

RECENT RESEARCH UPDATES





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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



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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.



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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