TAHOE: STATE OF THE LAKE REPORT 2010

UC DAVIS
TAHOE ENVIRONMENTAL RESEARCH CENTER

CONTENTS

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 and human activity have affected the lake's clarity, physics, chemistry and biology over that period. We also present the data collected in 2009. The data shown here reveal a unique record of trends and patterns – the result of natural forces and human actions that operate over time scales ranging from days to decades. These patterns tell us that Lake Tahoe is a complex ecosystem, and it behaves in ways we don't always expect. While Lake Tahoe itself is unique, the forces and processes that shape it are the same as those that apply in all natural ecosystems. Consequently, Lake Tahoe provides an analog for many other systems both in the western US and worldwide.

Our role as scientists is to explore that 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 those outside the scientific community and needs to take account of a host of other considerations beyond just the science. The annual UC Davis Tahoe: State of the Lake Report is intended to inform non-scientists about the most important variables that affect lake health. Until recently, only one indicator of Lake Tahoe's health status was widely used: the annual clarity (often called the Secchi depth, after the instrument used to collect the clarity data). In the Tahoe: State of the Lake Report, the UC Davis Tahoe Environmental Research Center (TERC) publishes many other environmental and water quality parameters that all provide indicators of the lake's condition.

This report is not intended to be a scorecard for Lake Tahoe. Rather, it 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: How much are invasive invertebrates affecting Lake Tahoe? Was Lake Tahoe warmer or cooler than the historical record last year? Are the inputs of algal nutrients to the lake declining? 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, 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 Veronica Alumbaugh, Brant Allen, Nancy Alvarez, Stephen Andrews, Patty Arneson, Sudeep Chandra, Bob Coats, Jill Falman, Bill Fleenor, Alex Forrest, Charles Goldman, Scott Hackley, Tina Hammell, Alan Heyvaert, Simon Hook, Debbie and Peter Hunter, Anne Liston, George Malyj, Dan Nover, Allison Oliver, Andrea Parra, Kristin Reardon, John Reuter, Bob Richards, Heather Segale, Travis Shuler, Todd Steissberg, Collin Strasenburgh, Raph Townsend, Katie Webb, Monika Winder, and Marion Wittmann to this year's report.

Funding for this enormous undertaking comes from a great many sources, spanning federal, state and local agencies, as well as UC Davis itself. While many other water quality variables could be tracked, funding ultimately limits what we measure. 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 and the U.S. Geological Survey. TERC's 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 National Aeronautics and Space Administration (NASA), the Desert Research Institute (DRI), and the University of Nevada, Reno (UNR). This monitoring data is also an integral part of many basic research projects funded by multiple sources. Without this data there are many questions that could not even be asked let alone answered.

This year we are also featuring some research highlights of 2009, taken from current projects where TERC is working in close and productive partnership with other researchers. The funding sources for those projects and additional researchers involved are acknowledged within those particular sections of the report.

We hope you find this report helpful and interesting. I welcome your comments.

Sincerely,

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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 to public agencies tasked with restoring and managing the Tahoe ecosystem, in part because it allows for the monitoring of progress toward reaching Tahoe's restoration goals and desired conditions.

This annual *Tahoe: State of the Lake Report* presents 2009 data in the context of the long-term record. While the focus is on data collected as part of ongoing, long-term measurement programs, this year we have also included updates on current research related to the impacts of the Angora Fire and the Asian clams on Lake Tahoe.

The report also includes data about changes in the algae composition and concentration, lake clarity and the effects of climate change on snowmelt timing, lake water temperature and density stratification. The UC Davis Tahoe Environmental Research Center has developed sophisticated computer models that help scientists more accurately predict how Lake Tahoe's ecosystem behaves. Long-term data sets are essential to refine the accuracy of those models and to develop new models as knowledge increases and new challenges arise. In times of rapid change, reliable predictive models are indispensable tools for Lake Tahoe Basin resource managers.

This report is available on the UC Davis Tahoe Environmental Research Center website (terc.ucdavis.edu).

Here are some of the highlights presented in the following pages.

RECENT RESEARCH UPDATES

Angora Fire

- Most nutrient and sediment concentrations in Angora Creek increased for the two years since the fire.
- Despite an increase in phosphorus and other constituent loads immediately downstream of the burn area, the overall impact on the Upper Truckee River and Lake Tahoe was insignificant.

Asian clams

- A control methodology to use rubber mats to deprive invasive clams of oxygen was tested and found to produce 100 percent mortality in Asian clams
- A large scale experiment is currently underway to test the long term effectiveness and deployment costs of an expanded control program.
- A multi-agency boat launch inspection and education program for all invasive species is an important component of the invasive species strategy. Over 20,000 boats were inspected in 2009, Mussels were found on ten of them.

METEOROLOGY

The Lake Tahoe ecosystem is highly influenced by meteorology. In the short term, meteorological conditions are expressed as daily variations in weather. In the long term, they are expressed as normal cyclical variations such as wet and dry cycles, and long-term trends related to global climate change.

Historical record:

- The nightly minimum temperatures recorded at Tahoe City have increased by more than 4 degrees F since 1910. (Fig. 7.1)
- Days when air temperatures averaged below freezing have generally decreased by 30 days per year since 1910, although 2009 was a colder than average year. (Figs. 7.2 and 7.3)
- Since 1910, the percent of precipitation that fell in the form of snow decreased from 52 percent to 34 percent. (Fig. 7.7)
- Peak snow melt averages 2 1/2

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[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 2009 report, water year data are from Oct. 1, 2007 through Sept. 30, 2008. Calendar year data are from Jan. 1, 2008 through Dec. 31, 2008.*

EXECUTIVE SUMMARY

(CONTINUED FROM PAGE 2.1)

weeks earlier than in the early 1960s. (Fig. 7.8)

Previous year:

- Precipitation in 2009 was slightly below the long-term average, but significantly wetter than the previous two years. This was largely due to exceptionally high spring precipitation (March and May). (Figs. 7.5 and 7.6).
- The decline in the percent of snow in 2009 was consistent with the long-term trend.

PHYSICAL PROPERTIES

Lake Tahoe's physical properties are largely a response to external factors, especially meteorology. Physical properties, in turn, determine the environment for all the lake's chemical and biological processes (see next sections).

Historical record:

- Lake level fluctuates throughout the year, and from year to year (Figs. 8.1 and 8.2)
- Water temperature (volume averaged) rose by more than 1 degree F in the past 38 years. (Fig 8.3)
- Surface water temperatures have risen since data collection commenced. (Figs. 8.4, 8.5 and 8.6)
- Density stratification of Lake Tahoe has increased over the last 39 years as surface water warmed due to climate change. (Fig. 8.8)

Previous year:

- In 2009, lake level fell to a low of 6222.76 feet on December 31, almost 3 inches below the natural rim. (Figs. 8.1 and 8.2). For over two months there was not outflow from Lake Tahoe to the Truckee River.
- Winter surface water temperatures were higher in 2009, due to the absence of deep mixing. (Fig. 8.5).
- The maximum depth of mixing in 2009 was approximately 700 feet. (Figs. 8.7 and 8.9).

NUTRIENTS AND PARTICLES

Lake Tahoe's clarity is determined especially by fine sediment particles, and also by nutrients. Tahoe's urban areas contribute 72% of fine particles, despite representing only 10% of the land base. Nutrients affect lake clarity by promoting algae growth. Offshore, algae make the water greenish and less clear. Along the shoreline, algae are a problem because it coats rocks with green slime.

The two nutrients that most affect algal growth are nitrogen and phosphorus. These nutrients are measured at various depths at TERC's mid-lake and western lake stations. One form of nitrogen that is readily available to algae—nitrate—enters the lake through stream and urban runoff, groundwater and atmospheric deposition. Phosphorus occurs naturally in Tahoe Basin soils and enters the lake from soil disturbance and erosion, as well as atmospheric deposition.

Historical record:

- Stream inputs of particles, nitrogen and phosphorus are directly linked to the annual amount of precipitation to the annual amount of precipitation via runoff and stream flow. (Figs. 9.3 to 9.5)
- Atmospheric deposition of nutrients, both in concentration and total loads, are also linked to precipitation. (Figs 9.6 and 9.7)
- Nitrogen concentrations in the lake have remained generally constant for many years. (Fig. 9.8)
- Phosphorus concentrations in the lake have been generally declining. (Fig. 9.9)

Previous year:

- The west-side watersheds contributed far more particles and nutrients to Lake Tahoe in 2009 (a three-fold increase over 2008). The east-side streams were similar to 2008. This is a reflection of the dry conditions of the previous two

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EXECUTIVE SUMMARY

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years. (Fig. 9.2)

- In 2009, the volume-weighted, annual average concentration of available phosphorus was just under 1.4 micrograms per liter (parts per billion); the lowest value since continuous monitoring began in 1980. (Fig. 9.9)
- The lowest concentration of particles in the lake occurred immediately after mixing in late February. The highest concentration is during the spring snowmelt in April. (Fig. 9.10)
- The highest concentrations of fine particles were in the Upper Truckee River, followed by Ward, Trout and Incline Creeks. (Fig 9.11).

BIOLOGY

The longest data sets for lake biology come from the base of the food web—the free-floating algae (or phytoplankton). This algae influences the lake's food web, clarity and aesthetics.

Historical record:

- Primary productivity, the rate at which algae produce biomass through photosynthesis, has been generally increasing since 1959. (Fig. 10.1)
- The average annual abundance of algae (by concentration of chlorophyll-a) has remained relatively uniform since 1996. (Fig 10.2)
- Since 1984, the annual average depth of the deep chlorophyll maximum has declined. (Fig. 10.4)
- Diatoms remain the dominant algal species and provide high quality food for aquatic species. (Fig 10.6)
- While phosphorus limited in the early part of the year, the lake is generally co-limited (needing both nitrogen and phosphorus) for optimum algal growth. (Fig. 10.8)

Previous year:

- Periphyton (attached algae) concentrations were similar to values recorded in 2008, with the exception of Tahoe City, which experienced a 60 percent decrease to the highest values ever recorded at that site. (Fig. 10.9)
- Periphyton distributions were significantly elevated along the north-east shoreline of the lake. (Fig. 10.10)

CLARITY

Clarity remains the indicator of greatest interest for Lake Tahoe because it tracks both degradation and the community's efforts to restore clarity to historic levels. Secchi depth (the point below the lake surface at which a 10-inch white disk disappears from view) has been measured continuously since 1968, and is the longest continuous measure of Lake Tahoe's water clarity.

In 2009, the annual average Secchi depth was 68.1 feet, a decline of approximately 1.5 feet from the previous year. This can in part be explained by the higher precipitation, particularly the high spring precipitation. Summer Secchi depths were significantly improved on the previous year, with an increase in summer clarity of over 10 feet.

In the last nine years, Secchi depth measurements have been better than predicted by the long-term linear trend. There is statistical support that Lake Tahoe's clarity decline has slowed significantly, and is now best represented by a curve. (Fig. 11.1)

EDUCATION AND OUTREACH

The public can learn about the science behind Lake Tahoe restoration at TERC's Incline Village education center (the Thomas J. Long Foundation Education Center). In 2009, over 9,400 people participated in our education and outreach activities. (Fig. 12.1)

There is now a second science education center located at the Tahoe City Field Station (Eriksson Education Center).

For more information about our education centers or education programs, contact tercinfo@ucdavis.edu or visit http://terc.ucdavis.edu.

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
- Number of inflowing streams: 63, the largest being the Upper Truckee River
- 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.
- Average residence time of water in 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: 66,000 (2000 Census)
- Number of visitors: 3,000,000 annually

ABOUT THE UC DAVIS TAHOE ENVIRONMENTAL RESEARCH CENTER (TERC)

The Tahoe Environmental Research Center is a year-round UC Davis program of research, education and outreach in the Tahoe basin.

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 Thomas J. Long Foundation Education Center, a learning resource that is free and open to the public.

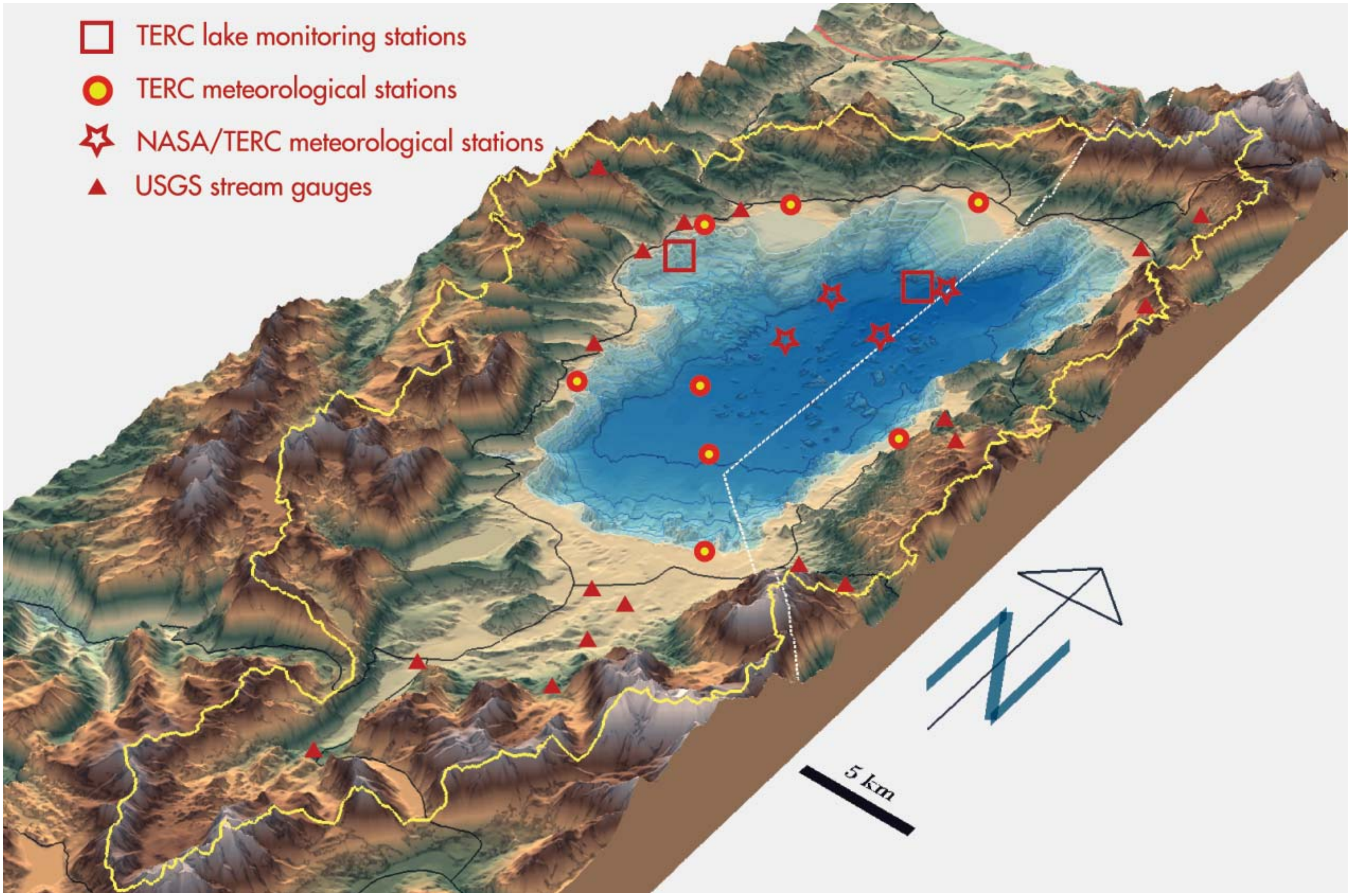
In Tahoe City, Calif., we operate a field station (housed in a fully renovated, former state fish hatchery) and the Eriksson Education Center (opened in July 2010). Tahoe City is also the mooring site for our three research vessels, the John LeConte, the Bob Richards and the Ted Frantz.

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

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

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

MAP OF TAHOE BASIN DATA COLLECTION SITES



TAHOE: STATE OF THE LAKE REPORT 2010

RECENT RESEARCH UPDATES

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RECENT RESEARCH UPDATES

Overview

Each year a different research areas emerge as the most topical in the State of the Lake Report. In the 2008 report, the focus was on the response of Lake Tahoe to the immediate effects of the Angora Fire, which had burned 3100 acres of the southern basin the previous July. With the discovery of an invasion of Asian clam in Lake Tahoe in 2008, the 2009 State of the Lake Report described the initial observations of this most recent threat.

This year the State of the Lake Report will revisit both of these topics, and provide an overview of recent research advances that have been made in relation to each topic.

The Angora Fire threatened water quality in Angora Creek, Upper Truckee River and Lake Tahoe with the potential for ash and sediment delivery to receiving waters in and downstream of the fire.
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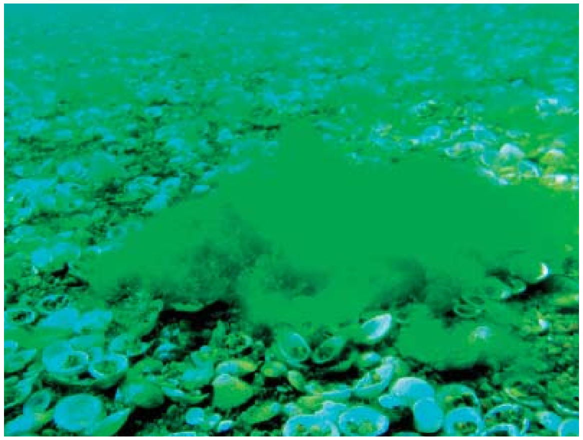


An extended algal bloom, resulting from the clams concentrating nutrients, can have long lasting impacts on the nearshore condition of Lake Tahoe. Residual dead and dying algae are washed up onto beaches where they decompose and influence nearshore water quality.

RECENT RESEARCH UPDATES

Angora Fire

While the impacts of the Angora Fire on Lake Tahoe due to the immediate atmospheric deposition were limited, larger concerns remained about the longer term inputs from stream flow from the burned watershed. With primary funding from the Lahontan Regional Water Quality Control Board, the US Army Corps of Engineers by way of a cooperative agreement with the California Tahoe Conservancy, and the US Forest Service – Lake Tahoe Basin Management Unit, researchers from UC Davis and the Desert Research Institute have been monitoring the stream intensively since the fire. The complete report *Water Quality Conditions Following the 2007 Angora Wildfire in the Lake Tahoe Basin*. 2010. J. Reuter, A. Heyvaert, A. Oliver, A. Parra and R. Susfalk has been submitted to Tahoe management agencies for review and comment. The US Geological Survey - Carson City, NV also contributed to this project by establishing and monitoring a new sampling station on Angora Creek near its confluence with the Upper Truckee River.

Smoke from the Angora Fire rises above Lake Tahoe. Photo courtesy of Timothy D. Rains.

The aftermath of the fire in the Angora Creek watershed.

Nutrient concentrations for Angora Creek for several time periods

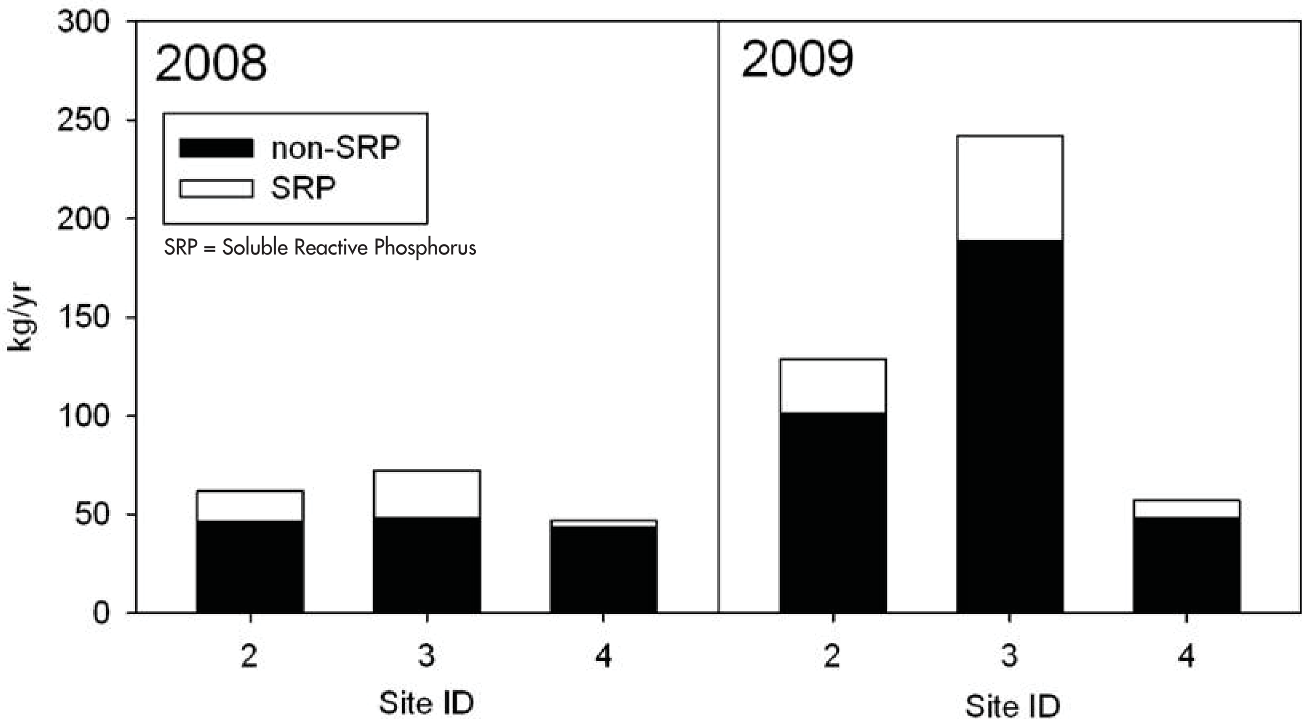
Water quality data collected at a monitoring site on Angora Creek, just upstream from an urban subdivision, allowed for an evaluation of pre-fire and post-fire sediment and nutrient concentrations in the creek. This site represents the cumulative effects of the burned, undeveloped, upland forest where both the erosion hazard and the severity of the fire were high. An historic dataset from this site from an earlier erosion control project, collected by the USFS – Lake Tahoe Basin Management Unit between 1991-2001, proved invaluable for this comparison. All the measured nutrient and sediment constituents, shown below, indicate a post-fire increase in nutrient concentrations – especially for nitrate (a form of nitrogen available to algae). An eventual decline in nitrate, as seen in 2009, is typically reported from many wildfire sites. All the other constituents, except soluble reactive phosphorus (SRP), showed an increase in concentration in Year 2 (2009), presumably due to increased precipitation and flow. Other studies in the western US suggest a period of 3-10 years is needed for a recovery to near-baseline conditions. There was no evidence of massive sediment or nutrient inputs from the burned area into Angora Creek.

	Pre-Erosion Project 1991 - 1997	Post-Erosion Project 1998 - 2001	Post- Angora Fire 2008	2009
Precipitation Range (inches/year)	36 - 91	34 - 73	40	54
Nitrate (µg/L)	6 ± 3	12 ± 11	72	59
Total Nitrogen (µg/L)	134 ± 45	190 ± 55	280	360
Soluble Reactive Phosphorus (µg/L)	2 ± 1	4 ± 2	7	7
Total Phosphorus (µg/L)	15 ± 5	15 ± 2	22	39
Total Suspended Sediment (mg/L)	2.4 ± 1.3	1.4 ± 0.8	3.4	6.5
Turbidity (NTU)	0.5 ± 0.1	0.9 ± 0.4	1.6	3.1

Data courtesy of DRI and UC Davis

Annual load of phosphorus as measured at three sites in WY 2008 and WY 2009

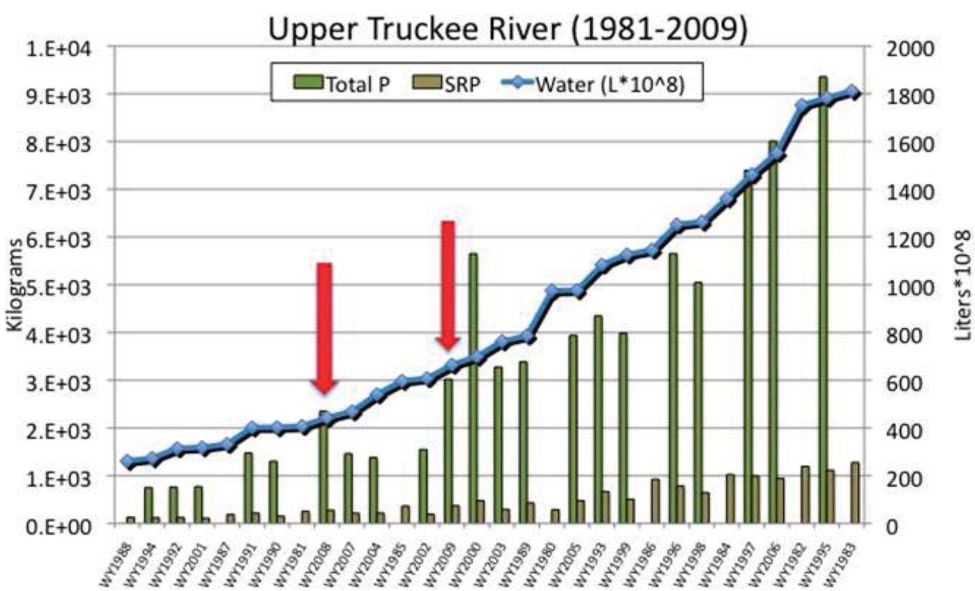
The annual downstream load of phosphorus carried by Angora Creek since the fire was evaluated at three monitoring sites downstream of the burn area. Sites 2 and 3 were located on Angora Creek immediately upstream and immediately downstream of the urban subdivision, while site 4 was positioned near the confluence of Angora Creek and the Upper Truckee River. Total Phosphorus load increased as the creek flowed through the urban landscape. This difference was most significant in Water Year (WY) 2009 when precipitation and flow was higher. In WY 2008, phosphorus load declined by approximately 35 percent before reaching the Upper Truckee River while in WY 2009 this reduction was 75 percent. The load reduction was most likely related to groundwater infiltration, which is characteristic of the wet meadow. In years of higher flow the wet meadow vegetation should act to also reduce downstream transport. Nitrogen showed a similar pattern.



Data courtesy of DRI and UC Davis

Annual loads of total phosphorus and soluble reactive phosphorus following the Angora fire

Following the Angora Fire there was concern that ash-laden runoff could travel down Angora Creek, into the Upper Truckee River (UTR) and consequently into Lake Tahoe. To determine if the impact of the Angora Creek fire-derived load could be seen in the annual nutrient load of the much larger UTR, the extensive database provided by the Lake Tahoe Interagency Monitoring Program (27-year pre-fire record) was utilized. Since nutrient concentration and load depend on hydrologic patterns and amount of flow, a total of 16 years from the historical database were selected to represent the flow and nutrient conditions in the Upper Truckee River. The annual UTR flows were plotted in increasing order for every year between 1981 and 2009 (blue line). The total P and SRP loads for the corresponding loads were plotted as bars on the same figure. Flow and load of total phosphorus and soluble phosphorus from Angora Creek in Water Years 2008 and 2009 had no statistically significant impact on the UTR. The red arrows in the charts below denote Water Years 2008 and 2009. Both fit within the accepted flow versus nutrient load relationship seen historically for the Upper Truckee River. Data for suspended sediments, total nitrogen and dissolved nitrogen showed similar relationships.



P = Phosphorus
SRP = Soluble Reactive Phosphorus

Data courtesy of DRI and UC Davis

RECENT RESEARCH UPDATES

Asian clams

Since the discovery of Asian clams (Corbicula fluminea) in large numbers in the south-east of Lake Tahoe in 2008, both the research community and management agencies operating in the Basin have responded swiftly. The multi-agency Lake Tahoe Aquatic Invasive Species Program was established to coordinate basin-wide prevention, control and eradication efforts. As part of the control efforts of this multi-agency partnership, a team of researchers from UC Davis TERC and the University of Nevada, Reno, have been conducting experiments to better understand the distribution and the behavior of Asian clams in Lake Tahoe as well as impacts to native biodiversity and nearshore ecology. Much of this effort has been focused on devising ways to control the spread and reduce the present concentrations of these invasive invertebrates in Lake Tahoe. Funding for these efforts have come from a variety of sources, including the Lahontan Regional Water Quality Control Board, Nevada Division of State Lands, the Tahoe Regional Planning Agency, the US Fish and Wildlife Service and the US Forest Service (through the Southern Nevada Public Lands Management Act). In addition, the Tahoe Resource Conservation District, California State Parks, Nevada Department of Wildlife, Tahoe Water Suppliers Association, Nevada Division of Environmental Protection and California State Lands Commission are members of this multiagency partnership. The localized populations of Asian clams in Lake Tahoe have densities amongst the highest observed worldwide, with over 6000 clams per square yard in the most heavily infected regions. The clams are present in highest concentration at water depths of between 20 to 30 feet, although they have been found at water depths in excess of 200 feet. Typically the clams burrow into sandy sediments to a depth of about 2 -3 inches.

Asian clams recovered from Lake Tahoe by UC Davis TERC researcher Marion Wittmann.

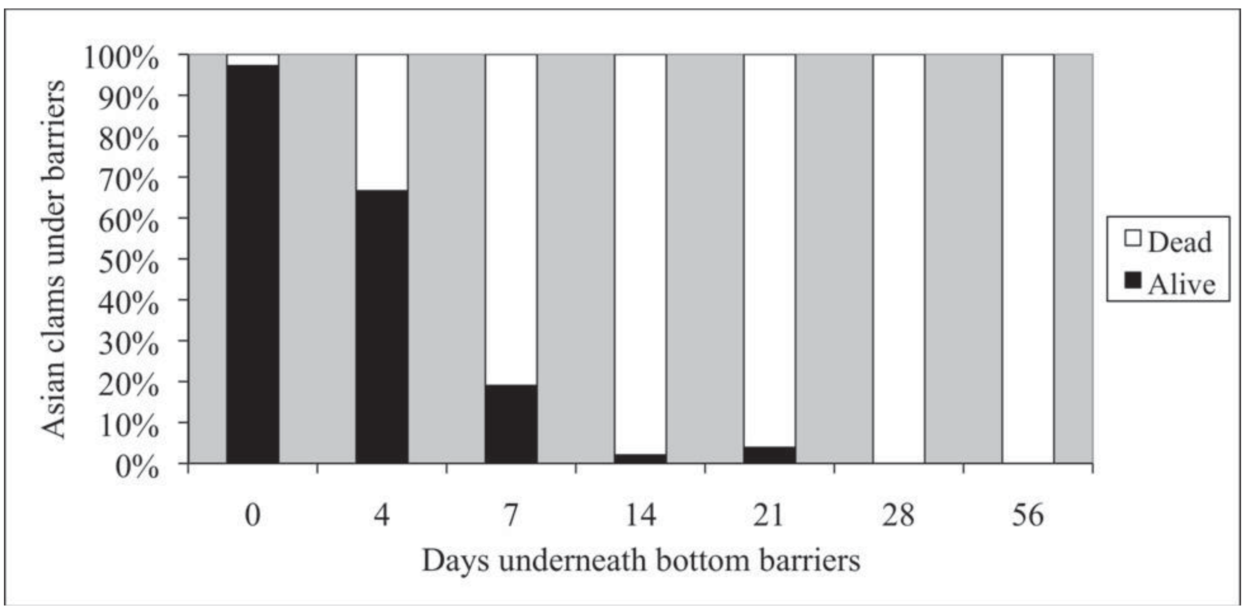
UC Davis TERC divers roll out rubber bottom-barrier mats to reduce oxygen levels below survivable concentration for clams.

The first 100 foot long strip of rubber mat laid out on the lake bottom is visible in Marla Bay on July 9, 2010.

RECENT RESEARCH UPDATES: ASIAN CLAMS

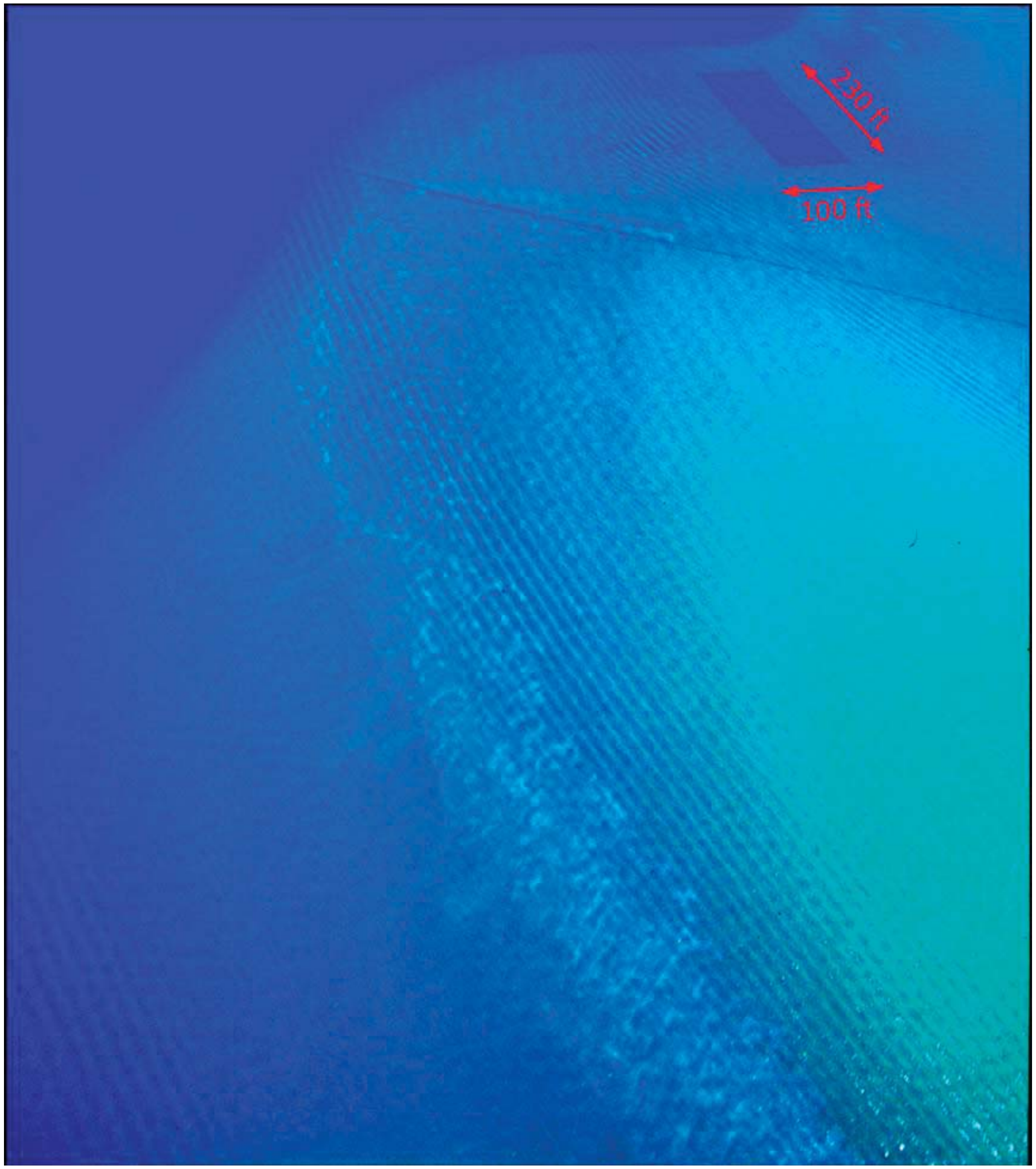
The percentage of Asian clam mortality under the bottom barriers. After 28 days all Asian clams were killed.

The control strategy that is currently being pursued is the application of thin rubber sheets (or barriers) on the lake bottom. These barriers have been shown to cut off the oxygen supply to the clams. The figure below shows the rate at which the Asian clams are killed following the application of the rubber barriers. Although oxygen concentrations immediately below the mats is reduced to zero within 2 days, it took approximately 4 weeks to kill all Asian clams under the barriers at peak summer water temperatures. These results were obtained during summer 2009, using small (10 feet x 10 feet) rubber barriers. Larger scale (100 feet x 230 feet or about ½ acre) barriers are now being tested at two locations in the lake to determine the cost and practicality of these large-scale deployments. Figure 6.8 shows one of the test sites in Marla Bay. The dark blue water indicates a sharp drop in the lake depth. The rectangular barrier test area is clearly visible in the upper right hand corner of the photograph. The thin line across the upper part of the image is a drinking water intake line. The whitish arc extending from the lower right hand corner to the upper central part of the photograph are clam shells (from dead clams) laying on the lake bottom at approximately 30 - 40 feet water depth.



Data courtesy of UC Davis TERC and UNR

RECENT RESEARCH UPDATES: ASIAN CLAMS

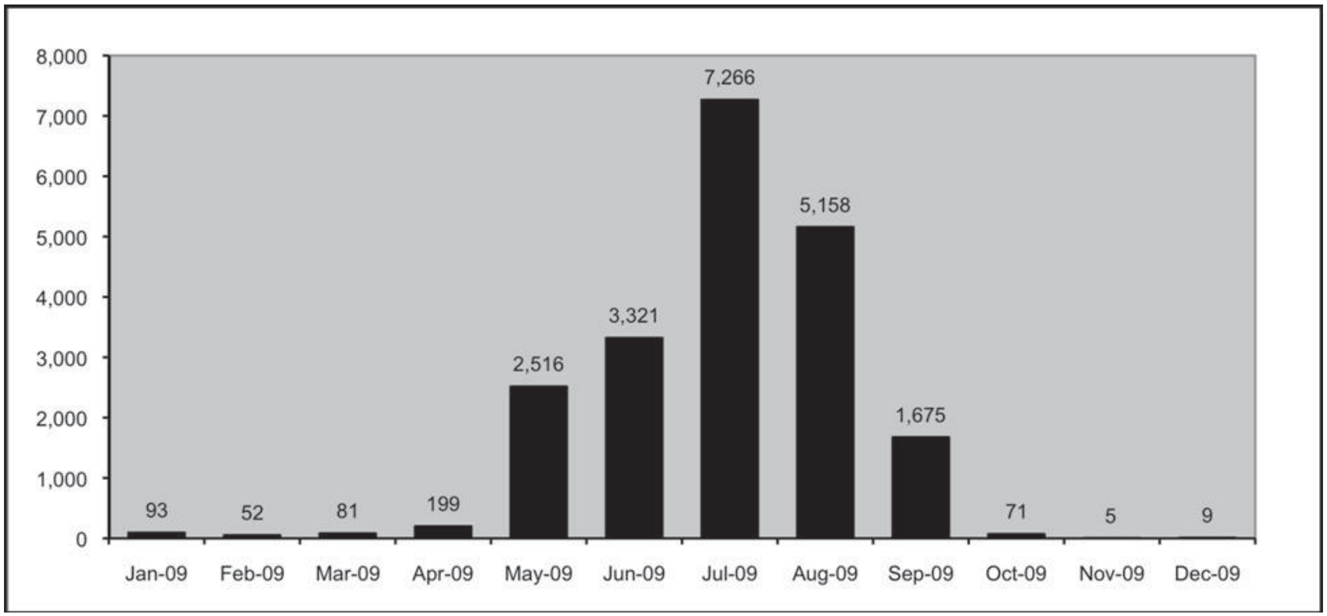


Aerial photograph of one of the bottom barrier test sites (courtesy B. Allen, UC Davis TERC)

RECENT RESEARCH UPDATES

The number of boats inspected at Lake Tahoe during 2009

In parallel with the research effort being conducted by the research community to control species present in Lake Tahoe, management agencies have been actively engaged in preventing new introductions of invasive species. Central to this effort is a comprehensive boat inspection program carried out by the Tahoe Regional Planning Agency and the Tahoe Resource Conservation District, and funded by the U.S. Fish and Wildlife Service. These agencies have developed one of the most comprehensive recreational boat inspection programs in the United States. The program was first implemented in 2008. Through this program, every boat entering Lake Tahoe is inspected for aquatic invasive species at boat inspection stations that are located at entry ways to the Tahoe Basin. The primary target of the boat inspections are quagga mussels. Although quagga mussels are not yet in Lake Tahoe, they do exist in several water bodies in California and Nevada, and can readily be transported by attaching to boats. The figure below provides the Lake Tahoe boat launch data for 2009. There were over 20,446 launch inspections performed during 2009, with the largest number being in July (7266). Approximately 63 percent of the boats were from California and over 33 percent were from Nevada. Quagga and zebra mussels were found on 10 of the 20,446 boats inspected; these vessels were quarantined and not permitted to enter the lake upon discovery of invasive mussels. Quagga mussels can inflict tremendous economic and ecological damage to lakes once they become established.



Data courtesy of K. Kasman and T. Thayer, TRPA

TAHOE: STATE OF THE LAKE REPORT 2010

METEOROLOGY

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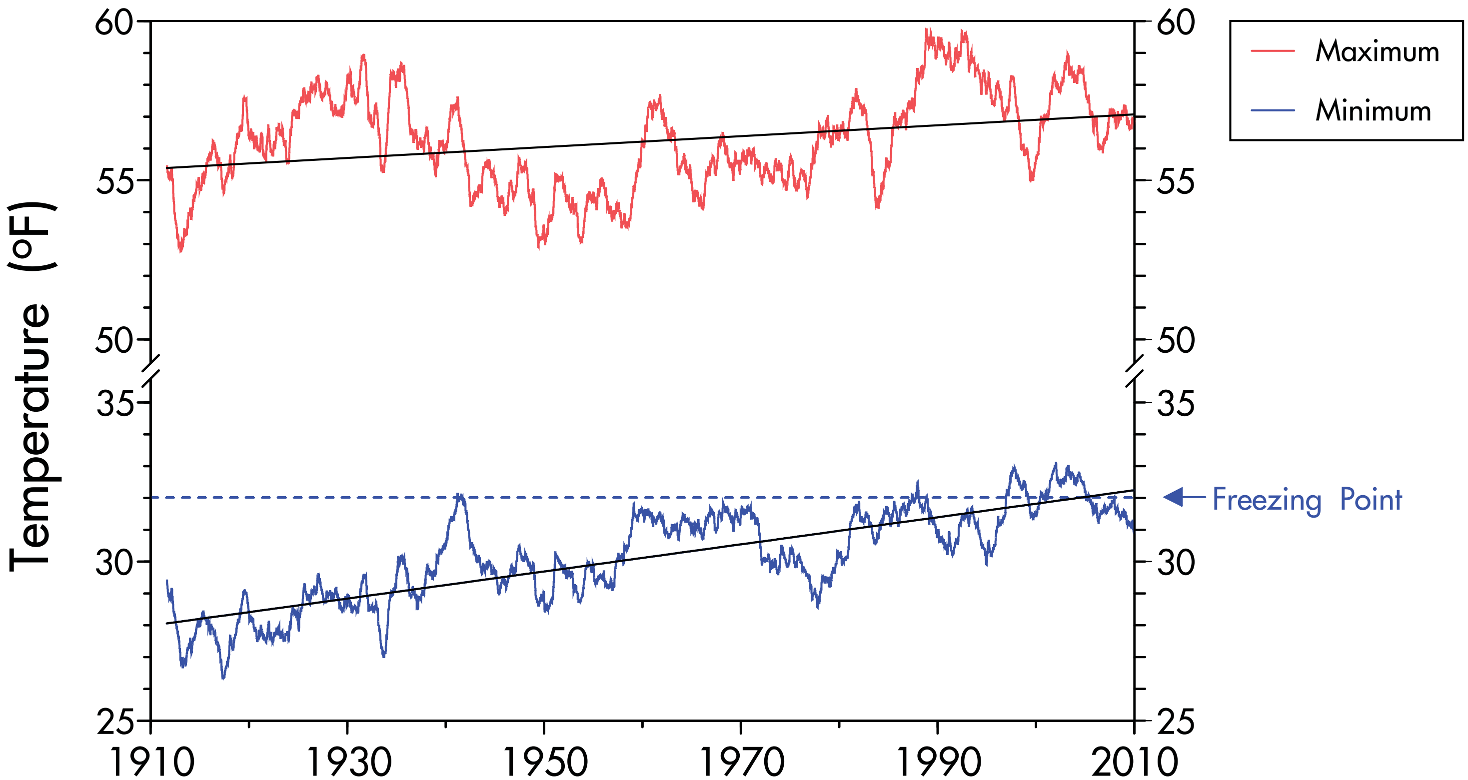
METEOROLOGY

Air temperature

Daily since 1911

Daily air temperatures have increased over the 98 years measured at Tahoe City. The trend in daily minimum temperature has increased by more than 4 degrees F., and the trend in daily maximum temperature has risen by less than 2 degrees F. The average 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.

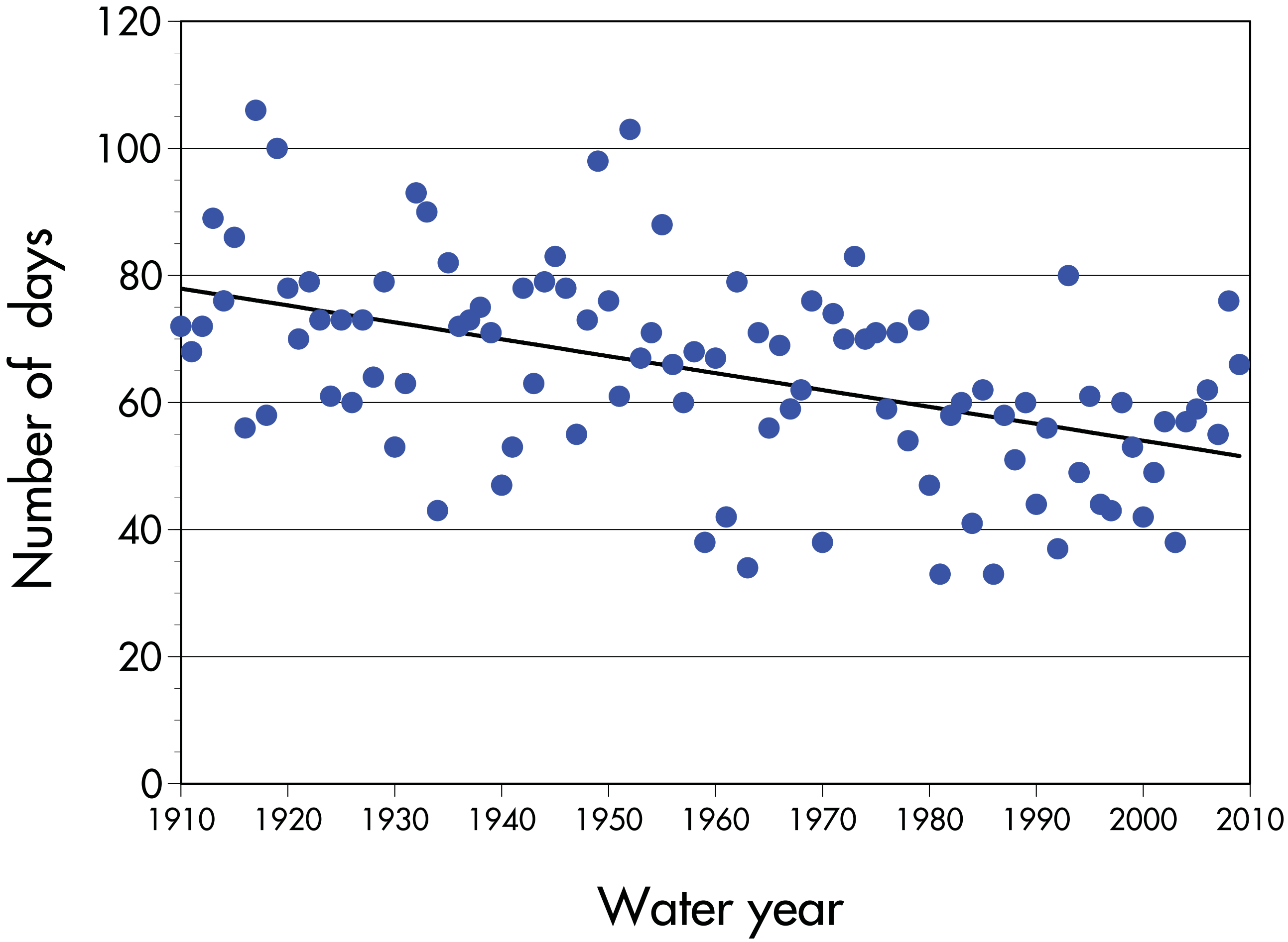


METEOROLOGY

Below-freezing air temperatures

Yearly since 1910

Although year-to-year variability is high, the number of days when temperatures averaged below freezing has declined by about 30 days since 1911. In 2009, the number of freezing days was above the long-term trend at 66 days.

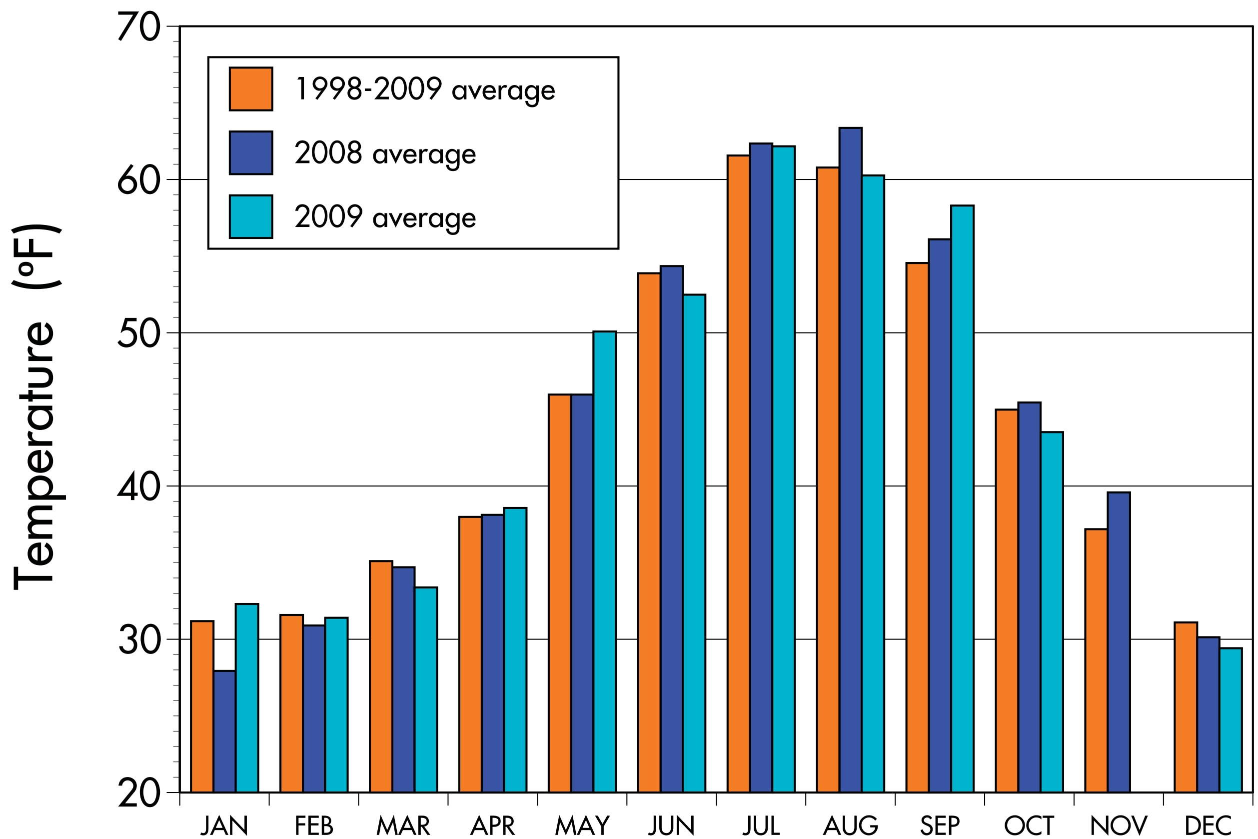


METEOROLOGY

Monthly air temperature

Since 1998

In 2009, January, April, May and September were warmer than either the previous year or the twelve-year average. The months of March, June, August, October and December were significantly cooler than the previous year and the twelve-year average.

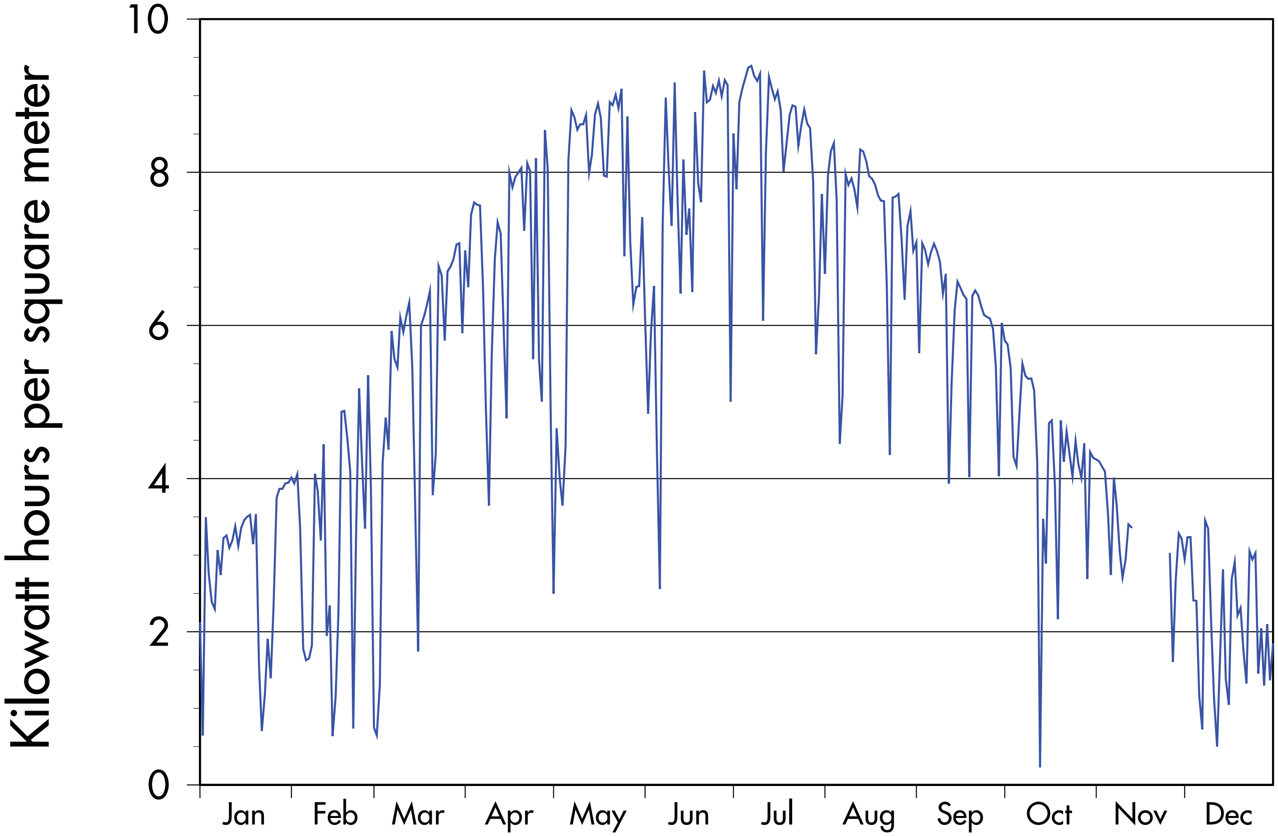


METEOROLOGY

Solar Radiation

Daily in 2009

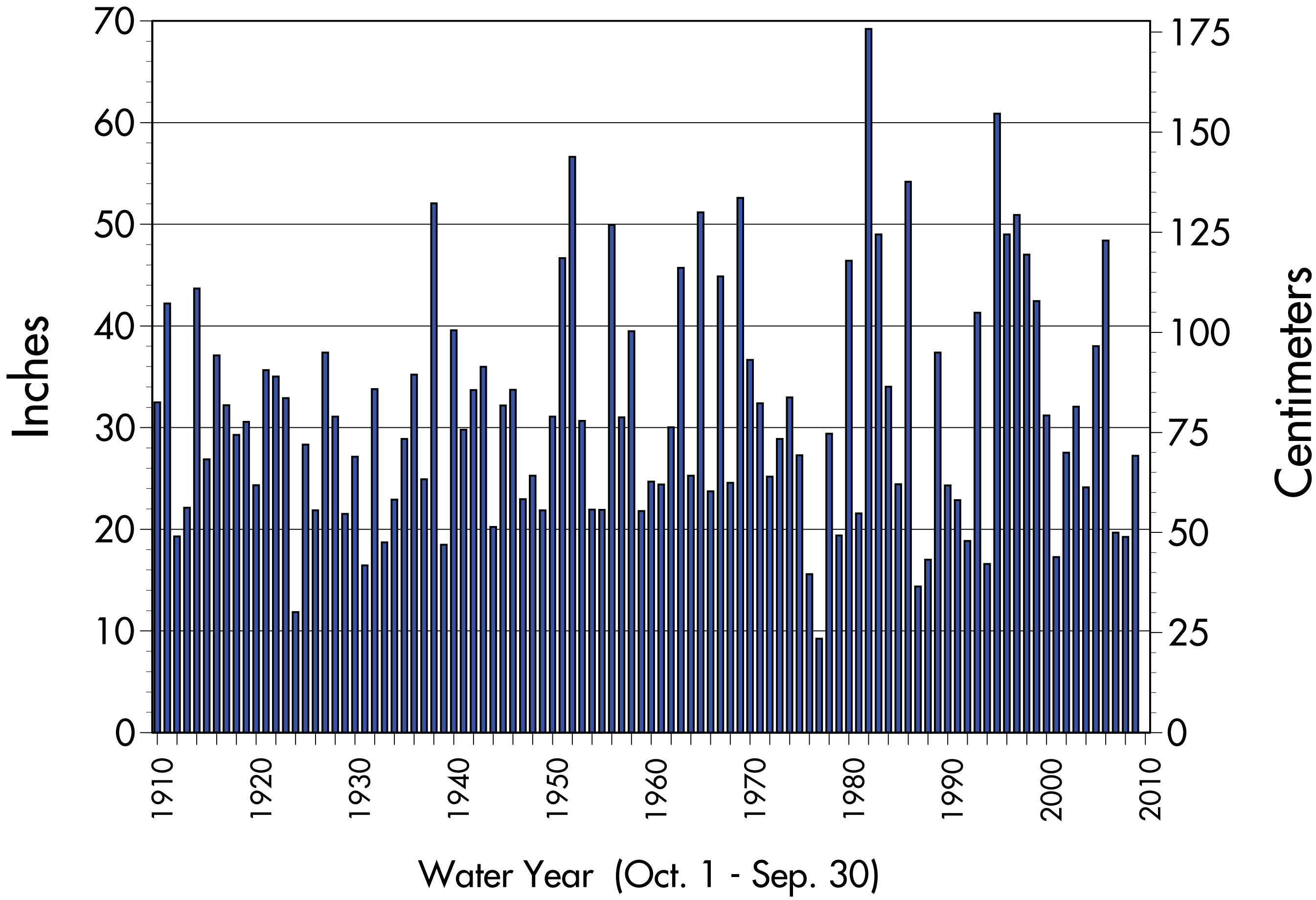
Solar radiation showed the typical annual pattern of increasing then decreasing, peaking at the summer solstice on June 21 or 22. Dips in daily solar radiation are due to clouds, smoke and other atmospheric constituents.



Annual precipitation

Yearly since 1910

From 1910 to 2009, average annual precipitation (water equivalent of rain and snow) at Tahoe City was 31.5 inches. The maximum was 69.2 inches in 1982. The minimum was 9.2 inches in 1977. 2009 was slightly below average, with 27.2 inches of precipitation. (Precipitation is summed over the Water Year, which extends from October 1 through September 30.)

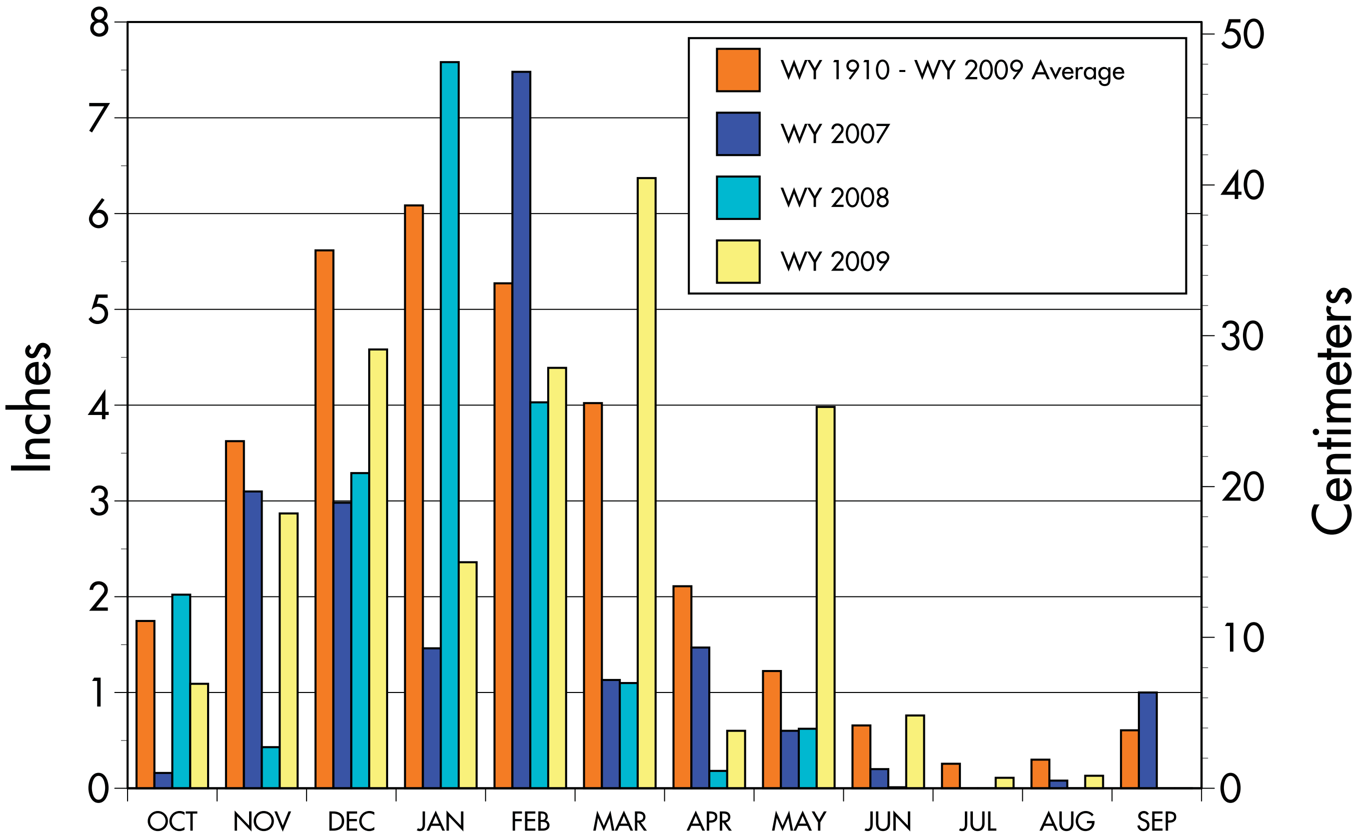


METEOROLOGY

Monthly precipitation

2007, 2008, 2009 and 1910 to 2009 Average

2009 was slightly below an average year in total precipitation. However, nine months were below the long-term average precipitation. An exceptionally wet spring, particularly the months of March and May, accounted for most of the precipitation. Precipitation in May was more than three times the long-term average. The 2009 Water Year extended from October 1, 2008, through September 30, 2009.



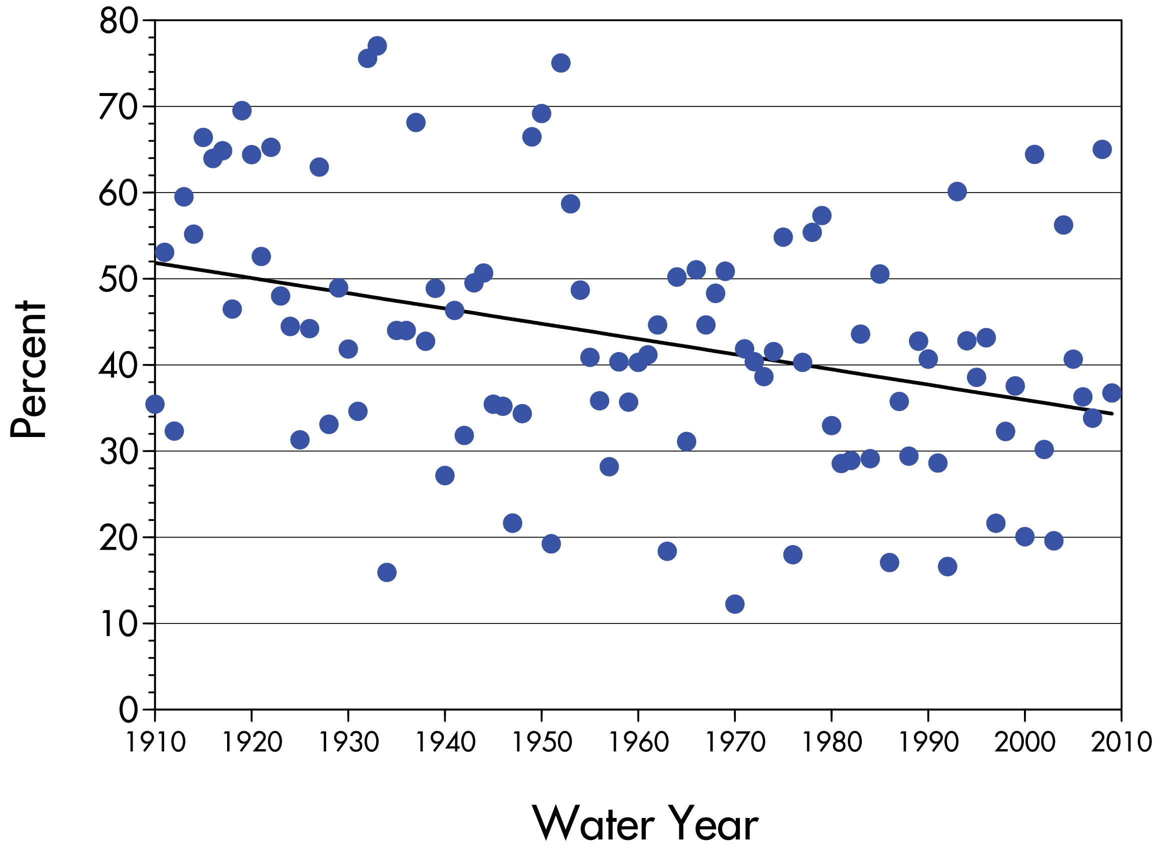
METEOROLOGY

Snow as a fraction of annual precipitation

Yearly since 1910

Snow has declined as a fraction of total precipitation, from an average of 52 percent in 1910 to 34 percent in present times. In Tahoe City, snow represented 37 percent of 2009 total precipitation, consistent with the long-term decline.

These data assume precipitation falls as snow whenever the average daily air temperature is below freezing. (Precipitation is summed over the Water Year, which extends from October 1 through September 30.)

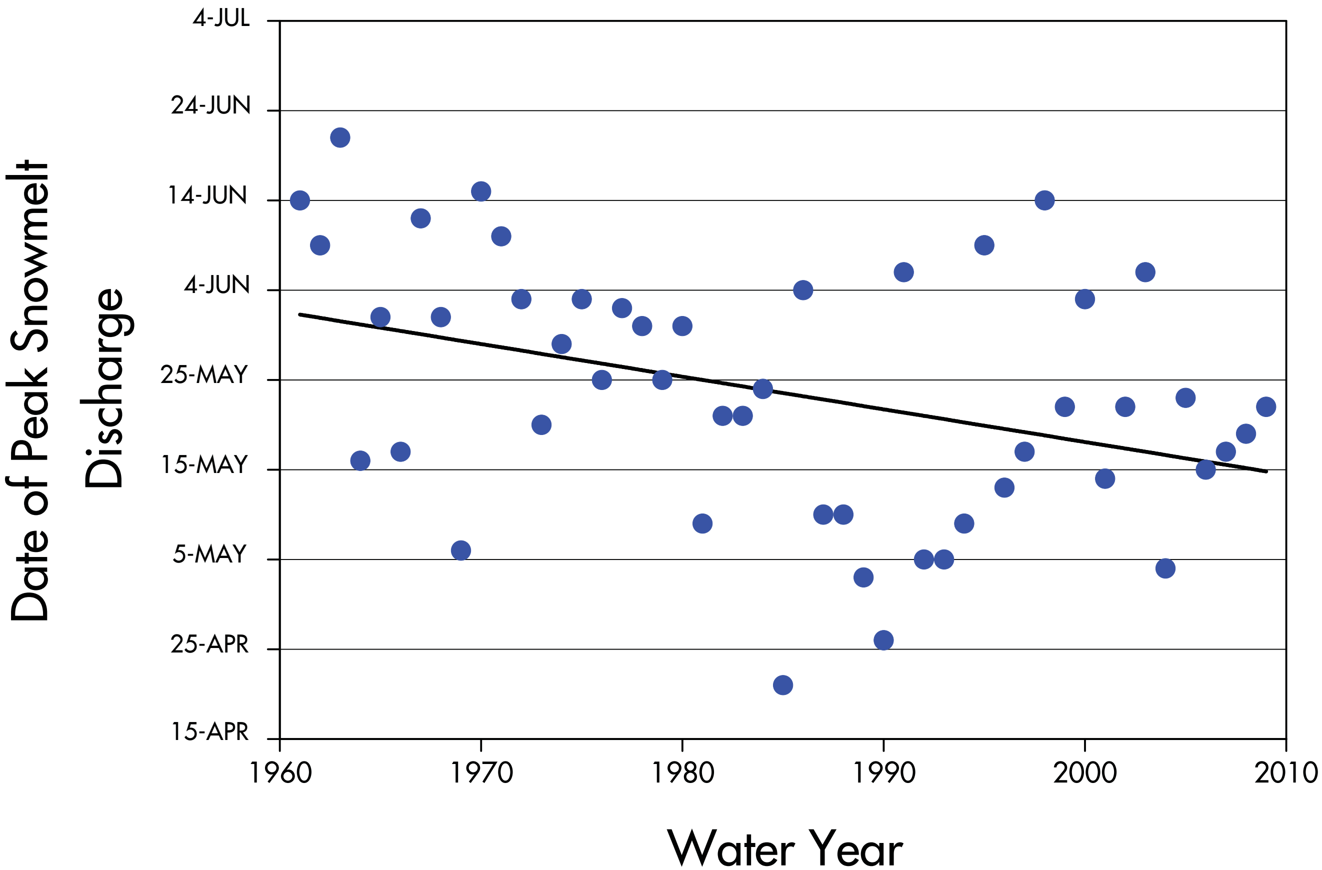


METEOROLOGY

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 2 ½ weeks. This shift is statistically significant and is one effect of climate change on Lake Tahoe. Peak snowmelt is defined as the date when daily river flows reach their yearly maximum. Daily river flows increase throughout spring as the snow melts because of rising air temperatures, increasing solar radiation and longer days. 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 2010

PHYSICAL PROPERTIES

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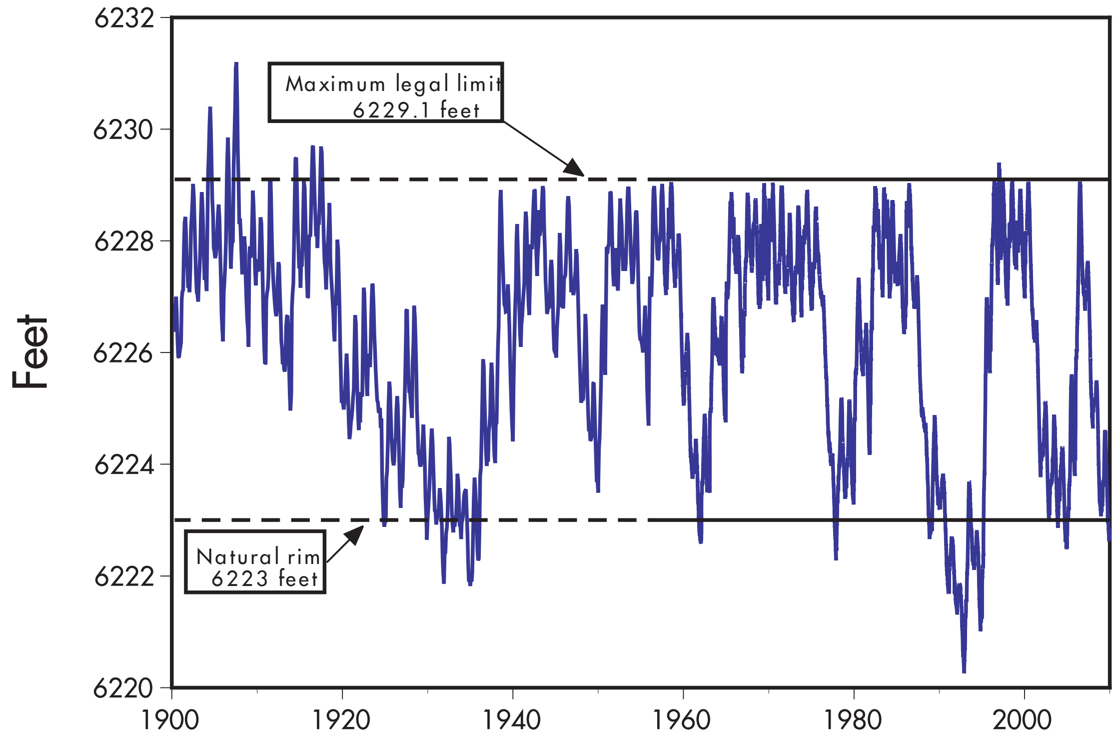
PHYSICAL PROPERTIES

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, and outflow via the Truckee River at Tahoe City. Despite the near-average precipitation, lake level generally fell in 2009. In 2009, the lake level rose by only 16.8 inches during snowmelt, compared with several feet in normal runoff years. The highest lake level was 6224.61 feet on June 15, and the lowest was 6222.76 feet on December 31, almost three inches below the natural rim. From October 28 to the end of the calendar year, there was no outflow from Lake Tahoe into the Truckee River.

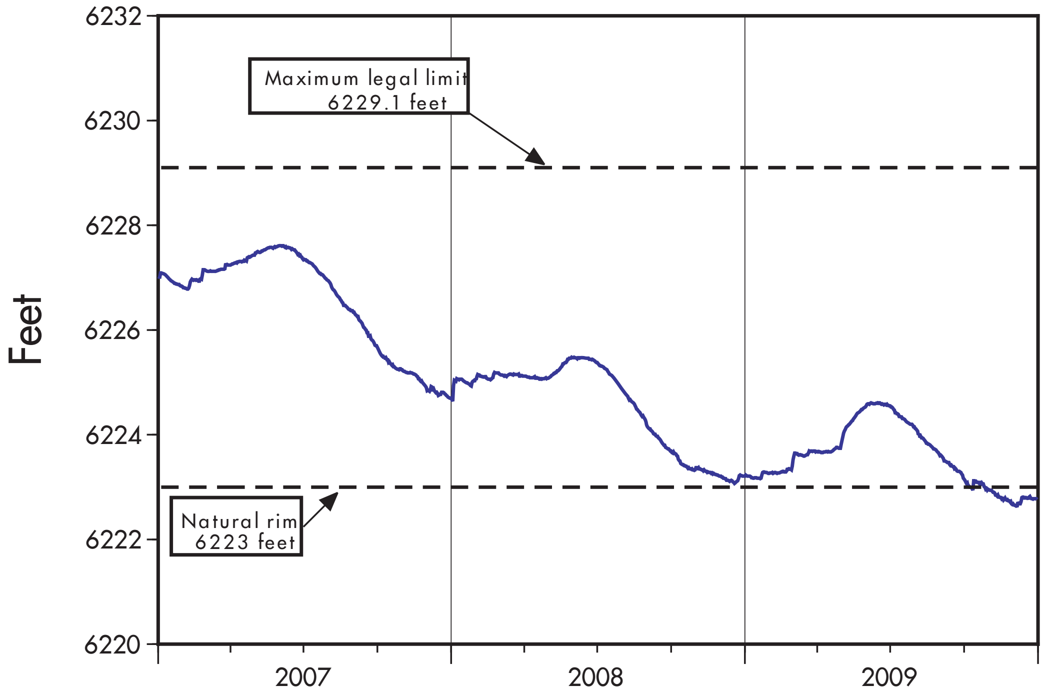


PHYSICAL PROPERTIES

Lake surface level

Daily since 2007

Identical data as used on page 8.1 except the period of record is shortened to 2007-2009. This more time resolved presentation of recent lake level data allows us to see the seasonal patterns in higher definition. Data clearly show the drop in lake level below the natural rim in the last quarter of 2009 as well as the annual periods of highest lake level (generally in June).

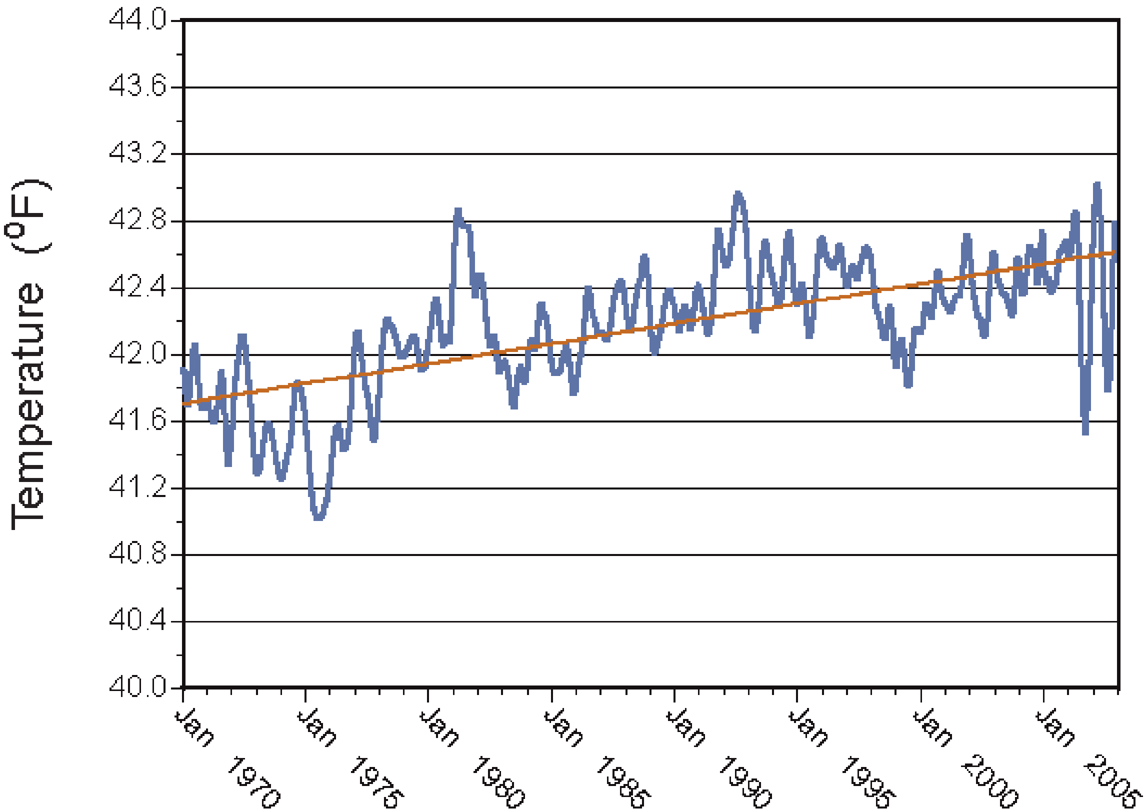


PHYSICAL PROPERTIES

Average water temperature

Since 1970

The volume-averaged temperature of Lake Tahoe has increased nearly a full degree since 1970, from 41.7 degrees F to 42.6 degrees F. (The monthly temperature profile data from the lake has been smoothed and deseasonalized to best show the long-term trend.)

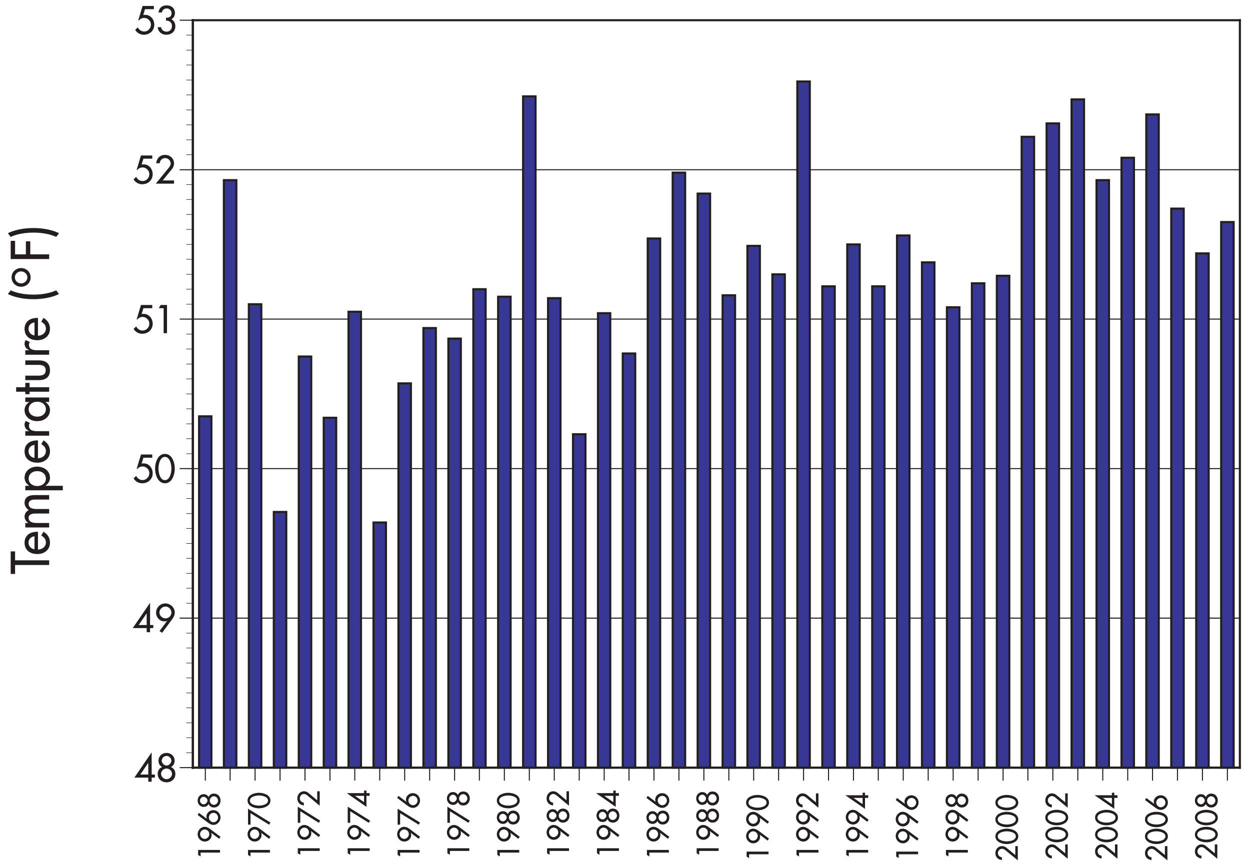


PHYSICAL PROPERTIES

Surface water temperature

Yearly since 1968

Surface water temperatures have been recorded at the mid-lake station since 1968. Despite year-to-year variability, water temperatures show an increasing trend. The average temperature in 1968 was 50.3 degrees F. For 2009, the average surface water temperature was 51.65 degrees F.

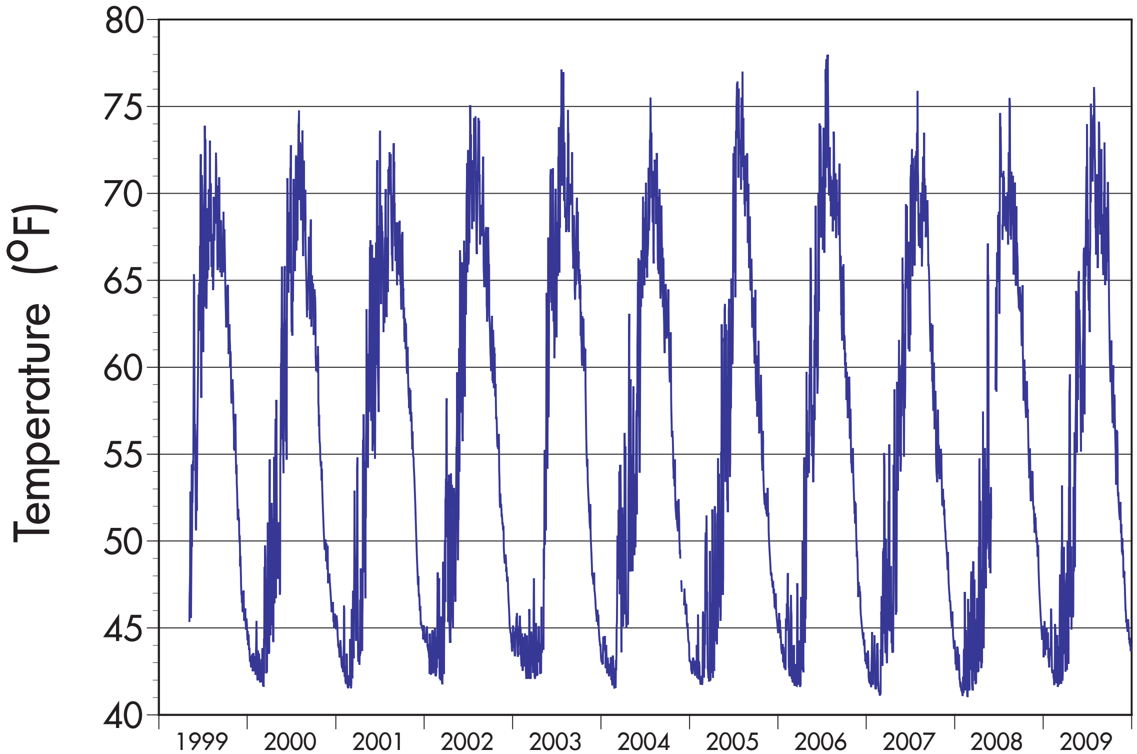


PHYSICAL PROPERTIES

Maximum daily surface water temperature

Every 15 minutes since 1999

Maximum daily surface water temperatures were similar in 2009 to the 2007 and 2008 values, although summer surface water temperatures continue to show a long- term increase. Since May 1999, the highest maximum daily surface temperature was 77.99 degrees F on July 26, 2006. The lowest maximum daily surface water temperature was 41.02 degrees F on Feb. 25, 2008. In the last decade, the 28 lowest maximum daily surface water temperatures occurred in 2007 and 2008. This may be attributable to the deep mixing that occurred in both those years. Surface water temperatures in winter were warmer in 2009 because of the absence of deep mixing. These data are collected by NASA and UC Davis from a buoy located near the center of the lake.

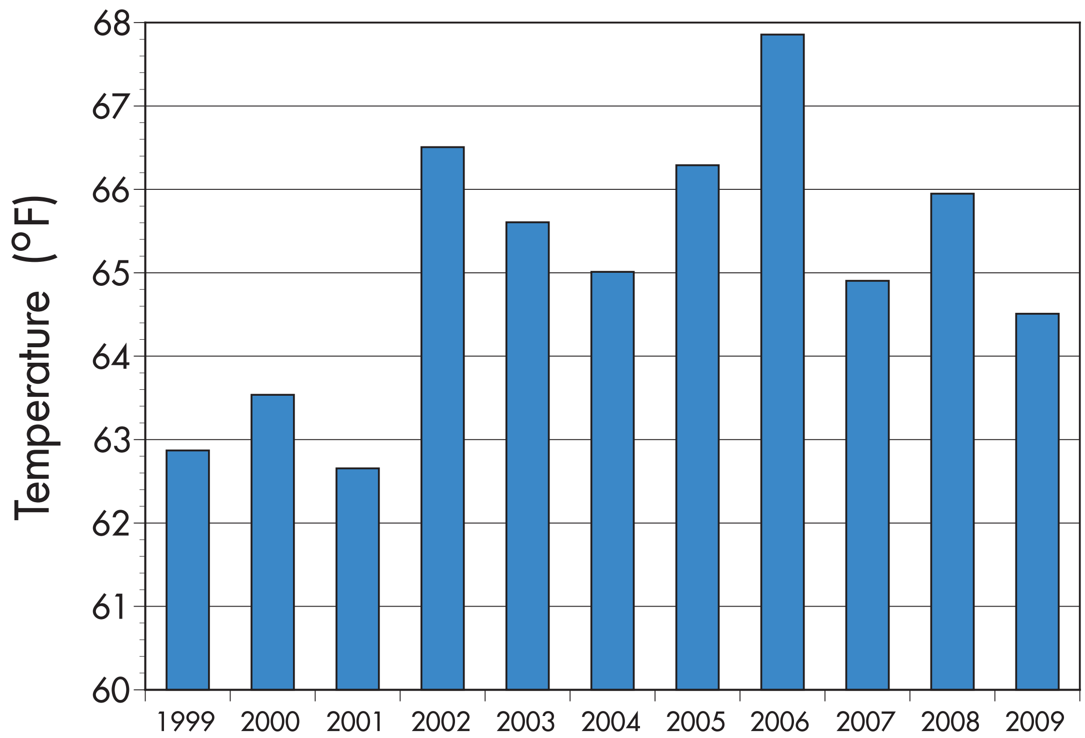


PHYSICAL PROPERTIES

July average surface water temperature

Since 1999

Since 1999, surface water temperature has been recorded every two minutes from four NASA/UC Davis buoys. Shown here are 11 years of average surface water temperatures in the month of July when water temperatures are typically warmest. In 2009, July surface water temperature averaged 64.5 degrees F, 1.5 degrees cooler than in 2008.

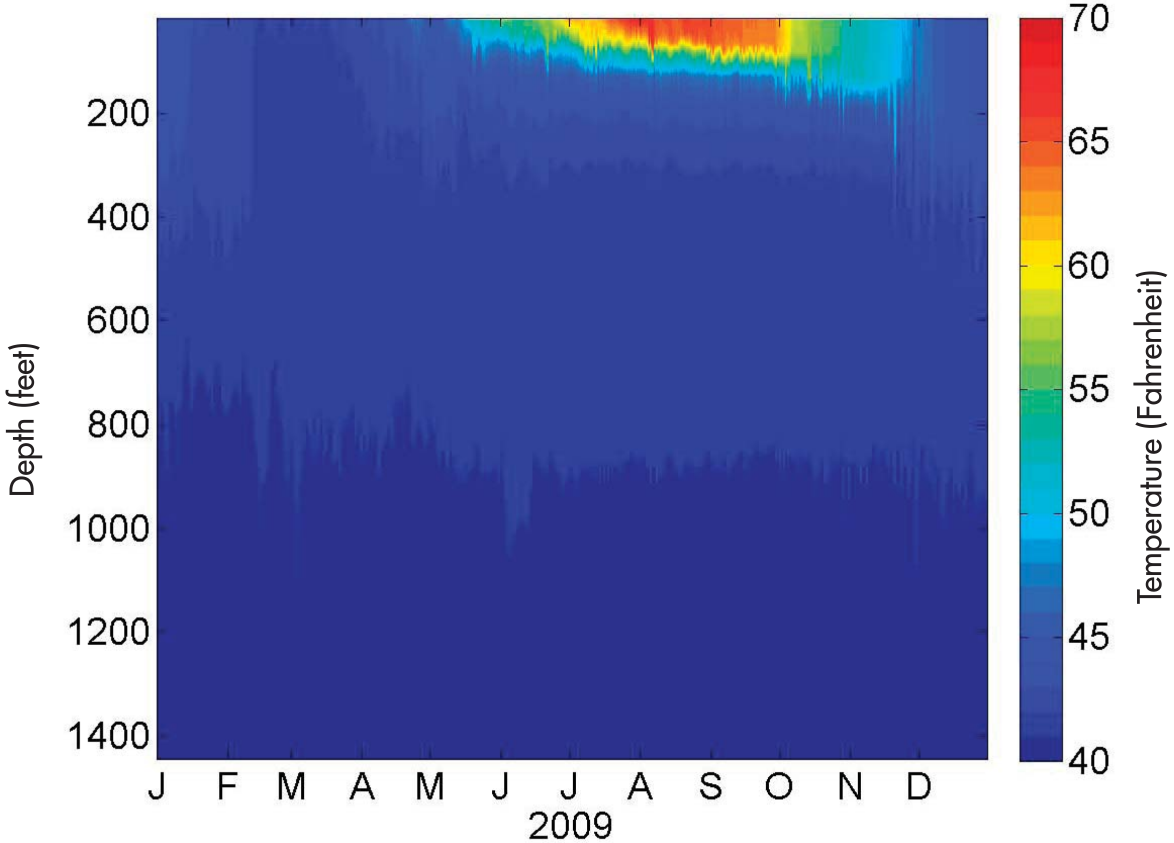


PHYSICAL PROPERTIES

Water temperature profile

In 2009

Water temperatures are measured continuously in the lake by a set of 20 thermistors, which are positioned on a taut, vertical mooring line from the lake bottom to the surface. These instruments record temperature to an accuracy of 0.005 degrees F every 2 minutes. Here the temperature is displayed as a color contour plot. The fluctuations at the junction between two color bands are evidence of internal waves. These represent large scale oscillations that continually move through the lake with amplitudes in excess of 200 feet. In 2009, the lake temperature followed a typical seasonal pattern. In early March, the lake surface was at its coldest. However, the lake did not mix throughout its depth (as evidenced by the color banding). The maximum depth of mixing was approximately 700 feet, well short of the lake's maximum depth of 1645 feet.



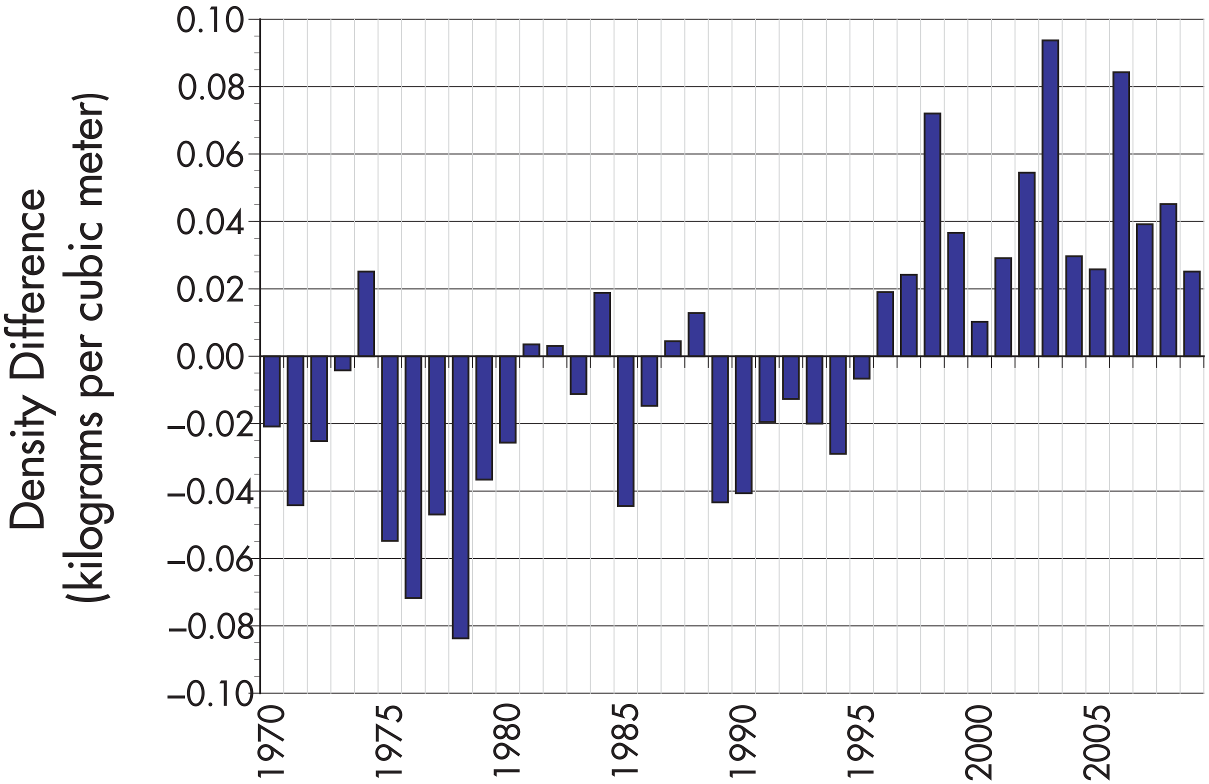
PHYSICAL PROPERTIES

Density stratification

Since 1970

Density stratification in Lake Tahoe has generally increased since 1970, as shown by the trend below. Each bar represents the annual average density difference between deep (100 to 165 feet) and shallow (0 to 33 feet) water, subtracted from the mean density. Density differences increase as Lake Tahoe's surface waters warm, making them less dense or lighter.

Increasing density stratification makes deep mixing of the lake occur less frequently. Density stratification is an indicator of resistance to deep lake mixing.

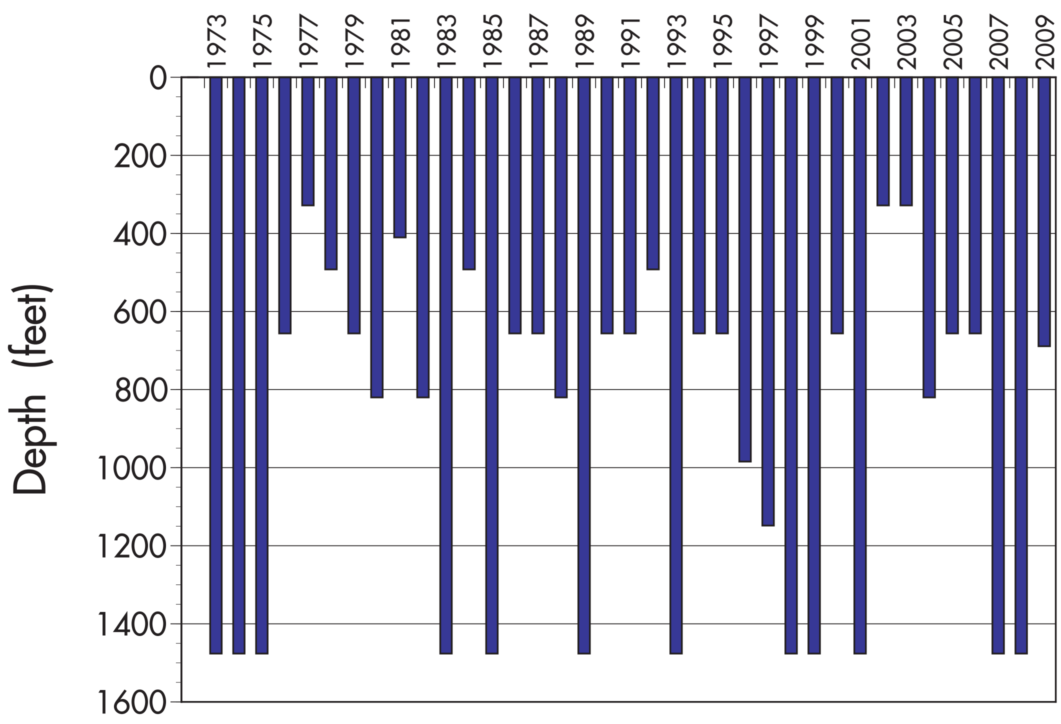


PHYSICAL PROPERTIES

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 storms helps to determine how deeply the lake mixes. Mixing depth has profound impacts on lake ecology and water quality. Deep mixing brings nutrients to the surface, where they promote algae growth. It also moves oxygen to deep waters, promoting aquatic life throughout the water column. The deepest mixing typically occurs in late February to early March. In 2009, Lake Tahoe mixed to a depth of approximately 700 feet.

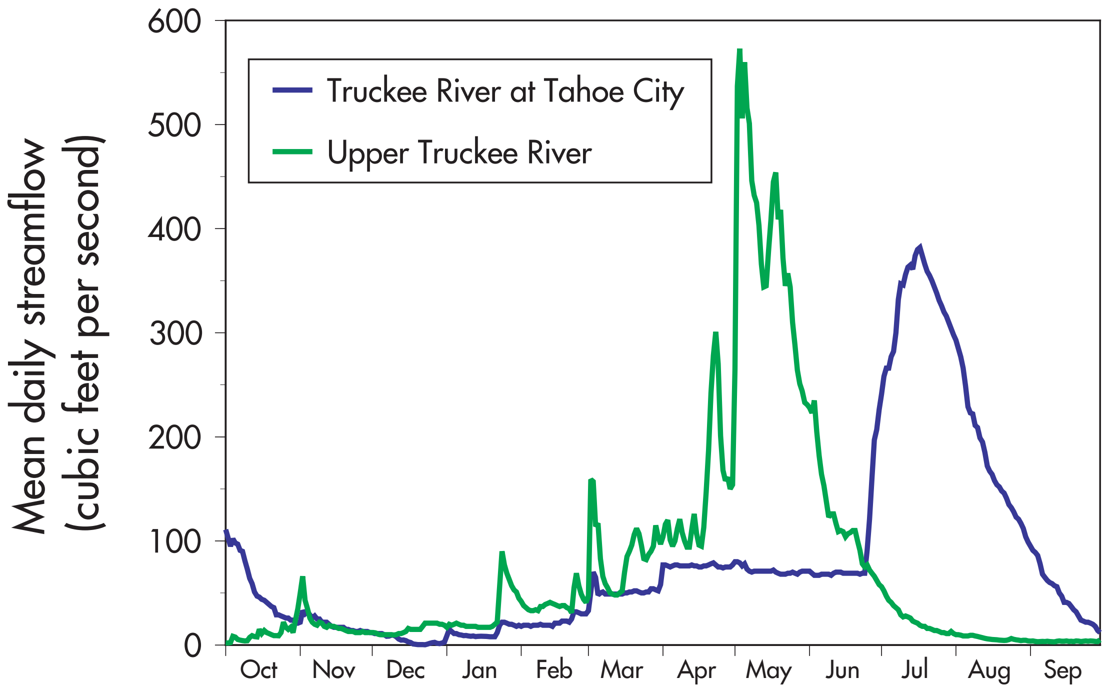


PHYSICAL PROPERTIES

Mean Daily Streamflow of Upper Truckee River vs. Truckee River

Water Year 2009

The Upper Truckee River, the largest stream to flow into Lake Tahoe, has a natural annual hydrograph for a snow-fed stream. The small peaks in the hydrograph represent rain events or short warm periods. The major peak in the hydrograph represents the peak in the spring snowmelt. The peak in 2009 was 573 cubic feet per second on May 3. The Truckee River is the only outflow from Lake Tahoe. The streamflow in the Truckee River is a regulated flow, with release quantity controlled by the Federal water master. The release rates are set according to downstream demands for water. The maximum discharge in 2009 was 382 cubic feet per second on July 17. Streamflow data are collected by the Lake Tahoe Interagency Monitoring Program (LTIMP).

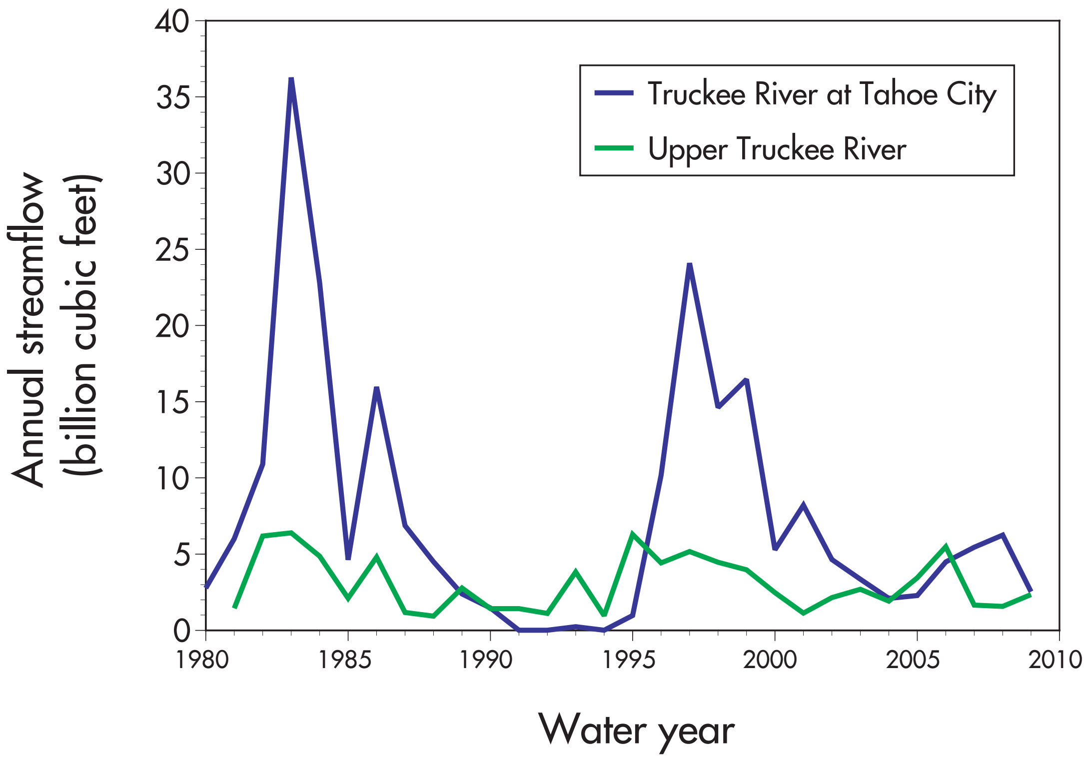


PHYSICAL PROPERTIES

Annual streamflow 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.



TAHOE: STATE OF THE LAKE REPORT 2010

NUTRIENTS AND PARTICLES

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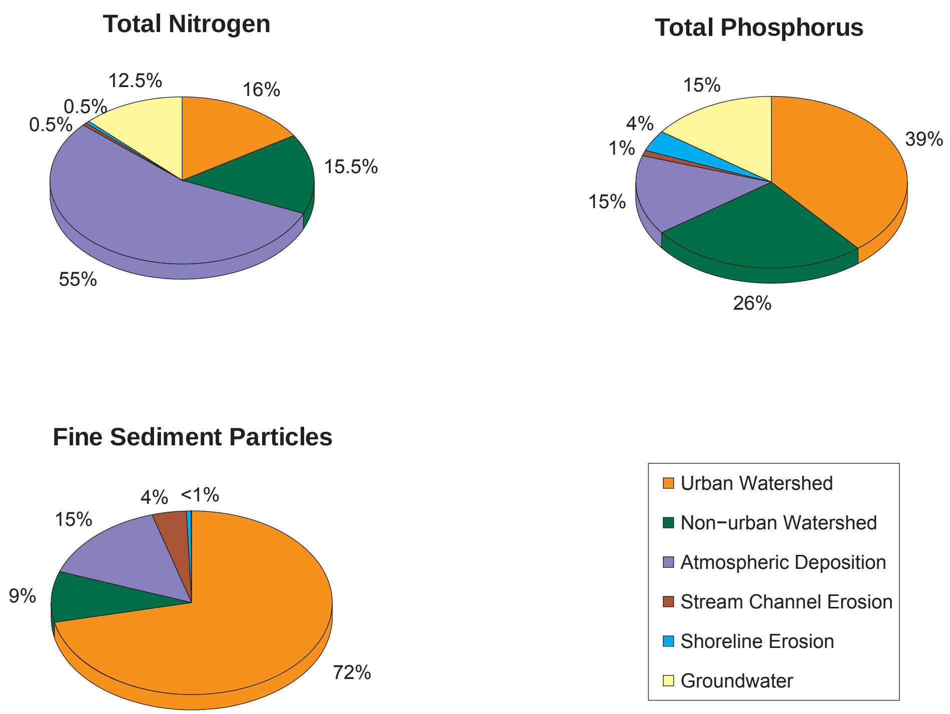
NUTRIENTS AND PARTICLES

Sources of clarity-reducing pollutants

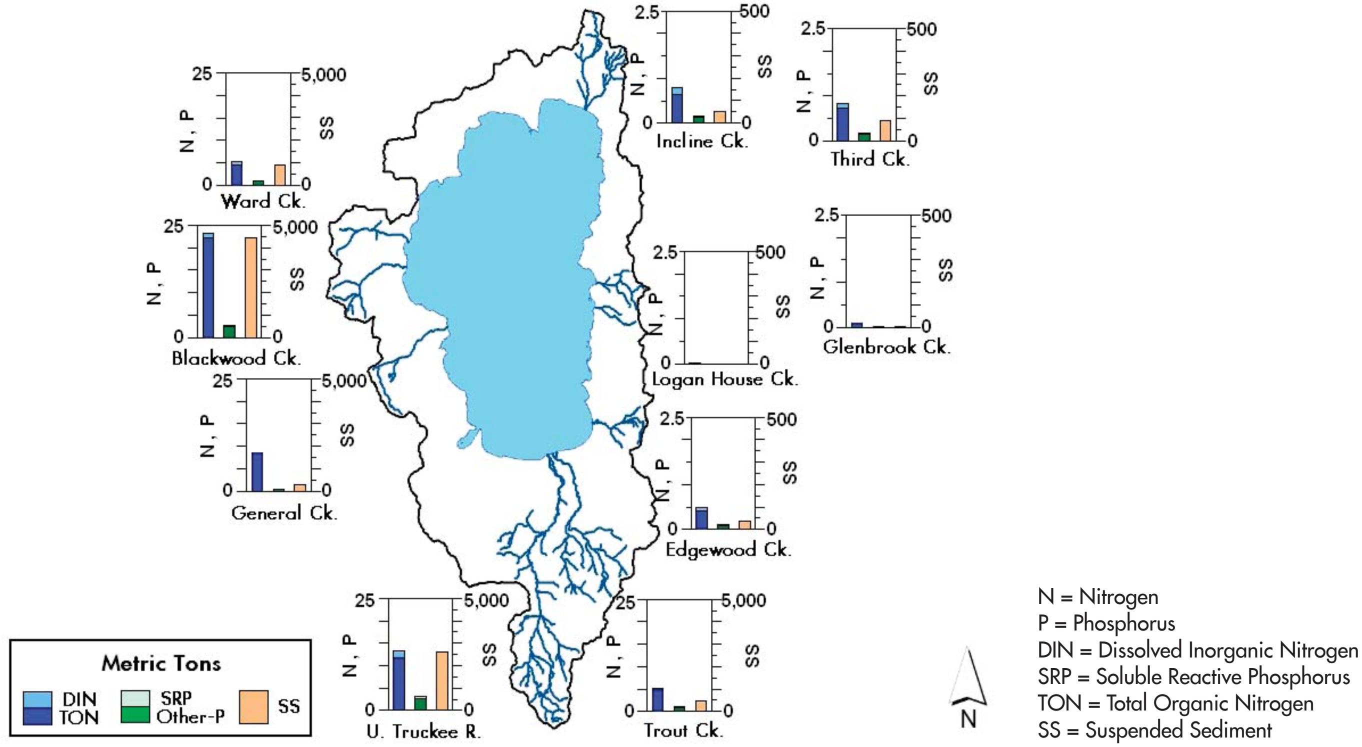
Previous research has quantified the primary sources of nutrients (nitrogen and phosphorus) and particulate material that are causing Lake Tahoe to lose clarity in its upper waters. Extremely fine particles, the major contributor to clarity decline, primarily originate from the urban watershed (70-75 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 also appeared in last year's State of the Lake Report 2009.)



NUTRIENTS AND PARTICLES

Pollutant loads from 10 watersheds

The Lake Tahoe Interagency Monitoring Program (LTIMP) measures nutrient and sediment input from 10 of the 63 watershed streams – these account for approximately half of all stream flow into the lake. Most of the suspended sediment contained in the 10 LTIMP streams is from the Upper Truckee River, Blackwood Creek, Trout Creek and Ward Creek, with the first two being the largest contributors. 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 significantly higher in 2009 compared to the previous year (3-fold); however, year-to-year variation is high as a result of annual precipitation patterns. The east-side stream loads were similar to the previous year. The LTIMP stream water quality program is managed 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.

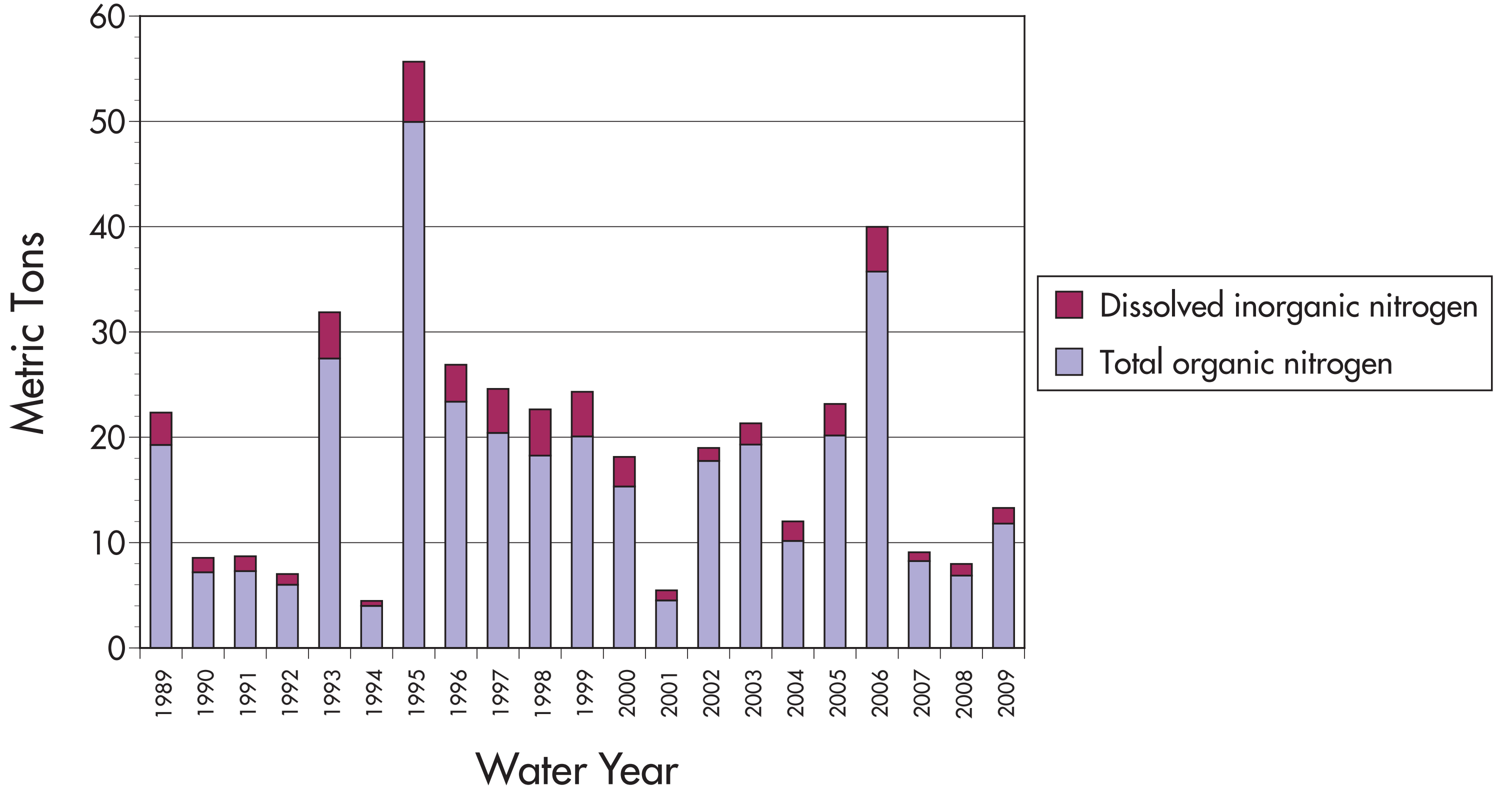


NUTRIENTS AND PARTICLES

Nitrogen contribution by Upper Truckee River

Since 1989

Nitrogen (N) is important because it, along with phosphorus (P), stimulates algal growth (Fig. 9.1 shows the major sources of N and P to Lake Tahoe). 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. Near-average precipitation in 2009 resulted in a nitrogen load that was larger than the previous year. The watershed burned in the Angora Fire (June 2007) drains directly to the Upper Truckee River. (One metric ton = 2,205 pounds.)

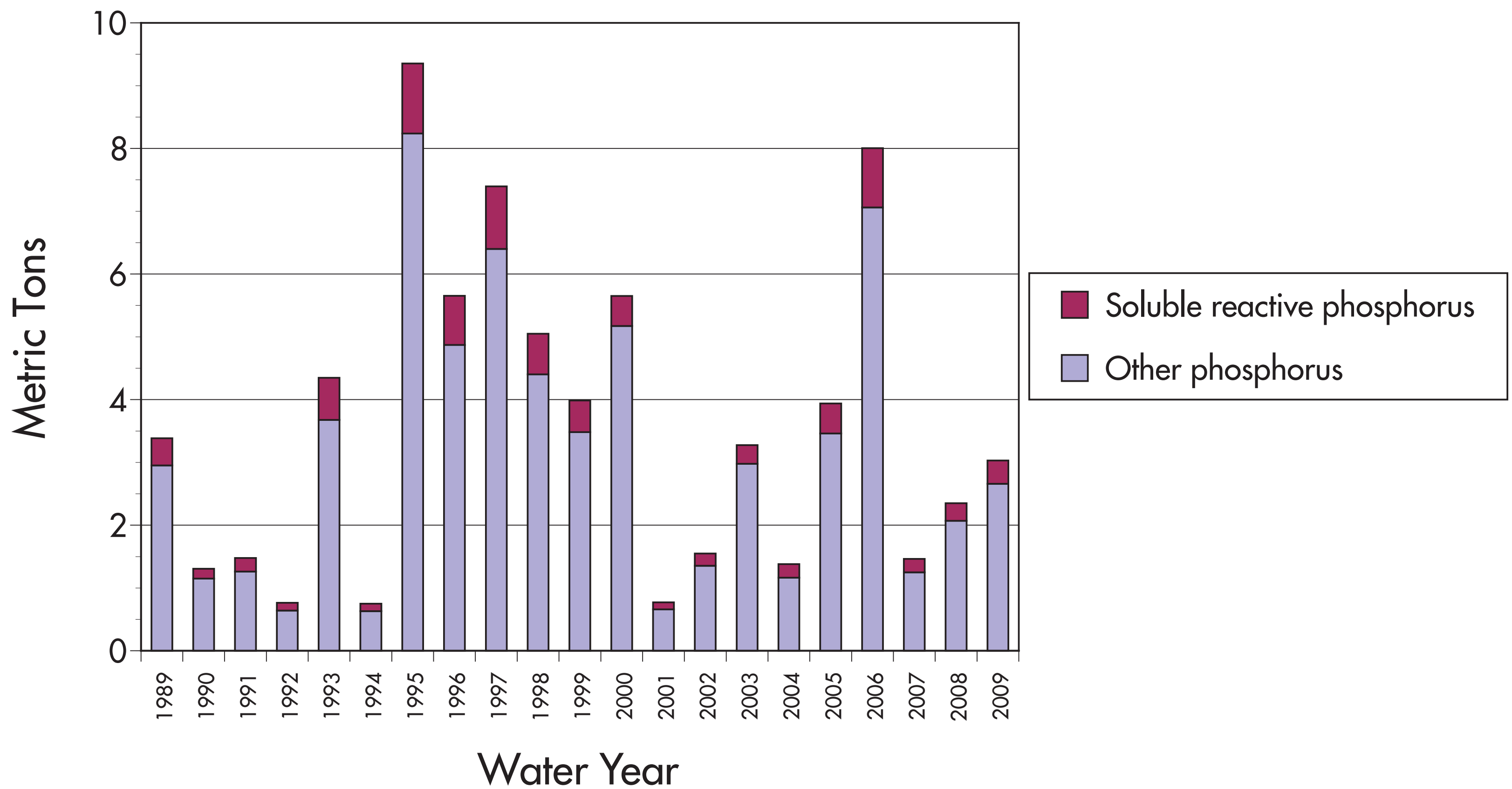


NUTRIENTS AND PARTICLES

Phosphorus contribution by Upper Truckee River

Yearly since 1989

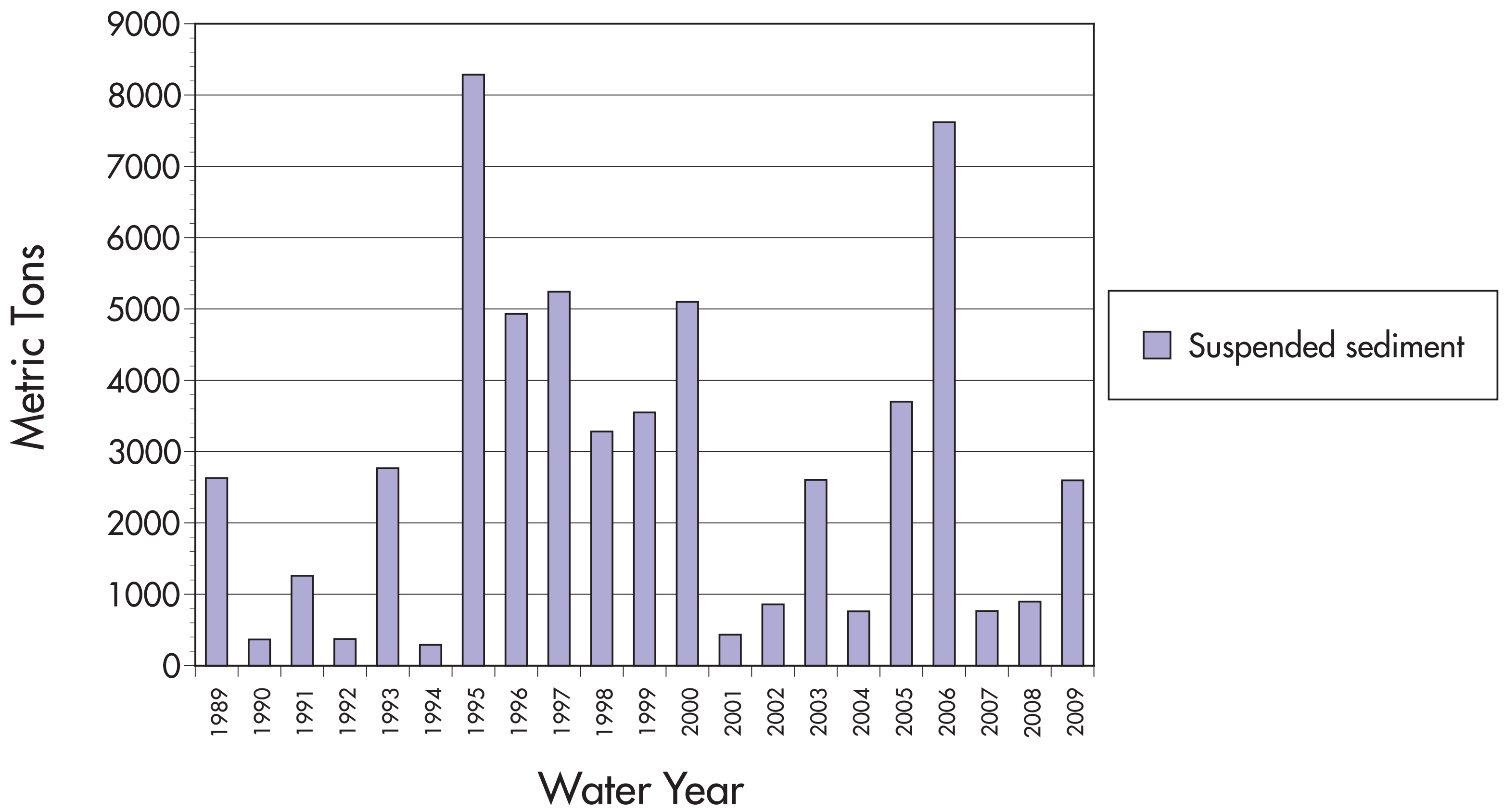
Soluble reactive phosphorus (SRP) is that fraction of phosphorus immediately available for algal growth. As with nitrogen (Fig. 9.3), the year-to-year variation in load largely reflects the changes in precipitation. Near-average precipitation in 2009 resulted in an increase in phosphorus load over the previous year. 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.)



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, interannual variation in sediment load over shorter time scales is more related to the latter. Near-average precipitation in 2009 resulted in a sharp jump (factor of three) in the suspended sediment load. 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.

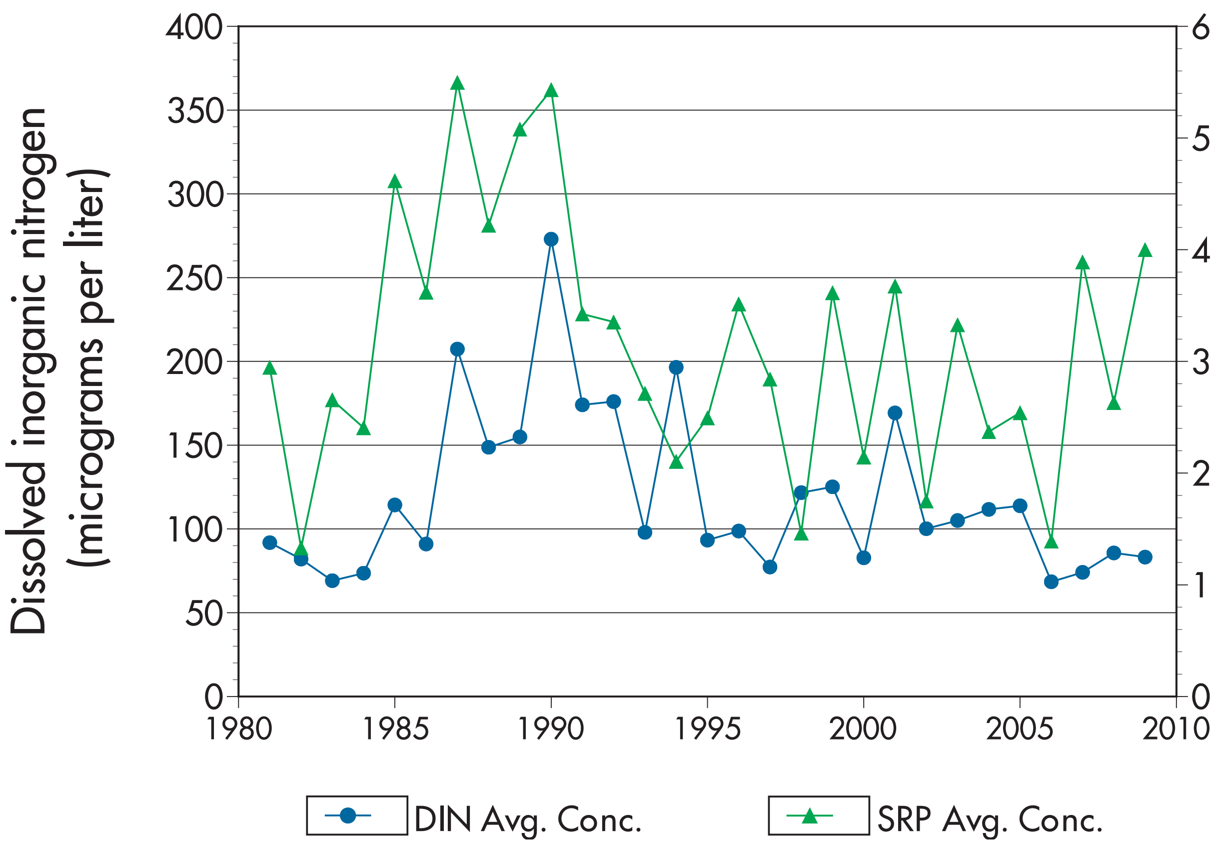


NUTRIENTS AND PARTICLES

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. Annual concentrations in precipitation of dissolved inorganic nitrogen (DIN) and soluble reactive phosphorus (SRP) vary from year to year. In 2009, concentrations of DIN in precipitation remained unchanged from the 2008 value, whereas the SRP concentration increased by 50 percent. A high degree of interannual variation in SRP concentration has been a common feature of the long term data set.

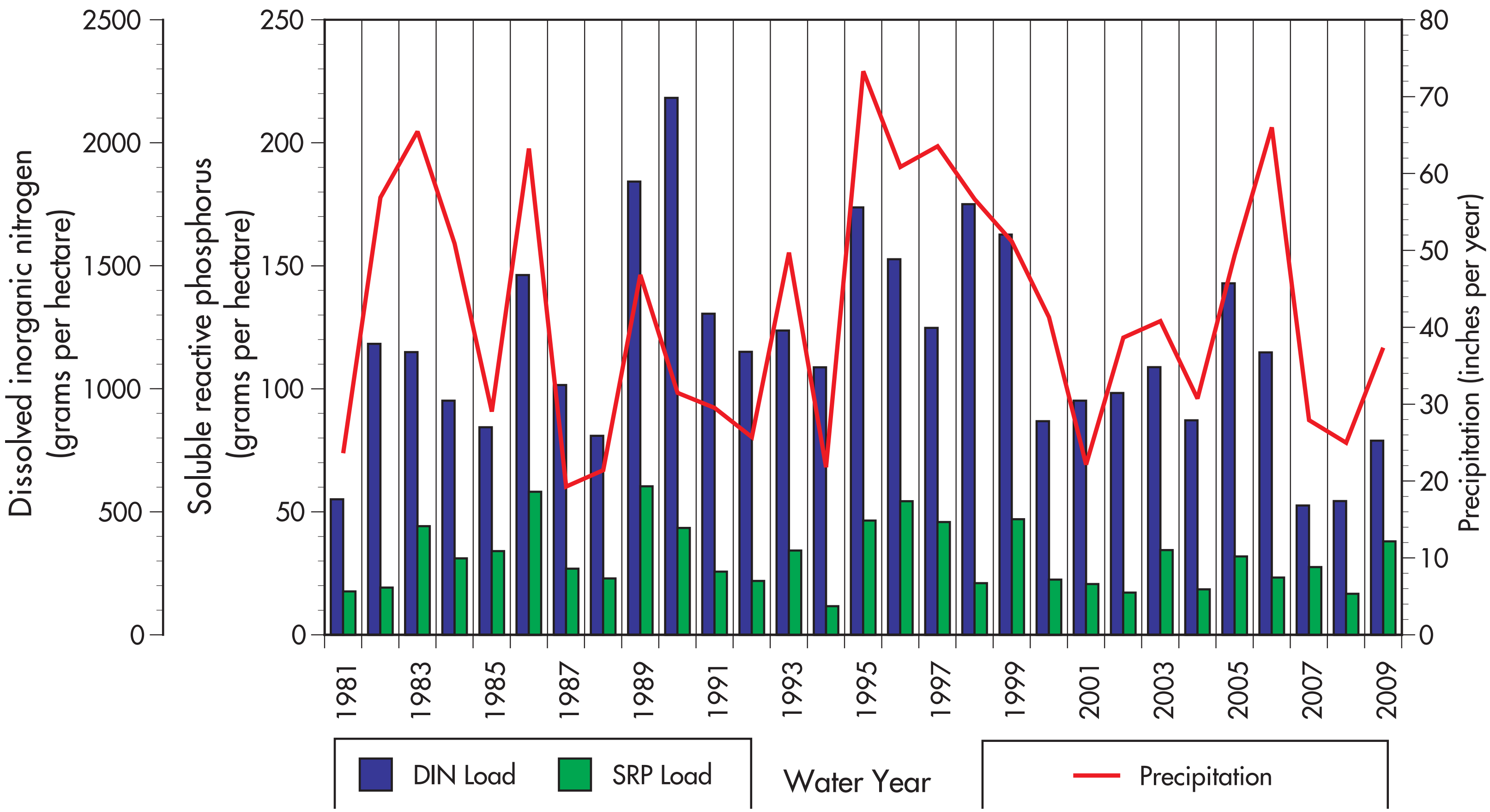


NUTRIENTS AND PARTICLES

Nutrient loads in rain and snow

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 2009, the nitrogen and phosphorus loads were close to the long-term averages.

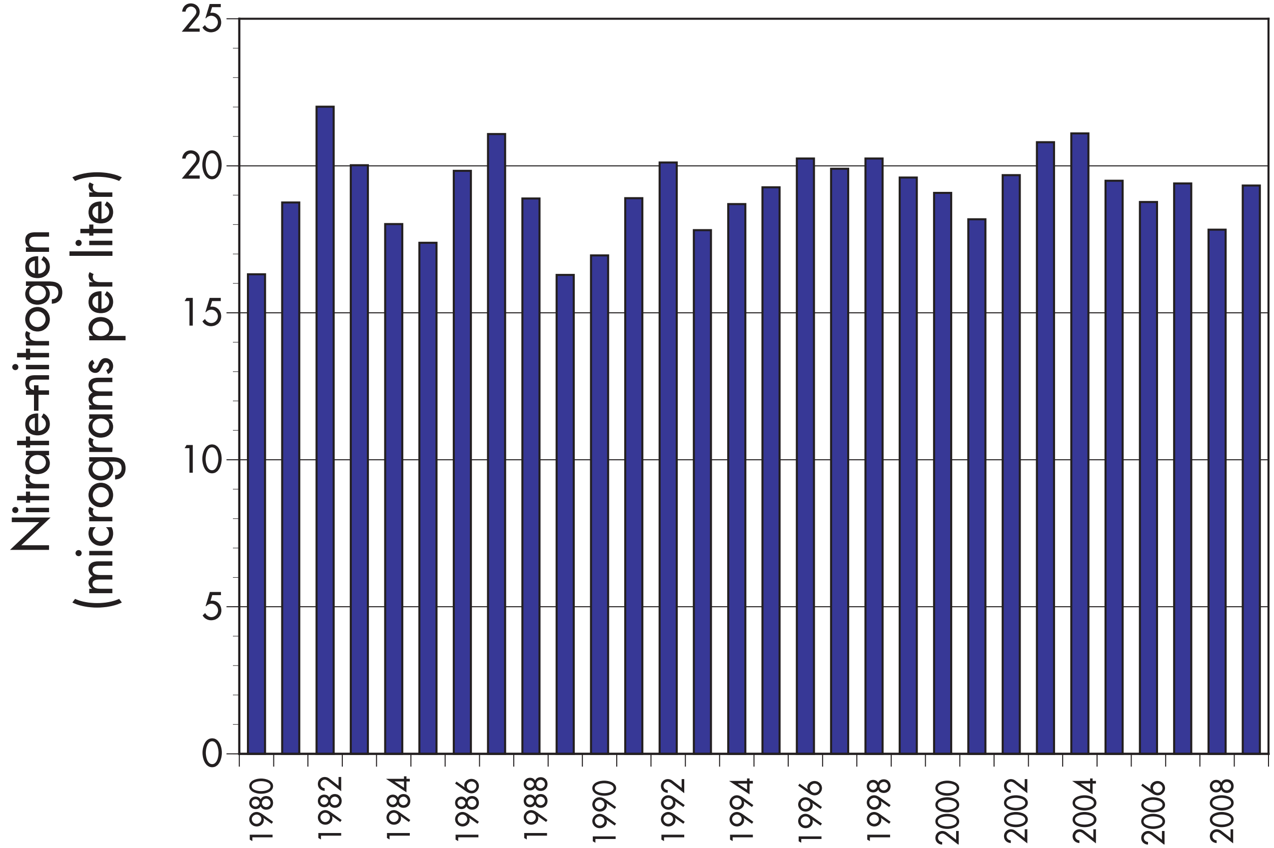


NUTRIENTS AND PARTICLES

Lake nitrate concentration

Yearly since 1980

Since 1980, the lake nitrate concentration has remained relatively constant, ranging between 16 and 22 micrograms per liter. In 2009, the volume-weighted annual average concentration of nitrate was approximately 19.3 micrograms per liter (or parts per billion). These measurements are taken at the MLTP (mid-lake) station. Water samples could not be collected in February, July and November in 2009.

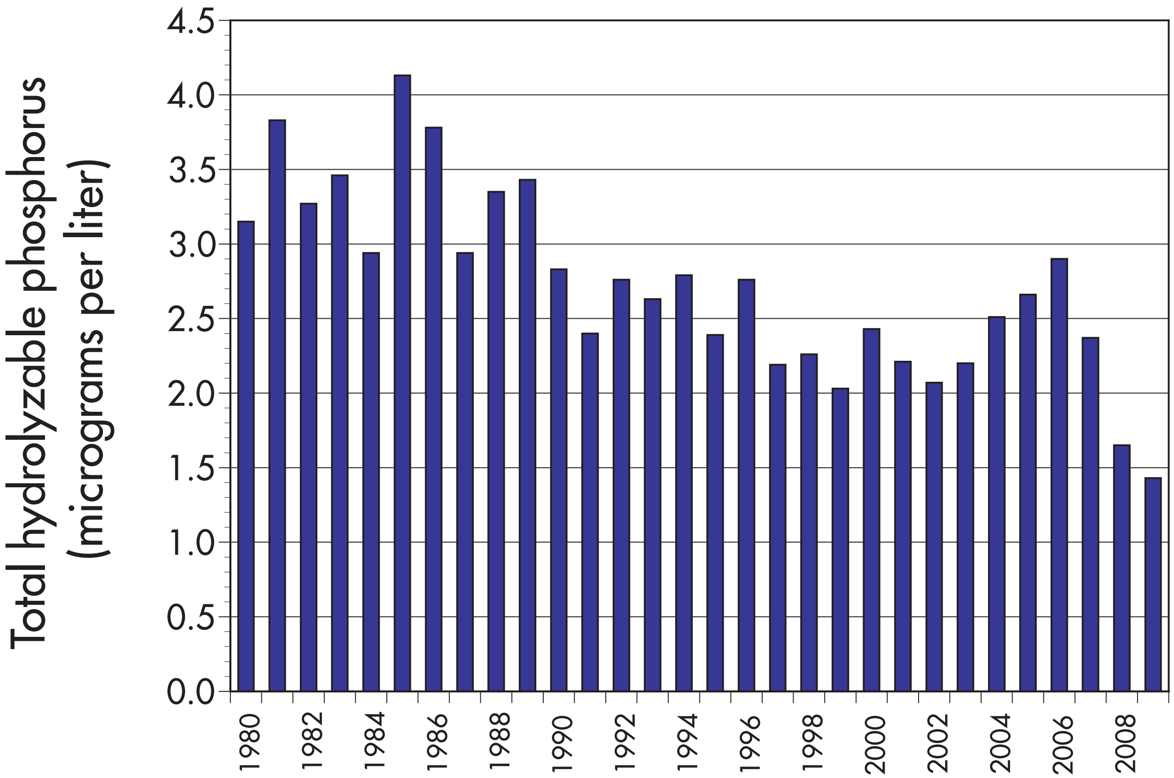


NUTRIENTS AND PARTICLES

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 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 2009, the volume-weighted annual average concentration of THP was 1.4 micrograms per liter, the lowest annual average since monitoring of this parameter began in 1980. Water samples could not be collected in February, July and November in 2009.

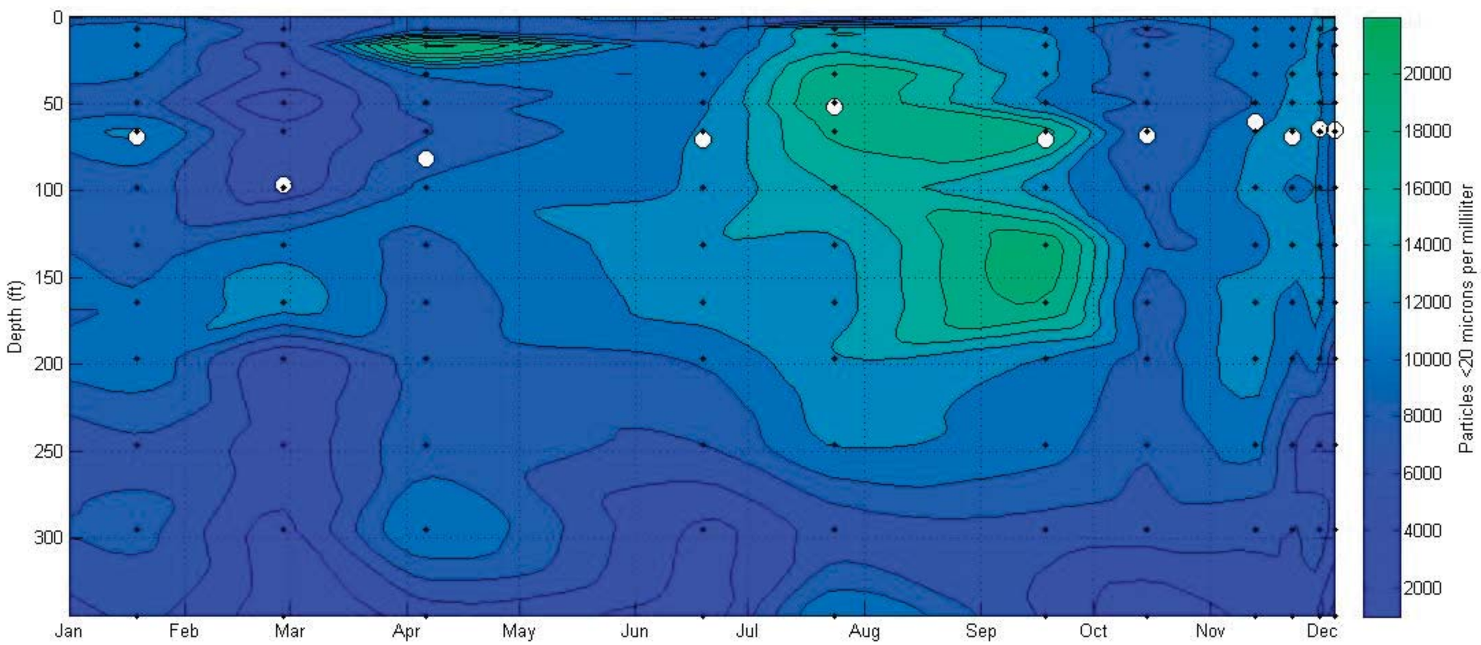


NUTRIENTS AND PARTICLES

Lake fine particle concentration

In 2009

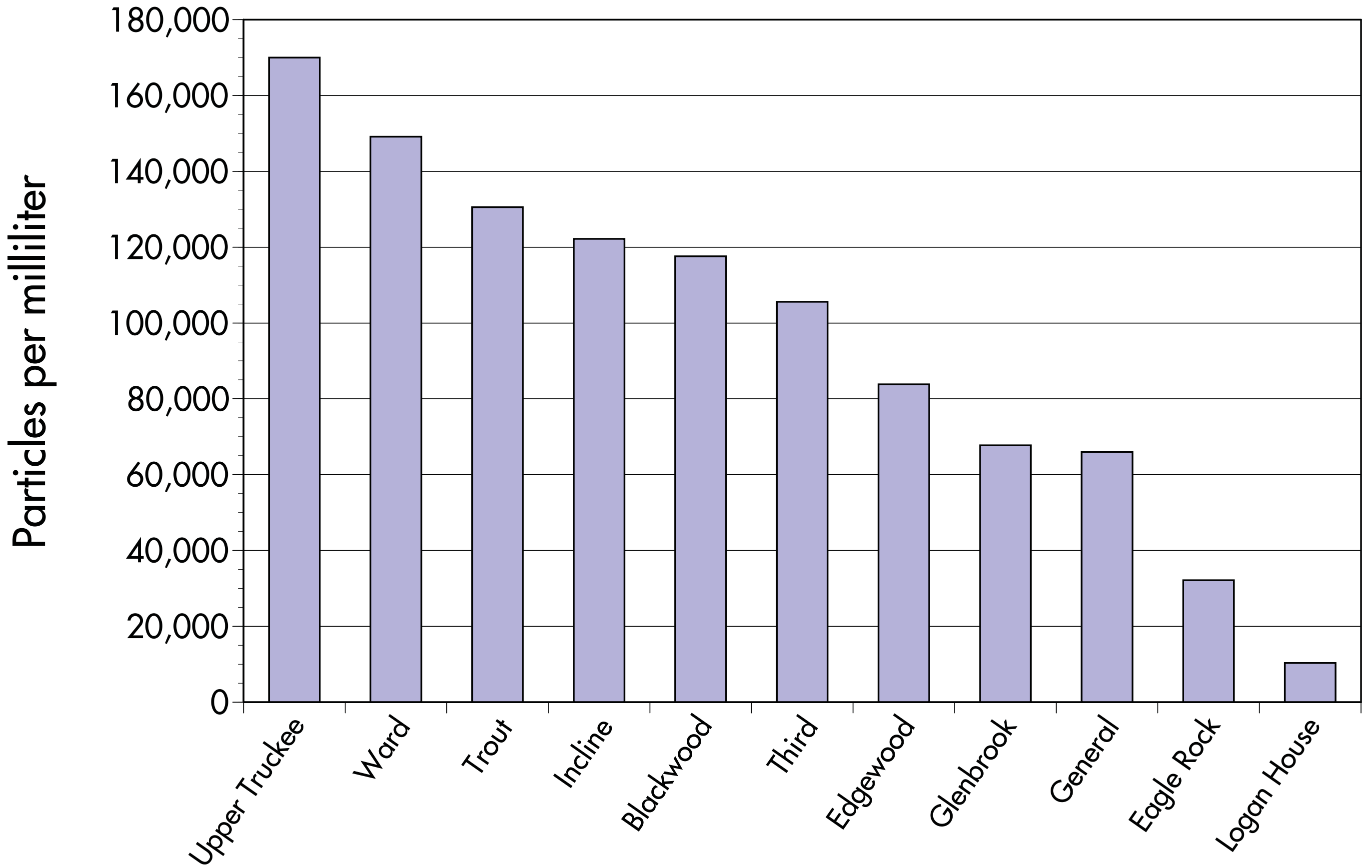
Fine particle (diameter < 20 microns) concentrations from samples collected at multiple depths in the lake are measured in the laboratory using laser diffraction principles. Here, color contours of particle concentrations at the Index Station (on the west side of the lake) are shown for lake depth and time throughout the year. The black dots indicate the dates and depths at which water samples were taken. The white circles show the corresponding Secchi depths taken on the same dates. Generally the more particles in the water column, the lower the Secchi depth. Of particular note is February 27, when a Secchi depth of 96 feet was recorded, corresponding to the lowest particle concentrations in the upper water column. The high concentration of particles in April is due to the spring snowmelt (see Fig. 8.10).



Stream fine particle concentration

In 2009

The annual average concentration of fine particles (diameter < 20 microns) in the 10 monitored LTIMP streams is shown in descending order below. The Upper Truckee River, Ward Creek, Trout Creek, Incline Creek and Blackwood Creek have the highest concentrations. The actual load of fine particles delivered by the streams also depends on the flow rate of the stream. It is important to note that fine particle concentration is different than suspended sediment concentration. The latter includes coarse silt and sand, which have little lasting impact on lake clarity, but which can affect stream condition.



TAHOE: STATE OF THE LAKE REPORT 2010

BIOLOGY

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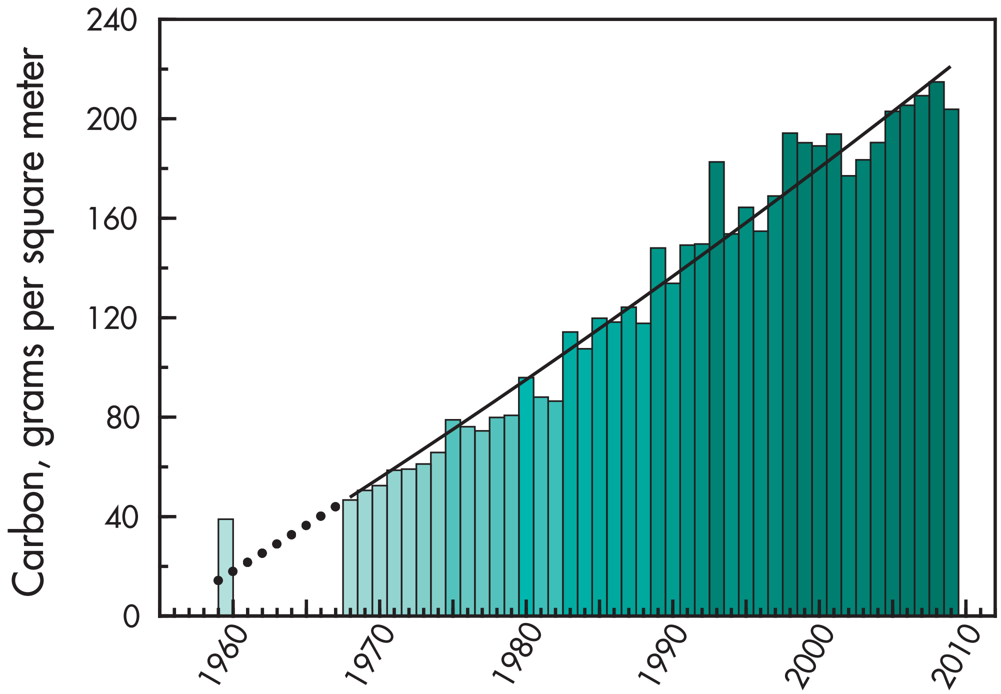
BIOLOGY

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. Primary productivity has generally increased over that time, promoted by nutrient loading to the lake, changes in the underwater light environment and a succession of algae species. In 2009, primary productivity was 203.8 grams of carbon per square meter.

Due to a combination of a major engine refitting and poor weather, the first primary productivity measurement for 2009 was not taken until July, followed by six measurements over the remainder of the year. In order to get a value of primary productivity that was representative of growth throughout the year, the following method was used. It was determined that for the last 20 years, productivity in the January-July period was on average 59.19% +/- 2.1% of the annual productivity. We estimated January-July PPr for 2009 by taking 59.19 percent of the predicted annual PPr for 2009, based on a statistical regression analysis using all the data from 1959 to 2008. We combined this value with the measured values for the remainder of the year. It is recommended that the annual estimate for 2009 be used with some caution; however, the variability seen between 2008 and 2009 is not uncommon and does not change our conclusions regarding the long-term trend.



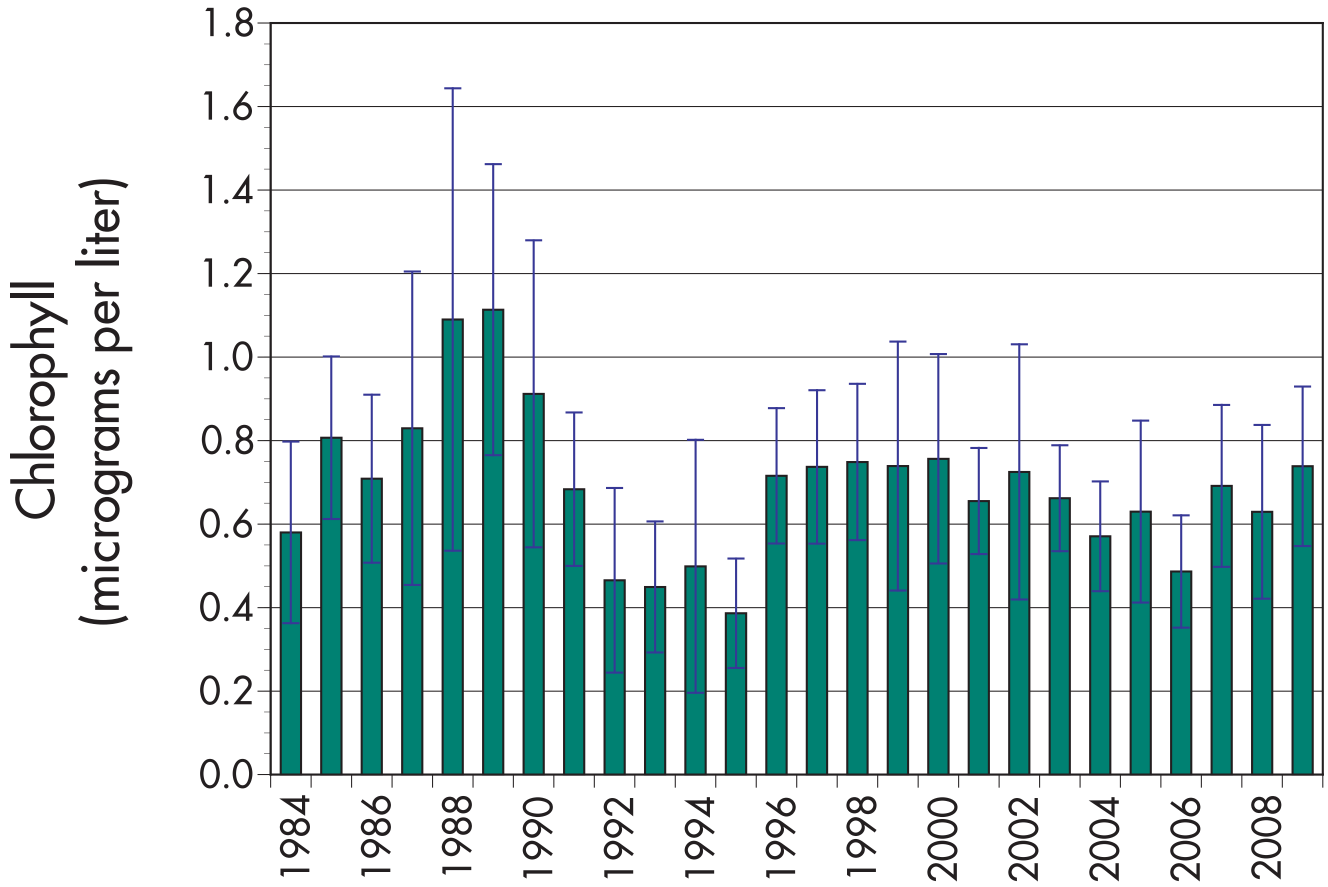
BIOLOGY

Algae abundance

Yearly since 1984

The amount of free-floating algae (phytoplankton) in the water is determined by measuring the concentration of chlorophyll *a*. Chlorophyll *a* is a common measure of phytoplankton biomass. Though algae abundance varies annually, it has not shown a long-term increase since measurements began in 1984.

The annual average value for 2009 was 0.74 micrograms per liter. The average annual chlorophyll *a* level in Lake Tahoe has remained relatively uniform since 1996.

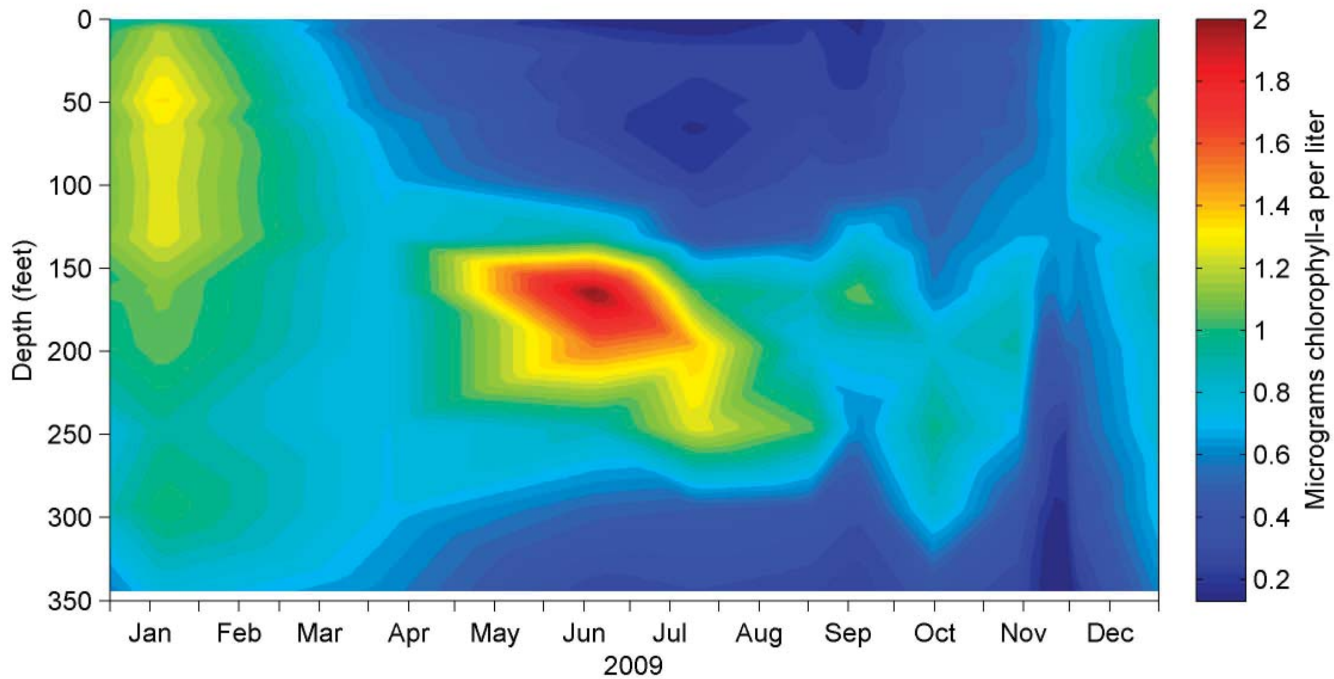


BIOLOGY

Algae concentration by depth

In 2009

The highest concentrations of algae (as measured by chlorophyll *a* concentration) occur in summer between the 100 and 200-foot depths. This discrete layer, known as the deep chlorophyll maximum, forms in spring and persists until winter mixing redistributes algae. In 2009, winter mixing began in late-November and early-December. The deep chlorophyll layer is below the Secchi depth (Figs. 11.1 and 11.2), and does not influence lake clarity until winter mixing relocates chlorophyll into the range of the Secchi disk (50 to 80 feet). The influence of the deep chlorophyll layer on deep-water light penetration, the production of organic matter that can reduce oxygen levels when decomposed by bacteria and other microbes, and food web dynamics, supports management decisions to continue to control nutrient loading.

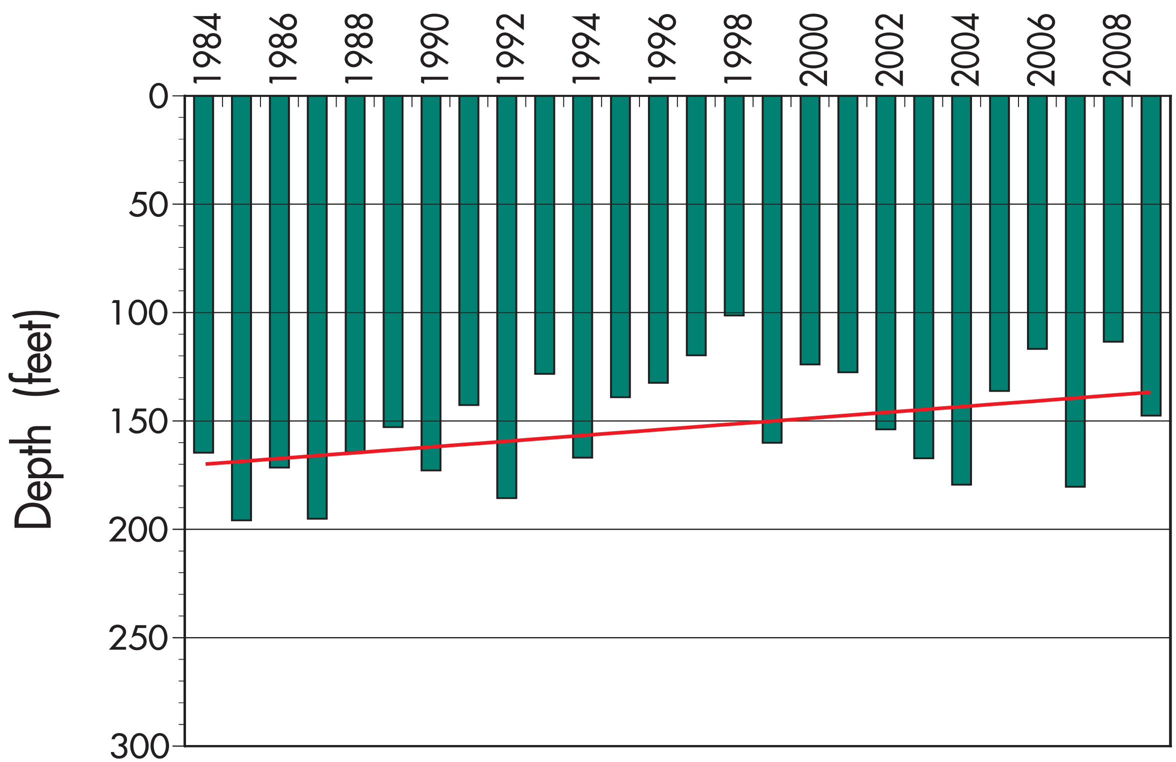


BIOLOGY

Depth of chlorophyll maximum

Yearly since 1984

The depth at which the deep chlorophyll maximum occurs varies from year to year. In 2009, the deep chlorophyll maximum was at about 146 feet, considerably deeper than the previous year's value of 115 feet. The deep chlorophyll maximum depth has generally been shoaling (getting shallower) over time, a trend believed to be linked to the decline in water clarity.

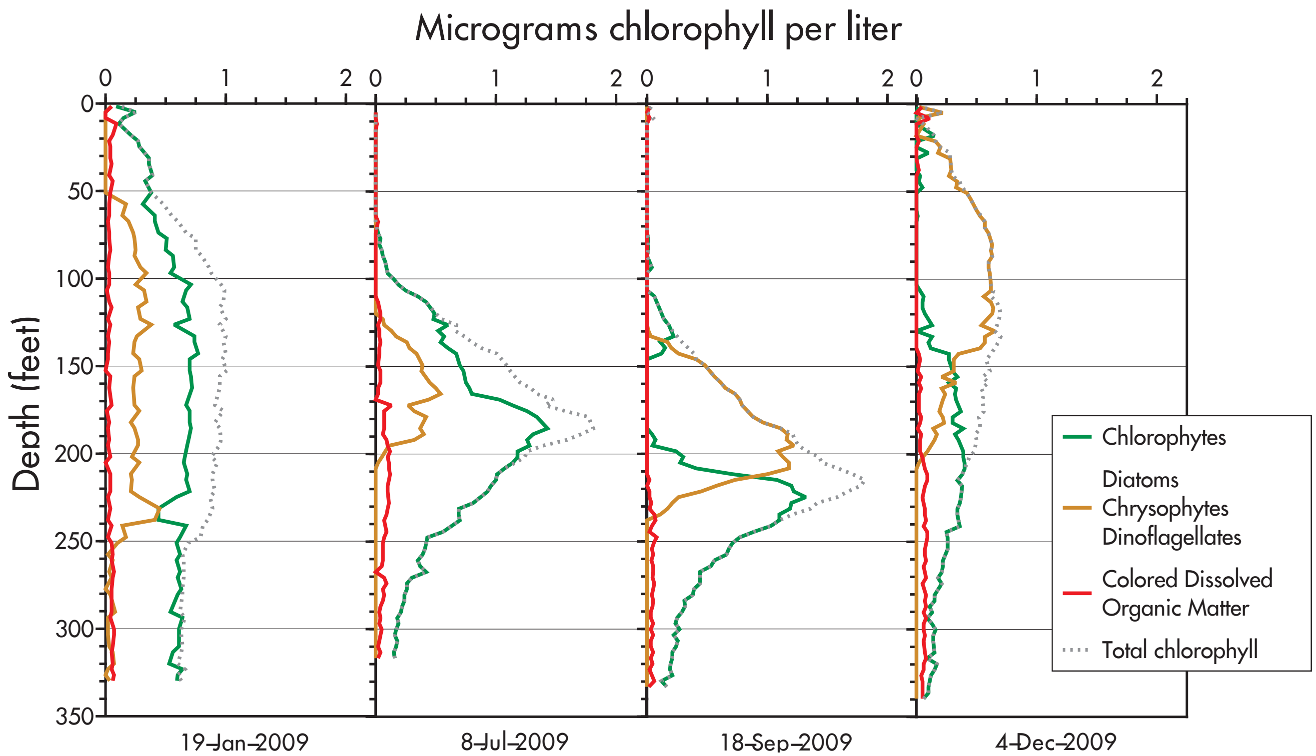


BIOLOGY

Algae group distribution by depth

In 2009

Lake Tahoe supports many types of algae. Different groups grow at various depths below the lake surface, depending on their specific requirements for light and nutrient resources. The four profiles below show how the distributions develop throughout the year. Two algal groups, chlorophytes (green algae) and diatoms, were dominant. Notice the separation in depth between these two groups with the chlorophyte peaks occurring about 50 feet deeper. This type of vertical separation is common in lakes as different algae coexist by occupying a unique depth range and thereby avoiding direct competition for resources.

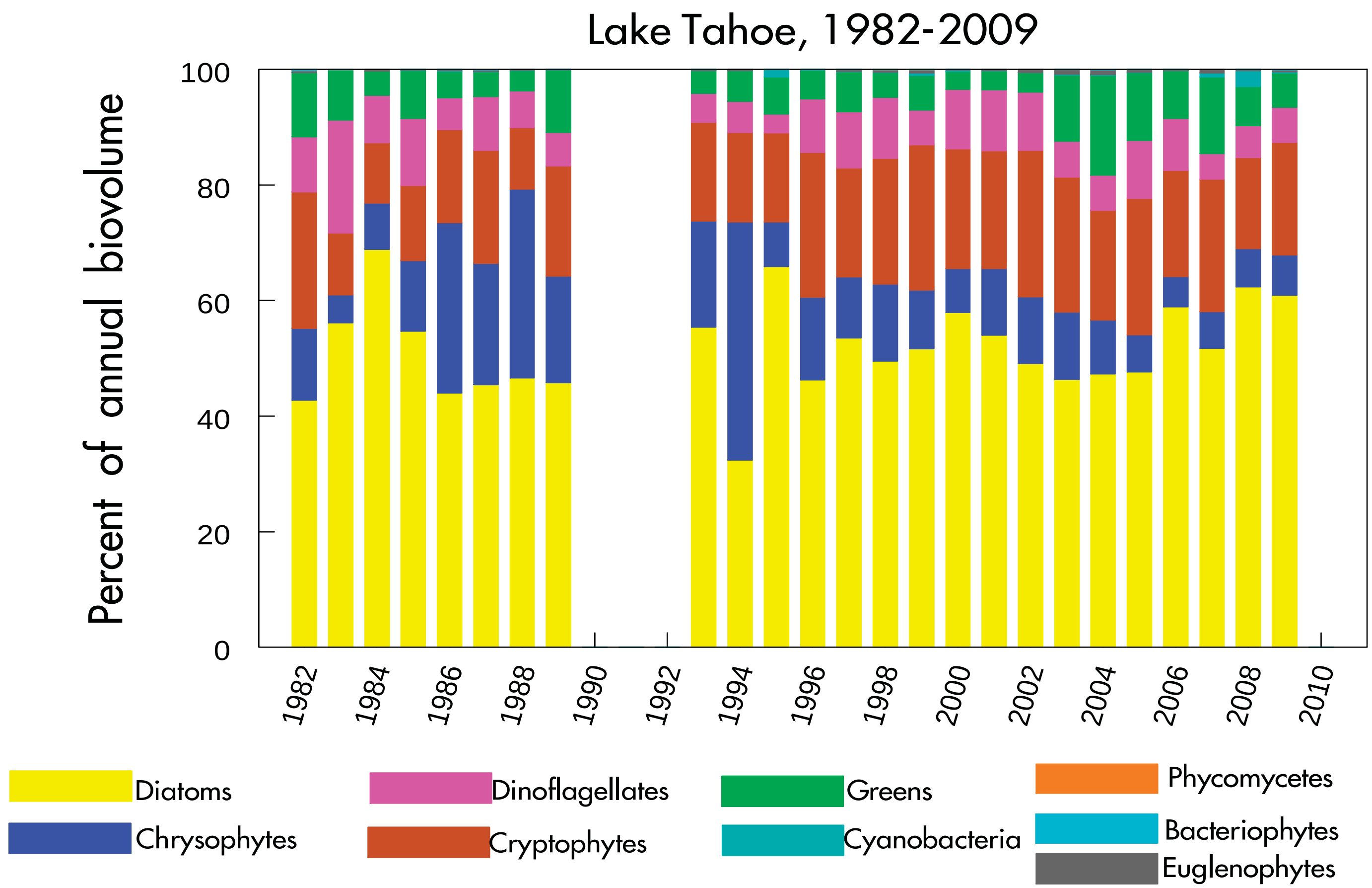


BIOLOGY

Algae groups as a fraction of total population

Yearly since 1982

The population, or biovolume, 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 biovolume each year. Chrysophytes and cryptophytes are next, comprising 10 to 30 percent of the total. While 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 in response to lake condition.

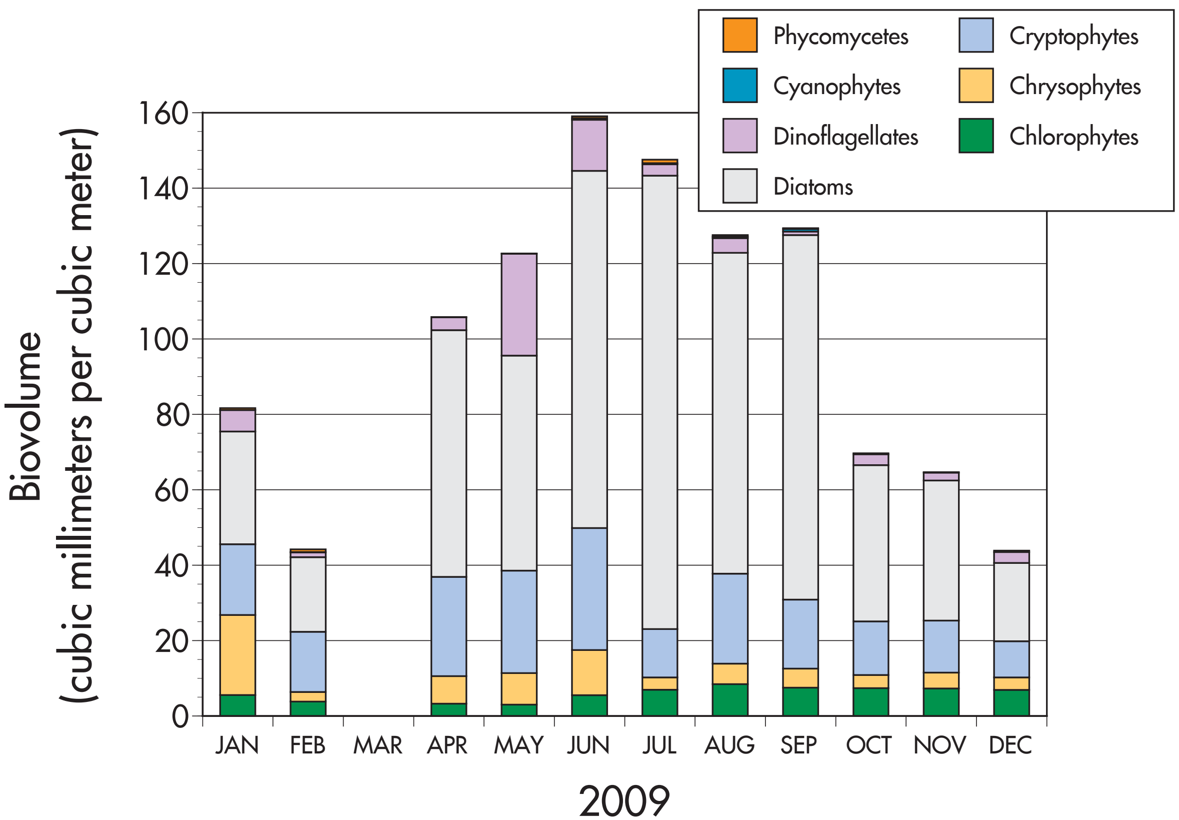


BIOLOGY

Algae groups as a fraction of total population

Monthly in 2009

Algae populations vary month to month, as well as year to year. In 2009, diatoms again dominated the phytoplankton community, especially in April-September when their biovolume was particularly high. While the relative importance of the chlorophytes (green algae) increased in the latter half of the year, their biovolume did not peak as dramatically in 2009 as it has in previous years.



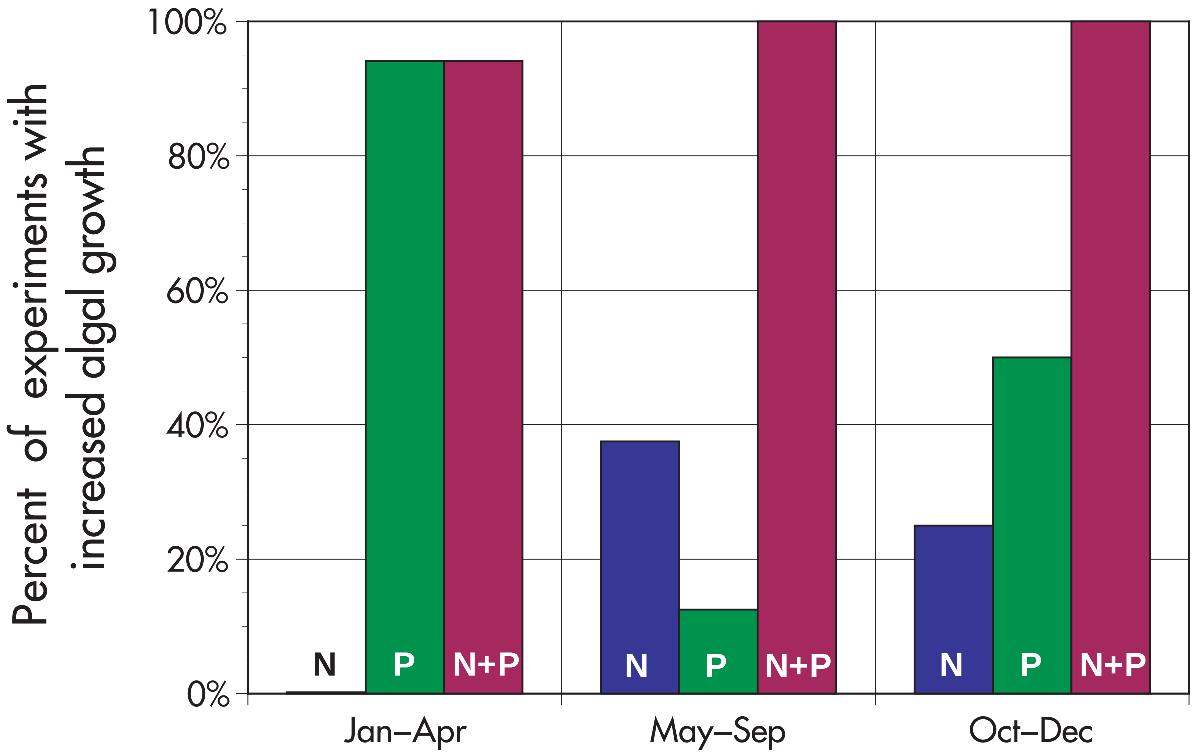
BIOLOGY

Nutrient limitation of algal growth

For 2002 - 2009

Bioassays determine the nutrient requirements of phytoplankton. In these experiments, nutrients are added to lake water samples and algal biomass is measured. These tests document both seasonal and long-term changes in nutrient limitation. Phytoplankton response to nutrient addition for the period 2002-2009 is summarized in the panels below. Between January and April, algal growth was limited purely by phosphorus (P). From May to September, Nitrogen (N) added by itself was more stimulatory, but the lake was co-limited, as shown by the greater response to adding both nutrients.

Phosphorus was more stimulatory from October to December, but co-limitation was again the dominant condition. These results highlight the role of nutrients in controlling algal growth. They also underscore the synergistic effect when both are available.

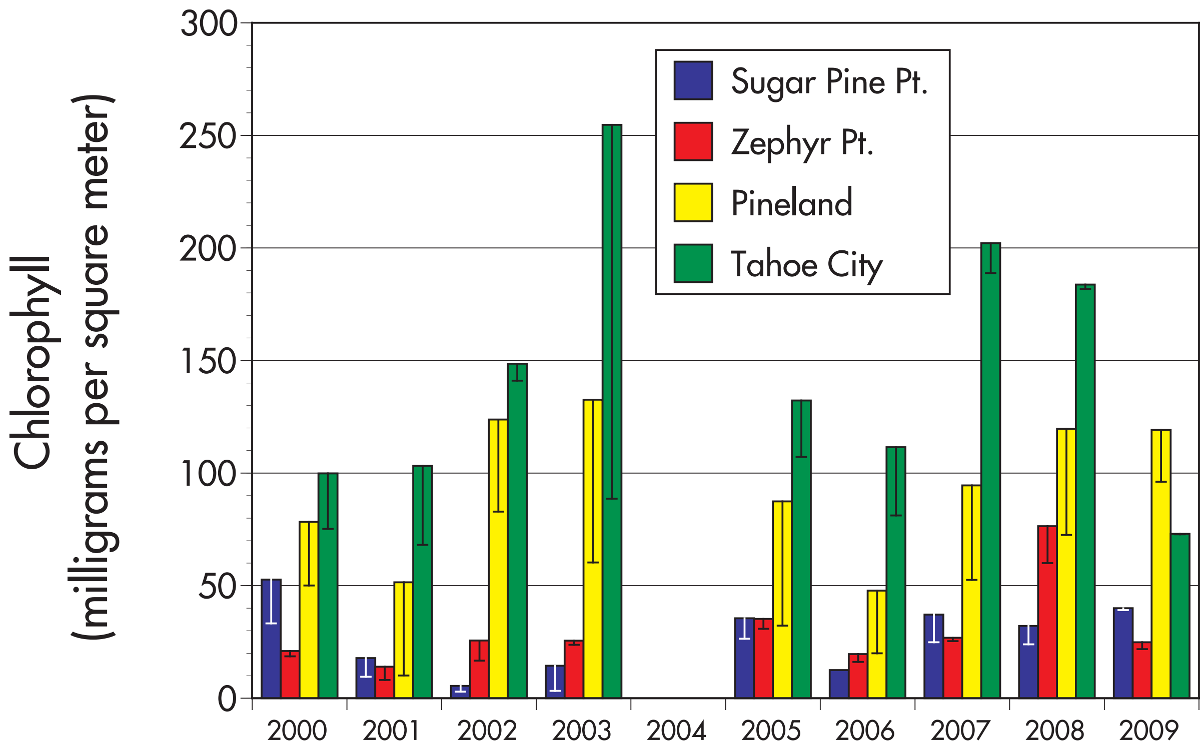


BIOLOGY

Shoreline algae populations

Yearly since 2000

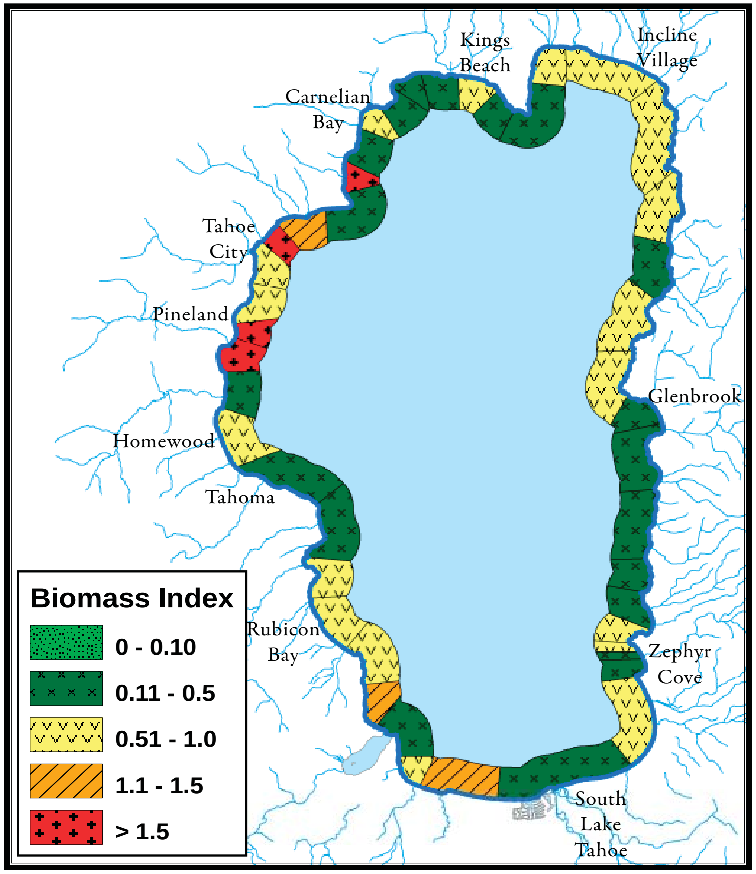
Periphyton, or attached algae, makes rocks around the shoreline of Lake Tahoe green and slimy, or sometimes like a very plush white carpet. Periphyton is measured eight times each year, and this graph shows the maximum biomass measured at four sites. In 2009, concentrations were near or above average. The two sites with the most periphyton (Pineland and Tahoe City) are closest to urban areas. Tahoe City dropped dramatically from previous years, and was lower than Pineland for the first time. Peak annual biomass at the less urbanized Zephyr Point site was back down to the usual level, from the high value experienced in 2008. To date, no statistically significant long-term trend in maximum periphyton biomass has been detected at any of these individual locations. However, the higher biomass at the more urban sites has been dramatic year after year.



Shoreline algae distribution

In 2009

Periphyton biomass was surveyed around the lake during the spring of 2009, when it was at its annual maximum. Nearly 45 locations were surveyed by snorkel in 1.5 feet of water. A Periphyton Biomass Index (PBI) was developed 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 percent of the local bottom area covered by periphyton multiplied by the average length of the algal filaments (cm). Zones of elevated PBI are clearly seen. (The width of the colored band does not represent the actual dimension of the onshore-offshore distribution.) Compared with 2008, there were higher concentrations of periphyton particularly in the north-east.



TAHOE: STATE OF THE LAKE REPORT 2010

CLARITY

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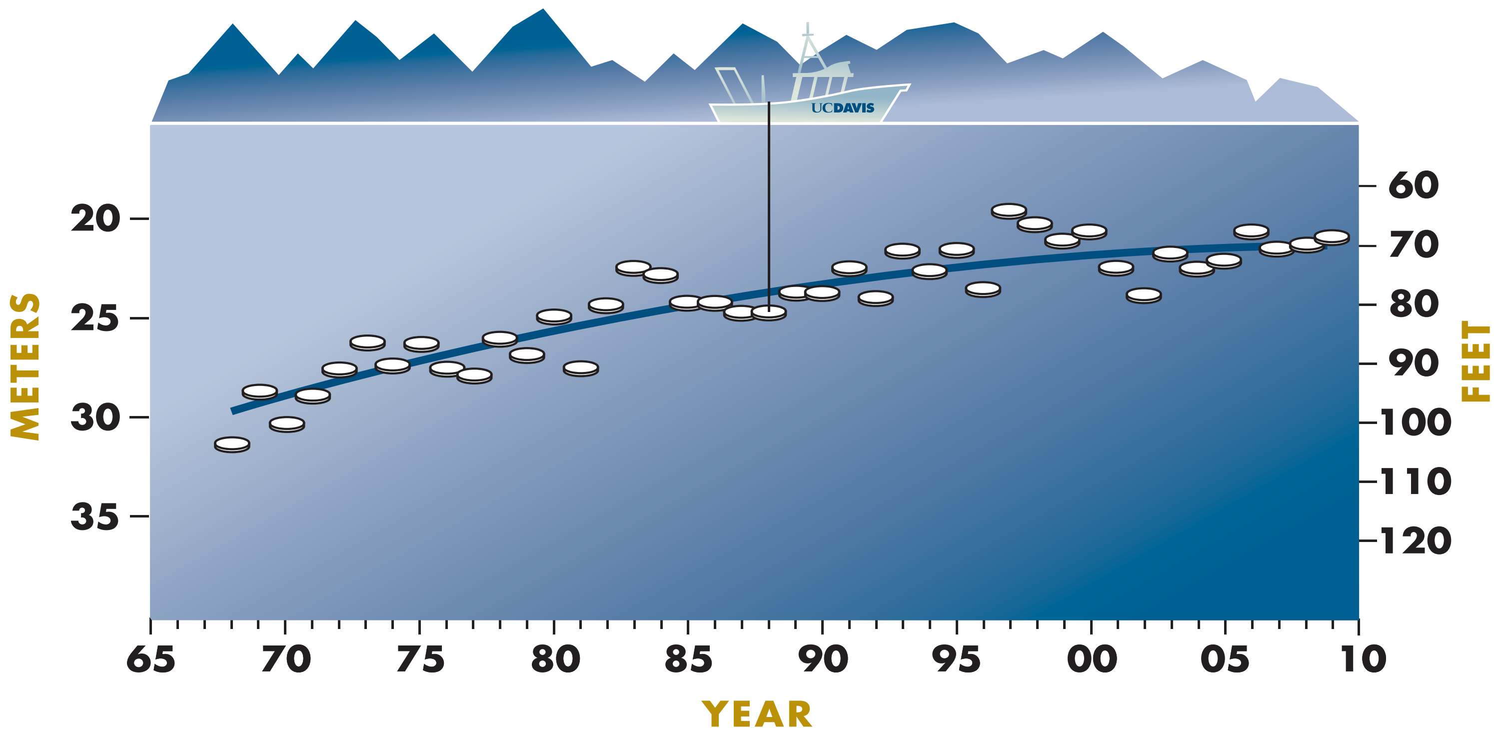
CLARITY

Annual average Secchi depth

Yearly since 1968

Secchi depth (the point below the lake surface at which a 10-inch white disk disappears from view) is the longest continuous measurement of Lake Tahoe clarity. The annual Secchi depth is the average of 20 to 25 readings made throughout the year. While lake clarity has improved for brief periods since 1968, the overall long-term trend has shown a significant decline. In the last nine years, Secchi depth measurements have been better than predicted by the long-term linear trend. Statistical analysis suggests that the decline in Lake Tahoe's clarity has slowed, and is now better represented by the curve below than a straight line. In 2009, the Secchi depth was 68.1 feet, a decline of 1.5 feet from the previous year. This can in part be explained by the increase in precipitation in 2009, up approximately 40 percent from the previous two years.

DECLINE OF WATER CLARITY AT LAKE TAHOE

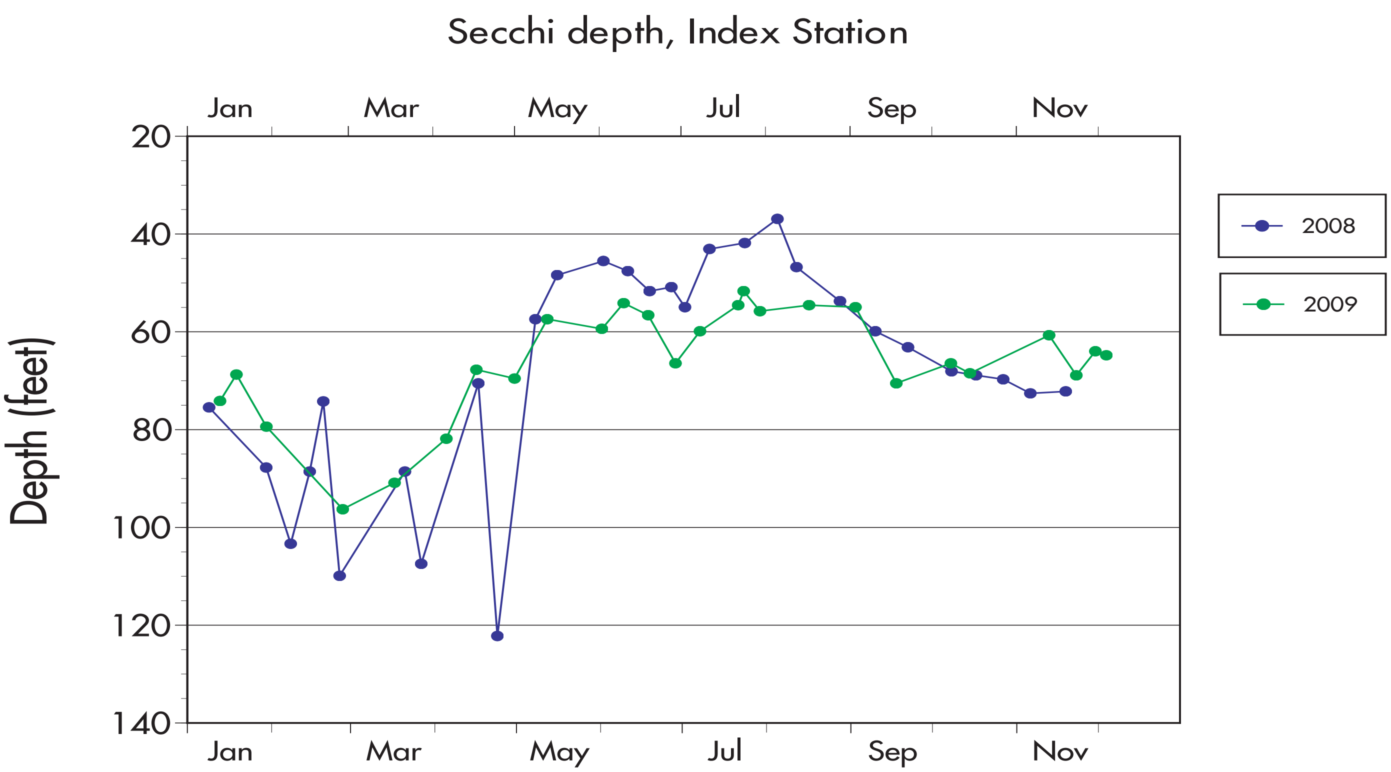


CLARITY

Secchi depth measurements

2008 and 2009

Secchi depth has a strong seasonal feature which was clearly expressed in 2009. The deepest Secchi depth readings (the clearest water) typically occur in winter and last year was no exception. In 2009, the deepest reading was 96.3 feet on February 27th, while the lowest (51.7 feet) was measured on July 24th. Comparing the 2008 and 2009 Secchi depth data, it is evident that summer Secchi depths actually improved from 2008. The high winter clarity in 2008 was due to the numerous upwellings that caused clear bottom water to be brought up to the surface (causing the spikey appearance). The annual average Secchi values (Fig. 11.1) represent the most robust indicator of the status and trend in Lake Tahoe clarity.

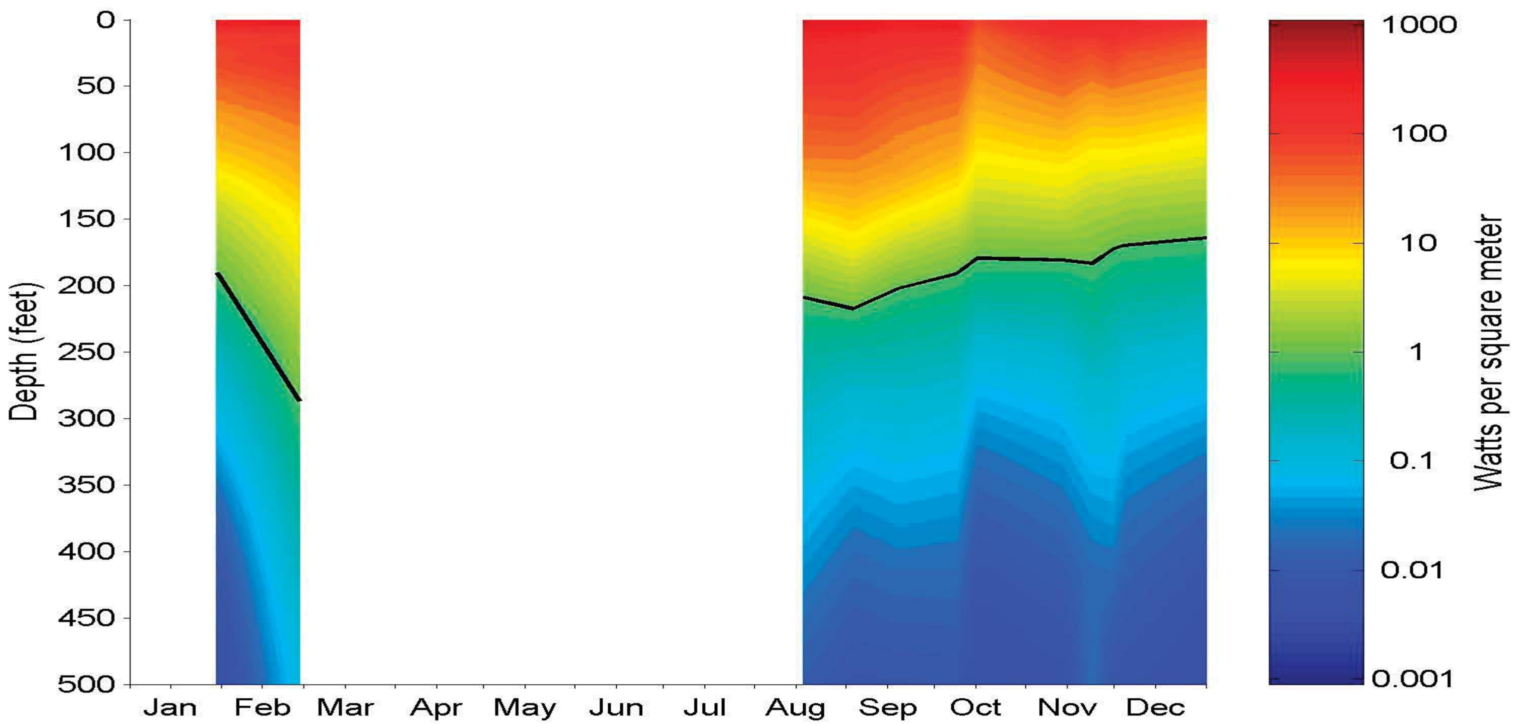


CLARITY

Penetration of photosynthetically active radiation

In 2009

Photosynthetically active radiation (PAR) is that part of solar radiation spectrum that is utilized in photosynthesis. The black line below shows the depth at which PAR is 1 percent of its level on the lake surface, known as the euphotic depth. PAR penetration varies throughout the year, but is often deepest in the summer when the sun is highest in the sky. In 2009, the euphotic depth increased in February when the lake was undergoing its deepest mixing and clear, deep water was brought to the surface (Fig. 8.9). The latter half of 2009 had similar PAR penetration to 2008. The data gap was due to instrument repairs and calibration.



TAHOE: STATE OF THE LAKE REPORT 2010

EDUCATION AND OUTREACH

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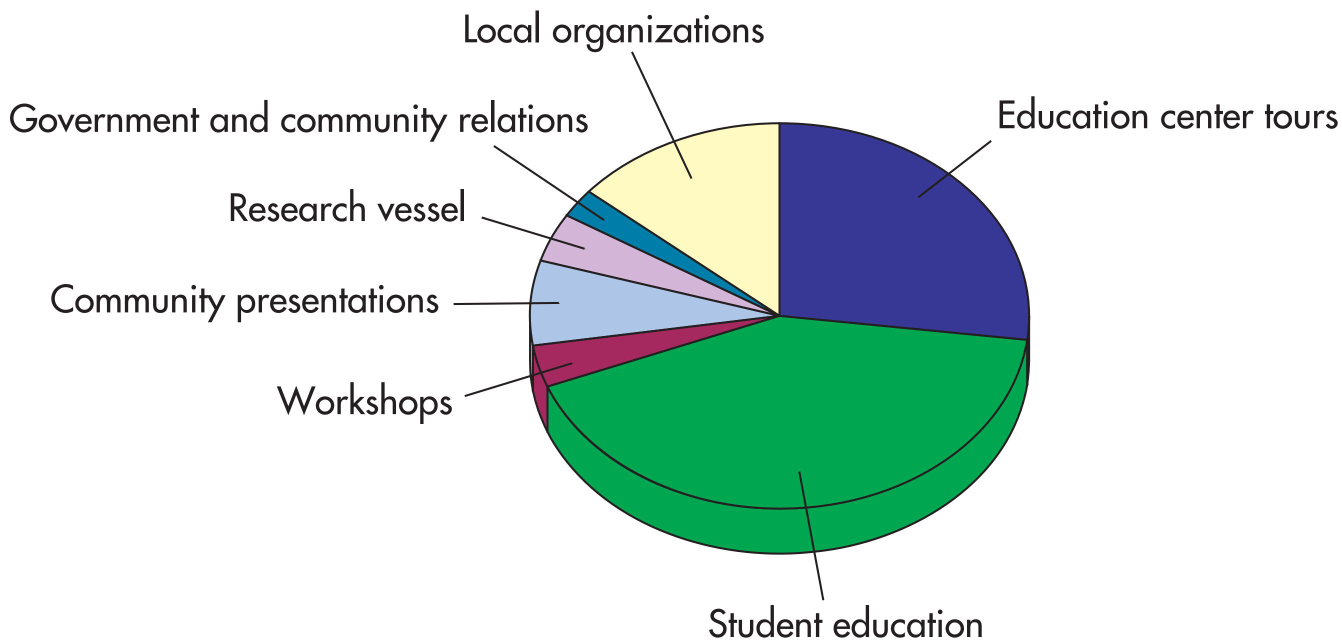
EDUCATION AND OUTREACH

TERC outreach

In 2009

Part of TERC's mission is education and outreach. During 2009, TERC recorded over 9,400 individual visitor contacts. The majority represented student field trips and visitors to the 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 education in the Tahoe basin. In 2009, these included AmeriCorps, COSMOS, Sierra Watershed Education Partnerships (SWEP), Space Science for Schools, Young Scholars and many others.



TOTAL NUMBER OF CONTACTS: 9443