Lake Tahoe Nutrient and Sediment Total Maximum Daily Load

Summer & Fall 2003 Newsletter

Progress on Research and Planning for Pollutant Load Reduction

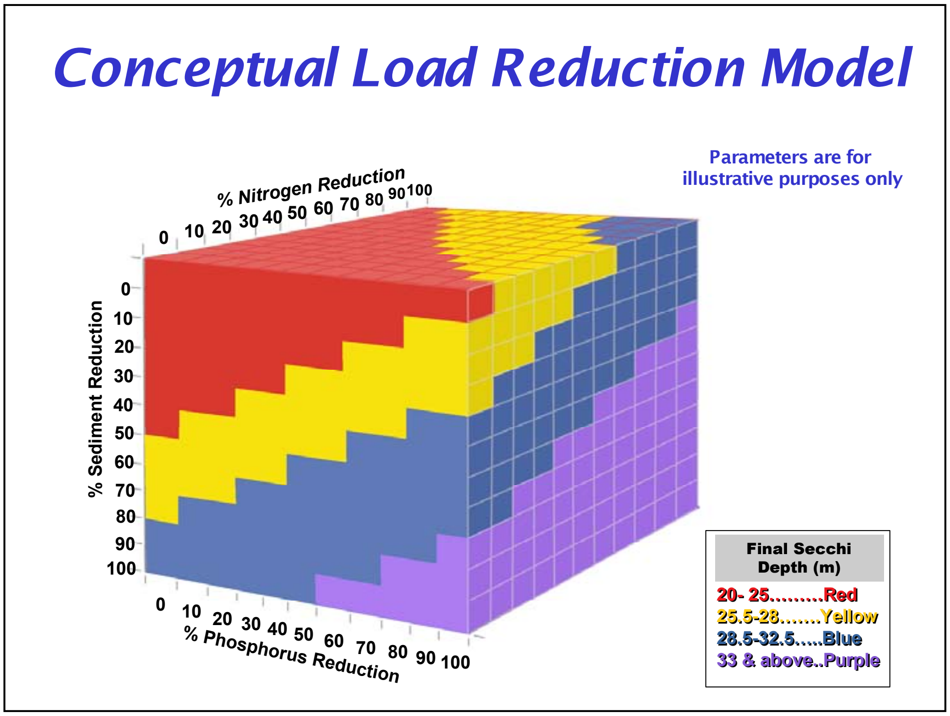
Consistent with past newsletters, our primary objective in this edition is to summarize progress on the variety of scientific research and administrative efforts underway on the Lake Tahoe Total Maximum Daily Load (TMDL). Several of these projects, providing key pieces of the TMDL puzzle, are already wrapping up, and their findings include intriguing and invaluable information. The Lahontan Regional Water Quality Control Board (RWQCB) and Nevada Division of Environmental Protection (NDEP) are concurrently anticipating the next steps in the process: 1) *deciding on the most feasible strategy* to achieve the necessary reductions in pollutant sources to stem and reverse the decline in Lake clarity, 2) *planning for the implementation* of the required load reduction projects, and 3) *developing a monitoring program* and adaptive management strategy to *verify the effectiveness* of the implementation plan.

Following the Phase I effort to calculate the total pollutant load or the lake's assimilative capacity, the next steps are Phase II—development of load reduction alternatives and allocations, and Phase III—implementation and monitoring. The first article below describes how we plan to carry out these next phases, and the second summarizes the draft findings of two critical pollutant loading studies funded by the U.S. Army Corps of Engineers, on groundwater and stream channel erosion. Finally, we report on significant progress on the optical component of the Lake Clarity model (introduced in the Spring 2003 newsletter).

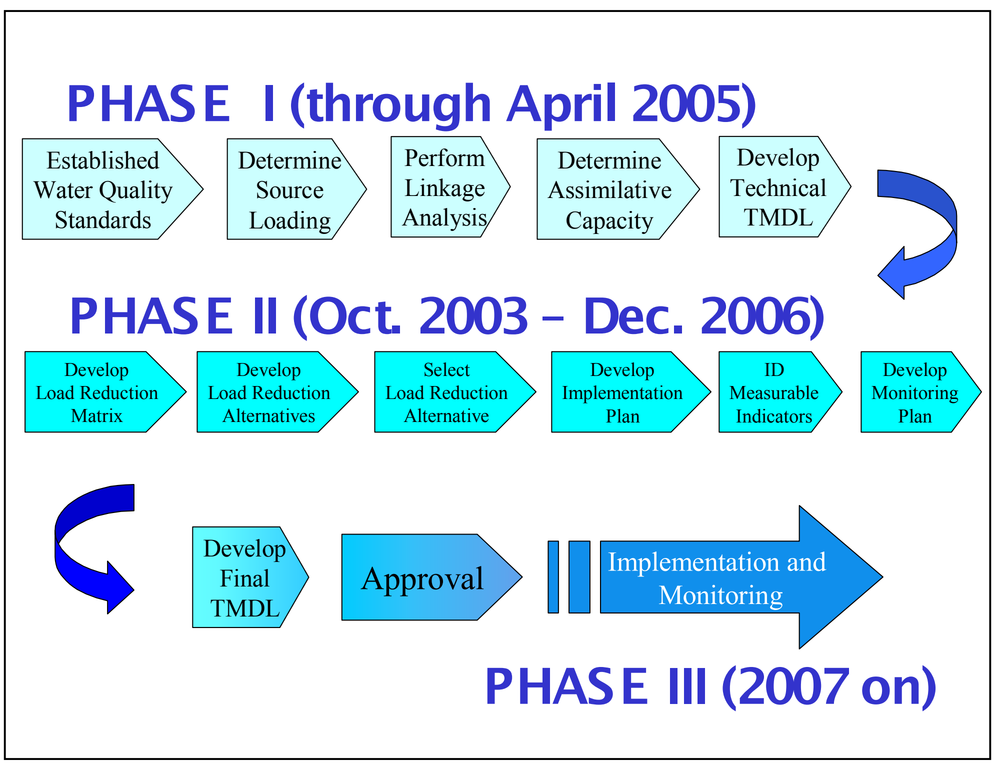
After the Technical TMDL: Load Allocation and Implementation Planning

Previous newsletters (see especially Fall 2002, "TMDL Approach" and "Timetable and Integration with Other Lake Tahoe Basin Environmental Documents") have described in detail how Lahontan RWQCB and NDEP will develop the "Technical TMDL" by April 2005. The Technical TMDL will produce estimates of current sediment and nutrient loads and their sources and will describe the basin-wide load reductions needed to achieve Lake Tahoe's target clarity of 30 meters Secchi depth. Required reductions in phosphorus, nitrogen, and fine sediment loads are best viewed as numerous potential combinations of the three pollutants, each of which would result in the desired water quality. These solutions are represented in the diagram on the next page as the "blue zone" within which there is a range of possible loading combinations. This cube includes phosphorus, nitrogen, and fine sediment load reductions ranging from no reduction of any pollutant (the upper left corner of the cube) to the hypothetical case where all pollutant loading is eliminated (the lower right corner). As noted, the current version of this diagram is conceptual and presented for illustrative purposes. When completed, results generated by the

Clarity Model will be incorporated into the cube as our best, scientifically informed estimate of expected lake response to overall pollutant loading.



Although these total (current and necessary future) basin-wide loads will be known within 18-20 months as part of the Technical TMDL, the full TMDL is not slated for adoption by the States of California and Nevada until early 2007. The intervening time will be used to (1) identify and quantify load reduction opportunities, (2) allocate the total load reductions among all existing and expected future pollutant sources, and (3) work in partnership with other Basin agencies and stakeholders to develop an implementation plan for achieving the necessary load reductions. Lahontan RWQCB and NDEP will achieve these goals with public and stakeholder participation and input. Both agencies are currently seeking additional funding to fully implement these phases and to deliver products and processes that are consistent with the intensive efforts underway to develop the Technical TMDL. We refer to these processes as Phase II and Phase III of TMDL development, each of which include their own steps, as portrayed in the adjacent diagram.



As depicted here and in the TMDL

project timeline on the back cover of this newsletter, Load Allocation and Implementation Planning are scheduled to begin soon, concurrent with development of the Technical TMDL. We anticipate that Phase II will begin with research into the development of a "Load Reduction Matrix," of which a conceptual example is illustrated in the adjacent table.

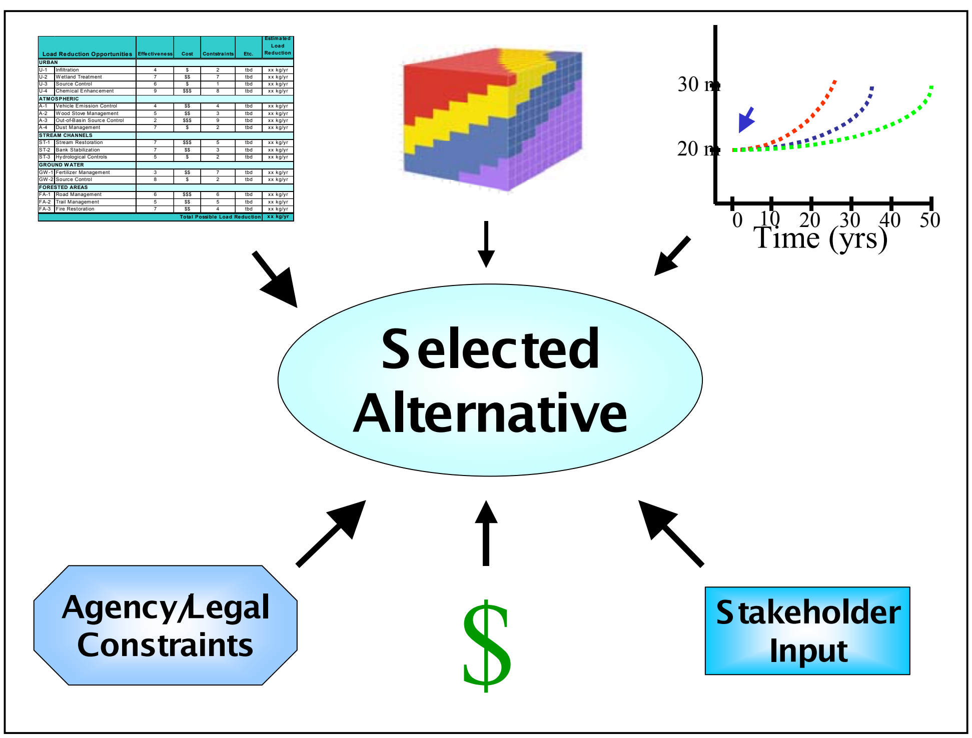
Example Load Reduction Matrix

Load Reduction Opportunities		Effectiveness	Cost	Contstraints	Etc.	Estimated Load Reduction
URBAN						
U-1	Infiltration	4	$	2	tbd	xx kg/yr
U-2	Wetland Treatment	7	$$	7	tbd	xx kg/yr
U-3	Source Control	6	$	1	tbd	xx kg/yr
U-4	Chemical Enhancement	9	$$$	8	tbd	xx kg/yr
ATMOSPHERIC						
A-1	Vehicle Emission Control	4	$$	4	tbd	xx kg/yr
A-2	Wood Stove Management	5	$$	3	tbd	xx kg/yr
A-3	Out-of-Basin Source Control	2	$$$	9	tbd	xx kg/yr
A-4	Dust Management	7	$	2	tbd	xx kg/yr
STREAM CHANNELS						
ST-1	Stream Restoration	7	$$$	5	tbd	xx kg/yr
ST-2	Bank Stabilization	7	$$	3	tbd	xx kg/yr
ST-3	Hydrological Controls	5	$	2	tbd	xx kg/yr
GROUND WATER						
GW-1	Fertilizer Management	3	$$	7	tbd	xx kg/yr
GW-2	Source Control	8	$	2	tbd	xx kg/yr
FORESTED AREAS						
FA-1	Road Management	6	$$$	6	tbd	xx kg/yr
FA-2	Trail Management	5	$$	5	tbd	xx kg/yr
FA-3	Fire Restoration	7	$$	4	tbd	xx kg/yr
					Total Possible Load Reduction	**xx kg/yr**

Parameters are for illustrative purposes only

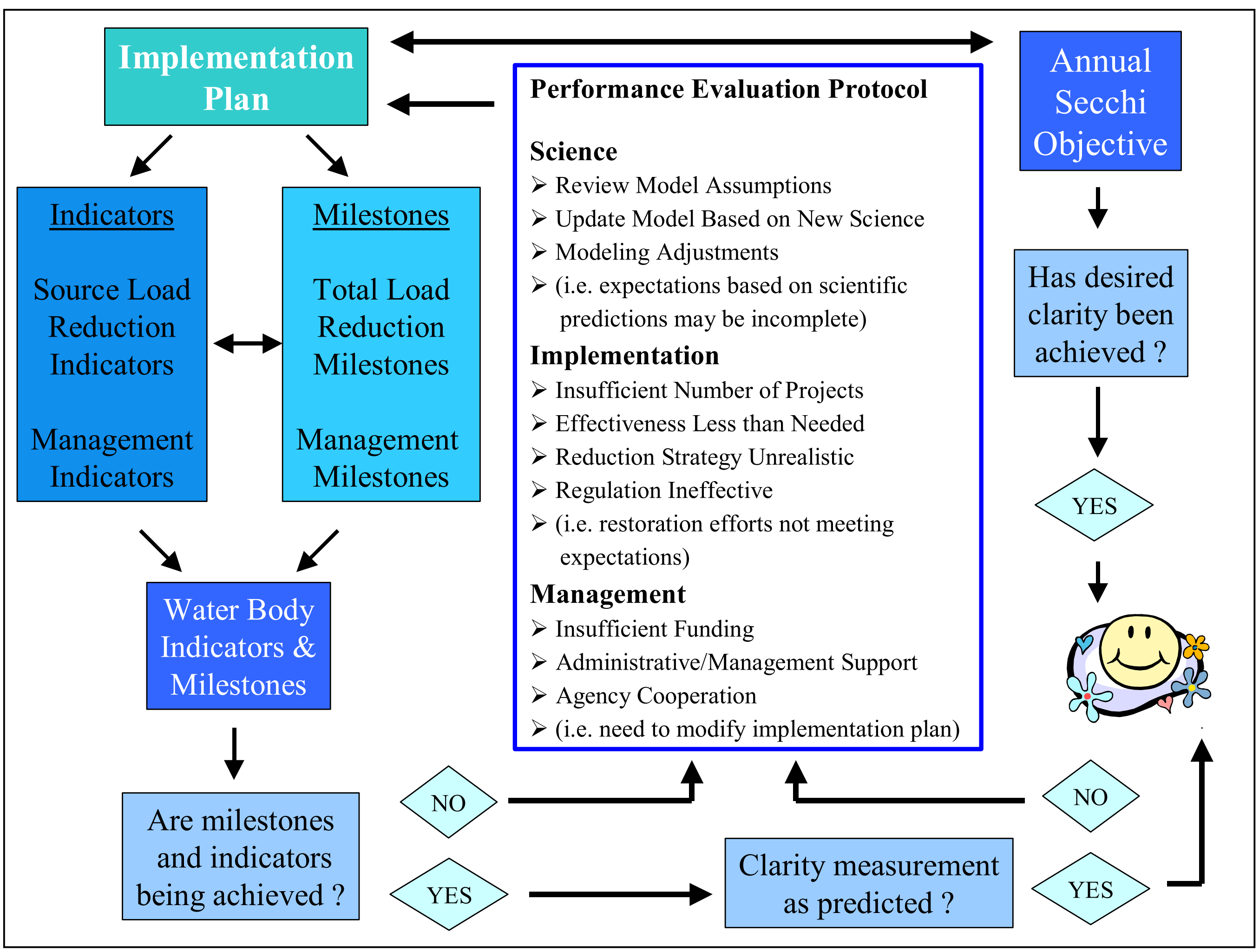
The Load Reduction Matrix will give us, for the first time, a quantitative road map for planning Environmental Improvement Program (EIP) and other restoration projects.

Current research on the effectiveness and cost of Best Management Practices (BMPs) will help us begin developing this matrix. The Load Reduction Matrix will form the heart of the load allocation process, in the same way that the watershed and lake clarity models are crucial to development of the Technical TMDL.



After compiling all existing information on BMP effectiveness and feasibility into the Load Reduction Matrix, we must develop combinations of BMPs that produce the necessary total reduction to achieve desired Lake Tahoe clarity. Working with stakeholders, Lahontan RWQCB and NDEP intend to produce a number of such load reduction scenarios or alternatives, each of which would constitute acceptable plans to reach the total pollutant loads called for by the TMDL. We anticipate that these scenarios will be evaluated relative to a variety of factors, such as an acceptable timeline for TMDL implementation, the total cost and other agency or legal constraints under which we operate.

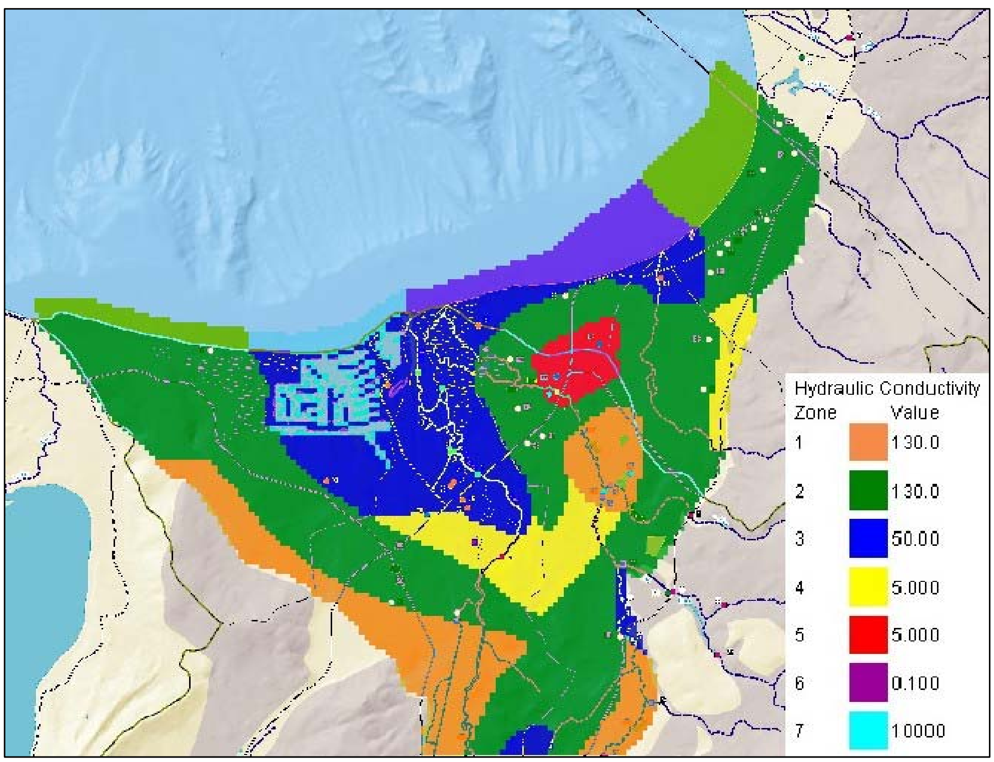
Finally, following selection of an appropriate and feasible load reduction scenario, TMDL regulations require that we develop an implementation plan, which includes a monitoring plan to track our progress and assist us in modifying our approach if necessary. The implementation plan will present a detailed process for achieving load reductions, beginning with current loads and resulting in the required reductions over an agreed-upon timeframe. Milestones will include interim load reductions at specified, regular intervals. The diagram below shows that the Implementation Plan will include watershed- and water body-based indicators and milestones and a Performance Evaluation Protocol. The Performance Evaluation Protocol will provide a systematic means for evaluating the effectiveness of the Implementation Plan and for making adjustments as necessary. It will incorporate evaluations of TMDL science, implementation and management. With sufficient resources to fully implement Phase II and to initiate Phase III, we believe that management and planning for restoring Lake Tahoe's historical clarity will be well on its way.



ARMY CORPS TO THE RESCUE: TWO KEY STUDIES COMPLETED

The U.S. Army Corps of Engineers has released draft reports on two projects that will contribute greatly to the effort to identify, quantify, and ultimately reduce key sources of pollutants that impair Lake Tahoe's clarity. The two sources being evaluated by the Army Corps and their associated researchers are groundwater and stream channel erosion. On August 18, 2003, the researchers presented their findings to a meeting of interested parties. The draft final reports are available at the Army Corps' "Lake Tahoe Basin Framework Study" Internet website, at http://www.spk.usace.army.mil/civ/tahoe/gw_study_draft_final.html and http://www.spk.usace.army.mil/civ/tahoe/tahoestream_draft_final.html, respectively. The reports are currently being revised in response to comments and will soon be issued in final form at the websites above.

The **Groundwater Evaluation** included a review of available nutrient data from existing wells and an assessment of likely inflow and nutrient loading from five regions comprising the entire lake shoreline. Due to the importance of groundwater as a drinking water source in the South Lake Tahoe region, sufficient data existed for the Army Corps to develop a groundwater model that simulates flow to the lake between Taylor Creek and Stateline. This model was used in conjunction with existing nitrogen and phosphorus concentration data from local wells to calculate annual nutrient loading to the lake in four distinct subregions and five discrete vertical layers within this area. Around the remainder of the lake's perimeter, sufficient data on geology and on groundwater elevation were not available to develop such a sophisticated model. Groundwater flow was estimated in these areas. An important conclusion from this report was that groundwater flow was a more critical factor than concentration in determining total nutrient loads into the lake.



Area of South Lake Tahoe in which groundwater movement to the lake was modeled, showing estimated values of hydraulic conductivity (in feet/day) for a soil layer approximately 25-50 feet below the surface.

The report estimates total dissolved nitrogen and total dissolved phosphorus loading to Lake Tahoe at 50,800 kg and 6,800 kg per year, respectively. Using these estimates to revise the existing nutrient budget for Lake Tahoe (see "Research and Data Collection" in Fall 2002 newsletter), groundwater represents 13 percent of the annual nitrogen load and 15 percent of the annual phosphorus load to the lake. Given the inherent uncertainties in determining groundwater flow rates and concentrations, these results compare very well with those obtained in previous studies, such as a 1997 U.S. Geological Survey report that estimated these values at 15 and 10 percent, respectively. Another finding of particular interest is that ambient or natural background loading may represent a substantial fraction of these total loads: possibly as much as 65 percent of phosphorus loading and 25 percent of nitrogen loading. If accurate, this suggests that urbanization has had a much larger effect on nitrogen contamination of groundwater than on phosphorus contamination.

Finally, the report qualitatively evaluates several potential sources of groundwater contamination and discusses possible ways to reduce or control these sources. Sources include fertilizers applied to public and private lands, sewage seeping from the collection system and pipes exporting it outside the basin or from abandoned septic tanks, and urban infiltration systems designed to intercept surface storm water runoff and absorb it into the ground. Options for reducing these sources include constructed wetlands where the plants themselves remove nutrients, permeable reactive treatment walls designed to intercept contaminated groundwater plumes, pretreatment of storm water runoff to remove nutrients before it is infiltrated, groundwater pumping to retard or reverse its movement into the lake, and implementation of best management practices, including use of awareness programs that focus on preventing contamination in the first place. Lahontan RWQCB and NDEP will incorporate the Army Corps' loading estimates into our Lake Clarity model, and will consider their evaluation of treatment and source control measures in developing our matrix of load reduction opportunities, as mentioned in the previous article.

U.S. Army Corps of Engineers Groundwater Evaluation team members include: (front row) Suzette Ramirez, Carolyn Meza, Meegan Nagy, Paige Caldwell, and Scott Gregory, and (back row) Phil Brozek, Tim Crummett, and Lew Hunter. (Team members not pictured include: Jon Fenske, Mak Shatila, JJ Baum, Teresa Rodgers, Melissa Kieffer, and Glenn Cox.)

USDA's National Sedimentation Laboratory (NSL) in late July released the draft **Sediment Loadings and Channel Erosion Report**. This report is the first comprehensive basin-wide evaluation of stream channel erosion and its related sediment contributions to Lake Tahoe. In contrast to upland processes such as sheet and rill erosion, for which most BMPs are designed, stream channel erosion mobilizes and transports sediment due to in-stream processes such as stream bank failure and channel-bed scour. Although these processes occur naturally, they can be greatly accelerated by watershed disturbances such as urbanization, timber harvesting, and grazing, among others. Streams typically exist in a state of dynamic equilibrium, as stream channels were created in response to relatively constant hydrologic patterns over time. This dynamic equilibrium can be upset as a result of changes in stream energy caused by channel modifications and increased flow rates resulting from more impervious surfaces. As a result, streams begin to seek a new equilibrium by modifying themselves to accommodate the increased stream energy.

Prior to this investigation, stream channel erosion was suspected to be a significant sediment contributor, but there was very little information available to indicate the magnitude of this erosion process and its resulting sediment contributions. Now that we are beginning to understand the role of sediment in reducing lake clarity, as illustrated in the following article in this newsletter, stream channel erosion may be considered a significant source of clarity-reducing soil particles. This study was designed to investigate this often overlooked source by combining detailed geomorphic (or stream channel-stability) evaluations, numerical modeling, and extensive review and compilation of a wealth of existing water quality monitoring data.

Part of the USDA ARS National Sedimentation Laboratory research team – Principal Investigator Dr. Andrew Simon on right with modeler Dr. Robert Wells

The NSL report methodically summarizes and evaluates existing historical water quality monitoring information, including the extensive Lake Tahoe Integrated Monitoring Program (LTIMP) database. This information was used to develop annual suspended sediment loads and yields for thirty-two locations around the Lake Tahoe Basin. As one might imagine, suspended sediment loads and yields vary greatly from year to year, from west to east, and from north to south across the basin. In general, sediment loading is higher during periods of increased stream flow. Stream flow is related to precipitation, and the northern and eastern areas of the basin receive less precipitation relative to the western and southern areas. Based on historical data reviewed in this report, median annual suspended sediment loads in the Lake Tahoe Basin range from 2200 tonnes per year (T/y) from the Upper Truckee River to 3 T/y from Logan House Creek. Computing annual sediment yields allowed NSL to determine sediment production per unit area in a watershed. Median annual sediment yields range from 66.4 T/y/km² in the Blackwood Creek watershed to 0.6 T/y/km² in the Logan House catchment area.

In combination with this review of historical data, field data were collected to support several aspects of this report. Given that the research scope covered the entire basin, it was essential that as much information as possible be collected first hand to evaluate channel, upland, and sediment-transport conditions throughout the basin. The magnitude and extent of stream channel erosion was determined using a number of different methods, including direct comparison of historical stream channel cross-sections, reconnaissance surveys of geomorphic conditions, and in-situ geomorphic assessments. Field surveys were used as input for numerical models to estimate the amount of total suspended sediment loads attributable to stream channel erosion. Model outputs were then calibrated and validated using the LTIMP data sets to make sure the models were simulating environmental conditions correctly.

Section of eroding stream bank along the Upper Truckee River. Exposed roots give an indication of the amount of soil loss.

As a result of these combined efforts, the NSL report reached several significant conclusions. One finding is that suspended sediment loads and yields due to stream channel erosion have been decreasing over time and that this decrease is expected to continue into the future. This is particularly useful, and encouraging, to TMDL developers determining basin-wide sediment sources and their magnitude. Some areas of the basin have seen dramatic decreases in sediment loading since the late sixties and early seventies, when the basin was experiencing rapid development. The study also concludes that the major storms in January 1997 appear to have flushed out stream channels, resulting in generally lower transport rates since then.

In the other hand, disturbed watersheds contribute considerably more suspended sediment in relation to adjacent, undisturbed watersheds. For example, General Creek is considered a "reference" stream for water quality monitoring because of a lack of significant disturbance in its watershed. General Creek watershed yields 9 T/y/ km^2. In contrast, yields from nearby Blackwood Creek and Ward Creek watersheds, which have experienced greater disturbance, are 66 and 34 T/y/ km^2, respectively. Disturbed watersheds also tend to generate a larger percentage of their suspended sediment loads from in-stream erosion processes than do undisturbed watersheds. The General Creek watershed generates 78% of its fine sediment contribution to Lake Tahoe from upland slopes and only 22% from in-stream sources, while the Upper Truckee River contributes as much as 51% of its fine sediment load from in-stream sources.

The NSL report quantifies the magnitude of sediment loading from stream channel erosion for the first time. This will allow NDEP and Lahontan RWQCB to identify stream channel erosion as a discrete pollutant source in the TMDL. This also enables resource managers to better manage this source of pollutants, by identifying areas of high erosion for prioritized restoration.

OPTICAL SUB-MODEL LOOKING GOOD, CONFIRMS IMPORTANCE OF FINE SEDIMENTS

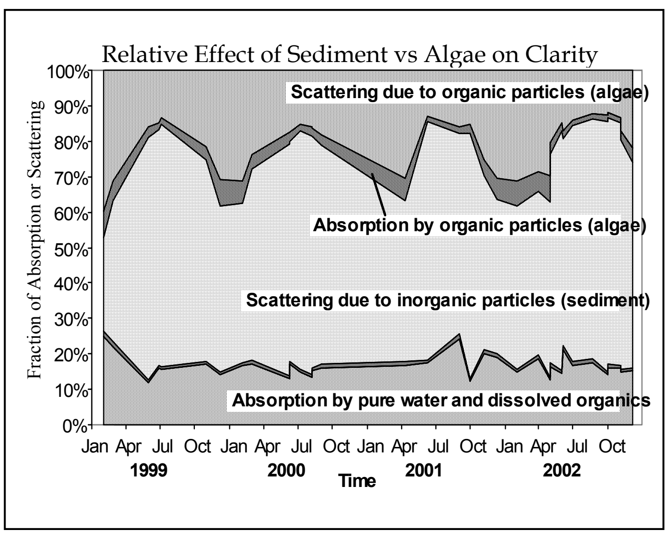
The Tahoe Clarity Model consists of four major component sub-models, (1) a *hydrodynamic sub-model* that simulates vertical mixing within the lake and stream inputs to the lake, (2) a *water quality sub-model* that describes how nutrients cycle, dissolved oxygen swings, and inorganic particles aggregate and sink, (3) an *ecological sub-model* that represents how organic particles (primarily phytoplankton algae) grow, die and settle out, and (4) an *optical sub-model* that predicts Secchi depth based on the number of particles, particle size and particle composition. This final component directly links the impact of particles (algae and fine sediment) to established water clarity standards.

Work on the optical sub-model has resulted in a number of interesting findings. Key developments and findings from this work were presented in poster form at the August Lake Tahoe Restoration Forum. Modelers have found that the optical sub-model agrees very well with observed Secchi depth measurements from the field. From 1999 to 2002, complete sampling for algal biomass, particle size distribution and particle composition was undertaken on 39 individual dates distributed throughout the seasons. The model captures the major seasonality of intra-annual changes in Secchi depth. When all four years of data are combined, the observed and predicted Secchi depths are nearly equal. To see if possible year-to-year differences had been masked by analyzing all the data simultaneously, observed versus modeled Secchi depth were then evaluated for each year independently. The results show a relative difference of less than 10 percent for any year, with a value of approximately 5 percent more common (see table above). These are very encouraging results. A description of the work has been sent for peer review to Dr. Steve Chapra of Tufts University, who is an international authority on lake modeling.

Secchi Depth (meters), mean ± standard deviation

	1999	2000	2001	2002	All Data
Observed	21.9±6.2	20.4 ±2.6	22.6 ±3.0	24.3 ±2.0	22.5 ±3.8
Modeled	22.5±4.1	21.7 ±1.9	23.8 ±4.5	22.1 ±2.8	22.4 ±3.2
RPD	2.74%	6.37% *	5.31%	-9.05% **	-0.44%

RPD = Relative Percent Difference; * means different at 0.05 confidence level; ** means different at 0.10 confidence level.



Using the Optical Sub-Model, the UC Davis modeling team also found that during the study period, observed Secchi depth was primarily the result of fine sediment (60% on average; see the lightest area in the adjacent graph), algae (25%) and dissolved organic matter (15%). This confirms the 1999 publication by the Tahoe Research Group that first suggested the importance of fine sediment to the Lake's clarity. These results also underscore the fact that controlling both fine sediment and nutrients will be important to the recovery of lake clarity.

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