United States Department of Agriculture

Forest Service

Pacific Southwest Research Station

September 2011

Tahoe Science Update Report

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The Forest Service of the U.S. Department of Agriculture is dedicated to the principle of multiple use management of the Nation's forest resources for sustained yields of wood, water, forage, wildlife, and recreation. Through forestry research, cooperation with the States and private forest owners, and management of the National Forests and National Grasslands, it strives—as directed by Congress—to provide increasingly greater service to a growing Nation.

Cover photo: Trout Creek, South Lake Tahoe, CA. Photo by Tiff van Huysen.

Preface

The Tahoe Science Update Report, 2011 provides an overview of completed, current, and new research projects in the Lake Tahoe Basin. The report focuses specifically on research projects supported by the **Tahoe Science Program** through funding from the Southern Nevada Public Land Management Act (SNPLMA) administered by the Bureau of Land Management and projects funded through the **Nevada** Division of State Lands **Lake Tahoe License Plate Program**. The report also identifies the Round 12 science themes and subthemes pending approval by the Secretary of the Interior as well priority research issues for agencies in the Lake Tahoe Basin. The electronic version of the report may be found on the USDA Forest Service-Pacific Southwest Research Station Tahoe Science Program website; the electronic version contains hyperlinks to publications and websites associated with the Tahoe Science Program.

Funding provided in part by
NATIONAL SYSTEM OF PUBLIC LANDS
SOUTHERN NEVADA PUBLIC LAND MANAGEMENT ACT
www.blm.gov/snplma

Notes:

1. Lead Investigators or contacts for projects are identified when known.
2. Hyperlinks to project websites and documentation (i.e., final reports, publications, and presentations) are provided for projects where available. Please try the hyperlinks and accessing publications on your own. If you do not have free access to publications through an academic institution or other entity or you are still unable to access documentation, please contact the Tahoe Science Program Coordinator for assistance. All hyperlinks were checked prior to publication of this report.
3. Hyperlinks and full names (e.g., of agencies or programs) are repeated throughout the report in the event that the report is not read in its entirety.
4. **The linked project titles in Appendix A will take you to the page within this report that contains the corresponding project description**.
5. **Reports, publications, and presentations are listed with their associated project description within the report**. Additional publications relevant to the Tahoe Basin are listed in Appendix B. A publication's digital object identifier (doi) is provided where available.
6. An attempt has been made to highlight the key results of projects that have been completed. Please consult the final reports for completed projects to obtain the results in their entirety. Expected completion dates for continuing or new projects are current but may not reflect recent requests to the USDA Forest Service-Pacific Southwest Research Station or the Bureau of Land Management regarding project timelines. Please contact the Tahoe Science Program Coordinator if you have questions or concerns regarding a project's expected completion date.
7. Projects funded through the Nevada Lake Tahoe License Plate Program are identified using the following symbol:

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INTRODUCTION

History of Research in the Lake Tahoe Basin

The Sierra Nevada region, including the Lake Tahoe Basin, is ecologically, socially, and politically complex. These complexities create unique opportunities and challenges for land managers, researchers, policymakers, and a multitude of other stakeholders with regards to natural resources management. Historical land use activities in the Sierra Nevada (e.g., Comstock era logging) coupled with more current activities (e.g., fire suppression, urbanization), have created ecosystems that are less resilient and less resistant to disturbances such as wildfire and insect and disease outbreaks. These ecosystems are also potentially vulnerable to climate change and its associated impacts (e.g., changes in hydrologic regimes). There is a need for management strategies aimed at restoring and maintaining the ecological integrity of these systems. However, these strategies must be formulated within a framework that accounts for multiple uses of forest lands and the multiple perspectives and values represented by the diverse group of entities invested in the Sierra Nevada region and the Tahoe Basin (e.g., federal, state, local, and tribal governments, federal and state agencies, nonprofit organizations, and private landowners). The Environmental Improvement Program (EIP) and the Lake Tahoe Restoration Act (LTRA) structured such a framework. Both the EIP and the LTRA identified Lake Tahoe and the surrounding basin as a unique natural resource that requires protection, preservation, and restoration. The EIP and LTRA also highlighted the need for scientific research to inform management goals and actions and identify uncertainties and knowledge gaps as they relate to the overall objectives of conserving and restoring the Lake Tahoe Basin. The Southern Nevada Public Land Management Act (SNPLMA), enacted in 1998, specifically allowed for funding from the sale of public lands by the Bureau of Land Management (BLM) to be set aside in support of LTRA projects. This funding supported both capital projects and agency-sponsored research projects.

In 2006, the USDA Forest Service-Pacific Southwest Research Station (PSW) became the sole federal agency sponsor and assumed responsibility of administering the SNPLMA funding as it related to research projects in the Lake Tahoe Basin. This resulted in the creation of the Tahoe Science Program, which strives to promote applied, timely, relevant research that addresses natural resource management needs in the basin. Through a competitive grant award program, the Tahoe Science Program identifies and facilitates funding of research projects high in technical merit and relevant to land management and regulatory agencies working in the Tahoe Basin. As part of the grant award program, the Tahoe Science Consortium (TSC) coordinates a competitive review process. The TSC and PSW work closely with one another throughout the review process to ensure that the review process is fair and that the research projects recommended for funding represent high quality science while addressing priority issues indentified by agencies. Thus, through the Tahoe Science Program, PSW has an important role as the liaison between researchers and agencies working in the basin. In addition, PSW and the TSC work to promote outreach, synthesis, and integration activities to ensure that research supported by the Tahoe Science Program addresses key management questions, includes input from agencies, produces tools that are useful and accessible, fosters collaboration and communication, builds on previous research, and ultimately addresses the science needs identified in the EIP. See Table 1 for a comparison of Lake Tahoe resource theme areas identified in Lake Tahoe Basin planning documents and reports, including the EIP.

Table 1. Comparison of resource theme areas in Lake Tahoe Basin plans. Adapted from *An integrated science plan for the Lake Tahoe Basin: conceptual framework and research strategies* (General Technical Report PSW-GTR-226, 2010, Hymanson and Collopy, editors).

TRPA 1987 Regional Plan: threshold categories	2000 Lake Tahoe watershed assessment	Pathway planning process	Environmental Improvement Program—update	Lake Tahoe science plan theme areas
Air quality	Air quality	Air quality	Improving air quality and transportation	Air quality
Soil conservation/ stream environment zone (SEZ)	Upland water quality/sediment and nutrient discharge	Soil conservation and SEZ habitats	Habitat and vegetation	Soil conservation
Water quality	Water quality	Water quality	Stormwater management	Water quality
Vegetation	Biological integrity and aquatic resources	Vegetation and fuels	(1) Forest health and fuels management (2) Habitat and vegetation	Ecology and biodiversity
Wildlife		Wildlife and fisheries	(1) Habitat and vegetation (2) Watershed management	
Fisheries			(3) Threatened, endangered, and sensitive species	
—	Socioeconomics	Socioeconomics	—	
Recreation		Recreation	Enhancing recreation and scenic resources	
—	—	Transportation	Improving air quality and transportation	Integrating the social sciences in research planning
Scenic resources	—	Scenic quality and resources	Enhancing recreation and scenic resources	
Noise	—	Noise	—	—
—	—	—	—	—
—	Adaptive management strategy	Lake Tahoe adaptive management system	Program support and applied science program	Science plan framework and overview conceptual model

Administration of the Tahoe Science Program

USDA Forest Service-Pacific Southwest Research Station

As the sole federal sponsor and agency responsible for administering the SNPLMA funding for the Tahoe Science Program, the USDA Forest Service-Pacific Southwest Research Station (PSW) issues the Request for Proposals each fall. Submitted proposals undergo an administrative review by PSW to ensure that each proposal meets the requirements set forth in the Request for Proposals and addresses research needs identified by the science themes and subthemes. PSW also issues the annual Tahoe Science

Update Report in the fall and works with the TSC to organize the biennial Tahoe Science Conference as well as other workshops and symposia to address science integration and outreach needs in the Lake Tahoe Basin. PSW also works directly with researchers to organize workshops and training sessions specific to researchers' projects. In addition, PSW coordinates with the Bureau of Land Management to administer funds for and track the progress of Tahoe Science Program research projects.

Tahoe Science Consortium

The Tahoe Science Consortium (TSC) is a unique partnership between two federal agencies and three academic institutions—USDA Forest Service-Pacific Southwest Research Station, U.S. Geological Survey, the Desert Research Institute, University of California-Davis, and the University of Nevada-Reno—dedicated to providing science to restore Lake Tahoe and its fragile watershed, manage its wildland-urban interface, and anticipate the impacts of climate change. The TSC oversees the selection of the science themes and manages the peer and agency review process for the Tahoe Science Program, prepares reports, and sponsors workshops, symposia, and interagency committees to enhance the integration of science in environmental restoration. It also sponsors a biennial Tahoe Science Conference that encourages scientists, engineers, artists, economists, environmental managers, regulators, policy-makers, business owners, federal, state, local and tribal representatives, and the general public from the Sierra Nevada and around the world to exchange ideas and develop collaborations to protect high alpine ecosystems under changing environmental and social climates.

Processes for Selecting Tahoe Science Research Themes and Research Projects

Research themes:

1. In the fall the TSC Committee of Scientists (COS) drafts an initial set of themes and develops these with input from agency representatives on the Partnership Coordination Team (a subcommittee of the Lake Tahoe Basin Executive Committee with representation from the Tahoe Regional Planning Agency [TRPA]). The themes are intended to correlate to themes used in the Tahoe planning efforts identified in Table 1.
2. The TSC directs subcommittees to develop subtheme questions for each of the theme areas.
3. After refining the subthemes, the science themes and subthemes are forwarded to the Partnership Coordination Team for review and approval.
4. Several additional groups, including the Tahoe Working Group, Lake Tahoe Federal Advisory Committee, Tahoe Regional Executives, and the SNPLMA Executive Committee review the themes and subthemes.
5. The Secretary of the Interior approves the themes and subthemes the following fall.

Research projects:

1. After the science themes have been approved by the Secretary of the Interior, PSW releases a Request for Proposals to address the research needs identified by the themes and subthemes. Researchers are allotted 6 to 8 weeks to submit proposals.
2. Proposals undergo an administrative review to ensure that they adhere to the guidelines set forth in the Request for Proposals.
3. Proposals are evaluated based on technical quality using a rigorous external peer review process administered by the TSC.
4. Proposals passing the technical peer review then undergo a relevancy review to evaluate whether the proposals will address agency management needs within the Tahoe Basin;

representatives of federal and state management agencies in the basin evaluate the proposals for relevancy.

5. The TSC peer review committee recommends projects to be funded within each theme based upon a synthesis of technical quality and relevancy, subject to funding availability.

Other Tahoe Science Program-Relevant Activities

Science and Management Integration Team

The Science and Management Integration Team (SMIT) is a standing group of agency representatives and scientists that meets regularly to exchange leading-edge scientific findings and evolving management issues. Its goal is to identify, prioritize, recommend, and communicate research and monitoring activities to accelerate the restoration of Lake Tahoe. Recently SMIT members developed fact sheets for the 2011 Lake Tahoe Summit, held in August, highlighting the integration of research and management with respect to aquatic invasive species (AIS), air quality, forest health, lake clarity, streams and meadows, and the Tahoe Science Program.

Nevada Division of State Lands Lake Tahoe License Plate Program

Lake Tahoe license plates are available through the Nevada Department of Motor Vehicles. The fees collected from the sale of these license plates go into a dedicated Lake Tahoe fund administered by the Nevada Division of State Lands. These funds are used to support projects and programs aimed at preserving or restoring the natural environment of the Lake Tahoe Basin. Similar to, though independent from, the Tahoe Science Program, the Lake Tahoe License Plate Program uses a competitive review process and addresses the goal of restoring Lake Tahoe through the EIP. This program funds public education outreach, water quality improvement projects and research, state park improvements, invasive species research and removal projects, and other research and monitoring studies. Several research and monitoring studies funded through the license plate program are relevant to the Tahoe Science Program and its science themes. Summaries of these studies are included under relevant headings in this report.

RESEARCH

The Tahoe Science Program supports applied research specific to the Lake Tahoe Basin that addresses the science needs identified in the EIP. This research addresses a diverse array of topics; 95 projects have been funded through this program in Rounds 5-11 in addition to support for the TSC (see Figure 1). Tahoe Science Program projects range from applied, hypothesis-driven research to synthesis work to the development of tools to help managers plan and evaluate management actions with respect to preservation and restoration goals.

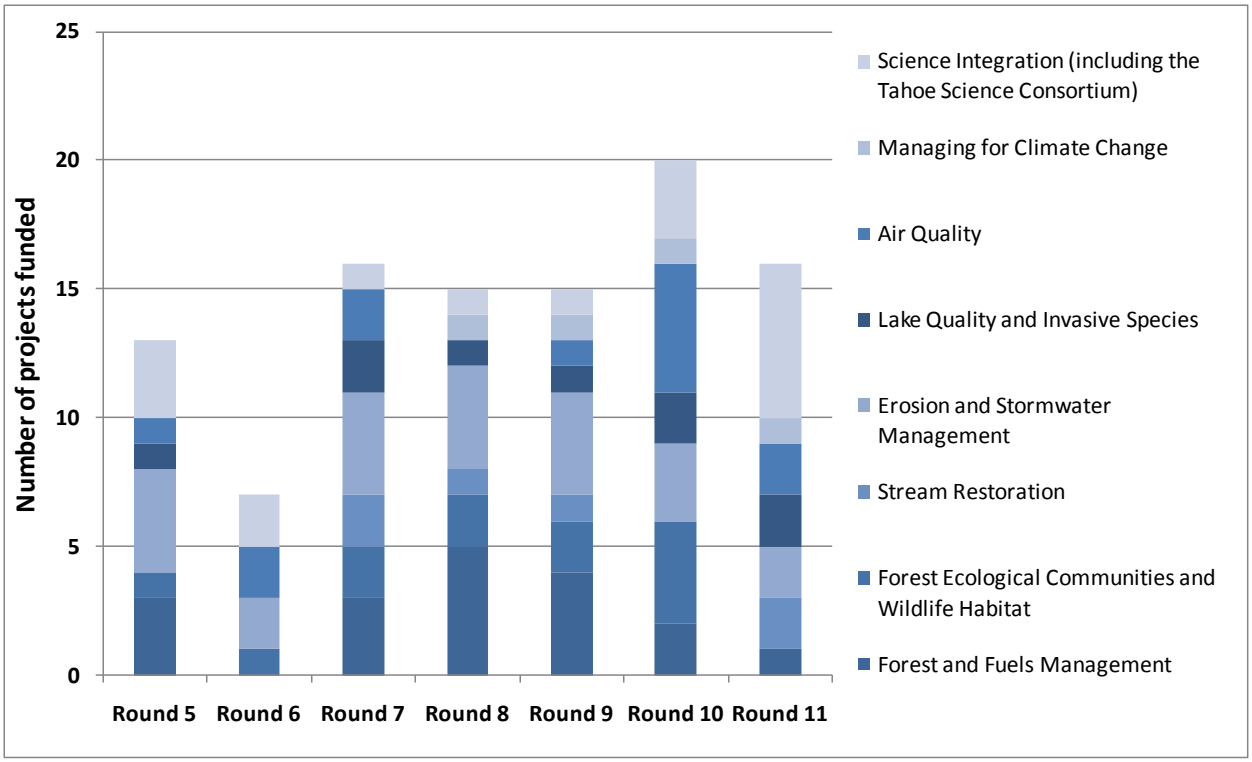

Figure 1. Number of applied science projects supported through the Tahoe Science Program with funding from the Southern Nevada Public Land Management Act by round and science theme area. Projects from Rounds 5 and 6 were categorized relative to the theme areas from Rounds 7-11.

Forest Health

Forest health research in the Lake Tahoe Basin covers numerous areas including: 1) vegetation management; 2) prescribed burning; 3) wildfires; 4) fuels management; 5) forest restoration; 6) soils; 7) genetics; 8) conservation; 9) insects and disease; 10) wildlife; 11) air quality; 12) water quality; and 13) climate change. Previous and current research projects seek to understand processes associated with forest ecosystems, how management actions impact forest ecosystems and other natural resources, and how forest ecosystems may respond to environmental change.

Completed Projects—Forest Health

ROUND 5

Riparian and upland fuels reduction monitoring

The USDA Forest Service-Lake Tahoe Basin Management Unit (LTBMU) has implemented numerous monitoring programs with respect to fuels reduction treatments. Please visit the Publications page on the LTBMU website for a current list of reports. The reports may be downloaded in PDF format.

Evaluation of wildfire and prescribed fire effects on water quality

This project, sponsored by the USDA Forest Service-Lake Tahoe Basin Management Unit (LTBMU) and implemented by the University of Nevada-Reno, was completed in 2008. This project addressed the impacts or potential impacts of alternative fire regimes on the transport of nutrients from uplands to Lake Tahoe via surface runoff. The researchers developed an ecological simulation model for analyzing the effects of varying fire regimes on nutrient cycling in forests throughout the Tahoe Basin. Key findings include: 1) the hypothesis that nitrogen (N) cycling dynamics are dominated by fire events more than by

decomposition processes is generally supported; 2) fire exclusion in the Tahoe Basin has likely increased litter and total ecosystem N and phosphorus (P) above their levels under historical fire regimes; and 3) leachate N has likely decreased due to lack of fire events associated with large pulses in N availability. The results from this project suggest that management strategies, such as prescribed fire, that reduce litter biomass will potentially reduce N and P in surface runoff.

Publications associated with this project:
Weisberg, P.J., S. Ganschow, W.W. Miller and D.W. Johnson. 2008. Validation of a landscape-level simulation model for analysing biomass management impacts on forest ecosystems. Final report to USDA Forest Service-Lake Tahoe Basin Management Unit, South Lake Tahoe, CA. 45 p.

ROUND 7

Analysis of 15 years of data from the California State Parks Prescribed Fire Effects Monitoring Program
Lead Investigators: *Alison Stanton and Bruce Pavlik (BMP Ecosciences)*
This study analyzed the existing Fire Monitoring Handbook (FMH) dataset to evaluate the effects of prescribed fire treatments on vegetation composition and structure, fuel loading, and potential fire behavior in mixed conifer stands. This study also evaluated the effectiveness of the California State Park fire monitoring program and provides recommendations for future monitoring efforts. A large number of key findings are presented in the final report with respect to forest structure and composition, fuel accumulation, and understory vegetation response. Monitoring recommendations are also provided for Malakoff Diggins State Park, Plumas-Eureka State Park, and Lake Tahoe Basin state parks. The final report is available on the USDA Forest Service-Pacific Southwest Research Station website.

Potential nutrient emissions from prescribed fire in the Lake Tahoe Basin
Lead Investigators: *Paul Verburg, Rick Susfalk, and Lung-Wen Antony Chen (Desert Research Institute)*
This field and laboratory study assessed carbon (C) and nitrogen (N) release as affected by fuel moisture during a prescribed fire near Incline Village (NV) following mechanical thinning. The field component of this study involved a pre- and post-fire fuel inventory to estimate C and N losses under fall fuel moisture conditions. The laboratory component of the study further investigated effects of moisture on nutrient release and speciation. Key results include: 1) total fuel reductions were close to 90% and C and N losses closely followed patterns in fuel mass reductions; 2) Soil extractable ammonium (NH_4^+) increased immediately following fire, but we no clear trends were observed for extractable nitrate (NO_3^-); and 3) increasing fuel moisture caused increases in total particulates, including $PM_{2.5}$ and C and N species, and gaseous ammonia (NH_3) emissions for several fuel types. Based on these results, the investigators suggest the following management implications: 1) treatments when fuel moisture is low will likely maximize fuel consumption while minimizing air quality impacts; and 2) dry burns increase fuel consumption which will reduce C sequestration; however, they also favor conversion of fuels to CO_2 which is an important greenhouse gas. The final report is available on the USDA Forest Service-Pacific Southwest Research Station Tahoe Science Program website.

Publications associated with this project:
Chen, L.-W. A., P. Verburg, A. Shackelford, D. Zhu, R. Susfalk, J.C. Chow and J.G. Watson. 2010. Moisture effects on carbon and nitrogen emission from burning of wildland biomass. Atmospheric Chemistry and Physics. 10:1–9. doi:10.5194/acp-10-1-2010

Workshop: Vegetation management in sensitive areas of the Lake Tahoe Basin
In 2008, the Tahoe Science Consortium held a workshop on vegetation management in the Tahoe Basin. During the workshop, agency representatives discussed their perspectives on vegetation management in

sensitive area designations of the Tahoe Basin. Case studies were presented and participants contributed to an open discussion regarding issues, concerns, and approaches to vegetation management. Based on these discussions, an independent panel generated a report (see link below) with recommendations for fuels treatments that address issues highlighted during the discussions, such as the regulatory structure in the basin, the need for management, monitoring, and tools specific to sensitive areas, fuel reduction workforces, outreach efforts, and the costs of fuel reduction treatments.

Publications associated with this workshop:
Miller, W., W. Elliot, B. Hartsough and S. Stephens**.** Independent panel review from Vegetation management in sensitive areas of the Lake Tahoe Basin: a workshop to evaluate risks and advance existing strategies and practices, March-April, 2008, Tahoe Center for Environmental Studies, Incline Village, NV.

Effects of fuels management in the Tahoe Basin: a scientific literature review
The USDA Forest Service-Pacific Southwest Research Station and the Tahoe Science Consortium produced a literature review in 2009 on the effects of fuels treatments on air quality, water quality, soils, vegetation, and wildlife in the Tahoe Basin. The report is available using the link above.

ROUND 8

Developing FCCS fuelbeds for the Angora fire region
Lead Investigators: *Roger Ottmar (USDA Forest Service-Pacific Northwest Research Station), Hugh Safford (USDA Forest Service-Pacific Southwest Region)*
The Fuel Characteristic Classification System (FCCS) was used to develop a set of past, current, and future fuelbeds for the USDA Forest Service-Lake Tahoe Basin Management Unit (LTBMU). Through group consensus of LBTMU managers, six major fuelbed types were identified that occur in the basin including: 1) Jeffrey pine-white fir; 2) red fir; 3) wet lodgepole pine; 4) whitebark pine-lodgepole; 5) mountain hemlock; and 6) mixed conifer. Fuelbed pathways were completed for each of the major fuelbed types and 88 fuelbeds were identified for development. Twenty additional fuelbeds were identified and developed to represent unique vegetation types that did not fall within the six fuelbed types. The fuelbeds were constructed using baseline fuelbeds provided within the FCCS and modified for local application using scientific and gray literature, photo series, plant association and forest community guides, and community descriptions. A fuelbed pathway handbook was compiled that includes the six fuelbed types, pathway schematics, fuelbed names and descriptions, fire behavior estimates and general photographs assigned to the fuelbeds. Thirty-one of the major fuelbeds and 20 of the unique fuelbeds were crosswalked to vegetation attributes from the Classification and Assessment with Landsat of Visible Ecological Groupings (CALVEG) data set and mapped for the LTBMU. The fuelbed pathway handbook, FCCS fuelbeds, and fuelbed map were presented at the meeting, “A Symposium on Forest Management Decision Support Tools,” held in 2010 at Incline Village, Nevada and at a workshop conducted the following day. Defining and mapping important fuelbeds for the LTBMU will enable managers to better plan restoration and wildlife habitat projects and account for potential fire hazard, smoke from wildland fire, and carbon. The final report is available on the USDA Forest Service-Pacific Southwest Research Station Tahoe Science Program website.

Plant community characterization and ranking of fens in the Lake Tahoe Basin
Lead Investigator: *Julie M. Evens (California Native Plant Society)*
The California Native Plant Society (CNPS) has produced a vegetation classification, map, and quantitative ranking of sites containing fens and wet meadows in the Lake Tahoe Basin.

Fen sites are classified by vegetation type diversity and presence of rare species; the sites are ranked with respect to ecological integrity and quality. The intent of the ranking system is to assist land managers with recognizing high priority fen sites for maintenance and restoration. The final report is available on the USDA Forest Service-Pacific Southwest Research Station Tahoe Science Program website.

Plant and animal responses to fuel treatments
Contacts: *Patricia Manley (USDA Forest Service-Pacific Southwest Research Station), Dennis Murphy (University of Nevada-Reno)*
National Forest System (NFS) land sites and four Nevada State Park sites were sampled for birds, small mammals, large mammals, ground-dwelling invertebrates, butterflies and plants. The data was analyzed to assess the effects of fuel reduction activities on wildlife potential, the long-term ecological trajectory of forests, and wildlife habitat. Key findings from the Nevada State Park sites include : 1) there were moderate changes in live vegetation as a result of treatments; 2) there was a greater impact on non-living components of vegetation (i.e.; snags and logs); and 3) wildlife exhibited no clear patterns of response to the treatments. A larger report that includes the state and NFS parcels will be produced at a later date. The final report is available on the Nevada Division of State Lands Lake Tahoe License Plate Program website.

Current and Continuing Projects—Forest Health

ROUND 7

Restoration and fuel treatment of Lake Tahoe's riparian forests
Lead Investigator: *Malcolm North (USDA Forest Service-Pacific Southwest Research Station)*
This study will determine the Tahoe Basin's historic riparian forest fire regime and stand conditions, and use modeling software to provide specific fuels guidelines for riparian forests while giving managers flexibility in meeting these objectives. Specifically, the research will: 1) determine the pre-suppression fire return interval, fire intensity, and historic stand structure and composition of riparian forests in white fir, mixed-conifer and Jeffrey pine forests of the Tahoe Basin; and 2) use reconstruction information and Fuels Management Analyst software to work with managers to develop targets for surface and ladder fuels by size class for different riparian forests. For most of the basin's riparian forests it is unlikely that frequent prescribed fire can be used to restore historic stand conditions and manage fuels. Given this limitation, managers will still want to mimic pre-suppression stand and fuel conditions because these are likely to restore habitat and fire behavior that have shaped riparian forests. By determining historic fire return interval and intensity and tree growth patterns and ages, stand reconstruction and fuels modeling can provide managers with specific guidelines against which to assess treatments.

Publications associated with this project:
Van de Water, K. and M. North. 2010. Fire history of coniferous riparian forests in the Sierra Nevada. Forest Ecology and Management 260:384-395. doi:10.1016/j.foreco.2010.04.032

Van de Water, K. and M. North. 2011. Stand structure, fuel loads, and fire behavior in riparian and upland forests, Sierra Nevada Mountains, USA: a comparison of current and reconstructed conditions. Forest Ecology and Management. 262:215–228. doi:10.1016/j.foreco.2011.03.026

Current expected completion date: September 2011

Restoring sugar pine in the Tahoe Basin: regeneration ecology and recruitment dynamics of sugar pine under various stand structures

Lead Investigators: *Kristen Waring and Natalie Angell (Northern Arizona University), Kevin O'Hara (University of California-Berkeley)*

Sugar pine (*Pinus lambertiana*), the largest pine tree in the world, has been declining owing to fire suppression, logging and white pine blister rust (*Cronartium ribicola*—a fungal disease introduced from Europe) for the past several decades. Sugar pine is not reproducing in sufficient numbers to sustain some of these populations. This research will develop tools for multi-aged stand management to enhance sugar pine populations and meet fuel reduction and restoration objectives. This project is nearly complete; the final report will be available on the USDA Forest Service-Pacific Southwest Research Station website soon.

Presentations associated with this project:

Angell, N. and K. Waring. Restoring stand structures to promote sugar pine (*Pinus lambertiana*) regeneration. Poster presentation. Society of American Foresters National Convention, September 30-October 4, 2009, Orlando, FL.

Angell, N. and K.M. Waring. Restoration of sugar pine (*Pinus lambertiana*) under various stand structures in the Lake Tahoe Basin, CA & NV. Poster presentation. Southwest Section of the Society of American Foresters Spring Section Meeting, April 17-18, 2009, Eager, AZ.

Current expected completion date: December 2011

Natural and anthropogenic threats to white pines from lower montane forests to subalpine woodlands of the Lake Tahoe Basin: an ecological and genetic assessment for conservation, monitoring, and management

Lead Investigators: *Detlev Vogler and Annette Delfino-Mix (USDA Forest Service-Pacific Southwest Research Station), Patricia Maloney (University of California-Davis), Joan Dunlap (USDA Forest Service-Placerville Nursery), Valerie Hipkins (USDA Forest Service-Institute of Forest Genetics)*

This study will create an ecological and genetic assessment for developing conservation and management strategies for white pines, given a changed and changing environment due to white pine blister rust (WPBR), mountain pine beetle, climate variability, past logging, and fire exclusion. The objectives of this study are: 1) establish a network of ecological monitoring plots in lower montane mixed-conifer forests (focal species-sugar pine), upper montane forests (focal species-western white pine), and subalpine woodlands (focal species-whitebark pine) in the USDA Forest Service-Lake Tahoe Basin Management Unit (LTBMU) to identify population structure and evaluate stressors associated with each of the 3 focal species; 2) identify population genetic structure and diversity, and WPBR-resistance frequency, for populations of each focal species; 3) develop demographic models to determine population dynamics; and 4) develop and test the efficacy of conservation and restoration strategies. With the information gathered, conservation and restoration treatments can be developed for populations that show impacts on genetics (low diversity, little or no rust resistance) and population dynamics (declining due to lowered recruitment and reproduction).

Publications associated with this project:

Maloney, P.E., D.R. Vogler, A.J. Eckert, C.E. Jensen, and D.B. Neale. 2011. Population biology of sugar pine (*Pinus lambertiana* Dougl.) with reference to historical disturbances in the Lake Tahoe Basin:

implications for restoration. Forest Ecology and Management 262:770–779. doi:10.1016/j.foreco.2011.05.011
Current expected completion date: June 2012

ROUND 8

Upland fuel reduction treatments in the Lake Tahoe Basin: forest restoration effectiveness

Lead Investigators: *Patricia Manley (USDA Forest Service-Pacific Southwest Research Station), Bruce Pavlik and Alison Stanton (BMP Ecosciences). Dennis Murphy (University of Nevada-Reno)*

The goal of this study is to provide forest managers with rapid feedback on the effectiveness and biotic response of hand and mechanical fuel reduction treatments currently being implemented in the specific forest types found in the lower montane zone in the Lake Tahoe Basin. The study will complete the evaluation of the effects of different fuel reduction treatments on vegetation composition and structure, fuel loading, modeled fire behavior, and animal species and communities (vertebrate and invertebrate). Helping managers in understanding how these elements respond to treatments is essential before they can address regional key management questions as identified in the Sierra Nevada Forest Plan Amendment Record of Decision (SNFPA ROD 2004). In the long term, this project will provide critical project-level data that managers can use to plan future treatments and schedule re-treatments. The reporting out of this effort will evaluate and streamline protocols, and develop indicators that managers can use in fuel treatment reduction prescriptions, in project implementation, and in performance assessment.

Current expected completion date: August 2012

Developing fuels treatments for balancing fuel reduction, soil exposure, and potential for erosion in the Tahoe Basin

Lead Investigators: *Andrew Stubblefield and J. Morgan Varner (Humboldt State University), Eric Knapp (USDA Forest Service-Pacific Southwest Research Station), Mark Grismer (University of California-Davis)*

The Angora fire brought attention to the need for fuel reduction treatments: mastication and prescribed fire to reduce the threat of catastrophic wildfire in the Lake Tahoe Basin. However, there is concern that these treatments could increase erosion rates, potentially impacting lake clarity. The goals of this study are to: 1) understand erosion thresholds in order to determine the optimal levels of surface fuel retention with mechanical mastication and prescribed fire treatments that maximize fire hazard/ fire severity reduction goals while minimizing the threat of erosion and sedimentation; and 2) understand the mechanisms by which burn patchiness (including sediment capture in islands of unburned fuel) can be created even under the current high fuel loading and fuel continuity in Tahoe Basin forests by linking fuel moisture with timing of prescribed fire and the pattern of the resulting burn. A runoff simulation experiment was conducted at 16 sites within the basin. The experiment imitated snowmelt by dripping 540 liters of water onto the top of 5 x 2 m erosion plots over the course of 36 minutes. Runoff was collected and weighed and sediment concentrations and particle sizes determined. At each site, plots were established covering a range of litter and duff cover and depth. The purpose of these plots was to measure erosivity and determine if a level of cover could be established that would minimize fire spread and fire line intensity, while still being sufficient to trap water and sediment within the plot. Results indicate that very minimal residual cover in both masticated and prescribed fire settings are sufficient to minimize erosion. The project is nearing completion and a draft final report is in preparation.

Presentations associated with this project:
Andrew Stubblefield presented results from field experiments associated with this project at the Lake Tahoe Interagency Monitoring Program (LTIMP) meeting on March 2, 2011 at the Tahoe Regional

Planning Agency office in Stateline, NV. The presentation was titled, "Erosion from fuel reduction and prescribed burn activities in the Lake Tahoe Basin: results from field experiments."
Current expected completion date: December 2011

Identifying spatially-explicit reference conditions for forest landscapes in the Lake Tahoe Basin, USA
Lead Investigators: *Alan Taylor (Penn State University), Carl Skinner (USDA Forest Service-Pacific Southwest Research Station), Hugh Safford (USDA Forest Service-Pacific Southwest Region)*
This study will: 1) identify the relationships among spatial variability in presettlement forest structure (composition, density, basal area, size structure), topographic variables, and spatial variability in fire regimes (fire return interval, season of burn) in the lower and upper montane forest zones of the Lake Tahoe Basin; and 2) develop a spatially explicit reconstruction of the presettlement forest landscape conditions and associated fire regimes for the Lake Tahoe Basin that can be used by land managers in restoring forest ecosystems. The results from this study will be used to generate digital geographic information system (GIS) data and maps of the presettlement forest landscape and presettlement forest compositional group summaries, including digital data on stand density, basal area, and tree diameter distributions.

Current expected completion date: September 2012

Nutrient and sediment loading predictions for prescribed fire using optimized WEPP model
Lead Investigators: *Drea Traeumer (Em Hydrology, LLC), Randy Foltz (USDA Forest Service-Rocky Mountain Research Station)*
This project will optimize the Water Erosion Prediction Project (WEPP) model and predict sediment and nutrient loadings from slash pile burning at the hillslope scale using rainfall simulators and *in situ* sample collectors for naturally occurring events. The investigators will be running another round of rainfall simulations in the fall of 2011 to obtain data for both the fall and spring seasons.

Current expected completion date: March 2012

Modeling the influence of management actions on fire risk and spread under future climatic conditions
Lead Investigators: *Matthew Hurteau and George Koch (Northern Arizona University)*
This project will update the Forest Vegetation Simulator (FVS) using a process-based model (3-PG) to predict species-specific tree growth rates under future climate scenarios. Management treatment impacts on changing Tahoe Basin forest conditions will then be examined using the spatially-explicit landscape model, Simulating Patterns and Processes at Landscape Scales (SIMPPLLE). These tools will facilitate engagement with land managers to identify which forest treatments can be practically implemented and how these treatments will influence the risk and spread of stand-replacing fire.

Current expected completion date: September 2012

ROUND 9

Evaluating alternative fuel treatments in the South Shore wildland-urban interface area
Lead Investigators: *Morris Johnson and Roger Ottmar (USDA Forest Service-Pacific Southwest Research Station)*
This project will develop fuels data and management alternatives needed to reduce fire hazard in the South Shore Project of the USDA Forest Service-Lake Tahoe Basin Management Unit (LTBMU), Tahoe National Forest. Using an integrated approach that links two commonly used tools-the Fire and Fuels

Extension to the Forest Vegetation Simulator (FFE-FVS) and the Fuel Characteristic Classification System (FCCS), a range of management alternatives appropriate for application in the wildland-urban interface (WUI) will be developed. Alternatives will include various combinations of forest thinning and surface fuel treatments, including the effect of treatments over time. Reducing fire hazard in the WUI is a high priority in the Lake Tahoe Basin. This approach will provide a clear, visual means of communicating WUI management alternatives to resource managers, local residents, and decision makers and will be applicable for other planning areas in the Lake Tahoe Basin WUI areas such as the Incline Hazardous Fuels Reduction and Forest Health Restoration Project. To date, the investigators have collected stand exam data, obtained GIS data, worked with programmers to discuss programming of the FFE-FVS and the FCCS, and have built a shrub and non-woody vegetation database.

Current expected completion date: October 2012

Silvicultural prescriptions to restore forest health

Lead Investigators: *Patricia Manley and Malcolm North (USDA Forest Service-Pacific Southwest Research Station), Dennis Murphy and T. Will Richardson (University of Nevada-Reno)*

This study will design and test a silvicultural prescription that leaves a clustered distribution of trees that more closely mimics historical distributions while also reducing fuels to determine the benefits gained in ecological restoration and the sacrifices made in altering fire behavior. It will also test the relative effects of the two prominent slash treatments: pile and burn and mastication. This study will examine the interaction of two overstory (regular canopy tree spacing [fire emphasis] and clustered tree retention [restoration emphasis]) and two understory (mastication and pile and burn) treatments and a control on measures of forest function (vegetation, soil properties, truffles), biological diversity (birds, small mammals, ants, invertebrates), and habitat and prey for key wildlife species of special concern (Northern Goshawk [*Accipiter gentilis*], California Spotted Owl [*Strix occidentalis*], and American marten [*Martes americana*]). To date, the investigators have conducted vegetation sampling, built databases, and validated small mammal data.

Current expected completion date: December 2013

Integrated decision support for cost-effective fuel treatments under multiple resource goals

Lead Investigators: *Greg Jones, Jody Bramel, Edward Butler, William Elliot, Kurt Krueger, and Janet Sullivan (USDA Forest Service-Rocky Mountain Research Station), Pablo Aracena, Woodam Chung, Marco Contrerassalgado, Solomon Dobrowski, and Carl Seielstad (University of Montana)*

Many communities in the Lake Tahoe Basin are at high risk for damage from wildfire. The USDA Forest Service-Lake Tahoe Basin Management Unit (LTBMU) and other land management agencies in the basin have collectively developed multi-jurisdictional fuel reduction and wildfire prevention strategies to address severe wildfire threats. Such strategies, however, have not yet been thoroughly evaluated in terms of fuels treatment effects on fire behavior, water quality, ecosystem processes, as well as their cost-effectiveness. There are a number of models that can address some of these effects independently, but the collective effects of fuels treatments have been neither addressed, nor incorporated into a decision making system for fuels management in the basin. There is a critical need to merge these systems into one decision support tool that streamlines analyses for identifying where, when, and how to treat to maintain desired fuel reduction and ecological goals, while meeting given resource and operational constraints. This project will develop an integrated decision support system and apply it in the Lake Tahoe Basin. This support system will combine the vegetation simulation capabilities of the Fire and Fuels Extension to the Forest Vegetation Simulator (FFE-FVS), the fire behavior capabilities of FlamMap, the water quality prediction capabilities of Forest Service Water Erosion and Prediction

Project (FS WEPP), and the spatial scheduling and cost effectiveness analysis capabilities of Multiple-resource Analysis and Geographic Information System (MAGIS) into one system. This will provide land managers the ability to spatially schedule fuel treatments on a landscape and to also analyze tradeoffs of different management strategies. The investigators are finalizing the Lake Tahoe Basin model application, including the associated OptFuels website and user documentation. The investigators will hold a final workshop to deliver the OptFuels system in late fall 2011 or spring 2012.

Presentations associated with this project:
Greg Jones, Jody Bramel, and Kurt Krueger led a workshop for Lake Tahoe Basin land managers on May 17-18, 2011 at the USDA Forest Service-Lake Tahoe Basin Management Unit office in South Lake Tahoe, CA to introduce the OptFuels system and obtain input from managers to optimize the tool for the Lake Tahoe Basin.

Current expected completion date: March 2012

Effects of pile burning in the Tahoe Basin on soil and water quality
Lead Investigators: *Ken Hubbert and Matt Busse (USDA Forest Service-Pacific Southwest Research Station), and Steve Overby (USDA Forest Service-Rocky Mountain Research Station)*
Pile burning has been adopted by most agencies to reduce fuels and fire hazard in the Tahoe Basin. From 1998 to 2007, a total of 11,708 acres have been mechanically- or hand-thinned with resulting slash piled and burned. Whether this practice results in detrimental changes in soil and water quality across a significant percentage of the treated area is unclear. Guidelines for pile burn size, spacing, and distance from stream environment zones (SEZs) are especially needed in the Tahoe Basin. This study will quantify the downward heat pulse for an assortment of pile sizes and conditions typical of Tahoe Basin burning. The resilience of key soil physical, chemical, and biological properties will be monitored for a two-year period following pile burning, and nitrate (NO_3^-) and phosphate PO_4^{3-}) movement in surface and subsurface runoff will be quantified.

Presentations associated with this project:
Hubbert, K., M. Busse, S. Overby, and C. Shestak. Soil heating beneath burn piles: effects on soil physical properties and water chemistry in the Lake Tahoe Basin. Poster presentation. ASA, CSSA, and SSSA International Annual Meetings, October 31-November 4, 2010, Long Beach, CA.

Current expected completion date: July 2012

Biodiversity response to burn intensity and post-fire restoration
Lead Investigators: *Patricia Manley and Angela White (USDA Forest Service-Pacific Southwest Research Station), Dennis Murphy and T. Will Richardson (University of Nevada-Reno)*
A high priority of forest management in the Lake Tahoe Basin, and throughout the west, is to reduce the risk of catastrophic wildfire. Forest management, the intensity of wildfire, and post-fire restoration activities all have direct and indirect effects on habitat suitability and quality, which can be additive or ameliorative. This study is building upon existing efforts examining pre- and post-Angora fire data to increase the sample size, improve the representation of various combinations of fire intensity and post-fire restoration treatments, include invertebrate sampling, and extend sampling to span a total of three years post-fire. The results of the study will aid in the challenge of retaining and restoring on-site biodiversity and determining how to manage future burned areas to enhance habitat and population recovery. Investigators have surveyed sites for birds using bird point counts, conducted nest searches, conducted small mammal trapping, and collected invertebrates at new sites. Vegetation data has also

been collected at new sites, including wildlife use. Databases have been built for the new project components and all the small mammal, bird, and vegetation data have been entered into the database and validated.

Current expected completion date: December 2012

Evaluation of montane forest genetic resources in the Lake Tahoe Basin: implications for conservation, management, and adaptive responses of *Pinus monticola* to environmental change

Lead Investigators: *Detlev Vogler and Annette Delfino-Mix (USDA Forest Service-Pacific Southwest Research Station), Patricia Maloney and David Neale (University of California-Davis)*

Forest trees species are primary terrestrial ecosystem components and conservation of their genetic resources warrants special attention. This study will evaluate the adaptive genetic diversity of forest resources in the Lake Tahoe Basin to detect the sensitivity and potential vulnerability of populations of *Pinus monticola* (western white pine) to environmental change (introduced organisms, climatic warming, and climate-driven outbreaks of native insects). Identifying patterns of adaptive variation at the landscape-level will constitute a valuable tool to design conservation, management, and forest health monitoring strategies for forest tree species. This study will take an ecological and genetic approach to better understand the interaction of landscape characteristics (geology, climatic gradients, soil properties) and evolutionary processes (gene flow, selection) on ecologically important plant traits (water-use efficiency, disease resistance, phenology, and growth) of western white pine across the USDA Forest Service-Lake Tahoe Basin Management Unit (LTBMU), to determine the adaptive potential of this forest tree.

Current expected completion date: September 2013

ROUND 10

Stocking guidelines for aspen restoration

Lead Investigators: *John-Pascal Berrill and Christa Dagley (Humboldt State University)*

Quaking aspen forest communities in the Lake Tahoe Basin are being encroached and out-competed by conifers that impact aspen vigor and stifle natural regeneration. Removal of conifers has been advocated, and is being tested around the Tahoe Basin. However, little is known about stocking and treatment persistence: specifically, how much growing space must be provided for aspen trees and their root sucker regeneration for vigorous growth to be sustained until the next restorative thinning? This research will provide aspen stand data and a decision support system for Tahoe Basin land managers involved in aspen restoration. The project will quickly generate interim stocking guidelines for restorative thinning treatments in aspen stands, followed by a rigorous analysis of growth, regeneration, and thinning response in aspen stands. The analysis culminates in development of a transparent, user-friendly stocking assessment model that will support management decision making for restoration treatment design and scheduling of future treatments.

Current expected completion date: October 2013

Evaluation of montane forest genetic resources: implications for conservation, management, and restoration of whitebark pine (*Pinus albicaulis*) in the Lake Tahoe Basin

Lead Investigators: *Detlev Vogler and Annette Delfino-Mix (USDA Forest Service-Pacific Southwest Research Station), Patricia Maloney and David Neale (University of California-Davis)*

This study will evaluate the adaptive genetic diversity of forest resources in the Lake Tahoe Basin to detect the sensitivity, resiliency, and potential vulnerability of populations of white pines species (sugar

pine, western white pine, and whitebark pine) to an introduced and invasive pathogen, *Cronartium ribicola* (causal agent of white pine blister rust, WPBR), climatic warming, and climate-driven outbreaks of native insects. Identifying patterns of adaptive variation at the landscape-level will constitute a valuable tool to design conservation, restoration, and forest health monitoring strategies for these forest tree species. An ecological and genetic approach will be used to better understand the interaction of landscape characteristics (geology, climatic gradients, soil properties, physiognomy) and evolutionary processes (gene flow, selection) on ecologically important plant traits (disease resistance, water use efficiency/drought adaptation, phenology, and growth). This approach will allow the adaptive genetic variation and potential to be determined, as well development of effective restoration and silvicultural strategies with local, diverse, and rust-resistant planting stock.

Current expected completion date: May 2013

ROUND 11

Adaptive management handbook and tools for vegetation management and estimation of pollutant loading from forested catchments

Lead Investigators: *Michael Hogan (Integrated Environmental Restoration Services, Inc.), Mark Grismer (Vadose Zone Hydrology and University of California-Davis)*

Efforts to reduce catastrophic fire potential in the Lake Tahoe Basin have resulted in a significant disparity between those efforts and efforts to minimize fine sediment particle (FSP, <16 µm) loading to Lake Tahoe under the Lake Tahoe Total Maximum Daily Load (TMDL). Logging and other vegetation management practices have potential to increase erosion and associated FSP loading to surface waters. This research will directly measure impacts of various vegetation management practices on soil function, hydrology and FSP transport, develop a set of cost-effective mitigation measures where impacts exist, and produce an adaptive management-based process and handbook for managers that will translate this data and other relevant studies into Tahoe Basin-specific planning, implementation and assessment tools. Field-measured data will be provided to reduce uncertainty and add credibility to hillslope- and catchment-scale modeling efforts (Water Erosion Prediction Project [WEPP] and others). A field-tested, scientifically-defensible handbook will integrate this information and data, thus supporting land managers in making more informed treatment decisions.

This research will develop a framework and process for translating the results of many recent, ongoing and upcoming research projects on the impacts of specific vegetation management practices, including burn piles and mechanical treatments, into useful tools for managers. This project complements previously funded Southern Nevada Public Land Management Act (SNPLMA) projects, including the Round 7 project, "Assessing the sources and transport of fine sediment in response to management practices in the Tahoe Basin using the WEPP Model ," the Round 8 projects, "Developing fuels treatments for balancing fuel reduction, soil exposure, and erosion potential in the Tahoe Basin," and "Nutrient and sediment loading predictions for prescribed fire using optimized WEPP model," and the Round 9 project, "Effects of pile burning in the Tahoe Basin on soil and water quality."

Current expected completion date: October 2013

Restoration strategies for whitebark, western white, and sugar pine in the Lake Tahoe Basin: ecological and epidemiological considerations

Lead Investigators: *Detlev Vogler and Annette Delfino-Mix (USDA Forest Service-Pacific Southwest Research Station), Patricia Maloney (University of California-Davis)*

Links with ecosystem health, resource conservation (vegetation, soil, and water), and biological diversity are central to the health of Lake Tahoe. The white pine species – whitebark (*Pinus albicaulis*), western white (*P. monticola*), and sugar pine (*P. lambertiana*) are important components in low to upland forest communities. Interactions among anthropogenic disturbances such as historical logging and fire suppression, an exotic pathogen (*Cronartium ribicola*, cause of white pine blister rust [WPBR]), and climate-driven outbreaks by *Dendroctonus ponderosae* (mountain pine beetle) have significantly affected populations of white pines in lower montane, upper montane and subalpine forests. White pine blister rust is one of the greatest threats to white pine sustainability and survival. In the Lake Tahoe Basin this invasive pathogen is significantly affecting recruitment potential and survival of small and intermediate-sized trees. Such adverse demographic effects can have long-lasting consequences on population structure and dynamics. Comstock era logging, in some locations, has reduced effective population numbers and genetic variation of sugar pine. Both influences (i.e., WPBR and historical logging) can significantly affect how these species respond to other stressors, such as global climatic change. Strong evidence of negative population and genetic effects warrants white pine restoration in the Lake Tahoe Basin. Mitigating anthropogenic influences will require restoring effective population numbers, deploying WPBR-resistant material, 'facilitating' recruitment, enhancing genetic variation, and planting drought-tolerant genotypes.

This research complements the Southern Nevada Public Land Management Act (SNPLMA) Round 7 project, "Natural and anthropogenic threats to white pines from lower montane forests to subalpine woodlands of the Lake Tahoe Basin: an ecological and genetic assessment for conservation, monitoring, and management," the Round 9 project, "Evaluation of montane forest genetic resources in the Lake Tahoe Basin: implications for conservation, management, and adaptive responses of *Pinus monticola* to environmental change," the Round 10 project, "Evaluation of montane forest genetic resources: implications for conservation, management, and restoration of whitebark pine (*Pinus albicaulis*) in the Lake Tahoe Basin," and the Nevada Division of State Lands Lake Tahoe License Plate Program, "Conservation, management, and adaptive responses of Sugar pine to environmental change." These studies will provide valuable information about suitable plant material for deployment in restoration projects for current and future environmental conditions in the Lake Tahoe region.

Current expected completion date: June 2014

Tree health within the Lake Tahoe Basin: interactions with fuel management treatments
Contact: *Bob Nowak (University of Nevada-Reno)*
The purpose of this project is to: 1) quantify the incidence and severity of tree diseases, pathogens, and other biotic and abiotic damaging agents on Nevada State Park and USDA Forest Service-Lake Tahoe Basin Management Unit (LTBMU)lands within Nevada; 2) quantify changes in incidence and severity of tree diseases, pathogens, and other damaging agents in areas that have been treated by the Nevada Division of Forestry and LTBMU; and 3) to use remote sensing technology to quantify tree crown damage to different fuel treatments. This project should assist land managers in evaluating the efficacy of fuel reduction treatments, determine how tree health varies with tree density, tree diameter and soil type and to provide an efficient and repeatable remote sensing protocol to quantify and monitor tree crown mortality.

Current expected date of completion: December 2011

Evaluation of montane forest genetic resources in the Lake Tahoe Basin
Contact: *Patricia Maloney (University of California-Davis)*
The objectives of this project are to: 1) determine the patterns of adaptive genetic variation across the Lake Tahoe Basin for genes controlling ecologically important plant traits (water-use efficiency, disease resistance, phenology, and growth) by genotyping individual adult sugar pines; and 2) determine the underlying genes that control adaptive phenotypic traits using an association genetics approach (phenotype and determine phenotypic plasticity of sugar pine individuals for water-use efficiency, disease resistance, phenology, and growth). Identifying patterns of adaptive variation at the landscape level will constitute a valuable tool to design conservation, management (restoration or reforestation) and forest health monitoring strategies for this tree species in the Tahoe Basin.

Current expected completion date: December 2011

Round 12 Forest Health Subthemes

Informing decisions for multi-objective forest management

Management and/or Policy Need

The Tahoe Fire Commission Report (2008) identified a need for resource managers and regulators to obtain tools that help them to better evaluate alternative strategies for reducing fire risk to public safety, property, and the environment. Current and future forest management activities may include hand thinning, cut-to-length harvest, whole tree removal, cable logging, mastication, chipping, understory and/or pile burning, road management, and defensible space practices. Well-designed decision support tools and systems can help to improve the planning and evaluation of forest treatment projects across diverse landscapes. Effective tools and systems also can generate shared understanding between implementers and regulators regarding risks, costs, and benefits of treatment alternatives. Innovative tools are needed to help design projects that meet all relevant forest management objectives including reducing wildfire risk, improving forest health and wildlife habitat, conserving native biodiversity, and protecting or improving of air quality, soil quality, and water quality (especially reducing fine sediment and nutrient loads that threaten lake clarity).

Description

Research is needed to refine, and/or validate tools, models, or sampling methods designed to improve forest management decision-making, which includes: 1) strategic planning; 2) project-level environmental impact analyses; 3) estimating the effects of treatment programs; and 4) implementation of the Lake Tahoe Total Maximum Daily Load (TMDL). To improve broad-scale long-term planning, research is particularly encouraged that will create linkages among existing decision support tools and result in integrated products that will aid in planning and evaluating forest management projects or programs to best achieve multiple relevant management objectives, while meeting applicable constraints. Research also is encouraged that leads to tools and decision support systems to better evaluate the economics of alternative strategies for managing forest vegetation, considering factors such as access, transportation routes and impacts, regulatory constraints, and potential ecological impacts unique to the Tahoe Basin. To improve project-level environmental impact analysis, or to estimate the effects of treatment programs, existing research could be synthesized and/or new field research conducted to validate and improve the accuracy of model outputs used to evaluate project or program effects. Research to improve TMDL implementation should help to better account for the potential impacts of forest management activities and wildfire on lake clarity. Research should include

efforts to collaborate with agency representatives and/or other research teams to ensure the products are well-supported and useful.

Improving WEPP-based analyses of forest management activities at the watershed scale

Management and/or Policy Need

Current and future forest management activities may include hand thinning, cut-to-length harvest, whole tree removal, cable logging, mastication, chipping, understory and/or pile burning, road management, and defensible space practices. Well-designed analytical tools, such as the Water Erosion Prediction Project (WEPP) suite of computer models, can be used to improve the planning and evaluation of forest treatment projects across diverse landscapes, and generate shared understanding between implementers and regulators regarding risks, costs, and benefits of treatment alternatives, particularly with regard to water quality impacts. At present, the WEPP suite of computer models is sufficiently robust to allow relatively rapid completion of complex evaluations of individual hillslopes, but not multiple hillslopes and features forming a complex watershed including roads and landings; the latter can be accomplished only by expert modelers using a research-grade version of WEPP. There is a management need for a validated, user-friendly, web-based, Tahoe Basin-specific, watershed version of WEPP. It must be sufficiently robust to help design and evaluate projects to ensure that they meet all relevant forest management and regulatory objectives related to water quality (e.g., fine sediment and nutrients).

Description

Research is needed to produce and validate a user-friendly, web-based, Tahoe Basin-specific, watershed version of WEPP. It must be sufficiently robust to help design and evaluate projects to ensure that they meet all relevant forest management and regulatory objectives related to water quality (i.e., fine sediment and nutrients). Research under this subtheme must include time and resources to support direct collaboration with both the USDA Forest Service-Lake Tahoe Basin Management Unit (LTBMU) and regulatory agencies throughout development of the specific research products. Research should specifically include tasks to support model validation using existing data, and to run a variety of simulations aimed at informing agencies of model sensitivity and limitations. Any existing data used for model validation or calibration must have been collected using ASTM methodologies, or shown through peer-reviewed studies to have been collected using valid and broadly accepted scientific methodologies. Integration of existing WEPP models, existing and emerging datasets, and other recognized building-blocks are strongly encouraged.

Impact of climate change on ecological communities and the evaluation of adaptation strategies

Management and/or Policy Need

Climate change is expected to broadly affect the Sierra Nevada in coming decades. Management agencies want to understand how ecological communities within the Lake Tahoe Basin, including forest communities, alpine communities, subalpine wetlands and other sensitive communities, will respond to these changing conditions over the next several decades. Current science emphasizes that adaptation strategies should be site-specific. Adaptation strategies could include thinning of forests to increase tolerance to drought and resistance to wildfire or insects, planting species or genotypes that may be more resilient to changing climate, genetic conservation of certain species, preservation of refugial habitats (including wetlands and riparian areas), assisted migration of species to suitable habitat, and development of wildlife corridors to facilitate migration. Such actions could be taken in anticipation of future changes or opportunistically following disturbances such as wildfires.

Description
New research and/or syntheses of previous research are needed to address one or more of the following issues: 1) establish the potential range of key climate conditions relevant to ecological processes and biological communities in the Tahoe Basin; 2) identify which ecological processes and biological communities in the Tahoe Basin are most vulnerable to the effects of climate change; 3) evaluate the effects of basin-specific adaptation strategies and treatments to conserve particular ecological processes and biological communities; and 4) guide the temporal and spatial design of forest treatments to avoid unacceptable ecological impacts while promoting long-term desired conditions (particularly in the Jeffrey pine, mixed-conifer, and lodgepole forest community types).

Watersheds, Habitat, and Water Quality

The Watersheds, Habitat, and Water Quality science them spans a wide range of research areas including (but not limited to): 1) habitat improvement and conservation; 2) aquatic and terrestrial invasive species; 3) stormwater characterization, management, and treatments; 4) stream restoration; 5) lake ecology; 6) watershed processes, restoration, and management; 7) water quality, including pollutant characterization, management, and reduction; 8) nearshore ecology and processes; 9) erosion; and 10) development, refinement, and assessment of modeling tools and monitoring standards and protocols.

Completed Projects—Habitat

ROUND 5

Role of urban forests in conserving and restoring biological diversity in the Lake Tahoe Basin

This study was sponsored by the USDA Forest Service-Lake Tahoe Basin Management Unit (LTBMU)and the Nevada Division of State Lands Lake Tahoe License Plate Program. The objectives of this study were to: 1) determine the effects of fragmentation and disturbance on the occurrence, abundance, composition, and productivity of vertebrates, vascular plants and select invertebrate species in an urbanizing landscape; 2) evaluate the potential for landscape-level thresholds of species persistence for select focal species based on the amount, distribution and quality of habitat; 3) investigate the validity of species expected to be strong indicators based on intrinsic characteristics based on empirical data; and 4) develop a predictive model that evaluates the relative effects of various acquisition, restoration, and development scenarios on individual species, species groups, and biological diversity.

Publications associated with this project:

Manley, P.N., S.A. Parks, L.A. Campbell and M.D. Schlesinger. 2009. Modeling development as a continuum to address fine-grained heterogeneity in urbanizing landscapes. Landscape and Urban Planning, 89:28-36. doi: 10.1016/j.landurbplan.2008.09.005

Manley, P. N., D.D. Murphy, L.A. Campbell, K.E. Heckmann, S. Merideth, M. Sanford, and M.D. Schlesinger. 2005. Biotic diversity interfaces with urbanization in the Lake Tahoe Basin. California Agriculture 60(2):59-64. doi: 10.3733/ca.v060n02p59

Manley, P.N. and D.D. Murphy. 2004. Roles of urban forests in conserving and restoring biological diversity in the Lake Tahoe basin: Interim Report 2003. Unpublished report. USDA Forest Service-Lake Tahoe Basin Management Unit, South Lake Tahoe, CA.

Manley, P. N. and D. D. Murphy. 2004. Roles of urban forests in conserving and restoring biological diversity in the Lake Tahoe basin: Interim Report 2004. Unpublished report. USDA Forest Service-Lake Tahoe Basin Management Unit, South Lake Tahoe, CA.

Development and evaluation of tools for monitoring ecosystem and species diversity across landscapes

Sponsored by the USDA Forest Service-Lake Tahoe Basin Management Unit (LTBMU), this project developed the Multiple Species Inventory and Monitoring (MSIM) protocol to provide a consistent and efficient method for obtaining basic presence/absence data and associated habitat condition data for a large number of individual species at sites that represent a probabilistic sample. It is designed to be implemented in association with Forest Inventory and Analysis (FIA) grid points on National Forest System lands.

Publications associated with this project:

Holthausen, R., R.L. Czaplewski, D. DeLorenzo, G. Hayward, W.B. Kessler, P. Manley, K.S. McKelvey, D.S. Powell, L.F. Ruggiero, M.K. Schwartz, B. Van Horne, and C.D. Vojta. 2005. Strategies for monitoring terrestrial animals and habitats. General Technical Report. GTR-RMRS-161. USDA Forest Service-Rocky Mountain Research Station, Fort Collins , Colorado, USA. 34 p.

Manley, P.N., B. Van Horne, J.K. Roth , W.J. Zielinski, M.M. McKenzie, T.J. Weller, F.W. Weckerly, and C. Vojta. 2006. Multiple species Inventory and monitoring technical guide. General Technical Report WO-GTR-73. USDA Forest Service-Washington Office, Washington, D.C., USA. 204 p.

Manley, P.N., M.D. Schlesinger, J.K. Roth, and B. Van Horne. 2005. A field-based evaluation of a presence-absence protocol for monitoring ecoregional-scale biodiversity. Journal of Wildlife Management 69(3):950-966. doi:10.2193/0022-541X(2005)069[0950:AFEOAP]2.0.CO;2

Manley, P.N. and B. Van Horne. 2005. The Multiple Species Inventory and Monitoring protocol: a population, community, and biodiversity monitoring solution for National Forest System lands. *In* C. Aguirre-Bravo and others, eds. Monitoring science and technology symposium: unifying knowledge for sustainability in the Western Hemisphere. 2004 September 20-24; Denver, CO. Proceedings RMRS-P-37CD. Fort Collins, CO: USDA Forest Service-Rocky Mountain Research Station. CD-ROM.

Manley, P.N., W. J. Zielinski, M.D. Schlesinger, and S.R. Mori. 2004. Evaluation of a multiple-species approach to monitoring species and ecosystem conditions at the ecoregional scale. Ecological Applications 14(1):296-310. doi: 10.1890/02-5249

Roth, J.K., P.N. Manley, M.M. McKenzie, M.D. Schlesinger. 2004. Multiple-species inventory and monitoring 2002 monitoring report. Unpublished report. USDA Forest Service-Lake Tahoe Basin Management Unit, South Lake Tahoe, CA. 187 p.

Avian nesting success in aspen habitats of the Lake Tahoe Basin

This project collected data on bird-habitat relationships. Please contact Please contact Liz Harrison at Nevada Division of State Lands for more information regarding this project.

Control the proliferation of invasive warm-water fish species in the Lake Tahoe Basin
Contact: *Sudeep Chandra (University of Nevada-Reno)*
The primary goal of this project is to minimize and control the proliferation of non-native warm-water fish species within Lake Tahoe. This project included an assessment of the current distribution of non-native species and their association with native species within the lake and fish habitat surveys to develop a geographic information system (GIS) layer displaying fish distributions in the littoral zone of Lake Tahoe. Key findings include: 1) warm-water fish densities of these fish are very low compared to other ecosystems and can be variable over time; 2) densities of warm-water fish were low around most of the lake with higher densities in some locations such as Meek's Marina and intermediate densities in the Tahoe Keys; 3) anecdotal observations indicate that bass may be in open water areas of the lake; 4) the ability of warm-water fishes to grow, reach maturity and spawn, and compete and/ or prey on native fishes and nonnative crayfish is largely governed by thermal regimes; 5) temperature models showed that all nearshore locations were thermally suitable for invasion of largemouth bass, bluegill, and likely other warm-water fishes; 6) largemouth bass likely utilize vegetation and will establish in nearshore areas containing nonnative water milfoil. The final report provides recommendations to prevent the widespread establishment of bass in Lake Tahoe and is available on the Nevada Division of State Lands Lake Tahoe License Plate Program website.

Development of nearshore fish indicators for Lake Tahoe
Contact: *Sudeep Chandra (University of Nevada-Reno)*
This project developed new metrics to assess short-, mid-, and long-term changes to the nearshore fishery in Lake Tahoe. This information will support evaluation and planning efforts associated with the Tahoe Regional Planning Agency's fisheries threshold which is currently in non-attainment. The results of this study suggest that ultraviolet (UV) transparency of nearshore sites significantly impacts the survival of warm-water fish larvae and could influence whether or not these potentially invasive fish species are able to establish successful spawning grounds in nearshore Lake Tahoe. Three strategic recommendations based on the findings were reported: 1) implement a program to more broadly identify priority non-attainment sites with warm water temperatures and low UV transparency; 2) regularly monitor non-attainment sites for the presence of largemouth bass and other centrarchid nests; and 3) assess what factors are reducing UV transparency in non-attainment sites. The final project report has been submitted; please contact Liz Harrison at Nevada Division of State Lands or Sudeep Chandra at University of Nevada-Reno for a copy of the final report.

An inventory and baseline monitoring of the bird fauna of the Carson Range, with emphasis on the Lake Tahoe Basin Nevada State and adjacent lands
Contact: *Will Richardson (University of Nevada-Reno)*
This project included the sampling of bird fauna across all vegetation and other land cover types, from lake level to summit peaks of the Carson range, and along the eastern slopes of the Carson range to moderate elevations. The sampling was designed to support a future monitoring scheme that uses breeding birds as one taxonomic group to assess environmental changes across the Nevada Tahoe Basin landscape. With the goal of enhancing and protecting Carson Range breeding bird populations and their

habitat, the researchers provide 10 habitat, management, and monitoring recommendations in the final report. The recommendations are based on results from a 2008-2009 survey, as well as a literature survey, discussions with other wildlife professionals working in the range, and the researchers' extensive experience with the avifauna of the Carson Range and the greater Lake Tahoe area. The recommendations are: 1) maintain vegetative structural diversity and habitat complexity; 2) maintain and encourage a diversity of riparian habitat types; 3) maintain conifer forests to limit tree densities; 4) maintain large, pure, viable stands of *Populus* cover; 5) maintain and encourage herbaceous ground cover; 6) maintain and encourage the cover of riparian shrubs, especially willow; 7) limit high-disturbance management activities (e.g., vegetation removal) to the non-breeding season, especially for habitats with limited areal extent in the Carson Range; 8) use standardized monitoring protocols; 9) consider reproductive success when monitoring populations and assessing habitat value; and 10) conduct intensive, long-term monitoring at selected sites. The final project report has been submitted; please contact Liz Harrison at Nevada Division of State Lands for a copy of the final report.

Asian clam pilot removal and monitoring project

Contact: *Sudeep Chandra (University of Nevada-Reno)*

This project was implemented by the Tahoe Regional Planning Agency. Efficacy of diver assisted suction removal, bottom barriers and a combination of both treatments for clam mortality and removal was explored. Researchers also conducted: 1) veliger tows to assess the potential for gamete, trochophore, veliger or pediveliger release as a result of the applied control strategies; and 2) monitoring and laboratory experiments to track changes in growth and biomass of algal blooms. Results from this study indicate: 1) declining algal biomass is due to the presence of clams and not natural decay, therefore clams may impact algal biomass in Lake Tahoe; 2) large clams filter feed at a rate faster than small clams; 3) clams filter algae from water column burrowed and unburrowed; 4) decreases in algal biomass may have cascading negative impacts through the trophic structure; 5) medium-sized clams will burrow deeper than the large and small clams, which prefer 1-6 cm; 6) during low temperature periods in Lake Tahoe fertilization does not occur in Asian clams, nor are there veligers or other Asian clam gamete detected in the water column; 7) clams burrow primarily in the top 6 cm, but were found up to 16 cm, therefore clams may affect the benthic community deeper than just the surface sediments; 8) benthic bottom barriers made of gas impermeable fabric such as ethylene propylene diene monomer (EPDM) are successful in reducing dissolved oxygen concentrations and causing the mortality of the invasive Asian clam (*Corbicula fluminea*), other non-target benthic macroinvertebrates, and has the potential for use in the treatment of dreissenid mussels, specifically the soft-sediment dwelling quagga mussel (*Dreissena bugensis*); 9) dominant taxa in plots (i.e., *C. fluminea*, oligocheates, amphipoda) were significantly reduced immediately after dredging and show increased abundances after warmer temperatures are observed during the summer months; 10) physically harvesting *C. fluminea* is effective in reducing the abundance of this invasive species; however, it also reduces associated invertebrate abundances and causes disruptions to the community structure of the macrobenthos; and 11) the use of a gas permeable fabric such as polyethylene is not suitable for Asian clam treatment since the treatment of Asian clam relies on the mechanism of anoxia-induced mortality through the reduction of dissolved oxygen. The final project report has been submitted; please contact Liz Harrison at Nevada Division of State Lands or Sudeep Chandra at University of Nevada-Reno for a copy of the final report.

Inventory and monitoring of butterflies

Contact: *Will Richardson (University of Nevada-Reno)*

This project was completed in 2008 and included sampling of butterfly fauna in the Lake Tahoe Basin (Nevada State Park lands in particular) and the Carson Range to provide baseline data for the support of a future monitoring scheme that uses butterflies as a taxonomic group to assess environmental change across the Nevada Tahoe landscape. The results of the sampling indicate that of the 103 species known to have occurred in the Carson Range above 1800 m, approximately 81 might now be considered to have currently, formerly, or periodically bred there: 17 as regular or historic non-breeding vagrants or passage migrants, and 6 as rare vagrants. Please contact Liz Harrison at Nevada Division of State Lands for a copy of the final report.

Current and Continuing Projects—Habitat

ROUND 8

The effects of ski resorts in the Lake Tahoe Region of California on population dynamics of the American marten

Lead Investigators: *Keith Slauson and William Zielinski (USDA Forest Service-Pacific Southwest Research Station)*

The project will assess whether ski resorts have a net negative, neutral, or positive effect on marten populations in the Lake Tahoe region by comparing differences between ski areas and control areas in terms of: 1) loss and fragmentation of suitable habitat; 2) marten density; 3) marten seasonal movements; 4) marten age structure and sex ratio; 5) proportion of female martens that reproduce; and 5) marten population stability. To date, the investigators have completed the field work, including live-capture and release, for the initial phases of the study, processed hair samples for genetic analysis, and submitted premolar teeth for aging.

Current expected completion date: December 2011

ROUND 9

Development of a risk model to determine the expansion and potential environmental impacts of Asian clams in Lake Tahoe

Lead Investigators: *Sudeep Chandra (University of Nevada-Reno), Geoffrey Schladow (University of California-Davis), Marion Wittmann (University of California-Davis, now at University of Notre Dame)*

Asian clam is rapidly colonizing Lake Tahoe with the demonstrated potential to alter the ecology of the lake via unprecedented levels of algal biomass in the nearshore, posing a major new threat to Lake Tahoe. This research is motivated by concerns of agency staff requests for assistance in developing control methods, predicting likely future locations for clam colonization, and assessing the impact of clams on both a local and entire-lake scale. The major objectives of this project are to advance the state of the science for freshwater bivalve invasion, and to develop a longer-term risk assessment of Asian clam growth, spread and impact. To date, researchers have: 1) completed benthic surveys along three transects ranging from 2 to 40 meter water depths in variable population density clam sites; 2) processed sediment hand cores from Asian clam beds for nutrient and chlorophyll content, and the distribution of Asian clams within the sediment column by size and frequency; 3) initiated laboratory experiments to assess clam growth and feeding rates; and 4) initiated field-based experiments to assess clam growth and spread.

Current expected completion date: August 2012

ROUND 10

Wildlife habitat occupancy models for project and landscape evaluations in the Lake Tahoe Basin

Lead Investigators: *Patricia Manley, James Baldwin, Ross Gerrard, and Angela White (USDA Forest Service-Pacific Southwest Research Station)*

The Lake Tahoe Basin needs a basin-specific evaluation tool that can provide reliable estimations of species occurrence across landscapes and over time in response to a variety of demands for evaluating current and potential future environmental conditions. The goal of this project is to use existing empirical field data that was collected in a systematic manner in the Lake Tahoe Basin to develop geographic range maps and habitat occupancy models for high priority forest-associated vertebrate species in the Lake Tahoe Basin. Habitat occupancy models will be built because they are more robust than abundance models in that they can account for variation in sampling effort and techniques, and the models are not as sensitive to sample year as abundance models. These models will facilitate site and landscape-scale evaluations of management treatments, climate change, and other change agents that affect forest structure and composition today and in the future.

Current expected completion date: November 2012

Ecological succession in the Angora fire: forest management effects on woodpeckers and keystone species

Lead Investigators: *Patricia Manley (USDA Forest Service-Pacific Southwest Research Station), Gina Tarbill (Sacramento State University)*

Woodpeckers are considered keystone species, due in part to their important role as cavity excavators. This project will investigate the role of primary cavity excavators in the facilitation of colonization of secondary cavity users. Nest webs will be created to investigate how secondary cavity users utilize woodpecker cavities in burned and areas under various restoration treatments. These nest webs illustrate where interrelationships between and among species are strongest, and it will allow predictions on both direct and indirect effects of fire severity and post-fire restoration practices on woodpeckers and secondary cavity users. The Angora burn area has a diversity of forest types that are characteristic of the montane zone in the basin, including Jeffrey pine, white fir, Sierran mixed conifer, red fir, subalpine conifer, and aspen. Thus, the results of this study will be applicable to montane forests throughout the basin and will help guide future forest management in terms of how best to enhance habitat conditions to promote the reestablishment of bird and small mammal communities in burned areas, and enhance conservation strategies of species of special concern in the Lake Tahoe Basin.

Current expected completion date: May 2012

Potential for pathogen growth, fecal indicator growth and phosphorus release under clam removal barriers in the Lake Tahoe Basin

Lead Investigators: *Stefan Wuertz and Geoffrey Schladow (University of California-Davis)*

The project is measuring the impact of clam barriers –rubber sheets that are spread on the bottom of Lake Tahoe to create anaerobic conditions to kill Asian clams – on the survival and re-growth of fecal indicator bacteria (FIB) and potential bacterial pathogens, and the release of soluble reactive phosphorus (SRP) from the anaerobic sediments that are produced through the treatment. The goals of the project are to: 1) establish if FIB can re-grow under low oxygen conditions underneath clam barriers positioned in the lake; 2) perform spiking experiments with fecal material to track the fate of FIB and

two relevant bacterial pathogens, *Campylobacter jejuni* and *Salmonella enteric*; and 3) quantify the release rates of phosphorus from the sediments associated with Asian clam growth in Lake Tahoe. This information is critical to helping agencies make an informed decision about both the benefits and risks of using bottom barriers to contain the spread of priority invasive species, and will be required as part of permitting associated with large-scale deployments of this technology. Researchers have finished conducting preliminary and winter microcosm experiments. An experiment running microcosms with algal biofilms in order to mimic conditions for rubber barriers that are installed during the summer is currently underway.

Current expected completion date: March 2012

Natural and human limitations to Asian clam distribution and recolonization—factors that impact the management and control in Lake Tahoe

Lead Investigators: *Marion Wittmann (University of California-Davis, now at University of Notre Dame), John Reuter and Geoffrey (University of California-Davis), Sudeep Chandra (University of Nevada-Reno)*

The invasive bivalve, Asian clam (*Corbicula fluminea*) is established and spreading in Lake Tahoe. In 2002, low density populations (2-20 individuals per m^2) were observed in the southeastern portion of the lake, and in 2009 densities up to 5000 individuals per m^2 were measured. The major objectives of this research are to: 1) understand the life history (including reproduction and growth) of deepwater clam populations and their relationship with associated benthic macroinvertebrate communities, chlorophyll concentrations, temperature, water currents and nearshore clam populations as a potential source or sink of recruits; 2) develop the relationship between treatment site selection (i.e., low population density site versus high density population center site) and rate of Asian clam recolonization; and 3) perform a cost efficiency analysis of rubber bottom barrier application that is dependent on recolonization rate and site selection. Field work including seasonal collections that relate to the barriers, clam growth experiments, and plankton tows are either complete or ongoing as scheduled. First, second, and third post-barrier removal sampling has occurred and an autumnal sampling is planned for later this year. Physical measurements at Nevada Beach using Acoustic Doppler current Profilers (ADCPs) and temperature data have occurred in the summer, fall and winter and currently the data analysis of these deployments are underway. All information has been communicated to agency participants at Asian Clam Working Group (ACWG) meetings.

Current expected completion date: November 2012

ROUND 11

The ecology of curly leaf pondweed (*Potamogeton crispus*) and the potential for control using bottom barriers in Lake Tahoe

Lead Investigators: *John Reuter (University of California-Davis), Sudeep Chandra (University of Nevada-Reno)*

Aquatic invasive species introduced in recent decades are dispersing and impacting the nearshore of Lake Tahoe. Curly leaf pondweed (*Potamogeton crispus*) was recently discovered in the southern portion of Lake Tahoe and is rapidly expanding along the littoral zone. Because of curly leaf pondweed's recent introduction and restricted range, it is a viable candidate for control or eradication in Lake Tahoe. Understanding the interactions between the ecology and management of an invasive species is essential in developing a successful control program. The major objectives of this project are to: 1) identify the role the "turion bank" of curly leaf pondweed plays in Lake Tahoe waters and the potential for this bank to contribute to the spread of the invasive species; 2) the susceptibility of this bank to the treatment of three kinds of bottom barriers; and 3) recommend and outline the method which should be employed

at the lake to prevent further expansion of the plant. This project directly addresses the need for control and management of this new and aggressive invasive plant species.

The proposed research builds upon an ongoing program in Lake Tahoe to control Eurasian watermilfoil using a combination of bottom barriers and hand removal. The barrier treatment methodology could ultimately improve the ecological health and aesthetic of the nearshore zone. Invasive macrophyte populations of Lake Tahoe are already having an impact to the nearshore water clarity and navigability via biomass accumulation. The efficient management and reduction of invasive aquatic macrophyte populations has the potential to remediate these impacts to the Tahoe nearshore. This project will help inform the Round 10 directed action "Nearshore ecology and aesthetics."

Current expected completion date: August 2013

Science to assist policy decisions regarding the prevention of invasive species: testing the survival and growth of quagga mussel in Lake Tahoe
Lead Investigators: *Sudeep Chandra (University of Nevada-Reno), Kumud Acharya (Desert Research Institute)*
Quagga and zebra mussels are establishing in western waterways with large densities in the Colorado River Aqueduct system and established populations in North Central California. This invasion is already having profound ecological and economic impacts in these ecosystems. There is a debate amongst scientists and managers on whether the current models that predict the distribution of Dreissenid mussels are accurate. Recently, for example, veligers have been detected in Colorado lakes, some of which have low calcium levels. Furthermore, a study in Lake George (New York) suggests that adult mussels are able to grow under low calcium conditions; however, the veliger recruitment determined from settlement bioassays is likely limiting. What will determine a source versus sink population may not be clear and deserves more attention for western water bodies. Current knowledge suggests that Lake Tahoe can support adult mussels for s short period of time; however, whether juveniles, and thus a reproducing population, can sustain is currently unknown. The proposed research will directly assess the habitat suitability of Lake Tahoe and its watershed to support the establishment of quagga mussel by testing the survivability of veliger to sub-adult stage using Lake Tahoe water. This information will be important for supporting the current efforts related to inspection and washing of boats entering Lake Tahoe.

This research is a direct progression from a pilot study funded by the U.S. Army Corps of Engineers and the Tahoe Regional Planning Agency in 2009 and from research that has been conducted on the lake's newest invader, the Asian clam. Currently there are multiple projects that address plant, invertebrate, and fish invasions in the nearshore areas of the lake. Recent study of Asian clam beds suggests elevated levels of calcium and substrate from this invader may promote quagga establishment in the lake. This research expands on the latest information related to clam invasions and will also assist in determining if Asian clam patches and associated clam beds may promote the invasion of quagga mussel. In addition this project will complement the SNPMA Round 9 project, "Development of a risk model to determine the expansion and potential environmental impacts of Asian clams in Lake Tahoe," the Round 10 project, "Natural and human limitations to Asian clam distribution and recolonization—factors that impact the management and control in Lake Tahoe" and the Round 10 directed action, "Nearshore ecology and aesthetics."

Current expected completion date: March 2014

Characterizing mountain lion distribution, abundance, and interactions with prey populations in Nevada

Contact: *Bill Longland (USDA Agricultural Research Service and University of Nevada-Reno)*

The purpose of this project is to obtain essential data to make informed management decisions regarding mountain lions and their prey while providing land-use planners with information to preserve critical habitat and travel corridors in Nevada. This project will: 1) model the genetic structure of mountain lions within Nevada and across state lines to identify distinct subpopulations and determine whether they interact as a metapopluation; 2) examine prey species selection and kill rates of collared lions in select populations; 3) refine and validate the Nevada Department of Wildlife mountain lion population model through extensive ground truthing of model parameters; and 4) determine the relative influence of environmental variables, human impact, immigration and other potentially relevant factors in regulating mountain lion distribution and abundance in different areas of Nevada including the Lake Tahoe Basin.

Current expected completion date: May 2012

Expansion of Asian clams in Lake Tahoe: a risk assessment of spread, habitat choice and potential impact

Contacts: *Sudeep Chandra (University of Nevada-Reno), Marion Wittmann (University of California-Davis, now at University of Notre Dame)*

This project will develop a risk analysis of Asian clam distribution and its environmental impact by examining structure, transport, life history, and energetics of existing populations discovered in Lake Tahoe. The specific objectives are to: 1) determine the environmental parameters that contribute to the establishment and expansion of clam beds; 2) develop a life history-growth model to determine potential growth and reproduction; 3) create a transport model that estimate the most favored pathways of young life stages of Asian clams; and 4) develop a preliminary understanding of clam impact on particle size distribution of phytoplankton and fine sediments.

Current expected completion date: September 2011

Status and distribution of the montane lagomorphs in the Lake Tahoe Basin

Contact: *Dennis Murphy (University of Nevada-Reno)*

This project is designed to understand the distribution of white-tailed jack rabbit in the Lake Tahoe Basin and surrounding areas of the Carson Range. Efforts will be focused on low-angle areas of open vegetation above 2,500 meters in elevation in the Tahoe Basin as well as the Mount Rose/Church/Houghton area and the Freel/Jobs/Jobs Sister area. Sights will be surveyed to determine potential areas of lagomorph activity and cameras will be installed in these locations to document their actual presence. Data collected will be analyzed to produce predictive results on detection probability and management recommendations.

Current expected completion date: September 2011

Natural and human limitations to Asian clam distribution and recolonization
Contact: *Sudeep Chandra (University of Nevada-Reno)*
This research is designed to: 1) study the life strategies of invasive Asian clam to better understand the possible links between shallow and deep water clam populations at Lake Tahoe; 2) study clam recolonization rates after the implementation of a large scale (1/2 acre site) rubber barrier pilot treatment project in Marla Bay and Lakeside Marina (pilot treatment has been separately funded); and 3) evaluate the economic efficiency of the rubber barrier treatment considering recolonization rates, labor costs of the rubber barrier treatment, and the number of treatments needed to maintain desired levels of Asian clam.

Current expected completion date: May 2012

Treatment of high priority noxious weeds in the public rights of way and Nevada State Parks
This project will treat of high priority historical infestations and new populations of surveyed, mapped and monitored noxious weeds on the Nevada side of the Lake Tahoe Basin within public rights-of-way and on Nevada State Park lands. Please contact Liz Harrison at Nevada Division of State Lands for more information regarding this project.

Completed Projects—Stormwater

ROUND 5

Tahoe Basin Regional Stormwater Monitoring Program (Tahoe Basin RSWMP Phase 1)
Lead Investigators: *Alan Heyvaert and Jim Thomas (Desert Research Institute), John Reuter (University of California-Davis), Wally Miller (University of Nevada-Reno), Zach Hymanson (Tahoe Science Consortium, now at California Tahoe Conservancy)*
This project was sponsored by the U.S. Environmental Protection Agency in recognition of the need for a comprehensive regional stormwater monitoring program in the Tahoe Basin to support water quality planning and the needs of the Lake Tahoe Total Maximum Daily Load (TMDL). Phase 1 of RSWMP produced: 1) a synthesized set of RSWMP goals and objectives that represent the mutual needs of regulatory, funding, and implementing agencies; 2) a conceptual plan which provides guidance on what to consider in the development of the detailed RSWMP technical and organizational plan (see citation below); and 3) an initial annotated bibliography for Tahoe Basin stormwater literature (Appendix B in the conceptual plan).

Publications associated with this project:
Heyvaert, A.C., J.E. Reuter, J. Thomas, W.W. Miller and Z. Hymanson. 2008. Lake Tahoe Basin Regional Stormwater Monitoring Program Conceptual Development Plan. Prepared in partnership with the Tahoe Science Consortium (http://www.tahoescience.org/). March 24, 2008.

ROUND 7

Development of a BMP Performance Assessment and Data Analysis System for the Tahoe Integrated Information Management System (TIIMS)
Lead Investigators: *Alan Heyvaert (Desert Research Institute), Marc Leisenring (Geosyntec Consultants), Nicole Beck (2NDNATURE, LLC), Brent Wolfe (Northwest Hydraulic Consultants)*

This project developed the Tahoe Stormwater and best management practice (BMP) Database to guide the collection of consistent and reliable information on stormwater runoff characteristics and Treatment BMP performance around the Tahoe Basin. This database has been developed in support of the Tahoe Regional Stormwater Monitoring Program (RSWMP) to provide a centralized, internet-accessible, reliable source of stormwater data collected by different groups associated with the Lake Tahoe Total Maximum Daily Load (TMDL) and RSWMP efforts. As existing information and new data are uploaded into the database, it will support the continued development, calibration and testing of load reduction models and other stormwater management tools, and it will provide a framework needed for tracking stormwater BMPs implementation, monitoring results, and maintenance activities. The final report will be available on the USDA Forest Service-Pacific Southwest Research Station Tahoe Science Program website soon; until then the report may be obtained from the Tahoe Science Program Coordinator.

Tahoe Basin particle size analysis and protocol development
Lead Investigators: *Alan Heyvaert, Todd Caldwell, and Wendy Trowbridge (Desert Research Institute), Daniel Nover, Geoffrey Schladow, John Reuter (University of California-Davis)*
The objectives of this project were to: 1) assemble and analyze available data on particle size characterization reported for samples taken from Lake Tahoe, from Tahoe Basin streams, and from Tahoe-area urban runoff; 2) conduct a set of comparative tests on the methods currently in use for particle size distribution (PSD) analysis; 3) investigate the use of surrogate measurements to complement or replace the explicit measurement of PSD; and 4) develop guidance for standardized analysis and reporting of new data by various groups. The final report discusses fine sediment particle concentrations in the lake, streams, and stormwater. The report also compares particle size analysis instruments and provides recommended operating procedures for these instruments. The final report will be available on the USDA Forest Service-Pacific Southwest Research Station Tahoe Science Program website soon; until then the report may be obtained from the Tahoe Science Program Coordinator.

ROUND 9

Development of a road cut and fill land-use category for the Pollutant Load Reduction Model (PLRM)
Lead Investigators: *Kevin Drake and Rachel Arst McCullough (Integrated Environmental Restoration Services, Inc.), Mark Grismer (University of California-Davis)*
The goal of this project was to develop the data and tools necessary to improve estimates of pollutant loading and load reductions from road cut and fill slopes. The researchers developed the Road Cut and Fill Slope Sediment Loading Assessment Tool (RCAT), a simple and repeatable field assessment methodology and spreadsheet tool designed to assist the Lake Tahoe erosion control and stormwater community in characterizing the functional condition of road cut and fill slopes and estimating the associated sediment and fine sediment particle (FSP) loading from these areas. The data outputs from this tool (sediment loads and runoff volumes) can be used in conjunction with the Pollutant Load Reduction Model (PLRM) or separately. The final report, RCAT spreadsheet tool, and user's guide are available on the USDA Forest Service-Pacific Southwest Research Station Tahoe Science Program website.

Tahoe Regional Stormwater Monitoring Program (Tahoe Basin RSWMP Initial Implementation)
Lead Investigators: *Alan Heyvaert, Jim Thomas, and Rick Susfalk (Desert Research Institute), John Reuter (University of California-Davis)*
Continuing work on the Tahoe Regional Stormwater Monitoring Program (RSWMP) was supported through Erosion Control Grants via funding for Southern Nevada Public Land Management Act (SNPLMA) capital projects. Phase 2 of the Tahoe Regional RWSMP began in 2009. The objective of Phase 2 was to develop a framework for systematic monitoring and evaluating of urban stormwater and management

practices. Phase 2 resulted in three documents describing the implementation process: 1) Tahoe RSWMP Data Quality Objectives; 2) Sampling and Analysis Plan; and 3) Quality Assurance Project Plan. The documents are available from the Tahoe Science Program Coordinator.

Cultured periphyton: demonstrating an ecologically-based process for nutrient and fine sediment removal in the Lake Tahoe Basin

Contact: *Alan Heyvaert (Desert Research Institute)*

This project demonstrated the effectiveness and applicability of cultured periphyton as an ecologically-based advanced treatment technology to reduce stormwater pollutant loadings in a real world setting located on the Nevada side of the Tahoe Basin. Key results include: 1) between 11–14 grams of phosphorus (P) were removed over a nine month period from an average flow of 9.4 L/minute (2.5 gal/min); average orthophosphate (SRP) levels were reduced by 36 percent (±16%) from already low influent concentrations; average nitrate (NO_3^-) concentrations were reduced by 60 percent (±48%); 2) nitrogen (N) fertilization helped to reduce SRP levels to 5 µg/L or less, substantially lower than observed during operation of the first pilot system and approaching the analytical detection limit; 3) treatment reduced mean NO_3^- effluent levels to 4 µg/L or less; 4) combined results from the two natural runoff events and from the two simulated runoff experiments allowed calculation of realistic load reductions for SRP (39% ±23%), total P (34% ±12%), NO_3^- (41% ± 30%), total Kjeldahl N (30% ±23%), suspended sediment (29% ±29%) and fine sediment particles (16% ±13%); 5) as a polishing system for a detention basin or a wetland, the cultured periphyton system can remove dissolved nutrients and fine sediments to levels not achieved by basins or wetlands alone. The final report is available on the Nevada Division of State Lands Lake Tahoe License Plate Program website.

Integrating private parcel water quality and fire defensible space information into SWQIC's existing Conditions Analysis and its pilot application to the Phase 3 portion of the Crystal Bay II Project Area

Contact: *Brian Judge (Tahoe Regional Planning Agency)*

This goal of this project was to develop an option to employ a more focused and refined existing conditions analysis memorandum procedure that focuses and retrieves more specific and useful project area information. This information will serve the effort to incorporate private parcel stormwater and fire defensible space measures into the Environmental Improvement Program (EIP) water quality project planning and permitting process and assist implementers and regulators in determining and evaluating the feasibility of more optimal stormwater project designs. Additionally, this project addressed the costs and benefits associated with achieving the highest pollutant load reductions through a more comprehensive approach to neighborhood storm water projects. Key findings include: 1) within the Formulating and Evaluating Alternatives (FEA) process, the identification and development of strong opportunities and constraints is essential to form the basis for formulating alternatives that are specific to the conditions of the project area; 2) emphasis should be placed on interpreting information collected for private property conditions to inform the Technical Advisory Committee (TAC) on the relative benefit that private property improvements may have on pollutant load reductions within the project area; 3) for the proposed defensible space algorithm, the proposed approach would use current Pollutant Load Reduction Model (PLRM) algorithms to simulate hydrology and surface runoff, while relying on Water Erosion Prediction Project (WEPP) output to estimate characteristic runoff concentrations. Please

contact Liz Harrison at Nevada Division of State Lands or Brian Judge at the Tahoe Regional Planning Agency for a copy of the final report.

Efficiency assessment of stormwater treatment vaults in the Round Hill General Improvement District
Contact: *Alan Heyvaert (Desert Research Institute)*
The Round Hill General Improvement District submitted a grant proposal for an extensive erosion control and water quality improvement project in 2001. The Desert Research Institute and the Tahoe Research Group were contracted to provide environmental monitoring for this project. The goal of the monitoring program was to perform an effectiveness evaluation of several proprietary stormwater treatment vaults that receive stormwater runoff from low-density residential neighborhoods near the southeast side of the Lake Tahoe Basin. The monitoring project showed that water discharged from the stormwater treatment vaults meets standards for discharge to groundwater for almost all events.

Final report:
Heyvaert, A.C., T. Mihevc, and R. Jacobson. 2005. Efficiency assessment of stormwater treatment vaults in the Round Hill General Improvement District-Final Report. Prepared for Nevada Tahoe Conservation District and Nevada Division of State Lands. DHS Publication No. 41216, Desert Research Institute, Reno, NV. 91 p.

Evaluation and enhancement of sediment retention and trapping devices
Contact: *Keith Dennett (University of Nevada-Reno)*
This research examined sediment retention and trapping devices installed in the Lake Tahoe Basin.

Publications associated with this research:
Ridenoure, B.D. “Evaluation and enhancement of the effectiveness of sediment trapping and retention devices installed on the Nevada side of Lake Tahoe.” MS thesis University of Nevada-Reno, 2007.

Please contact Liz Harrison at Nevada Division of State Lands for more information regarding the following projects:
Assessment of seasonal pollutant loading and removal efficiency of detention basins (2003)

Evaluation of effectiveness of three types of highway alignment best management practices for sediment and nutrient control (2004)

Current and Continuing Projects—Stormwater

ROUND 8

Potential of engineered floodplains and wetlands as fine particle BMPs: case study of Trout Creek and the Upper Truckee River

Lead Investigators: *Geoffrey Schladow, John Reuter, and Fabian Bombardelli (University of California-Davis)*

This goal of this project is to explicitly quantify the potential for engineered floodplains and wetlands as fine sediment best management practices (BMPs), and to explore methods whereby their efficiency can be maximized. This project will use a modeling approach and will link two types of models: 1) an urban hydrology model to represent particle loading from urban areas (Stormwater Management Model [SWMM]); and 2) a floodplain/wetland model that incorporates both the hydrodynamics and water quality/sediment removal (SIFT2D-WQ). The models will be calibrated and validated using a previously restored floodplain in the Tahoe basin (on Trout Creek) and then the potential for sediment removal from the Upper Truckee River will be quantified using the calibrated models. This project is nearly complete and the draft final report is in preparation.

Presentations associated with this research:
Stephen Andrews (graduate student, University of California-Davis) presented results from this study at the Lake Tahoe Interagency Monitoring Program (LTIMP) meeting on April 6, 2011. The presentation was titled, "2D numerical modeling of suspended sediment on the Trout Creek floodplain."

Current expected completion date: September 2011

Determining sources of highway runoff fine sediment in stormwater, streams, and Lake Tahoe using fingerprinting techniques

Lead Investigators: *Alan Heyvaert and Jim Thomas (Desert Research Institute)*

The goal of this project is to determine the sources of fine sediment in highway and roadway so that resource managers can make better informed decisions about where and how to implement appropriate best management practices (BMPs) to minimize the amount of fine sediment entering Lake Tahoe through stormwater runoff and streams. This study will: 1) determine source areas of the highway and road corridors where fine sediment is derived from road surfaces, road shoulders, or adjacent land surfaces contributing to highways and roads; 2) determine anthropogenic source contributions to highway and road runoff of fine sediment, including, for example, traction sand and vehicle sources, such as vehicle and tire wear, vehicle particulate emissions, and road surface wear (e.g., asphalt grinding); 3) develop a geographic information system (GIS) representation of potentially high, medium, and low contributing areas for fine sediment along highway and road corridors around the Lake Tahoe Basin; and 4) evaluate historical patterns in highway and roadway sediment contributions to Lake Tahoe by examining the fine sediment fingerprint record in lake cores. Sample collection, processing and analyses have been completed and the draft final report is in preparation.

Current expected completion date: September 2011

ROUND 9

Urban stormwater fine sediment filtration using granular perlite

Lead Investigator: *Russell Wigart (El Dorado County Department of Transportation)*

The goal of this research is to advance understanding in the Lake Tahoe Basin relative to media filtration options available for the treatment of fine sediment in urban runoff by evaluating perlite filtration

media. This research will quantify the water quality benefits, fine sediment treatment, and actual load reduction. This understanding will be used to evaluate the cost effectiveness of granular perlite relative to other treatment systems, and will also be used to accurately apply credits for the Pollutant Load Reduction Model (PLRM) and Lake Tahoe Total Maximum Daily Load (TMDL). Water quality benefits will be determined by comparing the turbidity, fine sediment concentration, and total suspended sediment between the unfiltered and filtered stormwater.

Current expected completion date: March 2012

Priority urban stormwater monitoring to directly inform the Pollutant Load Reduction Model (PLRM)
Lead Investigator: *Nicole Beck (2NDNATURE, LLC)*
This research will inform the Pollutant Load Reduction Model (PLRM) by: 1) building on previous analyses of existing data to create the PLRM Characteristic Runoff Concentration (CRC) and Characteristic Effluent Concentration (CEC) database; and 2) augmenting an initial phase of urban stormwater data collection initiated for the U.S. Army Corps of Engineers. The goals of this research are to: 1) provide improved scientific basis to estimate pollutant CRCs (focusing on very fine sediment) and their variability with land use conditions; and 2) estimate very fine sediment CECs for typical Lake Tahoe stormwater treatments (SWTs) and their variability with fundamental design parameters. Recently, 2NDNATURE staff: 1) maintained and downloaded instruments at all SWTs, which include Coon basin, Park Avenue basin, Blue Lakes, Eloise, Osgood, Wildwood and Rocky Point; 2) conducted Road Rapid Assessment Methodology (RAM) sampling in April; 3) entered Leveltroll data collected in the winter into the project database; 4) created surface water budgets for each basin; and 5) coordinated and documented road maintenance practices.

Current expected completion date: May 2012

Measuring the ability of floodplains to treat urban runoff in the Lake Tahoe Basin
Lead Investigators: *Geoffrey Schladow and Stefan Wuertz (University of California-Davis)*
This project will measure the mechanisms and the efficiency of fine particle removal from urban stormwater using floodplains. The project is based in the Cold Creek/Trout Creek floodplain, and utilizes the Cattlemans detention basin and the floodplain immediately downstream of it. Experiments separating the role of biofilm processes and gravitational settling will be conducted within the detention basin and on the floodplain downstream of the basin in response to both natural overflows of the basin and pumped flows of urban stormwater. The goals of the project are to: 1) quantify the effects of gravitational settling and biofilm processes in the removal of very fine (<20 µm) particles from urban stormwater; and 2) determine the elemental composition of both the stormwater itself and the particulate material to assess the potential for negative impacts to the resident floodplain biota and their food webs. This information will be used to help calibrate and validate a two-dimensional floodplain model that will enable floodplains to be designed to optimally treat urban stormwater. All field data have been collected; samples are now being processed and analyzed and data review has been initiated.

Current expected completion date: September 2011

ROUND 10

Tahoe stormwater particle assessment and management for urban and roadway runoff

Lead Investigators: *Alan Heyvaert and Jim Thomas (Desert Research Institute), John Reuter (University of California-Davis)*

The urban portion of the watershed contributes about 70% of the fine sediment that is delivered to Lake Tahoe. These fine particles significantly affect water clarity in this otherwise pristine lake. Current pollutant reduction strategies are targeting their removal through erosion control and stormwater treatment projects. This project will: 1) provide information to help establish reliable, calibrated relationship(s) between turbidity, the mass of size-fractionated suspended solids, and the number of <16 µm particles in stormwater runoff; 2) provide details on mechanisms involved in the removal of fine particles in vegetated best management practice (BMP) treatment basins; and 3) provide data on the efficiency of this commonly used BMP type, while also giving recommendations for design characteristics to increase fine particle removal. This project will inform he Lake Tahoe Total Maximum Daily Load (TMDL) program and associated efforts to improve lake clarity (e.g., Environmental Improvement Program). To date, monitoring sites have been identified and sampling and analysis has commenced for particle size distribution (PSD) analysis and fractional phosphorus concentrations. Experimental design and monitoring methods are in development for the Tahoe City Wetland Treatment System (TCWTS) hydraulic residence tests and configuration of the test plot system has been completed for particle removal experiments.

Current expected completion date: March 2012

Defensible space-erosion protection tools development

Lead Investigators: *Michael Hogan (Integrated Environmental Restoration Services, Inc.) and Mark Grismer (Vadose Zone Hydrology and University of California-Davis)*

This project fills a critical information gap identified in the Lake Tahoe Environmental Improvement Program (EIP), discussed briefly in the Lake Tahoe Total Maximum Daily Load (TMDL) Pollutant Load Opportunity Report and hinted at in nearly every defensible space directive– the need for practical residential defensible space practices that effectively reduce fire risk and while controlling erosion and reducing runoff. This research will identify, study and quantify defensible space practices around homes that are capable of reducing or eliminating fire risk, while minimizing erosion, protection water quality, infiltrating stormwater and snowmelt, reducing runoff and gaining acceptance from fire agencies and homeowners. Eight promising soil protection best management practices (BMPs) will be evaluated for both flammability and erosion control parameters. Both variables will be directly measured and, in coordination with BMP implementation staff, fire districts and homeowners, will implement the most mutually-effective BMPs at three residences to showcase defensible space practices that achieve both fire protection and erosion control-water quality objectives. The results will be developed such that they can be directly incorporated into TMDL load reduction estimation, tracking and crediting efforts through the Pollutant Load Reduction Model (PLRM) and the revision of the Tahoe Regional Planning Agency (TRPA) BMP Handbook. Currently, all erosion test plots were monitored starting in the end of June and ending in early July 2011. Field burn plots are scheduled to be monitored in September/October 2011.

Current expected completion date: December 2012

ROUND 11

Quantifying the benefits of urban stormwater management

Lead Investigator: *Nicole Beck (2NDNATURE, LLC)*

This research will integrate a number of reliable and cost-effective stormwater monitoring techniques with existing stormwater management tools customized for the Lake Tahoe Total Maximum Daily Load (TMDL) program to directly improve our quantitative estimates of the water quality benefits of key urban stormwater management practices. The research will focus on two priority research and management objectives: 1) provide the first set of comprehensive data to validate Pollutant Load Reduction Model (PLRM) catchment-scale estimates of pollutant loading and runoff using observed water quality and hydrologic data; and 2) quantify the effectiveness and feasibility of improved road maintenance practices to reduce urban catchment pollutant loads. PLRM models of catchments will be developed using catchment conditions and site specific meteorology. The catchment scale observations and protocols will be developed in a manner that could be adopted and continued as a long-term monitoring effort under the Regional Stormwater Monitoring Program (RSWMP) to provide status and trend data on urban stormwater pollutant loading and effectively refine the supporting stormwater tools. To address research objective #2, the research team will work directly with two jurisdictions responsible for maintenance of roads: the City of South Lake Tahoe (CSLT) and Washoe County. Within each monitored catchment a range of road maintenance practices will be developed, documented and implemented by the jurisdiction on the subject roads. The Road Rapid Assessment Model (RAM) tool and the previously defined controlled road experiments will be used to evaluate the condition of all roads within the catchments on regular intervals. The implementation of the Road RAM field observations combined with stormwater quality data over the 2012 water year will allow statistical and modeling analysis of the relative effectiveness of the road maintenance practices conducted. Cost of implementation of each road maintenance practice over the year will be included to provide both water quality improvement effectiveness and cost benefit comparisons of the various practices studied.

The PLRM is a stormwater pollutant load model for quantifying the expected load reductions of pollutants of concern to Lake Tahoe as a result of water quality improvement actions on urban lands. The actual condition of stormwater infrastructure associated with estimated load reductions from the PLRM can be verified using two Rapid Assessment and Management tools (BMP RAM and Road RAM). This research will augment and expand upon previous research and data collection efforts, including the Southern Nevada Public Land Management Act (SNPLMA) Round 9 project, "Priority urban stormwater monitoring to directly inform the Pollutant Load Reduction Model (PLRM)," and will directly inform a number of assumptions and concepts outlined in the September 2009 version of the Lake Clarity Crediting Program.

Current expected completion date: September 2013

Evaluation of alternative abrasives and snowplowing practices and road sweeping/vacuuming as source control BMPs for load reduction of fine sediment particles and phosphorus in urban roadway stormwater

Lead Investigators: *Hyun-Min Hwang and Raphael Townsend (University of California-Davis), Russell Wigart (El Dorado County Department of Transportation), Alan Heyvaert (Desert Research Institute)*

This project will evaluate the effectiveness of alternative abrasives and road sweeping and vacuuming, as best management practice (BMP) strategies for load reductions of fine sediment particles and associated phosphorus (P). The results of this study will help identify the sources and mobility of fine sediment particles in urban roadway runoff that will eventually help the development and

implementation of management plans such as source control and treatment control BMPs designed to target different sources.

This study will build upon the Southern Nevada Public Land Management Act (SNPLMA) Round 8 project, "Determining sources of highway runoff fine sediment in stormwater, streams, and Lake Tahoe using fingerprinting techniques." El Dorado County Department of Transportation (EDOT) investigated potential benefits of Washoe Septic Sand as source control for load reduction of fine sediment particles and reduced turbidity; this study will evaluate the effectiveness of this source control practice in actual road application tests. This study will also complement the SNPLMA Round 10 project "Tahoe stormwater particle assessment and management for urban and roadway runoff."

Current expected completion date: December 2013

Laboratory experiments on fine particle capture by submerged vegetation in stream environment zones (SEZs): the effects of vegetation density, biofilm development and particle composition
Lead Investigator: *Geoffrey Schladow (University of California-Davis)*
This project will focus on the measurement of fine particle capture efficiencies in a laboratory flume using analogs of the vegetation present in a stream environment zone (SEZ). The laboratory flume offers the ability to vary flow rate, substrate density (stems per square meter), stem width, particle concentration, and presence/absence of biofilms (biological surface coatings) in a repeatable fashion and to measure the changing particle size distribution and particle concentration over time. The size-specific removal efficiencies that can be calculated in this way can then be used as the basis for assigning removal efficiencies in any SEZ in the Tahoe Basin based on site-specific flow rate, vegetation type and density, and initial particle concentration. The values can also be used as part of a comprehensive stream/SEZ model and provide more detailed estimates of the effectiveness of SEZs in achieving restoration goals. The output from the proposed study can be used as the basis of site selection for future capital projects involving the use of SEZs for fine sediment removal, as the basis for assigning credits to project implementers for particle and nutrient removal, and as the basis for the design of sophisticated pump-back systems where flow through "treatment SEZs" could be controlled to better maximize fine particle removal.

This research is directly linked to ongoing research supporting environmental improvement projects in the Tahoe Basin including the Round 8 Southern Nevada Public Land Management Act (SNPLMA) study, "Potential of engineered flood plains and wetlands as fine-particle BMPs: case study of Trout Creek and the Upper Truckee River," and the SNPLMA Round 9-funded field study on biofilm development and particle capture in a stormwater detention basin, "Measuring the ability of floodplains to treat urban runoff in the Lake Tahoe Basin." A wetland condition assessment project sponsored by the U.S. Environmental Protection Agency (EPA) is addressing SEZs. This project team will communicate with the EPA team to ensure that there is consistency in the vegetative designations by the two teams.

Current expected completion date: July 2013

Tools to quantify urban stormwater load reduction from SEZ restoration actions
Lead Investigator: *Nicole Beck (2NDNATURE, LLC)*
This research will generate recommended methods to estimate: 1) pollutant load reductions expected from stream restoration projects; 2) load reduction benefits associated with the interception of urban stormwater outfalls to stream environment zones (SEZs); and 3) additional load reduction benefits if a degraded intercepting SEZ is restored. The methods will include necessary site-specific data collection

and reporting metrics to document pre- and post-restoration physical and geomorphic characteristics of a specific stream or SEZ. Collectively, these estimates will support a load reduction opportunity analysis of the feasible pollutant load reductions achievable via functional stream and SEZ restoration actions in the Tahoe Basin. Researchers will build upon and extend current monitoring of the Trout Creek site and evaluate additional SEZ sites. Analysis will be conducted by integrating outputs derived from a spatially explicit USGS modeling platform (SPAtially Referenced Regressions On Watershed attributes [SPARROW]), the Pollutant Load Reduction Model , and the Stream Load Reduction Tool (2NDNATURE, 2010). SPARROW will be employed for the Tahoe Basin, calibrated and validated using the wide array of existing land use, hydrologic and water quality data from a selection of watersheds. The estimation methods will be validated to the extent possible on site-specific stream and SEZ test sites, and used to inform a methodology to provide researchers and stormwater engineers with a consistent and relatively accurate method to estimate the pollutant load reductions from specific SEZ improvement projects. Available research will be analyzed to evaluate the feasibility and validity of approximating the urban derived pollutant loading to the upstream boundary of a stream restoration project, as well as the urban pollutant fraction retained.

This research will complement the following Southern Nevada Public Land Management Act (SNPLMA) projects: "Methodology to predict total and fine sediment load reductions as a result of channel restoration in Lake Tahoe streams," (Round 7), "Potential of engineered floodplains and wetlands as fine particle BMPS: case study of Trout Creek and the Upper Truckee River," (Round 8), "Measuring the ability of floodplains to treat urban runoff in the Lake Tahoe Basin," (Round 9), and "Priority urban stormwater monitoring to directly inform the Pollutant Load Reduction Model (PLRM)," (Round 9). In addition, this research will apply and scale the physical and geomorphic concepts developed in the Round 9 project, "Quantification and characterization of Trout Creek restoration effectiveness."

Current expected completion date: July 2013

Quantification of changes in water quality due to enhanced source control
Contacts: *Scott Brown (Nevada Tahoe Conservation District) and Nicole Beck (2NDNATURE, LLC)*
The intent of this project is to monitor matched roadway catchments in Washoe County to determine the water quality benefits of street sweeping (in terms of pollutant removal). Estimates of particulate matter on roadways before and after road sweeping will be determined using a "true HEPA" vacuum. Material captured in the "true HEPA" vacuum will be analyzed to determine the bulk size distribution of particulate matter. In addition, vehicular traffic will be counted periodically to evaluate impacts of traffic on fine sediment generation from road abrasives. Atmospheric monitoring equipment will be installed to determine atmospheric deposition of particles to the project sites. Lastly, multiple water quality samples will be collected automatically and analyzed for each runoff event.

Current expected completion date: December 2011

Hybrid BMP retrofit of primary roadway

Contact: *Scott Brown (Nevada Tahoe Conservation District)*

This project will implement a matched-catchment in Incline Village, Nevada and includes the design, construction and monitoring of multiple stormwater treatment best management practices (BMPs) based on low impact development (LID) concepts for a Washoe County public right-of-way. The LID improvements will allow stormwater to infiltrate in off-line systems to sequester fine sediment and other pollutants and will ensure that future events will not flush out captured pollutants. The monitoring design and data collection efforts will be completed to ensure effectiveness data can be input into the Pollutant Load Reduction Model (PLRM). The project tasks include: 1) design and install multiple infiltration BMPs in the Washoe County right-of-way based on low impact development (LID) concepts; 2) design and install at least two significantly different bioretention basin configurations which integrate with existing stormwater infrastructure; and 3) monitor the basin on the catchment and BMP scale for two years.

Current expected completion date: March 2013

Tahoe stormwater tools integration

Contact: *Jason Kuchnicki (Nevada Division of Environmental Protection)*

A number of tools have been developed for the local jurisdictions and departments of transportation (DOTs) to identify the most effective opportunities to reduce loading of fine sediment particles, phosphorus and nitrogen from entering Lake Tahoe through project and program implementation. This project will create a single Integrated Stormwater Tool that: 1) combines the functions of the Accounting and Tracking Tool, the best management practice Rapid Assessment Methodology (BMP RAM) and Road RAM; 2) enables direct uploads of Pollutant Load Reduction Model (PLRM) outputs; and 3) automatically populates Lake Clarity Crediting Program forms and standard reports. Development of this tool will include: 1) data and form alignment; 2) interface design and definition of outputs; and 3) online tool development.

Current expected date of completion: June 2012

Completed Projects—Stream Restoration

ROUND 7

Methodology to predict total and fine sediment load reductions as a result of channel restoration in Lake Tahoe streams

Lead Investigator: *Nicole Beck (2NDNATURE, LLC) and Catherine Riihimaki (Drew University)*

The goal of this project research was to develop, verify and document data collection and data analysis protocols to quantify and predict the water quality improvement (i.e., sediment load reductions) as a result of stream restoration projects. Stream reaches on the Upper Truckee River were instrumented and monitored to obtain continuous site-specific hydrology, in-stream fine sediment particles (FSP) vertical profiles, and floodplain FSP deposition for three consecutive snowmelt events (WY08-WY10). The research team applied the FSP concentration data obtained from passive samplers deployed along the upper and lower boundary of the non-entrenched site to estimate an FSP retention coefficient (RFSP) of 0.7 and an estimated FSP mass retained on the floodplain (SFSP) of 20.5 MT and 84.0 MT as a

result of the 2009 and 2010 spring snowmelt floods, respectively. This research provides evidence that FSP retention by floodplains does occur and may provide a significant FSP load reduction during overbank flow events.

The final report for this project is available on the USDA Forest Service Pacific Southwest Research Tahoe Science Program website:
2NDNATURE. 2011. Methodology to predict fine sediment load reductions as a result of floodplain inundation in Lake Tahoe streams. Prepared for the USDA Forest Service Pacific Southwest Research Station. Final Technical Report. April 2011.

ROUND 8

A comprehensive integration of past stream restoration efforts and future tools to evaluate and track the multitude of benefits by stream and meadows in the Lake Tahoe Basin

Lead Investigator: *Nicole Beck (2NDNATURE, LLC) with River Run Consulting and Environmental Incentives, LLC*

The goal of this project was to focus and improve the quality of stream restoration effectiveness evaluations in the Lake Tahoe Basin. The research team developed The Riparian Ecosystem Restoration and Effectiveness Framework (Framework) to focus the evaluation process and improve the communications when stream restoration practitioners are implementing specific restoration projects. The Framework process is expected to simplify: 1) the summary of existing conditions; 2) the development of testable restoration project objectives; 3) improve the quality of restoration project monitoring strategies; and 4) actualize the adaptive management process. The final report contains specific recommendations and guidelines on how to improve the quality of protocol and metric selection, analysis and reporting to increase the confidence in effectiveness monitoring results.
The final report is available on the USDA Forest Service-Pacific Southwest Research Station Tahoe Science Program website.

Current and Continuing Projects—Stream Restoration

ROUND 7

Application of enhanced stream-corridor modeling tools for adaptive management of Tahoe Basin streams

Lead Investigators: *Eddy Langendoen and Andrew Simon (USDA Agricultural Research Service-National Sedimentation Laboratory)*

The primary objectives of this study are to enhance and further validate the predictive, numerical models Conservational Channel Evolution and Pollutant Transport System (CONCEPTS) and Bank-Stability and Toe-Erosion Model (BSTEM) to fully realize their potential as state-of the-art tools for stream management in the Lake Tahoe Basin and elsewhere. This project will: 1) quantify the effects of riparian vegetation and bio-engineered treatments on the resistance of bank materials to hydraulic erosion and bank undercutting for inclusion into both models; 2) develop a near-bank groundwater model to integrate with CONCEPTS and BSTEM for the purpose of simulating pore-water pressures dynamically; 3) develop algorithms for CONCEPTS to simulate lateral migration of meandering channels in a deterministic fashion by accounting for hydraulic and geotechnical controls; and 4) validate the use of the CONCEPTS and BSTEM models at the project-scale for existing and restored reaches of selected Tahoe Basin streams using time-series historical data on flow, sediment transport and channel geometry. This project is nearing completion. The user manuals for the models are in preparation; the investigators will hold a workshop in the Tahoe Basin in late fall 2011 to conduct training on use of the models.

Current expected completion date: February 2012

ROUND 9

Quantification and characterization of Trout Creek restoration effectiveness

Lead Investigator: *Nicole Beck (2NDNATURE, LLC)*

Many stream and meadow restoration projects have been implemented throughout the Lake Tahoe Basin over the past two decades. However a consistent definition of restoration effectiveness has not been defined nor have standardized methods been established to monitor and evaluate pre- and post-restoration conditions. This research will: 1) apply the standardized approach of both simple and complex observations of Trout Creek to characterize pre- and post-restoration stream reach condition; 2) develop a simple methodology for the Stream Load Reduction Tool (SLRT) (2NDNDATURE, 2010)for local resource managers to predict the relative water quality benefits (total and fine sediment load reductions) as a result of stream morphologic modifications and floodplain restoration efforts using Trout Creek and Upper Truckee River as the tangible examples; and 3) enable load reductions from stream restoration to be accounted for in the Lake Tahoe Total Maximum Daily Load (TMDL) and Lake Clarity Crediting programs. Recently, 2NDNATURE staff have: 1) downloaded and maintained turbidity sensors during the spring snowmelt; 2) installed 4 passive samplers on 3 transects, with 2 duplicates in the Trout Creek floodplain, for a total of 15 passive samplers; 3) coordinated an aerial photo of Trout Creek at 160 cfs; 4) collected water samples from passive samplers from overbank flow on 4 separate events and submitted them to the lab for PSD analysis; 5) following the peak snowmelt, conducted a floodplain survey of sediment distribution and vegetation type; and 6) updated the database with 15 minute depth turbidity sensor data.

Publications associated with this project:

2NDNATURE, C. Riihimaki, Environmental Incentives, LLC, and River Run Consulting. 2010. Quantification and characterization of Trout Creek restoration effectiveness: focused development of a Stream Load Reduction Methodology (SLRT). Prepared for the USDA Forest Service-Pacific Southwest Research Station. 52 p.

Current expected completion date: June 2012

Rosewood Creek monitoring

Contact: *Rick Susfalk (Desert Research Institute)*

This project will continue a long-term monitoring effort on Rosewood Creek which is a major tributary to Third Creek in Incline Village, Nevada. Monitoring data will help support restoration designs of the middle reach of Rosewood Creek and post-construction data will provide an understanding of how stream restoration projects can reduce the delivery of nutrients and suspended sediments to Lake Tahoe. This project will also supplement previous monitoring on the lower reach restoration project in an effort to identify the efficiency of this project reducing suspended sediment loads. In addition, this data may be used for future calibrations of the CONservational Channel Evolution and Pollutant Transport System (CONCEPTS) model which was developed as part of the Lake Tahoe Total Maximum Daily Load (TMDL).

Current expected completion date: December 2011

Completed Projects—Water Quality

ROUND 5

Lake Tahoe Total Maximum Daily Load (TMDL)

This project was sponsored by the U.S. Environmental Protection Agency to support development of the Lake Tahoe Total Maximum Daily Load (TMDL) Program. A Lake Tahoe Total Maximum Daily Load Technical Report and Pollutant Reduction Opportunity Report were generated as part of this project.

Pelagic zone water quality and modeling of fine sediment sources, transport, and fate

This project was sponsored by the U.S. Environmental Protection Agency to: 1) establish a monitoring program to evaluate trends in lake particle composition; 2) gain a better understanding of the sources of fine sediments entering the lake; 3) evaluate other physical, chemical and biological processes that effect algal growth, particle distribution and clarity; and 4) further refine the Lake Clarity Model.

Groundwater modeling and monitoring

This project was sponsored by the U.S. Geological Survey to determine impacts to groundwater quality from infiltration practices over different land-use classes. Researchers examined the hydrogeologic conditions in a shallow aquifer and how the aquifer interacted with a stormwater-control system and Lake Tahoe. The final report (see citation below) describes: 1) the basin-fill aquifer and a stormwater-control system; quantifies components of the groundwater budget; and 2) characterizes the quality of stormwater, bottom sediment from a stormwater detention basin, groundwater, and nearshore lake and interstitial water. The report also includes results of a three-dimensional, finite-difference, numerical model, coupled with chemical data to evaluate responses of groundwater flow to stormwater runoff accumulation in the stormwater-control system.

Publications associated with this project:

Green, J.M., C.E. Thodal, and T.L. Welborn. 2008. Hydrologic and water-quality responses in shallow ground water receiving stormwater runoff and potential transport of contaminants to Lake Tahoe, California and Nevada, 2005–07. U.S. Geological Survey Scientific Investigations Report 2008–5162. 64 p.

Development of hydraulic design criteria*

This project was sponsored by the U.S. Army Corps of Engineers to establish hydraulic design criteria for best management practices (BMPs) based on hydrologic characteristics in the Tahoe Basin.

Development of a pollutant load reduction model*

The project was sponsored by the U.S. Army Corps of Engineers and implemented by Northwest Hydraulic Consultants; it focused on creating stormwater loading evaluation tools. The Pollutant Load Reduction Model (PLRM) is continually being informed by new research.

Refinement of pollutant event mean concentrations for various land types*

Lead Investigator: *Nicole Beck (2NDNATURE, LLC)*

This project was sponsored by the U.S. Army Corps of Engineers and implemented by 2NDNATURE, LLC. Researchers developed a data collection strategy to improve the scientific basis of the Pollutant Load Reduction Model (PLRM). Specifically, this strategy is meant to : 1) validate and refine the relative role of specific geographic, physical, anthropogenic and source control factors on the likely urban roadway condition; 2) estimate fine sediment particle (<16 µm) Characteristic Runoff Concentrations (CRCs) and variability relative to different road conditions; and 3) estimate fine sediment particle Characteristic

Effluent Concentrations (CECs) for typical Lake Tahoe stormwater treatment best management practice (BMP) types. The final report is available from 2NDNATURE, LLC.

*These studies were also supported with funding from Southern Nevada Public Land Management Act (SNPLMA) Round 6.

ROUND 6

Integrated BMP modeling: application to Tahoe TMDL

The project is sponsored by the U.S. Geological Survey. The objective of this study is to quantify the effectiveness of the Environmental Improvement Program (EIP) for lake water clarity restoration at a basin-wide scale using simulation modeling to inform water quality planning at the watershed scale. The primary deliverable of this project will be the customization of a basin-scale best management practice (BMP) model/module with subsequent incorporation into the Load Simulation Program in C++ (LSPC) watershed, land use-based, pollutant loading model that is currently being used in the Lake Tahoe Total Maximum Daily Load (TMDL).

ROUND 7

Predicting and managing changes in nearshore water quality

Lead Investigators: *Geoffrey Schladow and Fabian Bombardelli (University of California-Davis), Alan Heyvaert and Rick Susfalk (Desert Research Institute), Francisco Rueda (Universidad de Granada), Sudeep Chandra (University of Nevada-Reno)*

This goal of this project was to investigate the linkages between the physical and biological components in the nearshore zone of Lake Tahoe. Specifically, the objectives were to: 1) develop and test a three-dimensional hydrodynamic, thermodynamic, particle tracking and scalar transport model of the nearshore zone; 2) conduct detailed experiments to refine linkages between nutrients and particles (inorganic, detrital, and algal) to the nearshore zone, biological production (periphyton and planktonic algae), and factors controlling the spread of non-native plant and fish species; 3) conduct a spatial survey of nearshore conditions; 4) quantify the distribution and production of fish, periphyton, algae and non-native aquatic plants; 5) interpret water quality data in terms of the model results; and 6) develop potential nearshore management strategies and evaluate impacts on water quality issues. The draft final report for this project is in review.

Assessing the sources and transport of fine sediment in response to management practices in the Tahoe Basin using the WEPP model

Lead Investigators: *William Elliot (USDA Forest Service-Rocky Mountain Research Station), Erin Brooks and Jan Boll (University of Idaho), Joan Wu (Washington State University)*

The goal of this project was to test and develop the Water Erosion Prediction Project (WEPP) model as a management tool for evaluating the impacts of specific management practices on the generation of fine (< 20 µm) sediment transport at the hillslope and watershed scales in the Lake Tahoe Basin. The project provided a Tahoe-specific database which includes all the necessary soil, climate, and management input files to run the model at any location in the basin. The accuracy of the model was tested against 18 years of observed snow water equivalent depth, streamflow and sediment load data at the following relatively undisturbed watersheds in the Tahoe Basin. The project also provided Tahoe-specific soil and management input files for representing the impact of hillslope disturbances and subsequent restoration options on fine sediment loading. A simple web-interface tool was developed and populated with the Tahoe-specific input files to allow end users to easily predict the impact of disturbances on fine sediment loading from single hillslopes. For advanced users, algorithms were provided to simulate streamflow and fine sediment loading from large complex watersheds; these applications require users

to be familiar geographic information system (GIS) applications and basic programming languages. The final report is available on the USDA Forest Service-Pacific Southwest Research Station Tahoe Science Program website.

Improving road erosion modeling for the Lake Tahoe Basin and evaluating BMP strategies for fine sediment reduction at watershed scales

Lead Investigators: *Randy Foltz, William Elliot, and Natalie Wagenbrenner (USDA Forest Service-Rocky Mountain Research Station)*

The objectives of this project were to: 1) parameterize the Water Erosion Prediction Project (WEPP) model specifically for the Lake Tahoe Basin; 2) improve the current WEPP: Road interface; 3) validate the WEPP model for the Lake Tahoe Basin; and 4) develop a quantitative approach to identify erosional "hot spots" and the adequate best management practices (BMPs) to efficiently reduce the sediment transport to stream channels. Based on the results from this study and other road studies, the investigators suggest that WEPP users investigate predictions using ±50% of the effective hydraulic conductivity. For a typical native-surface road at Lake Tahoe, this method resulted in a WEPP model prediction range of approximately ±75% of the mean for both runoff and sediment mass. Using locally measured soil properties for input into the WEPP model, the study found that runoff and erosion predictions decreased in the Lake Tahoe Basin, where snowmelt is an important runoff-producing mechanism. In these conditions, small changes in effective hydraulic conductivity had large changes in annual runoff. Thus, applications of the Lake Tahoe example to other locations need to account for the balance between the importance of snowmelt and rainfall events. The final report is available on the USDA Forest Service-Pacific Southwest Research Station Tahoe Science Program website.

Publications associated with this research:

Foltz, R.B., W.J. Elliot, and N.S. Wagenbrenner. 2011. Soil erosion model predictions using parent material/soil texture-based parameters compared to using site-specific parameters. Transactions of the ASABE 54(4): 1347-1256.

Monitoring past, present, and future water quality using remote sensing

Lead Investigators: *Todd Steissberg and Geoffrey Schladow (University of California-Davis), Simon Hook (Jet Propulsion Laboratory [NASA/JPL])*

The goal of this project was to demonstrate the use of remote sensing for measuring water quality parameters at Lake Tahoe to obtain a whole-lake view of water quality changes. A semi-automated system was developed to utilize remotely sensed and field measurement data to quantify water clarity and near-surface chlorophyll *a* concentration measurements over the entire lake. The system was based on the use of Moderate Resolution Imaging Spectroradiometer (MODIS) satellite data. These data were used to create maps of water clarity and chlorophyll *a*. Key findings include: 1) lake-wide maps of Secchi depth and chlorophyll *a* concentration show significant variations, with the largest variations occurring close to shore; 2) Secchi depth is consistently lower on the east side of the lake; and 3) the distribution of clarity and chlorophyll *a* in the nearshore is often controlled by the transport processes within the lake. The final report and a summary of findings are available on the USDA Forest Service-Pacific Southwest Research Station Tahoe Science Program website.

ROUND 8

NICHES: Nearshore indicators for clarity, habitat, and ecological sustainability

Lead Investigators: *Sudeep Chandra (University of Nevada-Reno), Craig Williamson and James Oris (Miami University)*

This project synthesized information to determine: 1) the status of the nearshore native and non-native fish community; and 2) if there are quantifiable indicators and methodologies that can be created to determine the condition of the nearshore fishery. The researchers also conducted experiments to determine if ultraviolet radiation (UV) can be used to link nearshore and non-native fish ecology to the physical environment. Key findings include: 1) nearshore fish densities have undergone general decrease (58% of historically sampled sites) between 1988-89 and 2009; 2) UV exposure and *in situ* incubation experiments show that UV transparency of nearshore sites significantly impacts the survival of warmwater fish larvae and influences whether these potentially invasive fish species are able to establish in nearshore Lake Tahoe; and 3) measurements of UV transparency around the lake showed that more than half of the sites sampled were in non-attainment of the UV attainment threshold (UVAT), suggesting the potential for widespread warmwater fish establishment. These results suggest that the health of Lake Tahoe's nearshore native fishery is deteriorating and that a long-term nearshore monitoring and warmwater fish prevention program is necessary to further understanding of Lake Tahoe's nearshore native fishery. The final report is available from the Tahoe Science Program Coordinator.

ROUND 10

Lake Tahoe Total Daily Maximum Load (TMDL) Management System

This was a capital project sponsored by the U.S. Environmental Protection Agency. The final Total Maximum Daily Load (TMDL) report was submitted to the EPA in August 2011. The report was a collaborative effort between the Nevada Division of Environmental Protection and the Lahontan Regional Water Quality Control Board (California).The final TMDL report includes a Recommended Strategy to reduce fine sediment loading to the lake as well as an implementation plan developed within the context of adaptive management.

Linking onshore and nearshore processes

Contact: *Rick Susfalk (Desert Research Institute)*

This project was designed to demonstrate the utility of establishing a nearshore monitoring program using data collection buoys that will track changes in localized shorezone characteristics. Key results include: 1) a customized buoy provided more flexibility than commercial options; 2) on-board power consumption was not found to be an issue during the summer; however, operation during winter would require increased battery capacity and/or a reduction in power consumption obtainable through altering the frequency of monitoring and telemetry connections; 3) biofouling did not appear to impair turbidity readings as long as the sensor's wiping mechanism was activated prior to each measurement; 4) biofouling of the light transmissometer occurred between 7 to 11 days after manual cleaning, and resulted in a predictable linear decrease in light transmission values for an additional two weeks; 5) biofouling of either sensor was not significant during the colder water temperatures of April and May; 6) *in situ* turbidity and light transmittance measurements tended to mirror each other and indicated that nearshore clarity was much more variable than previously suggested by snapshot surveys; 7) turbidity should only be used in situations where one is interested in the degradation of nearshore clarity from particle sources, such as urban runoff or dredging operations; 8) light transmission is preferred in

situations where high clarity background conditions are of interest; 9) water clarity measured at the buoy 40 m offshore generally, but not always, reflected elevated turbidity events in the creeks; and 10) a buoy-based system provides the ability to continuously monitor nearshore water clarity, a deficiency in existing nearshore monitoring programs. Please contact Liz Harrison at Nevada Division of State Lands for a copy of the final report.

Current and Continuing Projects—Water Quality

ROUND 8

Development of a water quality modeling toolbox to inform pollutant reduction planning, implementation planning and adaptive management

Lead Investigators: *John Reuter and Geoffrey Schladow (University of California-Davis)*

In 2004, the Lake Tahoe Total Maximum Daily Load (TMDL) program began to develop the Tahoe Water Quality Toolbox. The Toolbox was intended to incorporate models and other tools that can be used by agencies, resource managers, planners, scientists, engineers, and Environmental Improvement Program (EIP) project implementers to help plan for achieving basin-wide load reduction goals. Using the modeling tools that have been developed, those under current revision, or those being developed, the goals of this project are to: 1) work with the water quality regulatory agencies to formally develop the envisioned Tahoe Water Quality Toolbox; 2) package selected models to include user-friendly protocols, documentation and application formats, leading to a means for technology transfer to basin users; 3) create conceptual and operational linkages between individual models as appropriate; and 4) update the Lake Tahoe Watershed Model to better address the critical issue of wildfire and pollutant runoff. This project is nearing completion. The final report is in preparation and a Toolbox training workshop will be held in the basin in late fall 2011.

Current expected completion date: December 2011

ROUND 10

Development and validation of the Tahoe Project Sediment Model

Lead Investigators: *William Elliot (USDA Forest Service-Rocky Mountain Research Station), Erin Brooks (University of Idaho), Drea Traeumer (Em Hydrology, LLC)*

The goal of this project is to develop the Tahoe Project Sediment Model (TPSM) online decision support tool that will be used by forest managers and planners in the Tahoe Basin to assess hillslope-scale fine sediment (<20 um) loads for the most common forest upland management practices in the basin under current and future climate scenarios. This study will: 1) compile a database of existing upland rainfall, runoff, and erosion experiments in the Tahoe Basin; 2) develop Water Erosion Prediction Project (WEPP) input files from existing datasets in the basin for the most common forest upland management practices; 3) develop a climate generation tool that creates current and future climate files for any project location in the Tahoe Basin; 4) develop the TPSM with user friendly protocols for evaluating the effects of alternative management practices on fine sediment loads; and 5) validate TPSM loading estimates for fine sediment (<20 µm) from current and proposed monitoring projects within the basin. The researchers have received responses from the two surveys: basin needs for watershed tools and available research data. Reports on both surveys have been drafted and are under review. The user needs survey results will be incorporated into the proposed predictive interface. The data survey results will be incorporated into a synthesis and will be used to calibrate or validate the enhanced TPSM interface. The user needs survey indicates that the users are most interested in models that predict sediment delivery associated with common fuel management practices and native surface roads.

Interest was low in recreational impacts, nutrient loading, and probability exceedance predictions. This information will be used in developing the TPSM and its documentation.

Current expected completion date: November 2012

Nearshore water quality monitoring at Lake Tahoe
Contact: *Rick Susfalk (Desert Research Institute)*
This project is designed to build off of previous research funded by the Nevada Lake Tahoe License Plate Program which tested the feasibility of using buoys to measure nearshore water quality conditions. This work will address and solve operational issues previously discovered during the initial study. Specifically, the project will implement a continuous one-year long buoy deployment to: 1) assess seasonal operations; 2) test a new anti-biofouling design for the light transmissivity and chlorophyll fluorescence sensors; and 3) assess depth-dependent changes in temperature, transmissivity, and relative chlorophyll using a temperature string and multi-level sampling.

Current expected completion date: November 2011

Round 12 Watersheds, Habitat, and Water Quality Subthemes

Understanding the impacts of aquatic invasive species

Management and/or Policy Need

The prevention of new introductions of aquatic invasive species (AIS) and the control of established invasive species is a high priority for Tahoe Basin resource management and regulatory agencies. Agencies have a need for ongoing quantitative information and clear recommendations to manage established invasive species and minimize their impacts. Information related to prevention is required to assess risks from individual species and to track environmental conditions that may facilitate new invasions. Information related to control of invasive species is needed to assess the effectiveness and potential environmental effects of various control strategies. Long-term status and trend monitoring of priority invasive species' abundance and distribution in nearshore habitats and streams in the Tahoe Basin and their environmental effects is needed for strategic planning efforts, and for assessment of their potential influence in meeting environmental quality targets.

Description

Research is needed to address one or more of the following issues: 1) synthesize and review existing data and develop a plan to monitor the effectiveness of control and prevention strategies in Lake Tahoe's nearshore environment, tributary streams, and other lakes of the region; 2) develop a predictive model/decision tool to assess the risk of priority invasive species introductions and establishment in the Tahoe Basin to inform AIS prevention program policies and management strategies; 3) determine the ability of quagga and zebra mussels to complete their lifecycle in the waters of the Lake Tahoe Basin; 4) assess the net economic impact and benefit of the Lake Tahoe AIS prevention program; and 5) research control techniques and strategies for extant species (e.g., treatment of satellite populations vs. source populations) to improve control program effectiveness, improve techniques to increase treatment efficiency and reduce recolonization rates, mitigating or avoiding the short-term effects of control measures on nearshore water quality and aesthetic indicators (biological, chemical, and physical), or mitigating the adverse legacy effects of AIS (e.g., removal of Asian clam shells). Researchers should plan

to collaborate with agency representatives and other research teams to ensure the products will meet agency information and evaluation needs.

Quantifying the benefits of urban storm water management

Management and/or Policy Need

Research associated with the Lake Tahoe Total Maximum Daily Load (TMDL) indicates that stormwater from urban land uses is the largest contributor and presents the greatest opportunity to reduce fine sediment particle (< 16 µm) and total phosphorous (P) loads to streams and Lake Tahoe. Roadways are a land use of primary concern, as these have the greatest pollutant yield potential. Improved characterization of urban stormwater is needed for the purposes of modeling both baseline loads and expected load reductions and for linking stormwater management actions to expected water quality benefits. In particular, there is a need to evaluate the effectiveness of roadway operations and maintenance practices (i.e., abrasive application and recovery methods) and enhance the ability to rapidly assess maintenance needs.

Description

Research is needed to address one or more of the following issue areas: 1) improve and/or validate existing tools, models and methods to estimate urban stormwater load reductions, including quantifying the effects of actions to reduce sediments and nutrient loads using stream environment zones (SEZs); 2) investigate the relationship between operations and maintenance activities, road composition, and estimated pollutant loading or load reduction, particularly roadway traction abrasive application and recovery practices; 3) improve the design of pollutant control/treatment technologies; and 4) test and evaluate the application of innovative or advanced stormwater pollution controls within the Tahoe Basin.

Increasing our understanding of special status species and communities

Management and/or Policy Need

The Tahoe Basin has several special status species and communities that are a focus of agency conservation and restoration efforts locally and also nationwide. Management agencies need applied research to help guide and evaluate conservation, restoration, protection, and control measures to conserve and/or restore special status species and communities, including an understanding of the mechanisms contributing to maintenance or decline of these species and communities over the long term. Special status species in the Tahoe Basin can serve as indicators of ecosystem health and associated improvements or declines, but this function requires a thorough understanding of their biology and the ecological processes affecting them. Research under this subtheme will aim to identify strategies, techniques, and standards that will best conserve and restore species and communities of special concern for which information is lacking.

Description

Research should focus on sensitive native species and habitats in the Tahoe Basin for which little is known, including deepwater plant communities, cushion plan communities, endemic invertebrates (i.e., the Tahoe stone fly and the blind amphipod), and the native freshwater mussel *Margaritifera falcata*. Research should address one or more of the following: 1) evaluate mechanisms maintaining or contributing to the decline of native species and communities; and 2) evaluate approaches to conserve or restore special status plant and animal species, communities of concern, or habitats threatened by invasive species or climate change. Research may incorporate conventional hypothesis-driven investigations or synthesis and review. Research on potential indicators should include analyses to assess how the proposed new indicators compare to existing applicable indicators. Researchers should

plan to collaborate with agency representatives and other research teams to ensure that agencies can apply the results.

Technical review of SEZ definition and classification system

Management and/or Policy Need

Agencies are reviewing the region's stream environment zone (SEZ) policies and updating the SEZ conservation program to improve its consistency with the U.S. Environmental Protection Agency's Wetland Program core elements (in response to state initiatives), to incorporate new scientific information, and to ensure management actions and policies are protective of desired SEZ functions. A need that underlies the update of all SEZ policies and program elements is the development and adoption of a SEZ classification system that assures the protection and conservation of desired SEZ functions. SEZ functions that agencies are interested in protecting and conserving include, but are not limited to: 1) providing habitat for native, special status, and riparian/wetland associated wildlife, fish and plant species and communities; 2) flood attenuation; 3) sustaining water quantity through groundwater recharge; 4) protecting surface and groundwater quality through buffering from conflicting land uses and activities; 5) providing water filtering/treatment services (particularly treatment of fine sediment and nutrients); 6) enhancing scenic quality; and 7) providing for high quality low-impact recreation experiences. A classification system would aid agencies in refining the definition of SEZ and the resource criteria used to delineate SEZ for mapping and field verification.

Description

Research is needed to answer the following question: What hydrogeomorphic, vegetation or soils classification system (or combination of classification systems) is most appropriate for protecting and conserving desired functions identified for SEZs in the Lake Tahoe Basin? Agencies are particularly interested in science-informed efforts and products that lead to the selection of a SEZ classification system, including: 1) conceptual models that illustrate the linkages among desired SEZ functions and SEZ structure, geomorphic setting, vegetation species composition and watershed position; 2) geographic information system (GIS) mapping and modeling approaches, and data and field verification methods that can be used to map the distribution, functions, relative condition and extent of identified SEZ types; and 3) an empirically-based identification of hydrogeomorphic, vegetation and soil field indicators of different SEZ types that can be used for on-the-ground SEZ delineation. Ultimately, agencies need: 1) maps that depict the aerial extent of different SEZ types and their associated condition across the Lake Tahoe Basin; and 2) scientifically defensible documentation that supports a field SEZ delineation approach, mapping approaches and products, and selected classification system. Research is expected to be conducted in collaboration with agency representatives to ensure products meet agency needs and should utilize all existing data and information.

Air Quality

Previous and current air quality research in the Tahoe Basin addresses such areas as sources and fates of air pollutants, vehicle and road-associated pollutants, emissions inventories, and monitoring standards. There is a need for additional emissions inventories as well as research to address continued monitoring needs, uncertainty associated with atmospheric deposition estimates, and identify strategies for reducing air pollution in the basin. This section includes meteorological research.

Completed Projects—Air Quality

ROUND 5

Source characterization of particulate matter depositing to Lake Tahoe

This project, sponsored by the U.S. Environmental Protection Agency and implemented by Desert Research Institute, was designed to chemically characterize road dust, road sweepings, traction control material, and soil parent materials and quantitatively relate their chemistry and mineralogy to the composition of particles suspended in the lake water column. These results may be used as an independent measure to bound the influence of road dust on lake water sediment.

Measurement and modeling of fugitive dust emissions from paved road travel in the Lake Tahoe Basin

Sponsored by the U.S. Environmental Protection Agency and implemented by Desert Research Institute, this study used the TRAKER road dust measurement system to measure seasonal and spatial changes in road dust emissions. The final report recommends the use of particulate matter (PM, specifically PM_{10}) compliant sweepers, anti-icing pretreatment, and avoidance of loose gravel for road surfaces.

Publications associated with this project:

Kuhns, H., D. Zhu, J. Gillies, A. Gertler, V. Etyemezian, and S. Brown. 2007. Measurement and modeling of fugitive dust emissions from paved road travel in the Lake Tahoe Basin. Final report to U.S. Environmental Protection Agency, Region 9. Desert Research Institute, Reno, NV. 128 p.

Zhu, D., H. Kuhns, S. Brown, J.A. Gillies, V. Etyemezian, and A. Gertler. 2009. Fugitive dust emissions from paved road travel in the Lake Tahoe Basin. Journal of the Air & Waste Management Association, 59:1219 -1229. doi: 10.3155/1047-3289.59.10.1219.

ROUND 6

Development of an air pollutant emissions inventory for the Lake Tahoe Basin that incorporates current and future land-use scenarios

This Desert Research Institute project, sponsored by the U.S. Environmental Protection Agency, developed a baseline emissions inventory that can be used to quantify and evaluate the contribution of various sources to ambient pollutant levels. In addition to the pollutants commonly included in an inventory (i.e., carbon monoxide [CO], nitrogen oxides [NOx], volatile organic compounds [VOCs],particulate matter [PM_{10} and $PM_{2.5}$], and sulfur dioxide [SO_2]), estimates of ammonia (NH_3), phosphorus (P), and phosphate (PO_4^{3-}) were also developed due to their contribution to the declining water clarity of the lake. Annual and seasonal inventories were developed. Since air quality models require spatially distributed pollutant emissions (i.e., gridded input), geographically distributed seasonal and temporal emissions estimates were also prepared as part of this work. A further aspect of this project was to develop a geographic information system (GIS)-based tool that can be used to update the baseline inventory in order to account for future development and changes in infrastructure. Based on the inventory results, the major contributors to ambient pollutant are as follows: 1) CO: mobile sources and residential fuel combustion; there is a strong seasonal dependence in the residential fuel combustion source; 2) PM_{10}, $PM_{2.5}$, P, and PO_4^{3-}: area wide sources, particularly residential fuel combustion and road dust re-suspension; emissions are significantly higher during the winter period; 3) NOx and NH_3: mobile sources are the dominant contributor; 4) VOCs: mobile sources, biogenic sources, and area wide sources all contribute to VOC emission. There is a strong seasonal dependence in the biogenic and area wide source contributions.

ROUND 7

Examination of dust and airborne sediment control demonstration projects

Lead Investigators: *Hampden Kuhns, Dongzi (Davis) Zhu, John Gillies, and Alan Gertler (Desert Research Institute), Steven Cliff and Yongjing Zhao (University of California-Davis)*

Completed in October 2010, this study assessed the impact of best management practices (BMPs) designed to reduce the contribution from road dust re-suspended by vehicles. Results from this study suggest that potential basin-wide road dust particulate matter (PM_{10}) emission reductions of ~67% of the present value may be achievable if the emission equilibrium reservoir can be reduced through regional street sweeping and anti-icing practices. To be most effective, emission control strategies should require that not only primary roads, but all roads, be swept after snowstorms to recover applied abrasive material. The final report is available on the USDA Forest Service-Pacific Southwest Research Station Tahoe Science Program website.

Lake Tahoe source attribution study: receptor modeling study to determine the sources of observed ambient particulate matter in the Lake Tahoe Basin

Lead Investigators: *Johann Engelbrecht, Alan Gertler, and Tony VanCuren (Desert Research Institute)*

Researchers analyzed ambient particle data to distinguish chemical species and to identify the sources of particular matter within the basin. The results from this study support the hypothesis that re-suspended paved road dust is the major source of particulate matter (PM_{10}) in the basin, and that the most important sources to control are road dust, followed by wood smoke and mobile sources. The final report and appendices are available on the USDA Forest Service-Pacific Southwest Research Station Tahoe Science Program website.

ROUND 9

Impacts of vehicle activity on airborne particle deposition to Lake Tahoe

Lead Investigators: *Dongzi (Davis) Zhu*, *Hampden Kuhns, John Gillies, and Alan Gertler (Desert Research Institute)*

This study integrates the results of previous and ongoing research to quantitatively examine how road dust emissions and atmospheric deposition are affected by several factors, including season, local wind conditions, vehicle class, vehicle speed, vehicle kilometers driven, road type, road maintenance practices, vegetative density, and proximity of the source road to the lake. Key results include: 1) proximity to the lake, prevailing wind directions, and traffic patterns play a dominant role in determining which roads have the greatest potential to deposit fine sediment into the lake; 2) emissions vary both by season and by location and vehicle kilometers traveled (VKT) are not evenly distributed in the basin's urban area; 3) approximately 2% of road emissions of particulate matter (PM_{10}) (20 Mg/year) and approximately 1.5% of total suspended particles (TSP) (35 Mg/year) is estimated to reach the lake; and 4) estimates of dry deposition to the lake are lower than calculated by the Lake Tahoe Atmospheric Deposition Study (LTADS). The final report will be available on the USDA Forest Service-Pacific Southwest Research Station Tahoe Science Program website soon; until then the report may be obtained from the Tahoe Science Program Coordinator.

ROUND 10

Visibility and monitoring standards for Lake Tahoe Basin: assessment of current and alternative approaches

Lead Investigators: *L.-W. Antony Chen, Xiaoliang Wang, and John G. Watson (Desert Research Institute)*

This project evaluated the current visibility measurements and technologies available for tracking haze in Lake Tahoe and provides recommendations for future monitoring, data analysis, and threshold

development. The final report recommends establishing measurements to estimate the chemical light extinction coefficient (b_{ext}) at a South Lake Tahoe site to: 1) allow regional and sub-regional visibility monitoring to be based on the same methods; 2) maintain reasonable continuity for tracking long-term trends; 3) relate receptor concentrations to source emissions; and 4) evaluate particulate matter (PM_{10} and $PM_{2.5}$) concentrations related to the National Ambient Air Quality Standards (NAAQS). Joining the national Interagency Monitoring of PROtected Visual Environments (IMPROVE) network is the most cost-effective approach to achieve these goals. To satisfy the requirement of the California state visibility standard, a nephelometer may also be installed to determine optical light scattering (b_{scat}). The final report will be available on the USDA Forest Service-Pacific Southwest Research Station Tahoe Science Program website soon; until then the report may be obtained from the Tahoe Science Program Coordinator.

Lake Tahoe visibility impairment source apportionment analysis

Lead Investigators: *Mark Green, L.-W. Antony Chen, and Dave DuBois (Desert Research Institute), John Molenar (Air Resource Specialists)*

The study concentrated on interpretation of 20 years of chemically speciated particulate matter ($PM_{2.5}$) aerosol data at Bliss State Park and 15 years worth of data at South Lake Tahoe. Key results include: 1) three-fourths of the increased light extinction at South Lake Tahoe compared to Bliss State Park was due to much higher organic carbon (OC)and elemental carbon (EC) aerosol at South Lake Tahoe, especially in winter; 2) seasonal patterns in light extinction were reversed for the two sites, with Bliss State Park having highest average values in summer due to wildfire impacts and South Lake Tahoe having highest average values in winter due to buildup of residential wood burning and traffic emissions under winter inversion conditions; 3) comparison of 20% best and worst visibility days at Bliss State Park for the regional haze rule (RHR) baseline period of 2000-2004 to 2005-2009 showed the cleanest days getting cleaner and the haziest days getting hazier, mainly due to increased OC and EC; 4) receptor modeling was using positive matrix factorization (PMF) resolved seven factors for Bliss State Park versus six factors for South Lake Tahoe, including a unique salting factor; and 5) receptor modeling using chemical mass balance (CMB) confirmed that a) biomass burning was the dominant source of $PM_{2.5}$ with increasing importance over time; b) low combustion efficiency (LCE) burning accounts for most of the biomass burning contribution; c) road dust and traffic contributions were much higher at South Lake Tahoe than at Bliss State Park; and d) industrial combustion and salting were minor sources. The final report will be available on the USDA Forest Service-Pacific Southwest Research Station Tahoe Science Program website soon; until then the report may be obtained from the Tahoe Science Program Coordinator.

Current or Continuing Projects—Air Quality

ROUND 10

Particulate emissions from biomass burning: quantification of the contributions from residential wood combustion, forest fires, and prescribed fires

Lead Investigators: *Daniel Obrist, Alan Gertler and Barbara Zielinska (Desert Research Institute)*

The goal of this study is to develop and use a specific characterization method to differentiate between particulate matter (PM) contributions in the Lake Tahoe Basin from residential wood combustion, wildfires, and prescribed fires. Deposition of PM is an important source of phosphorus (P) and sediment to Lake Tahoe, and leads to reductions in water clarity and decreases atmospheric visibility in the basin. The relative importance of PM emissions from various types of biomass combustion—i.e., domestic wood combustion, wildfires, and prescribed fires—is mainly based on seasonal observations without direct confirmation by measurements. This study will develop a method to specifically characterize PM emissions from domestic wood combustion, wildfires, and prescribed fire emissions by combining two

of the most commonly used biomass combustion tracers, soluble potassium (K^+) and levoglucosan, with detailed characterization of organic compounds (i.e., carbohydrates, anhydrosugars, lignin), and particulate-bound mercury (Hg). These chemical PM fingerprints are expected to provide a powerful tool for differentiation of PM emissions from different biomass combustion sources— including in-basin versus out-of-basin contributions—and will possibly also allow for evaluation of past fire history in the basin in soil and sediment records.

Current expected completion date: July 2012

Distribution of ozone, ozone precursors and gaseous components of atmospheric deposition in the Lake Tahoe Basin

Lead Investigators: *Andrzej Bytnerowicz, Haiganoush Preisler and Mark Fenn (USDA Forest Service-Pacific Southwest Research Station), Alan Gertler and Barbara Zielinska (Desert Research Institute)*

This study will characterize ozone (O_3), precursors of O_3 formation, and gaseous pollutants that are important contributors to atmospheric nitrogen (N) deposition in the Lake Tahoe Basin. Passive samplers will be used to monitor of O_3, nitric oxide (NO), nitrogen dioxide (NO_2), ammonia (NH_3), nitric acid (HNO_3) and volatile organic compounds (VOCs) on a network of 32 sites inside and outside of the basin. Distribution maps of the measured compounds for the entire basin will be created using statistical and geostatistical models. On a subset of sites, real-time O_3 concentrations will be measured with active UV absorption monitors to evaluate diurnal changes of the pollutant, passive O_3 samplers will be calibrated, and the data will be used for evaluation of the exceedances of O_3 air pollution standards in the basin. At the same sites N deposition will be measured with ion exchange resin (IER) collectors placed in forest clearings (bulk precipitation) and under tree canopies (throughfall). In the bulk and throughfall samples from the IER collectors, the stable isotope composition of NO_3^- (^{15}N and ^{18}O) and of NH_3 (^{15}N) will be measured to evaluate the origin of N deposition in the basin. Results of this study will help to evaluate the present and future potential of O_3 formation as well as the biological/ecological effects of N air pollutants and the resulting N deposition in the Lake Tahoe Basin. These results will also help to develop science-based management strategies aimed at improving air quality and ecological sustainability of the basin.

Current expected completion date: June 2013

Tahoe Climate Information System (TahoeClim)

Lead Investigators: *Kelly Redmond (Desert Research Institute) and Geoffrey Schladow (University of California-Davis)*

Weather and climate are well understood to be very important as primary drivers of atmospheric, ecological, limnological, biological, geological, hydrological and economic processes affecting the Tahoe Basin in myriad ways. Within the Tahoe Basin there is a heavy and steady demand for weather and climate information. A large amount of data and information already exist, but these data and information are not fully validated, processed or available from any single authoritative source. A joint collaboration between the Western Regional Climate Center at Desert Research Institute in Reno and the University of California-Davis Tahoe Environmental Research Center (TERC) will develop an accessible archive of historical and current meteorological and climatological data for the Tahoe Basin. The Tahoe Climate Information Management System (TahoeClim) will include all past and present observations from the principal weather and climate networks operating in the basin and National Aeronautics and Space Administration (NASA) space-borne thermal infrared imagery. A variety of specialized sites on and near the lake, and in and near the basin, will likewise be incorporated, including a small number to be added or augmented during this project. The data flow and management system

will be established to allow the continued assimilation and archiving of real-time data in the future. The data sets will include direct measurements from *in situ* locations, interpolated and infilled data on fine grids, three-dimensional hourly fields of data from the last five years, and synthesized information in the form of products, many of which can be generated directly by the users and therefore be more responsive to their needs. The intended audience encompasses the public, managers, politicians, the press, educators and students, but will meet the more stringent demands and standards of the environmental research community.

Current expected completion date: January 2013

Improving meteorological data and forecasts for prescribed burn-day decisions
Lead Investigators: *Timothy Brown (Desert Research Institute) and Narasimhan Larkin (USDA Forest Service-Pacific Northwest Research Station)*
This study addresses the issue of developing and/or improving meteorological data and monitoring tools for use in forecasting and making burn-day decisions for prescribed fires. Lake Tahoe Basin-specific products and deliverables from this project will include: 1) a 100-m gridded climatology of surface wind; 2) a 4-km mixing height climatology with associated transport wind; 3) a 100-m surface and upper level climatology; 4) 100-m resolution gridded operational forecasts of surface wind; 5) new weather station observations during the project period for an elevation transect within the Tahoe Basin; and 6) a customized smoke prediction website tool. These deliverables are developed from a suite of existing tools including the operational California and Nevada Smoke and Air Committee (CANSAC) forecast system at the Desert Research Institute, the Bluesky smoke prediction framework, WindNinja, and field weather instruments.

Current expected completion date: July 2012

ROUND 11
Secondary pollutant formation in the Lake Tahoe Basin
Lead Investigators: *Barbara Zielinska and Alan Gertler (Desert Research Institute), Andrzej Bytnerowicz (USDA Forest Service-Pacific Southwest Research Station), Wendy Goliff (University of California-Riverside), Chad Praul (Environmental Incentives)*
This study will characterize the precursors and pathways of secondary pollutant formation, including ozone (O_3), secondary organic aerosol (SOA) and ammonium nitrate (NH_4NO_3) in the Lake Tahoe Basin. Sites will be selected inside the basin to collect samples for detailed speciation of volatile organic compounds (VOC) and carbonyl compounds and to measure concentrations of ammonia (NH_3), nitrous acid (HONO), nitric acid (HNO_3), sulfur dioxide (SO_2) and fine particulate NH_4NO_3 and ammonium sulfate [$(NH_4)_2SO_4$] with a resolution of several hours. We will also collect particulate ($PM_{2.5}$) filter samples and continuously measure PM, O_3 and nitrogen oxide (NO/NO_2) concentrations. These data will be used for development of an air quality model to predict ozone and other secondary pollutants formation in the basin. The expected results from this study will provide tools for evaluation of the present and future potential of O_3, SOA and NH_4NO_3 formation as well as for interfacing with basin managers to support the development of science-based management strategies aimed at improving air quality and ecological sustainability of the Lake Tahoe Basin. In particular, the results of this study will be used to inform stakeholders which emissions should be more strictly regulated in order to attain air quality standards and reduce Lake Tahoe Total Maximum Daily Load (TMDL) pollutants delivered via the atmospheric deposition source category.

This research is logical continuation of previous efforts including the Southern Nevada Public Land Management Act (SNPLMA) Round 7 project , "Lake Tahoe source attribution study: receptor modeling study to determine the sources of observed ambient particulate matter in the Lake Tahoe Basin," and the SNPLMA Round 10 project, "Particulate emissions from biomass burning: quantification of the contributions from residential wood combustion, forest fires, and prescribed fires." These research efforts focus on understanding air quality and its effects on the human health-based national and state air pollution standards, and also on potential ecological impacts of air pollution and atmospheric deposition in the Lake Tahoe Basin.

Current expected completion date: March 2015

Evaluation of prescribed burn impacts on air quality and visibility in the Lake Tahoe Basin
Lead Investigators: *L.-W. Antony Chen, Mark Green, and Xiaoliang Wang (Desert Research Institute)*
Prescribed burning that is widely used for fuel reduction in the Tahoe Basin potentially impacts air and water quality, visibility, and human exposure to air toxins. A thorough evaluation of the impact of prescribed burning has not been achieved due to lack of field measurements for pile/under- burn emissions and spatiotemporal distribution of smoke plumes. This project will employ a unique combination of source and ambient monitoring systems and satellite remote sensing data to address this knowledge gap. Source measurements will yield emission factors of criteria pollutants including particulate matter (PM) and ozone (O_3) precursors, as well as particle size distribution, chemical composition, and light extinction coefficient. Ambient PM_{10}/$PM_{2.5}$ measurements will be made at sites representative of community exposure in the basin. The prescribed burning impact on air quality and visibility will be linked to burn and meteorological parameters leading to recommendations for future burning strategies (e.g., burn window, season, location [in- and outside the basin], and technique). The project will also establish a procedure to evaluate air quality through satellite data on a routine, cost-effective basis.

Results from this project are expected to contribute to best management practices (BMPs) for mitigating the environmental impact of prescribed burning. This project also complements several PM and visibility source apportionment studies conducted in Lake Tahoe, including three SNLPMA Round 10 projects: 1) "Visibility monitoring and standards for Lake Tahoe Basin: assessment of current and alternative approaches;" 2) Lake Tahoe visibility impairment source apportionment analysis;" and 3) "Particulate emissions from biomass burning: quantification of the contributions from residential wood combustion, forest fires, and prescribed fires."

Current expected completion date: March 2013

Round 12 Air Quality Subthemes

Improving the estimates of atmospheric deposition

Management and/or Policy Need

Atmospheric deposition to Lake Tahoe is the major source of nitrogen (N) and a substantial source of phosphorus (P) and particulate matter (PM) entering the lake. There is, however, significant uncertainty in deposition flux estimates. Further, the current estimates of atmospheric deposition loads only consider what falls directly onto the lake and do not consider what falls onto the surrounding watershed and then is subsequently transported to the lake by wind and water. To reduce this uncertainty, focused studies should be conducted to determine the sources and pathways of particle deposition. These results will better inform models used to assess future conditions, and will help to inform the prioritization of restoration efforts.

Description
Research that focuses on one of the following issues is needed, although integrated research addressing all issues are encouraged: 1) focused studies of the sources and pathways of particle deposition as well as improved estimates of deposition flux (i.e., gradient or eddy-correlation studies along with measurements of key chemical species); these studies should evaluate PM deposition rates in relation to surrounding land uses and proximity to the lake and the results should aim to better inform models, restoration efforts, and load reduction efforts, and provide methodologies to quantify estimates from actions to reduce loading of fine sediment particles and nitrogen to the lake; 2) synthesize existing data and information to develop improved estimates of atmospheric deposition in the Lake Tahoe Basin; and (3) review the existing atmospheric deposition monitoring approach and develop a revised sampling and analysis plan that will facilitate estimating total atmospheric deposition loads of key pollutants onto the lake coupled with the flux of pollutants from the watershed to the lake.

Managing air pollutants

Management and/or Policy Need
Exceedances of the ozone standards have been measured in the Lake Tahoe Basin, particularly when measured against California state standards. Local emissions due to burning and vehicle transport are known to reduce visibility and impact local air quality. In addition, out-of-basin transport of greenhouse gases, particulates, organic aerosols, and other airborne pollutants impact both air quality and lake clarity. Understanding these processes requires validated atmospheric models. Validating these models requires compiling an inventory of available emissions and meteorology data, and incorporating information from ongoing monitoring and focused research. Using Sparse Matrix Operator Kernel Emissions (SMOKE) or other emissions tools, an emissions file should be created for ready input into a Lake Tahoe Air Quality Modeling System (LTAQMS), including an emissions processing model, mesoscale meteorology model (MMM), and an air quality model (AQM). The LTAQMS needs to be designed to support regional regulation of air quality.

Description
Research is needed that focuses on one or more of the following issues: 1) inventory available emissions and meteorology data and identify and prioritize monitoring and research data needed to construct and validate a Lake Tahoe Air Quality Monitoring System (LTAQMS); any proposed sampling plan should consider integration with other atmospheric monitoring needs (e.g., meteorology, visibility, and criteria pollutants); and 2) review existing management and regulatory reduction strategies (e.g., the Tahoe Regional Planning Agency's [TRPA] Blue Boating Program and federal and state emission standards for watercraft, automobiles, buses and trucks) and use an air quality model to quantify viable alternative strategies for the reduction of ozone and other pollutants in the Lake Tahoe Basin; comparisons of the cost-effectiveness of each viable strategy should be included.

Integrating Science
The Integrating Science theme houses projects covering such areas as remote sensing research, data management systems, data synthesis, and environmental indicators.

Tahoe Science Consortium
The Tahoe Science Consortium is also house under the Integrating Science theme. Recent accomplishments of the Tahoe Science Consortium include:

1. Organizing a symposium on forest management decision support tools, which was held November 3-4, 2010 at the Tahoe Center for Environmental Sciences (Sierra Nevada College

campus), Incline Village, Nevada. The specific objectives of this symposium were to: 1) understand inputs, outputs, and intended applications for the Tahoe Basin-specific forest management decision support tools being developed or refined; 2) examine new datasets, including remote sensing and meteorology data, and how they apply to the support tools; 3) identify opportunities for science integration; and 4) identify future research needs. Approximately 65 people attended the symposium.

2. Working with science community representatives to organize a one-day meeting to discuss rainfall simulation protocols and validation of the Water Erosion Prediction Project (WEPP) model. This meeting was held on March 4, 2011 at the Tahoe Center for Environmental Sciences (Sierra Nevada College campus), Incline Village, Nevada. The discussion highlighted the need for identifying standard tools and monitoring, restoration, and mitigation techniques as well identifying which soil characteristics are most impacted by management activities.
3. Facilitating reestablishment of the Science and Management Integration Team (SMIT) to provide technical assistance to the agencies and to enhance coordination between scientists and managers, including the development of a charter and workplan. See the section "Other Tahoe Science Program-Relevant Activities" in this report for more information about SMIT.
4. Finalizing a wildfire rapid response plan. The plan is in the final stages of review and will be publicly available soon.
5. Initial planning for the biennial Tahoe Science Conference, which will be held May 22-24, 2012 on the Sierra Nevada College campus in Incline Village, Nevada.

Completed Projects—Integrating Science

ROUND 5

Land-cover characterization of the Lake Tahoe Basin

This was a capital project sponsored by the U.S. Geological Survey. This project: 1) mapped the current and historical state of the land surface in the Tahoe Basin; 2) analyzed patterns, rates, and trends in urbanization and land-use change; and 3) assessed the causes and possible environmental consequences of land-use change.

Publications associated with this project:

Raumann, C.G. 2007. Land-cover change in the southern Lake Tahoe Basin, California and Nevada, 1940-2002: U.S. Geological Survey Scientific Investigations Map 2962, scale 1:27,000

Raumann, C.G. and M.E. Cablk. 2008. Change in the forested and developed landscape of the Lake Tahoe Basin, California and Nevada, USA 1940-2002. Forest Ecology and Management 255: 3424-3439. doi: 10.1016/j.foreco.2008.02.028

Soulard, C.E. and C.G. Raumann. 2008. Historical orthoimagery of the Lake Tahoe Basin: U.S. Geological Survey Data Series 376

Tahoe Environmental Science System

Sponsored by the U.S. Environmental Protection Agency, the Tahoe Environmental Science System (TESS) developed from the Scientific Advisory Group (SAG) in response to the need for a more formalized structure to support science efforts in the Lake Tahoe Basin. The purpose of TESS was to provide evaluation and review of Southern Nevada Public Land Management Act (SNPLMA) projects, define future science and research needs in the basin, and oversee implementation of an adaptive management framework. TESS was the precursor to the Tahoe Science Consortium.

ROUND 10

Light Detection and Ranging (LiDAR) and multispectral geospatial data acquisition

This was a capital project sponsored by the U.S. Geological Survey and the Tahoe Regional Planning Agency (TRPA). High-resolution Light Detection and Ranging (LiDAR) and multispectral imagery covering the entire Lake Tahoe Basin was collected in the summer of 2010. Post-processing of the data verified location accuracy and complete basin coverage. The data was made publicly available in early 2011 through OpenTopography. Applications for this data include fuel treatment planning, fire behavior modeling, habitat restoration planning and evaluation, hydrologic modeling, accurate mapping of vegetation height, density, size, distribution and heterogeneity, terrain visualization, landform extraction, surface feature extraction, watershed and water quality evaluations, community planning, engineering surveys and planning, and natural resource monitoring and evaluation.

Current or Continuing Projects—Integrating Science

ROUND 5

Tahoe Integrated Information Management System (TIIMS)

Development of the Tahoe Integrated Management System (TIIMS) was originally funded through a capital project sponsored by the U.S. Environmental Protection Agency. TIIMS is a resource platform that provides web access to information and data concerning Lake Tahoe planning and restoration efforts. Continued maintenance and development of TIIMS is currently supported through a collaborative effort between multiple federal, state, and local agencies. The TIIMS Toolbox contains a suite of tools, including bibliographic and metadata search tools.

Tahoe Decision Support System

This was a capital project sponsored by the U.S. Geological Survey (USGS). The Tahoe Decision Support System (TDSS) is a tool being developed by the Science Section of the USGS Western Geographic Science Center and the Tahoe Regional Planning Agency. The tool provides resource managers with scientific information to guide management decisions. TSSS incorporates environmental and socioeconomic considerations and will provide tools to optimize long-term planning in the Tahoe Basin given an array of alternative planning scenarios. The first tool resulting from this project assessed a “business as usual” scenario. The tool may be accessed via the Tahoe Integrated Information Management System (TIIMS) website after obtaining a login from the TIIMS Administrator.

Publications associated with this project:

Halsing, D.L., Hessenflow, M.L. and A. Wein. 2005. The no-project alternative analysis: an early product of the Tahoe Decision Support. Journal of the Nevada Water Resources Association 2(1): 15-28.

Hessenflow, M. and D. Halsing. 2006. A simulation model of land-use change in the Lake Tahoe Basin of California and Nevada, as used in a Decision-Support System. In: Voinov, A., Jakeman, A.J., Rizzoli, A.E. (eds). Proceedings of the iEMSs Third Biennial Meeting: "Summit on Environmental Modelling and Software". International Environmental Modelling and Software Society, Burlington, USA, July 2006. CD ROM.

ROUND 6

Tahoe Decision Support System

Continued development of the Tahoe Decision Support System was supported in Round 6 and focused on software and integration support.

ROUND 10

Nearshore ecology and aesthetics

Lead Investigators: *Alan Heyvaert and Rick Susfalk (Desert Research Institute), Sudeep Chandra (University of Nevada-Reno), John Reuter, Geoffrey Schladow, and Scott Hackley (University of California-Davis), Marion Wittmann (University of California-Davis, now at University of Notre Dame)*

The nearshore environment of a lake ecosystem often remains a poorly studied area despite its importance to overall biodiversity and function of the lake. This is also true for Lake Tahoe where the nearshore environment also possesses important aesthetic and economic significance for tourism as visitor and resident interactions with the lake occur primarily in the nearshore. While there have been potential improvements to the open water habitat (e.g., clarity) of the lake, basin managers are now turning their attention to understanding nearshore processes. The objective of this study is to provide basin management agencies with science-based recommendations for the development of a long-term management and monitoring program for Lake Tahoe's nearshore environment. In particular, this study will focus on the evaluation of environmental indicators that can be used by managers to assess if nearshore desired conditions are being attained. We will review and synthesize existing nearshore science, management objectives, and current conditions in order to develop a conceptual model that relates nearshore environmental processes with the desired conditions identified by basin management agencies. Potential indicators will be evaluated for their scientific relevance, feasibility for implementation, and their ability to support management objectives. Scientifically defensible numeric or narrative standards will be suggested where possible. Lastly, a monitoring plan based on these indicators will be developed that addresses the natural temporal and spatial variability found within the nearshore environment. One important facet of this project will be the close collaboration with Nearshore Agency Working Group through a series of meetings and interactions to define, discuss, and contribute to this project's deliverables. A public forum will be held near the end of the project to obtain stakeholder input for consideration in the final report.

Current expected completion date: November 2012

Upland forest integrity

Lead Investigators: *Patricia Manley and Angela White (USDA Forest Service-Pacific Southwest Research Station), David Saah, Jarlath O'Neil-Dunne, Qi Chen, Tim Robards, and Shelly Cole (Spatial Informatics Group)*

This is a directed action project that will conduct research to help managers identify meaning indicators for upland habitat ecological condition. This research will include an independent test of indicators proposed in the draft "Healthy vegetation and hazardous fuels desired condition monitoring plan" (Greenberg and Dobrowski, 2009) by a collaborative interdisciplinary team. The draft monitoring plan identifies landscape extent of forest/non-forest types, forest structural class, and ecological condition as the indicators for the Healthy Vegetation Desired Condition (DC). Absent is an indicator to assess vegetation as wildlife habitat. Because viable monitoring systems are dependent on high quality institutional field data to estimate trends, this study proposes to resample a set of 100 established monitoring sites located throughout the basin to create additional Healthy Vegetation DC indicators and to field calibrate the direction and magnitude of change in plants, habitat for birds and small mammals, and bird populations that has occurred since the first measurement period (2002-2004). This project will ultimately test the ability of the proposed vegetation indicators to represent change in vegetation conditions, wildlife habitat and bird populations.

Current expected completion date: July 2013

ROUND 11

Mapping hard and soft impervious cover in the Lake Tahoe Basin using LiDAR and multispectral images: a pilot study of the Lake Tahoe land cover and disturbance monitoring plan

Lead Investigators: *Jarlath O'Neil-Dunne and David Saah (Spatial Informatics Group)*

This project will leverage existing investments in high-resolution multispectral imagery, Light Detection and Ranging (LiDAR), and vector geographic information system (GIS) data to map and quantify impervious cover for the Lake Tahoe Basin (LTB). We will use a repeatable and cost-effective analytical methodology, centered on Object-Based Image Analysis (OBIA) techniques, to map hard and soft impervious cover. This approach will overcome the limitations of previous mapping efforts that did not differentiate between impervious cover classes or ensure that impervious surfaces were properly connected, both of which are vital to management and modeling efforts. The end product will be a spatially detailed, accurate, attribute-rich, and realistic map of impervious cover within the LTB. In order to make the data accessible to other scientists, resource managers, and decision makers, this map and corresponding information will be delineated and summarized by ownership (e.g., parcels), environmental gradients/boundaries (e.g., watershed, soil type, soil capability class) and political boundaries (e.g., counties). Finally, we will pilot implement the proposed "Lake Tahoe land cover and disturbance monitoring plan" (Spatial Informatics Group 2009) using the derived impervious surface cover. The results from this pilot and the newly derived impervious cover input data will be compared to the previous assessment to gauge strengths and weaknesses between approaches and, if warranted, recommend ways to retrofit the previous assessment to the new approach.

The recent acquisition and availability of basin-wide LiDAR (available through OpenTopography) and WorldView-2 images, in conjunction with our proposed methodology, allows for a current and more precise assessment of both hard and soft cover. In addition, this type of imagery is considered ideal for long-term monitoring and allows for pilot implementation of the Lake Tahoe land cover and disturbance monitoring plan.

Current expected completion date: January 2013

Assessment of fire hazard/risk in the wildland-urban interface (WUI) and stream environment zones (SEZs)

Lead Investigators: *David Saah, Jason Moghaddas, Jarlath O'Neil-Dunne, and Qi Chen (Spatial Informatics Group)*

Around Lake Tahoe, sections of the stream environment zone (SEZ), especially those that contain the terminal portions of streams feeding into the lake, are within the wildland-urban (WUI) where potential impacts from wildfire are a key concern. A considerable effort has been underway within the Lake Tahoe Basin to mitigate these potential impacts. An understanding of how wildfire can impact both the WUI and SEZ, along with an assessment of mitigation efforts to date, is therefore critical. This study will characterize conditions in the WUI and assess the current potential for crown fire initiation and probability of burning for all mapped SEZ and WUI areas in the Lake Tahoe Basin under extreme or "problem" fire weather conditions. Where existing stream maps are available, this study will distinguish differences in these variables between annual and perennial streams, wetlands, and conifer- and/or hardwood-dominated riparian areas in lower, middle, and upper reaches of the Lake Tahoe watershed. In addition, we will evaluate the effects of all known planned fuels treatments over the next decade on the crown fire initiation and conditional burn probability in all mapped SEZ and WUI regions in the Lake Tahoe Basin.

This project complements the Southern Nevada Public Land Management Act (SNPLMA) Round 9 project, "Integrated decision support for cost effective fuel treatments under multiple resource goals," and the Round 10 project, "Management options for reducing wildlife risk and maximizing carbon storage under future climate changes, ignition patterns, and forest treatments," which both seek to evaluate the landscape-level effectiveness of different treatment scenarios on wildfire risk but without the focus on stream environment zones. The project team will consult with management agencies and coordinate with ongoing science projects to ensure that definitions and maps of SEZ and WUI are consistent across these efforts.

Current expected completion date: March 2013

Development of status and trend indicators for stream condition and other resources
Lead Investigators: *Andrew Stubblefield and Allison O'Dowd (Humboldt State University), Chad Praul (Environmental Incentives, LLC)*
Specific indicators have been identified that provide information to managers, policy-makers and the public regarding the status and trends of the air, land, people and water of the Lake Tahoe Basin. In the recent Environmental Improvement Program (EIP) update document, key goals for 2008-2018 include refining and implementing monitoring and evaluation programs to assess the status of environmental conditions and determine the effectiveness of EIP restoration projects. Other key goals include improving data and information management to utilize web-based systems and developing and adopting standard operating procedures for seamless data analysis and public reporting. This research will support these key EIP goals by collecting, synthesizing and cataloguing existing data sets in order to further develop and report status and trend indicators. Development of benthic macroinvertebrate indicators of stream ecosystem health will be a major focus of this project. Methods used will include Multi-Metric Indices of Biologic Integrity and the River Invertebrate Prediction and Classification System (RIVPACS). Results will include an improved and more sensitive index that is able to discriminate levels of aquatic disturbance thus providing an indicator of condition status and trends and effectiveness of restoration projects. Other elements of the research will include assembling and summarizing data sets related to: human health - drinking water quality; upland and aquatic special status species; environmental air quality – atmospheric deposition, and Lake Tahoe's chemical and biological parameters.

This research defines incremental development and advancement of the existing Tahoe Status and Trend Monitoring and Evaluation Program (M&E), which is a partnership of agencies responsible for reporting the status and trend of ambient conditions. The partnership is lead by the Tahoe Regional Planning Agency (TRPA) and USDA Forest Service-Lake Tahoe Basin Management Unit (LTBMU), but includes executive representation from Lahontan Regional Water Quality Control Board, Nevada Division of Environmental Protection, Nevada Division of State Lands, and the California Tahoe Conservancy. An M&E working group is already operating and will be engaged at key times during the project; additional agencies in the basin will be invited to join this group. Southern Nevada Public Land Management Act (SNPLMA) support has been used in development of a management system for the M&E Program through the Adaptive Management Framework (AMF) series of projects. The products of the AMF research include the M&E Program Manual which will guide development of many of the deliverables of this research. SNPLMA research funds have also supported a multitude of land management and research organizations to collect datasets which were analyzed for other needs. Many of these data sets will be leveraged as the central focus of one of the goals of this project.

Current expected completion date: August 2012

Remote sensing of Lake Tahoe's nearshore environment
Lead Investigators: *Geoffrey Schladow and Erin Hestir (University of California-Davis)*
The goal of this research is to use remotely-sensed data to retrieve fine sediment, chlorophyll, and colored dissolved organic matter (CDOM) concentrations from the water column in the nearshore, and to map the distribution of periphyton (attached algae), aquatic macrophytes (submerged plants), and clam beds in the nearshore of Lake Tahoe and variations in sediment type. High spatial resolution multispectral satellite imagery, moderate spatial resolution multispectral satellite imagery, and airborne hyperspectral imagery will be used. We will investigate both empirical and model-driven methods to map fine sediment, chlorophyll, and CDOM concentration, macrophyte communities, clam bed, periphyton, and substrate type. The empirical approach will first classify the optically shallow nearshore into the different bottom classes using the field data and spectral library first to train and then (independently) validate the classifier. This analysis allows the development of statistical correlations (e.g., regression modeling) whereby reflectance information can be used to predict the probability of the concentration of water quality constituents above a particular bottom type. Upon successful development, the statistical model can then be used to predict water quality in each image pixel given the reflectance value of that pixel. The second approach will use a radiative transfer model that simulates remote sensing reflectance of water given inputs of different aquatic optical properties. One of the key deliverables of the project is a cost-benefit analysis of remote sensing approaches for monitoring the nearshore environment and a manual for implementing remote sensing analysis for monitoring the nearshore environment.

Several previous Southern Nevada Public Land Management Act (SNPLMA) science studies will inform this project, including the Round 7 project, "Predicting and managing changes in nearshore water quality," the Round 9 project, "Development of a risk model to determine the expansion and potential environmental impacts of Asian clams in Lake Tahoe," and the Round 10 project, "Natural and human limitations to Asian clam distribution and recolonization-factors that impact the management and control in Lake Tahoe," as well as a project funded by the US Army Corps of Engineers that is conducting a baseline assessment of benthic species and developing recommendations for future assessments.

Current expected completion date: March 2013

Evaluating field and laboratory data for developing surrogate indicators to monitor fine sediment in the Tahoe Basin
Lead Investigators: *Alan Heyvaert (Desert Research Institute), John Reuter and Masoud Kayhanian (University of California-Davis), Nicole Beck (2NDNATURE, LLC)*
The Lake Tahoe Total Maximum Daily Load (TMDL) has determined that a 60–70% reduction in fine sediment particles will be needed to achieve a Lake Tahoe clarity target of 30 meters. Reliable and economical methods to monitoring and quantify the loading of fine sediment particles to the lake are needed in order to track pollutant load reductions over time resulting from water quality improvement projects. The goal of this research is to provide basin management agencies with science-based final recommendations for analytical methods and surrogate indicators of particle concentrations and characteristics appropriate to regulatory purposes and relevant to improved measurement and tracking of fine particle loading in the Tahoe Basin. Agency representatives will work in close collaboration with the project scientists to evaluate the available data, determine the quality of existing relationships between surrogate quantification techniques and associated particle numbers, and then provide recommendations for field and laboratory assessment of particle numbers and suitable proxies.

This project will use information from previous monitoring and research projects in the Lake Tahoe Basin, including the Pilot TMDL Stormwater Monitoring Program, the Pollutant Load Reduction Model (PLRM) Development Project, previous studies related to best management practice (BMP) evaluation, as well as the many research projects done since fine particles were first identified as a pollutant of concern. This project also will build upon information developed from other Southern Nevada Public Land Management Act (SNPLMA) projects which were funded to assemble available particle size data and test analytical methods for developing preliminary protocols (Round 7, "Tahoe Basin particle size analysis and protocol development"), and to acquire data on Characteristic Runoff Concentrations (CRCs) and Characteristic Effluent Concentrations (CECs) used in the Pollutant Load Reduction Model (PLRM) (Round 9, "Priority urban stormwater monitoring to directly inform the Pollutant Load Reduction Model (PLRM)"). Ongoing SNPLMA projects funded in Round 8 are in progress to determine sources of fine sediment in highway runoff (Round 8, "Determining sources of highway runoff fine sediment in stormwater, streams, and Lake Tahoe using fingerprinting techniques"), and to help establish relationships between turbidity, fine sediment and natural removal mechanisms (Round 8, "Potential of engineered flood plains and wetlands as fine-particle BMPs: case study of Trout Creek and the Upper Truckee River").

Current expected completion date: March 2014

Sand Harbor carrying capacity study
Contact: *Peter Maholland (Nevada Division of State Parks)*
This project includes the gathering of new and existing data related to social carrying capacity (completion of surveys evaluating visitor use, visitor experience and values) and environmental carrying capacity (e.g., water quality, habitat, vegetation) to evaluate the potential impacts of current use patterns at the Sand Harbor management unit of Lake Tahoe Nevada State Park. This data will be coupled with economic modeling to provide management recommendations for Sand Harbor and set carrying capacities. The study will be focused on the main beach, boat parking area and associated facilities, Diver's Cove, and group use area and picnic areas.

Current expected completion date: December 2011

Round 12 Integrating Science Subthemes

Understanding current and future resource conditions through analysis of remote sensing data
Management and/or Policy Need
The Round 10 Lake Tahoe Southern Nevada Public Land Management Act (SNPLMA) capital program included funding to acquire high-resolution Light Detection and Ranging (LiDAR) data and multispectral imagery for the Tahoe Basin. Analyses of these datasets and images are needed to develop information that agencies can use in the future planning of capital projects, to characterize current natural resource conditions, and to provide a baseline for comparison of future conditions resulting from the ongoing implementation of forest management and habitat restoration projects. Agencies especially need research results that integrate high-resolution LiDAR and multispectral imagery to further our understanding of land-use patterns and current and future natural resource conditions, and elucidate management options.

Description
Research is needed that addresses one or more of the following objectives: 1) provide a spatially-explicit determination of current forest structural classes across topographic features and model forest structure restoration strategies that include a range of tree density reductions and creation of openings based on: a) a range of opening sizes; (b) frequency distributions of opening sizes on the landscape; (c) rate of application of openings (e.g., number of openings by size per year); and (d) differences between intensity versus extent of openings; 2) analyze datasets and develop derivative products to: (a) reveal landscape-scale indicators of environmental condition and document remote sensing analysis methodologies to derive indicators; b) evaluate fire risk and the extent and distribution of defensible space in the urban intermix and wildland-urban interface (WUI); c) map hydrologic networks to inform fine sediment and nutrient pollutant load reduction project planning and/or floodplain management; or (d) assess the extent, type, and condition of stream environment zones (SEZs)and wetlands to guide environmental improvement restoration opportunities; and 3) develop spatial models and maps of habitat suitability for special status plant and wildlife species or communities of concern.

Identifying environmental indicators and development of approaches for monitoring and evaluation
Management and/or Policy Need
Land management and regulatory agencies need to evaluate whether their actions are effective at meeting environmental targets through the implementation of agency land-use and management plans. Credible evaluations require meaningful indicators of appropriate standards, and require development and implementation of monitoring plans to evaluate and report the status and trends of environmental indicators relative to established targets. Credible evaluations also require tools and protocols for consistent and comprehensive data management, analysis and reporting.

Description
Research is needed to address one of the following topic areas: 1) greenhouse gases emissions; 2) small lakes; 3) aquatic special status species and communities; 4) stream hydrology and sediment/nutrient loading; 5) terrestrial rare plants and special communities; 6) atmospheric particulate and nutrient lake deposition; 7) forest ozone impacts; or 8) noxious weeds. Research should address all of the following tasks: 1) synthesize and review previous and ongoing research efforts and available data to identify scientifically supported environmental condition indicators and reference conditions for a topic area identified above; 2) use the synthesized results to develop a topic-area-specific conceptual model that describes the contemporary understanding of factors and activities that affect the region's ability to achieve environmental and socioeconomic goals and targets; 3) prepare a monitoring and evaluation plan that can be implemented to measure the identified indicators and report on long-term status and trends of identified indicators relative to existing or proposed environmental or socioeconomic standards; 4) conduct pilot implementation of field, data management, evaluation and reporting protocols and procedures documented in the monitoring plan to maximize their utility; and 5) conduct and document technical analyses that compare and contrast proposed indicators with existing indicators and identified reference conditions with existing standards. Researchers should plan to work collaboratively with agency representatives to ensure the products will meet agency information and evaluation needs.

Climate Change
The potential impacts of climate change in the Lake Tahoe Basin are of growing concern. Researchers are investigating these potential impacts with respect to fire regimes, invasive species, forest ecosystem processes, hydrology, and management activities. In addition, the USDA Forest Service-Lake Tahoe Basin

Management Unit (LTBMU)is currently revising its forest plan; the revised plan will address climate change. More information about climate change in the Sierra Nevada is available on the USDA Forest Service- Pacific Southwest Research Station climate change website.

Completed Projects—Climate Change

ROUND 8

Predictive modeling of cheatgrass invasion risk for the Lake Tahoe Basin

Lead Investigators: *Brian Anacker and Susan Harrison (University of California-Davis), Hugh Safford (USDA Forest Service-Pacific Southwest Region)*

Cheatgrass (*Bromus tectorum*) is an exotic species of major concern that is increasingly detected in the Sierra Nevada. This notorious annual grass has been a major driver of ecosystem change in the intermountain west due to its tendency to dramatically increase the frequency of early season fires via the highly flammable nature of its early-drying herbage. While cheatgrass is present in some sites in the Lake Tahoe Basin (LTB), especially in drier, disturbed sites in the Carson Range, it is at a relatively early stage of invasion. Continued cheatgrass invasion and subsequent changes in fire regimes could result in increased frequencies of fire in forest and meadow habitats, loss of biodiversity and hydrologic function, and a lowering of habitat quality. This project examined the relationship between climate and the invasion of cheatgrass. In an effort to forecast if climate change and disturbance will trigger further cheatgrass establishment and spread, the investigators modeled the environmental factors related to current cheatgrass distribution and abundance in the LTB. Examining the distribution of cheatgrass along environmental gradients allowed the investigators to develop a spatially-explicit predictive risk model of cheatgrass invasion and to apply it under both the current climate and future climate scenarios. In addition, the investigators incorporated parameters for disturbance to improve model accuracy and predictive value. The resulting information will be useful for creating management scenarios to resist species invasion, restore natural communities, and sustain biodiversity and ecosystem function in the face of changing climate. The final report is available on the USDA Forest Service-Pacific Southwest Research Station Tahoe Science Program website.

The effects of climate change on Lake Tahoe, and implications for design of best management practices

Lead Investigators: *John Reuter (University of California-Davis) and Robert Coats (Hydroikos)*

In this study, researchers examined the potential effects of changing meteorological conditions on expected future air temperature, amount and type of precipitation, stream discharge, sediment and nutrient loading characteristics, best management practice (BMP) performance, lake mixing and water quality response using existing water resource models already developed for the Lake Tahoe Total Maximum Daily Load (TMDL). A sophisticated statistical downscaling methodology was applied to the model outputs of the of the Geophysical Fluid Dynamics Laboratory Model (GFDL) and the Parallel Climate Model (PCM) to produce simulated data records at a 12 km grid scale in the Tahoe Basin for the 21st Century (2000-2099). This methodology was applied given two emission scenarios from the 4th (2007) Assessment Report of the Intergovernmental Panel on Climate Change (IPCC): A2 ("Business as Usual"), with accelerating GHG emissions, and the more optimistic B1, in which GHG emissions level off by 2100. The results from this study indicate that the most significant impacts of a future, modeled climate change at Lake Tahoe are: 1) changes in hydrologic conditions, with a significant reduction in the amount of precipitation falling as snow in the Tahoe Basin; and 2) reduced frequency of complete vertical mixing of the lake; continued warming will increase the lake's thermal stability, and likely shut down its vertical mixing altogether. The final report is available on the USDA Forest Service-Pacific Southwest Research Station Tahoe Science Program website.

Current or Continuing Projects—Climate Change

ROUND 9

Hydrologic response of sub-alpine watersheds to climate change, Tahoe Basin

Lead Investigators: *Graham Fogg and Wes Christensen (University of California-Davis)*

The study is evaluating potential effects of climate change on the hydrologic regime that supports the occurrence and health of groundwater-sustained sub-alpine wetlands, also known as fens. Researchers are studying two fens in distinctly different geomorphologic settings. Field measurements are being used to evaluate the hydrologic flow systems, including inflows and outflows such as evapotranspiration. A calibrated model that links surface water and groundwater interactions (GSFLOW) is being developed to help assess the potential impact of climate change on the hydrologic budget, water levels, and water available for fen vegetation. The sensitivity of the calibrated model to measurement errors made in the field will be addressed and incorporated into the assessment of the response to climate change. To date, researchers have used existing data to develop and calibrate a preliminary 3D GSFLOW model for sensitivity analysis. The field data is now being used to recalibrate the model based on physical parameters and the systems' responses to precipitation events.

Current expected completion date: March 2012

ROUND 10

Management options for reducing wildfire risk and maximizing carbon storage under future climate changes, ignition patterns, and forest treatments

Lead Investigators: *Robert Scheller and Louise Loudermilk (Portland State University) Jian Yang and Peter Weisberg (University of Nevada-Reno) and Alison Stanton (BMP Ecosciences)*

This project will compare and evaluate long-term impacts of fire suppression, prescribed fire, wildfire, and fuel treatments on the long-term potential for Lake Tahoe forests to sequester carbon (C) or otherwise contribute to reducing greenhouse gas emissions in a global change context. Tradeoffs among management for C sequestration, prescribed fires, mechanical fuel treatments, and stochastically recurring large and severe wildland fires will be explicitly assessed. Predicted changes in climate and ignition patterns will be simulated along with changing fire spread behavior in response to future meteorological conditions, vegetation dynamics, and fuel treatments to examine long-term effects on C emissions, forest structure, and forest composition. Ultimately this project will demonstrate an operational method for explicit consideration of greenhouse gases in landscape-level forest management. The investigators have finished processing the downscaled projected climate data, calibrating the simulated fire dynamics, and calibrating the modeled forest carbon dynamics. They are now working on developing and implementing fuel treatment scenarios.

Presentations associated with this project:

The investigators held a successful manager workshop on May 26, 2011 at the Tahoe Regional Planning Agency in Stateline, NV. The investigators discussed implementation strategies for fuel treatments with the managers, which will help the investigators develop fuel treatment scenarios for model runs.

Current expected completion date: December 2012

For Round 12, the third subtheme within the Forest Health theme addresses climate change. Please see the Round 12 Forest Health Subthemes section for information regarding this subtheme.

APPENDIX A:
Tables of Tahoe Science Projects Funded Through SNPLMA

Table 1. Forest Health

Round	Project Title	Federal Sponsor	Expected Completion Date
5	Riparian and upland fuels reduction	FS-LTBMU	Completed
5	Evaluation of wildfire and prescribed fire effects on water quality	FS-LTBMU	Completed
7	Analysis of 15 years of data from the California State Parks Prescribed Fire Effects Monitoring Program	FS-PSW	Completed
7	Potential nutrient emissions from prescribed fire in the Lake Tahoe Basin	FS-PSW	Completed
7	Restoration and fuel treatment of Lake Tahoe's riparian forests	FS-PSW	September 2011
7	Restoring sugar pine in the Tahoe Basin: regeneration ecology and recruitment dynamics of sugar pine under various stand structures	FS-PSW	December 2011
7	Natural and anthropogenic threats to white pines from lower montane forests to subalpine woodlands of the Lake Tahoe Basin: an ecological and genetic assessment for conservation, monitoring, and management	FS-PSW	August 2012
8	Developing FCCS fuelbeds for the Angora fire region	FS-PSW	Completed
8	Upland fuel reduction treatments in the Lake Tahoe Basin: forest restoration effectiveness	FS-PSW	August 2012
8	Developing fuels treatments for balancing fuel reduction, soil exposure, and potential for erosion in the Tahoe Basin	FS-PSW	December 2011
8	Identifying spatially-explicit reference conditions for forest landscapes in the Lake Tahoe Basin, USA	FS-PSW	September 2012
8	Nutrient and sediment loading predictions for prescribed fire using optimized WEPP model	FS-PSW	March 2012
8	Modeling the influence of management actions on fire risk spread under future climatic conditions	FS-PSW	September 2012
9	Evaluating alternative fuel treatments in the South Shore wildland-urban interface area	FS-PSW	October 2012
9	Silvicultural prescriptions to restore forest health	FS-PSW	December 2013
9	Integrated decision support for cost-effective fuel treatments under multiple resource goals	FS-PSW	March 2012
9	Effects of pile burning in the Tahoe Basin on soil and water quality	FS-PSW	July 2012
9	Biodiversity response to burn intensity and post-fire restoration	FS-PSW	December 2012
9	Evaluation of montane forest genetic resources in the Lake Tahoe Basin: implications for conservation, management, and adaptive responses of *Pinus monticola* to environmental change	FS-PSW	September 2013
10	Stocking guidelines for aspen restoration	FS-PSW	October 2013
10	Evaluation of montane forest genetic resources: implications for conservation, management, and restoration of whitebark pine (*Pinus albicaulis*) in the Lake Tahoe Basin	FS-PSW	May 2013
10	Plant community characterization and ranking of fens in the Lake Tahoe Basin	FS-PSW	Completed
11	Adaptive management handbook and tools for vegetation management and estimation of pollutant loading from forested catchments	FS-PSW	October 2013
11	Restoration strategies for whitebark, western white, and sugar pine in the Lake Tahoe Basin: ecological and epidemiological considerations	FS-PSW	June 2014

Table 2. Watersheds, Habitat, and Water Quality—Habitat

Round	Project Title	Federal Sponsor	Expected Completion Date
5	Role of urban forests in conserving and restoring biological diversity in the Lake Tahoe Basin	FS-LTBMU	Completed
5	Development and evaluation of tools for monitoring ecosystem and species diversity across landscapes	FS-LTBMU	Completed
8	The effects of ski resorts in the Lake Tahoe Region of California on population dynamics of the American marten	FS-PSW	December 2011
9	Development of a risk model to determine the expansion and potential environmental impacts of Asian clams in Lake Tahoe	FS-PSW	August 2012
10	Wildlife habitat occupancy models for project and landscape evaluations in the Lake Tahoe Basin	FS-PSW	November 2012
10	Ecological succession in the Angora fire: forest management effects on woodpeckers and keystone species	FS-PSW	May 2012
10	Potential for pathogen growth, fecal indicator growth and phosphorus release under clam removal barriers in the Lake Tahoe Basin	FS-PSW	March 2012
10	Natural and human limitations to Asian clam distribution and recolonization—factors that impact the management and control in Lake Tahoe	FS-PSW	November 2012
11	The ecology of curly leaf pondweed (*Potamogeton crispus*) and the potential for control using bottom barriers in Lake Tahoe	FS-PSW	August 2013
11	Science to assist policy decisions regarding the prevention of invasive species: testing the survival and growth of quagga mussel in Lake Tahoe	FS-PSW	March 2014

Table 3. Watersheds, Habitat, and Water Quality—Stormwater

Round	Project Title	Federal Sponsor	Expected Completion Date
5	Tahoe Basin Regional Stormwater Monitoring Program (Tahoe Basin RSWMP Phase 1)	EPA	Completed
7	Development of a BMP Performance Assessment and Data Analysis System for the Tahoe Integrated Information Management System (TIIMS)	FS-PSW	Completed
7	Tahoe Basin particle size analysis and protocol development	FS-PSW	Completed
8	Potential of engineered floodplains and wetlands as fine particle BMPs: case study of Trout Creek and the Upper Truckee River	FS-PSW	September 2011
8	Determining sources of highway runoff fine sediment in stormwater, streams, and Lake Tahoe using fingerprinting techniques	FS-PSW	September 2011
9	Development of a road cut and fill land-use category for the Pollutant Load Reduction Model (PLRM)	FS-PSW	Completed
9	Tahoe Basin Regional Stormwater Monitoring Program (Tahoe Basin RSWMP Initial Implementation)	FS-LTBMU	Completed
9	Urban stormwater fine sediment filtration using granular perlite	FS-PSW	March 2012
9	Priority urban stormwater monitoring to directly inform the Pollutant Load Reduction Model (PLRM)	FS-PSW	May 2012
9	Measuring the ability of floodplains to treat urban runoff in the Lake Tahoe Basin	FS-PSW	September 2011
10	Tahoe stormwater particle assessment and management for urban and roadway runoff	FS-PSW	March 2012
10	Defensible space-erosion protection tools development	FS-PSW	December 2012
11	Quantifying the benefits of urban stormwater management	FS-PSW	September 2013
11	Evaluation of alternative abrasives and snowplowing practices and road sweeping/vacuuming as source control BMPs for load reduction of fine sediment particles and phosphorus in urban roadway stormwater	FS-PSW	December 2013
11	Laboratory experiments on fine particle capture by submerged vegetation in stream environment zones (SEZs): the effects of vegetation density, biofilm development and particle composition	FS-PSW	July 2013
11	Tools to quantify urban stormwater load reduction from SEZ restoration actions	FS-PSW	July 2013

Table 4. Watersheds, Habitat, and Water Quality—Stream Restoration

Round	Project Title	Federal Sponsor	Expected Completion Date
7	Methodology to predict total and fine sediment load reductions as a result of channel restoration in Lake Tahoe streams	FS-PSW	Completed
7	Application of enhanced stream-corridor modeling tools for adaptive management of Tahoe Basin streams	FS-PSW	February 2012
8	A comprehensive integration of past stream restoration efforts and future tools to evaluate and track the multitude of benefits by stream and meadows in the Lake Tahoe Basin	FS-PSW	Completed
9	Quantification and characterization of Trout Creek restoration effectiveness	FS-PSW	June 2012

Table 5. Watersheds, Habitat, and Water Quality—Water Quality

Round	Project Title	Federal Sponsor	Expected Completion Date
5	Lake Tahoe Total Maximum Daily Load (TMDL)	EPA	Completed
5	Pelagic zone water quality and modeling of fine sediment sources, transport, and fate	EPA	Completed
5	Groundwater modeling and monitoring	USGS	Completed
5	Development of hydraulic design criteria	USACE	Completed
5	Development of a pollutant load reduction model	USACE	Completed
5	Refinement of pollutant event mean concentrations for various land types	USACE	Completed
6	Integrated BMP modeling: application to Tahoe TMDL	USGS	Completed
7	Predicting and managing changes in nearshore water quality	FS-PSW	Completed
7	Assessing the sources and transport of fine sediment in response to management practices in the Tahoe Basin using the WEPP model	FS-PSW	Completed
7	Improving road erosion modeling for the Lake Tahoe Basin and evaluating BMP strategies for fine sediment reduction at watershed scales	FS-PSW	Completed
7	Monitoring past, present, and future water quality using remote sensing	FS-PSW	Completed
8	NICHES: Nearshore indicators for clarity, habitat, and ecological sustainability	FS-PSW	Completed
8	Development of a water quality modeling toolbox to inform pollutant reduction planning, implementation planning and adaptive management	FS-PSW	December 2011
10	Lake Tahoe Total Maximum Daily Load (TMDL) management system	EPA	Completed
10	Development and validation of the Tahoe Project Sediment Model	FS-PSW	November 2012

Table 6. Air Quality

Round	Project Title	Federal Sponsor	Expected Completion Date
5	Source characterization of particulate matter depositing to Lake Tahoe	EPA	Completed
5	Measurement and modeling of fugitive dust emissions from paved road travel in the Lake Tahoe Basin	EPA	Completed
6	Development of an air pollutant emissions inventory for the Lake Tahoe Basin that incorporates current and future land-use scenarios	EPA	Completed
7	Examination of dust and airborne sediment control demonstration projects	FS-PSW	Completed
7	Lake Tahoe source attribution study: receptor modeling study to determine the sources of observed ambient particulate matter in the Lake Tahoe Basin	FS-PSW	Completed
9	Impacts of vehicle activity on airborne particle deposition to Lake Tahoe	FS-PSW	Completed
10	Visibility and monitoring standards for Lake Tahoe Basin: assessment of current and alternative approaches	FS-PSW	Completed
10	Lake Tahoe visibility impairment source apportionment analysis	FS-PSW	Completed
10	Particulate emissions from biomass burning: quantification of the contributions from residential wood combustion, forest fires, and prescribed fires	FS-PSW	July 2012
10	Distribution of ozone, ozone precursors and gaseous components of atmospheric deposition in the Lake Tahoe Basin	FS-PSW	June 2013
10	Tahoe Climate Information System (TahoeClim)	FS-PSW	January 2013
10	Improving meteorological data and forecasts for prescribed burn-day decisions	FS-PSW	July 2012
11	Secondary pollutant formation in the Lake Tahoe Basin	FS-PSW	March 2015
11	Evaluation of prescribed burn impacts on air quality and visibility in the Lake Tahoe Basin	FS-PSW	March 2013

Table 7. Integrating Science

Round	Project Title	Federal Sponsor	Expected Completion Date
5	Land-cover characterization of the Lake Tahoe Basin	USGS	Completed
5	Tahoe Environmental Science System	EPA	Completed
5	Tahoe Integrated Information Management System (TIIMS)	EPA	Ongoing
5	Tahoe Decision Support System	USGS	Ongoing
10	Light Detection and Ranging (LiDAR) and multispectral geospatial data acquisition	USGS	Completed
10	Nearshore ecology and aesthetics	FS-PSW	November 2012
10	Upland forest integrity	FS-PSW	July 2013
11	Mapping hard and soft impervious cover in the Lake Tahoe Basin using LiDAR and multispectral images: a pilot study of the Lake Tahoe land cover and disturbance monitoring plan	FS-PSW	January 2013
11	Assessment of fire hazard/risk in the wildland-urban interface (WUI) and stream environment zones (SEZs)	FS-PSW	March 2013
11	Development of status and trend indicators for stream condition and other resources	FS-PSW	August 2012
11	Remote sensing of Lake Tahoe's nearshore environment	FS-PSW	March 2013
11	Evaluating field and laboratory data for developing surrogate indicators to monitor fine sediment in the Tahoe Basin	FS-PSW	March 2014

Table 8. Climate Change

Round	Project Title	Federal Sponsor	Expected Completion Date
8	Predictive modeling of cheatgrass invasion risk for the Lake Tahoe Basin	FS-PSW	Completed
8	The effects of climate change on Lake Tahoe, and implications for design of best management practices	FS-PSW	Completed
9	Hydrologic response of sub-alpine watersheds to climate change, Tahoe Basin	FS-PSW	March 2012
10	Management options for reducing wildfire risk and maximizing carbon storage under future climate changes, ignition patters, and forest treatments	FS-PSW	December 2012

APPENDIX B: Additional Relevant Publications and Resources

GENERAL

The USDA Forest Service-Lake Tahoe Basin Management Unit (LTBMU) has numerous reports covering a variety of topics, projects, and monitoring efforts. Please visit the LTBMU website Publications page to browse the list of reports available in PDF format.

Hymanson, Z.P. and M.W. Collopy, eds. 2010. An integrated science plan for the Lake Tahoe Basin: conceptual framework and research strategies. Gen. Tech. Rep. PSW-GTR-226. USDA Forest Service-Pacific Southwest Research Station, Albany, CA. 368 p.

Tahoe Regional Planning Agency (TRPA). 2011. TRPA Regional Plan Update, Draft Descriptions of Project Alternatives, Environmental Threshold Carrying Capacities.

FOREST FIRE, FUELS, AND SOILS

Beaty, R.M. and A.H. Taylor. 2008. Fire history and the structure and dynamics of a mixed conifer forest landscape in the northern Sierra Nevada, Lake Tahoe Basin, California, USA. Forest Ecology and Management. 255:707-719. doi: 10.1016/j.foreco.2007.09.044

California-Nevada Tahoe Basin Fire Commission. 2008. The Emergency California-Nevada Tahoe Basin Fire Commission report. Sacramento, CA: California Office of State Publishing.

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Carroll, E.M., W.W. Miller, D.W. Johnson, L. Saito, R.G. Qualls and R.F. Walker. 2007. Spatial analysis of a large magnitude erosion event following a Sierran wildfire. Journal of Environmental Quality. 36(4):1105-1111. doi: 10.2134/jeq2006.0466

Johnson, D.W., W.W. Miller, R.B. Susfalk, J.D. Murphy, R.A. Dahlgren and D.W. Glass. 2009. Biogeochemical cycling in forest soils of the eastern Sierra Nevada Mountains, USA. Forest Ecology and Management 258:2249-2260. doi: 10.1016/j.foreco.2009.01.018

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Safford, H.D., D.A. Schmidt and C.H. Carlson. 2009. Effects of fuel treatments on fire severity in an area of wildland–urban interface, Angora Fire, Lake Tahoe Basin, California. Forest Ecology and Management 258:773-787. doi: 10.1016/j.foreco.2009.05.024

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HABITAT (AQUATIC)

Chandra, S., M. Wittmann, A. Caires, A. Kolosovich, J. Reuter, G. Schladow, J. Moore and T. Thayer. 2009. Quagga mussel risk assessment - an experimental test of quagga mussel survival and reproductive status using Lake Tahoe water with a prediction of invasion into Western water bodies. Lake Tahoe Aquatic Invasive Species Integrated Management Strategy. Submitted to the Tahoe Regional Planning Agency and the Lake Tahoe Aquatic Invasive Species Coordination Committee.

Kamerath, M., B.C. Allen and S. Chandra. 2009. First documentation of *Salmincola californiensis* in Lake Tahoe, CA—NV, USA. Western North American Naturalist. 69(2):257-259. doi: 10.3398/064.069.0216

Kamerath, M., S. Chandra and B.C. Allen. 2008. Distribution and impacts of warm water invasive fish in Lake Tahoe, USA. Aquatic Invasions. 3(1):35-41. doi: 10.3391/ai.2008.1.1.7

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USACE. 2009. Lake Tahoe Region Aquatic Invasive Species Management Plan, California - Nevada. 86 p.

Wittmann, M., J. Reuter, G. Schladow, S. Hackley, B. Allen, S. Chandra and A. Caires. 2008. Asian clam (*Corbicula fluminea*) of Lake Tahoe: preliminary scientific findings in support of a management plan. 47 p.

HABITAT (TERRESTRIAL)

Borgmann, K. L. and M.L. Morrison. 2010. Factors influencing the frequency of nest parasitism by brown-headed cowbirds in the northern Sierra Nevada. Western North American Naturalist 70(2):137-143. doi: 10.3398/064.070.0201

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Scholl, A.E. and A.H. Taylor. 2006. Regeneration patterns in old-growth red fir–western white pine forests in the northern Sierra Nevada, Lake Tahoe, USA. Forest Ecology and Management 235: 143-154. doi: 10.1016/j.foreco.2006.08.006

Schlesinger, M.D., P.N. Manley and M. Holyoak. 2008. Distinguishing stressors acting on land bird communities in an urbanizing environment. Ecology 89(8):2302-2314. doi: 10.1890/07-0256.1

Stanton, A.E. and B.M. Pavlik. 2007. Implementation of the Conservation Strategy for Tahoe yellow cress (*Rorippa subumbellata*). 2006 Annual Report. Prepared for the Tahoe Yellow Cress Adaptive Management Working Group and Executive Committee. BMP Ecosciences, San Francisco, CA. 57 p.

STORMWATER

The California Department of Transportation (CDOT) website has numerous reports related to stormwater. Please visit the CDOT Reports page to browse the list of reports available in PDF format.

2NDNATURE and nhc. 2010a. Pollutant Load Reduction Model V.1: focused stormwater monitoring to validate water quality source control and treatment assumptions. Final Technical Report. Prepared for U.S. Army Corps of Engineers, Sacramento District. 118 p.

2NDNATURE and nhc. 2010b. Lake Tahoe Pollutant Loading Reduction Model (PLRM) database refinement final Phase II monitoring plan. Prepared for USDA Forest Service-Pacific Southwest Research Station. 167 p.

2NDNATURE, nhc and Environmental Incentives. 2009a. Best management practices maintenance Rapid Assessment Methodology: BMP RAM technical document. Prepared for the U.S. Army Corps of Engineers. 55 p.

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2NDNATURE. 2008. Water quality performance evaluation of Park Avenue detention basins; South Lake Tahoe, CA. Final Technical Report. Prepared for City of South Lake Tahoe Engineering Division. 117 p.

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STREAMS

2NDNATURE. 2006. CSLT Upper Truckee River sediment monitoring: Middle Reach (2002-2005). Prepared for the City of South Lake Tahoe. 26 p.

Sahoo, G.B., S.G. Schladow and J.E. Reuter. 2009. Forecasting stream water temperature using regression analysis, artificial neural network, and chaotic non-linear dynamic models. Journal of Hydrology 378:325-342. doi: 10.1016/j.jhydrol.2009.09.037.

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APPENDIX C: Tahoe Science Contact Information

Organization	Name and Title	E-mail	Phone Number	Area(s) of Emphasis
California Tahoe Conservancy	**Zach Hymanson**, Environmental Program Manager II	zhymanson@tahoe.ca.gov	530-543-6017	All
Lahontan Regional Water Quality Control Board	**Hannah Schembri**, Water Resources Control Engineer	hschembri@waterboards.ca.gov	530-542-5423	Lake Tahoe TMDL, particle deposition, stream restoration, water quality
Nevada Division of Environmental Protection	**Jason Kuchnicki**, Lake Tahoe Watershed Unit Branch Supervisor	jkuchnic@ndep.nv.gov	775-687-9450	Water quality
Nevada Division of State Lands	**Elizabeth Harrison**, Water Quality Program Manager	eharrison@lands.nv.gov	775-684-2736	Water quality
Tahoe Regional Planning Agency	**Shane Romsos**, Acting Measurement Department Manager	sromsos@trpa.org	775-589-5201	All
Tahoe Science Consortium	**Maureen McCarthy**, Executive Director	mimccarthy@unr.edu	775-881-7561	Air quality, science integration, visualization
USDA Forest Service-Lake Tahoe Basin Management Unit	**Holly Eddinger**, Ecosystem Supervisory Biologist	heddinger@fs.fed.us	530-543-2633	Invasive species and sensitive species
	David Fournier, Assistant Staff Officer	dfournier@fs.fed.us	530-543-2626	Forest vegetation and fuels
	Shana Gross, Ecologist	segross@fs.fed.us	530-543-2752	Climate change
	Sue Norman, Hydrologist	snorman@fs.fed.us	530-543-2662	Watershed restoration
USDA Natural Resources Conservation Service	**Woody Loftis**, District Conservationist	william.loftis@ca.usda.gov	530-543-1501 ext. 104	Soils, stream environment zones (SEZs), water quality, wetlands
U.S. Environmental Protection Agency	**Jack Landy**, U.S. EPA Lake Tahoe Basin Coordinator	landy.jacques@epa.gov	775-589-5248	Air quality, climate change, stream restoration, water quality
U.S .Fish and Wildlife Service	**Steve Chilton**, Aquatic Nuisance Species Coordinator	Steve_Chilton@fws.gov	775-589-5265	Aquatic invasive species and sensitive species
U.S. Geological Survey	**Tim Rowe,** Hydrologist and Lake Tahoe Liaison	tgrowe@usgs.gov	775-887-7627	Hydrology and water quality