TECHNICAL STAFF REPORT:

TOTAL MAXIMUM DAILY LOAD FOR SEDIMENT AND IMPLEMENTATION PLAN, HEAVENLY VALLEY CREEK, EL DORADO COUNTY, CALIFORNIA

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TABLE OF CONTENTS

.

LIST OF TABLES

LIST OF FIGURES

Section 1. Executive Summary

Heavenly Valley Creek is located in a small, high elevation forested watershed in the southeastern part of the Lake Tahoe Basin, in El Dorado County, California and Douglas County, Nevada. Since 1956, the upper Heavenly Valley Creek watershed has been disturbed by construction and maintenance activities at the Heavenly Valley (later renamed "Heavenly") ski resort. During the 1989-1990 listing cycle, Heavenly Valley Creek was placed on the list of impaired surface water bodies which require development of Total Maximum Daily Loads (TMDLs) pursuant to Section 303(d) of the federal Clean Water Act. Implementation plans are also required for TMDLs. Heavenly Valley Creek was listed due to impairment from sediment based on the historic information summarized in Section 3.1 below.

TMDLs are strategies to ensure the attainment of water quality standards. By definition, the "Total Maximum Daily Load" of a pollutant which can be allowed if standards are to be attained is equivalent to the sum of "wasteload allocations" for point sources of pollutants, "load allocations" for nonpoint sources, and an explicit or implicit margin of safety to allow for uncertainty in the analysis.

The California Regional Water Quality Control Board, Lahontan Region (Regional Board) has developed a TMDL for sediment in Heavenly Valley Creek which, when implemented, is expected to result in the attainment of applicable water quality objectives and the protection of beneficial uses. The beneficial uses of concern are those associated with aquatic habitat. The Regional Board is also considering adoption of a TMDL implementation program based substantially on completion of ongoing watershed restoration activities at the ski resort, and continuation of a comprehensive U.S. Forest Service monitoring program. (The watershed area affected by the TMDL is entirely within the boundaries of the Heavenly ski resort, on National Forest land administered by the U.S. Forest Service, Lake Tahoe Basin Management Unit.)

The TMDL and implementation program will be considered for adoption as amendments to the Regional Board's *Water Quality Control Plan for the Lahontan Region* (Basin Plan). This staff report summarizes the technical background for the proposed amendments. More detailed information is contained in supplementary reports which will be included in the administrative record of the Basin Plan amendment process.

Components of the TMDL

The TMDL includes:
- A problem statement
- Numeric targets
- Source analysis
- Linkage analysis
- Load allocations, and

- Discussion of the margin of safety and seasonal and annual variation.

The TMDL implementation program includes:
- A description of the remedial actions to be performed
- A monitoring program related to the numeric targets, and
- A schedule for review and revision of the TMDL.

Problem Statement. The TMDL focuses on the listed segment of Heavenly Valley Creek from the headwaters downstream to the resort permit boundaries. The problem statement includes assessment of existing instream and watershed conditions in relation to water quality standards and conditions in a nearby reference stream. Monitored suspended sediment concentrations have been higher than those at reference stations since the 1970s, and at times have exceeded a regional numerical suspended sediment standard. Sedimentation contributed to the degradation of benthic invertebrate communities in Heavenly Valley Creek as early as 1972, and to ranking of the stream as "marginal" fish habitat by 1982. By 1995, sediment delivery from the watershed was estimated to be about 14.5 times estimated sediment delivery under natural conditions.

Numeric Targets. The numeric targets interpret water quality standards (including narrative sediment objectives related to beneficial use support) and provide indicators of watershed health. They are an expression of desired future conditions associated with a stable watershed and a stream capable of supporting healthy aquatic habitat. The indicators and targets are identified in Tables 5 and 8. Attainment of numeric targets, will be evaluated in relation to conditions in a nearby reference stream and its watershed.

Source Analysis. The source analysis uses outputs from a model developed by the U.S. Forest Service to estimate sediment delivery to Heavenly Valley Creek from unpaved roads, ski runs, and undisturbed areas within the watershed, and calculations based on suspended sediment data collected in Heavenly Valley Creek between 1996 and 1999. The modeled "total impaired" sediment load (assuming no use of Best Management Practices or BMPs) is 150 tons/year (including both suspended and bedload sediment). The modeled load for1996-99, which reflects some improvement due to BMPs already implemented, is 116 tons per year. The estimated average annual historic total (suspended plus bedload) sediment loading for Hidden Valley Creek between 1991 and 1999 is 45 tons. Factors contributing to increased sediment delivery as a result of watershed disturbance include: highly erodible decomposed granite soils, steep slopes prone to avalanches and mass wasting, short growing season which makes revegetation difficult, and past ski resort maintenance practices which led to repeated disturbance. The total instream load for Heavenly Valley Creek is divided among hillslope source categories as follows: 62 % from roads, 32% from ski runs, and 6 % from undisturbed lands.

Linkage Analysis. The linkage analysis discusses the relationship between hillslope sediment production processes and effects on instream water quality and beneficial uses. It provides the basis for estimating the magnitude of sediment loading reductions, and the hillslope controls, necessary to attain water quality objectives and protect beneficial uses. An inferred linkage is used, with the assumption that the numeric target will adequately protect beneficial uses and therefore ensure compliance with narrative objectives because it is reasonably close to the estimated sediment load in Hidden Valley Creek. A literature review also indicates that attainment of the target should provide adequate habitat conditions for adult fish and that the creek's steep gradient and high degree of winter scour would not provide good spawning habitat even under natural sediment loading conditions. There is historic evidence that Heavenly Valley Creek was already degraded before the first applicable water quality standards were adopted, and reduction of sediment loading to "pristine" conditions may not be necessary to provide the required level of beneficial use protection. The instream loading capacity is set at 53 tons per year, as a 5 year rolling average, which (considering differences in watershed size) is considered reasonably close to the estimated 45 tons per year load in the reference stream, and which represents a 65% reduction in estimated historic loading. This substantial reduction is expected to expected to allow recovery of stream channel and riparian conditions over time and thus recovery of aquatic invertebrate communities and protection of adult fish populations.

Load Allocations. There are no point sources of sediment in the affected watershed. Therefore, the "wasteload allocation" for this TMDL is zero. Load allocations for instream total sediment are set for source categories (roads, ski runs, undeveloped lands, and proposed new development) in proportion to modeled hillslope sediment delivery reductions from each source after full application of Best Management Practices. Load allocations are summarized in Table 13.

Margin of Safety and Seasonal and Annual Variation. There is inherent seasonal and annual variation in sediment delivery to streams, and in the impacts of sediment on aquatic species during different critical life stages. The Heavenly Valley Creek TMDL addresses long term erosion patterns and instream impacts by using longer time frames for implementation and evaluation, and relies on an adaptive management approach. Load allocations are expressed as 5 year rolling averages to account for seasonal and annual variability. The TMDL and allocations are expected to promote recovery of aquatic habitat over time to the point which will support the beneficial uses of concern. The TMDL contains an implicit margin of safety, based on conservative assumptions, to compensate for uncertainty in the analysis, and to ensure that the allocations, when achieved, will result in attainment of standards.

Public Participation. Public participation for the TMDL will be provided through the Regional Board's Basin Plan amendment process (which includes public review under the California Environmental Quality Act, and adoption following a noticed public hearing), and through subsequent public review periods preceding approvals of the Basin Plan amendments by the California State Water Resources Control Board (State Board) and the U.S. Environmental Protection Agency (USEPA). The State Board will submit the Basin Plan amendments, with supporting documentation, to the USEPA for approval as TMDLs after they have been approved by the California Office of Administrative Law.

Implementation and Monitoring Programs. Because the entire subwatershed affected by the Heavenly Valley Creek TMDL is within USFS ownership, the responsibility for implementation rests with the USFS and its permittee, the Heavenly ski resort. The implementation program involves completion of a U.S. Forest Service- mandated watershed restoration program (funded by the resort) which calls for application of Best Management Practices for erosion control to all historically disturbed areas, and to all future development, in the subwatershed affected by the TMDL. The restoration program began in 1997 and is expected to be completed in 2006. It is an adaptive management program, involving annual evaluation of BMP effectiveness and refinement of management practices as appropriate.

Projected implementation of the TMDL also involves continuation of the existing U.S. Forest Service monitoring program (funded by the ski resort), which already addresses most of the instream and hillslope indicators. Bioassessment of benthic invertebrate communities, using a protocol which also assesses a variety of other instream and riparian conditions, will be added to the monitoring program.

The TMDL implementation plan for Heavenly Valley Creek is noncontroversial and there is a good probability of continued implementation. Formal commitments to the existing watershed restoration and monitoring programs have already been made by stakeholders including the Heavenly ski resort, the U.S. Forest Service, and the Tahoe Regional Planning Agency.

The Regional Board has authority under the Clean Water Act and the California Water Code to ensure implementation of the Heavenly Valley Creek TMDL in California. Initially, the Board will rely on the three-tier implementation approach outlined in the statewide *Plan for California's Nonpoint Source Pollution Control Program* (California State Water Resources Control Board, 2000). Authority to ensure implementation in Nevada includes the U.S. Forest Service's permitting authority over the Heavenly ski resort, and the bistate Tahoe Regional Planning Agency's charge under P.L. 96-551 to ensure attainment of the most stringent state and federal water quality standards. Attainment of water quality standards is projected to occur within 20 years of final approval of the TMDL (in 2021).

Review and Revision of the TMDL. Regional Board staff will review the annual monitoring reports produced by the U. S. Forest Service and will participate in the adaptive management approach to erosion control through the interagency technical advisory group. Progress toward attainment of the load allocations and of water quality standards will be reviewed at five year intervals, to coincide with the U.S. Forest Service's planned comprehensive reviews of monitoring data and the success of the erosion control program. (The first such review is being done in 2000.) If satisfactory progress is not being made, revision of the TMDL will be considered.

Section 2. Introduction

The Lahontan Regional Water Quality Control Board (Regional Board) is the California State agency responsible for water quality protection east of the Sierra Nevada crest. It is one of nine Regional Boards which function as part of the State Water Resources Control Board (State Board) system within the California Environmental Protection Agency. The Lahontan Regional Board implements both the federal Clean Water Act and the Porter-Cologne Water Quality Control Act, which is part of the California Water Code. Water quality standards and control measures for waters of the Lahontan Region are contained in the Regional Board's *Water Quality Control Plan for the Lahontan Region* (Basin Plan).

Under Section 303(d) of the Clean Water Act, the Regional Board must identify surface waters which are not meeting water quality standards and are not expected to do so even with the use of technology-based controls. For Section 303(d)-listed waters, the Regional Board must develop strategies called "Total Maximum Daily Loads" or TMDLs. TMDLs involve calculation of pollutant loads from all point and nonpoint sources in the watershed, and determination of the reductions in pollutant loads from each of these sources, which, when considered together with a "margin of safety," are necessary for attainment of standards. TMDL implementation programs are required under 40CFR 230.6 and the California Water Code, and California TMDLs and their associated implementation programs must be adopted as Basin Plan amendments.

Heavenly Valley Creek is a tributary of Trout Creek in the southeast portion of the Lake Tahoe watershed. The segment of Heavenly Valley Creek within the boundaries of the Heavenly Ski Resort (a U.S. Forest Service permittee) is Section 303(d)-listed for sedimentation problems related to watershed disturbance for ski resort development and maintenance. Sedimentation of Heavenly Valley Creek is of concern not only because of its impact on instream beneficial uses, but also because of its cumulative contribution to the degradation of Lake Tahoe through addition of sediment and sediment-bound nutrients. (Lake Tahoe is on the Section 303(d) list for significant loss of transparency and increased phytoplankton productivity, in violation of water quality standards.)

The Lahontan Regional Board proposes to amend its Basin Plan to incorporate a TMDL and an Implementation Plan to address sedimentation problems related to ski resort development in the upper watershed of Heavenly Valley Creek. The TMDL is based on past modeling of sediment loads and feasible loading reductions by the U.S. Forest Service, Lake Tahoe Basin Management Unit (USFS), on monitoring data, and other readily available information. The proposed Basin Plan amendment language for Heavenly Valley Creek includes the basic information required in TMDLs under federal regulations (40 CFR 130.2), summaries of the implementation and monitoring programs, and a schedule for review and revision of the TMDL. This staff report summarizes the technical background for the Heavenly Valley Creek TMDL and implementation program. The report is organized in a format similar to that used for TMDLs adopted directly for California waters by the USEPA, Region IX. However, it is <u>not</u> in itself the TMDL proposed for state adoption.

Section 3. Supporting Information for TMDL Components

The TMDL is based primarily on modeling data and other information in the draft and final Environmental Impact Statements (EISs) for the Heavenly Ski Resort Master Plan (Tahoe Regional Planning Agency, 1995 and 1996), on hillslope and instream monitoring data from USFS monitoring reports (Hazelhurst and Widegren, 1998 and Hazelhurst *et al*., 1999), and on unpublished USFS monitoring data (Sherry Hazelhurst, personal communication). Relevant excerpts from these reports, and from other reports cited in the "References" section, will be made part of the administrative record of the Basin Plan amendments. A detailed summary of the USFS model used as the basis for the TMDL source analysis and load allocations is included as Appendix 1 to this staff report. The administrative record will also include a separate environmental document prepared pursuant to the California Environmental Quality Act (CEQA) to address environmental and socioeconomic impacts of the proposed Basin Plan amendments.

The USEPA's (1999) protocol for developing sediment TMDLs states that projects which focus on implementation planning (and for which TMDLs are a by-product) can often use less complex methods of developing TMDLs because specific implementation actions can be identified, agreed to, and implemented without controversy. The protocol also states that less complex TMDLs are appropriate for small watersheds. Heavenly Valley Creek is located in a small (1341 acres) subwatershed where stakeholders have agreed upon and are already implementing a comprehensive sediment control program under an adaptive management approach. The TMDL can be considered a "by-product" of the development and implementation of the erosion control and monitoring programs in the 1996 Heavenly Ski Resort Master Plan. The Heavenly Valley Creek sediment TMDL uses a relatively simple sediment delivery model as the basis for the source analysis and load allocations, includes an implicit margin of safety, and relies on monitoring of multiple numeric indicators to demonstrate attainment of narrative water quality objectives over time. Regional Board staff believe that the implementation and monitoring programs support this "less complex" approach.

Section 3.1. Problem Statement

There is evidence from a variety of sources that, in comparison with other streams in the Lake Tahoe Basin with similar geology and less watershed disturbance, the water quality and beneficial uses of Heavenly Valley Creek have been significantly affected by increased sediment delivery from ski resort development. Documented instream problems include elevated suspended sediment concentrations and loading, degraded stream channel conditions, degraded benthic invertebrate communities and "marginal" fish habitat conditions (TRPA, 1996). Documented hillslope problems include modeled increases in sediment delivery to the stream from unpaved roads and ski runs, compared to modeled natural sediment yield from the watershed. Heavenly Valley Creek was classified as "impaired", and subsequently placed on the Section 303(d) list, during the Lahontan Regional Board's 1989-1990 water quality assessment cycle. Listing reflected the significance of sedimentation from historic disturbance throughout the upper watershed, and two significant mass wasting incidents in the 1980s.

The following is a more detailed summary of historic and existing sediment problems in relation to applicable water quality standards. Additional information on historic and existing conditions is provided in the discussion of numeric targets and indicators.

A. Watershed Overview

Geographic scope of TMDLs. Heavenly Valley Creek is a tributary of Trout Creek, which in turn is tributary to the Upper Truckee River and then to Lake Tahoe (Figure 1). The listed segment of Heavenly Valley Creek extends from the headwaters to the permit boundaries of the Heavenly ski resort (Figure 2). Its watershed is entirely within National Forest land administered by the U.S. Forest Service, Lake Tahoe Basin Management Unit (USFS/LTBMU). The LTBMU legally includes portions of the Tahoe, El Dorado, and Humboldt-Toiyabe National Forests, but is a separate administrative unit with its own Forest Supervisor and Land and Resource Management Plan (USFS, 1988). The LTBMU's plan has water quality protection as its primary goal.

Throughout this staff report, references to the "Heavenly Valley Creek watershed" and "Heavenly Valley Creek" refer to the subwatershed and Section 303(d) listed creek segment within the LTBMU and the ski resort permit boundaries. Heavenly Valley Creek flows for about a mile outside of the LTBMU boundary through private lands before joining Trout Creek. This lower segment has been affected by past wastewater disposal to land and by urban development. Insufficient monitoring data were available at the time the upper segment was listed to determine whether the lower segment should be included. The Tahoe Regional Planning Agency (1998) has since proposed a fish habitat restoration project for this segment. A TMDL for the lower segment, if needed, will be addressed as part of the future development of TMDLs for Lake Tahoe.

The TMDL analysis uses another tributary of Trout Creek as a reference stream. This stream has an undisturbed watershed, with streamflow, geology, and vegetation similar to those of Heavenly Valley Creek. Its watershed area is about 87 % of that of Heavenly Valley Creek (1162 acres vs. 1341 acres). The reference stream has no official geographic name but is called "Hidden Valley Creek" by USFS staff. Its location is shown in Figure 1.

The USFS model used in development of the TMDL source analysis and load allocations does not distinguish between sources in California and Nevada. The Nevada portion of the watershed (57 of 1341 acres) has no mapped surface waters. The TMDL addresses suspended sediment loads from the entire watershed. As noted in the discussion of the implementation program below, the USFS and the Tahoe Regional Planning Agency have already made formal commitments to the remedial erosion control and monitoring programs which are important components of the TMDL implementation plan, and these agencies have authority to ensure implementation in Nevada.

Geology, Soils, and Natural Hazards. Soils within the Heavenly Valley Creek watershed are highly erodible, excessively well drained, and contribute to high peak discharges during rainstorms or spring runoff. They are derived from granitic parent material, in all stages of decomposition. A number of the soils at the Heavenly resort have more rapid runoff once disturbed and bare, while runoff under natural conditions is usually moderate. Once disturbed, these soils are difficult to revegetate because of low fertility, low water holding capacity, and harsh climatic conditions (Etra, 1984). Under the Bailey land capability system used in land use and water quality planning and permitting in the Lake Tahoe Basin (see Section 5.4 of the Lahontan Basin Plan), most of the lands within the Heavenly Valley Creek watershed are capability Class 1 or 2 and would currently be allowed only 1 percent impervious surface coverage or permanent soil disturbance. In 1995, there were about 221 acres of roads and ski runs in the watershed (about 16.5% disturbance). Most of this watershed disturbance occurred before limits were placed on impervious surface coverage in the Lake Tahoe Basin. Disturbance after 1980 was mitigated under the requirements of the Regional Board and/or TRPA water quality plans.

The resort has steep to very steep slopes (30-70 percent), and sediment has the potential to reach Lake Tahoe rapidly because the Sky Meadow Reservoir in the Heavenly Valley Creek drainage provides the only significant opportunity to trap sediment. Following severe watershed damage from an August 1983 rainstorm, the reservoir filled almost to capacity (22-28 acre-feet) with sediment. Sediment was later removed from the reservoir to fill upgradient rills and gullies. There is no similar containment downstream of the reservoir. There are several existing landslides in the Heavenly Valley Creek watershed; the watershed is also avalanche- prone and includes four avalanche control areas.

***Climate and Hydrology*.** The Lake Tahoe Basin's climate includes cold wet winters and temperate, mostly dry summers. Precipitation comes from both winter Pacific storms and summer thundershowers; it falls as snow from October to April and as rain from May to September. Snow depths generally reach 8 to 12 feet in the mountains surrounding Lake Tahoe, usually in February or March. There are large seasonal and diurnal variations in temperature, and a short growing season (about 70 to 120 frost free days). The mean annual precipitation is 30 inches per year.

Heavenly Valley Creek originates from springs and seeps. Four first order channels merge to form two second order channels, which then merge as a third order creek. The main channel extends from Sky Canyon at 9,300 feet to the confluence with Trout Creek at 6,255 feet (Hazelhurst and Widegren, 1998). The stream slope ranges from 2.7 percent to 36 percent, with an average of 20.2 percent. The drainage density is 1.32 miles per square mile. The usual seasonal pattern involves low winter base flows and peak runoff period in May or June. (During drought years, peak snowmelt flow has been observed as early as March.) Summer flows are generally lower. The maximum recorded flow was 28 cfs in June 1983. Heavenly Valley Creek is generally perennial, but there have sometimes been periods with no flow. (The period of record includes the severe drought of the 1980s and early 1990s.)

Heavenly Valley Creek as a whole is about 4.4 miles long, with about 2.7 miles within the resort boundary. The listed segment of the creek has a drainage area of 2.1 square miles (1,341 acres, including about 57 acres in Nevada). The creek's elevation change is 3,400 feet (from 9,080 feet to 6,255 feet at its confluence with Trout Creek), although the watershed includes Monument Peak (elevation 10,058 feet). The average stream gradient is about 20 percent. The Heavenly Valley Creek watershed is called "Watershed CA-1" in some of the USFS maps and tables of modeling data which will be included in the administrative record for the Basin Plan amendments. Watershed boundaries are shown in Figure 3.

Sky Meadows Reservoir, located in the upper part of the watershed (Figure 2) stores water for use in snowmaking. It receives both natural inflow from a drainage area of about 550 acres and water imported from California and Nevada sources outside of the Heavenly Valley Creek watershed. The net effects of added runoff from manmade snow and summer diversions for irrigation of revegetated areas on summer flows in the creek have not been determined. However, diversions are a factor in the rating of fish habitat quality in the creek as "marginal" (TRPA, 1996).

Terrestrial Biota. The watershed is forested, although trees are sparse and stunted above about 9000 feet. Dominant forest associations include Mixed Conifer-Fir, Lodgepole Pine, and Red Fir. There are also brush communities dominated by sagebrush, manzanita, ceanothus, and mountain mahogany, and some areas dominated by forbs such as mule's ears, or by perennial grass. Vegetative cover is not continuous; large areas of unvegetated soil may occur between stands of shrubs (Etra, 1984).

There are about 83 acres of Stream Environment Zone (SEZ), in the Heavenly Valley Creek watershed, about 14 acres of which have been affected by human activities. "Stream Environment Zone" is a Lake Tahoe Basin land use planning category which includes lakes, streams, wetlands, and riparian areas, but which involves delineation criteria separate from federal wetlands criteria. Because of their filtering capacity for sediment and nutrients, protection and restoration of SEZs is considered important for protection of water quality throughout the Lake Tahoe watershed.

Over 250 species of resident and migratory vertebrate wildlife are known to occur in the Lake Tahoe Basin. Stream Environment Zones are considered especially important wildlife habitat. Sensitive wildlife species observed at or near the Heavenly ski resort include California spotted owl, great gray owl, northern goshawk, pine marten, Sierra

Nevada snowshoe hare, American badger, mountain quail, golden eagle, Cooper's hawk, and sharp-shinned hawk.

Fisheries and Aquatic Habitat. The degree to which the upper reaches of Heavenly Valley Creek historically supported game fish is unknown. The only trout native to the Lake Tahoe Basin is the Lahontan cutthroat trout, now listed as "threatened" under the federal Endangered Species Act. Many of the high elevation lakes and streams of the Lahontan Region were "fishless" until game fish planting, often with exotic species, began in the 19th century. Fish habitat in Heavenly Valley Creek has been classified as "marginal" since a 1982 survey (TRPA, 1996). Samples of benthic invertebrates at seven stations in Heavenly Valley Creek between 1972 and 1974 showed 151-7420 individuals per square meter, classified in 5-27 genera (Baker and Davis, 1976). See the discussion of sediment impacts on beneficial uses below for more information on aquatic habitat issues.

Land Use. The Lake Tahoe watershed as a whole was severely disturbed by 19th century logging and grazing. The extent of specific disturbance in the Heavenly Valley Creek and Hidden Valley Creek watersheds is unknown, but given its present high quality, Hidden Valley Creek may be assumed to have recovered from the disturbance. Development of ski resort facilities in the Heavenly Valley Creek watershed began in 1956. As of 1995, the 1341 acre watershed included 221 acres of ski runs and roads. Hydromodification of the creek has included construction of the snowmaking reservoir and associated pipelines, and placement of 200 yards of the creek into a culvert. Past construction practices involved preparing new ski runs by bulldozing all vegetation and removing the thin topsoil layer. Maintenance practices, called "summer grooming" involved repeated mechanical removal of rocks and vegetation from ski runs in order to allow skiing when snow was not deep. The current practice for construction of new ski runs involves cutting trees but leaving natural rocks, vegetation, and duff, and using snowmaking to maintain an obstacle-free cover for skiing. The USFS and U.S. Natural Resource Conservation Service have implemented a variety of erosion control and revegetation projects within the Heavenly resort boundaries since 1965, with varying degrees of success. However, the erosion control program which forms the basis of the current TMDL implementation program is the result of a comprehensive effort to document and meet restoration needs throughout the Heavenly Valley Creek watershed.

Projected new development in the watershed under the 1996 Master Plan includes four new ski lifts, a "Top Station" for the new resort gondola (most gondola facilities are in another watershed), four new ski runs, expansion of the snowmaking system, 3600 feet of new road, a reconstructed ski lodge, and a relocated maintenance building. Some of this construction has already occurred (USFS, 1998). Parts of two ski runs and the relocated maintenance building are within the Nevada portion of the watershed. New development is included in the TMDL load allocations below.

B. Applicable Water Quality Standards

Water quality standards in California include designated beneficial uses of water, and narrative and numerical water quality objectives (equivalent to federal "criteria") set to protect those uses. The designated beneficial uses of Heavenly Valley Creek and its tributaries are Municipal and Domestic Supply (MUN), Agricultural Supply (AGR), Groundwater Recharge (GWR), Water Contact Recreation (REC-1), Non-Contact Water Recreation (REC-2), Commercial and Sportfishing (COMM), Cold Freshwater Habitat (COLD), Wildlife Habitat (WILD), Rare and Endangered Species Habitat (RARE), Migration of Aquatic Organisms (MIGR), and Spawning of Aquatic Organisms (SPWN). Chapter 2 and Section 5.1 of the Basin Plan include definitions of each of these uses. With the exception of the RARE use, Hidden Valley Creek has the same designated beneficial uses as Heavenly Valley Creek. These are the uses of Trout Creek which apply upstream under the "tributary rule". (The Basin Plan states [page 3-13] that: "Where objectives are not specifically designated, downstream objectives apply to upstream tributaries.")

Not all of Heavenly Valley Creek's uses (e.g., MUN) are currently existing uses within the boundaries of the Heavenly ski resort. The RARE use was added in the 1995 Basin Plan update as a result of the presence of a small population of the threatened Lahontan cutthroat trout in 1990; however, the U.S. Fish and Wildlife Service has since determined that the creek does not constitute critical habitat for the trout (Sherry Hazelhurst, personal communication). Hikers are allowed recreational access to the watershed during the summer, but summer recreational (REC-1 and REC-2) use of the creek within the resort boundaries is probably relatively low compared to that of more easily accessible Lake Tahoe Basin streams. Winter recreational use of the watershed does not depend on the water quality or instream uses of the creek. The most important beneficial uses for purposes of interpreting the narrative sediment objectives are summarized in Table 1. Note that most of these uses are defined to encompass all types of aquatic organisms, not only fish.

Water quality objectives for Heavenly Valley Creek are set forth in Chapter 3 and Section 5.1 of the Lahontan Basin Plan. They include regionwide narrative objectives, narrative objectives for waters of the Lake Tahoe Basin, and numerical objectives which apply upstream from Trout Creek under the "tributary rule" cited above. No "site-specific" numeric objectives have been established for Heavenly Valley Creek *per se*.

The State water quality objectives of greatest importance for the proposed sediment TMDLs are the non-degradation objective, and three narrative objectives related to suspended and bedload sediment. The sediment objectives are cited in Table 2.
The nondegradation objective references State Water Resources Control Board Resolution 68-16 (which is included in the appendices to the 1995 Basin Plan). This resolution allows lowering of water quality in high quality waters only if specific findings can be made. No findings have ever been made by the State or Lahontan Regional Board to allow degradation of Heavenly Valley Creek in exchange for socioeconomic benefits. Lake Tahoe is a designated "Outstanding National Resource

Water" under federal antidegradation regulations. No degradation of such waters can be allowed even where significant socioeconomic benefits would result.

The Lahontan Basin Plan (Section 5.2) also contains several waste discharge prohibitions applicable to sediment discharges in the Lake Tahoe Basin. There are general prohibitions against discharge of any waste or deleterious materials, including waste earthen materials, to surface waters of the Lake Tahoe Hydrologic Unit (HU), and specific prohibitions against discharges or threatened discharges within 100 year flood plains and Stream Environment Zones (SEZs). The earliest relevant prohibition, against discharge of "deleterious materials" to surface waters of the Lake Tahoe Basin, was adopted in 1966 (California Regional Water Quality Control Board, 1966). There is also a prohibition (adopted in 1980) against discharges or threatened discharges as a result of impervious surface coverage in excess of the limits of the Lake Tahoe Basin land capability system (the "Bailey System"). For the Heavenly Valley Creek watershed, this prohibition limits any new disturbance to no more than 1% of the "project area", unless the exemption findings set forth in Chapter 5 of the Basin Plan can be made.

Table 1. Beneficial Uses of Heavenly Valley Creek Potentially Affected by Sedimentation.

Beneficial Use	Definition (from Lahontan Basin Plan)
Cold Freshwater Habitat (COLD)	Beneficial uses of waters that support cold water ecosystems including, but not limited to, preservation and enhancement of aquatic habitats, vegetation, fish, and wildlife, including invertebrates.
Rare Threatened, or Endangered Species (RARE)	Beneficial uses of waters that support habitat necessary for the survival and successful maintenance of plant or animal species established under state and/or federal law as rare, threatened, or endangered.
Migration of Aquatic Organisms (MIGR)	Beneficial uses of waters that support habitats necessary for migration, acclimatization between fresh and salt water, or temporary activities by aquatic organisms such as anadromous fish.
Spawning, Reproduction, and Development (SPWN)	Beneficial uses of waters that support high quality aquatic habitat necessary for reproduction and early development of fish and wildlife.

C. Interpretation of Narrative Objectives

All of the narrative objectives in Table 2 refer to protection of beneficial uses. The state Nondegradation Policy also requires that beneficial uses be protected even if lowering of water quality is permitted for purposes "of maximum benefit to the people of the State" (e.g., significant socioeconomic benefits).

Waters (1995) provides a comprehensive literature review of the impacts of suspended and deposited sediment on instream beneficial uses. These impacts include coating of "biologically active surfaces" of plants and animals (e.g., fish gills) by clay particles, abrasion and suffocation of attached algae, reduction of light for photosynthesis, and modification of animal behavior (e.g., invertebrate drift). Deposited sediment changes benthic invertebrate habitat in relation to substrate particle size, embeddedness of gravels, and loss of interstitial spaces, leading to changes in species composition and diversity.

Suspended sediment may have sublethal effects on fish including reduced feeding and growth, respiratory impairment, and physiological stress leading to reduced tolerance to disease and toxicants. Deposited sediment can have significant impacts on the reproductive success of salmonid fish by filling interstitial spaces in spawning gravels, reducing water and oxygen flow to fish embryos and fry, smothering of embryos and fry, and entrapment of emerging fry.

Watershed disturbance related to ski resort development and maintenance began in the Heavenly Valley Creek watershed well before the adoption of water quality standards for Lake Tahoe and tributary waters. Table 3 includes a chronology of important dates to

Table 2. Narrative Water Quality Objectives for Heavenly Valley Creek Related to Sedimentation.

Title	Objective Text
Sediment	The suspended sediment load and suspended sediment discharge rate of surface waters shall not be altered in a manner as to cause nuisance or adversely affect the water for beneficial uses.
Settleable Materials	Waters shall not contain substance in concentrations that result in deposition of material that causes nuisance or that adversely affects the water for beneficial uses. For natural high quality waters, the concentration of settleable materials shall not be raised by more than 0.1 milliliter per liter.
Suspended Sediment	Suspended sediment concentrations in streams tributary to Lake Tahoe shall not exceed a 90th percentile value* of 60 mg/L. (This objective is equivalent to the Tahoe Regional Planning Agency's regional "environmental threshold carrying capacity" standard for suspended sediment in tributaries.) *The Regional Board will consider revision of this objective in the future if it proves not to be protective of beneficial uses or if review of monitoring data indicates that other numbers would be more appropriate for some or all streams tributary to Lake Tahoe.*

* In this case, a 90th percentile value means that no more than 10 percent of all samples should have suspended sediment concentrations greater than 60 mg/L.

consider in defining baseline conditions for the interpretation of narrative objectives, including the nondegradation objective, and for determining the TMDL loading capacity.

The first available quantitative study of suspended sediment impacts on beneficial uses of Heavenly Valley Creek is that by Baker and Davis (1976), who sampled suspended sediment and macroinvertebrate communities at several stations between 1972 and 1974. Baker and Davis documented increased suspended sediment concentrations, and increased degradation of macroinvertebrate communities, at downstream stations below the area of greatest watershed disturbance. Earlier sediment studies of Tahoe Basin streams (not including Heavenly Valley Creek) were concerned with documenting highways and urban development on sediment loading to Lake Tahoe, and not with instream beneficial uses. Baker and Davis described then-existing development in the Heavenly Valley Creek watershed as follows (emphasis added):

> *"This watershed is dominated by ski trails which were stripped of vegetation when constructed. Other man-made disturbances include access roads, ski lift operations, stream crossings and random trails and roads developed by off-road vehicles."*

For purposes of the TMDL analysis, Regional Board staff assume that the watershed was significantly developed, and the creek's aquatic life uses were significantly affected by sediment, at the time that the Nondegradation Policy was adopted. This is important in evaluating the degree of beneficial use support required for compliance with the narrative objectives. (See the loading capacity linkage analysis section below.) Due to the implementation of erosion controls, and probable ecosystem recovery over time, current watershed conditions are assumed to represent improvement over those existing at the time the first applicable standard (the Nondegradation policy) was adopted. The extent of current aquatic life use support is unknown. The TMDL focuses on maximizing beneficial use support to the extent practicable. Progress toward enhancement of beneficial uses and attainment of narrative objectives will be defined in terms of improving trends in the parameters connected with the instream numeric targets discussed below.

D. Summary of Historic and Existing Concerns

In general, compared to the reference stream, Heavenly Valley Creek has higher suspended sediment concentrations, and more disturbed channel conditions. Suspended sediment concentrations have historically exceeded the 60 mg/L 90th percentile water quality objective. Modeled hillslope sediment delivery to the creek was about 14.5 times higher in 1995 than the estimated natural sediment delivery rate. Two different multiparameter indices of stream channel condition show significant problems in Heavenly Valley Creek. There is evidence of degradation of benthic macroinvertebrate communities as early as 1972, and fish habitat quality has been rated "marginal" since 1982. The following is a more detailed summary of concerns related to specific problem areas. The discussion of numeric targets below includes additional information on "existing" instream and hillslope conditions.

1. Instream Conditions.

Suspended Sediment. The reported annual mean suspended sediment concentration in Heavenly Valley Creek between 1970 and 1976 was higher than that in several other Tahoe Basin streams with relatively undisturbed watersheds (Skau and Brown, 1988). Baker and Davis (1976) found increased concentrations of suspended sediment at downstream stations in Heavenly Valley Creek, and high overall concentrations compared to a station above all disturbance on another Lake Tahoe Basin stream with a decomposed granite watershed. Baker and Davis were unable to find a reference station above all disturbance on Heavenly Valley Creek. Violations of the Tahoe Regional Planning Agency's "environmental threshold" standard for suspended sediment (equivalent to the Regional Board's subsequently adopted 60 mg/L objective) occurred during the 1980s (TRPA, 1995).

Evaluation of U.S. Forest Service monitoring data (Hazelhurst and Widegren, 1998; Hazelhurst *et al.*, 1999) shows that the numerical suspended sediment objective (60 mg/L as an annual 90th percentile value) was attained at most Heavenly Valley Creek stations in 1997 and 1998, although “borderline” violations occurred at the station farthest downstream. Annual mean suspended sediment concentrations for different Heavenly Valley Creek stations in 1997 ranged from 2.3 to 31.4 mg/L. The range in 1998 annual means was 8.0 to 20.6 mg/L. Annual mean concentrations for the reference stream, “Hidden Valley Creek” were 3.1 mg/L in 1997 and 4.0 mg/L in 1998. Both 1997 and 1998 were years with above average precipitation.

Stream Channel Conditions. By 1974, 200 yards of Heavenly Valley Creek had been placed within a culvert; Sky Meadow Reservoir was constructed in 1978. The culvert and reservoir have been identified as obstacles to fish migration, and obviously do not function as natural stream segments. The alterations to natural flow regimes as a result of diversions for snowmaking has been identified as a fish habitat concern, and altered flows may affect channel conditions.

In 1990, stream channel stability in Heavenly Valley Creek and Hidden Valley Creek was rated using the Pfankuch stream stability rating system. (No specific publication was cited for the Pfankuch methodology used in 1990; Hazelhurst et al. [1999] cite Pfankuch, 1978].) The overall Pfankuch rating for Heavenly Valley Creek was “fair to poor”, and observations included sedimentation quite evident throughout the creek, with deposits found filling pools and behind debris jams, log rounds from cut trees often found in one reach of the creek, and obstructions to flow such as hay bales in upper reaches of the creek, with some cutting around obstructions. The overall Pfankuch rating for Hidden Valley Creek, the reference stream, was “good”.

Table 3. Chronology for Evaluating Baseline Conditions for Compliance with Narrative Objectives

Date	Event
1956	Ski resort development begins in Heavenly Valley Creek watershed
1960	First diversions from Heavenly Valley Creek for resort use
1965	USFS begins erosion control work at Heavenly Ski Resort
1966	Lahontan Regional Board adopts prohibition against discharge of "deleterious materials" to surface waters of Lake Tahoe Basin
1968	California State Water Resources Control Board adopts Resolution 68-16, the statewide "Nondegradation Policy"
1969 -71	Studies of other Tahoe Basin streams document increased sedimentation in developed watersheds (Glancy 1973; Kroll, 1969)
1970-76	Skau and Brown (1988) study of suspended sediment loading in central Sierra streams including Heavenly Valley Creek

1971	Regional Board prohibits discharges or threatened discharges to 100 year flood plains of Lake Tahoe and its tributaries
1971	Regional Board adopts Interim Basin Plan (not approved by the USEPA) including narrative objective for "bottom deposits"
1972	Federal Clean Water Act, including "fishable/swimmable" goals, adopted
1972-74.	Regional Board staff study of Heavenly Valley Creek shows elevated suspended sediment levels and degradation of invertebrate communities downstream of ski resort development (Baker and Davis, 1976)
1973-74	Baker and Davis study cites USFS implementation of an erosion control project in the Heavenly Valley Creek watershed
1975	Regional Board adopts the *Water Quality Control Plan for the North Lahontan Basin*, including sediment-related objectives
1975	USEPA Water Quality Standards Regulation (40 CFR 131) which includes the federal antidegradation regulations, takes effect
1977	California Tahoe Regional Planning Agency adopts "*Criteria for the Development and Expansion of Ski Areas, Lake Tahoe Basin*" including BMP and monitoring requirements
1978	Sky Meadow dam and reservoir constructed
1980	State Water Resources Control Board adopts Lake Tahoe Basin Water Quality Plan, designating Lake Tahoe an Outstanding National Resource Water and strengthening regulatory controls through prohibitions related to the land capability system

The USFS is monitoring riparian condition in four stream reaches annually on a rotating basis using the USFS Stream Condition Inventory (SCI) procedure. Two reaches of Heavenly Valley Creek are included in the overall program. These reaches were surveyed in 1996 (Hazelhurst and Widegren, 1998). One reach is located in Sky Meadows and the other downstream near the ski area boundary. Six permanent stream cross sections were established during this survey and resurveyed in 1997. Most of the permanent stream cross sections, and new randomly selected cross sections were surveyed in 1998 (Hazelhurst *et al*. 1999). This report concludes (page 5-9):

> *"The SCI cross-sectional surveys performed on two reaches of Heavenly Valley Creek show some changes in channel morphology. The permanent cross-sections on both reaches have degraded since the 1997 survey, indicating net loss of material on the channel bottom. The random cross-sections indicate that reach HVC-1 is becoming narrower and deeper while reach HVC-2 is becoming shallower and wider".*

Reach HVC-1 is located in Sky Meadows (the relatively flat area near the reservoir); Reach HVC-2 is located near the ski resort boundary. The Hazelhurst *et al.* report includes additional data comparing stream cross sections within these two reaches and bankfull width measurements from random transects within the reaches, over two to three year monitoring periods. The transects showed "notable increases in bankfull width between the 1997 and 1998 surveys" for both reaches. However, because the transects were random, some of the difference could be attributed to variance in their locations.

Table 4. Historic Suspended Sediment Concentration Data for Heavenly Valley Creek and Other Tahoe Basin Streams (Values are annual means unless otherwise indicated.)

Stream and Years Sampled	Suspended Sediment (mg/L)	Reference
Heavenly Valley Cr., 1970-1976	29.7 (annual); 6.4 (non-snowmelt); 83.7 (snowmelt)	Skau and Brown, 1988
Heavenly Valley Cr. 1972-74	3.9 (dry season); 150 (runoff period)	Baker and Davis, 1976
Heavenly Valley Cr. 1980-1989	Range about 5-115	TRPA, 1995
Heavenly Valley Cr., 1997-1998	20.6-31.4	Hazelhurst and Widegren, 1998; Hazelhurst et al. 1999
Hidden Valley Creek, 1997-1998	3.1-4	Hazelhurst and Widegren, 1998; Hazelhurst et al. 1999
Lonely Gulch Creek, 1973-74	1.2- 4.16 mg/L (runoff period)	Baker and Davis, 1976
General Creek 1970-1976	10.1	Skau and Brown, 1988
Meeks Creek 1970-1976	4.5	Skau and Brown, 1988
Eagle Creek, 1970-1976	5.8	Skau and Brown, 1988

Aquatic Habitat Concerns. Between 1972 and 1974 Baker and Davis (1976) took Surber samples of benthic macroinvertebrates at several stations in Heavenly Valley Creek downstream of various amounts of watershed disturbance. Baker and Davis concluded that, compared with reference stations, downstream stations in disturbed areas had significant decreases in diversity, numbers and standing crop biomass of macroinvertebrates. Several genera of insects were eliminated at downstream stations. No later macroinvertebrate data are available for the listed segment of Heavenly Valley Creek.

The Tahoe Regional Planning Agency has regional "environmental threshold carrying capacity" standards for fish habitat quality, and reports on the attainment status of these and other standards at five year intervals. TRPA (1996) reported, based on U.S. Forest Service habitat surveys of Heavenly Valley Creek, that its fish habitat quality index rating in 1982 and 1996 was "marginal", and that the score *decreased* between 1982 and 1996. (The 1996 rating was probably based on the 1990 USFS survey summarize in TRPA.) The "marginal" classification is at the lower end of a "marginal" to "good" to "excellent" spectrum based on a point system; the 1982 score of 26 declined to 14 in 1996. The TRPA analysis indicated that the score could be upgraded to "excellent" (42 points) by increasing pools, improving substrate, shade canopy, and bank/channel stability, and removing barriers and diversions. (See the implementation section below for a summary of a proposed two phase fish habitat improvement project which would address these concerns.)

The only fish found in the listed segment of Heavenly Valley Creek in 1990 were seven Lahontan cutthroat trout. The population was probably established from trout planted in Sky Meadow Reservoir in 1980 and washed downstream during high flows in 1983. No Lahontan cutthroat trout were found in the creek in another survey in 1995. Heavenly Valley Creek is not identified in the USFWS's 1995 "Recovery Plan for the Lahontan

Cutthroat Trout, January 1995". In 1996, the LTBMU stated its intent to continue monitoring the creek for the trout between 1995 and 2000, and if trout were observed, to initiate consultation with the USFWS (Harris, 1996; TRPA, 1995).

2. Hillslope Conditions

In 1988 the LTBMU included the following statement in the "Issues, Concerns, and Opportunities" section of its Forest Plan's "Management Area Direction" for the Heavenly Management Area:

> *"Removal of boulders, tree stumps and other obstacles, as well as shaping of terrain on ski trails, has resulted in substantial soil disturbance leading to high rates of soil erosion and nutrient transport to Lake Tahoe. The decomposed granite soils are difficult to stabilize and revegetate. Since about 1965, major efforts have been made to stabilize eroding areas and establish protective cover of low vegetation at a cost in excess of $3 million. Although many acres of disturbed area have been stabilized, water quality standards have not been attained for much of the area. Major failures of some erosion structures occurred during a severe localized summer thunderstorm in 1983, requiring extensive repairs."*

(The Heavenly Management Area includes other watersheds in addition to that of Heavenly Valley Creek.) The problems described above prompted the LTBMU to develop the sediment delivery model described in Appendix 1, and to quantify relative sediment delivery rates from ski runs, roads, and undisturbed areas.

Section 3.2. Numeric Targets

Section 303(d) (1) C) of the Clean Water Act states that TMDLs "shall be established at a level necessary to implement the applicable water quality standards". The numeric targets developed for the Heavenly Valley Creek sediment TMDL are intended to interpret the narrative and numeric water quality objectives, which in turn provide for support of designated beneficial uses. Under existing law, numeric targets for TMDLs are goals, not enforceable water quality standards. The Regional Board can take enforcement action, consistent with the TMDL, for actual or threatened discharges to surface waters which violate applicable water quality standards (including beneficial uses and narrative and numeric water quality objectives).

The USEPA's protocol for developing sediment TMDLs (1999) states that in many cases it may be difficult to relate sediment mass loading levels to beneficial use impacts or source contributions because the variation of sediment yields with space and time make it difficult to derive meaningful "average" conditions, and to compare existing conditions with natural or background conditions. The protocol identifies alternative approaches to mass loading as a numeric target, including targets related to instream indicators such as substrate or channel condition, and aquatic biota. It also identifies potential hillslope indicators to complement instream indicators and targets. The use of multiple targets and indicators is advantageous in that it compensates for uncertainty about the effectiveness of individual indicators. Multiple indicators can also account for complex ecological processes including seasonal and annual differences in pollutant levels by measuring net long term change (USEPA, 1999, 2000). A variety of instream and hillslope indicators and targets have been identified for Heavenly Valley Creek, to complement the instream suspended sediment loading target reflected in the load allocations.

The instream numeric targets for Heavenly Valley Creek are desired future stream habitat conditions for fish and aquatic invertebrates, and provide a set of criteria for interpretation of the long term recovery of the aquatic life-related uses affected by sedimentation. The hillslope numeric targets measure the success of the implementation program in reducing sediment delivery to the creek. If these targets are attained, erosion rates and sediment delivery should decline to levels which will allow instream habitat and beneficial uses to recover, over time, from the impacts of excessive sedimentation in the past. The numeric targets are based on scientific literature, available monitoring data for the Heavenly Valley Creek and Hidden Valley Creek watersheds, and the LTBMU model described in Appendix 1 to this staff report.

Tables 5 and 8 summarize instream and hillslope numeric targets for the TMDL and the availability of data on existing and reference conditions. More detailed discussions of targets in relation to existing conditions are provided in the text below. Attainment of most of the instream targets will be measured in comparison to conditions in the reference stream, Hidden Valley Creek.

A. Instream Numeric Targets

The instream numeric targets in Table 5 were selected because they provide a range of physical, chemical, and biological indicators and because most of these parameters are already being monitored in Heavenly Valley and Hidden Valley Creeks. The LTBMU monitors several stations on Heavenly Valley Creek. Compliance with targets and load allocations will be evaluated at the "Property Line" station which is the farthest downstream and which has been used as the compliance point for waste discharge requirements for many years.

1. Suspended sediment concentration.

Suspended sediment concentration was chosen as an indicator because it is directly related to water quality objectives and load allocations, and because the long period of record for suspended sediment in Heavenly Valley Creek and other Lake Tahoe Basin streams will facilitate evaluation of improving trends in the future.

a. Numeric target

The numeric target is an annual mean suspended sediment concentration at the "Property Line" station, expressed as a 5 year rolling average, no greater than that observed in the reference stream, Hidden Valley Creek. (A 5 year rolling average is the arithmetic mean of 5 contiguous annual means. For example, in the fifth year, the mean of annual averages for years 1-5 will be calculated. In the sixth year, a new mean, based on years 2-6 will be calculated, and so on.) Since the 90th percentile suspended sediment concentration for Hidden Valley Creek is far below the 60 mg/L, 90th percentile numeric water quality objective for tributaries of Lake Tahoe, the use of a target based on five year rolling average conditions in Hidden Valley Creek will not be an issue which will cause misinterpretation of the data in regard to the numeric objective. This target will ensure compliance with both the numerical objective and the narrative objectives related to protection of beneficial uses.

b. Comparison of numeric target and existing conditions.

Table 4 above summarizes historical annual mean suspended sediment concentrations reported for Heavenly Valley Creek, Hidden Valley Creek, and other streams in the Lake Tahoe Basin with relatively undisturbed granitic watersheds. Although erosion control projects have been implemented in the Heavenly Valley Creek watershed for many years, the historical suspended sediment data cannot necessarily be interpreted to show improvements due to BMPs. Complicating factors include the episodic nature of suspended sediment concentrations even in "normal" water years, a lengthy drought period, several mass wasting incidents which required repair of BMPs, and changes in the monitoring program over time.

2. Total instream sediment load.

a. Numeric target

The numerical target for total instream sediment loading in Heavenly Valley Creek is 53 tons/year, expressed as a five year rolling average. This number reflects the modeled maximum feasible reduction in sediment leading with full application of BMPs to the watershed. It is believed to be close to natural conditions and reasonably comparable with the estimated 45 tons per year total sediment load in Hidden Valley Creek. The watershed of the monitored segment of Hidden Valley Creek is about 87 % of the size of Heavenly Valley Creek's watershed (1162 acres compared to 1341 acres). If Hidden Valley Creek's estimated total sediment load were increased by 13%, it would about 51 tons per year.

b. Comparison of numeric target and existing conditions. The estimated historic total (suspended and bedload) sediment loads for Heavenly Valley Creek and Hidden Valley Creek are 150 and 45 tons per year, respectively. (See the Source Analysis section, below.)

3. Pfankuch channel stability rating

The Pfankuch channel stability index (Pfankuch, 1978) involves rating 15 different parameters affecting stream stability while walking the length of the reach. Factors include riparian vegetation, cut banks, sand deposition, degree of scour, etc. The index rates stability for each reach as "Poor", "Fair", or "Good", and the LTBMU compares results of different surveys to rate trends for each reach with terms such as "Same", "Degenerating", "Improved", "Much Improved" (Hazelhurst and Widegren, 1998).

a. Numeric target.

The Pfankuch index ratings for monitored reaches of Heavenly Valley Creek should show an improving trend over time from "fair-poor" " to "good" (the rating for Hidden Valley Creek).

b. Comparison of numeric target and existing conditions

In 1990, the most recent year in which Pfankuch surveys were done, LTBMU staff rated Heavenly Valley Creek as "fair-poor" and Hidden Valley Creek as "good". More recent Stream Condition Index ratings are available for Heavenly Valley Creek (see the next section).

4. Stream Condition Index

The U.S. Forest Service, Pacific Southwest Region, uses a "Stream Condition Index", which also measures a number of variables affecting channel condition. The procedure includes classification of reaches using the Rosgen system; surveys of stream cross sections to detect aggrading or degrading conditions and thus movement of sediment; and changes in gradient, which also indicate downcutting and loss of bed material (Hazelhurst and Widegren, 1998).

In review of earlier drafts of the TMDL and implementation program, the Regional Board's scientific peer reviewer (Kondolf, 1999) criticized the applicability of the Pfankuch stability rating and Rosgen channel classification systems to the Heavenly Valley Creek situation, and suggested that changes in actual channel conditions be measured (including measurement of bed sediment through procedures such as the pebble count, and documentation of channel form through repeat surveys). The SCI includes both stream channel measurements and pebble counts. Pfankuch surveys are recommended as a TMDL indicator *in addition to* the SCI surveys to permit trend analysis in comparison with earlier results.

a. Numeric target

Over time, Heavenly Valley Creek should show a trend of increasing stability, and the SCI rating should approach that of Hidden Valley Creek.

b. Comparison of numeric target and existing conditions.

SCI surveys for Heavenly Valley Creek between 1996 and 1998 (Hazelhurst *et al*., 1999) show aggradation and degradation linked to annual differences in runoff; see the "problem statement" discussion above. SCI ratings are not yet available for Hidden Valley Creek.

5. Macroinvertebrate community health

Macroinvertebrate community health will be evaluated using the protocol developed by the Regional Board's consultant (University of California, Sierra Nevada Aquatic Research Laboratory) to provide the basis for eventual adoption of "biocriteria" water quality objectives. A description of this protocol is included in Section 5.4 below.

a. Numeric target

Over time, there will be improving trends in macroinvertebrate habitat quality and community metrics, and macroinvertebrate communities in Heavenly Valley Creek will be more similar to those in Hidden Valley Creek. (Once biocriteria have been adopted, the target may be changed to use more specific biocriteria metrics as indicators of adequate beneficial use support.)

b. Comparison of numeric target and existing conditions.

No recent biomonitoring data are available for Heavenly Valley and Hidden Valley Creeks. As noted above, Baker and Davis (1976) observed degradation of macroinvertebrate communities at stations in Heavenly Valley Creek downstream of ski resort development in the early 1970s. Due to differences in sampling protocols, it will not be possible to compare the Baker and Davis Surber sampling data directly with data obtained using current bioassessment methods (Thomas Suk, personal communication). The more recent fish habitat and stream channel studies summarized elsewhere in this staff report indicate that habitat conditions are still not optimal for macroinvertebrates in Heavenly Valley Creek.

B. Hillslope Numeric Targets

The hillslope targets in Table 8 were selected because they provide different ways of measuring the success of the implementation program, and because they are already being monitored by the LTBMU in the Heavenly Valley Creek watershed.

Table 5. Instream Indicators and Targets for Heavenly Valley Creek TMDL

Indicator	Target Value(s)	Reference
Suspended Sediment		
Suspended sediment concentration	Concentration no greater than annual average for Hidden Valley Creek during a year with similar precipitation and runoff.	Hazelhurst and Widegren, 1998; Hazelhurst *et al.*, 1999.

Instream total sediment load	Maximum 53 tons/year as a 5 year rolling average.	Data from Hazelhurst and Widegren, 1998; Hazelhurst *et al.*, 1999; unpublished LTBMU data, calculations by Stefan Lorenzato, SWRCB
Geomorphology Measures		
Pfankuch channel stability rating (composite rating includes numeric scores for 15 different indicators)	Increasing trend over time from "fair-poor" to "good" (comparable with overall rating of Hidden Valley Creek)	1990 Pfankuch method surveys by LTBMU staff of both creeks (TRPA, 1995, Appendix E)
USFS Region 5 "Stream Condition Index" (SCI)	Improving trends in channel morphology over time	Hazelhurst and Widegren, 1998; Hazelhurst *et al.,* 1999.
Biological Indicators		
Macroinvertebrate community health.	Improving trends in benthic invertebrate community metrics over time, approaching conditions in Hidden Valley Creek.	Baker and Davis, 1976 UC-SNARL bioassessment protocol (Thomas Suk, personal communication.)

1. Watershed disturbance (Percent Equivalent Roaded Area)

"Equivalent Roaded Area" is a term used in the USFS model (Holland, 1993) and the Heavenly Master Plan EIS (TRPA, 1995, 1996) as an index of watershed disturbance in relation to sediment delivery. An "equivalent roaded acre" is defined in terms of a standard road with specific characteristics, and the sediment delivery rate from this type of road in the Heavenly Ski Resort is modeled as 5 tons per acre. The "Percent Equivalent Roaded Area" index is calculated by dividing total equivalent roaded acres by the watershed area (1341 acres for the Heavenly Valley Creek watershed.) Percent ERA is proposed as an indicator for the TMDL because it is a simple indicator of the degree of restoration of disturbed areas over time. The USFS has adopted ERA targets for road and ski run categories as part of the erosion control program in the Heavenly Ski Resort Master Plan, and progress toward attainment of these targets is already being monitored and reported on (see USFS, 1998).

a. Numeric targets

The numeric target is reduction of watershed disturbance to a maximum of 2 percent ERA, based on the mitigation goal in the Heavenly Ski Resort Master Plan EIS (TRPA, 1995, 1996) and on estimated hillslope sediment delivery after full mitigation.

b. Comparison of numeric target and existing conditions

The LTBMU model estimated total ERA for the Heavenly Valley Creek watershed as 7.87 percent in 1995 and documented percent ERA for each modeled road and ski run segment (TRPA, 1995).

2. Effective soil cover.

Effective soil cover includes cover by living plants, downed woody debris, organic matter, and rocks (Hazelhurst and Widegren, 1998). As noted in the description of the watershed above, vegetative cover is naturally sparse in some parts of the watershed. The USFS model establishes specific percent cover targets for each specific road and ski run segment. Improvements in percent cover are measured by annual resampling of a number of randomly selected roads and ski runs in the ski resort as a whole.

a. Numeric target

Over time, the LTBMU's modeled cover targets for specific road and ski run segments within the Heavenly Valley Creek watershed should be met. Using the criteria in Tables 6 and 7, the overall percent cover ratings for roads and ski runs within the Heavenly Valley Creek watershed should be "good" or better.

b. Comparison of numeric target and existing conditions.

The LTBMU measured percent cover for individual road and ski run segments in 1991 during development of the model. Model results include specific targets for each segment. The LTBMU evaluates percent cover annually and uses the criteria in Tables 6 and 7 in its annual evaluations of ski runs and roads.

In 1997, the USFS (Hazelhurst and Widegren, 1998) sampled soil cover (by vegetation, organic matter, or rocks, as opposed to “bare” area) on 35 ski run and road segments randomly chosen from the resort as a whole, not only in the Heavenly Valley Creek watershed. Average cover on these runs had increased by 11% from levels measured in

Table 6. LTBMU Evaluation Criteria for Ski Runs (Hazelhurst *et al.*, 1999)

Rating	**Cover**	**Erosion**	**Mitigation**
Excellent	>70%	none	none
Good	>50%	little (sheet)	spot work
Fair	<50%	moderate (rills)	entire segments
Poor	<30%	heavy (gullies)	entire area

Table 7. LTBMU Evaluation Criteria for Roads (Hazelhurst *et al.,* 1999).

Rating	**Road Surface Rilling**			**Cut and Fill Slopes**	
	Extent	***Length***	***Depth***	***Erosion***	***Cover***
Excellent	none	none	none	none	>70%
Good	lite	<10m (30 ft)	<3 cm) 1 in	sheet; no	>50%

				fans/plumes	
Fair	moderate	<31m (100 ft)	<10 cm (4 in)	rills; small fans/plumes	<50%
Poor	heavy (gullies)	>31 m (100 ft)	>10 cm (4 in)	gullies; large fans/plumes	<30%

Table 8. Hillslope Indicators and Targets for Heavenly Valley Creek TMDL

Indicator	Target Value(s)	References
Percent Equivalent Roaded Area (ERA)	USFS targets and schedules for ERA reduction for ski run and road categories and for watershed as a whole; progress reported annually and evaluated at 5 year intervals.	TRPA 1995, 1996
Effective soil cover (vegetation, woody debris, organic matter, rocks) on ski runs and roads	Cover meets modeled mitigation targets set for specific road/run segments in watershed, and overall cover rating is "good" or better using criteria in Tables 6 and 7	TRPA 1995, 1996; Hazelhurst and Widegren, 1998; Hazelhurst *et al.,* 1999.

1991. In 1998 (Hazelhurst *et al.,* 1999) soil cover was assessed on 18 ski runs (over the resort as a whole) using fixed plots and random transects. The overall average for total coverage was 65%, up 18 percent from 1991. The range of total cover was 41% (on an older run) to 91% (on two newly cut runs where “state of the art” BMPs were used). Using the criteria in Table 6, ski run cover was between "good" and "excellent" for the sampled runs in 1998. Information is not available to provide a current overall rating for the runs in the Heavenly Valley Creek watershed.

Section 3.3. Source Analysis

Historic and potential future sediment sources in the watershed of the listed segment of Heavenly Valley Creek are nonpoint sources. There are no point sources within the watershed, and therefore this TMDL does not include wasteload allocations. As noted above, the scope of the TMDL analysis is limited to the upper portion of the Heavenly Valley Creek watershed, on National Forest land administered by the LTBMU, within the Heavenly Ski Resort permit boundaries. Because this subwatershed is within a single ownership, the source analysis emphasizes land disturbance categories, rather than dischargers. The source analysis below summarizes the results of (1) modeling by the LTBMU to quantify sediment delivery to Heavenly Valley Creek from various hillslope sources; and (2) calculations by State and Regional Board staff to estimate the existing instream suspended sediment loads attributable to different hillslope sources. In the source analysis, and elsewhere in this TMDL, loading figures are rounded to the nearest ton and expressed in English, rather than metric tons.

A. Data and Methods Used

The hillslope sediment source analysis is based upon results from the sediment delivery model described in Appendix 1, which was developed by the U.S. Forest Service, LTBMU. The model in turn uses several procedures described in the "WRENNS Handbook" (USFS, 1980) and the *Guide for Predicting Sediment Yields from Forested Watersheds* (USFS, 1981). The *Guide* is based on research in the Idaho Batholith, an area with decomposed granitic soils similar to those in the Lake Tahoe Basin. The WRENNs methodology involves segmenting watersheds into land types and land system inventories, and then allocating values for erosion hazard potential and sediment delivery ratios, to allow generation of erosion curves for each disturbance source in the watershed. Sediment delivery is estimated using a "Modified Universal Soil Loss Equation" from the WRENNS Handbook, with adjustments for rill and gully erosion and other modifications based on the Idaho batholith studies.

In 1991, USFS staff collected field data on 383 road, ski run, and undisturbed "segments" within the Heavenly Valley Creek watershed for input into the model. (The term "segment" is not defined by the LTBMU, but is apparently used in a similar sense to the Washington Forest Practices Board's (1997) definition of "road segments" as road lengths with generally similar characteristics such as topography and construction practices.) For all ski runs and roads, the segment acreage, slope length, gradient, percent canopy and cover (by vegetation, duff, etc.) were measured, and existing erosion control structures were evaluated. The LTBMU also modeled suspended sediment yield from undisturbed lands, using several different methods summarized in the Appendix. The Appendix also summarizes the model output data used in the TMDL source analysis. Although modeled "existing" sediment delivery is expressed as tons per year per disturbance category for the watershed as a whole, sediment delivery generally occurs as a long term process, with considerable seasonal and annual variation. The LTBMU model will be calibrated, using subsequent monitoring data including direct measurements of erosion, during the winter of 2000-2001 (Sherry Hazelhurst, USFS, personal communication).

Regional Board staff's initial approach to the Heavenly Valley Creek sediment TMDLs relied only on the hillslope modeling data. Comments on earlier drafts by the scientific peer reviewer (Kondolf, 1999) and by USEPA and State Water Resources Control Board staff led to a revised approach to source analysis and load allocations. Instream suspended sediment loads were calculated from instantaneous sediment concentrations and instantaneous flow values reported by the LTBMU for Heavenly Valley Creek between 1996 and 1999 (Hazelhurst and Widegren, 1998; Hazelhurst *et al*., 1999, and unpublished LTBMU data), and a spreadsheet model suggested by Dr. Kondolf. The calculation procedure is described below. Dr. Kondolf's calculations and the TMDL spreadsheet calculation results will be included in the administrative record of the Basin Plan amendments.

Sampling dates were converted to Julian dates, and added in decimal fractions of the dates to reflect sampling time during the day. Flows were converted from cubic feet per second to cubic meters per second, and flow was multiplied by suspended sediment concentration expressed as kilograms /cubic meter to yield kilograms/second (the sediment transport rate). The transport rate was multiplied by the number of days preceding the sampling date to obtain the total load in the interval since the previous sample. These values were combined to obtain cumulative kilograms of sediment transport over the year and converted to tons/year for comparison with the LTBMU sediment delivery estimates. This approach generally applies a given sediment concentration to all days between a given sample and the preceding sample, usually about one week. Exceptions were made for samples collected during a July 28,1997 thunderstorm: see Kondolf (1999).

Stefan Lorenzato, the State Water Resources Control Board's TMDL coordinator, performed Excel spreadsheet calculations using the procedure above and data for 1996 through 1999 for Heavenly Valley Creek. The modeled "existing" suspended sediment load for these four years was 93 tons per year. Assuming that this value is 80 percent of the total (with bedload 20 percent), the total "existing" sediment load was 116 tons/year. Bedload sediment data are not available for Heavenly Valley and Hidden Valley Creeks, but the literature (Woyshner and Hecht, 1988) suggests that in relatively undisturbed areas of the Lake Tahoe-Truckee region bedload sediment could be expected to be 15-20%.

Sherry Hazelhurst of LTBMU staff pointed out that suspended sediment loads calculated from monitoring data collected in the late 1990s should be expected to reflect water quality improvement as a result of BMPs already implemented. Using Ms. Hazelhurst's estimate of the effectiveness of BMPs implemented to date, the monitored sediment load was used to back-calculate the "total unmitigated load" of sediment to Heavenly Valley Creek as 150 tons/year. These calculations assumed that 75 percent of the planned BMPs have already been implemented, and that they are at 40-50 percent of their potential efficiency. Therefore, the BMPs are now achieving 35 percent of their expected control capability. Assuming that the BMPs will ultimately be 65 percent effective overall, about 22.75 percent (that is, 35% capability x 65% effectiveness) of the sediment load is now controlled. The total unmitigated load (150 tons per year) was obtained by multiplying the 116 tons/year load calculated from monitoring data by 0.7775.

Assuming a 1:1 relationship between hillslope sediment delivery and total instream sediment loads, the instream loads were apportioned among source categories based on percentage of the total from each category. The current TMDL analysis assumes that over the long term, sediment input will equal sediment output in a properly functioning stream. Therefore, the instream sediment loading estimate and the load allocations below do not account for instream sediment storage as a source or sink.

Table 9. Estimated Instream Total Sediment Loads for Heavenly Valley and Hidden Valley Creeks

	Total (Suspended + Bedload) Sediment Loads (tons/year)
Heavenly Valley Creek (estimated from monitoring data for 1996-99 Stefan Lorenzato, SWRCB)	116
Heavenly Valley Creek, estimated unmitigated load	150
Hidden Valley Creek (1991-1999, from unpublished LTBMU data)	45

B. Source Categories

The Heavenly Valley Creek TMDL groups hillslope sediment sources into the same categories used in the USFS sediment delivery model: unpaved roads, ski runs, and undisturbed lands. The modeling results do not distinguish between source areas in California and Nevada. The ski run and road categories are grouped separately in the USFS modeling results, and were modeled differently in that a separate coefficient was used to account for soil compaction on roads.

The USFS also measured impervious surface coverage (buildings, pavement, etc.) in the watershed (0.67 acres as of 1995), but did not include it as a sediment source in the model. Regional Board staff recognize that impervious surface coverage can affect erosion and sediment delivery by increasing runoff intensity. However, mitigation for increased surface runoff from impervious surface in the Heavenly Valley Creek watershed was provided separately from mitigation for modeled sediment delivery in the Heavenly Ski Resort Master Plan EIS (TRPA, 1995, 1996); the 1995 impervious surface was to be reduced to 0.13 acres. For purposes of the TMDL, the impacts of mitigated impervious surface on sediment delivery are assumed to be "de minimis", and this category is assigned a zero value in the source analysis and load allocations.

As noted in the Land Use section above, undeveloped lands in the Heavenly Valley Creek and Hidden Valley Creek watersheds may have been disturbed by 19th century logging and grazing. However, the high quality of Hidden Valley Creek indicates that, at least in terms of sediment delivery, these lands have recovered to natural or near natural levels. The estimated natural soil loss from the Heavenly Valley Creek watershed as a whole was 0.03 tons per acre per year. (Because of a discrepancy in the watershed area used in calculation of the total sediment yield for undeveloped lands which was used in the Master Plan EIS, Regional Board staff recalculated the yield using the 1341 acre watershed size used for yields for other source categories. The total modeled "existing" sediment yield becomes 559 tons/year rather than the 583 tons/year derived from the EIS. The derivation of the LTBMU's natural sediment yield figure is explained in the Appendix. This figure is within the range of sediment yields calculated from field measurements for other Lake Tahoe Basin streams and stream stations with relatively undisturbed watersheds (White and Franks, 1978; Rowe, 1998; Skau and Brown 1988).

Table 10 summarizes the modeled "existing" (1995) hillslope sediment delivery from different hillslope sources, and shows that 94 percent of the sediment delivery to Heavenly Valley Creek can be attributed to human activities. Table 11 apportions the calculated "existing" (1996 through 1999 loads) instream total sediment load among the hillslope sources using the same percentages of the total anthropogenic load.

Table 10. Source Analysis for Sediment Delivery to Heavenly Valley Creek.
(Sediment delivery figures are for the 1341 acre watershed.)

Source Category	**Area (acres)**	**Sediment Delivery (tons/year)**	**Percent of Total Load**
Roads	19	349	62
Ski Runs	182	176	32
Impervious surface	1	0*	0*
Undeveloped Area	1119	34	6
TOTAL	**1341**	**559**	**100**

* Sediment delivery from impervious surface is considered "de minimis".
** Number rounded upwards

Comparison of the calculated instream total sediment loads with estimated hillslope sediment yields from the LTBMU model (Tables 10 and 11) implies that the model greatly overestimated sediment delivery. However, it should be noted that the model is based on field measurements taken in 1991. Some erosion control work was done between 1991 and 1996, and intensive work under the master plan program began in 1996. The LTBMU (1998) estimated that restoration work done in the Heavenly Valley Creek watershed during 1998 alone was enough to reduce long term sediment loading by

159 tons per year. Therefore, the differences between the LTBMU's modeled data and the calculated instream sediment data may reflect reductions in sediment delivery since 1991 as well as the limitations of the model.

Table 11. Estimated Sources of Instream Sediment Loading to Heavenly Valley and Hidden Valley Creeks (Total suspended plus bedload sediment; values are rounded to the nearest ton.)

Source Category	**Loading (Tons/Year)**	**Percent of Total**
Heavenly Valley Creek		
Roads	93	62
Ski Runs	48	32
Undisturbed Lands	9	6
Impervious Surface	0	0
TOTAL	150	100%
Hidden Valley Creek		
Undisturbed Lands	45	100%
TOTAL	45	100%

Section 3.4. Loading Capacity Linkage Analysis

"Loading capacity" is the maximum amount of a pollutant a water body can assimilate and still meet its water quality standards. TMDL documents must describe the relationship between numeric targets and identified pollutant sources, and estimate the loading capacity for the pollutant of concern. The USEPA Region IX *Guidance for Developing TMDLs in California* (2000) states that the loading capacity is the critical quantitative link between the applicable water quality standards (as interpreted through numeric targets) and the TMDL, and that the linkage analysis section must discuss the methods and data used to estimate loading capacity.

It is difficult to predict precise relationships between hillslope sediment delivery and instream conditions, because linkages are often indirect (e.g., there may be a lag of years or decades between hillslope erosion and effects on instream uses), and because there is inherent seasonal and annual variability in hillslope erosion processes and instream physical, chemical and biological community conditions. Nevertheless, it is obvious from the literature in general and from studies at Heavenly Valley Creek in particular that watershed disturbance increases sediment delivery and that increased sediment delivery affects instream water quality and beneficial uses. The USEPA (1999) protocol for developing sediment TMDLs states that linkage analyses can be less precise in settings where TMDLs are to be done in phases, where a strong commitment to adaptive management exists, where issues are not highly controversial, and where stakeholders will take effective action for implementation. This is the case with the implementation and review/revision programs for Heavenly Valley Creek, which are discussed in Sections 5 and 6 below.

The applicable water quality standards for the Heavenly Valley Creek TMDL are instream aquatic life uses, and water quality objectives for sediment, suspended sediment, and settleable materials. The TMDL interprets these standards through multiple instream and hillslope indicators and numeric targets, with the baseline assumptions that:

- Some degree of water quality degradation and beneficial use impairment occurred due to ski resort development in the watershed before the adoption of the statewide Nondegradation Policy in 1968 and Regional Board adoption of water quality standards for the creek in 1975. This assumption is supported by the evidence summarized in Section 3.1.B, above.

- There is some amount of instream sediment loading above reference conditions under which beneficial uses will be supported and narrative water quality objectives met. This assumption is reasonable because of the inherent natural annual and seasonal variability of instream sediment levels, the uncertainty involved in modeling, and the variability of estimated "natural" suspended sediment concentrations and yields in undisturbed watersheds in the Lake Tahoe Basin. The assumption is also supported by LTBMU staff's "best professional judgement" conclusion (TRPA, 1995) that Heavenly Valley Creek will be adequately protected if hillslope sediment delivery is reduced to 335 tons per year.

These baseline assumptions are important because it may not be feasible to return the watershed to completely natural sediment yield conditions (at least on a human rather than a geologic time scale). The LTBMU model indicates that a 76% reduction in the 1995 hillslope sediment delivery level is the maximum feasible reduction which can be expected with full application of BMPs to roads, ski runs, and new development. (Some additional reduction in sediment delivery, and thus in instream sediment loading, may be possible from other planned restoration work at the ski resort, but this reduction has not been quantified for the Heavenly Valley Creek watershed. See Section 5.1.C, below.) Since "baseline" conditions for interpretation of standards reflect historic degradation, restoration of the creek to the presumably "pristine" conditions existing before ski resort development is not required as long as beneficial uses are adequately supported. The Heavenly Valley Creek TMDL focuses on maximizing beneficial use support to the extent practicable. The loading capacity and numeric targets are based on expectations of "reasonable further progress", defined as reductions in instream suspended sediment loading, and improving trends in instream habitat characteristics.

The TMDL uses an "inferred linkage" (USEPA Region IX, 2000) based on comparison of local reference conditions (in Hidden Valley Creek) with existing conditions in Heavenly Valley Creek. The conservative assumption is made that aquatic life uses will be adequately supported (and narrative water quality objectives will be met) when the total annual sediment loads in Heavenly Valley Creek are comparable to those in the reference stream, Hidden Valley Creek . The watershed of the monitored segment of Hidden Valley Creek is about 87 % of the size of Heavenly Valley Creek's watershed (1162 acres compared to 1341 acres). If Hidden Valley Creek's calculated sediment load were increased by 13%, the corresponding "target" level for Heavenly Valley Creek would be about 51 tons per year. The proposed TMDL target, 53 tons of sediment per year, expressed as a 5 year rolling average, reflects the assumption that BMPs will be 65 percent efficient when fully implemented. It appears to be reasonably comparable to reference conditions adjusted for differences in watershed size. The target is assumed to be substantially below the sediment load in Heavenly Valley Creek at the time standards became effective. It also represents a value believed to support beneficial uses in the creek.

Protection of beneficial uses of Heavenly Valley Creek related to fish habitat can be evaluated in relation to the Lahontan cutthroat trout, the original and only native trout species. A literature review indicates that the creek provides potentially good habitat for adult fish, but would be marginal rearing habitat even under natural conditions. This is due to the fact that the stream is very steep and in an area with high snowfall, and that Lahontan cutthroat trout spawn in spring when the early life stages are susceptible to the impacts of high snowmelt runoff.

In general early life stages (egg through the swim up stage) are the most susceptible to effects of sediment (Newcombe and MacDonald, 1991) The emergence of trout from redds can be reduce or entirely precluded if high amounts (greater than 25% by volume) of fine sediment are allowed to accumulate in redds. High concentrations of fine sediment diminish the dissolved oxygen concentrations by limiting circulation of well oxygenated water (McBrayer and Ringo, 1975). Fine sediment can also act to cement larger grains together creating a physical barrier to trout escaping from the gravel of the redd. High stream flows can mobilize gravel. Eggs incubating at these times are susceptible to physical injury or death from the grinding effects of gravel bed movement. Large amounts of snow that effectively constrain the channel and prevent water from spilling over the banks serve to accelerate stream flow and increase potential injury to incubating eggs (Erman *et al*.,1988).

No particle size analyses for Heavenly Valley Creek were available during development of this TMDL. However, because of the steepness of the watershed, Heavenly Valley Creek would probably tend to a coarse grain size distribution. High flows would tend to move very fine sediments downstream and out of the reach of concern. These high velocities could also regularly disturb spawning beds (Kondolf *et al*., 1991)

Newcombe and MacDonald (1991) reviewed the literature and evaluated suspended sediment concentration and “sediment intensity” as predictors of adverse effects on trout. They list some adverse effects at concentrations historically monitored in Heavenly Valley Creek. However, they have demonstrated that sediment concentration alone is not a good indicator of the severity of effects on trout. They argue for the use of a stress index based on concentration and duration of exposure as a more effective predictor of impacts.

The total sediment target for this TMDL is designed to capture the cumulative effects of sediment on fish and is set at a level believed to provide adequate habitat conditions for *adult* trout. The amount of spawning habitat within the reach is naturally limited (due to steepness and snow induced scour). It is unlikely that spawning habitat can be markedly increased within the listed reach. The existing habitat can be improved somewhat, but a greater improvement for the stream as a whole will occur if adults using this reach and spawning in lower reaches are provided excellent habitat. Improved habitat for adult fish will improve overall fitness of adults and result in improved egg quality. This should result in a net increase in survivorship.

The effects of sediment on adult fish are subtle. Behavioral changes and feeding patterns can be altered in situations of high suspended sediments. The load allocations established by this TMDL should result in sediment concentrations significantly below 100 mg/l, given the flow regime evaluated. For example the 1999 Property Line station showed only 2 samples about 56 mg/l and the total load for this year was estimated to be just over 53 tons. Newcombe and MacDonald reported few instances from the literature where suspended sediment concentrations at 50 mg/l to 100 mg/l level showed significant impacts on juvenile or adult fish. The most pronounced impact not associated with early life stages seems to be a reduction in growth. The duration of the exposure to the highest anticipated concentrations will contribute to any potential impact. In Heavenly Valley Creek, the highest concentrations can be expected during approximately 6 weeks from the middle of May to the end of June. Given the expected improvements in stream habitat, any growth reduction associated with this level of exposure to suspended sediment will not compromise adult trout and therefore the TMDL can be considered protective.

Long term evaluation of benthic invertebrate community metrics in Heavenly Valley Creek in comparison to those measured in other reference streams in the central Sierra Nevada will be needed to establish baseline levels and detect improving trends in benthic habitat uses. Data from Hidden Valley Creek will be used to capture the natural variations in stream flow and sediment loading. If adjustments in the loading capacity and/or load allocations for Heavenly Valley Creek are necessary in the future (e.g., due to large sedimentation events), data from Hidden Valley Creek can be used to define the proportional adjustments.

Section 3.5. TMDL and Load Allocations

TMDLs are the sum of "wasteload allocations" for point sources, "load allocations" for nonpoint sources, and an explicit or implicit "margin of safety". Because the modeled sediment loading to Heavenly Valley Creek is entirely from nonpoint sources, and no point source discharges are expected to be proposed in the future, the wasteload allocation is zero. The margin of safety, which is implicit, is discussed in Section 3.6 below.

The "loading capacity" for Heavenly Valley Creek is total annual instream sediment load of 53 tons measured as a 5 year rolling average. The loading capacity reflects the assumption that implementation of BMPs will, over time lead to a 65 percent reduction in the modeled "total impaired discharge" of 150 tons/year. Table 13 summarizes the proposed allocation of the mitigated instream sediment loading among all source categories. Allocations are in English rather than metric tons, are rounded to the nearest ton, and do not distinguish between sources in California and Nevada. The proposed load allocations reflect assumptions in the LTBMU model about the efficiency of Best Management Practices, and USFS modeling results which predict reductions in sediment yield from specific areas after application of BMPs. No reduction in modeled "background" sediment delivery from undisturbed lands is assumed.

The LTBMU model was used in the Heavenly Resort Master Plan EIS (TRPA, 1995, 1996) to identify specific remedial erosion controls for past watershed disturbance to be implemented in coordination with permitting of new ski area development. The modeled mitigation targets *in the EIS* assumed that full BMPs would <u>not</u> be applied to some disturbed areas. Since completion of the EIS, the LTBMU has decided to require application of BMPs to *all* disturbed areas (Sherry Hazelhurst, personal communication). Regional Board staff calculated the final hillslope load reductions by applying the BMP efficiencies used in the LTBMU model to the "unmitigated" sediment yields predicted in the EIS, and adding the reduced yields to yields predicted from "mitigated" categories. For example, the EIS predicted 63 tons/year sediment yield from mitigated roads, and 30 tons/year from unmitigated roads. The LTBMU assumed that BMPs applied to both roads and ski runs were 80% efficient in controlling sediment (except for roads which would be abandoned and restored, where 90% efficiency was assumed). After application of BMPs, sediment yield from the former "unmitigated" road category would be (0.20)(30 tons/year) = 6 tons per year. Addition of this figure to the 63 tons/year for the former "mitigated" road category gives a mitigated hillslope sediment delivery rate for roads of 69 tons/year.

The load allocations for instream sediment were calculated by reducing the estimated total existing instream load from each source category (Table 9) by a percentage equivalent to the projected reduction in hillslope sediment delivery for that category after full application of BMPs (Table 12). A load allocation for sediment loading from new development was added, as explained in the next paragraph. Load allocations are summarized in Table 13, below.

Table 12. Modeled Maximum Feasible Reductions in Hillslope Sediment Delivery with Full Application of BMPs.

Source Category	**Reduced Load (tons/year)**	**Percent of Total**
Roads	69	53
Ski Runs	27	21
Undisturbed Lands	34	26
Impervious Surface*	0	0
TOTAL	**53**	**100%**

*The contribution of impervious surface to sediment loading is considered *de minimis*. See the text.

Proposed new development in the Heavenly Valley Creek watershed (TRPA 1995, 1996) includes four new ski lifts, a "Top Station" for the new resort gondola (most gondola facilities are in another watershed), four new ski runs, 3600 feet of new road, replacement of an existing lodge, and a relocated maintenance building. (Portions of two ski runs and the maintenance building will be located on the Nevada side of the watershed.) LTBMU modeling results indicate that soil loss to the stream would be increased by 0.741 tons per year due to proposed new development (after application of full BMPs).

Table 13. Instream Load Allocations for Total Sediment in Heavenly Valley Creek

Source Category	**Load Allocation (tons/year as a 5 year rolling average)**	**Percent of Total**
Roads	28	53
Ski Runs	11	21
New Development	0.7	*
Undisturbed lands	14	26
Impervious surface*	0	0
TOTAL	53.7**	100%**

*The contribution of impervious surface to sediment loading is considered *de minimis*. See the text.
** The discrepancy between the total load allocations and the loading capacity (53 tons/year) is considered to be within the margin of error of the calculations.

Section 3.6. Margin of Safety, Seasonal Variations, and Critical Conditions

A. Margin of Safety

TMDLs must include an explicit or implicit margin of safety (MOS) to account for uncertainty in determining the relationship between discharges of pollutants and impacts on water quality. An explicit MOS can be provided by reserving (not allocating) part of the total loading capacity, and therefore requiring greater load reductions from existing and/or future source categories. An implicit MOS can be provided by conservative assumptions in the TMDL analysis. The Heavenly Valley Creek TMDL includes an implicit margin of safety. An explicit MOS was not included because the load allocations assume that full application of BMPs will provide the maximum feasible load reduction, and therefore further significant reductions in hillslope sediment delivery cannot realistically be expected.

Sources of uncertainty in the Heavenly Valley Creek analysis include: (1) uncertainty related to interpretation of the narrative objectives; (2) the limited amount of data currently available for some parameters, such as bedload sediment and aquatic life use support; (3) the limitations of the LTBMU model; and (4) the inherent seasonal and annual variability in sediment delivery and instream impacts of sediment common to all stream systems. Limitations of the model (discussed in TRPA, 1995) include the inability of a standard model to account for all of the temporal and spatial variability in sediment delivery in a unique natural ecosystem (and especially inability to predict interaction among the various elements of the model), the use of simplifying assumptions (e.g., about the efficiency of BMPs), and the fact that the model has not yet been calibrated. In comments on earlier drafts of the Basin Plan amendments and staff report, the scientific peer reviewer (Kondolf, 1999) criticized the LTBMU model because of the lack of calibration, and the use of best professional judgement, and pointed out that it overestimated sediment yield when compared to the results of calculations using actual suspended sediment measurements.

As currently proposed, the Heavenly Valley Creek TMDL provides an implicit margin of safety by:

<u>1) Interpreting compliance with standards through use of multiple, dynamic targets and indicators.</u>

The TMDL uses a range of indicators and target values, including both instream and hillslope indicators to measure compliance with standards and to account for areas where data are scarce (e.g. bedload sediment loads and impacts). The hillslope targets supplement the instream targets and provide goals more directly associated with management activities in the watershed. The expression of the sediment delivery and suspended sediment targets as 5 year rolling averages accounts for the inherent variability in annual sediment delivery rates.

<u>2. Incorporating conservative assumptions in the source analysis and development of load allocations.</u>

An "inferred linkage" between conditions in Heavenly Valley Creek and Hidden Valley Creek was used to develop the loading capacity and load allocations (See Section 3.4 above.) Hidden Valley Creek is assumed to represent "pristine" instream sediment loading conditions and the loading capacity is set close to those conditions. This provides an implicit margin of safety in the TMDL.

The source analysis and load allocations use a conservative assumption about the efficiency of BMPs (65 percent). Based on the load reductions and BMP efficiencies used in the LTBMU model, an maximum overall reduction of 76 percent in hillslope sediment delivery could be expected. The TMDL analysis further compensates for uncertainty in the model by basing load allocations on aggressive reductions in sediment delivery from all significant anthropogenic sources.

3) Incorporating a rigorous monitoring and review program and schedule which provide an ongoing mechanism to adjust the TMDL if, in the future the Regional Board finds that water quality objectives are not being met or that beneficial uses are not being protected.

Sections 5 and 6 of this staff report discuss the TMDL monitoring program and the Regional Board's planned schedule for review and revision of the TMDL. The adaptive management approach to implementation includes annual review of the program and monitoring data by an interagency technical advisory group; adjustment of management measures as appropriate; and comprehensive review and adjustments to the program every five years. In addition to TMDL monitoring for Heavenly Valley and Hidden Valley Creeks, monitoring of water quality and beneficial use support in downstream waters of the Upper Truckee/Trout Creek watershed will continue under the Lake Tahoe Interagency Monitoring Program and the Regional Board's Watershed Management Initiative program.

B. Seasonal Variations and Critical Conditions

All stream ecosystems, whether or not they have been disturbed by human activities, exhibit seasonal and annual variations in the rate of sediment delivery to the stream and in the impacts of sediment on stream organisms during different stages of their life cycles. Sediment impacts may be more important if they affect "critical conditions" of an organism's life cycle than if they occur at other times; e.g., sedimentation of spawning gravels can have particularly significant effects on early developmental stages of fish. Furthermore, there may be significant temporal lags and spatial disconnects between hillslope erosion events and the impacts of sediment on instream uses.

The TMDL uses multiple numeric targets and indicators in order to integrate the net cumulative effects of sedimentation over longer time frames. A variety of hillslope and instream indicators are used, and together, they address the effects of sediment loading, transport, deposition, and impacts on beneficial uses. The-loading capacity, and load allocations are expressed as 5 year rolling averages in order to account for natural seasonal and annual variation in sediment loads, with the recognition that trends may not be apparent within shorter time frames. Several numeric targets are also expressed as long term trends. The TMDL and load allocations are set at levels which, over time, will allow instream aquatic habitat to recover to a level which adequately supports aquatic life uses.

Section 4. Public Participation

Federal regulations include a minimum requirement that the public be allowed to review and comment on draft TMDLs. For TMDLs adopted as Basin Plan amendments in California, opportunities for public participation are provided through the amendment procedures summarized in the USEPA Region IX *Guidance for Developing TMDLs in California* (2000), and through the California Environmental Quality Act (CEQA) review process. The Regional Board maintains a large mailing list of parties interested in receiving draft Basin Plan amendments and/or hearing notices, and a separate large mailing list for agenda announcements. The Basin Plan amendment and CEQA review processes include opportunities for written public comments and testimony at a noticed public hearing. Written responses are required for written public comments received during the noticed public review period, and staff respond orally to late written comments and hearing testimony before the Regional Board considers adoption. The Lahontan Regional Board's Basin Plan amendments (including draft TMDLs) are now made available on the Internet and publicized through press releases. Further opportunities for public participation are also provided in connection with review and approval of Regional Board-approved Basin Plan amendments by the SWRCB and the USEPA. Documentation of public participation, including copies of hearing notices, press releases, written public comments and written responses, and tapes or minutes of hearing testimony, will be included in the administrative record of the Basin Plan amendments for USEPA review.

Section 5. Implementation and Monitoring

Section 5.1 Implementation Actions and Management Measures

A. Erosion Controls for Existing Disturbance

Implementation of the TMDL is the responsibility of the U.S. Forest Service, Lake Tahoe Basin Management Unit and the Heavenly Ski Resort. It involves continuation of the erosion control and monitoring programs which were agreed upon as mitigation for the 1996 Heavenly Master Plan, and which have been implemented for the ski resort as a whole since 1997, with addition of biomonitoring.

Implementation includes application of Best Management Practices to all disturbed areas in the watershed (Sherry Hazelhurst, USFS, personal communication). The following is a summary of the erosion controls planned for specific source categories. The management measures listed were those assumed in inputs to the LTBMU model; through the adaptive management approach, other measures may also be applied. Mechanical or vegetative BMPs which may be used as part of the remedial erosion control program include, but are not limited to: retaining structures at the foot of overly steep slopes, riprap, surface roughening, interception trenches or water bars, revegetation, and ground covers such as straw, bark or pine needle mulch.

1. Abandonment and restoration of 7.59 acres of existing unpaved roads which are not essential for ski resort operations. An overall assumption of 90 percent efficiency in reducing sediment delivery was made for this component of the implementation program. The model assumed use of the following management practices:

a. Use of water bars

b. Revegetation of the road and cut and fill banks with grass and/or shrubs. This was expected to increase Percent Canopy, Percent Ground Cover, and Percent Fine Roots to 35 percent. Where the slope is too steep for successful revegetation, it may be reshaped to reduce the slope or some other permanent stabilization measure may be used.

c. Increase road surface roughness through tracking or scarring. This was predicted to decrease the "available water" (R-Value) factor in the Modified Universal Soil Loss Equation from 4 to 2, and to increase the Surface Roughness from 0.25 to 2.0.

d. Cover embankments with mulch or straw, also increasing the Surface Roughness from 0.25 to 2.0.

2. Restoration of the 21.10 remaining acres of existing unpaved roads which are not planned for abandonment. The model input assumed the following mitigation measures:

a. Use water bars

b. Revegetate the road cut and fill banks with grass and/or shrubs in order to increase Percent Ground Cover and Percent Fine Roots factors to 25 percent. When the slope is too steep for successful revegetation, some permanent stabilization (e.g., rock retaining wall) will also be employed. (The modeling results show percent cover increases for specific road segments from 35-70%.)

c. Cover embankments with mulch or straw to increase the Surface Roughness Factor from 0.25 to 2.0 and increase Percent Cover to 20.

3. Restoration of 182 acres of existing ski runs. The model assumed implementation of the following mitigation measures, with an overall efficiency of 80 percent in reducing sediment delivery:

a. Use water bars.

b. Revegetate runs with grass and/or shrubs. The model assumed that revegetation would result in a maximum ground cover of 70 percent and percent fine roots one third of the percent cover. Vegetation increases surface roughness, and increases the model Roughness variable by 1 (e.g., from 2 to 3). If necessary, revegetation will include stabilization techniques such as use of tackifiers or erosion control blankets or netting. The vegetation will be maintained with water and fertilizer until it has been established and can survive on its own. If monitoring shows that revegetation efforts have failed in certain areas, they will be revegetated again, or more appropriate stabilization measures will be used.

c. Mulch or straw cover the embankments.

The LTBMU model identifies specific needs for BMPs to be applied to each existing road and ski run segment. The modeling results (see example in Appendix 1) summarize, for each ski run or road segment, the reason for mitigation, the percent slope before and after mitigation, the number of water bars, presence of mulch or straw cover, existing and mitigated percent cover (vegetation, duff, etc.), soil loss and Equivalent Roaded Area before and after mitigation, and the year in which mitigation will take place.

The remedial program also includes continuation under USFS oversight of erosion control projects designed by the U.S. Natural Resources Conservation Service before the watershed-wide needs survey using the LTBMU model.

The remedial erosion control program is an adaptive management program. LTBMU staff monitor a variety of parameters, including BMP effectiveness (see the discussion of monitoring, below) and evaluate monitoring results annually. Annual monitoring reports include site specific recommendations regarding management practices. If needed, adjustments in management measures for specific sites are made the following year. The mitigation program also includes provisions for restoration or repair of critical areas damaged by natural disasters. More comprehensive evaluations of the success of the remedial program are scheduled to occur every five years. The first five year evaluation is being done in 2000, and the LTBMU has convened an interagency Technical Advisory Committee, including Regional Board staff, to assist in the process.

B. Erosion Controls for New Construction

The ski resort master plan also requires full implementation of temporary and permanent BMPs for control of erosion and stormwater runoff for all new construction. The need for special management practices in connection with ski resort development in the Lake Tahoe Basin has been recognized since the 1970s (California Tahoe Regional Planning Agency, 1977). The Heavenly Ski Resort Master Plan EIS (TRPA 1995, 1996) identifies BMPs which might potentially be used in a variety of construction situations. For new ski runs, snowmaking pipelines will be placed above ground, and consequently will not increase soil erosion. The pipelines will be used for irrigation, which will increase the chance of success for any revegetation on the new runs. (Current construction practices for ski runs involve cutting trees but leaving other native vegetation, rocks, duff, etc. in place. Full revegetation may not be required for new runs.)

Project-specific BMPs will be identified in connection with environmental review and permitting for all new construction. The mitigation program includes formal inspections at the start of construction, at least twice per month during construction, and during and at the end of storm events. The program directs inspectors to require correction of inadequate BMPs whenever detected during other site visits. If BMPs are judged to be inadequate, construction must be halted until they are in place. The scheduling of restoration projects will be coordinated with that for new resort facilities so that restored areas will not be disturbed again.

C. Additional Watershed Mitigation

The TMDL implementation program consists of the erosion control measures outlined above and the monitoring program described below. Estimated sediment delivery reductions from these measures were used in development of numeric targets and load allocations. However, a number of other watershed restoration activities are currently planned in the Heavenly Valley Creek watershed under the Heavenly Ski Resort Master Plan, other LTBMU authority, and the Tahoe Regional Planning Agency's "Environmental Improvement Program" (TRPA, 1998). The reasonable certainty that these projects will be implemented adds to the implicit margin of safety for the TMDL.

Under the Heavenly Ski Resort Master Plan, mitigation will be required for new and existing impervious surface in the watershed. Potential mitigation measures include full stabilization and revegetation of the ground surfaces around the impervious surface, and use of infiltration trenches or other BMPs to minimize increased runoff.

Also under the Master Plan, 11 acres of disturbed Stream Environment Zone will be restored in the Heavenly Valley Creek watershed. Properly functioning SEZs act as filters to remove suspended sediment from surface runoff, and increased functional SEZ area will add to the modeled reductions in hillslope sediment loading. Additional specific SEZ mitigation may be identified during review of individual Master Plan projects. For example, CEQA/NEPA mitigation measures for the recently approved construction of a ski lodge and expanded snowmaking equipment in the Sky Meadows area of the Heavenly Valley Creek watershed include relocation of some existing facilities outside of the SEZ and the restoration of about 600 square feet of disturbed SEZ within Sky Meadows (U.S. Forest Service, 1998).

Between 1995 and 1998, the LTBMU evaluated all structures at the Heavenly ski resort (ski lifts, lodges, restrooms, snowmaking facilities, maintenance facilities, etc.) and identified specific needs for retrofitting of Best Management Practices. (Retrofit of BMPs to all existing development in the Lake Tahoe Basin is required by state and TRPA water quality plans; see Chapter 5 of the Lahontan Basin Plan.) Prioritized recommendations for retrofit are summarized in Hazelhurst *et al*. (1999). Potential BMPs include infiltration and runoff control systems, and revegetation and mulch of areas adjacent to structures to improve infiltration and prevent accelerated erosion. Retrofit will be included in summer restoration work based on priorities and master plan phasing. The potential reduction in sediment delivery to Heavenly Valley Creek from implementation of these BMPs has not been quantified or included in the TMDL. However, BMP retrofit should cumulatively (with remedial erosion control work for ski runs and roads) contribute to reduced sediment delivery, and attainment of instream standards.

The TRPA's Environmental Improvement Program (EIP) is a part of that agency's regional land use plan (which also incorporates the Heavenly Ski Resort Master Plan). The EIP identifies specific projects which TRPA believes must be implemented in order to attain regional environmental standards. It includes a two phase fish habitat restoration project for Heavenly Valley Creek. The first phase (EIP Project 404), to be implemented in 2004 at a cost of $50,000, would stabilize the banks of a 1 mile segment of the creek downstream of the ski resort through revegetation, raising the overall habitat rating of the creek from "marginal" to good. The second phase (EIP Project 710), which would address the segment of the creek affected by the TMDL, would be completed in 2007 at a cost of $500,000. It would improve stream channel morphology "as needed", including development of pools, improvement of bed substrate, and removal of barriers to fish passage created by roads and culverts. The project would also include facilitation of a water rights exchange to replace the stream diversion for snowmaking with another water source. The Phase II project is expected to raise the fish habitat rating of the entire stream from "good" to "excellent". Funding for the EIP has not yet been assured, but TRPA is actively seeking funds from Congress and other sources for the entire $900 million program.

The proposed instream improvements through the EIP will complement the hillslope sediment controls in the Heavenly Valley Creek watershed, which should be completed at about the same time. Together, these controls will help to ensure attainment of the narrative water quality objectives related to sediment.

Section 5.2 Schedules for Implementation and Attainment

A. Schedule for Implementation

The TMDL implementation program relies on continuation of the USFS erosion control and monitoring programs for the Heavenly ski resort, which are already being implemented under the Master Plan schedule discussed below. The Basin Plan amendments will include recommended schedules for implementation and monitoring, with recognition that these may be changed through the adaptive management program which includes consultation with Regional Board staff.

As explained in the *Heavenly 1998 Master Plan Projects CWE Compliance Report* (U.S. Forest Service, 1998), the master plan EIS included a 10-year schedule for restoration of ski run and road segments. The schedule included specific ski run and road segments to be restored in each of the 10 years after approval of the master plan and EIS. The scheduled also included flexibility for revision in coordination with specific development projects provided that 1) the scheduled total acreage for each year (for the ski resort as a whole) is restored; 2) the total scheduled reduction in Equivalent Roaded Acres is achieved each year (for the ski resort as a whole) and 3) within each watershed, there is a downward trend in each year. "Existing" conditions for evaluation of implementation were based on the 1991 LTBMU field measurements; however, the Master Plan EIS allowed Heavenly credit for restoration work performed between 1991 and 1996. In 1997, the LTBMU and the Heavenly ski resort developed a schedule for coordination of restoration work with development projects through 2000, which a NEPA analysis concluded was environmentally equivalent to compliance with the original Master Plan restoration schedule. According to the *Compliance Report,* over three times the originally scheduled acreage was restored in the Heavenly Valley Creek watershed in 1997. (Actual restoration included 34.82 acres of ski runs and 4.45 acres of roads.) Restoration work to be completed in 1998 alone was expected to reduce ultimate total soil delivery to Heavenly Valley Creek by 159.9 tons/year. Figures for the total cumulative reduction in long term sediment delivery to date (1991-2000) are not currently available. They will probably be included in the LTBMU five-year evaluation report which is due to be released in early 2001.

The 10 year schedule for implementation for the remedial erosion control program involves mitigating the most severe erosion sources first and progressing to the least severe. The most severe problems are to be addressed during the first seven years (1997-2003); the remainder of the remedial work is scheduled for Years 8-10 (2004-2006). As noted in Section 5.1.C above, the TRPA Environmental Improvement Program fish habitat restoration project for Heavenly Valley Creek (TRPA, 1998) is also scheduled to be completed by 2007.

Progress toward implementation will be evaluated through the adaptive management approach, including annual evaluations and adjustments of management practices, and more comprehensive reviews once every five years. Because the work scheduled for the second five years will produce relatively little reduction in erosion compared to the earlier work, implementation plans will be re-evaluated at the five -year point to determine if they still represent the best plan for reducing erosion. If not, a modified program will be developed and implemented.

B. Schedule for Attainment

The remedial erosion control program (installation of BMPs) is expected to be complete by 2006. However, recovery of the watershed and the stream ecosystem to the point where narrative water quality objectives are attained and instream beneficial uses are supported at a satisfactory level will probably be a decades-long process. As noted above, there can be significant spatial and temporal lags between erosion events and sediment delivery to streams, and between sediment delivery and sediment impacts on beneficial uses. Even after stabilization of the watershed, time will be required for flushing of existing excess sediment from Heavenly Valley Creek, and for recovery of instream aquatic life uses. As long as the current hydromodification of Heavenly Valley Creek (the reservoir and culverted section of stream) remains in place, recovery of the stream as a whole to "pristine" conditions cannot be expected. However, this TMDL analysis predicts recovery of benthic communities to conditions which attain standards (interpreted in terms of degraded "baseline conditions" as discussed in Section 3.1.C. above) within 20 years after the effective date of the TMDL (by 2021). This prediction is supported by modeling and monitoring results for the Heavenly ski resort which indicate that hillslope stability can be achieved within that time frame, and scientific literature which shows that disturbed benthic communities can recover quickly if suitable habitat is restored.

The LTBMU model predicts that disturbed acreage in the watershed, and the potential for sediment yield, will be significantly reduced after the first ten years. These expectations reflect the fact that many soil erosion BMPs (e.g., water bars, reduction of cutbank slopes, rock-lined drainage ditches, and graveling of roads) are effective immediately upon installation. Although revegetation must be fully established to be completely effective, even sparse vegetation provides some benefit during the interim period. Mulch of revegetated areas also provides interim erosion control.

Percent cover on ski runs for the ski resort as a whole has increased significantly since the first measurements in 1991. For the given subsample of ski runs, percent cover is now between "good" and "excellent", indicating attainment of the proposed target (Hazelhurst *et al.,* 1999). The results for the ski area as a whole cannot necessarily be extrapolated to the Heavenly Valley Creek watershed, but they indicate that there is a reasonably good chance of attainment of hillslope targets, which will eventually lead to attainment of instream standards.

The scientific literature (e.g., Hawkins *et al.* 1994) indicates that benthic invertebrate communities in streams can recover fairly rapidly following catastrophic disturbances such as volcanic eruptions, assuming that physical instream habitat conditions have recovered. In the Clearwater Basin near Mt. St. Helens, invertebrates in tributary streams recovered rapidly after scouring of sediment that revealed pre-1980 eruption substrate, and population densities were similar to those under reference conditions within two years. In Clearwater Creek, sculpin populations recovered to densities as high or higher than pre-eruption levels by 1985. Trout populations were only 20 % of previous levels in 1990, which was attributed to lack of spawning habitat; but trout condition was good due to rapid recovery of invertebrate prey (Hawkins *et al.,* 1994).

Section 5.3. "Reasonable Assurance" of Implementation

The USEPA's guidance for the development of TMDLs (1999, 2000) directs states to provide "reasonable assurance" that implementation activities will occur. The USEPA Region IX (USEPA, 2000) guidance cites a 1997 national policy

> *"that all TMDLs are expected to provide reasonable assurances that they can and will be implemented in a manner that results in attainment of water quality standards. This means that the wasteload and load allocations are technically feasible and reasonably assured of being implemented in a reasonable period of time. Reasonable assurances may be provided through use of regulatory, non-regulatory, or incentive based implementation mechanisms as appropriate".*

The sediment protocol document (USEPA, 1999) summarizes the direction in the draft revisions to the Section 303(d) regulations to the effect that:

> *"Reasonable assurance means a high degree of confidence that the wasteload allocations and or load allocations in TMDLs will be implemented by Federal, State or local authorities and/or voluntary action... . For nonpoint sources , reasonable assurance means that nonpoint source controls are specific to the pollutant of concern, implemented according to an expeditious schedule, and supported by reliable delivery mechanism and adequate funding".*

The Heavenly Valley Creek TMDL implementation program incorporates an erosion control program which is already in the fifth year of a ten-year implementation schedule. Lahontan Regional Board staff have a high degree of confidence that it will be completed on schedule. (See the discussion of authority for implementation, below.) The management practices outlined above are specific to sediment control, and have been used widely enough in the Lake Tahoe Basin and similar environments to provide confidence in their technical feasibility. The erosion control and monitoring programs are being funded by the Heavenly ski resort, which has adequate financial resources to ensure that erosion control work will be done on schedule and that monitoring will continue indefinitely.

Although there is ample regulatory authority to ensure implementation of the TMDL, there is also a high degree of stakeholder commitment to work for watershed restoration in the Lake Tahoe Basin as a whole. The Heavenly Valley Creek remedial program was designed and is being implemented in the context of the very comprehensive existing water quality control program for the entire Lake Tahoe watershed, which is summarized in Chapter 5 of the Basin Plan. Elements of the program relevant to control of sediment in the Heavenly Valley Creek watershed include: general and specific prohibitions against discharges or threatened discharges of sediment; limitations on impervious surface coverage; stormwater effluent limitations; mandatory implementation of temporary and permanent BMPs; protection of Stream Environment Zones and 100 year flood plains; and limitations on types of ski area facilities which can be constructed on high erosion hazard lands. The proposed TMDL is consistent with and will implement the water quality standards and control measures in Chapter 5 of the Basin Plan. The remedial work at Heavenly also falls within a larger interagency "Watershed Management Initiative" for the Trout Creek/Upper Truckee River watershed as a whole.

The regulatory authorities and stakeholder commitments which will affect the implementation of the TMDLs are described below and summarized in Table 14.

Lahontan Regional Board. The Regional Board has regulatory authority to enforce implementation of the TMDL under both the Clean Water Act and the California Water Code. The TMDL numerical targets themselves are not enforceable, except for those set at the level of water quality standards. Under Section 13360 of the California Water Code Regional Boards cannot specify the design, location, type of construction or particular manner of compliance with Board orders. The Board does have the authority to adopt waste discharge requirements, and/or a stormwater NPDES permit, to ensure compliance with water quality standards in Heavenly Valley Creek. The Board, or its Executive Officer may also require water quality monitoring programs which specify monitoring of specific parameters, separately from water quality permits (Water Code Section 13267). The Board's enforcement authority is summarized in Chapter 4 of the Basin Plan.

Initially, Regional Board staff intend to pursue implementation of the Heavenly Valley Creek TMDLs under the "three-tier" approach of the revised statewide nonpoint source control plan (California State Water Resources Control Board, 2000), and to treat the erosion control and monitoring programs as "self-determined implementation". Regional Board staff will continue to participate in the interagency technical advisory group which carries out annual and five year reviews of the Heavenly ski resort erosion control and monitoring programs. Regional Board staff will maintain oversight of maintenance activities at Heavenly through the existing waste discharge requirements and monitoring program (Board Order 6-91-36) and, under the three-tier approach, may request the Board to consider revising this order to include the TMDLs in the future. (The permit is scheduled for its next update in 2001.) The Regional Board will continue to act as a responsible agency under CEQA for new ski resort development projects as they are approved.

U.S. Forest Service. The LTBMU's *Land and Resource Management Plan* has water quality protection as its primary goal. In 1996, the LTBMU amended this plan to add commitments for implementation and monitoring of erosion controls to the "Management Area Standards and Guidelines" and "Proposed Resolution of Issues and Concerns" for the Heavenly Management Area. As part of the USFS Pacific Southwest Region (PSW), the LTBMU is also committed to ensure implementation of BMPs through a statewide Management Agency Agreement between the State Water Resources Control Board and the PSW. Through its permit for the Heavenly ski resort, the Forest Service has authority to ensure implementation of the erosion control and monitoring programs in both California and Nevada. These programs were required as mitigation for the Heavenly Ski Resort Master Plan under the National Environmental Policy Act (NEPA). The Master Plan allows the USFS to disapprove proposed new ski resort development if satisfactory progress is not being made on the remedial erosion control work.

The LTBMU is also committed to watershed restoration at Lake Tahoe as a partner in the Regional Board's Watershed Management Initiative for the Upper Truckee River/Trout Creek watershed (including Heavenly Valley Creek), and as the lead agency for the "Presidential Deliverables" program which resulted from President Clinton's visit to Lake Tahoe in 1997.

Tahoe Regional Planning Agency. The TRPA has been charged by Congress (under P.L. 96-551) to ensure attainment of the most stringent state and federal water quality standards within its jurisdiction. The TRPA has a *Water Quality Management Plan for the Lake Tahoe Region*, adopted under Section 208 of the Clean Water Act and approved by California, Nevada, and the U.S. Environmental Protection Agency. The Heavenly Ski Resort Master Plan, which includes the erosion control and monitoring programs incorporated into the TMDL implementation program, has been incorporated into TRPA's regional land use plan. (TRPA also approved the erosion control and monitoring programs as mitigation under its P. L. 96-551 environmental review process, which is legally separate from the CEQA and NEPA processes.) TRPA's land use and "Section 208" plans incorporate land use prohibitions (against 100 year flood plain SEZ disturbance, etc.) similar to the waste discharge prohibitions in the Regional Board's Basin Plan amendments, and require retrofit of BMPs for all existing development. Although TRPA's enforcement authority is not as comprehensive as the Lahontan Regional Board's, it does have authority to ensure implementation of the erosion control and monitoring programs in both the California and Nevada sides of the Heavenly Valley Creek watershed.

Section 5.4. Monitoring Plan

Monitoring of the success of watershed restoration efforts at Heavenly has been ongoing for many years to meet USFS and Regional Board requirements. The monitoring program approved under the Master Plan EIS is also a part of the mitigation monitoring program required under the California Environmental Quality Act (Public Resources Code Section 21081.6). The USFS currently monitors the following parameters for the ski resort as a whole:

- Water quality (specific conductivity, turbidity, suspended sediment, total nitrate/nitrite, total Kjeldahl nitrogen, total phosphorus, dissolved orthophosphate, chloride)

- Soil erosion, and effective soil cover for the ski area as a whole, using both fixed plots and 15 randomly selected ski runs, roads and undeveloped areas. Fixed plots have been established on 20 ski runs and 5 undeveloped sites for long term monitoring. Direct measurements of soil erosion will be obtained from erosion pins and troughs, and indirect measurements will be taken from actual soil cover components and a soil loss prediction model

- BMP effectiveness (temporary and permanent). Monitoring of vegetation will take place during the growing season

- Riparian and stream channel condition.

Hidden Valley Creek is also being monitored as a reference stream.

Table 15 summarizes the elements of the monitoring program needed to determine compliance with the Heavenly Valley Creek TMDL indicators and targets. With the exception of bioassessment of benthic macroinvertebrates, all of these elements are part of the ongoing USFS monitoring program. Regional Board staff recognize that sampling stations and frequencies may need to be changed over time as a result of the adaptive management approach to implementation. (BMP effectiveness is not proposed as a TMDL indicator, but it will continue to be monitored and used in evaluation of the success of restoration efforts.)

The following description of the bioassessment protocol proposed for addition to the monitoring program was provided by Thomas Suk of Regional Board staff.
The full protocol involves documenting physical habitat quality for benthic macroinvertebrates and sampling and identification of invertebrates from selected study reaches. Fieldwork includes mapping, permanent photo points and GPS data, and measurements of habitat characteristics such as current velocity, depth, width, substrate size, cobble embeddedness, bank stability, riparian cover, discharge, bank angles, slope, temperature, and sinuousity. (To the extent that physical habitat measurements are

Table 14. Authority for implementation of the Heavenly Valley Creek TMDL.

Agency	Authority/Commitment Related to Implementation
U.S. Forest Service, Lake Tahoe Basin Management Unit	• 1988 Land and Resource Management Plan • Pacific Southwest Region "Section 208" Plan and Management Agency Agreement (MAA) with State and Regional Boards, committing to implement BMPs • Partner in Upper Truckee River/Trout Creek WMI effort • Lead agency for Tahoe "Presidential deliverables" program
California Regional Water Quality Control Board, Lahontan Region and California State Water Resources Control Board.	• Clean Water Act • Porter Cologne Act • Nonpoint Source Plan (California State Water Resources Control Board, 2000) • Lahontan Basin Plan including Lake Tahoe Basin chapter • MAA with USFS, Pacific Southwest Region • Certification authority over TRPA "208 Plan" • Upper Truckee/Trout Creek is a "priority" Watershed Management Initiative (WMI) watershed
Tahoe Regional Planning Agency	• Congressionally enacted Tahoe Regional Planning Compact (PL 96-551) • Water Quality Management Plan for the Lake Tahoe Region ("Section 208 Plan) certified by CA, NV and USEPA • Regional Plan, incorporating Heavenly Ski Resort Master Plan and EIP • Partner in Upper Truckee River/Trout Creek WMI effort

similar to those already being measured in the LTBMU's stream channel condition assessment, it may be possible to eliminate duplicative measurements and reduce sampling costs.) Biological work includes collection, field processing, and preservation of stream invertebrate samples, and laboratory sorting, subsampling, and identification. Results are reported in terms of physical habitat quality and occurrence and density of aquatic macroinvertebrate taxa.

Biomonitoring stations for Heavenly Valley and Hidden Valley Creeks should be located at or near LTBMU monitoring stations for physical and chemical parameters. Numbers and locations of stations, and frequency of sampling will be determined in consultation with LTBMU and Heavenly staff. At least three to five stations should be sampled in Heavenly Valley Creek, and three to five in Hidden Valley Creek. Ideally, sampling should be conducted for two consecutive years to determine current conditions at the impacted and reference sites, and resampling should occur every two years thereafter to document trends.

The LTBMU produces annual monitoring reports, including management recommendations to improve standard practices. A technical advisory committee meets annually to review the data and discuss recommendations for implementation during the next field season. Monitoring results will also be used to develop recommendations to improve management practices over the longer term. A comprehensive report on the monitoring data is to be completed in 2000 to quantify conditions and trends compared to 1991 baseline conditions. Similar reviews will be done after 10 and 15 years of monitoring. The need for long term monitoring to document the success of erosion controls has been recognized, and the monitoring program is expected to continue indefinitely, although it may be modified over time to focus on the data which are most useful for ski area management and environmental protection.

Section 6 . Review and Revision of TMDL

Regional Board staff will continue to participate in the interagency technical advisory group convened by the U.S. Forest Service to review annual monitoring data. Staff will also participate in annual adaptive management planning, and in the comprehensive evaluations to be held at five year intervals. Regional Board staff will use the five-year reviews as vehicles for evaluation of progress toward attainment of load allocations and numeric targets. Because the load allocations are expressed as five year rolling averages, and other numeric targets are expressed as long term trends, the first decision point regarding needs for revision of the TMDL will probably occur after the second five-year review (in 2010). However, the University of California, Tahoe Research Group (TRG) is developing a separate, more sophisticated sediment/nutrient loading model for the Lake Tahoe watershed as a whole, which is expected to be used to develop TMDLs for Lake Tahoe. The TRG model will use different data and assumptions than the LTBMU model. If the results of the TRG model indicate that the LTBMU model significantly underestimated sediment loading to the Section 303(d)-listed segment of Heavenly Valley Creek, revision of the TMDL could be considered earlier. Revision could also be triggered earlier if calibration of the LTBMU model (planned for 2000-2001) leads to greatly different estimates of hillslope sediment delivery, if ongoing monitoring of erosion control work at Heavenly shows that the restoration program is <u>not</u> adequate to meet the hillslope targets, or if substantial new development (beyond the scope of the current master plan) is proposed in the watershed. The Lahontan Regional Board is now sponsoring biomonitoring of stream macroinvertebrates throughout the central Sierra

Nevada with a view toward developing water quality objectives incorporating "biocriteria". The results of the biomonitoring studies should provide more specific grounds for interpreting aquatic life use support in Heavenly Valley Creek, and for revision of the TMDL if needed in the future.

Table 15. Summary of Recommended TMDL Monitoring Program

Indicator	Sampling Location (s)	Sampling Frequency
Suspended sediment concentration	Heavenly Valley Creek "Property Line" station and Hidden Valley Creek	Monthly, with more frequent samples during snowmelt runoff
Suspended sediment loading	Heavenly Valley Creek at "Property Line" station, and Hidden Valley Creek	Calculated annually based on concentration and flow measurements
Pfankuch channel stability index	Heavenly Valley and Hidden Valley Creeks	At least once every 5 years.
USFS Region 5 Stream Condition Index	Heavenly Valley and Hidden Valley Creeks	Full surveys at least once every 5 years; continued annual monitoring of stream cross sections on Heavenly Valley Creek
Benthic invertebrate community health	3-5 stations each on Heavenly Valley and Hidden Valley Creeks	Baseline sampling for 2 consecutive years; and every 2 years thereafter
Percent Equivalent Roaded Area.	Entire watershed	Estimated annually based on restoration work completed to date
Effective soil cover (vegetation, woody debris, organic matter, rocks) on ski runs and roads	Annual random samples of roads and ski runs throughout resort as a whole	Cover increases for resort as a whole estimated annually based on measurements for sampled roads and runs
BMP effectiveness	Annual randomly sampled roads and ski runs throughout resort as a whole	Annual inspections; damaged BMPs are repaired or supplemented on a site specific basis

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References

Baker, J.A. and W.E. Davis, 1976. *Siltation Evaluation for the Lake Tahoe Basin*. California Regional Water Quality Control Board, Lahontan Region.

California Regional Water Quality Control Board, Lahontan Region, 1966. Lake Tahoe Water Quality Control Policy, July 1966.

California Regional Water Quality Control Board, Lahontan Region 1975. Water Quality Control Plan for the North Lahontan Basin.

California Regional Water Quality Control Board, Lahontan Region, 1995. *Water Quality Control Plan for the Lahontan Region* (as amended).

California State Water Resources Control Board, 1971. *Interim Water Quality Control Plan for the North Lahontan Basin*.

California State Water Resources Control Board, 2000. *Plan for California's Nonpoint Source Pollution Control Program.*

California Tahoe Regional Planning Agency, 1977. *Criteria for Development and Expansion of Ski Areas, Lake Tahoe Basin*, August 1977.

Erman, D.C., E.D. Andrews and M.Yoder -Williams. Effects of winter floods on fishes in the Sierra Nevada [Canada]. *Canadian Journal of Fisheries and Aquatic Sciences* 45 (12): 2195-2200. [Abstract].

Etra, J., 1984. *Forest Service Demonstration Plantings, Heavenly Valley, Fall 1984*. Lake Tahoe Basin Management Unit, U.S. Forest Service.

Glancy, P.A. 1973. *A Reconnaissance of streamflow and fluvial sediment transport, Incline Village area, Lake Tahoe, Nevada.* Nevada Division of Water Resources, Water

Resources Information Series Report 19. Prepared cooperatively by the U.S. Geological Survey.

Harris, R. 1996. Letter from Robert E. Harris, Forest Supervisor, U.S. Forest Service, Lake Tahoe Basin Management Unit, to Joel A. Medlin, Endangered Species Office, U.S. Fish and Wildlife Service, Sacramento CA, dated January 18, 1996. Mail Code: 2670.

Hawkins, C.P., J. Sedell, and S. Gregory. 1994. Recovery of Stream Ecosystems Following Catastrophic Disturbances. In P.M. Frenzen and two other compilers, *Mount St. Helens: Biological Recovery Following the 1980 Eruption.* General Technical Report, PNW GTR-342, U.S.D.A. Pacific Northwest Research Station. Available on the Internet: <http://vulcan.wr.usgs.gov/Volcanoes/MSH/Recovery/research_projects/html/#recovery_stream_ecosyst >.

Hazelhurst, S. and B. Widegren, 1998. *Heavenly Ski Resort 1997 Environmental Monitoring Report.* U.S. Forest Service Lake Tahoe Basin Management Unit.

Hazelhurst, S., B. Widegren, and M.Greene, 1999. *Heavenly Ski Resort 1998 Environmental Monitoring Report.* U.S. Forest Service Lake Tahoe Basin Management Unit.

Kondolf, G.M. 1999. *Peer Review Comments on Preliminary Draft of Basin Plan Amendments, Staff Report, and EA: Total Maximum Daily Loads and Implementation Plan for Sediment Loading to Heavenly Valley Creek, El Dorado County, California.* 29 November, 1999.

Kondolf, G.M. and 3 other authors, 1991. Distribution and stability of potential salmonid spawning gravels in steep boulder-bed streams of the eastern Sierra Nevada. *Transactions of the American Fisheries Society* 120 (2): 177-186 [Abstract].

Kroll, C.G. 1973. *Sediment Discharge in the Lake Tahoe Basin, California, 1972 Water Year*. U.S. Geological Survey Open- File Report, Menlo Park, CA September 19, 1973.

McBrayer, J.W. and R.D. Ringo, 1975. Study Report: Egg and Alevin Survival and General Spawning Conditions for Lahontan Cutthroat Trout in the Lower Truckee River During 194. U.S. Fish and Wildlife Service, Reno, NV.

Newcombe, C.P. and D.D. MacDonald, 1991. Effects of Suspended Sediments on Aquatic Ecosystems. *North American Journal of Fisheries Management* 11: 72-82.

Pfankuch, D.J., 1978. Stream Reach Inventory and Channel Stability Evaluation. USDA Forest Service, Northern Region. [Cited by LTBMU, but not reviewed by Regional Board staff.]

Rowe, T.G., 1998. Loads and Yields of Suspended Sediment and Nutrients for Selected Watersheds in the Lake Tahoe Basin, California and Nevada. U.S. Geological Survey. Available on the Internet <http://204.87.21.11/98proceedings/Papers/50-ROWE.html>.

Skau, C.M. and J.C. Brown, 1988. A Synoptic View of Nutrients and Suspended Sediments in Natural Waters of Forested Watersheds in East-Central Sierra Nevada. Pages 160-178 in I.G. Poppoff and 3 other editors, *Proceedings International Mountain Watershed Symposium, Lake Tahoe June 8-10, 1988.* Tahoe Resource Conservation District.

Tahoe Regional Planning Agency, 1987. *Regional Plan for the Lake Tahoe Basin*, as amended (3 Volumes).

Tahoe Regional Planning Agency and U.S. Forest Service, Lake Tahoe Basin Management Unit, 1995-96. *Draft and Final Environmental Impact Report/Statement, Heavenly Ski Resort Master Plan.* 5 Volumes. Prepared by Harland Bartholomew & Associates and subcontractors. (Draft dated April 1995; Final dated June 1996).

Tahoe Regional Planning Agency, 1996. *Draft 1996 Evaluation Report: Environmental Threshold Carrying Capacities and the Regional Plan Package for the Lake Tahoe Region.* December, 1996.

Tahoe Regional Planning Agency, 1998. *Environmental Improvement Program for the Lake Tahoe Region*. Draft for Initial Adoption.

.

U.S. Environmental Protection Agency, 1999. *Protocol for Developing Sediment TMDLs*, First Edition. Office of Water, Washington DC, EPA 841-B-99-004.

U.S. Environmental Protection Agency, Region IX, 2000. *Guidance for Developing TMDLs in California*, January 7, 2000.

U. S. Forest Service, 1980. *An Approach to Water Resources Evaluation of Non-point Silvicultural Sources (a procedural handbook).* EPA-600/8-80-012. Athens, GA: Environmental Research Laboratory. [This reference, commonly called WRENSS, was one of the key reference used by the USFS to develop the LTBMU, but it has not been reviewed by RWQCB staff.]

U. S. Forest Service, 1981. *Guide for Predicting Sediment Yields from Forested Watersheds.* [This was one of the key references used by the LTBMU to develop its model, but it has not been reviewed by RWQCB staff.]

U.S. Forest Service, 1988. *Land and Resource Management Plan, Lake Tahoe Basin Management Unit.*

U.S. Forest Service, 1998. *Heavenly Sky Meadows Lodge and Snowmaking Expansion Project: Environmental Assessment/Negative Declaration*, including *Appendix C.*

Heavenly Master Plan Projects CWE Compliance Report June 24, 1998. (Prepared by Parsons Harland Bartholomew & Associates, Inc. for USFS/LTBMU and Lahontan RWQCB).

Washington Forest Practices Board, 1997. *Statistical Methodology for Conducting Water Quality Standards Analysis,* Version 4.0, November 1997. Watershed Analysis Appendix B. Surface Erosion.

Waters, T. F., 1995. *Sediment in Streams: Sources, Biological Effects, and Control*. American Fisheries Society Monograph 7.

White, C.A. and A. L. Franks. 1978. *Demonstration of Erosion and Sediment Control Technology, Lake Tahoe Region of California*. Final Report March 1978. California State Water Resources Control Board.

Woyshner, M. and B. Hecht, 1988. Sediment, solute and nutrient transport from Squaw Creek Truckee River Basin, California. Pages 190-219 in *Proceedings: International Mountain Watershed Symposium: Subalpine Processes and Water Quality*. Edited by I.G. Poppoff, C.R. Goldman, S.L. Loeb, and L.B. Leopold. Published by Tahoe Resource Conservation District.

Appendix 1: Sediment Delivery Modeling for the Heavenly Valley Creek TMDL

The Section 303(d)-listed segment of Heavenly Valley Creek is a reach approximately 2.7 miles long which extends from the headwaters of the creek to the boundary of the U.S. Forest Service (USFS) permit area for the Heavenly ski resort. The watershed tributary to the listed segment has an area of 1341 acres. All of the modeling results discussed below refer to this portion of the watershed.

The sediment delivery model used in the Heavenly Valley Creek TMDL was developed by staff of the USFS Lake Tahoe Basin Management Unit (LTBMU) to identify watershed restoration needs under the Heavenly Ski Resort Master Plan (TRPA, 1995, 1996). The LTBMU based its model on several procedures described in the "WRENNS Handbook" (USFS, 1980) and the *Guide for Predicting Sediment Yields from Forested Watersheds* (USFS, 1981). The WRENNS Handbook is widely used by USFS resource managers to analyze the impacts of timber harvest activities on watersheds, and can be adapted to other types of land disturbance such as ski resort development. The *Guide for Predicting Sediment Yields* is based on extensive studies in the Idaho Batholith, an area with decomposed granitic soils similar to those in the Heavenly area. The LTBMU model (Holland, 1993; TRPA, 1995, 1996) applies the methodology from these two publications using field data collected at Heavenly in 1991 and 1995. Calibration of the model (based on subsequent monitoring data, including direct measurements of erosion) will occur during the winter of 2000-2001 (Sherry Hazelhurst, LTBMU, personal communication).

The USEPA's *Protocol for Developing Sediment TMDLs* (1999) states that the WRENNS methodology is a "mid-range" model (compared with simple and detailed methods), which is sensitive to changes in the driving forces that influence sedimentation. It represents a compromise between empirical and mechanistic models, and is reliable for order of magnitude accuracy. WRENNS is one of a group of models which segment watersheds into land types and land system inventories. Each land parcel in the watershed is allocated erosion hazard potential and sediment delivery ratio values that allow generation of erosion curves for each disturbance source on the watershed. The USEPA protocol document recommends that estimates of sediment delivery using WRENNS and similar models be based on field information collected for the specific purposes of the model; site-specific information has been used in the LTBMU model for Heavenly Valley Creek. The USEPA protocol also suggests that models such as WRENNS should be used with caution in cases where extreme watershed conditions predominate (e.g. very steep topography, landslide-dominated erosion, and radically variable precipitation regimes), and that other methods including the "Revised Universal Soil Loss Equation" or one of its variants might be preferable in mountainous regions. As explained below, the LTBMU model estimates sediment delivery using the "Modified Universal Soil Loss Equation" outlined in the WRENNS handbook, with adjustments for rill and gully erosion, and other modifications based on the Idaho batholith studies (USFS, 1981; Megahan and Kidd, 1972; Burroughs and King, 1989).

Model Results Used in TMDL Source Analysis

Sediment Delivery Estimation
The WRENSS Handbook includes a procedure for estimating soil loss which is an adaptation of the Universal Soil Loss Equation (USLE) for steeper forested lands. WRENNS also includes a method for estimating sediment delivery to a stream channel. The LTBMU model for Heavenly is numerically based on the Modified Universal Soil Loss Equation (MUSLE), used in conjunction with a sediment delivery ratio (Holland, 1993).

The following, from Holland (1993), is a summary of the types of data required for input into the WRENNS model, with notes on specific procedures used in the LTBMU model for the Heavenly ski resort. (Modeling results for the Heavenly Valley Creek watershed were based on field measurements of 266 road segments, 124 ski run segments, and 26 undeveloped or undisturbed segments..

"The WRENNS model requires the following data input to calculate sediment delivery (Tons/year):

1. Acres of Disturbance- Field surveys measured the width and length of ski run segments to obtain acreage estimates. Road prisms, cuts and fills were also measured likewise for each segment.

2. K-factor- This is the "soil erosivity " factor and represents the predominantly Cagwin/Toem soil association found in the Heavenly area. The K-factor is a reflection of the inherent properties of the soil that relate to erodibility. The K-factor currently used in the model is constant although further soils evaluation should provide enough information to vary the factor according to soil type.

3. Precipitation- This number represents the average rainfall over the ski area for a two year, six hour event. The number is taken from a precipitation map prepared by NOAA[the National Oceanographic and Atmospheric Administration.].This number is used to calculate the R-factor, a component in the MSLE [sic] for determining soil erosion (in Tons/Acre/Yr). The rainfall currently used in the model is constant for all areas on Heavenly. Further monitoring may indicate variable rainfall patterns in the Heavenly area and if this is determined then variable rainfall factors will be used in the model.

4. Slope gradient- The slope gradient is the vertical elevation difference between the lower boundary of a sediment source area and the stream channel divided by the horizontal distance. It reflects the slope over which sediment travels to reach a channel. For roads, the slope gradient is the cut and fill slope. This is the average slope gradient expressed as percentage slope. This and slope length are the two most important factors in the soil erosion estimate.

5. Slope length- this is the distance from the point of origin of overland flow to:

   a. the point where the slope decreases to the extent that deposition begins, or

   b. the point where runoff enters a well-defined channel that may be part of a drainage network or constructed channel such as a waterbar, or

   c. the downslope boundary of a disturbance.

6. Canopy cover- Defined, canopy cover consists of leaves and branches that do not directly contact the soil surface. At Heavenly, this constituent includes trees and high brush greater than 2 feet from the ground surface.

7. Ground cover- Ground cover is the material in actual contact with the soil surface and includes mulch, vegetation growing close to the ground and rock or vegetative debris greater than 3/4 inch across at its narrowest point.

8. Fine root percentage - This was estimated from the vegetation percentage estimated in the ground cover data. Assuming that the area covered by the vegetation above ground is equal to its fine root system below the percentage of fine roots is equal to the percentage of vegetation for a given segment surveyed.

9. Available water - This is defined in WRENNS as the transport agent of eroded material. It is the amount of rainfall or snowmelt remaining following infiltration that can runoff [sic] (overland flow) and transport eroded material. Water availability values vary by slope length and runoff. Further monitoring is required to determine the accuracy of the values currently used in the model.

10. Soil texture- This is based on the assumption that sediment delivery efficiencies are higher on an area dominated by fine textured materials than on an area dominated by coarse -textured materials if the other factors influencing sediment delivery are equal. It is a constant value throughout the Heavenly CWE evaluation derived from the following equation, the information of which is available in the SCS soil survey for the Lake Tahoe Basin:

Texture of eroded material = percent silt + percent fine sand

The soil texture used in the model reflects the texture of eroded material or [sic- for?] only one soil type found on Heavenly. Future soils evaluation will provide enough information to vary the soil texture by soil type.

11. Slope shape- Slope shape plays an important role in sediment delivery. Concave slopes will facilitate more efficient transport of sediment to a stream channel than convex slopes.

12. Delivery distance- This is defined as the distance between the point where overland flow leaves a segment and the point where it enters a defined channel connected to the watershed's drainage network. This channel can be :

    a. a live or ephemeral natural channel;

    b. a gully that empties directly into a stream channel or into a system of channels leading to a stream channel; or

    c. a waterbar that empties directly into a stream channel or into a system of channels leading to a stream channel.

13. Surface roughness- As in general cover, soil roughness affects sediment delivery compared to smooth soil surfaces. Rougher surfaces crate a more tortuous path way [sic] for eroded particles to pass over as well as more surface area for water to infiltrate. This factor ranges from 0 for smooth surfaces to 4 for rough surfaces, generally values used in the model range from 1-4."

Table 1 is an excerpt from an LTBMU table containing field data and other MUSLE factors for specific ski run segments.

The WRENNS model estimates only surface erosion, and does not include gully erosion. During the summer of 1991, on the California side of the ski resort (which includes most of the Heavenly Valley Creek watershed), LTBMU staff used transects to measure rill and gully erosion according to a U.S. Soil Conservation Service (SCS, 1966) procedure. This involves measuring rills encountered along a linear transect for width and depth, calculating the rill area in square inches from width and depth, and dividing the area by 84 to yield the soil loss in tons per acre for the specific plot. Assuming that rills are symmetrical and continuous for a certain distance, a cubic yard value can be derived. Based on the transects, ski runs with rills and/or gullies were assigned higher sediment delivery ratios to reflect the additional sediment production and increased delivery efficiency. These ratios were based on the extensive expertise of the field surveyor and were considered conservative estimates (Holland, 1993).

Disturbance Condition

A disturbance coefficient was applied to roads, to account for soil compaction.. While the WRENNS model automatically calculates a vegetative management factor (VM factor) it does so based on vegetative cover and soil surface conditions. Unpaved roads lack vegetative cover and the soil is compacted. Therefore, a higher VM factor is applied. Using information from Table IV-3 in Chapter Four of the WRENNS Handbook, a VM factor of 1.3 was used in the LTBMU model for all roads analyzed in the Heavenly ski resort (Holland, 1993). VM factors for sediment source areas are included in Table 1.

Data for individual road segments were entered into the LTBMU model to determine sediment delivery. Information for some segments was grouped for areas with similar slope gradients and landscape attributes; e.g., contiguous road segments were grouped together to define a length of switchback or a route adjacent to a creek or a road generally following the same gradient. Tables 2 and 5 include modeled sediment delivery data for groups of road segments.

Natural Sediment Yields

The LTBMU used several methods to estimate natural watershed sediment delivery rates, in order to compare results to ensure greater accuracy. These methods included use of data from a USGS study in the Incline Creek area, estimations using the WRENNS Handbook (USFS, 1980) and Guide for Predicting Sediment Yields (USFS, 1981), and comparisons to field data for suspended sediment in the undisturbed tributary for Heavenly Valley Creek. The USGS data (Glancy, 1988) showed annual sediment yields in undeveloped watersheds between 10 and 100 tons per square mile (0.016 and 0.156 tons per acre). Holland (1993) describes computation of natural sediment yield from the Heavenly ski resort based on methods in USFS (1981), and including a procedural rating for mass erosion hazards as described in Chapter 5 of the WRENNS handbook. The estimate was based on a worksheet with weighted factors for slope gradient, soil depth, subsurface drainage characteristics, soil texture, bedding structure and orientation, surface slope configuration and precipitation input. LTBMU staff determined a numerical rating using these factors, and a graph from USGS 1981, to obtain an average natural sediment rate of 40 tons per square mile (0.0625 tons/acre/year) for the Heavenly ski resort as a whole. LTBMU staff also used the average suspended sediment concentration for the undisturbed tributary of Heavenly Valley Creek between 1981 and 1987 to estimate natural sediment yield; the results corresponded to 7.7 tons per square mile (0.012 tons per acre per year), which did not represent total sediment. (This tributary is ephemeral, and the data included several very wet or very dry years, so results may not be representative even of "average" suspended sediment conditions. The LTBMU is now using another stream, "Hidden Valley Creek", as a reference stream.)

The LTBMU modeling data presented in TRPA (1995) include sediment yield estimates for specific undisturbed "segments" in the portion of the Heavenly Valley Creek watershed within resort boundaries. The 0.03 tons per acre per year figure, together with the 1341 acre watershed area used in the EIR/EIS, gives an overall estimate of 40 tons per year for undisturbed lands in the Heavenly Valley Creek watershed. The latter figure is the one used for undeveloped lands in the TMDL source analysis and load allocations.

Source Analysis

The "baseline" sediment delivery figures used in the TMDL source analysis reflect the modeled total sediment delivery figures for the road, ski run, and undeveloped lands categories in summarized in Table 2. (Model output data are also available for individual road and ski run segments.) The model results reflect the field data collected in

1991 (Table 1). (A subset of randomly selected roads and ski runs is being evaluated each year in relation to effectiveness of BMPs, but no comprehensive field survey of all road and run segments has been done since 1991.) These land use categories are used in the TMDL because they were the categories modeled by the LTBMU, because erosion was modeled slightly differently for roads (e.g., the compaction VM factor) and because different mitigation strategies (abandonment) were used for some roads as opposed to ski runs. (The Heavenly Valley Creek watershed includes about 57 acres within the state of Nevada; the Nevada portion does not include any mapped surface waters. The LTBMU model addressed the watershed as a whole, and it is not possible to separate California and Nevada loading categories.)

Model Results Used in TMDL Load Allocations

Mitigation and Management Factors

The WRENNS/MUSLE model does not account directly for certain management and mitigation activities which are important at Heavenly and which can significantly affect sediment delivery from a ski run or road. Table 3 below summarizes the management and mitigation coefficients the LTBMU model factored into a ski run or road's total sediment delivery value. Many of these coefficients were based upon research in the Idaho Batholith (Megahan and Kidd, 1972, Burroughs and King, 1989).

Table 3. Management and Mitigation Factors for Determining Sediment Delivery from Ski Runs and Roads (from Holland, 1993).

Description	Factor
Construction Timing/Maintenance	
Newly Constructed (first year only)	13.5
Second Year Construction	3.6
Regrading	4.0
Mitigation Measures	
Obliterated	0.05
Graveled	0.55
Riprap Fill	0.90
Successful brush fill barrier	0.93
Rocklined ditch	0.80

The following is an example of the use of the "Construction Timing/Maintenance" coefficients in the LTBMU model. The coefficient for a newly constructed ski run or road reflects significant soil instability during the first and second years following disturbance. A factor of 13.5 is multiplied into the road or run's modeled total sediment delivery for the first year after construction, and a factor of 3.6 is multiplied into modeled sediment delivery for the second year following construction. A ski run with sediment delivery initially calculated at 10 tons per year would, if newly constructed, have an adjusted sediment delivery rate of 135 tons per year (10 tons/yr x 13.5). The following year, estimated sediment delivery would drop to 36 tons/yr (10 tons/yr x 3.6) Thereafter, the estimated sediment delivery would be 10 tons/yr. If the ski run had erosion problems during the third year, its sediment delivery value for that year would be adjusted upwards to a value greater than 10 tons/year. If Best Management Practices (BMPs) such as well placed water bars and revegetation were used, estimated sediment delivery could be adjusted to fewer than 10 tons per year.

As a second example, assume that an unpaved road with an initial modeled sediment delivery of 7.5 tons per year is regraded. Estimated sediment delivery for the first year after regrading is raised to 30.0 tons/year (7.5 tons/yr x 4.0). Modeled sediment delivery drops to 7.5 tons/yr during the following year assuming that BMPs have been applied. If the same road is graveled and its ditch is rock lined, modeled sediment delivery is adjusted to 0.675 tons per year (7.5 tons/yr x 0.45 x 0.20).

Mitigation measures can be combined and their factors summed to reflect additional levels of erosion control. To do this, the factors under the "Mitigation Measures" heading in Table 3 must first be subtracted from 1.0. The resulting "erosion reduction factors" can then be summed. For example, assume that an unpaved road is graveled, its ditch rock-lined, and its fill riprapped. The reduction factors respectively are 0.45, 0.20, and 0.10. Their sum is 0.75. A "sum mitigation factor" of 0.25 is obtained by subtracting 0.75 from 1.0. The initially calculated sediment delivery value for the road is then modified by the sum mitigation factor to obtain a new value reflecting mitigation. Given an initial road sediment delivery value of 9 tons/year, modeled sediment delivery adjusted for mitigation would be 2.25 tons/year (9 tons/year x 0.25).

The LTBMU model allows erosion reduction factors to be summed with the limitation in most cases that mitigation is assumed not to reduce erosion beyond 80 percent (an erosion reduction factor cannot be greater than 0.80 or a sum mitigation factor less than 0.20). However, when roads are obliterated, the model allows elimination of up to 95 percent of the erosion potential, and the mitigation factor becomes 0.05 (Holland, 1993).

The LTBMU also evaluated the water quality impacts of impervious surface within the Heavenly master plan area, but did not include them in the model of sediment delivery because impervious surfaces generally do not contribute sediment. Impervious surfaces do cause increased runoff and may therefore have offsite impacts such as accelerated streamflow and increased erosion downstream. Impervious surface was accounted for in the overall LTBMU evaluation of the water quality impacts of the Heavenly Ski Resort Master Plan (TRPA, 1995, 1996) and mitigation was required for the impacts of impervious surface separately from the watershed restoration program on which the TMDLs are based.

Mitigation Strategy

LTBMU staff modeled sediment delivery reductions expected from ski run and road segments which were to receive specific types of mitigation. These included abandonment and restoration of a number of road segments, and application of BMPs at two different levels of intensity ("TOC" and "HIGH") to other roads and to ski runs. "TOC" is related to a watershed sensitivity index developed for the Heavenly Valley Creek watershed, and indicates that BMPs will bring this segment to a level which is not expected to cause significant cumulative impacts. "HIGH" indicates a level of BMPs which will bring sediment delivery from the segment below the "TOC" level. The modeled sediment delivery reductions are shown in Table 4; the "Reason for Mitigation" column shows road segments to be abandoned and restored ("ABANDON") and differentiates between the "TOC" and "HIGH" strategies for BMPs.

The Heavenly Ski Resort Master Plan includes a remedial erosion control program which targets all road segments with modeled erosion rates of over five tons per acre per year and all ski runs with modeled erosion rates over one ton per acre per year. Mitigation *under the Master Plan* for road segments and ski runs with lower modeled erosion rates was not considered to be necessary. Remedial erosion control projects have been implemented for the impacts of ski resort development in various parts of the Heavenly Valley Creek watershed since the 1970s, which may account for the lower erosion rates for some of these source areas. However, the USFS is now requiring full application of BMPs for *all* disturbed areas in the watershed. Regional Board staff's TMDL instream load allocations reflect the relative percentages of contributions from mitigated hillslope sources, using specific assumptions about BMP efficiency and about USFS plans to apply BMPs to all disturbed areas.

References:

Burroughs, E.R. and J.G. and King, 1989. *Reduction of Soil Erosion on Forest Roads.* USDA Forest Service Intermountain Research Station. General Technical Report INT-264, July 1989.

Glancy, 1988. Streamflow, Sediment Transport, and Nutrient Transport at Incline Village Lake Tahoe, Nevada, 1970-73. U.S. Geological Survey Water Supply Paper 2313.

Holland, A. 1993. *Cumulative Watershed Effects Analysis for the Heavenly Ski Area, U.S. Forest Service,* Lake Tahoe Basin Management Unit; included as Appendix E in Tahoe Regional Planning Agency, 1995. *Heavenly Ski Resort Master Plan*, Volume 2.

Megahan, W.F., and W.J. Kidd, 1972. Effect of Logging Roads on Sediment Rates in the Idaho Batholith. USDA Forest Service Intermountain Forest and Range Experiment Station, Resource Paper INT-123., Ogden UT

Tahoe Regional Planning Agency, 1995, 1996. Draft and Final Environmental Impact Report/Environmental Impact Statement, Heavenly Ski Resort Master Plan, 5 volumes.

U.S. Environmental Protection Agency, 1999. *Protocol for Developing Sediment TMDLs*, First Edition. EPA 841-B-99-004.

U.S. Forest Service, 1980. *An Approach to Water Resources Evaluation on Non-Point Silvicultural Sources (A Procedural Handbook).* U.S. Environmental Protection Agency publication, EPA-600/8-80-012. Environmental Research Laboratory, Athens GA. (commonly called the "WRENNS Handbook".).

U.S. Forest Service, 1981. *Guide for Predicting Sediment Yields from Forested Watersheds.*

U.S. Soil Conservation Service, 1966. *Technical Note Agronomy, No. 6,* June 1966.