TOTAL MAXIMUM DAILY LOAD FOR BEDDED SEDIMENT

BLACKWOOD CREEK, PLACER COUNTY

Final Staff Report

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California Regional Water Quality Control Board, Lahontan Region
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1 INTRODUCTION

The Lahontan Regional Water Quality Control Board (Water Board) is the California state agency responsible for water quality protection east of the Sierra Nevada crest. It is one of nine Water Boards in California, each generally separated by hydrological boundaries. Each Water Board consists of nine governor-appointed members who serve four-year terms. The Water Board, under its federally designated authority, administers portions of the Clean Water Act (CWA) within the Lahontan Region.

In accordance with the CWA, the Water Board has adopted the *Water Quality Control Plan for the Lahontan Region* (Basin Plan) that specifies water quality standards for waters in the Lahontan Region and implementation measures to achieve those standards. Section 305(b) of the CWA mandates biennial assessment of the nation's water resources to identify and list waters not meeting their water quality standards. These waters are listed in accordance with CWA section 303(d), and the list is commonly referred to as the 303(d) list. The CWA requires states to establish a priority ranking for impaired waters and to develop and implement Total Maximum Daily Loads (TMDLs) to address the impairments.

A TMDL is a written, quantitative assessment of water quality problems and contributing pollutant sources. It identifies one or more numeric targets for restoring beneficial uses based on applicable water quality standards, specifies the maximum pollutant load that can be discharged and still meet water quality standards, allocates pollutant loads among sources in the watershed, and provides a basis for taking actions needed to meet the numeric target(s) and water quality standards.

Blackwood Creek is a tributary of Lake Tahoe, located in the central portion of the North Tahoe Hydrologic Area (HA No. 634.20). The creek was first listed as an impaired water body on the 303(d) list in the “305(b) Water Quality Report for Water Years 1988 – 1989” (State Water Resources Control Board, 1990). The listing was based on known sedimentation problems associated with instream gravel mining in the 1960s and almost 100 years of grazing and logging. The United States Forest Service (USFS) is now the primary landowner in the watershed and has been active in restoring both upland and instream problem areas. Blackwood Creek is also listed for nitrogen, phosphorous and iron; it is anticipated that the upcoming Lake Tahoe TMDL will address the nitrogen and phosphorous listings. The iron listing remains unresolved, but iron detected in Blackwood Creek is believed to be due to natural sources.

Results from recent watershed assessment work (Swanson, 2003) indicate that Blackwood Creek's bedded (bedload) sediment load exceeds that expected for the watershed. Studies also indicate that additional instream restoration activities are needed to restore beneficial uses. Since the 1970s, the USFS has implemented measures to improve and restore watershed function. Many of these measures focused on restoring upland conditions. More recently, the USFS has completed projects to restore instream habitat, and plans to continue this work by removing or stabilizing large areas of excessive bedded sediment that are impairing channel form and function in Blackwood Creek.

Water Board staff recommends that the Lahontan Water Board certify that the USFS's actions will meet the requirements of a TMDL to address bedded sediment problems adversely affecting water quality and beneficial uses in Blackwood Creek. These actions will result in delisting Blackwood Creek for sedimentation/siltation but will not address the listing for nutrients and iron.   This TMDL staff report describes the scientific and technical basis for confirming bedded sediment impacts, developing numeric targets, determining sediment sources, and establishing watershed loading capacity.

2 PROBLEM STATEMENT

Excessive amounts of coarse sediment have adversely affected water quality and beneficial uses in Blackwood Creek and its riparian corridor. Review of aerial photography, combined with recent geomorphic investigations, indicates that stream channel modifications from a historical, instream gravel mine supplied excessive sediment to the creek channel. The pollutant in this sediment TMDL is bedded (or bed load) sediment, which can be described as large particles, such as sand, gravel, or cobbles, that bounce or roll along a stream bed, and eventually accumulate in a loose, unconsolidated form on the bottom of stream or lake beds. The impairment in Blackwood Creek is characterized by a loss of diverse aquatic and riparian habitat. The impaired segment occurs from the former gravel pit at its upstream end and extends to a location approximately 6000 feet downstream of the Barker Pass Road crossing (Figure 1). Within the impaired segment, Blackwood Creek flows in a widened, straightened, and incised channel with large, inset, gravel terraces resulting from excessive amounts of bedded sediment. The headwaters of Blackwood Creek are not considered to be impaired.

2.1 DESCRIPTION OF THE WATERSHED

2.1.1 General Description and Land Use

The Blackwood Creek watershed is situated on the western side of the Lake Tahoe Basin, approximately four miles south of Tahoe City. The Blackwood Creek watershed is about eleven square miles in area, and is approximately five miles long and two miles wide. The watershed is shown in Figure 1.

Watershed elevations range from 6,230 feet at Lake Tahoe to 8,878 feet at Twin Peaks, on the northwestern divide between the Blackwood and Ward creek basins. Four similarly sized forks of Blackwood Creek drain the upper third of the watershed: the North Fork, two branches of the Middle Fork, and the main stem of Blackwood Creek. The gradients of the individual forks are steep, on the order of 10 percent. At the confluence of the Middle Fork and the main stem, the gradient decreases abruptly to about one percent.

There is an extensive history of human disturbance in the Blackwood Creek watershed. Past activities included livestock grazing, logging and forest road construction, and in-stream gravel mining (Figure 2).

- Cattle and sheep grazing began in the 1860s. Overgrazing had degraded the range to such poor conditions that grazing was closed in the Blackwood Creek watershed by about 1960.

- Most of the marketable timber was cut from the watershed by 1898 to support the Comstock mines in Nevada (Murphy and Knopp, 2000). Second growth timber was also harvested from the mid-1950s through 1970 throughout the watershed (Stubblefield, 2002).

- Many miles of road, logging spurs, and skid trails were constructed to support timber harvest activities in the 1950s and 1960s.

- A gravel pit operated in the channel and floodplain from 1960 to 1968. The operation included moving the main stem of Blackwood Creek out of its channel and floodplain and into a diversion channel to facilitate gravel extraction in the creek (e.g., Stubblefield, 2002).

Due to environmental impacts, these activities were stopped over three decades ago.

Current activities in the Blackwood Creek watershed are primarily recreational based, including fishing, camping, hiking, biking, cross country skiing, snowmobiling, and limited off-highway vehicle (OHV) use. The Barker Pass Road is the only paved road in the watershed; it roughly parallels the main stem of the creek and exits the watershed to the west (Figure 1). One OHV trail parallels the main stem, crosses the North Fork and follows a subdued ridge between the Middle Fork and the north branch of the Middle Fork; it intersects Barker Pass Road at Barker Pass.

Much of the historical logging, grazing, and mining activities were conducted on private lands. The USFS has acquired almost all of the land in the watershed. There are residential properties in the eastern portion of the watershed in the vicinity of Highway 89 and Lake Tahoe.

2.1.2 Climate

The climate in the Blackwood Creek watershed is typical of similar watersheds in the Lake Tahoe Basin. Average annual precipitation within the watershed is approximately 60 inches. Along the western boundary of the Blackwood Creek watershed an average of 80 inches of precipitation is recorded yearly, and as elevations drop fairly rapidly eastward to Lake Tahoe, the average annual precipitation decreases to 40 inches (Tetra Tech, 2001). Precipitation in the watershed falls mainly as snow, with about 80 percent of the total annual precipitation occurring from November to April. Less than four percent of the annual precipitation comes as infrequent summer thunderstorms from July through September (Swanson, 2003). A summary of monthly precipitation for Tahoe City from 1850 to 2001 is presented in Figure 3.

In the winter months, daily temperatures average around 30°F, with highs averaging about 42°F and lows averaging around 23°F. It is not uncommon for winter temperatures to reach into the teens or single digits, but is rarely recorded below 0°F. Daily summer temperatures average 55°F, with the average high and low daily temperatures ranging between 71°F and 41°F, respectively. High temperatures in the summer seldom reach over 80°F (NRCS Data Exchange Station – Ward Creek #3).

2.1.3 Geology

The geology of the Blackwood watershed is composed of Tertiary volcanic rocks, Jurassic metasedimentary rocks, and Quaternary glacial deposits (Saucedo and Wagner, 1992). Water Board staff estimate that approximately 10 percent of the rock in the Blackwood watershed is metasedimentary. Below elevations of approximately 7000 feet, Quaternary fluvial and glacial deposits overlie the volcanic rocks. A few outcrops of volcanic rock are exposed along Blackwood Creek. The volcanic and glacial deposits are more easily eroded and produce relatively high rates of sediment yield.

The topography of Blackwood Canyon, which includes steep canyon walls and a narrow valley bottom, was formed by multiple periods of Pleistocene glaciation. Swanson (2003) identified numerous landslides that post-date the most recent glacial deposits (Figure 4), and considers these landslide deposits to be significant factors in both sediment production and fluvial processes (including grade controls and hydraulic barriers).

2.1.4 Soils

The National Resource Conservation Service (NRCS, 2007) recently completed an update of the soil survey for the Lake Tahoe Basin. The primary soil series are composed of volcanic parent material, including andesite and andesitic tuff. Soil units are described below:

Ellispeak-Rock Outcrop complex
The Ellispeak-Rock outcrop complex comprises about 10 percent of the watershed area. These are shallow, excessively drained soils of andesitic origin and dominate the south facing slopes in the northern portion of the watershed.

Kneeridge Gravelly Sandy Loam
The Kneeridge Gravelly Sandy Loam comprises about 10 percent of the watershed area. These are very deep, moderately well and well drained soils that formed in colluvium and/or till derived from andesite and andesitic lahar. The Kneeridge soils are found primarily on the gently sloped valley sides in the eastern half of the watershed. It covers the valley bottom to the former gravel pit.

Waca Very Gravelly medial Coarse Sandy Loam
The Waca Very Gravelly Medial Coarse Sandy Loam comprises about 30 percent of the watershed area. This series consists of moderately deep, well-drained soils formed in material weathered from andesitic tuff. Waca soils are mapped throughout the watershed.

Sky Gravelly Sandy Loam
The Sky Gravelly Sand Loam comprises about 15 percent of the watershed. This series consists of moderately deep, well drained soils that formed from andesitic tuff. The Sky soils are found primarily in the headwaters of the South Fork and along the southern ridge line.

Melody-Rock Outcrop Complex
The Melody-Rock Outcrop Complex series comprises about 15 percent of the watershed. This series consists of shallow, excessively drained soils that formed in colluvium over residuum weathered from volcanic rock. The Melody soils are found predominately in the southern headwaters of the watershed.

Approximately 10 percent of the watershed is a complex of the Sky and Melody series. This complex is located along the ridgelines of the watershed.

The soils in the floodplain of Blackwood Creek, downstream of the gravel pit, are classified as part of the Tahoe series and named the Tahoe complex. The soils of this series are described as very deep, very poorly drained soils that formed in alluvium derived from mixed material, predominantly andesitic lahar and granodiorite.

2.1.5 Hydrology

The Blackwood Creek watershed is an oval shaped drainage that trends southwest – northeast and covers approximately 11.2 square miles (Figure 1). The top third of the drainage is steeply sloped, with gradients commonly over 10 percent. Four main feeder streams to Blackwood Creek originate in the upper, western portion of the watershed, and are (from north to south) the North Fork, the north branch of the Middle Fork, the Middle Fork, and the main stem of Blackwood Creek. These stream segments converge about four miles from the mouth of Lake Tahoe, where gradients average about two percent. The lower section of Blackwood Creek flows through a broad, alluvial valley floor where gradients are about one percent. The impaired portion of Blackwood Creek occurs in this broad alluvial valley. Figure 5 shows profiles and slopes of Blackwood Creek and its main tributaries. Two smaller streams emanate from both the north and south ridges to join the main branch about 2 miles from the creek's terminus at Lake Tahoe.

The steep western portion of the watershed functions as a sediment transport reach. The transition from steep upland topography to a gently sloped valley indicates a depositional zone. The coarse substrate at this grade transition (above the Barker Pass Road Bridge) allows the stream to go dry (the flow goes subsurface) by August during years with normal precipitation. Creek flows usually resume a short distance downstream of this area.

Surface water flow has been monitored since 1960 at the U.S. Geological Survey (USGS) stream flow gage located just upstream of the Highway 89 bridge. Mean daily flows for water years 1961 to 2006 are shown in Figure 6. Surface water flow rates and quantities in Blackwood Creek are primarily determined by snowpack accumulation and subsequent melting, with peak runoff associated with spring thaw and rain on snow events.

The mean maximum monthly flow of 129 cubic feet per second (cfs) and the mean maximum daily flow of 151 cfs occur in May (Swanson, 2003). Infrequent rainstorms during the summer months usually become absorbed into the soil and typically do not significantly affect streamflow. Summer flows are usually between 1 and 4 cfs. Historical reports by California Department of Fish and Game (DFG) biologists mention Blackwood Creek going dry in the vicinity of the Barker Pass Road crossing (DFG, 1934; 1954).

Bankfull flow is estimated to occur at 290 cfs in Blackwood Creek (Swanson, 2003). Stream flow records indicate bankfull discharges or greater occur on the average every 1.5 years. Peak flows of 580 cfs have a recurrence interval of every three years, while peak flows of 1460 cfs have a recurrence interval of 10 years (Swanson, 2003). An average snow melt peak is about 150 cfs (Swanson, 2003). The largest peak flow on record of 2,940 cfs occurred on January 1, 1997, a rain on snow event with an estimated recurrence interval of 36 years. The ten largest peak flows on record are all associated with rain on snow events.

Streambed mobilization analysis by Tetra Tech (1999) indicated that channel changing flows are larger than a typical spring snow melt flow. The larger rain-on-snow events modify channel morphology while snowmelt peaks tend to “refine and sculpt the channel” (Swanson, 2003).

2.1.6 Biota

Red fir, white fir, western white pine, and Jeffrey pine dominate the upland hillslopes. As Blackwood Creek begins to decrease in gradient, the lower slopes and valley bottom are comprised of white fir, red fir, and lodgepole pines. The riparian corridor includes cottonwoods, aspens, alders, dogwoods, and willows. In the lower reaches of the valley, sedges, willows, and riparian grasses become more common in the remaining meadow environments, with lodgepole pines encroaching into desiccated meadow reaches.

A few aspen stands exist in the upper reaches of both the north and south forks, and some old growth stands of Jeffrey pine can still be found in the lower tributaries near the mouth (Murphy and Knopp, 2000). Meadows in the valley of the Blackwood Creek watershed, from the mouth upstream to the old gravel pit vicinity, have been identified as areas of potential hotspots for total bird species richness. The entire length of Blackwood Creek and tributaries were also ranked in the highest richness class for potential hotspots of plant species (Murphy and Knopp, 2000).

The Lake Tahoe Basin has over 200 species of birds, either as residents or regular visitors. Also present are some 60 mammals, eight reptiles, and about five different amphibian species. Many of these species can be expected to occur in the Blackwood watershed. A review of the California Natural Diversity Database[1] for the Homewood Quadrangle identified the following species as threatened, endangered, or of special concern.

- northern goshawk (DFG special concern)
- willow flycatcher (State endangered)
- Sierra Nevada snowshow hare (DFG special concern)
- Pacific fisher (Federal candidate, DFG special concern)
- Tahoe yellow cress (Federal candidate, State endangered)

Blackwood Creek has been described as one of the most productive and important tributaries for fishery resources in the Lake Tahoe Basin (Murphy and Knopp, 2000; Tetra Tech, 2001). Historically, Blackwood Creek provided habitat for as many as seven native species of fish. Lahontan cutthroat trout (LCT) and mountain whitefish were the most abundant and highly valued by both the native Washoe inhabitants and early Euro-American settlers. The Washoe established seasonal camps near the mouth of Blackwood Creek, utilizing spears, baskets, and fish traps to capture large cutthroat trout and whitefish.

After the arrival of Euro-Americans to the Lake Tahoe Basin in the 1850s, the composition of fish species inhabiting Lake Tahoe and its tributaries was dramatically altered. Commercial fishing greatly reduced populations of whitefish and Lahontan cutthroat trout in Lake Tahoe by the turn of the 20th century. Decades of over-fishing, pollution and obstruction of streams from logging and fluming activities, and the introduction of non-native species contributed to the extinction of LCT in Lake Tahoe. The last documentation of LCT in Lake Tahoe was reported in 1938 (Murphy and Knopp, 2000), while the last documented occurrence of LCT in Blackwood Creek appeared in a DFG stream survey report (DFG, 1934).

The DFG began stocking Blackwood Creek in the early 1930s, supplying fingerling and catchable trout for anglers on a regular schedule beginning in 1933. Brook and rainbow trout were the principal species stocked, with approximately 4,000 trout introduced into Blackwood Creek annually. Hatchery raised trout dominated Blackwood Creek's fishery to the end of supplemental trout stocking in 1953.

DFG personnel filed a fishery survey and resource assessment report in 1962. To assess angling success on Blackwood Creek, a creel census was conducted in lower Blackwood Creek over an early July weekend in 1961. Over the two days of the creel census, 118 anglers were interviewed and averaged a combined success rate of nearly one fish caught per hour, which was considered to be "good trout angling" (DFG, 1962). Nine years after stocking ceased, the report describes the resident trout population as "providing sufficient recreation for anglers."

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[1] http://www.dfg.ca.gov/bdb/html/cnddb.html

A stream survey conducted by DFG (1971) indicated that accumulated gravel and silt at the mouth of Blackwood Creek was not a significant barrier to fish migration during high flows, but also states "…this should be looked at during the fall." (A resident with a pier near the mouth of Blackwood Creek noted a reduction in water depth at his pier from about 12 feet to about one foot as a result of sediment deposition from Blackwood Creek.) This same survey identified spawning gravel conditions as "…fair to good throughout the stream."

2.2 BENEFICIAL USES OF BLACKWOOD CREEK

Water quality standards include designated beneficial uses of water and narrative and numeric water quality objectives (WQOs) established to protect those uses. Chapter 2 of the Basin Plan contains definitions of the beneficial uses assigned to waters in the Lahontan Region. The designated beneficial uses of Blackwood Creek are:

- Cold Freshwater Habitat (COLD)
- Commercial and Sportfishing (COMM)
- Migration of Aquatic Organisms (MIGR)
- Municipal and Domestic Supply (MUN)
- Water Contact Recreation (REC-1)
- Non-Contact Water Recreation (REC-2)
- Spawning, Reproduction and Development (SPWN)
- Wildlife Habitat (WILD)

The beneficial uses of particular concern are those related to aquatic and riparian habitat (COLD, SPWN, WILD), because those appear to be most sensitive to excessive sedimentation. The Basin Plan definitions of these beneficial uses are presented below:

- 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.

- 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.

- Wildlife Habitat (WILD): Beneficial uses of waters that support wildlife habitats including, but not limited to, the preservation and enhancement of vegetation and prey species used by wildlife, such as waterfowl.

2.3 WATER QUALITY OBJECTIVES

Sediment-related water quality objectives established in the Basin Plan are in both narrative and numeric forms.

2.3.1 Narrative Water Quality Objectives

The majority of sediment-related water quality objectives are expressed in narrative form based on the protection of beneficial uses. These WQOs are presented in Chapter 5 of the Basin Plan, and reproduced in Table 1.

Table 1
Sediment-Related Narrative Water Quality Objectives Contained in the Basin Plan

Objective	Description
Sediment	The suspended sediment load and suspended sediment discharge rate of surface waters shall not be altered in such a manner as to cause nuisance or adversely affect the water for beneficial uses.
Settleable Materials	Waters shall not contain substances 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.l milliliter per liter.
Suspended Materials	Waters shall not contain suspended materials in concentrations that cause nuisance or that adversely affects the water for beneficial uses. For natural high quality waters, the concentration of total suspended materials shall not be altered to the extent that such alterations are discernible at the 10 percent significant level.
Turbidity	Waters shall be free of changes in turbidity that cause nuisance or adversely affect the water for beneficial uses. Increases in turbidity shall not exceed natural levels by more than 10 percent.
Nondegradation Objective	Whenever the existing quality of water is better than the quality of water established in the Basin Plan as objectives (numeric or narrative), such existing quality shall be maintained unless appropriate findings are made under Resolution No. 68-16 "Statement of Policy with Respect to Maintaining High Quality Waters of California."

2.3.2 Numeric Water Quality Objective

Suspended sediment is defined by the USGS[2] as “sediment that is maintained in suspension by the upward components of turbulent currents or that exists in suspension as a colloid.” The Basin Plan includes a numeric WQO for suspended sediment for streams tributary to Lake Tahoe:

> Suspended sediment concentrations in streams tributary to Lake Tahoe shall not exceed a 90th percentile value of 60 mg/L (Basin Plan, page 5.1-10).

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[2] http://pubs.usgs.gov/wdr/2004/wdr-nd-04-1/htdocs/Output/intro.sw.04.html#885359

The USGS has collected daily stream flow data near the mouth of Blackwood Creek (USGS gauging station 10336660) since 1960. Beginning in 1974, the USGS, through the Lake Tahoe Interagency Monitoring Program (LTIMP), has collected surface water samples from Blackwood Creek for laboratory analyses, including suspended sediment concentration (SSC). Staff reviewed all SSC data, a total of 552 results, through September 2004[3].

The SSC data collected at the Blackwood Creek gauging station is targeted toward "storm runoff and spring snowmelt runoff" (Rowe et al., 2002). The sample bias toward high flow sample events is displayed in Figures 7 and 8. Figure 7 shows that about two-thirds of the suspended sediment samples were collected during the highest 25 percent of the flow regime. Figure 8 shows that about half of the suspended sediment samples were collected in April, May, and June. The 90th percentile SSC for the LTIMP dataset (through September 2004) is 374 mg/L.

Because of the sample bias toward high flow events, the 90th percentile of SSC data would also be biased high. For that reason, Staff does not believe that the existing SSC dataset is appropriate for direct comparison to the suspended sediment numeric WQO. To characterize the 90th percentile value, the dataset should be representative of conditions throughout the year. Therefore, to interpret compliance with the suspended sediment WQO, Staff used sediment rating relationships developed by Simon et al. (2003) to predict the 90th percentile SSC for Blackwood Creek.

Sediment rating relationships express the mathematical relationship between SSC data and streamflow data. The 90th percentile flow can be easily determined from the USGS flow data. The regression equations can then be used to estimate suspended sediment concentrations at the 90th percentile flow. Based on this method, Staff concluded that the 90th percentile suspended sediment WQO is being met at the Blackwood Creek gauging station.

Simon et al. (2003) reviewed the dataset for Blackwood Creek and developed rating relationships based on the LTIMP co-collected instantaneous stream flow and grab sample SSC measurements. The SSC data used by Simon et al. consisted of 483 samples collected from 1974 to 2002.

At Blackwood Creek, Simon et al. (2003) found that different flows required different rating curves. They also found that the flow-SSC relationships changed following the January 1997 flood event. These results, which indicate lower suspended-sediment loads following the January 1997 event, probably reflect a large flushing of stored sediment (Simon et al., 2003). The rating curves developed by Simon et al. (2003) are shown in Table 2.

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[3] http://nwis.waterdata.usgs.gov/ca/nwis/qwdata/?site_no=10336660&agency_cd=USGS

Table 2
Suspended Sediment Rating Relationships

Pre-1997 suspended sediment rating relations
• $L = 0.07*Q^{1.48}$ (flows less than 1.47 m^3/sec)
• $L = 1.15*Q^{2.09}$ (flows greater than 1.47 and less than 10.62 m^3/sec)
• $L = 1.35*Q^{2.18}$ (flows greater than 10.62 m^3/sec)
Post-1997 suspended sediment rating relations
• $L = 3.41*Q^{2.16}$ (flows less than 0.37 m^3/sec)
• $L = 0.865*Q^{1.11}$ (flows greater than 0.37 and less than 2.49 m^3/sec)
• $L = 0.12*Q^{3.37}$ (flows greater than 2.49 m^3/sec)
L = load in metric tons per day (1000 kg/day) Q = flow in cubic meters per second (m^3/sec)

The 90th percentile flow for the time period 1961 to 2006 is 107 cubic feet per second or 3.0 cubic meters per second (m^3/sec). By using this flow in the appropriate rating relationships above, daily loads at the 90th percentile flow are calculated. After conversion to equivalent units, the daily load is divided by the 90th percentile flow to calculate a 90th percentile suspended sediment concentration. Dimensional analysis shows that load divided by flow is equal to concentration:

(milligrams/day) / (liters/day) = milligrams/liter

The following results for daily loading and associated SSC are obtained using the 90th percentile flow and the appropriate rating equation:

Pre-1997:	11.4 metric tons per day	44 mg/L suspended sediment
Post-1997:	4.9 metric tons per day	19 mg/L suspended sediment

Therefore, the suspended sediment WQO, as estimated for the time period 1961 – 2006 using the rating curves described above, is met at the Blackwood Creek gauging station. For comparison purposes, using the post-1997 rating relationships, the calculated SSC at the mean maximum daily flow of 151 cfs (4.3 m^3/sec) is 44 mg/L, and at a summer flow of 4 cfs (0.11 m^3/sec) is 4 mg/L.

Staff also reviewed a second dataset with SSC information (USFS, 1994); these data were collected and presented by the USFS, Lake Tahoe Basin Management Unit (LTBMU). The LTBMU sampled four stations along the creek between 1980 and 1993. Sampling was concentrated during high flow periods. Over 500 samples were collected; only one sample exceeded 60 mg/L. This further indicates that suspended sediment concentrations probably meet the current WQO.

Although suspended sediment concentrations meet the WQOs, bedded sediment remains in the system at excessive levels. The following section describes the evidence of impairment in Blackwood Creek and ties the impairment to excessive bedded sediment.

2.4 BENEFICIAL USE IMPAIRMENT

WQOs are established to protect beneficial uses. Numeric WQOs are established such that an exceedance of the objective indicates an impairment of beneficial use(s); narrative WQOs are somewhat different. While narrative WQOs are also established to protect beneficial uses, they typically do not specify a level that is harmful. For example, the narrative WQO for settleable solids states:

> Waters shall not contain substances in concentrations that result in deposition of material that causes nuisance or that adversely affects the water for beneficial uses (Basin Plan, page 3-6).

Therefore, it is important to describe the conditions of impairment to demonstrate either a violation of a narrative WQO or an impaired beneficial use. This section focuses on the physical damage to the riparian and in-stream habitat of Blackwood Creek caused by excessive bedded sediment. This damage has impaired the COLD, SPWN, and WILD beneficial uses resulting in a violation of the settleable solids WQO. The impaired segment occurs from the gravel pit at its upstream end and extends to a location approximately 6000 feet downstream of the Barker Pass Road crossing (Figure 1).

These beneficial uses support aquatic and riparian ecosystems and have been impaired by excessive bedded sediment which resulted in a change from diverse and complex to homogeneous and low quality habitat. For example, riffles and pools that provided spawning and resting habitat for trout have been replaced with long, shallow runs that do not provide cover, spawning habitat, or food. This section also describes impairment, primarily to the MIGR[4] beneficial use, from several manmade structures.

2.4.1 Former Impairments to Fish Migration

In light of the complex history of the fishery in Blackwood Creek and Lake Tahoe, the fishery seemed to be in good condition from the 1930s through the 1950s; however, it was also stocked for most of that period. Even in 1971, after almost 10 years of in-stream gravel mining, DFG found the creek to be in fair to good condition. Until recently, two manmade structures likely impaired the MIGR beneficial use: (1) culverts installed at the Barker Pass Road crossing, and (2) the fish ladder at the diversion structure (Figure 9).

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[4] Basin Plan definition: Migration of Aquatic Organisms - 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.

- The USFS originally installed the fish ladder in 1979 to prevent headcutting upstream of the gravel pit. The area beneath the fish ladder became a deposition zone for coarse material (gravel and cobbles). It no longer provided adequate fish passage during high flows and surface flow disappeared in this deposited porous material during low flows (Tetra Tech, 1999). The USFS removed and replaced the fish ladder in 2001 with a boulder step-pool channel.

- In the fall of 2006, the USFS installed a clear-span bridge to replace the Barker Pass Road crossing, which had consisted of a 7-foot-diameter culvert set in a concrete roadway. Outfall height and water depth were barriers to fish migration. Additionally, high velocity flows that exited the former culvert caused scour and bank erosion downstream of the crossing. The bridge installation included the reconstruction of about 250 lineal feet of channel.

The removal and replacement of the fish ladder and culvert have removed the impairment associated with fish migration.

2.4.2 Excessive Bedded Sediment Effects on Channel Form

Fluvial environments are conveyance systems for water and sediment produced in a watershed. Sediment is an important, naturally occurring component of healthy streams and rivers that benefits many elements of the biologic community. However, an excessive amount of bedded sediment in streams can have adverse effects on the riparian and in-stream biologic communities, as well as recreational uses.

Bedded sediment can be described as large particles, such as sand, gravel, or cobbles that bounce or roll along a streambed, and eventually accumulate in a loose, unconsolidated form on the bottom of the stream. Excessive bedded sediment is stored primarily as bars, terraces, and gravel beds. These in-channel bars re-direct flows and cause increased bank erosion. Increased bank erosion widens the channel resulting in larger flows being contained within the main channel, further increasing bed and bank erosion. In this type of destabilized fluvial environment, large precipitation events cause extensive erosion of stream banks and flood plains, and remobilization of streambed material. The end result is a straightened channel with coarsened bed material and filled-in pools. Sparsely vegetated gravel bars replace ecologically valuable areas, including riparian habitat, wetlands, and meadows.

These changes to channel form and velocity distribution resulting from increased sediment deposition can limit the migration and movement of aquatic organisms. Undesirable substrate material can adversely impact swimming, wading, fishing, and aesthetic enjoyment of streams.

2.4.3 Instream and Riparian Habitat Impairment

The instream and riparian habitat impairment is distinguished by a dramatic change in the geomorphic character of the stream. The impaired portion of the stream occurs from the former gravel pit and extends several miles downstream (Figure 9). This area formerly consisted of pools and riffles in the stream, wet and dry meadows in the floodplain, and riparian vegetation providing shade and cover along the banks of the creek (Swanson, 2003). Barren deposits of sand and gravel, along with a wider and shallower creek with long shallow runs, have replaced much of this formerly diverse and complex habitat.

Gravel Pit

A gravel pit was constructed in a former meadow reach of Blackwood Creek and operated from 1960 to 1968 (Figures 9 and 11). The gravel pit operations included moving the main stem of Blackwood Creek out of its channel and floodplain and into a diversion channel to facilitate gravel extraction in the creek. The USFS decommissioned the diversion channel and returned Blackwood Creek to its original course in 1981. Beginning in 1987, the USFS installed gabion checkdams, removed or regraded relict mining berms, and added riparian vegetation to create a wetland environment in this area. The aquatic and riparian habitat degradation visible today and described below appears to have started shortly after the gravel pit construction (see Section 4).

Habitat Impairment

Aerial photographs from 1939 show Blackwood Creek to be contained in a narrow and meandering channel with a wide, vegetated floodplain in the area below where the gravel pit would be constructed. DFG records in 1934 and 1938 described Blackwood Creek as “a wonderful stream for spawning in normal winters,” having “good natural propagation,” and containing “beautiful pools, continuous shade, and shelter.” Swanson considers the 1939 aerial photograph (Figure 10) to show a relatively undisturbed channel condition and indicates that the channel was resilient, stating:

> “Large floods resulting from rain-on-snow events probably caused only limited changes in channel and floodplain morphology historically.” (page 48)

In 1962, DFG staff first described aquatic and riparian habitat degradation, reporting:

> “There has been considerable degradation through bank erosion, gravel removal, and lowered summer and fall flows. Soil from eroded banks has caused sedimentation which has reduced areas of food production, shelter and spawning” (DFG, 1962).

The DFG findings are supported by changes in stream channel patterns from 1939 to 1965 (Swanson, 2003). The 1965 channel is significantly wider and less sinuous than the 1939 channel (Figure 10). Swanson’s interpretation is that the channel is no longer able to withstand the force of large runoff events, stating:

> “Today, these large floods cause extensive, system-wide erosion of streambanks and floodplains. Even smaller snowmelt floods, which historically had limited

> morphological consequences, have the ability today to cause large changes in channel and floodplain morphology" (Swanson, 2003, pg. 48).

The relatively fragile environment from the cumulative affects of historical logging and grazing are important in the degradation of Blackwood Creek. For example, logging on the floodplain and in the riparian corridor reduced floodplain roughness and streambank stability, both of which provide resistance to change. Large gravel bars, or inset terraces, likely deposited during gravel pit operations, initiated a geomorphic change of Blackwood Creek. These inset terraces re-directed large snowmelt and rain on snow flows, eroding streambanks and widening the channel. As the channel widened, floodplain was lost and the creek lost ability to dissipate energy, which, in turn, fed the degradation process. Blackwood Creek has lost its resiliency to withstand large flow, and significant erosion now occurs during high flow events.

Below the gravel pit, bedded sediment deposition reduced the number and quality of pools and riffles, leaving calm shallow water runs and glides. Pools provide cover, shelter, and resting areas for fish. Riffles aerate the water, harbor most of the insect life, and are used by fish as primary feeding and spawning sites (e.g. NRCS, 2000). Swanson (2003) states: "Throughout the meadow reaches, pools were rare and of poor quality with little cover other than water depth" (page 51). This excess bedded sediment, as noted by Tetra Tech (1999), limited the availability of suitable rearing habitat. "Aggradation of gravels and cobbles throughout the lower portion of Blackwood Creek has resulted in widened and shallow channel habitat, generally unsuitable for older juvenile salmonid rearing habitat." The conversion of pool and riffle habitat to homogeneous shallow runs indicates that the COLD and SPWN beneficial uses are impaired.

The construction of the gravel pit, deposition of large gravel bars and associated erosion of stream banks also resulted in the loss of hundreds of acres of riparian cottonwood forest and meadow habitat (Todd, 1989). Wet and dry meadows and meandering channels have been replaced with alluvial wash (deposited bedded sediment filling the channel or outside of the channel) or dry vegetation species such as lodgepole pine. There has been an overall change from ecologically important and productive habitat to habitat with little ecological value, since much of it is nearly barren. Wetland and meadow habitats typically provide important environment for mammals, birds, and amphibians. For example, Swanson (2003) explains that salamanders share burrows excavated by mice and gophers. Replacement of wetland and meadow habitat with alluvial wash, which is unsuitable for burrowing, affects both mammals and amphibians. Staff believes the loss of acres of meadow and shrub communities is evidence of impairment of the WILD beneficial use.

While there is little quantitative data on species loss, it is clear that ecologically important instream, riparian, and floodplain habitat has been lost and beneficial uses of Blackwood Creek have been impaired.

3 NUMERIC TARGETS

CWA section 303(d)(1)(C) states that TMDLs "… shall be established at a level necessary to implement the applicable water quality standards." Water quality standards include the designated beneficial uses of waters and the water quality objectives established to protect beneficial uses. Because the applicable water quality objectives for this TMDL are narrative, rather than numeric, targets were developed to assess attainment of sediment-related water quality objectives and ensure protection of aquatic life beneficial uses. Targets for desired physical habitat in Blackwood Creek were selected from goals of the USFS's in-stream restoration project for Blackwood Creek (Swanson, 2003).

The targets apply to the reach of Blackwood Creek within the restoration project area. This is consistent with EPA's Sediment TMDL guidance (1999), which states that "indicators should be sensitive to geographical and temporal issues; they should be placed or located where impacts occur."

3.1 TARGET DEVELOPMENT

Targets were developed for Blackwood Creek based on the objectives of the USFS restoration project and geomorphic assessment work and recommendations by Swanson (2003). As outlined in Swanson (2003), the USFS objectives for the Blackwood Creek restoration project are:

1) A stream channel and riparian area that have reduced streambank erosion and improved water quality
2) A stream channel and floodplain that are dynamically stable with sediment transport continuity and floodplain connectivity
3) A range of aquatic habitats and associated riparian areas to improve and support the desired riparian ecosystem.
4) A stream channel and riparian restoration design that meets the management direction, goals, standards and guidelines of the Sierra Nevada Forest Plan Amendment.

To meet these objectives, Swanson recommended restoration of geomorphic processes through removal of bedded sediments, channel modification and/or revegetation. This will lead to the storage of sediment on the floodplain, with corresponding increases in groundwater elevation and vegetation growth. Successful revegetation will create the streambank and floodplain stability necessary to approximate historical stream and floodplain form and function. Swanson recommends several goals to evaluate restoration success:

- Increases in vegetative cover
- Increases in channel sinuosity
- Increases in reach-scale bank stability

Achieving the USFS restoration project objectives will restore the COLD, SPWN, and WILD beneficial uses. The project goals outlined above comprise the targets for this TMDL.

3.2 TARGETS

For each target, the long-term desired future condition is described, along with a measurable trend to assess interim progress. Given the inherent complexity of river processes, channel form, and riparian ecology, it is not possible to predict with certainty the response of a stream to restoration activities, or random events such as fires, droughts, floods, or climate fluctuations. Therefore, long-term desired conditions may require 20 years following restoration to become established (Swanson, 2003). However, progress towards these conditions should be measurable and sustainable. Interim measurable trends will provide a feedback loop to assess this progress and guide any additional restoration needs and efforts in subsequent years.

3.2.1 Vegetation

Discussion

Riparian vegetation plays an important role in the maintenance of stream and bank stability. The presence of vegetation in riparian areas reduces the rate of erosion and maintains a level of stability. Vegetation supports streambank soils, preventing or inhibiting collapse. Riparian vegetation provides cover and shade for fish, reduces stream temperatures, and is important habitat for other aquatic species.

Existing Conditions

According to Swanson (2003), much of the historical vegetation in the project area has been modified by human activities. Construction of the gravel pit directly destroyed a large meadow. Channel incision caused by gravel extraction disconnected floodplains upstream from the pit, resulting in conversion of floodplain vegetation communities to drier conditions. Throughout the upper half of Reach 6 (Figure 9), channel destabilization converted almost 20 acres of meadow and riparian shrub to alluvial wash.

Long-Term Target Conditions

Desired future conditions related to vegetation for meadow ecosystems such as Blackwood Creek are taken from the USFS's Sierra Nevada Forest Plan Amendment goals:

> The ecological status of meadow vegetation is late seral (50 percent or more of the relative cover of the herbaceous layer is late seral with high similarity to the potential natural community). A diversity of age classes of hardwood shrubs is present and regeneration is occurring. Vegetative rooting occurs throughout the soil profile; root masses stabilize streambanks against cutting action.

Interim Target

The interim target for vegetation is an increasing trend by year five following restoration in the establishment and maintenance of vegetation along the stream channel and floodplains.

Increasing vegetative cover will also indicate recovery of other important elements of stream and floodplain function, including:

- More stable alluvial wash areas due to increased vegetation. Additional vegetation and stabilization will provide better aquatic life habitat in these areas. Extensive alluvial wash areas are mapped in Reaches 2, 4, 5 and 6 of the USFS restoration plan. These areas are downstream from the former gravel mining area. Reach designations are shown in Figures 9, 10 and 12.

- Storage and sorting of fine sediment in the channel and on the floodplain, providing rooting substrate and moisture retention for more persistent vegetative cover. This will provide additional channel and floodplain stability and complexity.

- Increase in groundwater elevations, allowing widespread and long-term survival of plant communities. It is likely that destabilization of the channel resulted in the lowering of the floodplain groundwater table; therefore, increases in vegetation will indicate a more stable channel form is evolving.

- Resistance to erosive forces, resulting in reduction in fine and coarse sediment inputs, and increased channel sinuosity. For example, increased channel sinuosity will occur, in part, due to vegetation colonization of sediment deposits. Vegetation will stabilize these deposits, reinforcing increases in sinuosity. Vegetative establishment also tends to increase the hydraulic roughness of streambanks, another factor that tends to increase sinuosity, while stabilizing the streambanks from erosion.

3.2.2 Channel Sinuosity

Discussion

Sinuosity is the ratio of stream length to valley length; a sinuosity of 1 indicates a completely straight channel. Increased sinuosity provides more diverse and complex aquatic habitats and a channel that is better able to resist erosion when flows increase. The absorption of energy by meander bends protects the stream from excessive erosion and provides shelter for benthic invertebrates and fish during high flow events. The Blackwood Creek today channel is wider, straighter, and much less stable that the historical channel. The average sinuosity is currently 1.05, with a maximum value of 1.56 recorded in Reach 4 (Swanson, 2003).

The interim target for sinuosity is an increasing trend in channel sinuosity that is maintained following 25-year flood events. Initial increases in channel sinuosity will likely be accomplished through engineered solutions such as placement of debris jams and channel re-grading. Over time, it is expected that gains in other areas, such as vegetation trends, will result in improving channel and floodplain structure such that sinuosity will continue to increase.

Long-Term Target Conditions

Prior to human disturbance, Blackwood Creek channel was narrow and sinuous. In 1939, the average channel sinuosity in the project area was 1.6, with a maximum sinuosity of 1.77 recorded in Reach 3. Therefore, throughout the project area, the long-term average channel sinuosity should be greater than or equal to 1.6 by year 20 following restoration. It should be noted that flow conditions could significantly affect this long-term target. It is possible that a large rain on snow event could damage engineered controls or drought conditions may not provide sufficient flows to develop increased sinuosity.

3.2.3 Streambank Stability

Discussion

Streambank erosion is a natural process, but acceleration of this process leads to a disproportionate sediment supply, stream channel instability, land loss, habitat loss and other adverse effects (USEPA, 2006). Tetra Tech mapped eroding streambanks at Blackwood Creek (Figure 3.17, Tetra Tech, 1999). The majority of streambank erosion appears to occur in Reaches 3, 4, and 6.

Long-term Target Conditions

The Blackwood Creek stream restoration project should achieve 80 percent bank stability throughout the project area. This target is based on Swanson's (2003) suggested goal and is consistent with a Water Board staff literature review on streambank erosion benchmarks that represent desired conditions (LRWQCB, 2007).

In places, it may be expected that as initial channel migration occurs (due to increased sinuosity), increases in bank erosion may be observed. However, as vegetation increases, long-term bank erosion measurements should decrease in response.

4 SOURCE ASSESSMENT

The purpose of a source assessment is to characterize the types, magnitudes, and locations of sources of sediment loading to the waterbody. As explained in the Problem Statement, habitat impairment associated with excessive coarse sediment occurs from the former gravel pit area and extends for several miles downstream.

The Blackwood Creek sediment TMDL is distinct from many sediment TMDLs completed in California (e.g., Garcia River, Redwood Creek, Squaw Creek, South Fork of the Eel River, South Fork of the Trinity River). These sediment TMDLs primarily address ongoing upland watershed disturbances and suspended sediment-related impairment. In contrast, the primary impairment in Blackwood Creek is due to channel instability associated with bedded sediment from legacy land uses.

This section first discusses the upland areas of the Blackwood Creek watershed. While the uplands are not considered an ongoing source of bedded sediment, it is important to explain the restoration activities that led to this consideration. This section then describes how the former gravel mine operation was the likely source of excessive bedded sediment. The gravel mine is regarded as a historical source, while the current source is the bedded sediment that occurs as large gravel bars in the channel and floodplain of Blackwood Creek.

4.1 UPLAND CONDITIONS

The current upland areas of the Blackwood Creek watershed are not obvious sources of excessive sediment. Because neither logging nor grazing has occurred for over 30 years, the watershed has had significant time to heal from these activities. Additionally, the USFS has been working in the watershed since the late 1970s to mitigate impairments from past disturbance. The work has focused on erosion control and reducing runoff intensity.

Restoration of upland areas in the Blackwood Creek watershed includes:

- Elimination of grazing
- Discontinuation of timber harvesting
- Paving the Barker Pass road and armoring associated conveyances
- Installation of waterbars and closing of logging spurs
- Revegetation
- Stabilization of gullies
- Closing of four wheel drive trails in the north fork area
- Drainage improvement on the middle fork OHV trail

Swanson (2003) states that "…much of the readily treatable upland disturbance created by logging and grazing has already been addressed…"

4.2 HISTORICAL SOURCE OF BEDDED SEDIMENT

While it is not possible to point to a single cause of the degradation in Blackwood Creek, the timing suggests that the construction of the gravel pit and associated diversion channel was the primary cause (e.g., Swanson, 2003; Todd, 1989). Figure 11 is an aerial photograph obtained from DFG files that shows the gravel pit operation and diversion channel (DFG, 1960). “Of all the disturbances of the Blackwood watershed, the impact of a gravel quarry contributed the most to the destruction of riparian habitat” (Todd, 1989). The gravel pit was constructed in the Blackwood Creek stream channel, and operated from 1960 to 1968. Blackwood Creek was in good condition until floods in the early 1960s started the damage that still exists today.

> “In 1960, private interests began to remove gravel from 30 acres of stream zone. Fifteen acres of the floodplain was leveled and surfaced to provide a staging area for rock crushing and quarry operations. To mine the gravel, a diversion channel was constructed through which Blackwood was diverted around the excavation site. This left several large meanders of the creek free of water and open to use as a gravel pit” (Todd, 1989).

As explained by Todd (1989), Blackwood Creek was placed in a 2000-foot-long diversion channel south of the gravel pit. Bed and channel scour of the fragile, freshly exposed soils of the diversion channel is believed to have been a very large source of sediment. In addition to unstable soils, the diversion channel had a steeper gradient and was more efficient at moving water and sediment than the historical channel. Swanson (2003) noted:

> “During the gravel mining period, sediment yields were estimated at four times their normal rate for even minor runoff events (Suhr, 1971). Much of the increased sediment supply probably consisted of relatively coarse bedload.”

Prior to the construction of the gravel pit, this area of Blackwood Creek was a meadow set in a broad valley. Flood flows spread out across the meadow dissipating energy and depositing sediment. Swanson (2003), based on reviews of aerial photographs from 1939, described Blackwood Creek below the gravel pit area as a single-thread, meandering channel with an adjacent floodplain. Swanson states: “These features are consistent with a stable channel transporting relatively low volumes of bedload, and a stable and densely vegetated floodplain”. Swanson’s interpretation is confirmed by DFG’s observations in their August 31, 1938 field report that describes, “Beautiful pools, continuous shade, shelter.” Although there had been significant grazing and logging in the watershed up to that point, the Creek had a higher sinuosity, and significantly fewer debris jams, in-channel bars, and eroded banks.

Indications of the decline of the riparian habitat were noted in a 1962 DFG field report. The report states: “There is considerable degradation from bank erosion, gravel removal, and sedimentation from eroded banks reducing areas of spawning, shelter, and food production” (DFG, 1962). This is the first report in DFG files describing habitat degradation in Blackwood Creek; the timing correlates closely with the beginning of the gravel mining operation in 1960. Swanson's (2003) evaluation of aerial photographs supports the DFG observations. He noted that only a portion of the stream corridor, directly downgradient of Barker Pass Road crossing, had started to erode in 1965 aerial photographs.

Unfortunately for Blackwood Creek, relatively large flood events (instantaneous peak flows of over 1200 cfs) occurred in 1963, 1964, 1967, 1969, and 1970. Todd (1989) noted, "Gravel company records indicate that dike failures occurred several times during storm events sending a flood torrent through the mined area." The construction of the gravel pit and diversion channel magnified the effects of these floods on Blackwood Creek.[5] The increased sediment transport associated with the diversion channel and the gravel pit increased erosive power.

This situation lasted for almost 20 years. In the late 1970s, the USFS returned Blackwood Creek to its original alignment through the gravel pit area. The USFS stabilized the upstream end of the reclaimed gravel pit with a concrete grade control structure (the original fish ladder), which has since been replaced with a series of constructed step pools. The gravel pit has been filling with sediment and is believed to currently capture nearly all of the upstream bedload sediment (Tetra Tech, 1998). Therefore, the former gravel pit operations are not considered a current source of excessive sediment.

In summary, the evidence indicates the construction of the gravel pit and diversion channel led to the destabilization of the channel and floodplain. Erosion of the diversion channel and failures of the dikes in the gravel mining area are the primary sources of the excessive bedded sediment currently impairing the channel.

There is an important distinction to be made for this TMDL. The original, primary source of excessive bedded sediment was the gravel pit operations. The current source of excessive bedded sediment is the large gravel bars that exist within the channel and floodplain. The next section estimates the current load of excessive bedded sediment.

4.3 ESTIMATE OF CURRENT EXCESSIVE BEDDED SEDIMENT

As mentioned at the beginning of this section, this TMDL is unusual in that upland sources are not contributing excess pollutants to the water body. In this case, Water Board staff considers the sediment impairment and the sediment source to be the same. The excessive bedded sediment that is currently the primary impairment of Blackwood Creek is also the active pollutant source. Staff considers the large gravel bars that currently exist as a result of the historical gravel mining operations to be a pollutant source due to their mobility during large flow events and their adverse effects on the stream's beneficial uses.

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[5] The precipitation events that caused the channel-changing floods since the 1960s were comparable in size to more than 10 floods that occurred between 1850 and 1960. The creek used to absorb and recover from these events (Swanson, 2003).

Craig Oerhli, USFS Fluvial Hydrologist, identified the occurrence and estimated the area of excessive bedded sediment. Oerhli used aerial photographs from 2005 along with his knowledge of the drainage to map the areas of excessive bedded sediment. Using the reach convention of Swanson (2003), Oerhli estimated the following areas of excessive bedded sediment; these areas are shown in Figure 12.

- Reach 3 (below Barker Pass Road crossing): 96,000 ft^2 (2 acres)
- Reach 4: 210,000 ft^2 (5 acres)
- Reach 6: 850,000 ft^2 (19 acres)

Oerhli estimated the thickness of these deposits, based on channel bar height, to be approximately 4 to 6 feet. Using a total area of 1,156,000 square feet (the sum total of Reaches 3, 4, and 6), a bulk density for coarse gravel of 130 pounds per ft^3 (Maidment, 1993), and an average thickness of 5 feet yields a mass of about 751,400,000 pounds or about 380,000 tons.

5 LOADING CAPACITY AND LINKAGE ANALYSIS

The loading capacity is an estimate of how much bedded sediment Blackwood Creek can assimilate and still meet water quality objectives and support beneficial uses. The linkage analysis describes the link between the loading capacity and the applicable water quality standards (as interpreted through numeric targets) and provides the rationale for load reductions and allocations. The loading capacity and linkage analysis are presented below.

5.1 LOADING CAPACITY

Loading capacity is defined as the maximum amount of a pollutant that a water body can receive without violating water quality standards (40 CFR part 130.2(f).) The loading capacity must meet water quality standards and support the beneficial uses of Blackwood Creek. The TMDL interprets these standards based on cold freshwater habitat protection (the most sensitive beneficial use) through targets for desired conditions (Section 3). The load capacity for Blackwood Creek has been developed within the following context:

- The excess bedded sediment that exists in Blackwood Creek, below the new bridge at Barker Pass Road, is associated with past practices. The current loading of coarse sediment from upland sources to Blackwood Creek is not considered excessive.

- To restore beneficial uses, excess bedded sediment must be removed from the channel – floodplain system, either directly or indirectly. Therefore, the loading capacity is similar to the desired result after a removal action.

- Some degree of water quality degradation and beneficial use impairment occurred due to land development and other activities in the watershed before the adoption of the statewide Nondegradation Policy in 1968 and Water Board adoption of water quality standards for the Blackwood Creek in 1967.

It is not necessary for the Blackwood Creek watershed to reflect completely natural or pre-disturbance conditions in order to achieve water quality standards. Since baseline conditions for interpretations of standards reflect historical degradation, restoration of the creek to "pristine" conditions is not required as long as beneficial uses are adequately supported.

The bedded sediment load reduction needed to protect aquatic life beneficial uses is estimated at 30 to 70 percent (C. Oerhli, pers. comm., 2007). This reduction is based on USFS staff estimates of the restoration activities needed to meet their project objectives and restore beneficial uses. To meet these objectives, the USFS will physically remove or sequester in the flood plain deposits of excess bedded sediment. For the purposes of estimating both the load reduction and the resultant load capacity, Board staff used a load reduction of 50 percent, or the average value estimated by USFS staff. A reduction by 50 percent of the bedded sediments that currently exist in large gravel bars in the channel and floodplain will ensure sufficient protection of beneficial uses,

Load Reduction:

Sediment load reduction to achieve desired conditions:

50 percent reduction of existing load

380,000 tons * 0.5 = **190,000 tons**

Loading Capacity:

Loading capacity = (existing sediment load) – (load reductions needed to achieve desired biologic condition).

(380,000 tons) – (190,000 tons) = **190,000 tons**

Bedded sediment reduction and loading capacity are estimated here to give a relative sense of the in-channel improvements needed to protect water quality and beneficial uses. The success of the Blackwood Creek TMDL will not be directly measured by sediment mass reductions, because that is not a practical indication of beneficial use protection due to the difficulty associated with accurately measuring sediment reduction. The practical benchmarks to determine if desired conditions (and thus, the loading capacity) are achieved are the targets that measure the stream channel and floodplain response to restoration activities.

5.2 LINKAGE ANALYSIS

The linkage analysis describes the relationship or link between the numeric targets and the estimated loading such that the determination of sediment loading capacity is appropriate to support the beneficial uses for the waterbody.

In this TMDL, linkage between excess bedded sediment and impairment of cold freshwater beneficial uses was established using best professional judgment (e.g., Todd, 1989; Tetra Tech, 1998; Swanson, 2003). Target values for sinuosity, vegetation, and bank stability were selected to represent the desired physical habitat and biologic health of Blackwood Creek. These targets are based on the goals of the in-stream restoration project for Blackwood Creek (Swanson, 2003).

A primary goal of the Blackwood Creek restoration project is to protect and restore aquatic, riparian, and meadow ecosystems as directed in the USFS Sierra Nevada Forest Plan Amendment. These directives are described in an Aquatic Management Strategy (AMS) for the Sierra Nevada Province, which includes Blackwood Creek.

AMS goals are directly comparable to the goals of the TMDL; for example, the first AMS goal is to maintain and restore water quality to meet the goals of the Clean Water Act.

Additional AMS goals that relate directly to the beneficial uses of Blackwood Creek are shown in Table 3.

Table 3
Beneficial Uses Addressed by Blackwood Creek TMDL and Relevant AMS Goals

Beneficial Uses Addressed in TMDL	AMS Goals[1] for Blackwood Creek Restoration Project
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.	Water Quality Watershed Connectivity Floodplains and Water Tables Watershed Condition Streamflow Patterns and Sediment Regimes Stream Banks and Shorelines
WILD - Beneficial uses of waters that support wildlife habitats including, but not limited to, the preservation and enhancement of vegetation and prey species used by wildlife, such as waterfowl.	
SPWN - Beneficial uses of waters that support high quality aquatic habitat necessary for reproduction and early development of fish and wildlife.	

1. Definitions of AMS Goals:
Water Quality: Maintain and restore water quality to meet goals of the Clean Water Act and Safe Drinking Water Act, providing water that is fishable, swimmable, and suitable for drinking after normal treatment.
Watershed Connectivity: Maintain and restore spatial and temporal connectivity for aquatic and riparian species within and between watersheds to provide physically, chemically and biologically unobstructed movement for their survival, migration and reproduction.
Floodplains and Water Tables: Maintain and restore the connections of floodplains, channels, and water tables to distribute flood flows and sustain diverse habitats.
Watershed Condition: Maintain and restore soils with favorable infiltration characteristics and diverse vegetative cover to absorb and filter precipitation and to sustain favorable conditions of stream flows.
Streamflow Patterns and Sediment Regimes: Maintain and restore in-stream flows sufficient to sustain desired conditions of riparian, aquatic, wetland, and meadow habitats and keep sediment regimes as close as possible to those with which aquatic and riparian biota evolved.
Stream Banks and Shorelines: Maintain and restore the physical structure and condition of stream banks and shorelines to minimize erosion and sustain desired habitat diversity.

The load reduction for this TMDL is estimated by USFS staff based on their restoration plans to achieve desired conditions. The similarity between the USFS AMS goals for the restoration plan and designated beneficial uses for Blackwood Creek indicate that beneficial uses and water quality objectives should be achieved via the estimated load reduction.

6 TMDL, ALLOCATIONS, AND MARGIN OF SAFETY

6.1 TMDL AND ALLOCATIONS

A Total Maximum Daily Load is a calculation of the maximum amount of a pollutant that a waterbody can receive and still meet water quality standards, and includes an allocation of that amount to the pollutant's sources. Allocations describe how pollutant loads are distributed among sources. The loads are assigned or distributed such that the sum of the loads does not exceed the maximum allowable load to the waterbody.

TMDLs are the sum of wasteload allocations (WLA), load allocations (LA), and a margin of safety (MOS) (EPA, 1998). Wasteload allocations are the portion of the loading capacity that is allocated to existing or future point sources (SWRCB, 2005). There are no NPDES-regulated point sources in the Blackwood Creek watershed; therefore, the WLA is zero. Load allocations are the portion of the loading capacity that is allocated to existing or future nonpoint sources of pollution or to natural background sources. For this TMDL, the LA is the portion of bedded sediment deposited from past land uses that can be assimilated while protecting beneficial uses. The MOS accounts for uncertainty in the relationship between the TMDL and the water quality of the receiving waterbody. An implicit MOS is used in this TMDL (see discussion below).

Therefore, the TMDL for Blackwood Creek is expressed as follows:

Equation 6-1: $\text{TMDL} = \text{LA}$

Because the TMDL equals the loading capacity (USEPA, 1998), and the loading capacity (LC) was estimated to be 180,000 tons, the TMDL is expressed as:

Equation 6-2: $\text{TMDL} = \text{LC} = \text{LA} = 180{,}000 \text{ tons}$

Pursuant to 40 Code of Regulations part 130.7, TMDLs can be expressed as mass per unit of time, toxicity, or other appropriate measure. For the Blackwood Creek bedded sediment TMDL, it is appropriate to express the TMDL as the amount of bedded sediment allowed to remain in the system. This allocation is assigned to the USFS because it is the responsible land management agency.

6.2 MARGIN OF SAFETY

An implicit MOS was used in this TMDL that relies on both conservative assumptions made during load capacity estimations and adaptive implementation to achieve water quality standards. The conservative assumptions consist primarily of using conservative numbers for estimated area and bedded sediment density as part of the calculation of the current bedded sediment load. The estimated areas, which were based on aerial photograph review, likely include relatively stable areas within the gravel bars. The density used for the bedded sediment deposits is that of coarse gravel; gravelly sand deposits are about 15 percent less dense.

6.3 SEASONAL VARIATIONS AND CRITICAL CONDITIONS

The TMDL and required load reductions were derived from the USFS program to restore aquatic, riparian, and meadow ecosystems to their full functions. For example, the restoration plan is designed to withstand a 25-year flood event, create more desirable pool and riffle habitat to sustain aquatic life during low flow periods, and restore meadow and riparian habitat. Therefore, by meeting the load reductions and targets through implementation of the restoration plan, the stream ecosystem will be adapted to its seasonal variations and critical conditions.

Seasonal variation and critical conditions in Blackwood Creek include those during both low flows and high flows. Low flows are most directly critical to the aquatic organisms, as conditions during low flow include elevated water temperature and direct loss of habitat due to smaller stream size. The excessive amount of bedded sediment in the impaired segment of Blackwood Creek has filled pool habitat, widened and made shallower the stream channel, and has destroyed and/or inhibited the growth of riparian vegetation. The USFS restoration project addresses critical low flow conditions by creating more pool habitat, narrowing the stream channel, and increasing riparian vegetation. Increased pool habitat and riparian vegetation result in lower stream temperatures and greater cover from predators. A narrower channel will also provide deeper, cooler water during low flows. Therefore, the project is designed to protect the beneficial uses of the stream and achieve the associated narrative water quality objective during the low-flow critical condition.

High flows are critical to the degradation of aquatic habitat partly through the movement of bedded sediment. During high flow conditions, the USFS restoration project directly addresses the bedded sediment problem through removal or sequestration of the sediments, by providing additional sinuosity (and, hence, lower stream gradient and associated erosive energy), and through sculpting the channel to reconnect the stream with its floodplain, which also results in lower stream energy and erosion. The additional pool habitat resulting from the project also provides cover for fish during high flow events. The project is designed to withstand the 25-year flood event, an occurrence that has been exceeded only once in the historical flow record of Blackwood Creek (Swanson, 2003). By withstanding the 25-year flood event, the project is designed to reasonably protect the beneficial uses of the stream and achieve the associated narrative water quality objective during the high-flow critical condition.

7 IMPLEMENTATION

7.1 INTRODUCTION

TMDL implementation in the Blackwood Creek watershed is ongoing as a result of actions, both completed and planned, by the USFS. The USFS is the primary land manager in the watershed and is the sole entity assigned a load allocation to meet the TMDL. The USFS has a program in place to address the sediment impairment in Blackwood Creek, which it is actively implementing. Water Board staff have reviewed this program, and conclude that it is a reasonable approach to address the bedded sediment impairment and protect beneficial uses in the creek.

The *Water Quality Control Policy for Addressing Impaired Waters: Regulatory Structure and Options* (State Water Resources Control Board, 2005), indicates that where the "non-regulatory action of another entity" will implement a solution to a water quality impairment, the Regional Board may certify that the non-regulatory action will correct the impairment and implement the assumptions of a TMDL in lieu of adopting a redundant program.

Therefore, rather than adopting a duplicative program of implementation, the Water Board will follow a more streamlined process where it formally recognizes, via resolution at a public meeting, that the USFS's watershed restoration plan for Blackwood Creek is equivalent to the actions that would typically comprise an implementation plan for a TMDL and will result in attainment of water quality standards over time. These actions are outlined in this section, along with a discussion of the mechanisms that provide reasonable assurance that the TMDL will be implemented as needed. A schedule of review and revision is included.

7.2 COMPLETED AND PROPOSED RESTORATION ACTIVITIES

Since the 1970s, the USFS has implemented measures to improve and restore watershed function in Blackwood Creek. These measures are the same general activities that would be required under a TMDL implementation plan.

One of the initial efforts focused on the gravel pit area. This work included the re-diversion of the main channel out of its artificial bypass channel and into the gravel pit area. The USFS constructed a concrete cut-off wall and drop structure that allowed the creek to fall about 15 feet from the original channel bed to the gravel pit below. Decommissioning the diversion channel was a critical first step to TMDL implementation. The USFS also restored upland conditions to control sediment delivery to the creek. Management measures included ending grazing and new road construction and timber harvest restrictions. Restoration measures included road decommissioning and upgrading of drainage structures, stabilization of gullies, revegetation near the gravel pit area, and some instream and habitat enhancement measures (Swanson, 2003). The Barker Pass road has been stabilized through drainage improvements, surfacing, and revegetation of disturbed cuts and fills. Off-road vehicle routes in the stream zone have been closed (LTBMU, 1988). All of these activities have improved upland watershed conditions such that these areas are no longer a significant sediment source.

More recently, the USFS has focused on actions to restore instream channel form and function through the impaired portion of the stream, which occurs from the former gravel pit and extends several miles downstream. Since 2001, the USFS has completed two projects in this area, referred to as Phases 1 and 2 of the Blackwood Creek channel restoration. Phase 1, completed in 2001, involved replacement of the fish ladder with a sequence of step pools and riffles. Phase 2, completed in 2006, replaced the Barker Pass Road crossing with a clear-span bridge, and restored portions of the adjacent channel. The replacement of the failing fish ladder with a sequence of step pools and riffles directly restored the beneficial uses of MIGR, SPWN, and COLD in this area. The replacement of the low water crossing with the clear-span bridge removed impairments to the COLD and MIGR beneficial uses. Restoration activities associated with the Barker Pass Road crossing are expected to result in the restoration of Reaches 3 and 4, thereby removing the bedded sediment load impairment. Monitoring required by the restoration project and the TMDL will ensure this is the case. If additional restoration activities are needed in these areas, the Water Board has the authority to require the USFS to take appropriate action.

Phase 3 proposes to address two key reaches: restoration of 100 acres of channel and floodplain below the Barker Pass road crossing in Reach 6, and 50 acres of channelized creek and abandoned floodplain in Reach 1, above the recently restored fish ladder site. This phase will restore the COLD, SPWN and WILD beneficial uses of this impaired segment of Blackwood Creek. A conceptual design report for Phase 3 activities was submitted to the USFS in March 2007 (Swanson, 2007). A project funding request for $2.34 million for Phase 3 was approved during the Round 7 dispersal of the Sierra Nevada Public Lands Management Act. According to preliminary planning documents for Phase 3 (Oerhli, pers. comm., 2007), environmental analysis, permitting, and contract documents should be completed by mid 2008, with project implementation by late summer 2008.

7.3 REASONABLE ASSURANCE OF IMPLEMENTATION

USEPA’s national policy is that all TMDLs are expected to provide reasonable assurances that they will be implemented in a manner that results in attainment of water quality standards. 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 mechanisms and adequate funding” (USEPA, 1999). The restoration activities proposed by the USFS for Blackwood Creek are specific to the pollutant of concern, and are directly focused on the sources of that pollutant. Implementation of sediment control activities has been ongoing for decades in the watershed, and will be continued as described above. The following section describes the agency agreements that provide additional assurance of implementation, and the funding mechanism for Phase 3 of the Blackwood Creek restoration project

7.3.1 Consistency with USFS Goals

The completed and proposed restoration projects are consistent with USFS goals and objectives from national to local scales. At a national level, Goal 5 of the USFS Strategic Plan for 2004 through 2008 is to "Improve Watershed Condition." At a Regional level, the project is consistent with Sierra Nevada Forest Plan Amendment Standard and Guidelines, which include restoring impaired Riparian Conservation Areas (the Blackwood Project area is an RCA). And, locally, the project is consistent with the Lake Tahoe Basin Management Unit 1988 Forest Plan, which indicates that enhancement of water quality is the highest priority in terms of the Plan's Practice Standard and Guidelines. The project is an excellent candidate to meet the USFS's internal requirements, and the goals of TMDL implementation are consistent with the USFS goals and objectives (USFS, 2001a, 2001b).

7.3.2 Agency Agreements

In 1981, the USFS Pacific Southwest Region entered into a statewide Management Agency Agreement (MAA) with the State Water Resources Control Board. The MAA recognized and agreed on the following:

- The USFS was designated by the State Water Board as the Water Quality Management Agency for all activities on National Forest System Lands

- The practices and procedures set forth in the USFS 208 Plan constitute "sound water quality protection and improvement on National Forest lands"

- That Section 313 of the Federal Water Pollution Control Act mandates federal agency compliance with the substantive and procedural requirements of state and local water pollution control law

In the Lake Tahoe Basin, a Memorandum of Understanding (MOU) between the USFS and the Lahontan Water Board extends the statewide MAA to National Forest System lands in the Lake Tahoe Basin, including the Blackwood Creek watershed. The MOU specifies that the USFS and the Lahontan Water Board will work together to protect water quality and achieve the goals of the Clean Water Act, the California Water Code and the Basin Plan for the Lahontan Region. It sets forth procedures to improve coordination, minimize unnecessary reporting and duplication of effort, improve project planning, and reduce the need for regulation and enforcement.

This TMDL implementation plan is consistent with both the statewide MAA and the Lake Tahoe Basin-specific MOU because it is designed to meet the Basin Plan WQOs, protect and restore the beneficial uses of Blackwood Creek, reduce or eliminate duplication of effort, and eliminate the need for additional regulation. These agreements, along with the history of watershed restoration carried out by the USFS in Blackwood Creek, add assurance that needed restoration will be carried out to correct the impairments associated with bedded sediments in Blackwood Creek.

7.3.3 Financial Assurance

The Sierra Nevada Public Lands Management Act (SNPLMA) of 1998 allows the Bureau of Land Management to sell public land within a specific boundary around Las Vegas, Nevada. Proceeds from those sales are then made available for certain types of projects, including watershed restoration. In November 2003, the SNPLMA was amended to direct $300 million, over a period of eight years, to Lake Tahoe for implementation of the Federal Environmental Improvement Program. Projects that are funded by SNPLMA are submitted each year to the Secretary of Interior for approval. Funding for Phase 3 of the Blackwood Creek restoration project was approved in 2006 (Round 7 of SNPLMA funding). Additional funds may be requested as needed from the SNPLMA Special Account Reserve or Round 9 funding.

The anticipated amount for funding recommendations from the SNPLMA Special Account for the Lake Tahoe Restoration Projects is expected to be approximately $37.5 million annually until the amount allocated in accordance with section 342 of Public Law 108-108 is expended. In allocating each round of funding among Federal agencies for Lake Tahoe, if available, the Forest Service receives a minimum allocation of $20 million (SNPLMA Implementation Agreement, 2006, p. 36). This approval of Phase III funding demonstrates that adequate funding exists to reasonably assure restoration project implementation.

7.3.4 Adaptive Management

Adaptive management is an important component of the Sierra Nevada Forest Plan Amendment. Adaptive management allows an implementation plan to be flexible over time, as uncertainty exists in the management of ecosystems. Adaptive management relies on continuous adjustment and evaluation of methods and results to achieve the goals of the project. The USFS's commitment to an adaptive management approach provides additional assurance that TMDL implementation will result from the Blackwood Creek restoration project.

8 MONITORING

8.1 USFS PROJECT MONITORING PROGRAM

The LTBMU's *Adaptive Management Inventory, Monitoring, and Research Program* provides information on four main categories of monitoring: implementation, status-and-change, cause-and-effect, and research (USFS 2005).

The Adaptive Monitoring Program focuses its efforts on specific "issue areas." The Blackwood Creek restoration efforts are monitored under issue areas 1 and 2: "Lake Tahoe Clarity" and "Aquatic, Riparian and Meadow Ecosystems." Monitoring associated with Lake Tahoe Clarity evaluates the effects of a number of management practices that have the potential to affect Lake Tahoe clarity, including stream restoration, BMP effectiveness, and off-highway vehicle use. Aquatic, Riparian and Meadow Ecosystems monitoring primarily includes water quality, hydrologic function (floodplain connectivity, sediment transport regimes, and channel stability) and biological monitoring. A report summarizing monitoring results is prepared and distributed annually. Previously, restoration efforts in Blackwood Creek have been monitored under this program, and it is expected that TMDL implementation monitoring for Blackwood Creek will continue to be incorporated.

8.2 BLACKWOOD CREEK TMDL MONITORING

According the USFS Tahoe Project Proposal for the Blackwood Creek (SNPLMA Implementation Agreement, 2006, Appendix I-2, EIP #27.9), monitoring will include:

1. Channel and floodplain sediment storage
2. Groundwater elevations
3. Vegetative cover
4. Channel sinuosity
5. Channel complexity and diversity
6. Erosion and sedimentation within and from the project area
7. Channel dynamism
8. Terrestrial and aquatic habitat abundance and diversity

Monitoring elements 3, 4, 5, 6 and 7, above, will directly monitor the targets specified for this TMDL in Section 3: increasing trend in vegetative cover, sinuosity equal to or greater than 1.6, and bank stability of 80 percent.

To implement this project, the USFS must comply with the conditions contained in the NPDES construction activity storm water general permit[6]. This general permit regulates pollutants in storm water discharges associated with construction activity to surface waters within the Lake Tahoe Hydrologic Unit. Because the Phase 3 project involves work in a stream environment zone, the USFS will also need to obtain a prohibition exemption from the Water Board.

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[6] http://www.waterboards.ca.gov/lahontan/files/const_npdes_order_r6t_2005-0007_final.pdf

Because Phase 3 is a restoration project, the general permit requires the USFS to submit a detailed monitoring plan with annual performance criteria. Annual monitoring will be performed during construction activities associated with the Phase 3 restoration project. Following Phase 3 completion, monitoring and reporting for TMDL purposes should be completed at five-year intervals. The Water Board will require the monitoring plan to include tracking of the TMDL targets throughout the impaired segment (from the gravel pit to the downstream end of the Phase 3 project), and will describe specific monitoring locations within the impaired segment, frequencies, methods, quality assurance/quality control procedures and data submittal timelines.

8.3 TMDL REVIEW, REVISION, AND ATTAINMENT

Water Board staff will review the results of the annual TMDL monitoring for Blackwood Creek at five-year intervals, and assess the data to determine progress towards meeting the TMDL. According to Swanson (2003), long-term target conditions may require 20 years following restoration to become established. This estimate is consistent with other USEPA-approved TMDLs for sediment in the Lahontan Region (Heavenly Valley Creek TMDL for Sediment, Squaw Creek TMDL for Sediment). At the halfway point estimated for TMDL attainment (10 years following restoration project completion) Water Board staff will consider all data trends, along with progress on restoration project implementation to determine whether the TMDL will be revised to include additional requirements to remediate watershed conditions such that beneficial uses are adequately restored and protected.

The Water Board has authority to require technical and monitoring reports from the USFS pursuant to Water Code section 13267, and the Water Board may require such reports if it determines that additional information is needed to assess TMDL implementation. If needed, the Water Board has the authority to require additional restoration activities pursuant to Water Code section 13304.

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FIGURES