Soquel Creek
Streamflow Assessment Study

December 2019

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Acknowledgements

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Executive summary

Background

The Soquel Creek Watershed in Santa Cruz County, California, supports diverse habitat for a number of special status species, in particular steelhead and coho salmon (salmonids). Salmonids are considered indicator species as their presence, absence or abundance reflect the overall health and quality of an ecosystem and thus can be used as a proxy to diagnose ecosystem health. Management actions implemented for their recovery are therefore beneficial to other aquatic-dependent species. In Soquel Creek, one of the major limiting conditions to salmonid recovery is a lack of adequate late season (June through October) streamflow as flow levels dictate food abundance, dissolved oxygen content, and water temperatures – all important factors in both fish survival and successful reproduction.

This report is the culmination of a three-year study of streamflow conditions and land use patterns in the watershed aimed at better understanding rural water demand, availability, and implications for salmonid recovery. The ultimate goal of this work is to inform and help prioritize future water conservation projects to enhance late season streamflow conditions in strategic locations throughout the watershed.

Approach

Streamflow gaging: The only long-term record of streamflow in the Soquel Creek Watershed is the United State Geological Survey (USGS) Soquel Creek gage in the lower watershed, making it difficult to understand how streamflow conditions vary spatially throughout the watershed and how human water management practices influence streamflow conditions. In response to this data gap, the Resource Conservation District of Santa Cruz County (RCD) and Trout Unlimited (TU) designed a gage network in the upper portion of the watershed, an area where the majority of water users are not served by a municipal supplier.

Evaluation of habitat quality: Trends in salmonid monitoring data from the Juvenile Steelhead and Stream Habitat (JSSH) Program were evaluated to better understand where improvements to in-stream flow would have the most impact. Invasive plant species were mapped along certain portions of the riparian corridor to better understand their potential impact on water availability and habitat quality.

Quantifying human water demand: Two analyses were performed to estimate human water demand across the watershed. One coupled a combination of standardized water use estimates and known use rates with hand-digitized geospatial data that captured land use patterns (i.e. agricultural fields, irrigated lawns and turf, and different types of building structures). The other approach estimated water demand based on allotted water rights. In addition, a water availability analysis was completed in order to evaluate the viability of developing water storage projects to alleviate the effects of demand on late-season flow (a water right is required for such projects, requiring proof from the availability analysis that sufficient water exists to supply the storage tanks).

Findings

Streamflow gaging: Streamflow data from the gage network show that there are multiple diversions occurring throughout the watershed, causing streamflow conditions to drop by as much as 1 ft^3/s. Groundwater pumping and diversions from springs are also likely impacting summer streamflow conditions in the watershed, though the impacts of these diversions are much more difficult to detect in the gage network's data.

Evaluation of habitat quality: JSSH Program data show that, in general, steelhead juvenile densities are highest in the East and West Branches and the Upper Mainstem Soquel Creek for Size Class 1 (< 75 mm SL) and Size Class 2 (> 75 mm SL). Mean juvenile densities for both size classes show a negative trend from 1994 to 2018. However, higher densities have been reported for 2019, which is expected to change these trend lines. There was a marked decline in juvenile densities due to extremely low streamflow and pool disconnection in the East Branch during drought years (2014 and 2015).

The relationship between riffle and run average depth and juvenile densities is statistically significant for both Size Class 1 and 2. This shows that streamflow supports juvenile survival through a combination of increased habitat quantity (more depth and width) and quality (higher dry season flows increase food supply). In order to further examine the relationship between dry season flow and juvenile steelhead densities, the JSSH Program created a flow variable for mean June and mean September flow for each sampling site by developing a mathematical relationship between field-collected flow data and USGS Soquel Creek gage data. There is a significant negative relationship between Size Class 1 and the mean September flow variable. This relationship suggests that with higher flows, more juveniles grow into the larger Size Class 2. Although the data show a positive relationship between Size Class 2 and flow, the relationship was not significant.

Invasive and exotic plant species were found to be concentrated in areas impacted by human development, with the most common species in the lower watershed being vinca (*Vinca major*), English ivy (*Hedera helix*), French broom (*Genista monspessulana*), Cape ivy (*Delairea odorata*), acacia (*Acacia dealbata*), eucalyptus (*Eucalyptus spp.*), and pampas grass (*Cortaderia spp.*). Arundo (*Arundo donax*) and tree of heaven (*Ailanthus altissima*) also occur but populations are limited at this time.

Quantifying human water demand: Based on the remote sensing analysis we found that the focus study area (the area that drains to the point above Bates Creek) has about 52.6 acres of vineyard, 89 acres of orchard, 1.8 acres of irrigated turf, 27.8 acres of row crops, 9.5 acres of irrigated pasture, and over 7,600 marijuana plants. There are 1,663 commercial and residential structures within the focus area, as well as one school, four camps/conference centers, and five wineries.

Accounting for well and reservoir use, the total annual human surface water demand based on the remote sensing analysis was estimated at 267 AF. Based on the water rights analysis, we estimated demand to be 553 AF per year. While the magnitude of the demand differs, both analyses produced similar spatial patterns of human water need and potential impacts – both indicate the potential for higher human impact on streamflow in the West Branch and Lower Mainstem of Soquel Creek. Due to the fact that the remote sensing analysis was based on current land use patterns, we believe that its estimation of human water demand is more accurate than the results of the water rights analysis.

The water availability analysis indicated that there is adequate water available during the winter season (December 15 – March 31) for future water storage projects. The percentage of remaining unimpaired water available for future appropriation is currently above 4% at the lowest existing water right holder in the watershed. Along with the analysis on human water use, these data indicate that there is considerable opportunity to store water in the winter for summer use, while maintaining the water needed for ecological processes.

Recommendations

Our analyses suggest that there is sufficient water in the Soquel Creek Watershed to meet human needs on an annual basis. However, the streamflow monitoring work completed for this study suggests that human water management activities have a negative impact on streamflow during the dry season and thus the potential to impact salmonid survival in drier years. A primary goal for future streamflow enhancement work should be to complete projects that simultaneously ensure adequate water supply for human consumption and ecosystem functioning year-round.

We recommend the following suite of strategies for improving summer streamflow conditions in the Soquel Creek focus area:

1. Implement management-based streamflow enhancement projects that alter the timing, source, efficiency and/or management of human water use. Focus efforts in the areas of the Upper Mainstem, East Branch, and lower West Branch with highest juvenile steelhead densities. Strategies include:
    a. Reduce or eliminate direct dry season diversions by institutional (such as summer camps, conference centers and small mutual water companies), agricultural, and residential water users.
    b. Develop collaborative water management guidelines for areas with high volumes of residential pumping.
    c. Develop flow release projects and projects that reconnect springs to tributary streams.

2. Implement processed-based streamflow enhancement projects that restore the natural processes in the watershed, which influence the amount of water retained on and released from the landscape. Focus efforts in the East Branch as this is the area with the largest amount of undeveloped land. Strategies include:
    a. Improve the road drainage network in the watershed to reduce the flashy-ness of the system and to increase groundwater recharge.
    b. Develop upland recharge sites to retain water higher in the landscape.
    c. Develop coordinated efforts to slow, spread, and sink runoff.
    d. Implement restoration habitat restoration projects that reconnect the channel with the floodplain.
    e. Develop groundwater infiltration projects in low-sloped areas.

3. Focus invasive plant species eradication on species with the highest water use and fewest occurrences (arundo and tree of heaven) and then develop a plan to address other high water users such as eucalyptus and acacia.

1. Introduction

1.1 Purpose

This report is the culmination of a three-year study of streamflow conditions and land use patterns in the Soquel Creek Watershed in Santa Cruz County, California, aimed at better understanding rural water demand, availability, and implications for threatened steelhead and endangered coho salmon recovery. The ultimate goal of this work is to inform and help prioritize future water conservation projects to enhance late season streamflow conditions in strategic locations throughout the watershed.

1.2 Focus area location and background

The Soquel Creek Watershed is located in Santa Cruz County between the cities of Santa Cruz and Watsonville, on the Central Coast of California (Figure 1). It has a drainage area of approximately 42 mi^2 and empties into Monterey Bay, a designated National Marine Sanctuary. Elevations range from sea level to 3,000 ft at the crest of the southern portion of the Santa Cruz Mountains (RCDSCC 2003).

The watershed is comprised of a number of subwatersheds. Burns and Laurel Creeks combine to make the West Branch of Soquel Creek, with Hester Creek being a major tributary. Fern Gulch, Asbury Gulch, Amaya Creek, and Hinckley Creek flow into the East Branch of Soquel Creek. The West Branch and East Branch confluence (near the junction of Olive Springs Road with Soquel/Old San Jose Road) marks the start of the Mainstem, which has inputs from the Love Creek/Moores Gulch and Bates Creek/Grover Gulch sub-basins (approximately 6 mi and 2 mi from the ocean, respectively) (RCDSCC 2003). The focus area of this study is the upper portion of the watershed, starting at the lowest study gage above the confluence with Bates Creek (Figure 1).

Topography of the downstream portions of the watershed is gently sloping and becomes moderately to steeply sloping upstream. Watershed relief is dramatic, with elevations in the headwaters reaching over 3,000 ft only 10 mi from the ocean. The upper reaches of the watershed are characterized by steep slopes and narrow canyons. Deeply weathered bedrock, steep slopes, and earthquake activity in the San Andreas and Zayante fault zones along with heavy, prolonged rainfall often promote large-scale landslides (RCDSCC 2003).

Mixed conifer forests dominate the upper watershed, comprised of coast redwood, tan oak, madrone, and Douglas fir. Riparian trees such as sycamore, alder, cottonwood, and willow are found throughout the lower watershed growing in the remaining broad, open floodplains. Diverse habitats support a variety of special status species such as steelhead (*Oncorhynchus mykiss)*, foothill yellow-legged frog (*Rana boylii*), tidewater goby (*Eucyclogobius newberryi*), and western pond turtle (*Actinemys marmorata*) among others. Coho salmon (*Oncorhynchus kisutch)* were regularly found in the watershed historically but spawning in recent years has been very limited. Invasive and exotic plant species are concentrated in areas impacted by human development, with the most common species in the lower watershed being vinca (*Vinca major*), English ivy (*Hedera helix*), French broom (*Genista monspessulana*), Cape ivy (*Delairea odorata*), acacia (*Acacia dealbata*), eucalyptus (*Eucalyptus spp.*), and pampas grass (*Cortaderia spp.*) (Figure 2). Arundo (*Arundo donax*) and tree of heaven (*Ailanthus altissima*) also occur but populations are limited at this time.

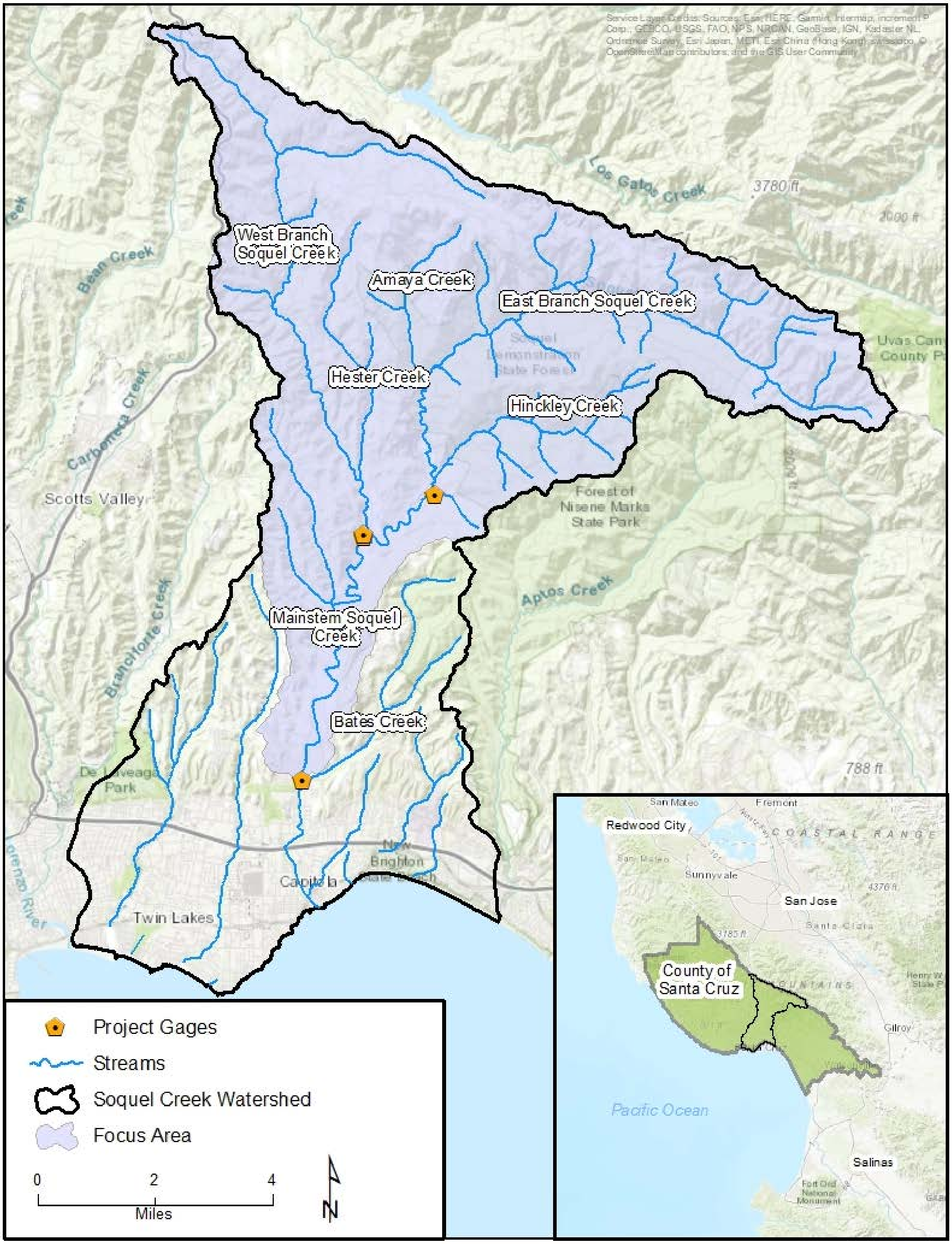

Figure 1. Soquel Creek Watershed location and study area (Focus Area).

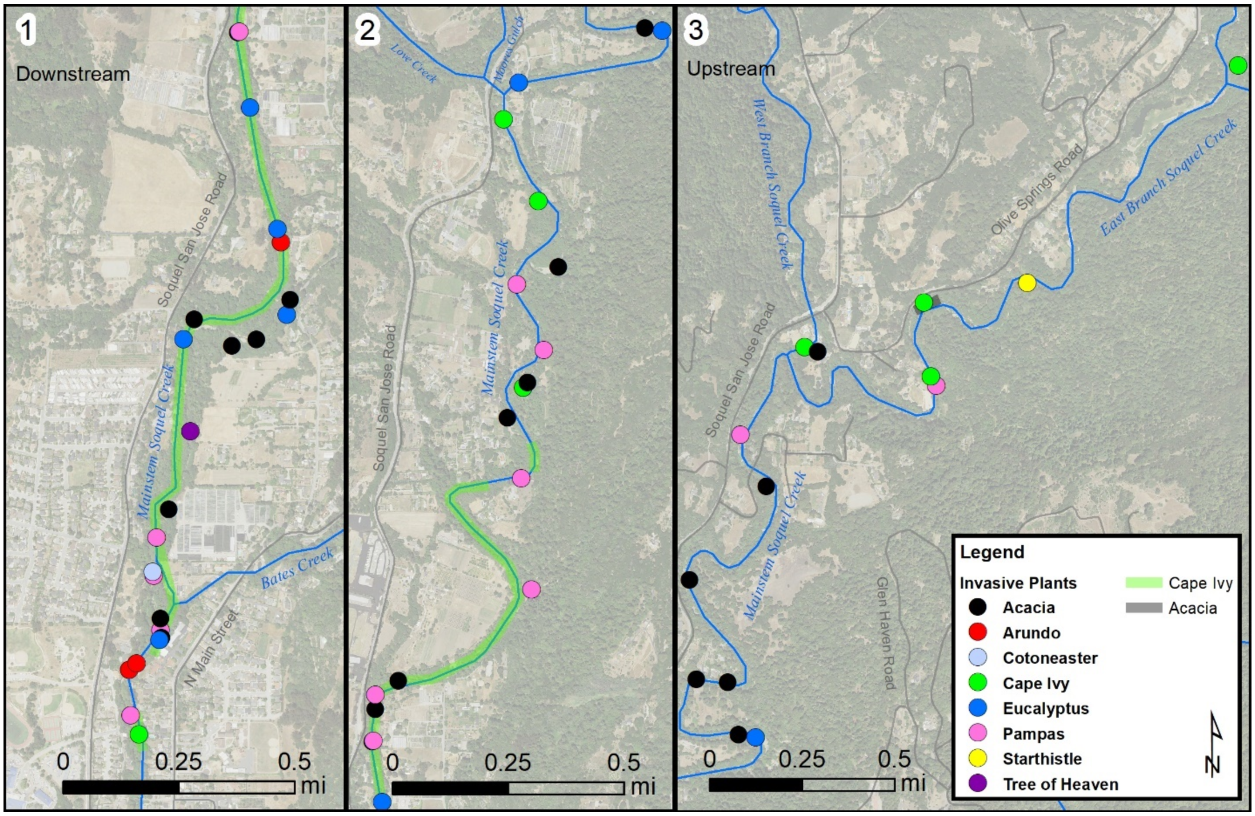

Figure 2. Invasive plant species observed in the lower Soquel Creek watershed during stream surveys from 10/22/19-11/7/19. The extent of the maps shows the extent of the surveys. Panel 1, on the left, starts at the Main Street footbridge and Panel 3, on the right, ends just below the terminus of Olive Springs Road. Note: vinca, English ivy, and French broom were not mapped due to their high abundances throughout the surveyed area.

The majority of the Soquel Creek focus area is within unincorporated Santa Cruz County; land use includes urban development, rural residential development, agriculture, parks and recreation, mining, and timber harvesting. Urban land uses occupy the lower portion of the watershed, transitioning above the Soquel Village to orchards, wholesale nurseries, and rural residential use. The unincorporated towns of Soquel and the City of Capitola, both located near the mouth of Soquel Creek, are the urban centers of the watershed. Human density in the lower areas of the watershed is relatively high compared to those in the upper portions. The Soquel Creek Water District provides the urban communities with potable water and Santa Cruz County provides wastewater treatment. Residents in much of the remainder of the watershed rely on wells or springs for potable water and septic systems to treat wastewater (RCDSCC 2003).

The middle to upper watershed is primarily rural residential with large tracts of land managed for resource extraction and preservation. Land use includes gravel mining, sustainable timber harvesting on the Soquel Demonstration State Forest (SDSF) and private timberlands, and preservation (a portion of the Forest of Nisene Marks State Park falls within the watershed). Roughly 25% of the headwaters of the Soquel Creek Watershed are State-protected lands. Logging has been conducted in the middle and upper watershed since the mid-nineteenth century (RCDSCC 2003).

1.3 Statement of problem/issues

The Soquel Creek Watershed Assessment and Enhancement Project Plan (RCDSCC 2003) documented reduced streamflow and water depth, due to water diversions and shallow groundwater wells, as major threats to adult and juvenile salmonid migration and survival in the watershed. Seasonal flows naturally diminish from May to the first rains in October or November. Additional loss from extractions for human use exacerbates this seasonal trend. When groundwater levels are low, some reaches of the creek frequently dry up, disconnecting pools in the late season and leading to fish stranding and mortality. Even if pools stay connected through the late season, low, shallow flows can threaten salmonid survival as they dictate dissolved oxygen, temperature, and food supply levels. Snider et al. (1995) found that optimal wetted useable area for juvenile coho salmon and steelhead in Scott Creek in northern Santa Cruz County (comparable to Soquel Creek in terms of watershed area) is provided at 20 ft^3/s. Juvenile habitat availability declines very rapidly as base flows fall below 8 ft^3/s, and only half of the maximum habitat remains at 5 ft^3/s to 6 ft^3/s. Median, late season flows in August, September, and October in Scotts Creek are 2 ft^3/s or less (providing a fraction of optimal habitat). Base flows in certain steelhead-bearing reaches of Soquel Creek often dip below 1ft^3/s in the late summer, illustrating the need for efforts to improve streamflow conditions.

Surface water rights for the Soquel Creek Watershed were adjudicated by the Santa Cruz County Superior Court in 1977. At that time, just over 300 riparian users were granted appropriative rights to draw from Soquel Creek, its tributaries, and stream-feeding springs. This ruling restricted surface water rights to select users and acknowledged that streamflow was a limited resource. However, no water master was appointed at the time of the adjudication, rendering the decree largely ineffective at holding water users accountable to its provisions. Illegal and legal diversions are occasionally inventoried by regulatory agencies but impacts to streamflow are unmonitored. Residential groundwater well use is also unregulated at this time, though a permit is required when drilling a new well.

Streamflow data are crucial for understanding the ecological health of the Soquel Creek Watershed as well as the impacts of human water management activities on the surrounding ecosystem. California's dynamic variability in precipitation makes streamflow conditions highly variable between years and dry season streamflow monitoring is an important component of ecological restoration and streamflow enhancement work. Streamflow data, from a thoughtfully distributed gage network, allows resource managers to quantify the impairment caused by human water management activities, identify priority reaches for restoration and enhancement projects, estimate the benefit of streamflow enhancement projects, and to better understand salmonid survival and recovery in the watershed.

2. Watershed conditions

2.1 Rainfall

The Soquel Creek Watershed is characterized by a Mediterranean climate, with cool, wet winters and warm, dry summers. Rainfall data collected over a 68-year period at the National Oceanic and Atmospheric Administration (NOAA) weather station in Santa Cruz show that 93% of the average annual rainfall occurs between November and May; less than 3% of the average annual rainfall occurs between June through September (Figure 3).

The computer model Parameter-elevation Regression on Independent Slopes Model (PRISM) indicates that average precipitation throughout the focus area is extremely variable, with the lower portion of the focus area receiving only slightly more than half the annual precipitation of upper region. PRISM data show 30 to 40 inches of rainfall in the lower half of the watershed annually, and more than 40 inches (and up to 60 inches across the northeast corner of the focus area) in the upper portion (Figure 4).

Long-term records from the Santa Cruz rain gage indicate that rainfall can be highly variable from year to year. Over the 68-year period of record (1951 through 2019) annual rainfall has varied from as little as 14 inches (2014) to as much as 60 inches (1998), with extended periods of low and high rainfall throughout the period of record (Figure 5).

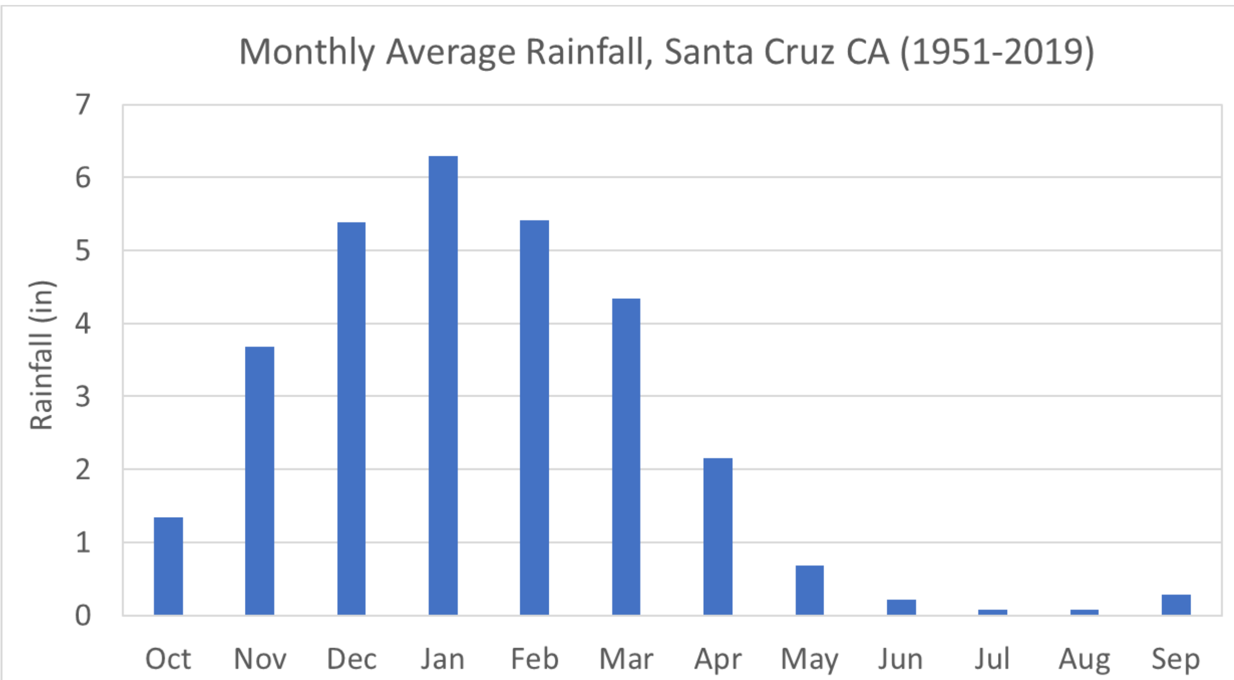

Figure 3. Average monthly rainfall recorded at Santa Cruz, CA, 1951 – 2019 (GHCND station USC00047916), showing the difference between late and dry season rainfall.

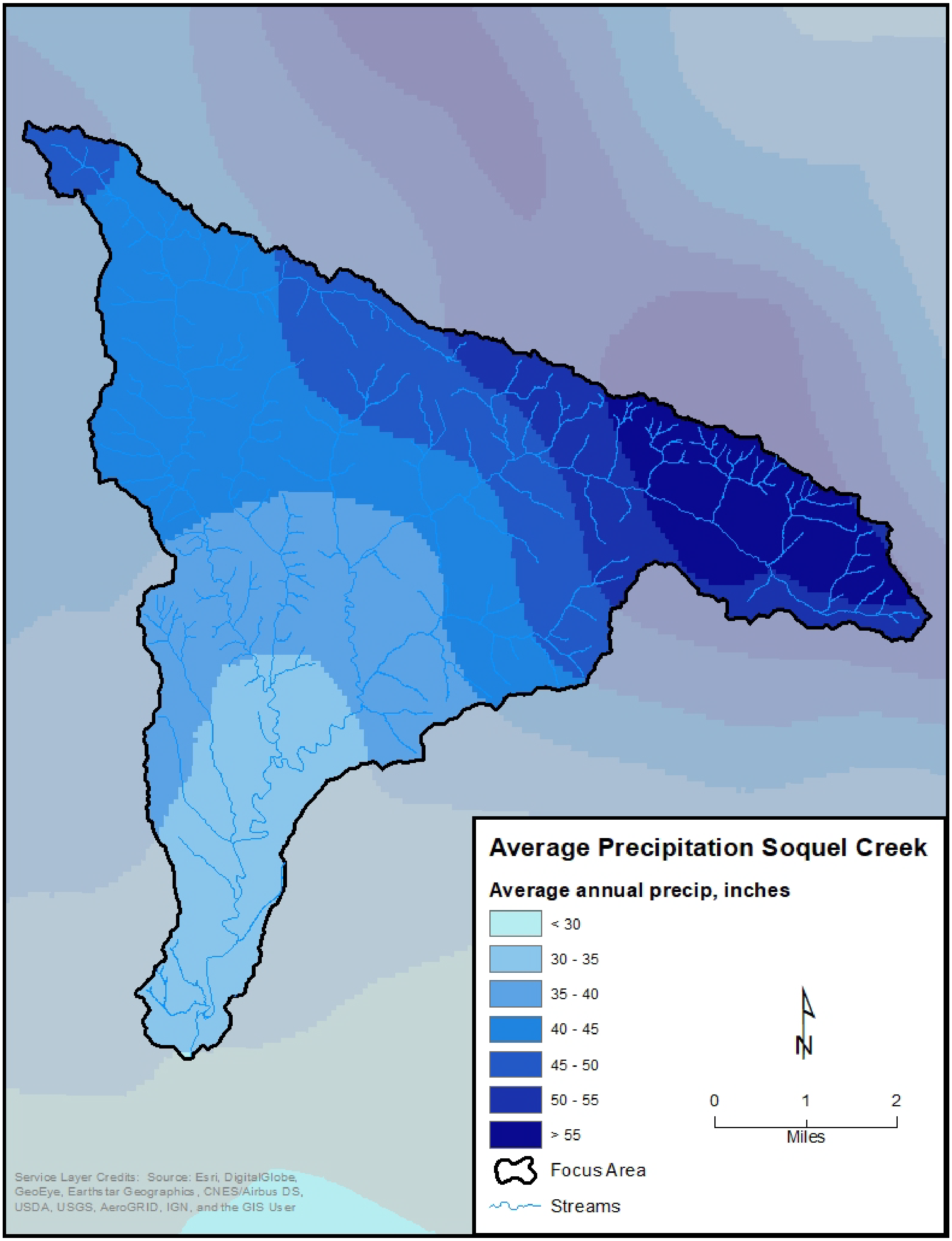

Figure 4. Average PRISM precipitation estimates across the Soquel Creek focus area showing higher precipitation in the upper portion of the study focus area.

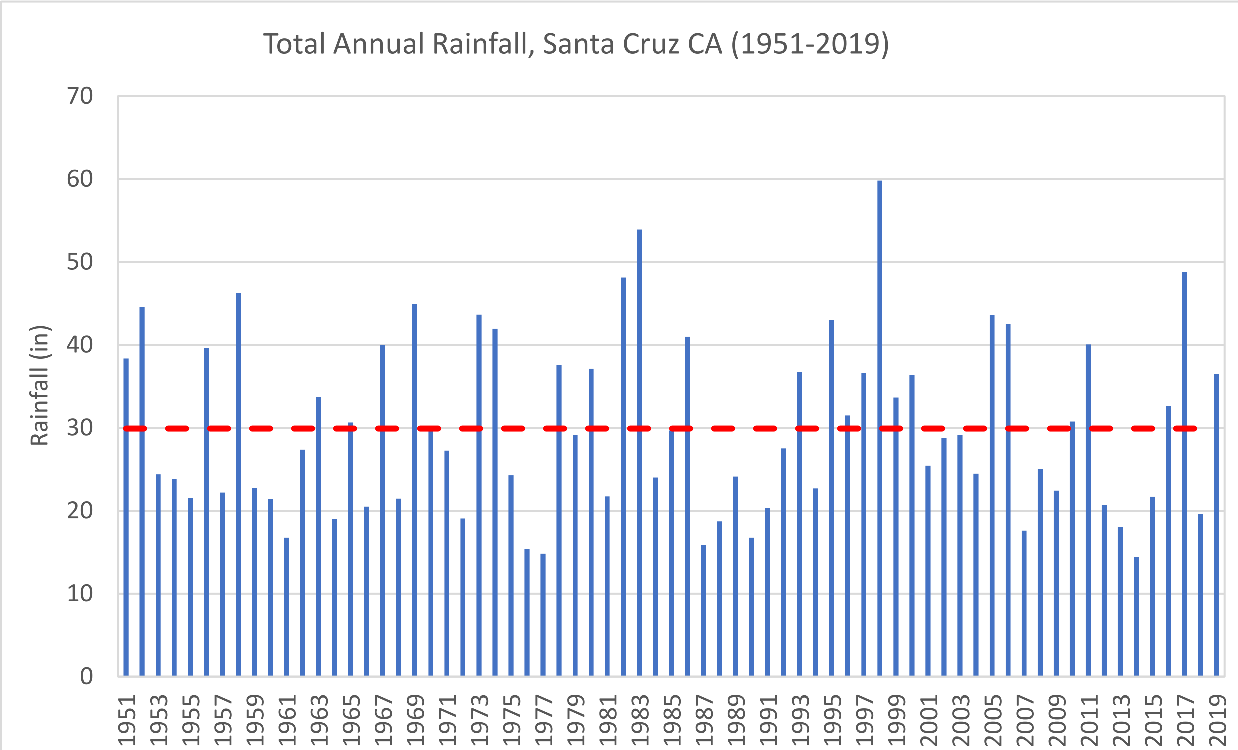

Figure 5. Annual rainfall, 1951-2019, in Santa Cruz, CA (red dotted line showing average annual rainfall).

2.2 Streamflow

2.2.1 Seasonal trends and long-term streamflow conditions in the watershed

Discharge data collected at the USGS Soquel Creek gage (11160000), dating back to 1952, provides a longer-term record of streamflow in the watershed. These data show that total annual and monthly discharge can vary significantly from year to year (Figure 6) and from month to month (Figure 7). The Soquel watershed received the maximum amount of discharge on record in 1983 (122,394 AF) and the minimum amount of discharge in 1977 (2,090 AF). The average discharge during the period of record is 30,813 AF and the median annual discharge is 22,979 AF. The second lowest amount of discharge on record was in 2014 with 3,144 AF.

Streamflow in the Soquel Creek Watershed shows seasonal trends that mirror rainfall patterns, with most flow concentrated in the wet season (December to April). On average, 94% of discharge is measured between November and May, and 6% occurs between June and October (Figure 7). Within the rainy season, streamflow occurs as a series of high-flow events during and directly following periods of rain, with a prolonged span of elevated base flow in the winter. Streamflow recedes following rain events and moves towards (and sometimes reaches) intermittence in late summer (Figure 8).

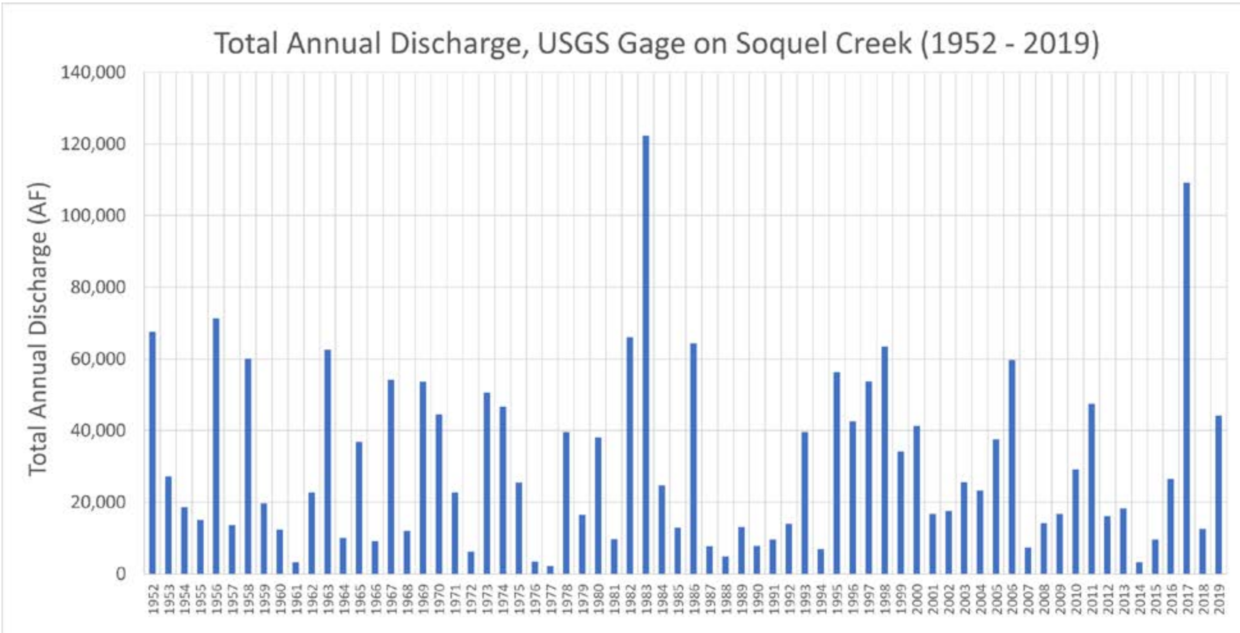

Figure 6. Annual discharge recorded at the USGS gage 11160000 in Soquel Creek, from 1952-2019, showing annual variation in discharge.

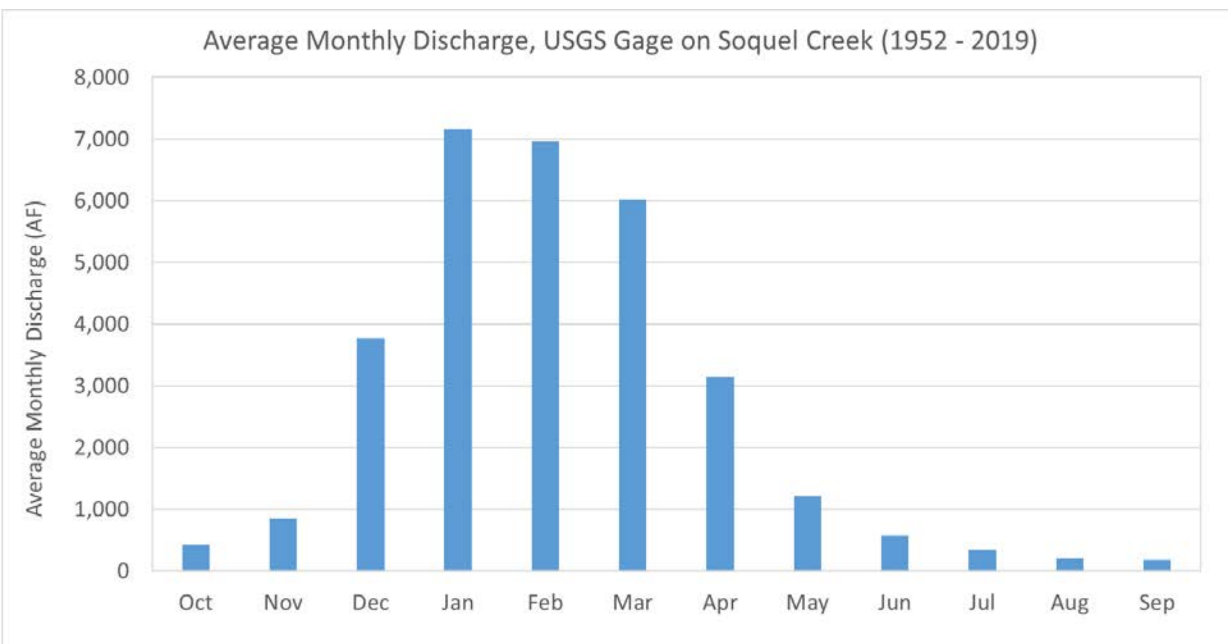

Figure 7. Average monthly discharge recorded at the USGS gage 11160000 in Soquel Creek, from 1952-2019, showing significant monthly variation in discharge.

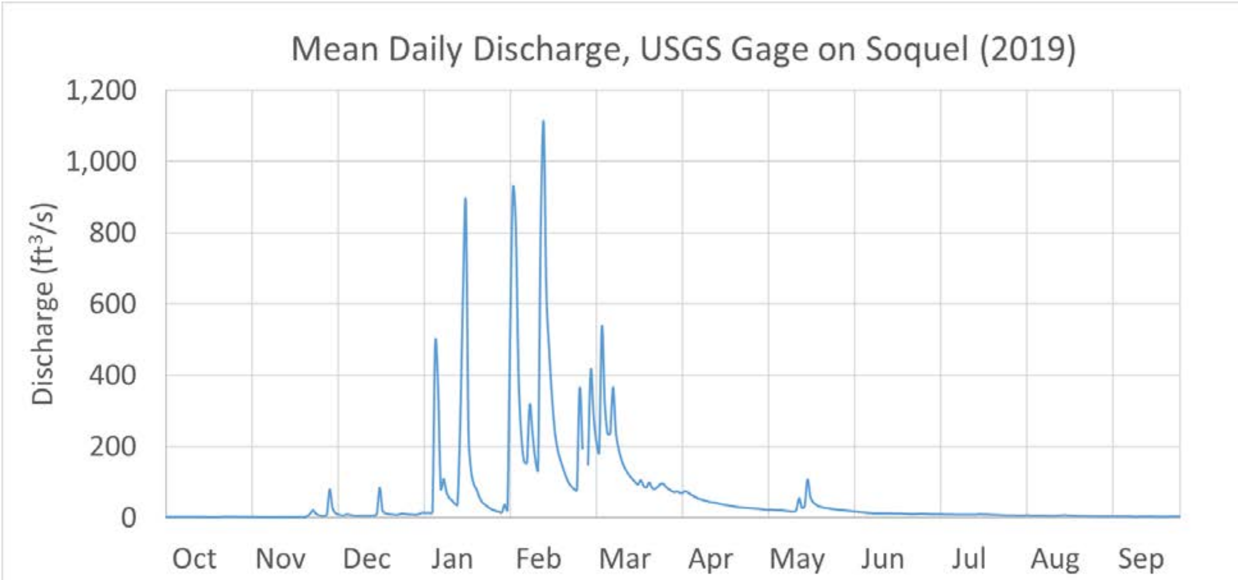

Figure 8. Mean daily discharge recorded at the USGS gage 11160000 in Soquel Creek, in 2019.

2.2.2 Quantifying streamflow in the focus area

With the location of the USGS gage in mind, the RCD and TU designed a gage network in the upper portion of the watershed to better understand streamflow conditions and support the goals of this study (Figure 9). In the gage network, gage site Sq04 – Upper East Branch Soquel Creek at the Olive Springs Quarry (Quarry) was selected as the reference gage. This gage site is in the SDSF, with a minimal amount of human water management occurring upstream of the site. Gage sites Sq01, Sq02, and Sq03 (Lower East Branch above the confluence, West Branch above the confluence, and Lower Mainstem Soquel Creek above Bates Creek respectively) were selected as the treatment gage sites because they are all located in areas downstream of known areas with human water use.

Each streamflow gage was operated following USGS standard procedures, as described in Rantz 1982. Field crews measured streamflow at approximately monthly intervals during the dry season (May through October) beginning in Water Year (WY) 2017 and ending at the conclusion of WY2019, following protocols adapted from the CDFW Standard Operating Procedures for Discharge Measurements in Wadeable Streams (CDFW 2013).[1] Using measured streamflow values, we developed rating curves to correlate streamflow with discharge at each site. In addition, we installed staff plates to detect pressure transducer drift and other factors that may cause rating shifts (i.e. changes in the relationship between stage and streamflow) over the course of the project.

[1] Rather than using Marsh-MacBirney current meters as described in CDFW (2013), we used a Price mini and Price AA current meters because TU's experience has suggested the Price mini current meter provides more accurate low-velocity measurements.

Figure 9. Gage locations in the Soquel Creek Watershed, with project gages in green and the USGS gage in blue.

2.2.3 Summer streamflow conditions in the focus area

Streamflow conditions in WY2017 (Figure 10)

The gage network was installed in late-July/mid-August 2017 to capture the most critical period of the dry season of WY2017. WY2017 was the wettest year during the 3-year study period. Long-term gage data from the USGS gage on Soquel Creek (11160000) shows that total annual discharge was approximately 255% higher than average, and summer streamflow conditions approximately 124% percent above average. Streamflow conditions in May 2017 were approximately 108% above average.

In WY2017, the East Branch of Soquel Creek was a gaining stream until October, the driest time of the year. The West Branch gage shows streamflow was lower than on the East Branch in August 2017, but by mid-October the West Branch maintained higher streamflow than the East Branch. Data from the gage above Bates Creek and the USGS gage on Soquel shows the Mainstem of Soquel Creek as a losing stream in late-July (when the gages were installed). This reach experienced periods of gaining and losing water throughout the summer season, which could be attributed to groundwater pumping activities along the Mainstem. Streamflow data at all three of the treatment gages show signals in the hydrograph likely related to human water management activities (described in more detail in section 2.2.4).

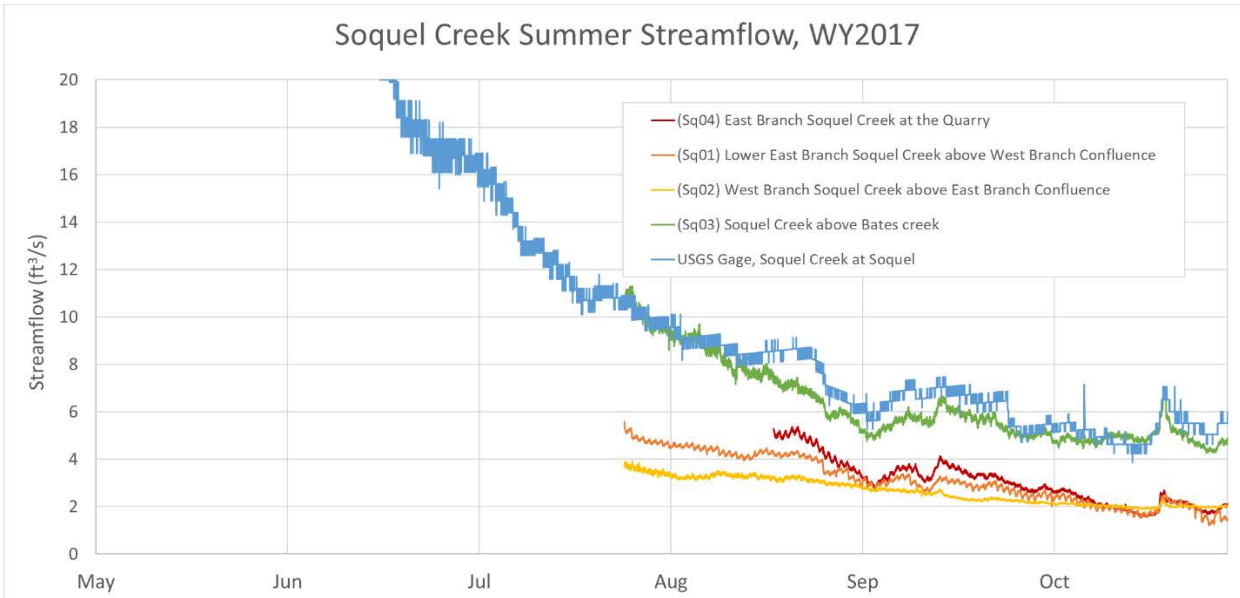

Figure 10. Streamflow conditions at the 4 project gages, plotted with the Soquel Creek USGS gage 11160000, in WY2017.

Streamflow conditions in WY2018 (Figure 11)

WY2018 was the driest year during the study period. Long-term gage data from the USGS gage on Soquel Creek show that total annual streamflow conditions were 59% below average, and summer streamflow conditions 33% below average, similar to what was experienced in the recent 2012-2016 drought. Streamflow in May 2018 was approximately 37% lower than average and 69% lower than in WY2017.

In WY2018, the East Branch of Soquel Creek became a losing stream in early June 2018, following a sharp dip in streamflow conditions likely caused by an instream rock dam (impoundment) or some other kind of human water management activity. Like in 2017, the gages show a pattern of lower flow on the West Branch compared to the East Branch early in the summer season and then higher flows on the West Branch later in the dry season. The West Branch gage showed that streamflow conditions in early May were approximately half of flow in the East Branch but by late-July the West Branch maintained higher flows than the East Branch. This may indicate that the West Branch has larger inputs from groundwater sources than the East Branch. Data from the gage above Bates Creek and the USGS gage on Soquel, show that the Mainstem remained a gaining stream for most of the summer season, with periods of loss in August and September, which could be attributed to groundwater pumping activities along the Mainstem. All four gage sites had sustained flow through September and October 2018 at a low base flow of approximately 0.5 – 2 ft^3/s (important to note considering it was a drier water year). All three treatment gages showed signals in the hydrograph related to surface water diversions/human water management activities.

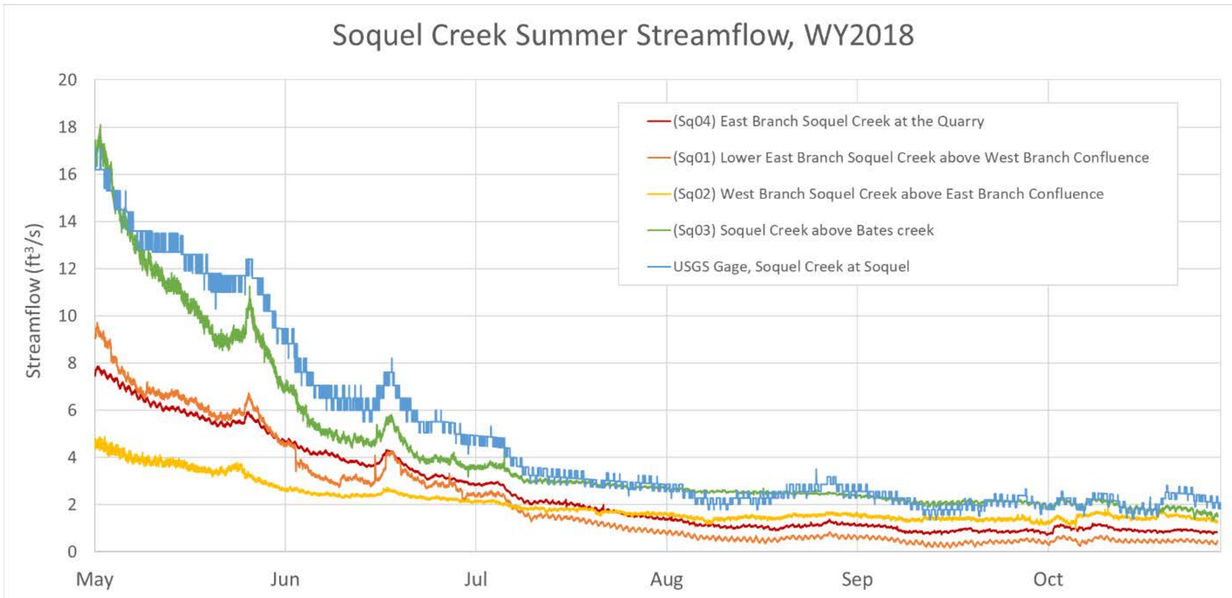

Figure 11. Streamflow conditions at the 4 project gages, plotted with the Soquel Creek USGS gage 11160000, in WY2018.

Streamflow conditions in WY2019 (Figure 12)

Long-term gage data from the USGS gage on Soquel Creek shows that total annual streamflow conditions in WY2019 were 43% above average, and summer discharge was 45% above average. Streamflow conditions at the USGS gage in May were approximately 47% higher than average, 29% below 2017 conditions, and 132% above 2018 conditions.

WY2019 data show that the large rain event in late May 2019 significantly increased streamflow conditions in early summer and boosted flow throughout the remainder of the summer. The data also show that the East Branch of Soquel became a losing stream in mid-August 2019, almost two months later than the transition in 2018, and a month and a half earlier than 2017 (note that 2017 was a much wetter year than 2019). The West Branch gage shows that flow was lower than the East Branch in early summer and nearly the same in late summer. Data from the gage above Bates Creek and the USGS gage on Soquel show that the Mainstem remained a gaining stream for most of the summer season, with periods of loss in July, August, and September. This pattern could be attributed to groundwater pumping activities along the Mainstem. All three treatment gages showed signals in the hydrograph related to surface water diversions/human water management activities.

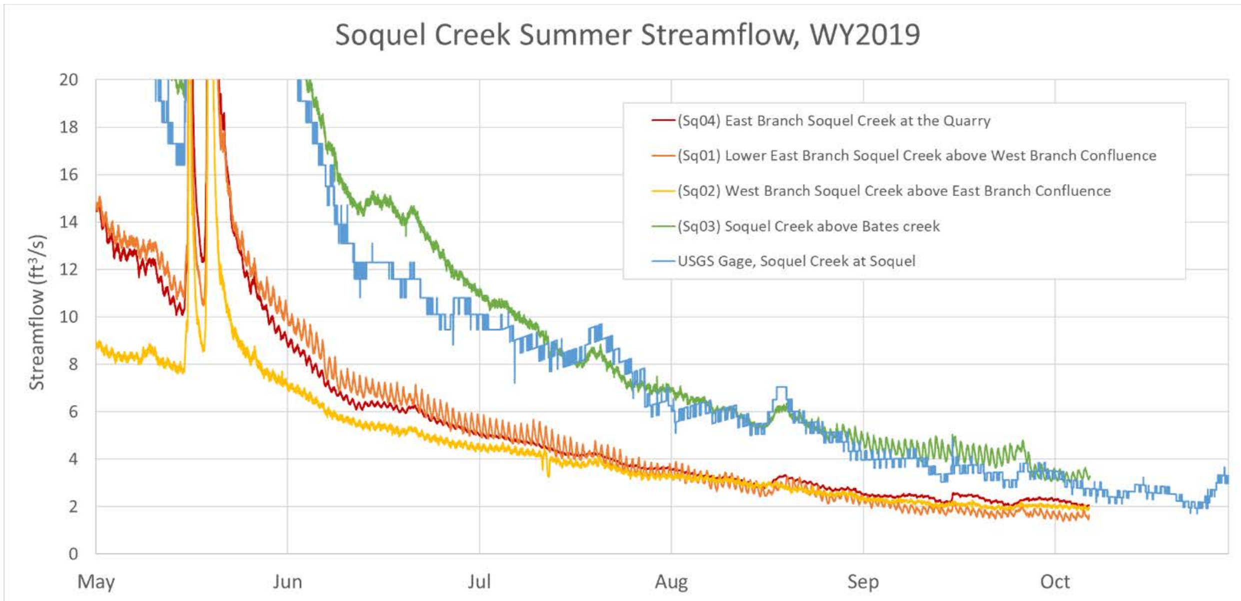

Figure 12. Streamflow conditions at the 4 project gages, plotted with the Soquel Creek USGS gage 11160000, in WY2019.

2.2.4 Impact of diversions on streamflow

Surface water direct diversions, groundwater pumping from wells located near the channel, and diversions from springs can all have significant impacts on summer streamflow conditions, especially during the driest time of year and in drought years. Surface water diversions are the easiest type of water management activity to detect in a hydrograph, but these actions do not necessarily have the largest impact on summer base flow. Surface water diversions tend to have an episodic impact on water levels and streamflow. When water is diverted directly from a stream, the diversion causes an immediate decrease in both water levels and streamflow. After the diversion has stopped, water levels and streamflow return to previous conditions. The distinct signal detected in a hydrograph from a direct diversion can be used to estimate the approximate location of the diversion, the pumping rate, and impact of the diversion on streamflow conditions.

Groundwater pumping and diversions from springs are much more challenging to identify in a hydrograph. Groundwater pumping and diversions from springs tend to have a more chronic impact on surface water conditions, with attenuated impacts, making it difficult to pinpoint in streamflow records. While we may not be able to determine the impact of groundwater pumping as precisely, we know that over larger times scales, decreased groundwater levels can result in decreased streamflow conditions. Gage data from sites in an upper and lower reach can indicate the approximate timing and duration of water loss in a reach, which could be an indication of groundwater pumping near the channel.

Streamflow data from the gage network identified several surface water diversions throughout the focus area. This section provides three examples of direct diversions/water management activities seen in the hydrograph at the three treatment gages during different WYs.

Figure 13 shows streamflow conditions captured at the reference (Sq04) and treatment (Sq01) gages on the East Branch of Soquel Creek. Data from the treatment gage show a significant drop in discharge in early June 2018, a magnitude of approximately 1 ft^3/s. This drop in flow is likely caused by an instream impoundment such as a rock dam, that held back a large portion of flow unit it filled and started spilling over. Figure 13 also shows several other drops in flow throughout the dry season of approximately 0.4 ft^3/s, or 180 gpm, possibly related to a small agricultural or residential water user.

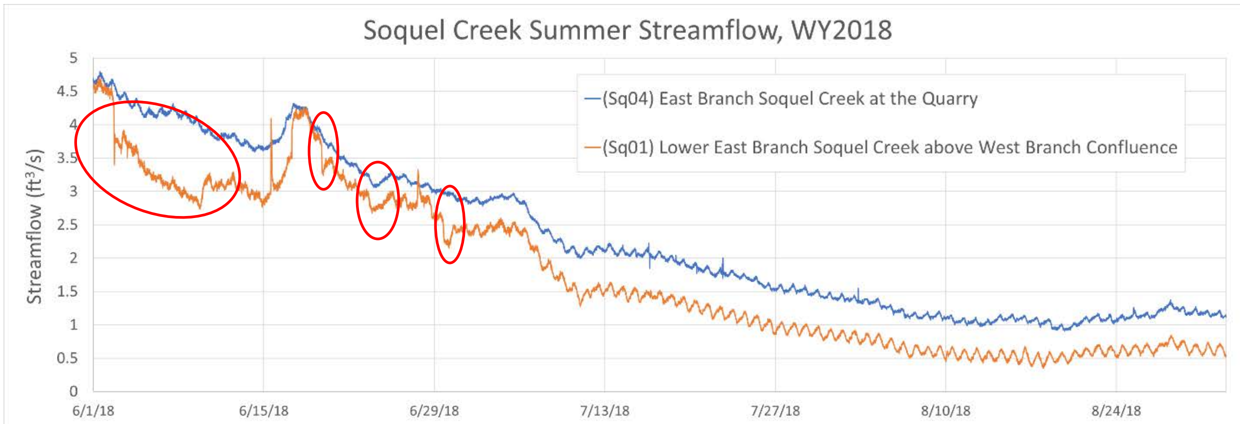

Figure 13. Summer streamflow conditions at the two gages on the East Branch of Soquel Creek in WY2018, showing the impact of water managment activities on streamflow conditions in early June at the treatment gage.

Figure 14 shows streamflow conditions at the treatment gage on the West Branch of Soquel Creek (Sq01) and reference gage on the East Branch of Soquel Creek (Sq04) in WY2019. Data from the treatment gage show significant drops in discharge in July 2019, a magnitude of approximately 0.7-1 ft^3/s, or 315-450 gpm. These drops in flow may be caused by an agricultural diversion based on the timing of the diversion and quantity of water drawn. In addition, Figure 14 shows that streamflow conditions at the treatment gage are much noisier than the reference gage, indicating that groundwater pumping, or several smaller residential diversions, may be occurring above the treatment gage.

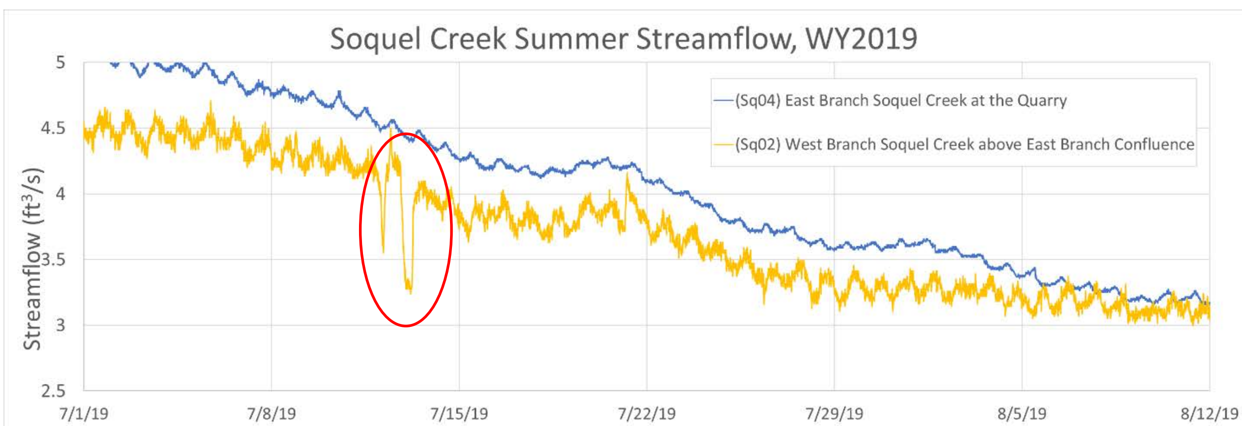

Figure 14. Summer streamflow conditions at the treatment gage on the West Branch of Soquel Creek and reference gage on the East Branch of Soquel Creek in WY2019, showing the impact of direct diversions on West Branch streamflow conditions in mid-July.

Figure 15 shows streamflow conditions at the treatment gage on the Mainstem of Soquel Creek above Bates Creek (Sq03), the treatment gage on the East Branch of Soquel Creek above the West Branch confluence (Sq01), and reference gage on the East Branch of Soquel Creek (Sq04) in WY2017. Gage data from Sq03 show drops in streamflow in late August and throughout September 2017, that are likely related to human water management activities. Gage data from Sq03 show Sq01's signals in the data, as well as several other diversions throughout the summer season. The additional drops in discharge detected at Sq03 have a magnitude of approximately 0.5-0.7 ft^3/s or 225-315 gpm, a diversion rate most commonly associated with agriculture pumping.

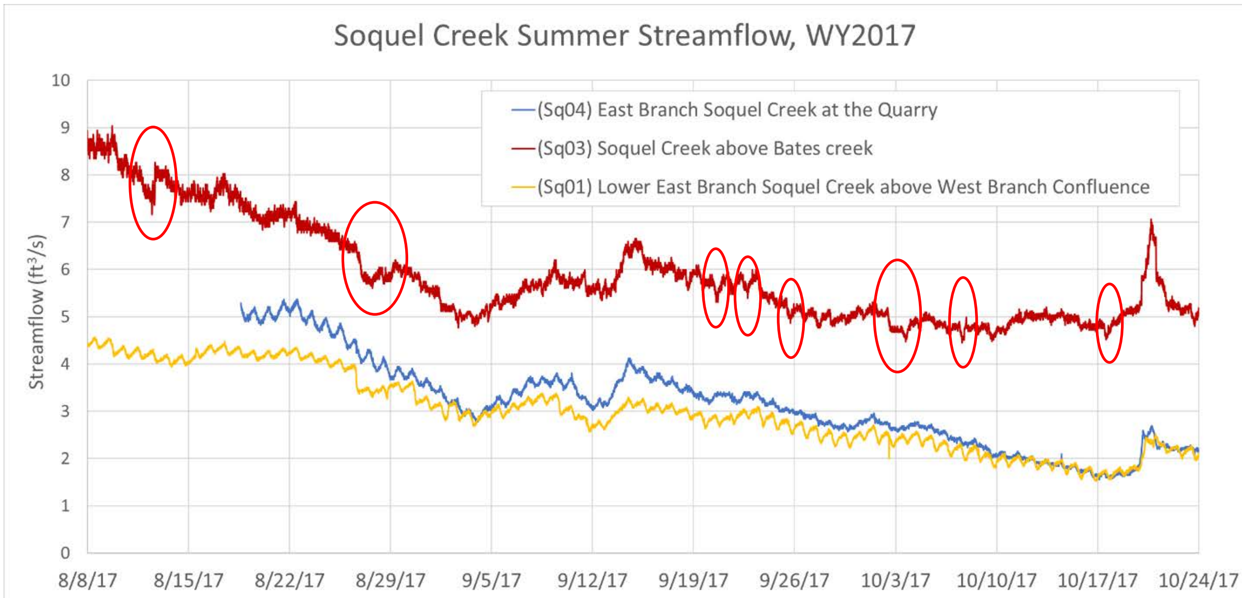

Figure 15. Summer streamflow conditions at the treatment gage on the Mainstem of Soquel Creek above Bates Creek (Sq03, red line), the treatment gage on the East Branch of Soquel Creek (Sq01, yellow line), and the reference gage on the East Branch of Soquel Creek (Sq04, blue line) in WY2017, showing direct diversions in the East Branch treatment reach and on the Mainstem.

2.3 Salmonid monitoring in the Soquel Creek Watershed

This section provides information on the status, life history and distribution of steelhead and coho salmon in the Soquel Creek Watershed. In addition, juvenile steelhead density data are examined in relationship to dry season flow conditions.

2.3.1 Status and life history

The Soquel Creek Watershed supports a viable population of steelhead *(Oncorhynchus mykiss)*, which are listed as threatened under the Federal Endangered Species Act (ESA). The watershed is also considered a recovery area for coho salmon *(Oncorhynchus kisutch)*, which are listed as endangered by both the Federal and State ESA, though a viable population is not present in the watershed at this time.

During the rainy season, the timing, duration and intensity of storms affect all salmonid life stages. Adult fish migrate from the ocean when flows are high enough to provide access into Soquel Creek. Steelhead adults migrate upstream throughout the rainy season from December to May. In normal and wet winters, steelhead migrate to spawning areas higher in the watershed. In dry and drought years, however, they may spawn lower in the watershed. Coho salmon adults migrate upstream during early winter (December to March) and depend on storms during this period to have access to the watershed. In late winter and early spring, both steelhead and coho salmon smolts need adequate streamflow to migrate out to the ocean. During dry and drought winters, passage for upstream migrating adults and downstream migrating smolts can be compromised by wide and shallow riffles.

Intense winter and spring storms can reduce the survival of eggs and sac fry through scour or smothering of redds (nests), while a mild winter or spring can result in high spawning success. In years with intense storms, steelhead that spawn later can have higher spawning success due to higher base flows later in the summer season. Overwintering juveniles require areas of low velocity or “winter flow refuge” such as undercut banks, boulders and large woody material to survive high flow velocities during storms.

Steelhead juveniles typically spend 1-2 years in freshwater, creating overlapping age classes of young-of-the-year (less than 1 year old) and 1+ (more than 1 year old). Steelhead use both stream and lagoon habitat for rearing. The City of Capitola manages Soquel Lagoon which provides productive rearing habitat in most years. After the lagoon is formed in late May, streamflow contributes to productive lagoon habitat. Coho juveniles typically spend one year in freshwater. Coho juveniles prefer cool, deep pools with ample large woody material and use lagoon habitats during outmigration but do not always use lagoon habitats for summer rearing.

During the dry season, streamflow affects both the quality and quantity of juvenile rearing habitat. In freshwater habitats, young salmonids depend on streamflow to carry “stream drift”, the aquatic and terrestrial insects that they eat. Since salmonids are cold-blooded, their metabolism fluctuates with stream temperatures. In cooler water temperatures, food requirements and growth rates are low. As stream temperatures increase, food requirements are higher for metabolic maintenance, but growth rates can be high with adequate food resources. Spring is an important period where good base flows and abundant macroinvertebrates support growth. By late summer and fall, juveniles are often in survival mode, depending on the low flows to carry enough food to survive. During this stressful, low-flow period, modest increases or decreases in flow make a considerable difference in juvenile salmonid survival, both in terms of food supply and water quality (dissolved oxygen, temperature, etc.)

2.3.2 Distribution in the Soquel Creek Watershed

There are approximately 25 miles of steelhead habitat in the Soquel Creek Watershed (Alley 2006). Steelhead occur throughout the Soquel Creek Mainstem, including the lagoon, East Branch Soquel Creek, and West Branch Soquel Creek. Steelhead occur also in tributary streams including Moores Gulch, Bates, Hester, Hinkley, and Amaya Creeks. On the East and West Branch and in the tributaries, steelhead distribution becomes limited by natural bedrock and boulder cascade features. On the West Branch, steelhead distribution is limited by two natural bedrock outcrops (Girl Scout Falls 1 and 2), which are passable only during wet or very wet winters. At the upper extent of West Branch, a dam precludes steelhead access to Burns and Laurel Creeks. On the East Branch, Asbury Falls and other boulder cascades restrict passage except during wet or very wet winters. In these areas with limited steelhead access, the species *O. mykiss* live as resident rainbow trout, who spend additional years in freshwater before outmigration or complete their life history in freshwater.

Coho salmon successfully spawned in the Soquel Watershed in 2008 and 2015 after an absence since before 1997. In 2008, coho juveniles were found in the East Branch Soquel Creek. In 2015, coho juveniles were in lower West Branch Soquel Creek and the Upper Mainstem.

2.3.3 Juvenile Steelhead and Stream Habitat Monitoring Program

The Juvenile Steelhead and Stream Habitat (JSSH) Program is a local, multi-agency program that funds the annual monitoring of fish, wildlife, and stream habitat for four Santa Cruz County watersheds – San

Lorenzo, Soquel, Aptos and Pajaro. The program consultant, D.W. ALLEY and Associates (DWA), collects data for eight long-term sampling sites in the Soquel Creek Watershed: four sites on the Mainstem, two sites on the East Branch, and two sites on the West Branch. During certain years, additional sites are also sampled.

This program samples steelhead juveniles during the dry season in late summer or early fall. For each sampling site, steelhead are collected in multiple habitat units (pool, riffle, run) and measured. With these data, DWA calculates densities (number of fish per 100 feet) for two size classes at each sampling site. Size Class 1 are fish less than 75 mm standard length and Size Class 2 are fish greater than 75 mm standard length. Size Class 1 juveniles are predominantly young-of-the-year (YOY) and are expected to spend an additional year in the watershed before migrating out to the ocean (outmigration). High densities of Size Class 1 indicate areas of successful spawning. Size Class 2 juveniles include both older juveniles (more than 1 year old) and YOY that grew well in their first year. Size Class 2 densities indicate areas in the watershed that support fast growing YOY and older fish that are expected to migrate out to the ocean the following winter and spring.

2.3.4 Monitoring program general findings and trends

This section describes patterns and relationships found in the JSSH database analysis website, http://scceh.com/steelhead.aspx, including both general patterns of juvenile steelhead densities across the sampling sites and how densities are related to dry season flow. Data from 1981, 1994, and 1997-2018 have been incorporated into the JSSH data analysis website. Data from 2019 has not yet been incorporated into the website but is included in this discussion. The relationships between flow and juvenile distribution and density are examined in 3 ways: (1) informal comparison of densities and flow year type (e.g. drought); (2) analysis of densities against all habitat variables collected in the monitoring program; (3) a specific analysis comparing densities and a flow variable.

In general, juvenile densities (both Size Class 1 and Size Class 2) are higher in the East and West Branch and the Upper Mainstem Soquel Creek (Sites 10, 12, 13a, 16, 19), than in the Lower Mainstem Soquel Creek (Sites 1, 4). Long term averages of Size Class 1 densities are highest at the two most upstream sites, East Branch Site 16 and West Branch Site 21. Prior to the most recent drought, the East Branch Site 16 (within SDSF) had consistently high densities of Size Class 1/young-of-the-year and remains an important spawning area. Long term averages of Size Class 2 densities are highest in the upper mainstem (Sites 10 and 12), East Branch (Sites 13 and 16) and West Branch (Site 21). In 2018, highest Size Class 2 densities were at upper mainstem (Sites 10 and 12) and West Branch (Site 21). Long term average densities of both Size Class 1 and 2 are lower at West Branch Site 19 compared to the other upper watershed sites (Figure 16).

Of the four watersheds in the JSSH monitoring program (San Lorenzo, Soquel, Aptos and Pajaro), Soquel has the second highest long-term average densities for Size Class 1. Of the four watersheds, Soquel has the lowest long-term average densities for Size Class 2, but the differences between watersheds are fewer for Size Class 1. This discrepancy between relatively high Size Class 1 densities and relatively low Size Class 2 densities could be attributed to multiple reasons, including low survival of YOY over the winter and into the following summer and low growth rates of YOY into Size Class 2.

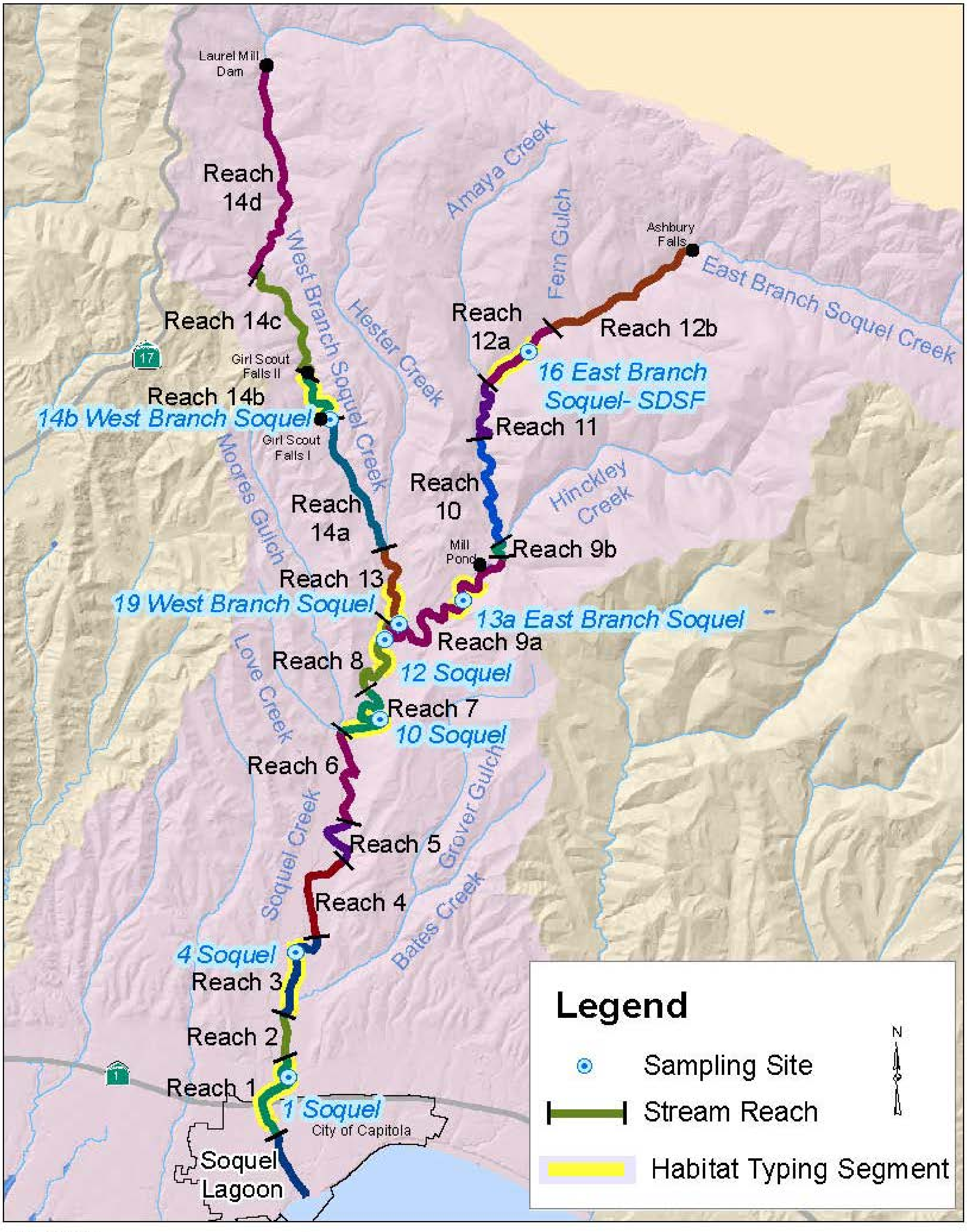

Figure 16. Juvenile Steelhead and Stream Habitat Monitoring Program steelhead sampling sites in the Soquel Creek Watershed. Figure courtesy of JSSH partners.

From 1998 to 2018, Size Class 1 densities were highest in 1997, 2002, 2004 and 2008. Size Class 1 densities were lowest in 2011, 2014 and 2015. High density years share a lack of intense spring storms that result in higher egg and fry survival and good spring flows to support juvenile survival and growth. Low density years included 2014 and 2015 which were drought years, and 2011, which had intense storms in April and June.

While both Size Class 1 and Size Class 2 densities vary from year to year, Size Class 2 densities fluctuate less than Size Class 1 densities. Size Class 2 densities were highest in 1997, 1998, 2005, 2010 and 2017. Size Class 2 densities were lowest in 2014, 2015 and 2016. High density years share good to excellent spring base flows and, except for 2017, a lack of intense spring storms. Low density years include drought years.

Both mean densities across all sites and individual sites show declining trend lines for Size Class 1 and Size Class 2. Both Size Class 1 and Size Class 2 show significantly negative trends between 1994 and 2018 with 22 data points for included sites. The general trend for juvenile steelhead densities is declining for both size classes but the decline is steeper for Size Class 1. The declining trend for Size Class 2 is moderated by some above average years. Higher densities have been reported for 2019, which is expected to change these trend lines.

Upper East Branch Site 16 shows a very marked decline in juvenile densities during the drought years of 2014 and 2015 due to extremely low streamflows and dry stream sections. The lower East Branch Site 13 does not show a similar marked decline.

2.3.5 Analysis of flow and juvenile densities

The data analysis website evaluates the relationships between the Size Class 1 and Size Class 2 densities and habitat variables collected for each sampling site. The data show a relationship between dry season flow and juvenile steelhead densities. The relationship between riffle and run average depth and juvenile densities is statistically significant for both Size Class 1 and 2. In addition, Size Class 1 densities vary with maximum depth and riffle length. Size Class 2 densities vary with maximum depth for riffle habitats, width for run habitats, and habitat width for pool habitats. These relationships demonstrate how streamflow supports additional juveniles through a combination of increased habitat quantity (more depth and width) and quality (deeper riffle and run habitat reflect higher dry season flow which increases food supply). Deeper habitat units also provide better cover from predators.

In order to further examine the relationship between dry season flow and juvenile steelhead densities, the JSSH program created a flow variable for mean June and mean September flow for each sampling site. The flow variable was calculated by developing a mathematical relationship between flow data collected in June and September and the USGS Soquel Creek gage. Looking at the Mainstem sites, there was no significant relationship between Size Class 1 and Size Class 2 densities and flow. Looking at all Soquel Watershed site densities and flows, there is a significant negative relationship between Size Class 1 and the mean September flow variable. While counterintuitive, this relationship suggests that with higher flows, more juveniles grow into the larger Size Class 2. Although the data show a positive relationship between Size Class 2 and flow, the relationship was not significant.

3. Human water needs

Quantifying human water needs in coastal watersheds is an important tool in watershed restoration to help resource managers identify the timing, location, and magnitude of water use. Estimating human water needs across a large landscape, such as the Soquel Creek Watershed focus area, is challenging and complex. Some water management activities, such as agricultural irrigation and residential water use, can be estimated using remote sensing while other activities are better estimated using other data sources. For this study, human water demand was estimated in four ways:

1. Remote sensing
2. Analysis of water rights data
3. A combination of remote sensing and ground well data
4. A combination of water rights and ground well data

Each method provides important insights into the location and scale of human water demand in the watershed. For this analysis, we estimate water use in four areas of interest, defined as the area above each study gage, as well as the focus area as a whole (Figure 17).

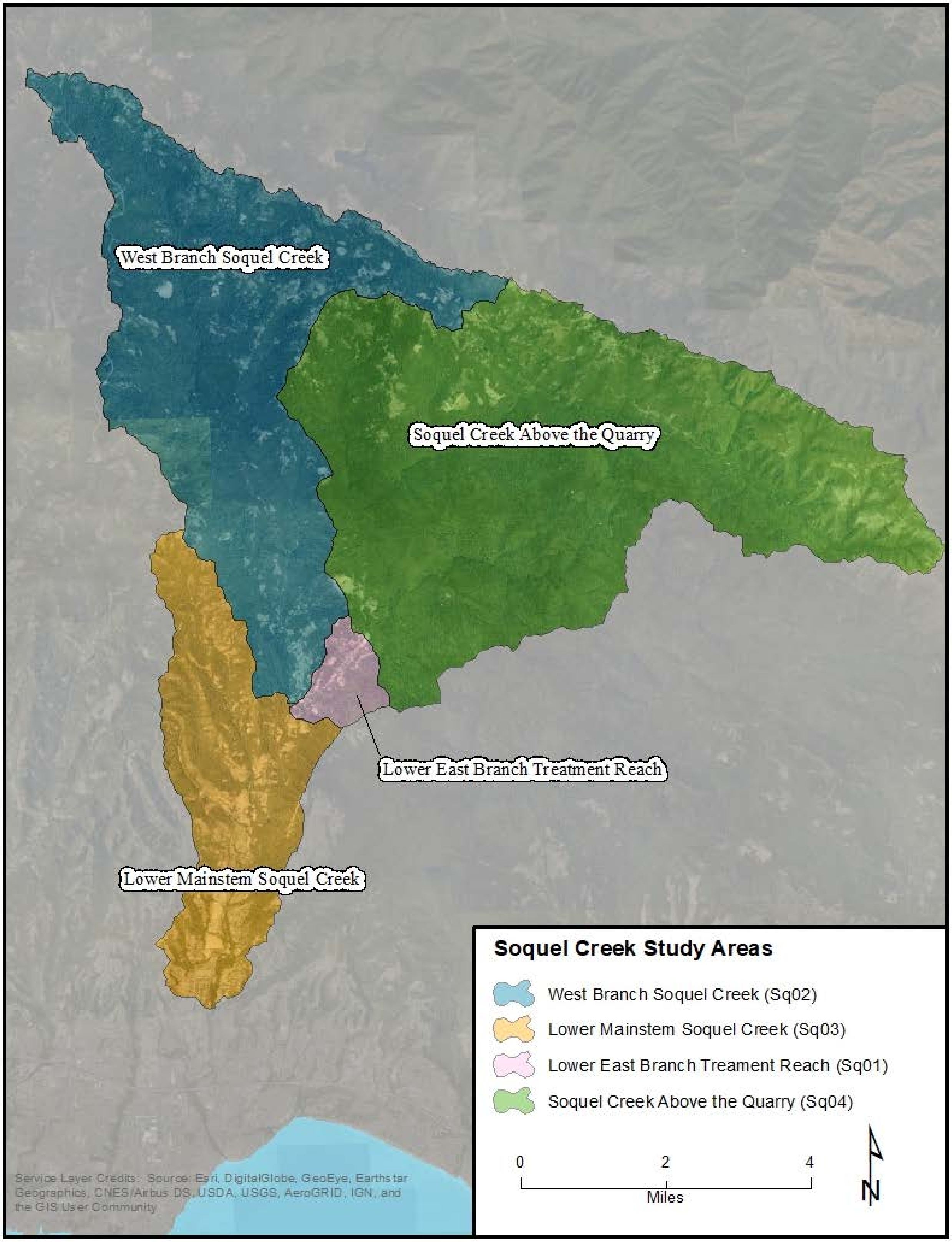

Figure 17. Gaged study areas examined individually for the human water use analysis within the Soquel Creek Watershed focus area.

3.1 Remote sensing analysis methods and results

Using high resolution aerial imagery of the watershed (eMI 2018) in ArcGIS and Google Earth Pro, the Trout Unlimited team digitized land use (Figure 18). Agricultural fields, irrigated lawns and turf, and building structures of different types were hand-digitized. A combination of standardized water use estimates and known use rates provided by the County of Santa Cruz was then applied to these data. The estimated use rates and assumptions involved for different types of uses are described below.

Agricultural water needs. Agricultural coverage was digitized to estimate the total acreage of agricultural land in each gaged study area. Total agricultural water need was then calculated based on regional per-area estimates of water use for different types of agriculture. Average per-acre water need estimates used for vineyards were drawn from a groundwater model produced for the region and estimates for use in Northern California, which reported an annual average of 0.4 acre-feet (AF) of water per acre of vineyard (HydroMetrics 2017). Much of the orchard area in the Soquel Creek Watershed is dry-farmed, so a low-end estimate of 0.23 AF per acre per year was applied based on estimates from the County Environmental Health Department. Sports fields and turf were assigned rates based on the time of year, ranging from 1.9 to 5 AF per acre annually, with higher use in summer and lower use in winter (Hanak and Neumark 2006). A report by the University of California Cooperative Extension estimated pasture irrigation as 2.3 AF per acre annually, and this value was applied conservatively to pastures with clear signs of irrigation from satellite imagery (UCCE 2015). Other row crops and nurseries (besides marijuana) were not distinguished by type and assigned regional estimates provided by the County of Santa Cruz, with water use totaling 2 AF per acre annually. All irrigation of vineyards, orchards, and pasture was assumed to take place during the 152 days considered summer months for this report.

Industrial (wineries). Digitized point structures were used to create an estimate of wine production water use as a separate factor from growing grapes on vineyard land. Winery water needs were only calculated for those vineyards that appeared to be affiliated (based on proximity, parcel ownership, or website information) with wine production facilities in each project area (e.g. not just tasting rooms, which were categorized as commercial structures) and for which there were production estimates available. Winery water use is a function of production: University of California, Davis researchers estimate that, on average, 6 gallons of water are used to make 1 gallon of wine (Adams 2011). Estimates of production were taken from local winery websites and industry databases.

Residential & commercial. Building structures in the study area were first identified as either agricultural (e.g. barn or shed), residential, residential storage (e.g. garage or shed), or commercial. For all structures identified as residential or commercial, a standard water use value of 355 gallons per day per structure for a five-month summer period (152 days) and 155 gallons per day for a seven-month winter period (213 days) was applied (CEMAR 2014). This use accounts for needs like handwashing, bathing, and drinking, as well as smaller landscaping in domestic settings (e.g. house plants, lawns, and pets). Because it includes residential irrigation needs our water use estimate accounts for a considerably greater water use in summer than in winter (a 130% increase in summer), which is a common feature for water use in California.

Schools. The one school in this focus area reports its water use to the County, so reported values were used in place of this estimate (County of Santa Cruz, personal communication).

Camps/conference centers/resorts. For those centers and camps not reporting their water use to the County of Santa Cruz, annual water use estimates were based on facility sizes and periods of operation.

The centers were assumed to have full occupancy for their periods of operation, as described by their websites. For those with no information online, estimates from similar camps with known water use in other watersheds were used. For centers specifying day use, the school rate of 4 gallons of water per day per person for toilet-use, hand-washing, and drinking were used. For those with explicit overnight use we assigned the regional household estimates, 355 gallons per household per day in the summer and 155 in the winter, to account for cooking, cleaning, bathing, etc.

Cannabis. Outdoor cannabis grows were identified using digital imagery. Each visible plant was counted, and water use was estimated based on a use rate of 6 gallons per plant per day from May through September. Indoor cannabis grows (greenhouses in locations associated with past or present outdoor grows) were estimated to have one plant per 1.115 square meters of greenhouse and water use was estimated at the same 6 gallons per plant per day rate (based on numbers described by Bauer et al. 2015).

The communities relying solely on municipal water from the Soquel Water District within the West Branch and Lower Mainstem Soquel Creek were excluded from this analysis.

Based on this remote sensing analysis we found that the entire focus area includes approximately 52.6 acres of vineyard, 89 acres of orchard, 1.8 acres of irrigated turf, 27.8 acres of row crops, 9.5 acres of irrigated pasture, and over 7,600 cannabis plants. There are 1,663 commercial and residential structures within the focus area, as well as one school, four camps/conference centers, and five wineries (Table 1). What follows is an in-depth analysis of land use and estimated human water need compared to stream discharge within each gaged study area.

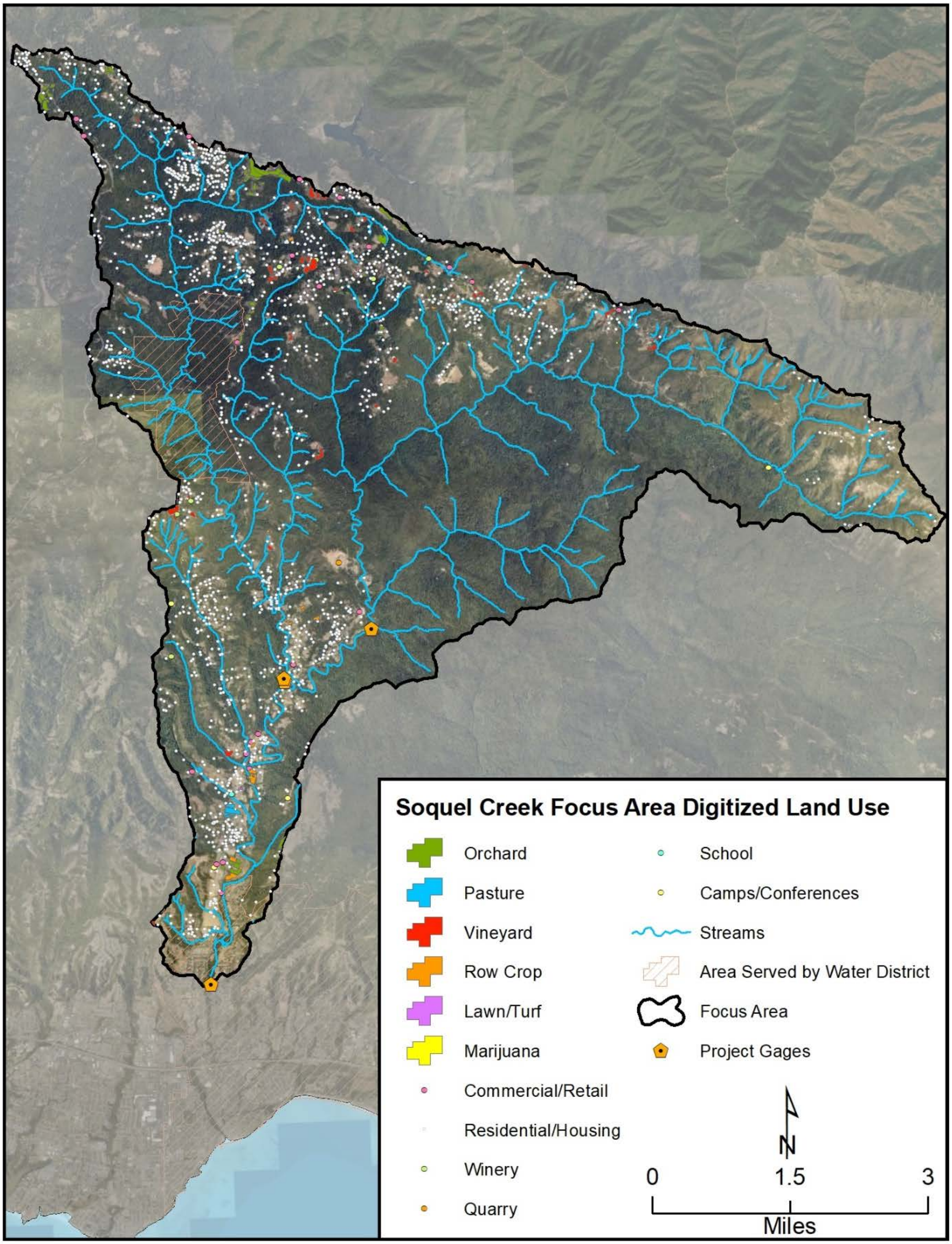

Figure 18. Digitized land use and point structures in the Soquel Creek focus area.

Table 1. Remotely sensed land use and human development in the Soquel Creek study, divided by interest area. Note: there is one camp in the West Branch that was not included in this analysis as it was not active at the time of the study.

Interest area	Vineyard (acres)	Orchard (acres)	Lawns/turf (acres)	Row crops and nurseries (acres)	Irrigated pasture (acres)	Marijuana (# of plants)	Commercial & residential (# of structures)	Schools (#)	Camps/ Conference centers (#)	Wineries (#)
(Sq04) Soquel Above the Quarry	14.9	6.1	0.8	1.3	-	3,669	322	-	1	-
(Sq01) Lower East Branch Treatment	-	-	-	1.2	-	-	56	-	-	-
(Sq02) West Branch	29.7	56.6	0.4	5.8	-	2,875	899	-	-	5
(Sq03) Lower Mainstem Soquel	8	26.2	0.6	19.5	9.5	1,144	386	1	3	-
Total for focus area	52.6	89	1.8	27.8	9.5	7,688	1,663	1	4	5

3.1.1 Upper East Branch above the quarry (Sq04)

Land use in the Upper East Branch Above the Quarry study area is visibly dominated by SDSF land with some acreage of agriculture and a small number of commercial and residential structures (Figure 19). There is also one summer camp and a quarry located within this study area.

Table 2 shows estimates of human water need in the Upper East Branch study area on an annual and summer scale based on the results of the land use digitization. We estimate that annual human water need within this study area is nearly 122 AF of water, while summer need is around 88 AF of water.

Table 2. Human water use estimates based on land use digitization for the Upper East Branch Above the Quarry study area on an annual and summer scale.

	Vineyard	Orchard	Lawns/turf	Row crops and nurseries	Marijuana	Commercial & residential	Camps/ Conference centers	Total Water Need (AF)
Summer water need (AF)	6.0	1.4	1.7	1.1	10.3	52.7	10.1	**88.3**

Annual water need (AF)	6.0	1.4	2.6	2.6	10.3	84.9	14.1	**121.9**

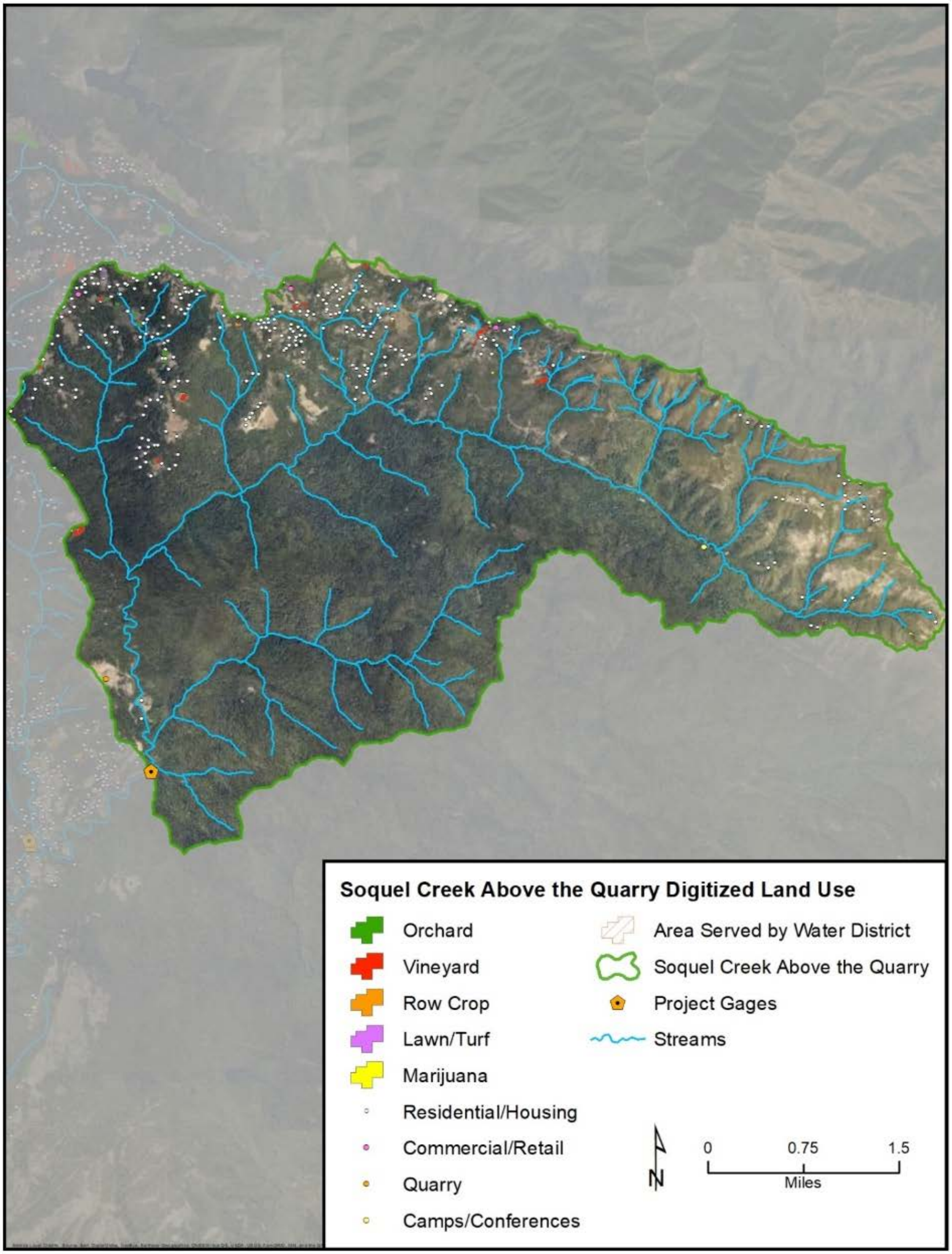

Figure 19. Digitized land use and point structures in the Upper East Branch Above the Quarry (Sq04) study area.

Because of the seasonal disparity in rainfall and discharge that characterizes the local climate, the timing of human water need when compared to water availability is extremely important in all study areas. Total summer discharge within coastal California streams is typically very low, and the study areas within the Soquel Creek focus area are no different. This is apparent especially when examined on a monthly timescale: Figure 20 shows monthly discharge for the Upper East Branch Above the Quarry study area across the years of this study compared to estimated human demand. In September 2018 when discharge was at a low of 55 AF, we estimate human demand to be around 17.5 AF, over 30% of the total discharge.

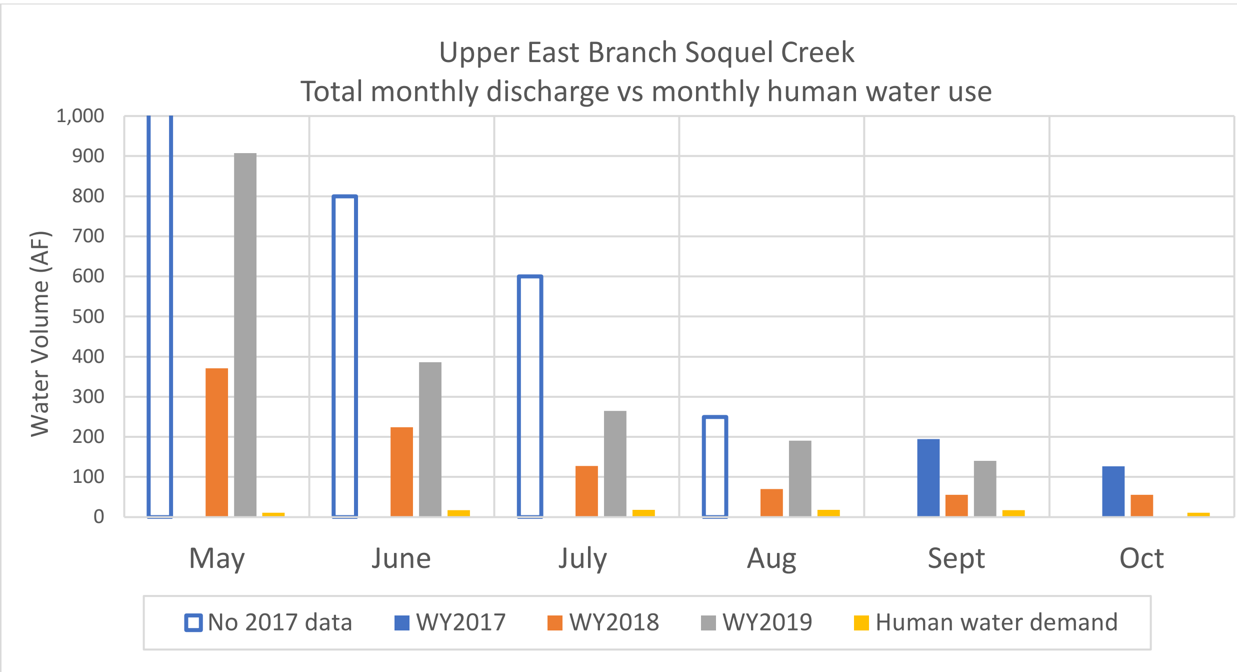

Figure 20. Monthly discharge compared to estimated human need at the Upper East Branch gage (SQ04).

3.1.2 Lower East Branch above the West Branch confluence (Sq02)

The Lower East Branch Above the West Branch Confluence study area is a small study area between the gage at the quarry and the gage above the confluence with the West Branch of Soquel Creek. It has very limited human land use, with some residential structures and row crops (Figure 21). Based on land use digitization, we estimate human water need in the Lower East Branch to be around 17 AF annually and 10 AF during the summer (Table 3).

Table 3. Human water use estimates based on land use digitization for the Lower East Branch Treatment Reach study area on an annual and summer scale.

	Row crops and nurseries	**Commercial & residential**	**Total Water Need (AF)**
Summer water need (AF)	1.0	9.3	**10.3**

Annual water need (AF)	2.4	14.9	**17.3**

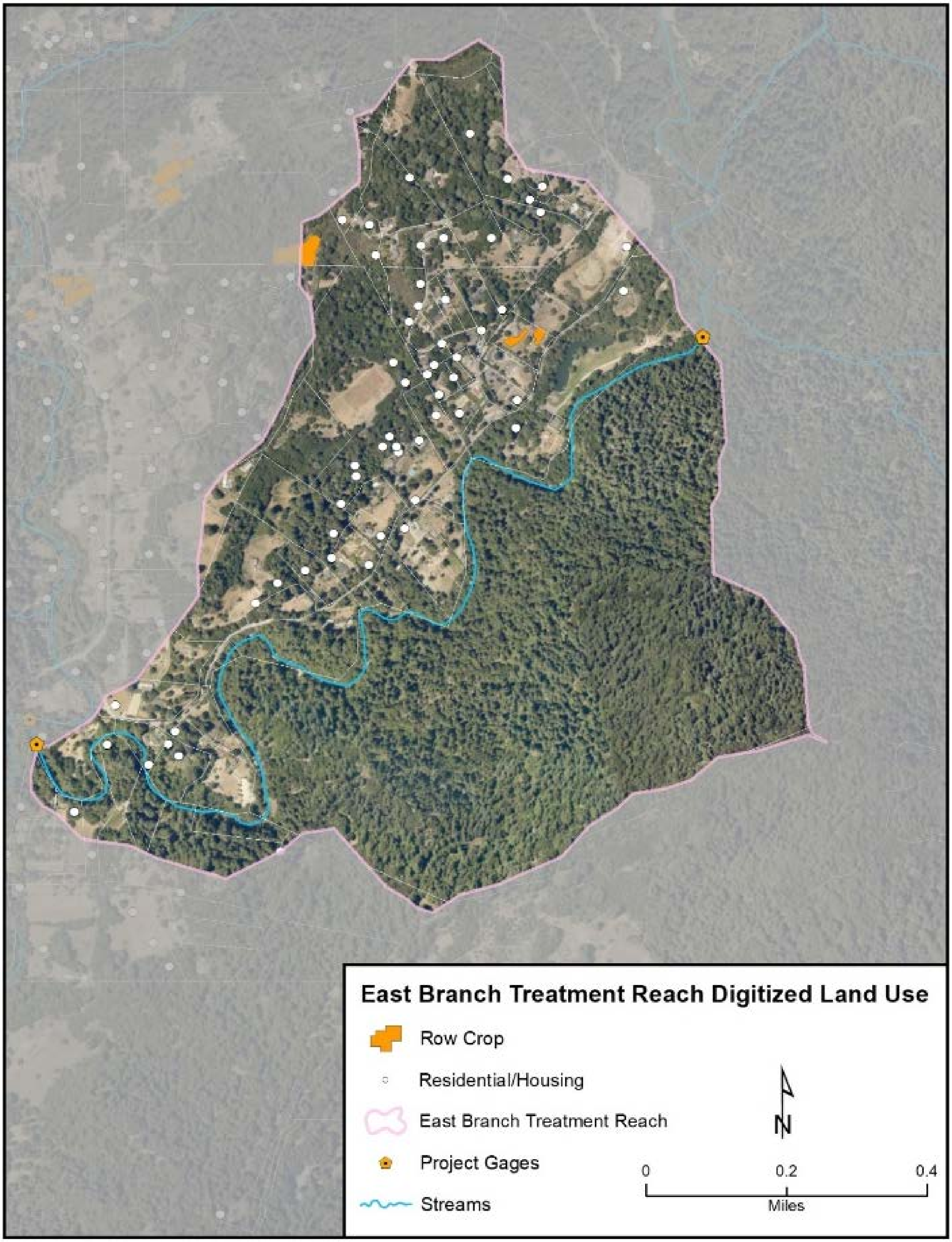

Figure 21. Digitized land use and point structures in the Lower East Branch Treatment Reach study area.

When comparing monthly summer discharge at this gage to upstream human summer demand, a similar picture to the Upper East Branch gage appears: discharge at the East Branch of Soquel Creek above the confluence is only just above estimated human demand. In September 2018 discharge was 26 AF with an estimated human demand of 19.5 AF—75% of total discharge (Figure *22*).

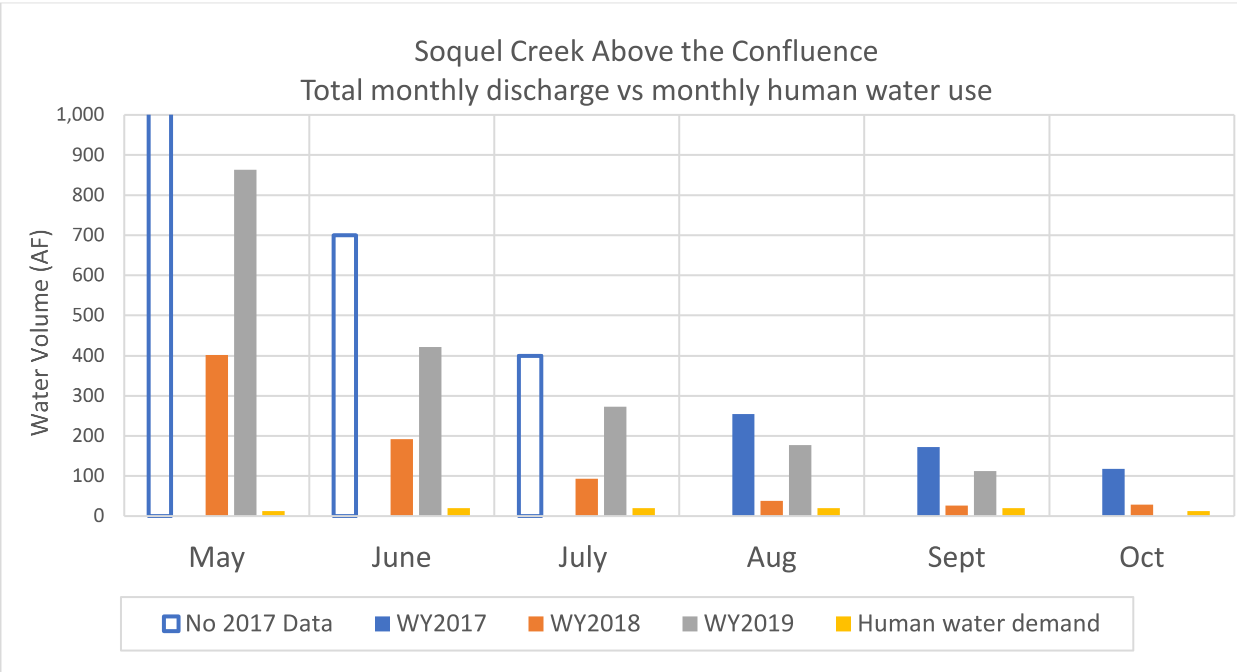

Figure 22. Monthly summer discharge compared to estimated human need for the East Branch Soquel Creek Above the Confluence study area (SQ02).

3.1.3 West Branch Soquel Creek (Sq01)

In the West Branch of Soquel Creek, there is a significant increase in the human footprint on the landscape. This study area contains residential and commercial structures, as well as wineries, orchards, vineyards, and other agricultural land uses (Figure 23).

We estimate an annual human water need of almost 287 AF, with 188 AF of that need occurring during the summer months (Table 4). West Branch Soquel Creek has significantly more human presence than the East Branch, and estimated human demand across each summer month in West Branch Soquel Creek is a significant portion of discharge in the drier late summer months: in September 2018 discharge was around 84 AF while human demand was 37AF—over 44% of the available water (Figure 24).

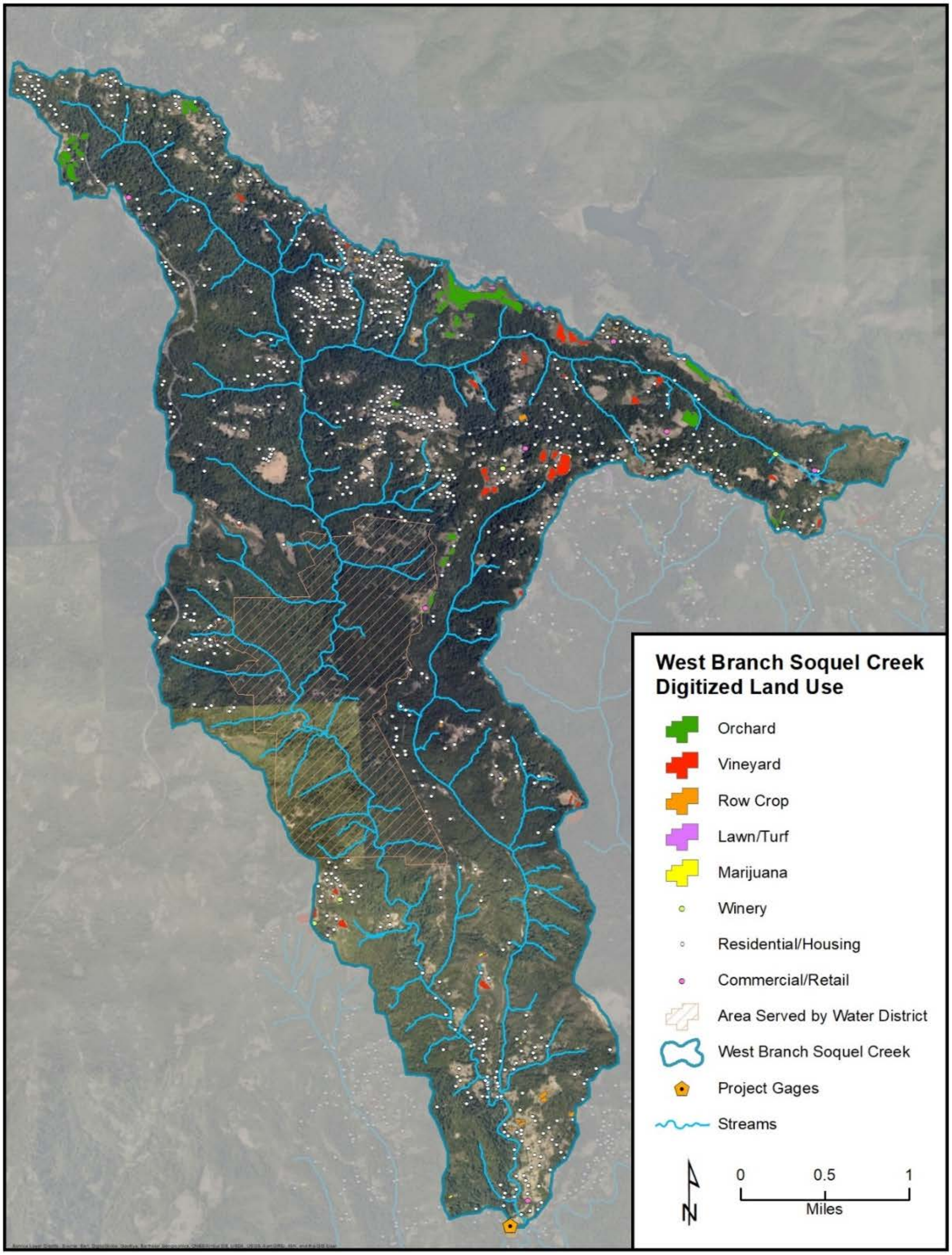

Figure 23. Digitized land use and point structures in the West Branch study area.

Table 4. Human water use estimates based on land use digitization for the West Branch Soquel Creek study area on an annual and summer scale.

	Vineyard	Orchard	Lawns/turf	Row crops and nurseries	Marijuana	Commercial & residential	Wineries	Total Water Need (AF)
Summer water need (AF)	11.9	13.0	0.8	4.8	8.1	148.9	0.4	**187.9**
Annual water need (AF)	11.9	13.0	1.3	11.6	8.1	240.0	0.9	**286.7**

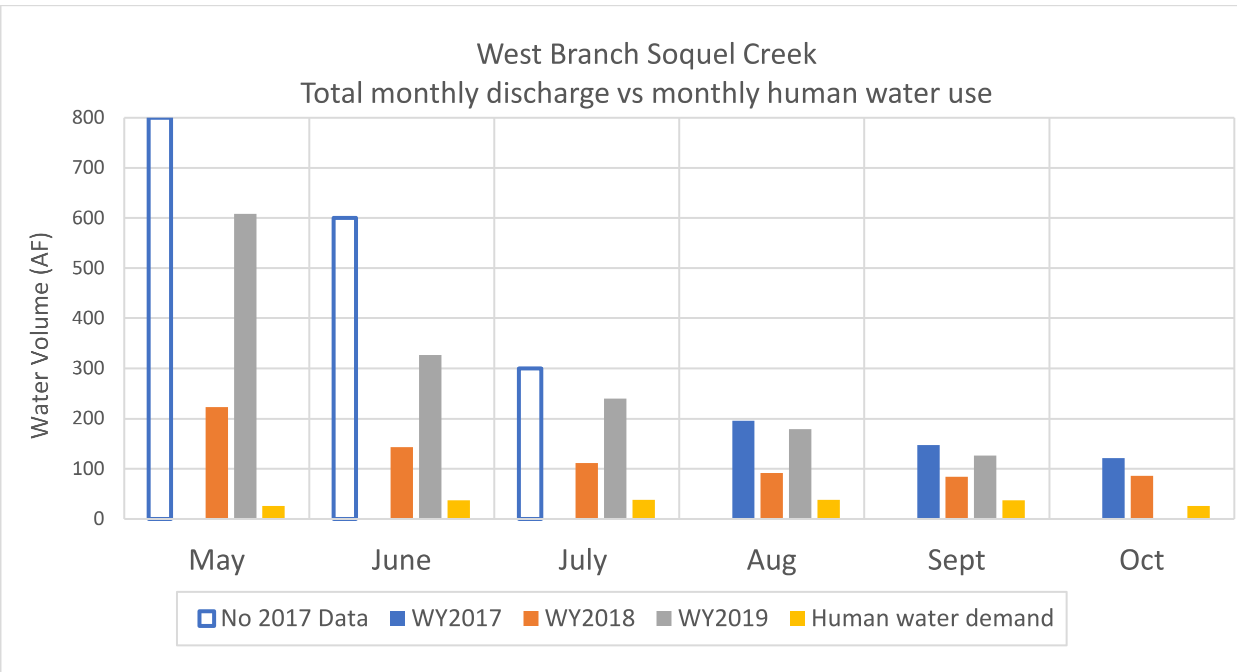

Figure 24. Monthly summer discharge compared to estimated human need for West Branch Soquel Creek (SQ01).

3.1.4 Mainstem Soquel Creek above Bates Creek (Sq03)

Mainstem Soquel Creek Above Bates Creek is the lowest study area within the focus area and is the closest to the more urbanized areas of the basin. Therefore, it is heavily impacted by human use and contains many agricultural uses (including irrigated pasture) as well as residences, camps, schools, and retail structures (Figure 25). We estimate human water need in the Lower Mainstem Soquel Creek study area to be 200 AF annually and 128 AF for the summer months (Table 5).

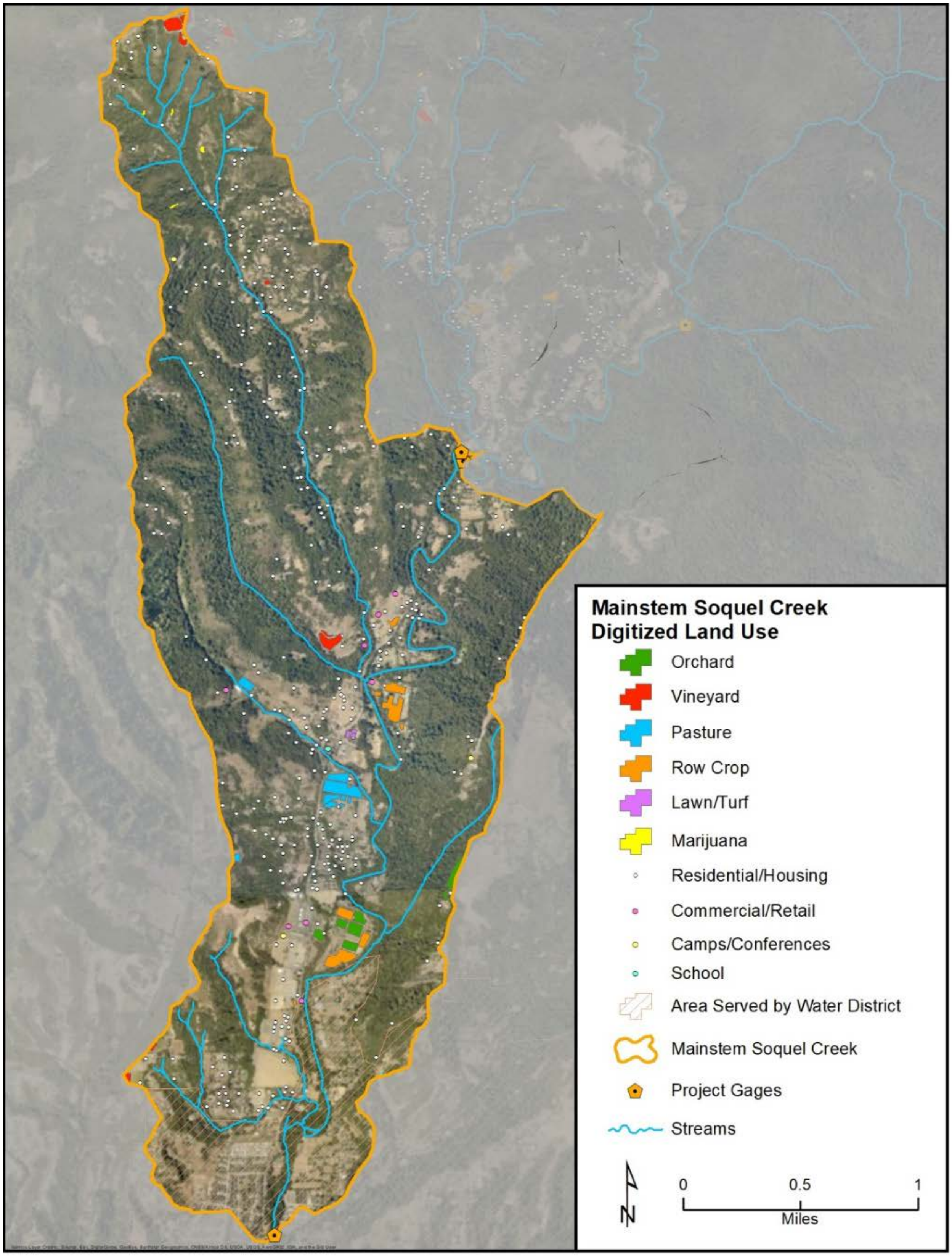

Figure 25. Digitized land use and point structures in the Lower Mainstem Soquel study area.

Table 5. Human water use estimates based on land use digitization for the Lower Mainstem Soquel Creek study area on an annual and summer scale.

	Vineyard	Orchard	Lawns/turf	Row crops and nurseries	Pasture	Marijuana	Commercial & residential	Schools	Camps/ Conference centers	Total Water Need (AF)
Summer water need (AF)	3.2	6.0	1.3	16.5	26.0	3.2	63.9	0.1	7.3	**127.5**
Annual water need (AF)	3.2	6.0	1.9	39.5	26.0	3.2	103.0	0.3	16.6	**199.7**

3.1.5 Entire focus area

Based on land use digitization, we estimate total annual human water need for the Soquel Creek focus area to be approximately 627 AF, and total summer need to be about 410 AF (Table 6). For the summer season, human water use in the entire focus area mirrors that of West Branch Soquel Creek. On a monthly scale, estimated human need in the focus area is a significant portion of discharge. In September 2018, discharge was 128 AF and human need is estimated at 81 AF—over 68% of the available surface water (Figure 26).

Table 6. Human water use estimates based on land use digitization for the entire Soquel Creek focus area on an annual and summer scale.

	Vineyard	Orchard	Lawns/turf	Row crops and nurseries	Pasture	Marijuana	Commercial & residential	Schools	Camps/ Conference centers	Wineries	Total Water Need (AF)
Summer water need (AF)	21.0	20.5	3.8	23.4	26.0	21.7	275.4	0.1	17.4	0.4	**409.7**
Annual water need (AF)	21.0	20.5	5.8	56.1	26.0	21.7	443.9	0.3	30.8	0.9	**626.9**

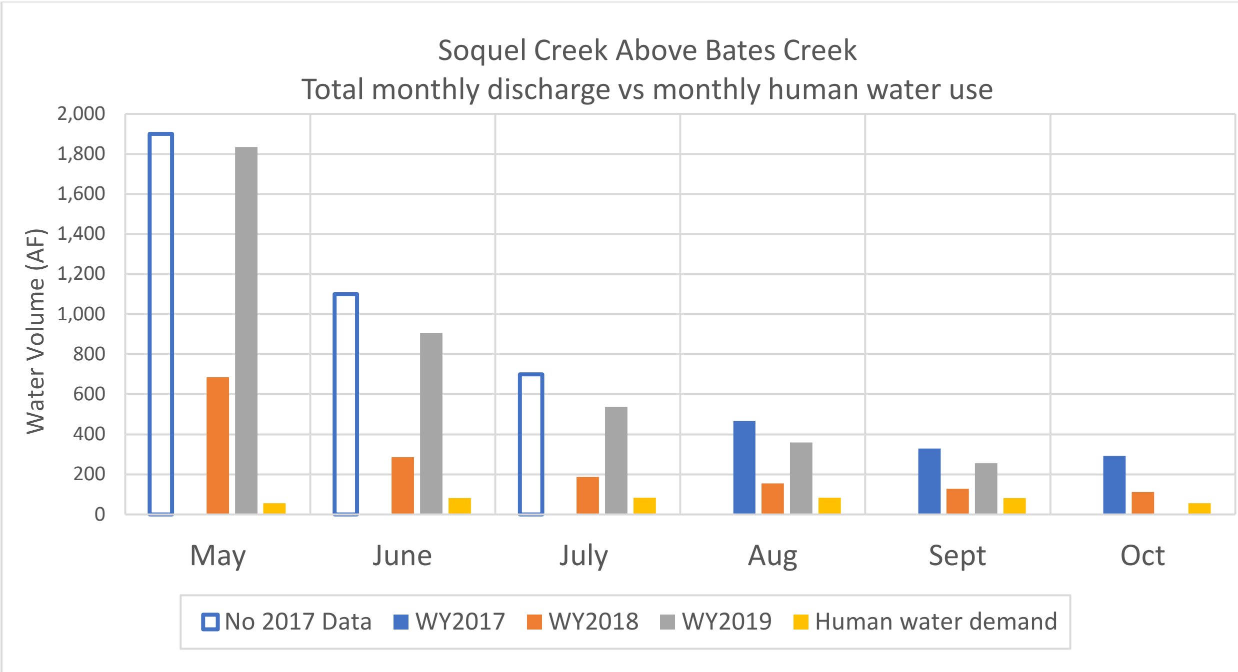

Figure 26. Monthly summer discharge compared to estimated human need for the entire focus area above Bates Creek (SQ03).

3.1.6 Remote sensing water use estimates per parcel

To spatially visualize areas with the highest estimated water demand and identify potential landowner partners and project areas, we calculated demand on a per parcel basis (Figure 27). Using ArcGIS, we merged parcel data with our digitized land-use and water use estimates to calculate the total demand per parcel. Due to the high density of residential houses, Figure 27 includes only parcels with a total estimated demand based on remote sensing of more than 1 AF per year. Analysis of this dataset shows that areas of high estimated water use fall in the western portion of the study area as well as in the Lower Mainstem of Soquel Creek—areas which may therefore benefit from projects with streamflow enhancement goals.

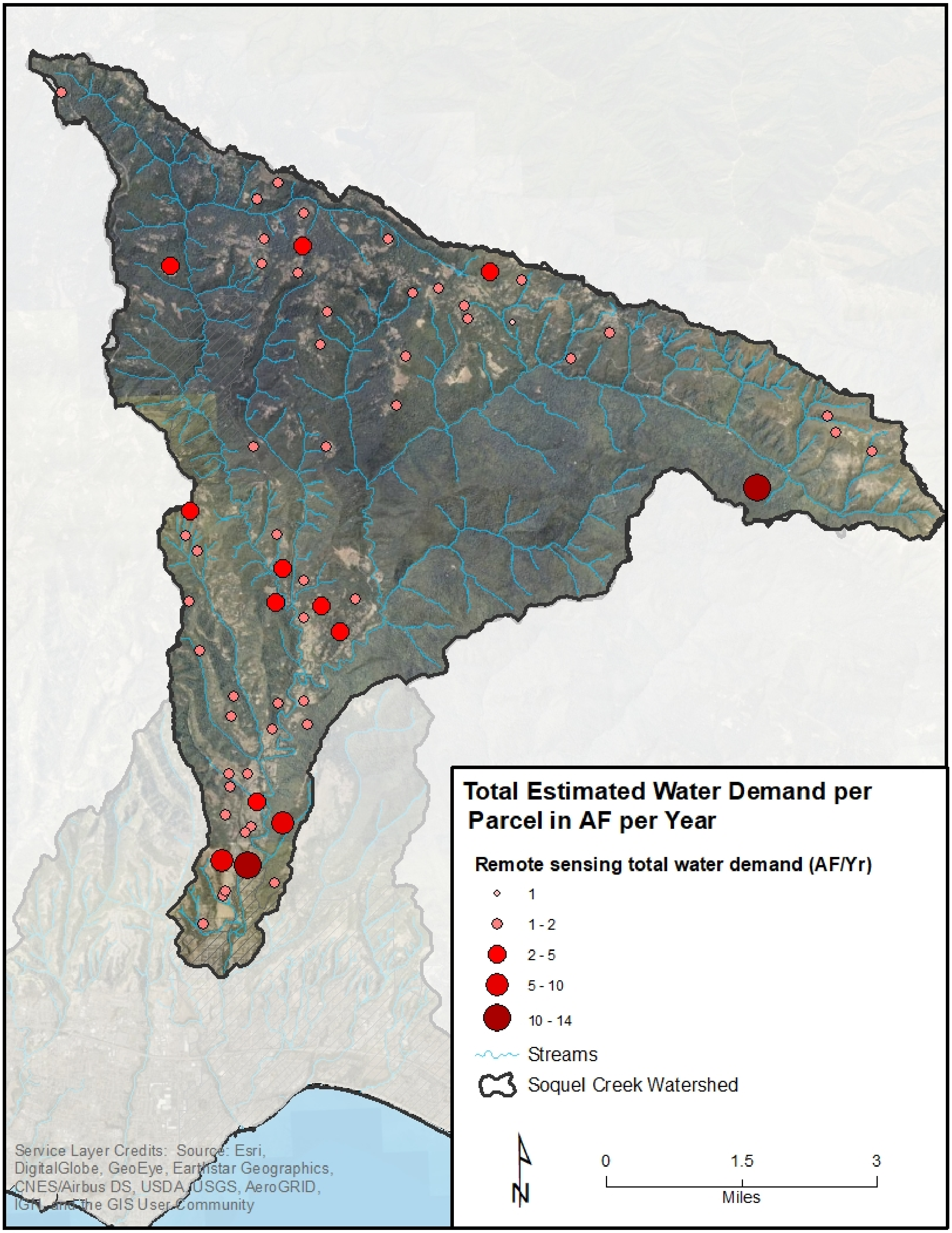

Figure 27. Total annual water demand in acre feet estimated on a per parcel basis using remote sensing.

3.2 Water rights in the Soquel Creek Watershed

The Soquel Creek Watershed was adjudicated in 1977. In the adjudication, water rights were assigned to select landowners in the watershed and, in total, include 302 permitted first, second, and third priority water rights for diversion from the creek and nearby springs. We converted the adjudication data from the printed court decree to a digital format for use and analysis in ArcGIS and then analyzed the 258 water rights that fall within the focus area for comparison with the remote sensing analysis (Figure 28). Later, in section 4.4, we present a water availability analysis that includes the entirety of the water rights as they would be presented in a petition for a new appropriative right for the watershed.

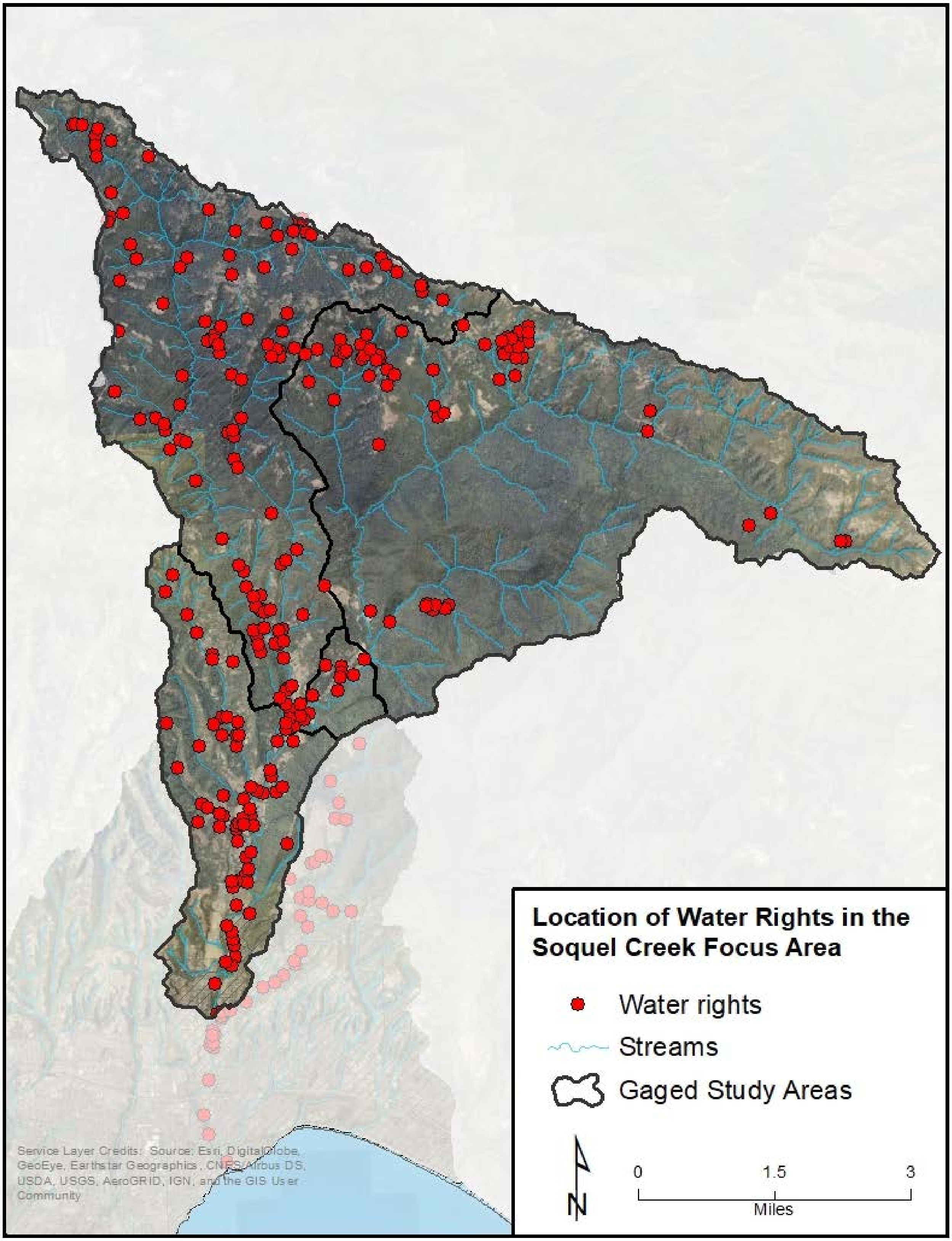

Figure 28. Water rights in the Soquel Creek study area.

3.2.1 Water rights in the Soquel Creek focus area

The 258 permitted water rights in the focus area vary greatly in terms of location and magnitude. Figure 29 shows the total annual permitted use in acre feet for first priority rights in the watershed—the larger, darker circles represent a larger amount of permitted use per year. The annual permitted diversion by the total of all first and second priority rights and the annual permitted diversion by the total of all first, second, and third priority rights are shown in Figure 30 and Figure 31, respectively. The latter represents the absolute maximum amount of water each right could legally divert in a year, though it is unlikely this demand is being met entirely by surface and spring water diversions (to be addressed shortly in our analysis of water rights in relation to groundwater wells, section 3.2.3). Furthermore, the decree states that "no priority class is entitled to the use of any water until all rights of all priority classes with lower numbers have been fully satisfied" and "water may be diverted under second and third priority class rights for consumptive purposes in any schedule of allotments only during such times as there is a visible surface flow at the downstream end of the stream or reach of stream for any particular schedule" (SWRCB 1977). Therefore, it is also unlikely that all first, second, and third priority rights would be exercised at the same time, but our analysis represents a hypothetical "worst-case" scenario.

Figures 29, 30, and 31 show a similar pattern to the remote sensing analysis—the majority of water rights with the highest permitted uses are located in the West Branch study area and along the Mainstem of Soquel Creek. The first, second, and third priority water rights add up to a total demand of 2,132 AF per year in the Soquel Creek focus area. Table 7 shows the demand for each type of water right as well as the total demand on each source within the focus area.

Table 7. Number and total demand in acre feet per year of water rights by type and source in the Soquel Creek focus area.

	Total water rights	Irrigation	Mixed use	Domestic	Stockwater	Sourced from Soquel Creek	Sourced from West Branch	Sourced from other stream	Sourced from spring
Number of water rights	258	30	91	136	1	46	14	59	142
Total Demand (AF/Yr)	2,131.7	517.1	1,256.3	353.8	4.5	674.0	68.3	436.0	953.5
Demand (ft^3/s)	2.96	0.71	1.74	0.50	0.01	0.93	0.09	0.60	1.32

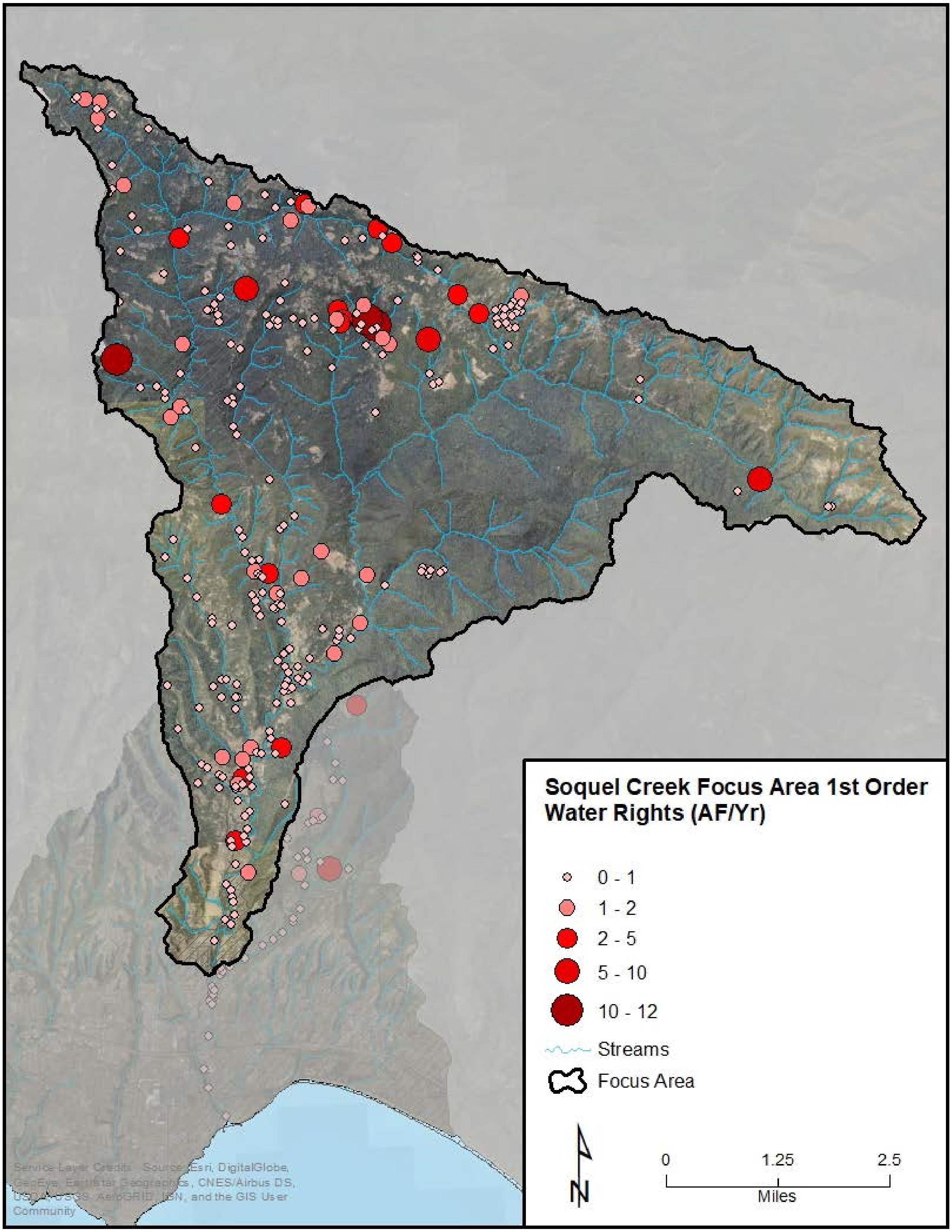

Figure 29. Total water use in acre feet per year permitted by 1st priority water rights in the Soquel Creek focus area.

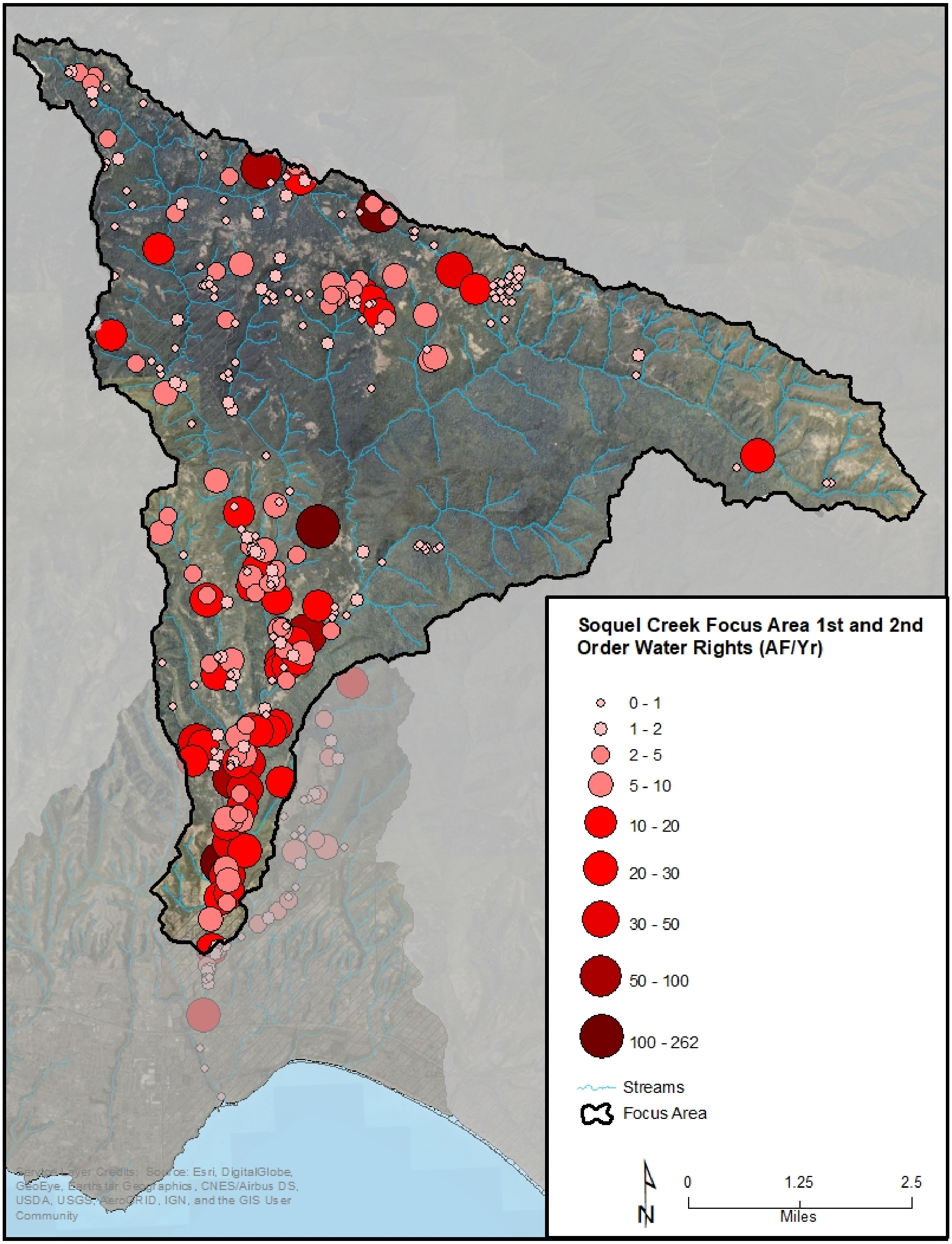

Figure 30. Total water use in acre feet per year permitted by the total of 1st and 2nd priority water rights in the Soquel Creek focus area.

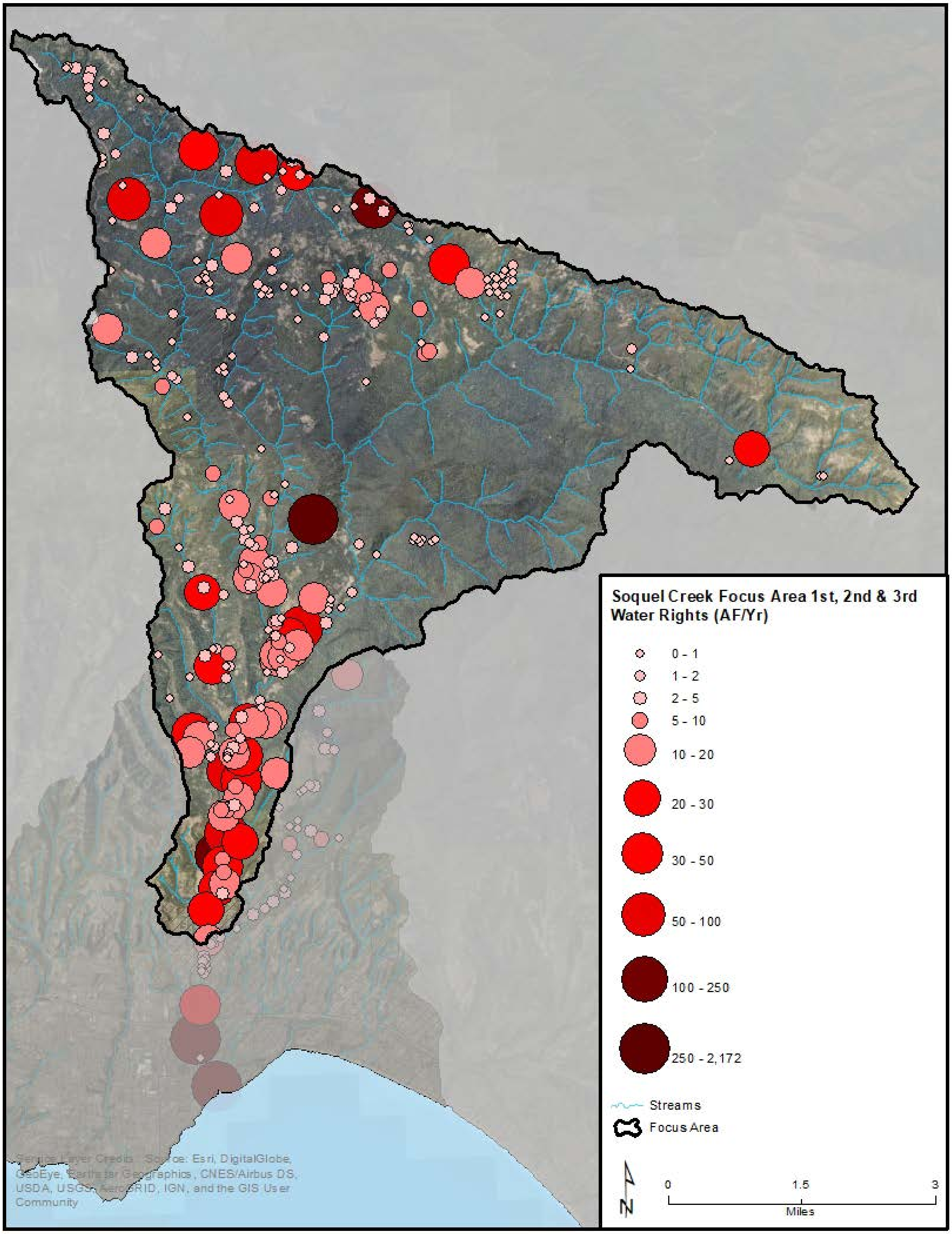

Figure 31. Total water use in acre feet per year permitted by 1st, 2nd, and 3rd priority water rights in the Soquel Creek focus area. This is the highest amount of water use that could legally be diverted in a year.

In the focus area, the highest number of water rights (142) are permitted to divert from springs (Figure 32) and the highest total demand (954 AFY) is also on springs (Figure 33).

As was previously mentioned, the downstream signal of spring and groundwater diversions is difficult to detect using surface water gages on Mainstem creeks. The majority of these water right diversion may not be detectable in the hydrograph, but they may still have a significant impact on discharge and available surface water in the watershed.

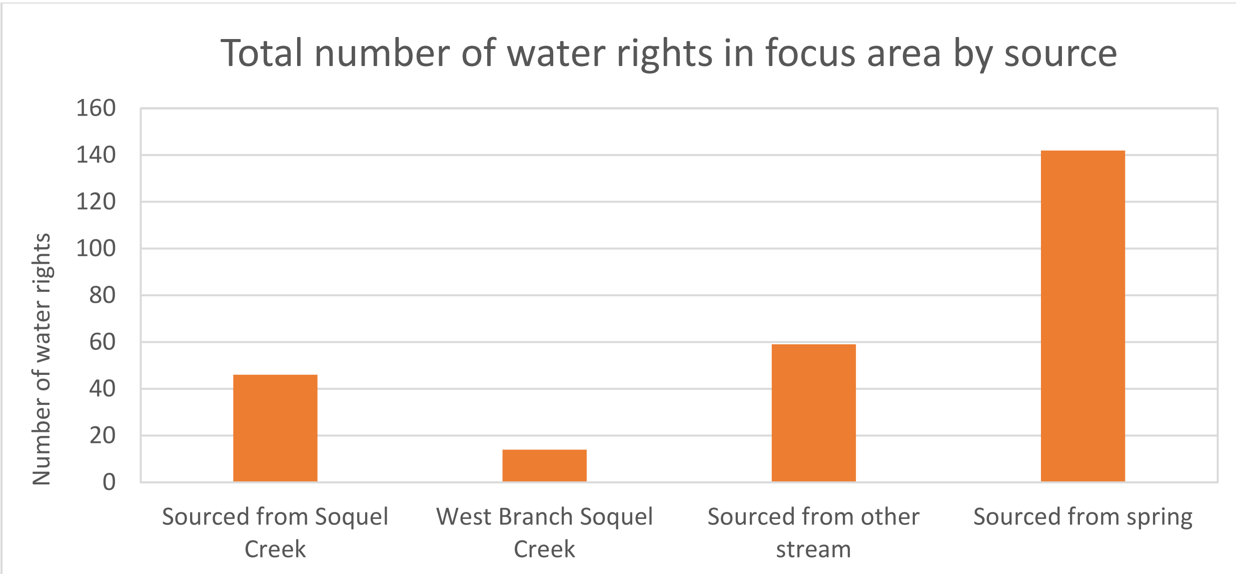

Figure 32. Number of water rights by source type for the Soquel Creek focus area.

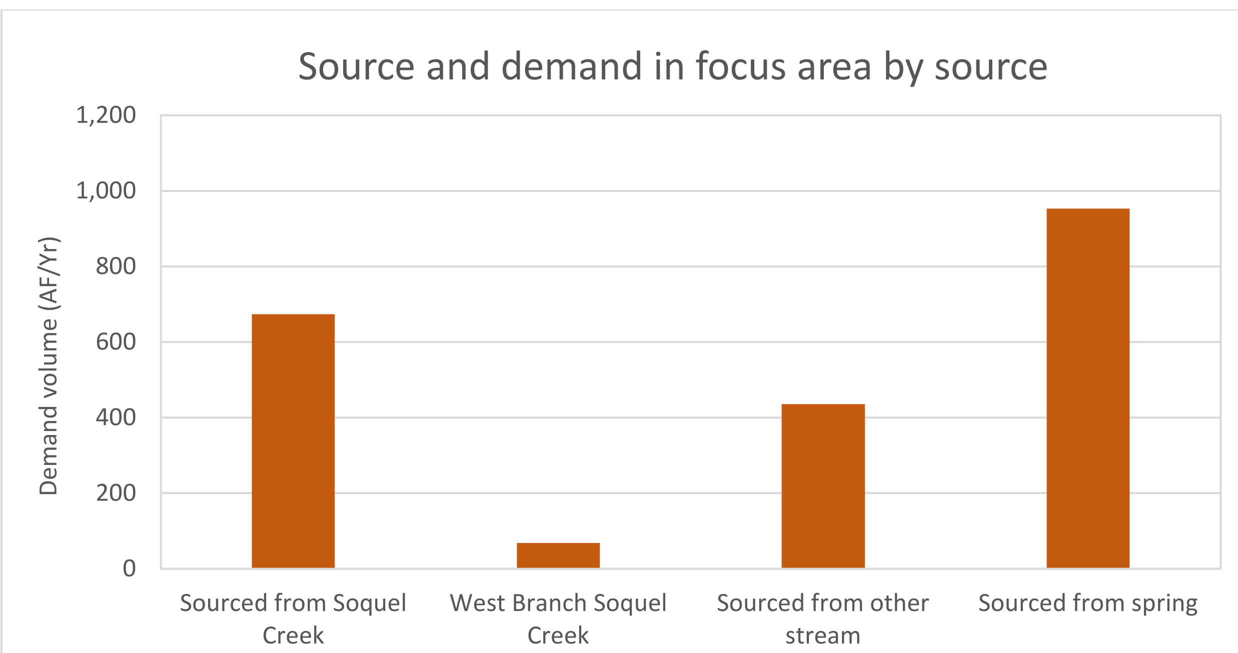

Figure 33. Total annual demand in acre feet per year of water rights by source type for the Soquel Creek focus area.

3.2.2 Remote sensing results vs. water rights results

On the surface, the two analyses produced very different results for estimates of human water demand: through remote sensing and application of water use estimates, we estimated human water demand for the focus area to be 627 AF per year, and through an examination of water rights we estimated total human demand at 2,132 AF per year. While the magnitude of the demand is very different, it is important to note that both methods produced similar spatial patterns of potential human need and impact. Figure 34 shows the remote sensing demand per parcel alongside the total demand of first, second, and third priority water rights - both indicate the potential for higher human impact on streamflow in the West Branch and Lower Mainstem of Soquel Creek. Due to the fact that the remote sensing analysis was based on current land use patterns, we believe that its estimation of human water demand is more accurate than the results of the water rights analysis. Moving forward, gauging the success of future water conservation efforts should be based on the remote sensing analysis.

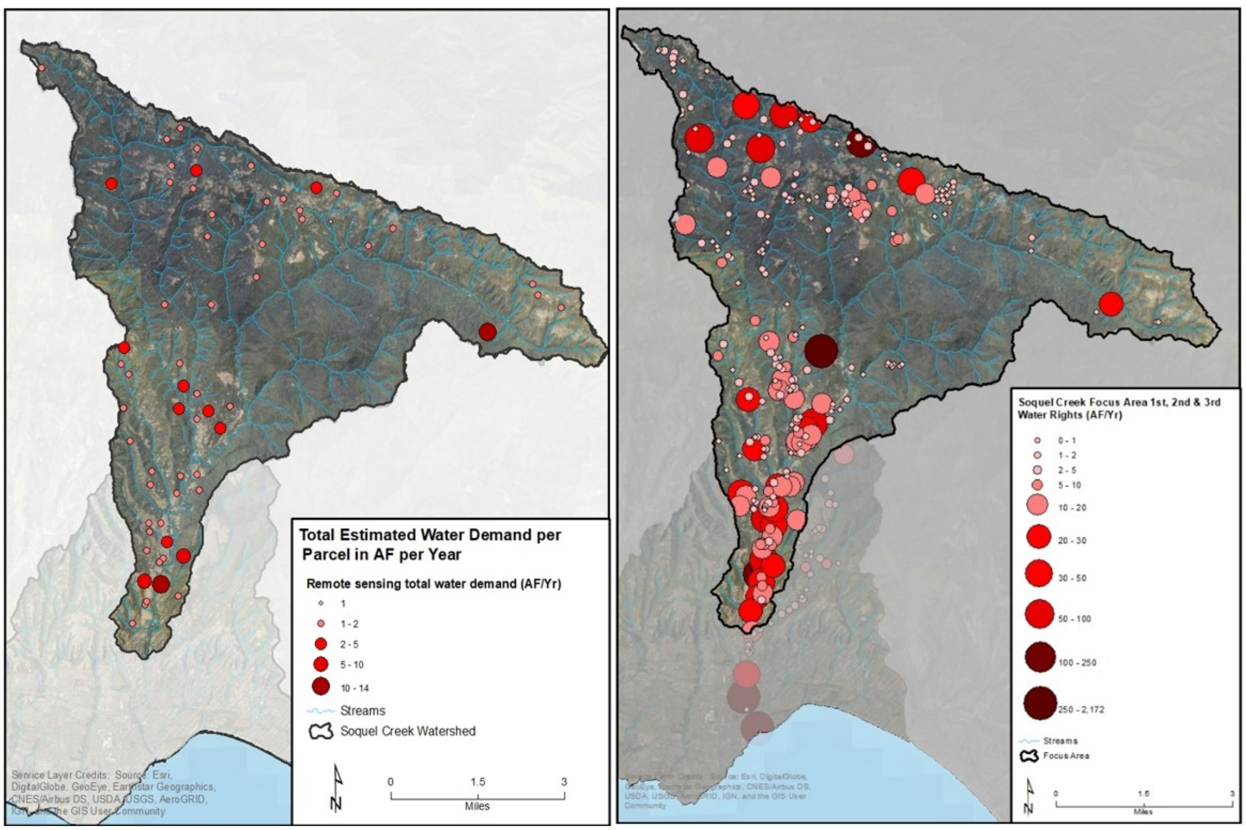

Figure 34. The total annual demand for each parcel in acre feet per year based on remote sensing (left) compared to the total demand in AF per year of 1st, 2nd, and 3rd priority water rights (right) in the Soquel Creek focus area. Note: symobology depicts different value ranges in each map.

3.2.3 Estimating human water demand not met by wells and reservoirs

As was previously mentioned, it is unlikely that the entirety of demand in either estimate (produced via remote sensing or water rights analysis) is being met by surface water diversions. In order to better estimate the total human need being met in this way, we compared our two estimates to the locations of groundwater wells and reservoirs in the focus area.

Within the focus area there are 1,420 active groundwater wells recorded by the County of Santa Cruz (Figure 35). We were also able to determine the locations and storage volumes of reservoirs within the focus area through the remote sensing analysis. The total acreage of the reservoirs was multiplied by a depth of 15 feet—a regional average for coastal California—to estimate their total storage capacity.

To further refine our water demand estimates to account for well and reservoir use, we took our total annual demand per parcel and subtracted total reservoir storage to account for the assumption that these parcels are using their stored water rather than surface water diversions. We then zeroed out demand for parcels with at least one well, assuming they are using groundwater to meet their needs rather than surface water. The final result is shown in Figure 36. Note that this map now takes into account parcels with water use less than 1 AF per year, as well as shows those parcels with “surplus” water, i.e. those with reservoir capacity higher than demand. If these assumptions are correct, our total estimate for human surface water need in the focus area is around 267 AF of water per year.

We updated the water rights analysis in the same way, subtracting reservoir storage capacity from total demand and zeroing out demand for parcels with at least one well (Figure 37). This map also takes into account those parcels with reservoir storage capacity greater than their water right demand and shows demand for water rights of all magnitudes. Based on this method of analyzing water rights, we estimate human surface water demand to be 553 AF per year.

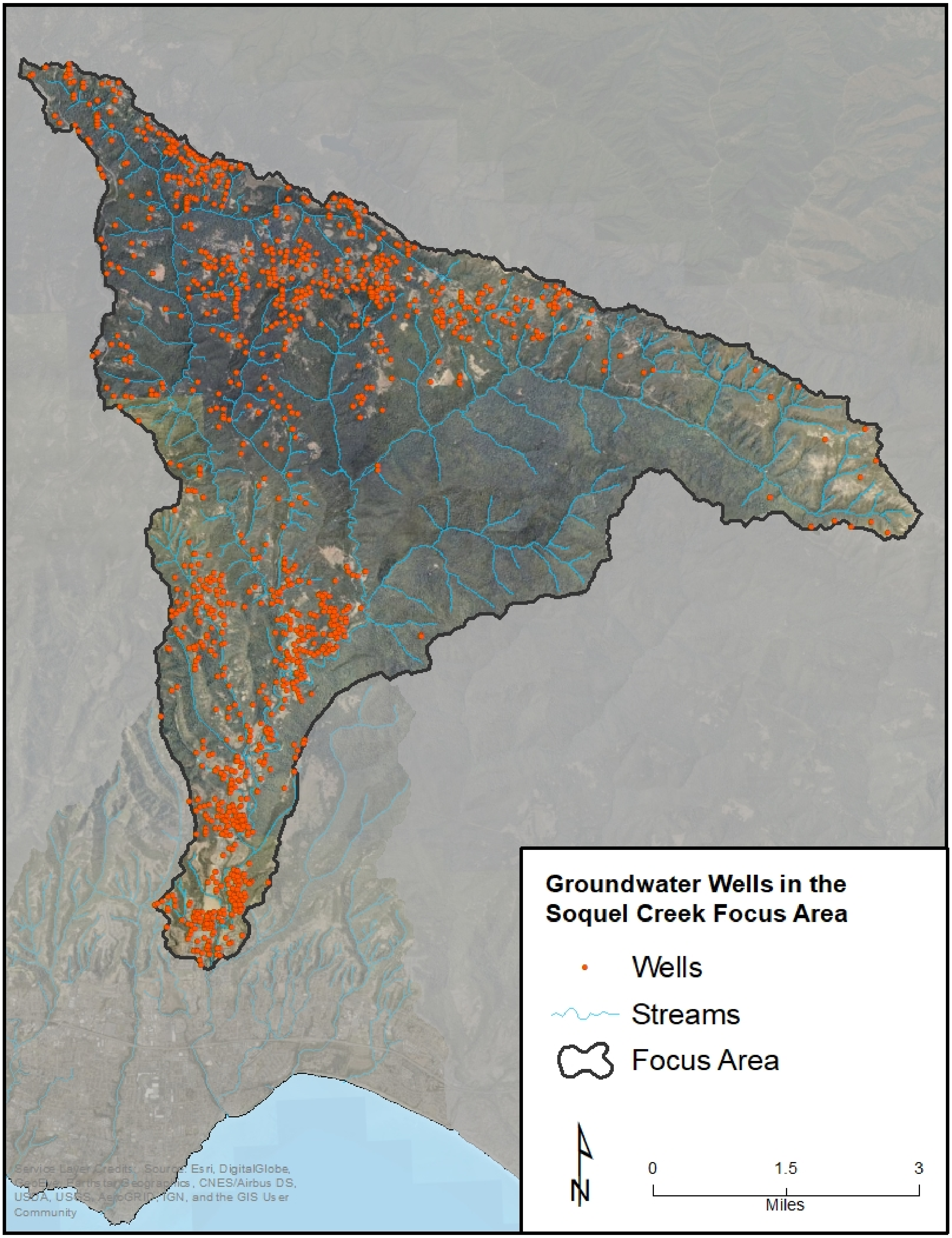

Figure 35. Locations of groundwater wells in the Soquel Creek focus area.

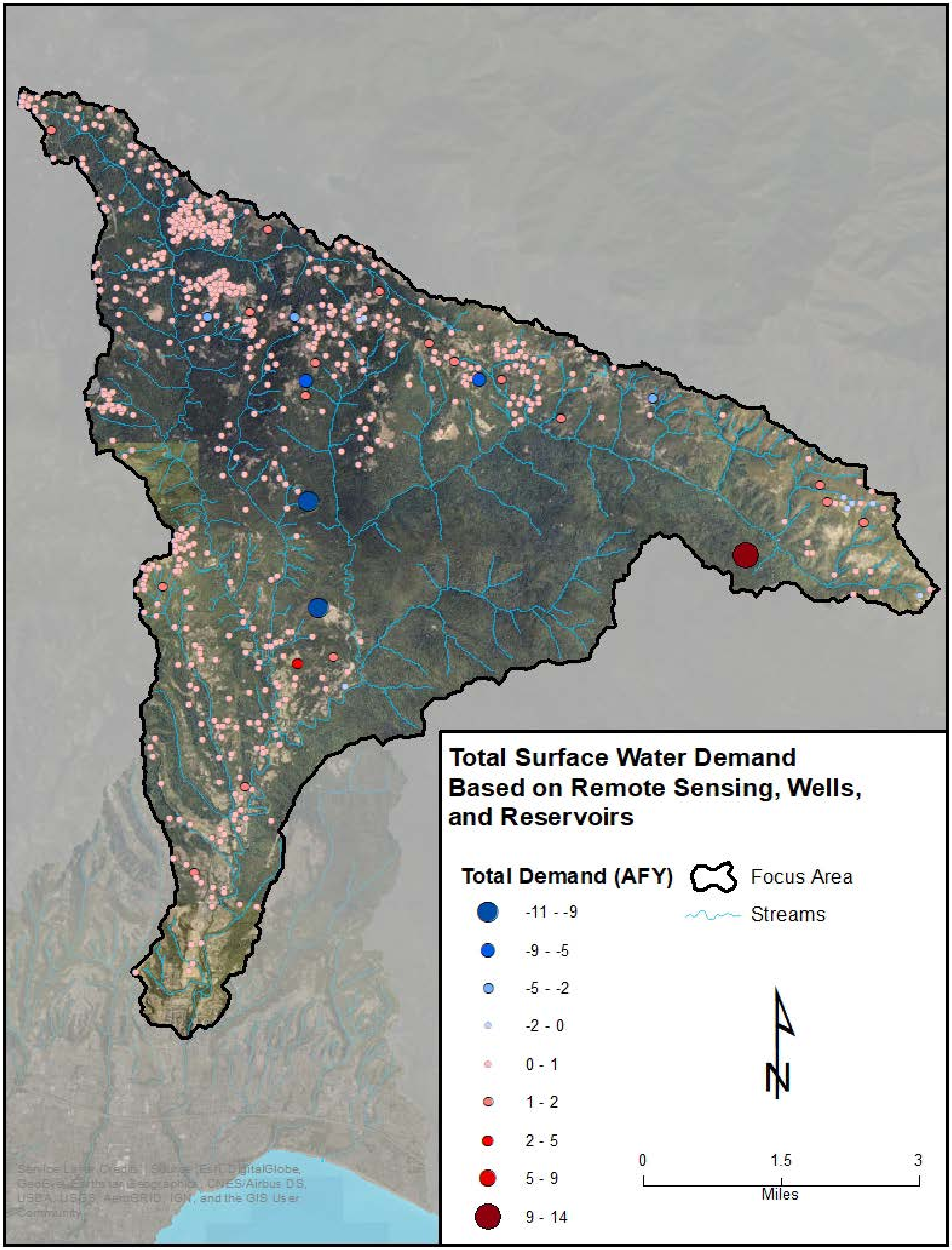

Figure 36. Total estimated surface water demand per parcel in acre feet per year. These data are based on the remote sensing analysis and assume that when groundwater wells and reservoirs are present, they are being used to meet water needs.

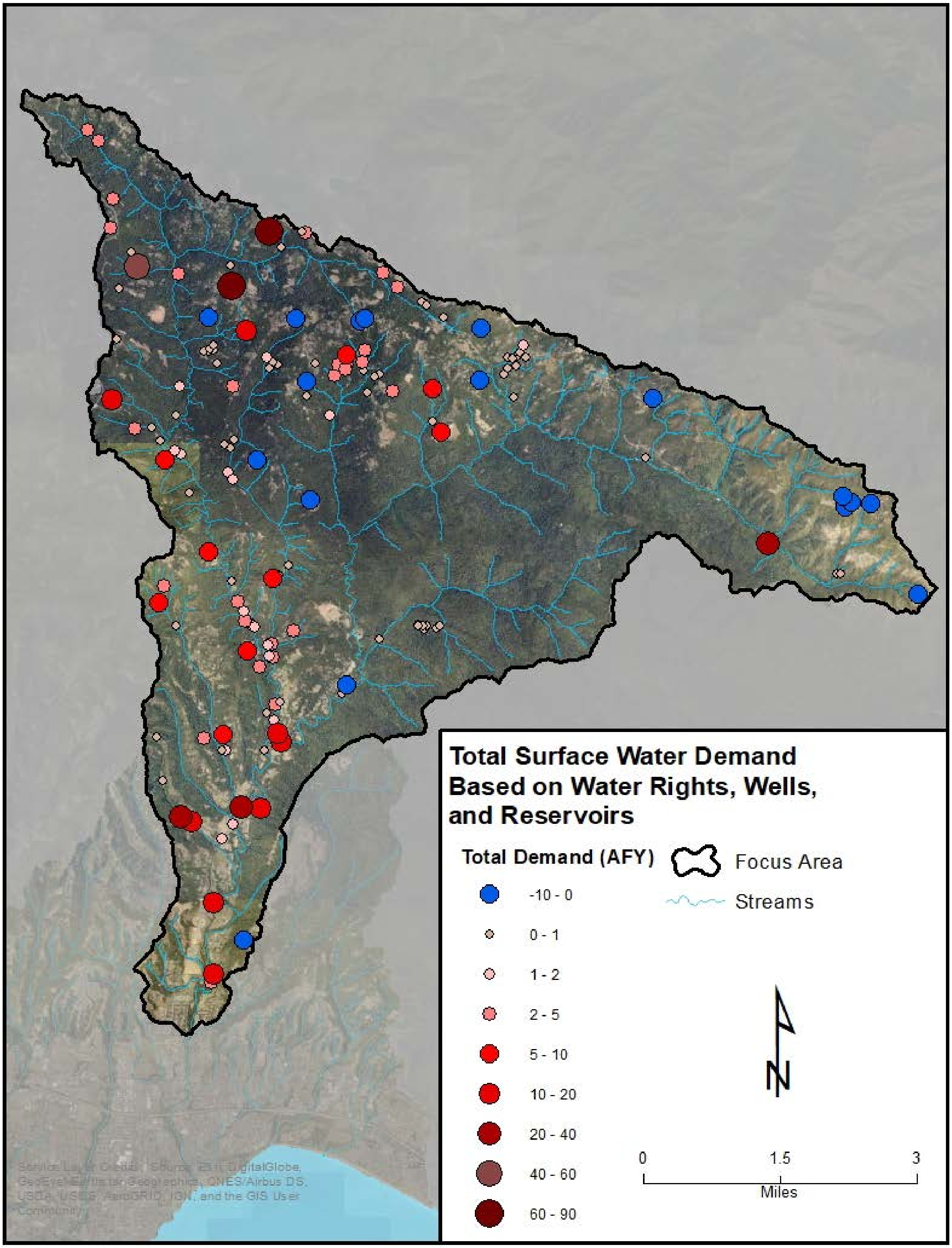

Figure 37. Total estimated surface water demand per parcel in acre feet per year. These data are based on the water rights analysis and assumes that when groundwater wells and reservoirs are present, they are being used to meet water needs.

4. Streamflow enhancement recommendations

Drawing from our analysis of streamflow conditions, fish distribution, water use estimates and water rights provided above, this section provides a suite of strategies for improving summer streamflow conditions in the Soquel Creek focus area. The strategies described below have been modeled after examples of similar type projects developed by the Russian River Coho Water Resources Partnership (RRCWRP). The strategies are broken into two main categories (1) management-based streamflow enhancement project recommendations and (2) processed based streamflow enhancement recommendations (RRCWRP, 2017).

4.1 Management-based streamflow enhancement project recommendations

Management-based streamflow enhancement projects include projects that alter the timing, source, efficiency and/or management of human water use. Our recommended strategies for water management-based projects include:

- Reduce or eliminate direct dry season diversions by institutional (such as summer camps, conference centers and small mutual water companies), agricultural, and residential water users from the Mainstem Soquel Creek and its tributaries (Section 4.1.1)
- Develop collaborative water management guidelines for areas with high volumes of residential pumping (Section 4.1.2)
- Develop flow release projects and projects that reconnect springs to tributary streams (Section 4.1.3)

There are several factors that determine whether a project will have a high or low impact on enhancing surface water conditions. Since the Soquel Creek Watershed has both surface water diversions and a high volume of groundwater pumping, we developed two sets of factors to consider when developing a streamflow enhancement project based on the source of water used:

For surface water diversions these factors include:

1. The total volume and seasonality of water demand
2. The rate of diversion
3. The location of the project relative to the amount of downstream salmonid summer habitat available

For groundwater pumping or spring diversion projects these factors include:

1. The total volume and seasonality of water demand
2. The proximity of the project to the creek
3. The pumping depth of the groundwater well relative to the stream elevation
4. The hydraulic conductivity of the groundwater aquifer
5. The continuity of geologic material between the stream bed and aquifer
6. The location of the project relative to the amount of downstream summer habitat available

4.1.1 Recommendations for reducing or eliminating direct dry season diversions

We recommend developing and implementing water storage and forbearance projects that reduce or eliminate both direct diversions and alluvial well-based dry season diversions from Soquel Creek and its tributaries. We recommend targeted outreach to all landowners along the Mainstem Soquel Creek, the West Branch, and the East Branch who have pipes in the creek to find willing landowners to develop streamflow enhancement projects. These projects could include some or all of the following components:

- Reduce as much demand as possible through conservation, reductions in irrigated acreage, and water efficiency improvements.
- Evaluate and develop alternative sources of water to meet water use needs, such as rainwater catchment, grey-water reuse or winter water storage.
- Develop or increase the volume of water storage available to facilitate changes in the timing of diversions from the dry season to the wet season.

Based on the results of our remote sensing, water rights, and well data analysis, we also recommend working with landowners with estimated high water use. Examples of such projects include:

Large institutional water users. We recommend working with large institutional water users such as summer camps (in the Upper East Branch and in the Lower Mainstem), conference centers (in the Lower Mainstem) and small mutual water companies (in the Upper West Branch). One camp was excluded from the analysis in the West Branch as it was not operational at the time of the study, but an opportunity exists as the owners plan to re-open it in the near future. Such projects can present important opportunities to improve flow, due to the magnitude of water demand.

Agricultural water users. Our remote sensing analysis shows that the Mainstem of Soquel Creek and the West Branch are areas with concentrated agricultural water uses. We recommend working with agricultural growers to reduce the amount of water being used through water efficiency projects, stormwater capture systems, and when and where possible, develop storage projects to alter the timing of surface water diversions and groundwater pumping from wells near the stream.

Residential water users. Based on our remote sensing analysis, we estimate that there is a large volume of residential water users relying on local water sources (i.e. direct diversions, diversion from springs, pumping from shallow wells, etc.) to meet their water needs primarily in the Upper East Branch and Upper West Branch of Soquel Creek. The cumulative demand of residential and commercial water users in the Soquel Creek study area is approximately 444 AF per year and is by far the land-use category with the largest water use in the watershed. For this reason, we recommend developing a storage and forbearance program or a collaborative water management program (described in more detail below).

4.1.2 Recommendations for a collaborative water management program

Based on the high density of residential water user in the lower treatment reach of the East Branch and Upper West Branch, as well as the high cost of water storage tanks, we recommend developing collaborative water management programs in neighborhoods with high densities of residential houses near the stream. This strategy involves:

- Working with small neighborhoods to develop a set of residents to belong to a collaborative water management group,
- Working with this group to coordinate the timing of groundwater pumping to reduce the instantaneous draw-down of groundwater, surface water levels, and streamflow, and
- Monitoring groundwater conditions and streamflow conditions in the area to document the impacts of the changes in water management.

4.1.3 Recommendations for flow release projects

Flow augmentation can be a useful and important tool in streamflow enhancement work. During the height of the recent drought (in 2015), the RRCWRP worked with willing landowners in tributaries to the Russian River to release water from agricultural ponds into the channel for the benefit of coho (2017). Water released from these ponds in 2015 showed a remarkable increase in streamflow conditions in TU's gage data. California Sea Grant's data suggested that 76% of the juvenile salmonids observed in Dutch Bill Creek (one of the tributaries with a flow release) at the beginning of summer rearing season were located in pools below the flow release that remained wetted as a result of the release. These flow release projects have been so successful that they have been implemented every year since 2015. Water quality considerations must be taken into account before any flow release is initiated.

Our remote sensing analysis indicates that there are several parcels in the West Branch of Soquel Creek with an excess of water storage. We recommend that, to the extent the landowners are willing and to the extent it is valuable, flow release projects be developed for use on a regular basis or in times of severe drought conditions.

In addition, we recommend exploring opportunities to reconnect springs in the watershed. Our water rights analysis indicates that springs in the focus areas can produce 953.5 AF of water each year for human water use. We recommend exploring opportunities to reconnect springs located in the East and West Branch of Soquel Creek with streams.

4.2 Processed-based streamflow enhancement project recommendations

Processed-based streamflow enhancement projects include projects that restore the natural processes in the watershed, which influence the amount of water retained on and released from the landscape. Based on our analysis of the current level of development in the watershed, we think that the development and land-use changes that have occurred in the watershed over the past century are likely impacting both the infiltration of rainfall and the landscape's ability to generate summer base flow. Although this study did not directly investigate the impacts of widespread development on the watershed's hydrologic and geomorphic character, we believe the landscape is influencing the hydrology of the system and could be improved with landscape-scale restoration activities.

Our brief invasive species survey showed that there are some high-water-use plant occurrences in the watershed (eucalyptus, acacia, tree of heaven, and arundo). We recommend controlling the spread of and removing the species with the fewest occurrences (arundo and tree of heaven) and then developing a plan to address eucalyptus and acacia spread.

Our remote sensing analysis shows that the East Branch of Soquel Creek has the largest areas of undeveloped land. Therefore, we recommend focusing process-based streamflow enhancement projects in the SDSF. Such strategies to improve the landscape's infiltration capacity could include:

- Improve the road drainage network in the watershed to reduce the flashy-ness of the system and to increase groundwater recharge.
- Develop upland recharge sites to retain water higher in the landscape.
- Develop coordinated efforts to slow, spread, and sink runoff.
- Implement restoration habitat restoration projects that reconnect the channel with the floodplain.
- Develop groundwater infiltration projects in low-sloped areas.

4.3 Water rights overview and water availability analysis

There are two basic water rights in California: riparian and appropriative water rights. A riparian water right entitles a landowner immediately adjacent to a stream (or other body of water) to use a reasonable amount of water for use on that property. Riparian rights are inherent to ownership of the land and cannot be lost through non-use. Additionally, water obtained with a riparian water right must be used within 30 days. An appropriative water right must be obtained from the State Water Resources Control Board (SWRCB) and is created for a specific quantity of water at a specific location for beneficial use. Unlike riparian water rights, appropriative water rights allow water to be stored and to be used at a later time. Appropriative water rights are junior to riparian rights and priority among appropriative users is established by date ("first in time, first in right"). These rights can be lost if they are not used.

As described previously, the Soquel Creek Watershed was adjudicated in 1977. In the adjudication, water rights were assigned to select landowners in the watershed and, in total, include 302 permitted first, second, and third priority water rights for diversion from the creek and nearby springs. If a future streamflow enhancement project involves water storage and forbearance, then it is likely that the landowner will need to apply for an appropriative water right, and as part of that process a water availability analysis will need to be conducted.

If this is the case, SWRCB will require a thorough evaluation of how additional water appropriation will affect existing water right holders. In order to evaluate the viability of developing new water storage projects and obtaining new appropriative water rights in the Soquel Creek Watershed, we performed a water availability analysis.

This water availability analysis provides all the calculations and data needed for evaluating whether additional water can be appropriated. Although Soquel Creek is not within the Policy for Maintaining Instream Flows in Northern California Coastal Streams (SWRCB 2014), this analysis uses the guidelines and methodology presented in the policy, as well as the December 15^{th} – March 31^{st} diversion season (so that a landowner can divert water in winter, when water is ample, for use in summer when water is scarce). This analysis uses the most downstream water right in the entire watershed as the point of analysis (POA) for which we determined:

- The total upstream demand of all water right holders,
- The upstream watershed area,
- The average annual precipitation,

- The unimpaired seasonal discharge,
- The impaired seasonal discharge, and
- The percent of water available for future appropriation.

The most downstream water right was selected as the POA because it is the senior water right holder with the greatest upstream demand.

To calculate the seasonal water right demand volume, we used the adjudicated water rights data which provides daily water use rates and multiplied it by the number of days in the diversion season. We used ArcGIS tools to calculate the upstream watershed area and average annual precipitation. Unimpaired flow was calculated at the POA based on a proration of USGS streamflow data, using the USGS Soquel Creek gage (11160000). In this analysis, we estimated unimpaired flow volume during the period of analysis based on historical streamflow data from that gage. We calculated average flow volume during the period of analysis (December 15th – March 31st) and scaled it to the POA by using a ratio of watershed area and average annual rainfall in the upstream watershed according to the equation in the SWRCB policy Appendix B.2.1.3:

QPOA = Qgage * (DAPOA / DAgage) * (PPOA / Pgage)

Where: ***QPOA*** = discharge estimated at the Point of Analysis, in cubic-feet per second; ***Qgage*** = unimpaired discharge recorded at the USGS gage on Soquel Creek (11160000), in cubic-feet per second; ***DAPOA*** = drainage area at the POA, in square miles; ***DAgage*** = drainage area at USGS gage on Soquel Creek (11160000), in square miles; ***PPOA*** = average annual precipitation of the POA, in inches; and ***Pgage*** = average annual precipitation of the USGS gage on Soquel Creek (11160000), in inches.

The resulting flow value was used as the unimpaired flow volume at the POA. To calculate the impaired discharge at the POA, we subtracted the upstream demand from the unimpaired flow volume and calculated the percent of water available for future appropriation.

Our analysis indicates that there is additional water available during the winter season (December 15 - March 31) for future appropriation. The percentage of remaining unimpaired water available for future appropriation is currently above 4% at the lowest existing water right holder in the watershed. Along with the analysis on human water use described in Section 3, these data indicate that there is considerable opportunity to store water in the winter for summer use, while maintaining the water needed for ecological processes.

Table 8 shows the results of the water availability analysis calculations for the most downstream water right in the Soquel Creek Watershed. The resulting statistic of this analysis is the percentage of water that remains, given the cumulative effect of upstream diversions, at the lowest water right in the watershed. If the amount of water accounted for in existing water right holders is less than 10% of average unappropriated discharge, it is possible for more water to be appropriated.

Our analysis indicates that there is additional water available during the winter season (December 15 - March 31) for future appropriation. The percentage of remaining unimpaired water available for future appropriation is currently above 4% at the lowest existing water right holder in the watershed. Along with the analysis on human water use described in Section 3, these data indicate that there is considerable opportunity to store water in the winter for summer use, while maintaining the water needed for ecological processes.

Table 8. Water availability table for the most downstream water right in the Soquel Creek Watershed (POA), for the diversion season Dec. 15 - Mar. 31.

	At lowest water right in watershed (POA)
Watershed area (mi^2)	42.5
Average precipitation (in)	41.5
Unimpaired flow (AF)	23,478
Total upstream demand (AF)	1,303.7
Water remaining instream (AF)	22,175
% of water remaining in stream	94%
% of water available for future appropriation	4%
Total volume of water available for future appropriation (AF)	**1,044**

4.4 Ensuring durable results

It is important that resource managers, water users, and funders ensure that any water restored to the system remains in stream and is protected from future use. There are several mechanisms through which this can be achieved. More information is available in A Practitioner's Guide to Instream Flow Transactions in California (SWIFT 2016).

4.4.1 Forbearance agreements

A forbearance agreement is a contract that is tied to the land and is recorded with the County on the property deed. Forbearance agreements have been widely used across coastal California and are an important tool for protecting instream flow gains achieved through storage and conservation projects. It sets the terms under which diversions and other water management practices can be initiated and operated, and those under which they must be ceased. In general, the terms and responsibilities are set between the project proponent and the landowner and/or water user.

4.4.2 Instream dedications

In addition to entering into a forbearance agreement, water users may file a water right change petition to dedicate their full or partial water right face amount to instream uses for fish and wildlife, under California Water Code Section 1707.

The benefit of an instream dedication is that it offers protection and durability for the instream water restored through projects that otherwise is unattainable with a forbearance agreement alone. It offers protection against other water diversions and provides legal recognition of the instream water to the State, and it allows funders, project proponents, and the landowner to ensure that water rights no longer used are not lost to the next appropriator or to new appropriators. Water users can also elect to add instream uses as a purpose of use without eliminating existing uses.

4.4.3 Monitoring and evaluation

A critical aspect of streamflow enhancement work is continued dry season monitoring throughout the gage network to document and quantify the success of the program. Long-term monitoring is important for ensuring compliance with water management conditions, for identifying changes in streamflow associated with water management practices, and for evaluating whether implemented projects have the benefit predicted. Without continuous long-term streamflow monitoring, it is impossible to know whether projects are sufficient to restore streamflow and aid in the recovery of salmonid populations within the Soquel Creek Watershed focus area. Monitoring funding is generally a major challenge for this type of work, however, recent and planned efforts of the Santa Cruz Mid-County Groundwater Agency (MGA) may help to fulfill the need. Additionally, we recommend that future streamflow enhancement implementation projects include monitoring in all future grant proposals.

4.4.4 Mid-County Groundwater Agency

The MGA is the Groundwater Sustainability Agency (formed in 2016) for the groundwater basin underlying the majority of Soquel Creek. It has identified Soquel Creek as a priority surface water system. The MGA is responsible for ensuring that groundwater management actions do not adversely impact other resources, including depletion of surface waters. The MGA recognizes that long-term streamflow gages will be needed to correlate changes in streamflow to groundwater extraction and that shallow monitoring wells located adjacent to the gages is critical for the data to be meaningful. Figure 38 displays the approximate locations best suited for installation of stream gages in order to be near the areas identified for shallow monitoring wells. The final locations may vary from the map due to access constraints. Placement of monitoring wells and gages is expected within a couple of years.

The gages will be permanent, although data collection will be focused on the dry season, since that is the time when groundwater has the most impact on surface water systems. The streamflow data collected will be evaluated annually with respect to groundwater level, climate, groundwater usage, and noted biological responses. Biological responses will include information obtained from The Nature Conservancy's Groundwater Dependent Ecosystems Pulse application that monitors the health of vegetation and available fish count data from the Santa Cruz County Juvenile Steelhead and Stream Habitat Monitoring Program.

Though the gaging locations in Figure 38 are different than those established by the RCD and TU, the three entities intend to work together to coordinate future gaging in the upper watershed.

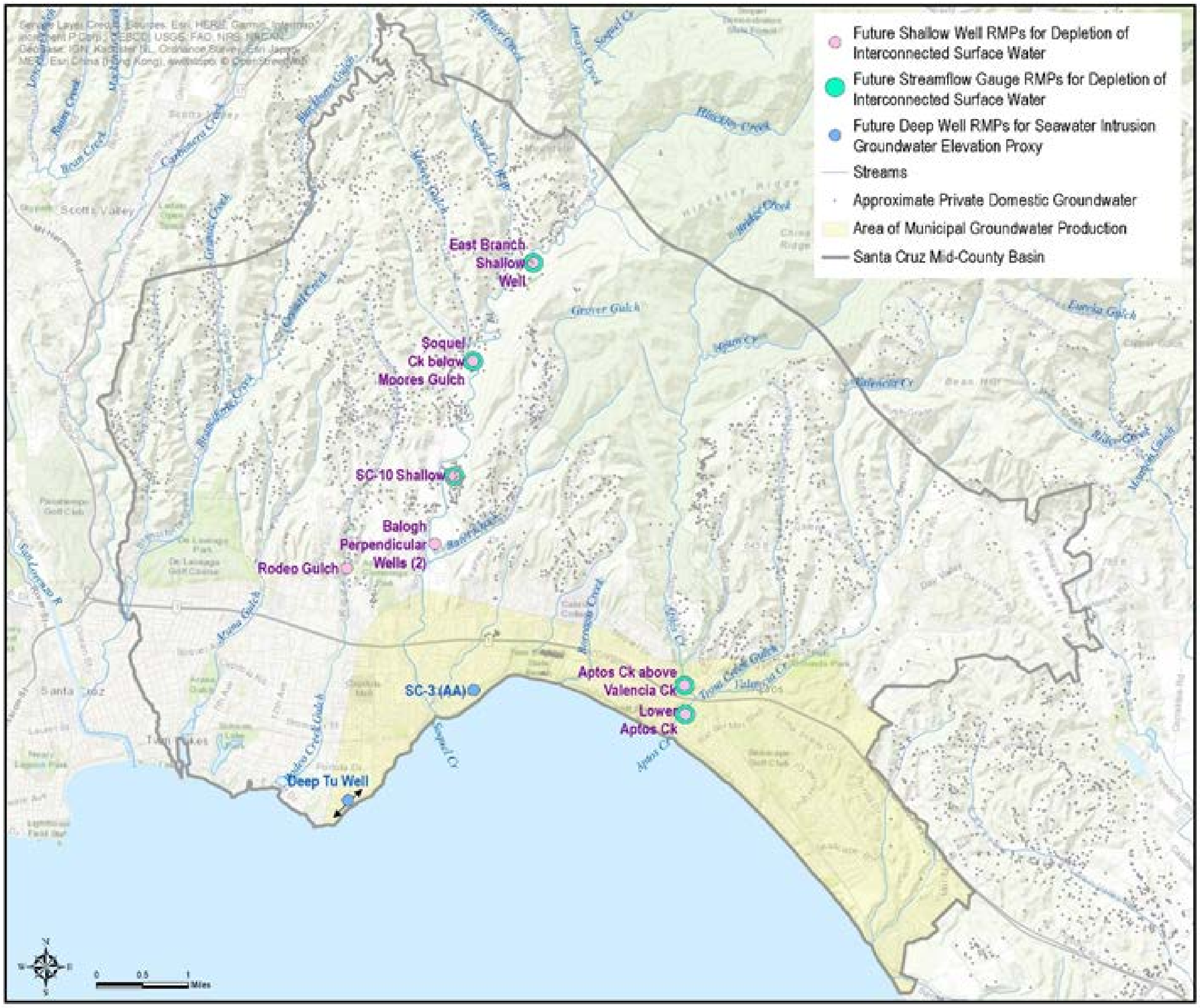

Figure 38. The approximate locations best suited for installation of stream gages in order to be near the areas identified for shallow monitoring wells. The final locations may vary from the map due to access constraints. Figure courtesy of the Santa Cruz Mid-County Groundwater Agency.

5. Conclusion

The Soquel Creek Watershed is critically important for steelhead and coho recovery. The JSSH program's monitoring work shows that steelhead juvenile densities are highest in the East and West Branch and the Upper Mainstem Soquel Creek. The data also show a relationship between dry season flow conditions and juvenile steelhead densities at the end of the dry season. This information suggests that future streamflow enhancement work should focus on restoring a more natural flow regime in the East and West Branch and Upper Mainstem Soquel Creek from June to October.

Our remote sensing and water rights analysis suggests that there is sufficient water in the watershed to meet human needs on an annual basis, but lack of streamflow can be an issue during the summer season, especially in dry years and during severe droughts. The streamflow monitoring work of this study suggests that human water management activities have a negative impact on streamflow during the dry season. Additionally, while summer stream discharge during above-average rainfall years like

2019 may be sufficient to meet human needs, discharge during severe drought years may fall below what humans require in the watershed. Therefore, a primary goal for future streamflow enhancement work should be to complete projects that simultaneously ensure adequate water supply for human consumption and ecosystem functioning year-round.

This report outlines a suite of streamflow enhancement recommendations, with recommendations on the approximate locations for targeted landowner outreach to develop specific types of flow enhancement projects. We recommend that future streamflow enhancement projects (1) reduce or eliminate dry season diversions in the East Branch, West Branch, and Upper Mainstem of Soquel Creek; (2) include flow release projects and reconnection of springs to streams and (3) include processed based enhancement projects that decrease stormwater runoff and improve infiltration and groundwater recharge in the East Branch.

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APPENDIX A

Technical Advisory Committee members were given an opportunity to comment on the Soquel Creek Streamflow Assessment Study. The comments below were received by Larry Freeman of Freeman Hydrologic Data Services.

Comment on Figures 10-12:

A practice used by the USGS to verify the validity of the computed discharge record is to plot the actual discharge measurements on the hydropraph. I make this general point for figures 10-12 where the complete water year hydrographs are plotted. Another useful piece of information would be a discussion about the confidence in the accuracy of the computations. For example, using USGS criteria, a record is rated as being Good, Fair, or Poor (+/- 5%, +/-8%, >8% margin of error). Record quality is based on the quality ratings of the discahrge measurements used to compute the records. This could be important information to consider when looking at hydrographs for diversion amounts and groundwater loss.

Comment on Section 2.2.3 *Streamflow conditions in WY2019 (Figure 12)*:

I would have liked to have an explanation (or at least a theory) about the cause of the significant loss in flow between Sq03 and USGS gage during the period of mid-June to early July 2019 (fig. 12). The 2018 WY hydrograph (fig. 11) shows just the opposite trend. It's entirely possible that the difference between these two sites during 2019 is due to rating and rating shift application either in the TU records or the USGS records.

Comment on Figure 14:

Figure 14. The regular daily 'noise' in the record for Sq02 (and all sites for that matter) could also be at least partially caused by normal diurnal fluctuations caused by daily temperature swings and daily changes in evapotranspiration. I see this "noise" in all of the records for each WY.