# TAHOE: STATE OF THE LAKE REPORT 2024

# PHYSICAL PROPERTIES

UCDAVIS
Tahoe Environmental
Research Center

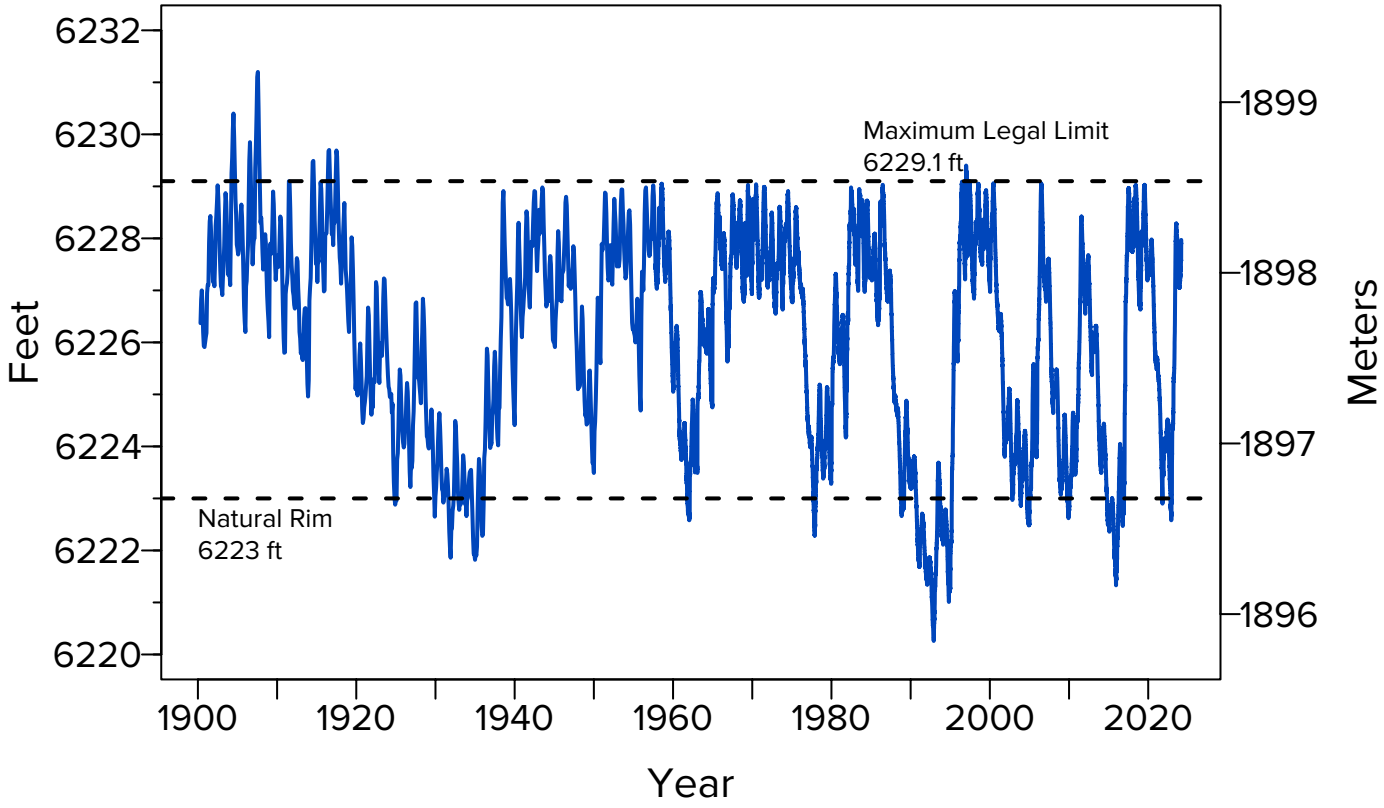
tahoe.ucdavis.edu

## Lake surface level

**Daily since 1900**

Lake surface level varies throughout the year. Lake levels rise due to high stream inflow, groundwater inflow, and precipitation of rain and snow directly onto the lake surface. It falls due to evaporation, in-basin water withdrawals, groundwater outflows, and outflows via the Truckee River at Tahoe City. In 2023, the highest lake level was 6,228.29 feet on July 21, and the lowest was 6,223.72 feet on January 1, 2023, just above the natural rim of the lake. The natural rim of the lake is at an elevation of 6,223 feet. Lake Tahoe fell below its rim on October 24, 2022, but rose back above it on December 27, 2022. When the lake was below its rim, outflows via the Truckee River ceased. Several episodes of lake level falling below the natural rim are evident in the last 114 years. The frequency of low water episodes appears to be increasing. The lowest lake level on record is 6,220.26 feet on November 30, 1992, 2.74 feet below the natural rim.

Data source: US Geological Survey level recorder in Tahoe City.

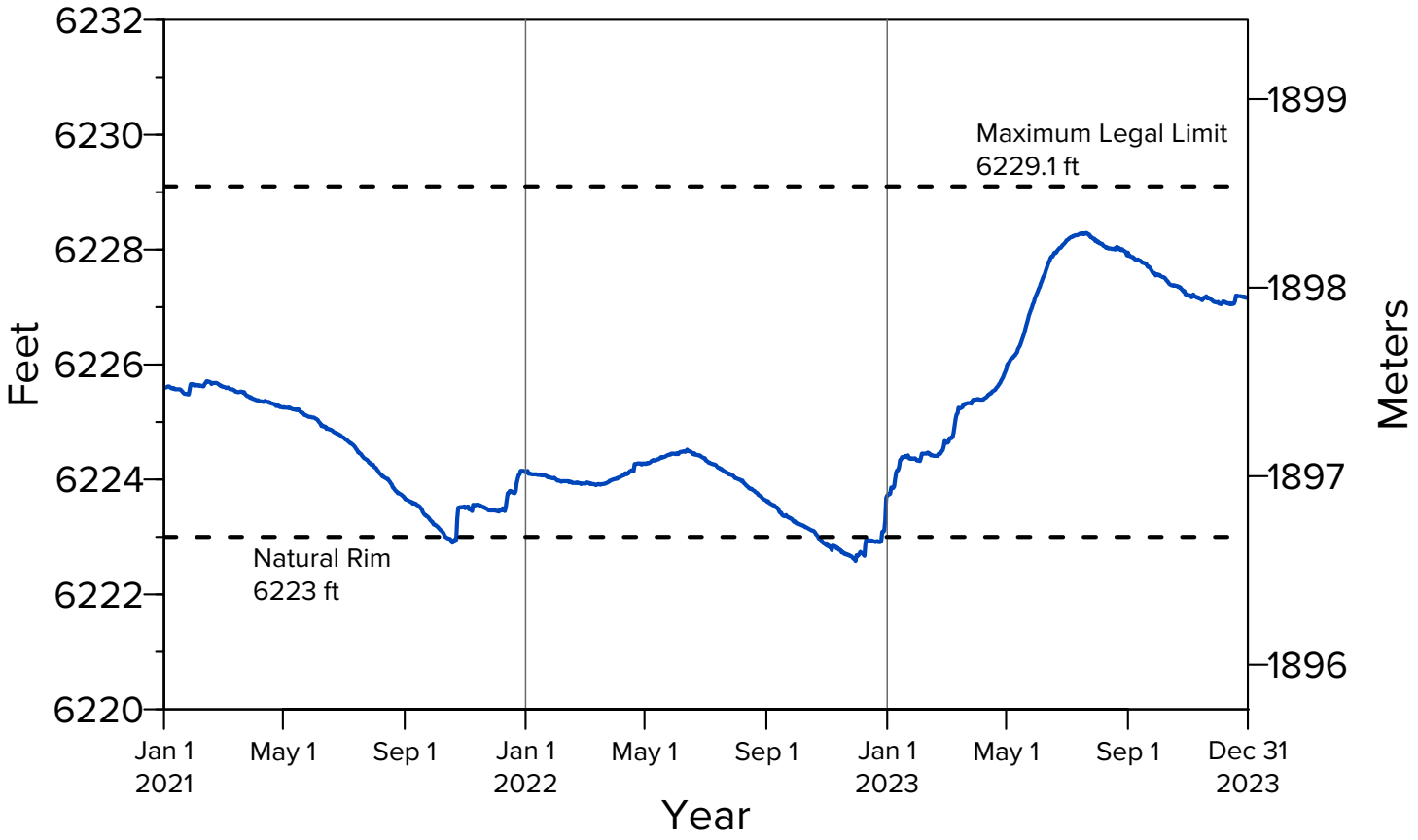


## Lake surface level

**Daily in 2021, 2022, and 2023**

The subset of lake surface data is extracted from the same data as in Fig. 8.1 for the most recent three years from 2021–2023. This more time-restricted presentation of recent lake level data better displays the annual patterns of rising and falling lake level in greater detail. In 2023, on account of the higher-than-average precipitation, the winter and spring rises in lake level are evident. Precipitation in December 2022, January and March 2023 produced sudden jumps in lake level. Snowmelt in spring continued the rise in lake level, but after July 21 the water level slowly fell.

Data source: US Geological Survey level recorder in Tahoe City.

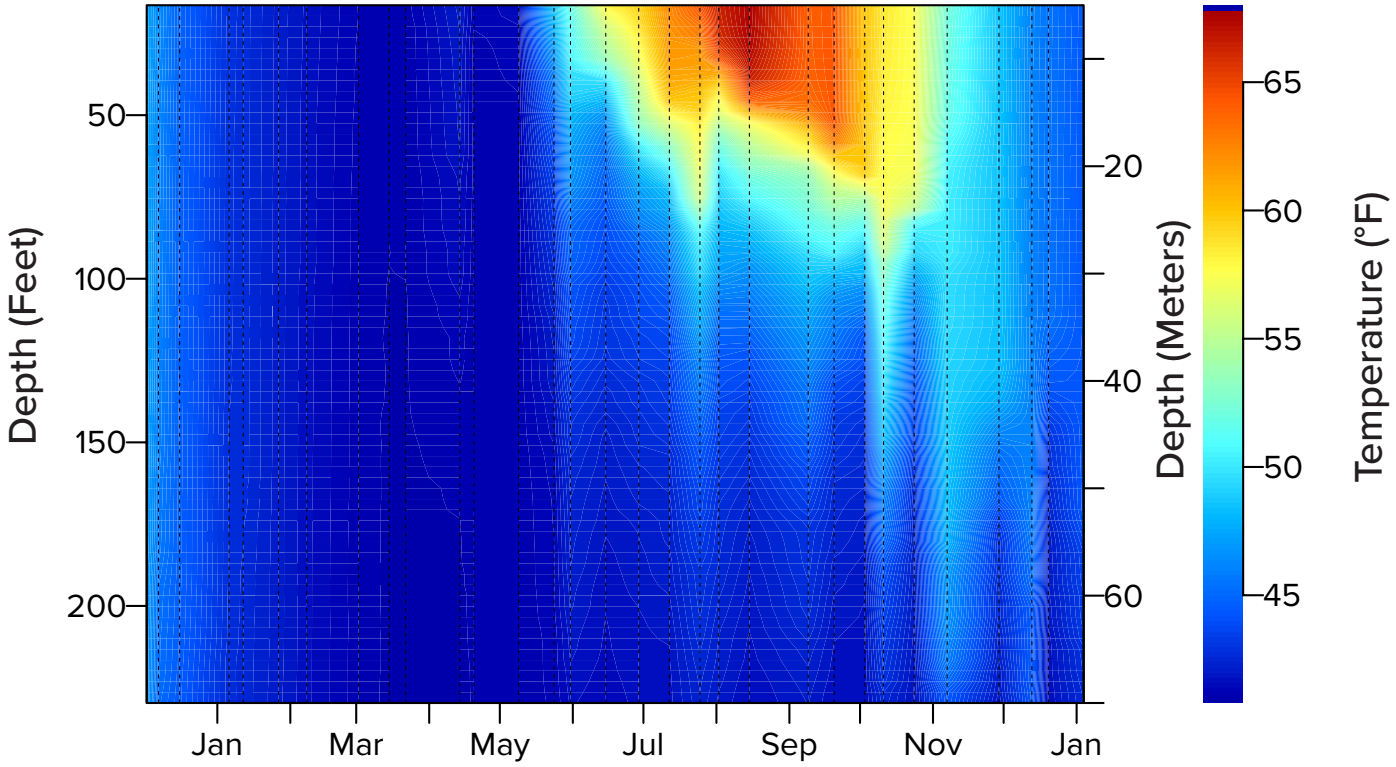


## Water temperature profile

**In 2023**

Water temperature profiles are measured in the lake using a CTD (conductivity, temperature, depth) profiler on the days indicated by the dashed vertical lines. The measured temperature is accurate to within 0.005 °F. The vertical distribution of water temperature is a very important lake attribute as it represents lake density. During the summer months, the warmer, lighter water remain suspended at the lake surface in the region above the thermocline known as the epilimnion. The temperature in the upper 230 feet (70 m) of Lake Tahoe is displayed as a color contour plot. In the early part of 2023, the lake temperature followed the typical seasonal pattern. In February and March, the lake surface was at its coldest, while it was at its warmest in August before fall cooling took place.

Data source: TERC lake monitoring.

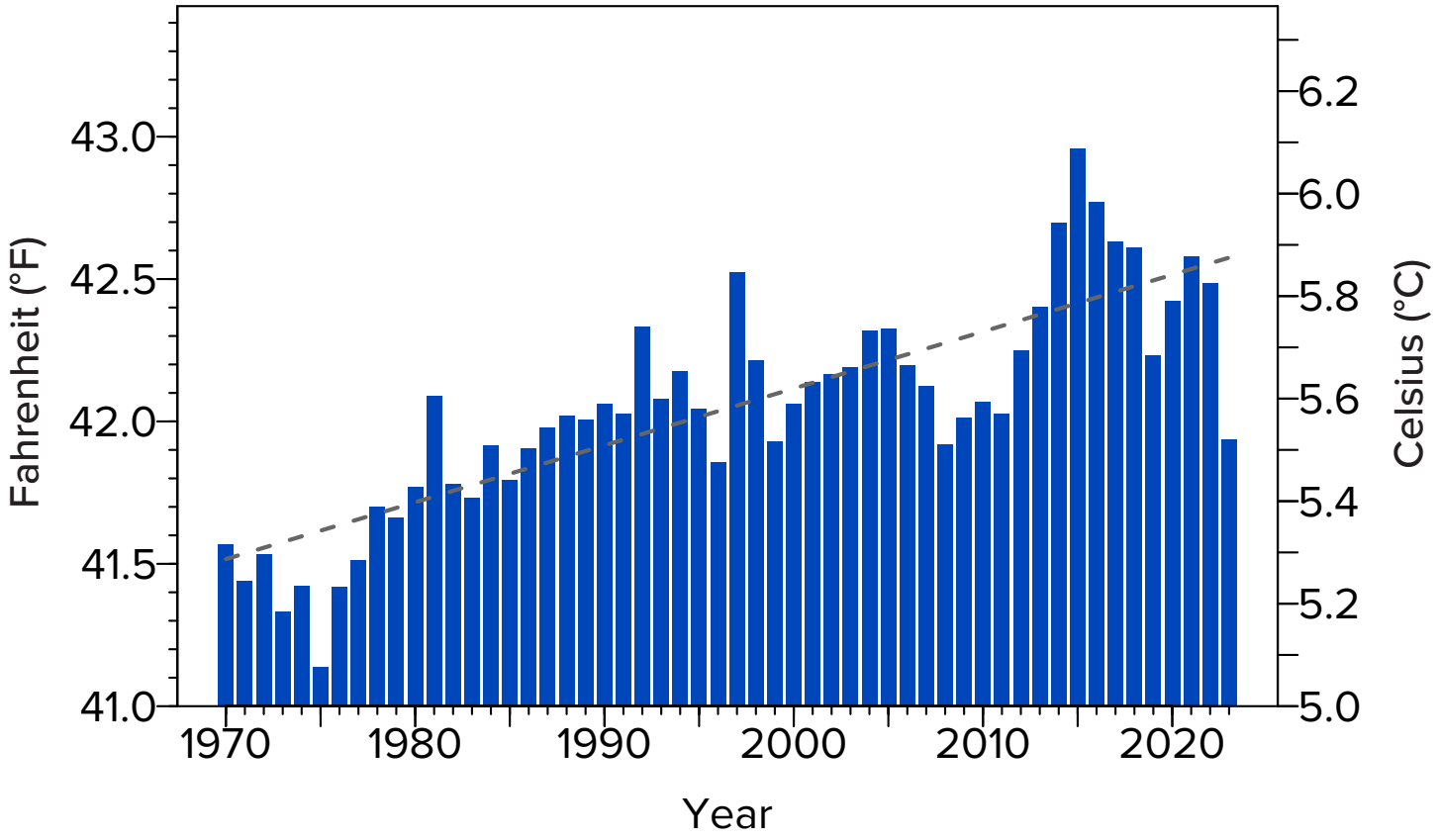


## Annual average water temperature

**Since 1970**

The volume-averaged temperature of the lake for each year since 1970 is shown. The trend line indicates that water temperature has increased by approximately 1.1 °F (0.6°C) since 1970. The annual rate of warming is 0.21 °F/decade (0.12 °C/decade). The monthly temperature profile data from the top to the bottom of the lake has been smoothed, and any seasonal influences were removed to best show the long-term trend. The 2023 annual average water temperature of 41.9 °F (5.5°C) was below the trendline.

Data source: TERC lake monitoring.

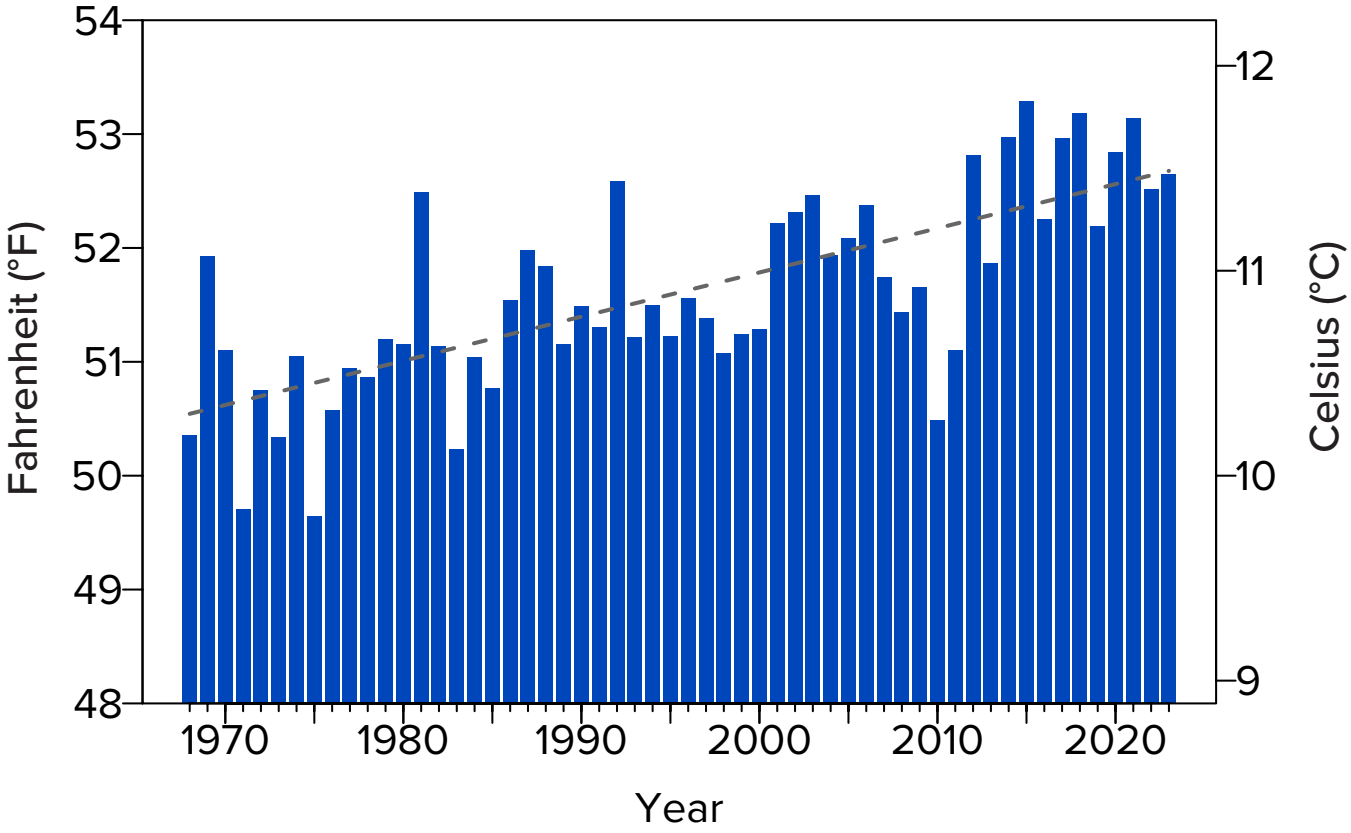


## Annual surface water temperature

**Yearly since 1968**

Surface water temperatures (measured at a depth of 5 feet) have been recorded monthly at the Mid-lake and Index stations from TERC's research vessels since 1968 and from four research buoys since 2007. Despite year-to-year and longer cyclical variability, the annual average surface water temperatures show an increasing trend. The average temperature in 1968 was 50.4 °F (10.2 °C). For 2023, the average surface water temperature was 52.7 °F (11.5 °C), right around the long-term trend line. The overall rate of warming of the lake surface is 0.39 °F (0.22 °C) per decade.

Data source: TERC lake monitoring.



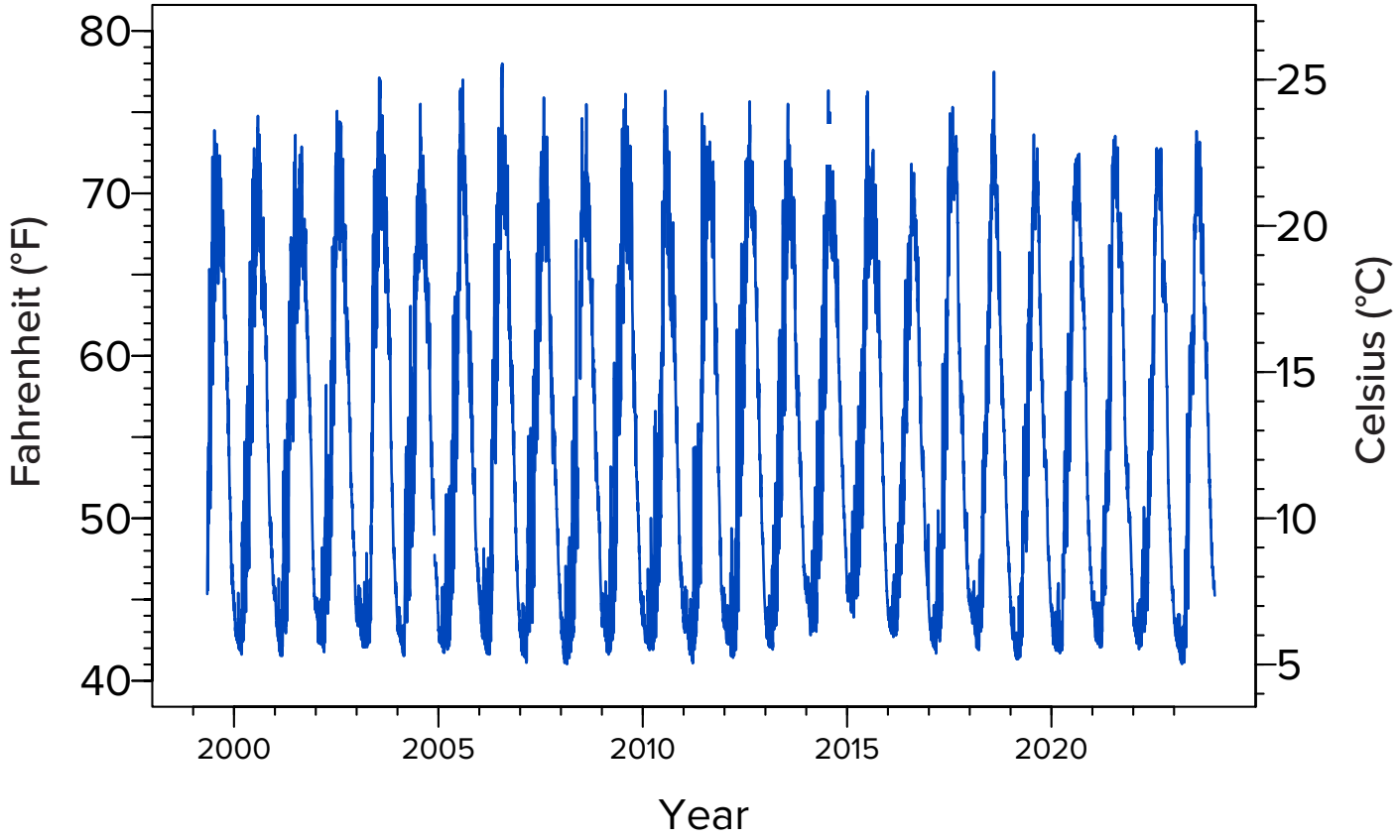
## Maximum daily surface water temperature

**Surface temperature measured since 1999 every 2 minutes**

The maximum daily surface water temperature follows a sinusoidal pattern, with the temperature being in equilibrium with the air temperature and other meteorological variables. In 2023, the highest maximum daily surface water temperature (summer) was 73.8 °F (23.2 °C), recorded on July 21. The lowest maximum daily surface water temperature (winter) was 41.0 °F (5.0 °C), which was recorded on March 13. This was relatively warm, due in part to the absence of deep mixing.

These data are collected from thermistors at a depth of 5 feet (1.5 m) that are attached to four research buoys located over the deepest parts of the lake. The highest daily value from among the four buoys is considered as the daily maximum.

Data source: TERC lake monitoring.



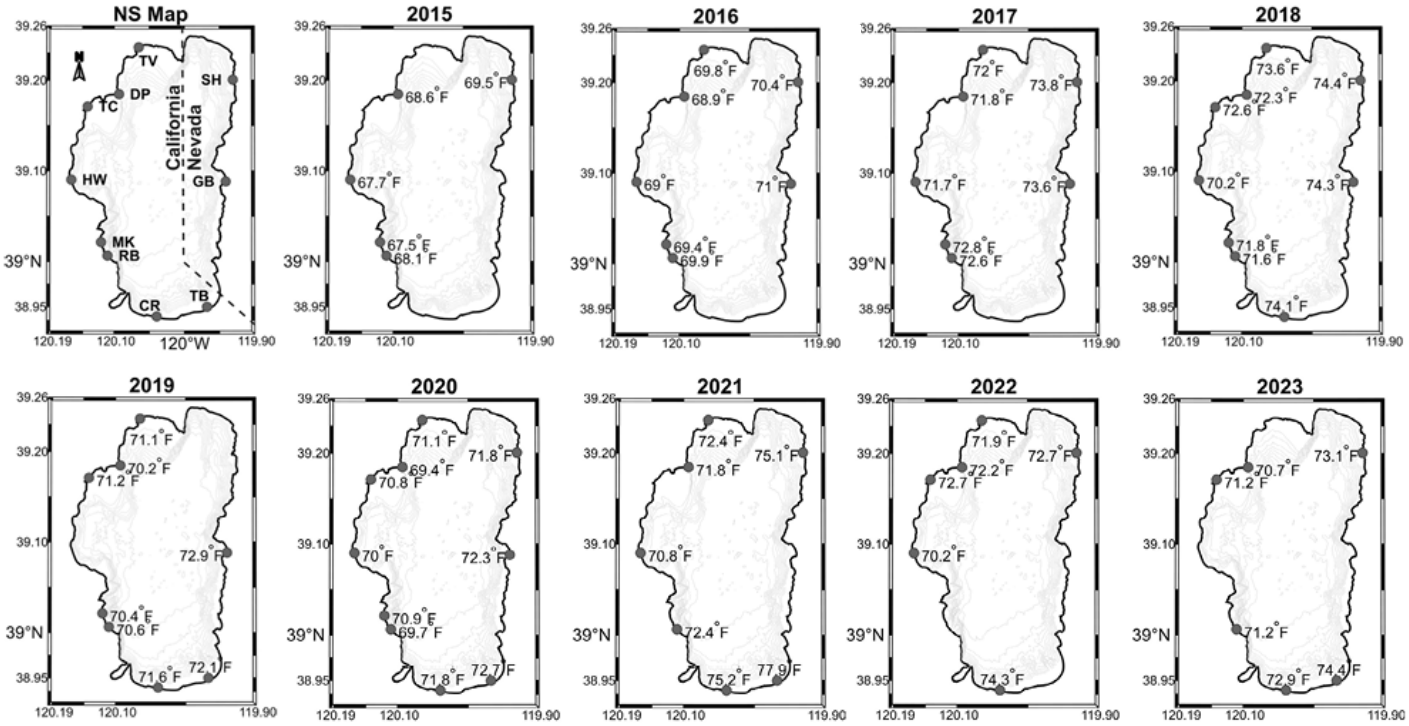
## Maximum annual nearshore water temperature

**Surface temperature measured by nearshore sensors**

In 2014, TERC began installing a network of nearshore water quality monitoring stations around the perimeter of Lake Tahoe. The monitoring program aims to improve understanding of water quality variability in the nearshore zone. In 2023 there were 10 active stations installed around Lake Tahoe, including one station on Cascade Lake, which feeds into Lake Tahoe. Each station consists of an optical instrument measuring turbidity (clarity), algal concentration, and dissolved organic matter concentrations, dissolved oxygen, along with a Conductivity Temperature Depth (CTD) sensor, measuring conductivity, water temperature, water depth, and wave height. An underwater cable connected to shore power and internet enables a real-time data feed with high resolution data every 30 seconds.

Nearshore Sensor Stations (clockwise from top): Tahoe Vista (TV), Sand Harbor (SH), Glenbrook (GB), Timbercove (TB), Camp Richardson (CR), Rubicon Bay (RB), Meeks Bay (MK), Homewood (HW), Tahoe City (TC), and Dollar Point (DP)

Data source: TERC lake monitoring.



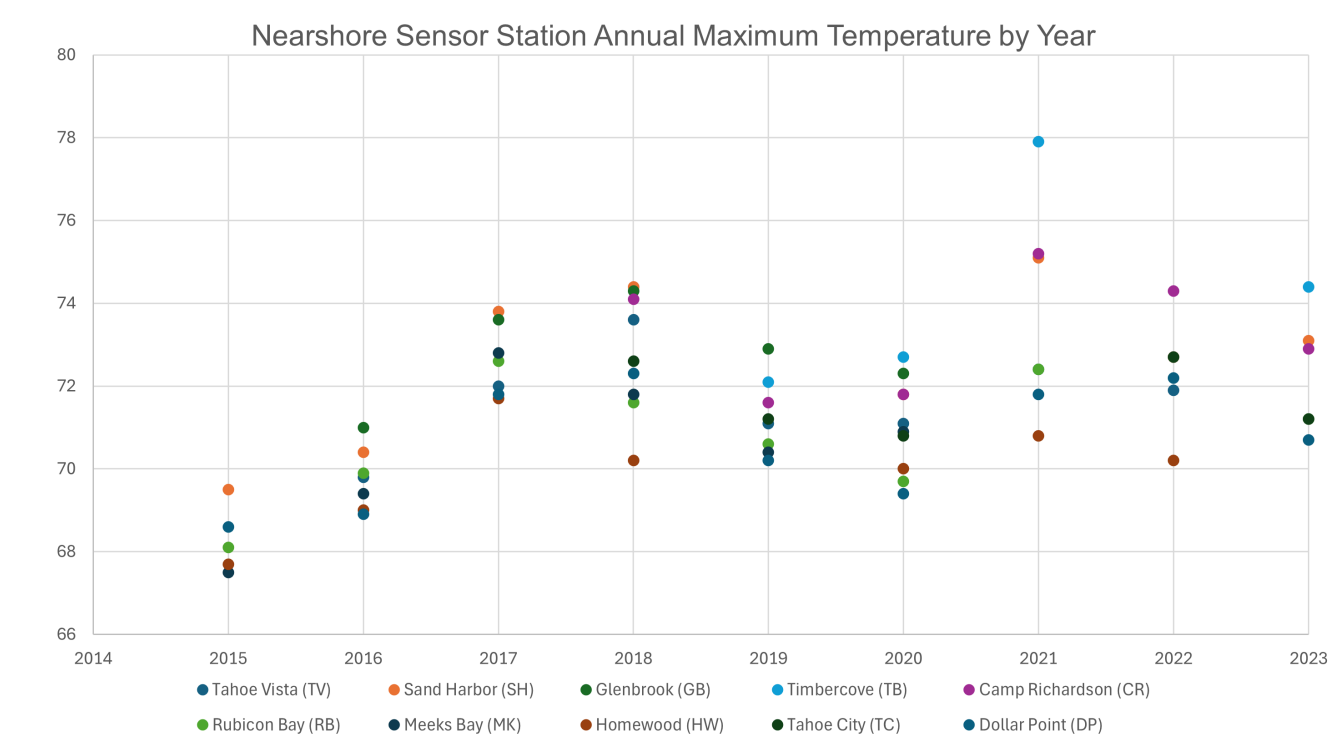
## Maximum annual nearshore water temperature, continued

**Surface temperature measured by nearshore sensors**

The strategic locations of the nearshore sensor network allow us to characterize the spatial heterogeneity of Lake Tahoe's nearshore while identifying the lake locations that tend to exhibit warmer temperatures as well as the locations with the most striking impact from the wind.

The figure shows an evident increase in the water temperature at all sites since 2015. The eastern shore tends to be warmer than the western shore because of the usual southwestern winds (the wind pushes the warmer surface water towards the east). The southern shore is exhibiting a rapid increase in temperature, likely due to the broad sediment shelf and shallow water column.

Data source: TERC lake monitoring.

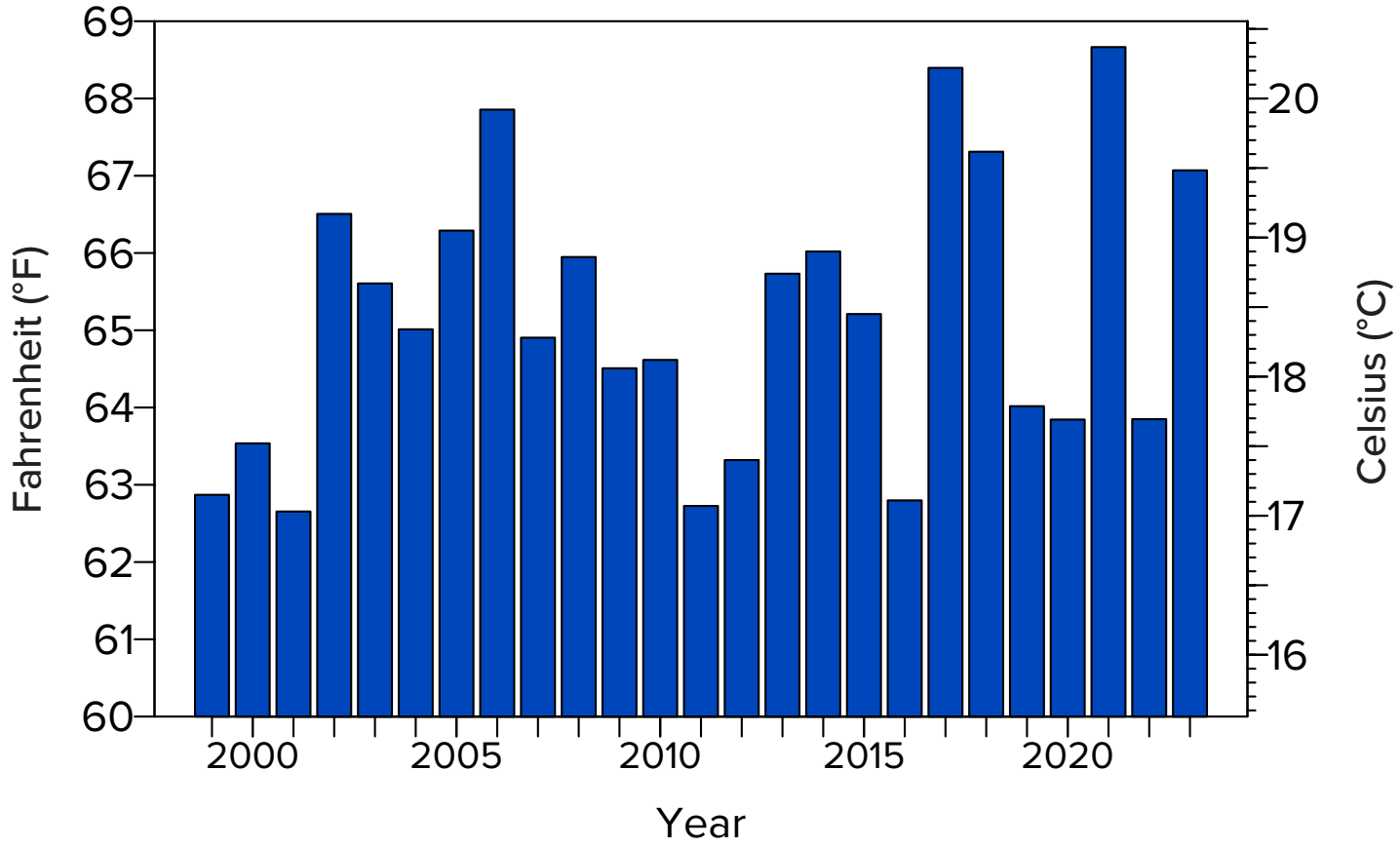


## July average surface water temperature

**Measured since 1999 every 2 minutes**

Surface water temperature has been continuously recorded since 1999 from four NASA/UC Davis buoys in the center of the lake. Shown here are 25 years of average surface water temperatures in the month of July when water temperatures are typically at their warmest and the greatest number of people are recreating on the lake. In 2023, July surface water temperature was relatively warm. It averaged 67.1 °F (19.5 °C). This was increase over the previous year. The long-term average is 65.2°F (18.4°C) for the 25-year period of record. These data are collected from thermistors at a depth of 5 feet (1.52 m) that are attached to four buoys located over the deepest portions of the lake.

Data source: TERC lake monitoring.



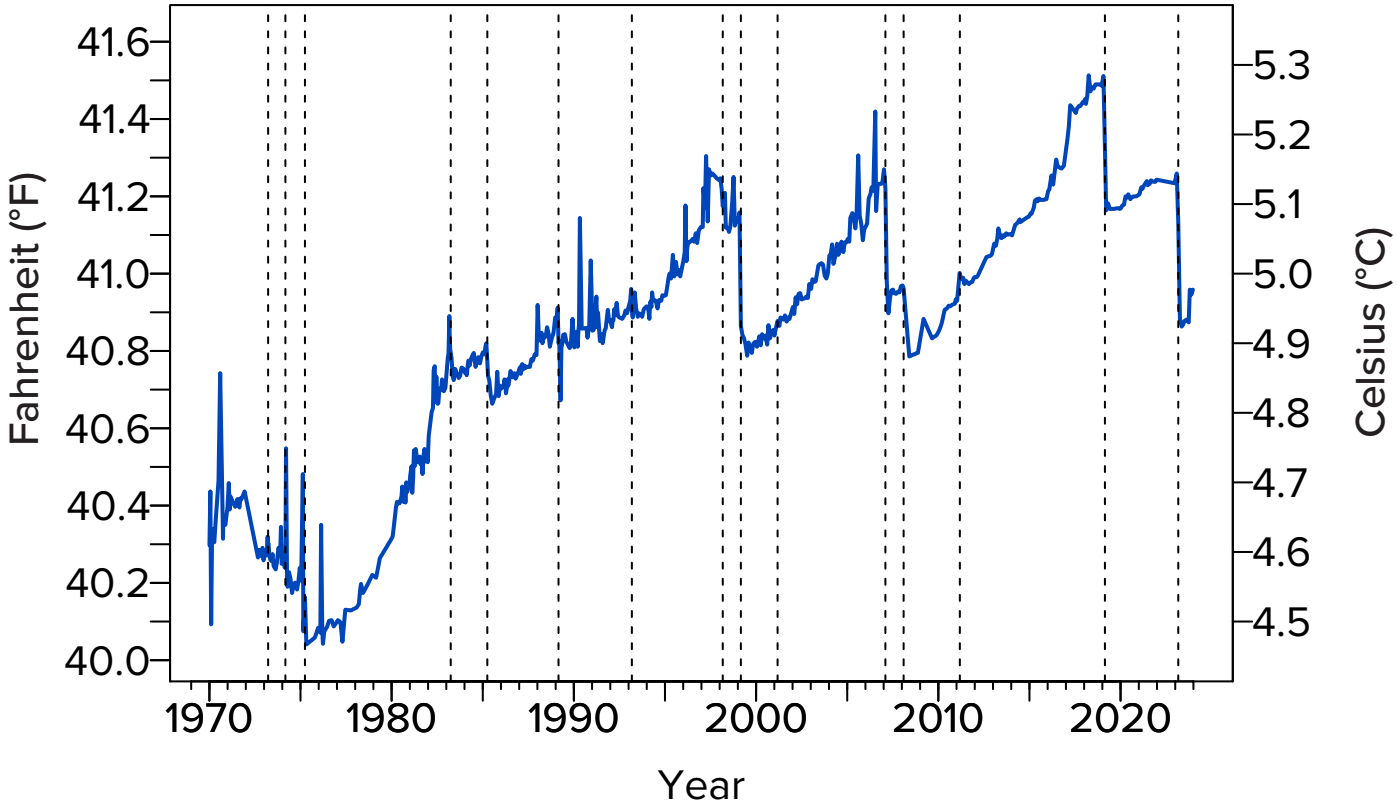
## Deep water temperature

**Monthly since 1970**

The water temperature at a depth of 1,320 feet (400 m) is indicative of conditions in the deeper waters (hypolimnion) of Lake Tahoe. The deep-water temperatures show a complex pattern of warming and sudden cooling. During deep mixing events (the dashed vertical lines), the temperature can drop "precipitously" over a short period of time, although these drops are generally less than 0.3 °F. The heating of the bottom water along with the fluctuations when deep mixing does not occur is an area of current research.

In general, bottom temperatures are warming. Complete vertical mixing is an event that allows a large amount of heat to escape from the lake. In 2023, there was deep mixing (see Fig. 8.9) and water temperatures dropped by 0.4 °F from 41.26 °F to 40.86 °F. Between the last two deep mixing events in 2011 and 2019, the rate of water warming was 0.07 °F/yr.

Data source: TERC lake monitoring.



## Depth of mixing

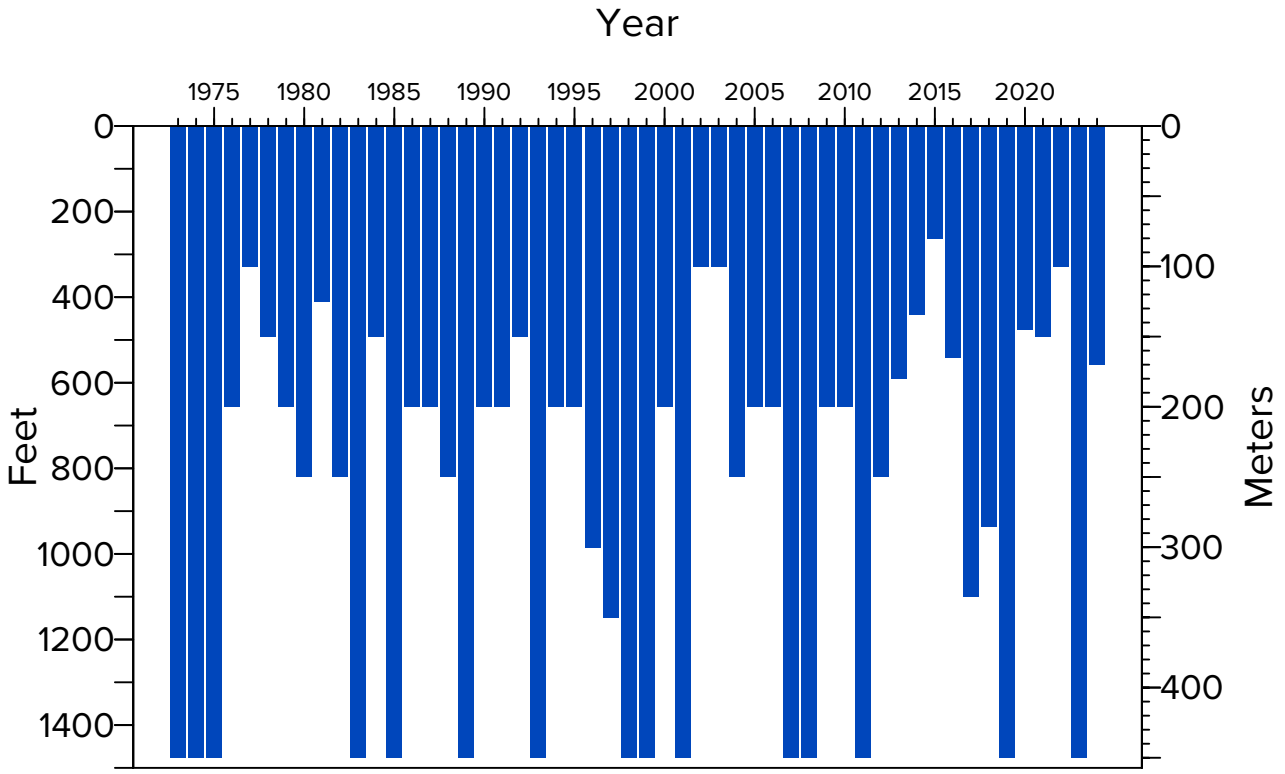
**Yearly since 1973**

The water of Lake Tahoe vertically mixes each winter as surface waters cool and sink downward. In a lake as deep as Tahoe, the intensity of cooling in winter determines how deep the lake mixes vertically. Mixing depth has profound impacts on lake ecology and water quality. Deep mixing brings nutrients to the surface, which promote algal growth. It also carries oxygen downward to deep waters, promoting aquatic life throughout the water column.

The deepest mixing typically occurs between February and March. On March 3, 2023, Lake Tahoe was observed to have mixed fully to a depth of 1476 feet (450 m). The duration of the 2023 mixing period is one of the longest recorded. This resulted because of the timing of a series of storms affecting the region.

Since 2013, the depth of mixing has been determined with high-resolution temperature profiles rather than nitrate concentration sampled at discrete depths. Continuous temperature measurements off Glenbrook provided additional confirmation data.

Data source: TERC lake monitoring.

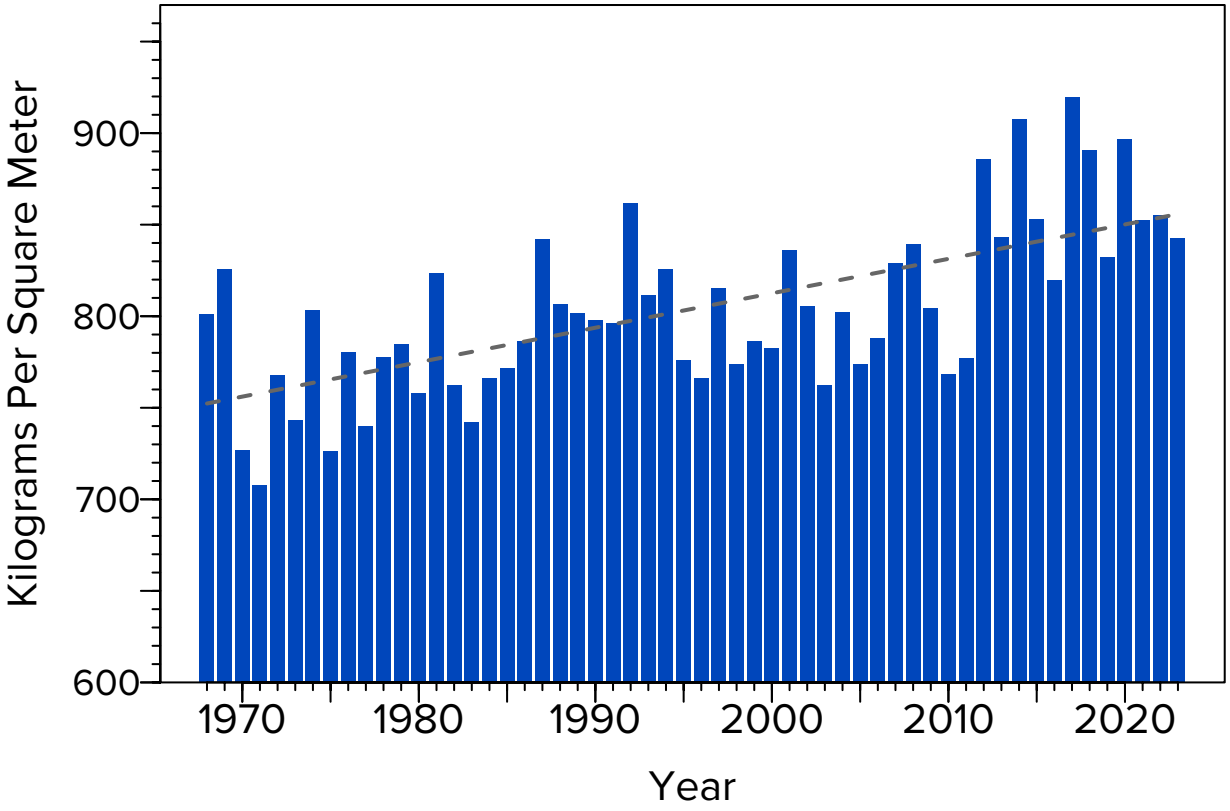


## Lake stability index

**Since 1968**

Increasing stability poses a potential threat to all lakes. When the lake has a vertical distribution of temperature, it has a corresponding distribution of density. Warmer and lighter water remains at the surface above the colder and denser water below. As the temperature difference between top and bottom increases, the lake is said to become more stable. The stability index is a measure of the energy required to vertically mix the lake when it is density stratified. The average stability index for the upper 330 feet (100 m) of Lake Tahoe is plotted for the period of May through October each year. The values are derived from temperature profiles taken at the Index Station at approximately 10- to 20-day intervals. There has been an overall increase in lake stability by 13.8 percent in the last 55 years.

Data source: TERC lake monitoring.

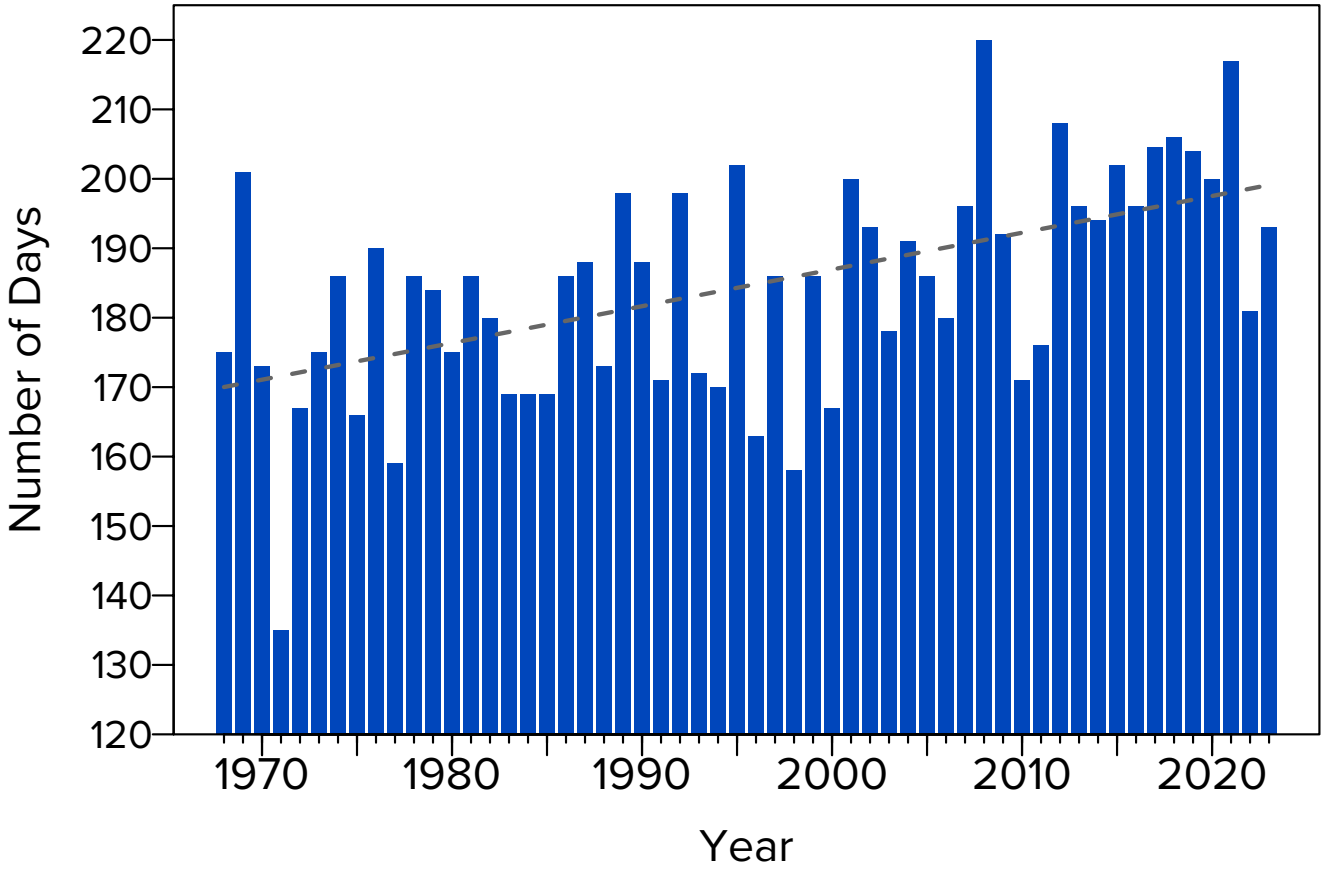


## Stratified season length

**Since 1968**

The stability index is a measure of the energy required to vertically mix the lake that can be evaluated for every day of the year. We define the stratification season as the number of days when the stratification index exceeds a value of 600 kilograms per square meter. Since 1968, the length of the stratification season has increased by 29 days, albeit with considerable year-to-year variation. In 2023, the length of the stratified season was 193 days.

Data source: TERC lake monitoring.



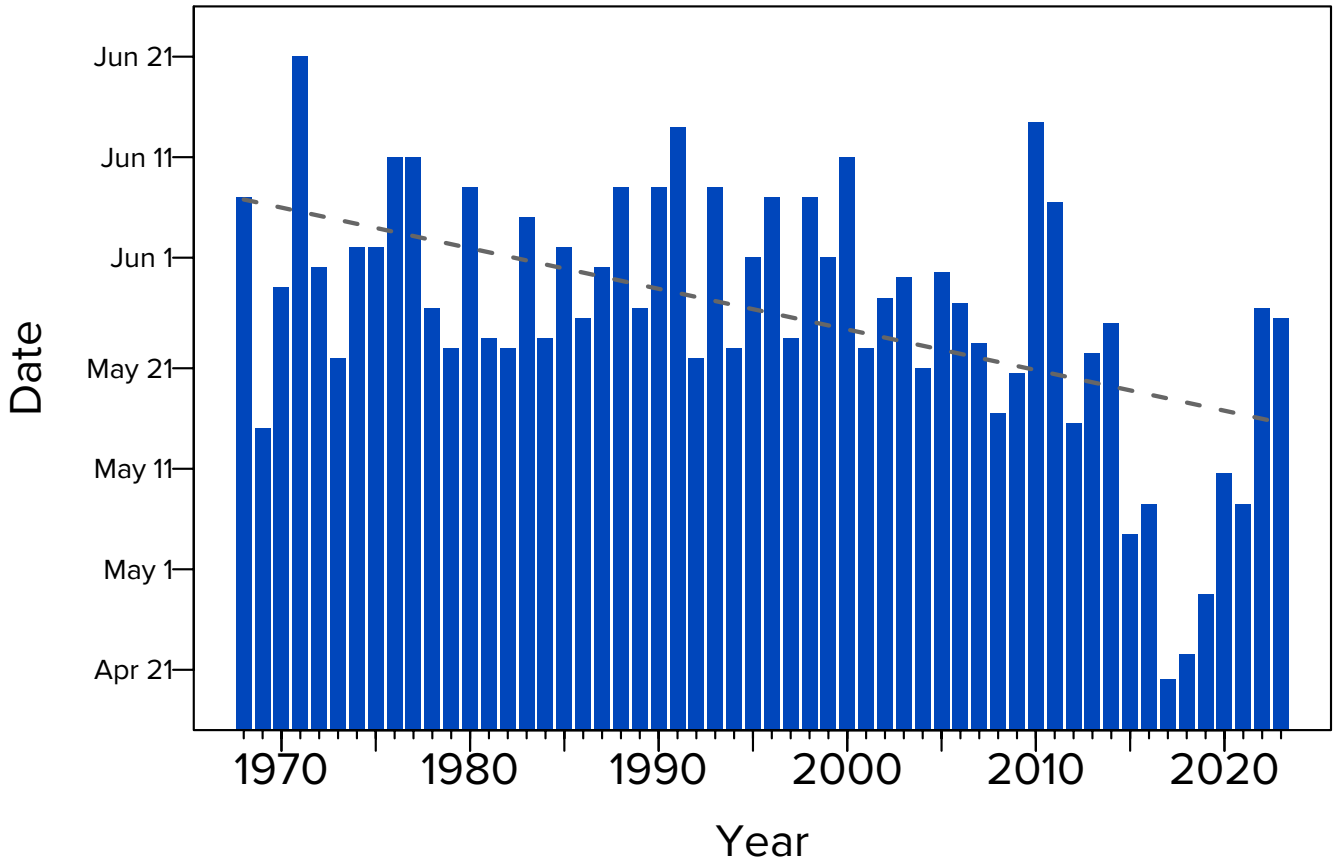
## Beginning of the stratification season

**Since 1968**

The amount of time that Lake Tahoe is stratified has been increasing since 1968. One reason for this is the increasingly early arrival of spring as evidenced by the earlier commencement of stratification.

In 2023, the stratification commenced relatively late, on May 26 (Day 146). This was almost two weeks later than the long-term trend line would have suggested.

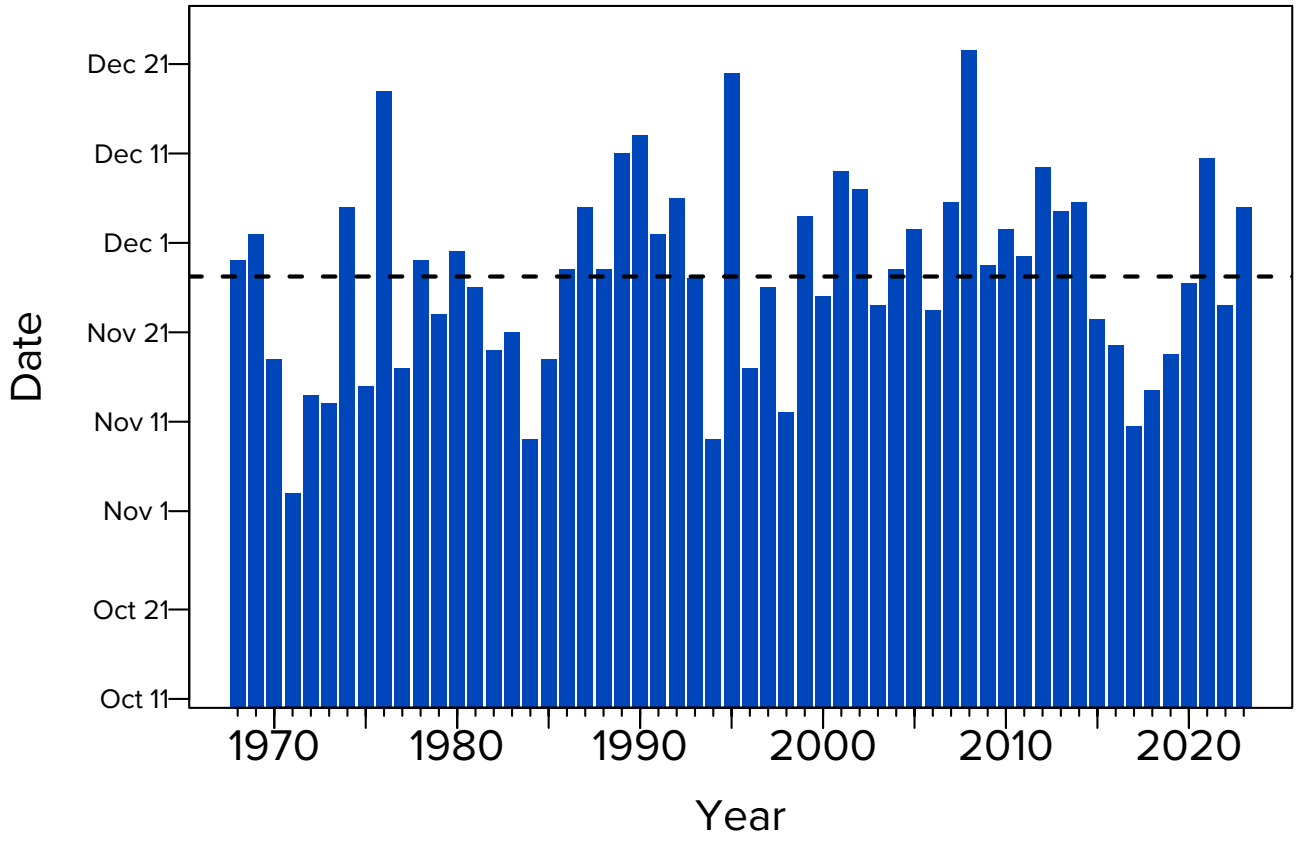
Data source: TERC lake monitoring.



## End of stratification season

**Since 1968**

The amount of time that Lake Tahoe is stratified appears to have increased by almost a month since 1968. The end of the stratification season has been extended, but not as much as the onset of stratification (See Fig. 8.12). Over the 55-year record, the end of stratification appears to have been extended by approximately one week. Although the trend is not statistically significant, extended duration of stratification can have important implications for lake mixing and water quality, such as the buildup of nitrate at the bottom of the lake and the timing of deep-water mixing events. The dashed black line indicates the long-term mean for the end of stratification date. In 2023, the end of stratification was five days later than the long-term mean.
Data source: TERC lake monitoring.

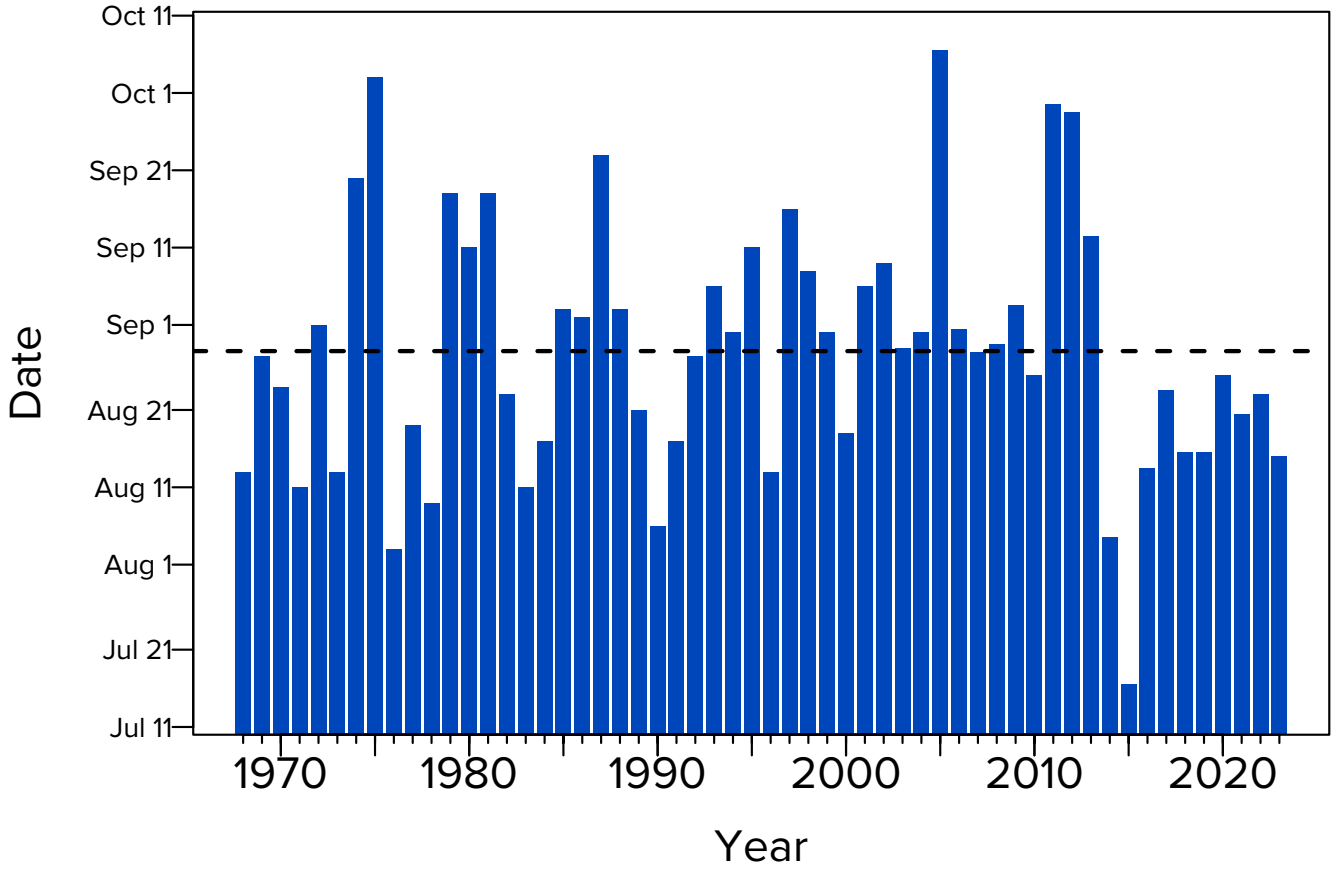


## Peak of stratification season

**Since 1968**

Over the last ten years the occurrence of the peak of stratification has been earlier than the long term mean date. The day of the year when lake stratification reaches its maximum value is the peak of stratification season. There is considerable year-to-year variation, but over time there has been no statistically significant change in when the peak occurs. The dashed line shows the long-term mean. In 2023, the peak occurred on August 15.

Data source: TERC lake monitoring.



## Onset of snowmelt pulse

**Yearly since 1961**

Although the date on which the onset of snowmelt commences varies from year to year, since 1961 it has shifted earlier by an average of over 16 days. The snowmelt pulse is calculated and averaged for five streams—the Upper Truckee River, Trout Creek, Ward Creek, Blackwood Creek, and Third Creek. This shift is statistically significant and is one effect of climate change at Lake Tahoe. In 2023, the onset occurred on April 24, thirty-five days later than the previous year. According to the regression line, since 1961, the onset of the snowmelt pulse has occurred earlier by 17 days than it did in 1961. The onset of the pulse is calculated as the day when flow exceeds the mean flow for the period January 1 to July 15. In the past, the peak of the stream hydrograph was used to estimate this metric.

Data source: US Geological Survey stream monitoring.