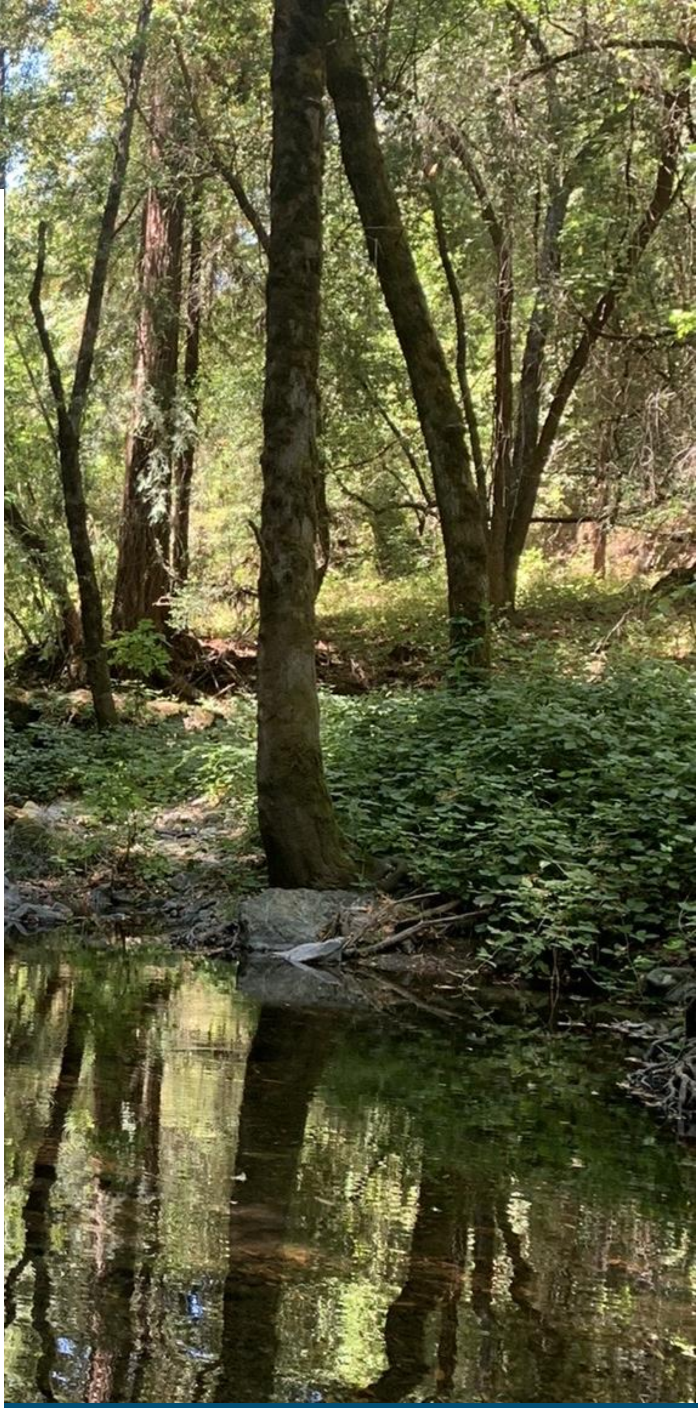

Mill Creek

Annual Environmental Monitoring Report WY2022

MARCH 31, 2023

Prepared for the Wildlife Conservation Board
By: Trout Unlimited and California Sea Grant

Contents

1. Introduction

The Russian River Coho Water Resources Partnership (Coho Partnership) identified insufficient summer streamflow as a primary limiting factor in the Mill Creek system and developed a Streamflow Improvement Plan outlining strategies and project types to enhance streamflow conditions in the watershed (RRCWRP 2015). In April 2020, Trout Unlimited (TU), California Sea Grant's Russian River Salmon and Steelhead Monitoring Program (CSG) and Sonoma Resource Conservation District (SRCD) (members of the Coho Partnership) were awarded a Wildlife Conservation Board (WCB) grant to enhance streamflow in the Mill Creek watershed (Russian River, Sonoma County). This Mill Creek Water Storage for Flow Enhancement Project aims to increase summer streamflow in the watershed by developing a series of storage and forbearance projects that will decrease dry-season demand on instream flows.

One aspect of this WCB project is to operate monitoring programs that provide baseline data on streamflow, and late-summer wetted habitat and water quality conditions in Mill Creek and the major tributaries of Felta, Wallace and Palmer creeks. The surveys conducted through this project characterize summer streamflow and habitat conditions in all accessible, anadromous reaches of stream over a period of three summers in order to document suitability for rearing juvenile coho salmon and steelhead and to demonstrate how stream conditions change over the study years, including with the implementation of streamflow enhancement projects. The project overview map (Figure 1) shows the streamflow gage locations in the Mill Creek watershed. This report is the second of three annual reports prepared by TU and CSG to describe the results of annual streamflow and environmental monitoring activities.

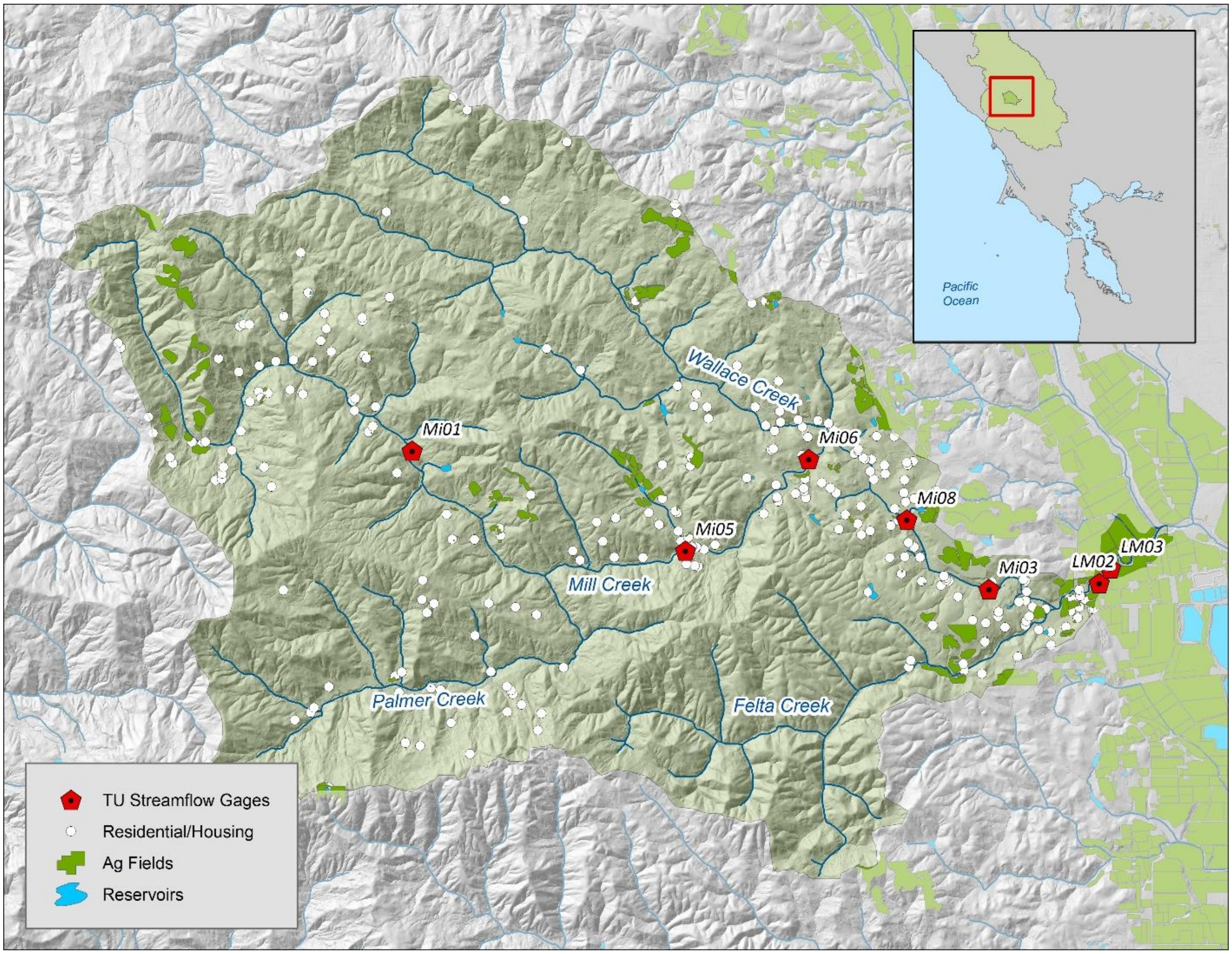

Figure 1. Project overview map, including TU's streamflow gage network and land use – showing potential water use in the watershed.

2. Fire

In summer 2020 the Walbridge fire, part of the LNU Lightning Complex fires, burned the upper portions of the Mill Creek watershed. Between August 17 and October 2, 2020, the fire burned more than 55,000 acres and destroyed more than 150 homes in the rugged hills of northwestern Sonoma County. Sixty-three percent of all accessible salmonid habitat within the Mill Creek watershed was within the Walbridge Fire footprint (https://caseagrant.ucsd.edu/blogs/the-walbridge-fire-and-salmon-habitat). The upper extent of Mill Creek, Felta, Wallace and Palmer creeks experienced extensive burning of the upslope forests as well as the riparian corridor (Figure 2). The burn intensity was greatest in the furthest upstream reaches of Mill Creek, leaving this area exposed to far greater solar radiation and erosion potential than the rest of the watershed. The impact of the fire on streamflow and habitat conditions is largely unknown. This study is the first empirical data collected and evaluated post fire, and this report describes two years of post fire conditions.

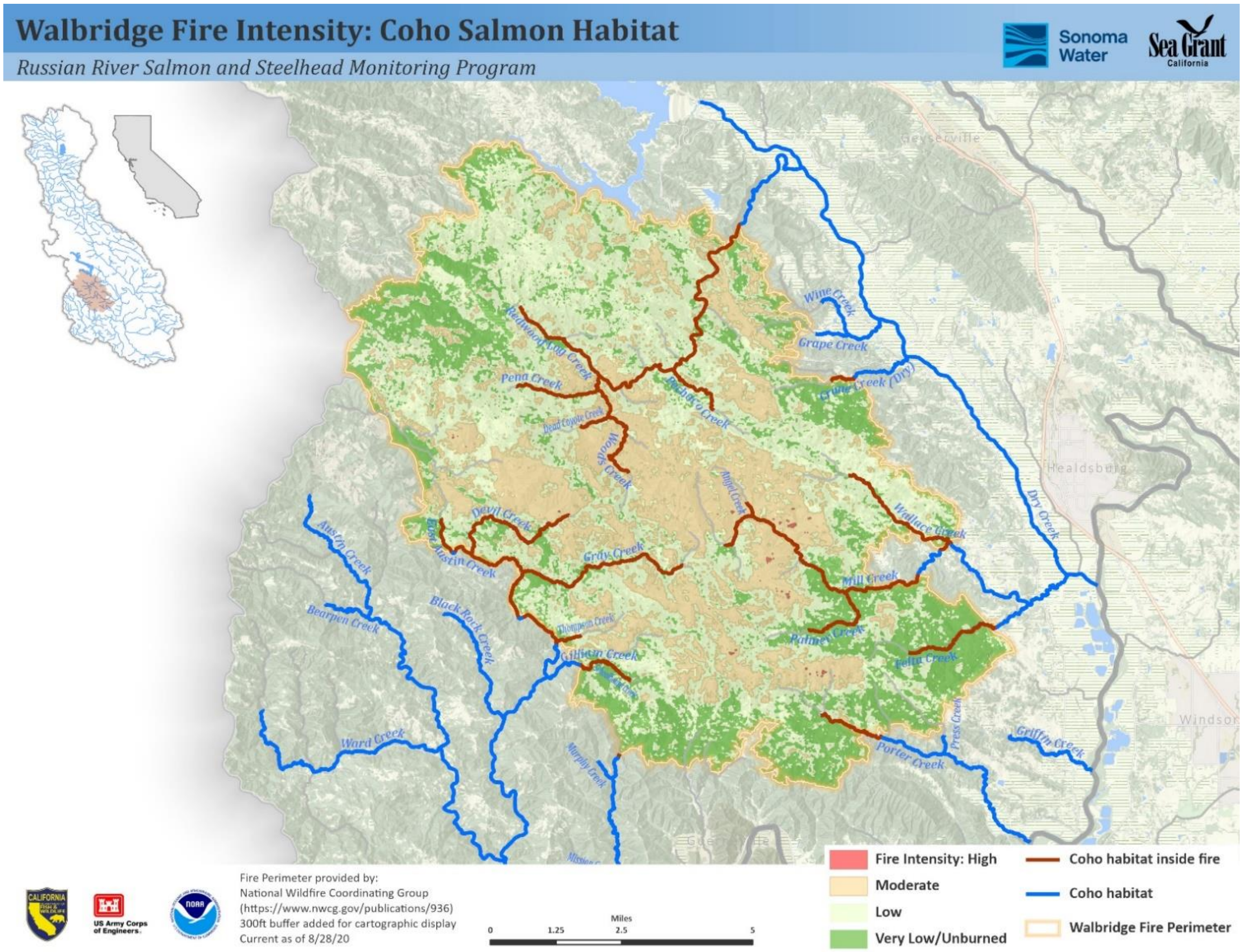

Figure 2. The Walbridge Fire footprint and fire intensity in relation to coho salmon habitat in the lower Russian River basin, including the Mill Creek watershed.

3. Rainfall

Rainfall data were recorded over an 81 water year (WY) period in nearby Healdsburg, CA at National Climatic Data Center (NCDC) Station # 3875 (Healdsburg station, hereafter), median average rainfall at the Healdsburg station is 37.5 inches (Figure 3). Total rainfall in WY2022 was 30.4 inches, 7.1 inches below median average, and 14.5 inches higher than WY2021 (15.91 inches).

Figure 4 shows total monthly rainfall recorded during in water WY2022, with the mean average monthly rainfall for the 81-year period of record. WY2022 experienced the highest rainfall over the water year in October (11.7 inches), followed by a storm in December 2021 (9 inches). WY2022 had notably dry winter, with substantially less than average rain in January, no rain in February, little rain in March, and below average rain in April. From a streamflow viewpoint, the water year was saved by a rain event in June (0.64 inches), which boosted early summer streamflow conditions at all gage sites.

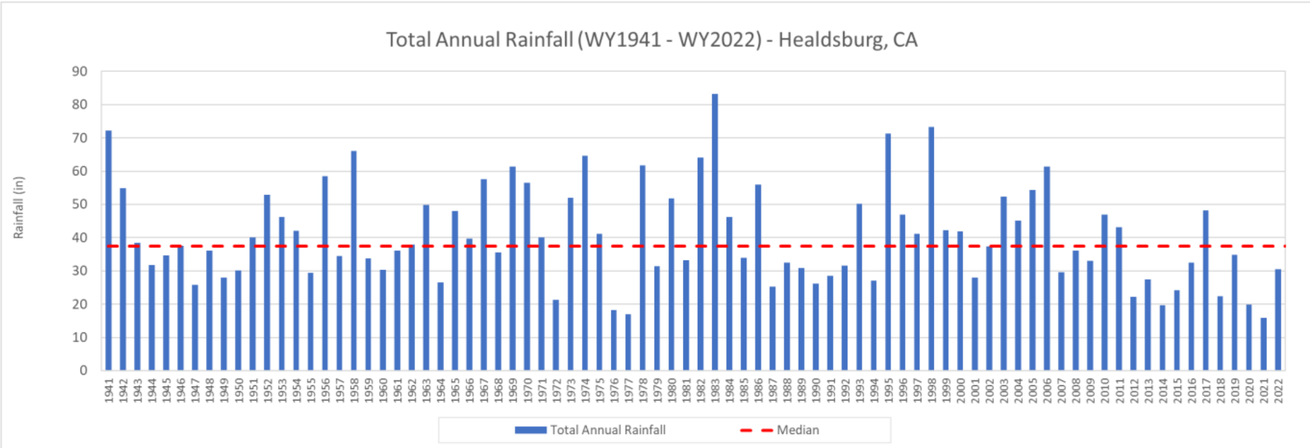

Figure 3. Total and median annual precipitation recorded in Healdsburg, CA (1941-2022) from NCDC station 3875.

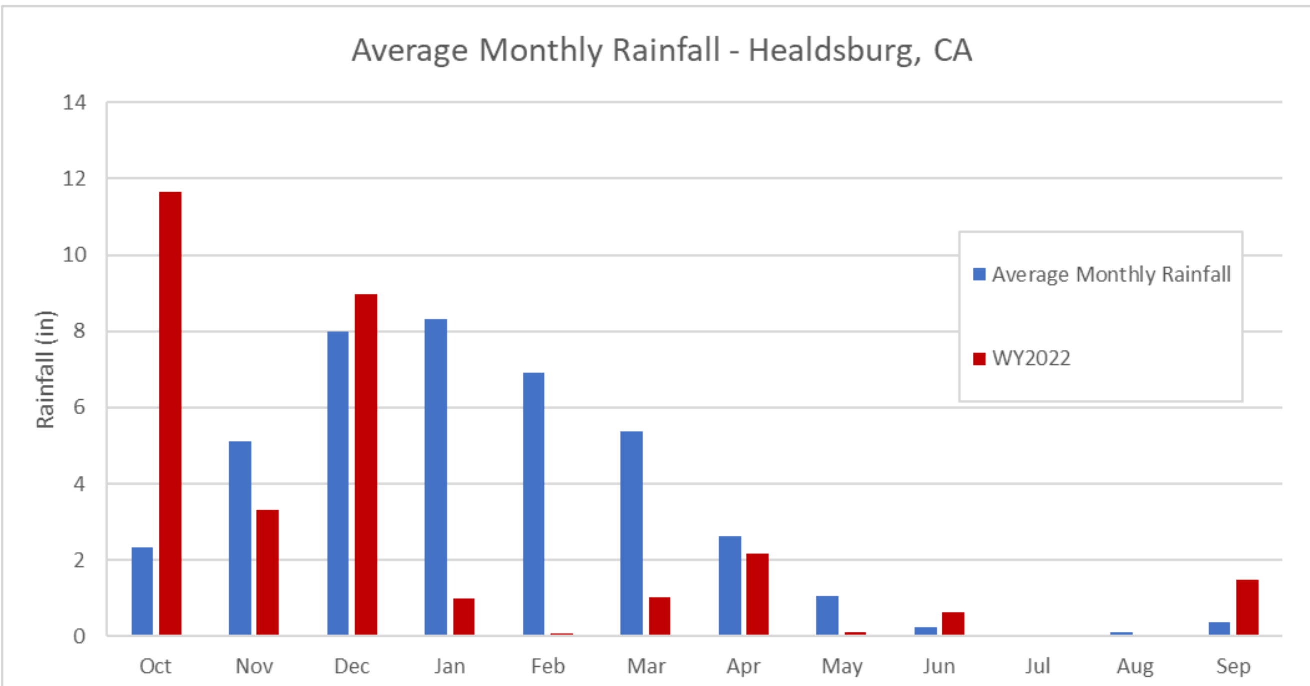

Figure 4. Total monthly precipitation in water year 2022 vs monthly average rainfall recorded in Healdsburg, CA from NCDC station 3875.

4. Streamflow

Streamflow was monitored at five sites in the upper Mill Creek watershed and two sites in the lower Mill Creek watershed (to evaluate surface and groundwater dynamics) (Figure 1). Adjusted stage data and discrete discharge measurements were used to develop hydrographs for each of the monitored sites for the study period. This section describes stage in WY2022 for all gage sites in the upper watershed, in order from upstream (Mi01) to the farthest downstream (Mi03).

(Mi01) Mill Creek at Bear Flat

At site (Mi01) Mill Creek at Bear Flat, stage began to rise in response to the first storms of the year in late October 2021 (Figure 5). The two largest storms of the year occurred in October and December. The highest peak flows of the year were observed on October 24, 2021. At its highest level, stage rose to 6.3 feet. Stage began to recede in early January, then rose in response to small storms in April. A low stage of 1.02 feet was reached in September 2022.

Figure 6 shows streamflow conditions at Mill Creek at Bear Flat WY2022. Streamflow in May 2022 started around 1.1 ft^3/sec and receded to 0.62 ft^3/sec. A drop in flow is detected from May 30th to May 31st. The 0.12 ft^3/sec drop in flow is likely caused by a surface water diversion or instream dam, located upstream from the gage site.

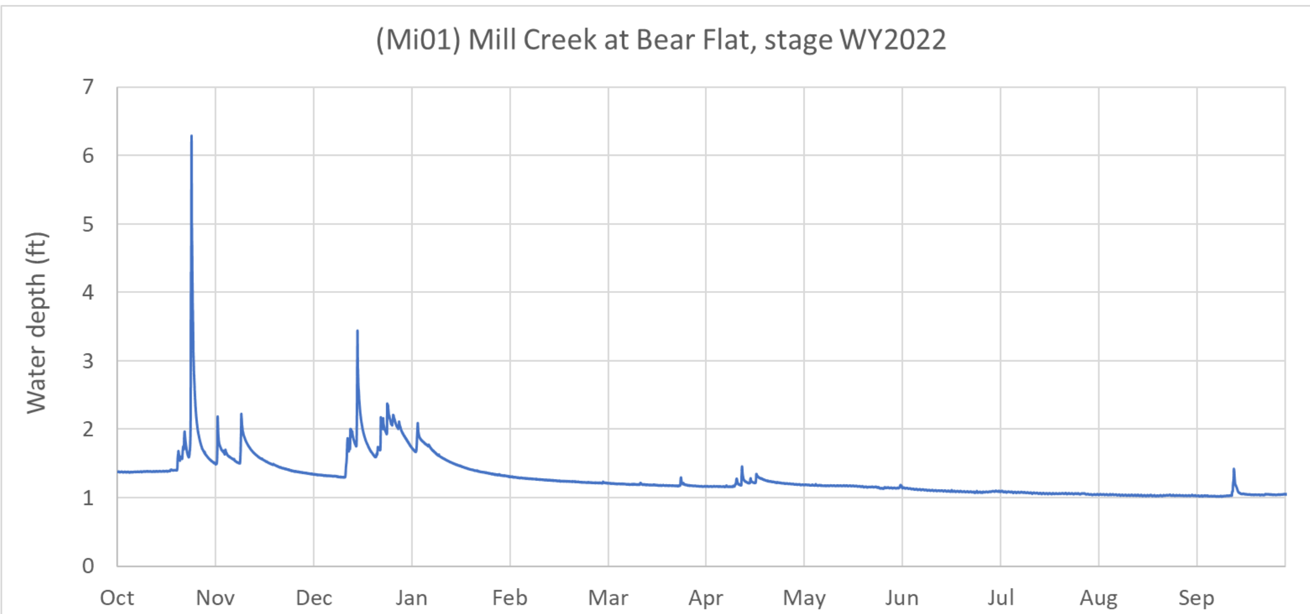

Figure 5. Stage at Mill Creek at Bear Flat, WY2022.

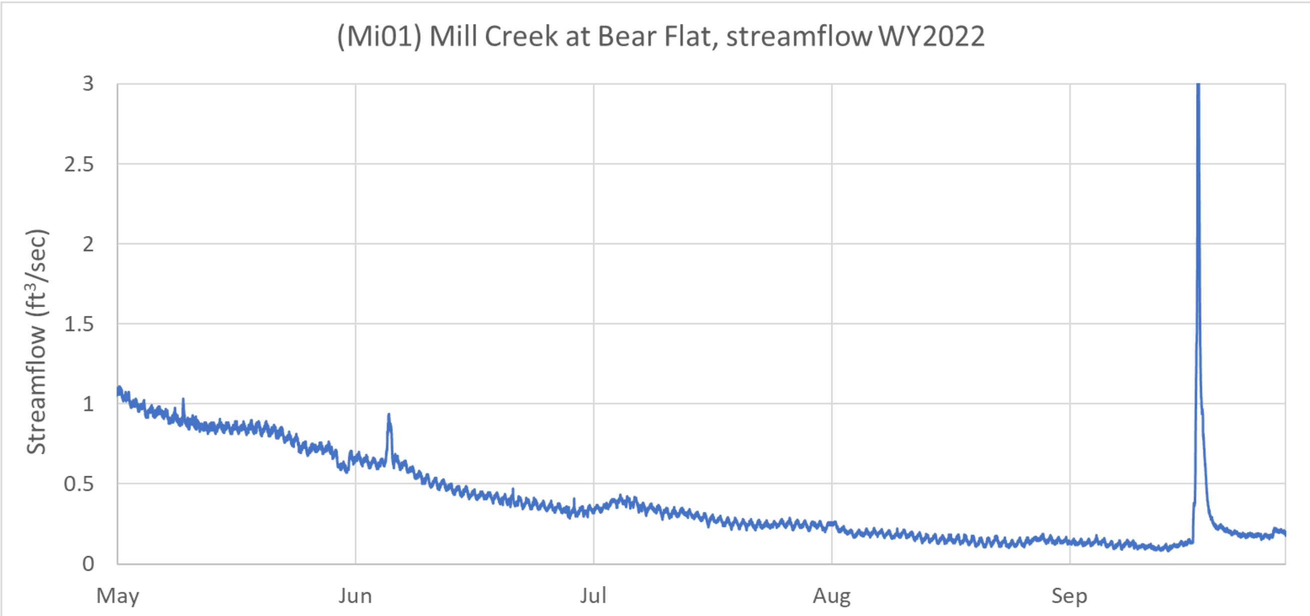

Figure 6. Streamflow at Mill Creek at Bear Flat, WY2022.

(Mi05) Mill Creek below Puccioni Road

At site (Mi05) Mill Creek below Puccioni Road stage began to rise in response to the first storms of the year in late October 2021 (Figure 7). The gage was dislodged during the year's peak flow on October 24, 2021, the highest recorded stage value for this event was recorded at 5.7 feet. The gage was re-installed in early January following the January 3rd storm, stage continued to recede post repair from January through April, then rose slightly in response to small storms in April. A low stage of 1.12 feet was reached in September 2022.

Figure 8 shows streamflow conditions at Mill Creek below Puccioni Road WY2022. Streamflow in May 2022 started around 2.9 ft^3/sec (approximately 1.8 ft^3/sec higher than the upstream gage site Mi01, Mill Creek at Bear Flat) and receded to 1.6 ft^3/sec. Several drops in flow are detected throughout the summer, Figure 9 shows streamflow conditions zoomed to highlight the diversion signals. The gage data shows 4 different diversion signals on a daily basis (ranging from 0.05-0.08 ft^3/sec), and 24 diversion signals on a weekly basis. These diversion signals are not recorded at the upstream gage (Figure 6), indicating that the diversions are occurring between the two gage sites.

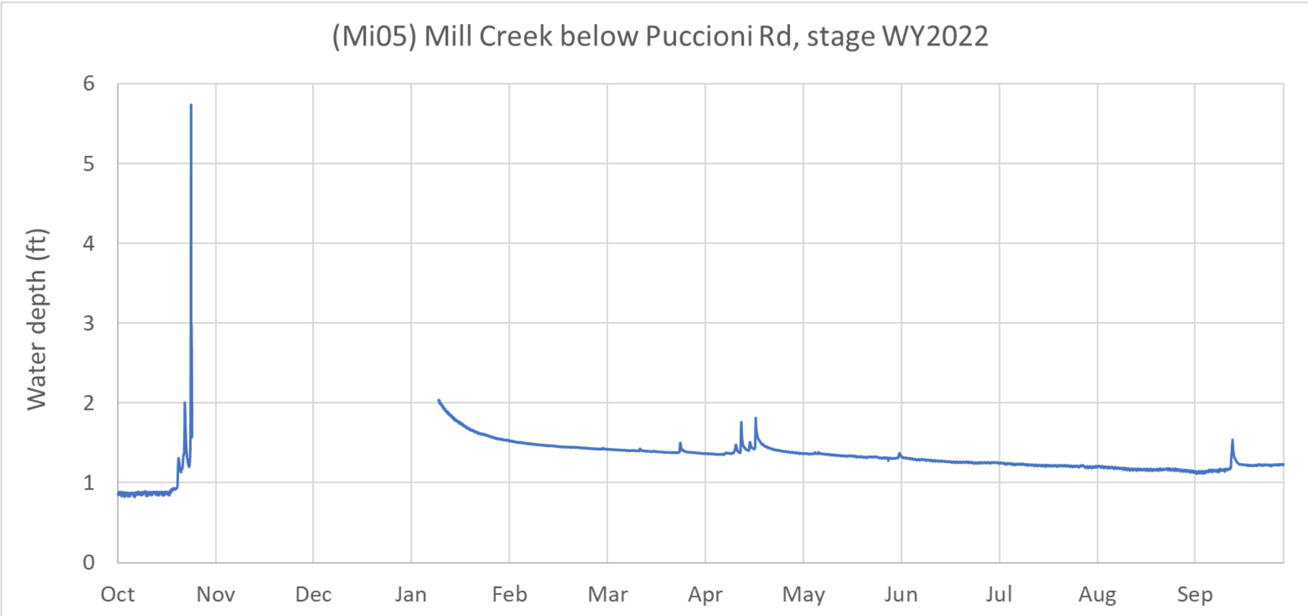

Figure 7. Stage at Mill Creek below Puccioni Road, WY2022.

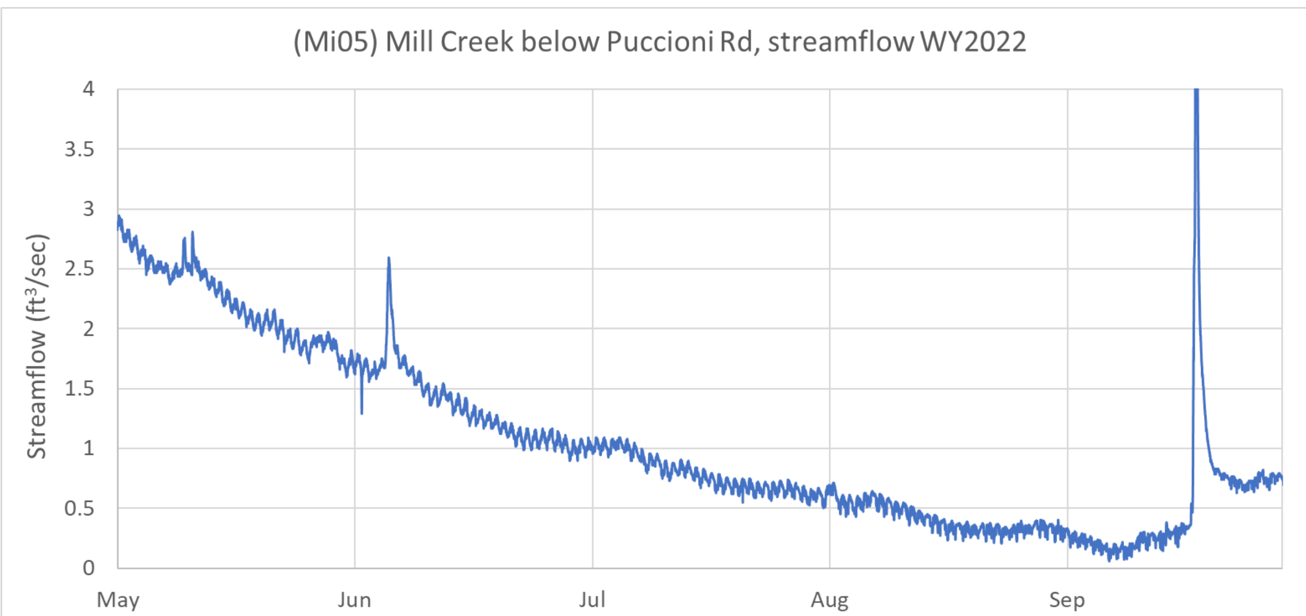

Figure 8. Streamflow at Mill Creek below Puccioni Road, WY2022.

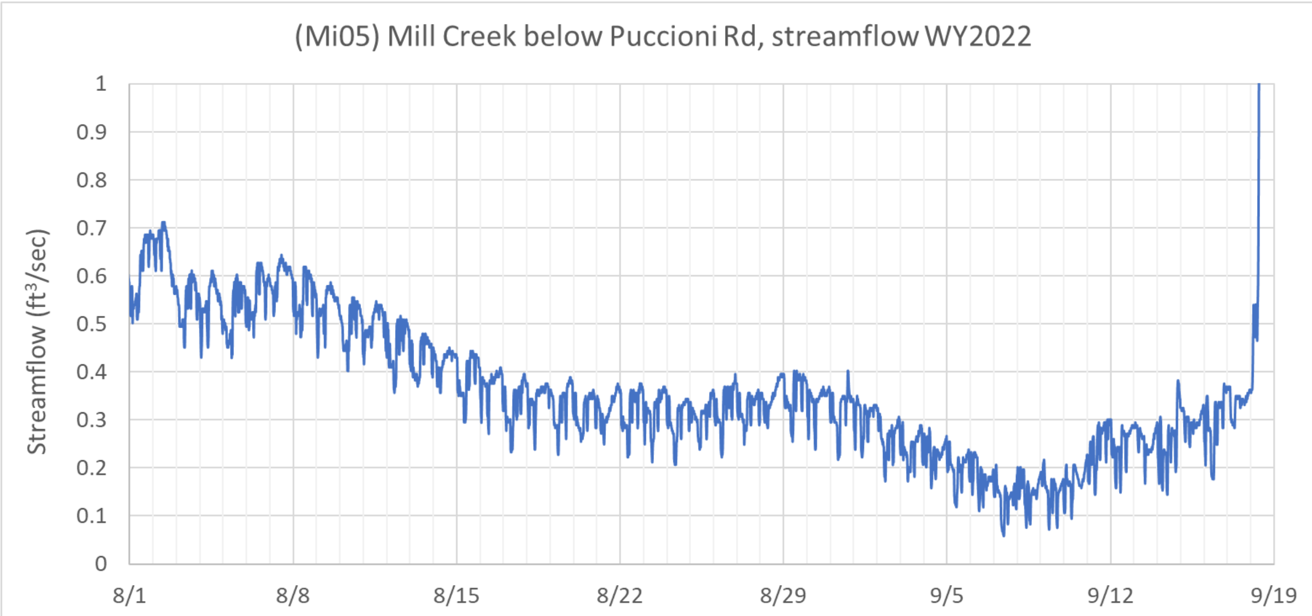

Figure 9. Streamflow at Mill Creek below Puccioni Road, WY2022, showing drops in streamflow caused by surface water diversions.

(Mi06) Mill Creek above Wallace Creek

At site (Mi06) Mill Creek above Wallace stage began to rise in response to the first storms of the year in late October 2021 (Figure 10). The two largest storms of the year occurred in October and December. The highest peak flows of the year were observed on October 24, 2021. At its highest level, stage rose to 7.9 feet. Stage began to recede in early January, then rose in response to small storms in April. A low stage of 1.6 feet was reached in September 2022.

Figure 11 shows streamflow conditions at Mill Creek above Wallace in WY2022. Streamflow in May 2022 started around 3.8 ft^3/sec (approximately 0.9 ft^3/sec higher than the upstream gage site Mi05, Mill Creek below Puccioni Road) and receded to 2.1 ft^3/sec. Several drops in flow are detected throughout the summer, Figure 12 shows streamflow conditions zoomed to highlight the diversion signals. However, the diversion signals recorded at Mi06 do not match those recorded at the upstream gage site (Figure 9), this is likely due to the influence of the tributary between the two gage sites. The gage data from (Mi06) Mill Creek above Wallace shows 2-3 different diversion signals on a daily basis (ranging from 0.19-0.02 ft^3/sec), and 16 diversion signals on a weekly basis.

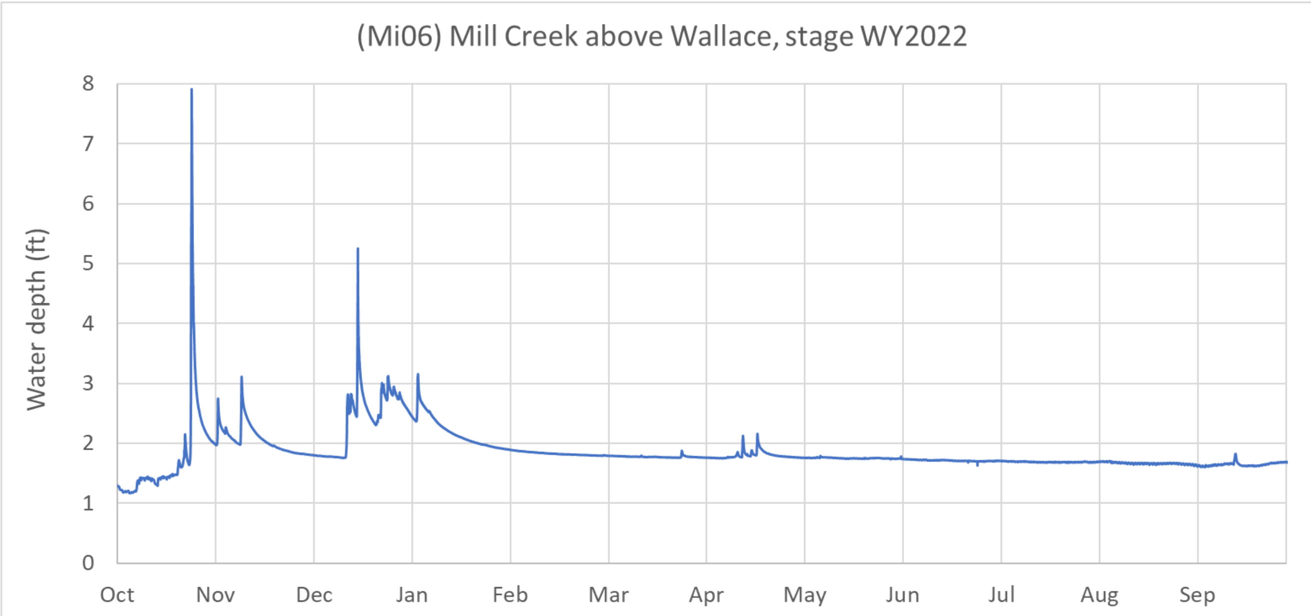

Figure 10. Stage at Mill Creek above Wallace, WY2022.

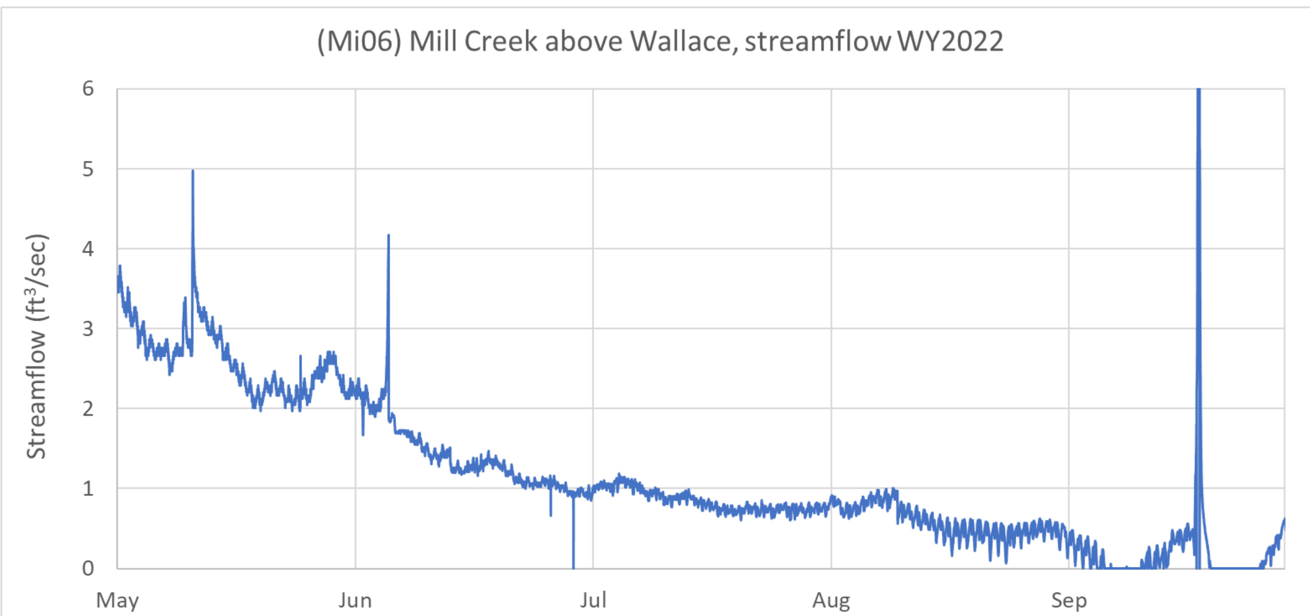

Figure 11. Streamflow at Mill Creek above Wallace, WY2022.

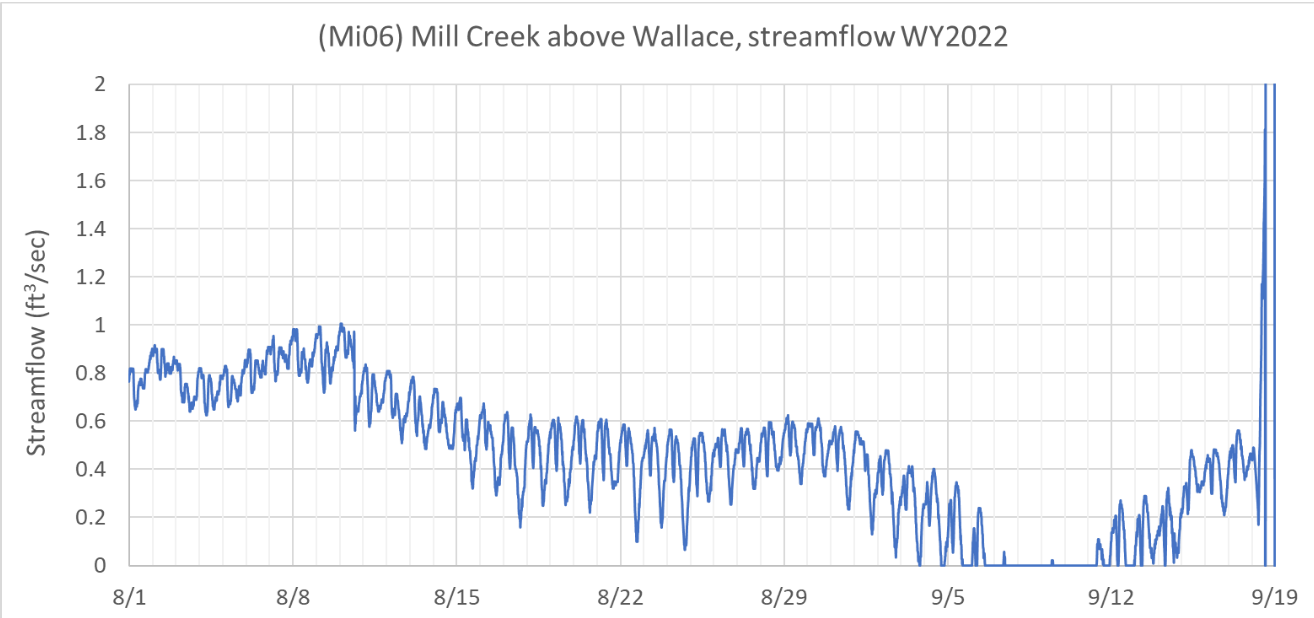

Figure 12. Streamflow at Mill Creek above Wallace, WY2022, showing drops in streamflow caused by surface water diversions.

(Mi08) Mill Creek at Mill Creek Lane

At site (Mi08) Mill Creek at Mill Creek Lane stage began to rise in response to the first storms of the year in late October 2021 (Figure 13). The two largest storms of the year occurred in October and December. The highest peak flows of the year were observed on October 24, 2021. At its highest level, stage rose to 10.7 feet. Stage began to recede in early January, then rose in response to small storms in April. A low stage of 0.9 feet was reached in September 2022.

Figure 14 shows streamflow conditions at Mill Creek at Mill Creek Lane in WY2022. Streamflow in May 2022 started around 4.7 ft^3/sec (approximately 1.1 ft^3/sec higher than the upstream gage site Mi06, Mill Creek above Wallace) and receded to 1.5 ft^3/sec. Several drops in flow are detected throughout the summer (Figure 14); however, the diversion signals recorded at Mill Creek at Mill Creek Lane do not match those recorded at the upstream gage site (Figure 12), this is likely due to the influence of the Wallace Creek tributary between the two gage sites. The large drops in flow recorded in May and in June are on the order of 0.3-1.84 ft^3/sec. Smaller drops in flow are recorded at sporadic intervals through the summer, with an increase in late August and September. The gage at Mill Creek at Mill Creek recorded the largest drops in flow than any other gage in upper watershed.

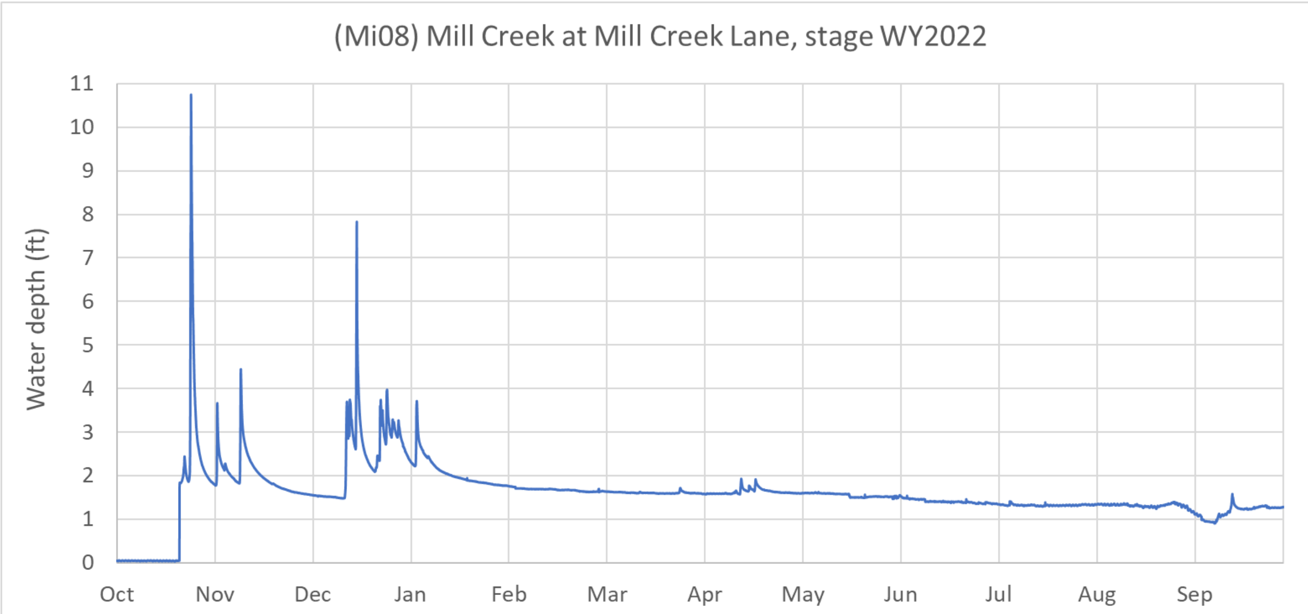

Figure 13. Stage at Mill Creek at Mill Creek Lane, WY2022.

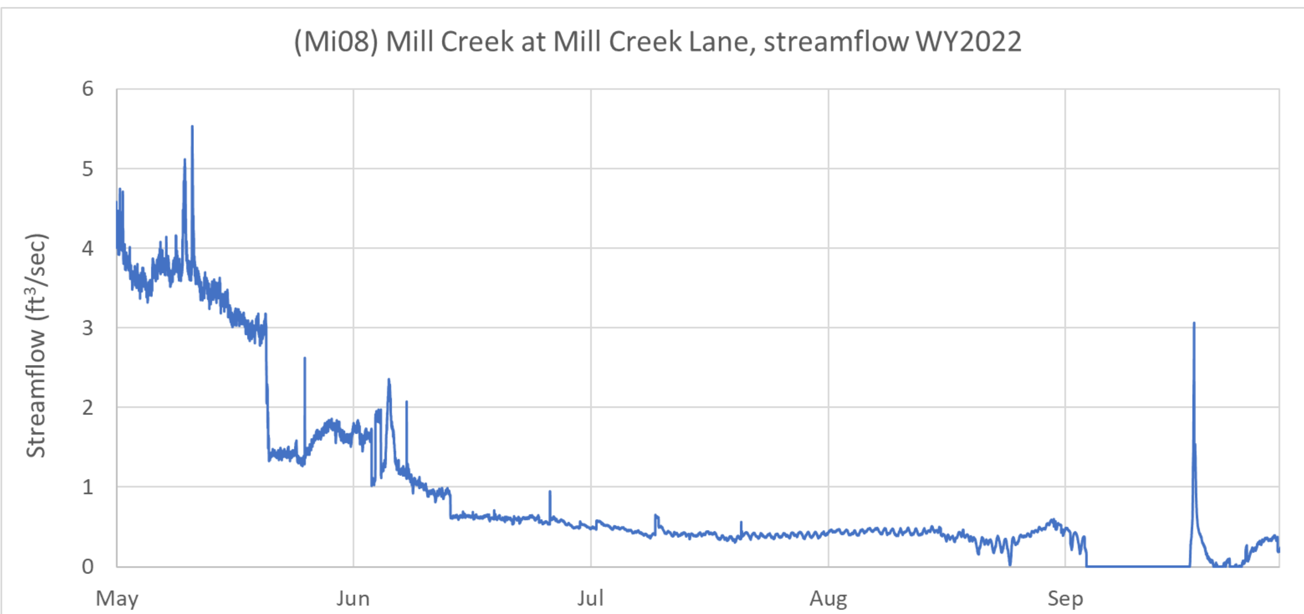

Figure 14. Streamflow at Mill Creek at Mill Creek Lane, WY2022.

(Mi03) Mill Creek above the falls

As seen at the other gages sites, stage at Mill Creek above the falls began to rise in response to the first storms of the year in late October 2021 (Figure 15). The highest peak flows of the year were observed on October 24, 2021, when stage rose to 7.7 feet. Stage began to recede in early January, then rose in response to small storms in April. A low stage of 0.19 feet was reached in September 2022.

Figure 16 shows streamflow conditions at Mill Creek above the falls in WY2022. Streamflow in May 2022 started around 4.8 ft^3/sec (approximately the same flow as the upstream gage site at Mill Creek at Mill Creek late, only 0.1 ft^3/sec higher) and receded to 1.59 ft^3/sec. Several drops in flow caused by surface water diversions are detected throughout the summer (Figure 16); however, the diversion signals recorded at Mill Creek at Mill Creek Lane do not match those recorded at the upstream gage site (Figure 14), this is likely due to alluvial deposits between the two gage sites. The two large drops in flow recorded in May and in June at the upstream gage (Figure 14) are not detected at this site, which is a little surprising given the magnitude of the flow decrease. Small drops in flow, likely caused by surface water diversions, are recorded at sporadic intervals through the summer at a pumping rate of 0.17 ft^3/sec.

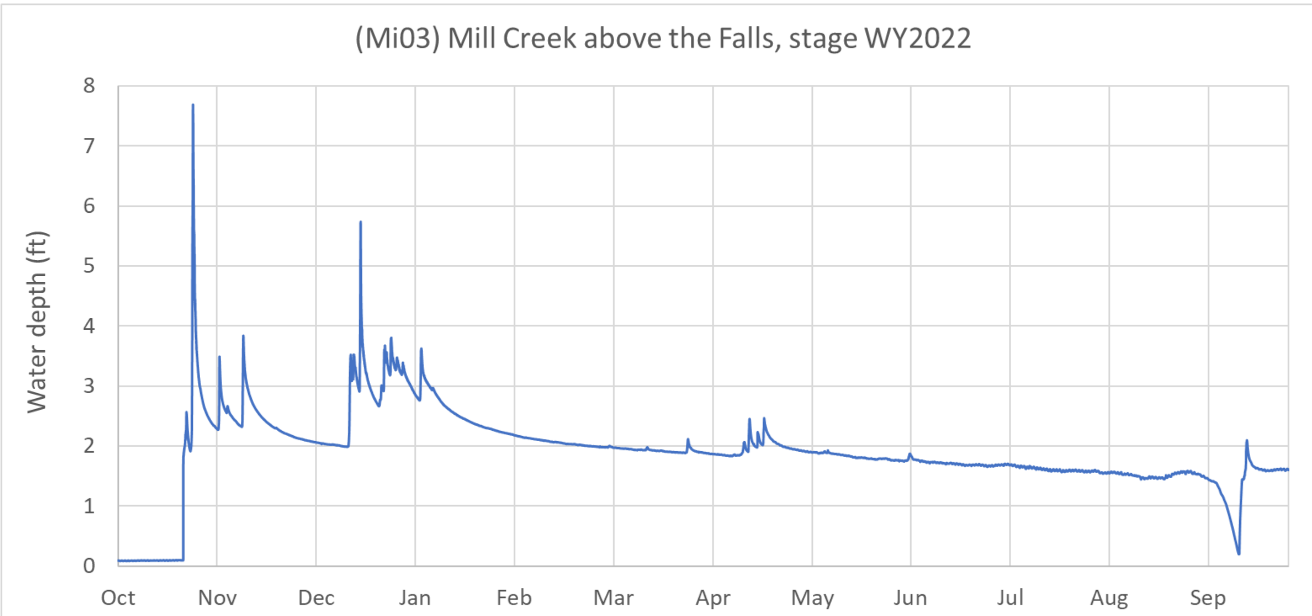

Figure 15. Stage at Mill Creek above the falls, WY2022.

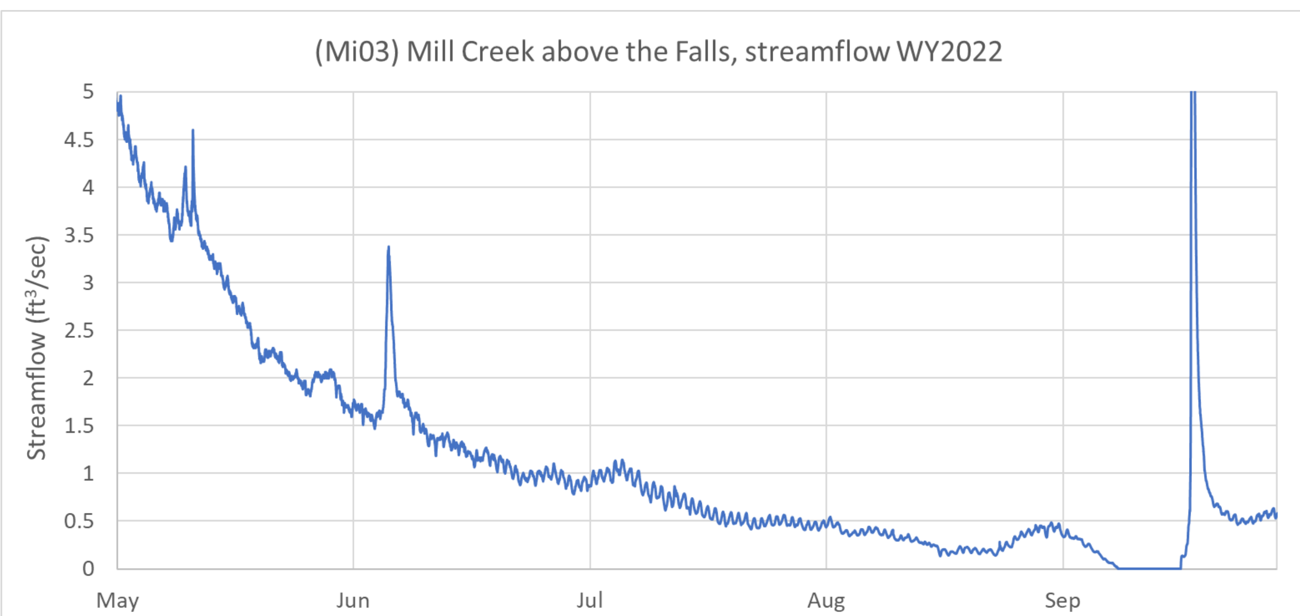

Figure 16. Streamflow at Mill Creek above the falls, WY2022.

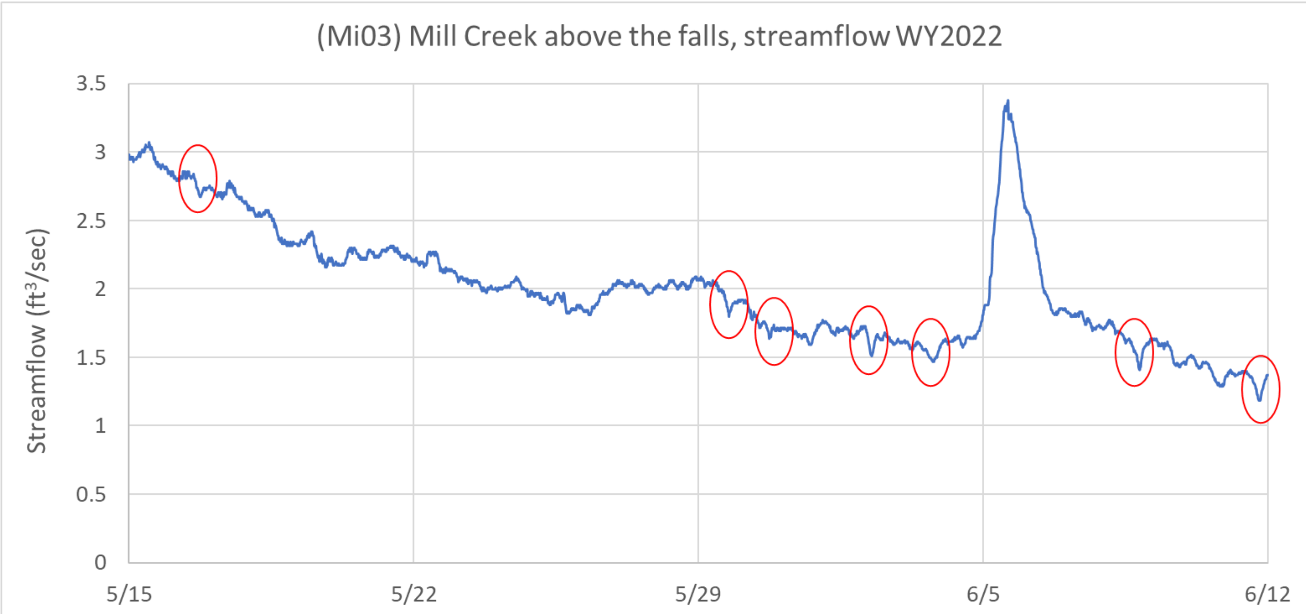

Figure 17. Streamflow at Mill Creek above the falls, WY2022, showing drops in streamflow caused by surface water diversions circled in red.

Mill Creek all gage sites

Figure 18 shows streamflow from May through September in WY2022 at all sites in the upper Mill Creek watershed. In the beginning of May streamflow increased from the most upstream gage site to the farthest downstream site (as you would expect with the increase in drainage area). This pattern continued at all gage sites through May except for the two lower sites (Mi08, Mill Creek at Mill Creek Lane and Mi03, Mill Creek above the falls) which became losing reaching in mid-May, during the time the gage at Mill Creek at Mill Creek lane detected large drops in flow. As the season progressed, the stream starts to show streamflow loss between upstream and downstream sites, and by August 2022 the middle gage site, Mill Creek above Wallace (creek) had the highest flow, likely due to the influence of Wallace Creek. By early September 2022 three of the five sites reached intermittency, with only the upper two gage sites maintaining flow.

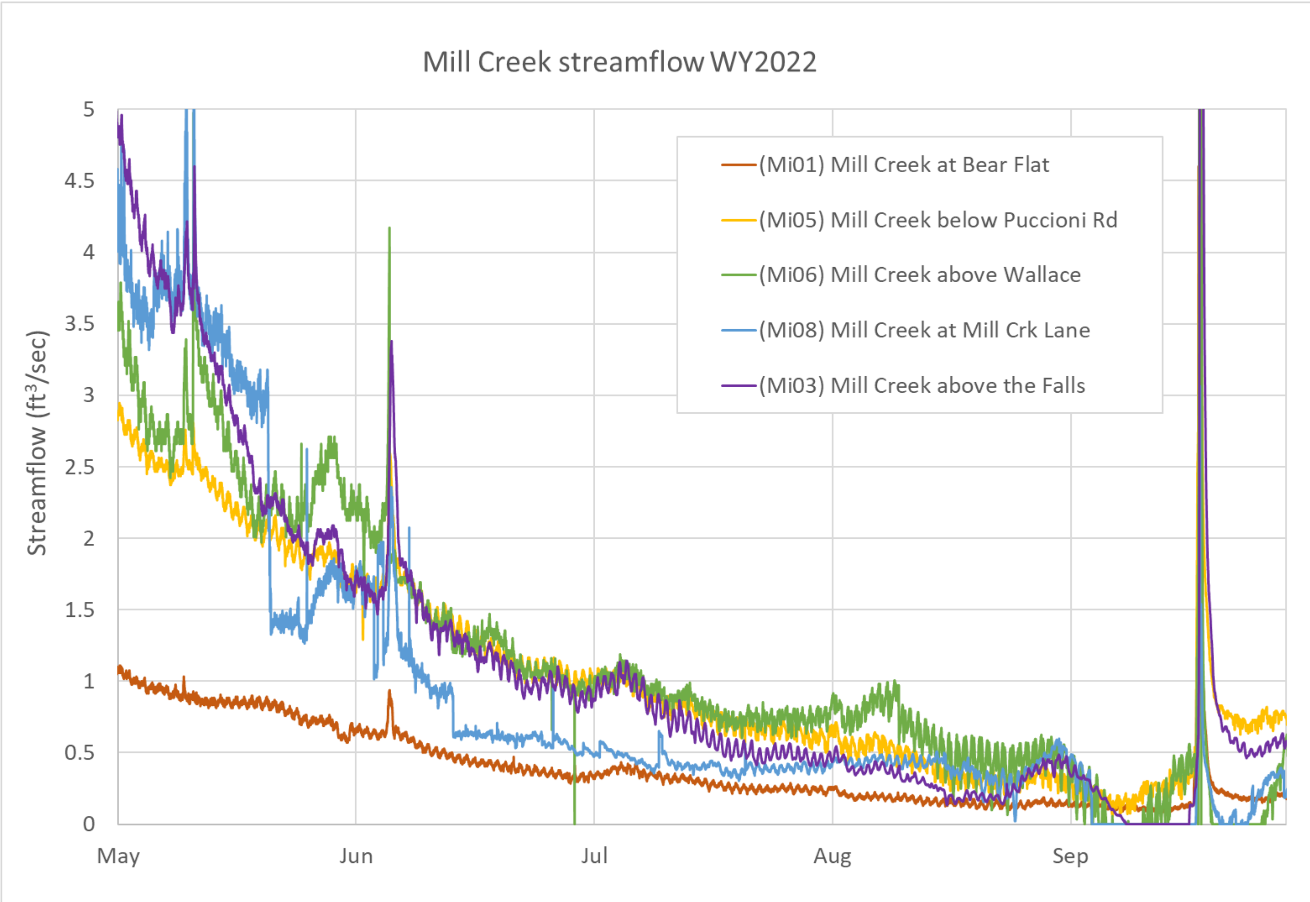

Figure 18. Streamflow at all Mill Creek sites, WY2022.

Streamflow and groundwater conditions – Lower Mill Creek

In WY2022 TU monitored two surface water gages (LM02 and LM03) and one continuous groundwater well gage (LM01) in the lower alluvial portion of Mill Creek (Figure 1). The lower portion of Mill Creek flows out of a confined bedrock canyon into a broad alluvial valley before joining Dry Creek, which then flows into the Russian River. The reach is highly incised and disconnected from its floodplain. The surrounding floodplain is primarily used for vineyards and small-scale agriculture. Due to the permeable nature of the underlying alluvial sediments in this reach, surface flows can be absorbed into the channel bed and underlying aquifers, causing the lower reaches of the channel to dry out in the summer months.

Figure 19 shows streamflow from March through late September at LM02 and LM03 for WY2023. LM02, the further upstream of the lower Mill sites, has a flow of about 5.3 ft^3/sec in early March, and LM03, further downstream, had a flow of about 4.6 ft^3/sec. Flow at both sites dropped steeply through March, then rose sharply due to a mid-April storm. Flows at both sites were similar to each other thought the spring and early summer, with flow at LM02 generally slightly higher than the downstream LM03 site. In early June, this relationship reversed as flows at LM02 began to drop more quickly than at LM03. LM02 dried to zero flow in late June, and flow at LM03 dried in late July.

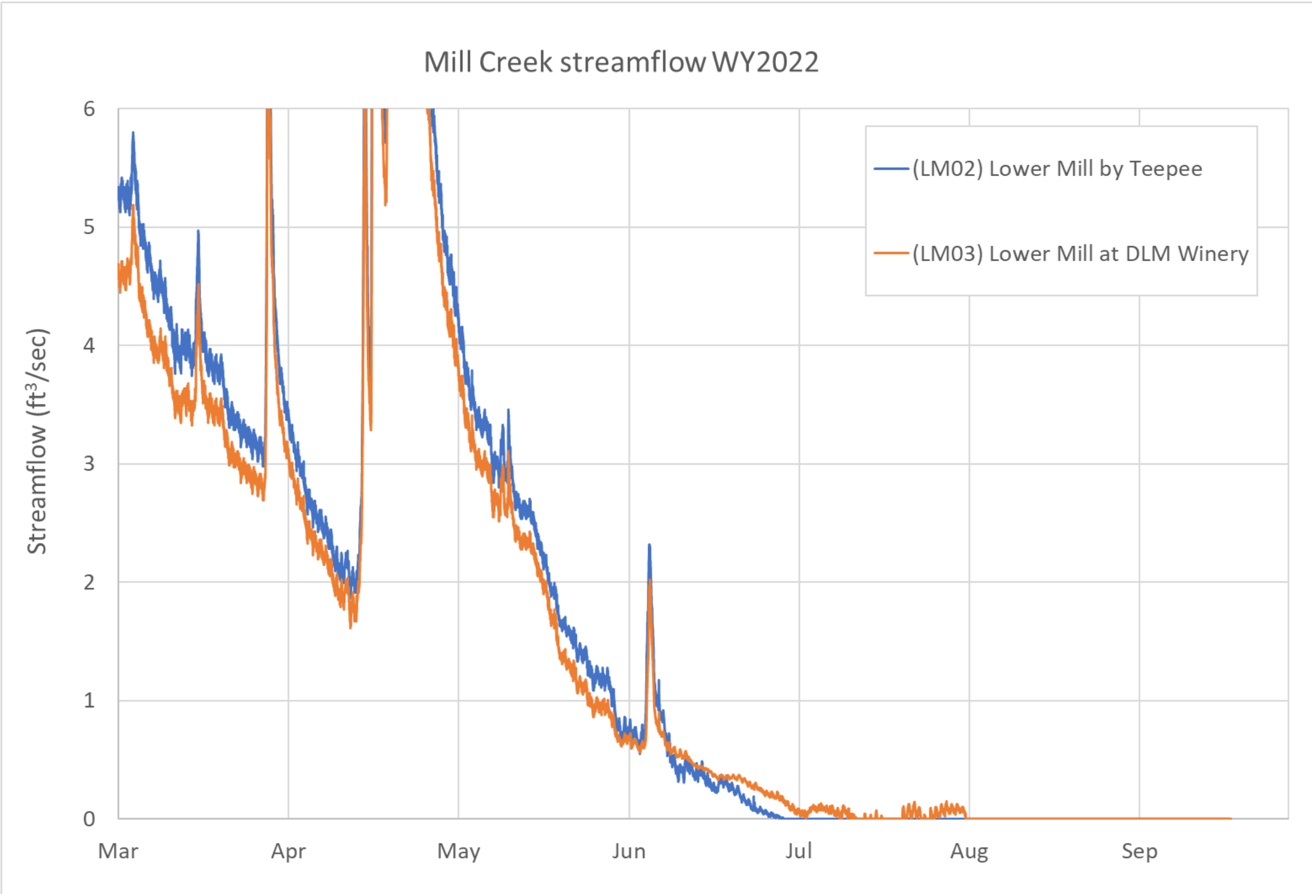

Figure 19. Streamflow at lower Mill Creek sites, WY2022.

Figure 20 shows continuous groundwater elevation in feet above mean sea level (MSL) at well LM01 (Unused Well 1) through WY2022, as well as the elevation of surface water at LM02 and LM03. LM01 is a well is adjacent to the channel slightly downstream of surface water gage LM02. A datalogger in this well reads 15-minute elevation data year-round. For the portions of the year that LM02 and LM03 were wetted, elevation data is shown in comparison to groundwater data. Note that elevations at LM03 are about 7 feet lower than LM01 and LM02 because LM03 is further downstream.

Early in WY2022 (October 2021), groundwater levels at LM01 were at a low of about 67.3 feet above MSL, as the previous summer and fall (WY2021) were extremely dry. The channel at LM02 and LM03 was dry at this time. Water levels rose sharply in late October 2021 in response to a large rainstorm. The surface water gages at LM02 and LM03 regained water and rose during this event as well. From late October through January, groundwater was reconnected with the surface water, and water levels at all sites rose and fell in response to winter storms. From mid-January to mid-June, ground and surface water levels declined slowly. In late June, flow at LM02 ceased, corresponding with groundwater levels dropping slightly faster. In early August, the downstream LM03 site reached zero flow. At this time, groundwater levels were declining more steeply, and continued to drop through mid-September, reaching a low point of 78.5 feet.

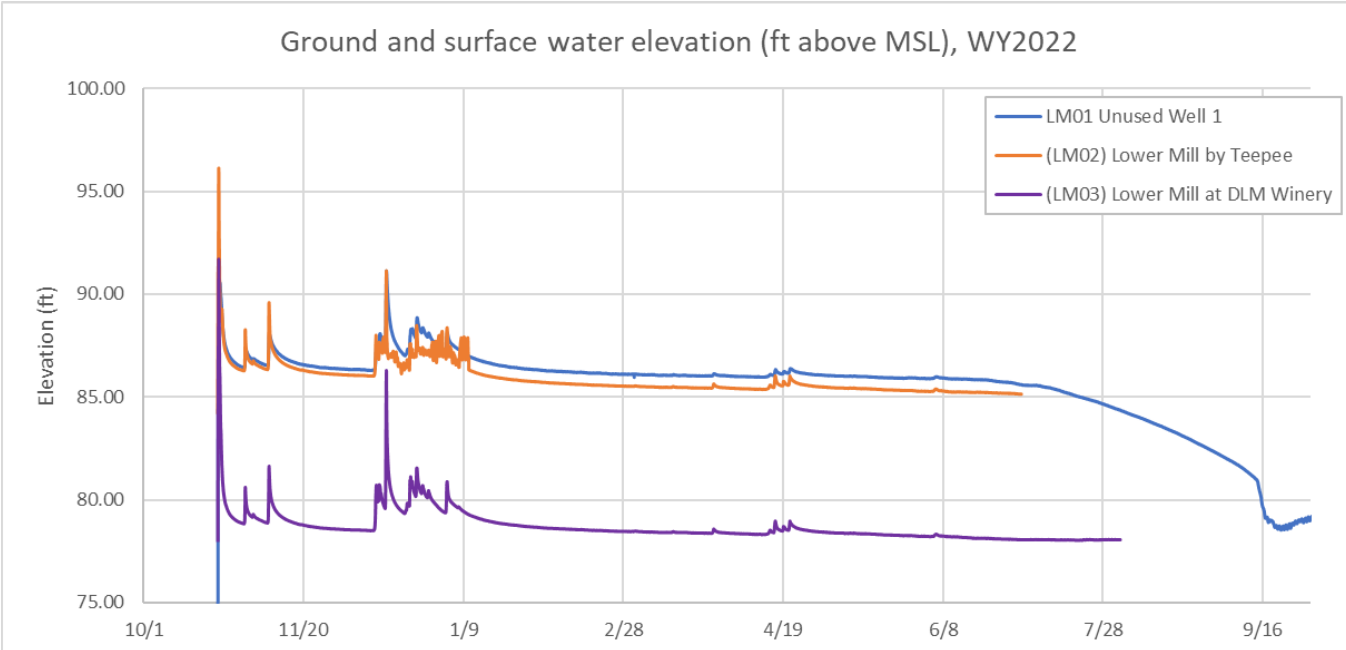

Figure 20. Continuous groundwater and surface water elevation, lower Mill Creek sites, WY2022.

5. Wetted habitat and water quality

CSG mapped stream channel conditions in the Mill Creek watershed during the driest period of 2022 using a protocol they developed to document wetted habitat available to fish. Wetted habitat surveys, also referred to as wet/dry mapping, were performed by walking the stream channel and recording wet and dry sections of stream length as lines on a GPS unit. The spatial data were then processed using a geospatial tool in ArcGIS, where the condition of "intermittent" was assigned to sections of stream with alternating short lengths (<50 feet) of wet and dry lines. Water temperature and dissolved oxygen (DO) concentrations were measured in wet pools at approximately 5-minute intervals using a handheld YSI probe. The full field protocol is available online (California Sea Grant 2021), and data processing procedures are described in the WCB contract report *Flow and survival studies to support endangered coho recovery in flow-impaired tributaries of the Russian River Basin* (California Sea Grant 2019).

The wetted habitat and discrete water quality measurement data from the Mill Creek watershed can be viewed in site-scale detail in the online wetted habitat dashboard that CSG created, which includes maps and data for all wetted habitat surveys completed by CSG and Sonoma Water between 2012 and 2022.

Wetted habitat results

Wetted habitat surveys were completed on all accessible reaches of Mill Creek on September 27-28, Wallace and Palmer creeks on September 28, and Felta Creek on September 27 and 29. Data were used to create a map displaying the spatial distribution of wet, dry and intermittent stream habitat (Figure 21). Extents of the stream channel for which we were not able to obtain access permissions are shown as grey lines.

Total stream channel length by late-summer habitat condition was calculated for each stream (Figure 22). At the end of the 2022 dry season, 82% of the 12.7 rkm surveyed in Mill Creek was wet and connected, 15% was dry and 3% was intermittent. Virtually all of the stream surveyed upstream of the Mill Creek Falls at Echols Road was continuously wet and connected, aside from a short length of intermittent and dry channel just upstream of the Angel Creek confluence (detail can be seen in the online dashboard). The vast majority of the channel surveyed below the Falls was dry or intermittent, aside from a wet section at the mouth of Mill Creek and a few additional, short wet stretches.

Late-September available wetted habitat in the tributary streams varied significantly (Figure 22), following general patterns observed in previous years (online dashboard). Of the 3.7 rkm surveyed in Felta Creek, 43% was wet and connected, 37% was dry and 20% was intermittent; of the 2.5 rkm surveyed in Wallace Creek, just 1% was wet and connected, 74% was dry and 25% was intermittent; and of the 2.9 rkm surveyed in Palmer Creek, 100% was wet and connected.

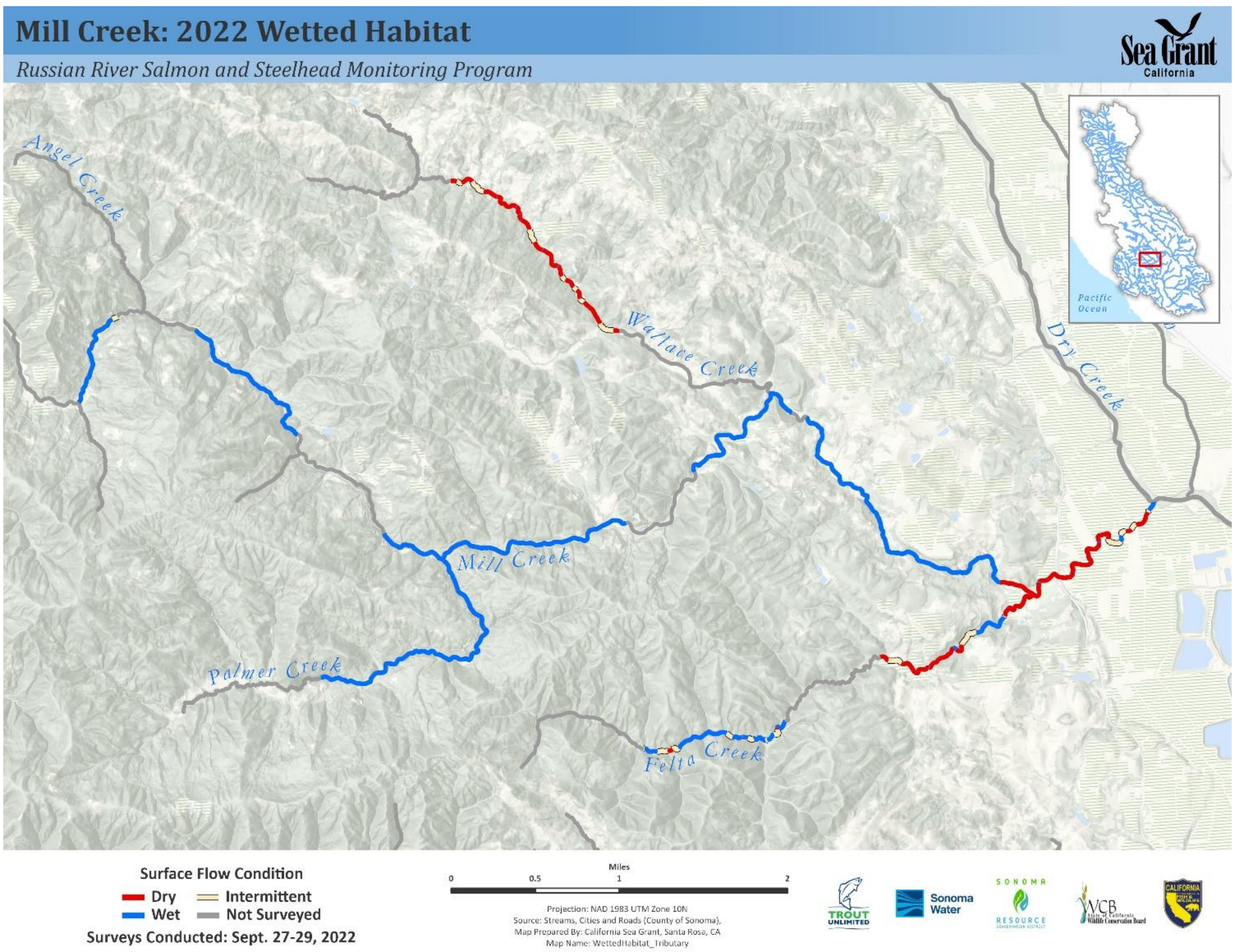

Figure 21. Wetted habitat conditions in the Mill Creek watershed, September 27-29, 2022. Grey lines denote areas where surveys did not occur due to lack of access permissions.

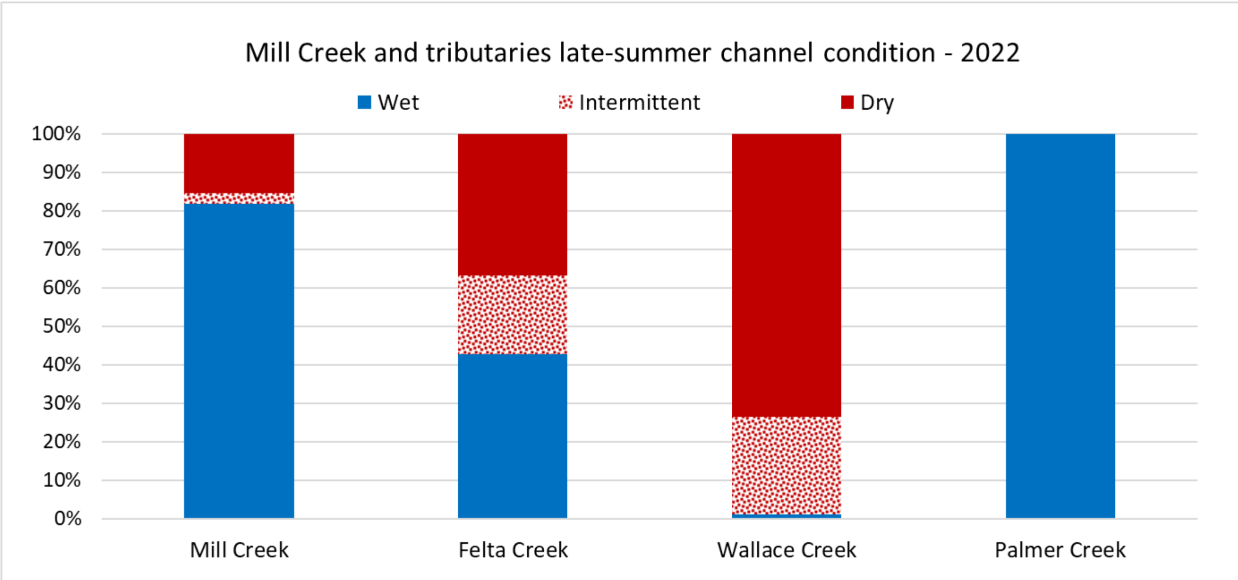

Figure 22. Total proportion of wet, dry and intermittent habitat present in accessible reaches of Mill, Felta, Wallace and Palmer creeks, September 27-29, 2022.

Water quality results

DO and water temperature were measured in Mill, Felta, Wallace and Palmer creeks during the September 27-29, 2022 wetted habitat surveys, in wet pools encountered at approximate five-minute intervals.

Suitable DO concentrations, which generally decrease under low flow conditions during the dry season, are essential for fish survival and fitness. The North Coast Regional Water Quality Control Board (NCRWQCB) has listed 6.0 mg/L as a daily minimum DO objective for the Russian River Hydrologic Unit (NCRWQCB 2015), and decreases in swimming speed and growth rate are known to occur below this concentration (U.S. Environmental Protection Agency 1986). Juvenile salmonids consistently avoid waters with DO concentrations below 5.0 mg/L (Washington State University Department of Ecology 2002). The lower limit to avoid mortality in salmonids is 3.0 mg/L (U.S. Environmental Protection Agency 1986). DO concentrations typically follow a diurnal pattern, with the highest values occurring later in the afternoon after peak photosynthesis by aquatic plants and algae, and lowest values occurring before sunrise, long after photosynthesis pauses and biotic consumption of oxygen continues. Note that discrete DO measurements were collected during daytime hours for this project and represent only a single point in time rather than daily minimum DO values.

DO concentrations were variable between pools and within stream reaches sampled, as were the number of pools sampled in each stream (Table 1). DO averaged 8.0 mg/L in Mill Creek, 5.2 mg/L in Felta Creek, 3.2 mg/L in Wallace Creek and 8.9 mg/L in Palmer Creek (Figure 23). When compared to the 6.0 mg/L regional objective, average DO concentrations were suitable for rearing salmonids at a stream scale in Mill and Palmer creeks, and below suitable levels in Felta and Wallace creeks, with the highest measured concentrations in Palmer Creek. Stream-scale average DO was above the 3.0 mg/L salmonid mortality threshold in all cases, though only by a slim margin in Wallace Creek. Since water quality data were not continuous, comparisons to the daily minimum objective and other thresholds only indicate whether targets were met at the time of measurement, not at the lowest point in a 24-hour period.

There were notable differences in DO concentrations across the watershed. We used CMP reach designations to summarize DO and water temperature data for Mill and Felta creeks at a spatial scale. Because Wallace and Palmer creeks each consist of a single CMP reach (WAL 2 and PAL 1, respectively), both stream-scale (Table 1, Figure 23) and reach-scale (Figure 24) data shown represent the entirety of the stream length sampled for those creeks. There was a clear delineation in DO suitability within Mill Creek. The reaches of Mill Creek from the Mill Creek Falls to the end of the survey extent above the confluence with Angel Creek (MIL 1.5-MIL 5) had DO concentrations ranging from 8.2-9.7 mg/L, on average for all pools sampled within each of the designated reaches (Table 1, Figure 24). This was well above the regional threshold (at the time of measurement) and sufficient to support rearing fish. Just 1 of the 43 pools sampled in those five reaches (2%) measured below 6.0 mg/L and none below the mortality threshold. By contrast, six of the seven disconnected pools sampled in the reach of Mill Creek from the mouth to just below the Mill Creek Falls (86%) were below the 3.0 mg/L mortality threshold, with an average concentration of just 2.3 mg/L for that reach (MIL 1). Average DO concentrations in both reaches of Felta Creek were below the objective and the proportion of pools that met suitability thresholds were the same in both reaches, with 57% of pools below the 6.0 mg/L regional objective and 29% below the 3.0 mg/L mortality threshold, despite a lower minimum DO measurement in the most impaired pool measured in FEL 1.

The optimum summer water temperature range for juvenile coho salmon is 10° to 15°C (McMahon 1983). At water temperatures greater than 20°C, significant decreases in swimming speed and increases in mortality due to disease have been noted, and water temperatures exceeding 25.5°C have been shown to be lethal to coho salmon (McMahon 1983). In the nearby Mattole River watershed, coho salmon were not present in suitable rearing habitat when the maximum weekly average temperature (MWAT) exceeded 16.7°C and maximum weekly maximum temperature (MWMT) exceeded 18°C (Welsh et al. 2001).

When averaged at a stream scale, water temperatures on the survey dates were essentially within the optimal temperature range for juvenile coho salmon in Mill, Felta, Wallace and Palmer Creeks, with the coolest temperatures in Palmer Creek and the warmest temperatures in Mill Creek (Table 1, Figure 23). At a reach scale, average temperatures were in the optimal range in all sampled reaches, with the warmest temperatures in the uppermost reach of Mill Creek that extends from the confluence with Angel Creek upstream for approximately 1.6 km (MIL 5)—the reach that experienced the most extensive riparian burning and timber removal due to the Walbridge Fire (Figure 24). Maximum water temperatures were below 18°C in all pools sampled throughout the watershed, with the exception of one pool in MIL 5. Note that discrete water temperature measurements only capture a single point in time and do not reflect variation between and within days (such as the warmest temperatures of each day), MWAT or MWMT. Comparisons to the above thresholds only indicate whether targets were met at the time of measurement.

Table 1. Minimum and average dissolved oxygen measurements and average and maximum water temperature measurements from pools sampled during wetted habitat surveys in Mill, Felta, Wallace and Palmer creeks, September 27-29, 2022. Mill and Felta creek reach names and all river kilometer (rkm) ranges reflect CMP designations, regardless of whether the full reach was surveyed.

Stream/reach	Rkm range	Number of pools sampled	Minimum DO (mg/L)	Average DO (mg/L) +/- 1 SD	Average water temperature (°C) +/- 1 SD	Maximum water temperature (°C)
Mill Creek	**All**	**50**	**0.2**	**8.0 +/- 2.8**	**15.3 +/- 1.1**	**18.2**
MIL 1	0 - 2.55	7	0.2	2.3 +/- 3.2	15.4 +/- 0.8	16.7
MIL 1.5	2.56 - 3.16	4	9.0	9.4 +/- 0.3	15.2 +/- 0.1	15.3
MIL 2	3.17 - 6.06	13	6.9	8.2 +/- 0.6	15.8 +/- 0.4	16.7
MIL 3	6.07 - 10.67	13	8.3	9.3 +/- 0.4	14.4 +/- 1.0	15.7
MIL 4	10.68 - 15.01	10	8.2	9.7 +/- 0.7	15.2 +/- 1.1	17.0
MIL 5	15.02 - 16.59	3	5.3	8.2 +/- 2.6	17.5 +/- 0.7	18.2
Felta Creek	**All**	**15**	**0.7**	**5.2 +/- 2.8**	**14.6 +/- 0.4**	**15.5**
FEL 1	0 - 2.05	7	0.7	5.0 +/- 3.4	14.7 +/- 0.6	15.5
FEL 3	3.53 - 5.18	8	1.7	5.3 +/- 2.4	14.5 +/- 0.2	14.7
Wallace Creek	**All**	**8**	**1.5**	**3.2 +/- 1.3**	**15.3 +/- 1.2**	**17.5**
Palmer Creek	**All**	**14**	**7.6**	**8.9 +/- 0.5**	**13.7 +/- 0.3**	**14.5**

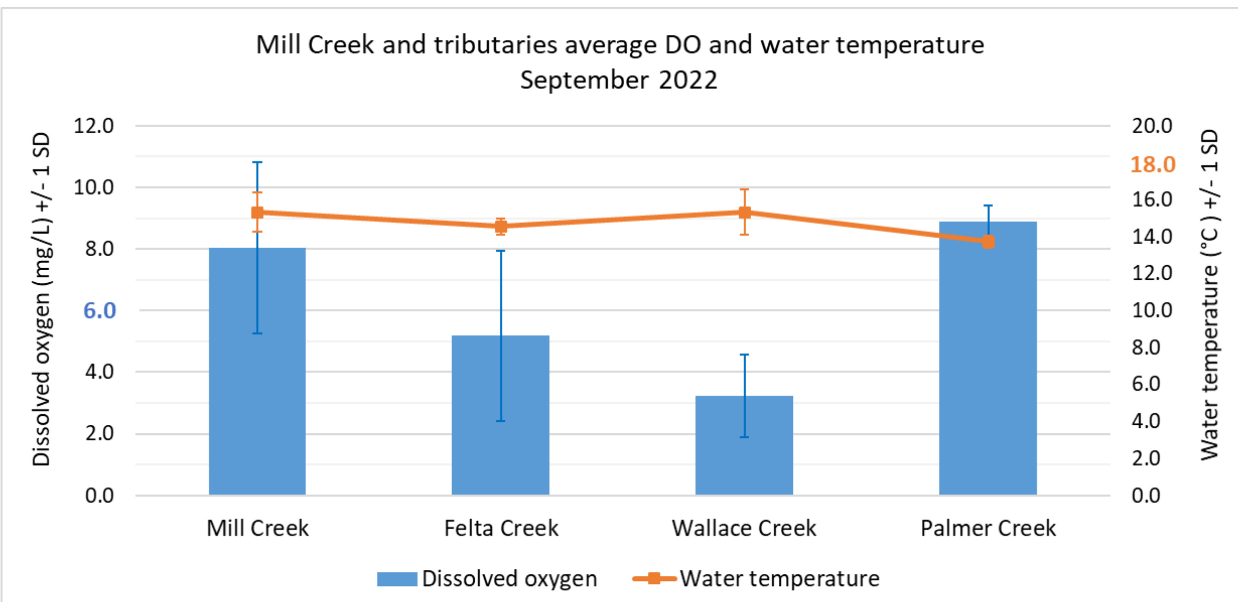

Figure 23. Average dissolved oxygen concentrations and water temperatures in pools sampled during wetted habitat surveys in Mill, Felta, Wallace and Palmer creeks, September 27-29, 2022. Colored values on y-axes indicate suitability thresholds for minimum dissolved oxygen (blue) and maximum water temperature (orange).

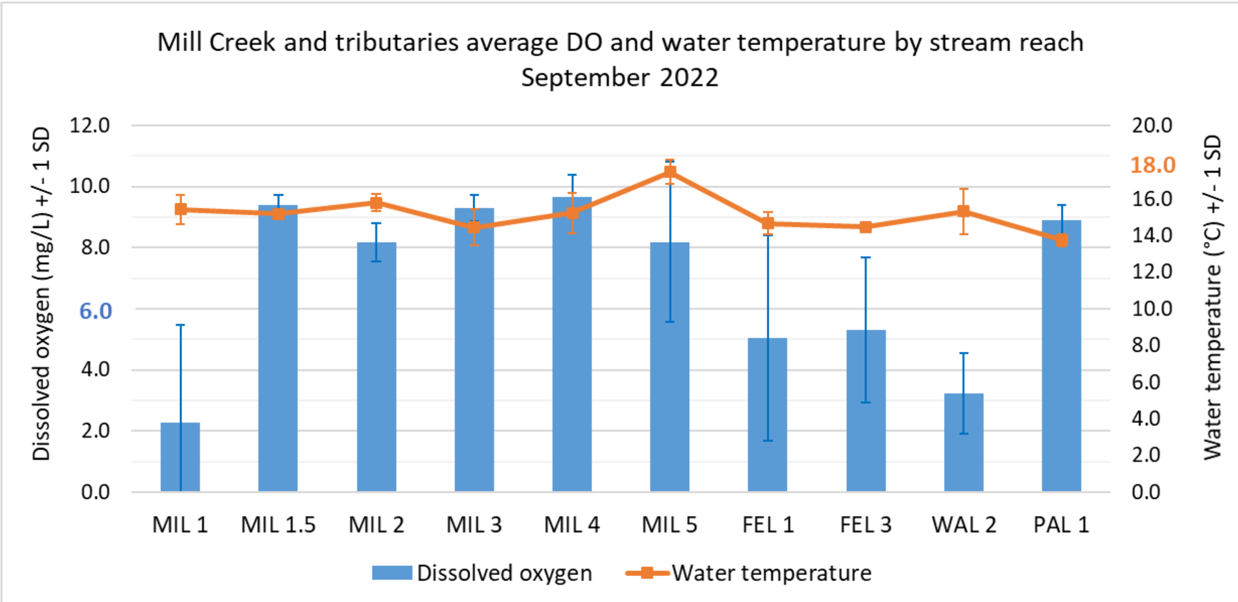

Figure 24. Average dissolved oxygen concentrations and water temperatures in pools sampled during wetted habitat surveys in CMP reaches of Mill, Felta, Wallace and Palmer creeks, September 27-29, 2022. Colored values on y-axes indicate suitability thresholds for minimum dissolved oxygen (blue) and maximum water temperature (orange).

6. Salmonid distribution in relation to wetted habitat

Salmonid redds

Spawner surveys were conducted by CSG and Sonoma Water in accessible reaches of Mill, Felta, Wallace and Palmer creeks at regular intervals over the winter of 2021/22. These surveys were conducted for implementation of the California Coastal Monitoring Program (CMP), as funded by California Department of Fish and Wildlife, and Broodstock Program monitoring, as funded by the U.S. Army Corps of Engineers. Survey methods followed procedures outlined in *Coho salmon and steelhead monitoring report: Winter 2021/22,* and detailed outcomes can be found in this report (California Sea Grant 2022a).

A total of 25 salmonid redds were observed in Mill Creek; four coho, 19 steelhead and two unknown salmonid species. Eleven redds were seen in Felta Creek; seven coho, 1 steelhead and three unknown salmonid species. No redds were seen in Wallace Creek and three redds were seen in Palmer Creek; two steelhead and one unknown salmonid species (California Sea Grant 2022a).

The winter 2021/22 redd distribution data were spatially joined to the September 2022 wetted habitat data in order to evaluate the suitability of summer rearing habitat in relation to observed spawning distribution (Figure 25). Of all redds observed in Mill Creek, 36% were in locations that remained wet and connected through the following summer, 52% in locations that dried and 12% in locations that became intermittent (Figure 26). Of the redds seen in Felta Creek, 9% (1 redd) was in a location that remained wet and connected and 91% were in locations that dried, while all redds (100%) observed in Palmer Creek were in locations that remained wet and connected through the 2022 dry season.

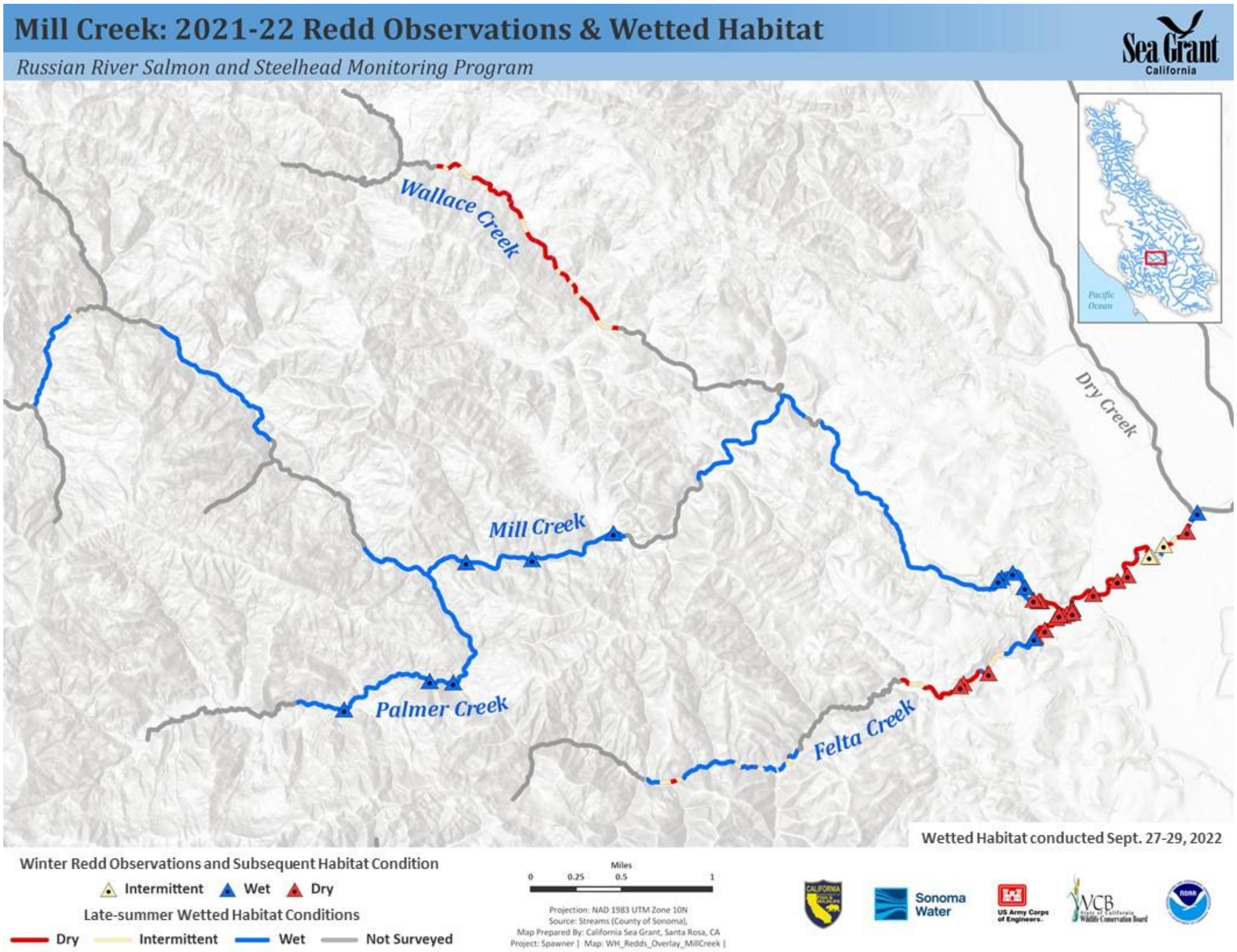

Figure 25. Winter 2021/22 salmonid redd observations in relation to September 2022 wetted habitat conditions in the Mill Creek watershed. Grey lines denote areas where surveys did not occur due to lack of access permissions.

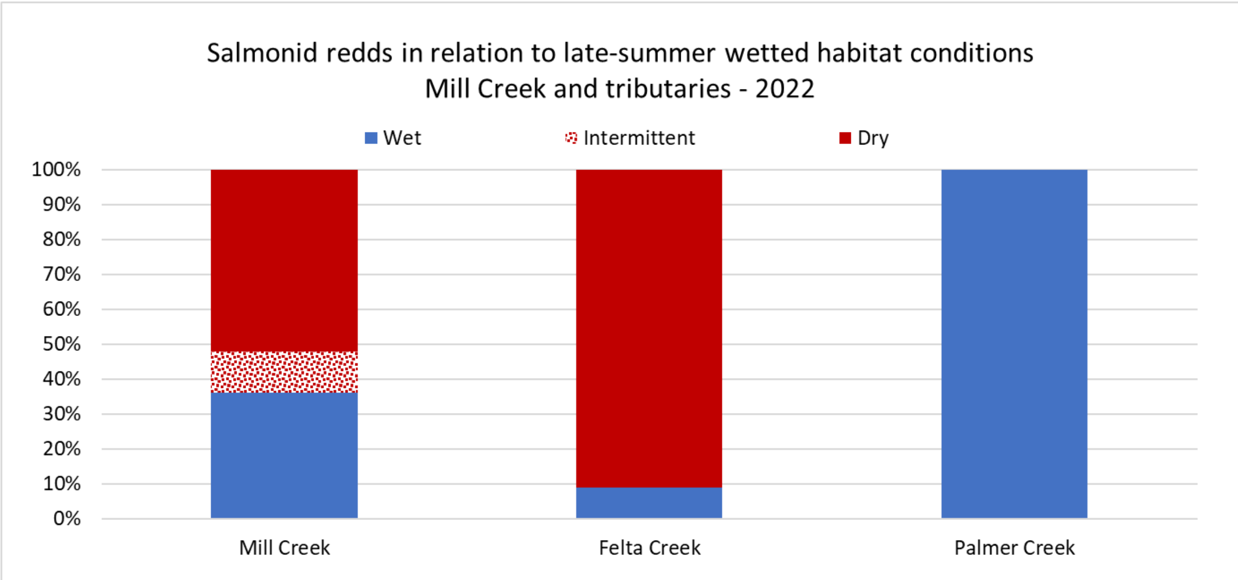

Figure 26. Proportion of winter 2021/22 salmonid redd observations in Mill, Felta and Palmer creeks that occurred in locations documented as wet, dry or intermittent in September 2022. No redds were observed in Wallace Creek.

Juvenile salmonids

Snorkeling surveys were conducted in Mill, Felta, Wallace and Palmer creeks by CSG and Sonoma Water from June 14-24, 2022 in order to document the relative abundance and spatial distribution of coho salmon and steelhead young-of-year (yoy). As with spawner surveys, these surveys were conducted for implementation of CMP and Broodstock Program monitoring efforts. Salmon and steelhead yoy were counted in every second pool using methods outlined in *Coho salmon and steelhead monitoring report: Summer 2022,* and detailed outcomes can be found in this report (California Sea Grant 2023).

In total, 258 coho and 415 steelhead yoy were observed in Mill Creek, 306 coho and 21 steelhead yoy in Felta Creek, no salmonids in Wallace Creek, and 97 coho and 136 steelhead yoy in Palmer Creek (California Sea Grant 2023). Since snorkel counts were only collected from every second pool, these numbers were doubled to generate expanded counts of 516 coho and 830 steelhead yoy in Mill Creek, 612 coho and 42 steelhead yoy in Felta Creek, and 194 coho and 272 steelhead yoy in Palmer Creek.

The juvenile salmonid distribution data from June 2022 were spatially joined to the September wetted habitat data to evaluate the availability of summer rearing habitat in relation to salmonid yoy presence (Figure 27). The total proportion of all yoy counted in each habitat condition—wet, dry and intermittent—was calculated in order to estimate the effect of stream drying and wetted habitat condition on juvenile fish (Figure 28). In Mill Creek, 52% of salmonid yoy were observed in pools that remained wet and connected, 47% in pools that later dried and 1% in locations that became intermittent. In Felta Creek, 35% were seen in pools that stayed wet and connected, 30% in pools that dried and 35% in areas that became intermittent. In Palmer Creek, 100% of salmonid yoy observed during snorkel surveys were in pools that stayed wet and connected through the 2022 dry season.

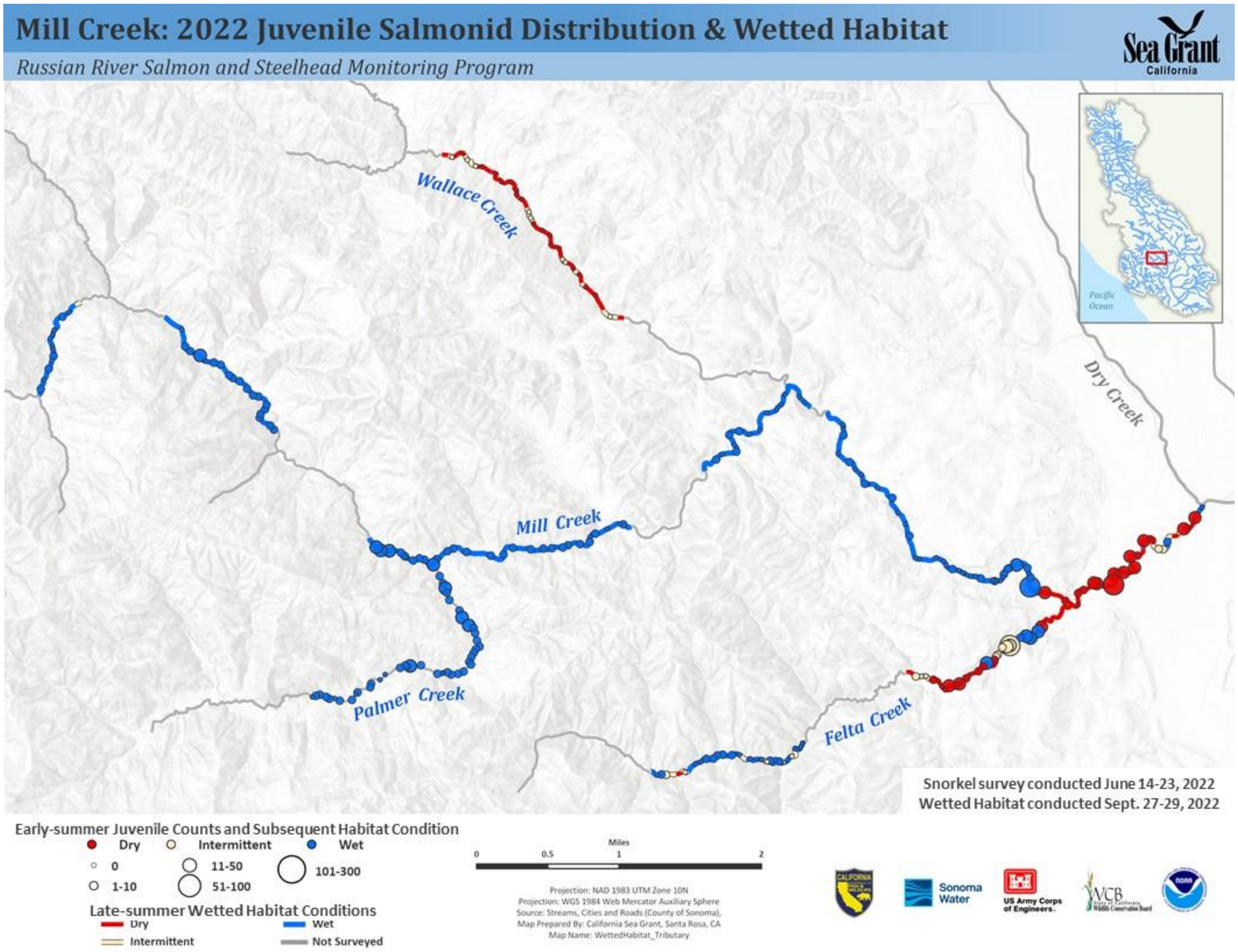

Figure 27. June 2022 salmonid young-of-the-year observations in relation to September 2022 wetted habitat conditions in the Mill Creek watershed. Grey lines denote areas where surveys did not occur due to lack of access permissions.

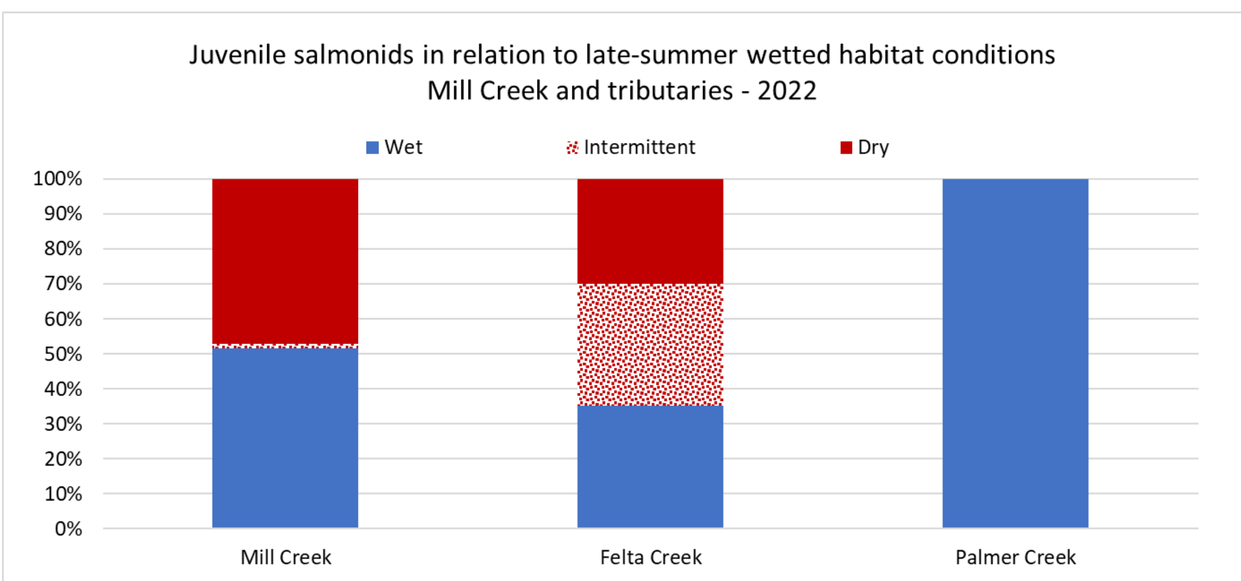

Figure 28. Proportion of June 2022 salmonid young-of-year observations in Mill, Felta and Palmer creeks that occurred in locations documented as wet, dry or intermittent in September 2022. No juvenile salmonids were observed in Wallace Creek.

7. Discussion

The 2022 water year in the Russian River watershed and the surrounding region was characterized by *severe drought* conditions and was wetter than during the *exceptional drought* of 2021 (https://droughtmonitor.unl.edu/Maps/MapArchive.aspx). Of the 194 km of channel in the 42 streams where wetted habitat surveys occurred in the lower Russian River watershed, 66% remained wet and connected through the summer of 2022 (California Sea Grant 2022b). Comparison of the 39 streams that were surveyed in both 2021 and 2022 revealed that there was 18% more wet and connected habitat at the end of the 2022 dry season (68% of total stream length) than in 2021 (50% of total stream length).

The gage data shows the watershed was gaining flow from upstream to downstream at the beginning of the dry season and began losing flow after the rain event in June. At the beginning of May 2022, streamflow increased from the most upstream gage site to the farthest downstream site (as you would expect with the increase in drainage area), this pattern continued at all gage sites through May, except for at the two lower sites (which became losing reaches in mid-May, when the gage at Mill Creek Lane detected large drops in flow). In mid-June the watershed started to show streamflow loss between upstream and downstream sites, and by August 2022 the middle gage site, Mill Creek above Wallace Creek had the highest flow. By early September 2022, three of the five sites reached intermittency, with only the upper two gage sites maintaining flow. This pattern, of the upper gages maintaining higher flows than the lower gages, is consistent with TU's previous years of data collection.

Many surface water diversion signals were detected through the upper Mill Creek gage network. The upper gage, (Mi01) Mill Creek at Bear Flat, shows relatively unimpaired flow. This gage site showed the largest impact from the recent fire in WY2021. In WY2021 this site showed larger than normal daily fluctuations in flow; flows appear to have settled to a consistent flow recession, with fewer daily fluctuations in WY2022. However, overall, flows at this gage may still be increased due to post-fire conditions. The gage at (Mi05) Mill Creek below Puccioni Rd showed the largest amount of instream diversions, with multiple pumping signals occurring daily. Streamflow enhancement projects in the reach between Mill Creek at Bear Flat and Mill Creek below Puccioni Rd would improve streamflow and habitat for fish, given the high frequency of pumping. The gage at (Mi06) Mill Creek above Wallace also detected daily diversion signals, which likely caused the stream to disconnect in September. The gage at (Mi08) Mill Creek at Mill Creek Lane showed the largest drops in flow in the early summer months (May and June), with a relatively smooth baseflow from mid-June to mid-August. However, the decrease in streamflow between Mill Creek above Wallace and Mill Creek at Mill Creek Lane indicates that groundwater pumping may be reducing surface flow. Water storage and forbearance projects that target groundwater pumping in this reach could potentially improve streamflow conditions. The hydrograph at (Mi03) Mill Creek above the falls gage showed the site was losing streamflow in mid-May and then shifted to a gaining reach from late May through August, and became a losing reach again in August and September. This inconsistent loss in flow indicates that water demands and management in the reach around Mill Creek Lane are significantly impacting surface water conditions.

Groundwater and surface water interactions in the lower portion of the Mill Creek watershed were heavily impacted by the year's rainfall patterns and particularly dry winter. Early in WY2022 (October 2021), groundwater levels were very low due to the previous summer and fall (WY2021) being extremely dry, and the channel in lower Mill Creek was dry, suspended above the water table. Both groundwater and surface levels rose sharply in late October 2021 in response to a large rainstorm, which was enough rain to keep groundwater connected to surface water from late October through January. WY2022's dry winter caused ground and surface water levels to decline slowly and conditions started dropping quickly by late June.

The Mill Creek watershed followed a similar trend between years as the lower Russian River basin, in general. At the end of the 2022 dry season, 68% of the 22 km of stream length surveyed in Mill, Felta, Wallace and Palmer creeks combined remained wet and connected. This was 26% more than in 2021, when just 44% of the same amount of stream length in the system remained wet through the summer. The amount of habitat that dried completely was less in 2022, at 24% of stream length sampled, as compared to 47% in 2021. The total length of channel that became intermittent was approximately the same between years, at 8% in 2021 and 9% in 2022. Palmer Creek retained the greatest proportion of late-summer, wet and connected habitat in 2022 (100%), followed by Mill Creek (82%), then Felta Creek (43%). Wallace Creek had virtually no wet habitat by the end of the summer (1%). This was similar to patterns observed between streams in 2021, when Palmer, Mill, Felta and Wallace creeks remained 90%, 50%, 16% and 0% wet and connected through the summer, respectively.

The distribution of wetted habitat available in the watershed was similar between the first two study years in some areas of the watershed, but varied in others (online wetted habitat dashboard). The majority of Mill Creek below the Falls, the lower reach of Felta Creek and all of Wallace Creek dried in the summers of 2021 and 2022. The vast majorities of Palmer Creek and Mill Creek above the confluence with Wallace Creek remained wet in both years. The biggest change in wetted habitat conditions between the first two study years was observed in the extent of Mill Creek from the Falls to just above the confluence with Wallace Creek, and in the upper reach of Felta Creek. This interannual variability suggests that these "marginal" reaches are relatively sensitive to environmental conditions and may be good targets for flow enhancement efforts aimed at decreasing days of surface flow disconnection. The number of days that pools are disconnected has been shown to have a negative correlation with the probability of coho salmon survival (Obedzinski et al. 2018), thus maintaining or restoring sufficient streamflow to keep pools connected through the summer is defined as a target in the Mill Creek Streamflow Improvement Plan (Russian River Coho Water Resources Partnership 2015).

Of the streams where juvenile salmonids were observed in 2022, Palmer Creek provided the greatest amount of proportional wetted habitat, with 100% of rearing salmon and steelhead yoy seen in areas that remained wet and connected. Mill Creek provided perennial habitat for approximately half (52%) of the salmonid yoy observed there and Felta Creek provided the lowest amount of wetted habitat for rearing fish, with just 9% of salmonid yoy counted in pools that stayed wet and connected through the dry season. Overall, 57% of the 1,233 salmon and steelhead yoy (expanded count of 2,466) observed in all study reaches in the Mill Creek watershed were in locations that remained wet through the 2022 dry season. About one third of rearing salmonids (34%) were present in locations that later dried completely and 10% were in locations that became intermittent. These results reinforce outcomes from 2021 and previous years and demonstrate, once again, that available/wet summer habitat is a limiting factor to fish in the watershed, particularly under drought conditions. The greatest detrimental impacts to rearing fish are seen in Mill and Felta creeks.

While the distribution of redds in relation to available late-summer habitat throughout all reaches sampled in the Mill Creek watershed in 2022 (33%) was slightly less than that documented in 2021 (38%), conditions were much more favorable to rearing salmonids in the wetter study year. In 2022, 20% more salmonid yoy (56%) were seen in locations that remained wet and connected, as compared to 2021 (36%). The difference between the relative proportion of redds and yoy located in wet areas in each year might be explained by juvenile fish dispersing from locations where they were spawned into wetter or drier areas at different rates. While a number of environmental and intrinsic factors can influence the movement of juvenile salmonids, this has not been quantified in Russian River tributaries. Note that the distribution of redds and juvenile fish in relation to late-summer habitat condition is not a simple reflection of the total amount of available wetted habitat, but also of annual variability in spawning distribution and juvenile fish movement. This is illustrated by the fact that more redds were seen in locations that dried or became intermittent in 2022 versus 2021, despite there being more available wetted habitat over all.

The section of Mill Creek below the Falls and all of Wallace Creek were highly DO impaired where water was present. DO conditions in the remaining reaches of Mill Creek (aside from a single pool in MIL 5) and all of Palmer Creek were well-suited for rearing fish, exceeding the 6.0 mg/L regional minimum daily objective established by the NCRWQCB. DO concentrations in Felta Creek were suboptimal, with about half of pools sampled (53%) below the regional objective and 17% below the 3.0 mg/L mortality threshold. At a stream scale, Palmer Creek had the best DO conditions. Average DO concentrations were substantially higher (by 1.0-5.4 mg/L) in all reaches sampled in the wetter year of 2022 than in 2021, with the exception of lower Felta Creek. This suggests that increases in summer streamflow and pool connectivity would also support improvements in DO conditions; an effect that has been documented in nearby streams such as Green Valley and Dutch Bill creeks (California Sea Grant 2020). Note that the number and locations of pools sampled for the current project varied between years and, once again, that the discrete DO measurements taken on the survey days only capture a single point in time and do not show variation in concentrations within and between days or the minimum daily values, which generally occur during the very early morning hours. Continuous DO loggers deployed in the study reaches over the summer months would allow for a more in-depth understanding of DO conditions and limitations in regards to supporting rearing salmonids.

Average water temperatures in all stream reaches sampled were in the optimal range, though the maximum temperature measured in the furthest upstream reach of Mill Creek, above the Angel Creek confluence (MIL 5), was slightly higher than the avoidance threshold for salmon. This reach experienced intensive burning during the 2020 Walbridge Fire (Figure 2). The fire and subsequent salvage logging operations resulted in the loss of much of the riparian cover in that area, leaving the stream corridor exposed to greater solar radiation than elsewhere in the watershed—even as compared to other areas within the fire footprint, like the Palmer Creek subwatershed, which sustained less damage from burning and logging. This increased UV exposure likely contributed to the higher water temperatures observed in upper Mill Creek. Water temperatures measured during wetted habitat surveys were generally similar between the study years; however, long-term water temperature data from a continuous logger operated by CSG in upper Mill Creek (at Bear Flat in MIL 4) showed an increasing trend in oversummer Maximum Weekly Maximum Temperatures (MWMTs) from 2020-2022 (post-Walbridge Fire), with 2022 values higher than 2021 and exceeding the 25.5°C lethal threshold for coho salmon (Nossaman 2022). We recommend continued DO and temperature monitoring within and outside of the fire-impacted areas of the watershed to track changes over this period of fire recovery and increasing climate volatility, as well as riparian restoration efforts to help remediate elevated summer water temperatures.

Overall, wetted habitat and water quality data from 2022 support outcomes from the first year of this project (Trout Unlimited and California Sea Grant 2022) and previous years sampled (online wetted habitat dashboard). General characterizations are as follows: 1) Palmer Creek provides high-quality habitat refugia for juvenile salmonids over the dry summer months and valuable hydrologic inputs into Mill Creek; 2) Mill Creek above the confluence with Wallace Creek generally provides suitable habitat, though temperatures appear to be increasing in fire-impacted reaches in the upper portion of the watershed; 3) summer rearing habitat in Mill Creek from the Falls upstream to the Wallace Creek confluence is marginal and habitat suitability varies depending on environmental conditions, with extensive impairment in extremely dry years (such as 2021) and substantial improvements in habitat in summers with even moderately higher streamflow (such as 2022); 4) Wallace Creek is not able to support rearing fish and does not provide hydrologic inputs into the Mill system; and, 5) Felta Creek offers limited summer habitat for juvenile salmonids and does contribute flow inputs to Mill Creek under most drought conditions (see https://droughtmonitor.unl.edu/Maps/MapArchive.aspx). However, the substantial improvements in available rearing habitat observed in the upper portion of Felta Creek in the wetter drought year of 2022 indicates that this marginal reach is quite responsive to changes in water year conditions and has the capacity to support juvenile salmonids with relatively minor increases in streamflow.

In the 2021 monitoring report for this project, we compared changes in streamflow and habitat quantity in Mill Creek and its tributaries in two similar drought years before and after the 2020 Walbridge Fire, concluding that there were increases in streamflow, late-summer wetted habitat and stream connectivity post-fire in the upper portions of Mill Creek and the tributary streams that were intensely burned (Trout Unlimited and California Sea Grant 2022). These changes likely resulted from reduced summer evaporative demand of the forest where high-intensity wildfire burned vast amounts of vegetation. Flow and wetted habitat data indicate that increased post-fire streamflow in the upper Mill Creek watershed likely persisted through the summer of 2022. Studies in other California watersheds show that low flows peaked two years post-fire (Saxe et al. 2018) and five years post-harvest (Coble et al. 2020), then decreased over time with forest regrowth. The hydrologic response to fire disturbance can vary between watersheds (Bart 2016). The 13-year streamflow record for Mill Creek shows that the recent fire has significantly increased summer streamflow and suggests that it would be prudent to manage forest regrowth in the Mill Creek watershed. We recommend using a holistic, landscape-scale approach that prioritizes improved streamflows for endangered and threatened salmonids (e.g., managing for reduced evapotranspiration rates associated with lower tree densities as opposed to the increased densities associated with successional forest regrowth).

While it is beyond the scope of this project to ascertain the full suite of impacts of the Walbridge Fire on fish habitat in the Mill Creek watershed, some additional effects are so striking that we would be remiss not to mention them anecdotally. For example, CSG surveyors have noted excessive sedimentation and loss of complexity in the upper portions of Mill Creek where steep, denuded slopes are actively eroding, landslides are prevalent, most of the instream woody structure was destroyed and many pools are filling in over time (CSG staff, personal communication). Additional observations related to fire and salvage logging impacts, as well other limiting factors to salmonids in the Mill Creek watershed, were presented at the 2022 Salmon Habitat Restoration Priorities Meeting and will likely be of interest to WCB and additional project partners (https://caseagrant.ucsd.edu/sites/default/files/MIL_SHaRP.pdf; Nossaman 2022). We recommend that studies be conducted to evaluate the dynamic, long-term impacts of wildfire and subsequent logging operations on streamflow, water quality and fish habitat in the Mill Creek watershed, and to support a plan for post-fire restoration.

Moving into the third sample year of the project, we plan to continue monitoring streamflow at all seven Mill Creek gage sites and to conduct a late-summer wetted habitat survey of all accessible reaches of Mill, Felta, Wallace and Palmer creeks. This will allow us to evaluate conditions in what is on track to be a wetter summer, build on our growing understanding of watershed conditions post-fire, help inform evolving project opportunities and document changes after streamflow project implementation.

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