.

Watershed	Number of residences	Number of wineries	Vineyards (acres)	Orchards (acres)	Other Crops (acres)	Total human water need (acre-feet/yr)
Sulphur Creek	37	2	255	0	0	185.9
York Creek	22	10	571	50.3	1.4	536
Mill Creek	21	7	198	0.3	0.4	139.2
Ritchie Creek	6	5	113.3	0	0	73.7

Mill Creek

The Mill Creek watershed has approximately 198 acres of vineyards, requiring an estimated 119 acre-feet of water annually. Eight wineries are located within the basin as well as a business that produces wine and distilled spirits. Based on individual winery production estimates, the total annual water used by wineries in the Mill Creek drainage is 1.5 acre-feet. The 21 residences within the watershed use an estimated 16 acre-feet of water annually. Based on these figures, the total estimated human water need is 139.2 acre-feet per year.

York Creek

The York Creek watershed contains about 571 acres of vineyards and 50 acres of olive orchards, requiring an estimated 343 acre-feet and 100 acre-feet of water per year, respectively. Ten wineries are located within the watershed, with varying amounts of production. We estimate that the total annual water use by wineries in the York Creek watershed is just over 4.8 acre-feet. The 22 residential households within the watershed require approximately 17.2 acre-feet of water annually. Based on these estimates, the total human water need for the York Creek basin is 536 acre-feet per year.

Sulphur Creek

Approximately 255 acres of vineyards are located in the Sulphur Creek basin, requiring an estimated 153 acre-feet of water annually. The two wineries there produce approximately 101,600 gallons of wine annually, corresponding to a need of 1.4 acre-feet of water for

production. There are 37 residences in Sulphur Creek, requiring approximately 28.9 acre-feet of water annually [10]. The total estimated human water need for the Sulphur Creek watershed is 183.4 acre-feet per year.

Water Balance Results

Comparing the human water needs in each of our study watersheds to the average rainfall and discharge provides an initial assessment for whether human water needs can be met through the water resources available on-site on an annual scale. Our analysis indicates that demand comprises a small fraction of the total discharge available (Figure 8).

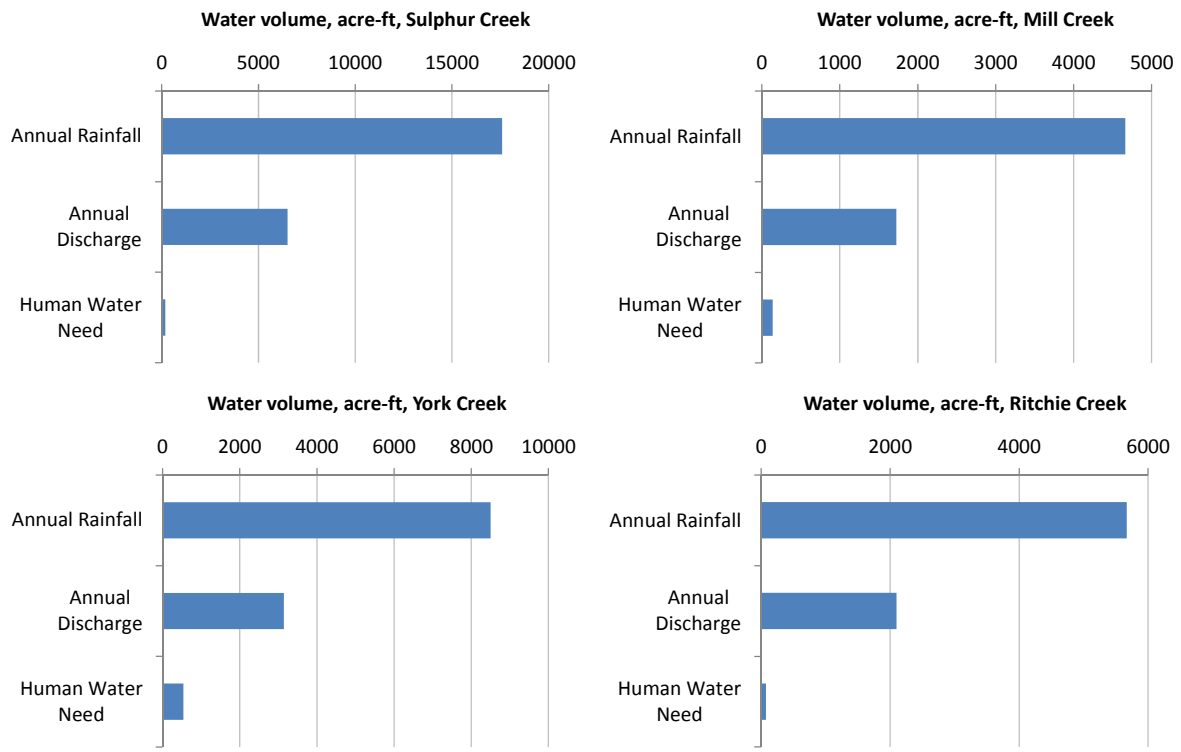

Figure 8. Comparison of rainfall, streamflow, and human water need in project watersheds.

While the Figure 8 graphs paint an optimistic picture about total water availability for human and ecological needs, examining streamflow against demand on a monthly basis highlights potential conflicts. In particular, demand during the dry season, when agricultural and residential needs are greatest, may constitute a large proportion (or even exceed) streamflow quantities.

[10] Residence sizes varied greatly in the Sulphur Creek watershed. There are several large estates with extensive landscaping, as well as several small vacation rental houses. We used the 708 gallons per day estimate for all households and assumed the differences would be accounted for when averaged.

We used data from the historical USGS streamflow gauge on Dry Creek to estimate the average monthly discharge from May through October, historically the driest months of the year experiencing the lowest streamflow levels. Then, for each of our focus basins, we estimated water need during the same period using the following approach: agricultural needs were divided evenly over six months, while industrial and residential needs were divided over twelve months.[11] To depict estimated discharge and water needs in each watershed together on one graph, we divided all calculated volumes by watershed area. The results, presented in Figure 9, indicate that water need in each watershed is at least an order of magnitude greater than likely discharge in all dry season months in all watersheds. Depending on how dry season water needs are met (*i.e.*, through stored water, groundwater extraction or direct diversion), satisfying demand may profoundly affect base flows and potentially the extent and quality of associated aquatic habitats.

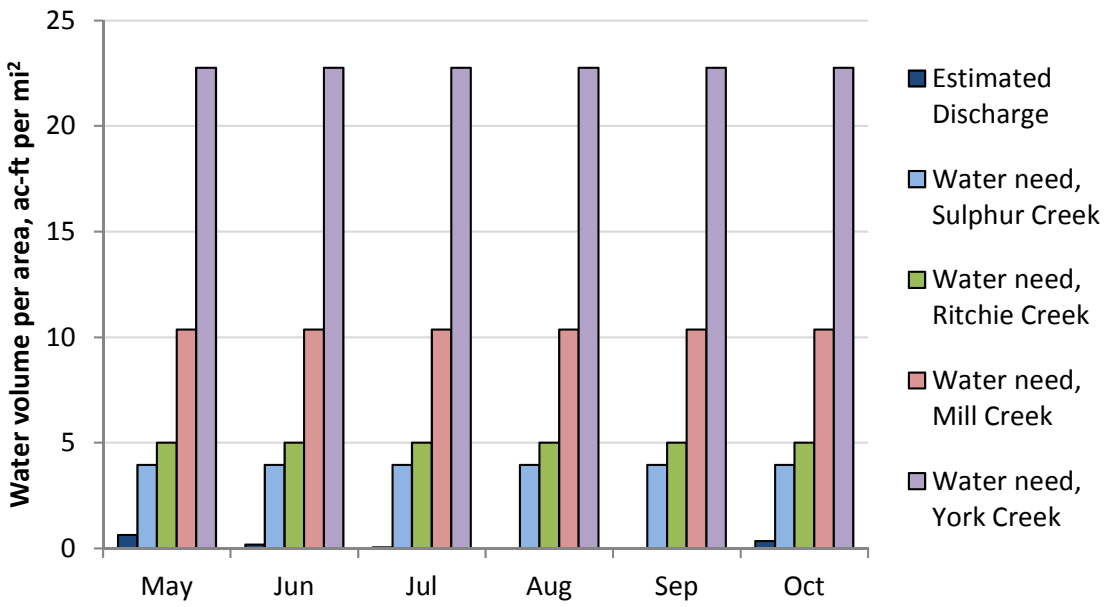

Figure 9. Estimated dry season monthly discharge and water need standardized by watershed area.

Regulatory Water Availability

Any streamflow enhancement program involving storage needs to be evaluated against State Board policies for northern California streams. The board's 2010 instream flow policy outlines three limitations on new appropriative water rights in the region: 1) all new appropriative water rights will be to water obtained during a winter diversion season of December 15 – March 31; 2) appropriative water rights will not be granted in a watershed where the total volume of

[11] While actual use patterns may vary by watershed and year to year, this approach seemed the most reasonable to take that did not involve detailed operational information from water users.

water rights during the winter diversion season exceeds 10 percent of the average annual discharge; and 3) appropriative water rights will not be granted if diversions in a watershed reduce the number of days above environmental flow thresholds (most frequently, the flow required to allow adult salmonid migration and spawning) by 10 percent (based on a long-term streamflow record). These limitations protect salmonids and habitat in different ways: the policy restricts diversions to the period when water tends to be plentiful, places a check on the total amount of water that can be appropriated, and caps the diversions cumulative effects relative to a specific biological criterion.

The first two policy elements are useful tools for understanding the potential for additional surface water appropriation in project watersheds.[12] We used existing data for each project area to see if additional surface water could be appropriated during the winter season. Water rights records were obtained through the State Board's Electronic Water Right Information Management System (eWRIMS) that describe the season of diversion for each water right, the total amount used for beneficial use and, where applicable, the applicable diversion rate.[13] Using these data and following the calculations described in Equation 1, we determined the amount of water appropriated in each of our project watersheds as a fraction of estimated discharge from the watershed (which the SWRCB refers to as "unimpaired" discharge).

The policy states it is unlikely that additional water will be appropriated if the total volume of water rights exceeds five percent of estimated winter discharge. According to this criterion, additional water is available for appropriation during the diversion season (Table 4).

Table 4. Winter diversion season discharge, sum of existing water rights during winter diversion season, and fraction of discharge held in water rights in study watersheds.

Stream	Measured or estimated winter discharge, ac-ft	Total winter water right volume, ac-ft	Proportion of discharge held in water rights
Dry	11,400		
Sulphur	5,200	131	2.5%
York	2,510	107	4.2%
Mill	1,380	6.9	0.5%
Ritchie	1,680	40	2.3%

In our analysis, Mill Creek has the lowest proportion of available water held in water rights (0.5 percent), while York Creek has the highest proportion (4.2 percent). All basins fall below the 5 percent policy standard.

[12] The third limitation is usually not explored until a particular project is defined and a proposed water right has undergone preliminary review by state and federal agencies.

[13] The State Board also has outlined a process for determining the proportion of existing water rights that needs to be considered in determining additional availability of water for appropriation. Water rights granted prior to the new policy's effective date often include diversions outside of the wet season.

Existing water storage

Agricultural use accounts for the largest proportion of human water need in each of the study watersheds, and many vineyards have developed water storage and obtained associated water rights allowing them to store water in winter for use as needed in summer. Figure 7 (above) shows that most (though not all) of the vineyards in the Ritchie, Mill and Sulphur creeks watersheds have a pond nearby and a water right for that pond. Vineyards that have associated ponds tend to be in the upper portions of the basin where they are located, while those that do not have reservoir storage tend to be in downstream portions of the watershed (especially in Mill and Sulphur creeks). The lower Ritchie Creek watershed is the location of Bothe-Napa State Park, which has no storage visible on aerial imagery.

Vineyards in the headwaters of York Creek also have reservoirs nearby that can provide water for irrigation, but unlike the other project watersheds, York Creek has a sizable amount of vineyard lands in the middle portion of the watershed without reservoir storage. Unless these vineyards use substantially less water than normal, they have the potential to be affecting stream habitat through direct surface water diversion or by groundwater pumping from wells proximate to the stream.

Napa River Valley

The Napa River in the study reach (between the Ritchie Creek confluence and Yountville) is generally low gradient and its channel is formed in alluvium. The favorable conditions of easily arable land and available surface and groundwater resources have led to the valley being intensely farmed, mostly in wine grapes. Extensive groundwater pumping near the river has the potential to affect streamflow levels during irrigation season, particularly from wells closest to the river. Wells depress the groundwater table locally (in a "cone of depression") and collectively may substantially reduce dry season discharge. Anecdotal information suggests that the Napa River in this reach has lower flows and higher temperatures in recent decades, and may even dry in some areas in some years. Consequently, a streamflow enhancement program for the Napa River watershed should address the scope of these effects and possible ways to moderate their severity.

We compared the total amount of water needed for irrigation each month through the growing season (May through October) to the average monthly discharge in the Napa River measured near St. Helena (centrally located in the project reach), considering only those vineyards closest to the Napa River (Figure 10). We first calculated the total acreage of vineyards and orchards in the area (5,995 acres and 137 acres, respectively), then estimated the water need applying per-acre use factors (as previously described). These estimates were refined by subtracting estimated storage in ponds near the mainstem Napa River (assuming that stored water was used to meet dry season need). We identified reservoirs in this area and digitized them in our project GIS, after which we determined volume using a previously established surface area-volume ratio for small reservoirs in northern coastal California (Deitch *et al.* 2013).

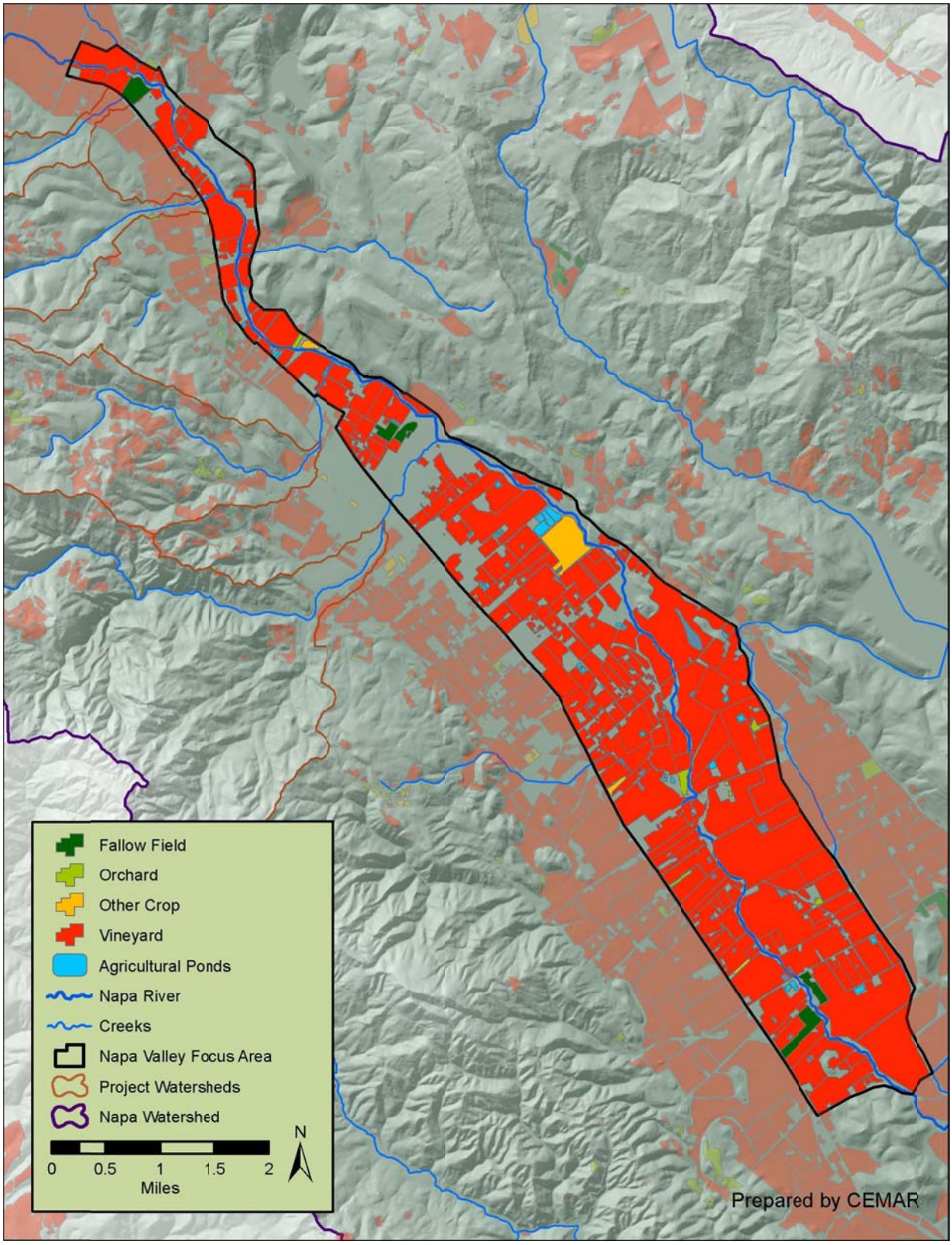

Figure 10. Agricultural coverage along the mainstem Napa River between the Ritchie Creek confluence and Yountville.

The analysis indicates that approximately 1,540 acre-feet of reservoir storage can be applied to meet total agricultural water need of about 3,600 acre-feet. The storage deficit of 2,520 acre-feet should be considered against average discharge in the Napa River during the dry season (May to October). We evenly distributed the demand for water during this six-month period and plotted it against average monthly cumulative streamflow (Figure 11).[14] The average Napa River cumulative discharge during this period is only 85 acre-ft, and the pattern of receding baseflow level over the course of the dry season leads to extremely large disparity between water need and discharge. Cumulative discharge in August and September average less than 5 acre-feet.

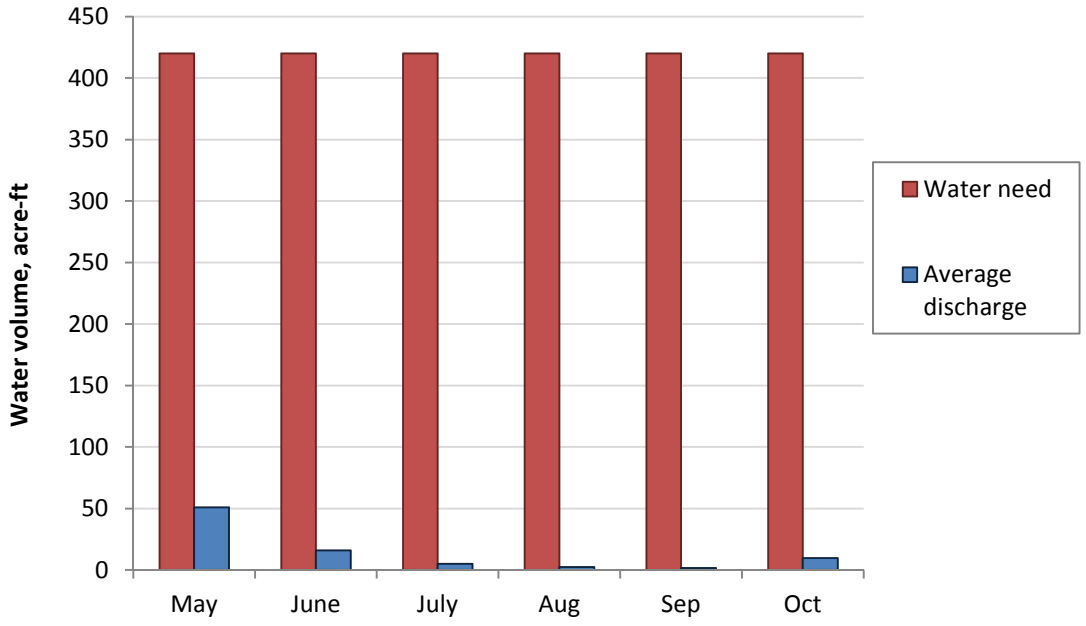

Figure 11. Average monthly water need and average monthly discharge in the vicinity of the Napa River near St. Helena, May through October.

Streamflow Improvement Projects

The concept of diverting water during winter, storing it and applying it during the dry season in order to reduce ecological impacts is appealing but deceptively simple. Our experience with California coastal watersheds shows that, while feasible, streamflow enhancement projects of this kind require substantial investments of time, expertise, funds and collaborative good will.

[14] Based on data collected at the USGS Napa River near St. Helena gauge, number 11453000, operated from 1939 to 2013.

In the following, we outline the steps that typically lead to successful implementation of individual storage projects as part of a larger program addressing streamflow in a watershed or in key sub-basins (like the current study's focus area). This information is provided as the basis for advancing such a program in the Napa River watershed.

Our approach to developing streamflow enhancement projects has several key components: gathering background information on the watershed, including information on biological resources and water use estimates; developing a water balance model to assess the impacts of various water diversion management options; and engaging water users to develop the legal and institutional framework for better water management. The current study provided the opportunity to progress on the first two topics and to establish a recommended path forward on the landowner engagement task (as described further below). Additional efforts needed in the future would entail:

1. Complete/refine watershed characterization

This task would add detail to our existing understanding of water supply and instream flows in the study area. Information concerning salmonid resources, fish passage barriers, streamflow diversion activities, diversion permit conditions, water right protests, and similar issues would continue to be compiled and reviewed in order to close data gaps. For example, the current study's analysis would be expanded using detailed hydrology data from new streamflow monitoring efforts. (See below.) Further, discussions with water users would yield greater precision in the water needs evaluation, as water rights records tend to overstate demand but dramatically undercount the number of diversions, since wells, “riparian rights,” and illegal diversions are not recorded. A completed watershed characterization would describe water supply infrastructure and related concerns such as groundwater/surface water relationships.

Vetted and accepted watershed characterizations are essential to develop successful projects as they provide the assumptions for the analysis proposed in subsequent tasks. Therefore, our approach involves working with partner organizations, local landowners and key stakeholders to contribute information, review the characterizations, and comment on their accuracy. The Napa County Resource Conservation District (Napa RCD) likely would direct the outreach component of a streamflow enhancement program.[15] Other important groups would include the Napa County Flood District , resource agencies including the CDFW and the National Marine Fisheries Service, the State Board's Division of Water Rights, conservation and farming collaboratives (*e.g.*, Fish Friendly Farming, Napa Sustainable Winegrowing Group), individual water users, and watershed restoration advocates.

[15] As part of this study, we consulted the Napa County RCD about involvement in a possible future streamflow enhancement program. This report is being delivered to the RCD for its consideration. Conversations between CEMAR and the RCD should not be considered to reflect their endorsement of new water conservation program in the Napa River watershed.

2. Develop Cooperative Framework with Landowners

The Napa County RCD has longstanding ties with many water users along the streams in the study area. By building on these long-term contacts, an outreach program could be developed around the concept of enhancing streamflow. In our experience, the level of participation in such a program is best determined by the landowners and can vary from willingness to hear presentations, to hosting a streamflow monitoring site, to developing a specific conservation project. Initially, this task involves producing outreach and educational materials to promote local involvement in the program and raise public awareness. The outreach component of a streamflow improvement program usually continues in parallel with the other tasks.

Meaningful streamflow enhancement is achieved when a sufficient number of landowners participate in a larger program with established goals and implementing procedures. This task ultimately develops the framework for the program, including legal and institutional aspects of water rights and water management activities. The framework is built cooperatively by the landowners, the resource agencies, and other stakeholder groups. Landowners who voluntarily agree to participate usually take an active role in designing the water use management plan, in monitoring, and in prioritizing projects for implementation. Our past and ongoing efforts suggest that inclusive stakeholder processes best develop study designs, evaluation criteria, water balance model assumptions, flow recommendations and other aspects of the framework, and lead to the shortest path to implementation.

3. Monitor Streamflow

Based on our experience, recent streamflow data and existing streamflow monitoring programs in the Napa watershed are not sufficient to complete planning for conservation projects in the study area. As part of the current study, we created a proposed gauge network for study area streams, shown in Figure 12. A streamflow improvement program for the Napa River would review this proposal and then create and implement a monitoring plan. Such plans would detail gauge locations, equipment types, costs, responsibilities, data management protocols and other details needed to assure that high quality data are used in the project.

Streamflow data illustrate how water management practices may affect streamflow locally and cumulatively in watersheds. The data can be used to quantify direct threats to natural processes that fish depend upon (*e.g*. sufficient flows for oxygenating redds, maintaining drift to provide a steady food supply, and connectivity for smolt migration and finding suitable habitat through the dry season). Streamflow data at impaired reaches also may show magnitudes of sudden flow changes associated with particular water needs. In this context, conservation outcomes can include reducing the number of irregular flow recessions, as well as prolonging the duration of flow persistence in each stream based on comparisons of impaired and unimpaired stream reaches (where appropriate based on physical, geological, and riparian characteristics). Flow data also define the opportunities for winter storage as an alternative to dry season diversions.

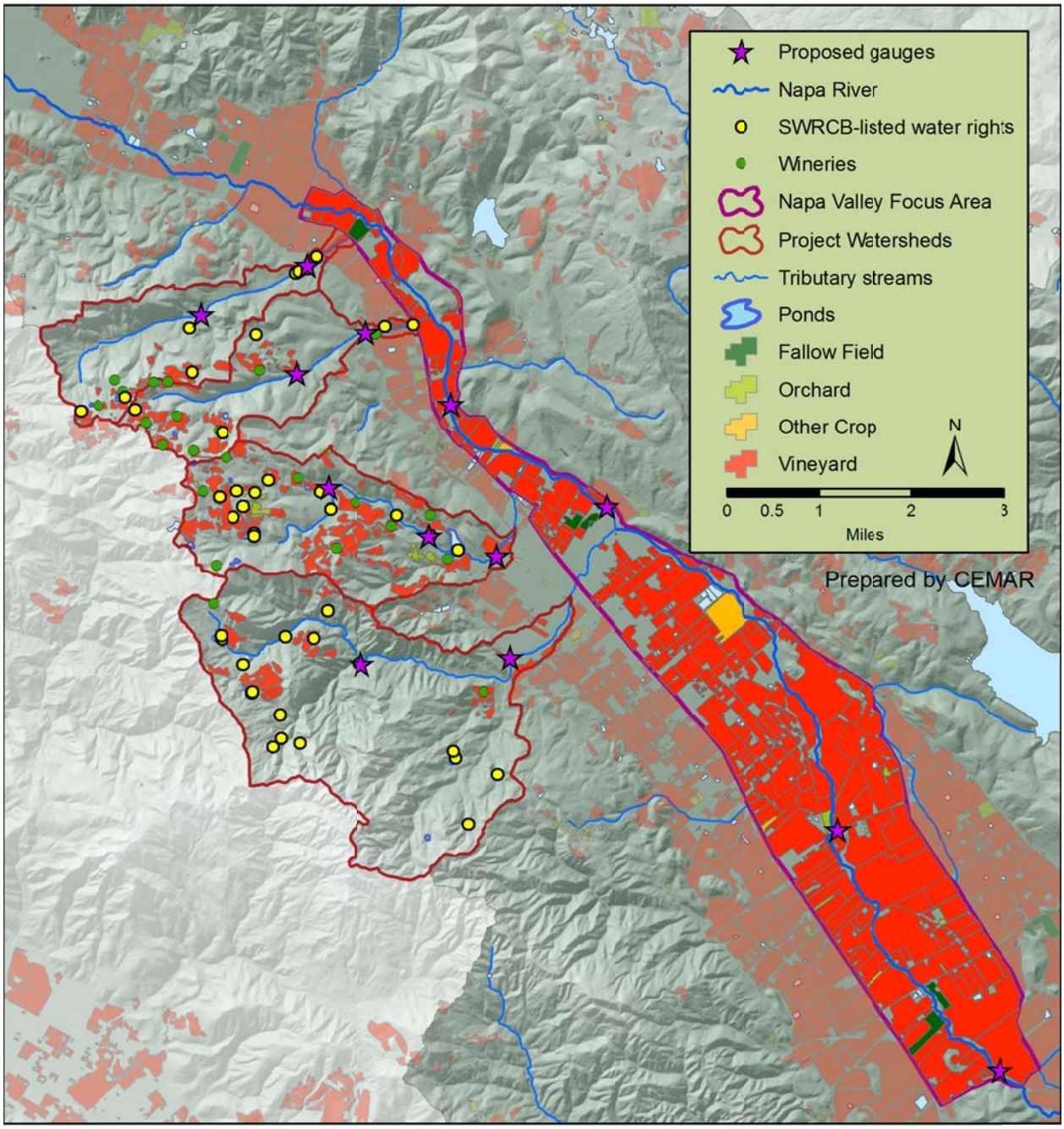

Figure 12. Location of proposed gauge network in flow restoration project areas.

4. Create Water Supply and Need Estimates

This task includes creating unimpaired and impaired flow analyses as part of a water balance model. While the current study developed screening level information and gathered much of the spatial information required for this step, implementing specific conservation projects would require a greater level of detail and precision in the understanding of water supply and water use. As landowner outreach is conducted, the project would refine water budgets in a spatially explicit GIS. We have developed such a tool that sums the total water need for any

watershed, moving from headwaters to the mouth. The framework illustrates how human water needs change moving downstream through the drainage network, and can identify locations where water needs pose the greatest threat to the various life history stages of salmonids.

The water balance model can be used to establish how much winter water storage is needed to alleviate water users' impacts on spring and summer flows. Determining such quantitative estimates is a necessary step toward water right permitting. The balance also allows us to focus on the most important water users in the analyzed basin and to predict the habitat benefits accrued by re-operating various diversions on a seasonal basis.

5. Produce Water Conservation Project Feasibility Report

Using the information from the other tasks described above, we can develop water conservation projects that are scientifically merited and feasible. Typically, we create a list of potential project locations and their associated project types. Depending on funding availability, technical complexity and other factors, promising projects are advanced by the stakeholders toward the conceptual design phase (often 30 percent design, useful for environmental review and permitting).

For the Napa River and the selected tributaries, we would expect priority actions to include a combination of farm ponds and water storage tanks for both potable and non-potable use. Often, a portion of demand can be met with rooftop rainwater, which is relatively easy to permit, while other water demand requires more complex changes in water rights. Where new appropriative water rights and instream flow dedications are required, project partners have the scientific foundation for pursuing them from the previously conducted work.

6. Conduct Site Specific Study

Some streamflow improvement projects involve developing additional information for water right applications or streambed alteration agreements. In such cases, site specific studies are used to establish the relationship between flow and habitat, and to produce specific criteria that assure biological goals will be met and impacts avoided. Instream flow assessments have been an area of contention historically, with substantial disagreement on appropriate methods and interpretation of results. Our efforts over the last several years in California coastal watersheds have helped advance this discussion, and have led to successfully permitted projects.

Useful site specific studies provide the ecological template for developing management plans for streams. They consider the magnitude, duration, frequency, timing, and rate of change necessary for a given habitat function at locations where winter diversions may occur, as well as spring, summer, and fall habitat needs as the dry season approaches and flows reach zero. The studies also show the reaches most conducive to summer flow restoration and the circumstances in which winter diversions are feasible given the regulatory landscape. In the

study area, a site specific flow study likely would be developed as a collaboration between the Napa RCD, resource agencies and other project stakeholders.

Conclusions and Recommendations

This study has several conclusions that help determine the direction of future efforts to enhance streamflow in a key reach of the Napa River and in several important tributaries. First, we identified the potential for existing and potential future water uses to affect important habitat areas. In the Ritchie and Sulphur creeks watersheds, the agricultural and residential footprints are small and the majority of vineyards have reservoirs sufficiently close to assume that the majority of irrigation water needs are being met. However, in Mill and York creeks, many vineyards do not have proximate reservoirs. Dry season irrigation at these locations via near-stream groundwater extraction or direct diversion of surface water could cause habitat effects. We also found a substantial storage deficit among water users close to the mainstem Napa River, implying that dry season water demands likely diminish the river's ecological capacities.

Our analysis also found that water is available in the focus areas to satisfy both human and biological needs. We estimated streamflow and water use volumes on a monthly basis, revealing *seasonal conflicts* rather than problems of *annual overallocation*. This conclusion suggests that efforts to enhance both storage and dry season streamflow are feasible and worth pursuing.

The study used available information on streamflow, water rights and water use for the study reach of the Napa River and the selected tributaries, but we noted that developing a *detailed water budget* would raise the level of discussions about these issues. As a first step, we recommend expanding the collection of streamflow data in a manner that produces highly reliable results.

Collecting streamflow data from project watersheds has proven to be one of the most useful and insight-producing components of our streamflow restoration projects. Continuous streamflow records, with frequent sampling intervals (*e.g.*, 15 minutes), show the heartbeat of the watershed: they allow us to characterize peak flows, base flows and all conditions in between. Streamflow data can show the magnitude, timing and frequency of changes that occur as a result of human activities, such as direct instream diversion or installation of flashboards to form onstream dams. These data also help us to demonstrate the benefits of new water storage projects on streamflow, which is important in attracting funding for project design and implementation.

In the Napa River region, several organizations are already monitoring streamflow, as described earlier in this report. We believe that additional collaboration between these entities and our organization could lead to highly useful data sets that could be shared, compared and made

available to all interested parties. In particular, our experience with equipment design, installation and maintenance as well our expertise with data collection, management, analysis and reporting could be applied well in the study area.

Another important study finding relates to the social climate around water in the Napa Valley: water is a sensitive subject! Like other communities that rely on irrigation water for high-value agricultural production, the Napa region reasonably should be expected to view streamflow enhancement efforts with a certain degree of suspicion. Therefore, landowner outreach for purposes of access, interviews and collaborations should be done carefully and patiently. Our experience suggests working with established groups such as the Napa RCD and with landowners known to be interested in the related issues of water supply reliability and sustainable resource management. We discussed possible partnerships with several governmental and non-governmental organizations (NGOs), and concluded that likely streamflow improvement project partners exist, but only if approached properly.

Once relationships are built around studying streamflow enhancement potential further, such a program would examine irrigation needs on selected vineyards. Particularly for vineyards without identified storage facilities, it would be beneficial to discuss the extent of dry season water use and how demand is being met. Though uncommon regionally, some vineyard practices require minimal irrigation in most years (with exceptions expected in especially hot, dry years). We also have observed instances where groundwater production occurs with little or no effects on streamflow (and associated habitat). Because water storage projects often have mutual benefit of increased water security, landowners often have preliminary ideas (at least) for ways to improve efficiency and increase water storage. An important next step in an overall streamflow enhancement program is improving understanding of the sources and uses of local water resources by engaging with landowners.

Overall, the Napa River area offers an outstanding opportunity to protect and enhance steelhead habitat through a streamflow enhancement program. The several tasks described earlier in this report that lead to implementing projects successfully could be carried out by a group of stakeholders including landowners, local agencies, NGOs, program technical support and funding partners. We highly encourage developing such a program for its steelhead restoration and water supply reliability benefits, and for its potential as a groundbreaking example among Bay Area watersheds.

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