2022

PACIFIC NORTHWEST WATER YEAR

IMPACTS ASSESSMENT

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Supported by the NOAA National Drought Information System

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ON THE COVER: The Skagit River delta near Mt. Vernon, Washington. Credit: Edmund Lowe

EXECUTIVE SUMMARY

Regional Water Year Conditions at a Glance

- The 2022 water year (October 1, 2021 – September 30, 2022) in Idaho, Oregon, and Washington (the Pacific Northwest; PNW) tied as the 13th warmest and ranked as the 52nd wettest since records began in 1895. Compared to the 1991–2020 normal period, regional temperature averages and total precipitation were near-normal for the PNW as a whole, but there was substantial regional variability, particularly for precipitation.
- Compared to the start of the water year, drought conditions improved over nearly the entire PNW by the end of the water year. The exceptions were central Oregon, south-central Oregon, and the very southern portion of Idaho, where drought persisted.
- An extended period in late winter (January 10–March 31) with below normal precipitation stalled snowpack development. Typically 56% of the PNW snowpack accumulates from January through March, but the dry period caused snowpack to be below median by April 1 across most of the PNW.
- Spring was wetter and colder than normal in all three states. Across the PNW, April–June 2022 ranked as the 3rd wettest since records began in 1895, with 146% of the 1991–2020 normal precipitation. April through June tied as the 14th coldest on record (–2.8°F below the 1991–2020 normal), allowing snowpack to build in the mountains and reducing water demand enough for either drought concerns to ease completely or drought impacts to be less than anticipated, depending on the basin.
- The direction of the temperature and precipitation anomalies flipped again to close out the water year: July–September ranked as the warmest (+3.6°F above the 1991–2020 normal) and 5th driest (56% of the 1991–2020 normal) on record for the PNW.

Impacts at a Glance

- The agriculture, drinking water, forestry, fisheries, recreation, hydropower, and stormwater sectors were affected by abnormally dry conditions. Impacts included reduced surface water availability, tree mortality, reduced streamflow, reduced power generation, and the closure of recreational lands due to wildfire, among others.
- The agriculture, drinking water, forestry, fisheries, recreation, and stormwater sectors were affected by abnormally wet conditions. Impacts included reduced drinking water quality, delayed planting and harvest, limited access for forestry research and monitoring, limited access to recreation, flooding of fish spawning areas, and water contamination, among others.
- Extreme temperatures also affected various sectors. For example, colder than normal temperatures impacted fruit trees throughout Washington, and warmer than normal temperatures combined with below normal precipitation extended the fire season to the start of water year 2023.

Response Actions at a Glance

- State drought declarations were issued for many counties in Oregon and Idaho as early as November 17, 2021 and continuing through June 7, 2022. Washington initially extended its 2021 drought declaration for five watersheds in the eastern part of the state, but then rescinded the declaration in response to cool and wet spring conditions that increased streamflows. Oregon issued a state of emergency in response to the wet spring for six northeastern counties.
- Responses to the annual Pacific Northwest Water Year Impacts Survey suggested high operational flexibility during drought conditions: more respondents changed operations in response to dry conditions than wet conditions.

Forecast Verification at a Glance

- A qualitative examination of two separate seasonal forecasts from the NOAA Climate Prediction Center showed that the seasonal precipitation swings were not predicted well. From January–March 2022, the PNW was much drier than forecasted, and from April–June 2022, the region was much wetter than forecasted. On the other hand, the April–June below normal temperatures were predicted a month in advance for a majority of the PNW.

1 PURPOSE

The purpose of this third Pacific Northwest (PNW) Water Year Impacts Assessment is to summarize the water year[1] conditions and sector impacts as a resource for future management of drought and other climate extremes. We gathered the information presented in this assessment in two main ways. The first was through two separate but similar annual Water Year Recap and Outlook meetings, one for Washington and Oregon, and the other for Idaho. The meeting objectives are to summarize the climate during the previous water year and to review climate and weather-related impacts on various sectors, focusing on drought and other extremes. The second mechanism informing this report was the Annual Pacific Northwest Water Year Impacts Survey.

The purpose of this assessment is to summarize the water year conditions and sector impacts as a resource for future management of drought and other climate extremes.

The assessment primarily reflects the information from the meeting discussions, the survey, and authors' expertise. We focus on continued regional drought, flooding, a cool and wet spring, a warm and dry summer, and their associated impacts.

1 A water year is defined as the 12 months beginning on October 1 and ending on September 30 of the following year (e.g., water year 2022: October 1, 2021-September 30, 2022).

2 LESSONS LEARNED

1. Lessons Learned from the Water Year 2022 Conditions and Associated Impacts

Lesson 1.1: For the second year in a row, spring was critical in determining the magnitude and extent of drought. The record wet April–June in 2022 was the mirror image of the record dry April–June 2021. Above normal precipitation and below normal temperatures in April–June drastically changed the outlook for drought for the remainder of the water year. This demonstrates the limitations of April 1 conditions for predicting water shortages and impacts later in the water year. Additionally, two sequential, anomalous springs potentially undermined the confidence of the public and natural resource managers in seasonal forecasts.

Lesson 1.2: Summer is also a critical season and can rapidly change the drought outlook. Despite a colder and wetter than normal spring, July–September in the PNW was the warmest on record, and that rapid switch to warm conditions caused water shortages and high fire danger in many areas.

Lesson 1.3: The extreme precipitation events of water year 2022 underscored the need for forecasters to communicate the possibility of a low probability, but high-impact event, along with seasonal forecasts. Seasonal climate outlooks are valuable resources for planning operations and are often used during the season to adjust operations in multiple sectors in the PNW. However, in water year 2022, the extreme precipitation in mid-November and the exceptionally wet and cold period in spring served as a reminder of the importance to consider and plan for within season, short-term variability, and low probability but high impact events.

2. Lessons Learned from Water Year 2022 about Improving Regional Response to Weather and Climate Conditions

Lesson 2.1: The abrupt transition from abnormally dry (January–March) to abnormally wet (April–June) and back to abnormally dry (July–September) was a challenge for forecasting and operations planning in multiple sectors. The abrupt variability in conditions itself is potentially more difficult to manage than the impacts of abnormally dry or abnormally wet conditions alone. For at least one sector, agriculture, the timing of the transition between dry (March) and wet (April) was particularly challenging because it occurred when annual irrigation allotments were being considered.

Lesson 2.2: The colder than normal spring was perhaps a more unusual challenge than a warmer than normal season because we have become accustomed to long-term warming trends in the PNW. Colder springs are not consistent with climate change projections, and the magnitude of the anomalies in 2022 and the timing of a particular cold snap in mid-April had considerable effects on agriculture. This serves as a reminder that natural variability in both temperature and precipitation still needs to be considered as well as long-term temperature trends.

Lesson 2.3: It is best practice for state responses to have the flexibility to adjust to abrupt changes in conditions. In May 2022, on the basis of the best data available at the time, Washington extended its 2021 drought declaration for five watersheds in eastern Washington and issued a drought advisory for all of eastern Washington. In July, when it became apparent that drought metrics and sectors were responding to the cool and wet spring, and notably that streamflow forecasts were improving, Washington canceled both the drought advisory and drought declarations. Washington state statutes on drought include the flexibility to amend or extend orders, and water year 2022 demonstrated that there is a need for that discretion. Even though conditions changed again during the warm summer, effects on water supply were limited, and major irrigation projects (e.g., the Yakima Project) received full water deliveries. For impacts that were reported in Washington, such as low streamflows that affected fish late in summer and drying wells for some smaller water systems, a state-issued drought declaration would not have been beneficial.

Lesson 2.4: Seasonal transitions between abnormally wet/dry and abnormally cold/warm conditions underscore the need to improve resiliency. Although seasonal weather forecasts generally are skillful, the extended dry period in January–March 2022 and the extended wet period in April–June 2022, for example, were not well forecasted. Preparation for all types of weather conditions remains important to build resiliency for all sectors.

3 WATER YEAR EVOLUTION

WATER YEAR 2022 AT A GLANCE*

8th warmest (tied with 2014); +0.7°F

53rd driest; –1.09 inches (97% of normal)

25th warmest (tied with 1900, 1918, 2014); +0.1°F

29th wettest; +4.05 inches (109% of normal)

15th warmest (tied with 1918, 2013, 2018); +0.5°F

54th driest; –0.52 inches (98% of normal)

*Anomalies relative to 1991–2020 normal; records since 1895 (Source: NOAA NCEI 2022)

Water Year Summary

The PNW 2022 water year temperatures were near-normal, but still ranked among the warmest years in the historical record, while the regional precipitation average was near-normal.

Averaged across the PNW, the 2022 water year tied 6 years (1958, 1967, 1987, 2004, 2013, and 2014) as the 13th warmest (+0.4°F) and was the 52nd wettest (since 1895; NOAA NCEI) with 102% of normal. Also from an area-wide perspective, the 2022 water year was cooler than the 2021 water year, but warmer than the previous two water years (2019 and 2020).

October–September 2022

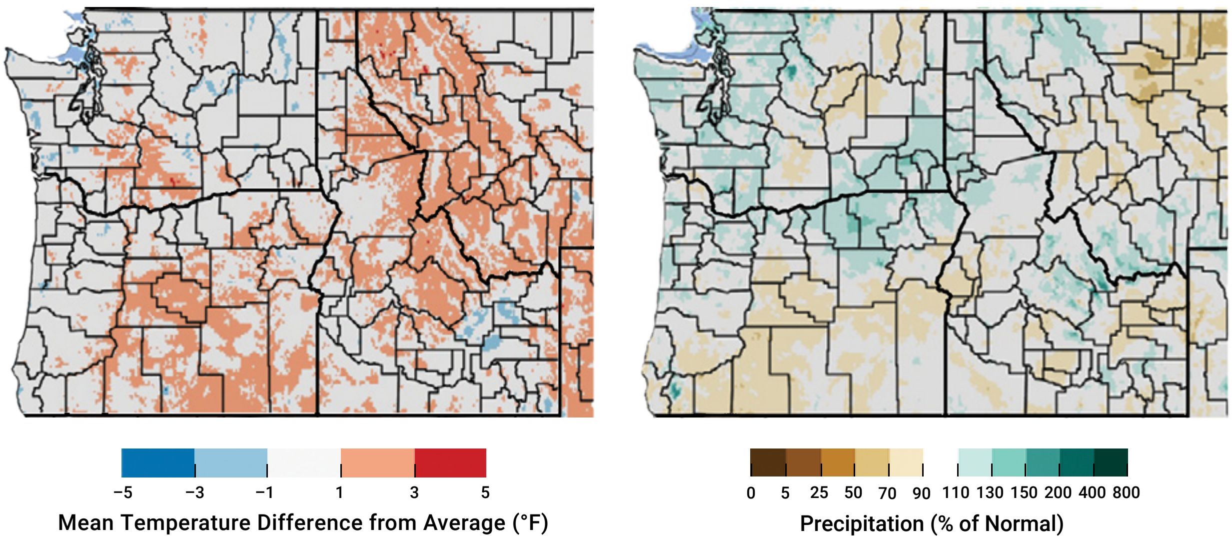
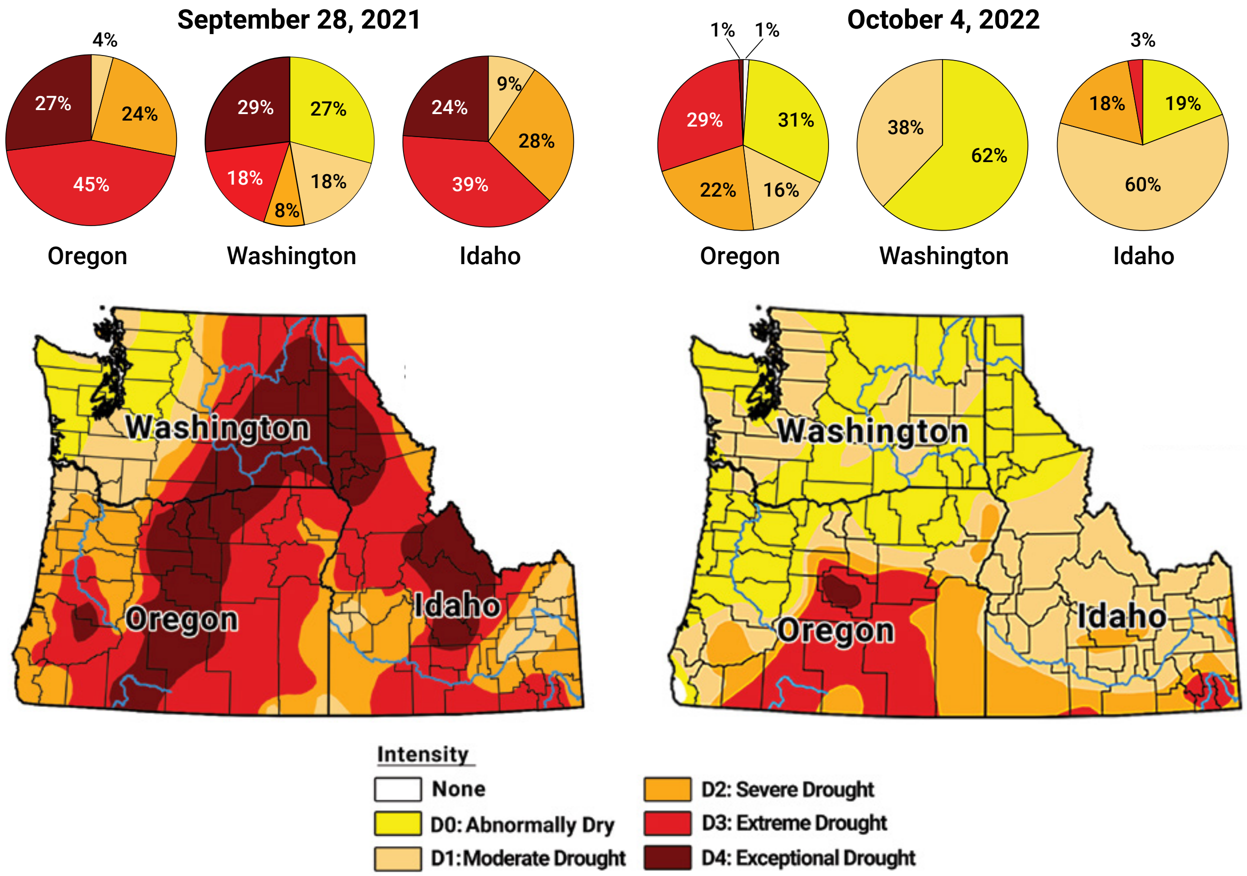


Figure 1: October 2021–September 2022 average temperature departures and precipitation percent of normal. The normal period is 1991–2020. Source: gridMET data through *Climate Engine*.

In addition, the 2022 water year was wetter than the last four water years (2018–2021), particularly 2020 and 2021, during which the regionally-averaged precipitation was 83 and 86% of normal, respectively. The period of 1991–2020 (*see page 11*) is used for the normal baselines throughout this assessment unless stated otherwise.

Water year temperature and precipitation anomalies were not spatially consistent throughout the PNW (*Figure 1*). Warmer than normal temperatures were more prevalent in Oregon and Idaho, as reflected in the state averages and rankings, while near-normal temperatures were more common in Washington. Spatial differences in water year precipitation within each state were more marked. Southern Idaho, southern and central Oregon, and central Washington had below normal precipitation, with water year totals between 70 and 90% of normal. Oregon was the driest of the three states relative to its normal. The remaining portions of the PNW had near-normal to above-normal water year precipitation, with totals between 90 and 130% of normal.

Overall, drought conditions improved over the course of the water year for most of the PNW. At the start of the 2022 water year, about 25% of each state's area was in exceptional drought, the most severe drought category recognized by the U.S. Drought Monitor (*Figure 2*). About 39% of Idaho, 45% of Oregon, and 18% of Washington were in extreme drought. The dire drought conditions at the start of the 2022 water year were due to a combination of factors. While some locations had low snowpack in 2021, even locations with normal snowpack that year were affected by a widespread, exceptionally dry spring, and a warm and dry summer, such that the 2021 water year ended with very dry conditions in some places. As a result, at the beginning of the 2022 water year, reservoir carryover was severely depleted across central and eastern Oregon and southern Idaho. By contrast, the



Yakima Basin in Washington began the water year with above average reservoir storage.

At the end of the 2022 water year, only a small area in central Oregon was in exceptional drought, and 29% of Oregon and 3% of Idaho were in extreme drought. While the area in severe drought was also less than at the start of the water year, a majority of the PNW was still experiencing either moderate drought or abnormally dry conditions. The weather conditions that led to drought reduction are described in more detail in the remainder of Section 3.

Figure 2: Pie charts and maps of drought conditions as characterized by the *U.S. Drought Monitor* on September 28, 2021 (*left*) and October 4, 2022 (*right*), the beginning and end of the 2022 water year, respectively.

Updated 30-Year Normals

Following the World Meteorological Organization (WMO) recommendation, long-term averages of temperature, precipitation, streamflow, and snowpack used to compare current conditions to average conditions, known as climate normals, have been updated. In previous *Water Year Impacts Assessments* (*2020*, *2021*), the 1981–2010 normals were used. The WMO requires that normals be updated every decade, and the 1991–2020 normals were released by NOAA in early 2021. The regional temperature, precipitation, snowpack, and streamflow summaries in this assessment compare the 2022 water year conditions to the 1991–2020 normals.

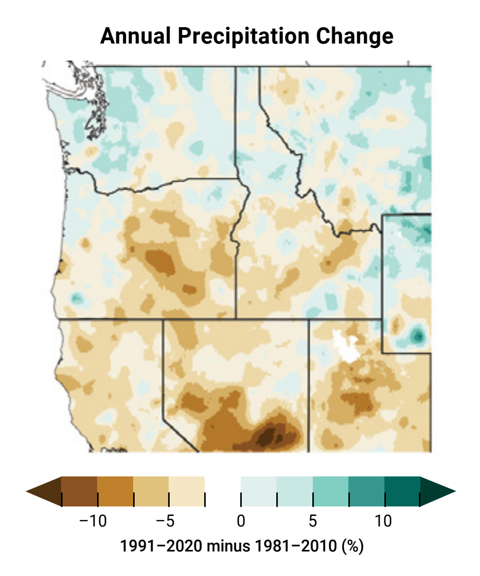


Figure 3: Annual (calendar year) precipitation change between the 1991–2020 normals and 1981–2010 normals (from *NOAA 2021a*).

How are the 1991–2020 normals different from the 1981–2010 normals? The 1991–2020 normals replaced the 1980s with the 2010s. Although normals are not intended to serve as indicators of climate change, and certainly are influenced by decadal variability, the updated annual temperature normals reflect warming over the PNW (*NOAA 2021a*, *b*). Averaged over the water year, normal statewide temperatures for Oregon, Idaho, and Washington increased by 0.5°F, 0.5°F, and 0.4°F, respectively. Because temperatures in each updated normal release generally are warmer, it is possible that a water year with near-normal temperatures still ranks as warm relative to the historical record. For example, Washington's 2022 water year ranking of 25th warmest despite near-normal temperatures is possible because the 1991–2020 normals are warmer than those of decades past.

There is more spatial variability in how the precipitation normals have shifted (*NOAA 2021a*). Average annual precipitation from 1991–2020 was higher throughout most of Washington, northwest Oregon, and northern Idaho but lower in central and eastern Oregon and southern Idaho (*Figure 3*). Averaged statewide, total water year precipitation was slightly less in Oregon (−0.40”) and greater in Washington (+0.79”). Total water year precipitation across Idaho was essentially the same during both periods (1991–2020 was a mere 0.07” drier). Similar to these changes in the precipitation normals, the 1991–2020 natural runoff estimates from the National Weather Service Northwest River Forecast Center (NWRFC) also shifted. The 1991–2020 natural runoff generally remained the same or increased in Washington and northern Idaho, and stayed the same or decreased across Oregon and southern Idaho (*NWRFC 2021*).

The 30-year snowpack normals from the Natural Resources Conservation Service (NRCS) have also been updated to the 1991–2020 period. Many SNOTEL stations were installed in the mid-1980s. Therefore, the 1991–2020 snowpack normals were based on more complete data than the 1981–2010 normals. Changes in normals for individual stations can be viewed on the NRCS website (*NRCS 2022a*). The changes in snowpack normals are more difficult to generalize than changes in temperature and precipitation normals since the difference between the 1981–2010 and 1991–2020 snowpack normals are more sensitive to the individual station records. The methods used to calculate the normals have also changed (*NRCS 2022b*). We encourage readers to explore the changes to the normals for SNOTEL stations that are within the watersheds where they work.

Seasonal Progression

Water year 2022 had many swings between abnormally wet and abnormally dry conditions and abnormally cold and abnormally warm temperatures. As such, the seasonal progression of temperature and precipitation characterizes the water year more completely than water year averages and totals. Although the October–September total precipitation was close to the 30-year normal for each state, there was a noticeable spread between the months ranking among the wettest or the driest in the 127-year record (*Figure 4*). For each state, with only a few exceptions, October, April, May, and June were abnormally to severely wet while February and March were abnormally to severely dry. The rankings for the end of the water year were more extreme for Washington and Oregon than Idaho. August was moderately dry in Washington, and September was moderately to severely dry in Washington and Oregon. In Idaho, both August and September were neutral. Precipitation from November through January varied among the states, with Washington's moderately wet November and Idaho's moderately wet December the most anomalous months within that time frame.

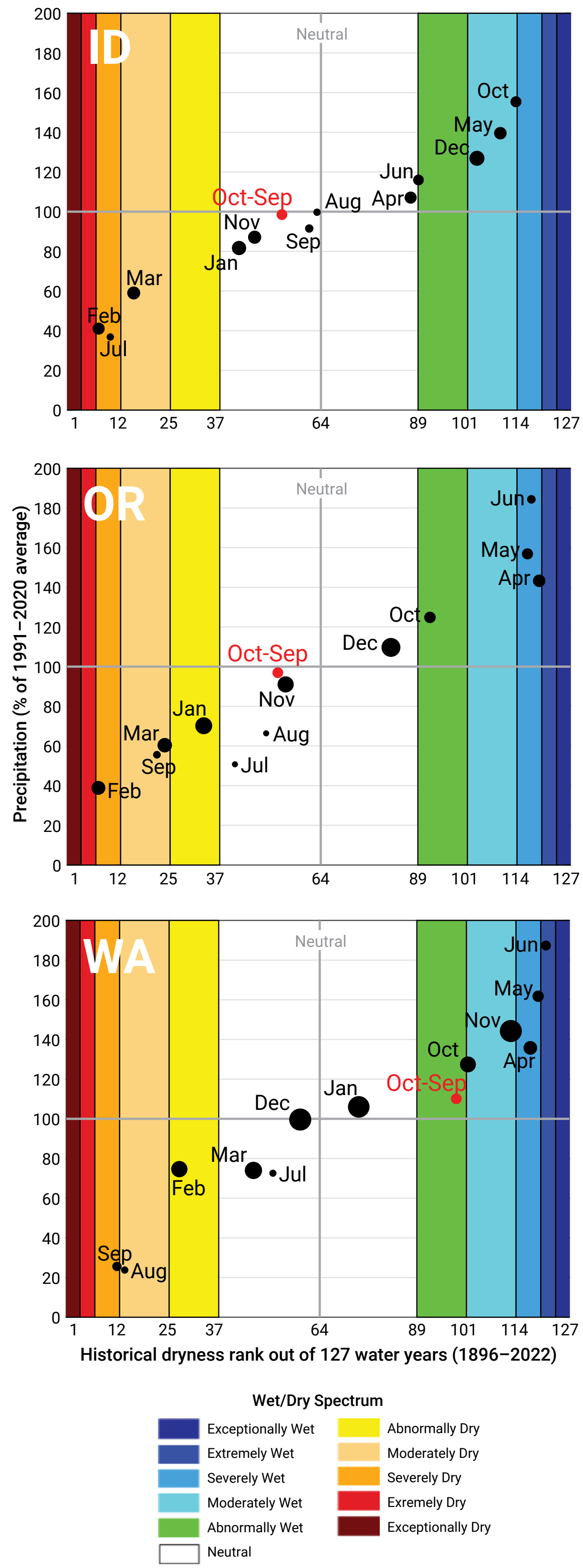


Figure 4: Monthly percent of normal (compared to 1991–2020 baseline) statewide precipitation as a function of the monthly precipitation rank during the last 127 water years for Idaho (*top*), Oregon (*middle*), and Washington (*bottom*). The red point illustrates the water year 2022 total. The colors corresponding to dry conditions are consistent with the U.S. Drought Monitor scale, and those corresponding to wet conditions with the *Climate Toolbox U.S. Water Watcher tool*. The sizes of the circles are scaled according to each month's relative average contribution to the water year total precipitation, from dry (*small*) to wet (*large*). NCEI nClimDiv data accessed on December 31, 2022.

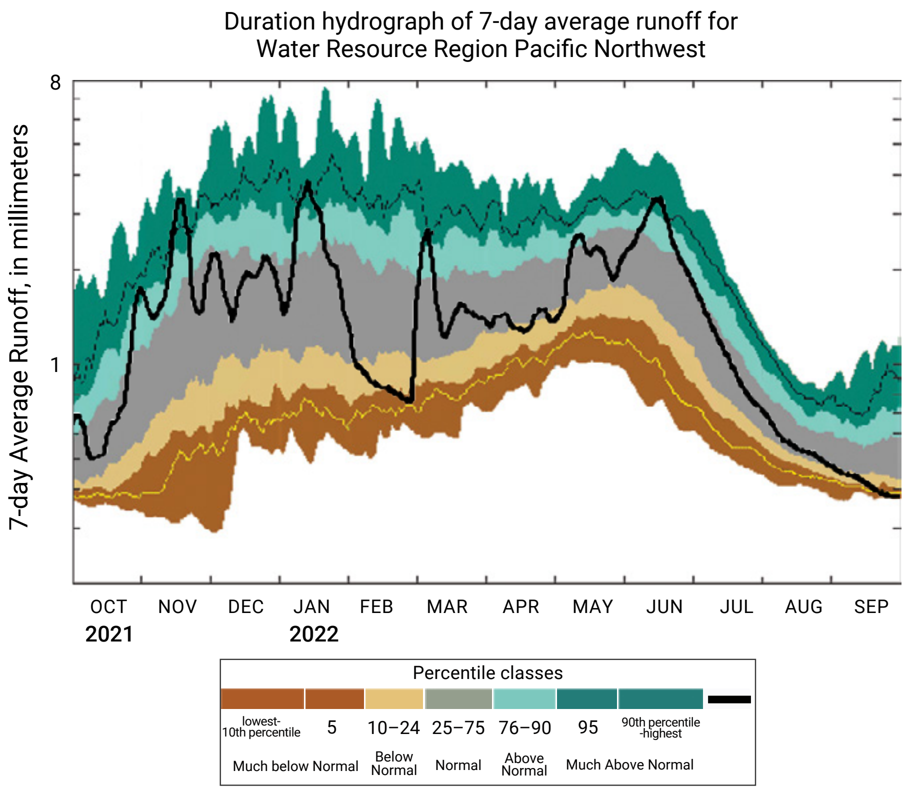


Figure 5: Seven-day average runoff over the PNW for water year 2022 and percentiles relative to the historical record. Source: *USGS*.

The relative wet and dry periods are also illustrated by the water year average streamflow across the PNW (*Figure 5*). Streamflow was above normal in mid-November and late December through early January, corresponding with wet periods of the water year. Streamflows in February and September were below normal, corresponding to dry periods of the water year.

Water year 2022 also had swings between abnormally warm and abnormally cold temperatures that went beyond typical seasonal changes. The most notable swing occurred from much colder than normal April–June temperatures to much warmer than normal July–September temperatures. Monthly and seasonal conditions are discussed in further detail in the next sections.

October–November 2021

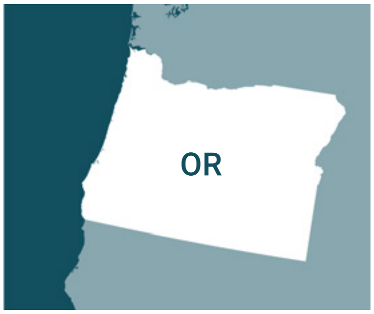
Temperature

October–November 2021 temperature anomalies were largely positive and tended to be greater in the interior of the Pacific Northwest. Idaho was the warmest of the three states relative to its normal for the 2-month period (*Figure 6*). Eastern Washington and eastern Oregon also began the water year warmer than normal, while temperatures west of the Cascade Mountains in both states were near-normal. The regional differences were due to October conditions; Washington and Oregon were mostly colder than normal in October while Idaho was warmer than normal. The entire PNW was warmer than normal in November.

Precipitation

October–November 2021 precipitation was above normal in most of the PNW, except for a swath of near-normal to below normal

OCTOBER–NOVEMBER 2021 STATISTICS*



18th warmest (tied with 1927, 1932, 1933, 1958, 1963, 1976, 2020); +1.2°F

60th wettest (tied with 1906); +0.23”, 103% of normal

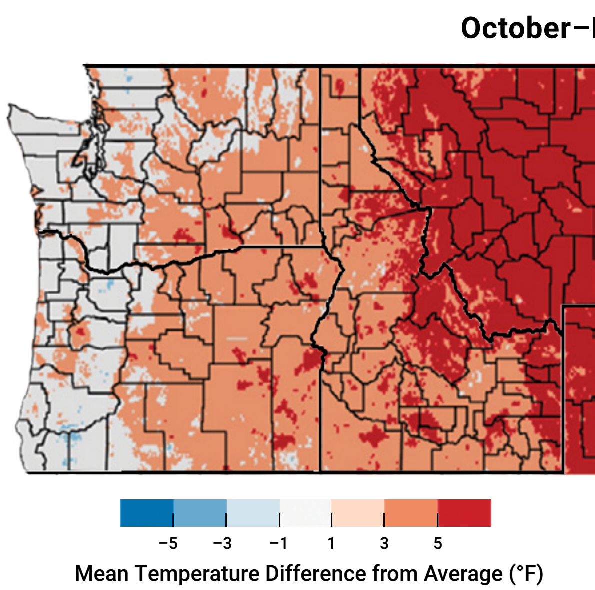
31st warmest (tied with 1974, 1980, 2012); +0.9°F

8th wettest; +3.95”, 138% of normal

13th warmest; +2.5°F

42nd wettest (tied with 2012); +0.71”, 116% of normal

*Anomalies relative to 1991–2020 normal; records since 1895. Source: NOAA NCEI 2022



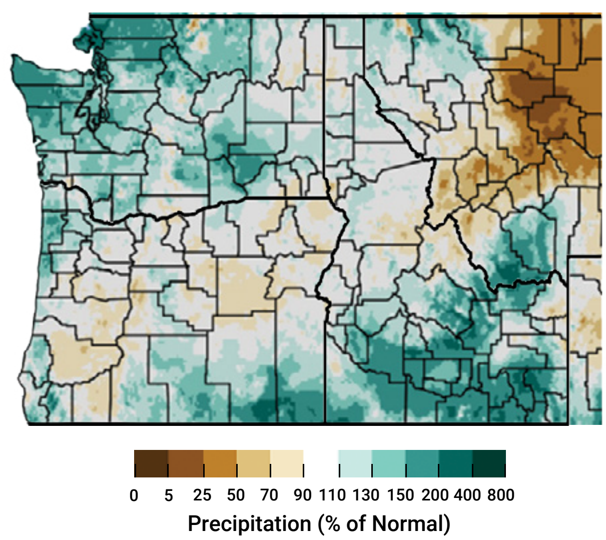


Figure 6: October–November 2021 average temperature departures and precipitation percent of normal. The normal period is 1991–2020. Source: gridMET data through *Climate Engine*.

precipitation through central Oregon (*Figure 6*). Washington was the wettest of the three states relative to its normal, with above-normal precipitation totals in both months.

Five separate atmospheric rivers caused major flooding on the Nooksack and Skagit Rivers in northwest Washington

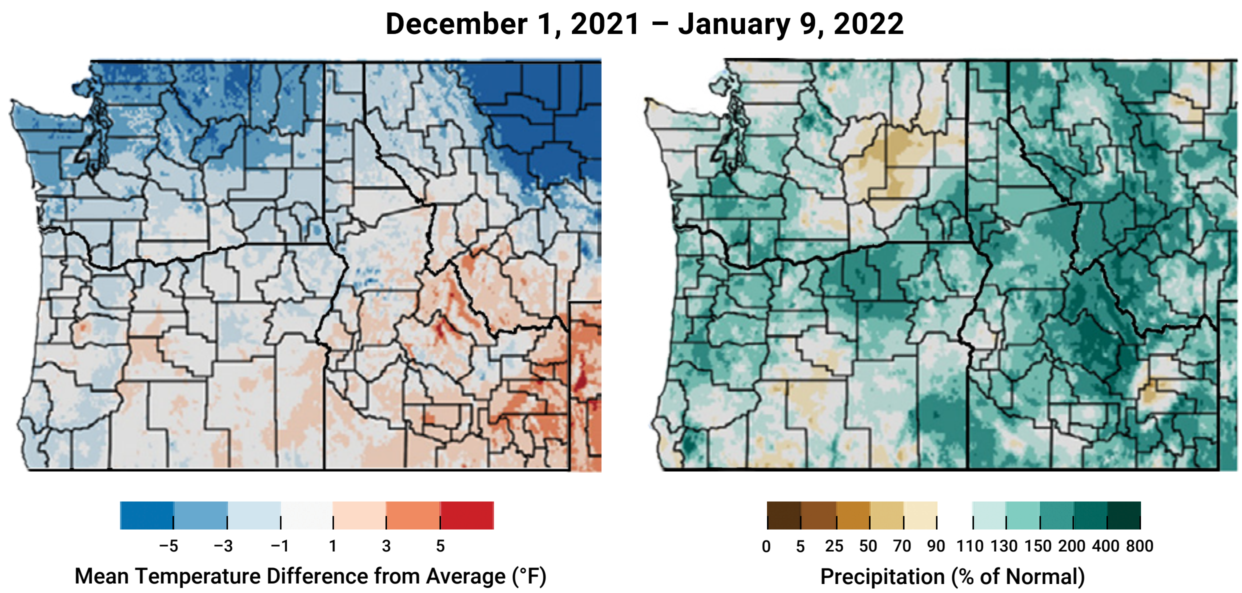


Figure 7: December 1, 2021 – January 9, 2022 average temperature departures and precipitation percent of normal. The normal period is 1991–2020. Source: gridMET data through *Climate Engine*.

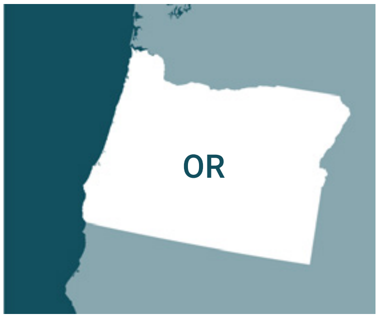
during November. In addition to flooding, landslides and power outages were reported throughout northwest Washington. The warm temperatures meant that most of the precipitation during this period fell as rain rather than snow. During the mid-November atmospheric river that affected British Columbia, Canada, and Whatcom, Skagit, and San Juan counties in Washington, two-day precipitation totals corresponded to a 50- and a 100-year event across the region. Peak streamflow return periods ranged between a 50- and 100-year event in Washington and exceeded a 100-year event in British Columbia (Gillett et al. 2022). Although the above normal precipitation was the main cause of the flooding, the mild temperatures that melted existing snowpack and the saturated soils from earlier atmospheric rivers also contributed. Climate change made this event, which is now the costliest natural disaster on record for British Columbia (*Hakai Institute*), much more likely to occur (Gillett et al. 2022).

December 2021

Snowpack

PNW snowpack was well below normal at the start of December, but snowpack built substantially through December 2021 and early January 2022. December 1 through January 9 was an active period during which temperatures were below- to near-normal and precipitation was near- to above-normal across a majority of the PNW (*Figure 7*). Snowfall was especially frequent and heavy at the end of December and in early January. By January 9, snowpack was normal to above normal throughout the PNW.

DECEMBER 1, 2021 SNOW WATER EQUIVALENT*



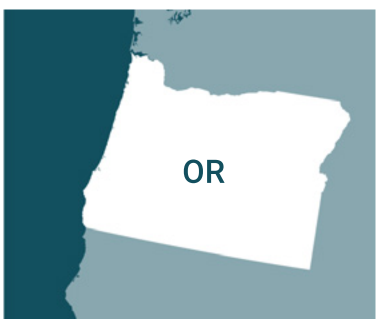
20% of median

49% of median

47% of median North of the Salmon River

65% of median South of the Salmon River

JANUARY 9, 2022 SNOW WATER EQUIVALENT*



154% of median

135% of median

126% of median North of the Salmon River

131% of median South of the Salmon River

*Statewide, compared to 1991–2020 median. Source: National Resources Conservation Service

January–March 2022

Temperature

January through March 2022 temperatures varied throughout the PNW, but were mostly warmer than normal, especially at higher elevations. Excluding the cold and snowy first 10 days of January, most of the PNW had near-normal to above-normal temperatures (*Figure 8*). The Snake River Valley and southeastern Idaho were the exceptions. In these regions, temperatures were well below normal, resulting in Idaho statewide average

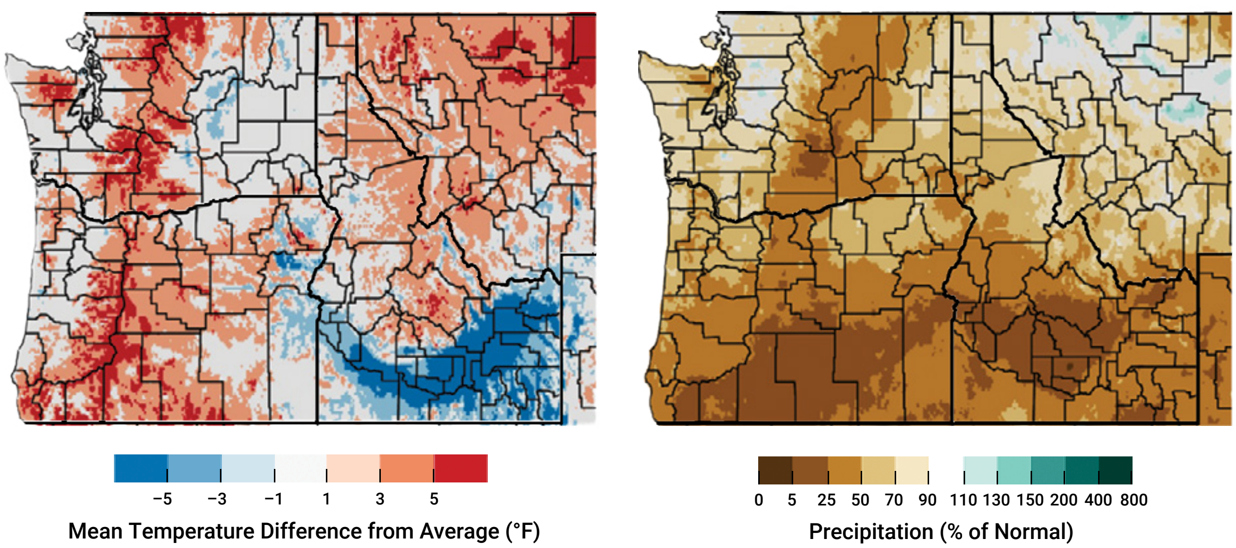
January–March temperatures that were below normal. Some areas of eastern Washington also had below normal temperatures. Temperatures in Oregon from January through March were the most spatially consistent and ranked as the 16th warmest on record.

Precipitation

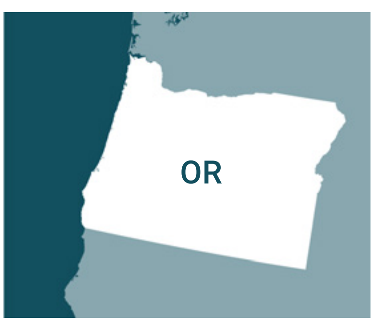
January 10 – March 31 precipitation was below normal

Figure 8: January 10 – March 31, 2022 average temperature departures and precipitation percent of normal. January 1–9, 2022 was excluded because it was a colder and wetter period that was included in *Figure 7*. The normal period is 1991–2020. Source: gridMET data through *Climate Engine*.

January 10 – March 31, 2022



JANUARY–MARCH 2022 STATISTICS*



16th warmest (tied with 1961); +1.1°F

8th driest; −4.85”, 58% of normal

33rd warmest (tied with 1931 and 2018); +0.1°F

41st driest; −1.92”, 87% of normal

55th warmest; −1.3°F

5th driest; −2.81”, 62% of normal

*Anomalies relative to 1991–2020 normal; records since 1895. Source: NOAA NCEI 2022

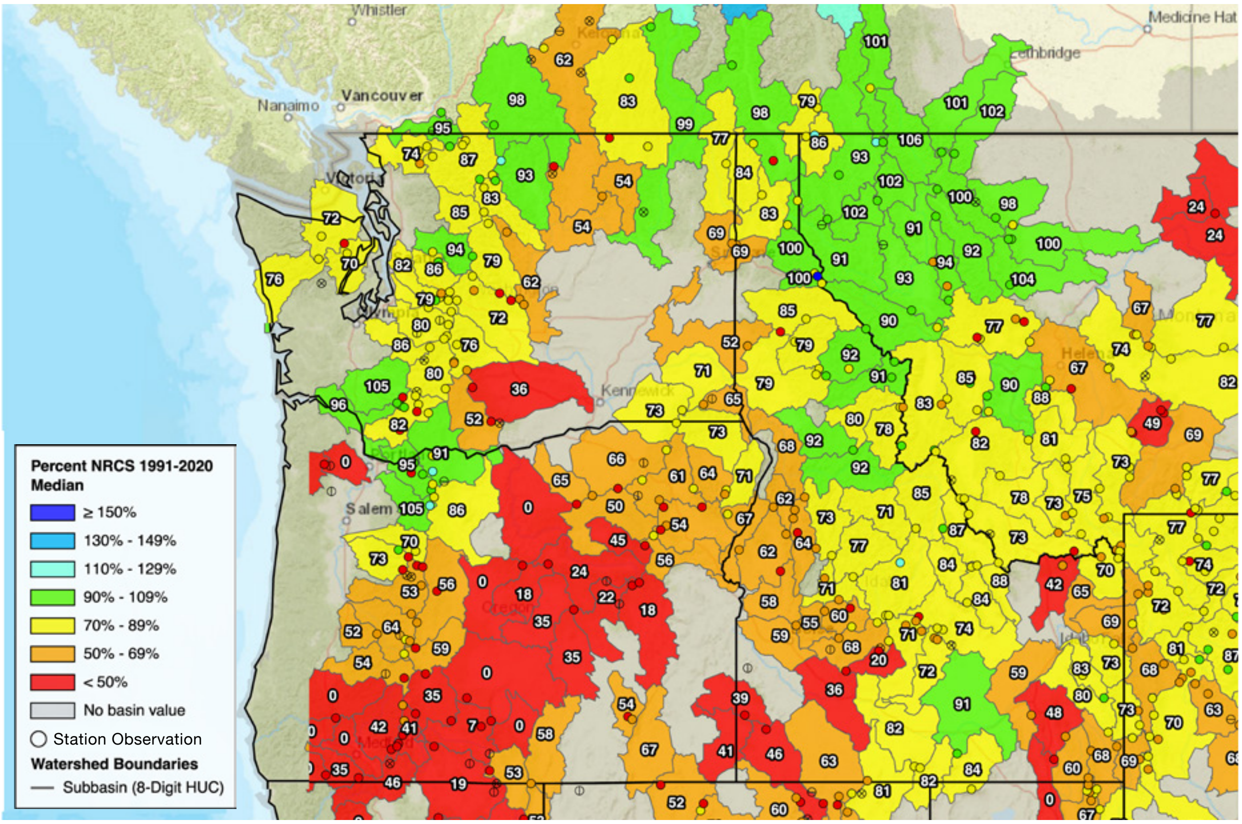
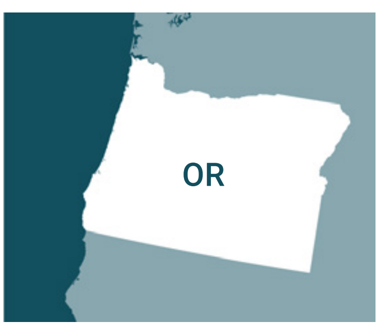


Figure 9: April 1, 2022 snow water equivalent (SWE) percent of 1991–2020 median. Station values may differ from the sub-basin average. Source: *NRCS*.

APRIL 1, 2022 SNOW WATER EQUIVALENT*



51% of median

80% of median

84% of median North of the Salmon River

69% of median South of the Salmon River

*Statewide, compared to 1991–2020 median. Source: National Resources Conservation Service throughout the PNW, particularly in parts of southern Oregon, southern Idaho, and the Lower Columbia Basin, where 5–25% of normal precipitation fell during that period. Of the three states, Oregon had the largest precipitation deficit for January–March, receiving 58% of normal precipitation. Numbers were marginally higher for Washington, mainly because of a wet period at the end of February in the central Puget Sound region.

Snowpack

According to the Natural Resources Conservation Service (NRCS), 56% of the PNW snowpack is typically accumulated from January through March. By April 1, which is near the usual date of peak snowpack, snowpack was below median throughout most of the sub-basins in the PNW (*Figure 9*). Statewide average snow water equivalent (SWE) was highest relative to normal north of the Salmon River in Idaho, at 84% of median. The lowest SWE was in Oregon, at 54% of median.

April–June 2022

Temperature

April–June 2022 temperatures were below normal throughout the PNW, with temperatures between 3 and 5°F below normal in much of the areas of all three states (*Figure 10*). Washington was the coldest relative to its normal of the three states. Averaged statewide, April–June temperatures in Washington, Idaho, and Oregon tied as the 6th, 9th, and 17th coldest on record, respectively. This represented a shift from the warmer than normal temperatures observed in the previous three months over much of the PNW. Within this cold spring, there were some notable cold snaps, particularly one in mid-April during which minimum temperatures were below freezing and snow fell throughout the PNW at most elevations.

Precipitation

In a marked swing from the below normal January–March precipitation, April–June precipitation was above normal for most of the region, with large areas receiving between 150 and

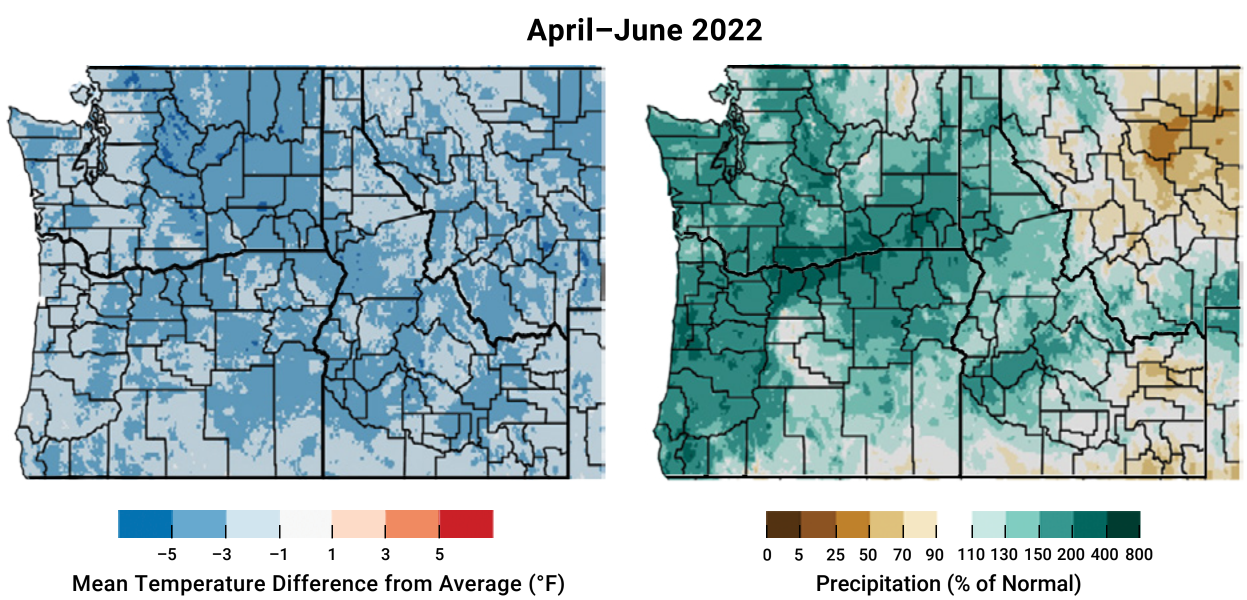
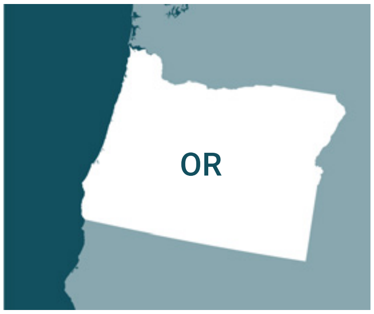


Figure 10: April–June 2022 average temperature departures and precipitation percent of normal. The normal period is 1991–2020. Source: gridMET data through *Climate Engine*.

APRIL–JUNE 2022 STATISTICS*



17th coldest (tied with 1902 and 1929); –2.8°F

2nd wettest; +3.83”, 157% of normal

6th coldest (tied with 1984); –3.2°F

3rd wettest; +4.39”, 157% of normal

9th coldest (tied with 1899, 1916, 1964, and 1984); –3.0°F

19th wettest; +1.35”, 121% of normal

*Anomalies relative to 1991–2020 normal; records since 1895. Source: NOAA NCEI 2022

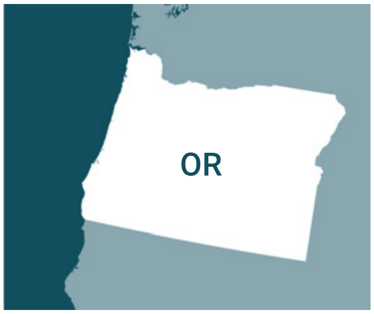
200% of normal precipitation. Above normal precipitation was more spatially consistent in Oregon and Washington than in Idaho. The April–June precipitation in Oregon and Washington ranked as the 2nd and 3rd highest on record, respectively. Parts of southern and southeastern Idaho were the exceptions, receiving between 70 and 90% of normal precipitation.

Snowpack

The below normal temperatures and above normal precipitation benefited mountain snowpack throughout the region. Statewide percentages of median snowpack were above normal in Oregon and Washington and near-normal in Idaho by May 1, 2022, representing actual growth in SWE in many locations. There were notable exceptions, however. The snowpack did not recover as well in southern Oregon, where there was a below normal snowpack on May 1 (*Figure 11*). Snowmelt begins in most basins in the PNW before May 1, so SWE can be above normal on May 1, but still below peak SWE earlier in the season, and can be misleading from a water supply perspective. Nevertheless, the snowpack recovery was beneficial for many basins throughout the PNW, and SWE in many basins reached its typical peak, just later in the season than normal. The Willamette Basin in Oregon is one example (*Figure 12*); the above median April 21 peak SWE was equivalent to the peak SWE that usually occurs on March 28. SWE in that basin recovered to the median, and snowmelt was later than usual.

Many other basins in the PNW gained SWE in April, but still ended the season with SWE below the median peak. For example, SWE in the Rogue-Umpqua basin in southern Oregon initially peaked in early January and then gradually declined until snowmelt began in late March (*Figure 12*). The colder and wetter than normal April arrested the snowmelt and allowed for a second peak, on April 23, at 70% of the median peak SWE

MAY 1, 2022 SNOW WATER EQUIVALENT*



117% of median

114% of median

108% of median North of the Salmon River

95% of median South of the Salmon River

*Statewide, compared to 1991–2020 median. Source: National Resources Conservation Service

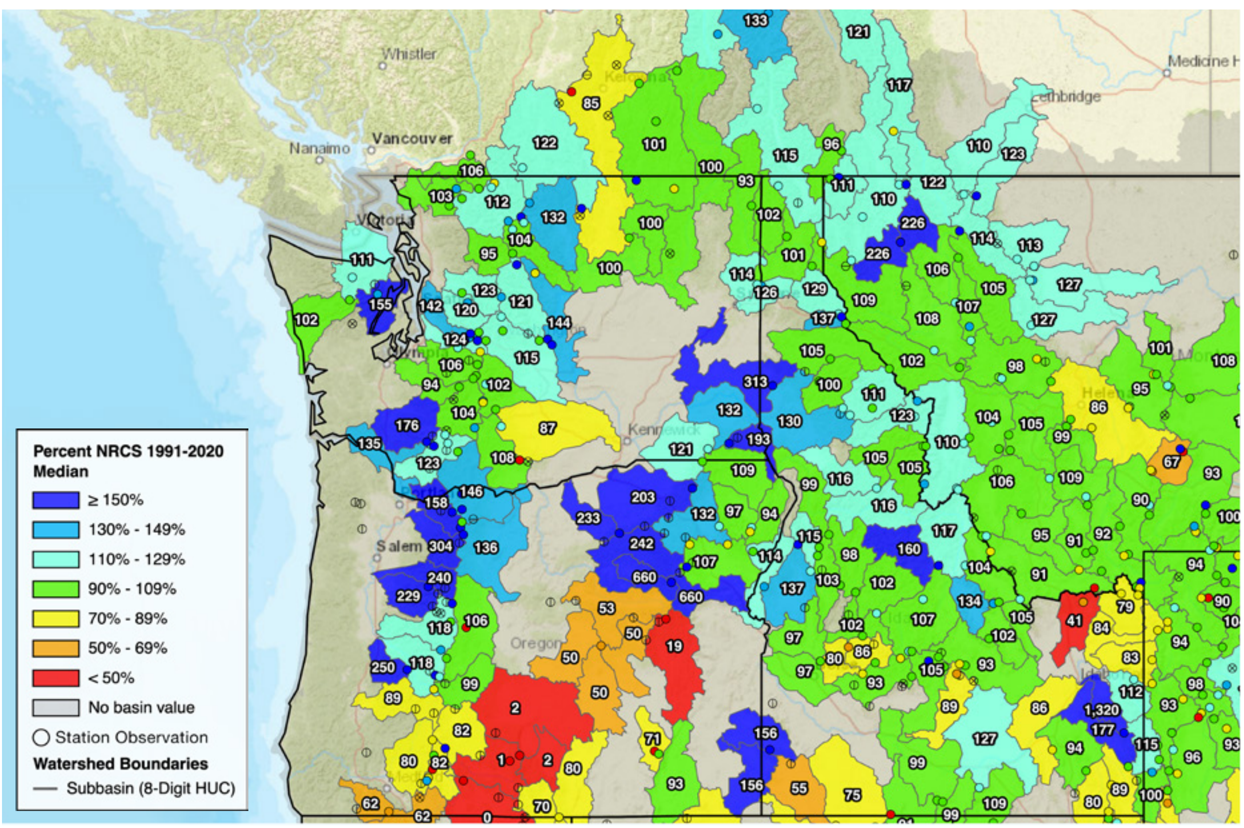


Figure 11: May 1, 2022 snow water equivalent (SWE) percent of 1991–2020 median. Source: *NRCS*.

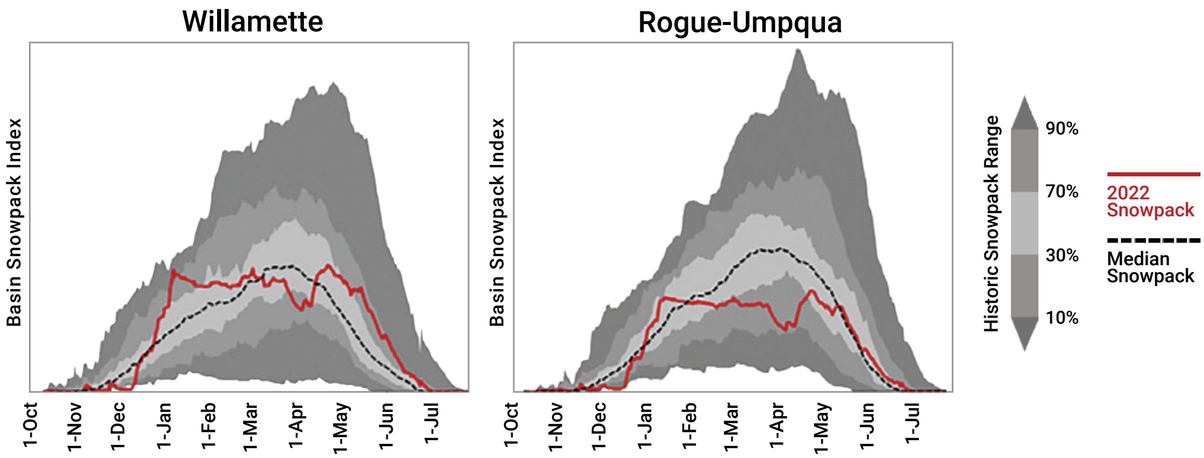


Figure 12: The Willamette and Rogue-Umpqua, Oregon, water year 2022 snowpack traces (*red line*) compared to normal (*dashed line*). Growth in snowpack during April resulted in near-normal peak SWE for the Willamette basin, whereas April SWE in the Rogue-Umpqua basin was below normal despite the growth. Source: Matt Warbritton USDA-NRCS.

(usually seen in early April). This secondary peak was critical in allowing the subsequent snowmelt to follow the usual timeline. The refreezing of the snowpack in April, due to the exceptionally cold temperatures, delayed snowmelt and eased drought in southern Idaho in particular. Overall, and in contrast to water year 2021, the timing of the snowmelt across most of the PNW was near normal or later than usual.

July–September 2022

Temperature

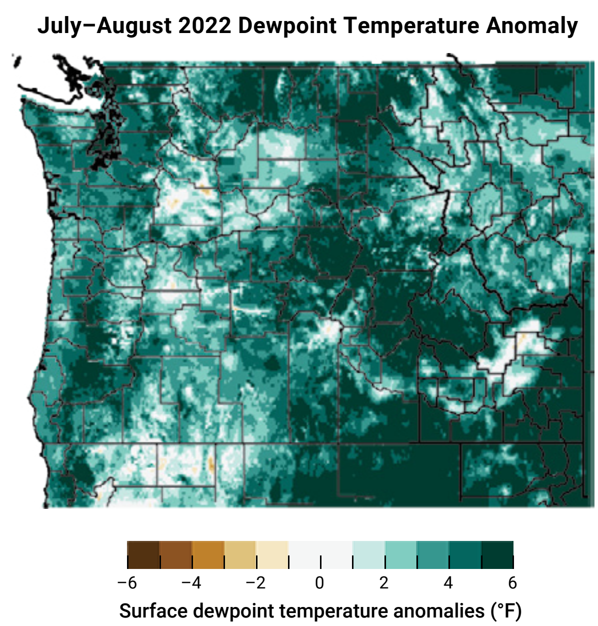
In contrast to April–June, average temperatures for July–September were 3–5˚F above normal throughout most of the PNW. July–September ranked as the record warmest for each state and for the PNW region. Dewpoint temperatures in July and August were above normal throughout most of the PNW, particularly in western Washington, western Oregon, and throughout Idaho (*Figure 13*).

Figure 13: July–August 2022 surface dewpoint temperature anomalies from the PRISM provisional monthly climate dataset. Anomalies are relative to 1991–2020.

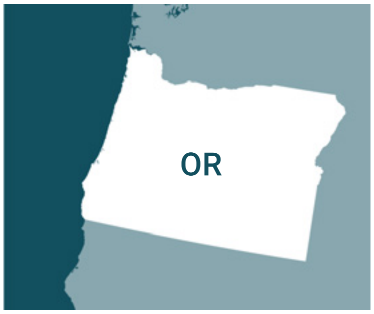
The higher humidity than usual in those locations reduced evaporative demand.

Precipitation

Summers in the PNW usually are dry. This was especially the case during the past water year with below normal July–September precipitation for most of the region, particularly in western Washington and northwest Oregon, where less than 5%



JULY–SEPTEMBER 2022 STATISTICS*



RECORD warmest; +3.7°F

9th driest (tied with 1934); −0.83”, 57% of normal

RECORD warmest; +3.5°F

2nd driest; −2.20”, 36% of normal

RECORD warmest; +3.8°F

31st driest; −0.56”, 78% of normal

*Anomalies relative to 1991–2020 normal; records since 1895. Source: NOAA NCEI 2022

July–September 2022

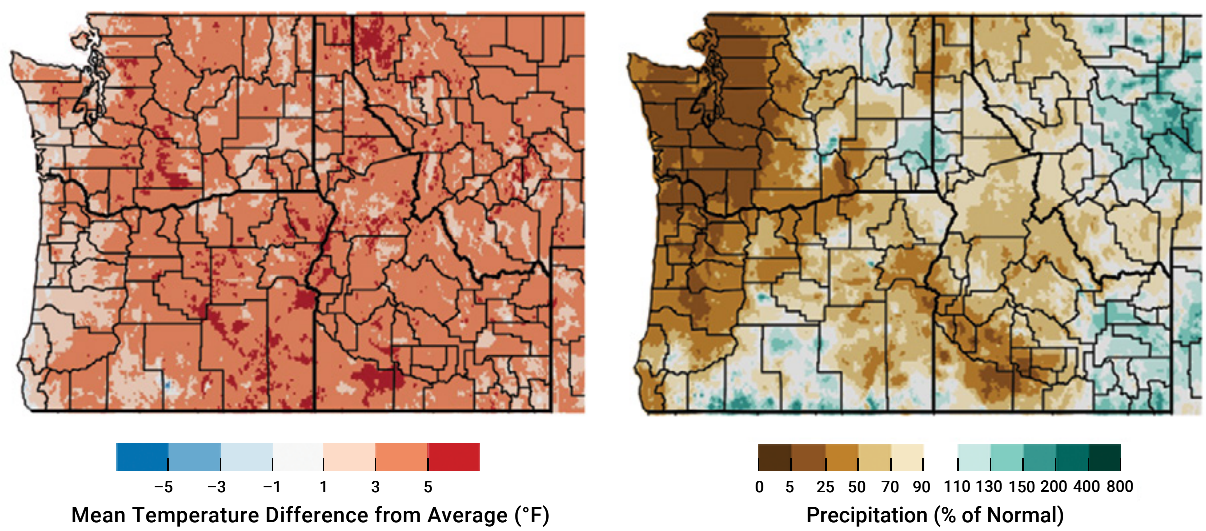


Figure 14: July–September 2022 average temperature departures and precipitation percent of normal. The normal period is 1991–2020. Source: gridMET data through *Climate Engine*.

of normal precipitation fell (*Figure 14*). The relatively high humidity reduced evaporative demand and helped to offset the extreme summer dryness to some extent. Some locations in north central Washington, southeast Washington, south central Oregon, and southeast Idaho received above normal precipitation, in part as a result of summer monsoonal moisture. Still, statewide July–September precipitation was among the lowest on record, with Washington and Oregon ranking as 2nd and 9th driest, respectively.

Multi-year drought

The weather and seasonal climate conditions for water year 2022 are reviewed above, but there are longer-term precipitation deficits across much of the PNW from the *2020* and *2021 water years*. The current drought cycle in much of the PNW began in fall 2019, at the start of the 2020 water year. Eighty-two percent of the PNW experienced a precipitation deficit over the last three water years (*Figure 15*). During this period, 5% of the PNW was short the equivalent of one full year of normal precipitation and 18% was short 80%. The greatest precipitation deficits were in central Washington, central Oregon, parts of southern Idaho, and southwest Oregon. These precipitation deficits are a major factor in the region's drought severity and persistence. Only 13% of the PNW experienced a precipitation surplus over the last three water years. These surpluses were mostly in western Washington and northeast Oregon, and the amounts were mostly less than 40% of the annual average.

The 36-month Standardized Precipitation Evapotranspiration Index (SPEI) ending September 2022 indicated drought throughout the PNW, with values less than –2.0 east of the Cascade Mountains in Oregon and Washington and in isolated locations in Idaho (*Figure 16*). The SPEI has both a precipitation and temperature component; indices less than –1.0 typically signify the beginning of drought, and drought severity increases as the index becomes more negative. The severity of long-term drought decreased during the 2022 water year, as measured by the SPEI, in western Washington, most of western Oregon, and southeastern Idaho. Long-term dryness persisted elsewhere in the PNW, and all short-term precipitation anomalies should be viewed through the lens of these long-term precipitation deficits.

3-Year Precipitation Deficits

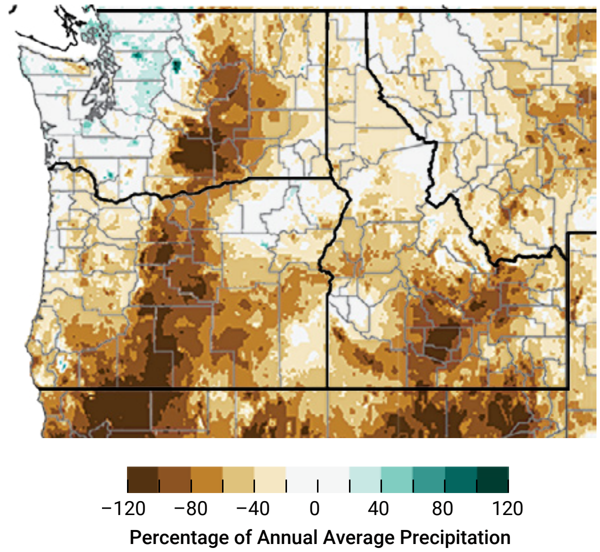


Figure 15: Precipitation deficit for the 3-year period from October 2019 – September 2022 as a percentage of annual average precipitation from the PRISM climate dataset. Values of –100% are equivalent to one complete year's worth of missing precipitation, values of 0% correspond to average precipitation over the 3-year period, and values of 100% indicate one full year's worth of surplus precipitation. The annual average precipitation values use 1991–2020 PRISM climatology.

36-Month Standardized Precipitation Evapotranspiration Index

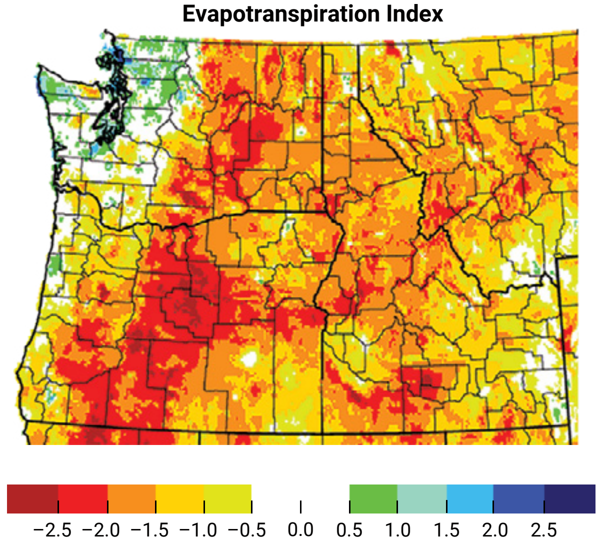


Figure 16: Three-year (36-month) Standardized Precipitation Evapotranspiration Index (SPEI) for the period ending September 30, 2022. Source: *West-Wide Drought Tracker*, using provisional PRISM data.

Two Contrasting Springs: Boise Basin, Idaho Recovery

Drought continued from 2021 through 2022 in most of southern Idaho, but the Boise basin was an exception. Snowpack in both years was below median—88% of median peak in 2021 and 71% of median peak in 2022—but similar to other areas of the PNW, the spring climates were drastically different between the two years.

In 2021, Idaho experienced an exceptional spring drought with precipitation ranking as the lowest since 1924. April–June Boise basin precipitation was 40% of normal and average temperatures in Boise County, representing the upper portion of the Boise basin, were 3.2°F above normal. These warm and dry conditions resulted in extremely low runoff. April–September runoff was estimated at 51% of normal, or 744,911 acre-feet (ac-ft). The Boise Reservoir system started with 454,000 ac-ft of carryover at the beginning of the 2021 water year and ended with 325,000 ac-ft of carryover.

In 2022, despite an even lower snowpack that peaked at 71% of the median, April–June was extremely cool (3.5°F below normal in Boise County) and wet (153% of normal for the Boise basin). April–September runoff was 73% of normal, or 1,070,816 ac-ft. The cool and wet conditions reduced agricultural demand and also delayed runoff long enough for the reservoir system to fill. Carryover at the end of the season was substantially above normal at 485,000 ac-ft. The recovery from drought and addition of 160,000 ac-ft to the reservoir system despite 71% of median snowpack was very unusual.

The comparison of 2021 and 2022 runoff in the Boise basin underscores the importance of spring conditions, as emphasized in the *2021 Water Year Impacts Assessment*. Runoff in 2022 was relatively high when compared to a handful of years with comparable low April 1 SWE ranging between 50–80% of median (*Figure 17*). Conversely, runoff in 2021 was much lower compared to another handful of years with comparable April 1 SWE (*Figure 17*).

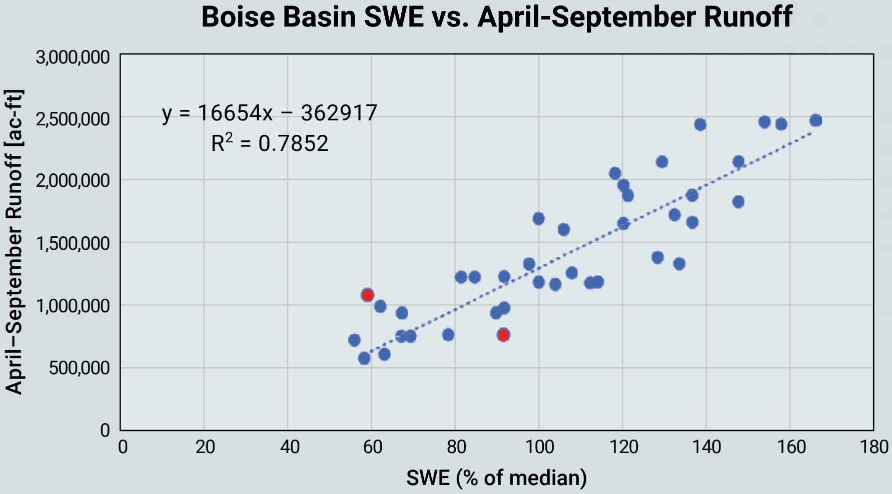


Figure 17: A comparison of April 1 SWE, measured as the percentage of median April–September runoff, in the Boise River basin. The two red dots represent 2021 (April 1 SWE: 93% of median; runoff: 744,911 ac-ft) and 2022 (April 1 SWE: 61% of median; runoff: 1,070,816 ac-ft). Source: *NRCS Interactive Map.*

4 WATER YEAR IMPACTS

Here we summarize impacts on multiple sectors in Oregon, Idaho, and Washington on the basis of three sources:

- The national Condition Monitoring Observer Reports (CMOR)
- The Annual Pacific Northwest Water Year Impacts Survey
- Presentations and discussions from the 2022 water year meetings

Information on drought and other climate conditions is critical to connect those conditions to their effects on local resources, people, and economies.

CMOR, established in 2018, allows members of the public to submit drought impact reports for their specific location at any time of year. The Annual Pacific Northwest Water Year Impacts Survey is distributed at the end of the water year to natural resource managers, agency staff, and all registrants for the water year meetings. Information from presentations and discussions at the 2022 water year meetings detailed here highlights particularly compelling climate impacts and responses within the region. Neither these sources nor the impacts presented in this assessment are exhaustive.

2022 Condition Monitoring Observer Reports

The Condition Monitoring Observer Reports on Drought (CMOR), provided by the National Drought Mitigation Center (NDMC) and the National Integrated Drought Information System (NIDIS), collects local observations of drought impacts to aid in drought monitoring and research. Observations inform the U.S. Drought Monitor and agencies that make drought-related decisions. For the 2022 water year, observers submitted 35 reports, mostly from Oregon, with a few from Washington and Idaho. Reports depict two themes:

Persistence of dry conditions in fall 2021: Observations of dry conditions from counties in eastern and western Washington indicated that the drought persisted from the 2021 water year into October of the 2022 water year. Observers described dry soils and a lack of water despite some initial fall rain. Local observations from fall 2021 also described tree and plant damage related to heat and moisture stress in northwestern counties in Oregon.

Extended dry period in winter 2022 that wasn't completely relieved by the wet and cool spring: Early winter 2022 was dry in much of Oregon, negatively affecting agriculture. Observations from counties in southern and eastern Oregon described dry conditions in January through March that reduced the growth of forage and other plants. Observations indicated that dry soils led to loss of topsoil, production of dust, poor quality and reduced production of hay, and reduced emergence and growth of native plants. Conditions were described as severely dry throughout much of the region.

Precipitation in May and June brought some relief to Oregon but was insufficient for crops to recover from the dry winter. Observers in southern and eastern Oregon who reported a dry winter also reported some relief from rain in spring and early summer, but indicated that the relief was short-lived and insufficient for recovery of some forage and other vegetation.

Wheat field in eastern Washington. Credit: Edmund Lowe

Yakima River, WA.
Credit: Ian Dewar

Annual Pacific Northwest Water Year Impacts Survey

The PNW Water Year Impacts Survey collects information on impacts of abnormally dry or wet conditions on the drinking water, agriculture, forestry, fisheries, hydropower, recreation, and stormwater sectors. The survey is distributed at the end of the water year. Characterization of abnormally dry or wet conditions is made by the survey respondents. Respondents may select impacts from a list or specify other impacts.

We distributed the 2022 water year survey in October 2022 via listservs of NIDIS, Office of the Washington State Climatologist (OWSC), Climate Impacts Group (CIG), PNW Tribal Climate Change Network, and Agriculture Climate Network; sent the survey to all registrants of the Oregon/Washington Water Year Meeting and the Idaho Water Year Meeting; and featured it in the OWSC monthly newsletter and the USDA Northwest Climate Hub newsletter. Sixty-eight people responded; 64% were employees of local, state, and federal agencies, and others were affiliated with Tribes, non-profit organizations, universities, irrigation districts, and power and water utilities. We include responses from agencies, resource managers, and producers, and in some cases responses may describe the same impacts. Impacts of abnormally wet conditions during the 2022 water year were reported by most sectors. By contrast, no impacts from abnormally wet conditions during the 2021 water year were reported.

SECTOR-SPECIFIC WATER YEAR IMPACTS

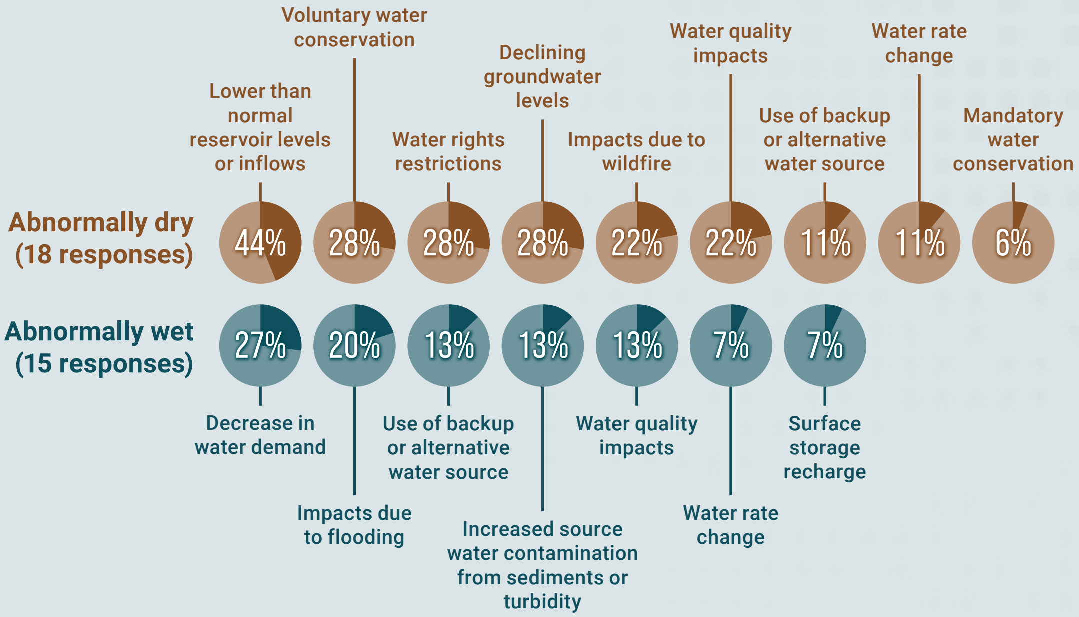
Water tower in Quincy, WA, April 7, 2022. Credit: Ian Dewar

Drinking water

Impacts on the drinking water sector were reported from watersheds across the Pacific Northwest, but primarily from counties and watersheds in southern Oregon. Of the 22 respondents, 18 (82%) reported impacts due to abnormally dry conditions and 15 (68%) reported impacts due to abnormally wet conditions. Lower than normal reservoir levels was the most common impact of dry conditions.

During the Oregon/Washington Water Year Meeting, participants described a greater need to truck water to small, rural communities, particularly in Oregon, and to use alternative water sources in general. Flood damage and lower water demand were the most commonly reported impacts of abnormally wet conditions.

DRINKING WATER IMPACTS SURVEY



2022 Effects of Anomalous Weather and Climate on Tree Fruit in Washington

Washington is the largest producer of apples and cherries in the United States. According to Washington State University's tree fruit specialist, Bernardita Sallato, both of those crops were adversely impacted by spring cold, early summer rain, and late summer heat during the 2022 water year.

The colder than normal temperatures beginning in April, along with strong winds, frost, and snow in mid-April, were especially impactful for cherries. Cherry trees bloom earlier than apple and pear trees, and are therefore more susceptible to frost damage. By April 12, cherry growers in Washington were already reporting about a 10% crop loss. Apples were also affected by frost damage (*Figure 18*). In addition to these direct impacts, the colder than usual spring, which coincided with bloom, reduced pollination and ultimately fruit yields. Washington's fruit trees rely heavily on honeybees as pollinators, and honeybees are less active in temperatures below 55°F, rain, snow, or wind.

Precipitation in June and early July caused cherries to crack right before harvest. Overall, Washington lost about 43% of its cherry crop in 2022. Because of these losses, the cherries that were harvested sold for about double their usual price. Although these high prices did not fully compensate for the loss of production, high prices were a silver lining for some growers in a year that was ultimately poor for cherry production.

Summer heat also affected both apples and cherries. Although the warmer than normal temperatures began after the cherry harvest, they affected buds for next year's crop and tree growth. Summer heat caused sunburn on apples and reduced fruit quality. At the time of this writing, total apple losses are unknown, but early indications are that the spring frost damage, summer sunburn, and effects of heat on fruit quality and storability caused a 50% loss in the Washington apple crop.

Figure 18. Apples with defects associated with 2022 weather conditions. Apples a. deformed due to reduced pollination, b. with calix end cracking due to early frost, and c. with sunburn immediately before harvest. Photo credit: B. Sallato.

Agriculture

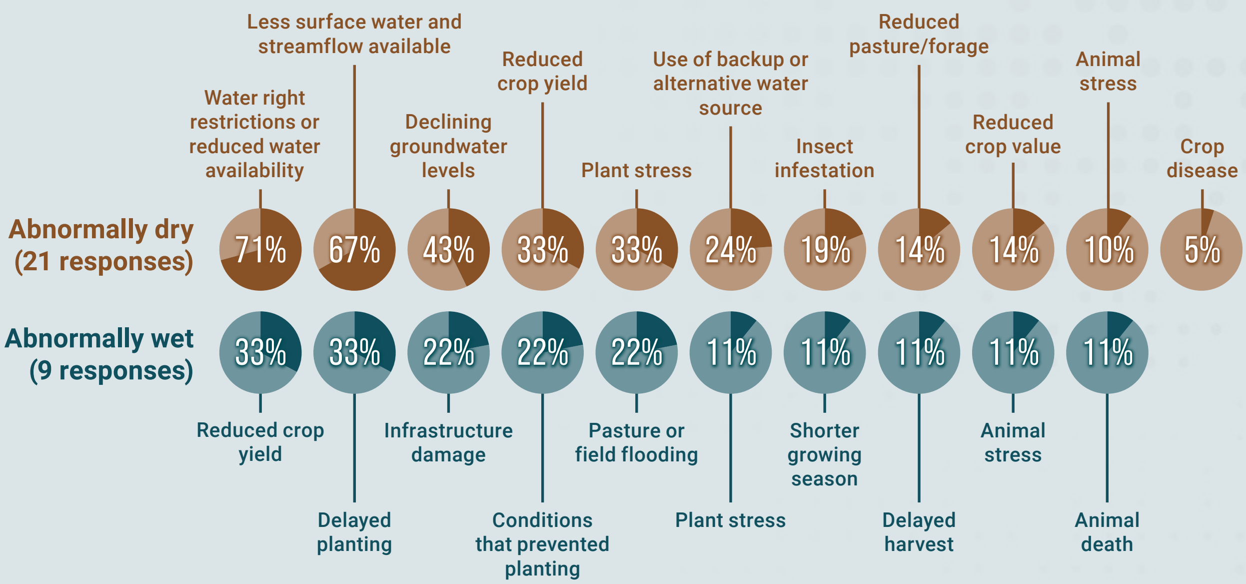
Of the 23 respondents, 21 (91%) reported impacts due to abnormally dry conditions and 9 (39%) reported impacts due to abnormally wet conditions. Similar to reported impacts on drinking water, impacts on agriculture were reported across the PNW and especially in southeast Oregon. Most respondents that noted impacts from abnormally dry conditions reported reduced surface water availability, water right restrictions, or less surface water and streamflow available.


Cornfield in Skagit Valley, Washington. Credit: Edmund Lowe

During the Oregon/Washington Water Year Meeting, participants described water shortages, which primarily affected irrigation districts and irrigation reservoirs, and greater conflict over water for agriculture, municipal uses, and fisheries. Water shortages caused water right curtailments and loss of agriculture production, and were regarded by some in the agriculture sector as isolated events rather than a trend. Drinking water systems that are small or dependent on shallow wells were affected by multi-year water shortages and gradual reductions in ground water. Lack of water also affected water quality.

Delayed planting and reduced crop yield were the most commonly reported impacts of abnormally wet conditions.

AGRICULTURE IMPACTS SURVEY



Idaho Fall Water Supply Meeting

In response to severely depleted reservoir levels at the start of spring 2022, snowmelt beginning in March, and low snowpack on April 1, the governor of Idaho took the extraordinary measure of declaring drought for all counties south of the Salmon River on April 29. Were it not for the extremely cool April and May in southern Idaho, 2022 could have been one of the worst droughts on record. At the Idaho Water Supply Meeting, NRCS Snow Survey staff indicated that they had not previously seen snowmelt initiate, then stop due to cold temperatures and rebuild, as occurred from March through May.

Total 2022 irrigation year (November 1, 2021 – October 31, 2022) water supply for the Upper Snake River Basin (*Figure 19*) was among the lowest since the early 2000s drought. Canal companies and irrigation districts that rely on senior natural flow rights generally fared better than those who rely on storage contracts that are filled by more junior water rights. April–June precipitation in the mountains of central Idaho, at the headwaters of the Boise and Payette basins, was in the top 30th percentile. This precipitation and cooler than normal temperatures allowed these basins to recover from drought and end the year with above normal reservoir carryover. The rest of southern Idaho, which received near-normal April–June precipitation, also benefited from the unusually cool weather, although water shortages were substantial. Storage space under Palisades Reservoir water rights only partially filled in 2022 and Palisades is the second largest reservoir in the Upper Snake Basin. Natural flow (the amount of water that can be delivered to water right holders) fell steadily from 90% to 74% of normal through the irrigation year (*Figure 20*).

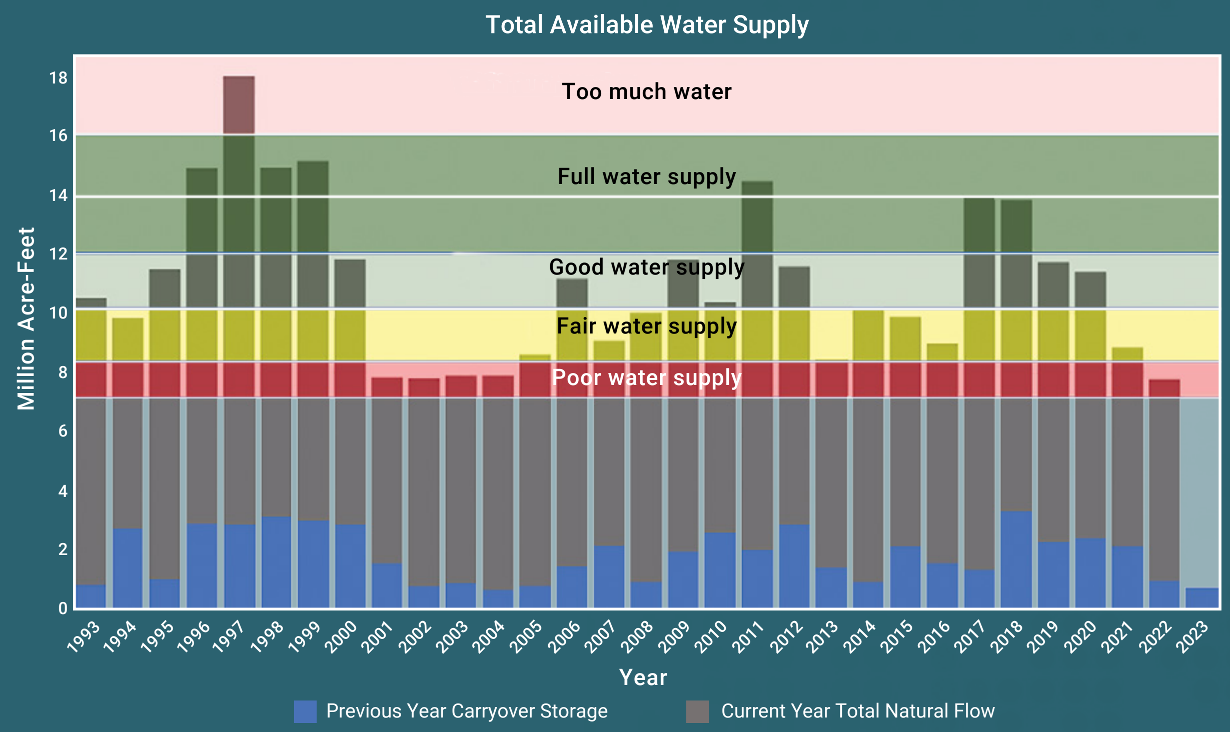


Figure 19: Total water supply in the Upper Snake River Basin, Idaho, for each irrigation year (November 1 to October 31). The blue bars are the total reservoir storage (Jackson Lake, Palisades, Henry Lake, Island Park, Grassy Lake, Ririe, American Falls, Lake Walcott, and Lake Milner reservoirs) at the start of each irrigation year and the gray bars are the estimates of natural flow on November 1 through October 31, ending on the year listed on the x-axis. The data for 2022 are preliminary. Source: Tony Olenichak, Water District 1 Watermaster.

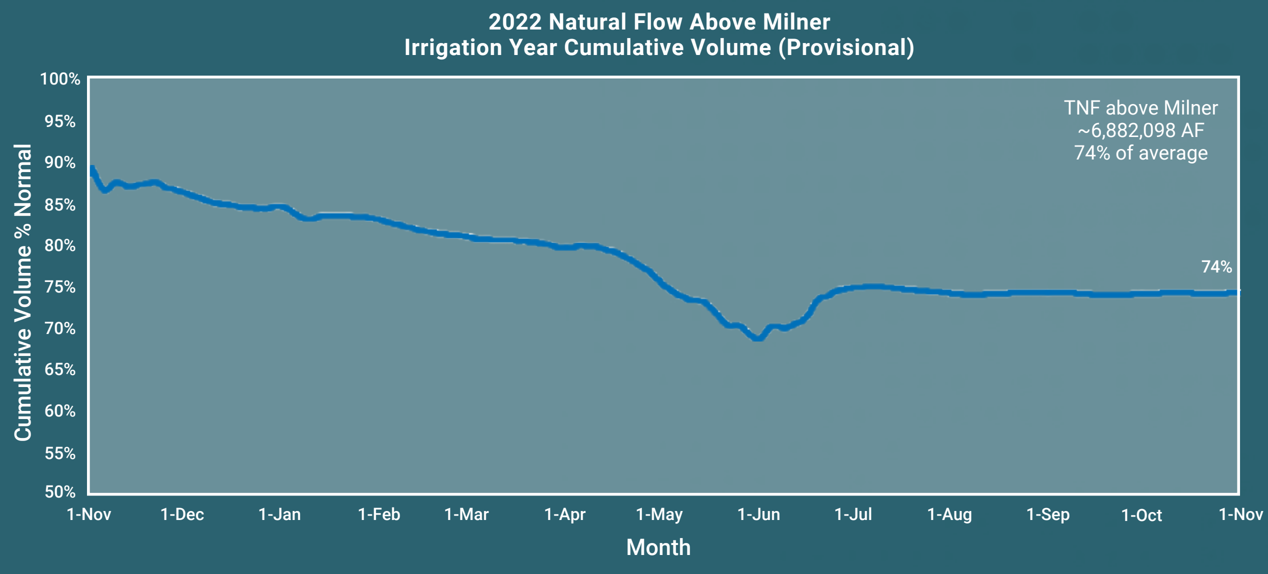


Figure 20: Natural flow of the Upper Snake River Basin for the 2022 irrigation year (November 1, 2021 to October 31, 2022) as a percent of normal. Source: Jeremy Dalling, USBR.

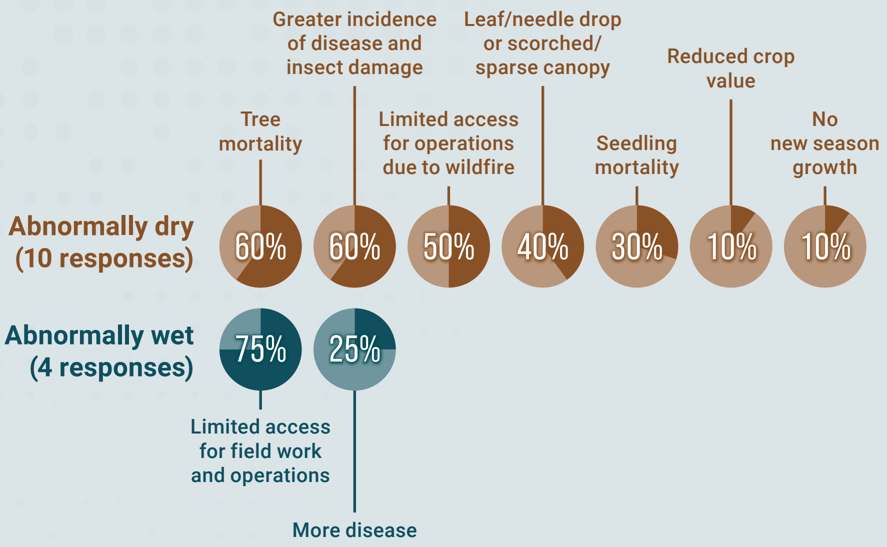
Forestry

Ten survey respondents reported impacts on forestry, all of which reported effects of abnormally dry conditions, and four respondents (40%) also reported effects of abnormally wet conditions. Impacts were reported across the PNW, especially the Umpqua basin. The most commonly reported impacts of dry conditions were tree mortality, insect and disease damage, loss of trees, and operational impacts due to wildfire. The most commonly reported impacts of wet conditions were limited access for fieldwork and tree disease.

Nooksack River along Mt. Baker Highway, Washington, with maple and alder trees showing fall colors. Credit: Edmund Lowe

During the Oregon/Washington Water Year Meeting, participants commented that the wet spring delayed the onset of the wildfire season, but effects of long-term drought on trees persisted and the wildfire season continued later than normal. By the end of the water year, wildfire risk was high across the region despite the wet spring, and the fire season extended into fall and water year 2023. Western Washington had some notable wildfires at the start of water year 2023, including one that closed a major transportation route and was close to critical watersheds for drinking water. According to the Bureau of Land Management Idaho Wildfire Information statistics, almost 500,000 acres burned in Idaho in the 2022 calendar year compared to an average of 370,000 acres per year for 2009–2018. Water Year Meeting participants also noted that large swings between wet and dry conditions have made it more difficult to use prescribed fires to reintroduce fire to particular landscapes.

FORESTRY IMPACTS SURVEY



Central and Southern Oregon 2022 Fir Tree Mortality

According to annual aerial survey data collected by the U.S. Forest Service, Oregon Department of Forestry, and Washington State Department of Natural Resources, there was significant fir tree mortality in 2022. High mortality of fir trees was surveyed across 1.1 million acres in Oregon and 66,000 acres in Washington (*Figure 21*). The ultimate cause of the fir tree mortality is believed to be drought, which weakens the trees and makes them more susceptible to insects and disease. Central and southern Oregon, where drought has occurred for multiple years, were particularly hit hard, with upwards of 50% mortality in some areas within the region. The area of fir tree mortality in Oregon ranks as the highest since the surveys began in 1952. This information was provided by Danny Depinte, the Pacific Northwest Region's Aerial Survey Program Manager, at the Oregon/Washington Water Year meeting; final numbers are now available at the *U.S. Forest Service website*. The U.S. Forest Service Northern Region and Intermountain Region covers Idaho, and 2022 aerial surveys by those groups identified approximately 30,000 acres of low severity fir tree mortality.

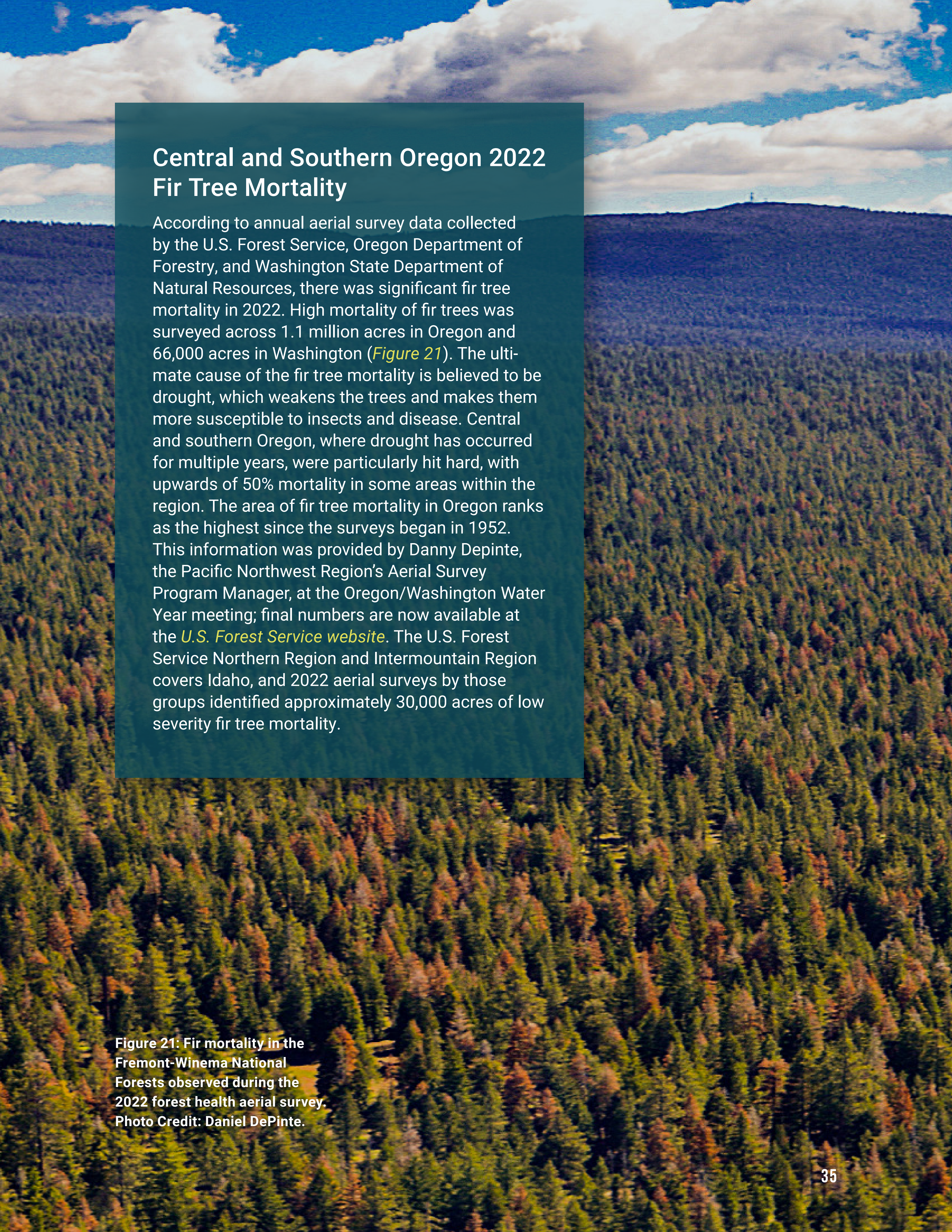


Figure 21: Fir mortality in the Fremont-Winema National Forests observed during the 2022 forest health aerial survey. Photo Credit: Daniel DePinte.

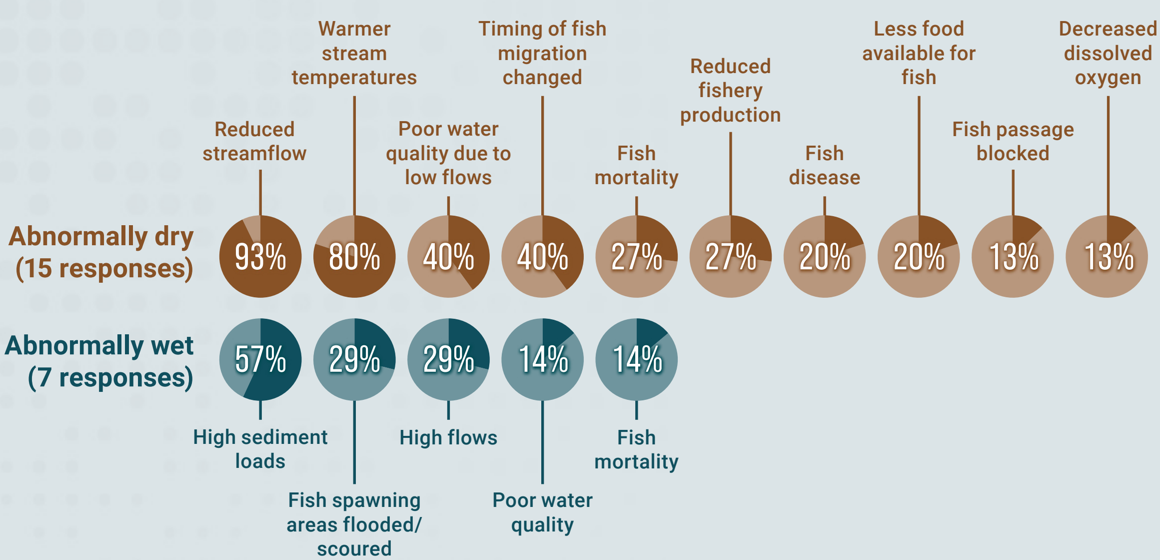
Fisheries

Fifteen survey respondents reported fisheries impacts; all reported impacts due to abnormally dry conditions, and seven (47%) also reported impacts due to abnormally wet conditions. Most impacts were reported for the Lemhi, Big Wood, Salmon, and Boise rivers in Idaho, the Willamette River in Oregon, and the Nooksack River in Washington. Almost all respondents reported reduced streamflows and warmer temperatures.

Sockeye salmon spawn in a shallow stream. Credit: Stefan Shug

During the Oregon/Washington Water Year Meeting, participants described that many fisheries across the region were greatly affected by low streamflows. Fisheries on the Olympic Peninsula were impacted at the end of the water year. Fish mortality in Whatcom County, Washington, was high due to low streamflows, warm water temperatures, and associated increases in diseases.

FISHERIES IMPACTS SURVEY



2022 Stressors on Chinook Salmon in the Nooksack Basin

The extreme precipitation swings during the 2022 water year affected spring run Chinook salmon in the Nooksack Basin, as reported by the Nooksack Indian Tribe's geomorphologist, Michael Maudlin, at the Oregon/Washington Water Year Meeting. The full extent of the impacts has not yet been determined, and it may be years until it is completely known due to the time it takes for the spawning and juvenile fish present in the basin in 2022 to return as adults.

The flooding on the Nooksack River in November 2021, estimated to have a return interval of 50 to 100 years or between a 1 and 2% chance of occurring in any given year (Gillett et al. 2022; *USGS StreamStats* using Nooksack at Ferndale: 12213100), caused significant and costly impacts to humans, including infrastructure damage. Flooding coincided with the spring run Chinook's incubation and rearing life stages, affecting salmon at a vulnerable time. There are primarily three ways Chinook could be affected by a flood of this magnitude during fall: 1) the scouring of eggs causing loss of incubating salmon, 2) loss of juveniles that were flushed down the river and unable to survive in saltwater, and 3) stranding of fish in floodplain areas from which they were unable to swim to the main river. Human actions to manage and repair infrastructure damage from floods can also negatively impact fish. For example, temporary roads built over rivers may not allow for fish passage and bank production projects can reduce the quality of habitat for fish. Although sediment removal can reduce future flooding in some cases, it can also negatively impact spawning habitat. Based on the low number of out-migrating juvenile salmon estimated in spring 2022, salmon co-managers believe that the flood had a considerable impact on the spring run Chinook population, but won't know the complete extent of the impacts until adults start returning to the watershed in three or four years.

In addition, preliminary numbers for 2022 indicate that hundreds of spring run Chinook died pre-spawning due to low flow conditions in summer. Summer streamflows are relevant to all stages of the spring run Chinook life cycle, and spawning in particular can be negatively impacted because the fish come into the Nooksack basin during that time of year. Lower flows allow the water temperatures to warm more quickly, and during late summer 2022, there were several instances of water temperatures above the lethal migration temperature (21°C). For example, the South Fork of the Nooksack exceeded that threshold in late July and approached it again in mid-August (*Figure 22*). Not only can the warm temperatures kill the fish, but warmer temperatures, even those that are below the lethal migration threshold, allow disease to spread.

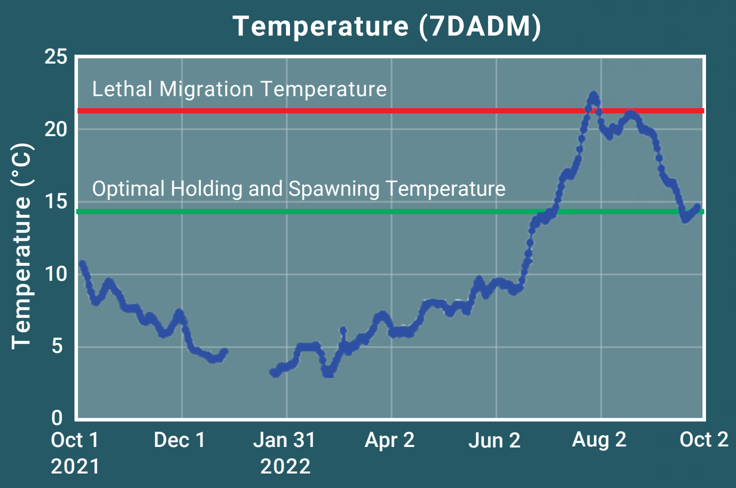
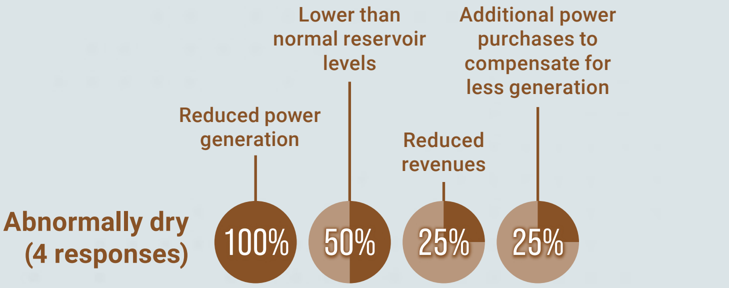
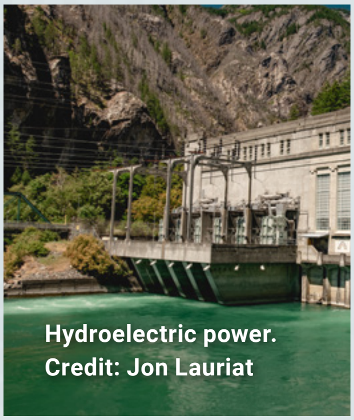
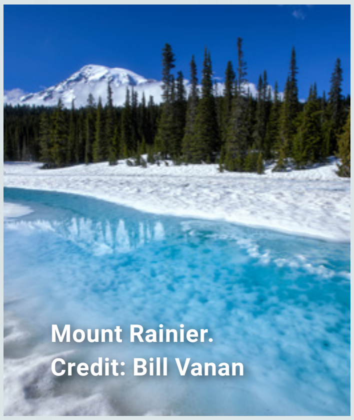


Figure 22: Water year 2022 7-day average maximum water temperature from the South Fork of the Nooksack River at Saxon Bridge, Washington (U.S. Geological Survey gauge 12210000). The lethal migration temperature (21°C) and optimal holding and spawning temperature (<14.5°C) for Chinook are plotted for reference. Source: Michael Maudlin, Nooksack Indian Tribe.

HYDROPOWER IMPACTS SURVEY




Hydroelectric power.
Credit: Jon Lauriat


Mount Rainier.
Credit: Bill Vanan

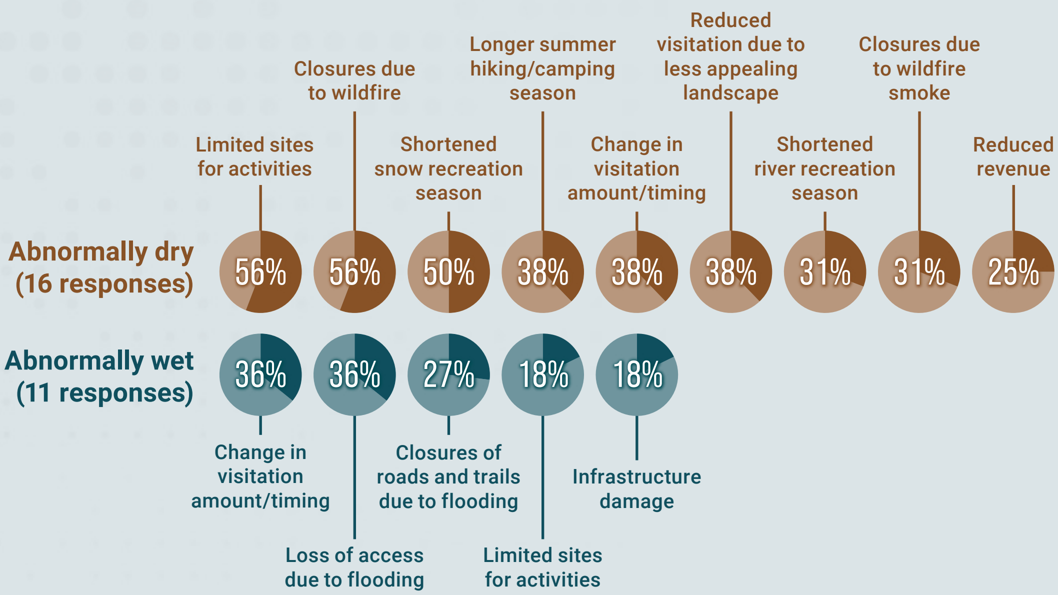
Hydropower

Four respondents reported impacts on hydropower; all reported impacts due to abnormally dry conditions, and one also reported impacts due to abnormally wet conditions. The primary impacts on hydropower associated with abnormally dry conditions were reduced hydropower generation and low reservoir levels. Impacts were reported for southern Idaho and eastern Washington.

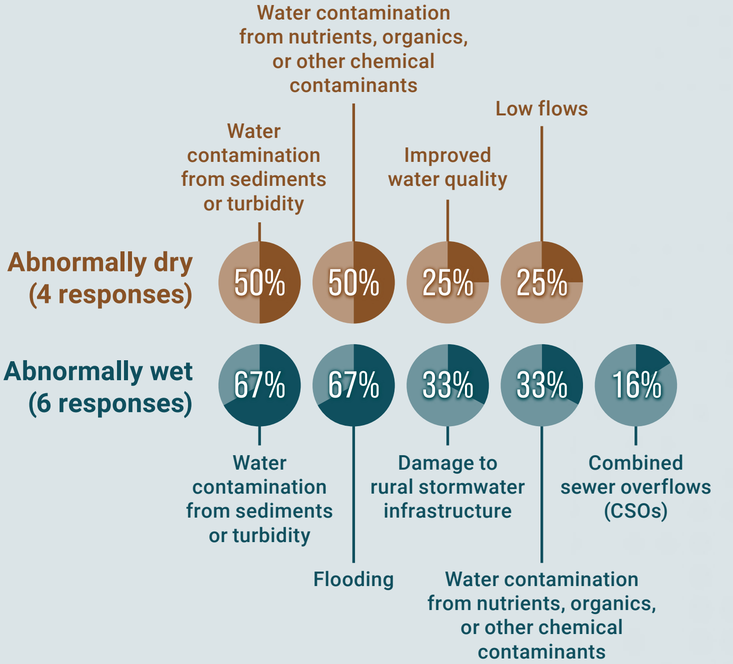
Recreation

Seventeen respondents reported impacts on recreation. Of these, sixteen (94%) reported impacts associated with abnormally dry conditions and 11 (64%) reported impacts associated with abnormally wet conditions. Impacts on recreation were reported across the PNW, with the Mt. Hood area and Deschutes basin highlighted.

RECREATION IMPACTS SURVEY



STORMWATER IMPACTS SURVEY



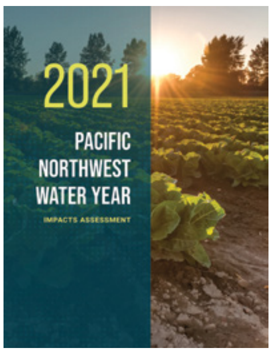
Stormwater

Seven respondents reported impacts on stormwater. Of these, four (57%) reported impacts associated with abnormally dry conditions and six (87%) reported impacts associated with abnormally wet conditions. Stormwater was the only sector for which a greater number of respondents reported impacts of wet rather than of dry conditions. The primary reported impact of both wet and dry conditions was water contamination. Impacts associated with wet conditions were reported for northwest Washington and for specific areas in Idaho, including Canyon County and the Clearwater, Grande Ronde and Lower Snake basins.

Flooded road in Snoqualmie Valley, Washington. Credit: Ian Dewar

New 2021 Water Year Reports

One advantage of our PNW Water Year Assessments is that they are available shortly after the end of the water year. Accordingly, much of the information included in the assessments is preliminary. Several summaries and reports on the 2021 water year (October 1, 2020 – September 30, 2021) or the 2021 and 2022 calendar years have been made available since our *2021 PNW Water Year Impacts Assessment* was released in February 2022.



***2021 Pacific Northwest Water Year Impacts Assessment*. Credit: NOAA NIDIS**

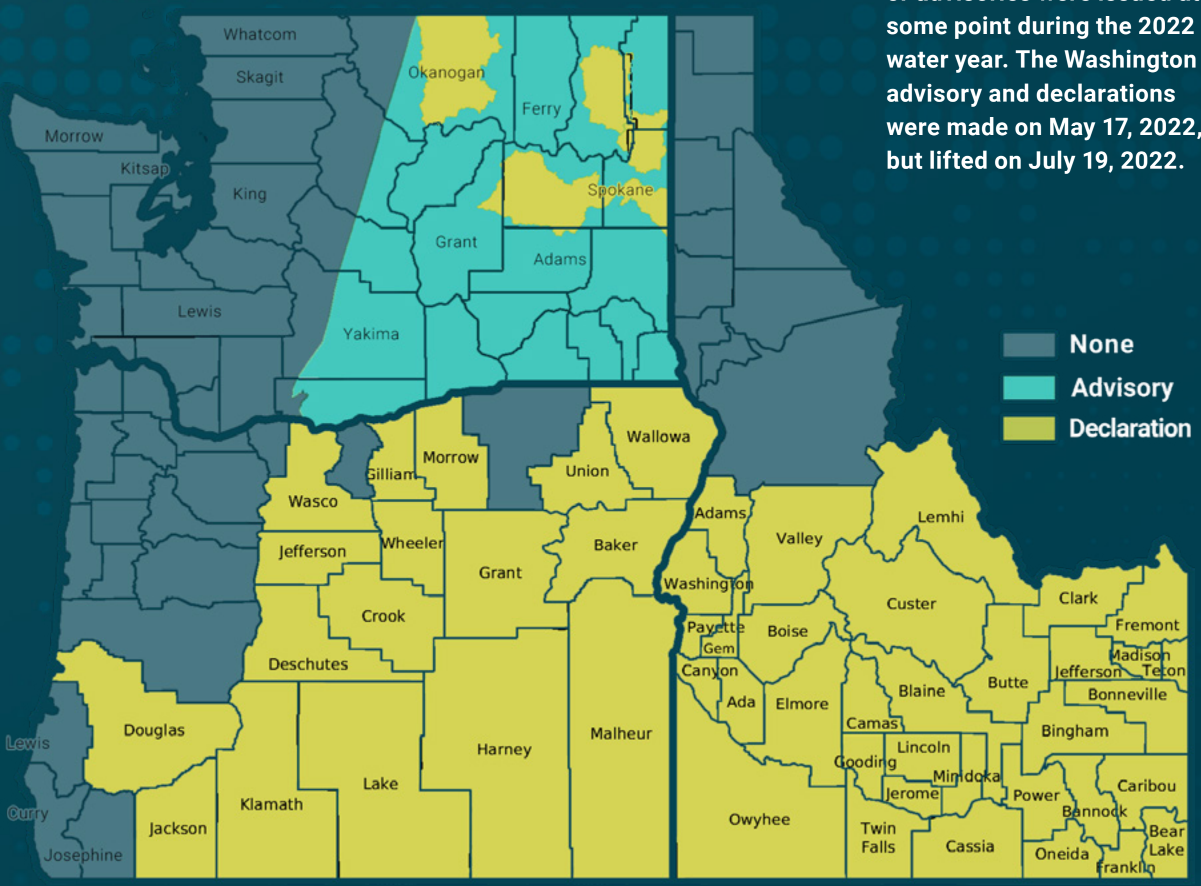
The *2021–2022 California Current Ecosystem Status Report*, released in March 2022, focused on the marine ecosystem along the west coast with the goal of informing fisheries management (*NOAA CCIEA 2022*). A brief summary can be found *here*, and a report focused on the 2022 water year will be released in spring 2023. A more localized marine perspective can be found in the annual *Puget Sound Marine Waters Report*, which summarizes the oceanic, atmospheric, and terrestrial influences on the Puget Sound for the calendar year (*PSEMP 2020*; *PSEMP 2021*).

Many scientific studies of the PNW June 2021 heat wave have been released since our last assessment. Consistent with the 2021 water year assessment, they show that while a warming climate was a contributor to this extreme heat event, the specific atmospheric pattern was the main driver of the heat wave. McKinnon and Simpson (2022), for example, concluded that the probability of an event of this magnitude is very low in climate model simulations and that it likely occurred by chance, or a "bad deal of the cards." Schumacher et al. (2022) further teased apart the influences and found that dry soils (i.e., pre-existing drought conditions) played a role in the extreme temperatures over the PNW during the 2021 heat wave, although the specific weather pattern was the greatest factor. They estimated that the atmospheric circulation explained 82% of the temperature anomalies over the warmest 5-day period, low soil moisture 10%, and ocean anomalies 1%, and gave a conservative estimate of the contribution of background warming from climate change of 6%. While the climate change contribution to the magnitude of the extreme temperatures was relatively small, its contribution to the likelihood of the event occurring was much larger, as it is estimated that the event was 150 times more likely to occur in our warming climate (Philip et al. 2022).

Regardless of the mechanisms, the event had wide-ranging consequences, and a number of new studies quantified those impacts. For example, Raymond et al. (2022) surveyed heat wave damage to PNW intertidal shellfish and found widespread negative outcomes that may continue to impact ecosystems and fisheries for many years to come. Heat damage to vegetation and tree seedling mortality were mentioned in the *2021 PNW Water Year Impacts Assessment*, and we now have estimates of the area of heat scorch observed through aerial surveys (by U.S. Forest Service, Oregon Department of Forestry, and Washington Department of Natural Resources) in western Oregon and western Washington. The June 2021 heat wave caused distinctly scorched foliage on the south and west sides of trees, and directly damaged tree crowns. The surveys mapped a total of 229,000 acres of heat damage across western Washington and western Oregon. Because most of southwest Oregon was obscured by smoke during the aerial surveys, that area was not examined (*WA DNR, 2022*; *ODF and USFS, 2022*).

STATE LEVEL & SECTOR-SPECIFIC RESPONSES

Figure 23: Counties or watersheds in the PNW for which drought declarations or advisories were issued at some point during the 2022 water year. The Washington advisory and declarations were made on May 17, 2022, but lifted on July 19, 2022.



State Responses

In the PNW, state drought declarations are used to facilitate the temporary transfer of water rights and offer short-term solutions to water supply challenges. The declarations are primarily used by the agricultural sector, although Washington, for example, has used emergency drought funds for drinking water purposes. Legislation passed in 2020 in Washington now allows emergency drought funds to be used for projects that build long-term drought resiliency, not strictly for emergency projects.

Drought declarations (*Figure 23*) were issued at varying times of the year for each state. In Oregon, 18 counties received state drought declarations through executive orders signed by Governor Brown. The first drought-related executive order of the 2022 water year was issued for Curry County on November 17, 2021. Drought in Klamath County wasn't declared until March 4, 2022, and a majority of the declarations were made between March and mid-May. The final Oregon drought declaration, for Wasco County, was issued on June 7, 2022. In Idaho, Governor Little approved 34 county drought declarations, spanning all of southern Idaho below Idaho County, on April 29.

On May 17, 2022, the Washington State Department of Ecology, with Governor Inslee's approval, extended the drought declaration that was issued in 2021 for five watersheds in the northeastern portion of the state. The rest of eastern Washington was included in a Drought Advisory that was issued to promote early awareness of the possible development of drought conditions. As a result of the cool and wet spring, both the Drought Advisory and Drought Emergency were lifted on July 19.

Emergency proclamations were also made in response to the weather and climate conditions in both Oregon and Washington. In Oregon, a state of emergency was issued statewide on December 23, 2021, due to the forecast of heavy snow, extreme cold, and potential travel disruptions and power outages. On January 26, 2022, a state of emergency was declared for Clackamas, Clatsop, Columbia, Curry, Douglas, Lane, Lincoln, Multnomah, Polk, and Yamhill counties due to a winter storms with high winds, rain, flooding, landslides, power outages, and transportation infrastructure damage that began on December 30, 2021, and continued through January 10, 2022. The wet spring (May 21 through June 15) prompted the proclamation of a state of emergency for Crook, Jefferson, Umatilla, Union, Wallowa, and Wheeler counties on July 13, 2022. On July 25, twenty-five Oregon counties were included in a state of emergency due to heat. Five emergency conflagration acts were issued between August 2 and September 9, 2022, as a result of wildfires in Wasco, Josephine, Wallowa, and Lane counties. On August 27, a statewide state of emergency was issued given the threat of wildfires.

In western Washington, a state of emergency was declared on November 15, 2021 for 14 counties, and December 1 for one county, due to the heavy rain, wind, flooding, and landslides associated with the atmospheric rivers described in this assessment. On January 7, 2022, a statewide emergency was declared in response to the rain and snow that began on December 17, 2021, and caused hazardous driving conditions and road closures over the mountain passes. No weather-related proclamations were made during spring or summer.

Sector-Specific Changes in Operations

The Annual Pacific Northwest Water Year Impacts Survey asked respondents if they modified operations *in anticipation of* or *in response to* abnormally dry or wet conditions during the water year. More than half of the respondents in most sectors indicated that they changed operations in response to abnormally dry or wet conditions.

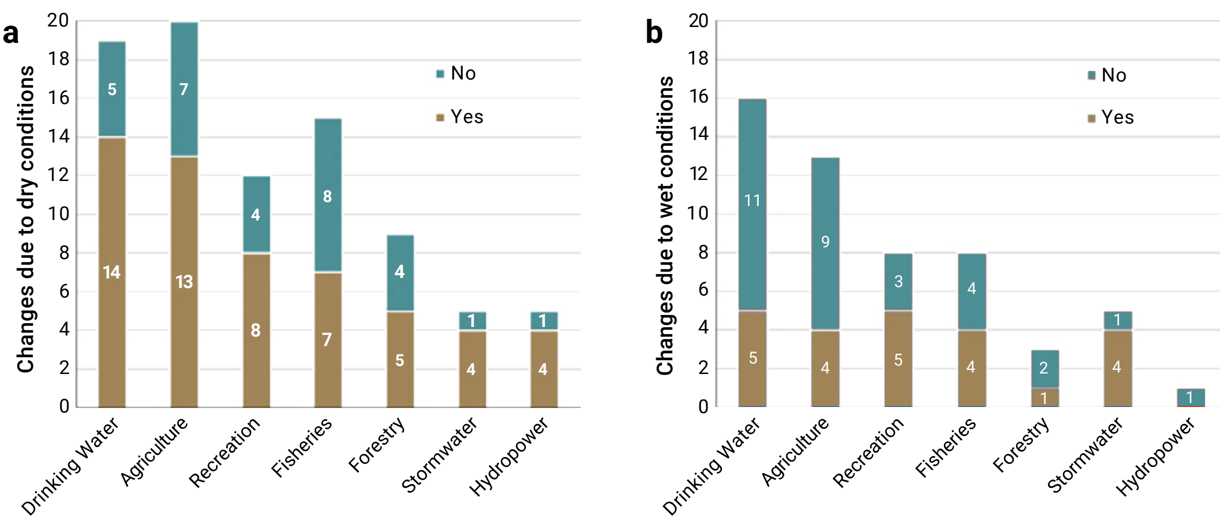
Survey responses suggested high operational flexibility during drought conditions. More respondents changed operations in response to dry conditions than wet. Seventy-four percent of respondents in drinking water, 65% of respondents in agriculture, and 67% of respondents in recreation indicated that they changed operations due to abnormally dry conditions. In general, a lower percentage of respondents in each sector changed operations in response to abnormally wet conditions. The exceptions were the recreation and stormwater sectors, in which 63% and 80% of respondents, respectively, changed operations.

Drinking water sector: Operational changes reported in response to abnormally dry conditions in the drinking water sector included water conservation, altered pumping regimes, and use of alternative water supplies, especially in the case of wells with insufficient water.

Agriculture sector: Operational changes reported in response to abnormally dry conditions in the agricultural sector included planting different crops, reductions in water use, and more supplemental pumping. No specific examples were given for operational changes due to wet conditions.

Recreation sector: All operational changes reported in response to abnormally dry conditions in the recreation sector were related to wildfire. Changes included reducing or restricting recreational activities and increasing staff and equipment to respond to wildfire. Operational changes reported in response to abnormally wet conditions in the recreation sector generally include delayed openings and reduced access due to the cold, wet spring.

Figure 24: Annual PNW Water Year Impacts Survey responses to whether operations in multiple sectors were changed in response to unusually (*a*) dry or (*b*) wet conditions.



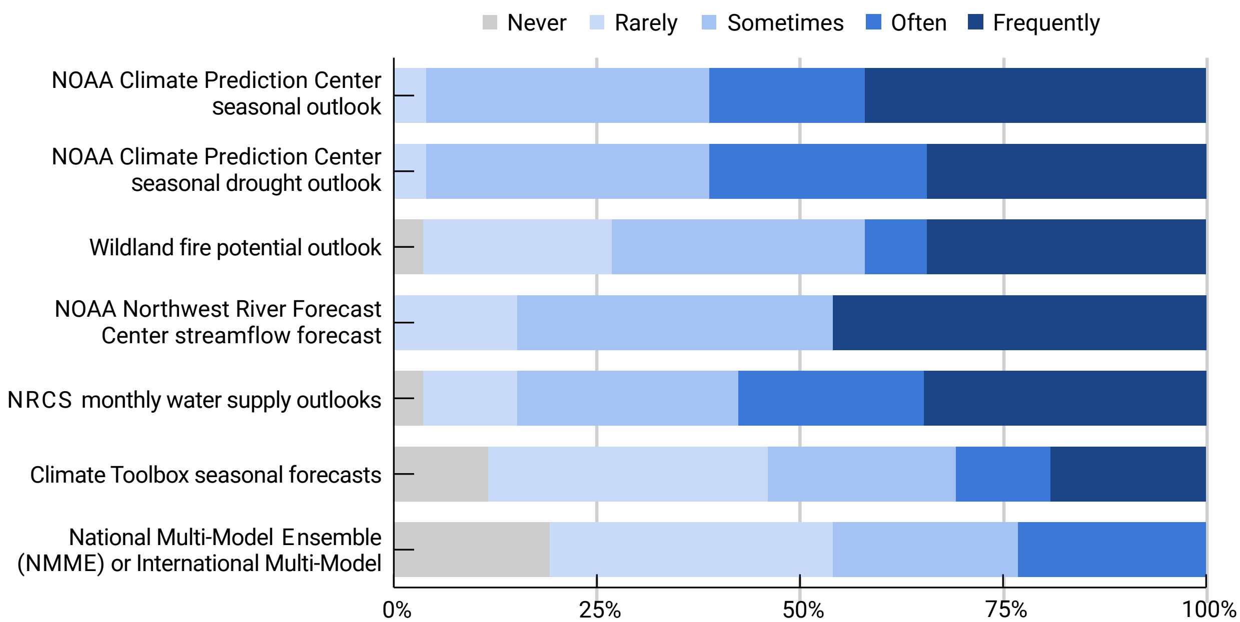


Figure 25. The Annual PNW Water Year Impacts Survey responses to the question, "During the water year, how often do you use these seasonal forecasts and outlooks?"

Changes in Operations Based on Forecasts and Outlooks

Most respondents of the Annual PNW Water Year Impacts Survey used seasonal outlooks or forecasts during the water year at least sometimes. Both the NOAA Climate Prediction Center seasonal outlook and drought outlook were used "often" or "frequently" by 60% of the survey respondents. Other respondents indicated that outlooks are too vague to be useful, and some indicated that they relied on recent historical data and past experience.

Survey respondents described some specific ways that they use seasonal forecasts and outlooks, with most responses in the following categories.

- Optimize resources such as water, energy, and visitation to recreation sites.
- Communications, guidance, alerts, and other forms of outreach with customized messages based on outlooks and forecasts.
- Manage timing of activities and operations such as river-based construction projects, field work, planting, and monitoring.

6 FORECAST VERIFICATION

La Niña was predicted, and emerged, in the tropical equatorial Pacific Ocean during winter 2021–2022, marking the second consecutive winter with La Niña conditions. Typically, La Niña events are associated with colder and wetter than normal winters in the PNW, with above normal snowpack by April 1, although there is some variability in the strength of that relationship throughout the PNW.

NOAA's Climate Prediction Center (CPC) and other centers for long-term forecasts use empirical relationships based on past La Niña events, other observed properties of the global climate system that provide predictability, and projections from global atmosphere-ocean climate models to produce the seasonal weather predictions.

Most of our survey respondents are familiar with and use the NOAA Climate Prediction Center (CPC) seasonal outlooks.

The majority of seasonal forecasts made during the 2022 water year were consistent with those typical La Niña relationships. Since most of our survey respondents are familiar with and use the CPC seasonal outlooks, we qualitatively examined the accuracy of two example seasonal forecasts, one for January through March 2022 (JFM) and one for April through June 2022 (AMJ).

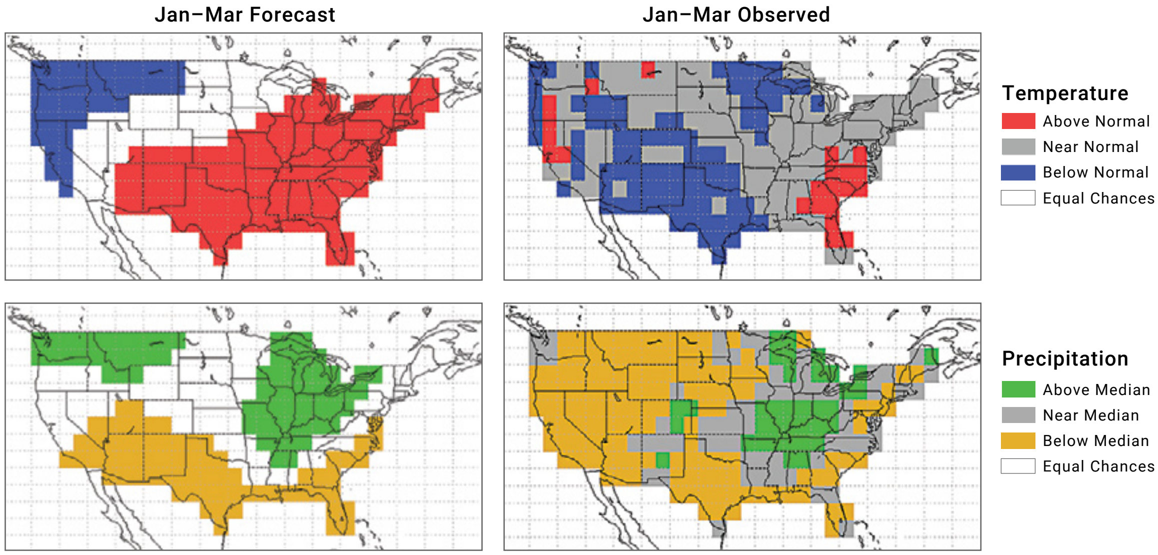


Figure 26: Categorical temperature and precipitation forecasts for January–March 2022 (JFM), issued in December 2021, compared to observations for those months. Source: *Climate Prediction Center*.

January–March 2022 Forecast and Verification

The CPC temperature forecast for JFM issued in December 2021 (*Figure 26*) favored higher odds of below-normal temperatures for nearly the entire PNW. Southernmost Idaho and northern Nevada and Utah had equal (33% each) chances of below, near-normal, or above-normal JFM temperatures.

Both forecasted and observed temperatures in most of western Washington, coastal Oregon, northern Idaho, east central Oregon, and southern Idaho were below normal. Observed JFM temperatures across most other areas of the PNW were near-normal, one category different from the below-normal temperature forecast. The exceptions were the central and southern Cascade Mountains of Oregon and southern portion of the Idaho panhandle, where JFM temperatures were above normal, two categories different from the forecast.

JAN–MAR 2022 FORECAST

The region was much drier than the forecast indicated.

The CPC precipitation forecast for JFM indicated above-median precipitation for all of Washington, northern Oregon, northern Idaho, and central eastern Idaho (*Figure 26*). Most of Oregon and the remaining areas of Idaho had equal chances of below, equal to, or above-median precipitation. The JFM precipitation forecast issued in December 2021 turned out to be inaccurate for the entire region; the drier than normal conditions were not foreseen given the presence of La Niña in the tropical Pacific. Observed precipitation totals for JFM were below median for nearly the entire PNW with the exception of western Washington and northern Oregon, where observed precipitation was near-median but forecasted precipitation was above-median.

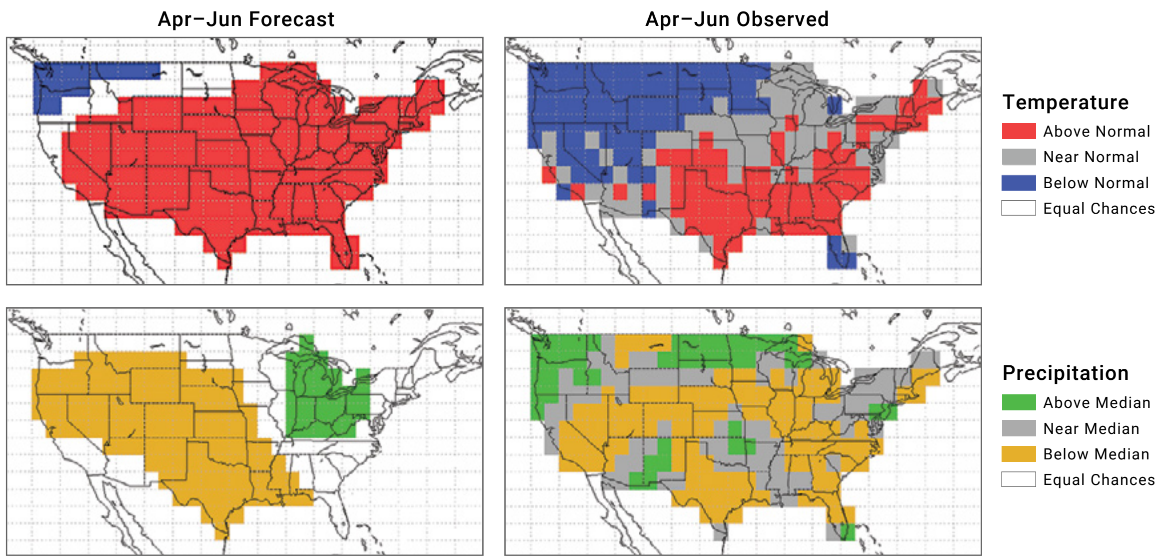


Figure 27: Categorical temperature and precipitation forecasts for April–June 2022, issued in March 2022, compared to observations for that period. Source: *Climate Prediction Center*.

April–June 2022 Forecast and Verification

The CPC temperature forecast for AMJ issued in March 2022 (*Figure 27*) favored higher odds of below-normal temperatures for Washington, northern Oregon, central Oregon west of the Cascade Mountains, and northernmost Idaho. Equal odds of below-normal, near-normal, or above-normal temperatures were forecasted across the majority of the rest of the PNW, but southern Oregon, southeast Idaho, and the southern-most portion of Idaho had elevated odds of above-normal AMJ temperatures.

Observed AMJ temperatures were below normal throughout the entire PNW, resulting in a mostly accurate forecast. Those areas in southeast Oregon and southern Idaho for which above normal temperatures were forecasted were the only true miss in the seasonal temperature outlook.

APR–JUN 2022 FORECAST

The region was much wetter than the forecast indicated, though the forecasted below-normal temperatures were as observed.

The above-median AMJ precipitation was not well-predicted. The CPC precipitation forecast for AMJ indicated higher chances of below median precipitation through most of Oregon and Idaho, and equal chances of the three outcomes for most of Washington. Observed AMJ precipitation was above median in all of Washington, most of Oregon, and parts of Idaho. Observed precipitation in all of the remaining areas in the PNW was near-median, except for a small area of south central Idaho where below-median precipitation was both forecasted and observed.

These forecast verifications are recent examples, and should not be generalized. They illustrate that two periods of anomalous precipitation during the 2022 water year (the drier than normal January–March and the wetter than normal April–June) were not anticipated in the CPC seasonal outlooks. The observed seasonal temperature anomalies from January–March 2022 were patchier than the extensive anomalies that were forecasted, as is typical. During the 2022 water year, the April–June temperature outlook appeared to be more skillful than the January–March outlook.

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2022

PACIFIC NORTHWEST WATER YEAR

IMPACTS ASSESSMENT

Supported by the
NOAA National Drought
Information System