TAHOE: STATE OF THE LAKE REPORT 2014

UC DAVIS
TAHOE ENVIRONMENTAL RESEARCH CENTER

THE TAHOE: STATE OF THE LAKE REPORT 2014 IS DEDICATED TO THE MEMORY OF OUR FRIEND AND SUPPORTER BOB ANDERSON.

Wind data collected from the weather station built into the Anderson's flagpole has been invaluable to efforts to understand the complexity of Lake Tahoe and to preserve its extraordinary beauty for future generations.

FUNDING TO ASSEMBLE AND DISTRIBUTE THIS REPORT
WAS PROVIDED BY THE CALIFORNIA TAHOE CONSERVANCY, UC DAVIS AND
THE GENEROSITY OF DONORS WHO SUPPORT SCIENCE TO SAVE THE LAKE

CALIFORNIA TAHOE CONSERVANCY

One UC DAVIS

CONTENTS

(CONTINUED ON NEXT PAGE)

CONTENTS, CONTINUED

INTRODUCTION

The University of California, Davis, has conducted continuous monitoring of Lake Tahoe since 1968, amassing a unique record of change for one of the world's most beautiful and vulnerable lakes.

In the *UC Davis Tahoe: State of the Lake Report*, we summarize how natural variability, long-term change and human activity have affected the lake's clarity, physics, chemistry and biology over that period. We also present the data collected in 2013. The data shown reveal a unique record of trends and patterns – the result of natural forces and human actions that operate at time scales ranging from minutes to decades. These patterns clearly indicate that Lake Tahoe is a complex ecosystem, behaving in ways we don't always expect. This was exemplified this year by the decrease in the abundance of the diatom *Cyclotella* in the lake, and the corresponding increase in summer clarity. While Lake Tahoe is unique, the forces and processes that shape it are the same as those acting in all natural ecosystems. As such, Lake Tahoe is an analog for other systems both in the western U.S. and worldwide.

Our role is to explore this complexity and to use our advancing knowledge to suggest options for ecosystem restoration and management. Choosing among those options and implementing them is the role of management organizations that need to account for a host of other considerations. This annual report is intended to inform non-scientists about some of the variables that affect lake health. Until recently, only one indicator of Lake Tahoe's health status was widely reported: the annual clarity (often called the Secchi depth, after the instrument used to collect the clarity data). In this report we publish many other environmental and water quality factors that all provide indications of the lake's condition.

This report sets the context for understanding the changes that are seen from year to year and those that are observed over a time scale of decades: Was Lake Tahoe warmer or cooler than the historical record last year? Are the inputs of algal nutrients to the lake declining? How is the drought affecting Lake Tahoe? And, of course, how do all these changes affect the lake's famous clarity?

The data we present are the result of efforts by a great many scientists, engineers, students and technicians who have worked at Lake Tahoe throughout the decades since sampling commenced. I would, however, like to acknowledge (in alphabetical order) the contributions of Brant Allen, Veronica Alumbaugh, Nancy Alvarez, Patty Arneson, Fabian Bombardelli, Janet Brewster, Andrea Buxton, Sudeep Chandra, Bob Coats, Michael Dettinger, Angie Elliot, Kristen Fauria, Bill Fleenor, Alex Forrest, Allison Gamble, Charles Goldman, Scott Hackley, Tina Hammell, Bruce Hargreaves, Alan Heyvaert, Simon Hook, Andrea Hoyer, Debbie Hunter, Peter Hunter, Camille Jensen, Darren Kramer, Anne Liston, Patricia Maloney, George Malyj, Tom Mathis, Patricio Moreno, Mark O'Berry, Faye-Marie Pekar, Kristin Reardon, John Reuter, Bob Richards, Gerardo Rivera, Dave Rizzo, Derek Roberts, Francisco Rueda, Goloka Sahoo, Heather Segale, Heather Sprague, Raph Townsend, Alison Toy, Shohei Watanabe and Katie Webb, to this year's report.

Funding for the actual data collection and analysis has come from many sources over the decades. While many additional water quality variables could be tracked, funding ultimately limits what we measure and report on. Current funding for the long-term monitoring and analysis is provided by the Lahontan Regional Water Quality Control Board, the Tahoe Regional Planning Agency, the U.S. Forest Service, the U.S. Geological Survey and UC Davis. Our monitoring is frequently done in collaboration with other research institutions and agencies. In particular we would like to acknowledge the U.S. Geological Survey (USGS), the Desert Research Institute (DRI), the University of Nevada, Reno (UNR), the National Aeronautics and Space Administration (NASA), and the U.S. Forest Service (USFS). Some data are also collected as part of research projects funded through a variety of sources. Without these data there are many questions that could not even be asked let alone answered.

This year we are presenting updates on some recent research, as well as providing updates on the lake monitoring efforts. These new research results highlight some of the most exciting findings of work that is still in progress, and will be reported on fully in the months and years to come.

Sincerely,

Geoffrey Schladow, director

UC Davis Tahoe Environmental Research Center
291 Country Club Drive
Incline Village, NV 89451

gschladow@ucdavis.edu

(775) 881-7563

EXECUTIVE SUMMARY

The long-term data set collected on the Lake Tahoe ecosystem by the University of California, Davis and its research collaborators is an invaluable tool for understanding ecosystem function and change. It has become essential for responsible management by elected officials and public agencies tasked with restoring and managing the Tahoe ecosystem. This is in large part because it provides an independent basis for assessing the progress toward attainment of Tahoe's restoration goals and desired conditions while at the same time building our understanding of the natural processes that drive the ecosystem.

This annual *Tahoe: State of the Lake Report* presents data from 2013 in the context of the long-term record. While the focus is on data collected as part of our ongoing, decades-long measurement programs, this year we have also included sections summarizing current research on establishing a novel, basin-wide Nearshore Water Quality Network, the monitoring of algal growth potential in the nearshore, climate change (from the past and into the future), dissolved oxygen loss from the deepest parts of the lake, the wave environment of Tahoe, wetland design guidelines, and nearshore clarity changes due to storms.

The UC Davis Tahoe Environmental Research Center (TERC) has developed sophisticated computer models that help scientists better predict and understand how Lake Tahoe's water moves and how the entire ecosystem behaves. Long-term data sets are an essential element in constantly refining the accuracy of those models and in developing new models as knowledge increases and new challenges arise. These models could be used to address a variety of questions – where would a contaminant spill be carried?; what are the likely next locations for the spread of invasive species within the lake?; will lake oxygen be depleted by climate change; and what will the consequences be?

With respect to **weather**, 2013 saw the continuation of dry conditions for a second year at Lake Tahoe. The winter of 2012-2013 had 80 percent of the long-term average precipitation. The fraction of precipitation that fell as snow continued the downward trend at 32 percent. While December 2012 was exceptionally wet, January through April 2013 were all well below the long-term mean. Air temperatures were colder in winter and warmer in summer than the long-term average. The number of days with below-freezing temperatures was close to the long-term trend line of declining below-freezing days. As a consequence, the peak in the timing of the snowmelt was also close to the long trend line of earlier occurrence of spring conditions, occurring on May 15.

Lake level rose by only 6" during the spring snowmelt, one of the lowest increases on record. The elevation difference between peak lake level and the lowest lake level in 2013 was 2.73 feet, falling at an average rate of decline of 1.1 inches per week. The volume-

(CONTINUED ON NEXT PAGE)

[1]"Previous year" for some parameters means data collated in terms of the water year, which runs from October 1 through September 30; for other parameters, it means data for the calendar year, January 1 through December 31. Therefore, for this 2014 report, water year data are from Oct. 1, 2012 through Sept. 30, 2013. Calendar year data are from Jan. 1, 2013 through Dec. 31, 2013.

EXECUTIVE SUMMARY

(CONTINUED FROM PAGE 2.1)

averaged lake temperature rose again in 2013. Following the cooler temperatures of the last decade, it is now close to the long-term trend of increasing temperature. July surface water temperatures were the highest recorded in 5 years, at 65.6 deg. F, an increase of 1.8 deg. F over the previous year. Other consequences of climate change could also be seen in the rising temperature of the deep waters of the lake. In the last 38 years bottom temperatures have increased by over one deg. F.

Lake Tahoe did not **mix** to its full depth in 2013, the second consecutive year in which this has not happened. Instead, the maximum depth of mixing was only 590 feet, reached in March. The lack of mixing was due to a second year of above average lake stability. The upper 330 feet of the lake stayed stratified for 187 days, three weeks longer than what was typical when the record began.

River releases from Lake Tahoe to the Truckee River occur at the dam in Tahoe City. Water temperature has been monitored there by the USGS since 1993. Though the data set is incomplete, there is evidence that the summertime release temperatures have increased significantly over that period, suggesting potential impacts on downstream fish spawning. Summer (July-September) water releases have increased for the last two years, despite falling water levels in both of those years.

The input of **stream-borne nutrients** to the lake was low again in 2013 due to the low precipitation and subsequent run-off. Both phosphorus and sediment inputs from the streams were even lower than 2012, although still larger than the loads during the drought years of the early 1990's.

Overall **in-lake** nitrate concentrations have remained relatively constant over the 33 years of record. By contrast, in-lake phosphorus concentrations display a downward trend over the same period, having decreased by almost 50 percent.

Biologically, the primary productivity of the lake continued its long-term increase in 2013, with the annual average value of 230.9 grams of carbon per square meter. The reasons for this increase are believed to be linked to a long-term shift towards smaller algal species that have the ability to process nutrients faster. Despite the increase in lake productivity, the concentration of chlorophyll in the lake has remained relatively constant over time. In 2013 there was a decrease in the abundance of diatom cells in the lake, down from the peaks experienced in 2009 to 2011. In particular the concentration of *Cyclotella* was reduced. This small-sized diatom can exert a large influence on lake clarity. Higher numbers of this group over the last six years compared to historical values had been linked to climate change and had resulted in summertime clarity reductions. This year's reduction

EXECUTIVE SUMMARY

(CONTINUED FROM PAGE 2.2)

coincided with an improvement in clarity.

Periphyton, or attached algae, on the rocks around the shoreline continues to show variability from site to site. The long-term monitoring program has helped identify those areas of the shoreline that are consistently displaying periphyton levels that are undesirable. Lake Tahoe agencies are now keenly aware of the need for further investment in science to better understand the root causes of nearshore degradation in general. A recent report prepared by researchers from TERC, DRI and UNR laid out a strategy for nearshore monitoring that would provide a minimum level of status and trend analysis. A more detailed set of studies to explain what is causing nearshore degradation, focused on the known problem areas, will elucidate the processes and mechanisms that are controlling nearshore conditions. While some of the strategies utilized for restoring midlake clarity will also benefit the nearshore, a focus on projects that directly affect the urban nearshore are important. TERC's new real-time nearshore water quality network will play a crucial role in those efforts by creating a link between nearshore water quality and measured meteorology, streamflow and stormwater flow.

This year the annual average **Secchi depth**, a measure of lake clarity, was consistent with the long-term halt in clarity degradation. While the annual clarity value was 5 feet lower than last year (a degree of inter-annual variability that is not unexpected), this was mainly due to the high precipitation that occurred in the early winter. Year-to-year fluctuations are the norm, and the long-term goal must be seen as attaining a level of clarity which on average meets the basin's standards. Summer clarity was almost identical to the previous year at 63.8 feet, and continues the recent cycle of improvement. It has improved by over 13 feet from values that were measured just 2 years ago.

In **new research**, TERC is launching the Real-time Nearshore Water Quality Network in August 2014. This unique partnership between private property owners and science will see the deployment of advanced instruments at 20 sites around the shoreline. The instruments will provide minute-by-minute data on the key water quality indicators of nearshore health and will allow researchers to begin exploring solutions that agencies can implement.

Climate change research continues to be a major focus. Using a combination of our long-term data sets and powerful modeling techniques, it is possible to quantitatively examine how climate change has affected Lake Tahoe in the past and will continue to affect it through the present century. Changes in the length of the seasons will alter the way in which water moves in

EXECUTIVE SUMMARY

(CONTINUED FROM PAGE 2.3)

the lake, leading to the possible loss of dissolved oxygen at the bottom of the lake. To measure this threat and to prepare mitigation measures, TERC is conducting autonomous measurements of dissolved oxygen from the deepest parts of the lake. These types of data are unique, and are of value to understanding the threats to freshwater ecosystems worldwide as well as here at home.

Understanding how best to control **invasive species**, particularly Asian clam, is an ongoing priority. TERC and its research partner UNR are continuing to work with agency staff on an experiment to control the satellite population of this invader at the mouth of Emerald Bay. The site has presented new challenges that are unique to Emerald Bay compared with other regions of the lake. These include strong currents, complex sub-surface conditions that permit oxygen-rich water to reach deeply buried clams, and cold water conditions that our divers need to contend with in winter. Despite the challenges, there has been clear evidence of some success, including clam mortality of about 90%. This project is a great example of the growing collaboration between science and resource managers.

Stormwater monitoring and the designing of new infrastructure to help control lake clarity has been a major focus. Working with agencies in the basin we are monitoring the loads of fine particles that are delivered to the lake by drains and culverts every time it rains. We have also developed LiDAR based maps that are being used to identify small depressions in the landscape that can be used to locate hundreds of "distributed detention basins" that have the capacity to store and infiltrate stormwater before it reaches the lake. Constructed wetlands are another important tool, and student research has provided important data on how they should best be designed.

The **waves** we often see on the lake have also been shown to impact the lake. While they are the most important factor in resuspending sediment in the nearshore region, research has shown that the sediment there is coarse and it quickly settles back down. On the other hand, the waves produced by large winter storms can generate tremendous damage to nearshore infrastructure and property. New modeling tools now allow us to predict these waves for any set of storm conditions.

This report is available on the UC Davis TERC website (http://terc.ucdavis.edu/stateofthelake/).

ABOUT LAKE TAHOE AND THE TAHOE BASIN

- Maximum depth: 1,645 feet (501 meters), making it the 11th deepest lake in the world and 2nd deepest lake in the United States
- Average depth: 1,000 feet (305 meters)
- Lake surface area: 191 square miles (495 square kilometers)
- Watershed area: 312 square miles (800 square kilometers)
- Length: 22 miles (35 kilometers)
- Width: 12 miles (19 kilometers)
- Length of shoreline: 72 miles (116 kilometers)
- Volume of water: 39 trillion gallons
- The daily evaporation from lake Tahoe (half a billion gallons) would meet the daily water needs of 5 million Americans or 10 million Australians
- The number of algal cells in Lake Tahoe is approximately 30 million trillion
- All these algae, if stacked on a football field, would stand 9 feet tall and weigh 15,500 Tonnes
- Number of inflowing streams: 63, the largest being the Upper Truckee River
- Number of large lakes worldwide with annual clarity exceeding Tahoe's: Zero
- Number of outflowing streams: one, the Truckee River, which leaves the lake at Tahoe City, Calif., flows through Truckee and Reno, and terminates in Pyramid Lake, Nev.
- Length of time it would take to refill the lake: about 600 years
- Average elevation of lake surface: 6,225 feet (1,897 meters)
- Highest peak in basin: Freel Peak, 10,891 feet (3,320 meters)
- Latitude: 39 degrees North
- Longitude: 120 degrees West
- Age of the lake: about 2 million years
- Permanent population: 55,000 (2010 Census)
- Number of visitors: 3,000,000 annually
- Vehicle miles traveled (VMT) on a midsummer's day: about 2,000,000 miles

ABOUT THE UC DAVIS TAHOE ENVIRONMENTAL RESEARCH CENTER (TERC)

The UC Davis Tahoe Environmental Research Center is a global leader in research, education, and public outreach on lakes that provides critical scientific information to help understand, restore, and sustain the Lake Tahoe Basin and other systems worldwide.

TERC's activities are based at permanent research facilities in the Tahoe Basin and at the University's main campus in Davis, California, about 90 miles west of the lake.

Our main laboratories and offices are in Incline Village, Nevada, on the third floor of the Tahoe Center for Environmental Sciences building. On the first floor, we operate the Tahoe Science Center funded by the Thomas J. Long Foundation, a learning resource that is free and open to the public.

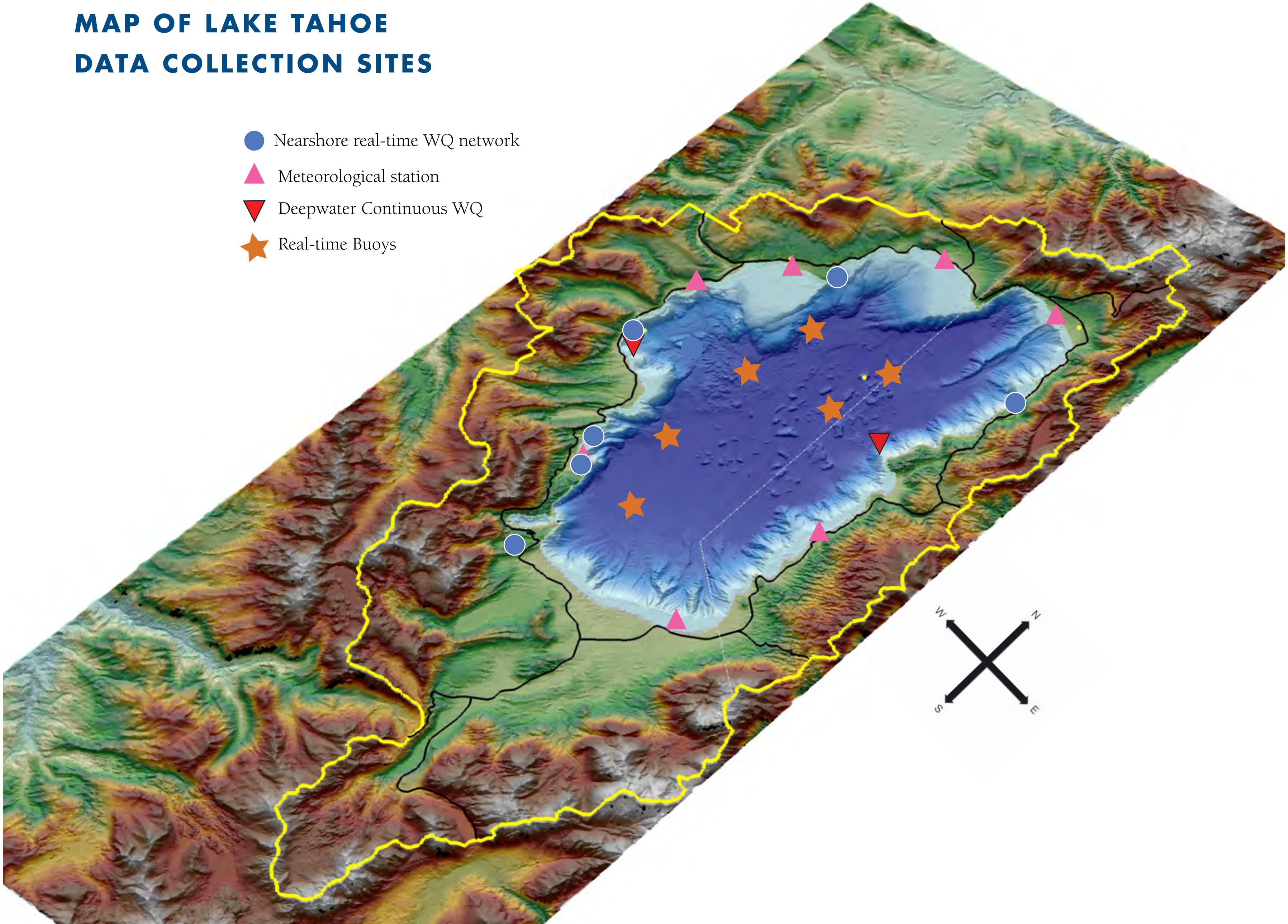
In Tahoe City, California, we operate a field station (housed in a fully renovated, former state fish hatchery) and the Eriksson Education Center. Tahoe City is also the mooring site for our research vessels, the John LeConte and the Bob Richards.

Our secondary laboratories and offices are located on the UC Davis campus at the Center for Watershed Sciences and in Wickson Hall.

Our website (terc.ucdavis.edu) has more information about our programs, including:

- Information for potential students, staff, faculty, research collaborators and visitors;
- Access to near-real-time data gathered by our growing network of sensors;
- An extensive list of Tahoe research publications;
- Exhibits and events at the Education Centers; and
- Information about supporting our research and learning programs.

MAP OF LAKE TAHOE DATA COLLECTION SITES



TAHOE: STATE OF THE LAKE REPORT 2014

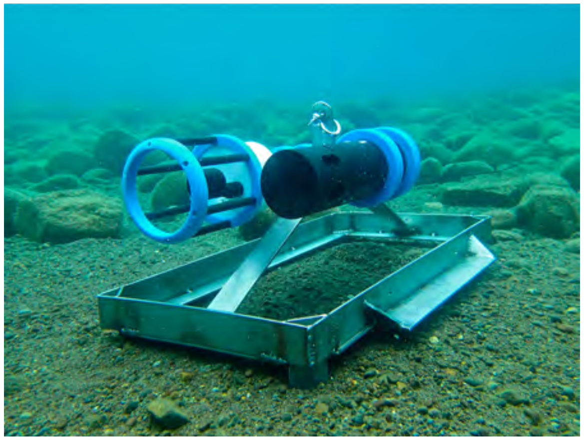
RECENT RESEARCH UPDATES

UC DAVIS
TAHOE ENVIRONMENTAL RESEARCH CENTER

RECENT RESEARCH UPDATES

Overview

While the State of the Lake Report is primarily intended to focus on the trends emerging from long term data collection efforts, this section presents the results of some current and short term projects. In some cases the projects are complete, but in most cases this section provides a preview of some new and exciting research directions. This year we chose to highlight projects from across the full spectrum of our research endeavors. This includes our new Nearshore Network, continued monitoring of algal growth in the nearshore, climate change (both the trends from past measurements and projected trends from computer simulations), measurements of oxygen from the depths of the lake, the monitoring of urban stormwater, new measurements to assist in the design of constructed wetlands, measuring the impact of storms on nearshore clarity, and waves generated by storms.



A real-time nearshore water quality station being tested in Lake Tahoe. Photo: B. Allen

A wave breaking at Obexer's Marina. A new wave model for Lake Tahoe has been developed. Photo: D. Kramer

Wash-off simulator used to collect artificial stormwater samples. Photo: R. Townsend

RECENT RESEARCH UPDATES

The Nearshore Network - Instrumenting Lake Tahoe

TERC has been working to launch a world-first, real-time nearshore water quality network at approximately 20 sites around the Tahoe basin. The first six stations, spanning both California and Nevada, are scheduled to be installed this summer.

Each station measures water temperature and conductivity, water level, turbidity, algal concentration and dissolved organic material. Extra sensors can be added in the future as additional funding is acquired. An underwater cable supplies power to each station and returns the data, which will be instantly displayed on the internet.

Why are these nearshore data so important?

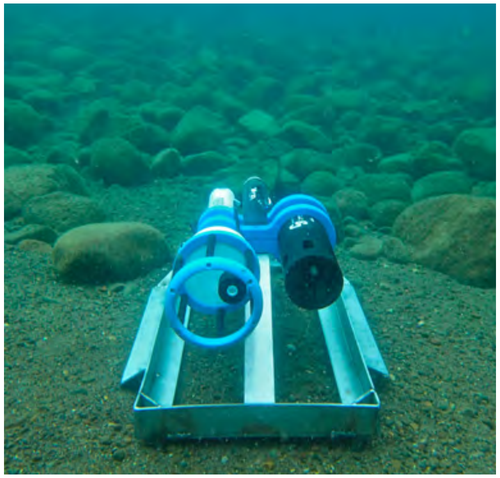
Unlike the deep portion of the lake, the nearshore is subject to sudden changes in water quality. These changes occur in response to storms, inflows from streams and storm drains, local erosion, or drift from other parts of the lake. And every part of the nearshore responds differently. The nearshore water quality network will allow scientists and agencies to better understand the causes of degradation, to better implement projects to ameliorate the deterioration and to understand appropriate and meaningful threshold standards for nearshore conditions.

The data will be referenced to the identical measurements being taken at one of the mid-lake buoys in collaboration with NASA-JPL. In this way, it will be possible to relate the evolving nearshore water quality with conditions at the center of the lake. The data will also be used to provide public education through online displays at TERC's Tahoe Science Center and at other locations around the basin.

Funding for this project (along with access to docks) is being provided through a unique partnership between lakefront property owners, other private donors in the Tahoe basin, instrument manufacturers and TERC. Each donor is supporting the operation of one nearshore sensor for a period of four years, and making possible the collection of a consistent, water quality data set for the area of the lake that most people come in contact with.

Graduate student Derek Roberts testing the RBR Maestro (white instrument) and the Turner C-3 (black instrument) Photo: G. Schladow

The six instrument transportation cases and cables aligned in the Tahoe City Field Station. Photo: D. Roberts



A nearshore monitoring station, with its cable (top) carrying data to shore. Photo: B. Allen

RECENT RESEARCH UPDATES

Nearshore Monitoring - Algal Growth Potential

Beginning in August, 2013, TERC began routine monitoring of Algal Growth Potential (AGP) at 11 shallow nearshore sites and 2 mid-lake sites. The purpose of the AGP experiments is to compare levels of algal growth in the nearshore to identify emerging problem areas. AGP is the peak biomass in samples achieved during a 2 week lab incubation and the results largely reflect the ability of phytoplankton to grow at each site. Availability of the nutrients nitrogen (N) and phosphorus (P) in the water and levels of nutrients previously taken up by algae (known as luxury uptake), are important factors which contribute to growth.

Four times a year, samples of lake water containing phytoplankton are collected from just below the surface at Tahoe City, Kings Beach, Crystal Bay, Glenbrook, Zephyr Cove, Timber Cove, Tahoe Keys nearshore, Camp Richardson, Rubicon Bay, Sunnyside and Emerald Bay. A north and a south mid-lake site are also sampled. The water is returned to the lab at TERC, divided into flasks and incubated under controlled light and temperature for approximately two weeks. Algal growth as measured by changes in chlorophyll *a*, is tracked throughout the experiment. The peak chlorophyll *a* concentration achieved is the AGP for a site.

The Lahontan Regional Water Quality Control Board standard specifies that the mean annual AGP at nearshore sites should not exceed twice the mean annual AGP at a mid-lake reference station.

TERC researchers collecting nearshore water near Kings Beach for an AGP experiment. Photo: S. Hackley

Scott Hackley examining metaphyton and preparing to measure Algal Growth Potential. Photo: A. Toy

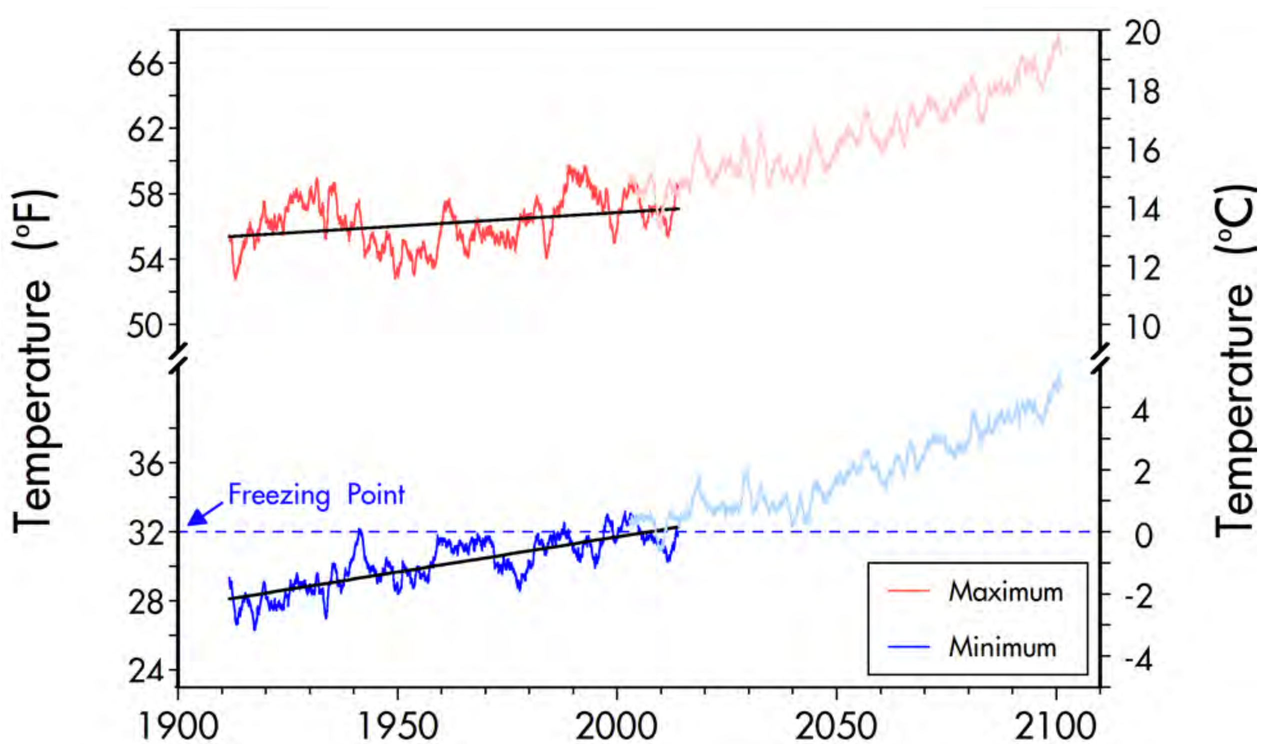
RECENT RESEARCH UPDATES

Climate Change - The Past and the Future

Air Temperature

TERC is at the forefront of measuring and predicting the impacts of climate change on Lake Tahoe. Using the best available estimates of possible future climate conditions, we have been working to determine how the basin and the lake may respond to the types of changes that are in store for the region.

Air temperature is a key driving variable that is widely expected to increase under all future climate scenarios. Using one of the more likely scenarios, it is possible to plot the maximum and minimum air temperatures (with the seasonal changes removed) that Lake Tahoe has already experienced together with the projected air temperatures over the next 100 years (provided by M. Dettinger, USGS). The results suggest that the maximum and minimum temperatures will both increase at a faster rate in the future and increase by as much as 8 deg. F over today's values.



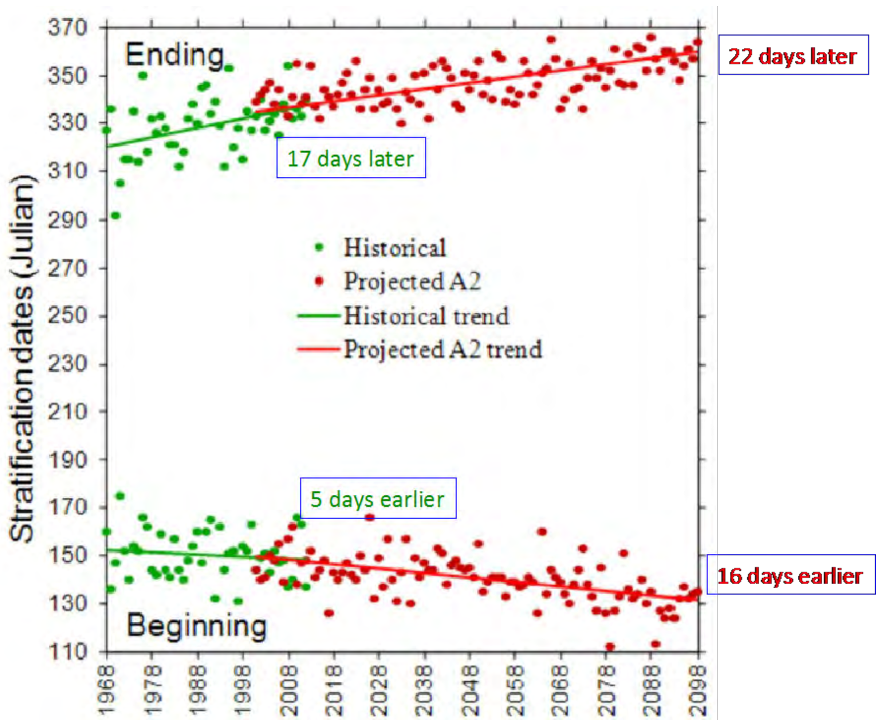
The trend of past minimum and maximum air temperatures (darker colored data on the left) together with projected future temperature trends (lighter colored data on the right).

RECENT RESEARCH UPDATES

Climate Change - The Past and the Future, continued

Length of Seasonal Stratification

A characteristic of lakes is that they stratify during the warm part of the year. The warmer, lighter water at the surface floats on top of cooler, denser water. When this occurs the supply of oxygen to the deeper parts of the lake is cut off (see Planning for Climate Change). TERC has measured and modeled this temperature stratification for the past and the future, respectively. Since 1968, stratification has increased by 22 days, starting 5 days earlier in the spring and ending 17 days later in the fall. By 2100 this is expected to increase by an additional 38 days, 16 more in spring and 22 more in fall. This overall lengthening in the stratification season from 6 months in 1968 to 8 months in 2100, due to climate change, is already having impacts on the lake's water quality and ecology.



The day of the year when stratification commences (spring) and ends (fall). Day 150 is May 30. Day 320 is November 16.

RECENT RESEARCH UPDATES

Climate Change - Can Anything Be Done?

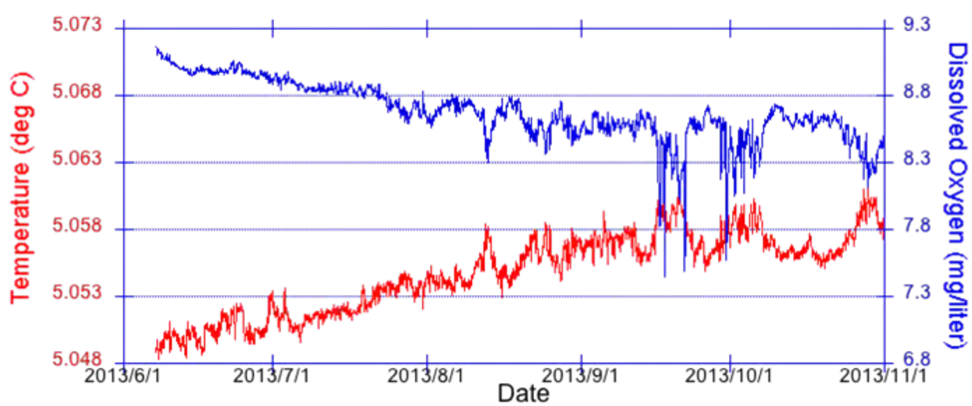
Of the many possible impacts of climate change on lakes, the most likely is an increase in the temperature of the surface waters compared to the deep waters. When this occurs, the increased density difference makes it more difficult for the lake to mix in winter. Deep lakes like Tahoe may cease to mix all the way to the bottom, leading to dissolved oxygen (DO) being depleted faster than it is renewed - eventually leaving no dissolved oxygen in the deep waters.

The consequences of this are dire. Without DO, fish and other aquatic organisms cannot survive. Additionally, when oxygen is depleted, nutrients which have been stored in the bottom sediments for thousands of years can undergo a chemical change and be release back into the water. This can lead to the release of an almost limitless reservoir of nutrients such as algae-growing nitrogen and phosphorus directly into the lake.

To begin to address the question we must know the rate at which oxygen is being depleted during the summer months. At two locations on the lake bottom, TERC has deployed high accuracy oxygen sensors. One location is at a depth of 1450 feet (440 m) off Glenbrook on the east side of the lake. The other is at a depth of 400 feet (120 m) off Homewood on the west shore. By measuring changes in DO over time, the depletion rate becomes apparent.

As the data from Glenbrook shows, during the summer period from June to about September there was a decline in dissolved oxygen (blue line) at a rate of approximately 0.15 mg/liter/month. If that rate were maintained throughout the year, it could take 5-10 years of no deep mixing to deplete all the oxygen. However, there appear to be other internal processes taking place that slow this decline in oxygen. Between late September and early November, oscillations in temperature (red line) cause the oxygen to fluctuate rapidly. What is happening? These temperature fluctuations are likely produced by very large, deep waves known as internal waves. These have the ability to keep the bottom layers of Lake Tahoe partially stirred from within. Just how important they are, and how much they will slow the inevitable oxygen decline is an unanswered research question.

What can be done to mitigate the loss of oxygen in the deep water? The best we can do is to slow the rate of oxygen decline, so that a new balance between lake mixing and oxygen consumption can be attained without DO reaching zero. By reducing organic material produced in the lake (algae) this may be possible. The most effective way to achieve that is to reduce the influx of nutrients, especially phosphorus, to the lake. Projects such as wetland and marsh restoration, urban stormwater capture and reduced fertilizer application on gardens all contribute toward that end.

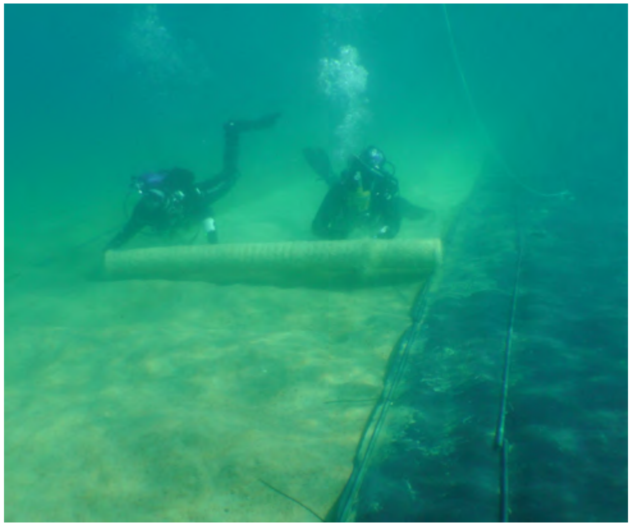


Water temperature (red) and dissolved oxygen (blue) at a depth of 1450 feet Glenbrook. The decline of DO is slowed by internal deep water oscillations starting in September.

RECENT RESEARCH UPDATES

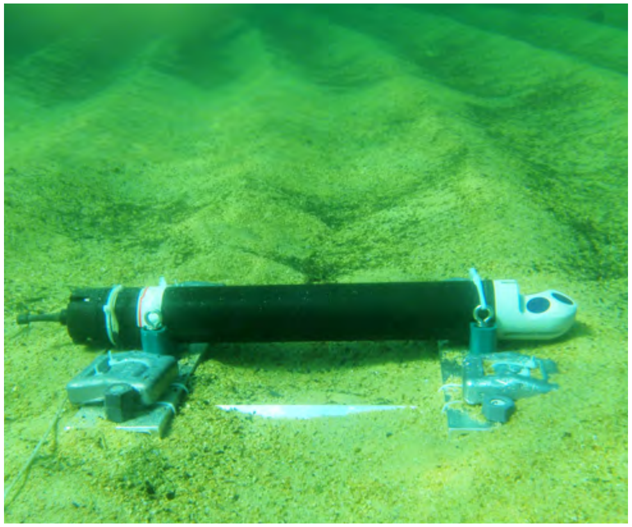
Invasive Species

Researchers from TERC and University of Nevada, Reno (UNR) have been teaming with the TRPA, California State Parks, the Lahontan Regional Water Quality Control Board and the Tahoe RCD to attempt the major control and possible eradication of a satellite population of Asian clams at the mouth of Emerald Bay. This population was unique due to its isolation from other populations and relative small scale. Previous experiments with treated areas up to 0.5 acres in other parts of the lake were found to kill 99.8% of the clams at similar depths in the lake. The mouth of Emerald Bay presented unique habitat in Lake Tahoe for clam survival and challenging conditions for the use of bottom barriers. High currents at the mouth tended to overturn barriers, and the porous and heterogenous nature of the material at the mouth (a glacial moraine) allowed the flow of oxygen rich water through the sediment and under the barriers. Despite the difficulties, a substantial reduction in clam density (90% mortality) was achieved across the treatment area based on sampling through October 2013. Like the successful control of invasive aquatic weeds in Emerald Bay, it seems that multiple control strategies implemented in a highly coordinated and integrated fashion will be required to fully control the Asian clam population at the mouth of Emerald Bay.



Divers unrolling benthic barriers in Emerald Bay. Photo credit: J. Brockett

Surface operations during the deployment of benthic mats in Emerald Bay. Photo credit: B. Allen



An Aquadopp, used to measure current velocities in Emerald Bay. The large sand waves in the background are additional evidence of the high current speeds. Photo credit: B. Allen

RECENT RESEARCH UPDATES

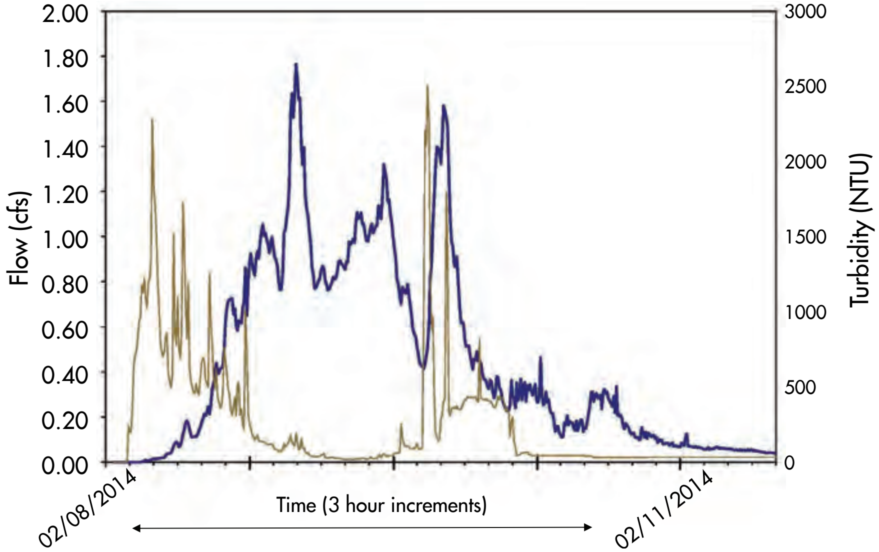
Stormwater Monitoring

Stormwater monitoring projects include efficiency studies on Best Management Practices (BMP's) for controlling urban runoff and the pollutants that runoff transports as well as testing the effectiveness of management activities.

With support from California Proposition 84 stormwater grant funds, TERC has been partnering with the Tahoe Resource Conservation District (Tahoe RCD) and other research institutions to measure pollutants in urban runoff at Lake Tahoe. This effort, referred to as the Regional Storm Water Monitoring Program (RSWMP) will help evaluate the combined effectiveness of pollutant control measures.

The graph below shows turbidity, a measure of the cloudiness of water, and storm drain flow over a 3-day period at Tahoma. In the two stormwater runoff events (the blue peaks) shown, the turbidity is highest at the very beginning of the stormwater flow event. The peak turbidity is over 2500 NTU. By comparison, mid-lake water is typically less than 0.1 NTU.

Urban stormwater being discharge directly to the lake via a culvert at the end of Pasadena Ave. (South Lake Tahoe). Research is directed at reducing the amount of stormwater and pollutants reaching the lake. Photo: R. Townsend



Stormwater flow and turbidity through a roadside culvert at Tahoma in 2014 during a pair of rain events. Data from A. Parra, Tahoe RCD

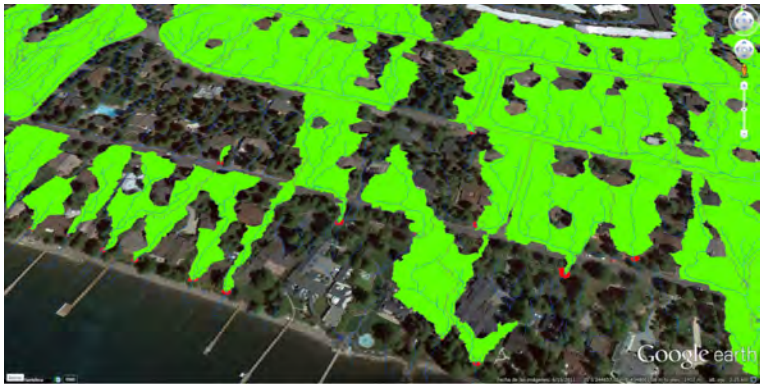
RECENT RESEARCH UPDATES

Distributed Detention Basins

Stormwater from the urbanized areas around Lake Tahoe is known to be the largest source of clarity reducing contaminants, such as fine particles and nutrients. Using LiDAR data we have been able to construct the hydrological flow paths of urban runoff in these areas. Combined with the micro-scale topography that the LiDAR data provides, we have identified potential sites for hundreds of small, distributed detention basins through the Tahoe Basin. Collectively they can hold back and infiltrate 100 times more stormwater than is presently happening.

The detention basin sites that have been identified are small, and as a result are cheaper to permit and construct and they can readily blend into the environment. Working with the California Tahoe Conservancy and the Tahoe Resource Conservation District we are helping to identify the best sites and establish monitoring protocols that will allow this novel approach to be fully tested prior to broad scale implementation.

TERC partnered with Dr. Juan Francisco Reinoso and Dr. Carlos Leon from the University of Granada, Spain, in the design and the undertaking of this research project. The initial funding was from SNPLMA, and subsequent funding was provided by the Tahoe Resource Conservation District.



Urban watershed capture areas (green) for detention basins (red) in a part of Incline Village, NV

Red areas indicate potential distributed detention basins locations in a part of South Lake Tahoe

RECENT RESEARCH UPDATES

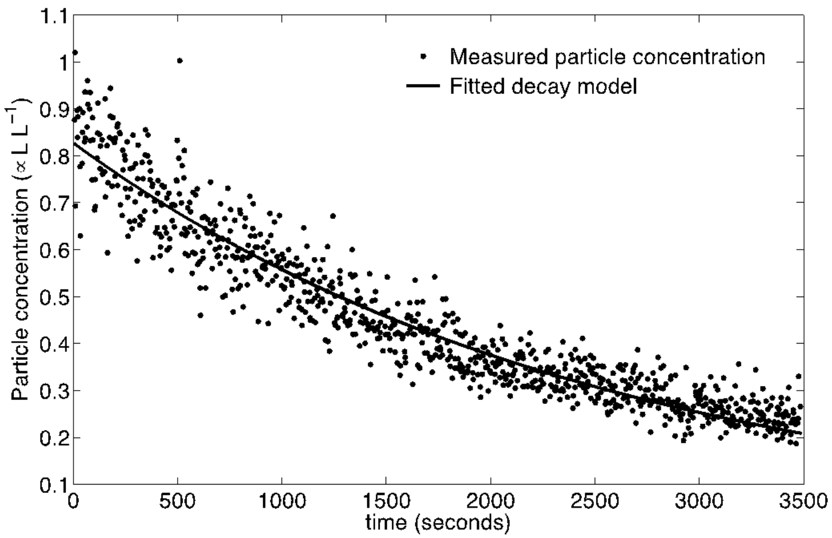
Planning and Designing Constructed Wetlands in the Tahoe Basin

The loss of natural wetlands is a major factor in the decline of water quality and ecosystem health worldwide. At Lake Tahoe the problem is exacerbated by the fact that there is little flat land available to construct artificial wetlands. This requires that we understand how to maximize their efficiency so as to capture the most fine particles and associated nutrients.

Graduate student Kristen Fauria has completed a SNPLMA-funded laboratory study to assess the particle capture efficiency of plants. Using a laboratory flume (a tank with water flowing through it), Kristen used banks of synthetic plants to represent the foliage in a submerged wetland. The variables that were examined included the flow rate, the plant density, and the effect of biofilms (the slimy, microbial films that form on submerged objects). The experiments used actual road dust collected in the Tahoe basin (supplied by Russ Wigart, El Dorado County).

The results indicated that within 1 hour of contact time, fine particle concentrations could be reduced by 80-90%. Removal rates were affected by particle size, flow velocity, stem density, and presence of biofilm. Low to medium stem densities produced the greatest removal efficiencies. Generally, greater contact times were conducive to particle removal, in part because they give greater opportunity for biofilms to develop and function.

Synthetic plants in the experimental flume after an experiment. Accumulation of fine sediment is clearly evident. Photo: K. Fauria.



An example of the reduction of fine particles over time in the laboratory flume. A four-fold removal was achieved in one hour (3600 seconds).

RECENT RESEARCH UPDATES

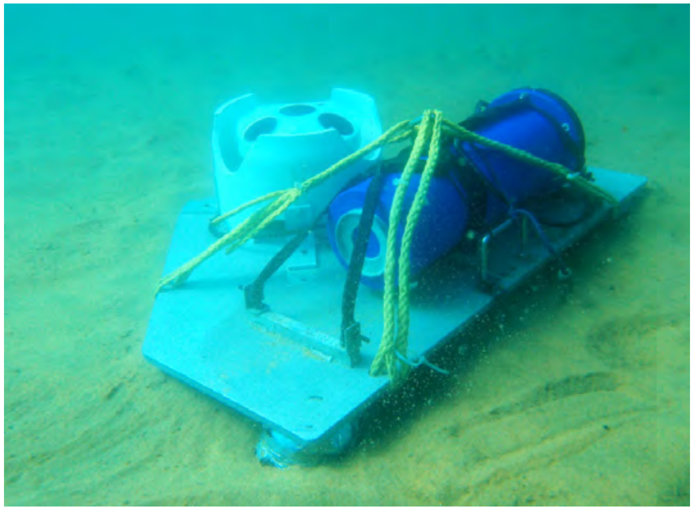
What Causes Cloudiness in Shallow Water?

The shallow water around the edge of Lake Tahoe sometimes appears cloudy, even when streams and storm drains are not flowing. What causes this? Recent research by graduate student Kristin Reardon has shed some light on this issue.

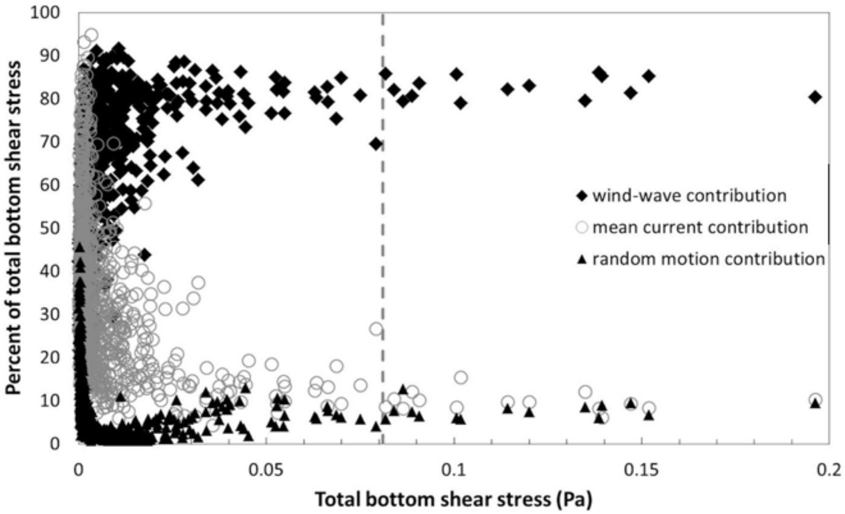
Instruments were installed in about 16 feet of water off the south shore of Lake Tahoe during winter as part of a SNPLMA-funded project.

Detailed measurements were made of the current velocity, wave height, particle concentration and water temperature. The results indicated that wind driven waves were the primary cause of sediment resuspension, the process in which sediment is lifted back into the water column and clouds the water. When conditions were such that a critical threshold was surpassed and resuspension occurred, waves were responsible for 80% of the sediment resuspension.

A key finding of the study was that the wave resuspension had a very short-lived impact on near-shore clarity. This was because the particles that were resuspended were relatively large (>100 microns) and rapidly settled back to the bottom when the waves died down.



The Acoustic Wave and Current (AWAC) profiler measured both current velocity and wave heights.



The magnitude of the shear stress at the lake bed determines if sediment is resuspended or not. When the critical value is exceeded (dashed vertical line) the data indicates that waves (diamonds) produce 80-90% of the shear stress.

RECENT RESEARCH UPDATES

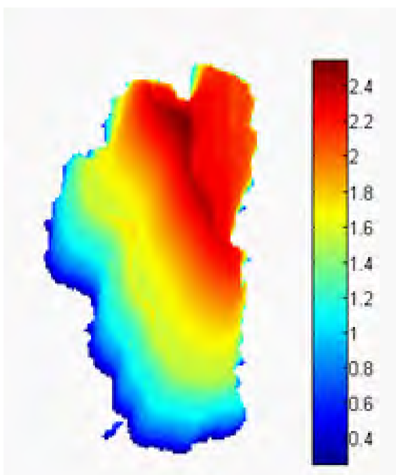
Waves in Lake Tahoe

How high can waves get at Lake Tahoe? This question was addressed by TERC as part of the ARkStorm study – a project to look at emergency preparedness in the Tahoe basin in response to a huge (yet still plausible) winter storm. Based on a set of wind data provided by the US Geological Survey, graduate student Patricio Moreno ran a version of the computer model STWAVE that he had adapted specifically for Lake Tahoe.

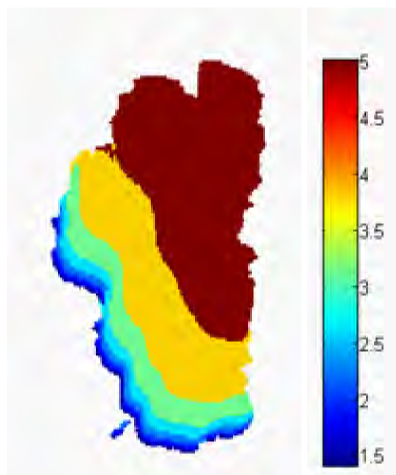
In the case of a southwesterly wind, the largest waves form in the northeast of the lake. Wave data are commonly expressed as the "significant wave height," defined as the mean of the highest one third of the waves. Typically there will be a wave twice the height of the significant wave height every 12 hours, and waves 50% higher than the significant wave height at least every 15 minutes.

The left hand figure below shows the significant wave heights generated for a sustained southwesterly wind speed of 54.7 miles per hour. The significant wave height is about 7 feet (2.2 m) maximum. There is a likelihood that some waves in excess of 14 feet will be observed during a day. A wave 11 feet high will break about every 15 minutes. The wave periods, or the time between successive wave crests, are shown in the middle figure below. The periods are approximately 5 seconds at the location of the highest waves, meaning waves will be breaking every 5 seconds.

Two things are important to consider. First the location of the highest waves will vary with the wind direction, so a northerly wind of the same magnitude would produce similar waves on the south shore of the lake. Second if such a storm was to occur at a time when lake level was near the maximum, and if the effects of the likely storm surge were included, there would be considerable local flooding and damage to public infrastructure and private property.



Distribution of significant wave heights. The colors indicate wave height in meters.



Distribution of wave periods. The colors indicate the period in seconds.

Waves breaking over Obexer's Marina with a strong easterly wind. Photo: D. Kramer

TAHOE: STATE OF THE LAKE REPORT 2014

METEOROLOGY

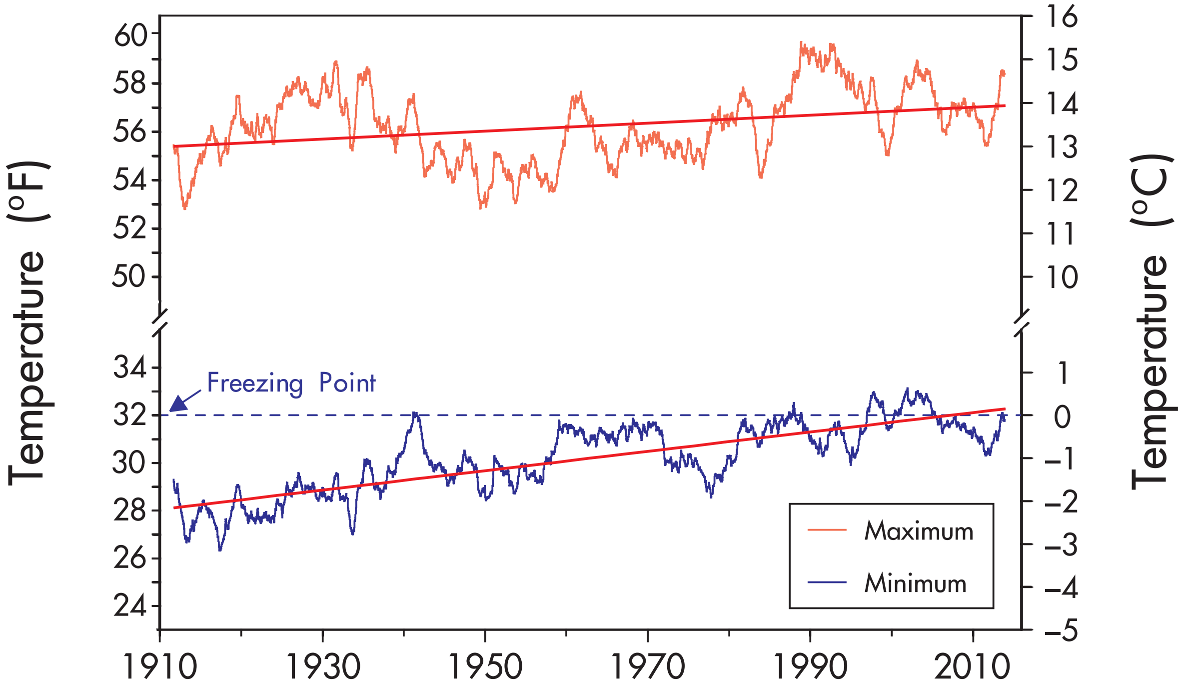
UC DAVIS
TAHOE ENVIRONMENTAL RESEARCH CENTER

METEOROLOGY

Air temperature

Daily since 1911

Over the last 100 years, the daily air temperatures measured at Tahoe City have increased. The long-term trend in daily minimum temperature has increased by 4.2 °F (2.3 °C), and the long-term trend in daily maximum temperature has risen by 1.7 °F (0.9 °C). The trend line for the minimum air temperature now exceeds the freezing temperature of water, which points to more rain and less snow, as well as earlier snowmelt. These data have been smoothed by using a two-year running average to remove daily and seasonal fluctuations. 2013 was warmer than the previous year, which came at the end of a decade-long cooling trend. The average minimum and maximum air temperatures over time since 1911 are 30.2 °F (-1.0 °C) and 56.3 °F (13.5 °C), respectively.



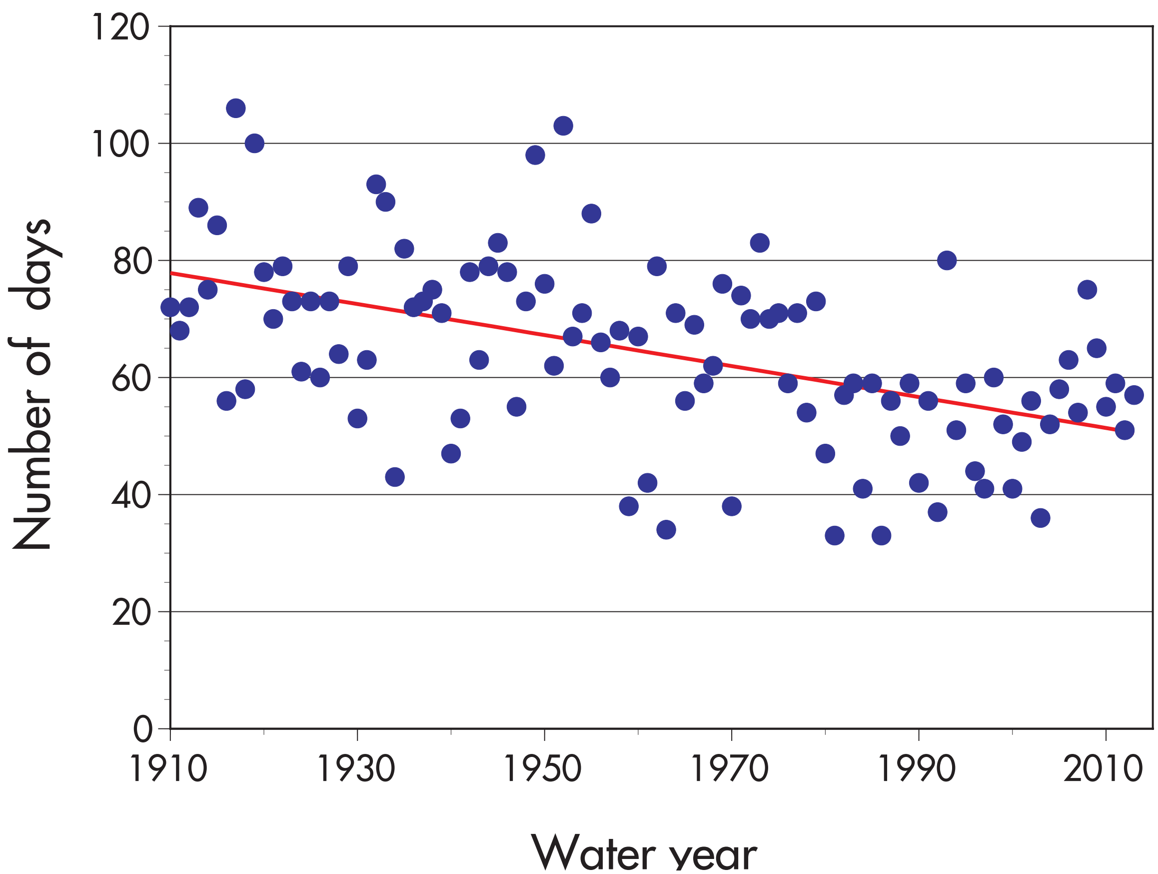
METEOROLOGY

Below-freezing air temperatures

Yearly since 1910

The method used for this analysis sums the number of days with daily average temperatures below freezing between December 1 and March 31 for each Water Year (WY). Although year-to-year variability is high, the number of days when air temperatures averaged below freezing has declined by about 27 days since 1911. In WY 2013, the number of freezing days was 57.

Note: The Water Year extends from October 1 through September 30.

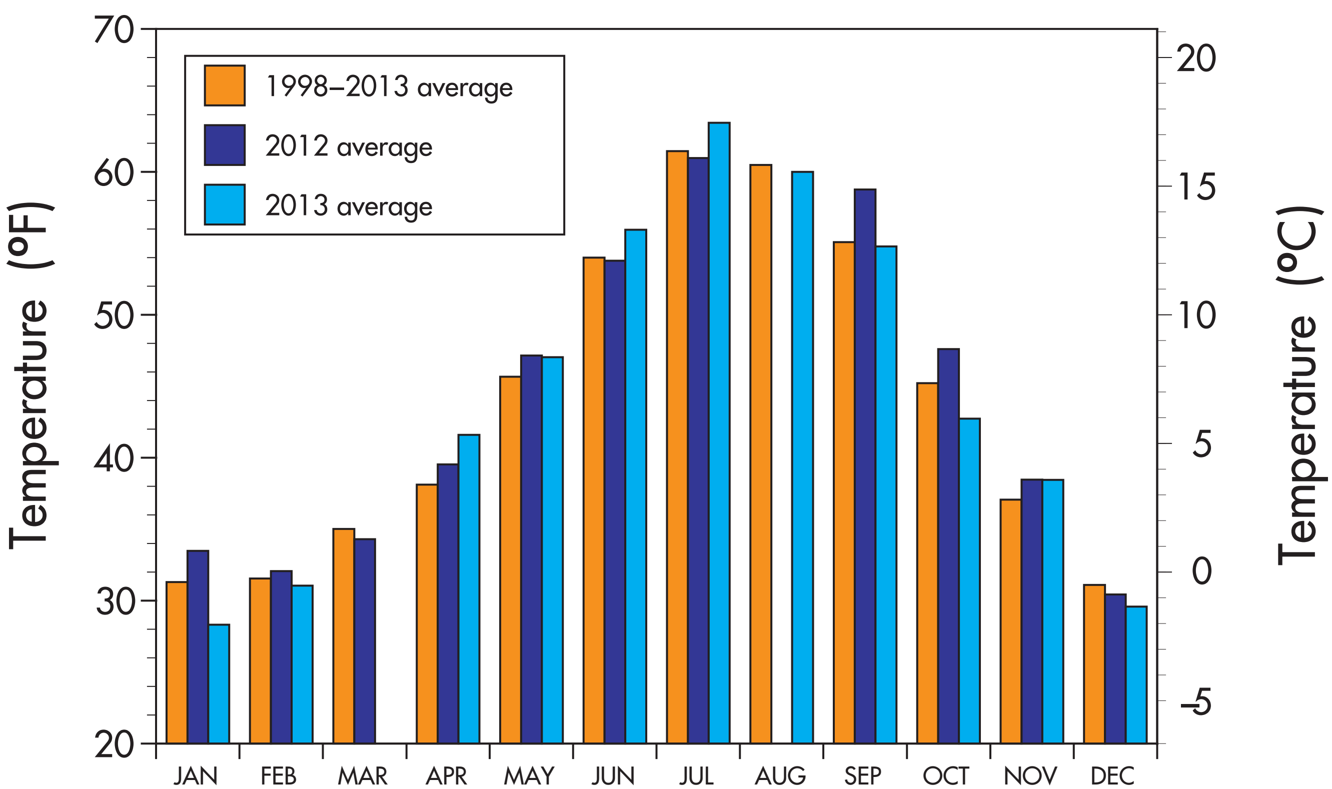


METEOROLOGY

Monthly air temperature

Since 1998

In 2013 monthly air temperatures were distinguished by being colder that the long-term mean during the winter months and warmer than the long-term mean in the summer months. In January, 2013, the air temperature was more than 3 degrees F cooler than the mean and more than 5 degrees cooler than the previous year. April through July were all warmer months than the long-term average. These trends are all consistent with the drought conditions that were experienced in the basin.

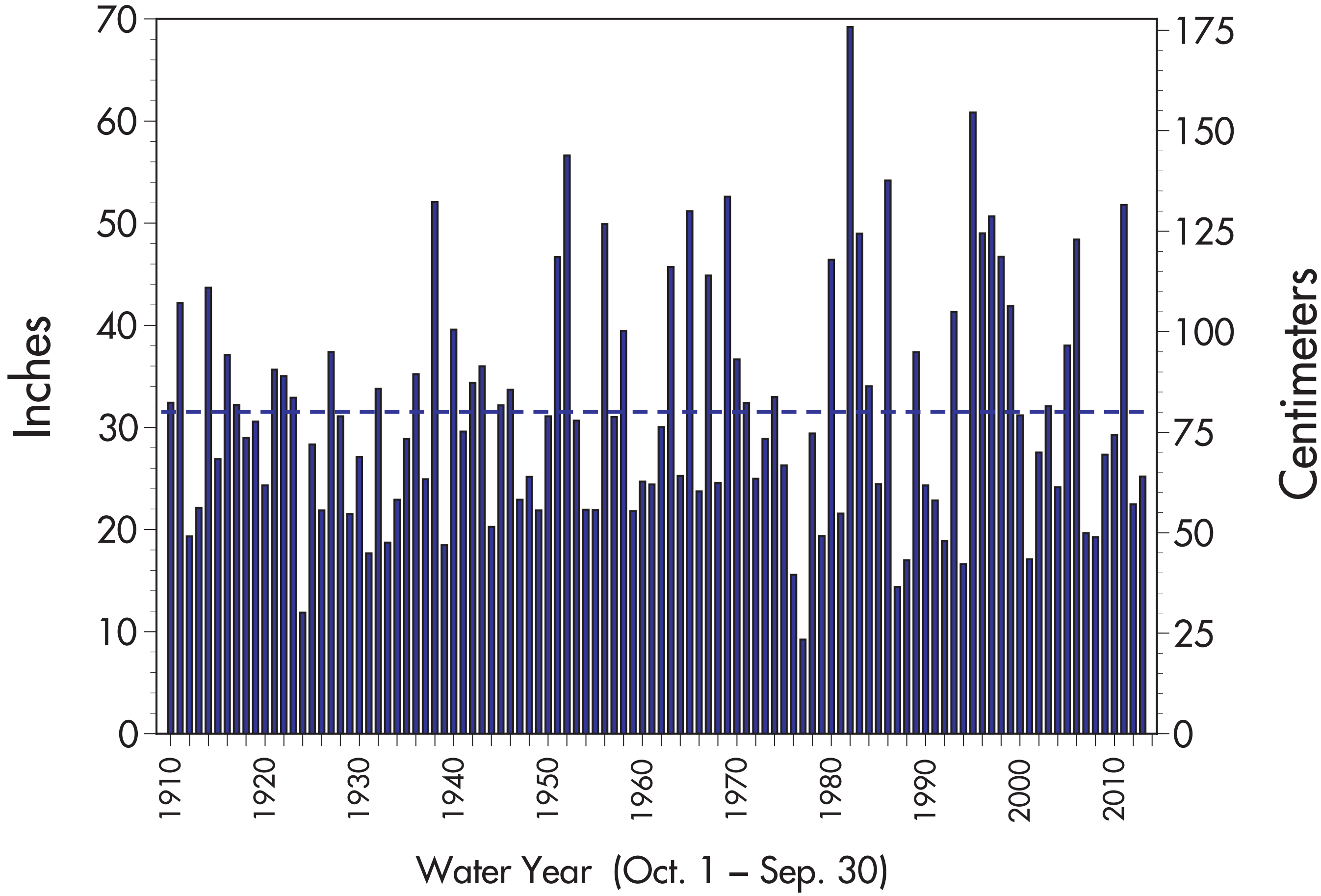


METEOROLOGY

Annual precipitation

Yearly since 1910

From 1910 to 2013, average annual precipitation (water equivalent of rain and snow) at Tahoe City was 31.53 inches. The maximum was 69.2 inches in 1982. The minimum was 9.2 inches in 1977. 2013 was well below average, with 25.19 inches, following the previous dry year which had 22.48 inches of precipitation. The long-term mean of 31.53" is shown by the dashed line. Generally there is a gradient in precipitation from west to east across Lake Tahoe, with almost twice as much precipitation falling on the west side of the lake. (Precipitation is summed over the Water Year, which extends from October 1 through September 30.)

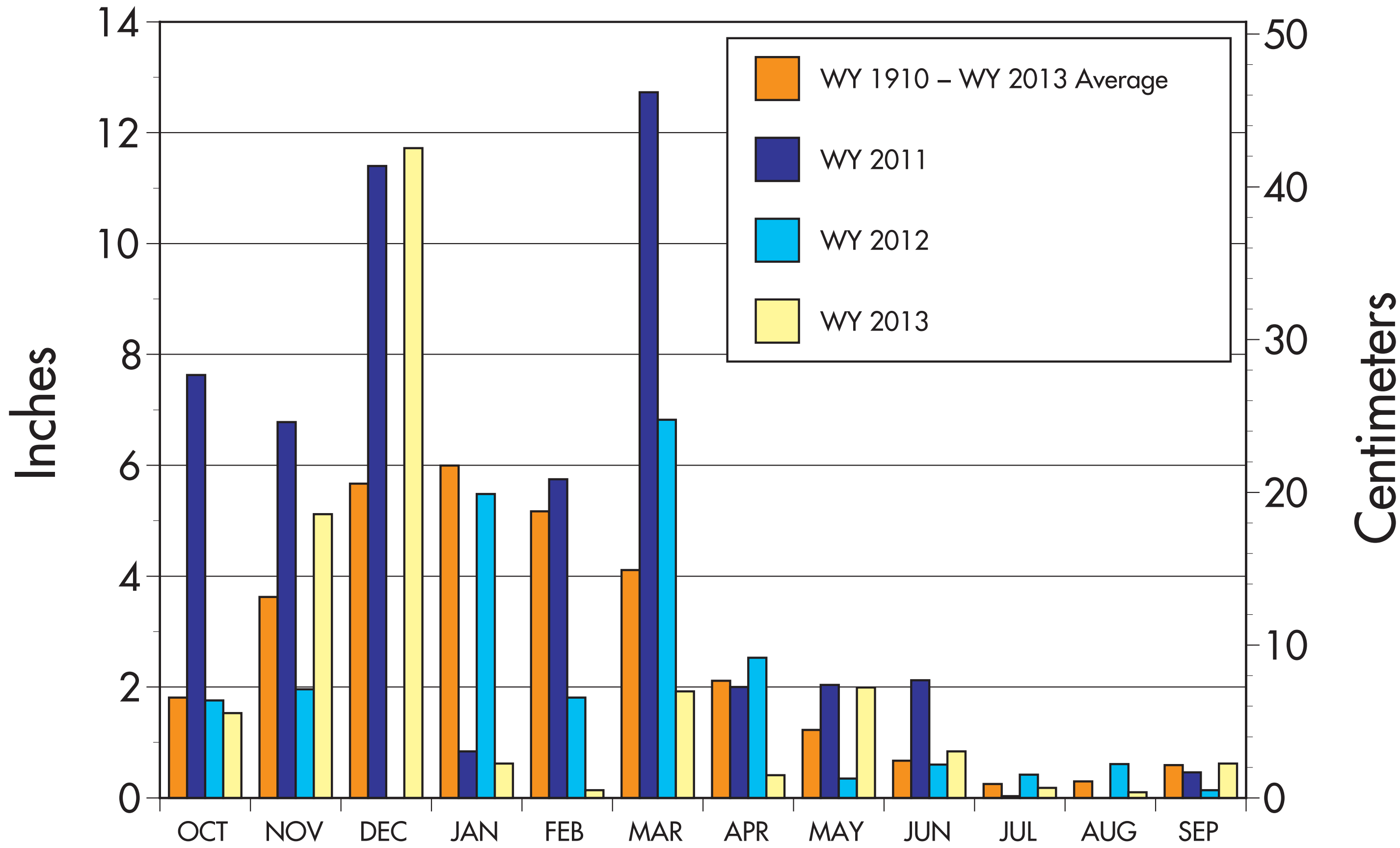


METEOROLOGY

Monthly precipitation

2011, 2012, 2013 and 1910 to 2013 Average

2013 was well below average in total precipitation. This is clearly evident in the comparison of the monthly precipitation with the previous two years and the long-term average. Monthly precipitation was particularly low from January through April. The monthly precipitation for Aug-2011 (WY 2011), and Dec-2011 (WY 2012) was 0 inches. The 2013 Water Year extended from October 1, 2012, through September 30, 2013.

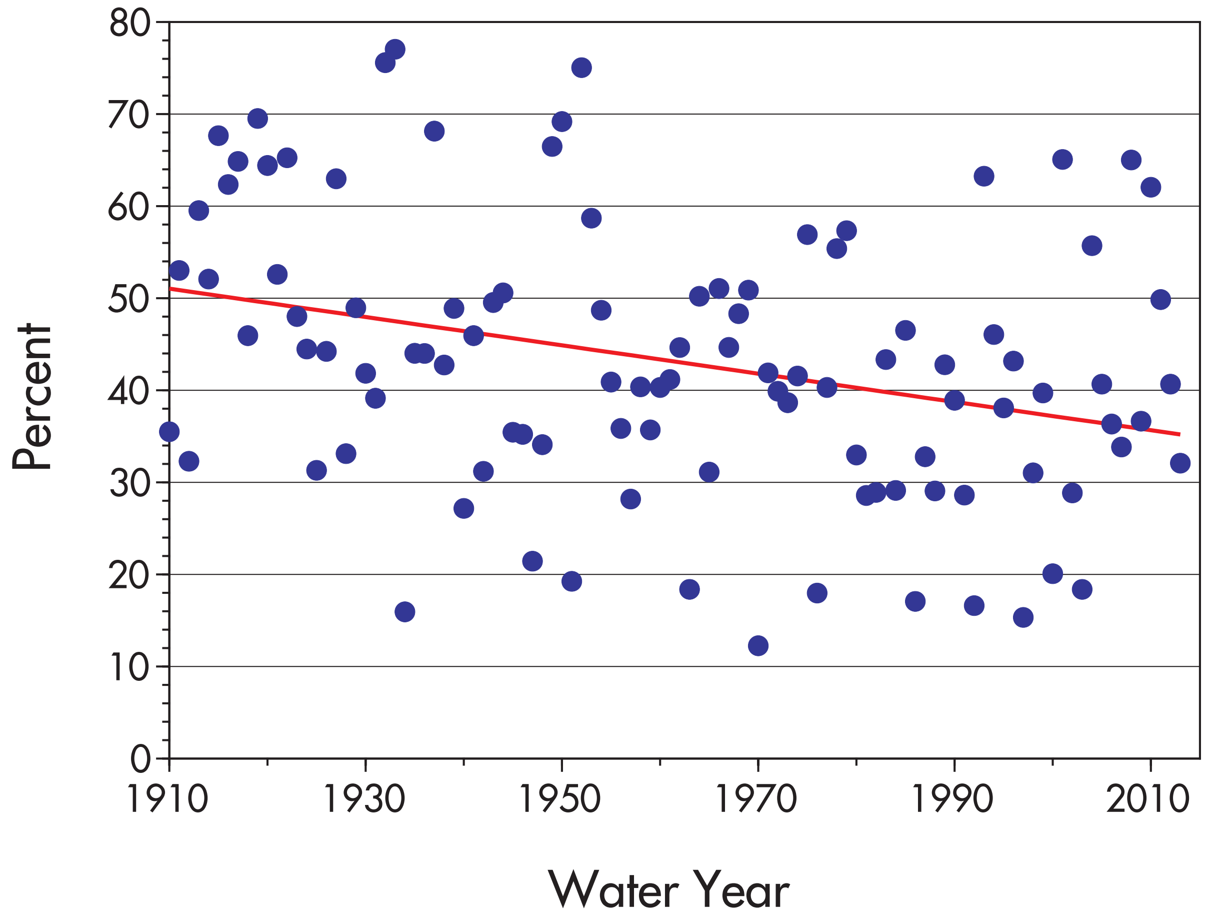


METEOROLOGY

Snow as a fraction of annual precipitation

Yearly since 1910

Snow has declined as a fraction of total precipitation, from an average of 51 percent in 1910 to 35 percent in present times according to the line of best fit. In Tahoe City, snow represented 32 percent of the 2013 total precipitation, slightly below the long-term trend. These data are calculated based on the assumption that precipitation falls as snow whenever the average daily temperature is below freezing. (Precipitation is summed over the Water Year, which extends from October 1 through September 30.)



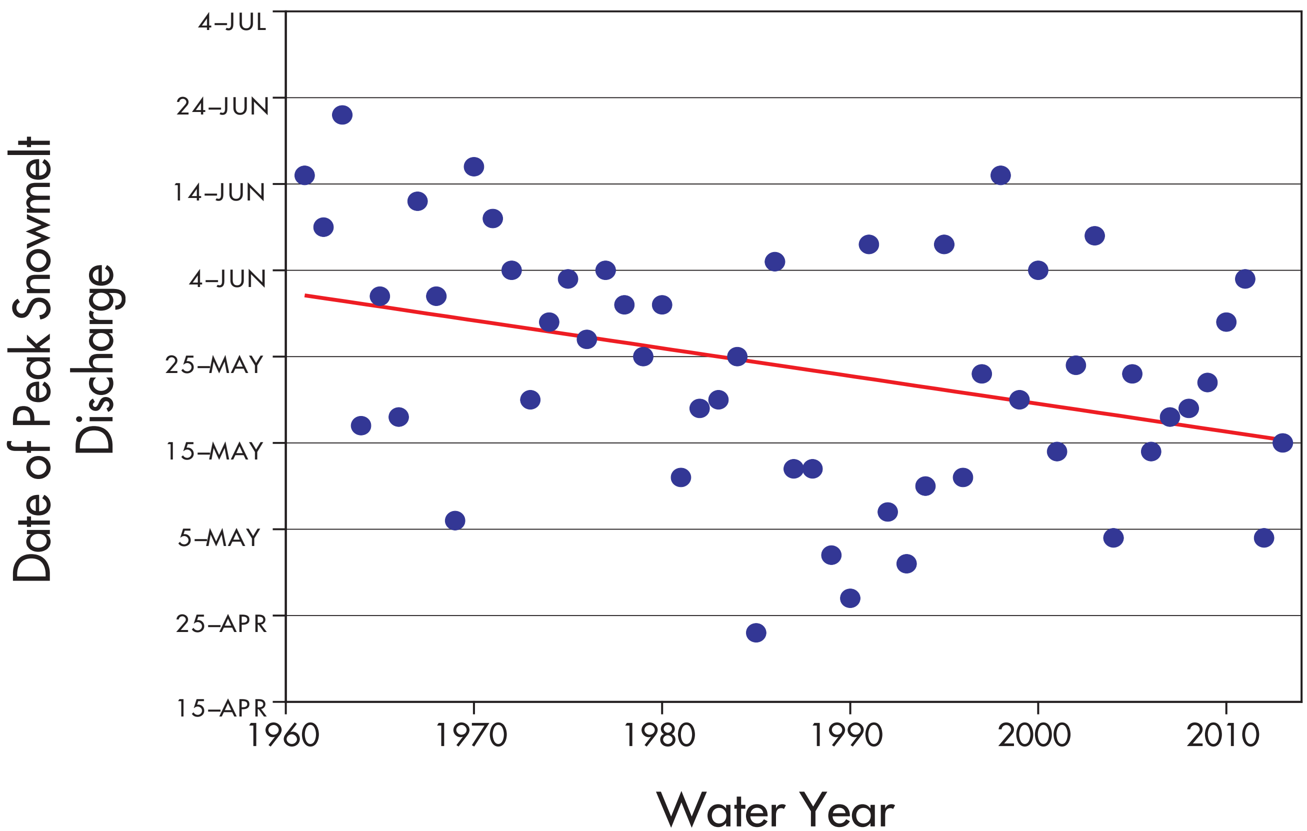
METEOROLOGY

Shift in snowmelt timing

Yearly since 1961

Although the date on which peak snowmelt occurs varies from year to year, since 1961 it has shifted earlier an average of over 2 weeks (16.6 days). This shift is statistically significant and is one effect of climate change at Lake Tahoe.

Peak snowmelt is defined as the date when daily stream flows reach their yearly maximum. Daily stream flows increase throughout spring as the snow melts because of rising air temperatures, increasing solar radiation and longer hours of daylight. The data here are based on the average from the Upper Truckee River, Trout Creek, Blackwood Creek, Ward Creek, and Third Creek.



TAHOE: STATE OF THE LAKE REPORT 2014

PHYSICAL PROPERTIES

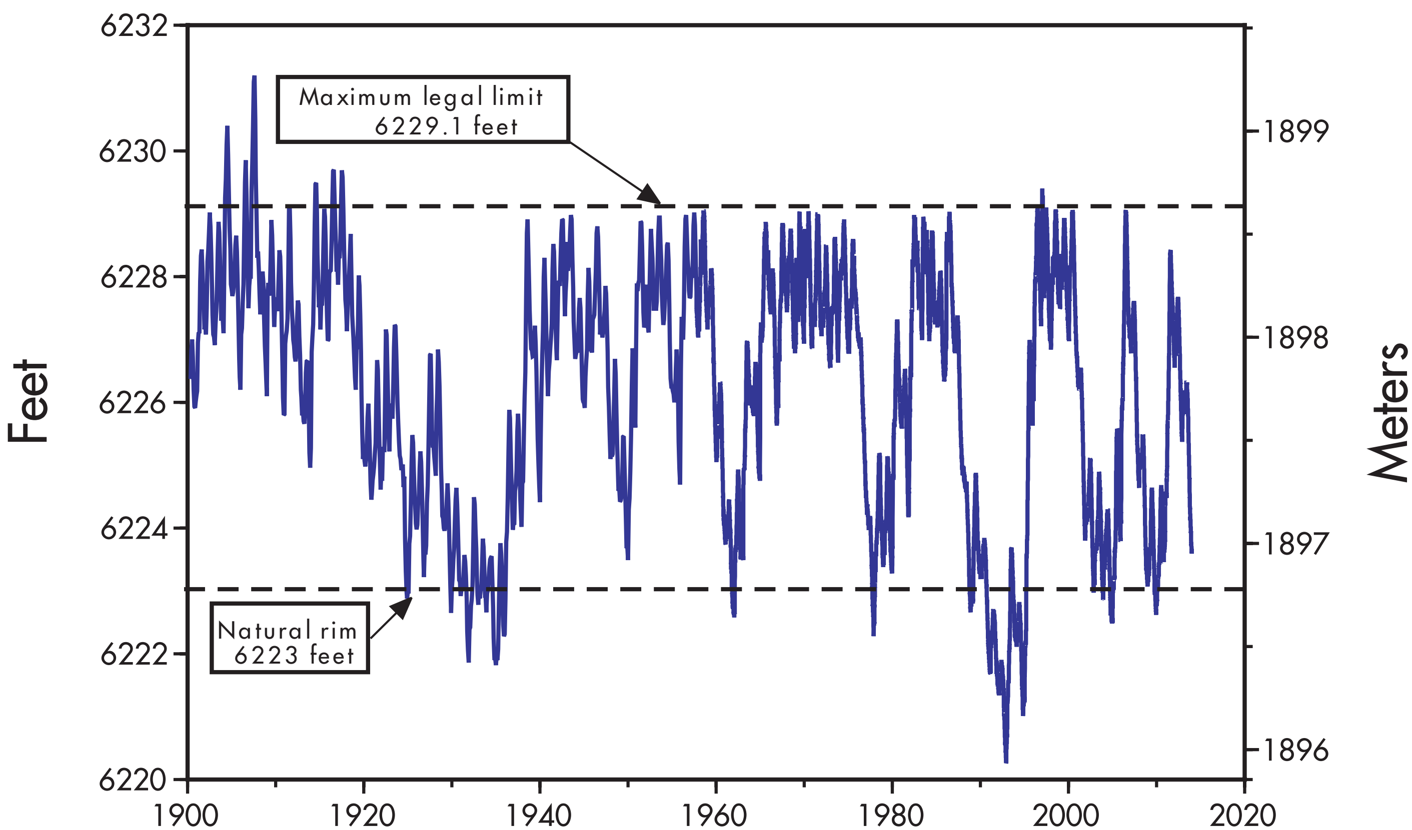
UCDAVIS
TAHOE ENVIRONMENTAL RESEARCH CENTER

PHYSICAL PROPERTIES

Lake surface level

Daily since 1900

Lake surface level varies throughout the year. It 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 fell during 2013. The highest lake level was 6226.32 feet on May 18 and again on June 9, and the lowest was 6223.59 feet on December 31. In 2013, the lake level rose by only 6 inches during snowmelt, compared with 3.9 feet in 2011.

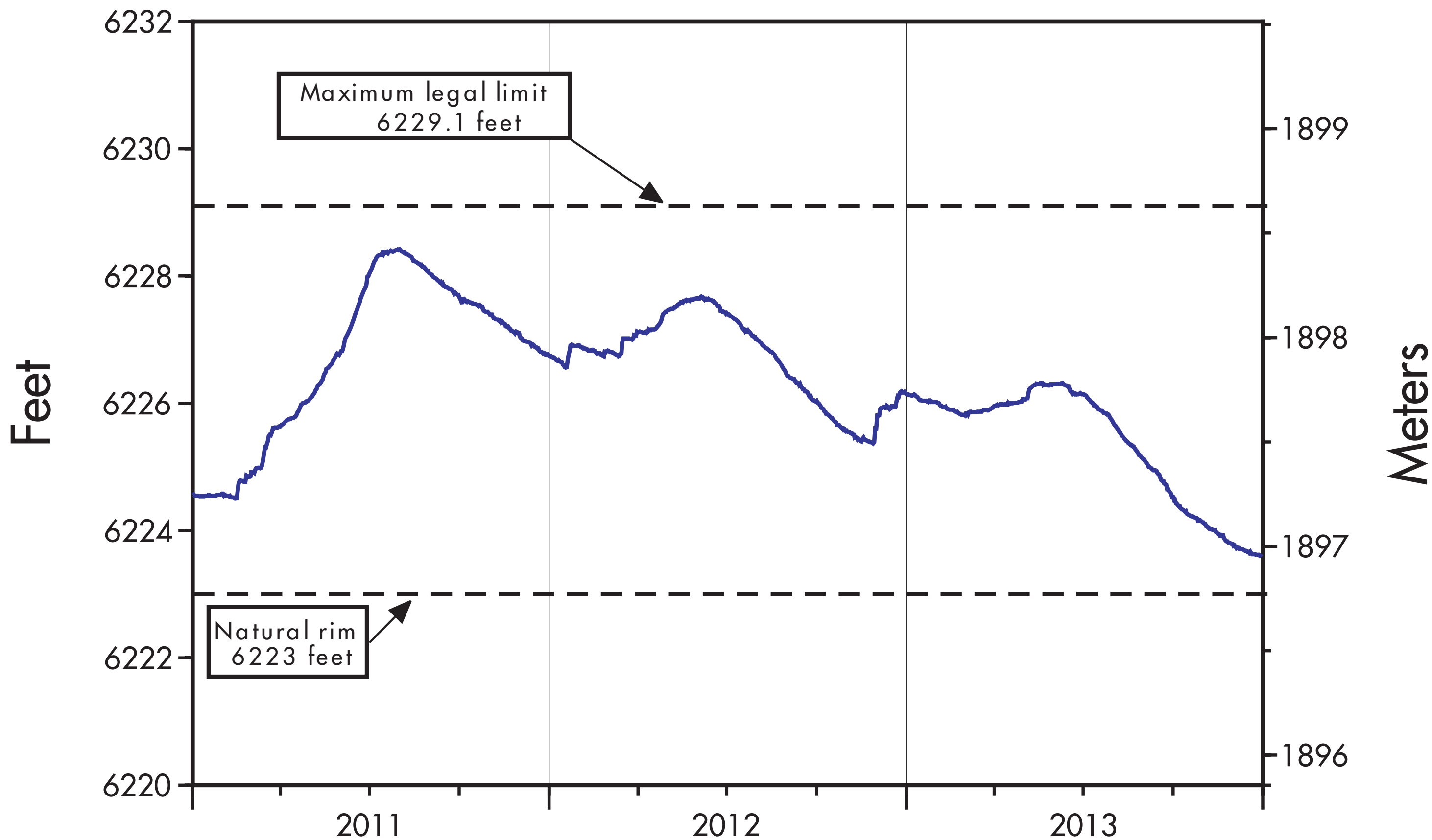


PHYSICAL PROPERTIES

Lake surface level, continued

Daily since 2011

Displayed below is the lake surface data from 2011-2013 extracted from the same data on page 8.1. This more detailed presentation of recent lake level data allows us to see the seasonal patterns in greater detail. Data clearly show the lake level only 7 inches above the natural rim at the end of 2013 as well as the timing of highest yearly lake levels in late spring following snowmelt. The effects of the high snowfall in December 2012 on lake level are clearly evident.

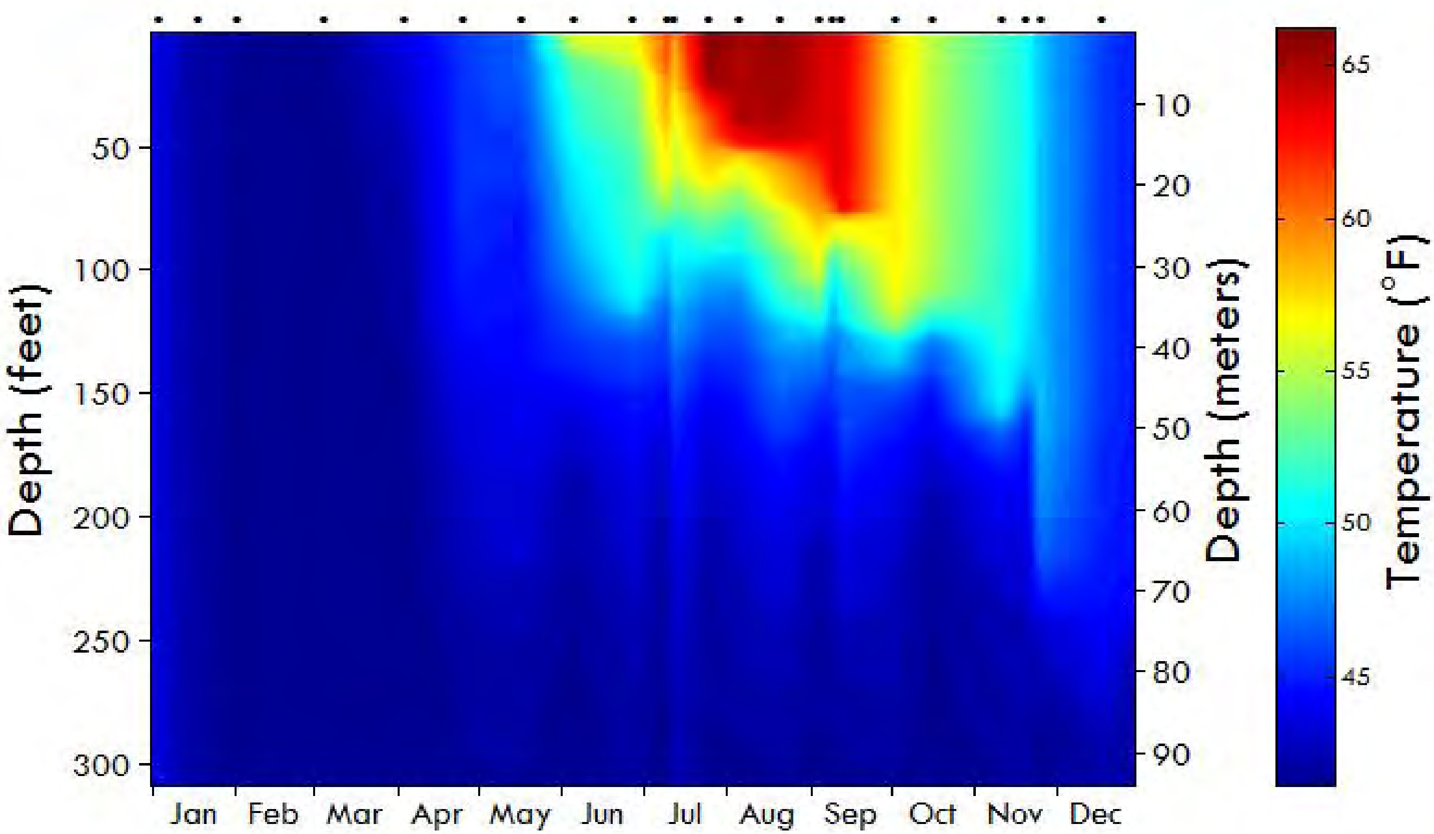


PHYSICAL PROPERTIES

Water temperature distribution

In 2013

Water temperature profiles are measured in the lake using a Seabird CTD at the times indicated by the dots along the top of the figure. The temperature is accurate to within 0.005 °F. Here the temperature in the upper 330 feet is displayed as a color contour plot. In 2013, the lake temperature followed a typical seasonal pattern. In late March, the lake surface was at its coldest. The beginning of the 2013-2014 winter mixing is evident at the end of the plot, with the surface layer both cooling and deepening. By the end of 2013, mixing had proceeded to only 245 feet (74 m), a relatively shallow amount.

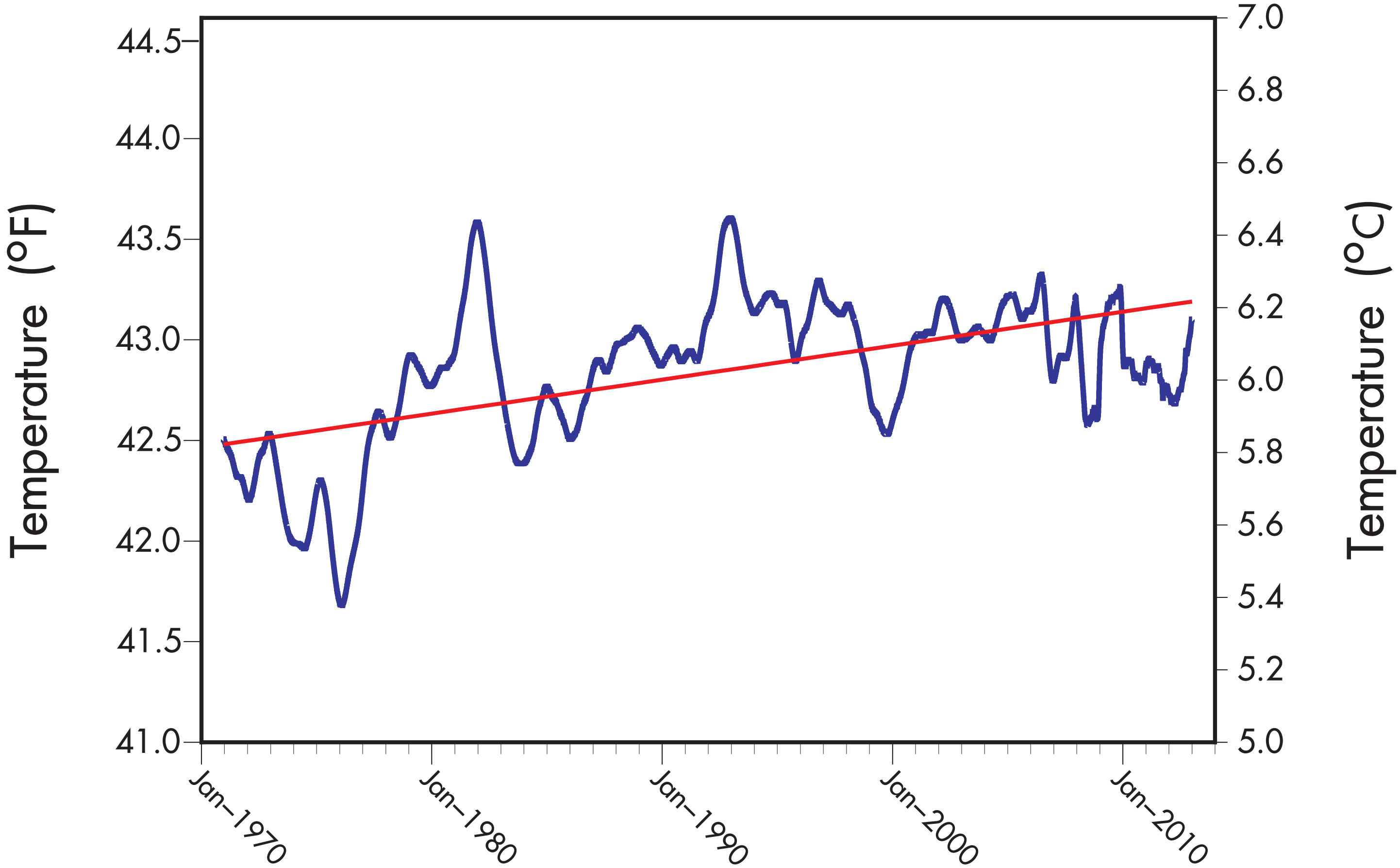


PHYSICAL PROPERTIES

Average water temperature

Since 1970

The trend in the volume-averaged temperature of Lake Tahoe has increased by approximately 0.7 °F since 1970. The annual rate of warming is 0.017 °F (0.0094 °C). The monthly temperature profile data from 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 considerably greater, but an unusual number of deep mixing years since 1997 have slowed the warming rate.

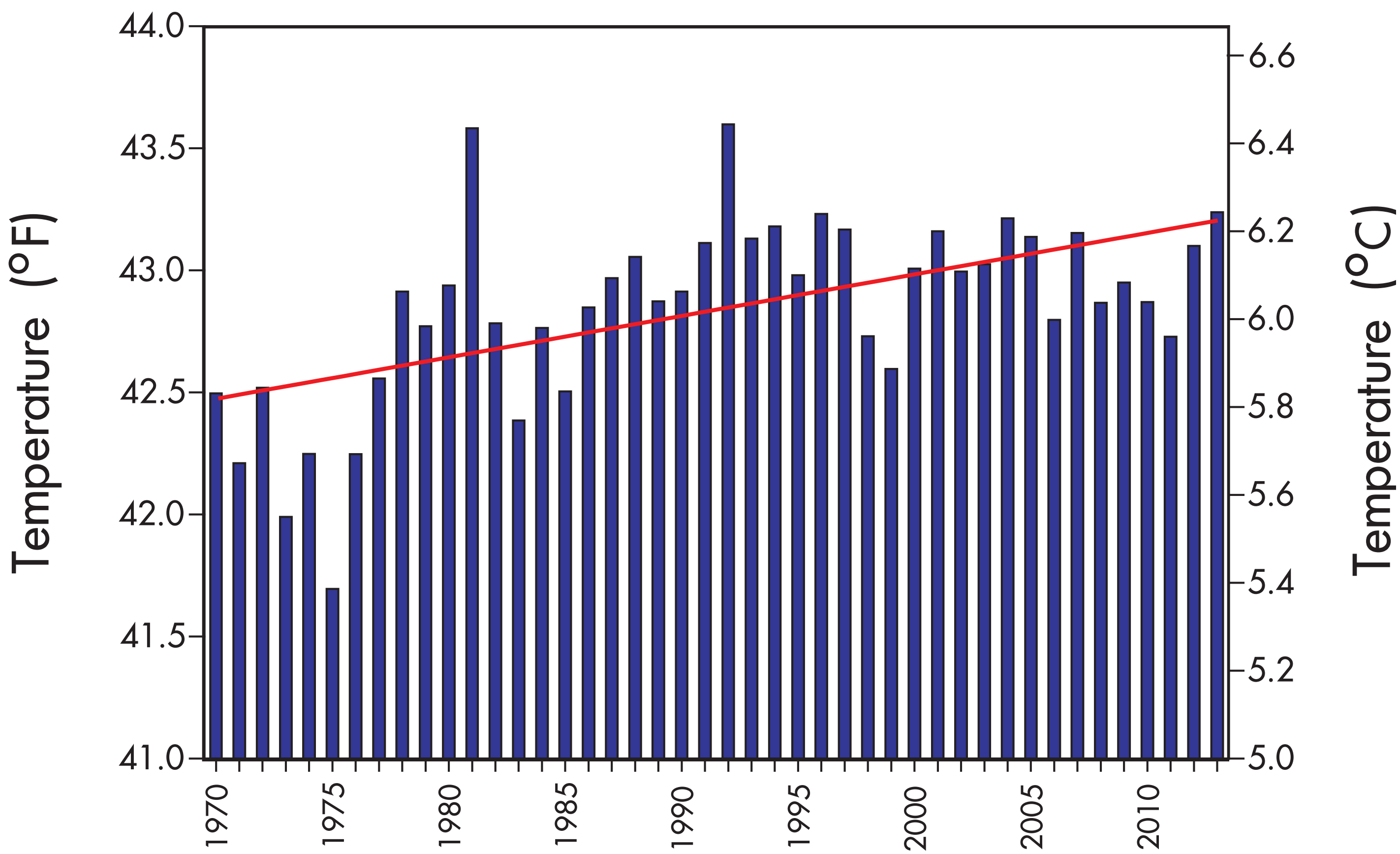


PHYSICAL PROPERTIES

Annual average water temperature

Since 1970

The volume-averaged temperature of the lake for each year since 1970 is shown. In 2013 the volume-averaged temperature increased by 0.14 °F (0.08 °C) over the previous year. The years with the largest decreases in temperature generally correspond to those years in which deep mixing occurred. Years with increases in temperature are often associated with a lack of deep mixing.

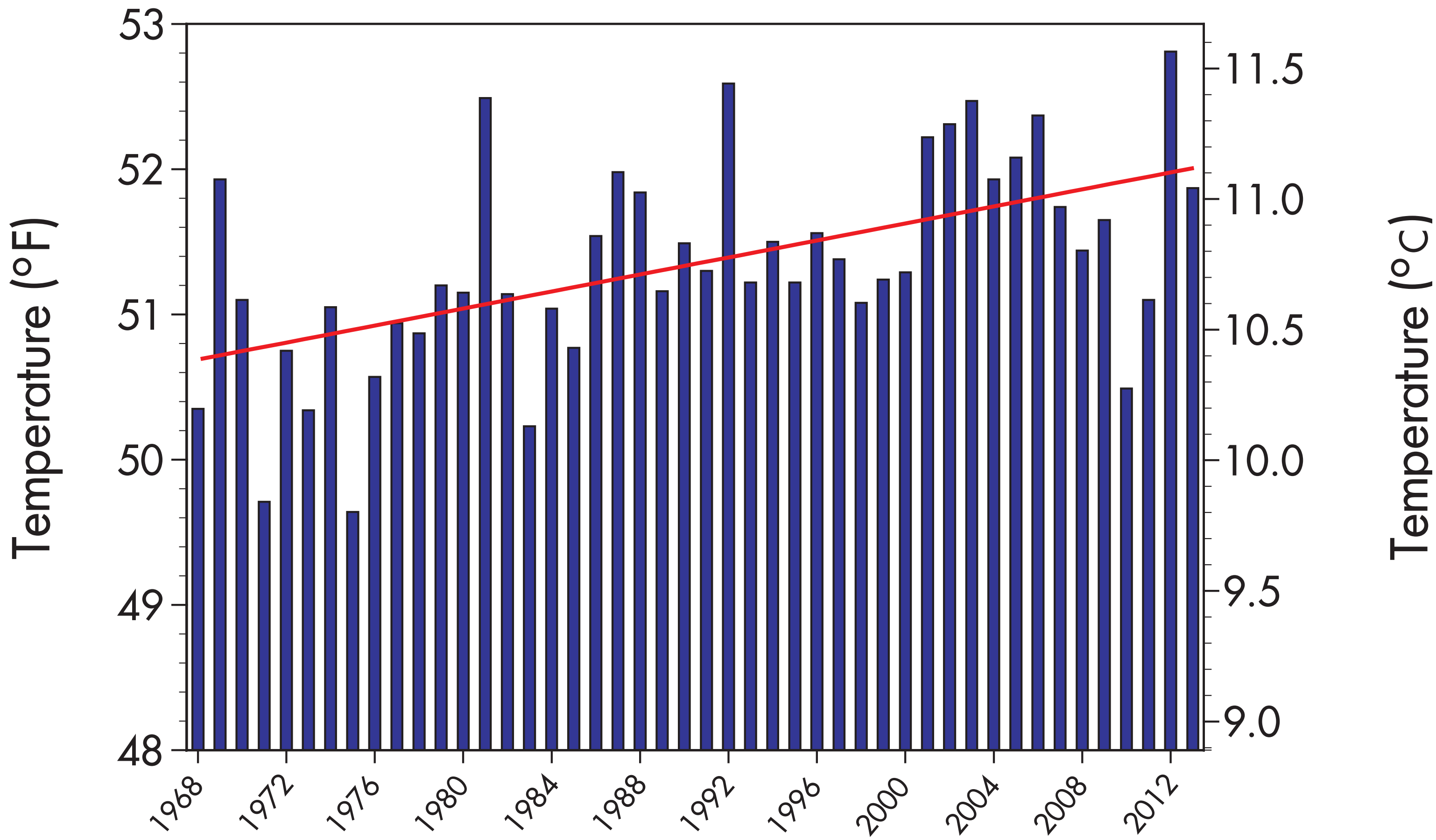


PHYSICAL PROPERTIES

Surface water temperature

Yearly since 1968

Surface water temperatures have been recorded monthly at the mid-lake station since 1968 from the R/V John LeConte. Despite year-to-year variability, the annual average surface water temperatures show an increasing trend. The average temperature in 1968 was 50.3 °F (10.2 °C). For 2013, the average surface water temperature was 51.9 °F, a decrease of 0.9 °F (0.5 °C) over 2012, the warmest year yet recorded. The overall rate of warming of the lake surface is 0.029 °F (0.016 °C) per year.

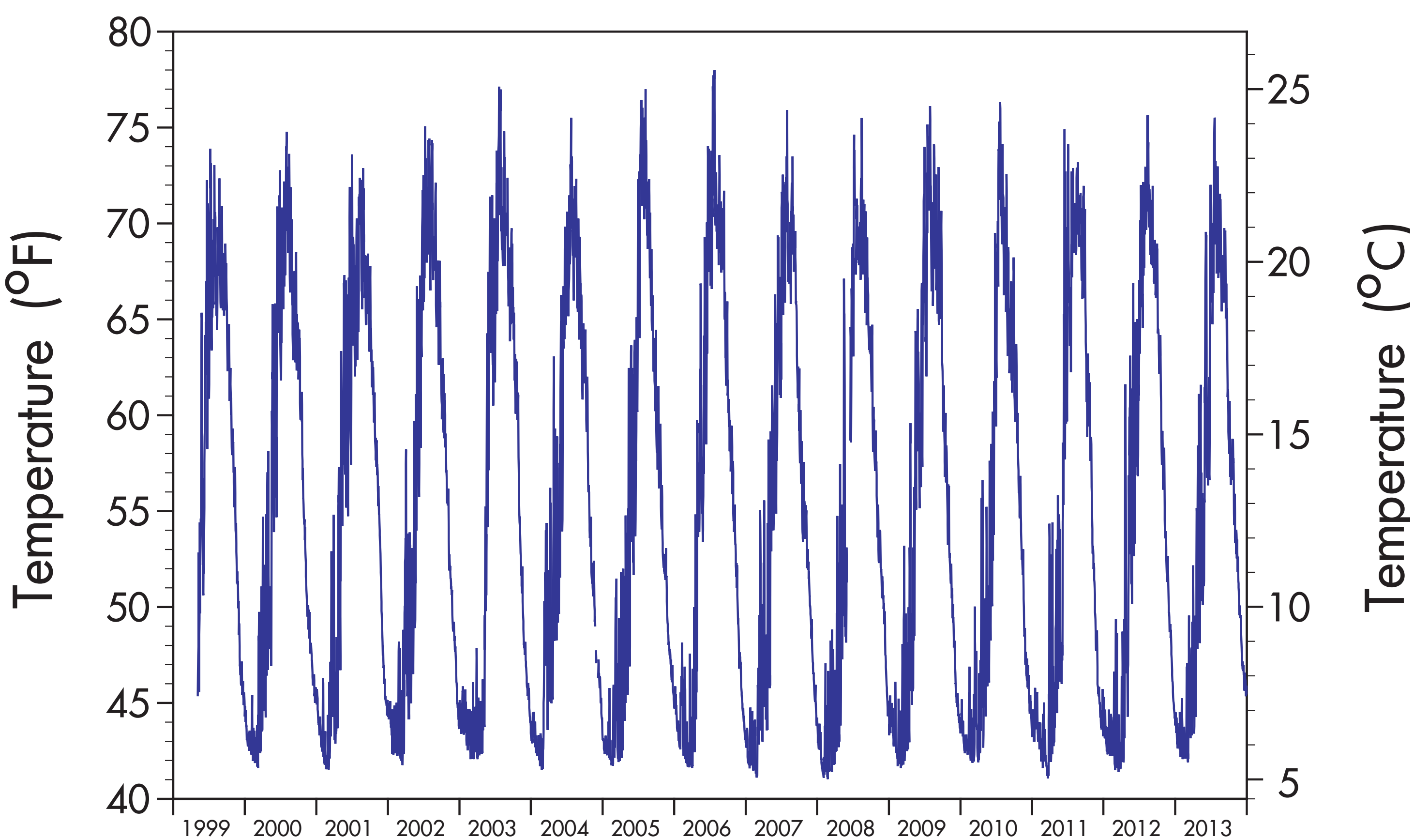


PHYSICAL PROPERTIES

Maximum daily surface water temperature

Surface temperature measured every 2 minutes since 1999

The maximum daily surface water temperature in 2013 was similar to 2012. The highest maximum daily surface water temperature was 74.32 °F, which was recorded at 2pm on July 20, 2013. The lowest maximum daily surface water temperature was 41.41 °F, which was recorded at 6:50am on March 10, 2012. These data are collected in real-time by NASA and UC Davis from 4 buoys located over the deepest parts of the lake.

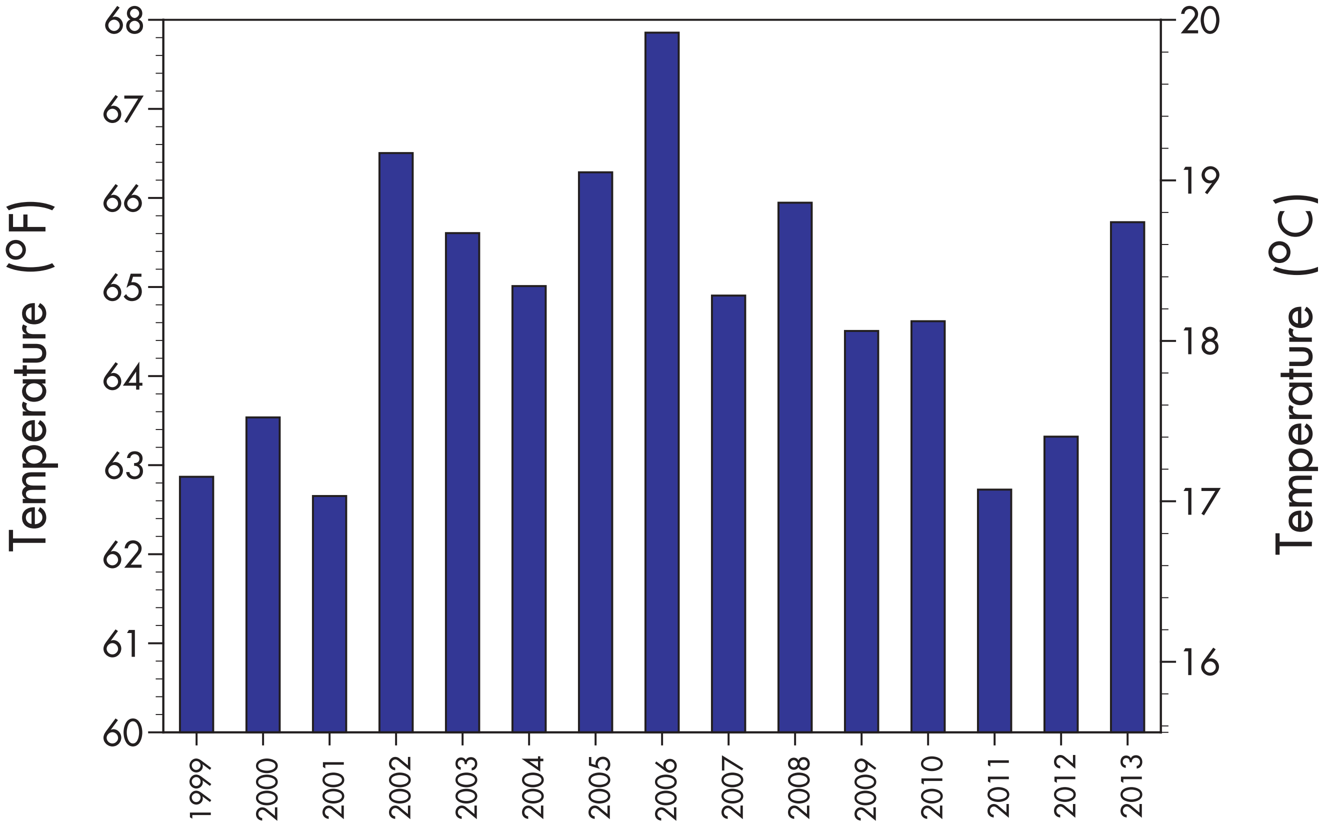


PHYSICAL PROPERTIES

July average surface water temperature

Measured every 2 minutes since 1999

Since 1999, surface water temperature has been recorded every two minutes from four NASA/UC Davis buoys. Shown here are 15 years of average surface water temperatures in the month of July when water temperatures are typically warmest. In 2013, July surface water temperature averaged 63.3 °F, compared with 62.7 °F in 2011. This increase is most likely attributable to the absence of deep lake mixing in 2012, an event that cools the surface layers of the lake. The average for the 14 year period is 64.7 °F.

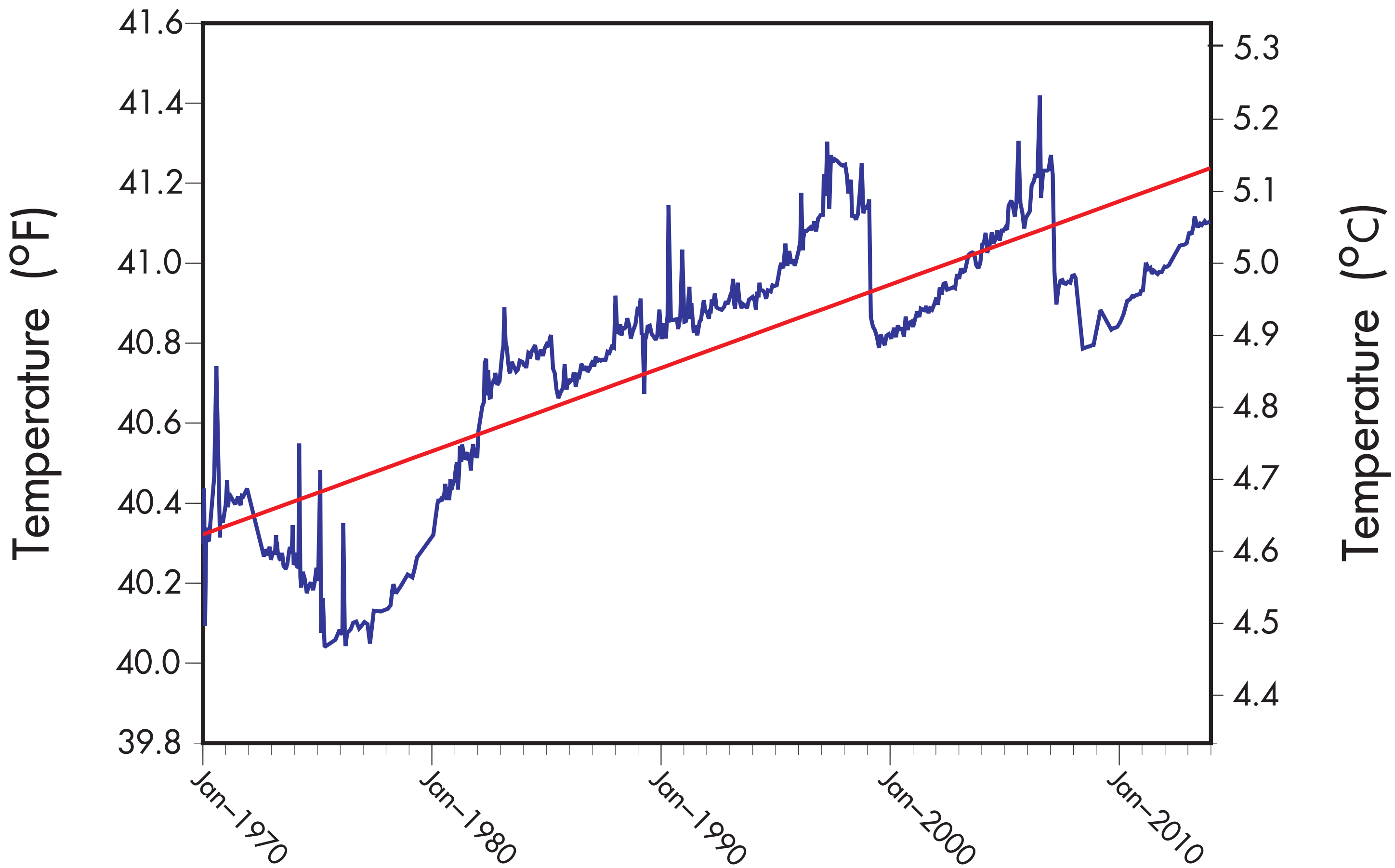


PHYSICAL PROPERTIES

Deep water temperature

Since 1970

The water temperature at a depth of 1320 feet (400 m) is indicative of conditions in the deeper waters (hypolimnion) of Lake Tahoe. Since 1970 the deep water temperature has increased by approximately 1 °F (0.6 °C), at an annual rate of 0.021 °F (0.012 °C), a rate of warming slower than the surface water. This increase has not been steady but 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 short spikes of temperature increase are temporary effects caused by motions of internal waves.

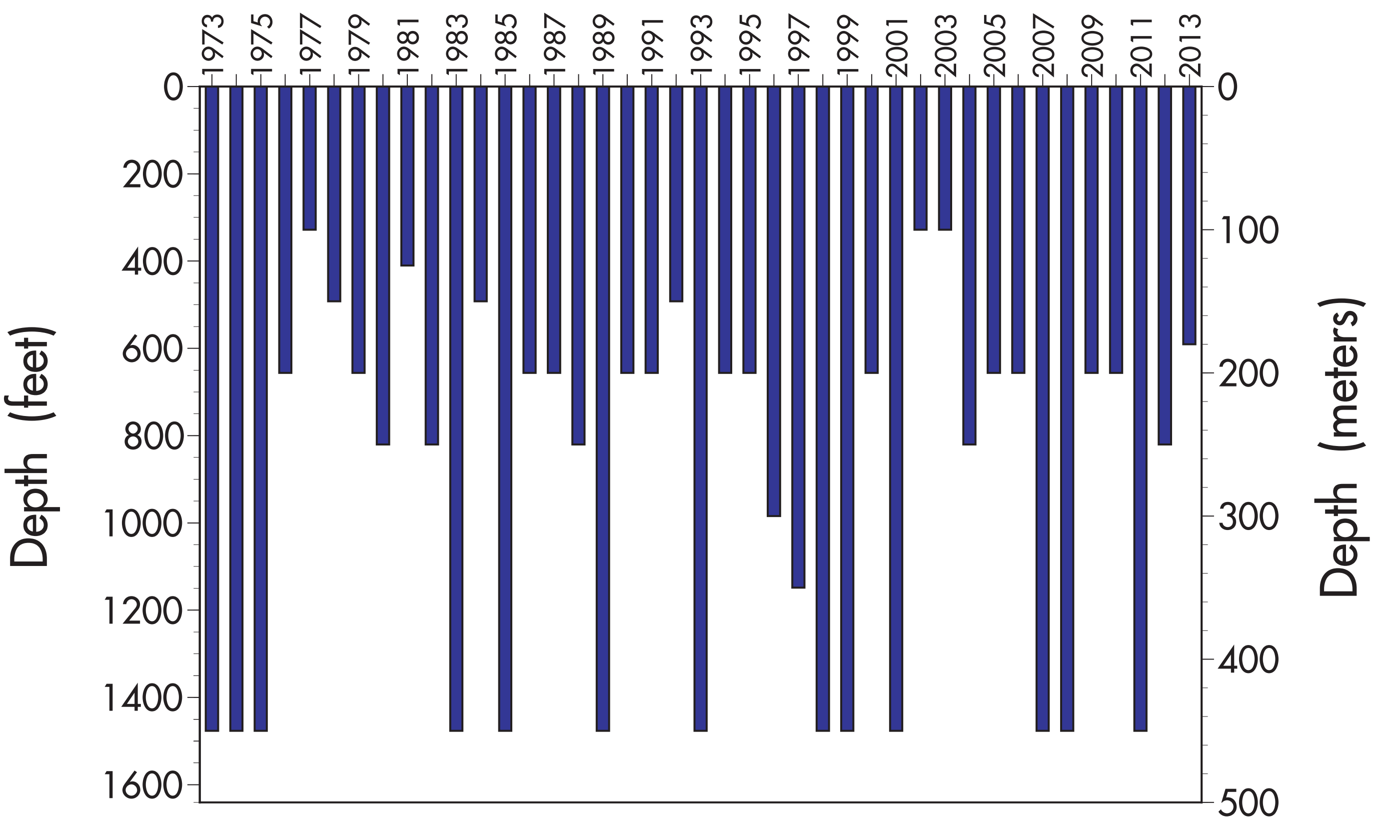


PHYSICAL PROPERTIES

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 helps to 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 2013, Lake Tahoe mixed to a depth of only 600 feet (180 m). This lack of deep mixing most likely contributed to the warmer surface temperature and the generally higher clarity. Beginning in 2013, the depth of mixing is based on high-resolution temperature profiles rather than nitrate concentration sampled at discrete depths.

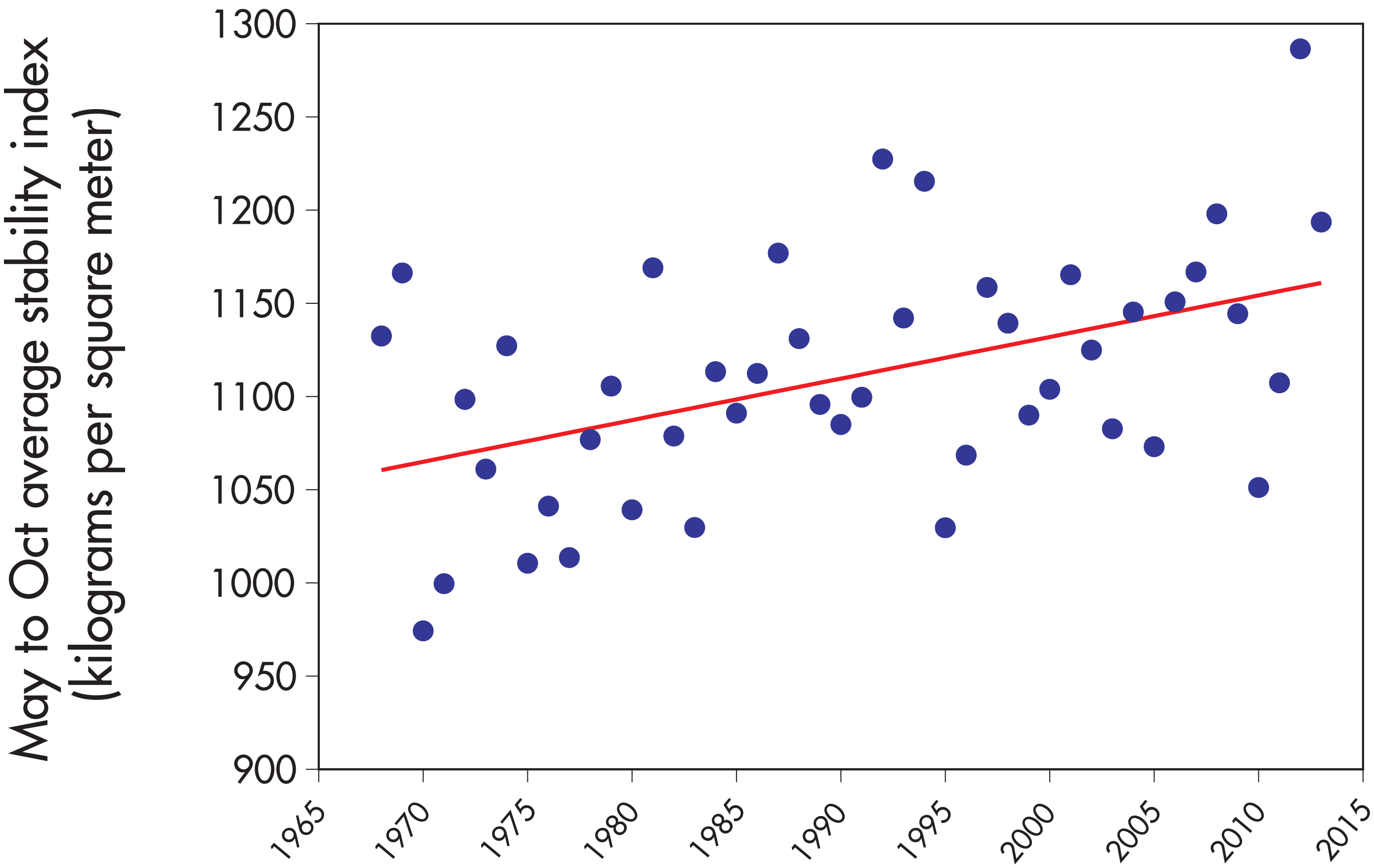


PHYSICAL PROPERTIES

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, denser 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 10% in the last 45 years.

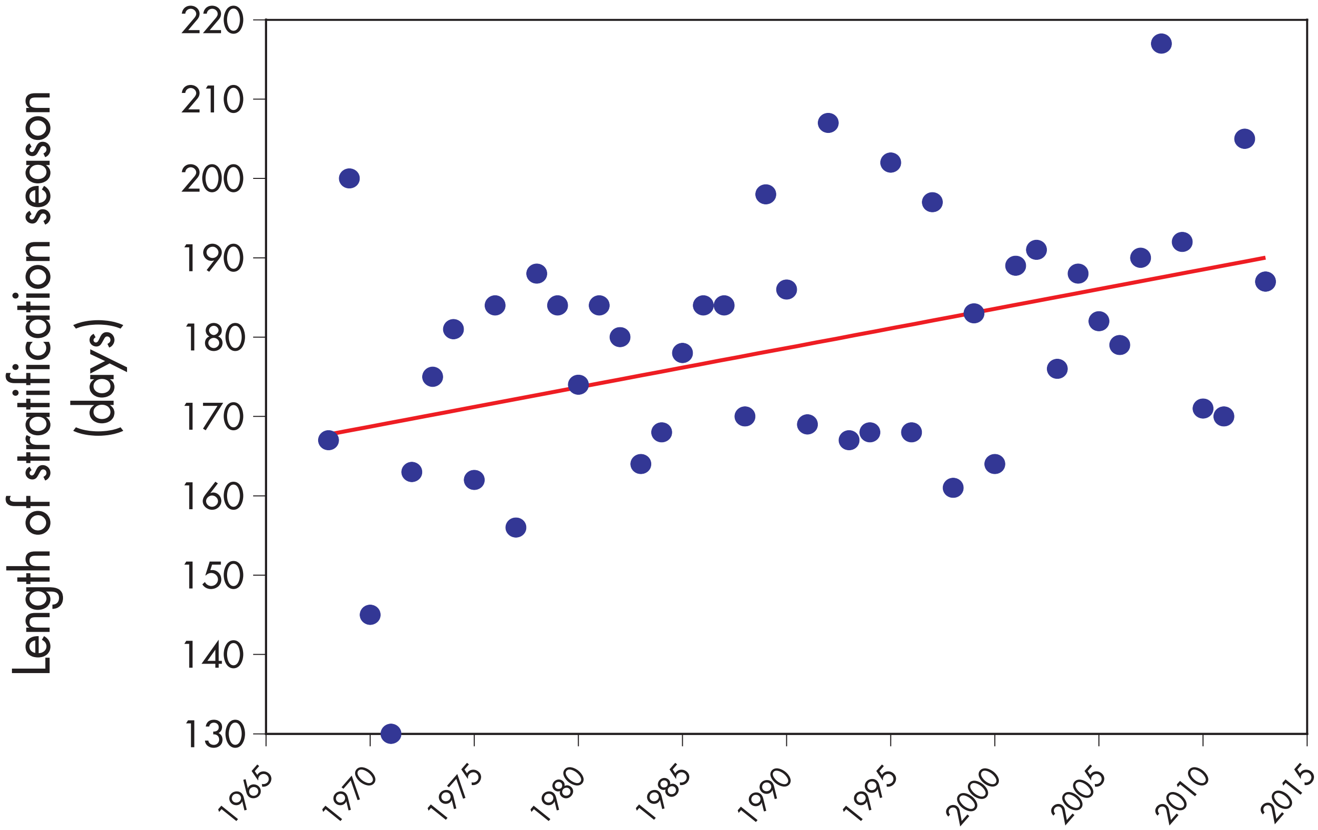


PHYSICAL PROPERTIES

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 lengthened, albeit with considerable year-to-year variation. Overall the stratification season has lengthened by approximately three weeks. See section 6.5 for more information on this trend.

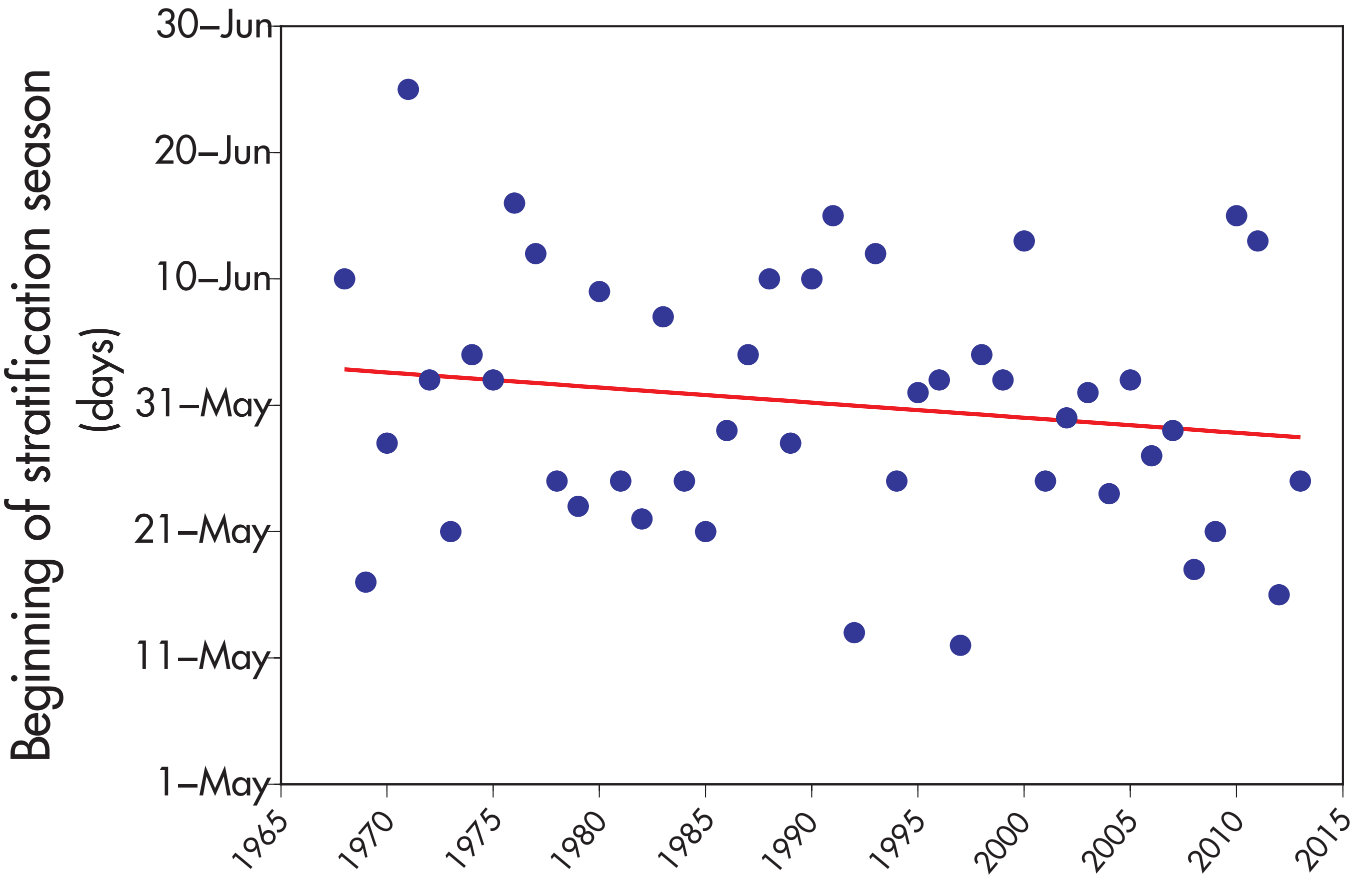


PHYSICAL PROPERTIES

Beginning of the stratification season

Since 1968

The length of time that Lake Tahoe is stratified has lengthened since 1968 by approximately three weeks. The commencement of stratification appears to occur earlier in the year by approximately three days on average. The commencement of the stratification season is typically in late May or early June.

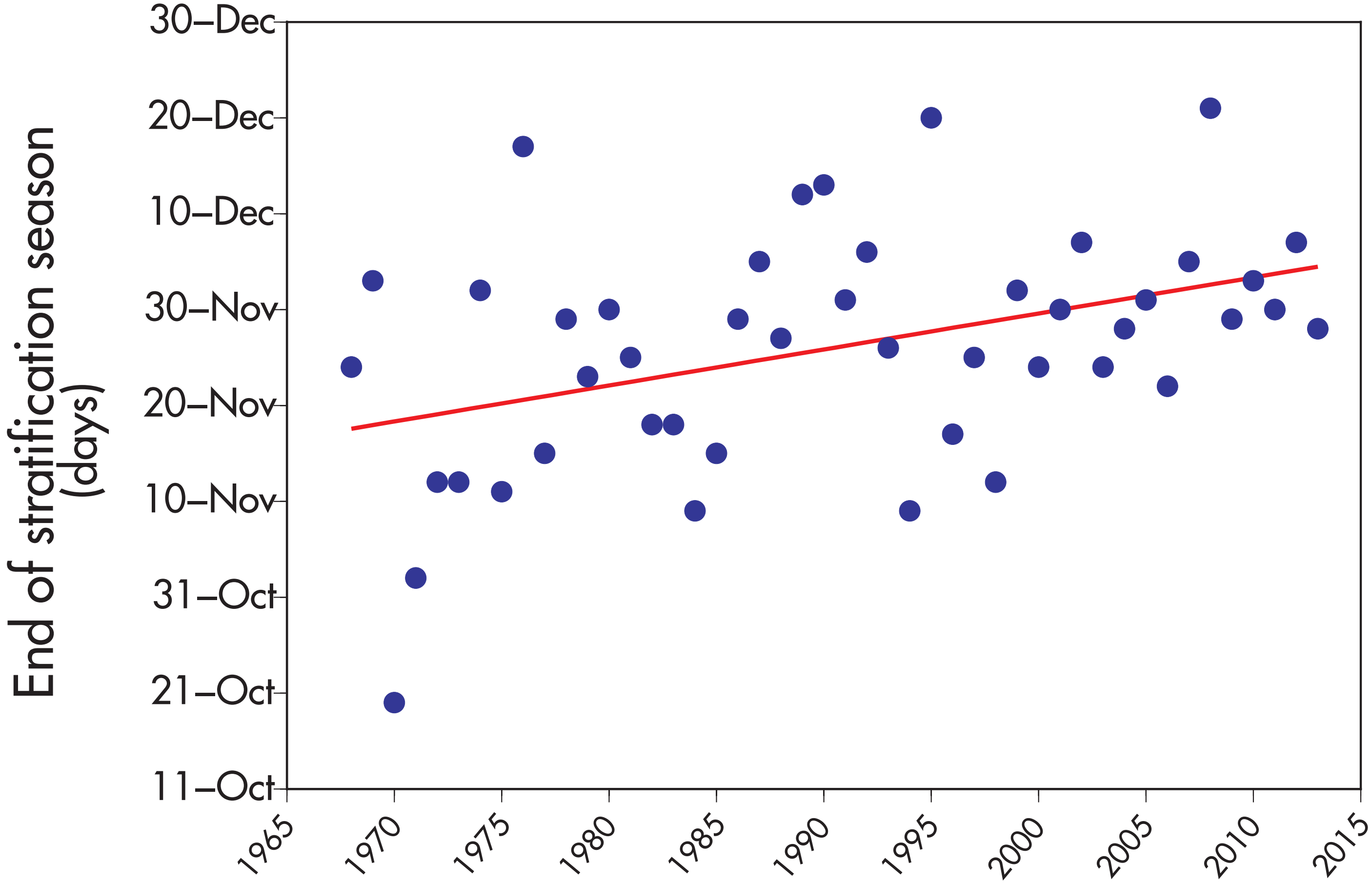


PHYSICAL PROPERTIES

End of stratification season

Since 1968

The length of time that Lake Tahoe is stratified has lengthened since 1968 by approximately three weeks. The end of stratification appears to have been extended by approximately 18 days on average. In other words, the fall season for the lake has been considerably extended. In the late 1960's stratification ended in mid-November. Now it ends in early December. This has important implications for lake mixing and water quality.

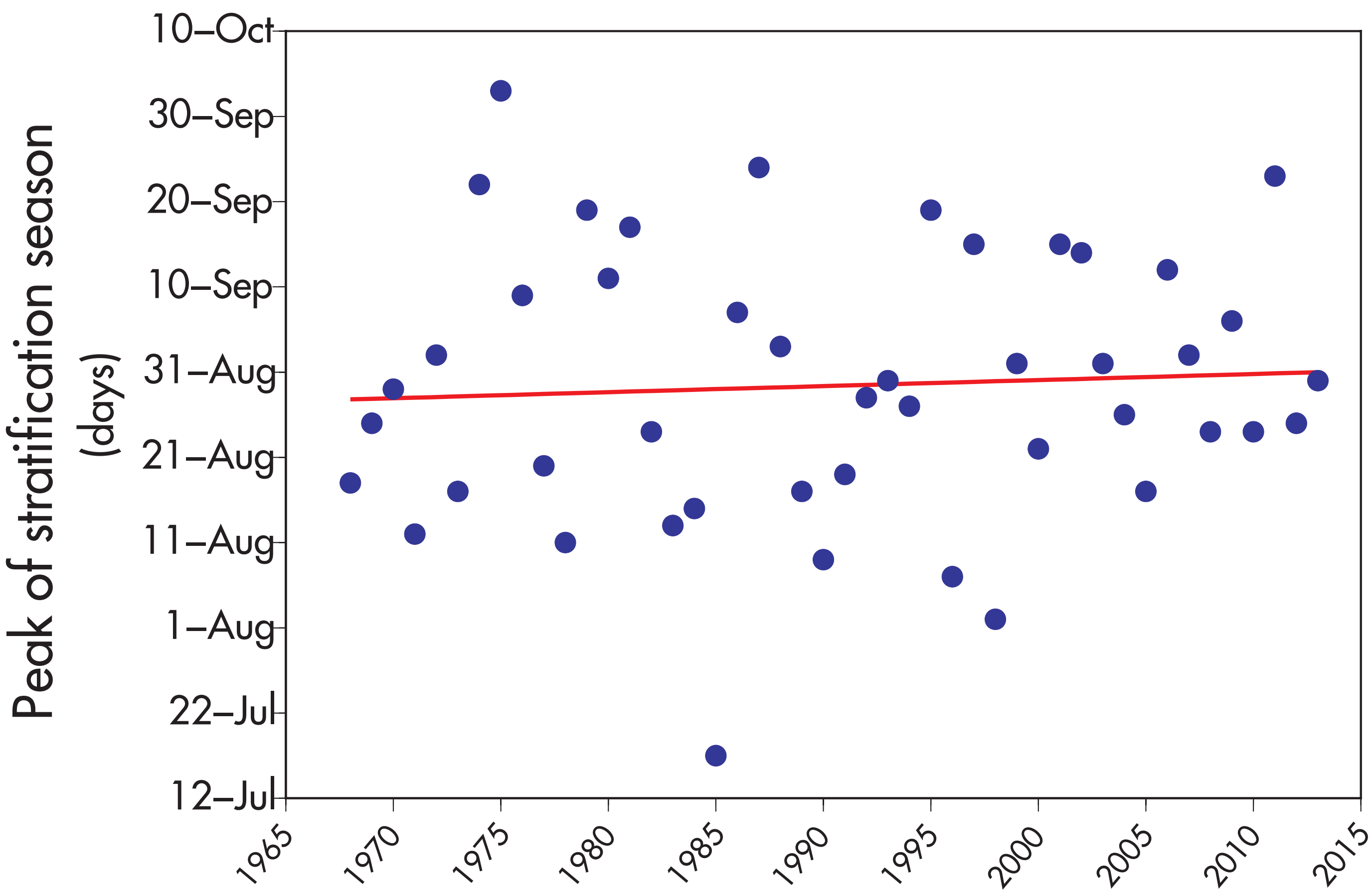


PHYSICAL PROPERTIES

Peak stratification value

Since 1968

The maximum value that the stability index obtains for each year has been plotted. As can be seen, the strength of the stratification has not changed significantly since 1968. However, as the previous figures indicate, the lake now remains density stratified for a longer period of time.



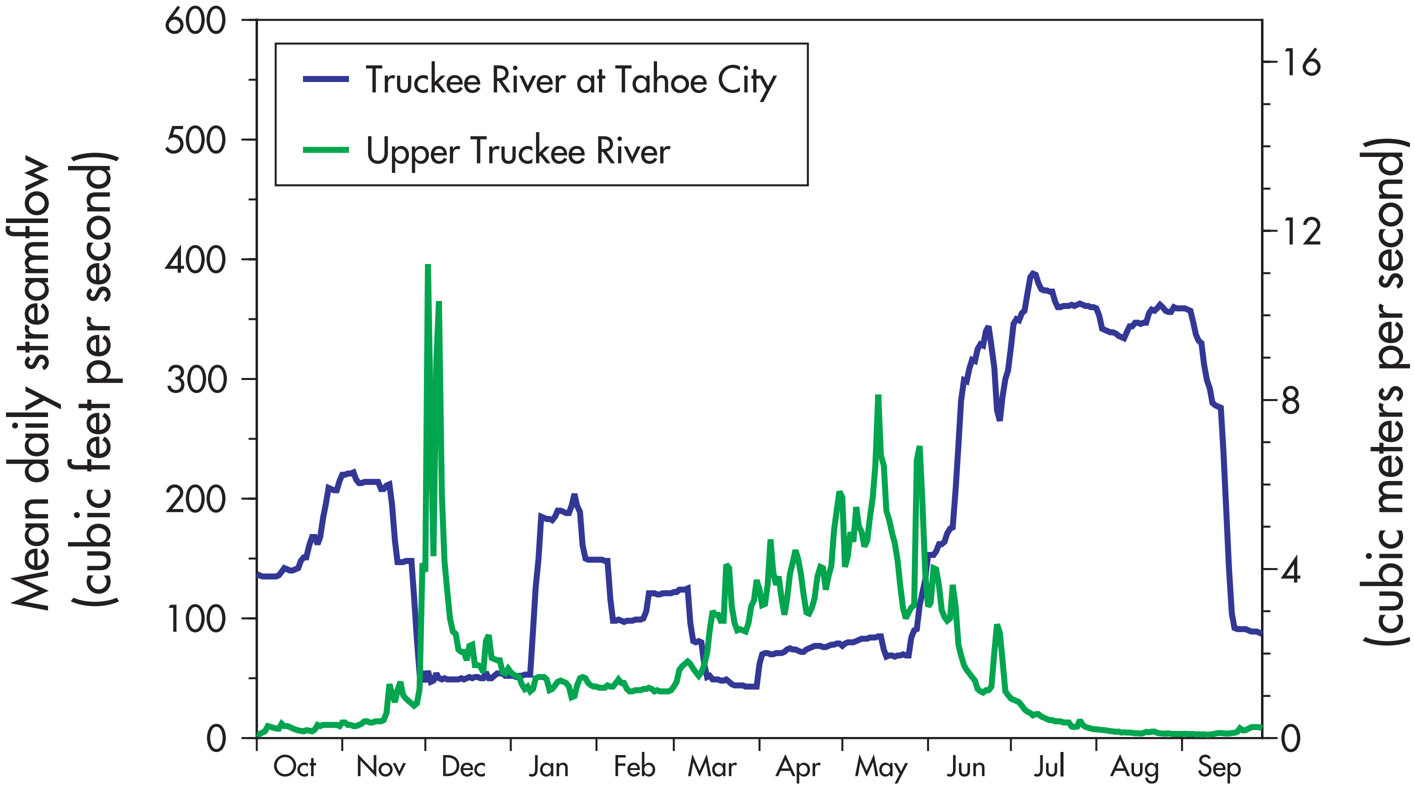
PHYSICAL PROPERTIES

Mean daily streamflow of Upper Truckee River vs. Truckee River

Water Year 2013

The largest inflowing stream to Lake Tahoe is the Upper Truckee River, which has a natural annual hydrograph typical of a snow-fed stream. The small peaks in the hydrograph represent rain events or short warm periods in winter or spring. The extended seasonal increase (March-June) represents the snowmelt. In 2013 there were two peaks. The first in December had a higher peak streamflow (365 cubic feet per second), but overall a lesser volume of water compared with the spring snowmelt in May (287 cubic feet per second). The peaks were considerably smaller than in 2012 (678 cubic feet per second).

The Truckee River is the only outflow from Lake Tahoe. It is a regulated flow, with release quantity controlled by the Federal water master. As a result, the hydrograph has extended times of near-constant outflow. The release rates are set according to downstream demands for water and concerns for flooding. The maximum discharge in 2013 was 388 cubic feet per second (similar to the previous year), and the peak temperature of the discharge was 72.5 °F (22.5 °C) on July 21. Streamflow data are collected by the US Geological Survey under the Lake Tahoe Interagency Monitoring Program (LTIMP).

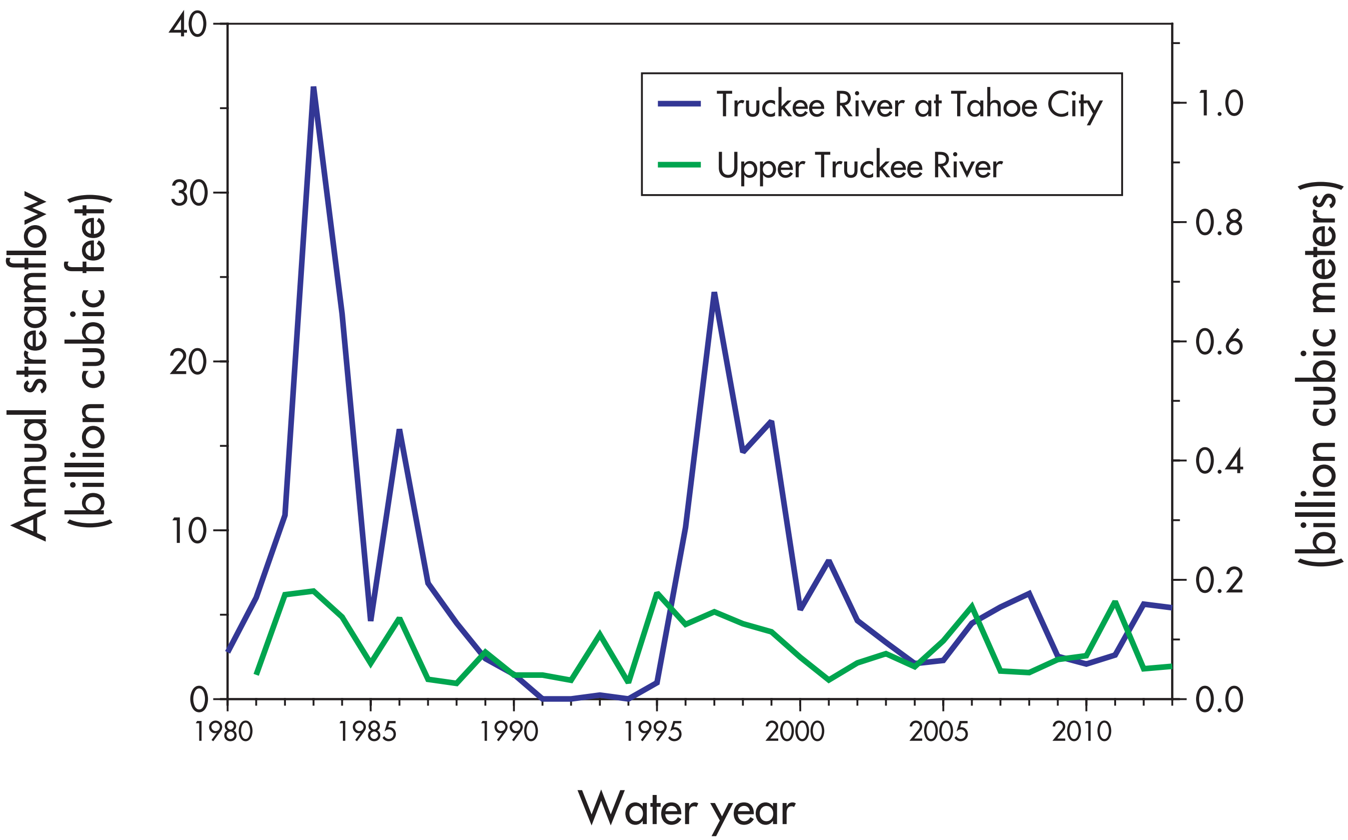


PHYSICAL PROPERTIES

Annual Discharge Volume for Upper Truckee River and Truckee River

Since 1980

Flow into Lake Tahoe (e.g. Upper Truckee River) and discharge out of Lake Tahoe (Truckee River at Tahoe City) have shown considerable variation since 1980. The large peaks in discharge from the lake correspond to years when precipitation (and therefore total inflow) was the greatest, e.g. 1982-1983, 1986, 1995-1999. Similarly, the drought-like conditions in the early 1990s and the low precipitation years in the beginning of the 2000s also stand out. Since many of the pollutants of concern for Lake Tahoe's clarity enter along with surface flow, year-to-year changes in clarity are influenced by precipitation and runoff. The average Upper Truckee annual inflow volume since 1981 is 3.05 billion cubic feet, while the average annual outflow through the Truckee River is 7.23 billion cubic feet. In 2013 discharges into and out of the lake were well below the long-term averages. The Upper Truckee River inflow volume was 1.95 billion cubic feet. The Truckee River discharge was 5.40 billion cubic feet.

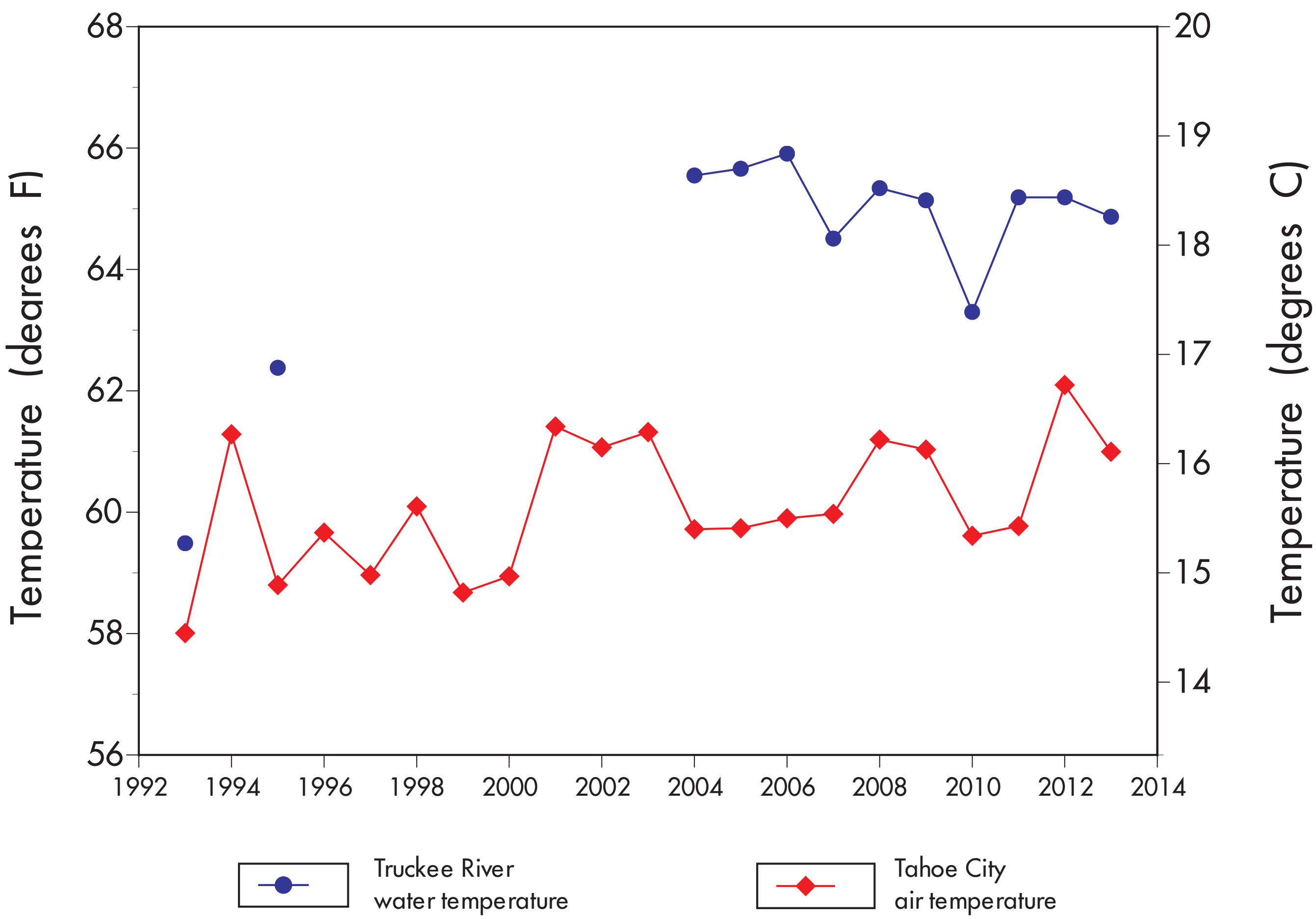


PHYSICAL PROPERTIES

Truckee River July-September Water Temperatures

Since 1993

Water temperature of the Truckee River as it departs Lake Tahoe in the summer months (July-September) is measured by the US Geological Survey. Data gaps prevent a complete pattern, but the measurements suggest that a 4-5 °F (2.2-2.8 °C) rise in the average temperature may have occurred since 1993. Average air temperatures from Lake Tahoe for the same period also suggest a temperature rise but at a lower rate. Elevated river temperatures can negatively impact downstream fish spawning.



PHYSICAL PROPERTIES

Truckee River Summer Discharge and Lake Elevation

Since 1980

Flow rate of the Truckee River as it departs Lake Tahoe in the summer months (July-September) and lake level for the same period is measured by the US Geological Survey. Here the relationship between these two variables is evident, with mean daily river discharge typically showing a one – two year lag from the lake elevation. Gage height is measured relative to a datum of 6,220 feet. Release of water from Lake Tahoe is controlled by the Federal Water Master.

TAHOE: STATE OF THE LAKE REPORT 2014

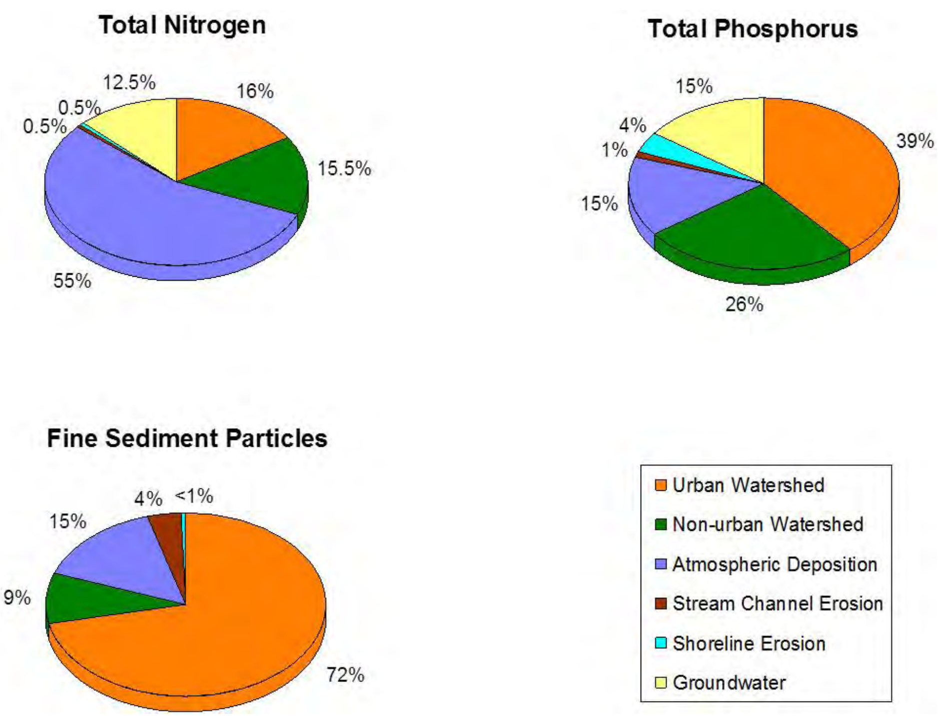
NUTRIENTS AND PARTICLES

UC DAVIS
TAHOE ENVIRONMENTAL RESEARCH CENTER

NUTRIENTS AND PARTICLES

Sources of clarity-reducing pollutants

Previous research has quantified the primary sources of nutrients (nitrogen and phosphorus) and particulate material that are causing Lake Tahoe to lose clarity in its upper waters. One of the major contributors to clarity decline are extremely fine particles that primarily originate from the urban watershed (70-75 percent), even though these areas cover only 10 percent of the land area. For nitrogen, atmospheric deposition is the major source (55 percent). Phosphorus is primarily introduced by the urban (39 percent) and non-urban (26 percent) watersheds. These categories of pollutant sources form the basis of a strategy to restore Lake Tahoe's open-water clarity by agencies including the Lahontan Regional Water Quality Control Board, the Nevada Division of Environmental Protection, and the Tahoe Regional Planning Agency. (Data were generated for the Lake Tahoe TMDL Program and this figure appeared in previous years' State of the Lake Reports.)



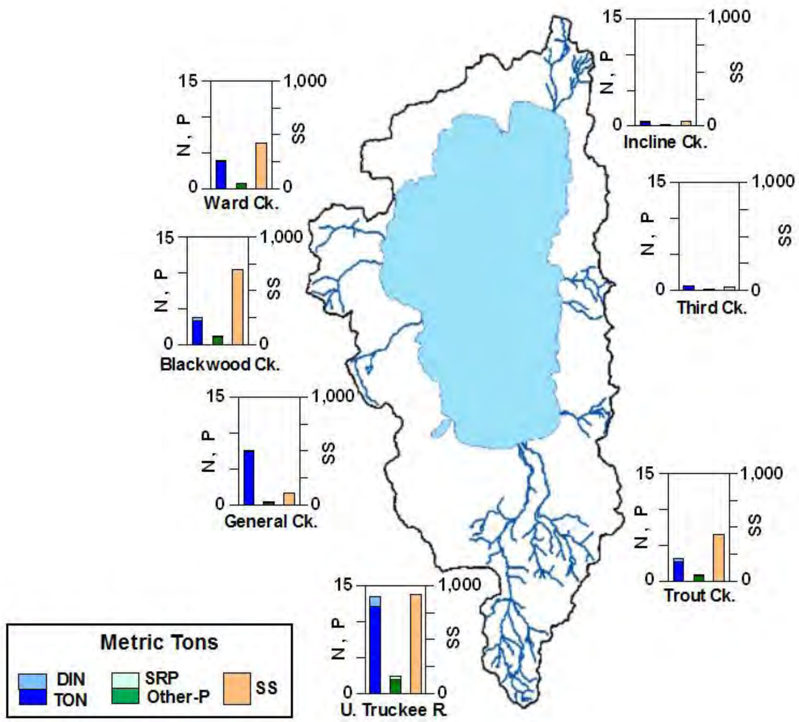
NUTRIENTS AND PARTICLES

Pollutant loads from seven watersheds

In 2013

The Lake Tahoe Interagency Monitoring Program (LTIMP) measures nutrient and sediment input from seven of the 63 watershed streams – a reduction of three streams since 2011. Most of the suspended sediment contained in the 7 LTIMP streams is from the Upper Truckee River, Blackwood Creek, Trout Creek and Ward Creek. Over 75 percent of the phosphorus and nitrogen comes from the Upper Truckee River, Trout Creek and Blackwood Creek. Pollutant loads from the west-side streams were a factor of four lower in 2013 and 2012, compared with 2011. This was largely due to the drier years that the basin experienced.

The LTIMP stream water quality program is supported by the U.S. Geological Survey in Carson City, Nevada, UC Davis TERC and the Tahoe Regional Planning Agency. Additional funding was provided by the USFS – Lake Tahoe Basin Management Unit.



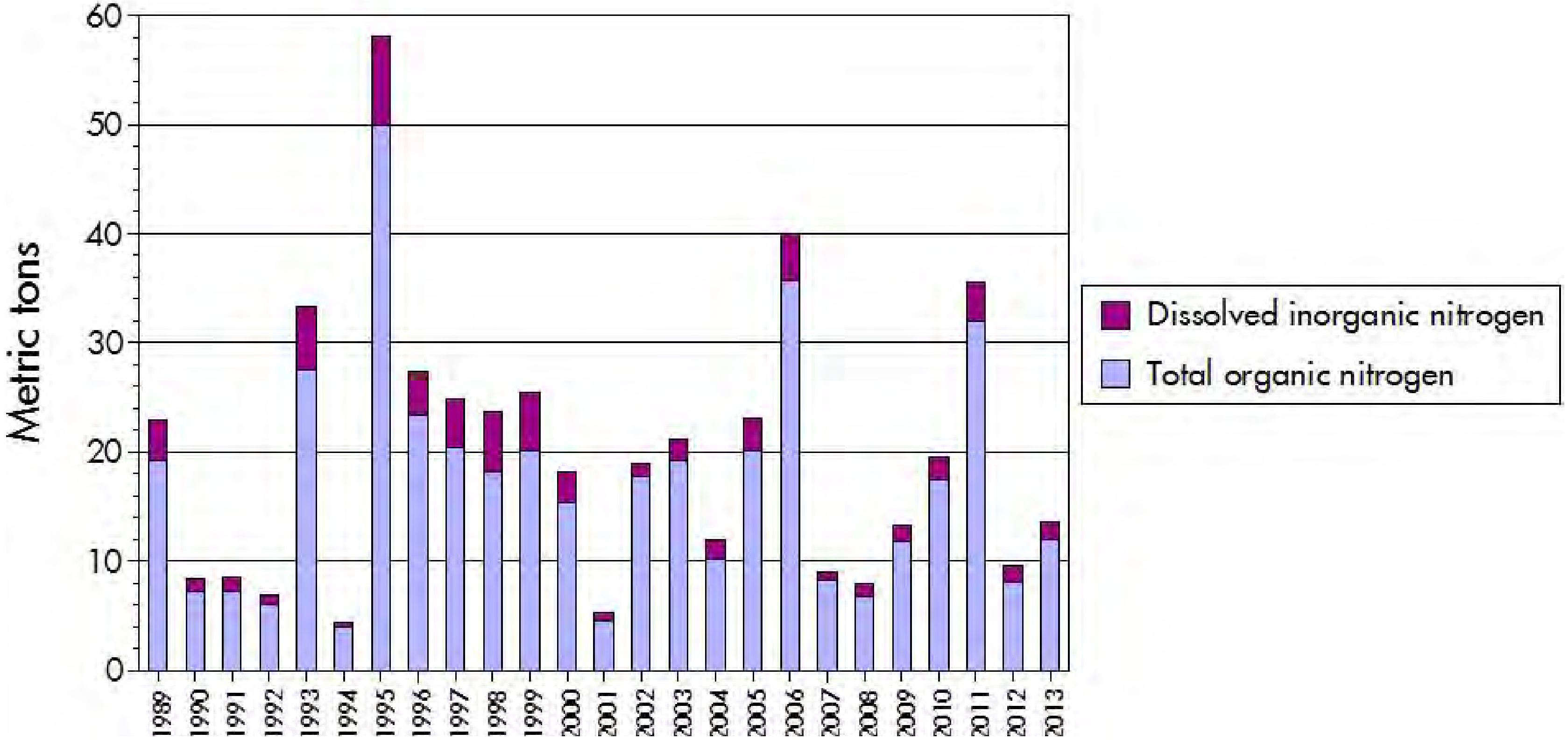
N = Nitrogen
P = Phosphorus
DIN = Dissolved Inorganic Nitrogen
SRP = Soluble Reactive Phosphorus
TON = Total Organic Nitrogen
SS = Suspended Sediment

NUTRIENTS AND PARTICLES

Nitrogen contribution by Upper Truckee River

Yearly since 1989

Nitrogen (N) is important because it, along with phosphorus (P), stimulates algal growth. The Upper Truckee River is the largest of the 63 streams that flow into Lake Tahoe, contributing about 25 percent of the inflowing water. The river's contribution of dissolved inorganic nitrogen (nitrate and ammonium) and total organic nitrogen loads are shown here. The year-to-year variations primarily reflect changes in precipitation. For example, 1994 had 16.6 inches of precipitation and a low nitrogen load, while 1995 had 60.8 inches of precipitation and a very high nitrogen load. Similarly 2013 had 25.19 inches of precipitation and 2012 had 22.48 inches of precipitation. (One metric ton = 2,205 pounds.)

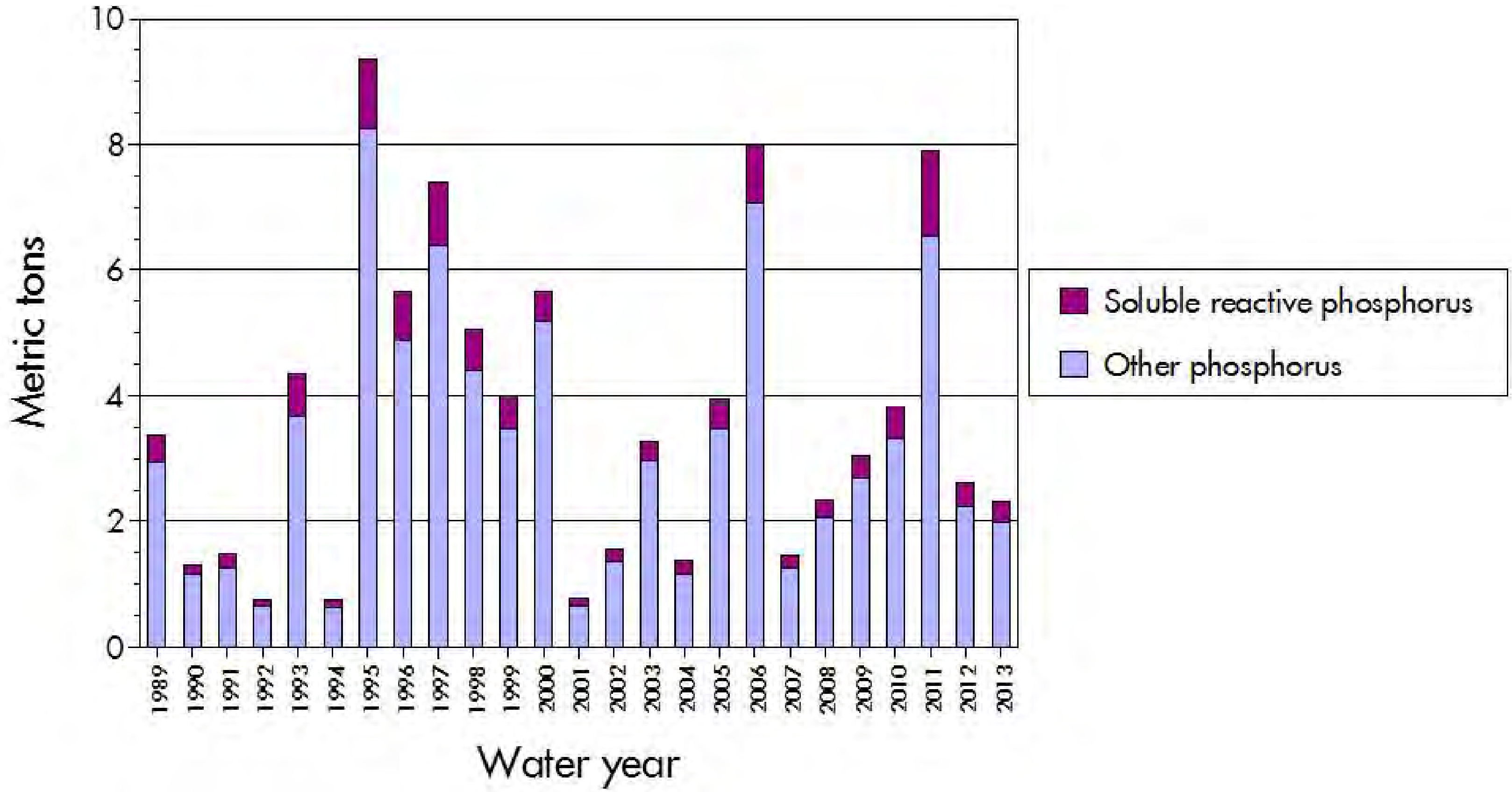


NUTRIENTS AND PARTICLES

Phosphorus contribution by Upper Truckee River

Yearly since 1989

Soluble reactive phosphorus (SRP) is that fraction of phosphorus immediately available for algal growth. As with nitrogen, the year-to-year variation in load largely reflects the changes in precipitation. Below average precipitation in 2013 resulted in a factor of four reduction of the phosphorus load over 2011. Total phosphorus is the sum of SRP and other phosphorus, which includes organic phosphorus and phosphorus associated with particles. (One metric ton = 2,205 pounds.)

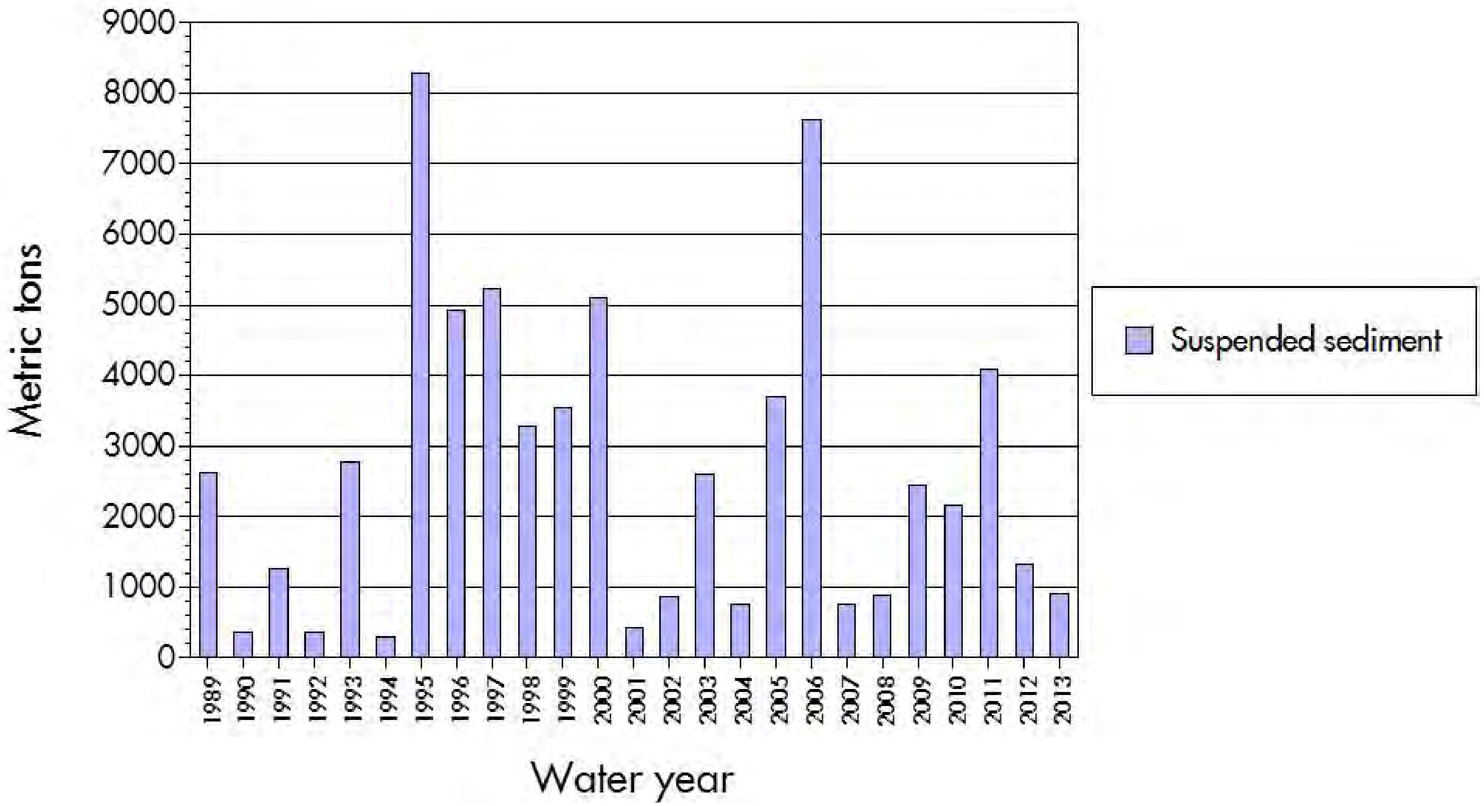


NUTRIENTS AND PARTICLES

Suspended sediment contribution by Upper Truckee River

Yearly since 1989

The load of suspended sediment delivered to the lake by the Upper Truckee is related to landscape condition and erosion as well as to precipitation and stream flow. Certainly, inter-annual variation in sediment load over shorter time scales is more related to the latter. Below average precipitation in 2013 resulted in a factor of four decrease of the suspended sediment load compared with 2011. This and the previous two figures illustrate how greatly changes in hydrological conditions affect pollutant loads. Plans to restore lake clarity emphasize reducing loads of very fine suspended sediment (less than 20 microns in diameter). Efforts to restore natural stream function and watershed condition focus on reducing loads of total sediment regardless of size, as well as restoration of habitat for plants and wildlife.

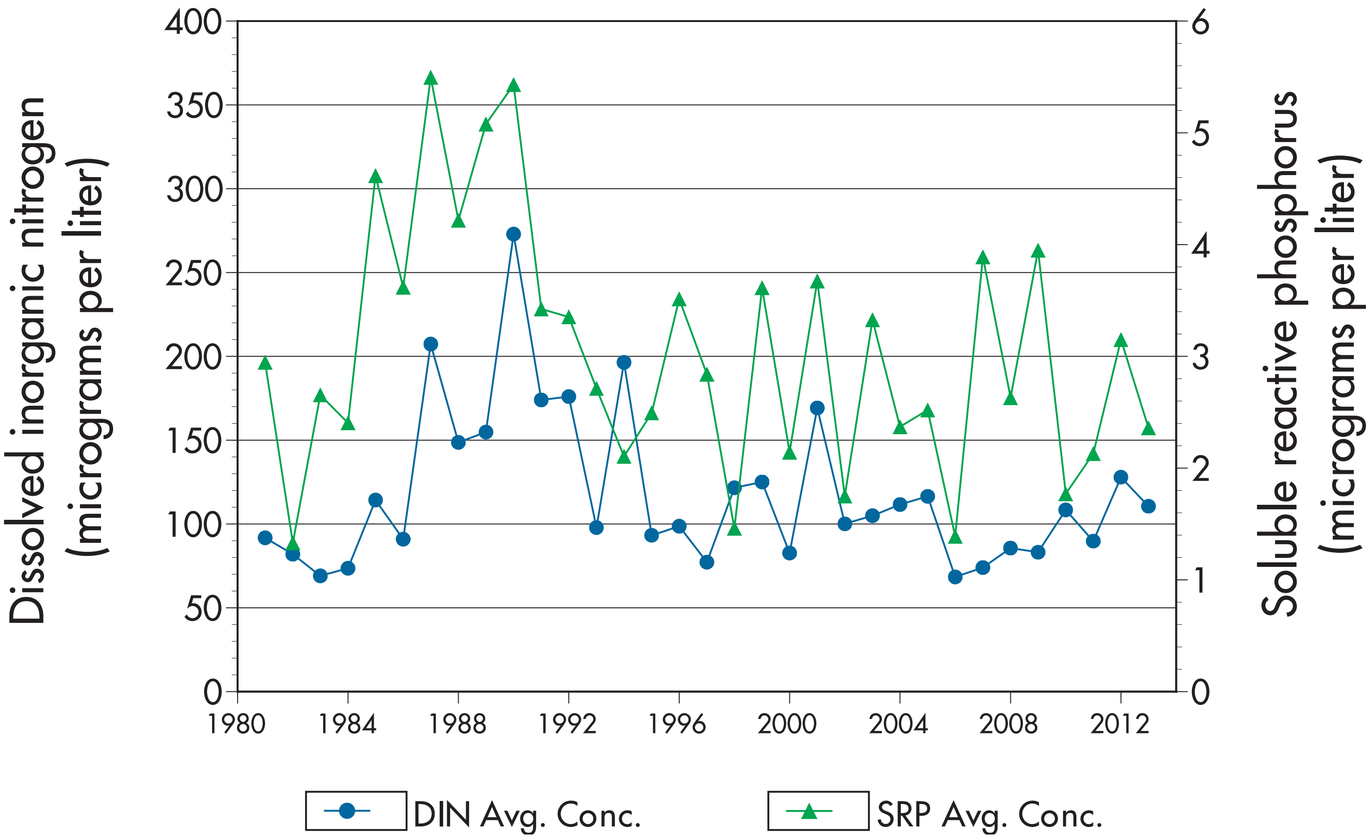


NUTRIENTS AND PARTICLES

Nutrient concentrations in rain and snow

Yearly since 1981

Nutrients in rainwater and snow (called wet deposition) contribute large amounts of nitrogen, but also significant phosphorus, to Lake Tahoe. Nutrients in precipitation have been measured near Ward Creek since 1981, and show no consistent upward or downward trend since peaking in the late 1980's. Annual concentrations in precipitation of dissolved inorganic nitrogen (DIN) and soluble reactive phosphorus (SRP) vary from year to year. In 2013, concentrations of DIN and SRP decreased from the previous year. The ratio of N:P concentration in precipitation is on average 42:1 (±16). As this is the concentration in precipitation, it is not necessaarily affected by the relatively dry conditions of 2013.

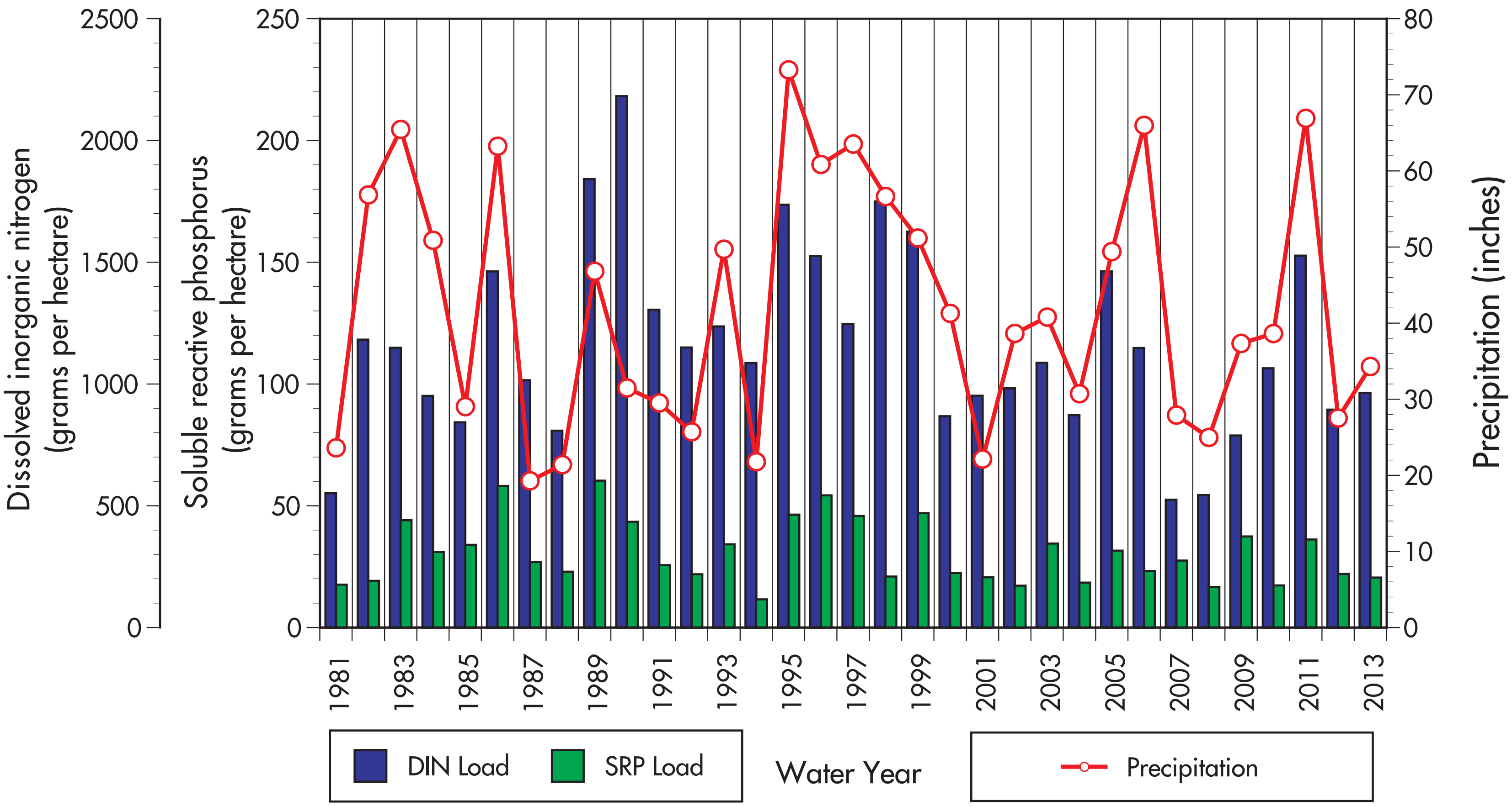


NUTRIENTS AND PARTICLES

Nutrient loads in rain and snow

Yearly since 1981

The annual load for wet deposition is calculated by multiplying the concentration of dissolved inorganic nitrogen (nitrate and ammonium) and soluble reactive phosphorus (in the previous graph) by total annual precipitation. While nitrogen and phosphorus loads from precipitation have varied from year to year at the Ward Creek monitoring site, no obvious long-term trend has emerged. In 2013, the nitrogen and phosphorus loads were within the range seen in previous years.

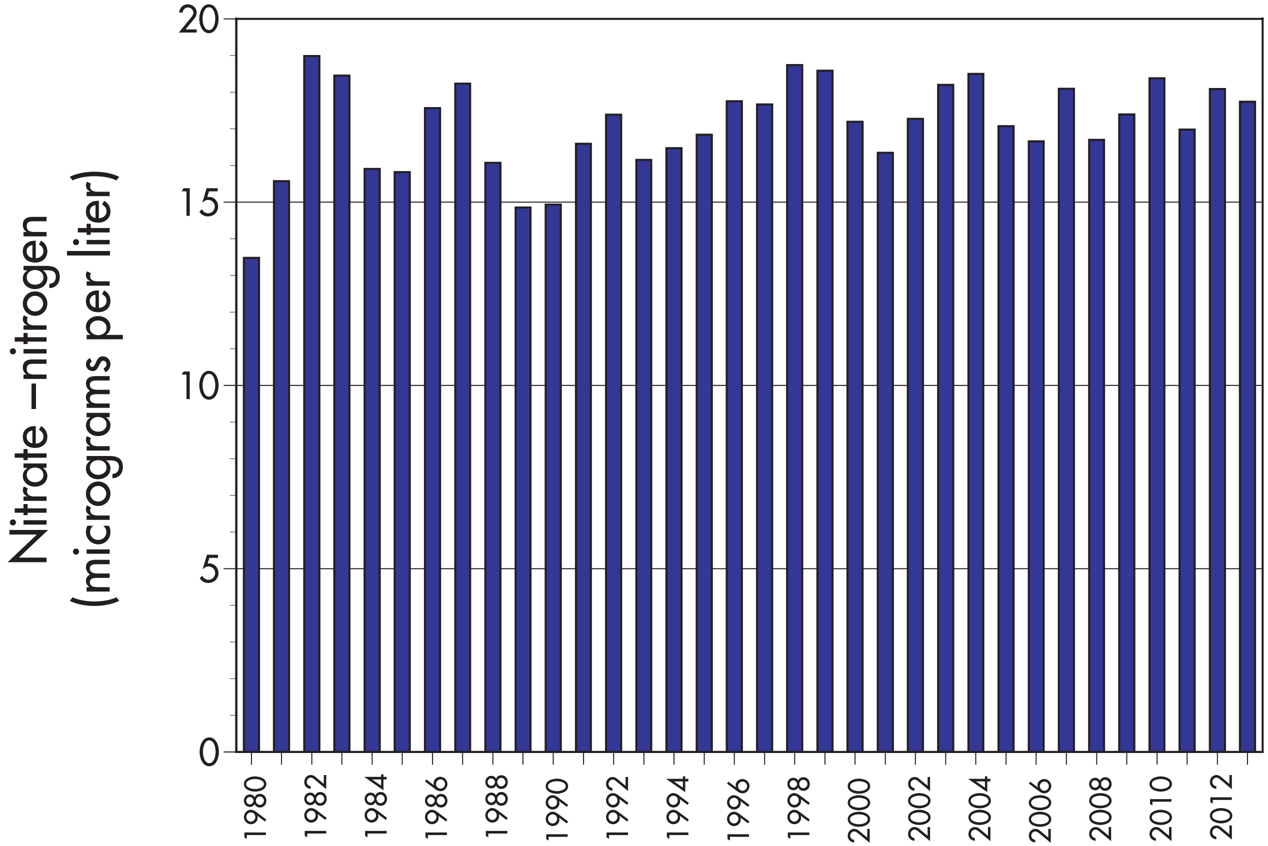


NUTRIENTS AND PARTICLES

Lake nitrate concentration

Yearly since 1980

Since 1980, the volume-weighted annual average concentration of nitrate-nitrogen has remained relatively constant, ranging between 13 and 19 micrograms per liter. In 2013, the volume-weighted annual average concentration of nitrate-nitrogen was 17.7 micrograms per liter. Water samples are taken from the R/V John LeConte at the MLTP (mid-lake) station at 13 depths from the surface to 450 m. The nutrient analysis is performed at the TERC laboratory in Incline Village, Nevada.

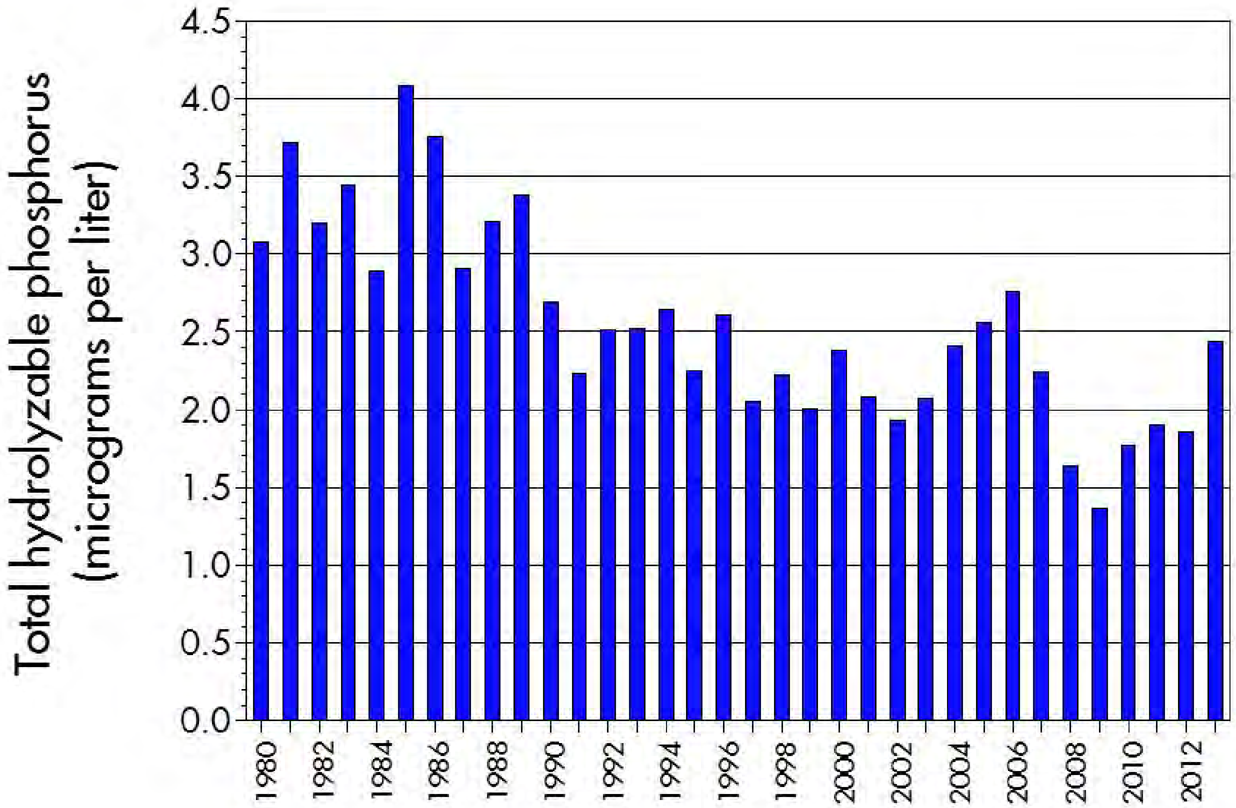


NUTRIENTS AND PARTICLES

Lake phosphorus concentration

Yearly since 1980

Phosphorus naturally occurs in Tahoe Basin soils and enters the lake from soil disturbance and erosion. Total hydrolyzable phosphorus, or THP, is a measure of the fraction of phosphorus that algae can use to grow. It is similar to the SRP that is measured in the streams. Since 1980, THP has tended to decline. In 2013, the volume-weighted annual average concentration of THP was approximately 2.4 micrograms per liter, an increase over the previous year. Water samples are taken from the R/V John LeConte at the MLTP (mid-lake) station at 13 depths from the surface to 450 m. The nutrient analysis is performed at the TERC laboratory.



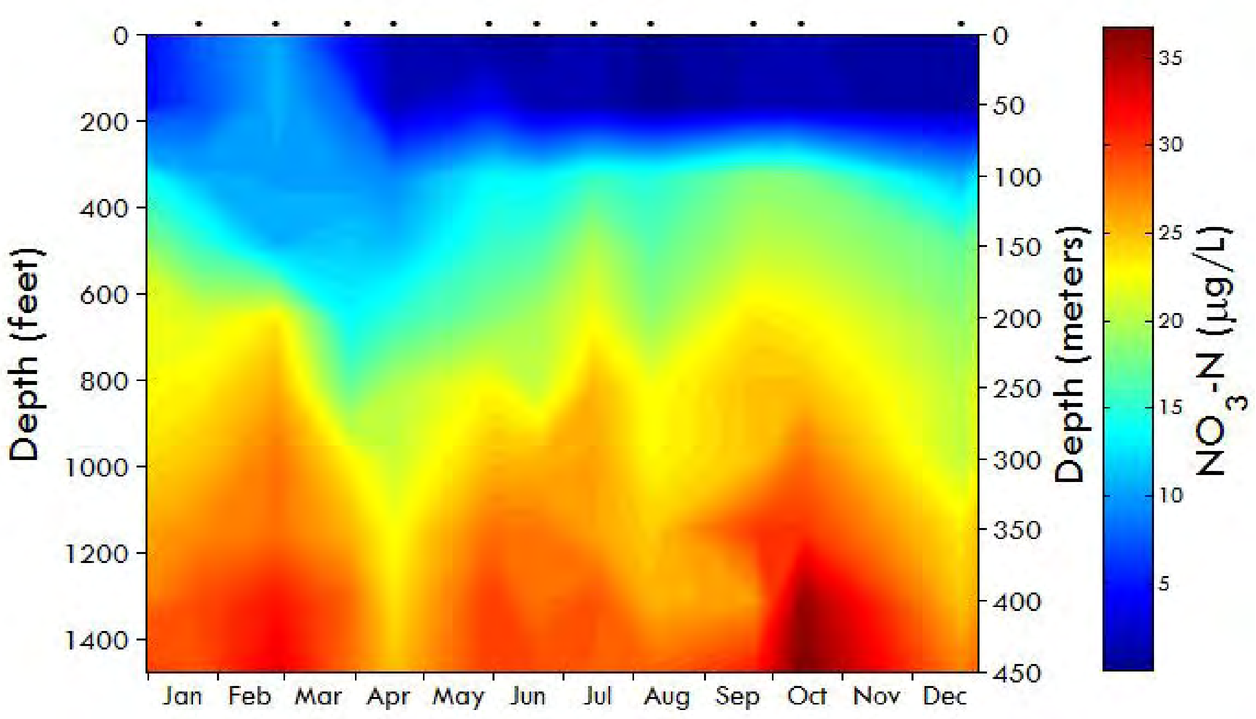
NUTRIENTS AND PARTICLES

Nitrate Distribution

In 2013

Water samples are collected approximately every month (on dates indicated by dots at the top of the figure) at 13 depths at the middle of the lake, and analyzed in the TERC lab for nutrient concentrations. Here the nitrate concentration is shown in the form of color contours.

Most evident in this figure is the vertical distribution of nitrate. Concentrations below a depth of about 400 feet are generally high. The surface waters, where there is sunlight to enable algae to grow usually has low concentrations of nitrate. Although most of the nitrate enters at the surface through atmospheric deposition, it is rapidly used up by the algae. As algae eventually sink and decompose, the nitrate they consumed eventually reappears deep in the lake. At these depths, however, there is insufficient light for algae to grow and to assimilate the nutrients. When deep lake mixing occurs, the deep nitrate can be brought back to the surface. This process is evident in February-March. An increase in nitrate at the surface (light blue color) is being produced by the mixing of water down to 590 feet. 2013 was a year with very shallow mixing, and so most of the nitrate remained trapped in the deep water.



NUTRIENTS AND PARTICLES

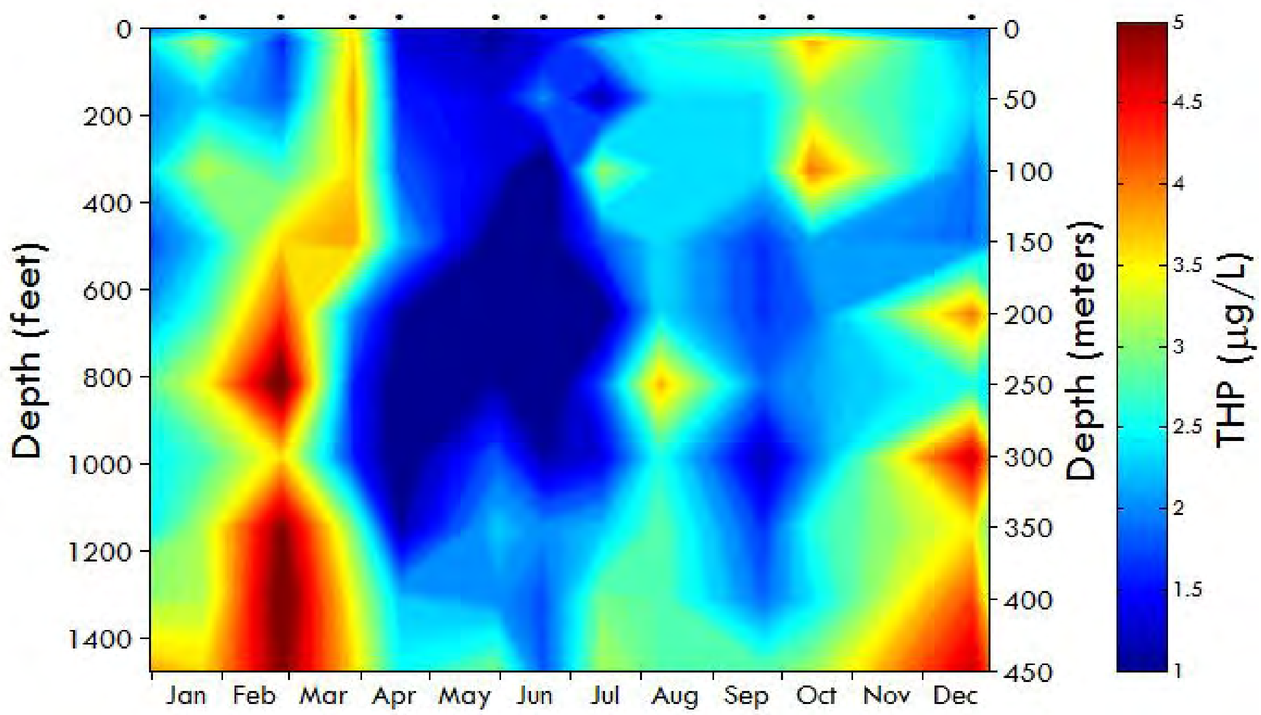
Phosphorus Distribution

In 2013

Water samples are collected approximately monthly (on dates indicated by dots at the top of the figure) at 13 depths at the middle of the lake, and analyzed in the TERC lab for nutrient concentrations. Here the total hydrolyzable phosphorus (THP) concentration (the fraction of the phosphorus that can be most readily used by algae) is shown in the form of color contours.

Unlike the nitrate distribution, there is relatively little vertical distribution of THP. Phosphorus mainly enters the lake in association with fine particles. Because of the low snowmelt volumes and the cold conditions, when snowmelt occurred in March much of the phosphorus was carried with the flow deep into the lake. The phosphorus that remained in the surface was quickly consumed and by April concentrations were extremely low.

Unlike nitrate, which can remain dissolved in the water column, THP is strongly adsorbed to particles, so when algae settle and decompose, the THP is quickly adsorbed to particles which can then settle quickly in the deep water.



NUTRIENTS AND PARTICLES

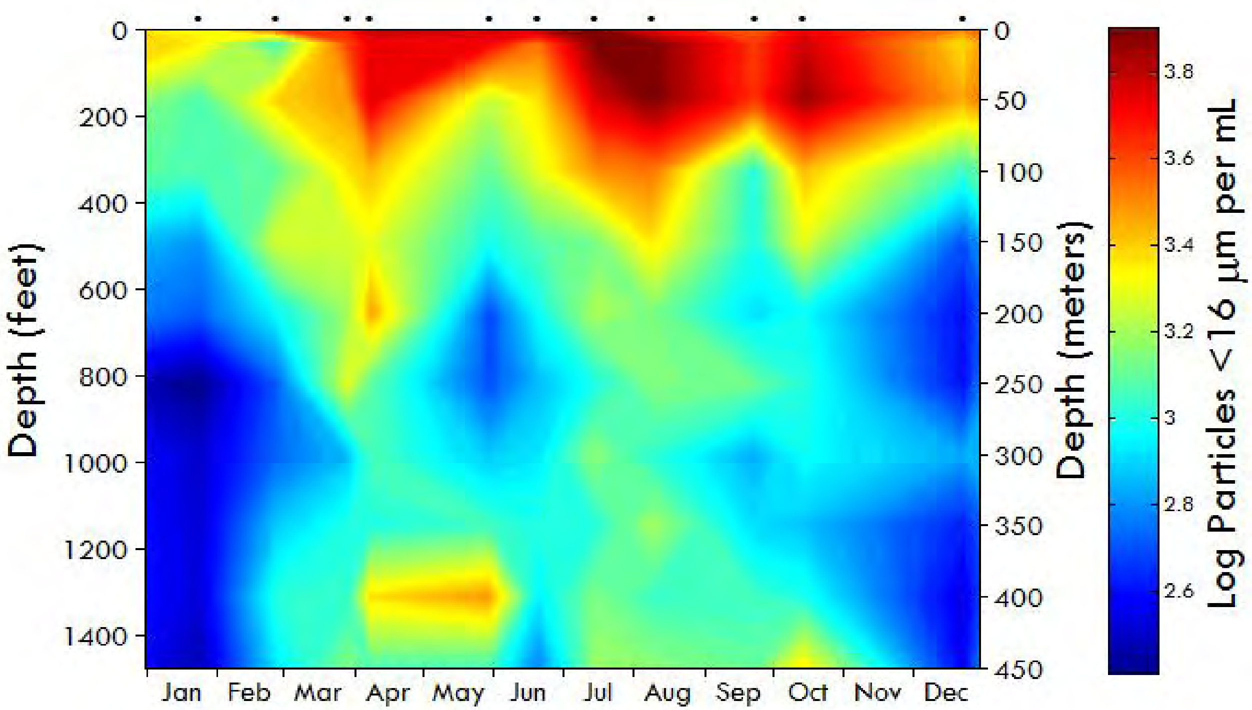
Fine Particle Distribution

In 2013

Water samples are collected approximately monthly (on dates indicated by dots at the top of the figure) at 13 depths at the middle of the lake, and analyzed in the TERC lab for the concentration of fine particles in 15 different bin sizes. Here the distribution of the finest particles (0.5 to 8 microns) are shown in the form of color contours.

Clearly evident in the figure is that the highest concentrations of fine particles (red tones) are concentrated in the upper part of the lake. In the early part of the year (winter), when clarity is generally highest, surface concentration of particles is the lowest. A reduction in surface particle concentration is also evident in December. In winter there is also the lowest concentrations of fine particles in the deep water. This is due to them aggregating and settling out.

The high concentration values at a depth of about 1300 feet in April and May is believed to be due to some of the very cold snowmelt water plunging to the deep part of the lake on account of its high density.



TAHOE: STATE OF THE LAKE REPORT 2014

BIOLOGY

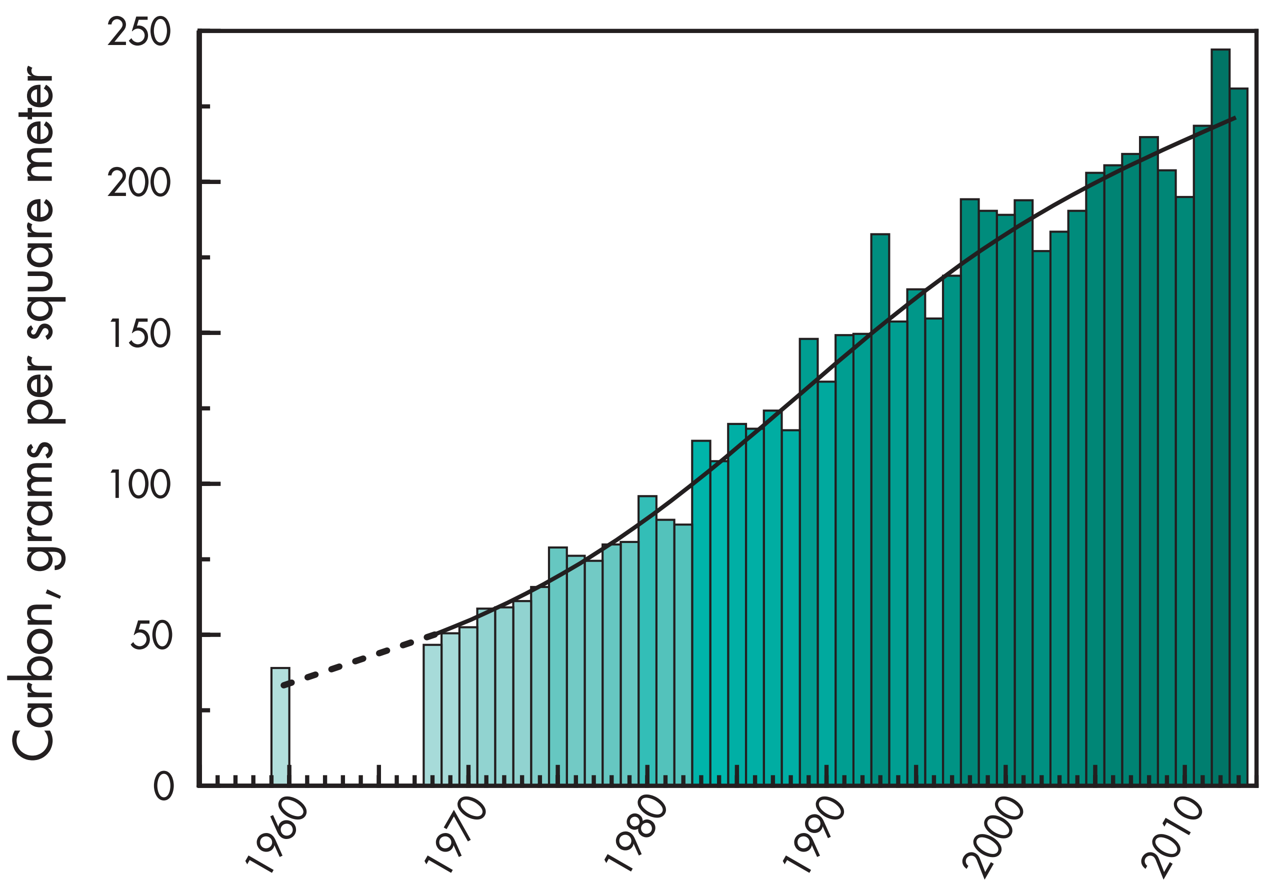
UC DAVIS
TAHOE ENVIRONMENTAL RESEARCH CENTER

BIOLOGY

Algae growth (primary productivity)

Yearly since 1959

Primary productivity is a measure of the rate at which algae produce biomass through photosynthesis. It was first measured at Lake Tahoe in 1959 and has been continuously measured since 1968. Supported by nutrient loading into the lake, changes in the underwater light environment and a succession of algal species, the trend shows primary productivity has generally increased over time. In 2013 we saw a slight decrease in primary productivity to 230.9 grams of carbon per square meter, but this was still the second highest volume on record.

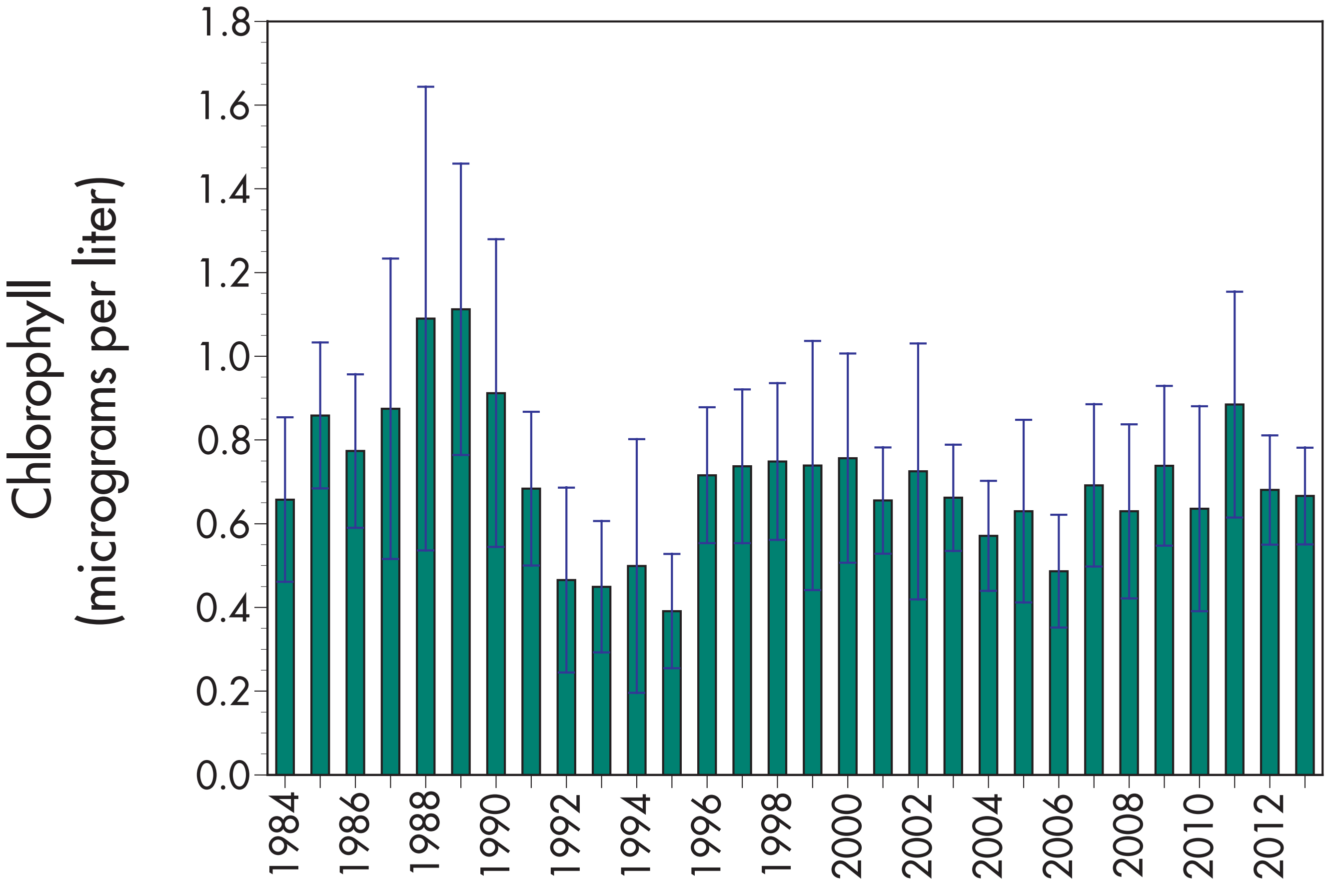


BIOLOGY

Algae abundance

Yearly since 1984

Algae (phytoplankton) are the base of the Lake Tahoe food web, and essential for lake health and the well-being of the entire ecosystem. The amount or biomass of free-floating algae in the water is determined by extracting and measuring the concentration of chlorophyll-*a*, a photosynthetic pigment that allows plants to absorb energy from the sun. Though the value varies annually, it has not shown a significant increase since measurements began in 1984. The annual average value for 2013 was 0.67 micrograms per liter. The average annual chlorophyll-*a* level in Lake Tahoe has remained relatively uniform since 1996. For the period of 1984-2013 the average value was 0.70 micrograms per liter.



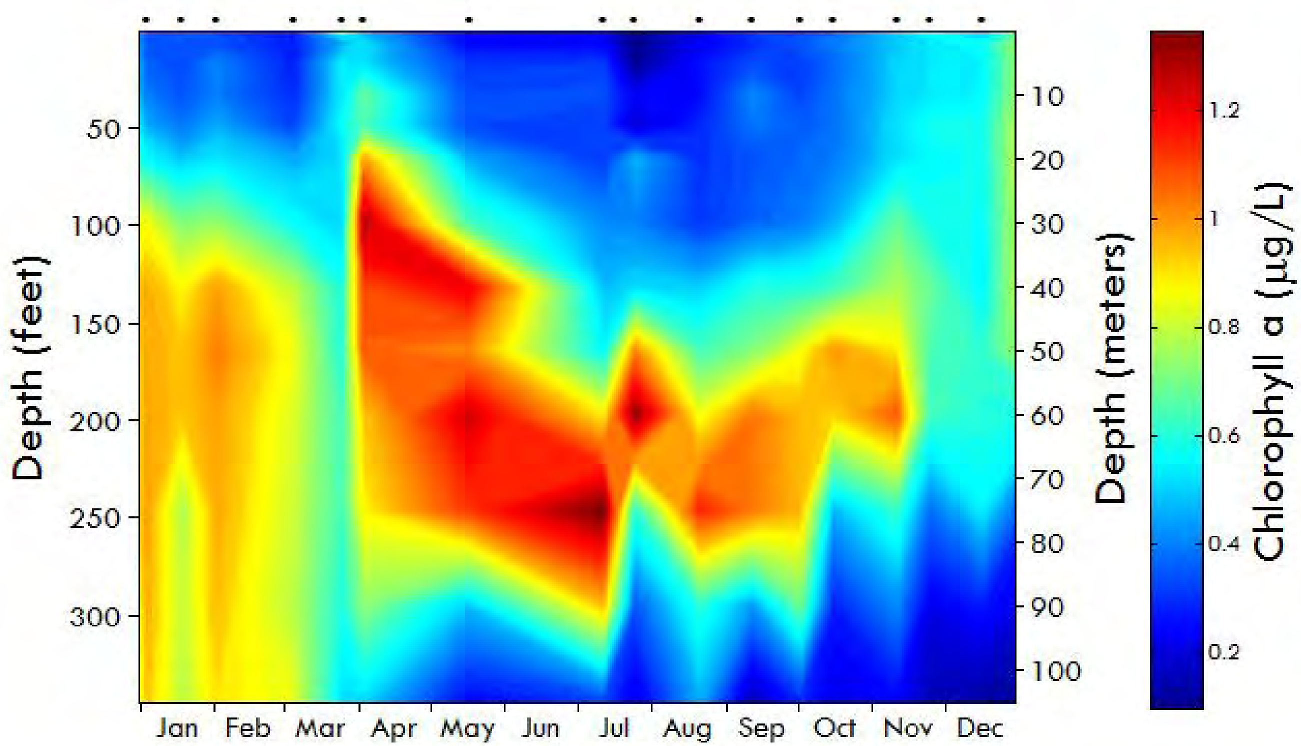
BIOLOGY

Chlorophyll-*a* distribution

In 2013

The distribution of algae (measured as chlorophyll–*a*) is the result of a combination of light availability, nutrient availability, mixing processes and to a lesser extent water temperature. This figure shows color contours of chlorophyll-*a* concentration down to a depth of 350 feet. Below this depth concentrations are near zero due to the absence of light.

Lake Tahoe has a "deep chlorophyll maximum", that is in the range of 100-200 ft. At that depth the light and nutrient conditions are most favorable for algal growth. In the early part of the year, the algae were distributed over a greater depth range because of the deep mixing processes that were occurring. With the onset of thermal stratification, the algae were confined to a discrete band. Throughout the year concentrations decreased as nutrients were depleted. In December, the commencement of deep mixing again redistributed the algae over a broader depth range. This period when algae are lifted into the surface water usually coincides with a decrease in water clarity.

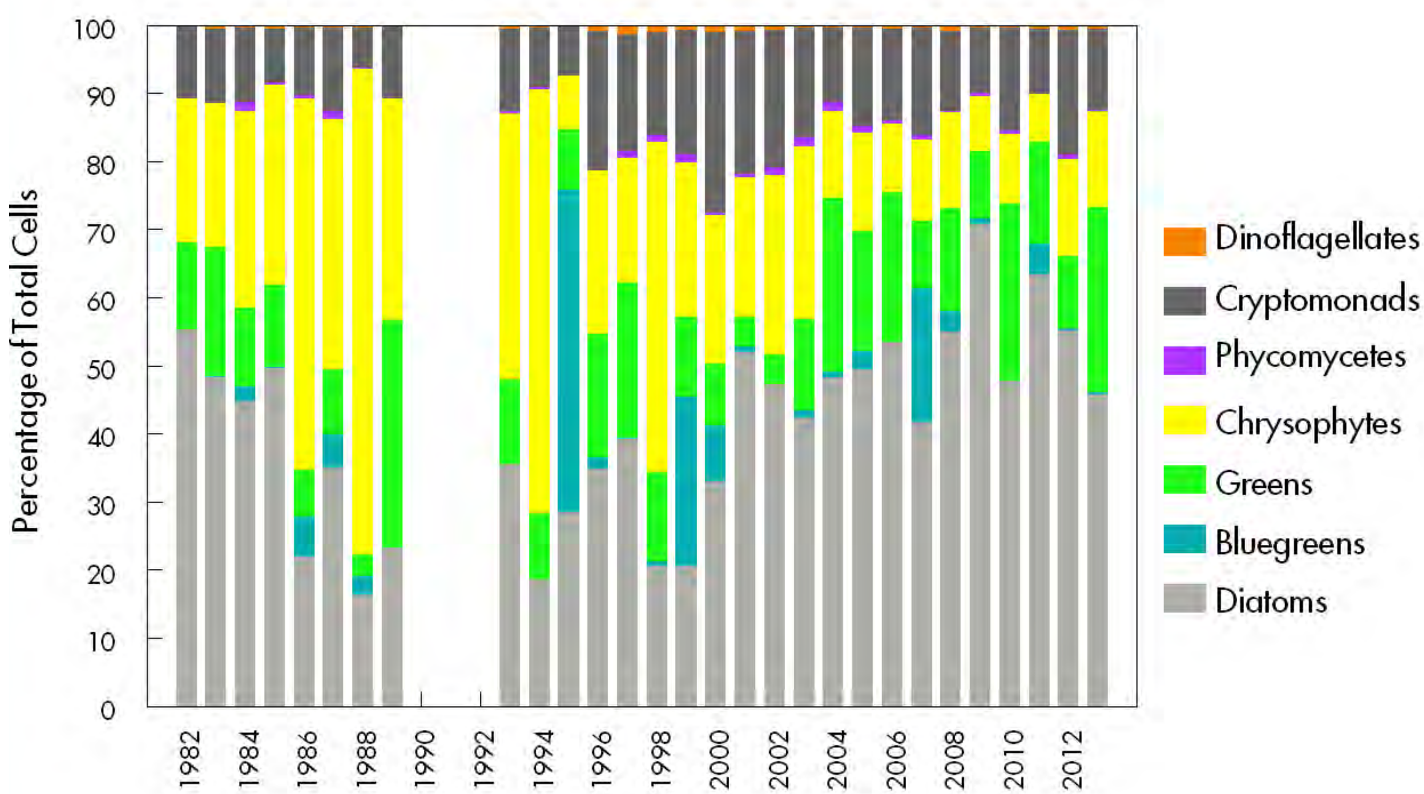


BIOLOGY

Annual distribution of algal groups

Yearly since 1982

The amount of algal cells from different groups varies from year to year. Diatoms are the most common type of alga, comprising 40 to 60 percent of the total abundance of algal cells each year. Chrysophytes, cryptophytes and green algae are next, comprising 10 to 30 percent of the total. While the proportion of the major algal groups show a degree of consistency from year-to-year, TERC research has shown that the composition of individual species within the major groups is changing, both seasonally and annually, in response to lake conditions.

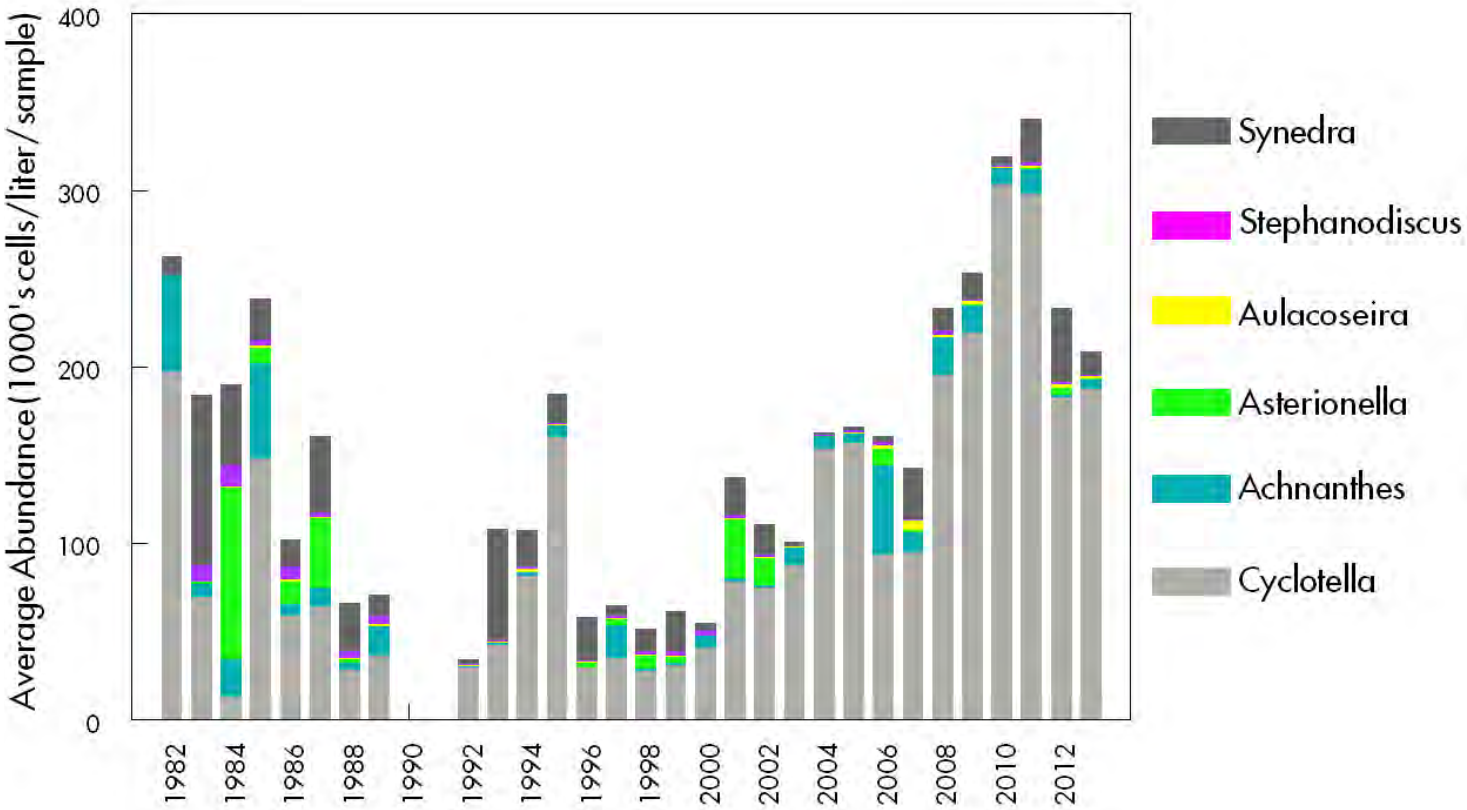


BIOLOGY

Abundance of dominant diatom species

Yearly since 1982

Diatoms have been the dominant algal group at Lake Tahoe for all but a few years since 1982. Diatoms are unique in that they are enclosed within a cell wall made of silica called a frustule. Here the dominant diatom species at Lake Tahoe between 1982 and 2013 are shown. Huge inter-annual variations are evident, both in the overall abundance and in the relative composition. Generally *Cyclotella gordonensis* is the dominant diatom species in Lake Tahoe.

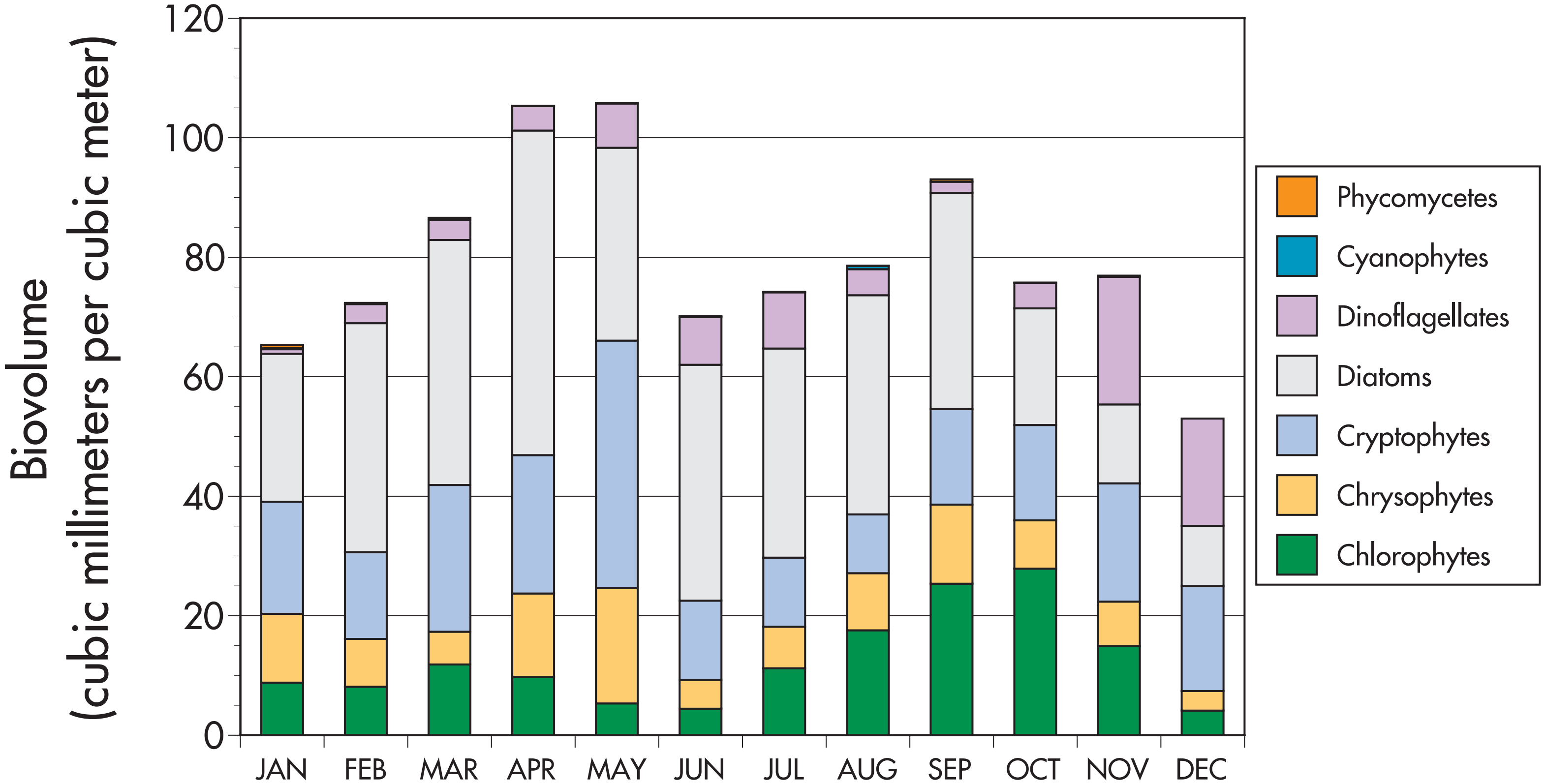


BIOLOGY

Algal groups as a fraction of total population

Monthly in 2013

Algae populations vary month to month, as well as year to year. In 2013, diatoms again dominated the phytoplankton community, especially in the first six months of the year. Diatom concentrations peaked in April and May (the "spring bloom"). Even at the peak of the bloom, algal cells occupied only one ten-millionth of the water in the lake. The peak biovolume in 2013 (105 cubic millimeters per cubic meter) was 35% lower than the peak in 2012. If all the algae in Lake Tahoe were spread out on a football field, they would fill it to a height of 9.2 feet (2.8 m).

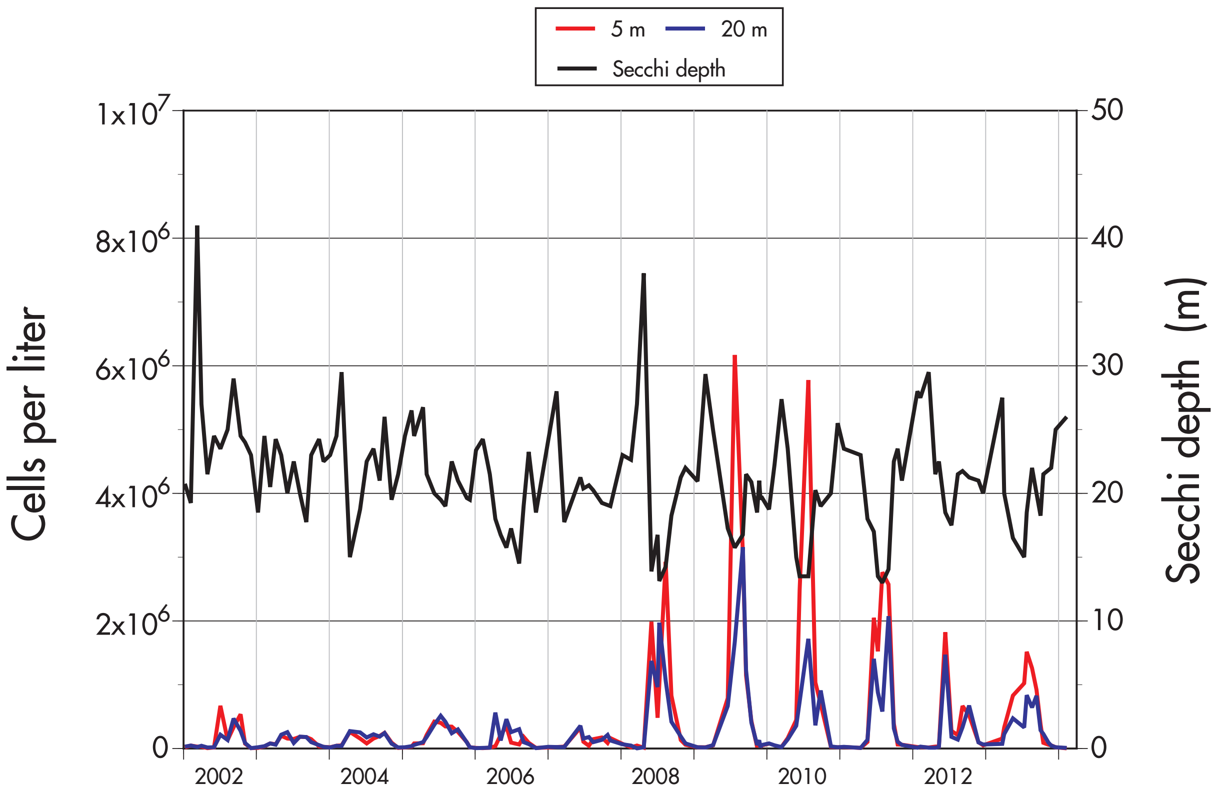


BIOLOGY

Predominance of *Cyclotella sp.*

From 2002 through 2013

In 2008, one species of algae, *Cyclotella gordonensis*, started to dominate the make-up of algae at Lake Tahoe. The cells range in size from 4 - 30 microns in diameter. During the summer, the smallest cells, 4 - 5 microns, control the community in the upper euphotic zone. This size range is ideal for light scattering, and the growing numbers of *Cyclotella* in 2008-2011 were believed to be in large part responsible for the major decline in summer clarity in those years. In 2013 the concentration of *Cyclotella* cells continued to decrease, and summer clarity was relatively high for the second year running. The blue and red lines below indicate the concentrations of *Cyclotella* at depths of 20 m (66 ft) and 5 m (16.5 ft) respectively. The black lines indicate the individual Secchi depths taken since 2002. The summer values of Secchi depth coincide perfectly with the changes in *Cyclotella* concentration.

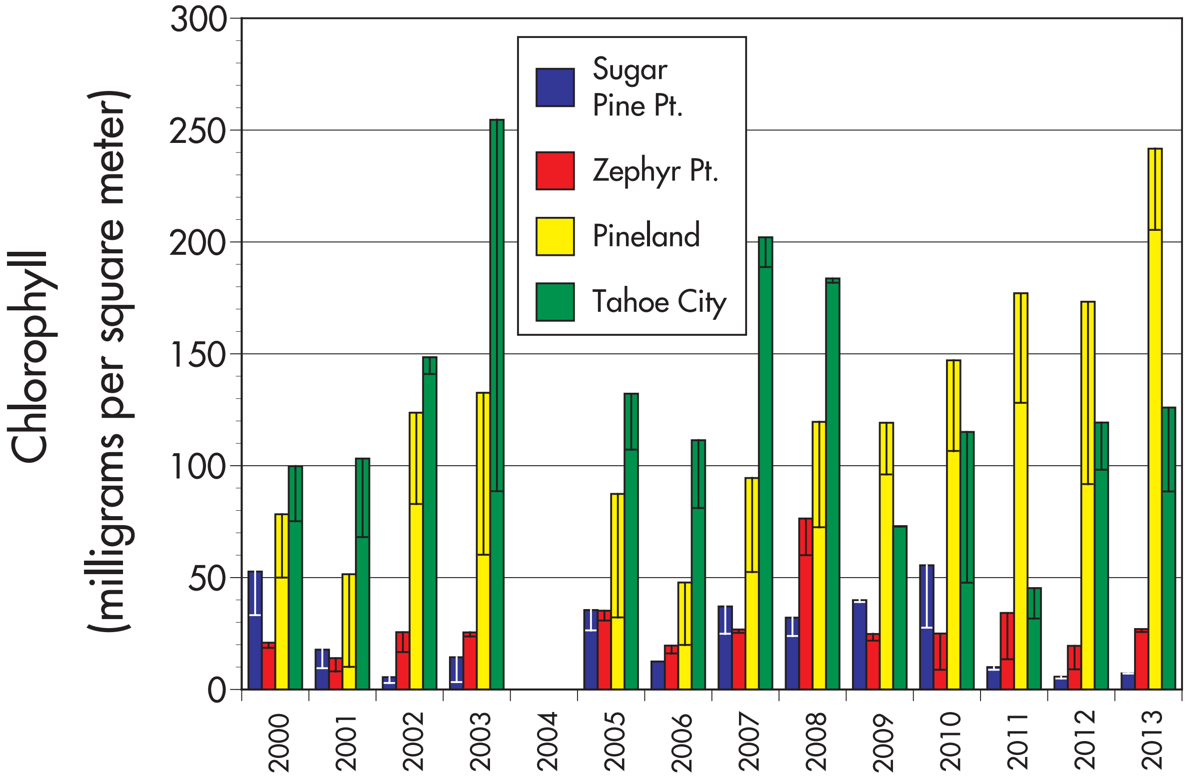


BIOLOGY

Shoreline algae populations

Yearly since 2000

Periphyton, or attached algae, makes rocks around the shoreline of Lake Tahoe green and slimy, or sometimes like a very plush white carpet. Periphyton is measured eight times each year, and this graph shows the maximum biomass measured at four sites. In 2013, concentrations at Sugar Pine Pt. (no urban influence) were below the long-term average. Tahoe City (heavily urbanized) and Zephyr Pt. were close to the long-term average. The site with the most periphyton (Pineland) is close to an urban area, and was at the highest level ever recorded. While monitoring periphyton is an important indicator of near-shore health, it is clear that greater attention to the mechanisms of periphyton growth is required if a decrease in attached algae is the desired end goal.



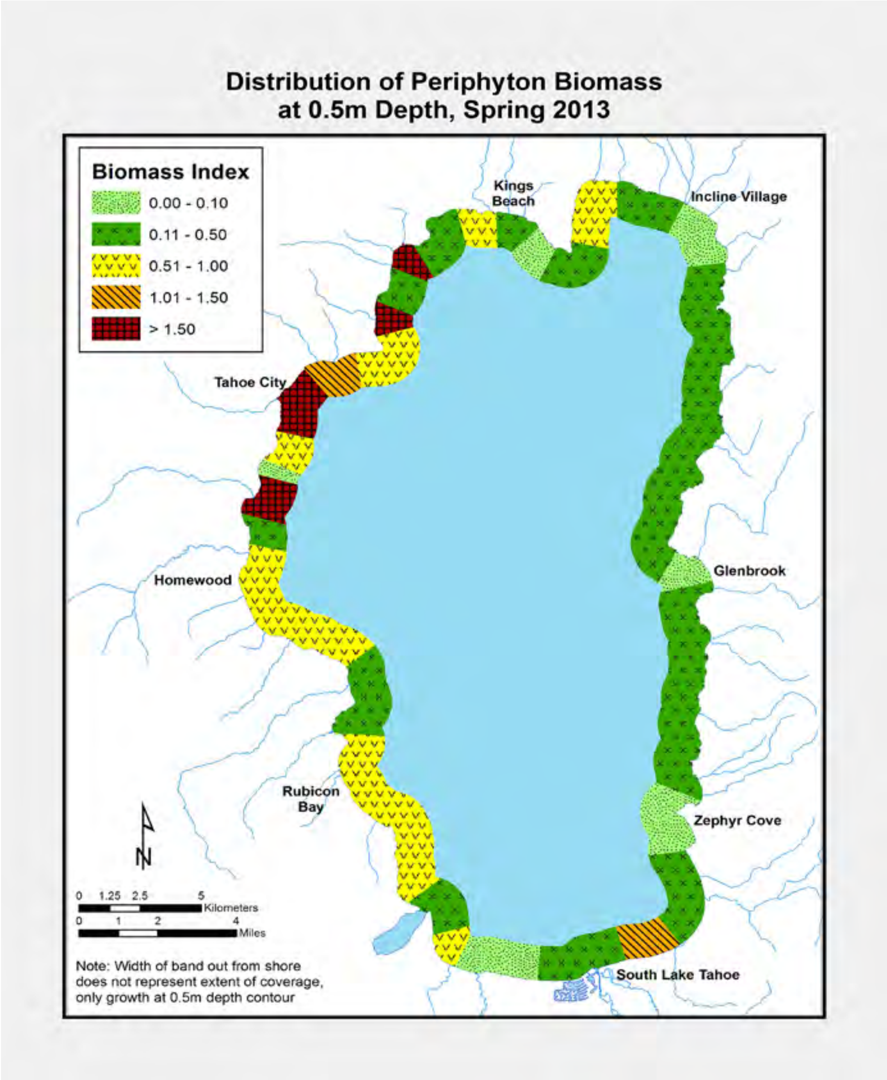
BIOLOGY

Shoreline algae distribution

In 2013

Periphyton biomass was surveyed around the lake during the spring of 2013, when it was at its annual maximum. Nearly 45 locations were inspected by snorkel survey in 1.5 feet (0.5 m) of water. A Periphyton Biomass Index (PBI) is used as an indicator to reflect what the casual observer would visually detect looking into the lake from the shoreline. The PBI is defined as the fraction of the local bottom area covered by periphyton multiplied by the average length of the algal filaments (cm). Zones of elevated PBI are evident, particularly along the north and west shores of Lake Tahoe, although elevated levels of periphyton are also observed in South Lake Tahoe. Overall conditions in 2013 were slightly improved compared to 2012.

Note: The width of the colored band does not represent the actual dimension of the onshore-offshore distribution. Similarly its length does not represent the precise longitudinal extent.



TAHOE: STATE OF THE LAKE REPORT 2014

CLARITY

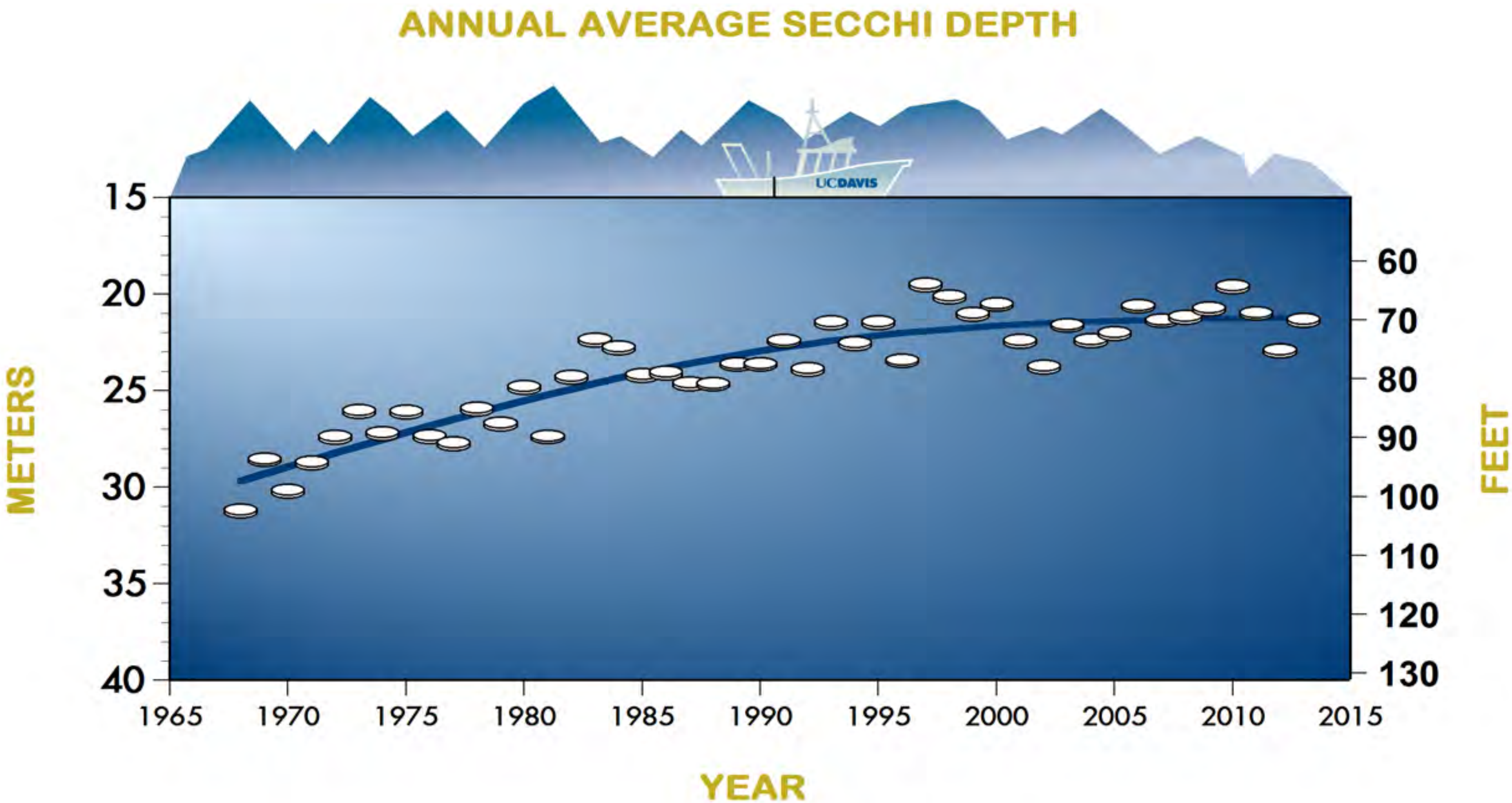
UC DAVIS
TAHOE ENVIRONMENTAL RESEARCH CENTER

CLARITY

Annual average Secchi depth

Yearly since 1968

In 2013 the annual average Secchi depth was 70.1 feet (21.4 m), a decrease of 5 feet over the previous year, but still well above the lowest value recorded in 1997 of 64.1 feet (19.5 m). The annual average clarity in the past decade has been better than the prior decade. From 2004-2013 the average clarity was 70.0 feet (21.3 m). The clarity level is the average of 25 individual readings taken throughout the year. The highest individual value recorded in 2013 was 90.2 feet (27.5 m) on March 25, and the lowest was 49.2 feet (15.0 m) on July 12. It is important to understand the causes behind clarity change and to evaluate past actions and future investments.

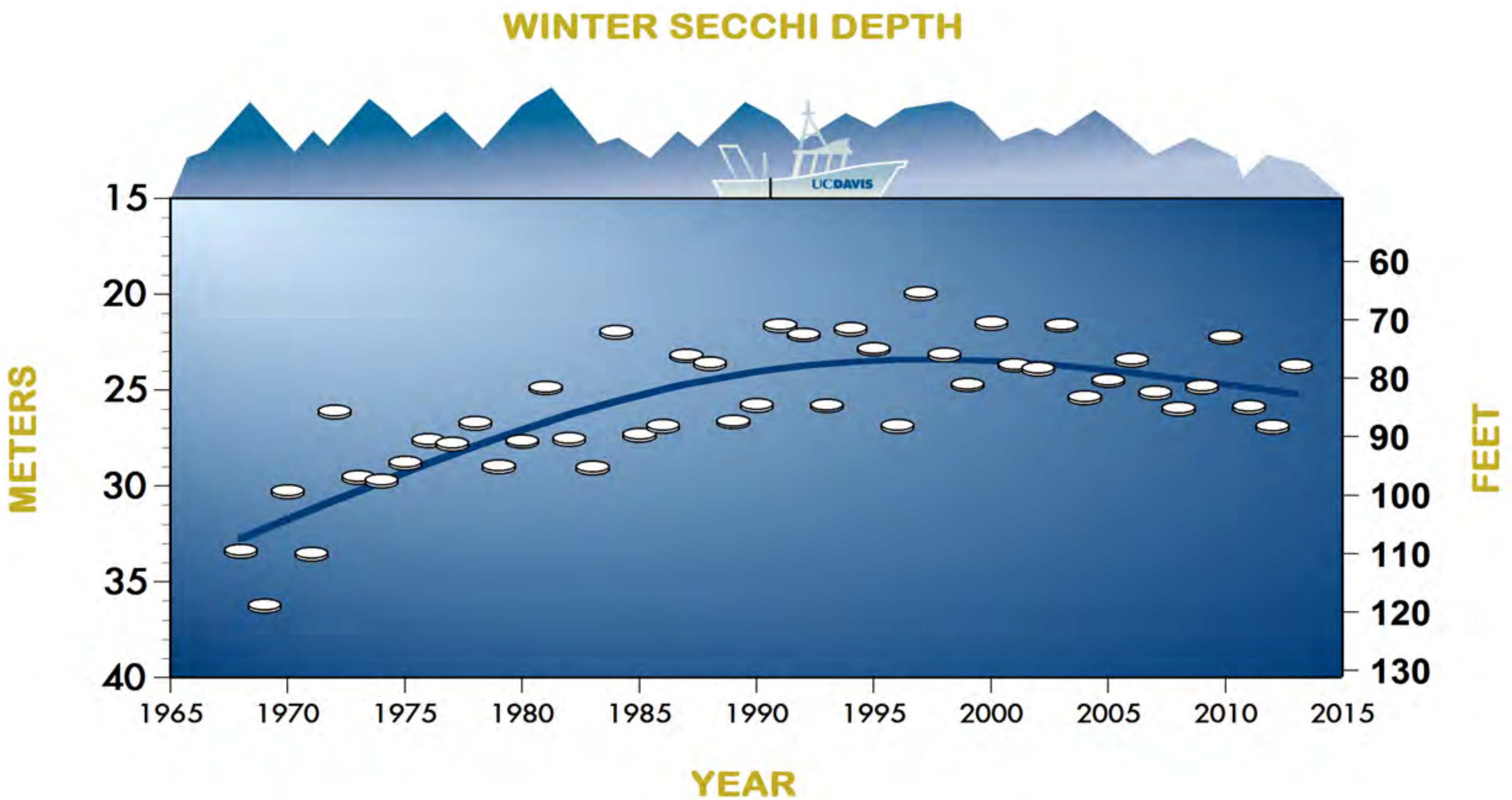


CLARITY

Winter Secchi depth

Yearly since 1968

Annual winter (December-March) Secchi depth measurements from 1968 to the present indicate that winter clarity at Lake Tahoe is showing definite improvement. In 2013, although 10 feet less than the previous year, the winter clarity was 77.9 feet (23.7 m). This is well above the lowest reading, seen in 1997. Large stream inflows in winter of 2012/2013 were mainly responsible for the decrease. The reasons behind the overall improvement in winter clarity are not fully understood, but are possibly tied to reductions in the quantity of fine particles from urban stormwater.

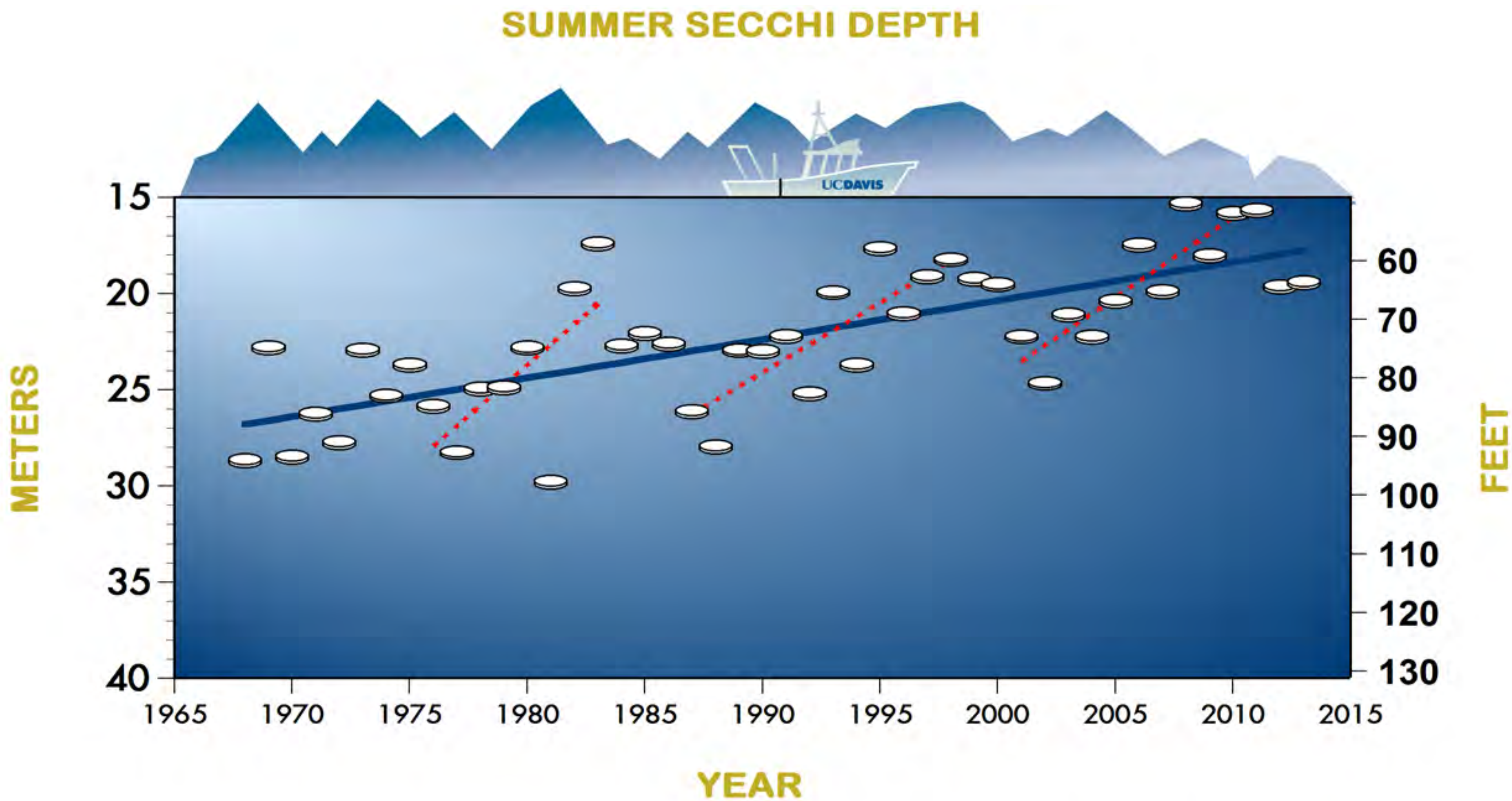


CLARITY

Summer Secchi depth

Yearly since 1968

Summer (June-September) clarity in Lake Tahoe in 2013 was 63.8 feet (19.4 m), almost identical to the value from 2012. This coincided with a decline in the concentration of small algal cells in 2013. Despite this improvement, the summer trend is dominated by a consistent long-term degradation but with a noticeable 10-15 year cyclic pattern. The red dashed lines are linear regressions for the periods: a) 1976 to 1983, b) 1987-1998, and c) 2001 to 2011. The most recent improvement may be a continuation of this cyclical trend. The reasons behind this periodicity are being investigated.



CLARITY

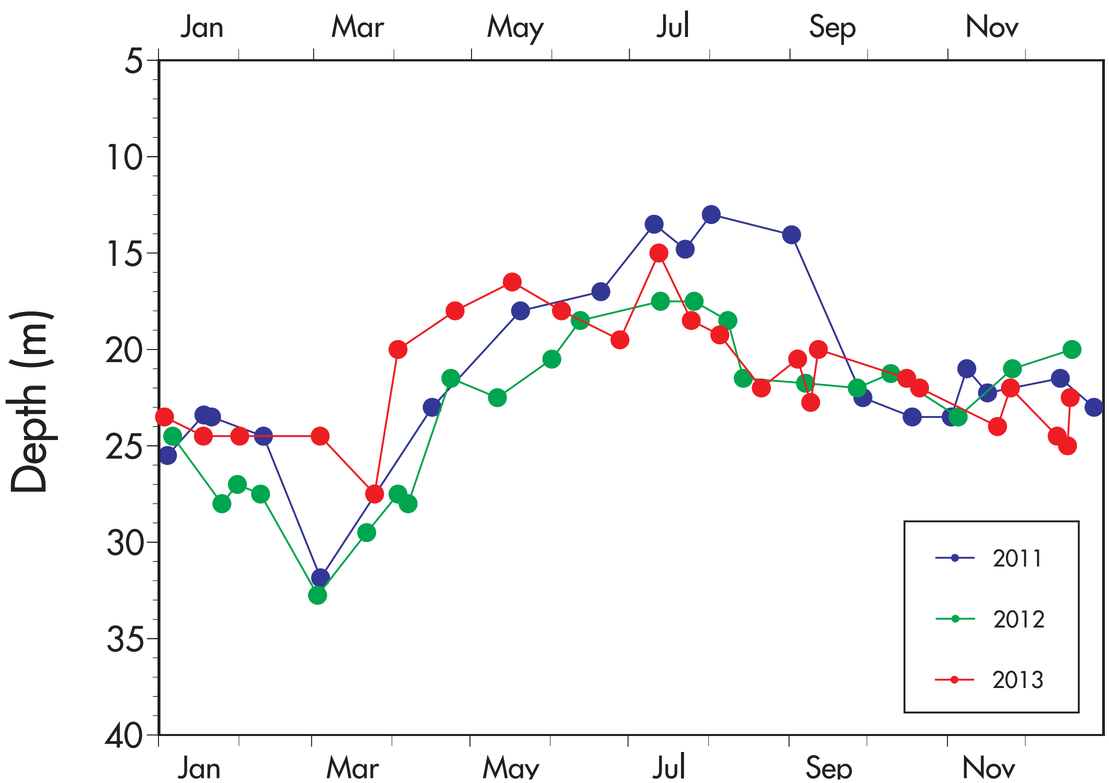
Individual Secchi depths

2011, 2012, 2013

Here the individual Secchi depth readings from the Index station on the west side of the lake for 2011,2012 and 2013 are plotted. For all three years it is evident that there is a distinct seasonality – Secchi depth is generally higher in the fall and winter months, and lowest in the spring and summer. The maximum Secchi depth often occurs around the time of deepest mixing (March). All three years reflected these trends.

2013 was the poorest year for clarity in the winter months. This is believed to be due to high precipitation in the previous December and the subsequent melt-off during the dry months that followed. Summer conditions, however, were very good owing to the small volume of spring snowmelt and the shallow depth of mixing in March.

Secchi values can be seen to sometimes vary considerably over short time intervals. This is evident in early September and early December in 2013. Such short-term variability is common in lakes. In this case the sudden changes are likely due to wind-driven upwellings.

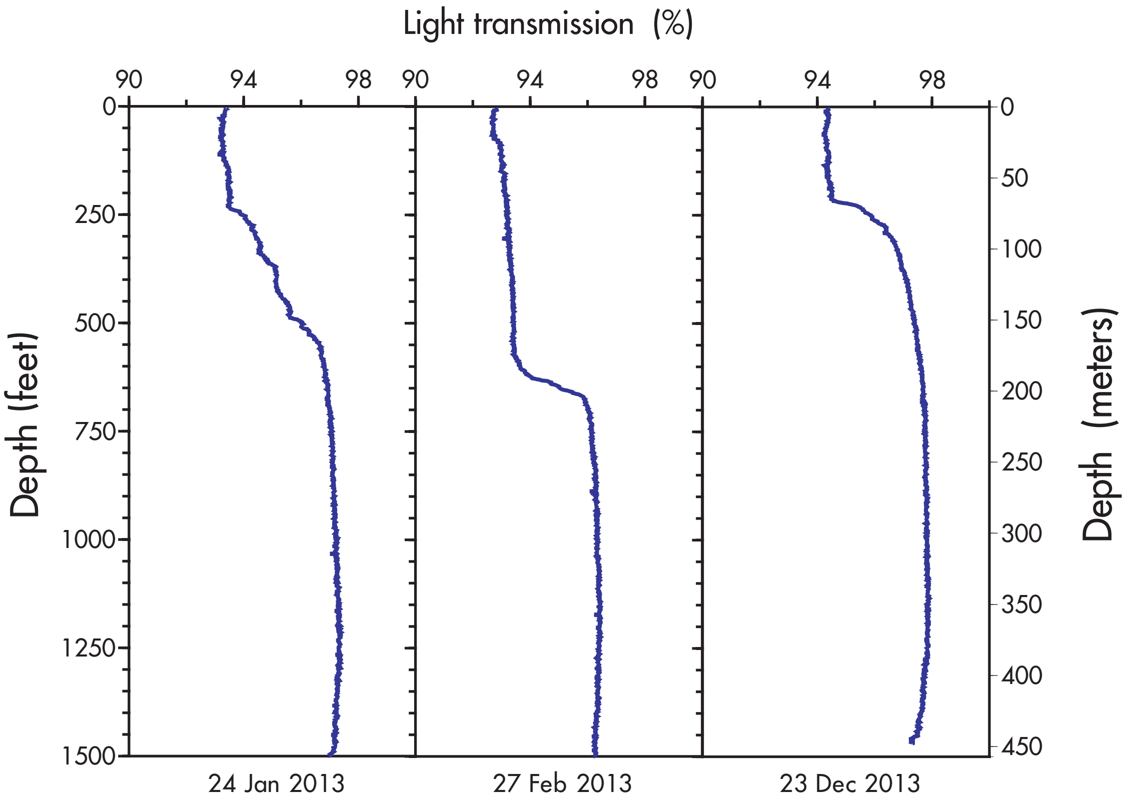


CLARITY

Light transmission

In 2013

A light transmissometer emits a specific wavelength of light and measures the percentage of that light transmitted over a 10 inch path. Clearer water results in a higher percentage of light transmission. Here, the light transmission measured at every depth in the lake is shown at three times in 2013. The "steps" in transmission at 200 feet, 240 feet, and 550 feet in the profiles indicates the depth of active lake mixing on those dates. It is also evident that the lowest light transmission is in the surface layers where between 93 and 94 percent of light is transmitted. The highest light transmission is in the very deepest parts of the lake where as much as 97 percent of the light can be transmitted. The reason for the improvement in deep water is that fine particles aggregate into larger particles that rapidly settle out in the deep water. Large particles do not scatter light as much as fine particles. The vertical trend in light transmission correspond very well with the distribution of fine particles in Figure 9.12.



TAHOE: STATE OF THE LAKE REPORT 2014

EDUCATION AND OUTREACH

UC DAVIS
TAHOE ENVIRONMENTAL RESEARCH CENTER

EDUCATION AND OUTREACH

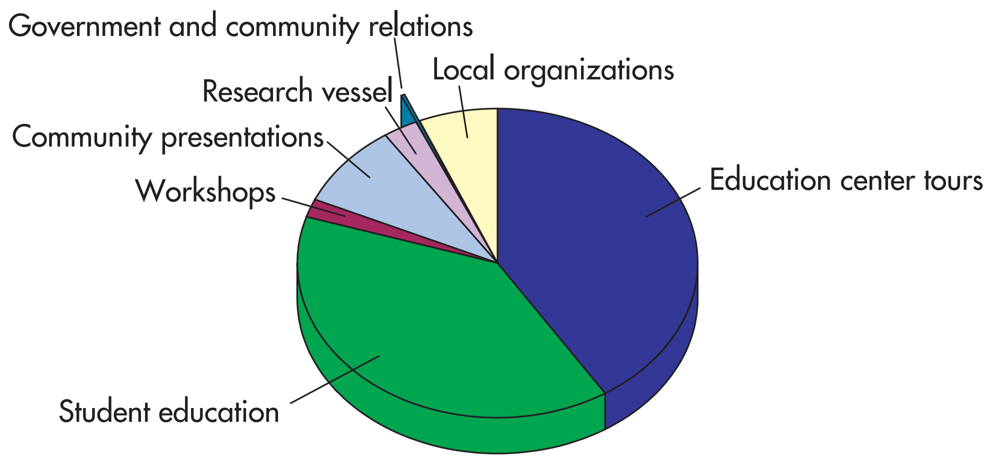
TERC education and outreach

In 2013

Part of TERC's mission is education and outreach. Our public, K-12, teacher professional development, and volunteer programs are designed to spark the imagination and curiosity of our visitors and participants and to sow the seeds of stewardship of our vital, yet fragile, freshwater ecosystems.

During 2013, TERC recorded 12,105 individual visitor contacts. The majority represented student field trips and visitors to the Tahoe Science Center (Thomas J. Long Foundation Education Center) at Incline Village. In addition, TERC hosts monthly public lectures and workshops, makes presentations to local organizations and takes a limited number of visitors out on our research vessels. TERC organizes and hosts annual events and programs including Children's Environmental Science Day, Science Expo, Youth Science Institute, Trout in the Classroom program, Project WET workshops, Summer Tahoe Teacher Institute and a volunteer docent training program.

TERC also partners with numerous groups to deliver environmental science education in the Tahoe basin. In 2013, these included AmeriCorps, COSMOS, North Tahoe Environmental Education Coalition, Sierra Nevada College, Sierra Watershed Education Partnerships (SWEP), South Tahoe Environmental Education Coalition, UC Davis Young Scholars, and many others.



TOTAL NUMBER OF CONTACTS: 12,105

EDUCATION AND OUTREACH

TERC educational exhibits

In 2013

New activities such as "Why is Tahoe Blue?" and "Measuring Clarity", the new interactive iPad application "Healthy and Unhealthy Lakes", and the game "Race to Save Lake Tahoe" provide Tahoe Science Center visitors with hands-on science focused on Lake Tahoe research and stewardship.

A new 3-D movie "Let's Go Jump in the Lake", funded by the National Science Foundation, will take viewers under the water to look at different organisms that live in the lake and the physical processes that moves them around. Due for completion in fall 2014, the movie will view Lake Tahoe at different time intervals. These range from a snapshot of a singular moment, the daily routine, and the dramatic change that occurs through the seasons.

"Why is Tahoe Blue?" and "Measuring Clarity" were developed to provide more hands-on activities for science center visitors.

Student evaluators test out the new "Race to Save Lake Tahoe" stewardship board game during exhibit development.

Coming soon: "Let's Go Jump in the Lake" 3-D movie is still under development.

EDUCATION AND OUTREACH

TERC educational programs

In 2013

In addition to providing education center tours for the general public, the TERC Education Team provides high quality informal science education to more than 4,400 third- through eleventh-grade students by hosting over 80 field trips each year.

Other K-12 educational programs include Trout in the Classroom, coordinated in partnership with Sierra Watershed Education Partnerships, which is designed to teach students about the ecology, biology, and history of trout and other aquatic life. This year, we raised Lahontan cutthroat trout in an aquarium in the science center. Students from schools around the region also raised trout for release into local waterways. A small group of select high school students participate in the annual Youth Science Institute from January through May. Through this afterschool program participants work with scientists, conduct science experiments and share science activities with other students.

School groups visit for informal science education programs on water, geology, ecology, and biology, including a new aquatic food web modeling activity.

AmeriCorps member Kristen Reichardt watches as Lahontan cutthroat trout eggs hatch and the small alevins begin swimming.

Youth Science Institute participants from high schools around the region conduct multiple science activities over the 16-week afterschool program.

EDUCATION AND OUTREACH

TERC educational programs, continued

In 2013

Each year we train new volunteer docents at our annual June Docent Training. Volunteer docents become local experts and lead tours at our two science centers. Volunteers also participate in garden work each year to make the Tahoe City Field Station's native plant demonstration garden a beautiful community resource.

Visitors that come to our science centers can view exhibits, watch 3-D movies, and participate in citizen science by conducting water quality monitoring, investigating plant phenology, and bird watching. Public participation in scientific research is educational for adults and children and provides useful data for scientists.

Additionally, for the past several years, TERC has hosted a summer Tahoe Teacher Institute for educators from both California and Nevada.

Visitors can wear lab coats for family photos and conduct citizen science including water quality monitoring and plant phenology.

Volunteer docents lead tours at our two science centers and make science come alive for visitors.

Teachers come to Lake Tahoe for the Tahoe Summer Institute to improve their proficiency in environmental science topics and learn new science activities.

EDUCATION AND OUTREACH

TERC special events

In 2013

TERC hosts monthly lectures throughout the year on various environmental issues, new scientific research and related regional topics of interest. Recent topics have included, “The Art of the Anthropocene”, “What’s in Your Extra Virgin Olive Oil?”, “Music, Memory and the Brain”, and “Lake Tahoe: Climate Change and a Worldwide Crisis for Inland Waters”.

Special events hosted annually include Project WET training workshops (February), Science Expo (March), Green Thumb Tuesdays (July - August), Summer Teacher Institute (July), Children’s Environmental Science Day (August), and Earth Science Day (October).

The annual Science Expo held each March brings in more than 1,000 third-, fourth- and fifth-grade students for hands-on science activities that cover a different theme every year. In 2014 the theme was “Earth and Space”. Next year the theme will be Life Sciences.

Public lectures are held monthly at the Incline Village location and Green Thumb Workshops are held at the Tahoe City Field Station throughout the summer. Sponsors help make these events free to the community.

Children’s Environmental Science Day is held annually each August with hands-on science activities designed for kids ages six and up. Scientists and management agencies from all across the Tahoe basin participate to make this a community event that builds knowledge and develops partnerships.

The UC Davis Tahoe Environmental Research Center is a global leader in research, education, and public outreach on lakes that provides critical scientific information to help understand, restore, and sustain the Lake Tahoe Basin and other systems worldwide.

TERC Administrative Office

Watershed Science Building
University of California, Davis
One Shields Avenue
Davis, CA 95616-8527
Phone: (530) 754-TERC (8372)
Fax: (530) 754-9364

TERC Incline Village Laboratory and the Tahoe Science Center

291 Country Club Drive
Incline Village, NV 89451
Phone: (775) 881-7560
Fax: (775) 832-1673

TERC Tahoe City Field Station

2400 Lake Forest Road
Tahoe City, CA 96145
Phone: (530) 583-3279
Fax: (530) 583-2417

http://terc.ucdavis.edu

FULL REPORT AVAILABLE AT

HTTP://TERC.UCDAVIS.EDU/STATEOFTHELAKE/

UC DAVIS
TAHOE ENVIRONMENTAL
RESEARCH CENTER