CLASS ONE ARBORICULTURE
EXPERT TREE CARE

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[redacted]

[redacted]

Mr. [redacted]

Per your request, I inspected the trees at [redacted] at [redacted] to assess the cause of tree mortality. I met with property manager [redacted] y [redacted] and his co-worker [redacted] on [redacted] at [redacted] to collect data for this report. The cause of the tree mortality observed at the campground was an extended period of drought followed by insect infestation.

Site Observations

I walked a loop with [redacted] and [redacted] around the campground that passed approximately 60% of the campsites and restrooms, sampling each of three zones of tree mortality on the property. The path of my investigation is shown in Figure 1.

There were two dominant tree species at the campground: white fir (*Abies concolor*) and lodgepole pine (*Pinus contorta* ssp. *murrayana*). Along the lakefront, the trees were younger and were mostly pines. In a gradient moving away from the lake, the species composition included more fir trees and fewer pines.

Dead and declining trees were scattered throughout the campground in three distinctly different regions of mortality. The greatest mortality was along the west-facing lakefront trees, where about 60-70% of the trees were either dead or nearly dead at the time of my observation. An interior area that bordered Rancheria creek had approximately 20-30% mortality. Finally, the interior areas of the campground away from the lake and creek still had significant tree loss, but the rates were significantly lower due to a combination of site conditions and species composition. In the interior area, I observed approximately 10-15% mortality. A map showing the relative concentration of tree decline is shown in Figure 2.

Lakefront Trees

Near the lake, tree mortality was higher for three reasons: species composition, root development, and western exposure. First, the trees immediately along the lake tended to be lodgepole pine. Anecdotally, lodgepole pines tend to be more susceptible to drought stress than the white fir. This may be because white fir needles are thicker and waxier, helping them retain water better than the thinner needles of the lodgepole pines.

Next, the trees near the lake had developed shallow root systems in response to the saturated soil conditions at the lake's natural water level. However, the lake level declined substantially during the period of drought, making water less available to the lakefront tree roots. In contrast, trees further from the lake had grown deeper roots and were able to access a less-variable source of water.

Finally, the lakefront trees had western exposure, which creates the hottest afternoon temperatures and the latest afternoon sun exposure. Also, snow melts earlier in the spring on the west-facing slopes, reducing the window of time in which snow melt is a source of available soil moisture. The trees with full western exposure had much higher transpiration rates and thus used their water resources more rapidly throughout each day.

The lakefront trees were comprised of trees that were more susceptible to decline. They had less available water due to a drop in the lake's water level and the early season snow melt. And western exposure put a higher water demand on them. Together, these three factors predisposed them to bark beetle infestation.

Interior Trees

The interior portions of the campground further from the lake had lower mortality rates, but there were still a substantial number of dead trees. There were more fir trees relative to pines in the overall population than near the lake, but the pines were more severely impacted by the drought and insect infestation.

The area at the northern edge of the campground bordering Rancheria Creek had a higher mortality rate than the interior trees away from both the creek and the lake. Like with the lakefront trees, there were more pines than firs closer to the creek. There was also a substantial change in the water level during the drought, likely reducing the availability of water to these trees. But the mortality was lower than by the lakefront because there were more firs and because the exposure was to the north and not the west.

The tree decline and mortality spanned a period of the past 2-3 years. [redacted] told me that dead tree removal operations have been in process since 2018, but the tree mortality had increased substantially in 2019, leading to the closure of the campground. [redacted] said the park did not have a plan for disposal of the dead material, so it was left lying on the ground next to the cut stumps. I observed felled trees that had been lying on the ground 1-2 years and some that had been felled within the past few months. Trees marked for removal that had not yet been felled were marked with blue paint.

The timing of tree felling paralleled the mortality distribution over the three general areas of the campground. Recent and 1-2 year old felled trees were distributed around the entire campground. Even distribution of timing shows that the tree mortality occurred gradually over time over the entire campground. Even when all of the dead trees had been cleared out of one area of the campground at a particular point in time, the decline and death of neighboring trees continued. To address the advance of tree decline over time, the felling operations were repeated multiple times in each area of the campground over the past 2 years. About 70% of the campsites I observed had at least one adjacent dead or dying tree that had not yet been felled.

The cause of tree loss was consistent for all of the dead trees I observed. I did not observe any evidence of fire damage, flood, or any other catalyst for mortality.

Rainfall Data

Rainfall data shows an ongoing condition of chronic drought stress on the trees at [redacted] over the past 5 years. To document the history of drought in the area, I queried rainfall data from the National Oceanic and Atmospheric Administration (NOAA) [redacted] https://www.cnrfc.noaa.gov/monthly_precip_2020.php

The history of rainfall for the [redacted] weather station provided most of the data shown in Figure 3. Some of the time periods had missing data, so I filled in these gaps using historical weather data from Weather Underground: https://www.wunderground.com/history/
The time periods filled with supplemental data are noted below the table.

From October 2014 (the beginning of the 2015 water year) through March of 2020, the only year with rainfall higher than normal for the area was 2017. All of the other years had below-normal rainfall levels, especially 2015, 2016, and 2018.

Looking closer at the monthly rainfall data, 2017 had very high precipitation in January and February but had rainfall that was far below normal for all other months of the year. 41 of the year's 48 inches of rain fell in a short period of time. A similar concentration of rainfall occurred in March of 2018, where 15 of the year's 26 inches of rain fell in one month. In both cases, there was inadequate time for the soil to absorb the rainfall. Thus, much of the rainfall was not available for the trees in those years. Even though 2017 had a "normal" rainfall total, its heavy concentration in January in February still predisposed the trees to drought stress during the remainder of the year. And in 2018, which was already a dry year, less than 10 inches of rain fell in the other 11 months of the year. The chronic drought then became a predisposing factor that led to subsequent insect infestation.

Insect Infestation

On the trunk of every dead tree I inspected and on most trunks of heavily stressed trees, there was evidence of bark beetle activity. I did not observe the beetles themselves at my site visit, but I did observe their galleries. Based on my inspection of the galleries, the attacking insects may have been Pine Engraver Beetles (*Ips sp.*) or Mountain Pine Beetle (*Dendroctonus ponderosae*) on the pines and Fir Engraver Beetle (*Scolytus ventralis*) on the firs. Additional investigation would be necessary to conclusively determine the species of boring insect present in the trees.

There were many entry/exit holes in the bark of the affected trees. Some of the entry/exit holes were dry, indicating the trees' sap flow had been cut off before the holes were bored. Some trees were exuding sap from the boreholes, indicating sap flow was still active when the boreholes were made. Dead trees and trees with advanced symptoms of decline had bark that was loosely attached to the trunk. I peeled off the bark in sections, revealing galleries between the bark and the heartwood.

Ordinarily, healthy trees' defense against bark beetles is sap pressure. Dense healthy foliage undergoing photosynthesis creates suction pressure that draws water up through the conductive stem tissue towards the top of the tree. When an attacking bark beetle bores through the bark and into healthy conductive tissue, the sap pressure pushes the beetle back out of its hole, creating a pitch tube. The sap flow congeals over time, and the tree eventually seals off the borehole wound site.

But when a tree is already stressed, it has lower sap pressure. If an attacking beetle is able to bore past the slower active sap flow, then the beetle can become established under the bark. Trees become predisposed to insect attack when they are already stressed by drought because drought reduces the sap flow. Here, a history of drought in the area predisposed the trees at [redacted] to attack, leading to a high boring beetle population and subsequently the observed tree mortality.

New Solar Exposure

As some of the trees began to die in 2018, their losses also led to further stresses upon adjacent trees. Remaining trees that were formerly protected by their neighbors became exposed to new sun, which exacerbated the already-established trend of decline.

In a dense forest stand, trees compete with each other for light and resources. Before the drought began, the aggregate forest canopy was so dense that it blocked out the light to the trees' lower branches, leading to a concentration of foliage at the tops of the mature overstory trees. When some of the older trees died off from drought and insect infestation, the remaining trees were newly exposed to the sun. The increase in solar exposure led to an increase in the rate of evapotranspiration water loss, putting a greater water demand on the newly exposed trees.

Whereas some of the dead trees may have survived the drought stress alone, their new exposure ended up being a sufficient catalyst to predispose these trees to bark beetle infestation like the others.

Forest Order

On [redacted] the [redacted] was added to a list of recreation areas closed by a forest order. The reason for the closure was a large volume of tree mortality had led to hazardous conditions. Dead trees or branches are more brittle and have a higher likelihood of failure than healthy trees and branches. In the interest of public safety, the forest service closed the campground to mitigate the risk to campers.

[redacted]

Conclusion

The original catalyst for the tree mortality at [redacted] was the severe drought that persisted for years prior to the closure of the campground. Rainfall was below normal for 4 out of the past 5 years. Precipitation during those years was concentrated into a short period of time, leaving little time for it to infiltrate into the soil to become available for the trees. As a result of the chronic drought stress, the trees were predisposed to bark beetle infestations. The beetle infestations were the direct and final cause of the trees' death.

Tree mortality took place over the past two years, and it may be expected to continue through the next year or longer, even if growing conditions are favorable.

My observations were all-visual. I relied upon information I was provided regarding the history of the site and management of the trees.

Let me know if you have any further questions,

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Site Map

[redacted]

Figure 1: Ca [redacted] collect data for this report.

[redacted]

Imagery ©2020 Google, Imagery ©2020 Maxar Technologies, USDA Farm Service Agency, Map data ©2020 200 ft

Figure : Campgro nd map marked with the three areas of observe l relative tree mortality.

[redacted] Rainfall Data

Water Year	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	TOTAL
2020	0.04	2.04	5.60	1.64	0.52	6.76							16.60
2019	0.00	4.00	1.80	1.30	17.24	8.12	2.08	4.68	0.20	0.24	0.00	0.00	39.66
2018	0.48	1.56	0.32	1.20	1.40	15.68	5.04	0.28	0.12	0.04	0.00	0.00	26.12
2017	0.00	1.10	0.00	25.92	15.44	5.16	0.13	0.44	0.04	0.00	0.00	0.60	48.83
2016	1.18	3.36	7.76	9.68	0.00	0.00	0.51	0.96	1.27	0.35	0.11	0.03	25.21
2015	0.16	1.08	3.84	0.48	3.56	0.84	1.88	0.88	0.52	0.32	0.00	0.00	13.56
NORMAL	2.44	4.92	5.83	8.50	8.31	7.56	3.39	1.85	0.67	0.35	0.24	1.22	45.28

Missing data filled from Wunderground

2019 Oct	Jan	Sept							
2018 Oct	Jan								
2017 Oct	Nov	Dec	Feb						
2016 Oct	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	
2015 Aug	Sept								

Figure 3: Historical rainfall data for [redacted] CA.

Figure : Example of typical mortality in the interior area of the campground away from the lake and creek. About 10-15% of the trees had died.

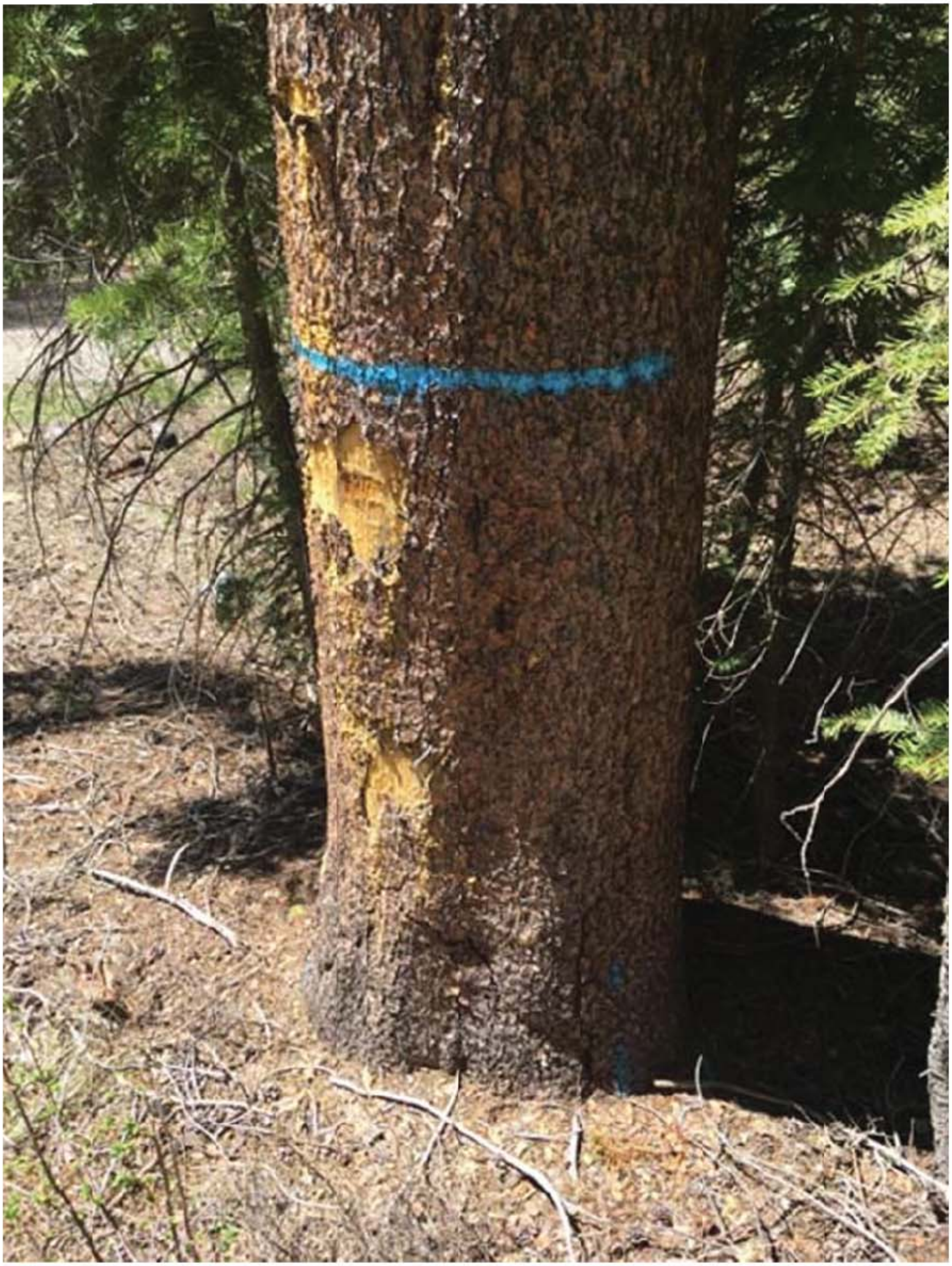

Figure : Trees were marked for removal with blue paint. Sap exudation indicates this tree died recently.

Figure : Close up showing entry/exit holes of the bark beetles on a typical dead tree at the campground.

Figure : Underneath the loosely-attacehd bark, I observed bark-borer galleries.

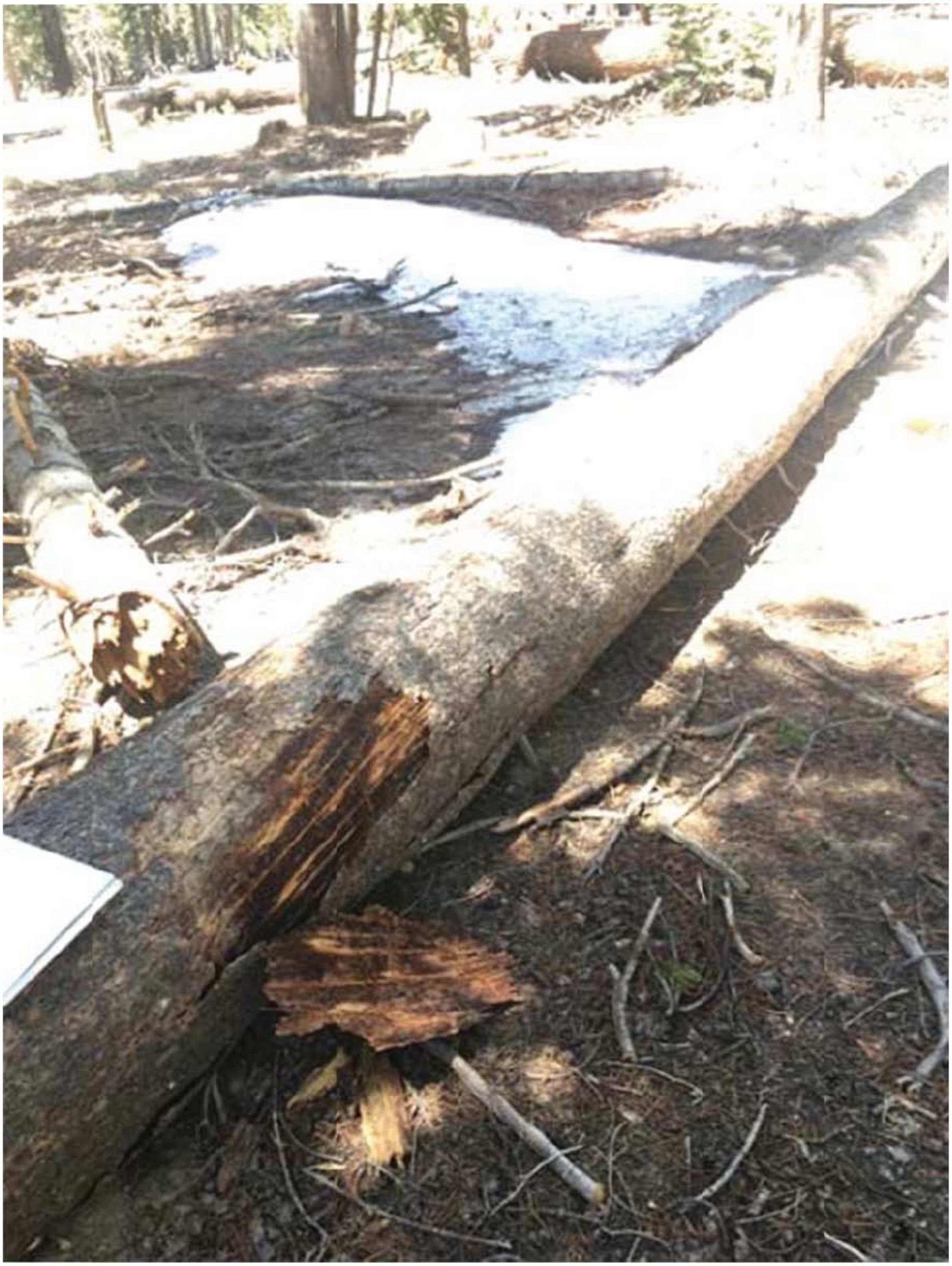

Figure : A recently-felled tree in the interior area of the campgrou id had typical signs of bark beetle activity.

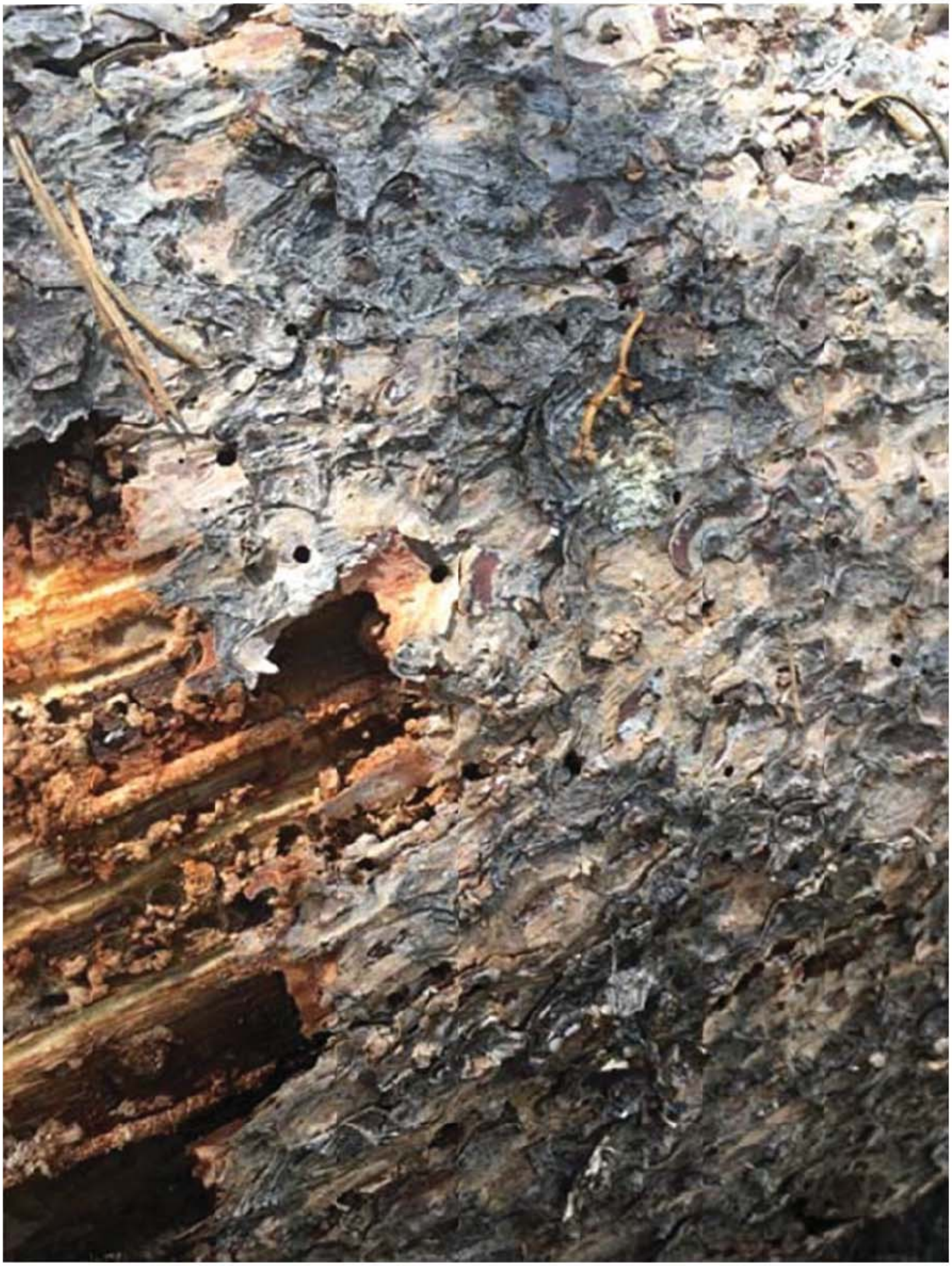

Figure ': Another c ose up of the galleries (left) and entry/exit hole; (right) on a dead tree.

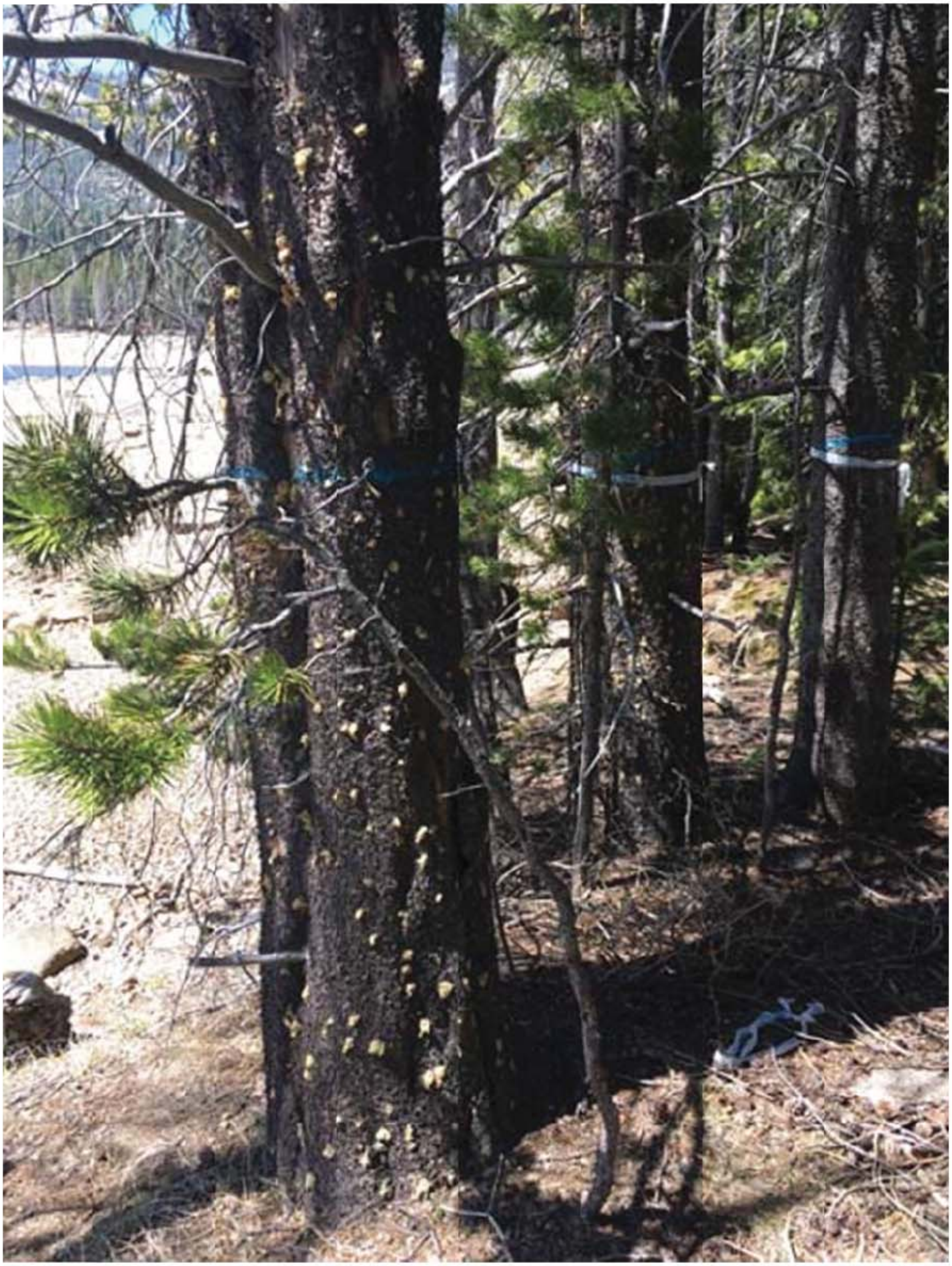

Figure 10: Example of heavily infested tree showing sa) exudation from the entry/exit holes in the trun :. This tree vas growing near the lake.

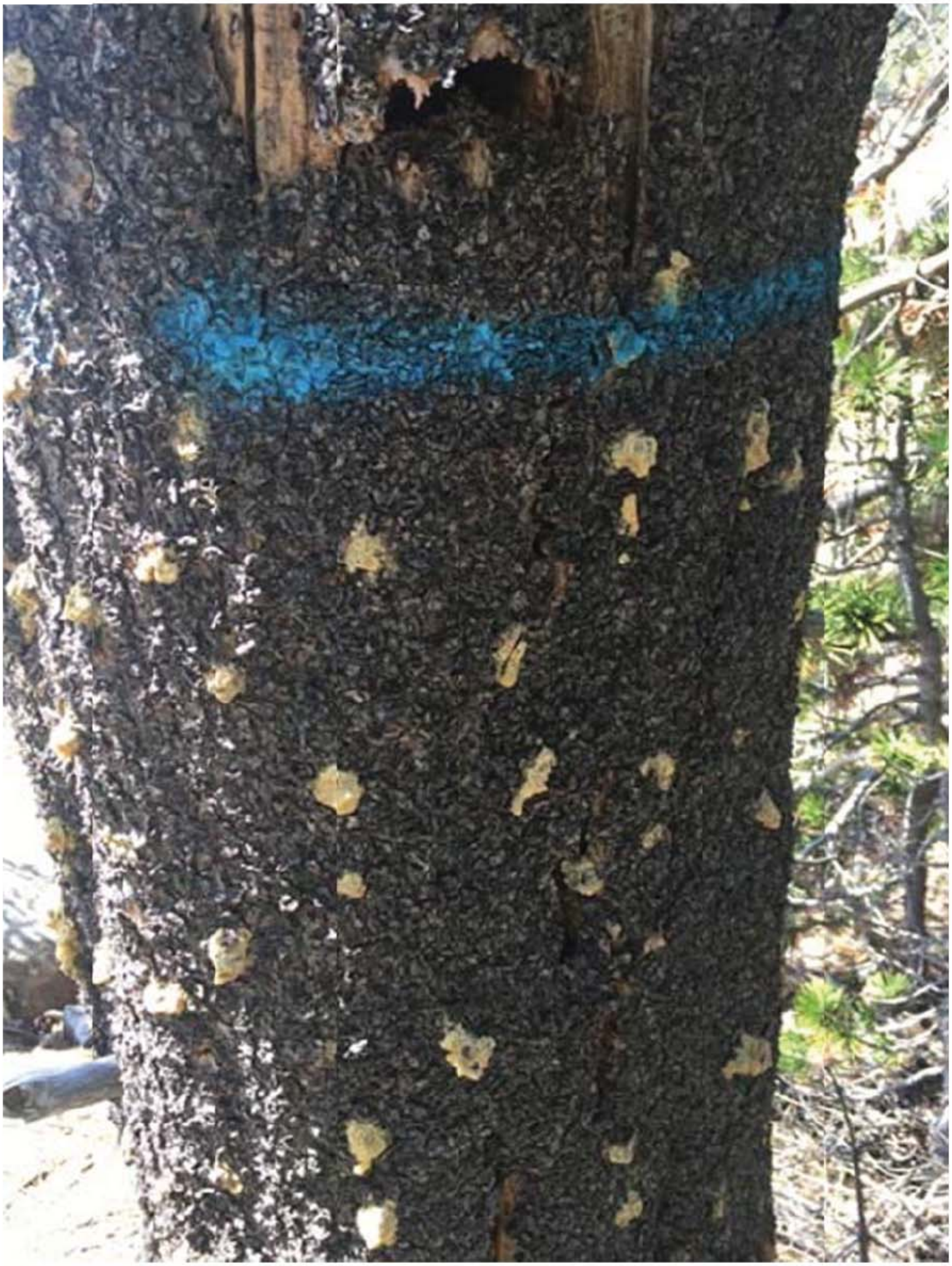

Figure 11: Close up showing the entry/exit holes with s ıp exudatio ı, indicating the tree had died recently.

Figure 12: Typical interior trees developed foliage concentrated near the top, making them more exposed to sun whe . neighboring trees died and were removed.

Figure 13: Interior trees lost their lower branches due to competition with neighboring trees in the past. When the neighboring trees were removed, the remaining trees were exposed to new sun, further stressing them. These pines in the foreground are not likely to survive for much longer.

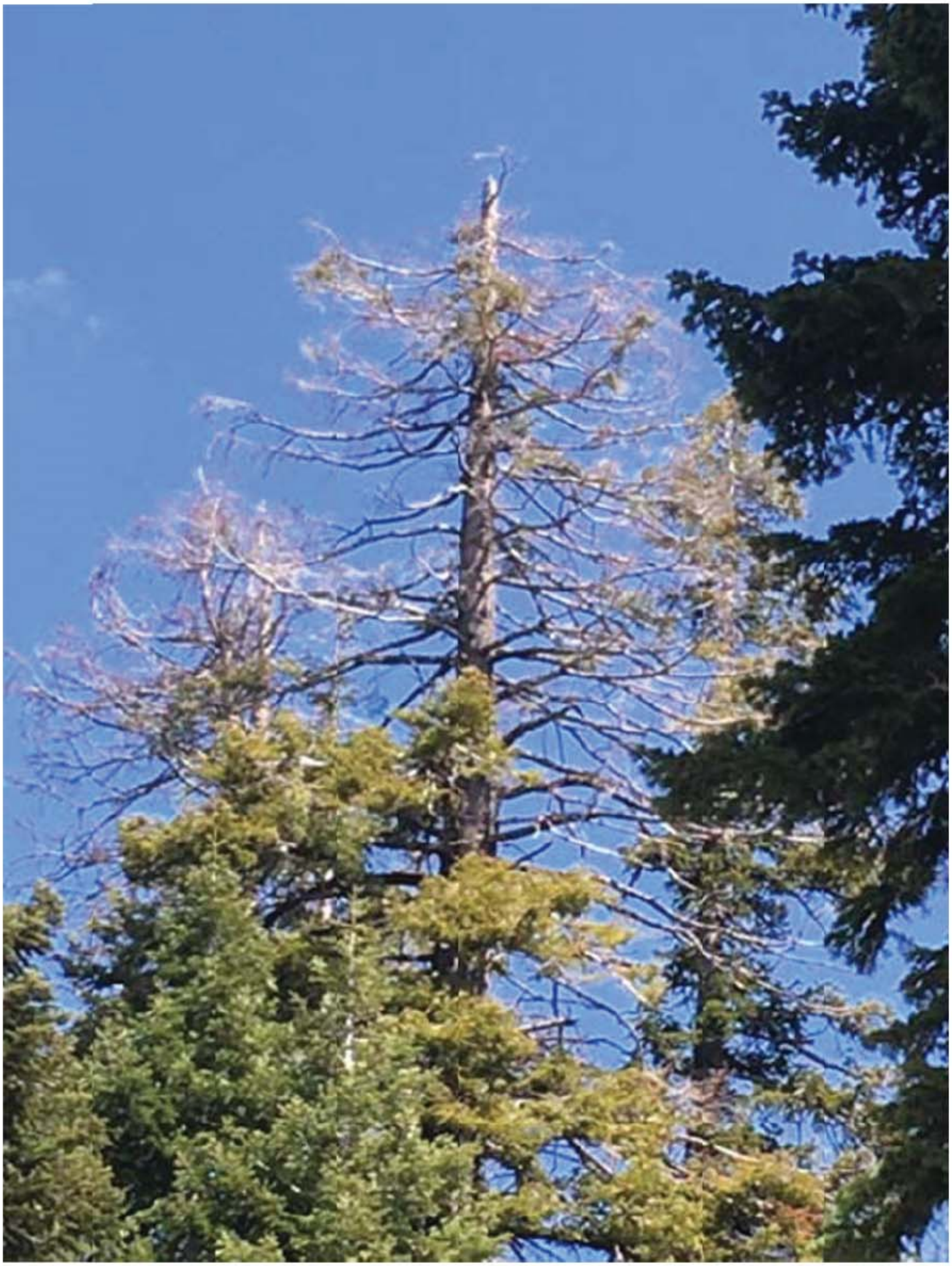

Figure 14: Typical tip dieback on a declining tree. Trees like this were alive at the time of my observations, but they may be expected to continue to decline.

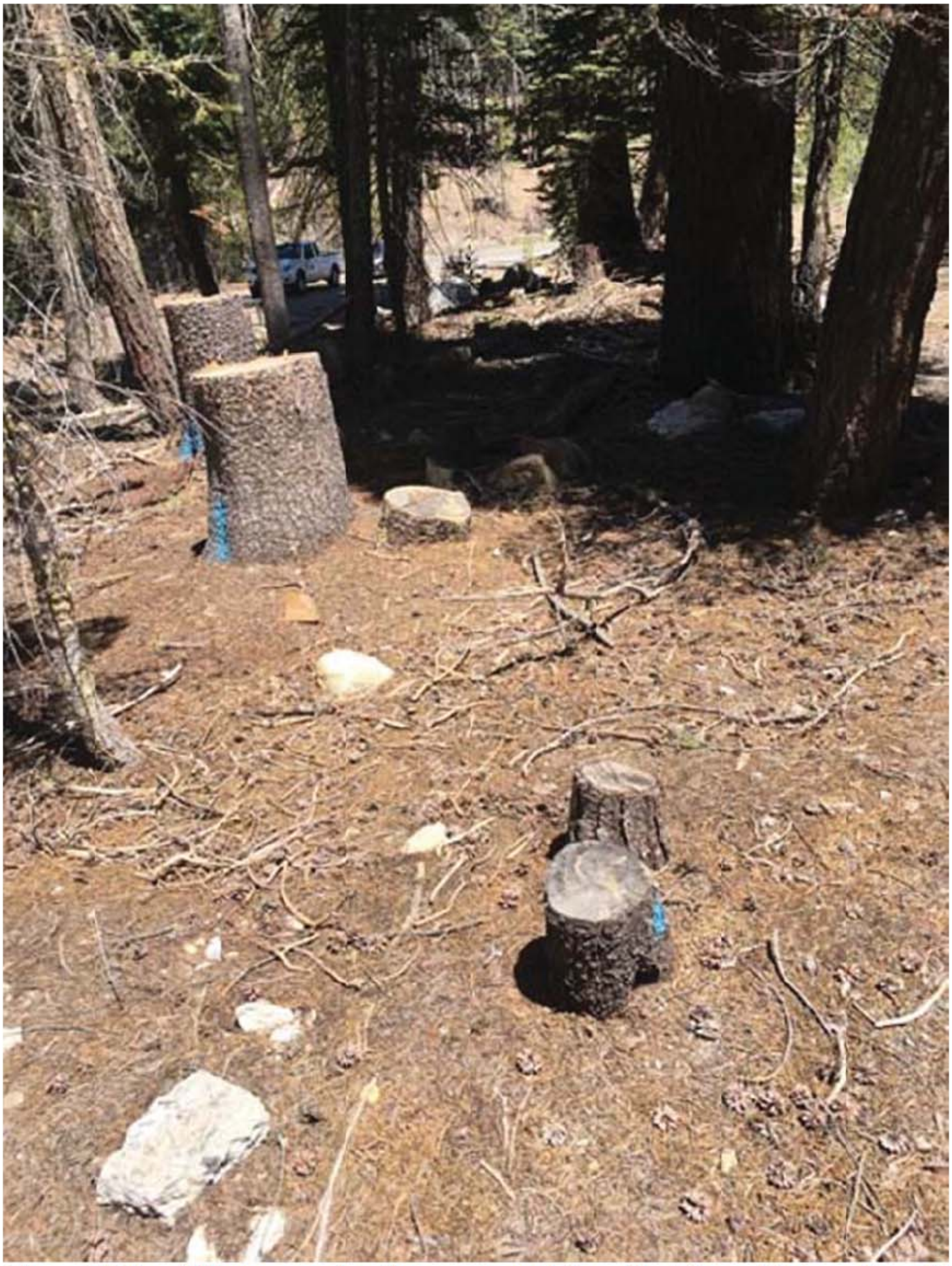

Figure 15: Tree felling occurred on the campground throughout the past 2 years. Two older stumps from about 2 years ago (foreground) can be seen near some more recent stumps from the past few months (middle ground, left).

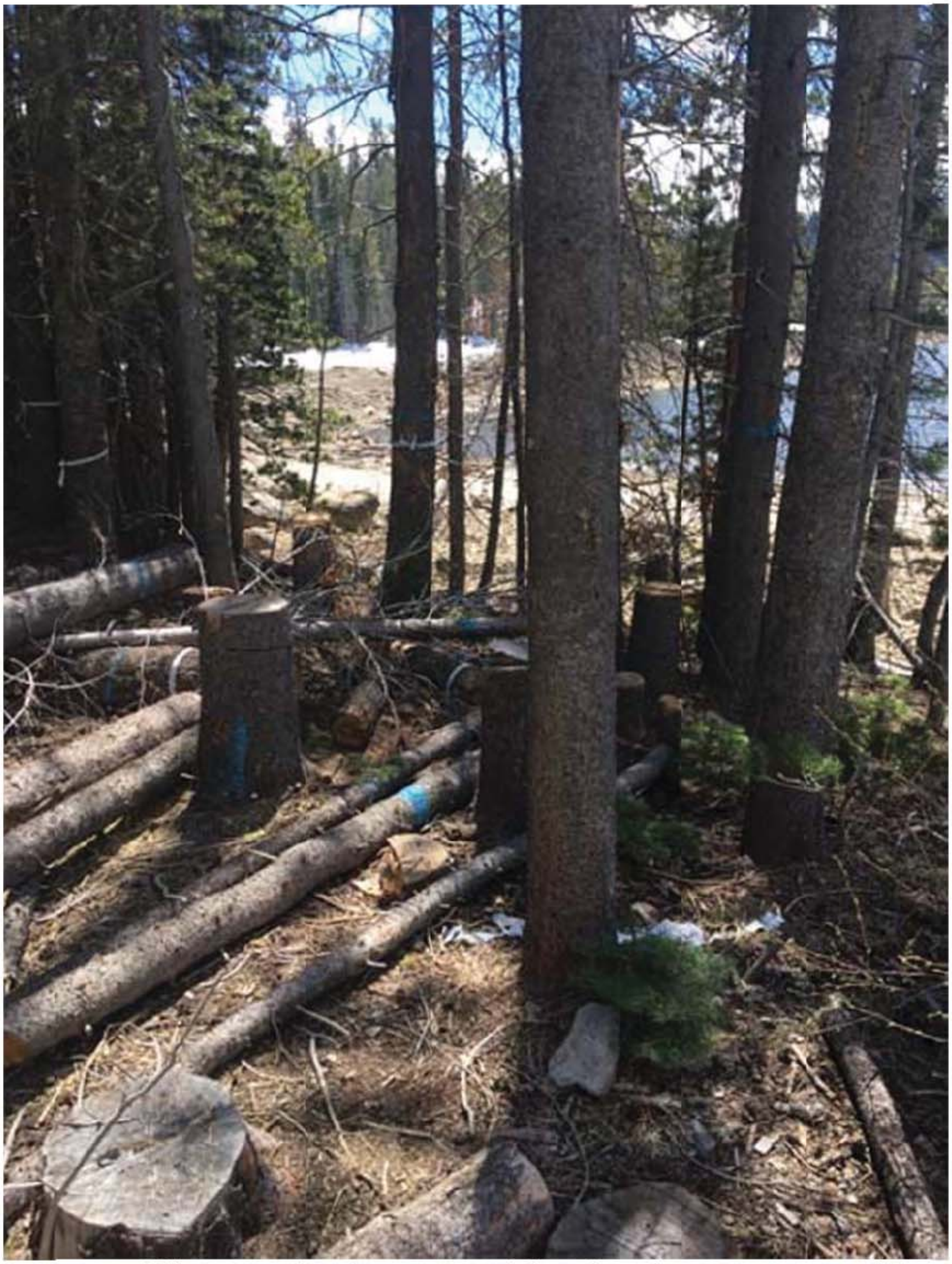

Figure 16: Tree felling occurred on the campground throughout the past 2 years. An older stump from about 2 years ago (lower left) can be seen near some more recent stumps from the past few months (middle ground).

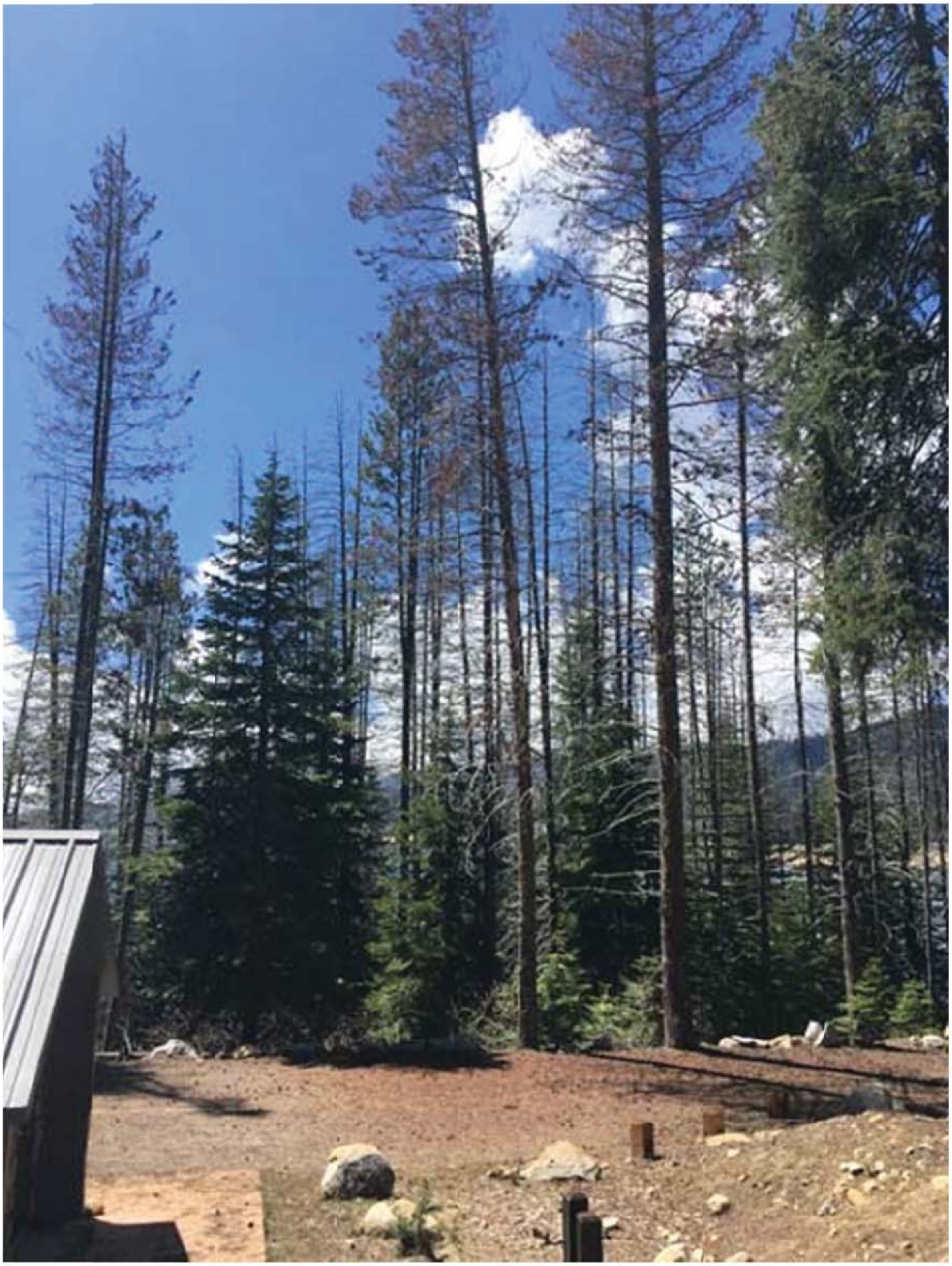

Figure 17: Near the lakefront, tree mortality was significantly higher than in the interior areas of the campground.

Figure 18: The rocky/sandy area in the foreground would have been covered by the lake's natural water level. The water level in the lake was very low at the time of my site visit.

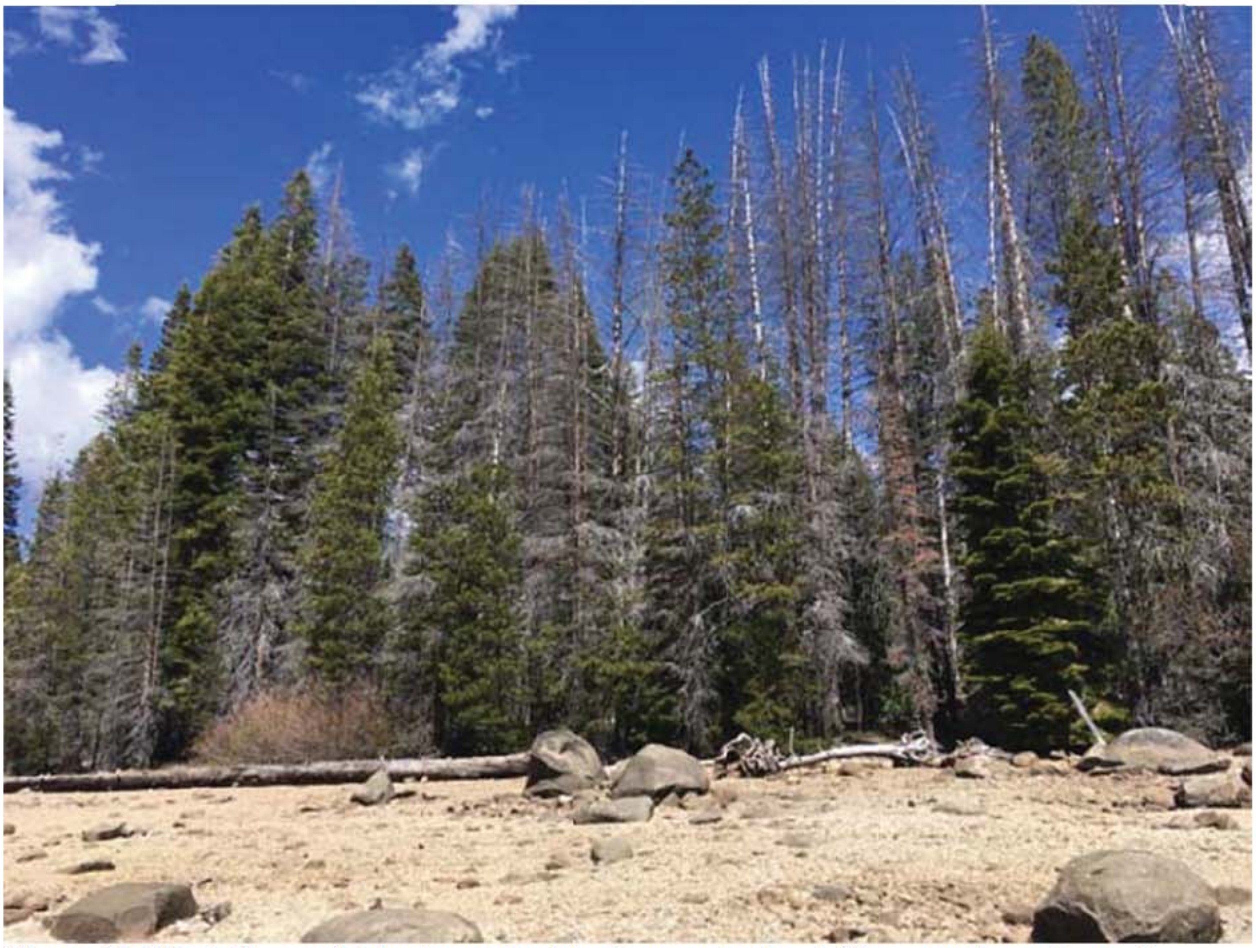

Figure 19: Mortality was highest near the lake. Low water level (foreground, sandy area) contributed to drought stress.

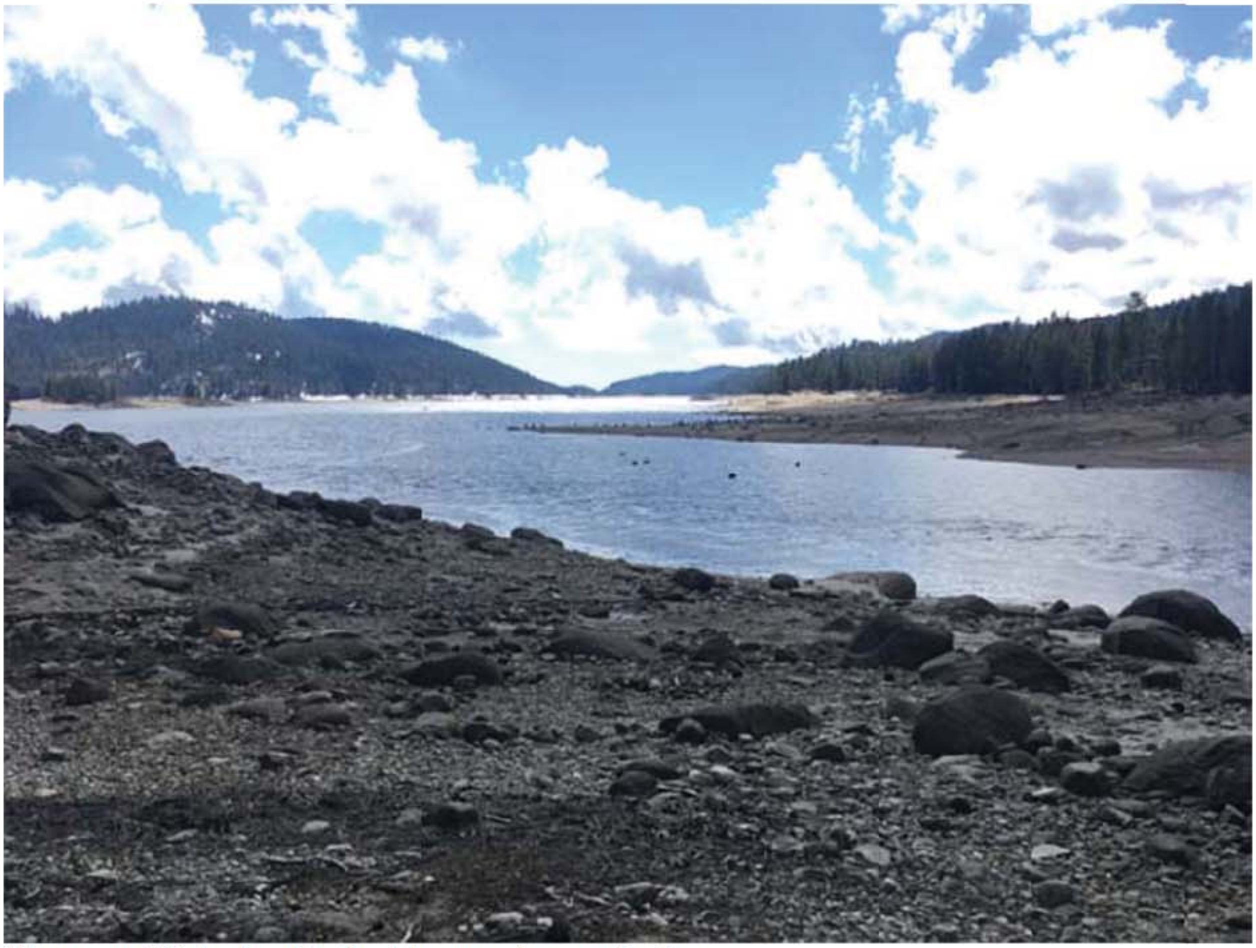

Figure .0: Water level in the lake was abnormally low.

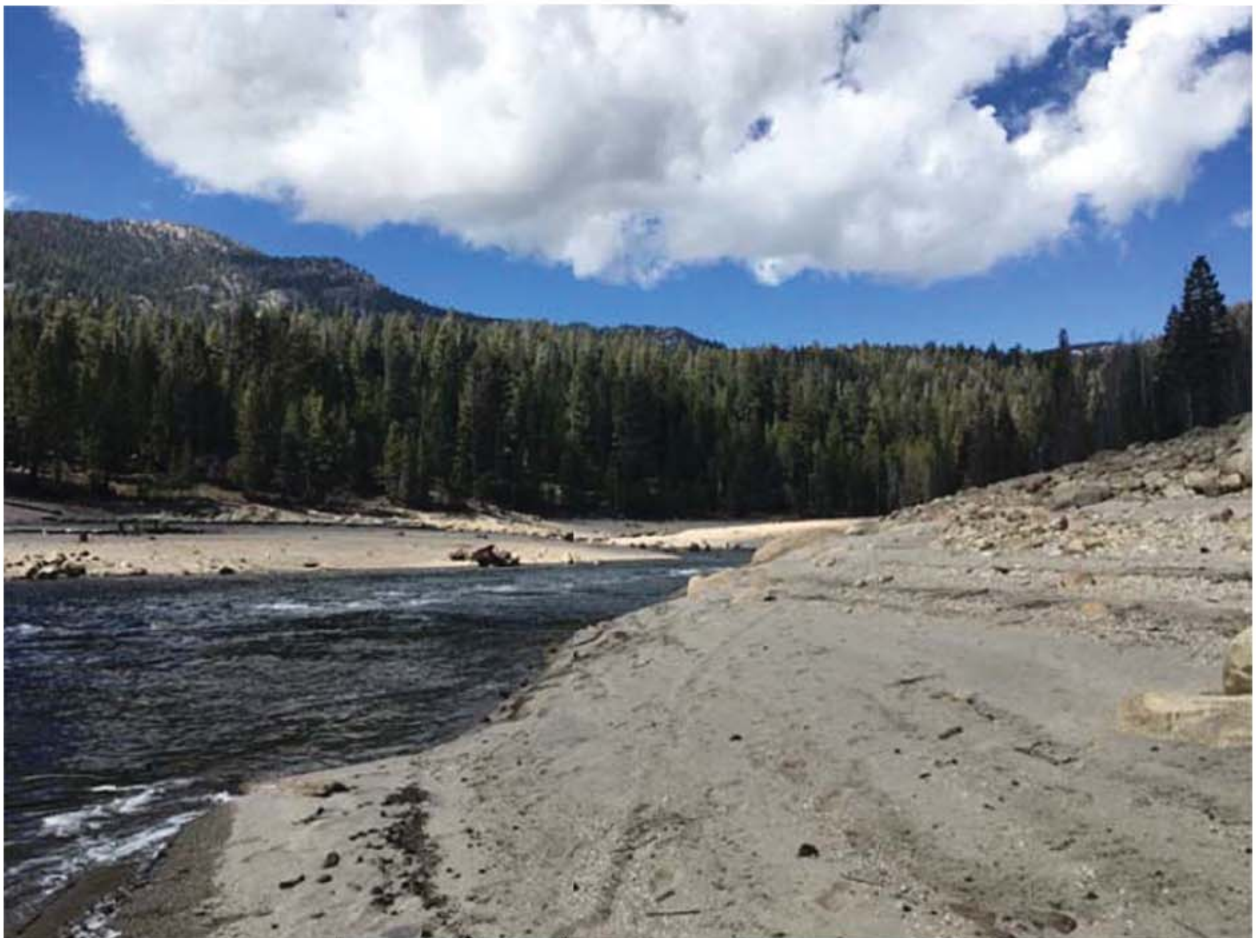

Figure 1: Water level in [redacted] [redacted] which feeds [redacted] was abnormally low.

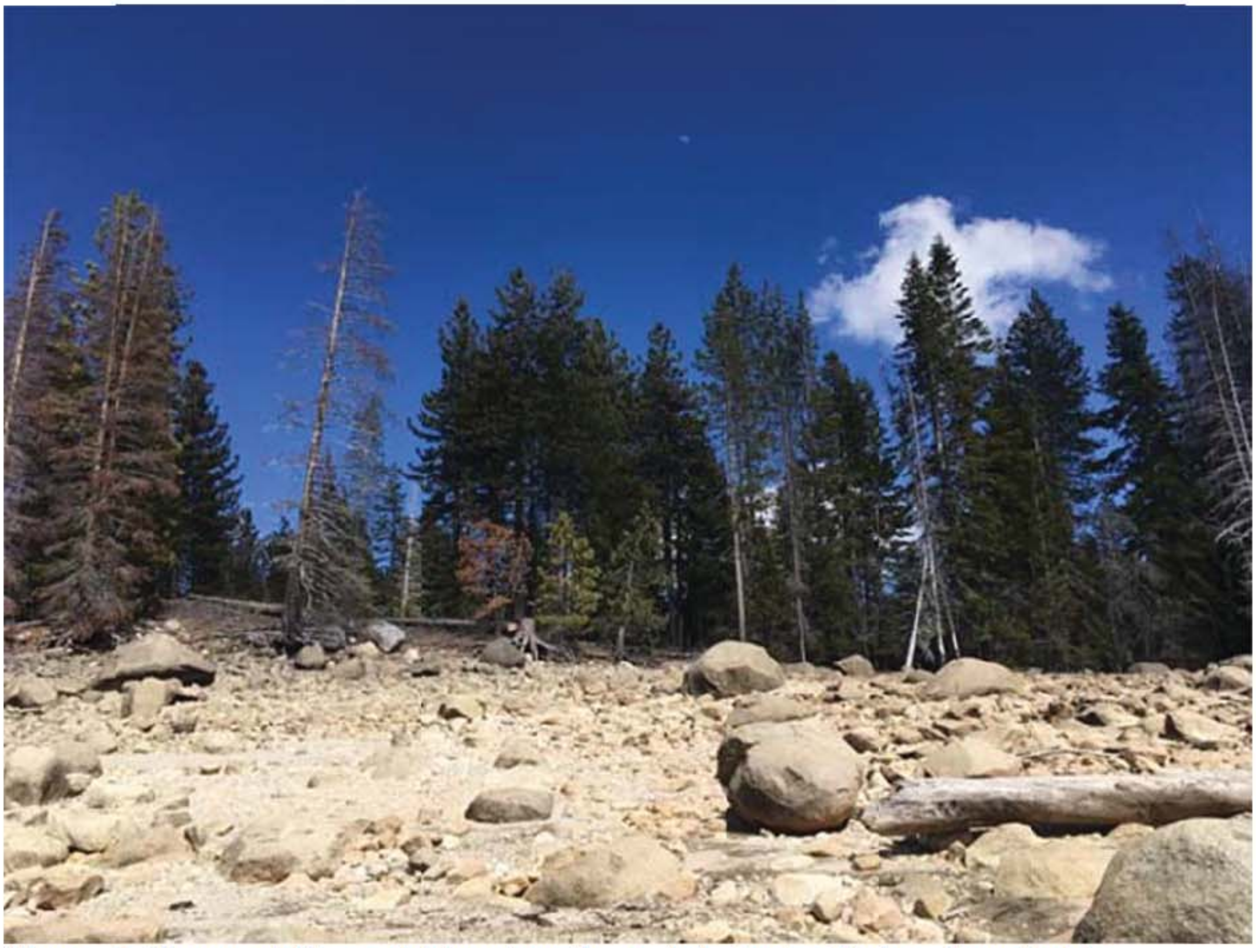

Figure 2: Tree mortality was higher along the creek, but not as high as along the lake.