LAKE TAHOE NUTRIENT AND SEDIMENT TOTAL MAXIMUM DAILY LOAD

SUMMER 2004 NEWSLETTER

Nevada Division of Environmental Protection Lahontan Regional Water Quality Control Board

This edition is a slight departure from our usual practice of reporting on the scientific research studies that will help us calculate the total allowable sediment and nutrient loads necessary to protect Lake Tahoe's amazing clarity and to determine the sources of those pollutants. While those studies continue to produce exciting results, California and Nevada's water quality agencies have been evaluating project needs to complete subsequent phases of the Total Maximum Daily Load (TMDL). These include research into allocating pollutant loads, implementation planning and tracking, and monitoring during TMDL implementation. The TMDL project team from the Lahontan Regional Water Quality Control Board (RWQCB) and the Nevada Division of Environmental Protection (NDEP) has been focused on drafting workplans and securing funding for these project components. Key efforts include:

- Producing an inventory of water quality improvement projects constructed to date in the Lake Tahoe Basin, a first step in the effort to determine load reductions achieved thus far and to allocate future loads to the primary sources (TMDL Phase II as described in http://www.swrcb.ca.gov/rwqcb6/TMDL/Tahoe/Summer-Fall_2003_TMDL_Newsletter_v2.pdf);
- Assessing the feasibility of tracking TMDL implementation (Phase III) by means of remote sensing, a state-of-the-art technology for monitoring Lake Tahoe clarity and hydrodynamic processes from outer space; and
- Developing a water quality trading system that could constitute the foundation for the TMDL implementation plan and for actually achieving necessary load reductions in the most efficient and cost-effective manner (Phases II and III).

The articles below describe these efforts and their potential contributions to the TMDL.

DEVELOPING AN INVENTORY OF STORM WATER QUALITY IMPROVEMENT PROJECTS FOR LAKE TAHOE BASIN

Water quality improvement projects have been implemented throughout the Lake Tahoe Basin over the last several decades. Since 1997, these projects have been conducted as part of the Tahoe Regional Planning Agency's (TRPA) Environmental Improvement Program (EIP). These projects typically integrate a variety of best management practices (BMPs) to either infiltrate storm water runoff into the ground or treat it to prevent storm water pollutants from entering the lake or its tributaries. Revegetation, retaining structures and slope stabilization are referred to as source control, because they focus on preventing pollutants from being picked up by the runoff. Treatment of pollutants already contained in the runoff is typically accomplished by conveying the runoff to an area where it may be infiltrated into groundwater, such as a wetland or retention basin, or by using mechanical or chemical pretreatment devices. Each BMP implemented helps the goal of preserving and protecting the amazing clarity of Lake Tahoe.

Unfortunately, tracking of storm water quality improvement projects has not kept pace with the scientific understanding of lake clarity over the past several decades. Record keeping has been complicated by the fact that Lake Tahoe is a bi-state water, with a multitude of local jurisdictions, funding sources, and implementing agencies. As a result, there is no single source of information on the number and types of such projects that have been implemented in the Basin. In addition, no comprehensive supporting Geographic Information System (GIS) layer exists of these completed projects.

Project Purpose

To help resolve this issue, the United States Forest Service has funded the Nevada Tahoe Conservation District (NTCD) to compile an inventory of storm water quality improvement projects implemented throughout the Lake Tahoe Basin. NTCD is working cooperatively with the Lahontan RWQCB, NDEP, and the TRPA on this project. The TMDL project team sees great value in assembling this information into a single format, and eventually housing it on the Tahoe Integrated Information Management System website, where it may be easily accessed and continually updated. This inventory will assist regulatory and management agencies in many ways. For example, funding agencies will be able to easily track measures of progress toward meeting restoration goals. If future project designers can easily determine what BMPs are near a proposed project, an existing storm water detention basin could be shared and expanded rather than building a new one. Project information will be represented in the TMDL watershed model, in order to calculate existing pollutant loading into the Lake and to allocate future loads.

Project Plan

The project team will be collecting information on completed water quality improvement projects to:

- establish a unified basin-wide data base,
- develop a GIS representation of projects and treated areas, and
- perform initial work necessary to establish an automated web-based project tracking tool.

The inventory is focused on multi-parcel (i.e. not residential) water quality improvement projects funded by a combination of federal, state, and/or local agencies.

Phase 1

Phase 1 is nearing completion. One of the major initial focuses of work was to determine the availability, location, and form of data on completed water quality improvement projects. NTCD staff compiled a preliminary list of completed projects based on information provided by the primary funding agencies, California Tahoe Conservancy (CTC) and Nevada Division of State Lands (NDSL), as well as by the California and Nevada Departments of Transportation. NDSL maintains centralized files of Nevada projects with as-built records (descriptions of what was actually built) for completed projects, while in California, individual implementing agencies (Placer and El Dorado counties and the City of South Lake Tahoe) have this information.

With the preliminary project list in hand, NTCD, Lahontan and TRPA staff met to review TRPA's GIS-based layer of water quality improvement project locations, along with a supporting list of projects. Their GIS layer shows treated areas for about 80 percent of EIP water quality projects, but is based on permitted, not as-built, drawings. TRPA's supporting list of projects will be an important link between EIP project names and numbers and the specific project information we obtain from implementing agencies. TRPA offered to assist with GIS work and provided us with a water quality-related subset of EIP projects.

The project team has also met with the Placer County Department of Public Works and the El Dorado County Department of Transportation. Placer County maintains a limited spreadsheet-style database that includes information such as project name, file number, EIP number, and completion dates. El Dorado County has offered to provide us a copy of their database for project tracking.

Preparation for Phase 2

Project staff are currently refining a spreadsheet that will be used for data entry during file reviews. We will be tracking some basic information on the water quality improvement projects including EIP project name and number, the implementing and funding agencies, and federal, state, and local funding amounts. With respect to individual projects, we intend to track (if applicable):

- project location and area treated,
- project design flow and/or volume,
- bypass flow information,
- type(s) and quantities of individual BMP(s),
- monitoring information availability (yes or no),
- maintenance plan availability (yes or no), and
- maps of as-built treated areas.

We intend to combine this information with TRPA's GIS layer of treated areas. Because TRPA's layer is based on planned (as opposed to as-built) information, we will survey implementing agencies staffs and spot check approximately 10 – 20 percent of the projects to evaluate if the plan information agrees with the collected as-built information.

Future BMP Research

In order to integrate existing and future storm water quality improvement projects and their impacts into the TMDL, it will be necessary to know not only where and how many of them there are, but also their effectiveness. This is the subject of another TMDL research study, which is soon to be completed and will be described in a future newsletter. As part of TMDL Phase II (pollutant load allocation and implementation planning), this research will be further expanded to determine the potential for future water quality improvement projects, addressing not only storm water but also the numerous other sources of pollutants that impact lake clarity. Stay tuned…

LAKE TAHOE WATER QUALITY AS SEEN FROM SPACE

Lake Tahoe's clarity and temperature (a key, related limnological variable) can be monitored remotely, rather than by immersing sensors directly into the lake. "Remote sensing" instruments detect visible light and heat radiated from the lake and can be mounted on devices as close to the lake as buoys or as distant as satellites, although measurements from outer space must be adjusted to account for atmospheric and other effects. The data obtained may then be correlated with in-lake measurements using more conventional devices such as thermometers or a Secchi disk, enabling scientists to determine water quality conditions at the time when remote measurements are made on a much wider spatial scale (e.g. lake-wide) than can be determined from land- or lake-based measurements (which provide information only about the point being measured). Thus, remote sensing allows scientists to greatly expand their knowledge and understanding of lake processes by making synoptic surveys or "snapshots" of the whole lake at a single moment. This raises the possibility that we may someday be able to represent (or model) the lake's full three-dimensional complexity.

Pure water such as Lake Tahoe's reflects blue light. The higher the algal or sediment content of the water, the more light in the green and brown light ranges are reflected. Remote sensing of water color can be used to measure water quality variations both around the lake's surface area and over time. Remote sensing of water temperature can be used to assess biological activity, measure upwellings (the movement of cold, deep waters to the surface due to wind), and track currents. Images from older satellites such as the National Aeronautics and Space Administration's (NASA) Landsats (several of which have been launched since 1972) have long been used to measure oceanic water quality. Inland water bodies typically require more complex analytical techniques than marine waters, because they generally contain a much wider variety of organic and inorganic substances. However, because of the low chlorophyll content of Lake Tahoe, it is sufficiently similar to the oceans that many of the same data and techniques used to study the oceans can be used to study Lake Tahoe.

Fig. 1 NASA buoy on Lake Tahoe equipped with instruments that continually monitor the lake's temperature and surface meteorology.

Dr. Simon Hook of NASA has selected Lake Tahoe as an ideal location to validate the thermal infrared (temperature) measurements of an instrument called the Advanced Spaceborne Thermal Emission and Reflectance Radiometer (ASTER). ASTER is mounted on one of NASA's state-of-the-art Earth Observing System satellites called Terra, which was launched in 1999. In order to check the ASTER observations from 705 km (448 miles) in the sky, NASA mounted a variety of monitoring equipment on four buoys in Lake Tahoe (see Figure 1) and has intensified data acquisition from numerous satellites that fly regularly over the lake.

In addition to monitoring temperature, remote sensing instruments have the ability to measure nearshore and possibly even deep-water clarity, as well as circulation or movement of water around the lake's surface. Remotely sensed information on lake clarity could be an effective way to track the lake's optical properties, including variations between locations on the lake, rather than relying exclusively on specific measurements at a representative index station or at particular points on the lake's surface. Information on circulation is critical to understanding both depth-related and surface hydrodynamic processes, which are essential for eventually developing a fully three-dimensional Lake Clarity Model (see http://www.swrcb.ca.gov/rwqcb6/TMDL/Tahoe/Spring_2003_TMDL_Newsletter.pdf).

Near-shore Clarity

Portions of the lake's bottom are visible from space just as they are from the shoreline or from a boat traveling close to it. The lake's bottom drops off extremely steeply around most of its perimeter, so clarity can only be measured directly using reflected visible light along a relatively narrow band just off the lake's shoreline. Because the lake's bathymetry or underwater topography was mapped very accurately by the United States Geological Survey (USGS) in 1998, combining these visible underwater features with their known depth allows a near-shore clarity 'map' to be generated around the lake's edge (Figure 2). This shore zone clarity map represents a snapshot of the clarity over the entire perimeter of the lake for an instant in time from a single satellite acquisition. Since ASTER and Landsat can take such pictures every 16 days (weather permitting), these data could be used to monitor changes in near-shore lake clarity.

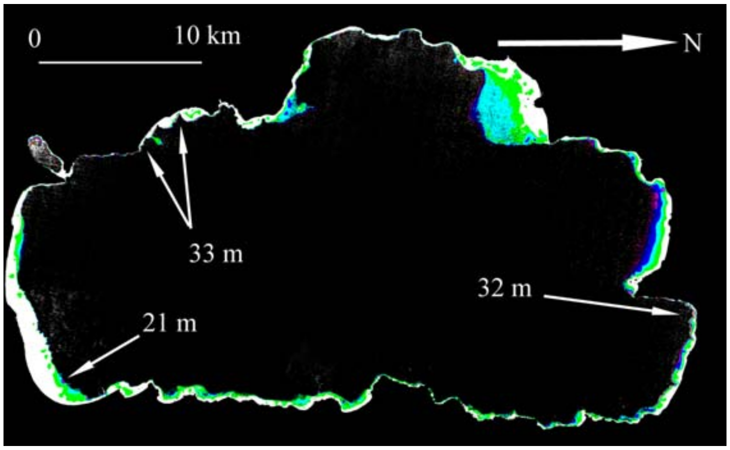

Fig. 2 Nearshore clarity map derived from ASTER data and a digital elevation model. Color changes represent increasing depth to bottom. Depth to the visible bottom is indicated at certain points.

A clarity map like that in Figure 2 is very useful but care must be taken in applying the data in a rigorous, quantitative manner. In order to do so, a variety of factors, such as the amount of incoming radiation, and any variation in the bottom reflectance or the properties of the atmosphere above the lake at the time of data acquisition, must be carefully taken into account. One of the most common approaches for addressing these factors is to periodically make in situ measurements of near-shore clarity (a process known as ground truthing) at the same time as the satellite is collecting its data.

Deep Water Clarity

Lowering a standardized Secchi disk into the water until it is no longer visible is the primary method for measuring deep water clarity at Lake Tahoe and elsewhere. Considerable research has been undertaken by the limnological community to develop a methodology to convert Secchi disk measurements into a more quantitative, objective optical measurement. The optical properties that primarily affect the Secchi depth can be measured with other instruments such as transmissometers and spectroradiometers. In order to derive similar objective optical measurements from satellite data as are made directly on the lake, it is necessary to correct for effects of the atmosphere and the air-water interface. Such corrections are difficult and therefore, if in situ measurements are available, a more common approach is to correlate the satellite data with the in situ data. Such correlations or regressions have been widely used to determine chlorophyll concentrations in the oceans but typically perform poorly in more optically complex inland waters. Interestingly, the concentrations of chlorophyll and other components at Lake Tahoe are similar to the oceans, so these approaches may work well at Lake Tahoe. If current plans to add optical instruments to the buoys are successful, the data obtained could then be coupled with the satellite data to start to understand the local relationships between the satellite radiances and Lake Tahoe clarity.

<u>Measuring Lake Circulation</u>

Circulation is an especially important yet difficult to measure factor affecting Lake Tahoe clarity. Lake mixing means that pollution from a single source or input can affect clarity throughout the lake, or conversely may not be visible at the input's location. Although circulation has been measured by tracking buoys left to drift along the surface, circulation patterns over the entire lake surface must be inferred from where the individual buoys go. Surface temperature measurements derived from satellite data have been used by oceanographers for many years to map ocean currents based on tracking a parcel of water at given temperature over time. Satellite derived temperature measurements have also been used to look at upwelling along coastlines where cold water is drawn to the surface, an extremely important source of nutrients that results in sudden increases in biological activity. A similar approach can be used to track circulation and upwelling events in inland water bodies. Both Landsat and ASTER have sufficient spatial resolution to map currents and upwellings. In order to extract the temperature information from the satellite data, it is necessary to correct the data for atmospheric and surface effects.

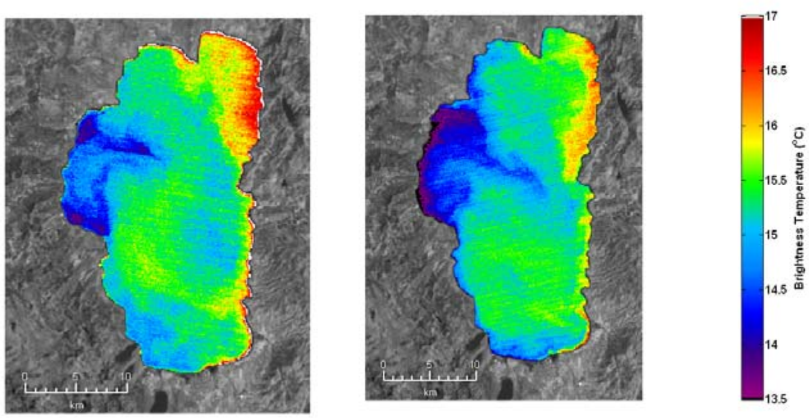

Fig. 3 Landsat ETM+ thermal band image acquired on 7/21/2001, 10:28 PST (first image) and ASTER thermal band image acquired at 22:05 PST (second image).

Figure 3 shows surface temperature maps derived from ASTER data during an upwelling event. The first image was taken on July 21, 2001, at 10:28 AM. The second image was taken about twelve hours later. Since these are temperature measurements, the data can be acquired during the day or during the night. During the day, cold water is seen upwelling near the western shore around Homewood (first image). The upwelling is induced by sustained high winds from the west and southwest that drive the warm water to the east, allowing cold water to upwell in the west. The cold water is eventually driven across the lake as can be seen in the nighttime (second) image. The current speed can be derived by tracking the position of a parcel of water in the day and night image. This speed can also be checked by the time at which the cold water arrives at each of the NASA buoys. The cold water brings nutrients that provide the opportunity for increased biological activity. NASA recently funded a U.C. Davis student to use the satellite derived temperature data to help model lake circulation. More information about the collaborative efforts of NASA and U.C. Davis is available at: http://laketahoe.jpl.nasa.gov and http://remote.ucdavis.edu/tahoe_location.asp .

Conclusion

Due to the promise of remote sensing as an ideal complement to on-lake monitoring of Lake Tahoe deep water and near-shore clarity, the Lahontan RWQCB and Nevada DEP are interested in investigating its feasibility and in implementing a regular satellite imaging program, if appropriate. Such a program would allow for synoptic monitoring of TMDL implementation, once projects are underway to restore lake clarity. Done regularly, this monitoring will enable scientists and regulators to obtain a whole-lake view of near-shore clarity, to track lake mixing and better correlate particular events such as upwelling (and associated clarity responses), and could possibly improve our ability to evaluate regional pollutant sources near their area of origin and before they become mixed into the larger lake.

Key Personnel: Dr. Simon Hook is a research scientist at the NASA/JPL in Pasadena, CA. His research involves the use of remotely sensed data for geological and ecological studies with special emphasis on instrument calibration and validation. He is assisted by Dr. Abtahi and Mr. Alley. Dr. Abtahi is responsible for the equipment on the Lake Tahoe buoys and developed the radiometer used for the validation of the thermal infrared data. Mr. Alley is responsible for the radiative transfer models that are used to model and correct for atmospheric effects in the remotely sensed data. Todd Steissberg, a postdoctoral student with Dr. Geoff Schladow at UCD, was recently funded by NASA to work on using the remotely sensed data for studying upwellings at Lake Tahoe.

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Innovative Lake Tahoe Pollutant Trading Project Receives $1.14 Million EPA Grant

The Lake Tahoe Basin was one of only 14 watersheds around the country to be awarded a "Targeted Watershed" grant on July 19, 2004 by the U.S. Environmental Protection Agency (EPA). The purpose of the $1.14 million grant is to help restore Lake Tahoe's historic clarity by developing an innovative pollutant trading program. The Lahontan RWQCB and NDEP jointly requested the grant in January 2004; our proposal and an EPA Fact Sheet on the Targeted Watersheds Grant Program may be viewed at http://www.epa.gov/twg/.

EPA's program this year emphasized projects that incorporate market-based incentives, consistent with its recently issued "Final Water Quality Trading Policy" (see: http://www.epa.gov/owow/watershed/trading/tradingpolicy.html). This policy encourages trading programs that facilitate implementation of TMDLs through "market-based approaches, which can create incentives for innovation, emerging technology, voluntary pollution reductions and greater efficiency in improving the quality of the nation's waters."

The Lahontan RWQCB and NDEP intend to utilize the grant to:

- Identify innovative sediment and nutrient control technologies, which include, among others, advanced storm water treatment, stream bank stabilization, and methods for reducing atmospheric deposition;
- Calculate the total pollutant load reduction potential based on a comprehensive analysis of all opportunities, including conventional and innovative technologies or programs; and
- Establish protocols for trading load reductions achieved by various pollution control projects and jurisdictions, to achieve the most efficient and cost-effective basin-wide approach to restore lake clarity.

A proposed pollutant trading system tailored to the Lake Tahoe Basin will be produced by the end of 2005, along with models for evaluating pollutant load reduction projects. By that time, the total load reductions necessary to protect and restore the clarity of Lake Tahoe will have been determined by the TMDL project.

This information will then be used within a collaborative, public process known as "Pathway 2007," in which the U.S. Forest Service, Tahoe Regional Planning Agency, Lahontan RWQCB, and NDEP will update their land use and resource management plans in a coordinated approach. The Pathway 2007 process will involve a wide range of stakeholders that will use the tools developed from the Targeted Watershed grant activities and the TMDL to determine the best pollution control alternatives and a pollutant reduction trading system for achieving the overall load reductions needed.

Upon hearing the news of the grant award, Harold Singer, Executive Officer of the Lahontan Regional Board said, "This grant fills a significant need for the Regional Board, Nevada, and our other partners in our efforts to restore Lake Tahoe's clarity. Crafting a system that tracks reductions in sediment and nutrient loading to the Lake and that allows the stakeholders to evaluate the cost and effectiveness of different loading reduction scenarios is very important to the overall success of our restoration efforts. A pollutant trading system may help Tahoe stakeholders achieve the greatest benefits for Lake Tahoe while minimizing the expenditure of private and public dollars."

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