USDA

United States
Department of
Agriculture

Forest Service

Pacific Southwest
Research Station

General Technical Report
PSW-GTR-226
May 2010

An Integrated Science Plan for the Lake Tahoe Basin: Conceptual Framework and Research Strategies

Editors

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Front cover: Lake Tahoe view from Mount Rose Highway scenic pullout, looking northwest toward Tahoe City, California. Back cover: Lake Tahoe view from Mount Rose Highway scenic pullout, looking south. Both photographs by Peter Goin.

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U.S. Department of Agriculture, Forest Service
Pacific Southwest Research Station
Albany, CA
General Technical Report PSW-GTR-226
May 2010

Published in cooperation with:
U.S. Environmental Protection Agency
Region 9

Chapter 1: Overview[1]

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Introduction

A complex suite of interrelated changes has occurred in and around the Lake Tahoe basin over the last 150 years. These changes have substantially affected the atmospheric, aquatic, and terrestrial environments, as well as socioeconomic conditions in the basin (Elliott-Fisk et al. 1996, Lindström et al. 2000). Human responses to these changes have taken many forms; however, the overall trend shows a transition from policies favoring unrestricted use of habitats and living resources for development and economic benefit, to policies favoring limitations on development and increased habitat conservation and restoration (see Elliott-Fisk et al. 1996 for a review). This transition ultimately led to the policy declaration establishing the Tahoe Region Planning Compact (Public Law 96-551), which aims to ensure equilibrium between the region's natural endowment and its human-developed environment, and to the subsequent state of California designation of Lake Tahoe as an Outstanding National Resource Water under the Federal Clean Water Act (LRWQCB 1995).

The known effects of past actions and the unique character of the Lake Tahoe basin have led to broad-based support for substantive conservation and restoration efforts over the last two decades (CTC 2006, Elliott-Fisk et al. 1996, Murphy and Knopp 2000, U.S. Public Law 106-506 2000, TRPA 2001). Increased attention and funding over the past decade, in particular, have resulted in remarkable progress toward restoration goals, along with considerable information on the strengths and weaknesses of different approaches to addressing the substantial restoration challenges (Elliott-Fisk et al. 1996; Murphy and Knopp 2000; TRPA 2002, 2007). Restoration has focused not only on Lake Tahoe, but also on the entire watershed. Special attention has been given to the highly interdependent nature of terrestrial and aquatic habitats, and the multifaceted socioeconomic conditions that influence the Tahoe basin ecosystem (Elliott-Fisk et al. 1996, Murphy et al. 2000). The Lake Tahoe basin is recognized as a highly complex physical, biological and social environment, and the challenges posed by its restoration and continued management for multiple benefits are paralleled by few other locations.

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[1] Citation for this chapter: Hymanson, Z.P. 2009. Overview. In: Hymanson, Z.P.; Collopy, M.W., eds. An integrated science plan for the Lake Tahoe basin: conceptual framework and research strategies. Gen. Tech. Rep. PSW-GTR-226. Albany, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station: 1–17. Chapter 1.

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Conservation and restoration of the Lake Tahoe basin ecosystem have required the sustained engagement of federal, state and local governments, as well as the private sector. These entities have worked together to develop and implement a variety of programs and activities aimed at achieving common environmental and social goals (TRPA 2001, 2007). Yet determining how to proceed with conservation and restoration efforts in the face of limited information remains a central challenge to these efforts. Science (e.g., monitoring, research, and modeling), particularly applied science completed to inform adaptive management, provides a promising set of tools to address information limitations that affect our ability to select and implement effective management strategies. The coordination of scientific activities with management actions is at the core of an effective adaptive management approach (Manley et al. 2000). However, effort is required to organize and describe the science activities needed to inform an adaptive management system focusing on the conservation and restoration of a complex system. This document presents the results of science community efforts to organize and describe the initial elements of an integrated science plan for the Lake Tahoe basin: a conceptual framework for science operating in an adaptive management system, and focused research strategies covering topic areas of relevance to Tahoe basin management and conservation. Separate, agency-led efforts are underway to develop other essential elements of an integrated science plan, including programs for status and trends and effectiveness monitoring, new data applications aimed at converting data into information and knowledge, and the integration of monitoring and applied research efforts.

Approach for Developing This Science Plan

This science plan was developed through a collaborative effort among agency, science community, and stakeholder representatives to identify and refine science information needs for the Lake Tahoe basin. The main purpose of this effort was to develop a set of research strategies to address key uncertainties and information gaps that challenge resource management and regulatory agencies. The research needs identified in these strategies are based on assessments of the issues and information needs that currently confront government agencies and stakeholders working in the basin. The resulting strategies are intended to guide future research efforts and to help maximize the information gained from future science investments.

The plan begins by presenting an overview of a conceptual model and framework that identify issues of concern in the Tahoe basin and describe how science can work to inform polices, management strategies, and actions within the context of a Lake Tahoe basin adaptive management process. Next, the plan presents five chapters describing focused research strategies for the theme areas of (1) air quality, (2) water quality, (3) soil conservation, (4) ecology and biodiversity, and (5) integrating the social sciences in research planning. Each research strategy describes the knowledge gaps and research needs for relevant issues of concern (i.e., subthemes). Scientists worked with resource management agency representatives and stakeholders to identify relevant subthemes (e.g., fire and fuels management is one subtheme under the Ecology and Biodiversity theme area), and to identify the management issues and information needs associated with each subtheme (e.g., minimizing adverse impacts to wildlife is one management issue under the fire and fuels management subtheme). For each subtheme, the authors summarize the current state of knowledge, identify remaining uncertainties and knowledge gaps, and list science activities that address the uncertainties and knowledge gaps.

The research strategy theme areas were chosen based on an examination of resource areas considered in four management plans or planning processes: (1) the 1987 Lake Tahoe Basin Regional Plan, (2) the 2000 Lake Tahoe Watershed Assessment, (3) the Pathway planning process,[3] and (4) update of the Environmental Improvement Program for the Lake Tahoe basin (table 1.1).

Three common needs drive the recommendations presented in each research strategy:

- Increasing our understanding of the factors and processes driving change.
- Developing the tools and understanding to predict future conditions in the Lake Tahoe basin and permit comparisons among alternative futures.
- Providing information to inform future management decisions aimed at conserving and restoring the natural and human environments of the Lake Tahoe basin.

Each research strategy concludes with a presentation of near-term research priorities. Near-term research priorities are based on input received from agency and stakeholder representatives during subtheme identification, as well as the best professional judgment of the authors. Several factors (e.g., changing agency priorities, funding levels, the emergence of new issues or new information, and

[3] The Pathway planning process (formerly known as Pathway 2007) is a collaborative planning effort among four partner agencies, including the Tahoe Regional Planning Agency, USDA Forest Service, the California Lahontan Regional Water Quality Control Board, and the Nevada Division of Environmental Protection. These agencies are working together to update important resource management plans for the Lake Tahoe basin, which will guide land management, resource management, and environmental regulations over the next 20 years. This planning process is ongoing and is referred to as "Pathway" or "Pathway planning process" in this document. More information about the Pathway planning process is available at http://www.pathway2007.org/.

Table 1.1—A comparison among theme areas considered in four Lake Tahoe basin planning documents or processes and the Lake Tahoe Science Plan

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[a]	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[a]	Water quality	Water quality	Storm water management	Water quality
Vegetation[a]	Biological integrity and aquatic resources	Vegetation and forest fuels	(1) Forest health and fuels management (2) Habitat and vegetation	Ecology and biodiversity
Wildlife[a]		Wildlife and fisheries	(1) Habitat and vegetation (2) Watershed management (3) Threatened, endangered, and sensitive species	
Fisheries				
—	Socioeconomics	Socioeconomics	—	Integrating the social sciences in research planning
Recreation		Recreation	Enhancing recreation and scenic resources	
—	—	Transportation	Improving air quality and transportation	
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

[a] Theme areas considered in the June 6, 2001, key management questions. See "A Review of Science Planning and Support in the Lake Tahoe Basin" below for more information about development of the key management questions.
— = not applicable, TRPA = Tahoe Regional Planning Agency.

the availability of new technologies) can simultaneously affect the applicability of chosen research priorities. Thus, the selected priorities are best reviewed and revised regularly to ensure the current science needs and priorities reflect the changing information needs and evolving priorities of agencies charged with the welfare of the Lake Tahoe basin. For this reason, this science plan is considered a living document. The agency, stakeholder, and science community representatives active in the Lake Tahoe basin all share the continuing responsibility to revisit and update this document in the future.

A Review of Science Planning and Support in the Lake Tahoe Basin

Over the last 30 years, there have been several efforts to organize and describe the science needed to improve our understanding of the Lake Tahoe basin ecosystem and inform management actions. The most substantial efforts include the following:[4]

- Research Needs for the Lake Tahoe Basin (LTARCB 1974). A National Science Foundation funded project, which aimed to "encourage research needed to achieve the planning and management objectives of public and private entities" and to "provide scientific expertise and data to support effective planning and management programs." Information shortfalls that compromised management of the Tahoe basin's air, water, vegetation, fish and wildlife, social sciences, and resource systems were identified. More than 80 separate research needs were proposed.
- Lake Tahoe Environmental Assessment (WFRC IRTF1979). The compilation and analysis of information prepared in support of this assessment evaluated data for a number of resources, habitats, and socioeconomic factors. These were pivotal evaluations formally introducing the concepts of carrying capacity and environmental thresholds, which were central to the scientific underpinnings of the 1987 Lake Tahoe Basin Regional Plan.
- Lake Tahoe Case Study (Elliott-Fisk et al. 1996). This document took a science-based approach to provide an ecosystem and policy assessment of the Lake Tahoe basin. The case study synthesized information from these assessments to inform the Sierra Nevada Ecosystem Project, and identified future science-based management needs for the Lake Tahoe basin.
- Environmental Improvement Program (EIP) (TRPA 2001). The EIP described a series of program areas and projects, which if implemented, would advance the Lake Tahoe basin toward attainment of the environmental thresholds identified in the 1987 Lake Tahoe Basin Regional Plan. The science and research portion of the EIP (updated and expanded in 2001) identified threshold and EIP-related research and monitoring projects designed to (1) advance scientific understanding of ecosystem processes and threshold attainment, (2) refine planning and restoration strategies, and (3) improve and quantify the effectiveness of capital improvement projects.

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[4] Information on science planning is taken in part from Murphy (2000).

- Lake Tahoe Watershed Assessment (Murphy and Knopp 2000). This document provided a synthesis of 20 years of research publications and reports dealing with the atmospheric, aquatic, and terrestrial environments; the living resources associated with these environments; and socioeconomic conditions. Like the documents that precede it, this assessment included recommendations for research and monitoring. The assessment also presented an adaptive management strategy, describing a means of organizing current information, and linking management planning with essential science activities.
- Key Management Questions (SAG 2001). Scientists and agency representatives worked together to develop a list of Key Management Questions (KMQ) to direct new research and monitoring efforts in the Lake Tahoe basin. Some of the KMQs were periodically revised and updated (2002–04) to reflect the most important questions that land managers, project implementers, and regulators had about land use decisions and methods to improve ecosystem health in the Lake Tahoe basin. Tahoe basin agency executives prioritized some of the KMQs. This information was used by federal and state agencies to develop budgets for future science funding.

The documents described above range from lists of research needs and questions to indepth reviews and issue-specific analyses. In some cases, the documents also describe processes and approaches for obtaining new scientific information. To varying degrees, all of these efforts provided recommendations for the kinds of science activities, and in several cases, the specific studies needed to address existing uncertainties and information gaps.

In several cases, it was implicitly assumed that providing a description of the science needs for the Lake Tahoe basin would lead to establishment of a sustained program for addressing those needs. However, such a program has never been established and, with the exception of water quality, information gains for many critical issue areas generally lag behind the information needs of managers and policymakers. In some cases, these information gains are lacking because the necessary studies have not been initiated or completed. In other cases, these information gains have not been realized because of a lack of synthesis and analysis of existing data.

With the exception of the KMQs, none of the science plans prepared for the Lake Tahoe basin have been supported by sustained science planning processes that provide a means for objective prioritization and regular revision. Unfortunately, the KMQ planning process eventually fragmented with different issue areas receiving varying degrees of attention. Functional science planning processes are critical to ensuring that a science program remains relevant and responsive to management information needs. Support for science planning also is needed to ensure that any funds available for new science address the highest priority information needs.

In addition to efforts to organize and describe science needs, other efforts have improved the organization of science entities and implementation of science activities in the Tahoe basin. A persistent challenge has provided the motivation to improve science organization and implementation:[5]

> For years the academic and management communities could not agree on a scientific agenda that would answer both key management and research questions. Many times, scientific work was not deemed pertinent to what the agencies wanted, and the management questions were not articulated in ways the science community could use.

Explicit efforts to address this challenge were formalized in 1999 with the signing of a memorandum of understanding (MOU) with a primary focus on priority research, monitoring, evaluation, and outreach supporting Tahoe basin management goals. The entities signing this MOU (Tahoe Regional Planning Agency [TRPA], University of Nevada, Reno [UNR], Desert Research Institute [DRI], University of California, Davis [UCD], U.S. Department of the Interior, Geological Survey [USGS], and the U.S. Department of Agriculture, Forest Service [USFS]) committed to work collaboratively to:

- Establish a joint steering committee to evaluate the EIP to determine what environmental issues may benefit from broader research inquiry.
- Further develop and improve the communication and coordination among existing research groups working in the Tahoe basin to prevent duplication of efforts and provide the maximum interdisciplinary teamwork necessary to resolve the most important environmental issues.
- Contribute to TRPA's development of a research master plan and set of guiding principles for research inquiry in the Lake Tahoe Region related to priority preservation, restoration, and enhancement needs.
- Encourage the development of competitive research proposals with peer review to achieve the highest caliber of scientific assessment of problems facing the Lake Tahoe region.
- Identify monitoring tasks and evaluations that would be assured continuance to fully inform the research community evaluating the Lake Tahoe region.

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[5] York, T. 2008. Personal communication. Environmental scientist. California Tahoe Conservancy, 1061 Third Street, South Lake Tahoe, CA 96150.

- Develop outreach plans to convey research results and options to the public in general and specifically to the communities within the Lake Tahoe region.

In 2000, the TRPA requested the MOU participants convene a Lake Tahoe Science Advisory Group (SAG). The SAG also included representatives from numerous state, federal, and local agencies. Key objectives of the SAG were to (1) develop a scientific work plan that would dovetail with restoration efforts and management objectives and (2) coordinate/facilitate the operating principles of a Tahoe Environmental Science System identified in a second MOU signed in February 2000. The SAG, in conjunction with a number of work groups active in the Tahoe basin, identified critical information needs requiring attention for effective management decisions. This was intended to be an ongoing process that included two key components: (1) development of a series of KMQs, and (2) development of a science plan, produced by the research institutions, which addressed the KMQs. Although the SAG did prepare KMQs for a number of theme areas (table 1.1 and summarized above), funding and resource commitments to produce a science plan did not occur.

Over time, support and commitment to the SAG and its goals declined. Select agencies did pursue new funding initiatives to support scientific investigations related to specific agency needs (e.g., technical studies for the Lake Tahoe total maximum daily load, and the Lake Tahoe Air Deposition Study). However, with the exception of water quality studies, efforts to organize collaborative science efforts within and among issue areas continued to struggle.

In 2003, the federal government began providing funding to support implementation of the Lake Tahoe Restoration Act (U.S. PL 106-506 2000). Some of this funding was reserved for new science; however, the persistent challenge identified above continued to compromise the processes for identifying science needs and the objective selection of projects for funding. In addition, all parties recognized that the SAG had neither the charge nor the resources to develop a vision, structure, and program capable of supporting science and research as it applies to Lake Tahoe basin restoration (TRPA and USCOE 2005). Thus, discussions were initiated in December 2003 among members of the science community and staff from the TRPA, the U.S. Environmental Protection Agency, and the U.S. Army Corps of Engineers to evaluate and possibly restructure SAG operations to better support allocation of federal funding under the Lake Tahoe Restoration Act. These discussions led to a proposal for an enhanced science community group known as the Tahoe Science Consortium (TSC). In 2005, science community and agency representatives signed an MOU forming the TSC,[6] and establishing its primary objective: "To provide environmental managers and decision makers with comprehensive and well-synthesized scientific findings drawn from research, monitoring, and modeling." The TSC is a partnership among five research organizations: (1) UNR; (2) UCD; (3) DRI; (4) the USFS, Pacific Southwest Research Station, and (5) the USGS, Carson Science Center. The TSC operates independently of the management and regulatory agencies working in the Tahoe basin, and TSC efforts have focused on:

- Science planning: Working with Lake Tahoe basin agency representatives to develop regional monitoring approaches for specific issue areas, and developing a science plan for the Lake Tahoe basin that identifies and prioritizes research needs. These efforts are intended to contribute to the primary objective of the TSC.
- Peer review: Administering or conducting the scientific peer review of research proposals, science products, or technical programs related to Lake Tahoe basin management and restoration. Independent peer review is intended to ensure that science activities conducted in the basin are scientifically sound, and that the results are technically credible.
- Technical assistance: Providing scientific input and technical advice to resource management and regulatory agencies that addresses management issues and concerns as they arise.

After nearly a decade of effort, agency and science community representatives have made progress in addressing the persistent challenge affecting science organization and implementation. Formation of the TSC concurrently with increased investments and commitments by the TSC partners represents major efforts of the science community to better address Lake Tahoe basin science needs on a sustained basis. In addition, the establishment of two new working groups (the Tahoe Science Agency Coordination Committee, and the Science and Management Integration Team) has provided greater organizational capacity for agencies to communicate management issues and information needs to the science community, and to provide the ongoing support for science planning processes. Efforts now focus on sustaining progress.

[6] More information about the TSC and its member organizations is available at http://www.tahoescience.org/.

Advancing an Applied Science Program in the Tahoe Basin

Clear policy direction and agency commitments are essential to advancing an effective science program. The Lake Tahoe Restoration Act (PL 106-506) sets forth the primary policy directive for providing and sustaining an effective science program in the Tahoe basin:

> The Secretary shall provide for continuous scientific research on and monitoring of the implementation of projects on the [EIP] priority list, including the status of the achievement and maintenance of environmental threshold carrying capacities.

This overarching policy directive is supported by several policies and goals within the TRPA (TRPA 1986) and through implementation of the Federal Vision for the EIP (Lake Tahoe Basin Executives 2006).

Fundamentally, science comprises several practices and principles, which are applied in an integrated fashion to provide objective and verifiable approaches to acquiring new information that addresses uncertainties and knowledge gaps. To effectively support the ongoing information needs of resource management and regulatory agencies, these practices and principles are best organized and implemented as an integrated science program that includes the means to provide timely information in formats useful to agency representatives and decisionmakers.

Conceptually, the efforts and activities of an integrated science program can be divided among three basic elements: (1) monitoring, (2) empirical research, and (3) data application. To be effective, however, efforts need to be integrated across all three elements, and the allocation of resources among all elements is essential. This is the basis for the conceptual framework presented in chapter 2.

The brief review of past science planning efforts presented previously shows that merely producing a science plan is not enough to ensure the establishment of a sustained science program that can deliver useful information covering a diversity of issues. Clear policy direction is essential, but a deeper level of commitment among all relevant parties would enhance progress from planning to implementation. An explicit assumption of this effort is that the agencies charged with responsibility for the welfare of the Lake Tahoe basin will work to establish the funding, resources, and infrastructure necessary for sustained implementation of an applied science program. The TSC is prepared to work with agency representatives to make a sustained science program for the Lake Tahoe basin a reality.

Geographic Scope and Environmental Setting[7]

Lake Tahoe and its tributary watersheds together make up the Lake Tahoe basin (fig. 1.1). In most cases, the Lake Tahoe basin encompasses the entire geographic scope of this science plan. Where appropriate, however, the scope is broadened to consider external factors (e.g., regional meteorology or climate change) that can substantially influence conditions or future management actions within the basin.

The Lake Tahoe basin lies in the east-central portion of the Sierra Nevada mountain range and on the western boundary of the Great Basin. It is a montane, lacusterine-dominated ecosystem with several physical characteristics that make it a unique feature of the Sierra Nevada mountain ecosystem (table 1.2).

The broad elevation range of the basin (1900 to 3050 m [6,200 to 10,000 ft] above sea level) and a topography that strongly controls precipitation and temperature combine to yield a wide diversity of montane vegetation types, ranging from coniferous forests and woodlands, riparian forests, subalpine to alpine meadows, various wetland communities, and Great Basin shrublands. Soils are thought to act as a secondary control (after climate) of vegetation patterns. Geology within the basin is dominated by granitic rocks and soils in the southern portions, with an overlay of volcanic rocks and soils in the northern portions. The diversity of plant communities and vegetation types creates a broad spectrum of wildlife habitats. Numerous fish and invertebrate species occupy the stream and lake habitats, but in many cases, introduced species dominate (Chandra 2003).

Human activities have had and continue to have a dominant influence on the natural resources and environment of the Lake Tahoe basin. These activities include numerous past and present habitat and species modifications (e.g., logging; urban, commercial, roads, and infrastructure development; recreation; fire suppression; water diversion; species extirpations and introductions; habitat enrichment; and habitat restoration). Most anthropogenic activities are considered stressors to the natural environment, so restoration projects generally aim to remove or reduce the effects of these stressors. Humans and their activities will remain dominant components in the Lake Tahoe basin ecosystem, so ensuring the equilibrium between the basin's natural endowment and its human-provided environment remains the primary directive.

[7] Information on geographic scope and key physical characteristics is taken in part from Elliott-Fisk et al. (1996).

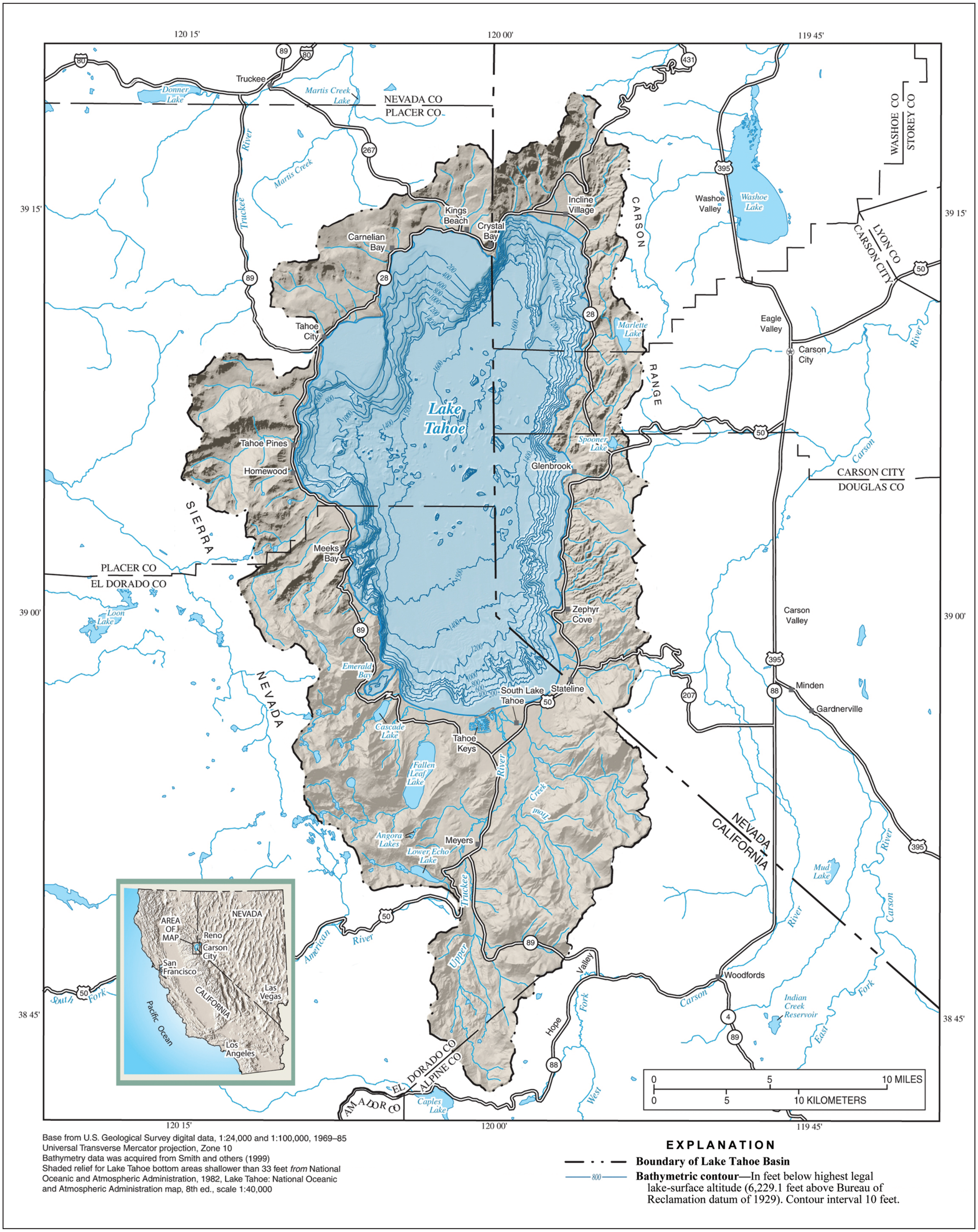

Figure 1.1—Plan view of the Lake Tahoe basin illustrating select hydrologic and bathymetric features, major roadways, and political boundaries. The area of shaded relief indicates the watershed boundary. Courtesy of the U.S. Geological Survey.

Table 1.2—Key physical characteristics of the Lake Tahoe basin

Characteristic	Size	Comment
Basin surface area	1300 km^2	
Land surface area	800 km^2	
Developed land surface area	83 km^2	The developed land area occupies about 10.5 percent of the total land area and includes residential, commercial, institutional, utilities, and transportation development.
Undeveloped land surface area	~717 km^2	The undeveloped land area occupies about 89.5 percent of the total land area. This area is dominated by undeveloped montane forest habitat.
Lake surface area	500 km^2	The lake surface area comprises about 38 percent of the basin surface area, yielding a watershed area to lake area ratio of ~1.6:1.
Maximum lake depth; mean lake depth	502 m; 313 m	Lake Tahoe is the 11^{th} deepest lake in the world.
Lake width and length	19 km × 35 km	
Lake volume	~156 km^3	The top 6 ft of Lake Tahoe is operated as a draw-down reservoir with a nominal yield of 903 million m^3.
Average water residence time	650 years	Average residence time of most pollutants of concern is on a decadal time scale or less.
Number of watersheds draining into Lake Tahoe	63	Tributary inflow annually delivers about 430 million m^3 to Lake Tahoe.
Number of drainages out of Lake Tahoe	1	The Truckee River flows northeast from Lake Tahoe to Pyramid Lake, Nevada.

Using This Document and Target Audience

This science plan includes six chapters that present a conceptual framework and focused research strategies for five topics of importance to the Lake Tahoe basin ecosystem. Chapter two presents the conceptual framework and overview conceptual model for this science plan. Further, the chapter describes the foundational elements and approach for establishing an integrated science program as part of a Lake Tahoe basin adaptive management system. The overview conceptual model will orient readers to the important issues covered in this plan and the relationships among those issues. Five theme-specific research strategies make up the core of this science plan. These chapters cover the topics of air quality, water quality, soil conservation, ecology and biodiversity, and integrating the social sciences in research planning.

The research strategies in this science plan differ in scope and breadth because of the diversity of management issues that exist among the theme areas and variations in the state of knowledge. Past efforts to obtain knowledge in each of the theme areas have not been equal (TRPA 2007), so different levels of investment are needed to progress. For example, we now have a Lake Tahoe clarity model that can be used to predict conditions and analyze the effects of alternative management strategies aimed at improving Lake Tahoe water clarity. Thus, some research needs identified in the "Water Quality" research strategy will include options for improving the validity and predictive capabilities of this model. In contrast, we are struggling to obtain and aggregate basic regional socioeconomic data for the Lake Tahoe basin that can inform us about trends in the human environment. These differences in knowledge base compromise our ability to understand and quantify interactions among resources, habitats, processes, and stressors. Continued commitment of future resources and funding across all five theme areas is believed to be the best strategy to even out the disparity in our knowledge base.

Each research strategy is meant to serve as a stand-alone document. We think this approach is most useful because government agency representatives and stakeholders often seek issue-specific information. This approach also should aid those agencies dealing with multiple theme areas, because they are internally organized across distinct programs that generally coincide with the different theme areas. However, this stand-alone approach affected the way cross-cutting issues are treated. Through the course of preparing this science plan, several issues that cut across multiple theme areas were identified:

- Quantification of key environmental indicators
- Model application and development
- Adaptive management functionality and effectiveness
- Research and policy implementation
- Effects of climate change
- Effects of fire

The stand-alone organization of the research strategies means information on cross-cutting issues is presented under multiple theme areas. For example, those wanting to learn about the research needed to improve our understanding of climate change effects will need to review the appropriate section in several chapters. Although this organizational approach means the reader will have to do more work to synthesize information on cross-cutting issues, this approach does allow for better integration of cross-cutting issues within each theme area.

The target audience for this document includes those individuals within government agencies and the stakeholder community that have a role in the protection and management of the Lake Tahoe basin ecosystem. We hope this document is of particular use to those individuals who find themselves responsible for deciding if and how new funding for science should be allocated.

English Equivalents

When you know:	Multiply by:	To get:
Meters (m)	3.28	Feet
Kilometers (km)	.621	Miles
Square meters (m^2)	10.76	Square feet
Square kilometers (km^2)	.386	Square miles
Cubic meters (m^3)	35.3	Cubic feet

References

California Tahoe Conservancy [CTC]. 2006. California Tahoe Conservancy 20th anniversary report. South Lake Tahoe, CA. 60 p.

Chandra, S. 2003. The impact of nonnative species introductions and cultural eutrophication on the Lake Tahoe food web over time. Davis, CA: University of California, Davis. 92 p. Ph.D. dissertation.

Elliott-Fisk, D.L.; Cahill, T.C.; Davis, O.K.; Duan, L.; Goldman, C.R.; Gruell, G.E.; Harris, R.; Kattelmann, R.; Lacey, R.; Leisz, D.; Lindstrom, S.; Machida, D.; Rowntree, R.; Rucks, P.; Sharkey, D.; Stephens, S.; Ziegler, D. 1996. Lake Tahoe case study. Addendum to the Sierra Nevada Ecosystem Project; final report to Congress. University of California, Centers for Water and Wildland Resources. Wildland Resources Center Report No. 36. http://ceres.ca.gov/snep/pubs/web/PDF/~A_C07.PDF. (October 15, 2008).

Lahontan Regional Water Quality Control Board [LRWQCB]. 1995. Water quality standards and control measures for the Lake Tahoe basin. In: Water quality control plan for the Lahontan region, north and south basins. Chapter 5. http://www.waterboards.ca.gov/lahontan/water_issues/programs/basin_plan/references.shtml. (October 15, 2008).

Lake Tahoe Area Research Coordination Board [LTARCB]. 1974. Research needs for the Tahoe basin. Prepared with the support of the National Science Foundation, Office of Intergovernmental Science and Research Utilization, Grant No. GI-39556. 29 p.

Lake Tahoe Basin Executives. 2006. A federal vision for the environmental improvement program at Lake Tahoe. http://www.fs.fed.us/r5/ltbmu/local/ltbec/index.shtml. (October 15, 2008).

Lindstöm, S.; Rucks, P.; Wigand, P. 2000. A contextual overview of human land use and environmental conditions. In: Murphy, D.D.; Knopp, C.M., eds. Lake Tahoe watershed assessment. Volume I. Gen. Tech. Rep. PSW-GTR-175. Albany, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station. 736 p. Chapter 2.

Manley, P.N.; Tracy, J.C.; Murphy, D.D.; Noon, B.R.; Nechodom, M.A.; Knopp, C.M. 2000. Elements of an adaptive management strategy for the Lake Tahoe basin. In: Murphy, D.D.; Knopp, C.M., eds. Lake Tahoe watershed assessment. Volume I. Gen. Tech. Rep. PSW-GTR-175. Albany, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station. 736 p. Chapter 7.

Murphy, D.D. 2000. Introduction and key findings. In: Murphy, D.D.; Knopp, C.M., eds. Lake Tahoe watershed assessment. Volume I. Gen. Tech. Rep. PSW-GTR-175. Albany, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station. 736 p. Chapter 1.

Murphy, D.D.; Knopp, C.M. 2000. Lake Tahoe watershed assessment. Volume I. Gen. Tech. Rep. PSW-GTR-175. Albany, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station. 736 p.

Science Advisory Group [SAG]. 2001. Lake Tahoe basin key management questions. South Lake Tahoe, CA. 9 p.

Smith, J.L.; Stone, J.C.; Rowe, T.G.; Gardner, J.V. 1999. Selected hydrologic features of Lake Tahoe Basin and surrounding area, California and Nevada, 1998. Water Resources Investigations Report 99-4031. Reston, VA: U.S. Department of the Interior, Geological Survey. 1 sheet.

Tahoe Regional Planning Agency [TRPA]. 1986. Monitoring and evaluation. Regional Plan for the Lake Tahoe basin: goals and policies. Stateline, Nevada. http://www.trpa.org/documents/docdwnlds/goals.pdf. (October 15, 2008).

Tahoe Regional Planning Agency [TRPA]. 2001. Environmental Improvement Program: The cooperative effort to preserve, restore, and enhance the unique natural and human environment of the Lake Tahoe region. Stateline, Nevada. http://www.trpa.org/default.aspx?tabindex=10&tabid=227. (October 15, 2008).

Tahoe Regional Planning Agency [TRPA]. 2002. 2001 Threshold Evaluation Report. Stateline, Nevada. http://www.trpa.org/default.aspx?tabindex=1&tabid=174. (October 15, 2008).

Tahoe Regional Planning Agency [TRPA]. 2007. Lake Tahoe Environmental Improvement Program accomplishments report 1997–2006. Stateline, Nevada. http://www.tiims.org/Content/Projects/EIP/default.asp. (October 15, 2008).

Tahoe Regional Planning Agency; U.S. Army Corps of Engineers, Sacramento District [TRPA and US COE]. 2005. Final letter report. Workgroup to Develop the Tahoe Science Consortium Lake Tahoe Basin Nevada and California. On file with: U.S. Army Corps of Engineers, Sacramento District, 1325 J Street, Sacramento, CA 95814.

U.S. Public Law 96-551. 1980. Tahoe Regional Planning Agency Compact. In: HR 8235, 96 United States Congress. (December 19, 1980).

U.S. Public Law 106-506. 2000. Lake Tahoe Restoration Act. In: HR 3388, 106 United States Congress. (November 13, 2000).

Western Federal Regional Council Interagency Regional Task Force [WFRC IRTF]. 1979. The Lake Tahoe Environmental Assessment. [Place of publication unknown]. 240 p.