Water Availability Analysis

Paul Nikolau
432 Dutch Henry Canyon Road
Calistoga, CA 94515

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Paul Nikolau

Prepared by:

O'Connor Environmental, Inc.
P.O. Box 794, 447 Hudson Street
Healdsburg, CA 95448
www.oe-i.com

NAPA PBES REVIEW DRAFT

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Michael Sherwood PG #8839
Geologist/Hydrologist

William Creed, BS
Hydrologist

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Contents

Introduction

The applicant is seeking permits to plant approximately 2.5 acres of vineyard at 432 Dutch Henry Canyon Road (APN 018-050-072). This parcel is located approximately three miles northeast of Calistoga in the Dutch Henry Canyon watershed within the County of Napa's Hillside Groundwater Zone (Figure 1). It currently contains a single primary residence supplied by a private well. Water for the proposed vineyard will be supplied by the existing well.

This Water Availability Analysis (WAA) was developed based on the guidance provided in the Napa County Department of Planning, Building, & Environmental Services' Water Availability Analysis Guidance Document formally adopted by the Napa County Board of Supervisors in May 2015. The WAA includes the following elements: estimates of existing and proposed water uses within the project recharge area, compilation of drillers' logs from the area and characterization of local hydrogeologic conditions, analyses to estimate groundwater recharge relative to proposed uses (Tier 1), and a screening analysis of the potential for well interference at neighboring wells located within 500 ft of project wells or springs within 1500 ft (Tier 2).

Limitations

Groundwater systems of Napa County and the Coast Range are typically complex, and available data rarely allows for more than general assessment of groundwater conditions and delineation of aquifers. Hydrogeologic interpretations are based on the drillers' reports made available to us through the California Department of Water Resources, available geologic maps and hydrogeologic studies, and professional judgment. This analysis is based on limited available data and relies significantly on interpretation of data from disparate sources of disparate quality. Existing and proposed future water use on and near the project site is estimated based on information received from the applicant and on regionally appropriate water duties for the observed and expected uses. The recharge estimates presented below are based on established soil water balance modeling techniques for calculating infiltration recharge and they do not explicitly simulate surface water/groundwater interaction in perennial streams or bedrock geology in controlling percolation of infiltrating water to aquifers.

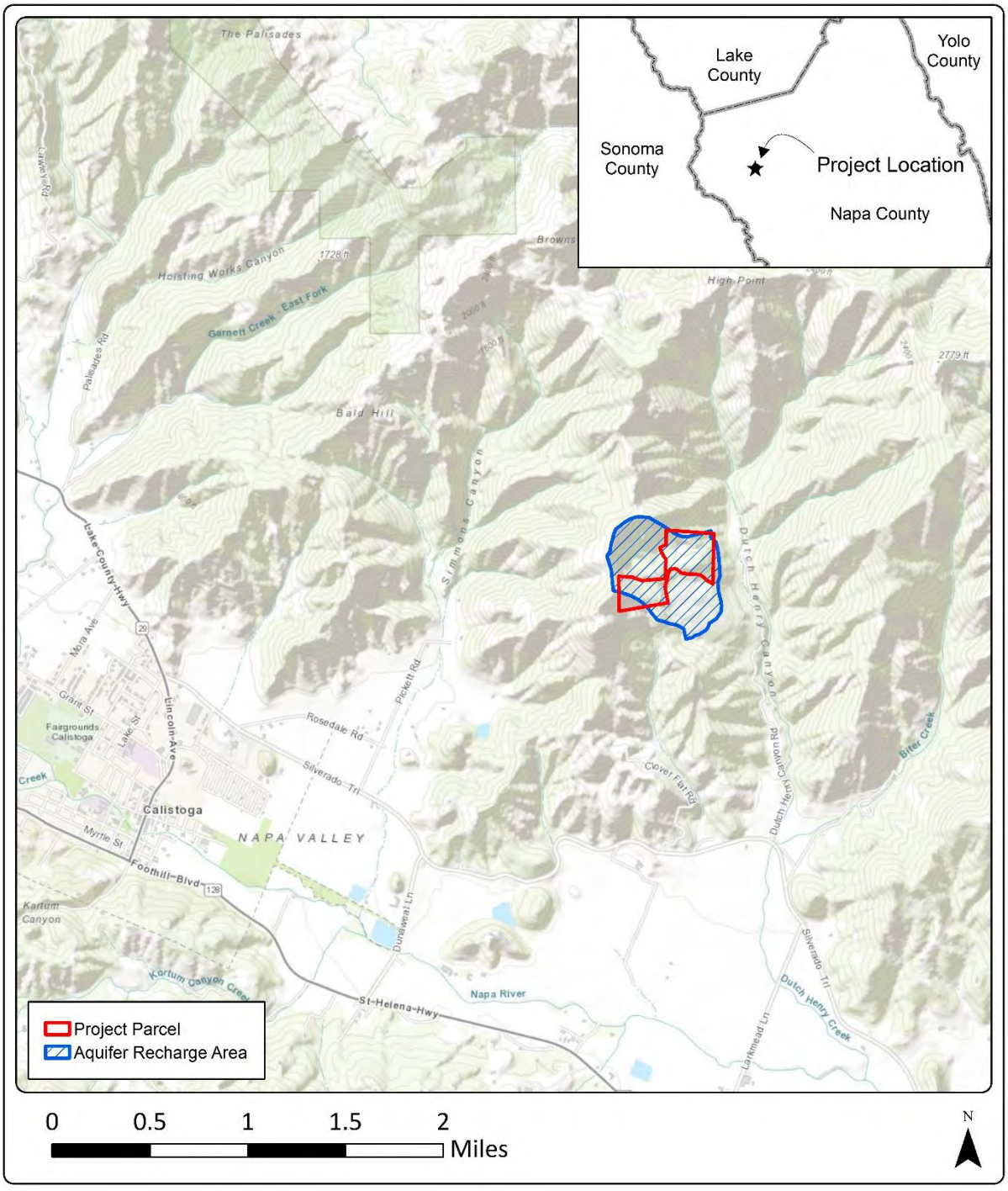

Figure 1: Project location map.

Hydrogeologic Conditions

The project parcel is located on the western edge of Dutch Henry Canyon, northeast of City of Calistoga and the Napa Valley (Figure 1). Dutch Henry Canyon and the ridgelines to the east and west are underlain by Pliocene-aged Rhyolite of Calistoga. The Rhyolite of Calistoga is described as "rhyolitic to rhyodacitic domes and flows… composed of highly variable assemblages of massive or flow banded rhyolite, intercalated crystal and lithic tuff, lithoidal welded tuff, and agglomerate" (Delattre and Gutierrez, 2013). Hydrothermal alteration is believed to be widespread, increasing clay content throughout and leading to localized mineralization along faults. Several landslides are mapped within Dutch Henry Canyon, including a large, approximately 0.3 mi^2 landslide underlying much of the project parcel (Figure 2). This landslide consists of highly-fractured and reworked material derived from the Rhyolite of Calistoga.

The Sonoma Volcanics (which includes the Rhyolite of Calistoga) is considered a low-yielding aquifer with reported well yields typically ranging between 16 and 50 gpm. However, yields in excess of 100 gpm have been reported (LSCE and MBK, 2013). Some units, such as unwelded tuff and volcanic sediments are somewhat more productive but overall are still considered low yielding. Bedrock units such as the andesite and rhyolite lava flows have very low primary porosity and groundwater occurs primarily in fractures, resulting in highly variable well production. Where these fracture networks are extensive, aquifers can have relatively high transmissivities (Nishikawa, 2013).

Well Data

Well Completion Reports for wells near the project parcel were obtained through the California Department of Water Resources' Well Completion Report Map Application and through the County of Napa Planning, Building, and Environmental Services Department's Electronic Document Retrieval system. The subset of these logs which could be accurately georeferenced based on parcel and location sketch information is discussed below. Logs for these wells are compiled in Appendix A.

The project well (Well 1) was completed to a depth of 240 ft in 1991. The driller's log indicates that in the upper 50 feet fractured volcanic rock in addition to tuff, ash, and sands were encountered, likely indicative of landslide deposits. Below 50 feet, the borehole encountered rhyolite, volcanic ash, and fine-grained volcanic rock, consistent with the Rhyolite of Calistoga. At the time of completion, the well had a static water level of 25 ft and an estimated yield of 3 gpm. It is screened from depths of 30 to 240 feet. The static water level and top of the screened interval are likely within the lower portion of the landslide deposits.

Well completion reports could be accurately georeferenced for 10 other nearby wells, all of which are completed in the Rhyolite of Calistoga (Wells 2 – 11, see Figure 2 and Table 1). These wells are typically completed to depths of 200 to 600 feet and have moderate to low yields of less than 50 gpm. One well has a reported yield in excess of 100 gpm. This may be due either to

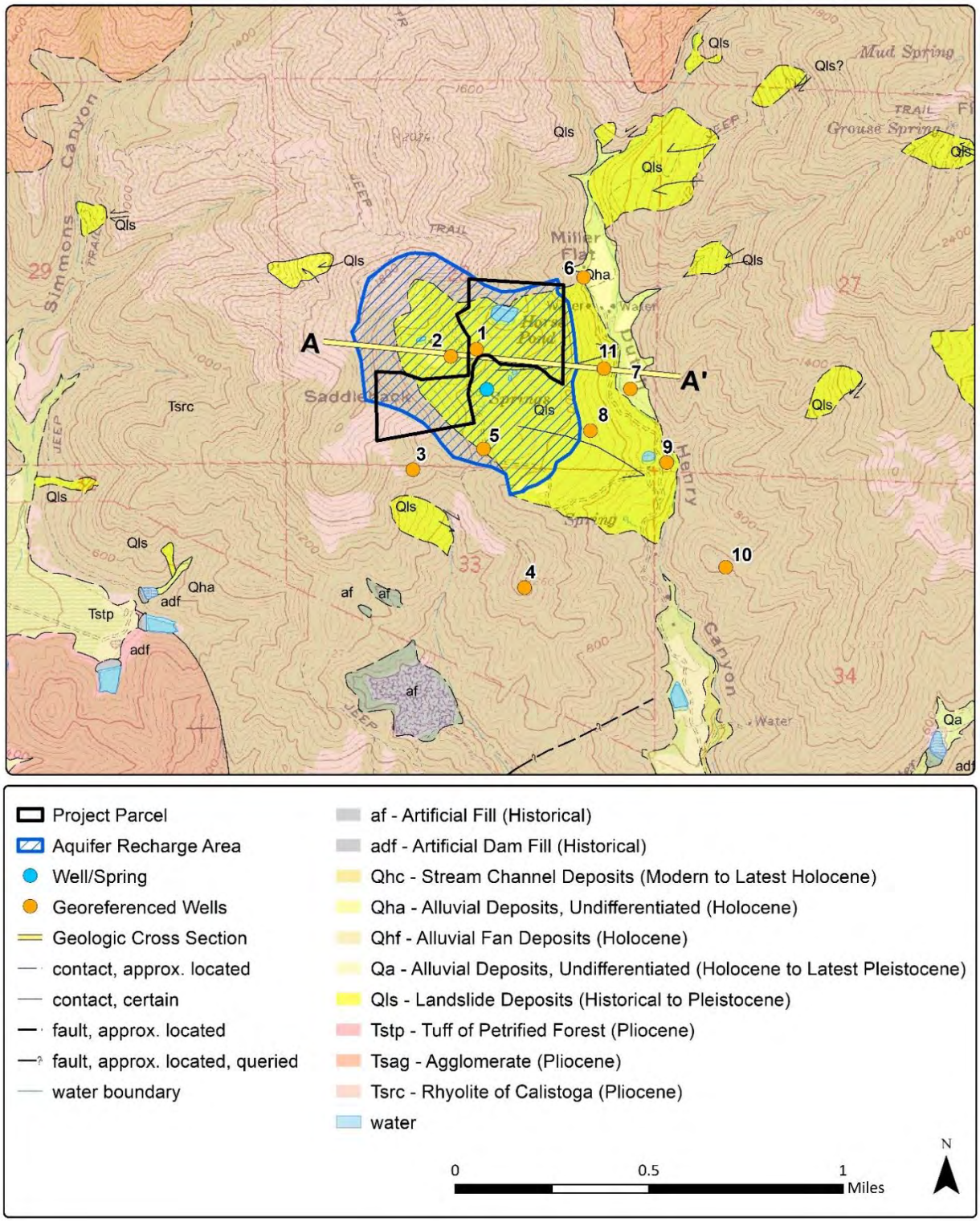

Figure 2: Surficial geology and locations of wells in the vicinity of the project parcel. Surficial geology based on data from the Preliminary Geologic Map of the Calistoga 7.5-Minute Quadrangle (Delattre and Gutierrez, 2013)

more transmissive local fracture zones or to differences in testing methods. Two dry holes were also encountered. Static water levels are typically 100 feet or less, although a few wells reported significantly deeper levels (Table 1). Driller's logs typically indicate white, grey, and brown volcanic rocks with some darker volcanic rocks, ash, tuff, and clay. These materials are consistent with the Rhyolite of Calistoga.

Table 1: Well completion details for wells in the vicinity of the project parcel.

Well ID	1	2	3	4	5	6
Year Completed	1991	1983	1998	2012	1997	2017
Completed Depth (ft)	240	215	165	555	256	604
Static Water Level (ft)	25	115	30	400	28	50
Estimated Yield (gpm)	3	25	30	4	40	20
Top of Screen (ft)	30	140	24	215	26	435
Bottom of Screen (ft)	240	215	185	555	256	595
Geologic Map Unit	Qls/Tsrc	Tsrc	Tsrc	Tsrc	Tsrc	Tsrc
DWR WCR No.	433495	119537	813039	947963	520824	e0356187

Well ID	7	8	9	10	11
Year Completed	1998	1992	1982	1987	1992
Completed Depth (ft)	240	205	130	620	550
Static Water Level (ft)	27	N/A	25	420	N/A
Estimated Yield (gpm)	120	0	50	15	0
Top of Screen (ft)	40	N/A	30	460	N/A
Bottom of Screen (ft)	210	N/A	130	620	N/A
Geologic Map Unit	Tsrc	Tsrc	Tsrc	Tsrc	Tsrc
DWR WCR No.	536043	384889	103496	245526	e020595

Geologic Cross Section

A geologic cross-section oriented west to east is shown in Figure 3 (see Figure 2 for location). Elevations along this cross-section range from 1,800 feet on the ridgeline west of the project parcel to 800 feet near Dutch Henry Creek. Well logs indicate that the Rhyolite of Calistoga underlying the ridgeline is spatially extensive, although older members of the Sonoma Volcanics may be present at depth. Quaternary-aged landslide deposits are mapped on the project parcel, and the scarp, main body, and toe are visible in the cross-section. The Driller's Log from Well 1 indicates that these deposits are on the order of 50 to 100 feet on the project parcel. However, the Driller's log from Well 2 does not call out materials consistent with landslide deposits, suggesting that the depth of these materials may vary significantly over short distances. The depth of the landslide deposits between the project parcel and Dutch Henry Creek are unknown.

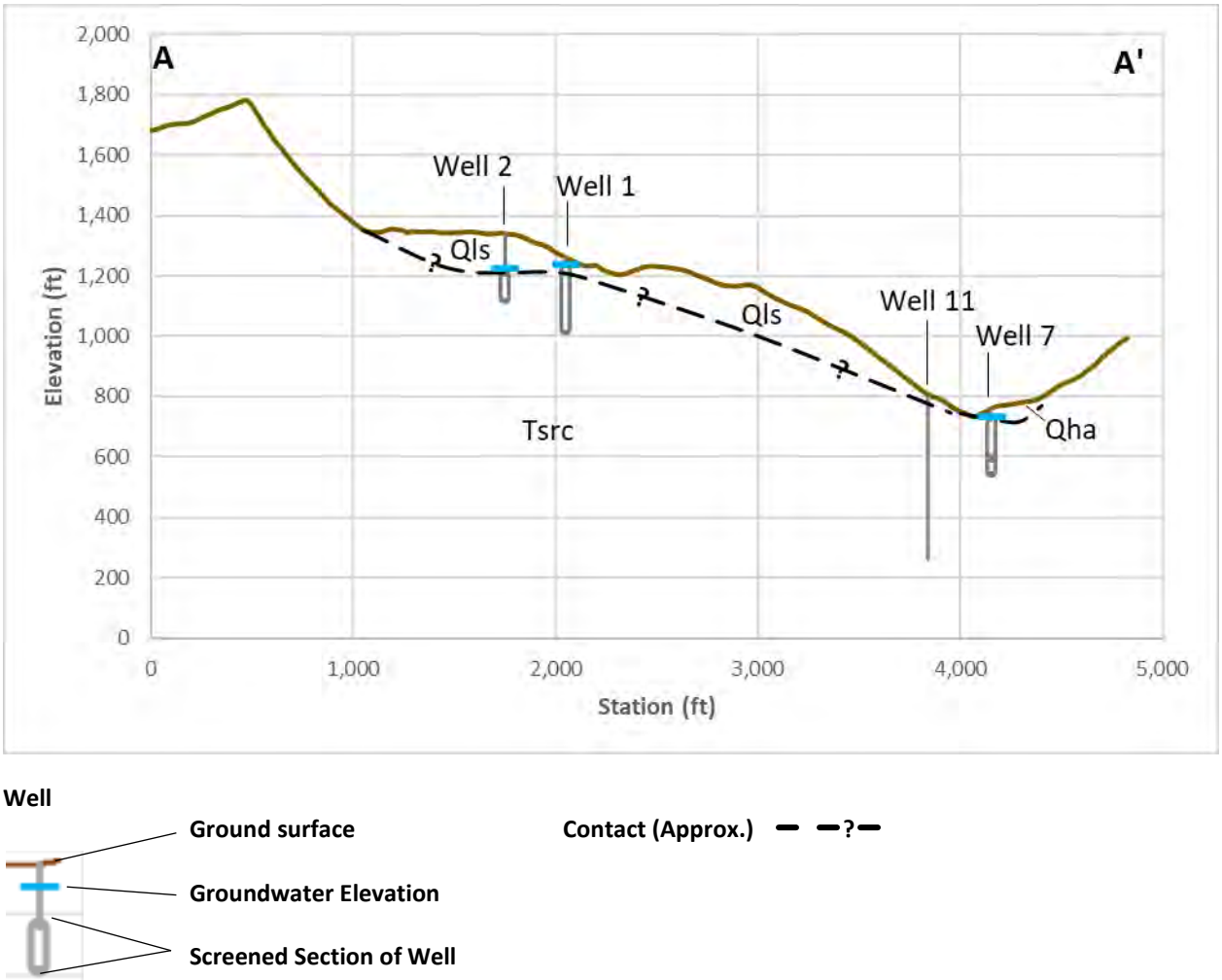

Figure 3: Hydrogeologic cross section A -A' through the project parcel (see Figure 2 for location and geologic map units).

Project Recharge Area

The project aquifer is conceptualized as the landslide scarp and the uphill areas draining to it. This scarp forms a well-defined drainage centered on the project parcel (Figure 2). Although the project aquifer is believed to be primarily within the underlying Sonoma Volcanics, groundwater flow patterns are believed to mimic surface topography. The downhill (eastern) boundary is defined by the 960 ft contour, level with the bottom of project wells screened interval. As defined the project recharge area covers approximately 158 acres. The project aquifer is believed to be located primarily within the Rhyolite of Calistoga. Although the uppermost portion of Well 1 is screened within the Quaternary-aged landslide deposits, the well is primarily screened within the underlying volcanics and has similar properties to many nearby wells screened exclusively within the volcanics. Because the Rhyolite of Calistoga is fine grained and typically has very low primary porosities, the project aquifer is likely confined or semi-confined.

Water Demand

Within the project recharge area, water demand was estimated for both the existing and proposed conditions. This area was heavily impacted by the 2020 Glass Fire. Water use estimates detailed below reflect the pre-fire condition assuming parcels are rebuilt to their previous configuration. Water use numbers do not include any change or expansion of pre-fire water uses on any neighboring parcels.

Uses on the project parcel were determined using site details provided by the project applicant and verified using satellite imagery. Uses on other neighboring parcels within the project recharge area were determined using satellite imagery. Water use rates were estimated using data from the County of Napa's Water Availability Analysis Guidance Document dated May 12, 2015.

Existing Use

In the existing condition the project parcel contains a single primary residence with a pool. Table 3 presents assumed use rates and total use on the project parcel. All existing uses are supplied by Well 1. There is an existing off-stream pond on the parcel which is not used for water supply and will not be used in the future. This pond is identified as non-jurisdictional in the California Department of Water Resources (DWR) Electronic Water Rights Information Management System (eWRIMS)(CA DWR Application ID NJ00024).

Neighboring parcels within the project recharge area contain two primary residences, one secondary residence, two pools, and approximately 21.1 acres of vineyard (Figure 4). One of these parcels also has a large, approximately 4,000 ft^2 lawn. Water use for 1,000 ft^2 of this lawn may be considered to be included in the residential use estimate; water use for the remaining 3,000 ft^2 was calculated separately. Table 4 summarizes uses and use rates for water demand on neighboring parcels within the project recharge area.

Based on these uses, water demand within the project recharge area is approximately 13.75 acre-ft/yr (Table 2). Of this, 0.85 acre-ft/yr is from the project parcel (Table 3). The remaining 12.90 acre-ft/yr comes from neighboring parcels, primarily vineyard irrigation on APN 018-050-058 (Table 4).

Proposed Use

In the proposed condition approximately 2.5 acres of vineyard will be planted on the project parcel. For the purposes of this report it is assumed that all irrigation water will come from the existing well. The project is estimated to increase groundwater use on the parcel by 1.25 acre-ft/yr to 2.10 acre-ft/yr (Table 5). Total water use within the project recharge area is estimated to increase to 15.00 acre-ft/yr.

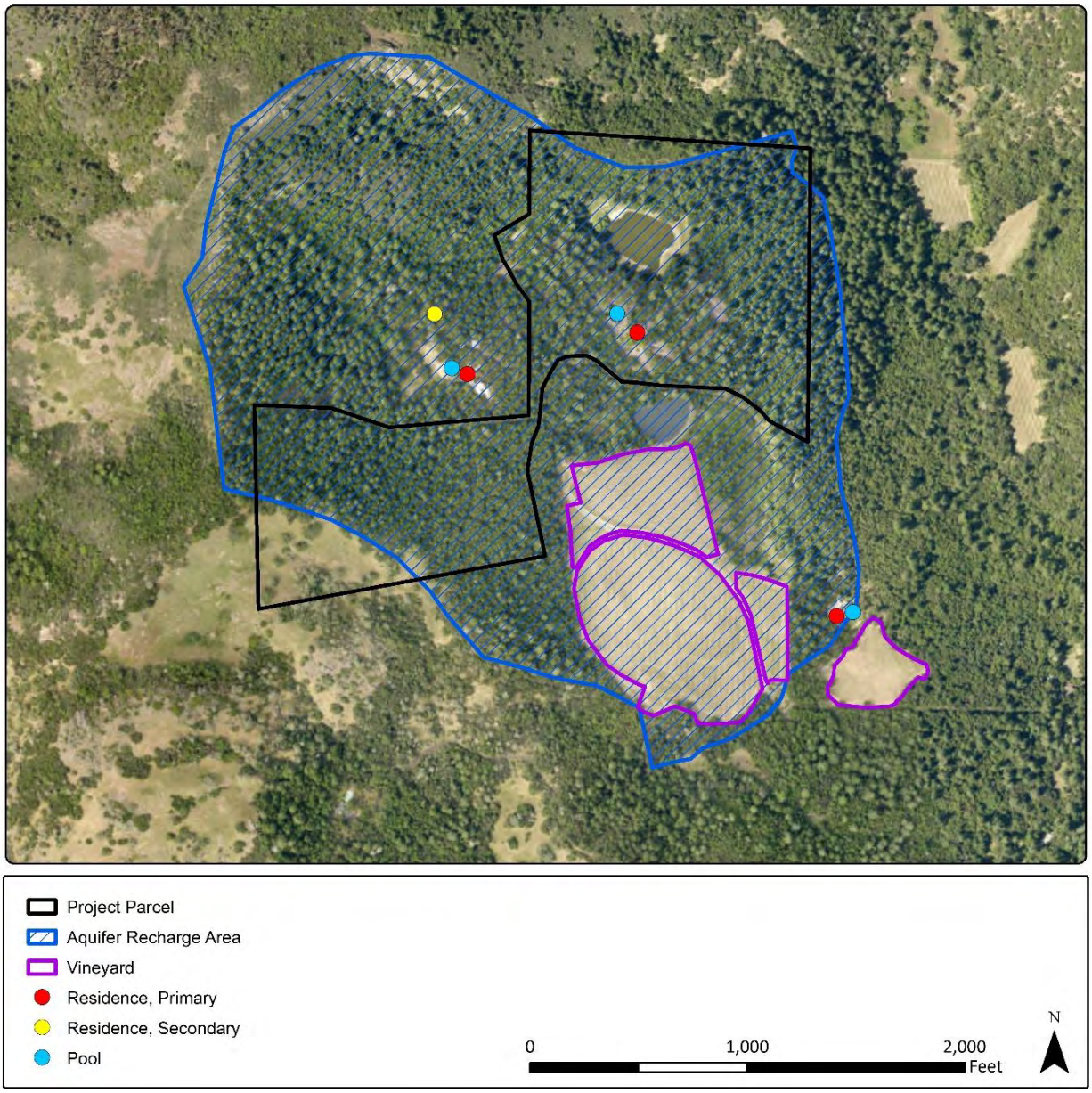

Figure 4: Water uses within the project recharge area.

Table 2: Estimated groundwater use within the project recharge area in the proposed and existing conditions.

	Existing Condition (acre-ft/yr)	Proposed Condition (acre-ft/yr)
Project Parcel	**0.85**	**2.10**
Residential Use	0.85	0.85
Irrigation Use	0.00	1.25
Neighboring Parcels	**12.90**	**12.90**
Residential Use	2.35	2.35
Irrigation Use	10.55	10.55
Total	**13.75**	**15.00**

Table 3: Estimated groundwater use from the project parcel in the existing condition.

	# of Units	Use per Unit	Annual Water Use (AF/yr)
Residential Use			**0.85**
Residences, Primary	1 Residence	0.75 AF/Residence	0.75
Pools	1 Pool	0.10 AF/Pool	0.10
Total			**0.85**

Table 4: Estimated groundwater use on neighboring parcels in the existing and proposed condition.

	# of Units	Use per Unit	Annual Water Use (AF/yr)
Residential Use			**2.35**
Residences, Primary	2 Residences	0.75 AF/Residence	1.50
Residences, Secondary	1 Residence	0.35 AF/Residence	0.35
Pools	2 Pools	0.10 AF/Pool	0.20
Lawn, Additional	3000 sq. ft.	0.10 AF/1,000 sq. ft.	0.30
Agricultural Use			**10.55**
Vineyard	21.1 Acres	0.50 AF/acre/yr	10.55
Total			**12.90**

Table 5: Estimated proposed water demand from the project parcel.

	# of Units	Use per Unit	Annual Water Use (AF/yr)
Residential Use			**0.85**
Residences, Primary	1 Residence	0.75 AF/Residence	0.75
Pools	1 Pool	0.10 AF/Pool	0.10
Agricultural Use			**1.25**
Vineyard	2.5 Acres	0.50 AF/acre/yr	1.25
Total			**2.10**

Groundwater Recharge Analysis

Groundwater recharge within the project recharge area was estimated using a Soil Water Balance (SWB) of Napa County developed by OEI. This model implements the U.S. Geologic Survey's SWB modeling software and produces a spatially distributed estimate of annual recharge. This model operates on a daily timestep and calculates runoff based on the Natural Resources Conservation Service (NRCS) curve number approach and Actual Evapotranspiration (AET) and recharge based on a modified Thornthwaite-Mather soil-water-balance approach (Westenbroek et al., 2010). Details of this model are included in Appendix B.

Groundwater recharge was simulated for Water Year 2010 and 2014. Water Year 2010 was chosen to represent average conditions. During this water year, annual precipitation totals across most of Napa County were close to their long-term 30-year averages. Simulated precipitation averaged 43.4 inches across the project recharge area and simulated actual evapotranspiration (AET) averaged 21.9 inches. Simulated groundwater recharge varied from 5.7 to 15.1 inches across the recharge area, with a spatial average of 11.2 inches. Components of the water balance were also calculated for the project parcel and are very similar to those calculated for the project recharge area (Table 6).

Water Year 2014 was selected to represent drought conditions. During this water year precipitation ranged from 41 – 73% of the long-term average across Napa County. Simulated precipitation averaged 23.8 inches across the project recharge area and simulated AET averaged 15.7 inches. Simulated groundwater recharge varied from close to zero to 6.2 inches across the recharge area, with a spatial average of 3.7 inches.

Table 6: Summary of water balance results estimated by the SWB model for WY 2010 & 2014.

	2010 Normal Year		2014 Dry Year	
	inches	% of precip	inches	% of precip
Precipitation	43.4	-	23.8	-
AET	21.9	50%	15.7	66%
Runoff	10.8	25%	7.8	33%
Δ Soil Moisture	-0.5	-1%	-3.4	-14%
Recharge	11.2	26%	3.7	16%

Groundwater recharge estimates can also be expressed as a total volume by multiplying the estimated recharge rate by a representative area. For the 158-acre project recharge area, average annual groundwater recharge is estimated to be 147.5 acre-ft/yr. During dry years such as Water Year 2014, recharge is estimated to be 48.7 acre-ft/yr. For the approximately 39-acre project parcel, these calculations yield an estimated average annual recharge of 36.4 acre-ft/yr and a dry year recharge rate of 12.0 acre-ft/yr. (Table 7).

Water balance estimates are available for several nearby watersheds that are predominately underlain by the Sonoma Volcanics including Conn, Redwood, Milliken, and Tulucay Creeks. Average annual recharge for these watersheds is estimated to range from 5% in Tulucay Creek to 21% in Conn Creek (LSCE, 2013). Regional estimates are also available for the Napa River watershed, the Santa Rosa Plain, Sonoma Valley, and the Green Valley Creek watershed. These regional analyses estimated that mean annual recharge was equivalent to between 7% and 28% of mean annual precipitation (Farrar et. al., 2006; Flint and Flint 2014, Kobor and O'Connor, 2016; Wolfenden and Hevesi, 2014).

Comparisons to these water balances are useful for determining the overall reasonableness of the results; precise agreement among these estimates is not expected owing to significant variations in climate, land cover, soil types, and underlying hydrogeologic conditions and owing to differences in spatial scale and methods for water balances. A local factor that is highly influential in our local-scale water balance is the high annual precipitation on Mount St. Helena, believed to be the greatest in Napa County (PRISM, 2010). Due largely to these higher precipitation rates, SWB modeling shows that more water was available for groundwater recharge, both in terms of annual depth and as a percentage of the annual water balance, than anywhere else in Napa County (Appendix B). The watersheds referenced above, particularly Milliken and Tulucay Creeks, receive significantly less precipitation than the project parcel and recharge rates in these watersheds may be significantly less than in the project recharge area.

Table 7: Comparison of proposed water use to average annual groundwater recharge for the project recharge area and for the project parcel.

Domain	Total Proposed Demand (ac-ft/yr)	Average Water Year (2010)			Dry Water Year (2014)		
		Recharge (ac-ft/yr)	Recharge Surplus (ac-ft/yr)	Demand as % of Recharge	Recharge (ac-ft/yr)	Recharge Surplus (ac-ft/yr)	Demand as % of Recharge
Project Recharge Area	15.0	147.5	132.5	10%	48.7	33.7	31%
Project Parcel	2.1	36.4	34.3	6%	12.0	9.9	17%

Comparison of Water Demand and Groundwater Recharge

The total proposed groundwater use within the project recharge area is estimated to be 15.0 acre-ft/yr. This use is equivalent to 10% of the 147.5 acre-ft of recharge received by the project recharge area during an average water year. A similar comparison can be drawn for the project parcel. Estimated use of 2.1 acre-ft/yr, is 6% of the 36.4 acre-ft/yr of recharge received on the parcel during an average year (Table 7). Even during dry years, water use within the project recharge area and on the project parcel still only accounts of for a small fraction of annual recharge. Given the surplus of groundwater recharge available, water use associated with the proposed project is highly unlikely to result in reductions in groundwater levels or depletion of groundwater resources over time.

Well Interference Analysis

The County of Napa's WAA Guidance Document indicates that a well interference analysis (Tier 2 Analysis) is required if neighboring wells are located within 500 feet of a project well or if a spring is located within 1,500 feet of a project well. The nearest well (Well 2) is located approximately 360 feet west of the project well on an adjacent parcel. Additionally, there is a developed spring or shallow well approximately 550 feet south of the project well that is used for agricultural water supply (Figure 5). Therefore, a well interference analysis is required.

The nearby well is screened at depths of 140 to 215 feet, entirely within the Rhyolite of Calistoga (map unit Tsrc) underlying the mapped landslide deposits. This partially overlaps with the screened interval of the project well, which is screened at similar depths in the rhyolite, as well as shallower portions of the rhyolite and the overlying landslide deposits (Table 1). As such, there is anticipated to be some degree of hydraulic connectivity between these two wells. The nearby spring originates from the mapped landslide deposits. The elevation of this spring is approximately 80 feet below the top of the project parcel. This places the spring level with the screened interval of Well 1 and the two may be hydraulically connected.

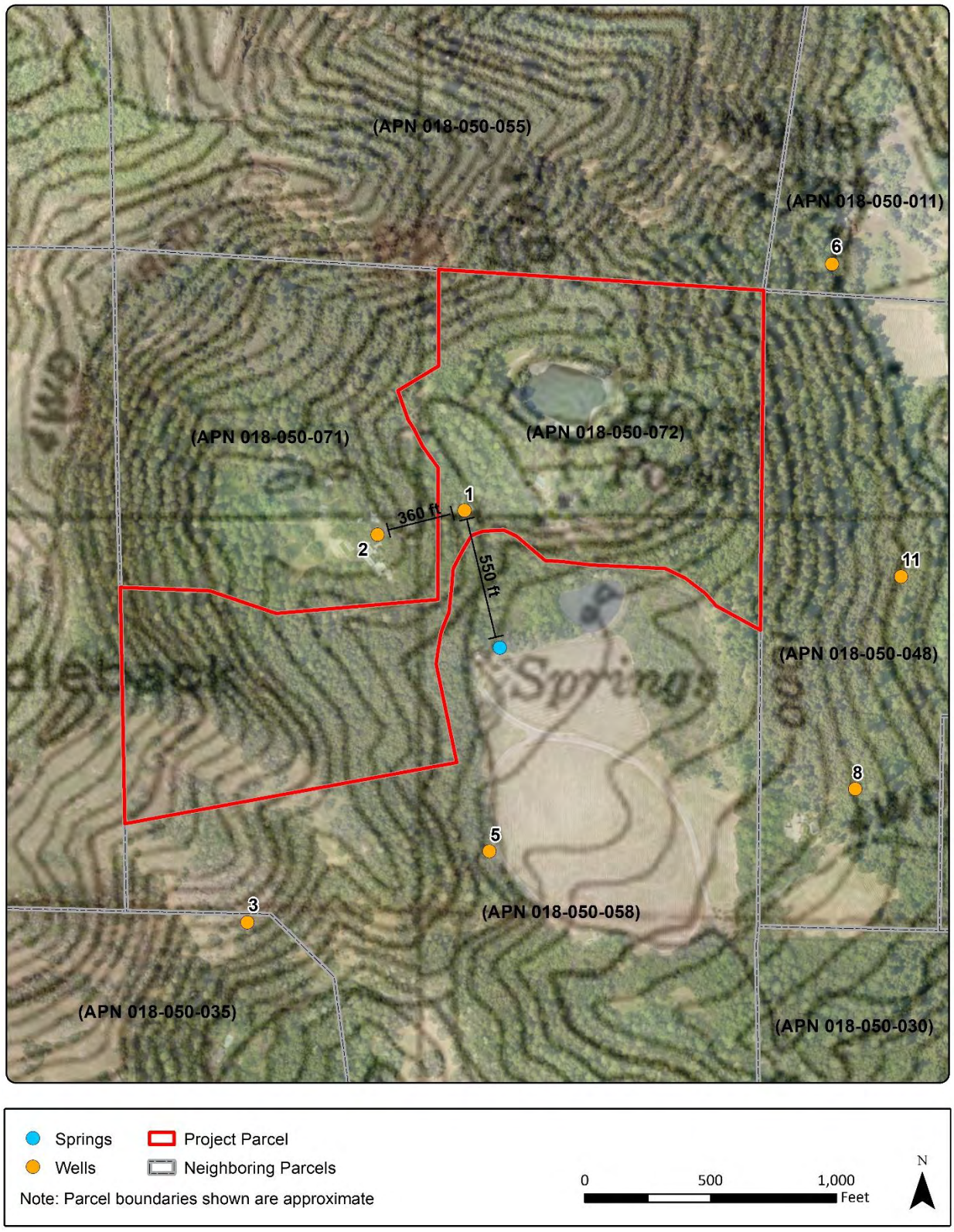

Figure 5: Locations of nearby wells and springs

The magnitude of potential drawdown caused by pumping from the project well at Well 2 and the nearby spring was estimated using the Theis equation. Estimated drawdown values were then compared to permissible drawdown criteria from the County of Napa's WAA Guidance Document.

Several assumptions are made when using the Theis equation:

1. The aquifer is homogeneous, isotropic, uniformly thick and of infinite areal extent.
2. Prior to pumping, the piezometric surface is horizontal
3. The fully penetrating well is pumped at a constant rate.
4. Flow is horizontal within the aquifer.
5. Storage within the well can be neglected.
6. Water removed from storage responds instantaneously with a declining head.

The County of Napa's WAA Guidance document pertaining to WAA's allows for 10 to 15 feet of water level drawdown attributable to well interference. For wells with a casing diameter of six inches or less, such as Well 1, drawdown of 10 feet is recommended as a threshold of concern. To estimate potential drawdown at Well 2 and the nearby spring, the Theis equation requires estimates of aquifer transmissivity and storativity, as well as a pumping rate and duration.

Hydrogeologic Properties

The storativity of a confined aquifer may be calculated as the product of specific storage (S_s) and saturated aquifer thickness (b). The Napa County WAA Guidance Document reports the specific storage of fissured rocks similar to the project aquifer as $1x10^{-6}$ to $2.1x10^{-5}$ $feet^{-1}$. The screened interval of Well 4 extends from 30 to 240 feet in depth, giving an estimated saturated aquifer thickness of 210 ft. Note that the static water level was five feet above the top of the screened interval at the time of completion. Using this estimate, the storativity of the project aquifer is believed to be between $2.1x10^{-4}$ and $4.4x10^{-3}$.

Aquifer transmissivity is defined as the product of hydraulic conductivity (K) and saturated aquifer thickness (b). The Napa County WAA Guidance Document reports the hydraulic conductivity of fractured basalt to be between 0.01 and 100 ft/day. Hydraulic conductivities for this unit are reported to be representative of other bedrock members of the Sonoma Volcanics, such as the Rhyolite of Calistoga. Using these estimates of hydraulic conductivity and saturated thickness, the transmissivity of the project aquifer is believed to be between 2.1 and $2.1x10^{4}$ ft^2/day.

Pumping Regime

Estimates of pumping duration (t) in the proposed condition were determined from estimates of annual water demand. Well will supply water for approximately four acres of vineyard, a primary residence, and a pool. Details of the vineyard irrigation schedule have not been determined at

the time of this report. However, assuming a typical 6-month (26-week) irrigation season, the proposed irrigation demand of 1.25 acre-ft/yr is equivalent to a weekly demand of 15,700 gallons/wk. Adding the estimated weekly residential demand of 5,300 gallons/wk (i.e., 0.85 acre-ft/yr) gives a weekly pumping volume of 21,000 gal/wk. Considering the low, 3 gpm yield of the project well, it is likely that water will need to be stored in tanks and that the well will need to operate more or less continuously to meet demand. Based on this, a worst-case pumping regime where the project well was operated at 3 gpm for a 24-hour period. If a higher capacity pump is installed it will likely need to cycle on and off periodically. Using the theory of image wells, for a similar daily pumping volume, drawdown at neighboring wells and springs will also be similar even if the well is pumped at a higher rate (Driscoll, 1986).

Estimated Drawdown

The Theis equation was evaluated to estimate drawdown induced by Well 1 at Well 2 and the nearby spring. All calculations were performed analytically using the Cooper-Jacobs approximation. Given the range of estimated storativity and transmissivity, the Theis equation was evaluated for several combinations of these parameters. Drawdown at Well 2, 360 feet away, is estimated to range from less than 0.01 ft to 0.21 ft. Drawdown at the spring, 550 feet away, is estimated to be 0.01 ft or less (Table 8). Given that estimated drawdown at both location is less than screening criteria of 10 feet, this drawdown is not considered significant, and no further analysis is required.

Table 8: Estimated drawdown at nearby wells and springs.

Combination	1	2	3	4
Storativity ()	$2.1x10^{-4}$	$4.4*10^{-3}$	$2.1x10^{-4}$	$4.4*10^{-3}$
Transmissivity (ft^2/day)	2.1	2.1	21,000	21,000
Drawdown at Well 2 (ft)	0.21	< 0.01	0.02	0.01
Drawdown at Spring (ft)	< 0.01	< 0.01	0.01	0.01

Summary

The applicant proposes to plant approximately 2.5 acres of vineyard on the project parcel. This vineyard as well as existing residential uses will be supplied by an existing well constructed in the Rhyolite of Calistoga. As a result of this project, water demand on the project parcel is estimated to increase from 0.85 to 2.10 acre-ft/yr. Application of a Soil Water Balance (SWB) model resulted in an average annual recharge of approximately 36.4 acre-ft/yr across the project parcel and 147.5 acre-ft/yr across the project recharge area. Proposed project use represents 6% of the mean annual recharge across the project parcel while use across the larger recharge area is estimated to be 10% of total recharge. These results indicate that the project is unlikely to result in declines in groundwater elevations or depletion of groundwater resources over time.

One well (Well 2) and one developed spring on neighboring parcels are close enough to the project well to require a Tier 2 analysis. Application of the Theis Equation shows that drawdown at the nearby well will be between 0.01 and 0.21 feet; estimated drawdown at the nearby spring is estimated to be 0.01 ft or less. These estimates of drawdown are significantly less than the County screening criteria of 10 feet. Thus drawdown is not considered significant and further analysis is not required.

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APPENDIX A

WELL COMPLETION REPORTS

Well 1

DWR

Page 1 of 1

Owner's Well No. _____

Date Work Began 11-6-91, Ended 11-14-91

Local Permit Agency Napa County Environmental Mgmt.

Permit No. 29684 Permit Date 11-8-91

STATE OF CALIFORNIA

WELL COMPLETION REPORT

Refer to Instruction Pamphlet

No. 433494

DWR USE ONLY — DO NOT FILL IN

STATE WELL NO./STATION NO. 09N06W27

LATITUDE _____ LONGITUDE _____

APN/TRS/OTHER _____

GEOLOGIC LOG

ORIENTATION (✓) XX VERTICAL ___ HORIZONTAL ___ ANGLE ___ (SPECIFY)

DEPTH TO FIRST WATER 30 (Ft.) BELOW SURFACE

DEPTH FROM SURFACE Ft.	to Ft.	DESCRIPTION *Describe material, grain size, color, etc.*
0	45	Fractured vol. rock/tuff/sands
45	50	volcanic ash/sands
50	55	black fractured volcanic rock
55	85	volcanic rhyolite
85	88	fine black fractured vol. rock
88	100	rhyolite
100	135	light gray volcanic ash
135	150	50% rhyolite/ 50% gray ash
150	160	mixed colored frac. vol. rock
160	240	80% rhyolite/ 20% gray vol. ash

TOTAL DEPTH OF BORING 240 (Feet)

TOTAL DEPTH OF COMPLETED WELL 240 (Feet)

WELL OWNER

CITY _____ STATE _____ ZIP 94515

WELL LOCATION

Address same

City _____

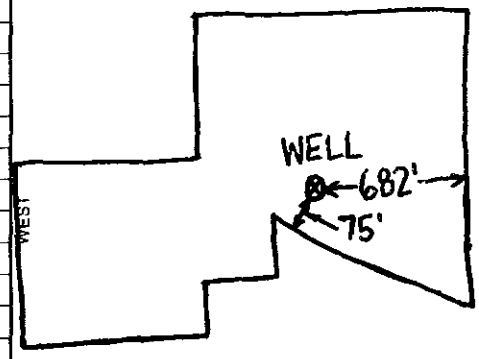
County Napa

APN Book 018 Page 050 Parcel 033

or Township 9 N. Range 6 W. Section 27

or Latitude 38 DEG. 36 MIN. _____ SEC. NORTH Longitude 122 DEG. 30 MIN. _____ SEC. WEST

LOCATION SKETCH



Illustrate or Describe Distance of Well from Landmarks such as Roads, Buildings, Fences, Rivers, etc. PLEASE BE ACCURATE & COMPLETE.

ACTIVITY (✓)

XX NEW WELL

MODIFICATION/REPAIR

___ Deepen

___ Other (Specify)

___ DESTROY (Describe Procedures and Materials Under "GEOLOGIC LOG")

PLANNED USE(S) (✓)

___ MONITORING

WATER SUPPLY

XX Domestic

___ Public

___ Irrigation

___ Industrial

___ "TEST WELL"

___ CATHODIC PROTECTION

___ OTHER (Specify)

DRILLING METHOD Rotary (mud) FLUID _____

WATER LEVEL & YIELD OF COMPLETED WELL

DEPTH OF STATIC WATER LEVEL 25 (Ft.) & DATE MEASURED 11-14-91

ESTIMATED YIELD* 3 (GPM) & TEST TYPE air lift

TEST LENGTH 4 (Hrs.) TOTAL DRAWDOWN 230 (Ft.)

* *May not be representative of a well's long-term yield.*

CASING(S)

DEPTH FROM SURFACE Ft.	to Ft.	BORE-HOLE DIA. (Inches)	TYPE (✓) BLANK	SCREEN	CON-DUCTOR	FILL PIPE	MATERIAL / GRADE	INTERNAL DIAMETER (Inches)	GAUGE OR WALL THICKNESS	SLOT SIZE IF ANY (Inches)
0	23	11								
23	240	9								
0	30		x				PVC	6	SDR-21	
30	240			x			PVC	6	SDR-21	1/8"

ANNULAR MATERIAL

DEPTH FROM SURFACE Ft.	to Ft.	TYPE CEMENT (✓)	BENTONITE (✓)	FILL (✓)	FILTER PACK (TYPE/SIZE)
0	22	x			grout
22	240			x	pea gravel

ATTACHMENTS (✓)

___ Geologic Log

___ Well Construction Diagram

___ Geophysical Log(s)

___ Soil/Water Chemical Analyses

___ Other _____

ATTACH ADDITIONAL INFORMATION, IF IT EXISTS.

CERTIFICATION STATEMENT

I, the undersigned, certify that this report is complete and accurate to the best of my knowledge and belief.

NAME HUCKFELDT WELL DRILLING (PERSON, FIRM, OR CORPORATION) (TYPED OR PRINTED)

ADDRESS 2110 Penny Lane CITY Napa STATE Ca ZIP 94559

Signed Lloyd Huckfeldt (WELL DRILLER/AUTHORIZED REPRESENTATIVE) DATE SIGNED 11-15-91

C-57 LICENSE NUMBER 439786

DWR 188 REV. 7-90

IF ADDITIONAL SPACE IS NEEDED, USE NEXT CONSECUTIVELY NUMBERED FORM

Well 2

18·050-07/

QUADRUPLICATE
Use to comply with local requirements

STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES

WATER WELL DRILLERS REPORT

Do not fill in
No. 119537

Notice of Intent No.
Local Permit No. or Date
State Well No.
Other Well No.

(1) OWNER: Name Jorgen Hildebrant
Address 1601 Grandview Drive
City Berkeley CA Zip 94701

(2) LOCATION OF WELL (See instructions):
County Napa Owner's Well Number 18-050-21
Well address if different from above Dutch Henry Canyon Rd.
Township Calistoga Range Section
Distance from cities, roads, railroads, fences, etc.

WELL LOCATION SKETCH

(3) TYPE OF WORK:
New Well [X] Deepening [ ]
Reconstruction [ ]
Reconditioning [ ]
Horizontal Well [ ]
Destruction [ ] (Describe destruction materials and procedures in Item 12)

(4) PROPOSED USE:
Domestic [X]
Irrigation [ ]
Industrial [ ]
Test Well [ ]
Stock [ ]
Municipal [ ]
Other [ ]

(5) EQUIPMENT:
Rotary [ ] Reverse [ ]
Cable [ ] Air [X]
Other [ ] Bucket [ ]

(6) GRAVEL PACK:
Yes [ ] No [X] Size
Diameter of bore 8 3/4"
Packed from to ft.

(7) CASING INSTALLED:
Steel [ ] Plastic [X] Concrete [ ]

From ft.	To ft.	Dia. in.	Gage or Wall
0	140	6	160

(8) PERFORATIONS: ~~Power saw~~ machine
Type of perforation or size of screen

From ft.	To ft.	Slot size
140	215	1/8 x 3

(9) WELL SEAL:
Was surface sanitary seal provided? Yes [X] No [ ] If yes, to depth 20 ft.
Were strata sealed against pollution? Yes [ ] No [X] Interval ft.
Method of sealing cement

(10) WATER LEVELS:
Depth of first water, if known 160 ft.
Standing level after well completion 115 ft.

(11) WELL TESTS:
Was well test made? Yes [X] No [ ] If yes, by whom? driller
Type of test Pump [ ] Bailer [ ] Air lift [X]
Depth to water at start of test 115 ft. At end of test ft
Discharge 25 gal/min after hours Water temperature
Chemical analysis made? Yes [ ] No [X] If yes, by whom?
Was electric log made? Yes [ ] No [X] If yes, attach copy to this report

(12) WELL LOG: Total depth 215 ft. Depth of completed well 215 ft.

from ft.	to ft.	Formation (Describe by color, character, size or material)
0	15	Top soil
15	85	Soft, multi-color brn. volc. rock w/ hard strs.
85	175	Hard brn. multi-color rock w/ soft strs.
175	205	Hard brn. & blk. rock w/ soft brn. strs.
205	215	Multi-color rock soft

Work started 1-11 19 83 Completed 1-14 19 83

WELL DRILLER'S STATEMENT:
This well was drilled under my jurisdiction and this report is true to the best of my knowledge and belief.
SIGNED Harold Gregson (Well Driller)
NAME Doshier & Gregson Drilling, Inc. (Person, firm, or corporation) (Typed or printed)
Address 5365 Napa-Vallejo Highway
City Vallejo Zip 94589-9679
License No. 294001 Date of this report 1-17-83

DWR 188 (REV. 7-76) IF ADDITIONAL SPACE IS NEEDED, USE NEXT CONSECUTIVELY NUMBERED FORM

ORIGINAL
File with DWR

Well 3

STATE OF CALIFORNIA
WELL COMPLETION REPORT
Refer to Instruction Pamphlet

DWR USE ONLY — DO NOT FILE IN

18-050-035
STATE WELL NO./STATION NO.
LATITUDE LONGITUDE
APN/TRS/OTHER

11/6/98

1 of 1
Owner's Well No. 1
Date Work Began 8-25-98 Ended 9-9-98 No. 813039
Local Permit Agency NAPA COUNTY ENVIRONMENTAL HEALTH
Permit No. 6247 Permit Date 8-25-98

GEOLOGIC LOG

ORIENTATION (✓) ✓ VERTICAL ___ HORIZONTAL ___ ANGLE ___ (SPECIFY)
DRILLING METHOD ROTARY FLUID ___

DEPTH FROM SURFACE ft	to ft	DESCRIPTION (Describe material, grain size, color, etc.)
0	65	CLAY
65	95	CLAY VOLCANIC ASH & ROCK MIX
95	185	VOLCANIC ROCK

RECEIVED
NOV 2 1998
DEPARTMENT OF ENVIRONMENTAL MANAGEMENT

TOTAL DEPTH OF BORING 185 Feet
TOTAL DEPTH OF COMPLETED WELL 185 Feet

WELL OWNER

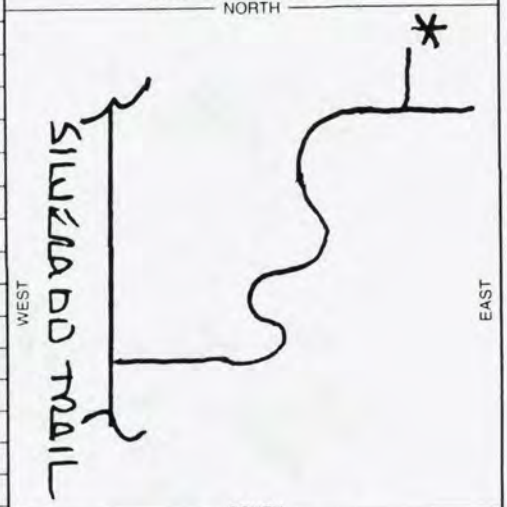
Name SHARON TATE
Mailing Address 432 DUTCH HENRY CANYON
CITY CALISTOGA STATE CA ZIP 94515

WELL LOCATION

Address 432 DUTCH HENRY CANYON
City CALISTOGA
County NAPA
APN Book 18 Page 050 Parcel 35
Township ___ Range ___ Section ___
Latitude ___ DEG ___ MIN ___ SEC NORTH
Longitude ___ DEG ___ MIN ___ SEC WEST

LOCATION SKETCH

NORTH



SOUTH

Illustrate or Describe Distance of Well from Roads, Buildings, Fences, Rivers, etc. and attach a map. Use additional paper if necessary. PLEASE BE ACCURATE & COMPLETE.

ACTIVITY (✓)

___ NEW WELL
MODIFICATION/REPAIR
✓ Deepen
___ Other (Specify)
___ DESTROY (Describe Procedures and Materials Under "GEOLOGIC LOG")

PLANNED USES (✓)

WATER SUPPLY
✓ Domestic ___ Public
___ Irrigation ___ Industrial
MONITORING ___
TEST WELL ___
CATHODIC PROTECTION ___
HEAT EXCHANGE ___
DIRECT PUSH ___
INJECTION ___
VAPOR EXTRACTION ___
SPARGING ___
REMEDIATION ___
OTHER (SPECIFY) ___

WATER LEVEL & YIELD OF COMPLETED WELL

DEPTH TO FIRST WATER 10 (Ft.) BELOW SURFACE
DEPTH OF STATIC WATER LEVEL 30 (Ft.) & DATE MEASURED 9-9-98
ESTIMATED YIELD * 30 (GPM) & TEST TYPE AIR LIFT
TEST LENGTH 2 (Hrs.) TOTAL DRAWDOWN N.A (Ft.)
* May not be representative of a well's long-term yield.

CASING (S)

DEPTH FROM SURFACE ft	to ft	BORE-HOLE DIA (inches)	TYPE (✓) BLANK	SCREEN	CONDUCTOR	FILL PIPE	MATERIAL GRADE	INTERNAL DIAMETER (inches)	GAUGE OR WALL THICKNESS	SLOT SIZE IF ANY (inches)
0	24	9½	X				F480 PVC	5"	.200	
24	185	8½	XX				F480 PVC	5"	.200	.032

ANNULAR MATERIAL

DEPTH FROM SURFACE ft	to ft	TYPE: CEMENT (✓)	BENTONITE (✓)	FILL (✓)	FILTER PACK (TYPE SIZE)
0	22	X			
22	185			X	3/8 PEA GRAVEL

ATTACHMENTS (✓)

___ Geologic Log
___ Well Construction Diagram
___ Geophysical Log(s)
___ Soil/Water Chemical Analyses
___ Other ___

ATTACH ADDITIONAL INFORMATION, IF IT EXISTS

CERTIFICATION STATEMENT

I, the undersigned, certify that this report is complete and accurate to the best of my knowledge and belief.

NAME D. BESS WATER WELL DRILLING (PERSON, FIRM, OR CORPORATION) (TYPED OR PRINTED)
ADDRESS 1115 MT GEORGE AVE CITY NAPA STATE CA ZIP 94558
Signed ___ (WELL DRILLER/AUTHORIZED REPRESENTATIVE) DATE SIGNED 9-30-98
C-57 LICENSE NUMBER 487027

DWR 188 REV. 1/95

IF ADDITIONAL SPACE IS NEEDED, USE NEXT CONSECUTIVELY NUMBERED FORM

Well 4

PLICATE Requirements

WELLS-WL

DWR USE ONLY — DO NOT FILL IN

STATE WELL NO./STATION NO.

LATITUDE LONGITUDE

APN/TRS/OTHER

STATE OF CALIFORNIA

WELL COMPLETION REPORT

Refer to Instruction Pamphlet

No. 0947963

Page ___ of ___

Owner's Well No. ___

Date Work Began 3-20-12 Ended 4-9-12

Local Permit Agency Napa County

Permit No. E12-00113 Permit Date 3-12-12

GEOLOGIC LOG

ORIENTATION (✓) ✓ VERTICAL ___ HORIZONTAL ___ ANGLE ___ (SPECIFY)

DRILLING METHOD rotary FLUID air

DEPTH FROM SURFACE Ft. to Ft.	DESCRIPTION *Describe material, grain size, color, etc.*
0 150	brn mash & boulders
150 350	hard brn mash & bk rock
350 555	hard gry ash, strks of brn & gry sandstone

TOTAL DEPTH OF BORING 555 (Feet)

TOTAL DEPTH OF COMPLETED WELL 555 (Feet)

RECEIVED

OCT 23 2012

DEPT. OF ENVIRONMENTAL MANAGEMENT

WELL OWNER

Name James & Sharon Tate

Mailing Address 432 Dutch Canyon rd.

CITY Calistoga STATE CA ZIP 94515

WELL LOCATION

Address 370 Dutch Henry Canyon

City Calistoga

County Napa

APN Book ___ Page ___ Parcel 018-050-051

Township ___ Range ___ Section ___

Lat ___ DEG. ___ MIN. ___ SEC. N

Long ___ DEG. ___ MIN. ___ SEC. W

LOCATION SKETCH

Illustrate or Describe Distance of Well from Roads, Buildings, Fences, Rivers, etc. and attach a map. Use additional paper if necessary. ***PLEASE BE ACCURATE & COMPLETE.***

ACTIVITY (✓)

✓ NEW WELL

MODIFICATION/REPAIR
___ Deepen
___ Other (Specify)

___ DESTROY *(Describe Procedures and Materials Under "GEOLOGIC LOG")*

USES (✓)

WATER SUPPLY
✓ Domestic ___ Public
___ Irrigation ___ Industrial

MONITORING ___
TEST WELL ___
CATHODIC PROTECTION ___
HEAT EXCHANGE ___
DIRECT PUSH ___
INJECTION ___
VAPOR EXTRACTION ___
SPARGING ___
REMEDIATION ___
OTHER (SPECIFY) ___

WATER LEVEL & YIELD OF COMPLETED WELL

DEPTH TO FIRST WATER 350 (Ft.) BELOW SURFACE

DEPTH OF STATIC WATER LEVEL 400 (Ft.) & DATE MEASURED 4-9-12

ESTIMATED YIELD * 4 (GPM) & TEST TYPE AIR LIFT

TEST LENGTH 3 (Hrs.) TOTAL DRAWDOWN 500 (Ft.)

** May not be representative of a well's long-term yield.*

CASING (S)

DEPTH FROM SURFACE Ft. to Ft.	BORE-HOLE DIA. (Inches)	TYPE (✓) BLANK	SCREEN	CONDUCTOR	FILL PIPE	MATERIAL / GRADE	INTERNAL DIAMETER (Inches)	GAUGE OR WALL THICKNESS	SLOT SIZE IF ANY (Inches)
0 24	11"	X				PLASTIC	5"	200	
24 215	9"	X				"	"	"	
215 555	9"	FACT			PREF	"	"	"	3/32

ANNULAR MATERIAL

DEPTH FROM SURFACE Ft. to Ft.	TYPE CEMENT (✓)	BENTONITE (✓)	FILL (✓)	FILTER PACK (TYPE/SIZE)
0 24	X			
24 555	WELL	PACK		

ATTACHMENTS (✓)

___ Geologic Log
___ Well Construction Diagram
___ Geophysical Log(s)
___ Soil/Water Chemical Analyses
___ Other ___

ATTACH ADDITIONAL INFORMATION, IF IT EXISTS.

CERTIFICATION STATEMENT

I, the undersigned, certify that this report is complete and accurate to the best of my knowledge and belief.

NAME Pulliam Well Drilling (PERSON, FIRM, OR CORPORATION) (TYPED OR PRINTED)

ADDRESS 2877 Piedmont CITY Napa STATE Ca. ZIP 94558

Signed Bill Pulliam C-57 LICENSED WATER WELL CONTRACTOR

DATE SIGNED 4-11-12 C-57 LICENSE NUMBER 248677

DWR 188 REV. 05-03

IF ADDITIONAL SPACE IS NEEDED, USE NEXT CONSECUTIVELY NUMBERED FORM

ORIGINAL

Well 5

DWR

of 1

STATE OF CALIFORNIA

WELL COMPLETION REPORT

Refer to Instruction Pamphlet

No. 520824

DWR USE ONLY — DO NOT FILL IN

STATE WELL NO./STATION NO. 8N/05W-05R1

LATITUDE

LONGITUDE

APN/TRS/OTHER 7/24

Owner's Well No. 1

Date Work Began 5-12-97 , Ended 5-19-97

Local Permit Agency Co of Napa E.M.

Permit No. 44633 Permit Date 5-19-97

GEOLOGIC LOG

ORIENTATION (✓) ✓ VERTICAL ___ HORIZONTAL ___ ANGLE ___ (SPECIFY)

DEPTH TO FIRST WATER ___ (Ft.) BELOW SURFACE

DEPTH FROM SURFACE Ft.	to Ft.	DESCRIPTION *Describe material, grain size, color, etc.*
0	26	Top Soil
26	58	Loose Gravel / Boulders
58	160	Volcanic Cinder Ash
160	256	Ash White Some Rock possible Small Veins of Water in Rock formations

RECEIVED

JUL 17 1998

DEPT. OF ENVIRONMENTAL MANAGEMENT

TOTAL DEPTH OF BORING 256 (Feet)

TOTAL DEPTH OF COMPLETED WELL 250 (Feet)

WELL OWNER

Name 432 Mr & Mrs Craig Heinark

Mailing Address 538 Edgewood Pl

River forest IL 60305

CITY STATE ZIP

WELL LOCATION

Address 432 Dutch Henery Rd

City Calistoga

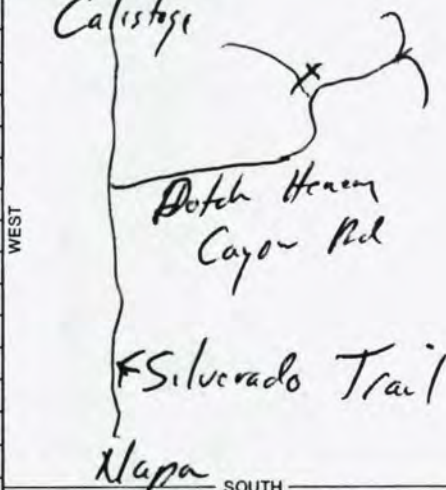
County Napa

APN Book 18 Page 050 Parcel 58

or Township ___ Range ___ Section ___

or Latitude ___ DEG. ___ MIN. ___ SEC. NORTH Longitude ___ DEG. ___ MIN. ___ SEC. WEST

LOCATION SKETCH



Illustrate or Describe Distance of Well from Landmarks such as Roads, Buildings, Fences, Rivers, etc. PLEASE BE ACCURATE & COMPLETE.

ACTIVITY (✓)

___ NEW WELL

MODIFICATION/REPAIR

___ Deepen

___ Other (Specify)

___ DESTROY *(Describe Procedures and Materials Under "GEOLOGIC LOG")*

PLANNED USE(S) (✓)

___ MONITORING

WATER SUPPLY

___ Domestic

___ Public

___ Irrigation

___ Industrial

___ "TEST WELL"

___ CATHODIC PROTECTION

___ OTHER (Specify)

DRILLING METHOD Rotary FLUID

WATER LEVEL & YIELD OF COMPLETED WELL

DEPTH OF STATIC WATER LEVEL 28 (Ft.) & DATE MEASURED 5-2-97

ESTIMATED YIELD* 40 (GPM) & TEST TYPE Air Lift

TEST LENGTH 2 (Hrs.) TOTAL DRAWDOWN 250 (Ft.)

* *May not be representative of a well's long-term yield.*

CASING(S)

DEPTH FROM SURFACE Ft.	to Ft.	BORE-HOLE DIA. (Inches)	TYPE (✓) BLANK	SCREEN	CONDUCTOR	FILL PIPE	MATERIAL / GRADE	INTERNAL DIAMETER (Inches)	GAUGE OR WALL THICKNESS	SLOT SIZE IF ANY (Inches)
0	26	8 3/4	X				PVC F480	5	200	
26	256	8 3/4		X			PVC F48	5	200	032

ANNULAR MATERIAL

DEPTH FROM SURFACE Ft.	to Ft.	TYPE CEMENT (✓)	BENTONITE (✓)	FILL (✓)	FILTER PACK (TYPE/SIZE)
0	21	✓			
21	250			✓	3/8 Rock

ATTACHMENTS (✓)

___ Geologic Log

___ Well Construction Diagram

___ Geophysical Log(s)

___ Soil/Water Chemical Analyses

___ Other ___

ATTACH ADDITIONAL INFORMATION, IF IT EXISTS.

CERTIFICATION STATEMENT

I, the undersigned, certify that this report is complete and accurate to the best of my knowledge and belief.

NAME D. Bess Pump & Well (PERSON, FIRM, OR CORPORATION) (TYPED OR PRINTED)

1115 MT George Ave Napa Ca 94558

ADDRESS CITY STATE ZIP

Signed Dave Bess WELL DRILLER/AUTHORIZED REPRESENTATIVE

5-5-97 DATE SIGNED

447027 C-57 LICENSE NUMBER

DWR 188 REV. 7-90

IF ADDITIONAL SPACE IS NEEDED, USE NEXT CONSECUTIVELY NUMBERED FORM

Well 6

E16-00484 well id

File Original with DWR

Page 1 of 2

Owner's Well Number Well #2

Date Work Began 08/21/2017 Date Work Ended 9/12/2017

Local Permit Agency Napa County Environmental Health Services

Permit Number E16-00484 Permit Date 7/20/16

State of California

Well Completion Report

No. e0356187

DWR Use Only – Do Not Fill In

State Well Number/Site Number

N W

Latitude Longitude

APN/TRS/Other

Geologic Log

Orientation ◉ Vertical ○ Horizontal ○ Angle Specify

Drilling Method Direct Rotary Drilling Fluid Bentonite mud

Depth from Surface Feet	to Feet	Description Describe material, grain size, color, etc
0	5	Brown clay and cobbles
5	58	Brown and red clay
58	604	Light gray, green and black rock

RECEIVED NOV 06 2017 Napa County Planning, Building & Environmental Services

Total Depth of Boring 604 Feet

Total Depth of Completed Well 595 Feet

Well Owner

Redacted Per California Water Code §13752

Well Location

Address 530 Dutch Henry Canyon Road

City Calistoga County Napa

Latitude ___ Deg. ___ Min. ___ Sec. N Longitude ___ Deg. ___ Min. ___ Sec. W

Datum ___ Decimal Lat. ___ Decimal Long. ___

APN Book 018 Page 050 Parcel 011

Township ___ Range ___ Section ___

Location Sketch

(Sketch must be drawn by hand after form is printed.)

North

West East

South

Illustrate or describe distance of well from roads, buildings, fences, rivers, etc. and attach a map. Use additional paper if necessary. **Please be accurate and complete.**

Activity

◉ New Well
○ Modification/Repair
○ Deepen
○ Other
○ Destroy
Describe procedures and materials under "GEOLOGIC LOG"

Planned Uses

◉ Water Supply
☑ Domestic ☐ Public
☐ Irrigation ☐ Industrial
○ Cathodic Protection
○ Dewatering
○ Heat Exchange
○ Injection
○ Monitoring
○ Remediation
○ Sparging
○ Test Well
○ Vapor Extraction
○ Other

Water Level and Yield of Completed Well

Depth to first water ___ (Feet below surface)

Depth to Static Water Level 50 (Feet) Date Measured 09/08/2017

Estimated Yield * 20 (GPM) Test Type Air Lift

Test Length 4.0 (Hours) Total Drawdown 580 (Feet)

*May not be representative of a well's long term yield.

Casings

Depth from Surface Feet	to Feet	Borehole Diameter (Inches)	Type	Material	Wall Thickness (Inches)	Outside Diameter (Inches)	Screen Type	Slot Size if Any (Inches)
0	20	18 1/2	Conductor	Steel	.25	12 1/4		
20	604	10						
0	435		Blank	PVC Sch. 40	SDR21	6		
435	455		Screen	PVC Sch. 40	SDR21	6	Milled Slots	0.032
455	475		Blank	PVC Sch. 40	SDR21	6		
475	495		Screen	PVC Sch. 40	SDR21	6	Milled Slots	0.032

Annular Material

Depth from Surface Feet	to Feet	Fill	Description
0	20	Cement	
20	160	Filter Pack	3/8 Pea Gravel
160	595	Filter Pack	#6 Sand

Attachments

☐ Geologic Log
☐ Well Construction Diagram
☐ Geophysical Log(s)
☐ Soil/Water Chemical Analyses
☑ Other Site Map

Attach additional information, if it exists.

Certification Statement

I, the undersigned, certify that this report is complete and accurate to the best of my knowledge and belief

Name Weeks Drilling & Pump Company
Person, Firm or Corporation

P.O. Box 176 Sebastopol CA 95473
Address City State Zip

Signed June Angelini 10/31/17 177681
C-57 Licensed Water Well Contractor Date Signed C-57 License Number

DWR 188 REV. 1/2006

Well 6, cont.

File Original with DWR

Page 2 of 2

Owner's Well Number Well #2

Date Work Began 08/21/2017 Date Work Ended 9/12/2017

Local Permit Agency Napa County Environmental Health Services

Permit Number E16-00484 Permit Date 7/20/16

State of California

Well Completion Report

No. e0356187

DWR Use Only – Do Not Fill In

State Well Number/Site Number

N W

Latitude Longitude

APN/TRS/Other

Geologic Log

Orientation ◉ Vertical ○ Horizontal ○ Angle Specify

Drilling Method Direct Rotary Drilling Fluid Bentonite mud

Depth from Surface Feet	to Feet	Description Describe material, grain size, color, etc
0	5	Brown clay and cobbles
5	58	Brown and red clay
58	604	Light gray, green and black rock

Total Depth of Boring 604 Feet

Total Depth of Completed Well 595 Feet

Well Owner

Redacted Per California Water Code §13752

Well Location

Address 530 Dutch Henry Canyon Road

City Calistoga County Napa

Latitude ___ Deg. ___ Min. ___ Sec. N Longitude ___ Deg. ___ Min. ___ Sec. W

Datum ___ Decimal Lat. ___ Decimal Long. ___

APN Book 018 Page 050 Parcel 011

Township ___ Range ___ Section ___

Location Sketch

(Sketch must be drawn by hand after form is printed.)

North

West East

South

Illustrate or describe distance of well from roads, buildings, fences, rivers, etc. and attach a map. Use additional paper if necessary. **Please be accurate and complete.**

Activity

◉ New Well

○ Modification/Repair

○ Deepen

○ Other ___

○ Destroy

Describe procedures and materials under "GEOLOGIC LOG"

Planned Uses

◉ Water Supply

☑ Domestic ☐ Public

☐ Irrigation ☐ Industrial

○ Cathodic Protection

○ Dewatering

○ Heat Exchange

○ Injection

○ Monitoring

○ Remediation

○ Sparging

○ Test Well

○ Vapor Extraction

○ Other ___

Water Level and Yield of Completed Well

Depth to first water ___ (Feet below surface)

Depth to Static Water Level 50 (Feet) Date Measured 09/08/2017

Estimated Yield * 20 (GPM) Test Type Air Lift

Test Length 4.0 (Hours) Total Drawdown 580 (Feet)

*May not be representative of a well's long term yield.

Casings

Depth from Surface Feet	to Feet	Borehole Diameter (Inches)	Type	Material	Wall Thickness (Inches)	Outside Diameter (Inches)	Screen Type	Slot Size if Any (Inches)
495	515		Blank	PVC Sch. 40	SDR21	6		
515	535		Screen	PVC Sch. 40	SDR21	6	Milled Slots	0.032
535	555		Blank	PVC Sch. 40	SDR21	6		
555	595		Screen	PVC Sch. 40	SDR21	6	Milled Slots	0.032

Annular Material

Depth from Surface Feet	to Feet	Fill	Description
0	20	Cement	
20	160	Filter Pack	3/8 Pea Gravel
160	595	Filter Pack	#6 Sand

Attachments

☐ Geologic Log

☐ Well Construction Diagram

☐ Geophysical Log(s)

☐ Soil/Water Chemical Analyses

☑ Other Site Map

Attach additional information, if it exists.

Certification Statement

I, the undersigned, certify that this report is complete and accurate to the best of my knowledge and belief

Name Weeks Drilling & Pump Company (Person, Firm or Corporation)

P.O. Box 176 (Address) Sebastopol (City) CA (State) 95473 (Zip)

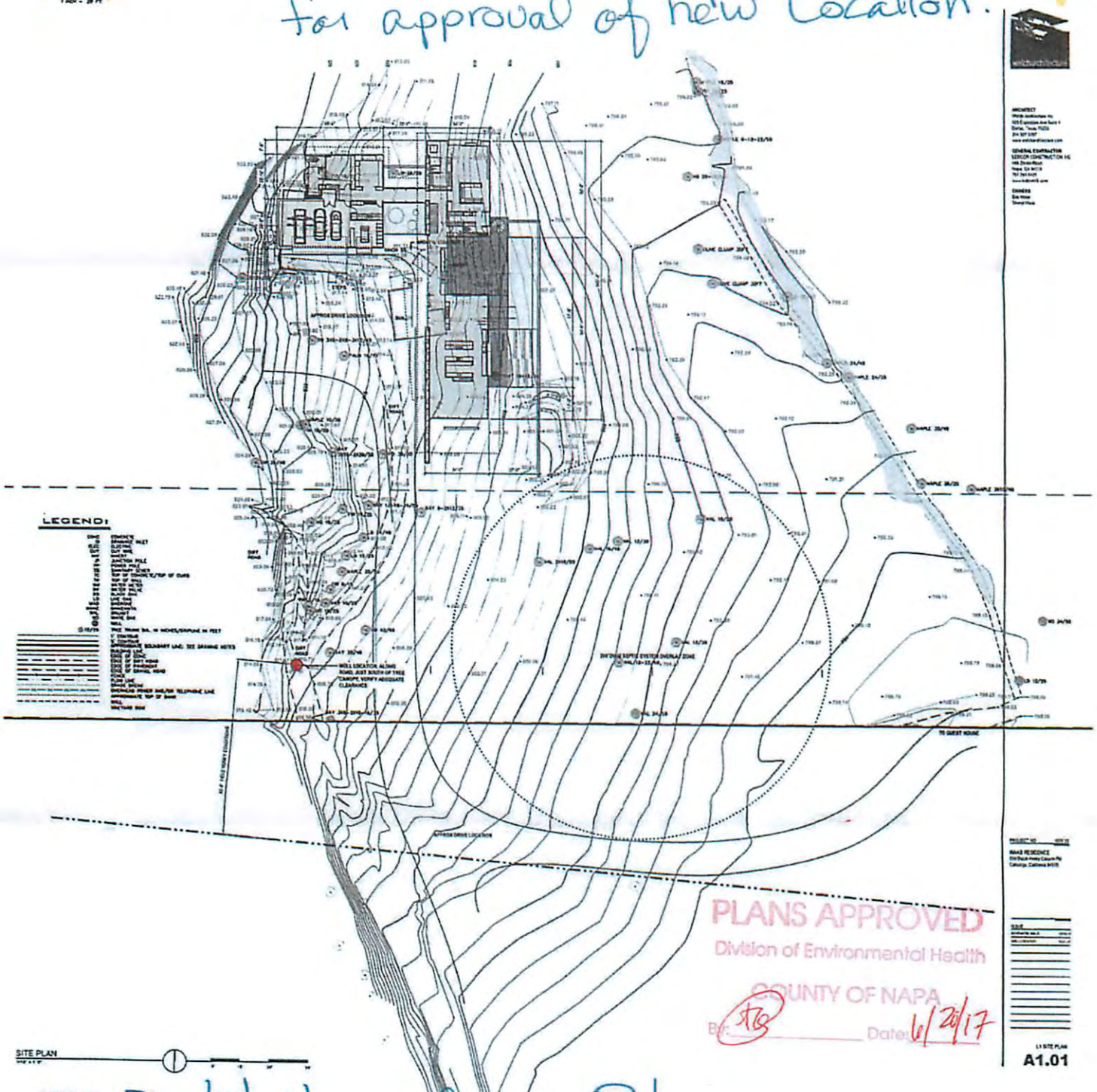
Signed [signature] (C-57 Licensed Water Well Contractor) 10/31/17 (Date Signed) 177681 (C-57 License Number)

DWR 188 REV. 1/2006

Well 6, cont.

018-050-011
E16-00484

6/19/17: Revised Site Map submitted for approval of new Location.



530 Dutch Henry Canyon Rd
Calistoga, Ca.
APN# 018-050-011

WEEKS DRILLING & PUMP COMPANY
P.O. Box 176
Sebastopol, CA 95473-0176

Well 7

PLICATE
l Requirements

Page 1 of 1

Owner's Well No. _____

Date Work Began 4-13-98 , Ended 4-17-98

Local Permit Agency Napa County Environmental Mgmt.

Permit No. 96-10212 Permit Date 4-13-98

STATE OF CALIFORNIA

WELL COMPLETION REPORT

Refer to Instruction Pamphlet

No. 536043

18-050-048

DWR USE ONLY — DO NOT FILL IN

STATE WELL NO./STATION NO.

LATITUDE LONGITUDE

APN/TRS/OTHER

GEOLOGIC LOG

ORIENTATION (✓) X VERTICAL ___ HORIZONTAL ___ ANGLE ___ (SPECIFY)

DEPTH TO FIRST WATER 40 (Ft.) BELOW SURFACE

DEPTH FROM SURFACE Ft.	to Ft.	DESCRIPTION *Describe material, grain size, color, etc.*
0	40	brown clay with embedded rock
40	60	mixed sand & gravel
60	85	gray volcanic mix
85	108	blue/gray clay
108	120	volcanic mix
120	125	light brown clay
125	170	volcanic mix
170	175	gray ash
175	190	ryholite (volcanics) hard
190	205	gray ash
205	240	hard volcanic ryholite

RECEIVED

MAY 18 1998

ENVIRONMENTAL MANAGEMENT

TOTAL DEPTH OF BORING 240 (Feet)

TOTAL DEPTH OF COMPLETED WELL 220 (Feet)

WELL OWNER

Name Robert Yeakey

Mailing Address 2600 Spring Mtn. Road

CITY St. Helena STATE CA ZIP 94574

WELL LOCATION

Address 386 Dutch Henry Canyon

City Calistoga

County Napa

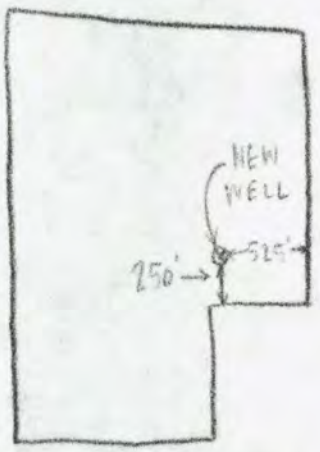
APN Book 18 Page 050 Parcel 48

or Township ___ Range ___ Section ___

or Latitude ___ DEG. ___ MIN. ___ SEC. NORTH Longitude ___ DEG. ___ MIN. ___ SEC. WEST

LOCATION SKETCH

NORTH



SOUTH

Illustrate or Describe Distance of Well from Landmarks such as Roads, Buildings, Fences, Rivers, etc.
PLEASE BE ACCURATE & COMPLETE.

ACTIVITY (✓)

X NEW WELL

MODIFICATION/REPAIR

___ Deepen

___ Other (Specify)

___ DESTROY *(Describe Procedures and Materials Under "GEOLOGIC LOG")*

PLANNED USE(S) (✓)

___ MONITORING

WATER SUPPLY

X Domestic

___ Public

___ Irrigation

___ Industrial

___ "TEST WELL"

___ CATHODIC PROTECTION

___ OTHER (Specify)

DRILLING METHOD Rotary FLUID bentonite

WATER LEVEL & YIELD OF COMPLETED WELL

DEPTH OF STATIC WATER LEVEL 27 (Ft.) & DATE MEASURED 4-17-98

ESTIMATED YIELD* 120 (GPM) & TEST TYPE air lift

TEST LENGTH 2 (Hrs.) TOTAL DRAWDOWN N/A (Ft.)

** May not be representative of a well's long-term yield.*

CASING(S)

DEPTH FROM SURFACE Ft.	to Ft.	BORE-HOLE DIA. (Inches)	TYPE (✓) BLANK	SCREEN	CONDUCTOR	FILL PIPE	MATERIAL/GRADE	INTERNAL DIAMETER (Inches)	GAUGE OR WALL THICKNESS	SLOT SIZE IF ANY (Inches)
0	40	10	X				PVC F480	5	SDR-21	
40	160			X			PVC F480	5	SDR-21	1/8
160	170		X				PVC F480	5	SDR-21	
170	210			X			PVC F480	5	SDR-21	1/8
210	220		X				PVC F480	5	SDR-21	

ANNULAR MATERIAL

DEPTH FROM SURFACE Ft.	to Ft.	TYPE CEMENT (✓)	BENTONITE (✓)	FILL (✓)	FILTER PACK (TYPE/SIZE)
0	22	X			concrete
22	220			X	pea gravel

ATTACHMENTS (✓)

___ Geologic Log

___ Well Construction Diagram

___ Geophysical Log(s)

___ Soil/Water Chemical Analyses

___ Other ___

ATTACH ADDITIONAL INFORMATION, IF IT EXISTS.

CERTIFICATION STATEMENT

I, the undersigned, certify that this report is complete and accurate to the best of my knowledge and belief.

NAME HUCKFELDT WELL DRILLING
(PERSON, FIRM, OR CORPORATION) (TYPED OR PRINTED)

ADDRESS 2110 Penny Lane CITY Napa STATE CA ZIP 94559

Signed [signature] WELL DRILLER/AUTHORIZED REPRESENTATIVE

DATE SIGNED 4-21-98

C-57 LICENSE NUMBER 439-746

DWR 188 REV. 7-90

IF ADDITIONAL SPACE IS NEEDED, USE NEXT CONSECUTIVELY NUMBERED FORM

Well 8

#3949

13-0050-049

STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES

WATER WELL DRILLERS REPORT

PLICATE
comply with local requirements

Do not fill in

No. 384889

Notice of Intent No. _____
Local Permit No. or Date _____

State Well No. _____
Other Well No. _____

(1) OWNER: Name John Auerbach
Address P.O. Box 83
City St. Helena, CA ZIP 94574

(2) LOCATION OF WELL (See instructions):
County Napa Owner's Well Number 18-050-15
Well address if different from above Dutch Henry Canyon Road
Township _____ Range _____ Section _____
Distance from cities, roads, railroads, fences, etc. _____

WELL LOCATION SKETCH

(3) TYPE OF WORK:
New Well ☒ Deepening ☐
Reconstruction ☐
Reconditioning ☐
Horizontal Well ☐
Destruction ☒ (Describe destruction materials and procedures in Item 12)

(4) PROPOSED USE:
Domestic ☒
Irrigation ☐
Industrial ☐
Test Well ☐
Municipal ☐
Other ☐
(Describe)

(5) EQUIPMENT:
Rotary ☒ Reverse ☐
Cable ☐ Air ☒
Other ☐ Bucket ☐

(6) GRAVEL PACK:
Yes ☐ No ☑ Size _____
Diameter of bore 12¼"
Packed from 220 to 30 ft.

(7) CASING INSTALLED:
Steel ☐ Plastic ☐ Concrete ☐

(8) PERFORATIONS:
Type of perforation or size of screen

From ft.	To ft.	Dia. in.	Gage or Wall	From ft.	To ft.	Slot size

(9) WELL SEAL:
Was surface sanitary seal provided? Yes ☒ No ☐ If yes, to depth 30 ft.
Were strata sealed against pollution? Yes ☐ No ☐ Interval _____ ft.
Method of sealing Bentonite Pellets & Concrete

(10) WATER LEVELS:
Depth of first water, if known _____ ft.
Standing level after well completion _____ ft.

(11) WELL TESTS:
Was well test made? Yes ☐ No ☐ If yes, by whom? _____
Type of test Pump ☐ Bailer ☐ Air lift ☐
Depth to water at start of test _____ ft. At end of test _____ ft.
Discharge _____ gal/min after _____ hours Water temperature _____
Chemical analysis made? Yes ☐ No ☐ If yes, by whom? _____
Was electric log made Yes ☐ No ☐ If yes, attach copy to this report

(12) WELL LOG: Total depth 220 ft. Completed depth _____ ft.

from ft.	to ft.	Formation (Describe by color, character, size or material)
0	3	Topsoil
5	40	Gray Rock & Brown Clay
40	100	Brown, Black, & Red Rock Fract
100	115	Lt. Brown & Gray Rock String Gray Clay
115	145	Green, Red, & Brown Rock Stringers Gray Hard
145	160	Lt. Gray Rock Hard
160	175	Gray Rock String Brown Hard
175	190	Lt. Gray Hard Rock Temp 82°
190	205	Lt Gray String Hard Green Rock Temperature 90°
		DRY HOLE

CONFIDENTIAL
NOT FOR PUBLIC USE
WATER CODE SEC. 13752

RECEIVED
APR 16 1992
DEPT. OF ENVIRONMENTAL MANAGEMENT

Work started 3-30 19 92 Completed 4-9 1992

WELL DRILLER'S STATEMENT:

This well was drilled under my jurisdiction and this report is true to the best of my knowledge and belief.

Signed _____ (Well Driller)
NAME DOHIER-GREGSON INC.
(Person, firm, or corporation) (Typed or printed)
Address 5365 Napa-Vallejo Highway
City Vallejo ZIP 94589
License No. 258826 Date of this report 4-14-92

DWR 188 (REV. 12-86) IF ADDITIONAL SPACE IS NEEDED, USE NEXT CONSECUTIVELY NUMBERED FORM 86 96355

Well 9

IAL

File with DWR

STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES
WATER WELL DRILLERS REPORT
018 060 004

Do not fill in
No. 103496 25R

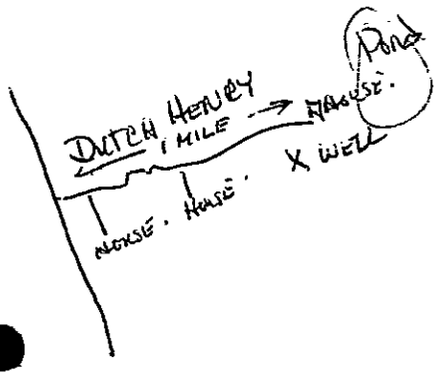
State Well No.
Other Well No. 09N06W27R

[redacted] of Intent No.
Local Permit No. or Date

(1)
Addr
City.

(2) LOCATION OF WELL (See instructions):
County. Napa Owner's Well Number 18-060-04
Well address if different from above Dutch Henry Canyon Rd
Township St. Helena Range Section
Distance from cities, roads, railroads, fences, etc.

WELL LOCATION SKETCH



(3) TYPE OF WORK:
New Well [X] Deepening [ ]
Reconstruction [ ]
Reconditioning [ ]
Horizontal Well [ ]
Destruction [ ] (Describe destruction materials and procedures in Item 12)

(4) PROPOSED USE:
Domestic [X]
Irrigation [ ]
Industrial [ ]
Test Well [ ]
Stock [ ]
Municipal [ ]
Other [ ]

(5) EQUIPMENT:
Rotary [X] Reverse [ ]
Cable [ ] Air [X]
Other [ ] Bucket [ ]

(6) GRAVEL PACK:
Yes [X] No [ ] Size 3/4
Diameter of bore 6 7/8
Packed from 22 ft. to 130 ft.

(7) CASING INSTALLED:
Steel [X] Plastic [ ] Concrete [ ]

From ft.	To ft.	Dia. in.	Gage or Wall
0	30	6 5/8	.188

(8) PERFORATIONS:
Type of perforation or size of screen

From ft.	To ft.	Slot size
30	130	1/8x3"

(9) WELL SEAL:
Was surface sanitary seal provided? Yes [X] No [ ] If yes, to depth ft.
Were strata sealed against pollution? Yes [ ] No [X] Interval ft.
Method of sealing cement

(10) WATER LEVELS:
Depth of first water, if known 25 ft.
Standing level after well completion 25 ft.

(11) WELL TESTS:
Was well test made? Yes [X] No [ ] If yes, by whom? driller
Type of test Pump [ ] Bailer [ ] Air lift [X]
Depth to water at start of test 25 ft. At end of test ft
Discharge 50 gal/min after hours Water temperature
[redacted]ical analysis made? Yes [ ] No [X] If yes, by whom?
Was electric log made? Yes [ ] No [X] If yes, attach copy to this report

(12) WELL LOG: Total depth ft. Depth of completed well ft.

from ft.	to ft.	Formation (Describe by color, character, size or material)
0	5	top soil
5	10	clay
10	55	multi color brown rock; fract w/boulders
55	67	brown & gray clay w/multi color rock - soft
67	90	hard multi color rock, fract
90	121	brown fract rock w/stringers of clay
121	130	green clay & rock

Work started 2/25 1982 Completed 3/5/ 1982

WELL DRILLER'S STATEMENT:
This well was drilled under my jurisdiction and this report is true to the best of my knowledge and belief.
SIGNED (Well Driller)
NAME Doshier & Gregson Drilling, Inc (Person, firm, or corporation) (Typed or printed)
Address 5365 Napa Vallejo Hwy
City Vallejo, Ca Zip 94589-9679
License No. 294001 Date of this report 3/8/82

DWR 188 (REV. 7-76) IF ADDITIONAL SPACE IS NEEDED, USE NEXT CONSECUTIVELY NUMBERED FORM

Well 10

18-060-021

PLICATE
use or comply with
local requirements

STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES
WATER WELL DRILLERS REPORT

Do not fill in
No. 245526

Notice of Intent No.
Local Permit No. or Date
State Well No.
Other Well No.

(1) OWNER: Name Tom Scripps
Address 440 Brannon #101
City San Francisco Zip 94107

(2) LOCATION OF WELL (See instructions):
County Napa Owner's Well Number 18-060-21
Well address if different from above Dutch Henry Canyon Rd.
Township Range Section
Distance from cities, roads, railroads, fences, etc.

WELL LOCATION SKETCH

(3) TYPE OF WORK:
New Well [X] Deepening [ ]
Reconstruction [ ]
Reconditioning [ ]
Horizontal Well [ ]
Destruction [ ] (Describe destruction materials and procedures in Item 12)

(4) PROPOSED USE:
Domestic [ ]
Irrigation [ ]
Industrial [ ]
Test Well [ ]
Stock [ ]
Municipal [ ]
Other [ ]

(5) EQUIPMENT:
Rotary [ ] Reverse [ ]
Cable [ ] Air [X]
Other [ ] Bucket [ ]

(6) GRAVEL PACK:
Yes [X] No [ ] Size
Diameter of bore 9 7/8" & 8 3/4"
Packed from 24' to 620' ft.

(7) CASING INSTALLED:
Steel [ ] Plastic [X] Concrete [ ]

(8) PERFORATIONS: Machine
Type of perforation or size of screen

From ft.	To ft.	Dia. in.	Gage or Wall	From ft.	To ft.	Slot size
0	460	6	.200	460	620	.200

(9) WELL SEAL:
Was surface sanitary seal provided? Yes [X] No [ ] If yes, to depth 24 ft.
Were strata sealed against pollution? Yes [X] No [ ] Interval 20 ft.
Method of sealing Grout

(10) WATER LEVELS:
Depth of first water, if known ft.
Standing level after well completion 420 ft.

(11) WELL TESTS:
Was well test made? Yes [X] No [ ] If yes, by whom? Driller
Type of test Pump [ ] Bailer [ ] Air lift [X]
Depth to water at start of test 420 ft. At end of test 620 ft.
Discharge 15 gal/min after 2 hours Water temperature
Chemical analysis made? Yes [ ] No [ ] If yes, by whom?
Was electric log made? Yes [ ] No [ ] If yes, attach copy to this report

(12) WELL LOG: Total depth 620 ft. Depth of completed well 620 ft.

from ft.	to ft.	Formation (Describe by color, character, size or material)
0	2	Topsoil
2	40	Med hard brown rock
40	85	Med hard lt gray rock
85	115	Med hrd grn rock & lt,dk gray rock stringers
115	130	Lt & dk gry rock brown clay imbedded
130	175	Med hrd lt gry rock fractures
175	205	Hard gray rock fractures
205	220	Hard grn ,lt gry rock fractures
220	265	Hrd dk, lt gry rock fractures
265	295	Med hrd grn,wht,gry rock fractures
295	320	Med hrd grn & gry rock fratures
320	370	Med hrd grn rock fractures lt & dk gray rock stringers
370	450	Hard lt gray & grn rock fractures
450	500	Hard dk & lt gry rock fractures
500	580	Hard lt gray rock [illegible]
580	620	Hard Lt gray,grn,wht rock fractures

Work started 7-28 19 87 Completed 8-15 19 87

WELL DRILLER'S STATEMENT:
This well was drilled under my jurisdiction and this report is true to the best of my knowledge and belief.
SIGNED (Well Driller)
NAME Doshier & Gregson Inc. (Person, firm, or corporation) (Typed or printed)
Address 5365 Napa-Vallejo Hwy
City Vallejo, CA Zip 94589
License No. 294001 Date of this report 8/18/87

DWR 188 (REV. 7-76) IF ADDITIONAL SPACE IS NEEDED, USE NEXT CONSECUTIVELY NUMBERED FORM

Well 11

ORIGINAL
File with DWR

STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES

WATER WELL DRILLERS REPORT

Do not fill in

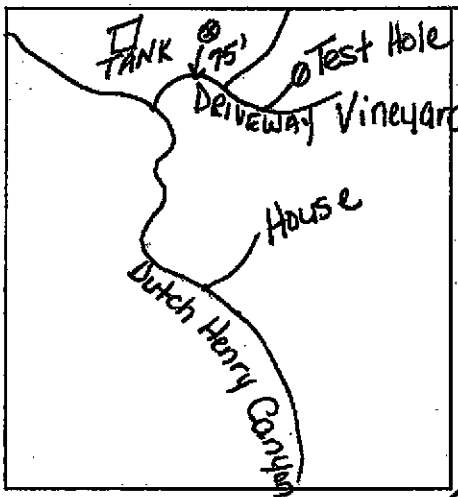
No. 384891

Notice of Intent No. _____
Local Permit No. or Date _____

State Well No. 09N 06W
Other Well No. _____

(2) LOCATION OF WELL (See instructions):

County Napa Owner's Well Number 18-050-15
Well address if different from above Dutch Henry Canyon
Township _____ Range _____ Section _____
Distance from cities, roads, railroads, fences, etc. _____



WELL LOCATION SKETCH

(3) TYPE OF WORK:

New Well ☒ Deepening ☐
Reconstruction ☐
Reconditioning ☐
Horizontal Well ☐
Destruction ☐ (Describe destruction materials and procedures in Item 12)

(4) PROPOSED USE:

Domestic ☐
Irrigation ☐
Industrial ☐
Test Well ☒
Municipal ☐
Other ☐
(Describe)

(5) EQUIPMENT:

Rotary ☒ Reverse ☐
Cable ☐ Air ☒
Other ☐ Bucket ☐

(6) GRAVEL PACK:

Yes ☐ No ☑ Size
Diameter of bore 12¼"
Packed from _____ ft. to _____ ft.

(7) CASING INSTALLED:

Steel ☐ Plastic ☐ Concrete ☐

From ft.	To ft.	Dia. in.	Gage or Wall

(8) PERFORATIONS:

Type of perforation or size of screen

From ft.	To ft.	Slot size

(9) WELL SEAL:

Was surface sanitary seal provided? Yes ☐ No ☐ If yes, to depth _____ ft.
Were strata sealed against pollution? Yes ☐ No ☐ Interval _____ ft.
Method of sealing _____

(10) WATER LEVELS:

Depth of first water, if known Unknown ft.
Standing level after well completion _____ ft.

(11) WELL TESTS:

Was well test made? Yes ☐ No ☐ If yes, by whom? _____
Type of test Pump ☐ Bailer ☐ Air lift ☐
Depth to water at start of test _____ ft. At end of test _____ ft.
Discharge _____ gal/min after _____ hours Water temperature _____
Chemical analysis made? Yes ☐ No ☒ If yes, by whom? _____
Was electric log made Yes ☐ No ☒ If yes, attach copy to this report

(12) WELL LOG:

Total depth 550 ft. Completed depth _____ ft.

from ft.	to ft.	Formation (Describe by color, character, size or material)
0	5	Topsoil
5	24	Brown Clay, Gray Rock Imbedded
24	85	Brown, Red, Black Rock Fract
85	100	Brown, Red, Black Rock Fract
100	130	Brown Clay String Gray-Brown Rock
130	160	Red, Green, Black, Brown Rock
160	190	Brown, Gray Clay
190	220	Gray Clay String Black Rock
220	275	Lt. Gray, White Rock Hard Fract
275	310	Lt. Gray, White Rock Hard Fract
310	325	Lt. Gray, White Rock Hard
325	400	Lt & Dk Gray Rock Stringers White Ash
400	445	White Ash Stringer Lt. Gray & White Rock Hard
445	500	Lt. Gray, White Rock Stringer White Ash
500	520	Dk, Lt Gray Rock White ASh
520	535	White Ash
535	550	White Ash Stringers Gray Rock

Work started 4-13-92 19__ Completed 4-30-92 19__

WELL DRILLER'S STATEMENT:

This well was drilled under my jurisdiction and this report is true to the best of my knowledge and belief

Signed Raymond Hebster (Well Driller)

NAME DOSHIER-GREGSON, INC. (Person, firm, or corporation) (Typed or printed)

Address 5365 Napa-Vallejo Highway

City Vallejo ZIP 94589

License No. 258826 Date of this report 5-8-92

APPENDIX B

NAPA COUNTY GROUNDWATER RECHARGE ANALYSIS

Napa County Groundwater Recharge Analysis

Introduction

Developing accurate estimates of the spatial and temporal distribution of groundwater recharge is a key component of sustainable groundwater management. Efforts to quantify recharge are inherently difficult owing to the wide variability of factors controlling hydrologic processes, the wide range of available tools/methods for estimating recharge, and the difficulty in assessing the accuracy of estimates because direct measurement of recharge rates is, for the most part, infeasible (Healy 2010, Seiler and Gat 2007).

Numerical modeling is a common approach for developing recharge estimates. Soil-water-balance modeling is one category of numerical models particularly well-suited for estimating recharge across large areas with modest data requirements. This study describes an application of the U.S. Geological Survey's (USGS) Soil Water Balance Model (SWB) (Westenbroek et al. 2010) to develop spatial and temporal distributions of groundwater recharge across Napa County. This model operates on a daily timestep and calculates surface runoff based on the Natural Resources Conservation Service (NRCS) curve number method and potential evapotranspiration based on the Hargreaves-Samani methods (Hargreaves and Samani 1985). Actual evapotranspiration (AET) and recharge are calculated using a modified Thornthwaite-Mather soil-water-balance approach (Westenbroek et al. 2010).

It is important to note that the SWB model focuses on surface and soil-zone processes and does not simulate the groundwater system or track groundwater storage over time. The model also does not simulate surface water/groundwater interaction or baseflow; thus, the runoff estimates represent only the surface runoff component of streamflow resulting from rainstorms and the recharge estimates represent only the infiltration recharge component (also referred to as diffuse recharge) of total recharge (stream-channel recharge is not simulated).

This modeling work and summary report has been prepared by O'Connor Environmental, Inc., for it's private use in relation to Water Availability Analyses (WAA) prepared on behalf of private clients for projects using groundwater in "hillside" areas of Napa County as required by Napa Planning, Building & Environmental Services. The modeling to-date is complete in its current form but remains subject to revision; it is considered a working draft with information suitable for use to support WAA projects. Parties interested in obtaining more information regarding the modeling or who may wish to offer comments should contact O'Connor Environmental, Inc.

Model Development

The model was developed using a 30-meter (98.4 ft) resolution rectangular grid. Water budget calculations were made on a daily time step. Key spatial inputs included a flow direction map developed from the USGS 1 arc-second resolution Digital Elevation Model (DEM), a land cover map derived from the U.S. Forest Service (USFS) CALVEG dataset that was supplemented by a database of agricultural areas maintained by the County of Napa (Figure 1), a distribution of Hydrologic Soil Groups (A through D classification from lowest to highest runoff potential; Figure 2), and a distribution of Available Water Capacity (AWC) developed from the NRCS Soil Survey Geographic Database (SSURGO) (Figure 3).

A series of model parameters were assigned for each land cover type/soil group combination including an infiltration rate, a curve number, dormant and growing season interception storage values, and a rooting depth (Table 1).

Infiltration rates for hydrologic soil groups A through D were applied based on Cronshey et al. (1986) (Table 2) along with default soil-moisture-retention relationships based on Thornthwaite and Mather (1957) (Figure 4). Curve numbers were assigned based on standard NRCS methods. Interception storage values and rooting depths were assigned based on literature values and from previous modeling experience including a SWB model covering Sonoma County and calibrated using runoff volumes from several stream gages (OEI 2017).

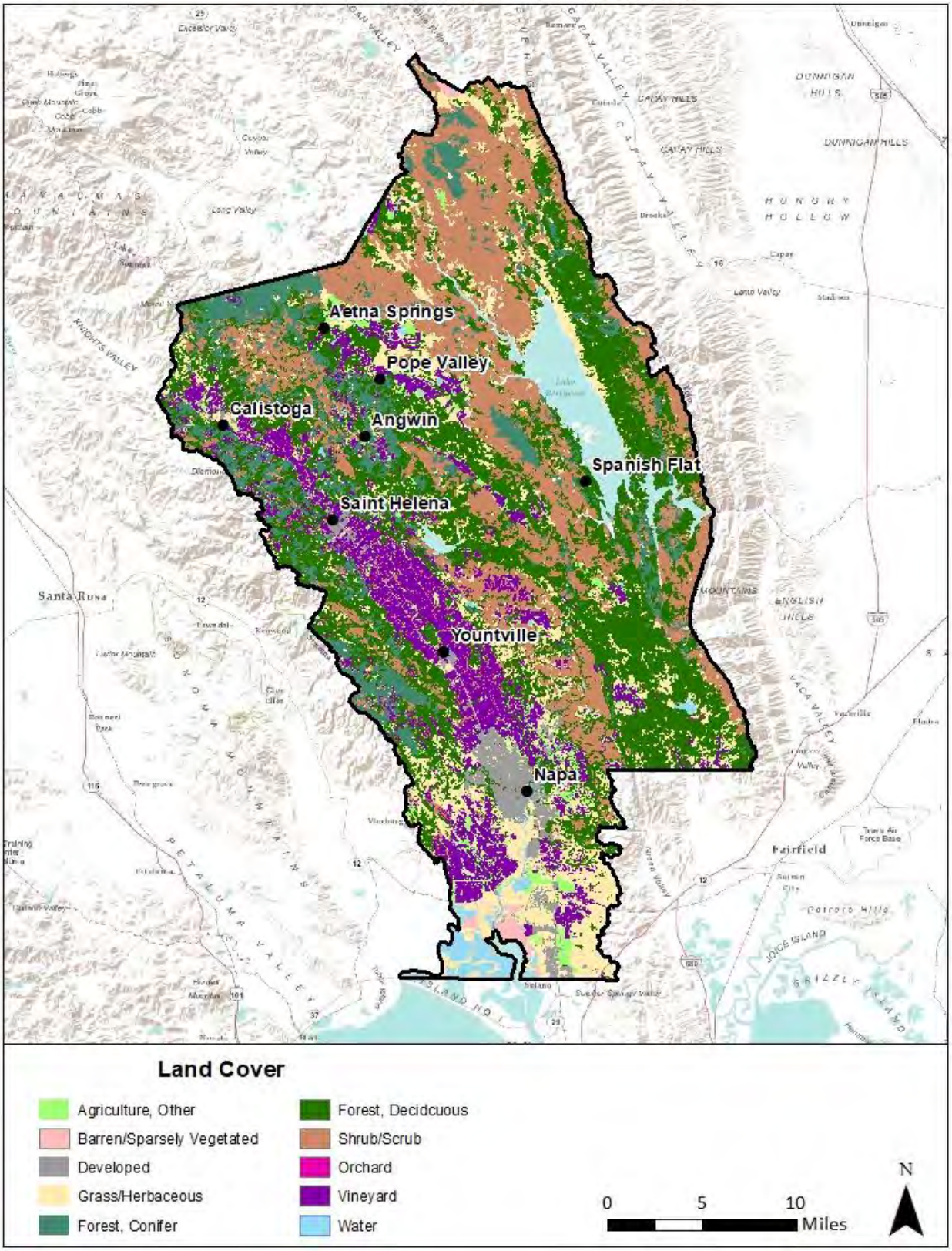


Figure 1: Land cover distribution used in the Napa County SWB model.

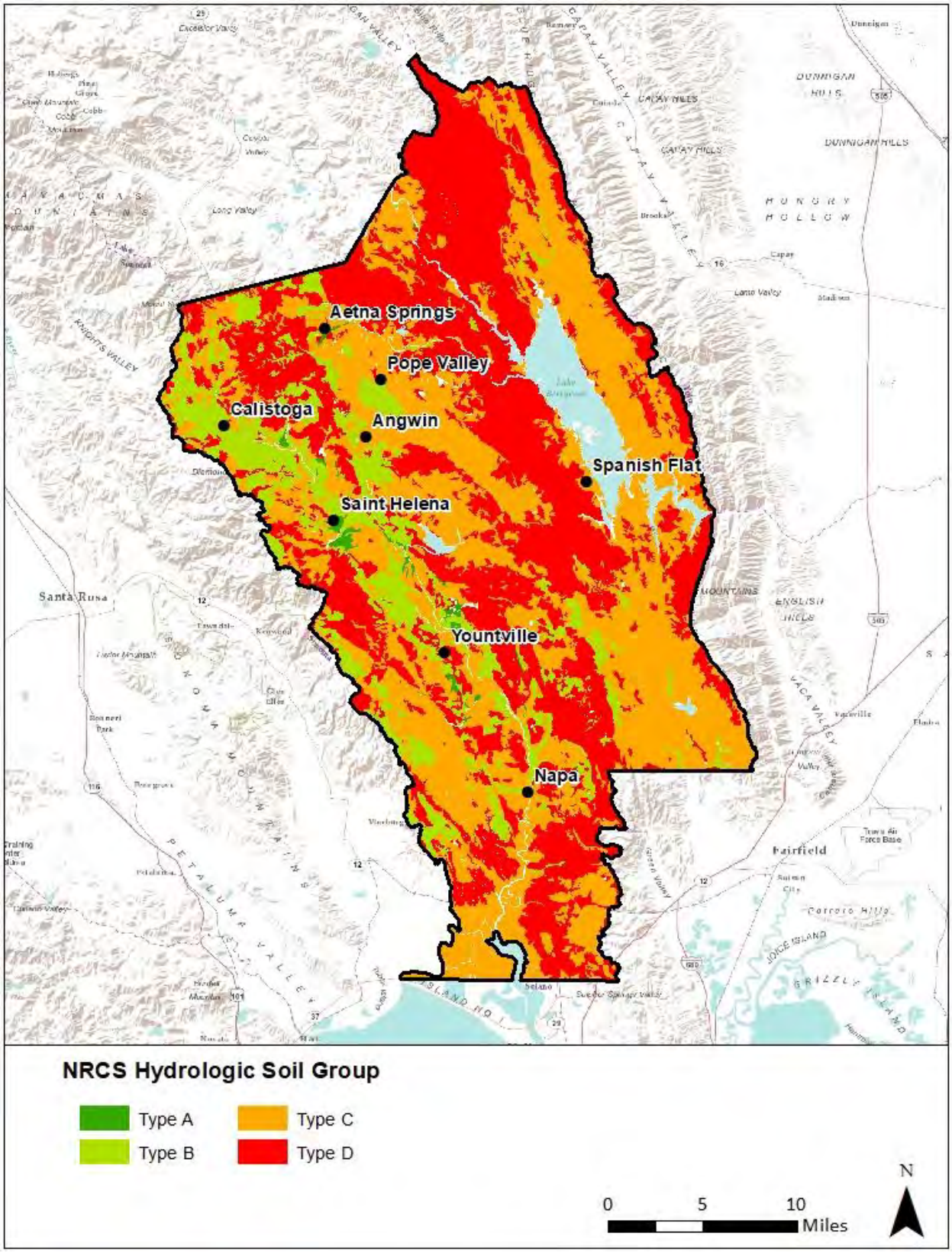


Figure 2: Hydrologic soil group distribution used in the Napa County SWB model.

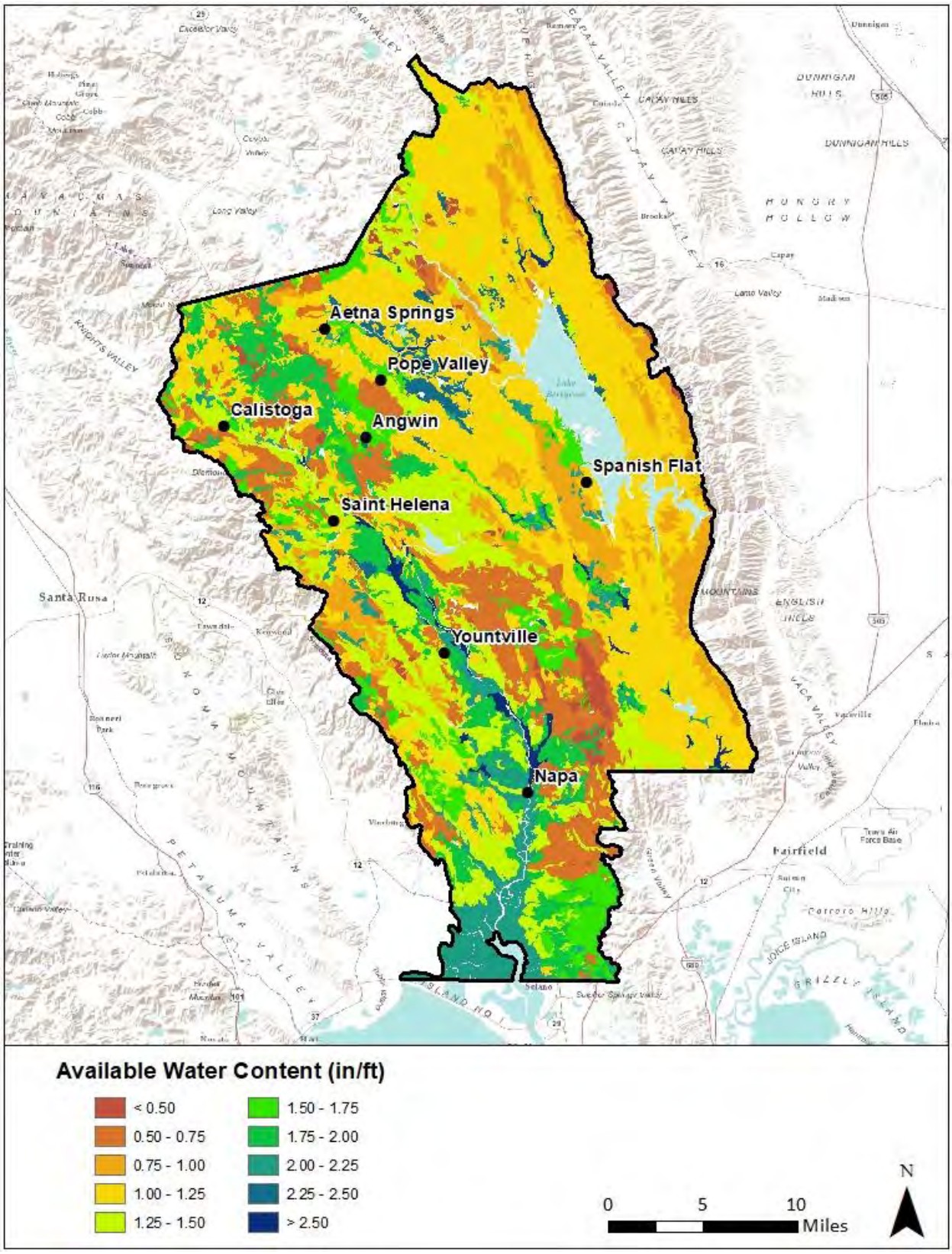


Figure 3: Available water capacity distribution used in the Napa County SWB model.

Table 1: Soil and land cover properties used in the Napa County SWB model.

Land Cover	Interception Storage Values ()		Curve Number by NRCS Soil Type ()				Rooting Depth by NRCS Soil Type (ft)			
	Growing Season	Dormant Season	Type A	Type B	Type C	Type D	Type A	Type B	Type C	Type D
Agriculture, Other	0.080	0.040	38	61	75	81	2.0	1.9	1.8	1.7
Barren	0.000	0.000	77	86	91	94	0.0	0.0	0.0	0.0
Developed	0.005	0.002	61	75	83	87	2.3	2.1	2.0	1.8
Grassland/Herbaceous	0.005	0.004	30	58	71	78	1.3	1.1	1.0	1.0
Forest, Coniferous	0.050	0.050	30	55	70	77	5.9	5.1	4.9	4.7
Forest, Deciduous	0.050	0.020	30	55	70	77	5.9	5.1	4.9	4.7
Shrub/Scrub	0.080	0.015	30	48	65	73	3.2	2.8	2.7	2.6
Orchard	0.050	0.015	38	61	75	81	3.2	2.8	2.7	2.6
Vineyard	0.080	0.015	38	61	75	81	2.2	2.1	2.0	1.9
Water	0.000	0.000	100	100	100	100	0.0	0.0	0.0	0.0

Table 2: Infiltration rates for NRCS hydrologic soil groups (Cronshey et al. 1986).

Soil Group	Infiltration Rate (in/hr)
A	> 0.3
B	0.15 - 0.3
C	0.05 - 0.15
D	<0.05

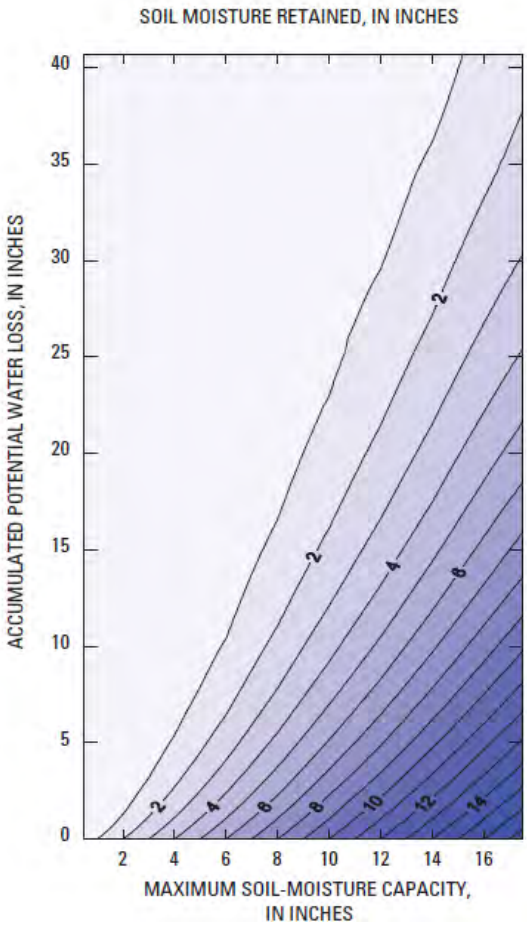


Figure 4: Soil-moisture-retention table (Thornthwaite and Mather 1957).

The SWB model utilizes daily precipitation and mean daily temperature data derived from climate stations. To account for the spatial variability of these parameters, daily precipitation and mean daily temperature were input as gridded (spatially-distributed) time-series. The gridded precipitation time-series was created using data from 15 weather stations in Napa County, and the gridded mean temperature time-series was created using data from 8 stations (Table 3). These stations were selected based on completeness of the records and to provide station data representative of the range of climates experienced in the county. Data was obtained from the California Data Exchange Center (CDEC), the National Climatic Data Center (NCDC), and from Napa One Rain.

To create the gridded time-series, the model domain was divided into discrete areas represented by individual weather stations (Figures 5 and 6). This delineation was based on climate variations described by existing gridded mean annual (1981-2010) precipitation and temperature data (PRISM 2010) and local knowledge of climatic variations across the county.

For the precipitation time-series, each area representing a weather station was subdivided into four to twenty-three zones based on 1-inch average annual precipitation contours. Within each zone the raw station data was multiplied by a unique scaling factor. This scaling factor was calculated as the ratio of average annual precipitation within a zone to average annual precipitation at the representative rain gage. In certain locations, typically near the boundary of areas represented by gages located on the valley bottom and at higher elevations, this scaling was unable to smoothly resolve differences in annual and event precipitation totals. To more accurately estimate precipitation near these boundaries, precipitation records from the two gages in question were averaged using weights calculated proportionally to the difference between PRISM mean annual precipitation at a rain gage and within a selected zone. The resulting gridded time-series is comprised of 220 individual time-series based on the scaled station data from 15 stations.

The assignment of temperature stations was based on the understanding that the spatial variability of temperatures across Napa County is relatively homogenous, with elevation being the primary variable. Temperature records were classified either as Mountain, Valley Bottom, or East County and applied within areas the PRISM datasets described as being similar. To smooth the transition from Mountain zones to Valley Bottom and East County zones, Hillside zones were created where the temperature records of the two nearest gages were averaged.

Missing and suspect data was encountered in the raw precipitation and temperature data from the weather stations used by the model. Values that were significantly outside the typical range, and where similar observations were not found at nearby stations, were removed from the datasets. These and missing values were filled using scaled data from other nearby stations. Precipitation data used for gap filling was scaled using the ratio of the 1981 to 2010 mean annual precipitation (PRISM 2010) between the two stations. Temperature data was scaled using the ratio of the 1981 to 2010 mean monthly minimum and maximum temperatures (PRISM 2010) between the two stations.

The current analysis focuses on Water Year 2010 (October 1, 2009 – September 30, 2010) and Water Year 2014 (October 1, 2013 – September 30, 2014). These years were selected because they represent periods with data available from most weather stations in the county and where most stations reported annual precipitation totals close to the long-term average (WY 2010) and significantly below the long term average (WY 2014). Based on a comparison between station data and PRISM average precipitation depths during Water Year 2010, rainfall averaged 101% of long-term average conditions and ranged from 78% at Lake Hennessey to 111% at the Napa County Airport. In Water Year 2014, rainfall averaged 55% of long-term average conditions and ranged from 41% at Lake Hennessey to 73% at the Napa State Hospital (Table 3).

Table 3: Weather stations used in the Napa County SWB model. See Figures 7- 9 for associated timeseries.

Station	Data Used	1981 - 2010 Mean Annual Precip (in)	WY 2010		WY 2014	
			Precip (in)	% Avg	Precip (in)	% Avg
Angwin[1]	Precip & Temp	42.54	44.64	105%	25.04	59%
Atlas Peak[1]	Precip & Temp	41.76	39.04	93%	20.08	48%
Berryessa[1]	Precip & Temp	28.97	28.16	97%	13.97	48%
Calistoga[2]	Precip	39.41	41.75	106%	18.18	46%
Knoxville Creek[1]	Temp Only	-	-	-	-	-
Lake Hennessey[3]	Precip Only	34.09	26.52	78%	13.92	41%
Mt. George[3]	Precip Only	31.15	29.64	95%	18.24	59%
Mt. Veeder[3]	Precip Only	44.81	46.44	104%	28.6	64%
Napa County Airport[2]	Precip & Temp	21.14	23.56	111%	9.87	47%
Napa River at Yountville Cross Rd[3]	Precip Only	31.86	32.72	103%	14.93	47%
Napa State Hospital[2]	Precip & Temp	26.81	28.85	108%	19.66	73%
Petrified Forest[3]	Precip Only	42.39	46.6	110%	22.84	54%
Redwood Creek At Mt. Veeder Road[3]	Precip Only	34.71	37.36	108%	23.48	68%
Saint Helena[2]	Precip & Temp	37.43	39.11	104%	19.11	51%
Saint Helena 4WSW[1]	Precip & Temp	45.44	47.88	105%	28.88	64%
Sugarloaf Peak[3]	Precip Only	32.20	26.16	81%	17.12	53%

1 – Data accessed from California Data Exchange Center (CDEC)
2 – Data accessed from National Climate Data Center (NCDC)
3 – Data access from Napa One Rain

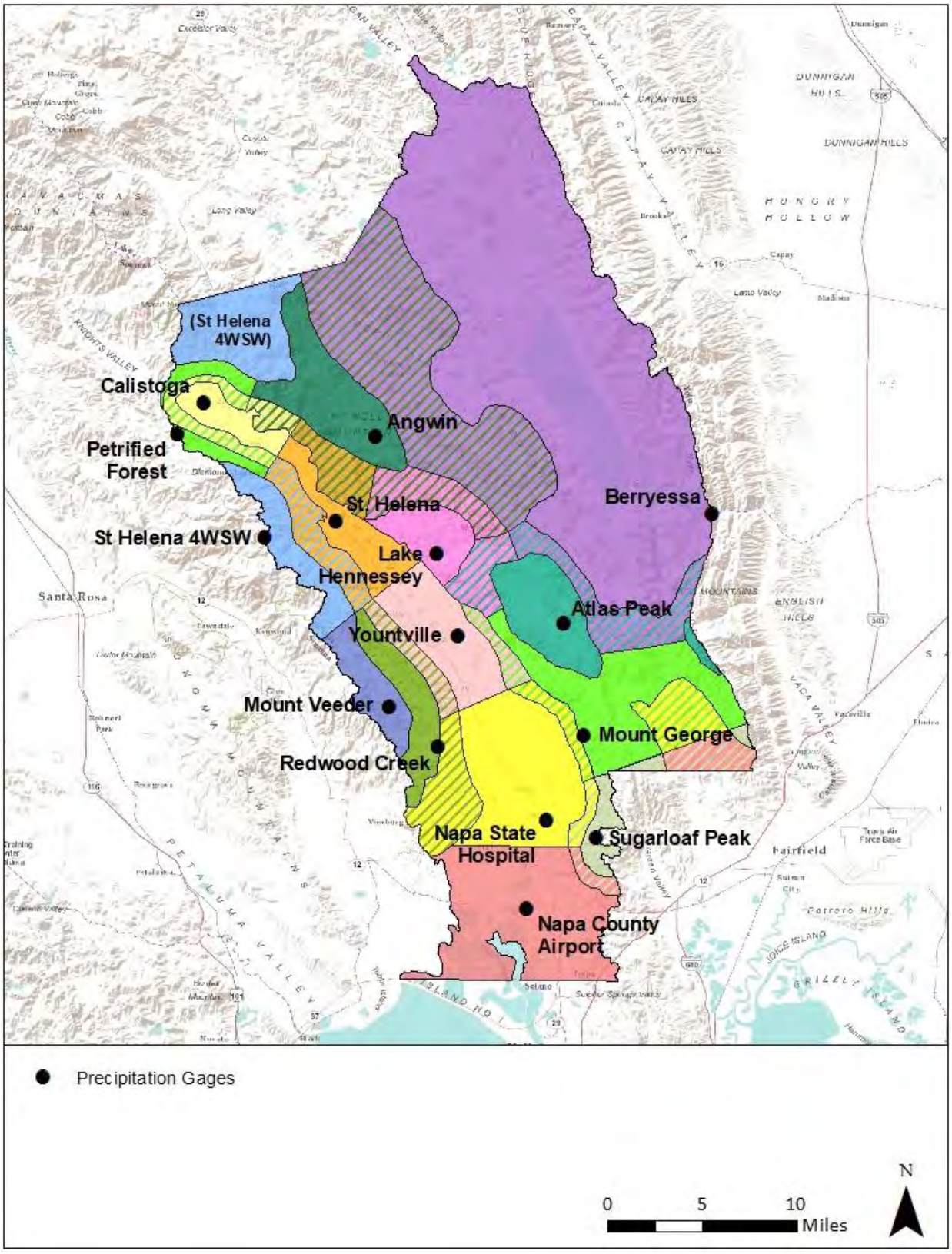


Figure 5: Precipitation zones used in the Napa County SWB model. Hatching indicates areas where two precipitation records were averaged across a zone.

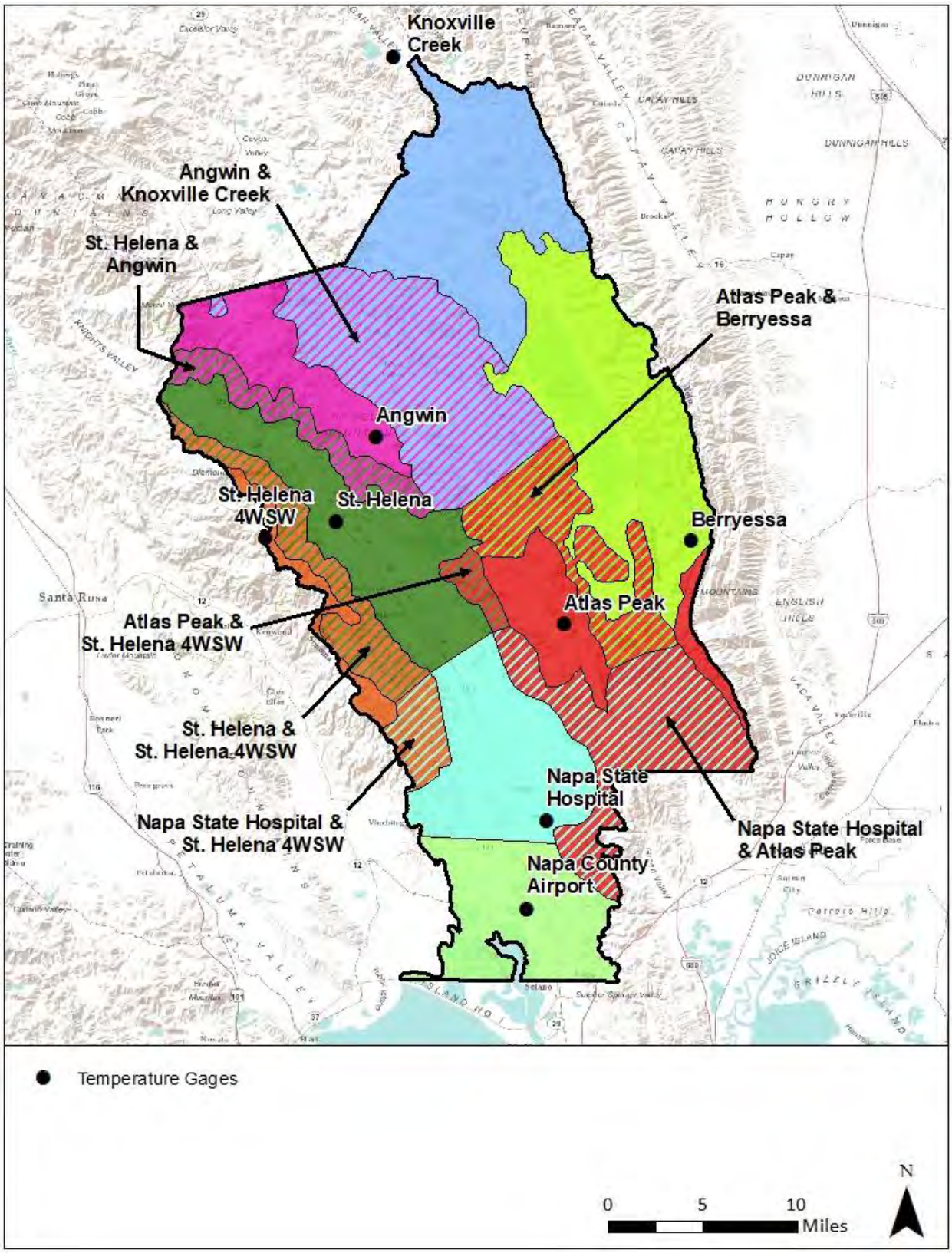


Figure 6: Temperature zones used in the Napa County SWB model. Hatching indicates areas where two temperature records were averaged across a zone.

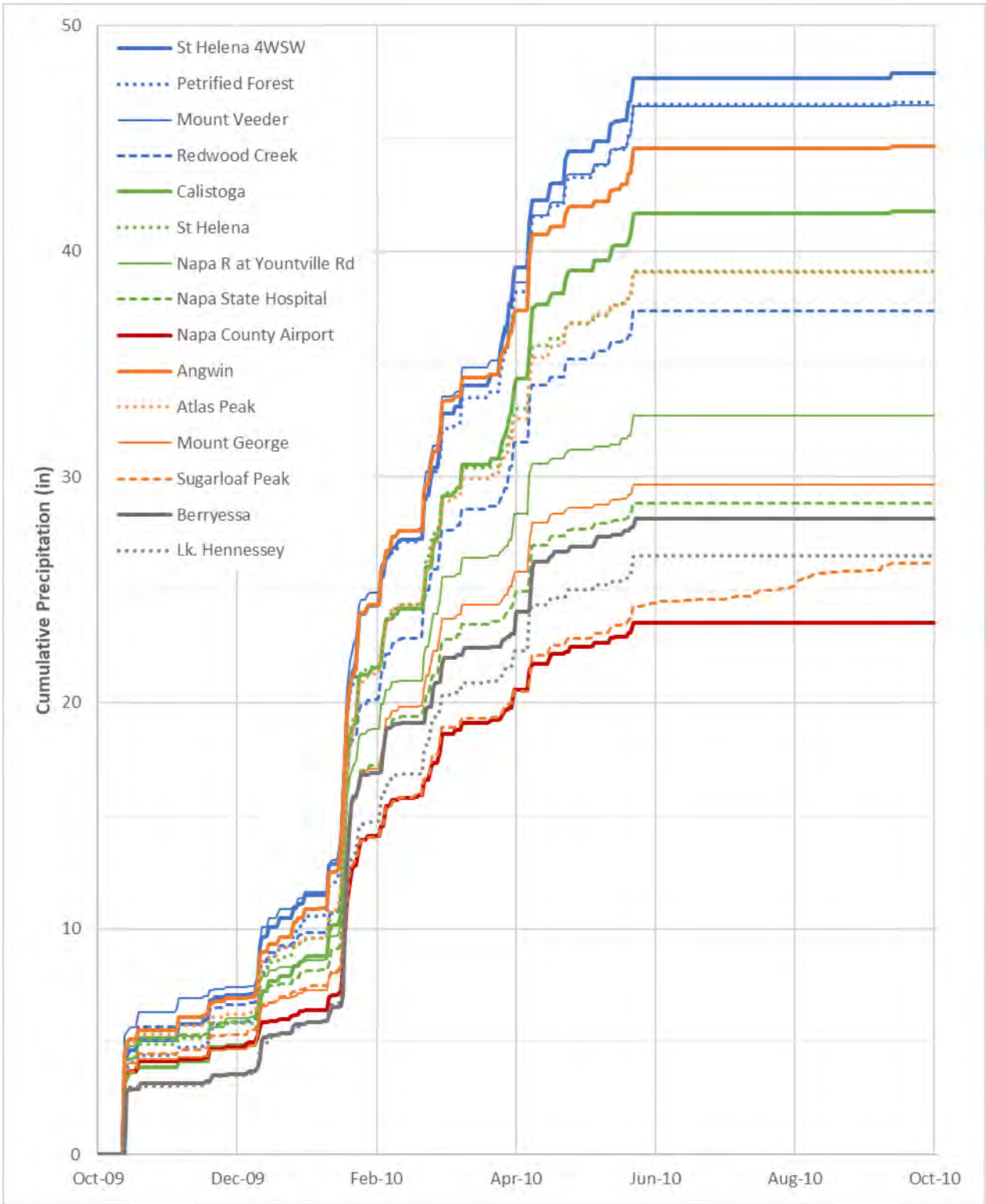


Figure 7a: Daily precipitation data used in the Napa County SWB model for WY 2010.

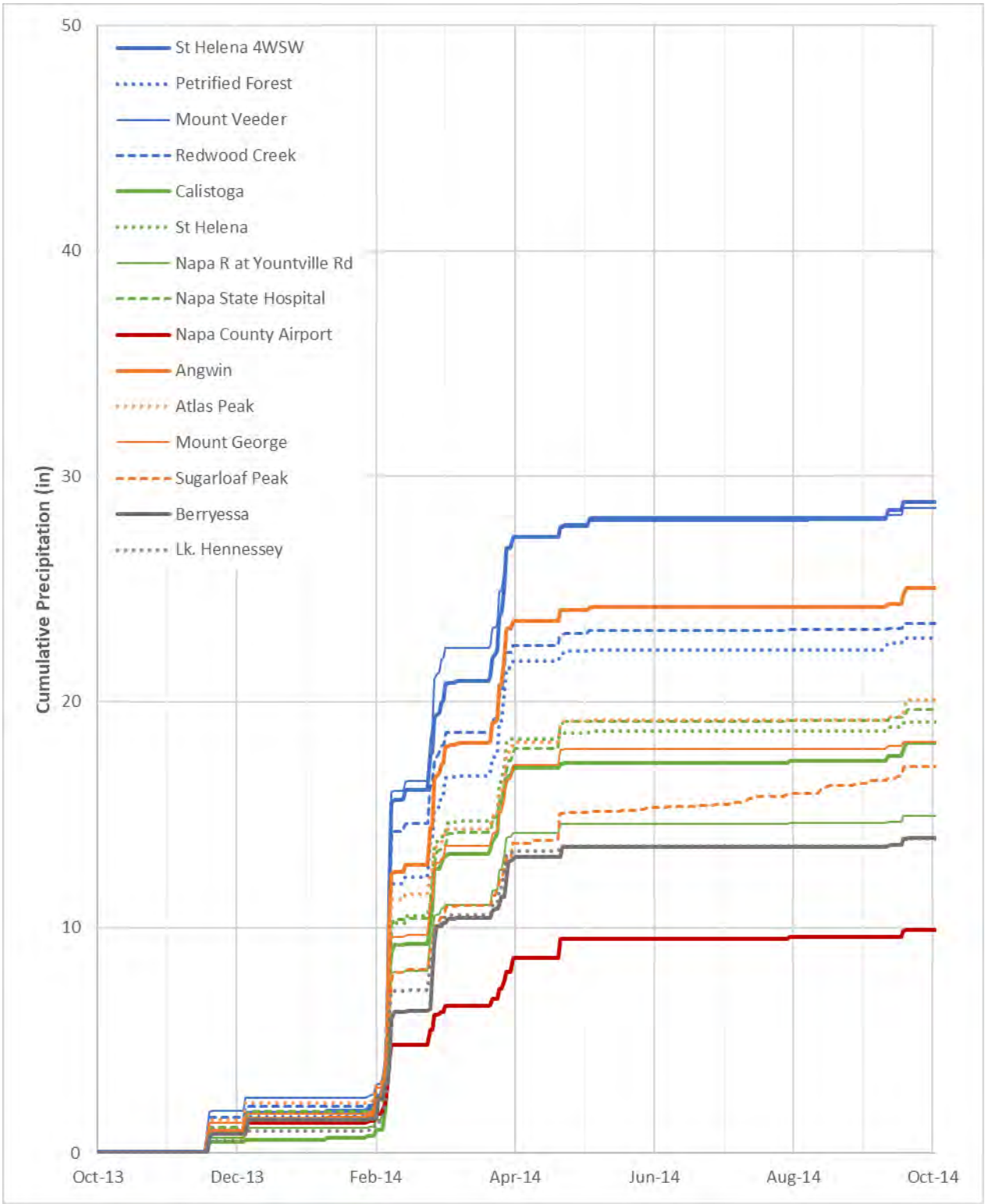


Figure 7b: Daily precipitation data used in the Napa County SWB model for WY 2014.

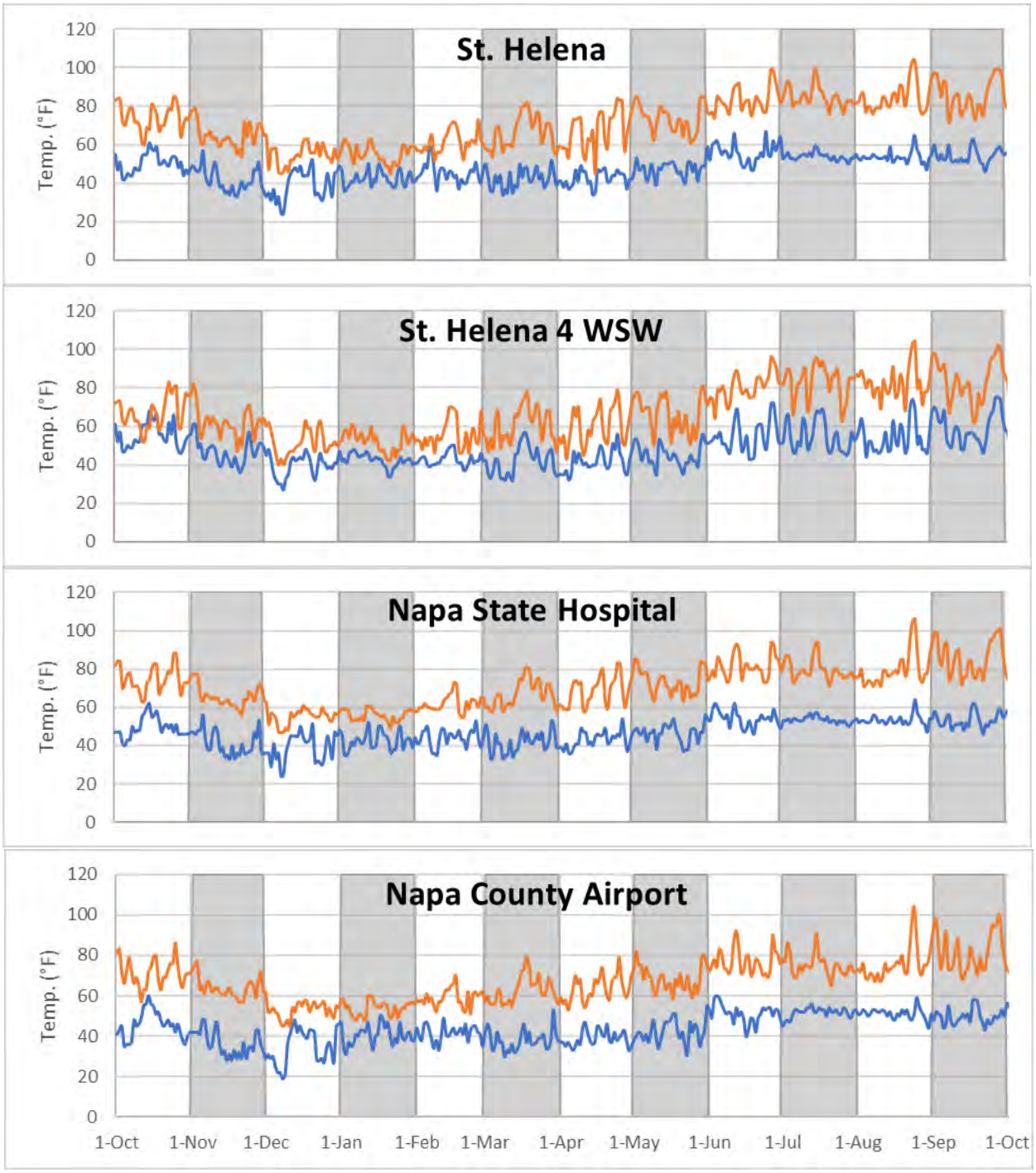


Figure 8: Daily minimum and maximum temperature data used in the Sonoma County SWB model for WY 2010.

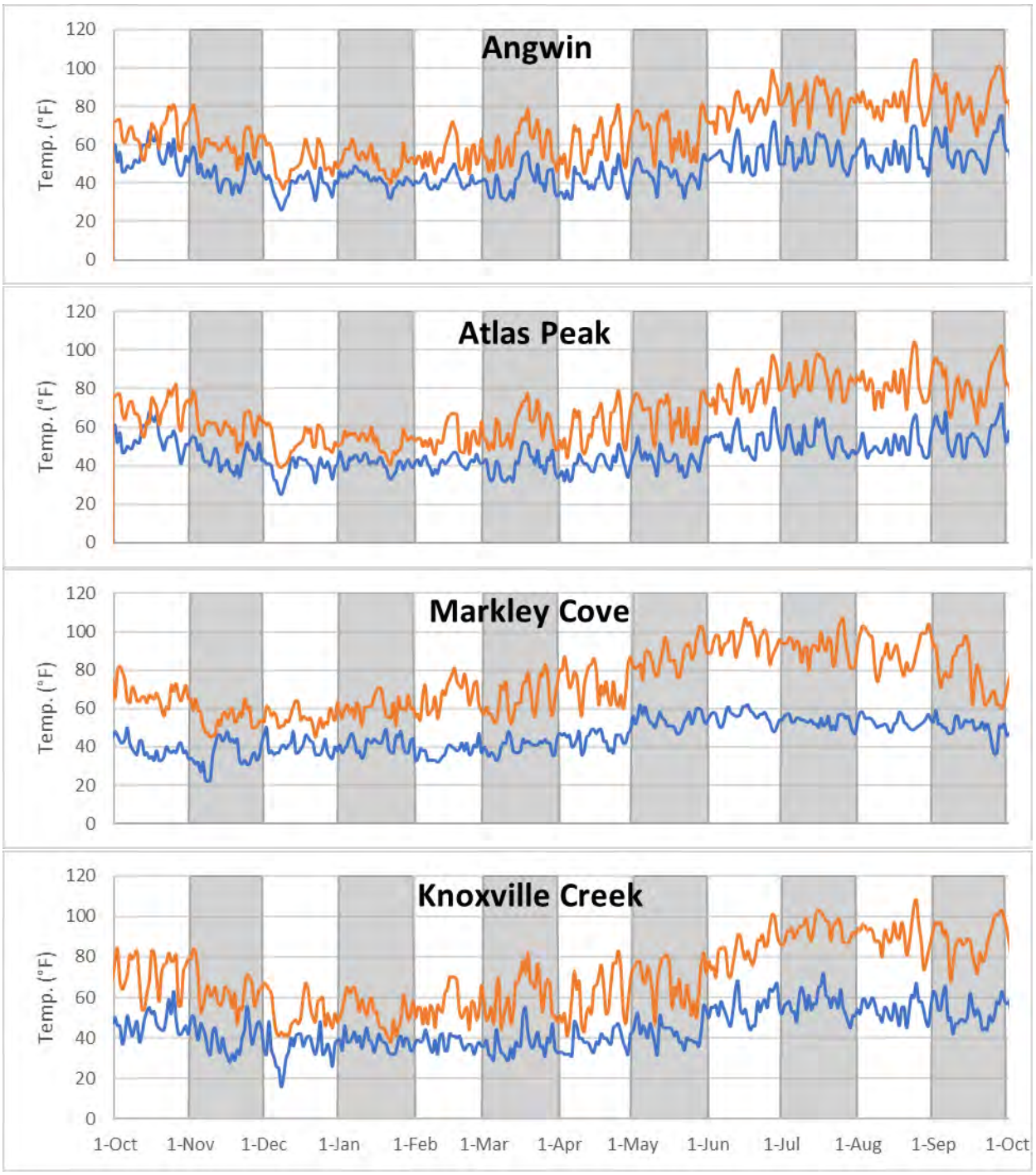


Figure 8 – cont.

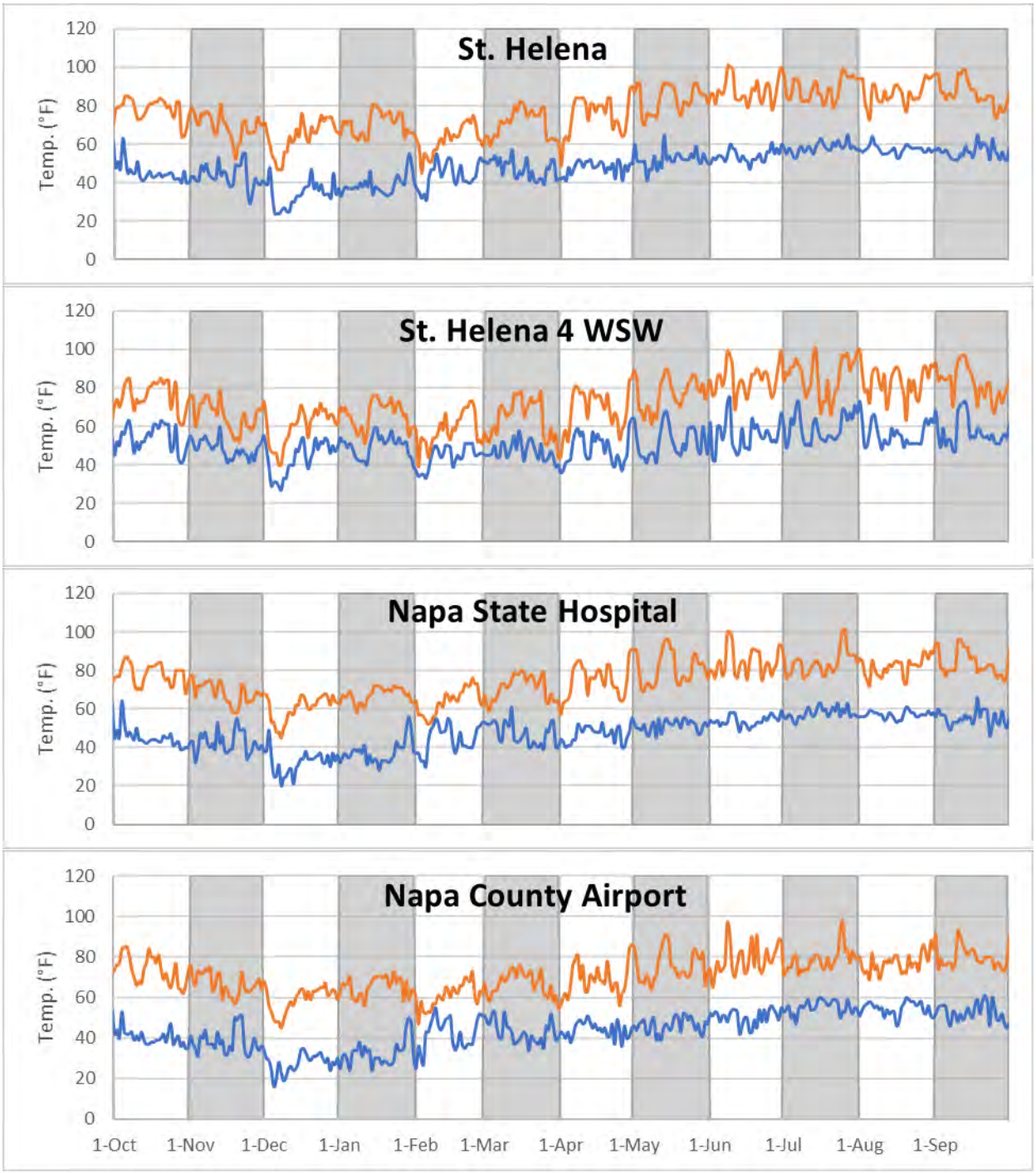


Figure 9: Daily minimum and maximum temperature data used in the Sonoma County SWB model for WY 2010.

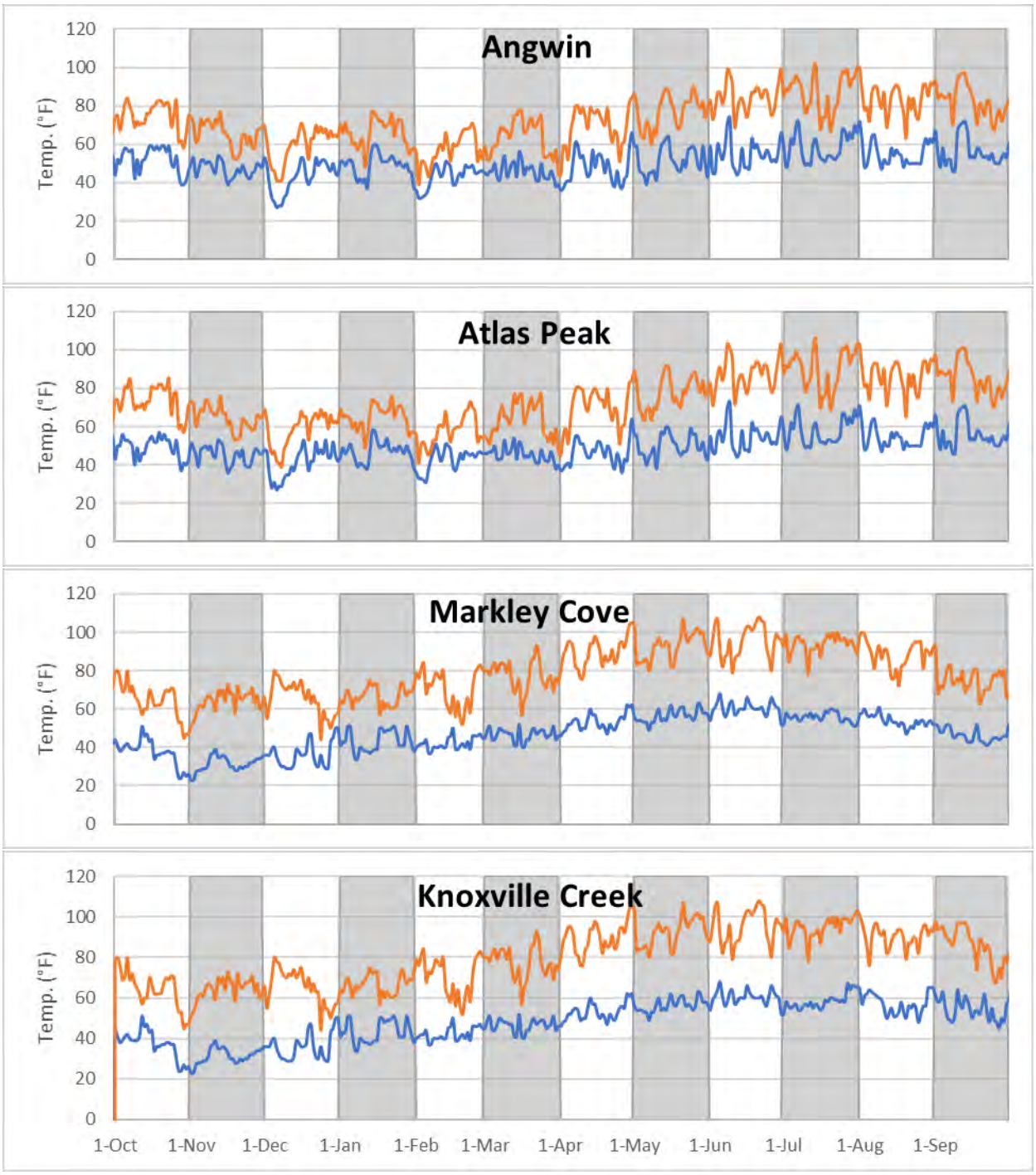


Figure 9 – cont.

Model Calibration

Available data are insufficient to calibrate the Water Year 2010 and 2014 SWB simulations; however, the land cover and soil properties used in the model were obtained from a previously prepared and calibrated SWB model of Sonoma County (OEI 2017). The Sonoma County model was calibrated against total monthly runoff volumes derived using baseflow separation of streamflow data for five watersheds within Sonoma County. Gages were selected because they represented relatively small watersheds (1.2 – 14.3 mi^2) without significant urbanization, diversions, groundwater abstraction, reservoir impoundments, or large alluvial bodies where significant exchanges between surface water and groundwater may be expected. These attributes are desirable because the hydrographs can more readily be separated into surface runoff and baseflow components and the surface runoff pattern is more directly comparable to the SWB simulated surface runoff which does not account for water use, reservoir operations, or surface water/groundwater exchange.

SWB utilizes a simplified routing scheme whereby surface runoff is routed to downslope cells or out of the model domain on the same day in which it originates as rainfall, thus it is not capable of accurately estimating streamflow over short time periods. The use of the total monthly surface runoff volumes provided a means of calibrating the Sonoma County SWB model to measured surface runoff data within the limitations of the model's approach to simulating surface runoff.

The SWB model of Sonoma County reproduced seasonal variations in surface runoff in all five calibration watersheds. Monthly Mean Errors (ME) ranged from -0.2 to 0.4 inches with a mean value of 0.1 inches. Annual surface runoff totals ranged from an under-prediction of approximately 10% at Franchini Creek to an over-prediction of approximately 19% at Buckeye Creek, with a mean over-prediction of approximately 6% across the five watersheds. These results indicate that the SWB model was able to reproduce monthly surface runoff volumes with a reasonable degree of accuracy and that the model tends to over-predict surface runoff somewhat, suggesting that the model may generate a low-range estimate of recharge.

Although the climate in Napa County is slightly drier than in Sonoma County, the vegetation, soils, and geology are similar and parameters calibrated using data from Sonoma County should be applicable to Napa County. Calibration of the Napa County SWB model was not performed due to a lack of publicly-available contemporary discharge records in suitable watersheds. Contemporary discharge records exist for USGS gaging stations located along the Napa River near St. Helena and Napa, but the watersheds above these gages are large and contain significant groundwater abstraction, reservoir impoundments, and alluvial bodies. USGS gages on smaller watersheds in Napa County have been inactive since 1983 or earlier. Discharge records exist through Napa One Rain for several streams gaged by the Napa County Resource Conservation District (RCD) but the RCD has cautioned against use of these discharge records for calibration purposes due to incomplete rating curve development.

Estimates of groundwater recharge are also available from an earlier model prepared by Luhdorff and Scalmanini Engineers and MBK Engineers (LSCE 2013). This report provided estimates of average annual recharge as a percentage of average annual precipitation for nine watersheds in Napa County. Averaged across the same nine watersheds, the SWB model predicts significantly higher rates of recharge than the model prepared by LSCE, which predicts slightly lower AET but significantly more runoff (Table 4). Differences in methodology between these two models complicate direct comparisons. The LSCE model calculated infiltration into the soil as the difference between monthly precipitation and discharge volumes within each watershed. Discharge volumes were calculated from USGS stream gages and included both direct runoff and baseflow from groundwater. Inclusion of baseflow with direct runoff in these calculations may inappropriately reduce the estimated volume of water infiltrated into the soil and available for recharge.

Table 4: Comparison of results from SWB model and Luhdorff and Scalmanini model.

USGS Gage	HUC	Mean Precip, 2010 (in)	Mean AET, 2010 (% Precip)		Mean Runoff, 2010 (% Precip)		Mean Recharge, 2010 (% Precip)	
			SWB	LSCE	SWB	LSCE	SWB	LSCE
Conn Ck nr Oakville	11456500	34.8	59%	53%	21%	25%	21%	21%
Dry Ck nr Napa	11457000	41.5	56%	50%	18%	43%	25%	6%
Milliken Ck nr Napa	11458100	32.3	52%	41%	20%	51%	28%	8%
Napa Ck at Napa	11458300	36.6	61%	43%	16%	46%	23%	11%
Napa R nr Napa	11458000	39.5	56%	48%	20%	35%	24%	17%
Napa R nr St Helena	11456000	47.9	46%	45%	23%	42%	30%	14%
Redwood Ck nr Napa	11458200	39.6	53%	49%	26%	40%	22%	10%
Tulucay Ck nr Napa	11458300	27.0	64%	49%	16%	47%	20%	5%

Model Results

The principal elements of the annual water budget simulated with the Napa County SWB model for Water Years 2010 and 2014 are presented in map form in Figures 10 - 19 and in tabular form for 27 major watershed areas in Napa County (Tables 5 - 8). The watersheds are based on USGS HUC-12 watersheds and are named for the stream which comprises the largest proportion of the area; in many cases the areas consist of multiple tributary streams (Figure 20).

In Water Year 2010 (representing "average" hydrologic conditions) precipitation varied from 21.8 inches in the Ledgewood Creek watershed to 53.3 inches in the Saint Helena Creek watershed (Figure 10, Table 5). Actual evapotranspiration (AET) ranged from 13.4 inches in the Jackson Creek watershed to 25.2 inches in the Saint Helena Creek watershed (Figure 11). Surface runoff ranged from 3.4 inches in the Ledgewood Creek watershed to 13.5 inches in the Saint Helena Creek watershed (Figure 12). Recharge ranged from 3.3 inches in the Ledgewood Creek watershed to 14.4 inches in the Saint Helena watershed. (Figure 13). Small decreases in soil moisture storage (up to 1.8 inches) occurred in most watersheds, with changes in most

watersheds being less than an inch (Figure 14). Note that the San Pablo Bay estuaries have been excluded from these comparisons.

Expressed as a percentage of the annual precipitation, AET ranged from 77% in the Ledgewood Creek watershed to 45% in the Jackson Creek watershed (Table 6). Surface runoff ranged from 15% of precipitation in the Ledgewood Creek watershed to 42% in the Jackson Creek watershed. Recharge ranged from 10% of the precipitation in the Jackson Creek watershed to 27% in the Saint Helena watershed.

In Water Year 2014 (representing "dry" hydrologic conditions during the second year of an extreme three-year drought) precipitation varied from 10.1 inches in the American Canyon Creek watershed to 32.2 inches in the Saint Helena Creek watershed (Figure 15, Table 7). Actual evapotranspiration (AET) ranged from 10.3 inches in the Jackson Creek watershed to 17.8 inches in the Saint Helena Creek watershed (Figure 16). Surface runoff ranged from 0.7 inches in the American Canyon Creek watershed to 13.2 inches in the Saint Helena Creek watershed (Figure 17). Recharge ranged from 0.6 inches in the Wragg Canyon watershed to 4.1 inches in the Saint Helena watershed. (Figure 18). Large decreases in soil moisture storage of between 2.3 and 4.3 inches were also simulated (Figure 19).

Expressed as a percentage of the annual precipitation, AET ranged from 55% in the Saint Helena Creek watershed to 121% in the Jackson Creek watershed (Table 8). These very large AET rates caused significant decreases in soil moisture. Decreases in soil moisture ranged from 9% of precipitation in the Saint Helena watershed to 36% in the American Canyon Creek watershed. Surface runoff ranged from 7% of precipitation in the American Canyon Creek watershed to 41% in the Saint Helena Watershed. Recharge ranged from 18% in the Milliken Creek Watershed to 5% in the Jackson Creek and Wragg Canyon watersheds.

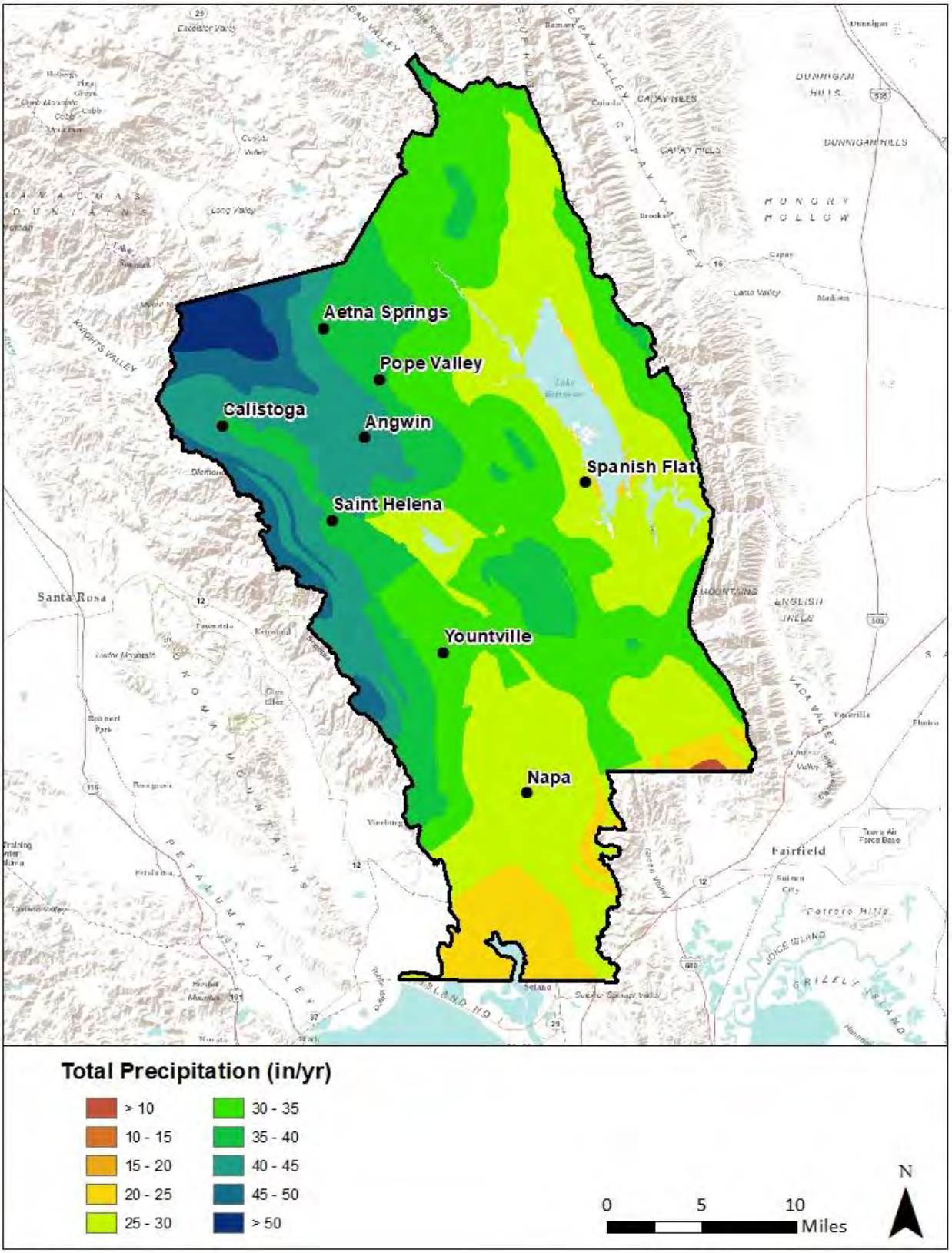


Figure 10: Water Year 2010 precipitation simulated with the Napa County SWB model.

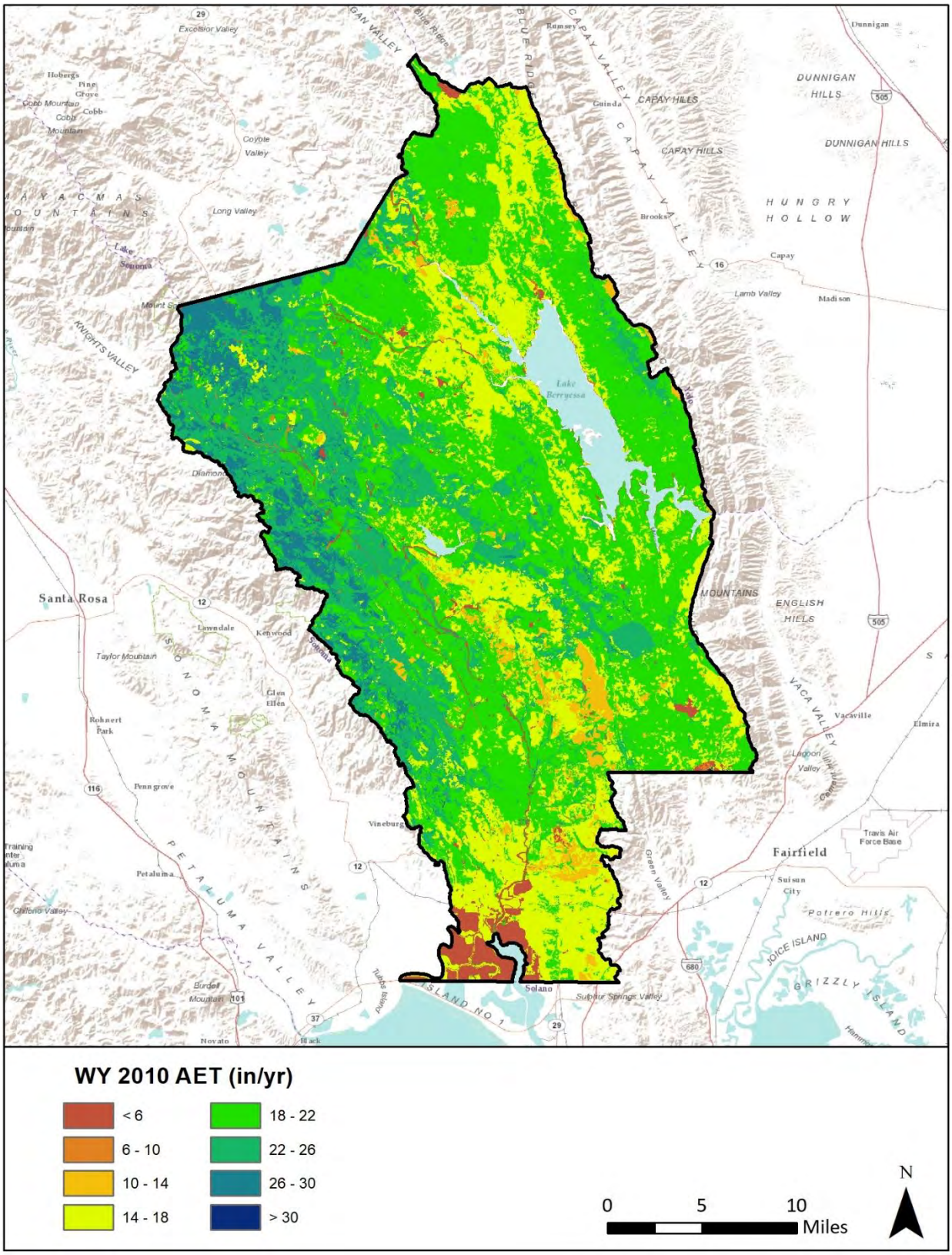


Figure 11: Water Year 2010 AET simulated with the Napa County SWB model.

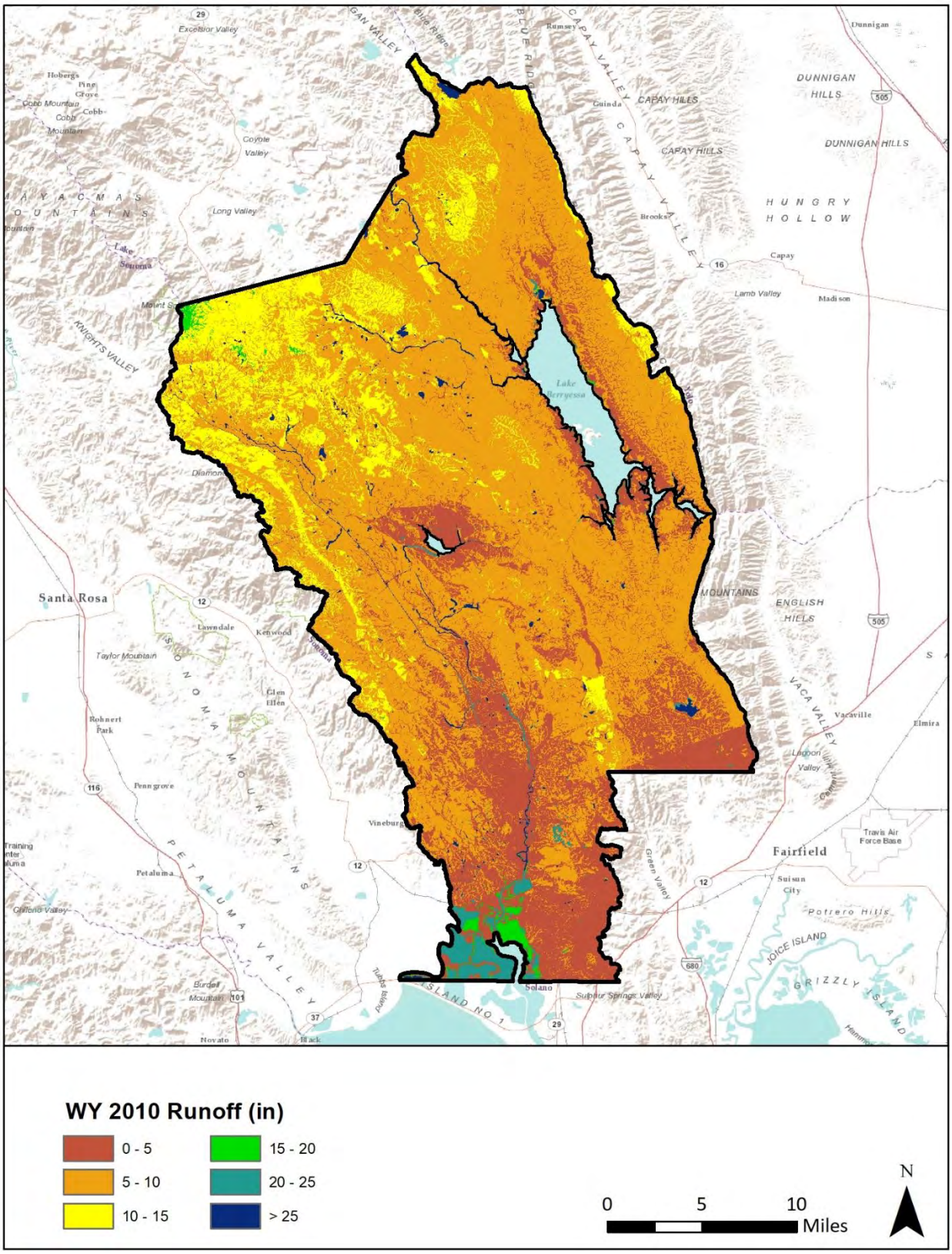


Figure 12: Water Year 2010 runoff simulated with the Napa County SWB model.

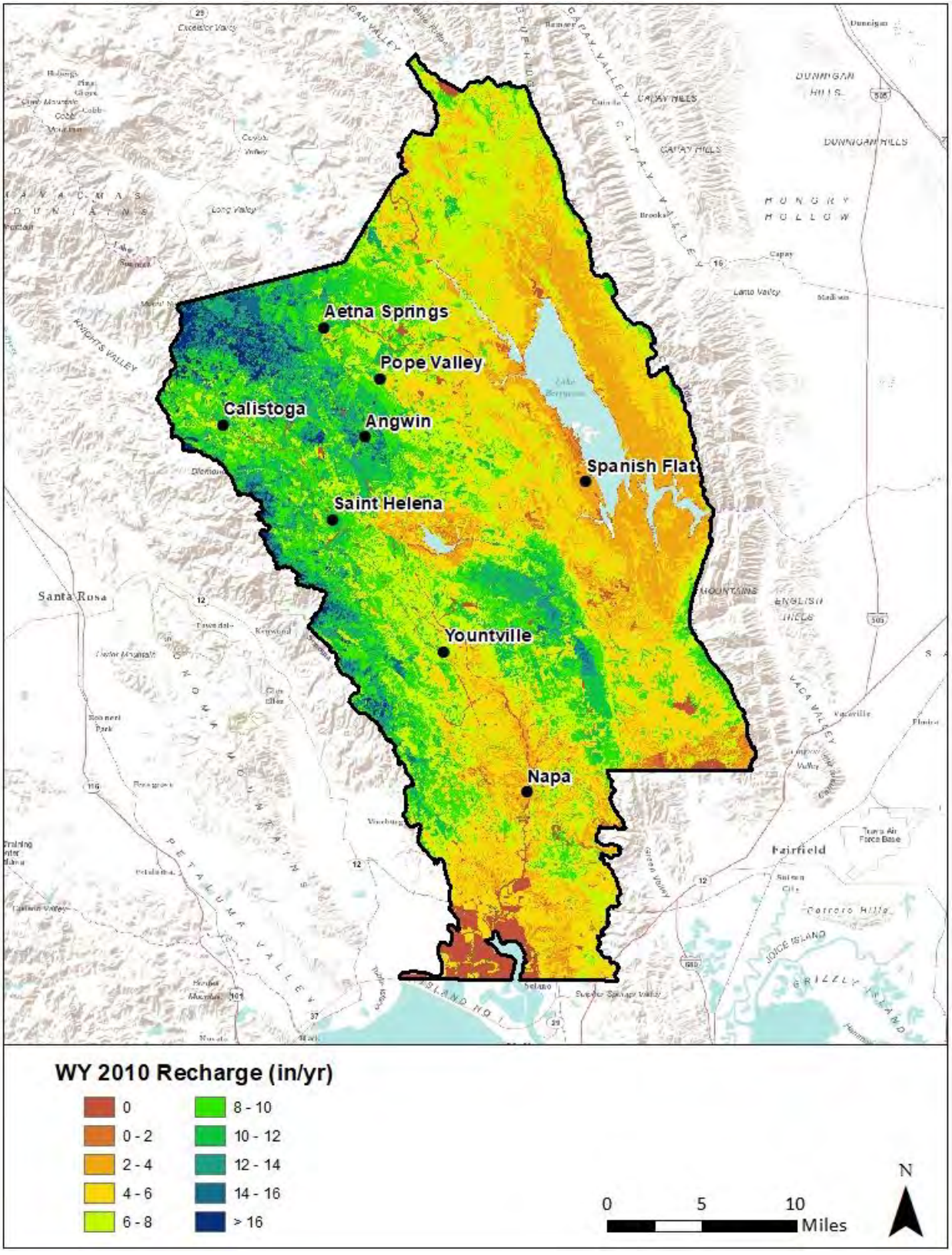


Figure 13: Water Year 2010 recharge simulated with the Napa County SWB model.

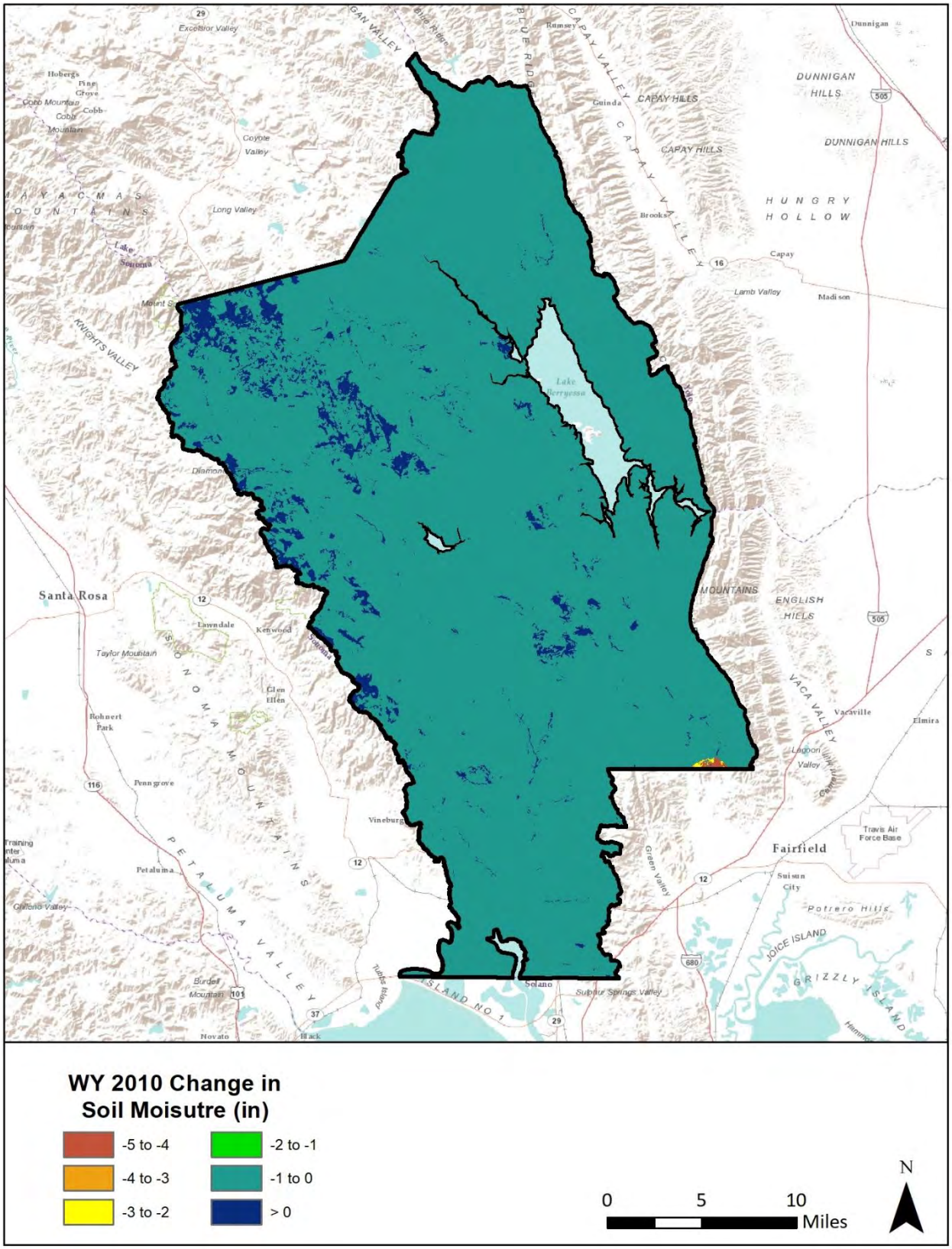


Figure 14: Water Year 2010 change in soil moisture content simulated with the Napa County SWB model.

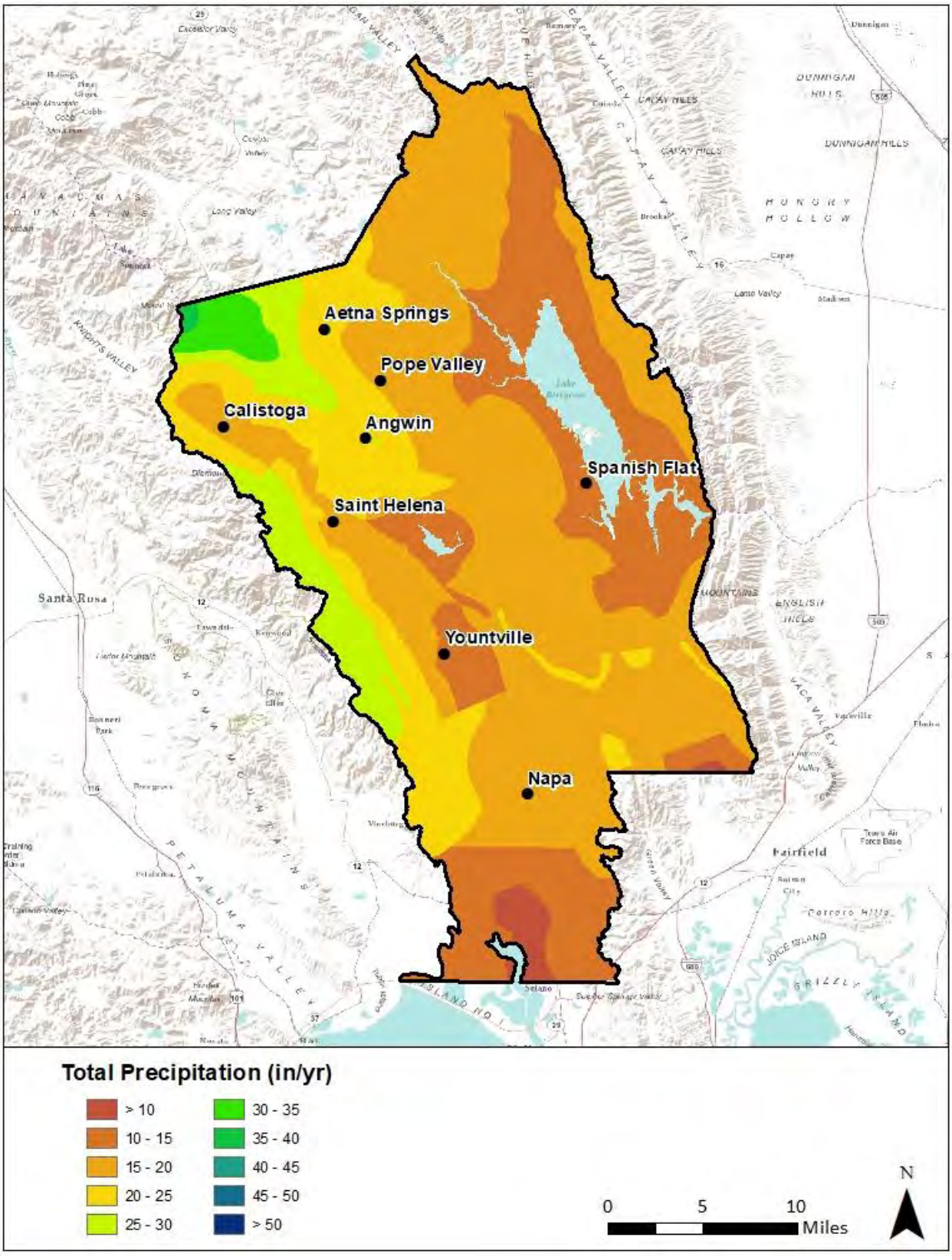


Figure 15: Water Year 2014 precipitation simulated with the Napa County SWB model.

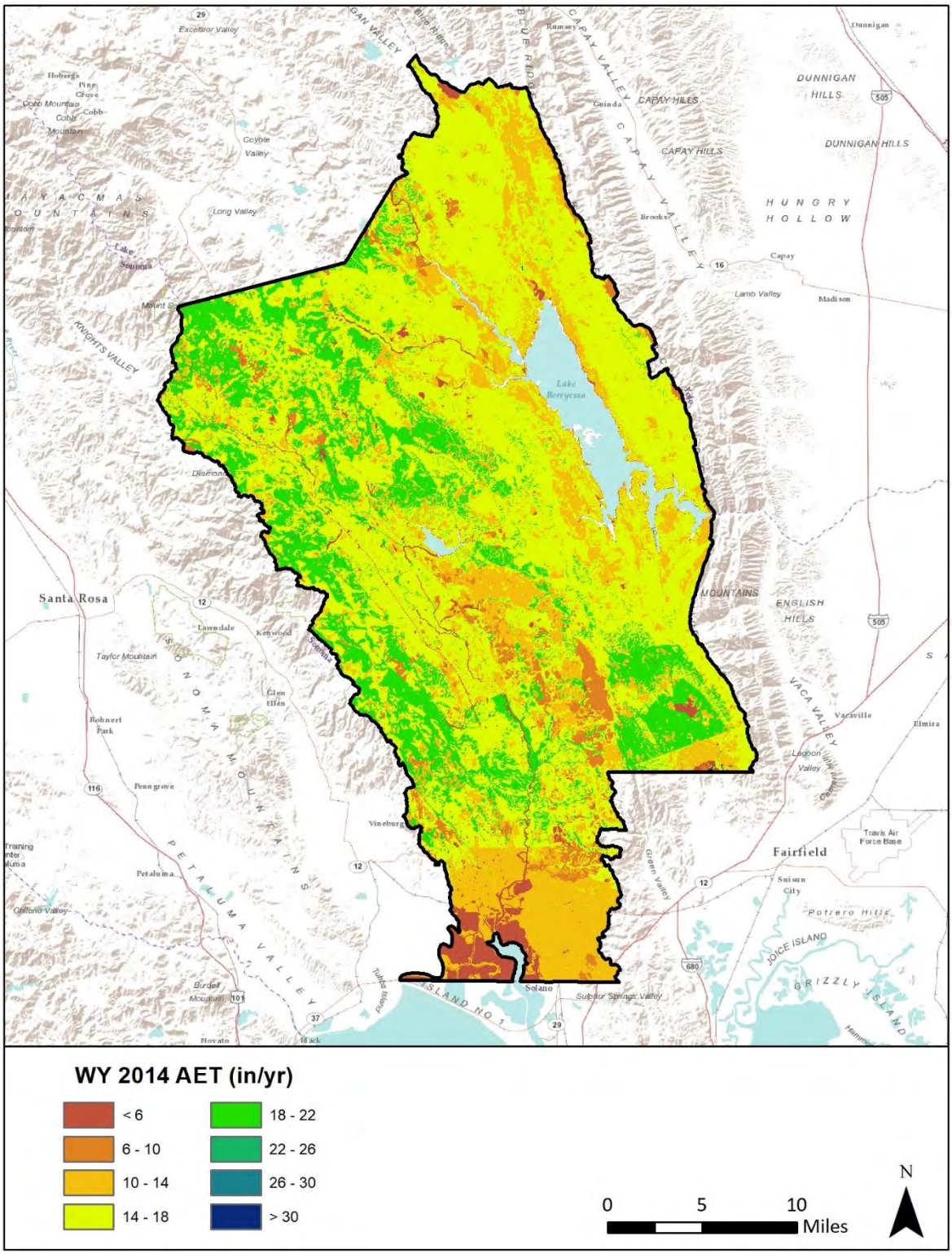


Figure 16: Water Year 2014 AET simulated with the Napa County SWB model.

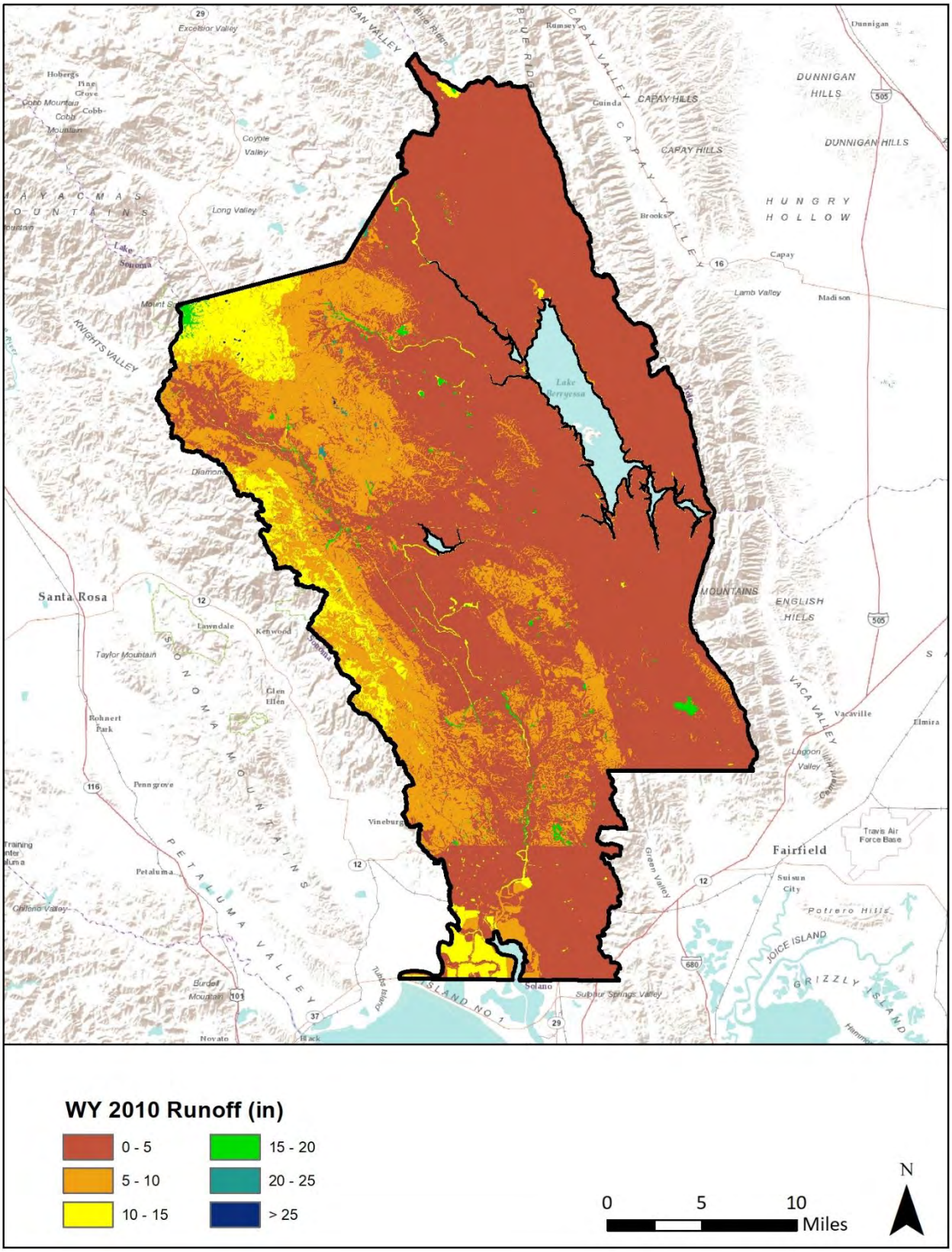


Figure 17: Water Year 2014 recharge simulated with the Napa County SWB model.

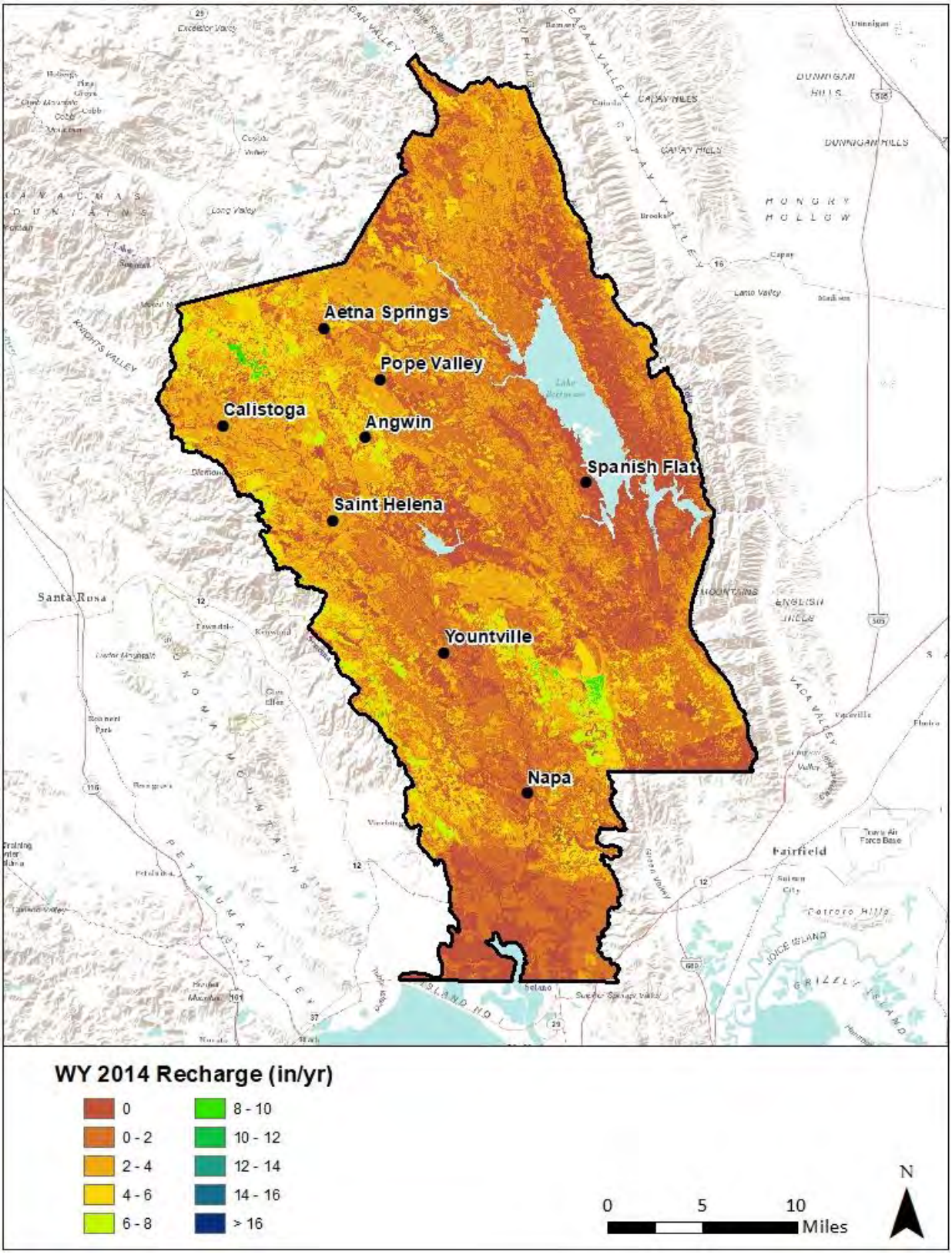


Figure 18: Water Year 2014 recharge simulated with the Napa County SWB model.

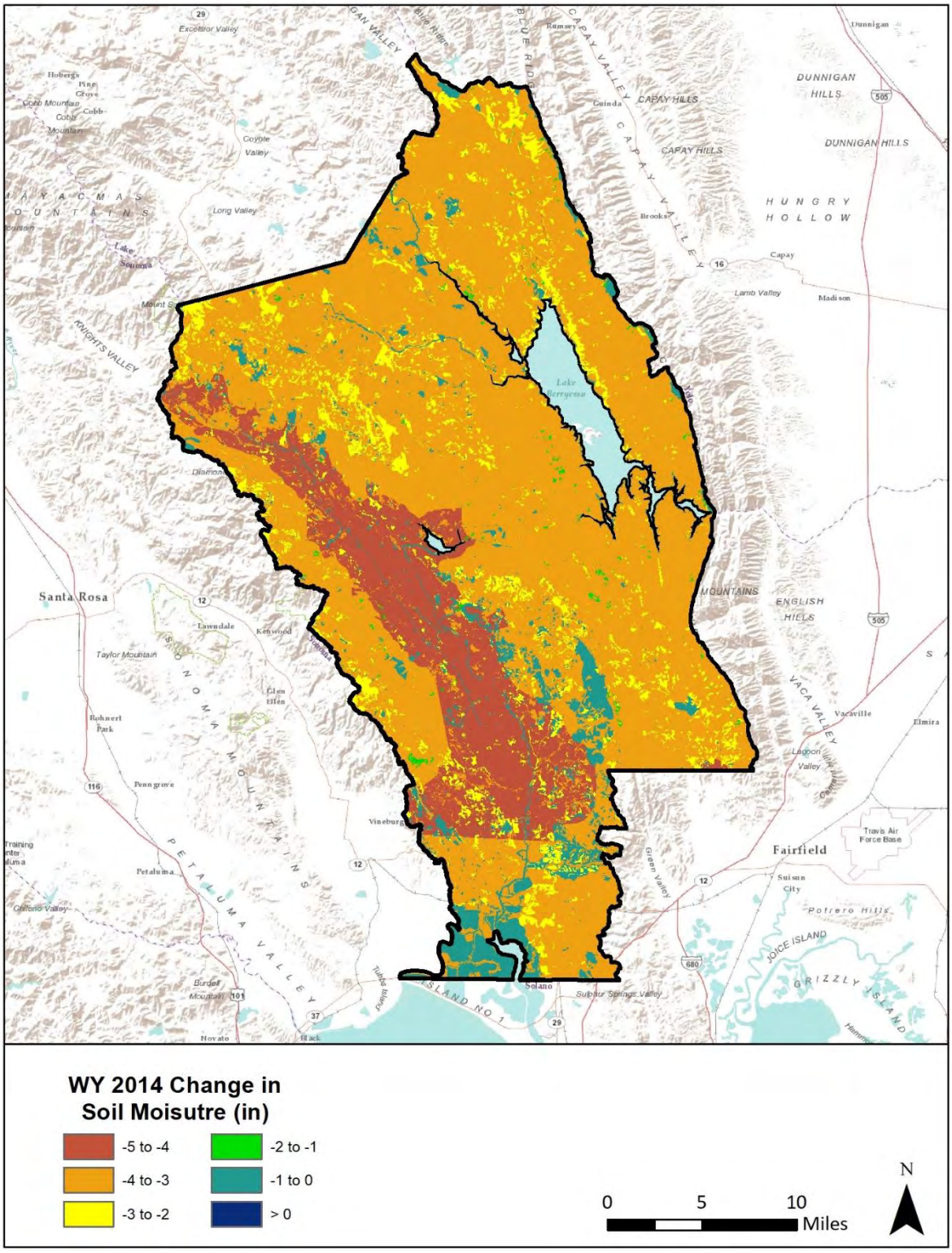


Figure 19: Water Year 2014 change in soil moisture content simulated with the Napa County SWB model.

Table 5: Simulated precipitation and recharge values averaged across HUC-12 watersheds in Napa County for Water Year 2010 expressed as depths. See Figure 20 for watershed locations.

Name	Drainage Area (mi^2)	Precipitation (in)	AET (in)	Surface Runoff (in)	Recharge (in)	Soil Moisture Change (in)
American Canyon Creek	10.8	24.1	16.3	3.7	4.7	-0.6
Bucksnort Creek	1.9	47.9	24.5	12.1	11.1	0.1
Butts Creek-Putah Creek	49.9	33.0	17.4	9.7	6.2	-0.7
Capell Creek	43.0	31.1	19.1	7.4	5.0	-0.6
Carneros Creek	29.7	28.0	18.6	5.2	5.5	-0.6
Chiles Creek	32.0	34.6	21.1	7.1	6.8	-0.5
Dry Creek	28.8	37.0	22.2	7.2	8.4	-0.5
Hunting Creek	12.0	33.7	19.0	9.7	5.7	-0.8
Jackson Creek-Putah Creek	54.5	29.9	13.4	12.6	3.0	-0.5
Lake Curry-Suisun Creek	16.4	30.7	18.9	6.5	5.9	-0.6
Lake Hennessey-Conn Creek	20.0	35.1	19.6	8.5	7.3	-0.4
Ledgewood Creek	6.4	21.8	16.9	3.4	3.3	-1.8
Lower Eticuera Creek	44.0	30.0	17.7	8.1	4.7	-0.7
Lower Napa River	45.0	31.7	19.9	5.6	6.7	-0.6
Lower Pope Creek	31.8	33.9	18.0	9.7	6.5	-0.6
Maxwell Creek	35.1	34.7	19.6	8.7	6.9	-0.6
Middle Napa River	60.3	39.9	22.8	8.5	9.2	-0.5
Milliken Creek	29.7	30.9	16.9	6.6	7.9	-0.6
Rector Creek-Conn Creek	22.3	32.8	18.0	7.1	8.2	-0.7
Saint Helena Creek	7.7	53.3	25.2	13.5	14.4	0.1
San Pablo Bay Estuaries	19.5	23.9	8.1	13.8	2.3	-0.3
Tulucay Creek	34.2	26.1	16.7	4.6	5.4	-0.7
Upper Eticuera Creek	25.6	31.2	17.2	8.6	6.1	-0.8
Upper Napa River	44.6	44.7	23.6	10.6	10.8	-0.4
Upper Pope Creek	21.7	44.5	22.7	10.5	11.5	-0.3
Wooden Valley & Suisun Creeks	23.3	29.0	19.0	5.1	5.5	-0.6
Wragg Canyon-Putah Creek	34.2	28.3	16.3	8.6	3.3	-0.6

Table 6: Simulated precipitation and recharge values averaged across HUC-12 watersheds in Napa County for Water Year 2010 expressed as a percentage of precipitation. See Figure 20 for watershed locations.

Name	Drainage Area (mi^2)	Precipitation (in)	AET (%)	Surface Runoff (%)	Recharge (%)	Soil Moisture Change (%)
American Canyon Creek	10.8	24.1	67%	15%	19%	-3%
Bucksnort Creek	1.9	47.9	51%	25%	23%	0%
Butts Creek-Putah Creek	49.9	33.0	53%	29%	19%	-2%
Capell Creek	43.0	31.2	61%	24%	16%	-2%
Carneros Creek	29.7	29.7	66%	19%	20%	-2%
Chiles Creek	32.0	34.6	61%	21%	20%	-1%
Dry Creek	28.8	37.8	60%	20%	23%	-1%
Hunting Creek	12.0	33.7	56%	29%	17%	-2%
Jackson Creek-Putah Creek	54.5	29.7	45%	42%	10%	-2%
Lake Curry-Suisun Creek	16.4	30.7	61%	21%	19%	-2%
Lake Hennessey-Conn Creek	20.0	36.0	56%	24%	21%	-1%
Ledgewood Creek	6.4	21.8	77%	15%	15%	-8%
Lower Eticuera Creek	44.0	30.0	59%	27%	16%	-2%
Lower Napa River	45.0	31.7	63%	18%	21%	-2%
Lower Pope Creek	31.8	33.9	53%	29%	19%	-2%
Maxwell Creek	35.1	34.7	56%	25%	20%	-2%
Middle Napa River	60.3	40.4	57%	21%	23%	-1%
Milliken Creek	29.7	30.9	55%	21%	26%	-2%
Rector Creek-Conn Creek	22.3	32.8	55%	22%	25%	-2%
Saint Helena Creek	7.7	53.3	47%	25%	27%	0%
San Pablo Bay Estuaries	19.5	23.9	34%	58%	10%	-1%
Tulucay Creek	34.2	26.1	64%	18%	21%	-3%
Upper Eticuera Creek	25.6	31.2	55%	28%	19%	-3%
Upper Napa River	44.6	44.7	53%	24%	24%	-1%
Upper Pope Creek	21.7	44.5	51%	23%	26%	-1%
Wooden Valley & Suisun Creeks	23.3	29.0	65%	18%	19%	-2%
Wragg Canyon-Putah Creek	34.2	28.3	58%	31%	12%	-2%

Table 7: Simulated precipitation and recharge values averaged across HUC-12 watersheds in Napa County for Water Year 2014 expressed as depths. See Figure 20 for watershed locations.

Name	Drainage Area (mi^2)	Precipitation (in)	AET (in)	Surface Runoff (in)	Recharge (in)	Soil Moisture Change (in)
American Canyon Creek	10.8	10.1	12.3	0.7	0.7	-3.6
Bucksnort Creek	1.9	28.8	17.6	11.5	2.6	-3.0
Butts Creek-Putah Creek	49.9	16.9	14.2	3.9	1.9	-3.2
Capell Creek	43.0	15.8	14.8	3.1	1.1	-3.1
Carneros Creek	29.7	15.0	14.7	4.6	2.0	-3.7
Chiles Creek	32.0	18.3	16.5	3.7	1.5	-3.3
Dry Creek	28.8	21.5	16.5	6.8	2.5	-3.7
Hunting Creek	12.0	16.7	15.4	3.1	1.6	-3.4
Jackson Creek-Putah Creek	54.5	14.9	10.3	6.1	0.7	-2.3
Lake Curry-Suisun Creek	16.4	18.4	16.1	3.7	1.9	-3.4
Lake Hennessey-Conn Creek	20.0	19.1	14.8	5.7	2.2	-3.2
Ledgewood Creek	6.4	12.2	13.9	1.7	0.8	-4.3
Lower Eticuera Creek	44.0	14.9	14.0	2.6	1.3	-3.1
Lower Napa River	45.0	19.4	15.9	5.0	2.2	-3.6
Lower Pope Creek	31.8	17.8	14.5	4.5	2.0	-3.2
Maxwell Creek	35.1	18.3	15.9	3.8	2.0	-3.3
Middle Napa River	60.3	21.3	16.5	6.6	2.5	-3.7
Milliken Creek	29.7	18.7	13.7	4.5	3.4	-2.9
Rector Creek-Conn Creek	22.3	16.5	13.6	4.0	2.3	-3.4
Saint Helena Creek	7.7	32.2	17.8	13.2	4.1	-3.0
San Pablo Bay Estuaries	19.5	10.4	6.0	5.6	0.5	-1.6
Tulucay Creek	34.2	14.6	13.5	2.6	1.7	-3.3
Upper Eticuera Creek	25.6	15.5	14.1	2.5	2.1	-3.2
Upper Napa River	44.6	22.9	16.2	6.9	3.3	-3.5
Upper Pope Creek	21.7	25.6	16.8	8.5	3.5	-3.2
Wooden Valley & Suisun Creeks	23.3	17.9	16.4	3.1	2.0	-3.5
Wragg Canyon-Putah Creek	34.2	14.1	12.6	3.6	0.6	-2.8

Table 8: Simulated precipitation and recharge values averaged across HUC-12 watersheds in Napa County for Water Year 2014 expressed as a percentage of precipitation. See Figure 20 for watershed locations.

Name	Drainage Area (mi^2)	Precipitation (in)	AET (%)	Surface Runoff (%)	Recharge (%)	Soil Moisture Change (%)
American Canyon Creek	10.8	10.1	121%	7%	7%	-36%
Bucksnort Creek	1.9	28.8	61%	40%	9%	-10%
Butts Creek-Putah Creek	49.9	16.8	84%	23%	11%	-19%
Capell Creek	43.0	15.8	94%	20%	7%	-20%
Carneros Creek	29.7	17.6	98%	30%	13%	-25%
Chiles Creek	32.0	18.4	90%	20%	8%	-18%
Dry Creek	28.8	22.1	77%	32%	12%	-17%
Hunting Creek	12.0	16.7	92%	18%	10%	-20%
Jackson Creek-Putah Creek	54.5	14.7	69%	41%	5%	-16%
Lake Curry-Suisun Creek	16.4	18.4	88%	20%	10%	-19%
Lake Hennessey-Conn Creek	20.0	19.6	78%	30%	12%	-17%
Ledgewood Creek	6.4	12.2	114%	14%	7%	-35%
Lower Eticuera Creek	44.0	14.9	94%	18%	9%	-21%
Lower Napa River	45.0	19.4	82%	26%	11%	-19%
Lower Pope Creek	31.8	17.8	81%	25%	11%	-18%
Maxwell Creek	35.1	18.3	87%	21%	11%	-18%
Middle Napa River	60.3	21.8	77%	31%	12%	-18%
Milliken Creek	29.7	18.7	74%	24%	18%	-16%
Rector Creek-Conn Creek	22.3	16.5	83%	24%	14%	-21%
Saint Helena Creek	7.7	32.2	55%	41%	13%	-9%
San Pablo Bay Estuaries	19.5	10.4	58%	53%	4%	-16%
Tulucay Creek	34.2	14.6	93%	18%	12%	-23%
Upper Eticuera Creek	25.6	15.5	91%	16%	14%	-21%
Upper Napa River	44.6	22.9	71%	30%	14%	-15%
Upper Pope Creek	21.7	25.6	66%	33%	14%	-12%
Wooden Valley & Suisun Creeks	23.3	17.9	91%	17%	11%	-20%
Wragg Canyon-Putah Creek	34.2	14.1	90%	26%	5%	-20%

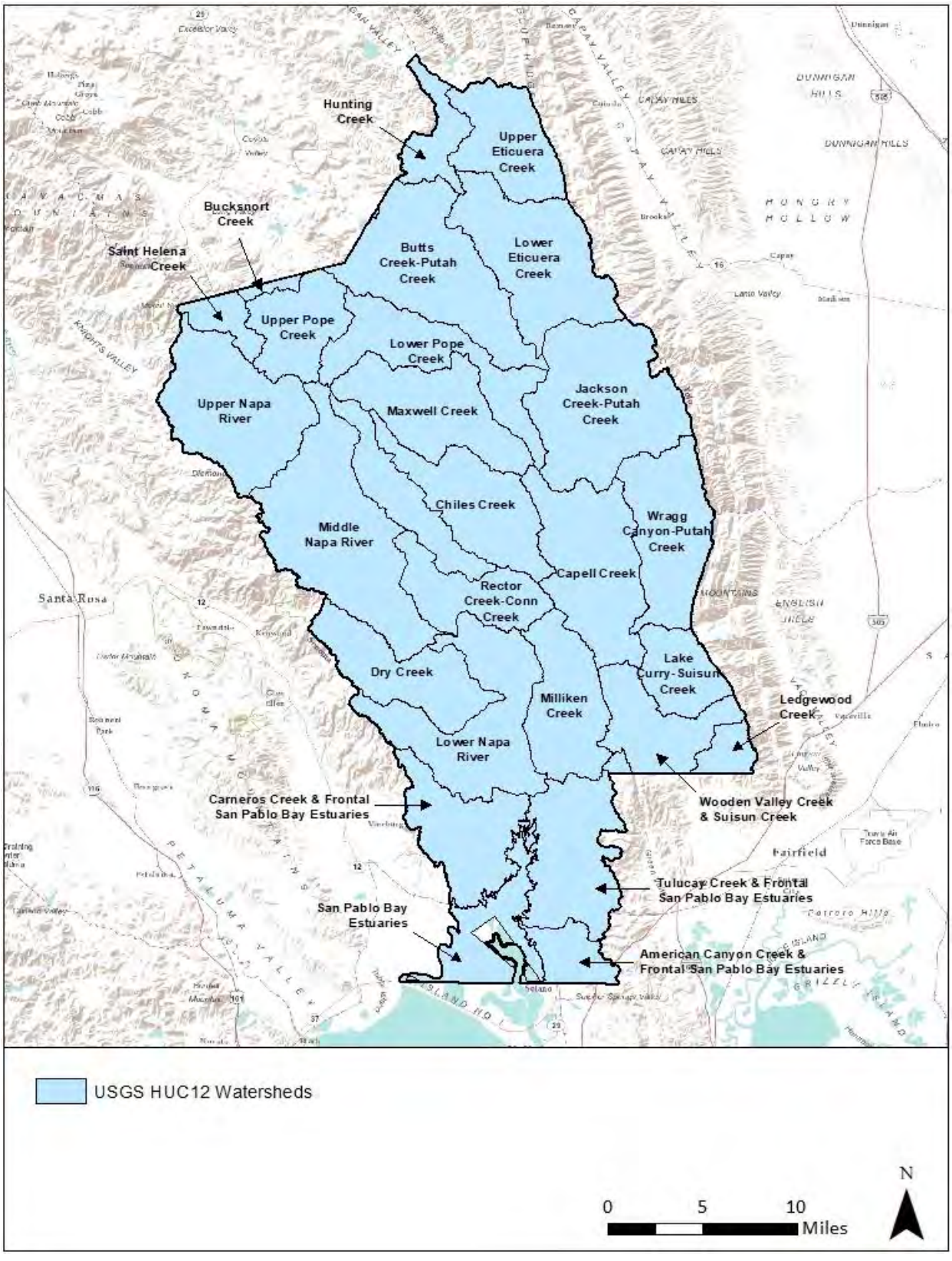


Figure 20: Major watersheds areas used to summarize water budget information in Tables 5 - 8.

Discussion and Conclusion

Numerous previous modeling studies have estimated water budget components in several larger watershed areas in Sonoma and Napa Counties including the Santa Rosa Plain, the Green Valley and Dutch Bill Creek watersheds, and the Sonoma Valley (Farrar et. al., 2006; Kobor and O'Connor, 2016; Woolfenden and Hevesi, 2014). Comparisons to these water budgets are useful for evaluating the SWB results, but one would not expect precise agreement owing to significant variations in climate, land cover, soil types, underlying hydrogeologic conditions, and different spatial scales of modeling studies. These regional analyses estimate that average annual recharge varies from 7% to 19% of the annual precipitation. The equivalent county-wide value from this study is slightly higher at 20%.

Water budgets for the Napa River and selected sub-basins were also estimated in a previous study by Luhdorff and Scalmanini Engineers and MBK Engineers (LSCE 2013). The LSCE study estimated that, as a percentage of annual precipitation, AET comprised slightly less, runoff significantly more, and recharge substantially less of the typical annual water budget. LSCE (2013) calculated infiltration of precipitation based on the difference between total monthly streamflow at selected gaging stations and total monthly precipitation for the gages' drainage area. Streamflow volumes include both direct runoff (overland flow and interflow) and baseflow from groundwater. Inclusion of baseflow with direct runoff in these calculations may inappropriately reduce the estimated volume of water infiltrated into the soil and available for recharge; the LSCE approach therefore tends to underestimate groundwater recharge. Additionally, many of the gauging stations used for the analysis are located in reaches that may be significantly influenced by upstream reservoir releases, surface water diversions, groundwater abstraction, and/or surface water groundwater exchanges, further complicating the interpretation of the LSCE (2013) runoff rates and the interrelated calculations of AET and recharge rates. In contrast, the SWB model presented here is based on calibrated parameter values developed for a similar model in Sonoma County which was calibrated to gauges specifically selected to minimize the effects of reservoir releases, water use, or significant surface water/groundwater interaction, and after separating and removing the baseflow component of streamflow.

The recharge estimates presented here arguably represent the best available county-wide estimates produced at a fine spatial resolution using a consistent and objective data-driven approach. This analysis focused on two Water Years, 2010 and 2014, which represent average and drought conditions respectively. Input parameters were determined based on literature values and values calibrated through prior modeling experience in Sonoma County.

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