

TAHOE: STATE OF THE LAKE REPORT 2018

PHYSICAL PROPERTIES



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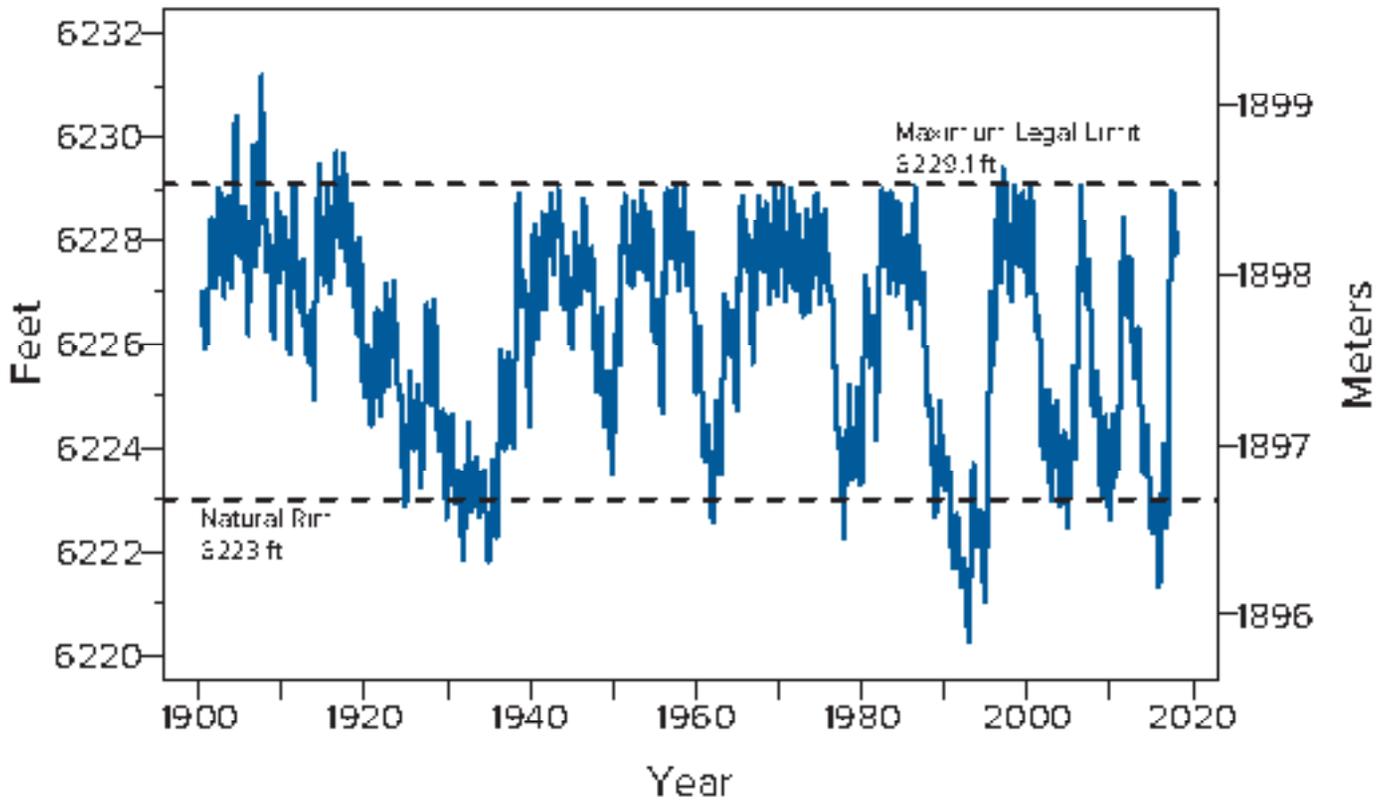
Lake surface level

Daily since 1900

Lake surface level varies throughout the year. Lake level rises due to high stream inflow, groundwater inflow, and precipitation directly onto the lake surface. It falls due to evaporation, in-basin water withdrawals, groundwater outflows, and outflow via the Truckee River at Tahoe

City. Overall, lake level rose 5.7 feet during 2017. The highest lake level was 6,229.0 feet on July 7, and the lowest was 6,223.3 feet on January 1. The natural rim of the lake is at an elevation of 6,223 feet. Lake Tahoe was above its rim for the entire year. When the lake is below its rim, outflow via

the Truckee River ceases. Several episodes of lake level falling below the natural rim are evident in the last 114 years. The frequency of such episodes appears to be increasing.



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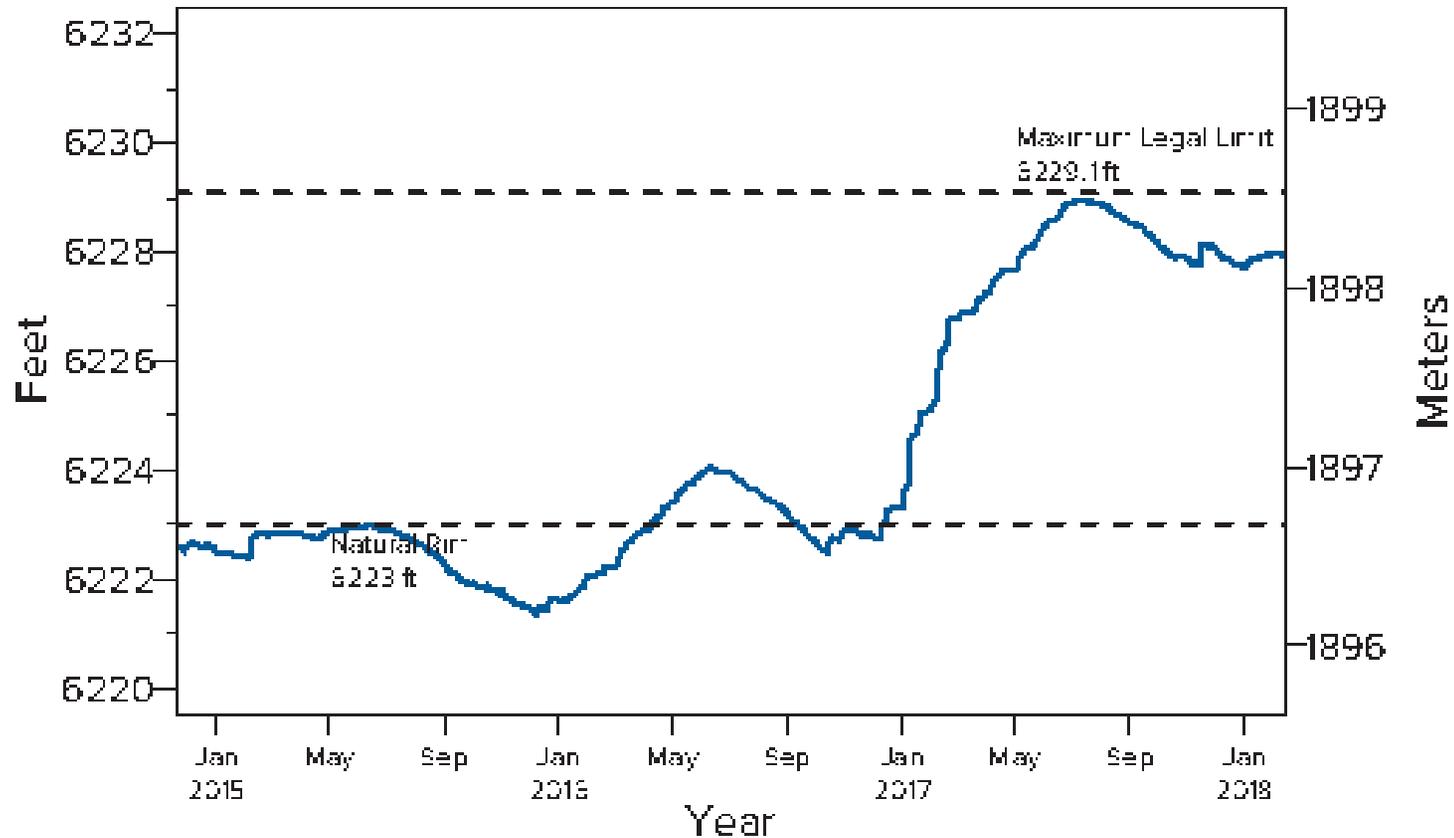
Lake surface level, continued

Daily since 2015

Displayed below is the lake surface data from 2015-2017 extracted from the same data on page 8.1. This more time-restricted presentation of recent lake level data allows us to see the annual patterns of

rising and falling lake level in greater detail. Data clearly show the effects of the five-year drought with the lake below the natural rim, and then the rapid rise during the first six months of 2017. The fall off in

lake level in the latter half of the year was primarily due to evaporation.



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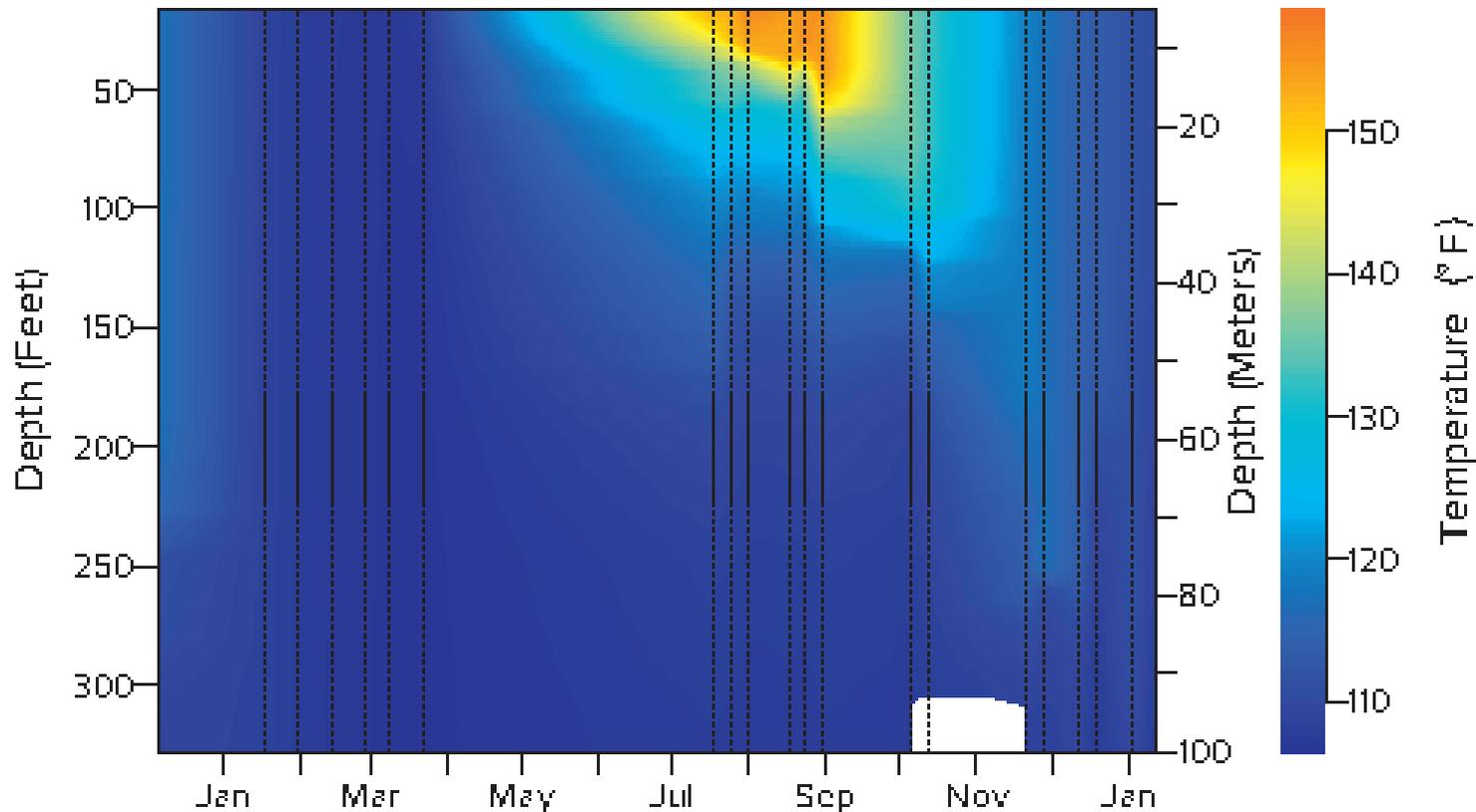
Water temperature profile

In 2017

Water temperature profiles are measured in the lake using a Seabird CTD (conductivity, temperature, depth) profiler at the times indicated by the dashed vertical lines. The temperature is accurate to within 0.005 °F. Here the temperature in the upper 330 feet

(100 m) is displayed as a color contour plot. In 2017, the lake temperature followed a typical seasonal pattern. In February-March, the lake surface was at its coldest, while it was at its warmest at the end of August. The deepening of the warm water zone toward the end of

the year is the result of winter mixing, although in 2017, the fall mixing was reduced from earlier years. Profiles from April to July were discarded due to instrument malfunctions.



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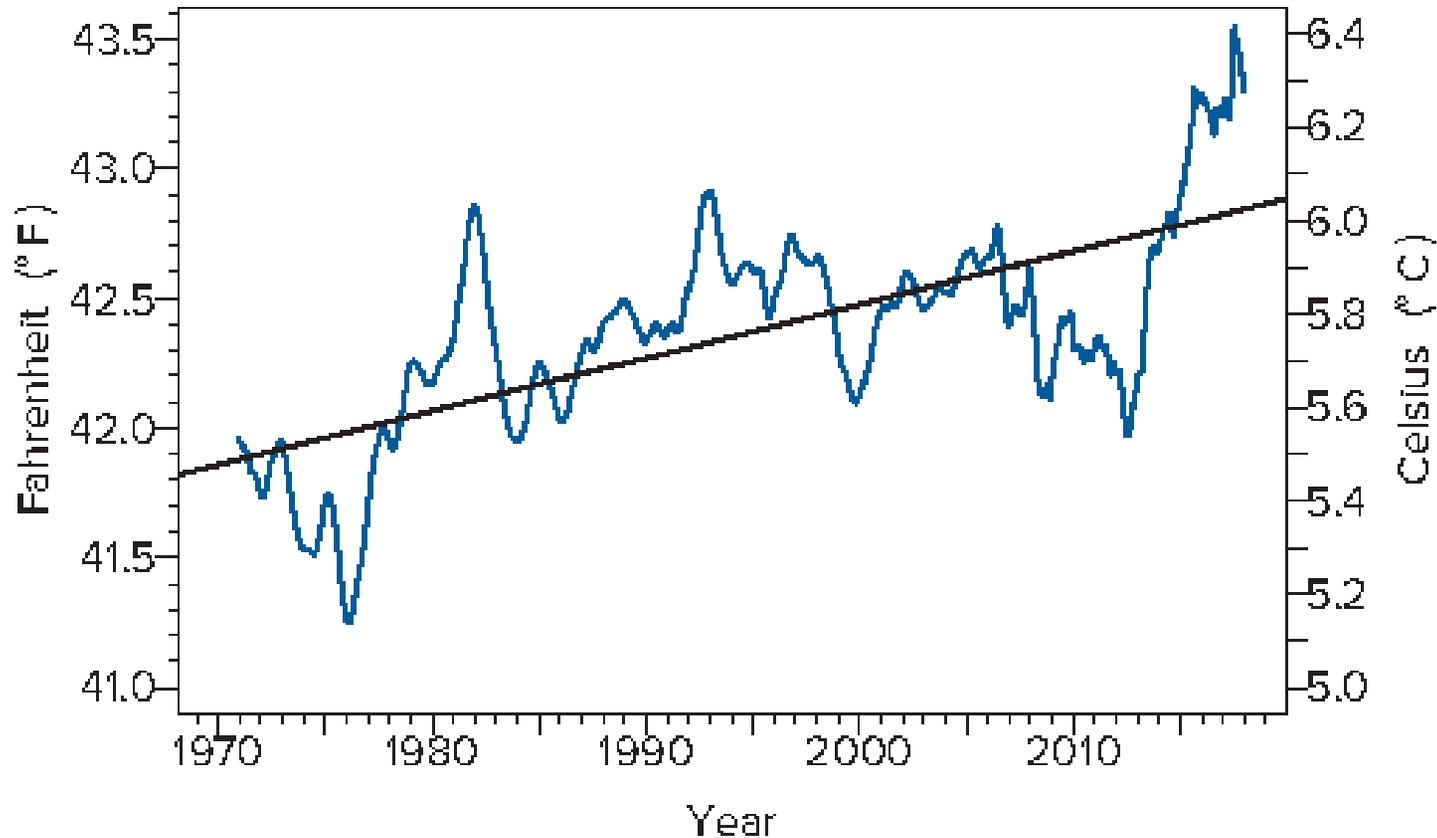
Average water temperature

Since 1970

The trend in the volume-averaged temperature of Lake Tahoe has increased by approximately 0.96 °F since 1970. The annual rate of warming is 0.020 °F/year (0.011 °C/year). The monthly

temperature profile data from the top to the bottom of the lake has been smoothed and seasonal influences removed to best show the long-term trend. Up until the late 1990s, the warming rate was high,

but the large number of deep mixing years between 1997 and 2011 caused the lake temperature to cool. Since that time, warming has accelerated to its highest recorded rate.



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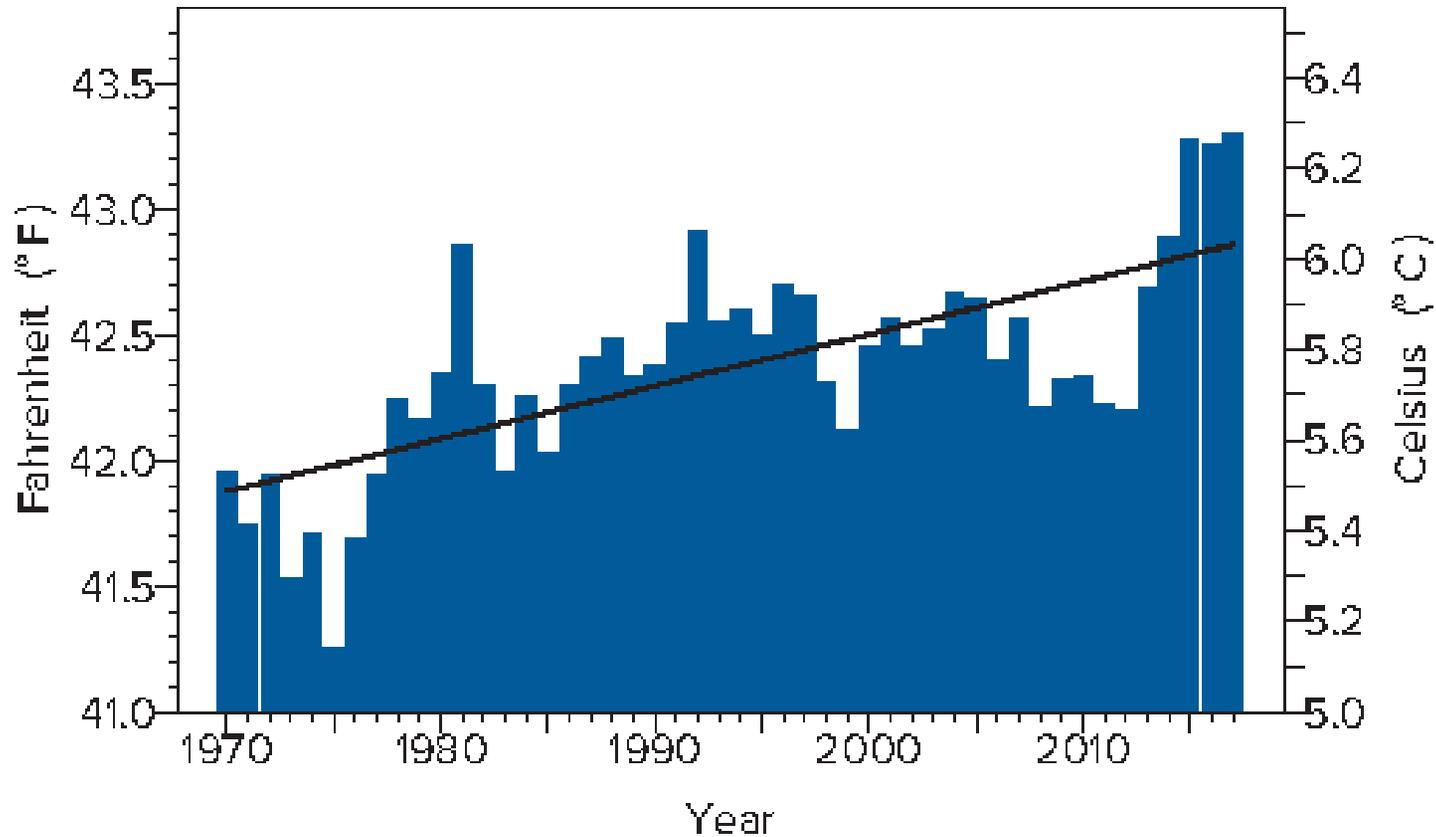
Annual average water temperature

Since 1970

The volume-averaged temperature of the lake for each year since 1970 is shown. In 2017, the volume-averaged temperature increased by only 0.04 °F (0.02 °C) over

the previous year, but bringing it to the warmest value recorded. Since 2012, the average temperature of the lake has warmed by 1.1 °F (0.61 °C). Increases

in temperature generally correspond to those years in which deep mixing did not occur. In 2017, deep mixing did not occur for the sixth year in a row.



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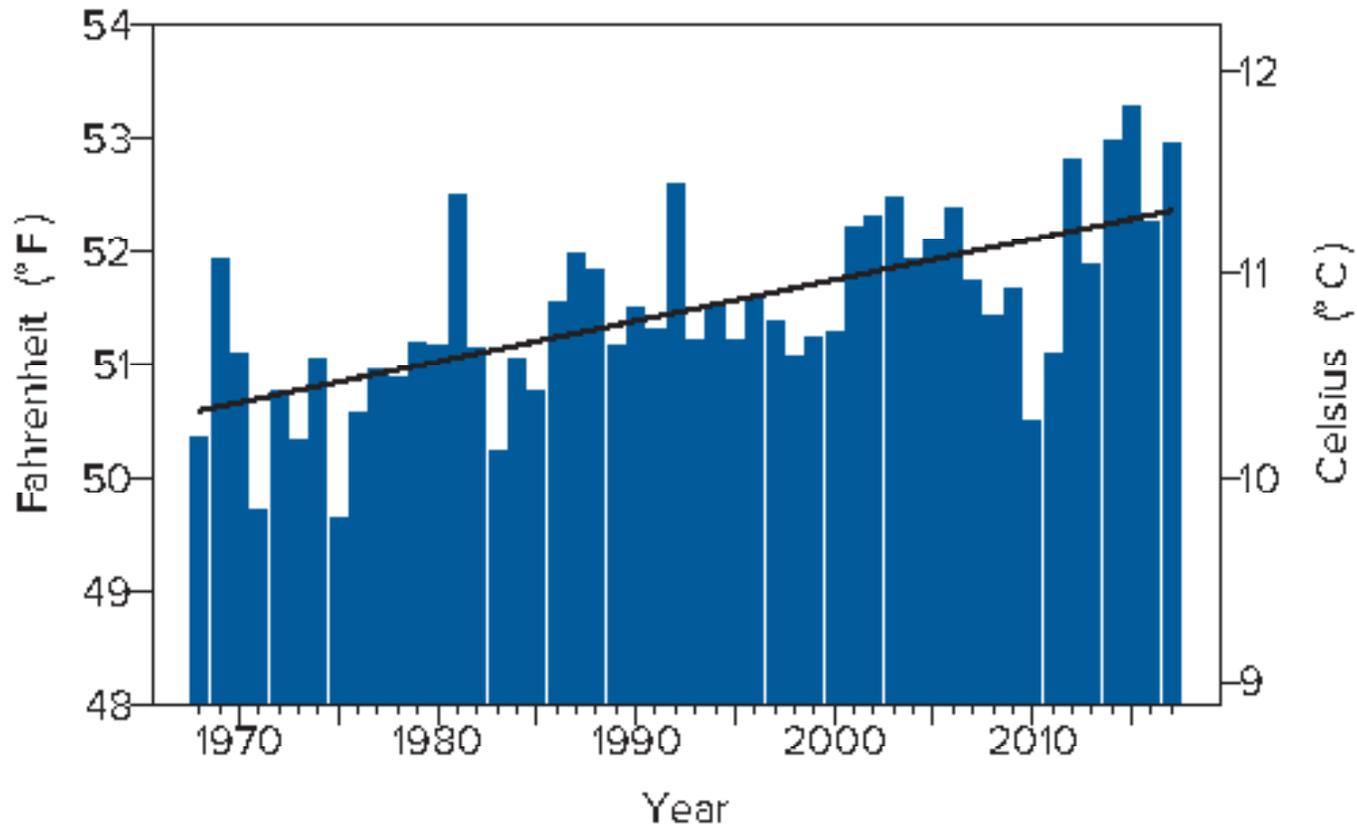
Surface water temperature

Yearly since 1968

Surface water temperatures have been recorded monthly at the Mid-lake and Index stations since 1968 from the R/V John LeConte and the R/V Bob Richards. Despite year-to-year variability,

the annual average surface water temperatures show an increasing trend. The average surface water temperature in 1968 was 50.3 °F (10.2 °C). For 2017, the average surface water temperature

was 53.0 °F (11.6 °C). The overall rate of warming of the lake surface is 0.036 °F (0.020 °C) per year.



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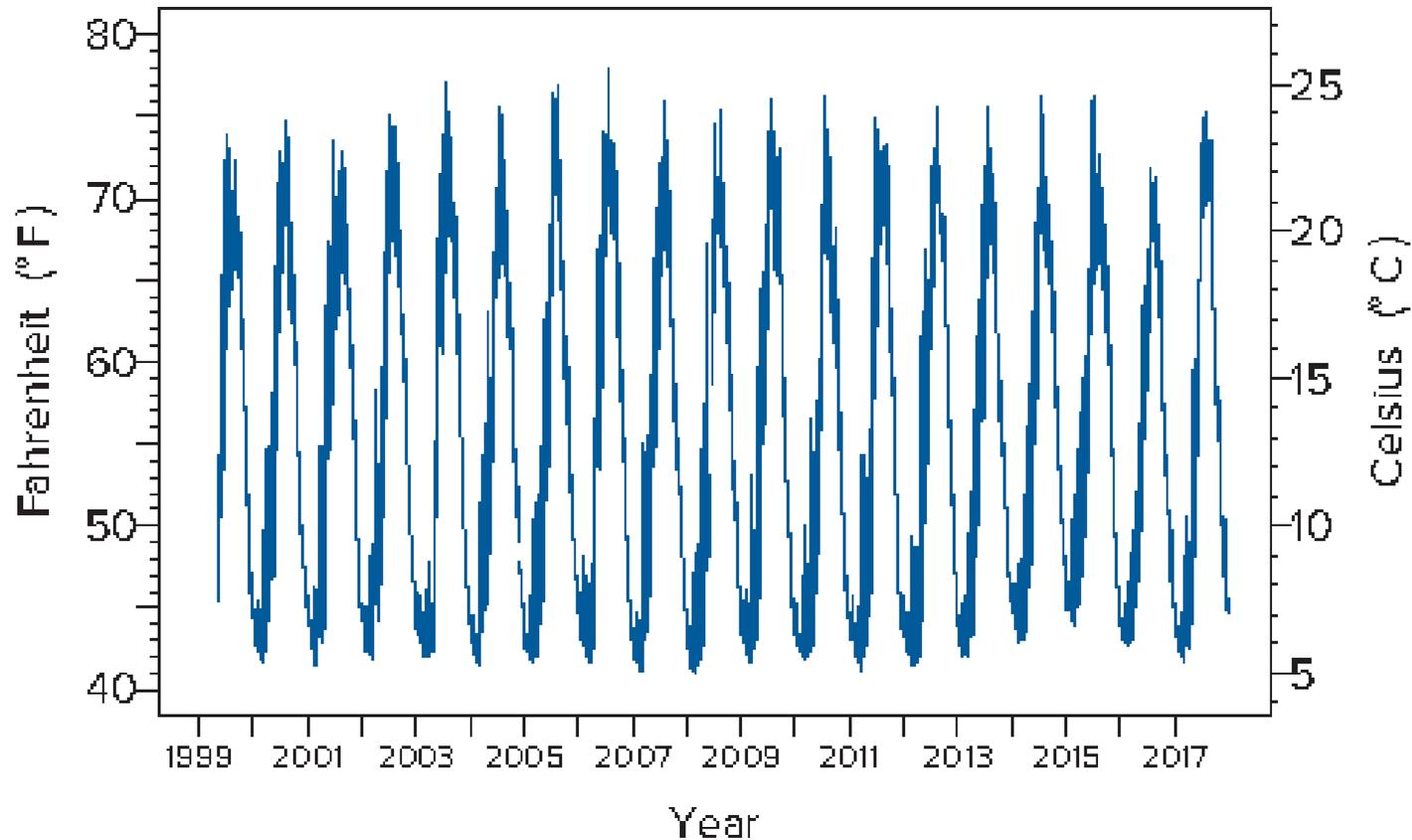
Maximum daily surface water temperature

Surface temperature measured since 1999 every 2 minutes

The daily surface water temperature records are based on continuous (every 2 min.) data collection. In 2017, the highest maximum daily surface water temperature (summer) was 75.31 °F,

which was recorded on August 1, 2017. This was 2.27 °F warmer than the previous year. The lowest maximum daily surface water temperature (winter) was 41.68 °F, which was recorded on March

6, 2017. This was 0.72 °F cooler than the previous year. These data are collected in real-time by NASA-JPL and UC Davis from 4 buoys located over the deepest parts of the lake.



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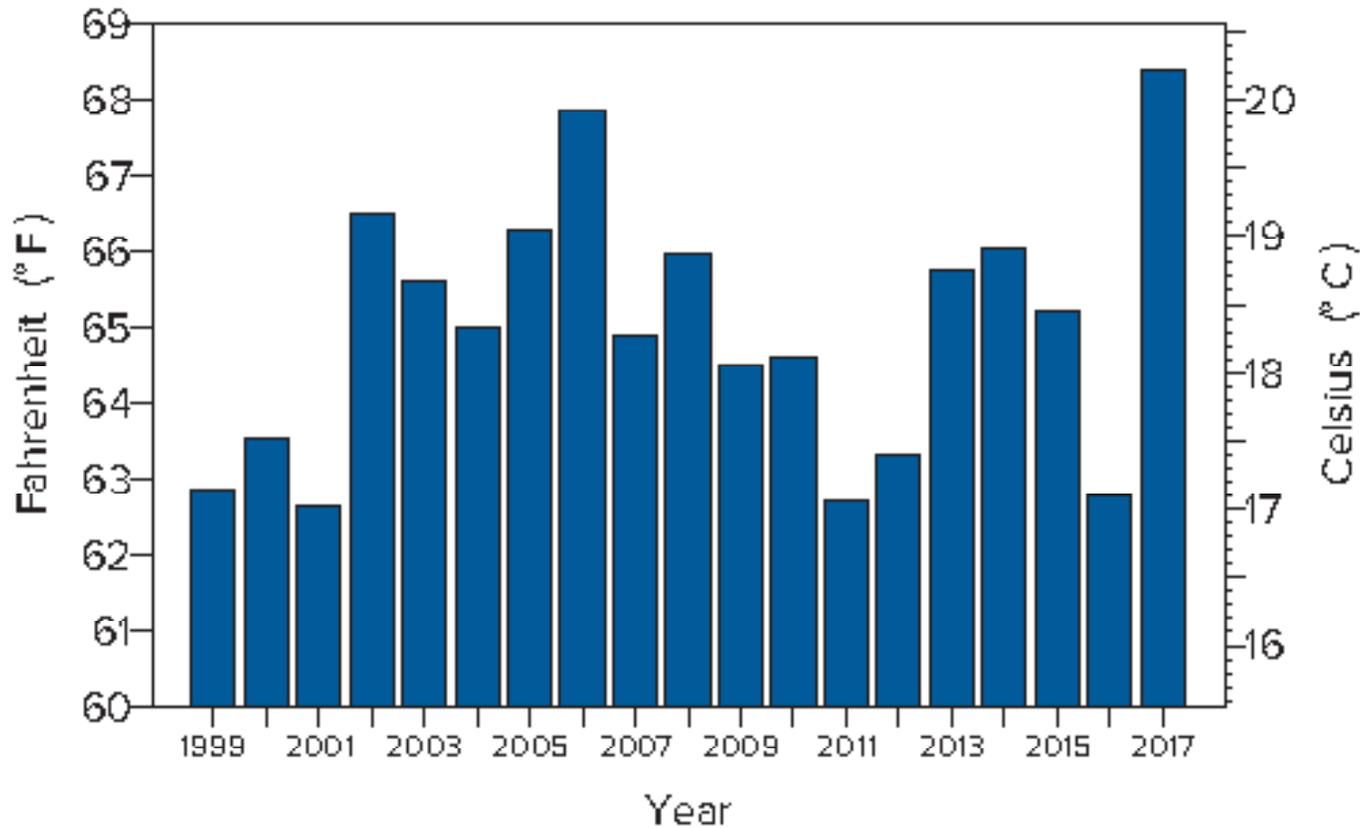
July average surface water temperature

Measured since 1999 every 2 minutes

Since 1999, surface water temperature has been recorded every two minutes from four NASA/UC Davis buoys. Shown here are 19 years of average surface water temperatures in the month of July, when

water temperatures are typically warmest. In 2017, July surface water temperature averaged 68.4 °F, an astounding 6.1 °F above the 2016 value. It was the warmest July on record. Low winds combined

with elevated air temperatures in July were responsible for the warm water temperatures. The average July surface water temperature for the 19-year period is 65.0 °F.



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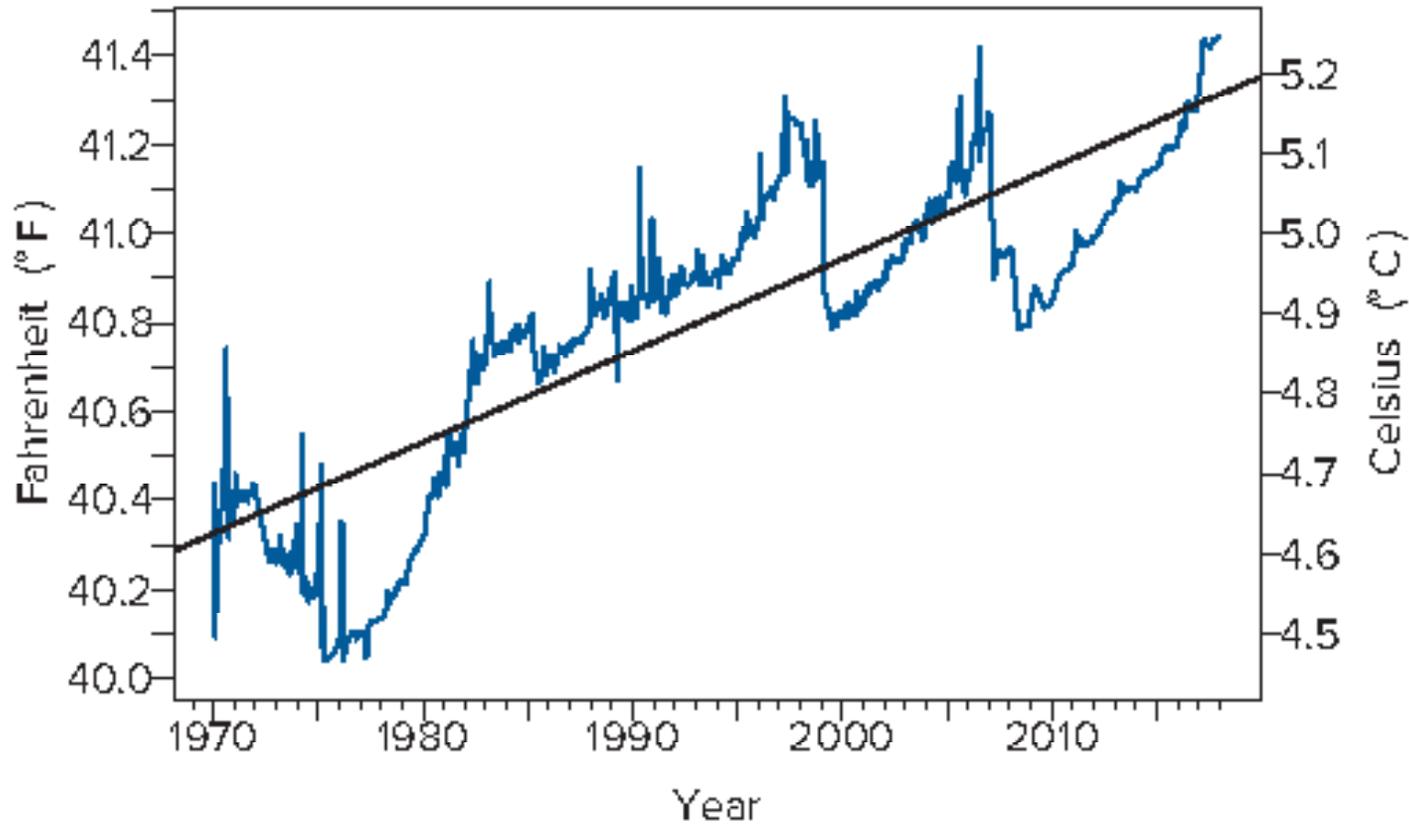
Deep water temperature

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. Since 1970, the deep water temperature has increased by 0.95 °F (0.53 °C), at an annual rate of 0.020 °F (0.011 °C), a rate of warming that is half

that of the surface water. This increase has not been steady and is punctuated by occasional drops in temperature. These coincide with times when the lake completely mixes to the bottom, an event which allows a huge amount of heat to escape from the lake. The impact of Lake

Tahoe's lack of deep mixing in the last seven years is evident by the accelerating increase in bottom warming. The short spikes of temperature increase are temporary effects caused by the motions of internal waves (or seiches) and other transient phenomena.



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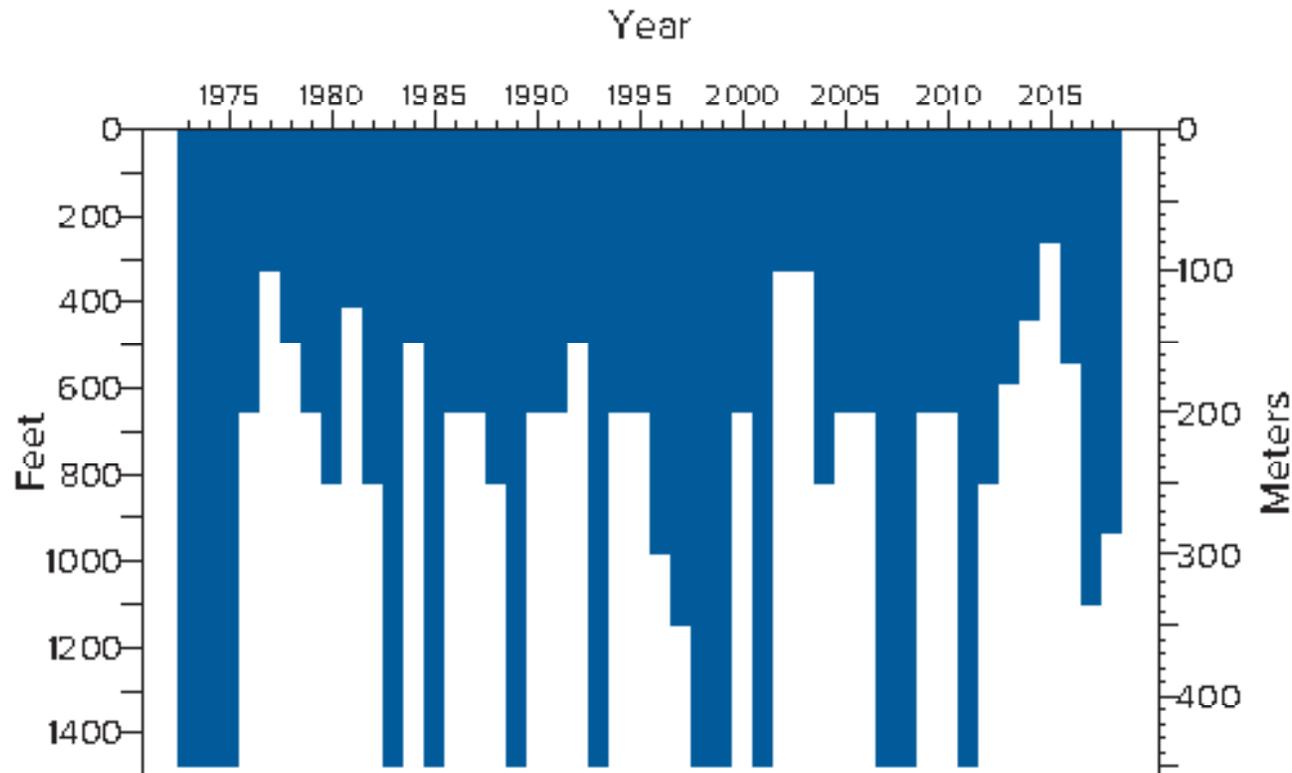
Depth of mixing

Yearly since 1973

Lake Tahoe mixes each winter as surface waters cool and sink downward. In a lake as deep as Tahoe, the wind energy and intense cooling of winter determine how deep the lake mixes. Mixing depth has profound impacts on lake ecology and water quality. Deep mixing brings nutrients to the surface, where they promote algal growth. It also moves

oxygen to deep waters, promoting aquatic life throughout the water column. The deepest mixing typically occurs between February and March. In 2017, Lake Tahoe mixed to a depth of 1,099 feet (335 m). In 2018, Lake Tahoe mixed to a depth of only 935 feet (285 m), a little more than half of the total depth. This lack of deep mixing most likely contributed to the warm

surface and bottom temperature, the continuing buildup of nitrate in the lake, and the generally lower clarity. Beginning in 2013, the determination of the depth of mixing has been based on high-resolution temperature profiles rather than nitrate concentration sampled at discrete depths.



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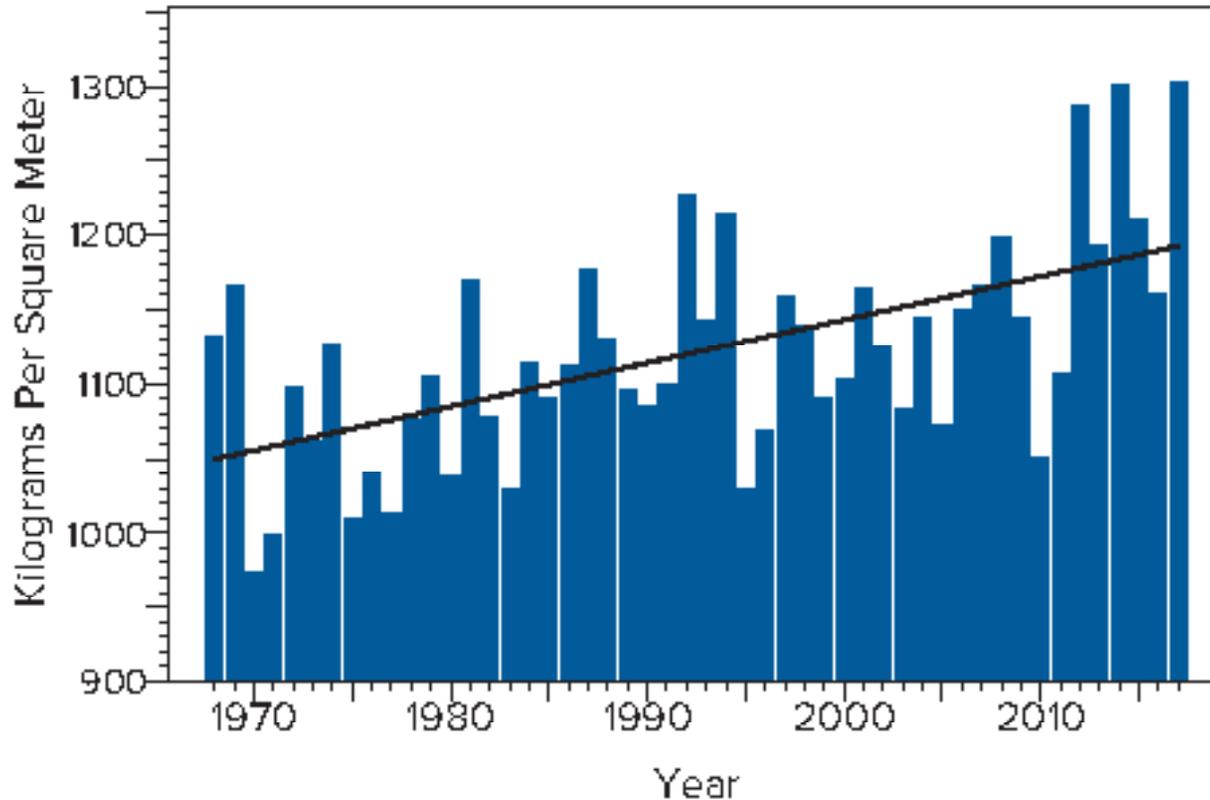
Lake stability

Since 1968

When the lake has a vertical distribution of temperature, it has a corresponding density distribution, with warm and lighter water at the surface and colder, heavier water at depth. The stability index is a measure of the energy required to fully mix the water column when its

density is 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 10-20 day intervals.

There has been an overall increase in lake stability by over 13 percent in the last 50 years. In 2017, the stability of the lake reached its highest recorded value. This is consistent with the continued absence of deep mixing, the warm surface temperatures and the reduced clarity.



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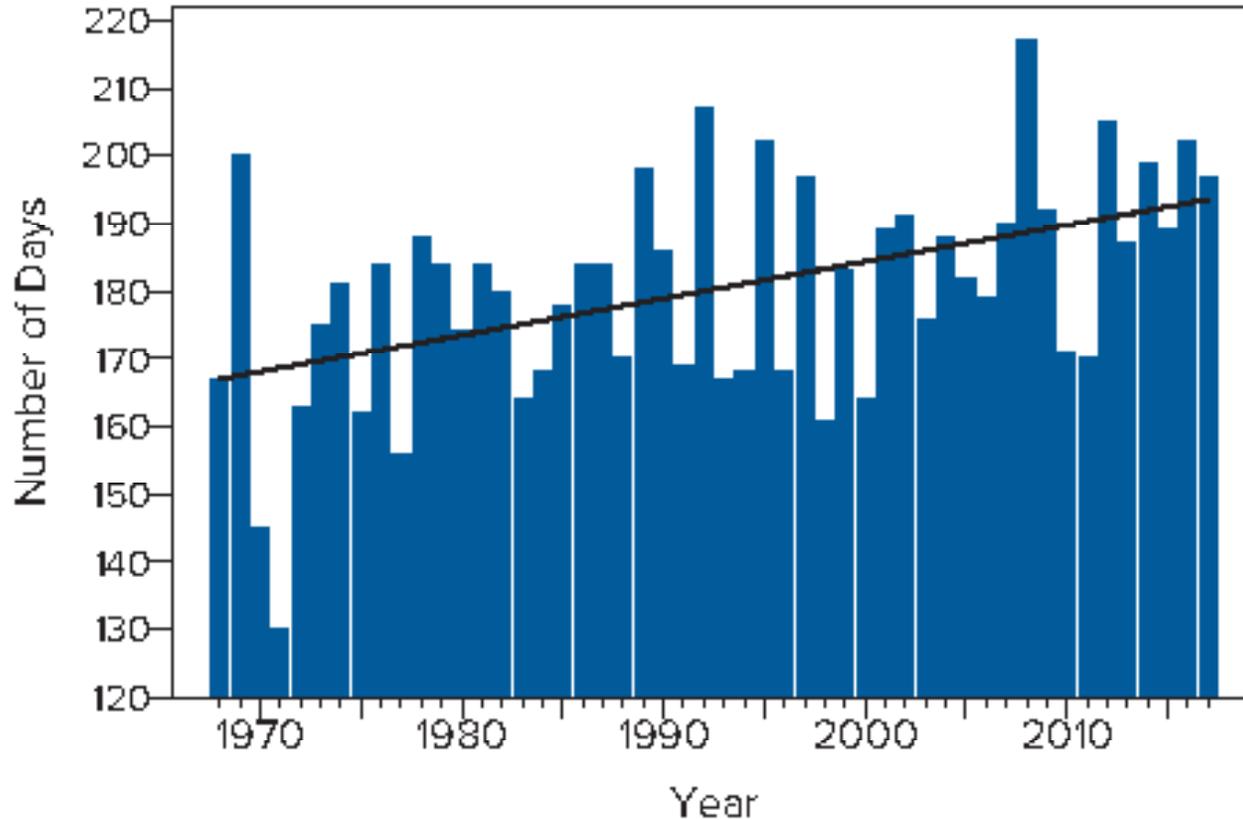
Stratified season length

Since 1968

The stability index, a measure of the energy required to fully mix the lake, can be evaluated for every day of the year. We define the stratification season as the length of time when the stratification

index exceeds a value of 600 kilograms per square meter. Since 1968, the length of the stratification season has increased, albeit with considerable year-to-year variation. Overall, the stratification

season has lengthened by 26 days. In 2017, the length of the stratified season was 197 days.



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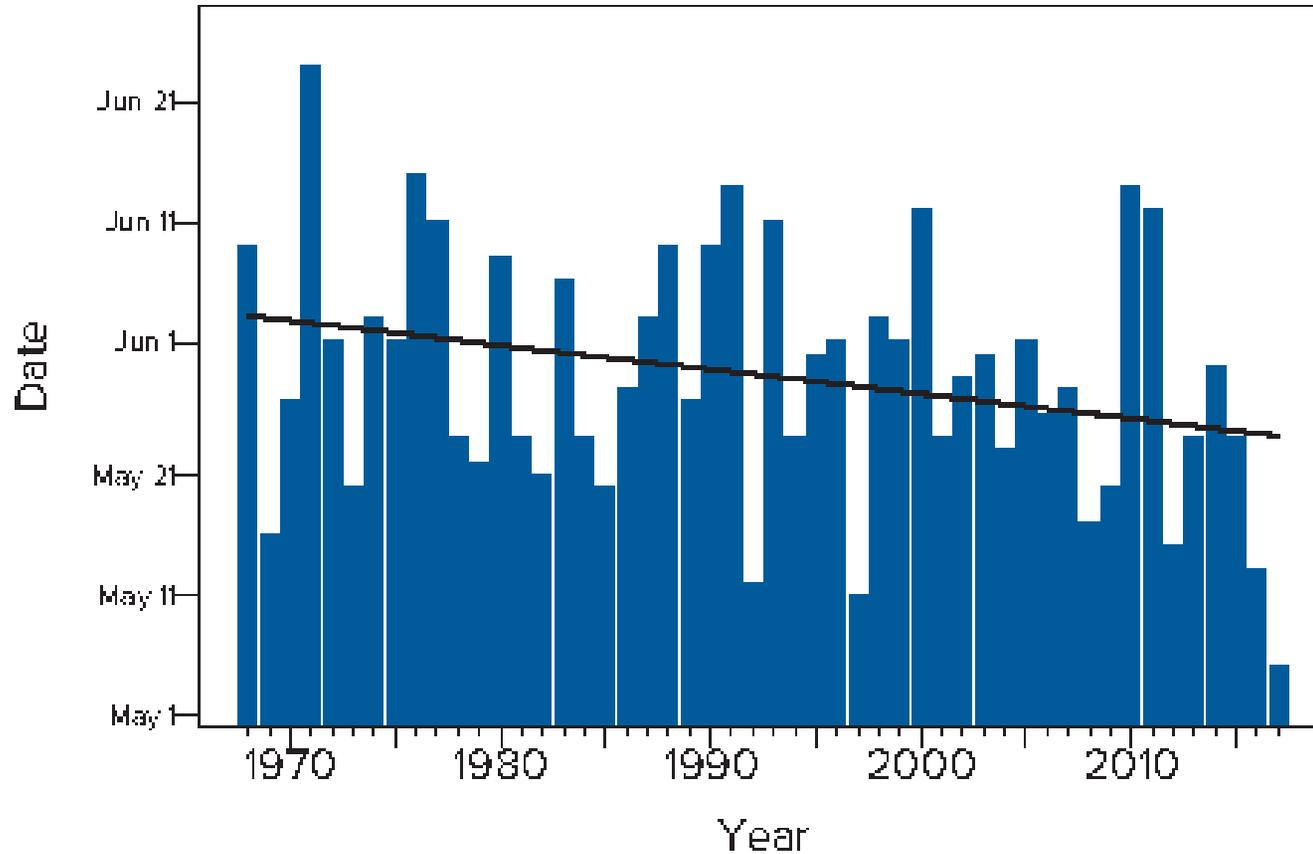
Beginning of the stratification season

Since 1968

The amount of time that Lake Tahoe is stratified has been lengthening since 1968. One reason for this is the increasingly early arrival of spring as

evidenced by the earlier commencement of stratification. Stratification occurs approximately ten days earlier than it did in 1968. The commencement of the

stratification season is typically in late May or early June. In 2017, stratification began on Day 126 (May 5), the earliest such date on record.



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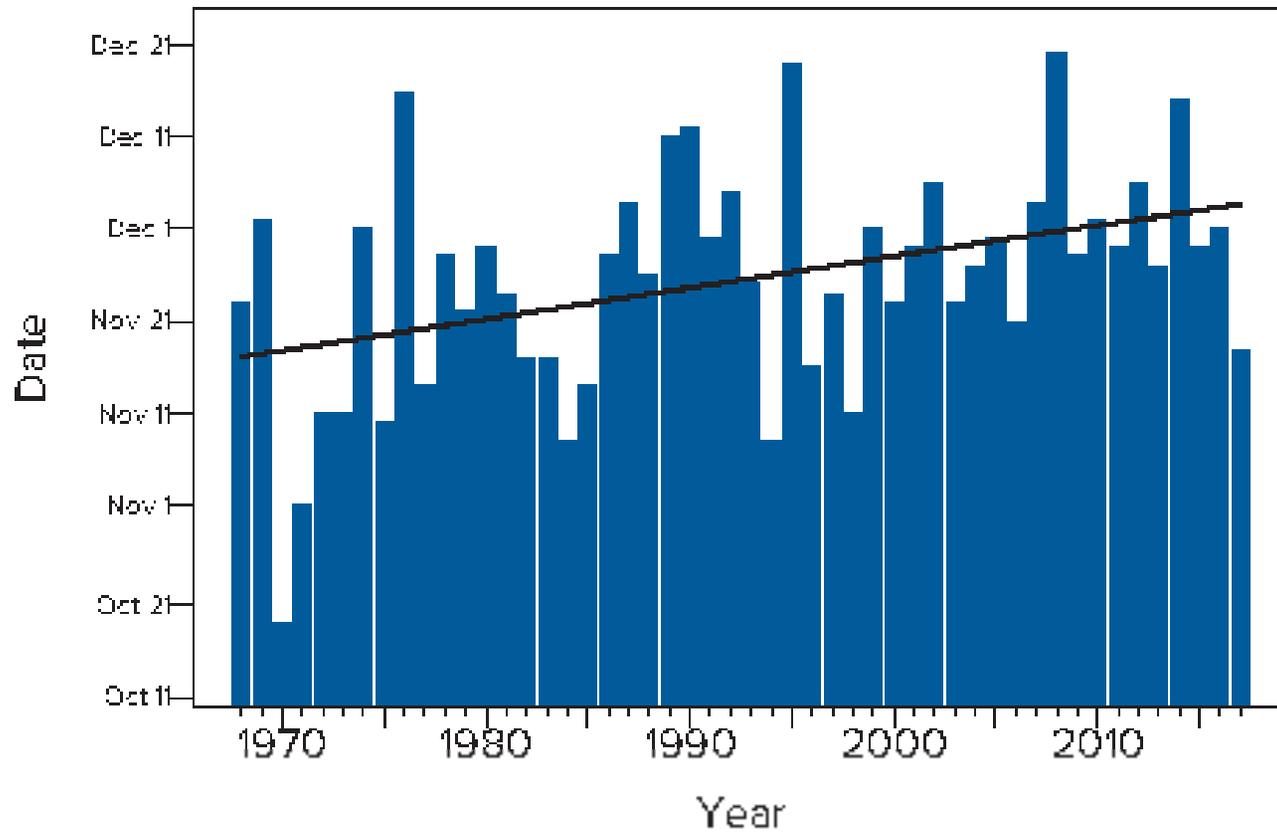
End of stratification season

Since 1968

The amount of time that Lake Tahoe is stratified has lengthened since 1968 by almost four weeks. The end of stratification appears to have been

extended by approximately 17 days on average. In other words, the fall season for the lake has been considerably extended. In the late 1960s, stratification

ended in mid-November. Now it often ends in December. In 2017, stratification actually ended on Day 322 (November 18), on account of an early winter storm.



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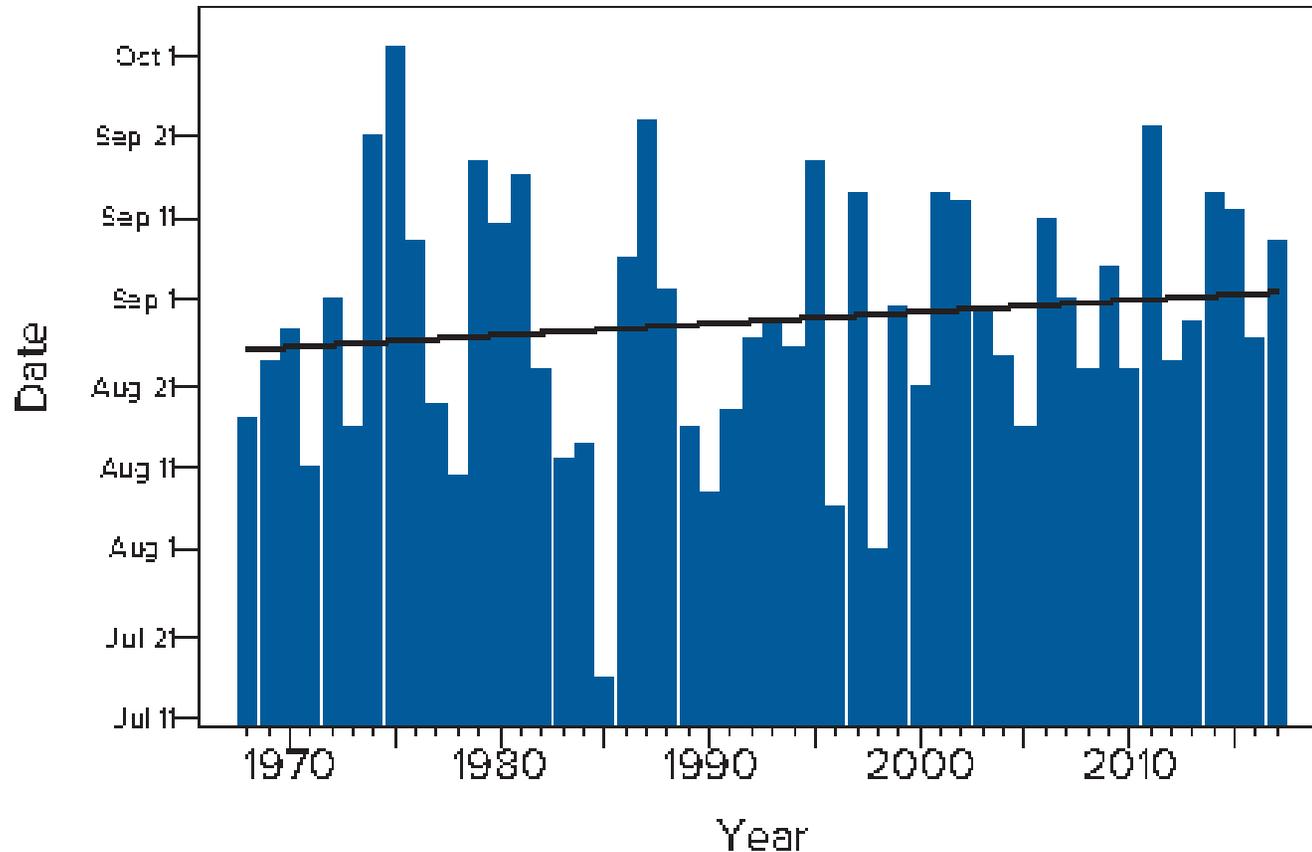
Peak of stratification season

Since 1968

The day of the year when lake stratification reaches its maximum value has been plotted. There is considerable

year-to-year variation, but over time there has been only a slight delay in when the peak occurs. In 2017, the peak occurred

on September 8, later than the previous year. This was 7 days later than the long-term trend would have indicated.



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Mean daily streamflow of Upper Truckee River vs. Truckee River

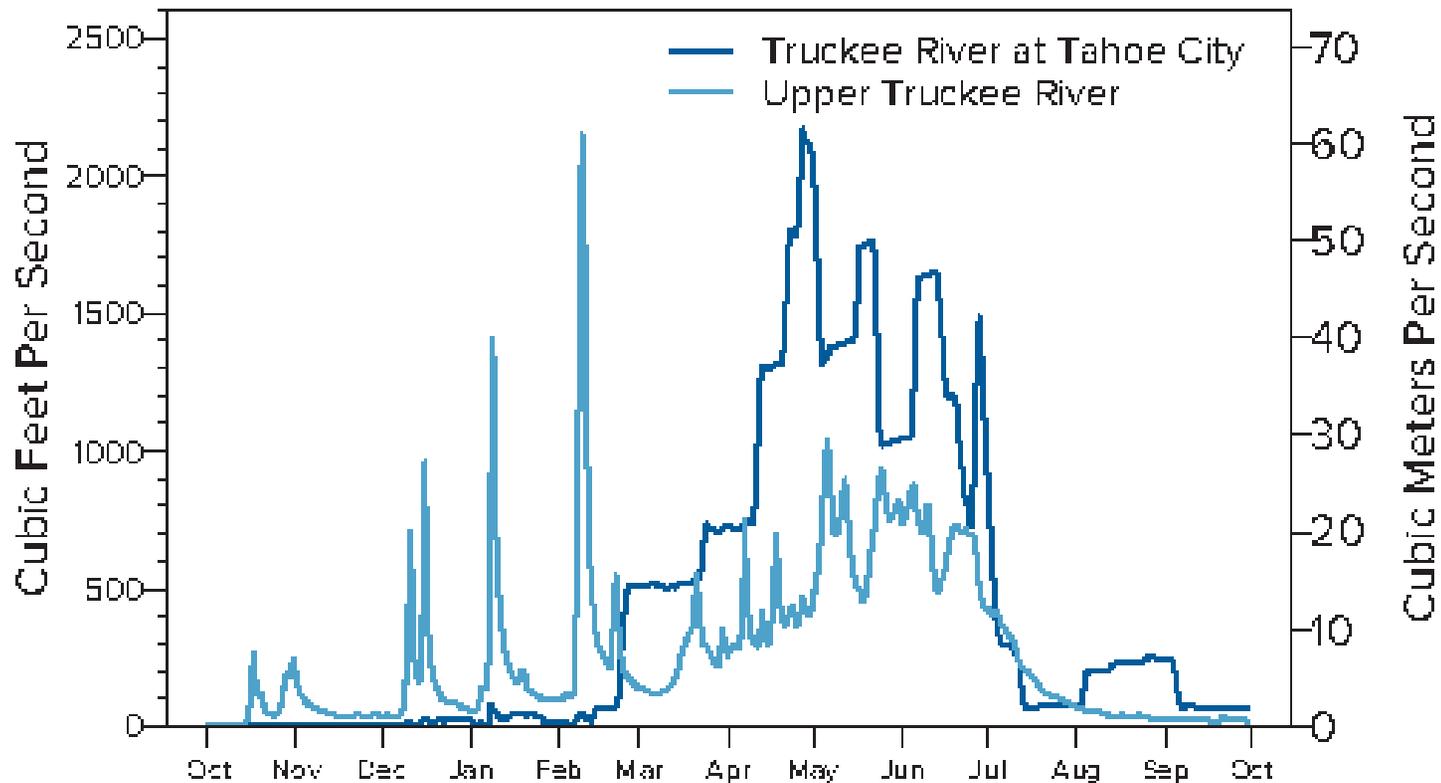
Water Year 2017

The largest stream flowing into Lake Tahoe is the Upper Truckee River. The small peaks in the hydrograph generally represent rain events or short warm periods in winter or spring. The extended seasonal increase (March-July) represents the snowmelt. The peak snowmelt flow was approximately 1040 cfs, compared to the long-term average of 300 cfs. The

Upper Truckee River is estimated to represent about 25% of the stream inflow to Lake Tahoe.

The Truckee River is the only outflow from Lake Tahoe. It is a regulated flow, with release quantity controlled by the Federal Water Master. Typical maximum summer discharge is approximately 300 cfs in mid-June. In 2017, the peak

daily discharge was 2170 cfs on April 27. Large outflows were necessary to make storage volume available in the lake in case of unexpectedly rapid snowmelt. Streamflow data are collected by the U.S. Geological Survey under the Lake Tahoe Interagency Monitoring Program (LTIMP).



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Onset of snowmelt pulse

Yearly since 1961

Although the date on which snowmelt commences varies from year to year, it has shifted earlier an average of 16 days since 1961. This shift is statistically significant and is one effect of climate

change at Lake Tahoe. In 2017, peak snowmelt occurred on April 25, over 5 weeks later than the previous year. The onset of the pulse is calculated as the day when flow exceeds the mean flow for the

period January 1 to July 15. The value for five gauged streams are averaged. In the past, we used the peak of the stream hydrograph to estimate this property.

