Draft
Water Quality and Aquatic Resources Monitoring Program for the Ralston Afterbay Sediment Management Project—2005 Annual Report

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Acronyms and Abbreviations

BMI	benthic macroinvertegrates
CSBP	California Stream Bioassessment Procedure
MFAR	Middle Fork American River
mm	millimeters
PCWA	Placer County Water Agency
SPT	Sediment pass-through

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Executive Summary

Placer County Water Agency (PCWA) is implementing a sediment management project at Ralston Afterbay to address continued sedimentation of the reservoir that threatens the reliability of power generation at the Ralston and Oxbow Powerhouses. The sediment management project has two components. The first consists of dredging approximately 75,000 cubic yards of sediment from the upstream end of the reservoir and placing the dredged material downstream of Ralston Dam on Indian Bar. The sediment would be configured to allow high flows to mobilize and transport it to the river downstream of the dam. The second component consists of reoperating the dam during high-flow events to pass greater quantities of fine sediment beyond the dam. Sediment pass-through (SPT) operations would be conducted whenever river flows exceed approximately 3,500 cfs at Ralston Dam.

A secondary objective of the sediment management project is to restore the natural migration of coarse and fine sediment that occurred in the project area before the dam was constructed. The transport of sediment, especially intermediate-sized material (gravel, pebble, and cobble), is critical for maintaining high-quality, diverse habitat for fish and benthic invertebrates in gravel-bed streams (Waters 1995). Following dam construction, these materials continue to be transported from the reaches below the dam but are not replaced from upstream sources, resulting in the loss of important habitat (Kondolf and Matthews 1993). Other effects include scouring and deepening of the channel below the dam and associated increases in substrate size (channel armoring), a process that has been occurring below Ralston Dam since construction (Stiehr pers. comm.).

The combination of SPT operations and sediment disposal at Indian Bar has been identified as a viable and economical approach for managing sediment at Ralston Afterbay while mitigating the long-term effects of sediment retention on aquatic habitat downstream of the dam. Past efforts to mitigate the effects of sediment retention in reservoirs on salmon and trout streams in California have focused primarily on augmenting the supply of spawning-size gravels (Parfitt and Buer 1980). These efforts, which include placing gravel on bars and riffles and installing artificial and natural gravel-retaining structures downstream of dams, can be costly and ineffective over the long term. A more satisfactory alternative is to attempt to maintain important habitat attributes below dams by managing water releases and sediment in ways that preserve as much as possible the geomorphic processes that existed before the dams were constructed (Ligon et al. 1995).

In 2002, PCWA implemented the Indian Bar Pilot Project to evaluate the first component of the sediment management project and address concerns regarding recreational uses at Indian Bar (Jones & Stokes 2002a). In September 2002, PCWA placed 45,000 cubic yards of sediment on Indian Bar and an additional 28,900 cubic yards at PCWA's disposal site on Ralston Ridge. The pilot project includes consideration of potential strategies for increasing the sediment volume at Indian Bar while maintaining or enhancing recreational opportunities.

In 2001, PCWA initiated a monitoring program to ensure compliance of the sediment management project with established water quality objectives and to evaluate potential project effects on aquatic habitat and benthic macroinvertebrates (BMI) in the MIDDLE FORK AMERICAN RIVER (MFAR) downstream of Ralston Dam. The primary objectives of the monitoring program are to:

- quantitatively evaluate project compliance with the water quality objectives established by the Central Valley Regional Water Quality Control Board in its Water Quality Control Plan (1998),
- quantitatively evaluate project effects on aquatic habitat and BMI communities downstream of Ralston Dam, and
- provide PCWA with the annual monitoring results to evaluate project effects and implement appropriate corrective measures if necessary.

The monitoring program was designed to meet these objectives by using a before-after, control-treatment sampling design in which key parameters are sampled in locations upstream and downstream of the project site before and after the initiation of project activities. This design relies on preproject (baseline) patterns and trends in resource conditions in the treatment and control reaches to detect and measure potential project effects during the postproject phase. In 2001, four treatment and three control reaches (Table 1) were selected for aquatic habitat and BMI monitoring based on several criteria designed to maximize the ability of the monitoring program to detect project effects (Jones & Stokes 2002b). A detailed description of the objectives, hypotheses, monitoring parameters, sampling design, and analytical methods is presented in the monitoring plan (Appendix).

This report presents the results of the fourth and final year of preproject monitoring. Water year 2005 was an important baseline year because, for the first time since monitoring began, spring flows fell within the target range for SPT operations (>3,000 cfs at Ralston Dam), allowing an assessment of the effects of such flows on aquatic habitat and BMI communities under preproject conditions (i.e., in the absence of SPT operations). The results of monitoring in 2001, 2002, and 2004 were reported in three previous annual reports (Jones & Stokes 2002b, 2003, 2005). Monitoring was conducted in 2004 to evaluate the geomorphic and biological effects of a gate malfunction and spill that occurred at Ralston Dam on August 5, 2004 (Jones & Stokes 2004, 2005). Although not representative of project operations, this event provided a unique opportunity to better understand the responses of the MFAR and its biota to high flows and sediment input and thereby facilitate interpretation of future project effects.

Monitoring in 2005 helped to reinforce earlier predictions and conclusions regarding the geomorphic character of the river and the general attributes and responses of the BMI community to variability in habitat conditions among the monitoring reaches. Overall, preproject monitoring was successful in characterizing several important baseline patterns and trends in aquatic habitat and BMI communities that will serve as benchmarks for evaluating potential project effects during the postproject monitoring period:

- The channels of the MFAR, Rubicon River, and North Fork MFAR are inherently stable; despite substantial variation in the magnitude and duration of annual peak flows, no significant changes or trends in channel profiles or substrate size composition have been detected since 2001.
- The stability and high sediment transport capacity of these reaches are reflected by the dominance of coarse-grained substrates (cobbles and boulders) and the transient nature of fine sediments resulting from local inputs (August 2004 spill event) and other watershed sources.
- Reach differences in substrate size composition reflect differences in channel gradient, confinement, and sediment supply, best illustrated by the general longitudinal gradient in substrate size composition between Ralston Dam and Otter Creek.
- Slight increases in the proportion of small to intermediate-sized sediments (fines, gravel, and pebbles) throughout the project area since 2002 suggest a potential short-term increase in sediment loads from upstream sources in recent years.
- BMI communities in the project area, which appear to be highly resilient to natural and human-caused disturbances, are generally similar to the communities found in other regulated, mid-elevation rivers in the Sierra Nevada.
- Although exhibiting high spatial and temporal variability, several BMI metrics indicate general reach differences and longitudinal patterns in habitat quality related to channel gradient, substrate size composition, and degree of flow modification associated with hydropower operations.
- Several key BMI metrics and taxa have shown consistent relationships and responses to habitat alteration, including changes in substrate size composition and embeddedness.

Water year 2006 will mark the first year of postproject monitoring following significant entrainment of sediment from the Indian Bar Sediment Disposal Site in late December and early January 2005–2006. Extremely high flows resulting from the New Year's storm (>50,000 cfs peak flows at the Foresthill gage on December 31, 2005) resulted in the estimated mobilization of 13,782 cubic yards of sediment deposited on Indian Bar. Consequently, a major focus of 2006 monitoring will be to document any changes in channel geometry, substrate conditions, and BMI communities below Ralston Dam as a result of this event. Because of high spring and summer flows, aquatic habitat and BMI monitoring is scheduled for October 2006.

Recommendations for future monitoring are:

- conduct the first year of postproject aquatic habitat and BMI monitoring in October 2006 to evaluate the effects of the high winter flows and Indian Bar sediment contributions in winter 2005—2006; and
- conduct 2 to 3 years of postproject water quality, aquatic habitat, and BMI monitoring following each occurrence of SPT operations in accordance with the flow conditions identified in the CDFG's streambed alteration agreement.

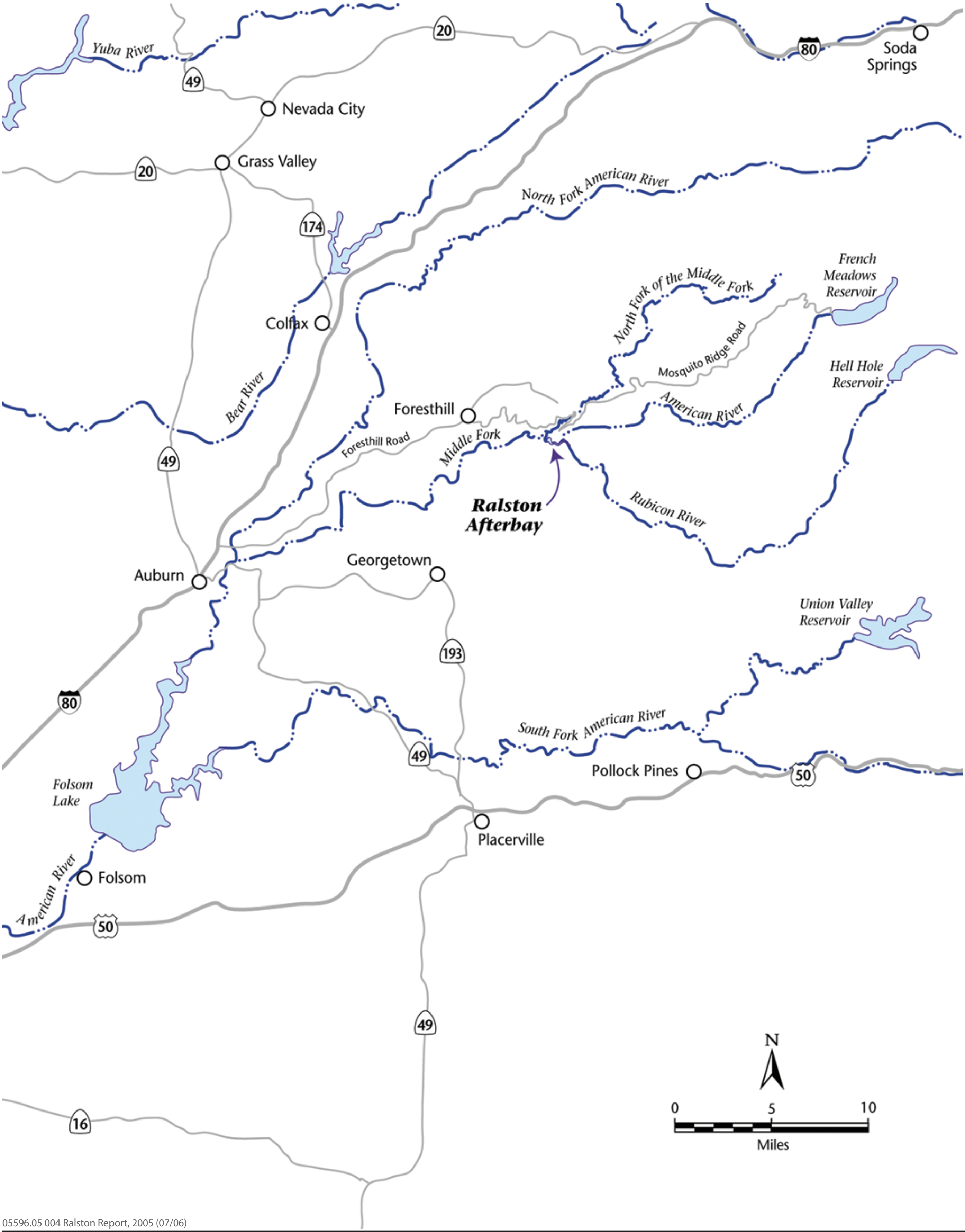
Additional recommendations for future water quality monitoring will be identified following analysis of the data collected to date.

Introduction

PCWA operates the Middle Fork Project, a series of reservoirs and powerhouses on the Middle Fork American River (MFAR) and the Rubicon River in the central Sierra Nevada (Figure 1). The Middle Fork Project includes Ralston Afterbay, a reservoir created by the construction of Ralston Dam in 1966. The dam and reservoir are located on the MFAR at the confluence of the MFAR and the Rubicon River, on the border of Placer and El Dorado Counties. Ralston Afterbay serves as the afterbay for the two largest powerhouses of the Middle Fork Project (Middle Fork and Ralston Powerhouses) and the forebay for Oxbow Powerhouse.

PCWA is implementing a sediment management project at Ralston Afterbay to address continued sedimentation of the reservoir that threatens the reliability of power generation at the Ralston and Oxbow Powerhouses. The primary objectives of the sediment management project are to create sediment storage capacity in Ralston Afterbay, maintain operational flexibility of Ralston Dam and Oxbow Powerhouse, and delay the complete sedimentation of Ralston Afterbay. PCWA issued and adopted an initial study/mitigated negative declaration for the Ralston Afterbay Sediment Management Project in August 2001.

The sediment management project has two components. The first consists of dredging approximately 75,000 cubic yards of sediment from the upstream end of the reservoir and placing the dredged material downstream of the dam on a 7-acre portion of Indian Bar. The sediment would be configured to allow high



05596.05 004 Ralston Report, 2005 (07/06)

Jones & Stokes

Figure 1
Regional Location

flows to mobilize and transport it to the river downstream of the dam. The second component consists of reoperating the dam during high-flow events to pass greater quantities of fine sediment beyond the dam. SPT operations would be conducted whenever river flows exceed approximately 3,500 cfs at Ralston Dam.

In 2002, PCWA implemented the Indian Bar Pilot Project to evaluate the first component of the sediment management project and address concerns regarding recreational uses at Indian Bar (Jones & Stokes 2002a). In September 2002, PCWA placed 45,000 cubic yards of sediment on Indian Bar and an additional 28,900 cubic yards at PCWA's disposal site on Ralston Ridge. The pilot project includes consideration of potential strategies for increasing the sediment volume at Indian Bar while maintaining or enhancing recreational opportunities. Additional sediment placement locations (e.g., Junction Bar) may be considered in the future.

A secondary objective of the sediment management project is to restore the natural migration of coarse and fine sediment that occurred in the project area before the dam was constructed. The transport of sediment, especially intermediate-sized material (gravel, pebble, and cobble), is critical for maintaining high-quality, diverse habitat for fish and benthic invertebrates in gravel-bed streams (Waters 1995). Following dam construction, these materials continue to be transported from the reaches below the dam but are not replaced from upstream sources, resulting in the loss of important habitat (Kondolf and Matthews 1993). Other effects include scouring and deepening of the channel below the dam and associated increases in substrate size (channel armoring), a process that has been occurring below Ralston Dam since construction (Stiehr pers. comm.).

Efforts to mitigate the effects of sediment retention in reservoirs on salmon and trout streams in California have focused primarily on augmenting the supply of spawning-size gravels (Parfitt and Buer 1980). These efforts, which include placing gravel on bars and riffles and installing artificial and natural gravel-retaining structures downstream of dams, can be costly and ineffective over the long term. A more satisfactory alternative is to attempt to maintain important habitat attributes below dams by managing water releases and sediment in ways that preserve as much as possible the geomorphic processes that existed before the dams were constructed (Ligon et al. 1995).

The combination of SPT operations and sediment disposal at Indian Bar has been identified as a viable and economical approach for managing sediment at Ralston Afterbay while mitigating the long-term effects of sediment retention on aquatic habitat downstream of the dam. These activities would allow the river to mobilize a broad range of sediment sizes and carry them downstream, as occurred naturally before the dam was constructed. The reintroduction of sediment below the dam is expected to have beneficial effects on aquatic habitat and biota downstream of the dam. No adverse impacts on water quality and aquatic resources are expected because project effects would likely be limited to small, temporary increases in turbidity and sedimentation above ambient levels during high-flow events. Past analyses and modeling of the hydraulic and sediment transport characteristics of the MFAR indicate that the channel is inherently stable and therefore relatively insensitive to changes in discharge and sediment supply (Harvey pers. comm.).

In 2001, PCWA initiated a monitoring program to ensure compliance of the sediment management project with established water quality objectives and to evaluate potential project effects on aquatic habitat and BMI in the MFAR downstream of Ralston Dam. The primary objectives of the monitoring program are to:

- quantitatively evaluate project compliance with the water quality objectives established by the Central Valley Regional Water Quality Control Board in its Basin Plan (1998),
- quantitatively evaluate project effects on aquatic habitat based on changes or trends in streambed characteristics and BMI populations downstream of the reservoir (treatment areas) relative to changes or trends in unaffected areas (control areas), and
- provide PCWA with the results of annual monitoring so that it can evaluate project effects and implement appropriate corrective measures if the data indicate that the sediment management project is adversely affecting water quality and aquatic resources in the MFAR.

The monitoring plan is contained in the Appendix of this report. This plan includes a detailed description of the objectives, hypotheses, monitoring parameters, sampling design, and analytical methods for water quality, aquatic habitat, and BMI monitoring. The reach selection process, reach descriptions, and photographs were presented in the 2001 annual report (Jones & Stokes 2002b). The following is a summary of preproject monitoring activities and events from 2001 through 2005.

2001

The first year of preproject monitoring was conducted in 2001 in accordance with the monitoring plan described in the first annual report (Jones & Stokes 2002b).

2002

The monitoring plan was revised in 2002 to comply with permit requirements and agency requests for the proposed Indian Bar Pilot Project (Appendix). Revisions to the plan included:

- identifying target flows and conditions for triggering postproject monitoring and evaluation of SPT operations and sediment disposal at Indian Bar,
- surveying and conducting pebble counts of the Indian Bar disposal site before and after significant entrainment events,

- evaluating pebble counts as an alternative method for assessing the size composition of riffle substrates at monitoring sites,
- implementing updated BMI sampling protocols to ensure consistency with the California Stream Bioassessment Procedure (CSBP),
- monitoring channel cross sections at selected pools upstream and downstream of Ralston Afterbay, and
- monitoring water temperature continuously at the water quality monitoring stations.

The second year of preproject monitoring was conducted in 2002 in accordance with the revised monitoring plan. Because winter and spring flows in 2000–2001 and 2001–2002 did not reach the levels needed to fully characterize preproject conditions (Figure 2), a third year of preproject monitoring was recommended, subject to the occurrence of flows within the target range for SPT operations (>3,500 cfs at Ralston Dam). Accordingly, no monitoring was conducted in 2003 and no monitoring was scheduled in 2004 following the lack of target flows in winter and spring 2002–2003 and 2003–2004 (flows were in the target range for only 1 day on May 4, 2003 [see Figure 2]).

2004

On the morning of August 5, 2004, an electronic control malfunction resulted in the release of approximately 1,400 acre-feet of water from Ralston Afterbay. The event lasted approximately 4 hours and resulted in a peak flow of 5,850 cfs in the MFAR at the Foresthill gage. At the request of PCWA, Jones & Stokes conducted reconnaissance surveys immediately after the event to qualitatively assess the effects of the spill on aquatic resources below Ralston Dam (Jones & Stokes 2004). Subsequently, Jones & Stokes conducted aquatic habitat and BMI sampling in August and October 2004 to quantitatively evaluate the status of aquatic habitat and BMI communities downstream of the dam. Although not representative of project operations, the spill event provided a unique opportunity to better understand the responses of the MFAR and its biota to high flows and sediment input and thereby facilitate interpretation of future project effects.

2005

The final year of preproject monitoring was conducted in 2005. For the first time since monitoring began, flows in the MFAR below Ralston Dam reached the target levels for SPT operations (>3,500 cfs at Ralston Dam) (Figure 2), allowing an assessment of the response of aquatic habitat and BMI communities to such flows in the absence of SPT operations. In addition, monitoring in 2005 provided an opportunity to further evaluate the condition of aquatic habitat and BMI communities in the MFAR below Ralston Dam following the August 2004 spill event.

This report describes the results of 2005 monitoring and summarizes several key preproject patterns and trends in aquatic habitat and BMI communities that will

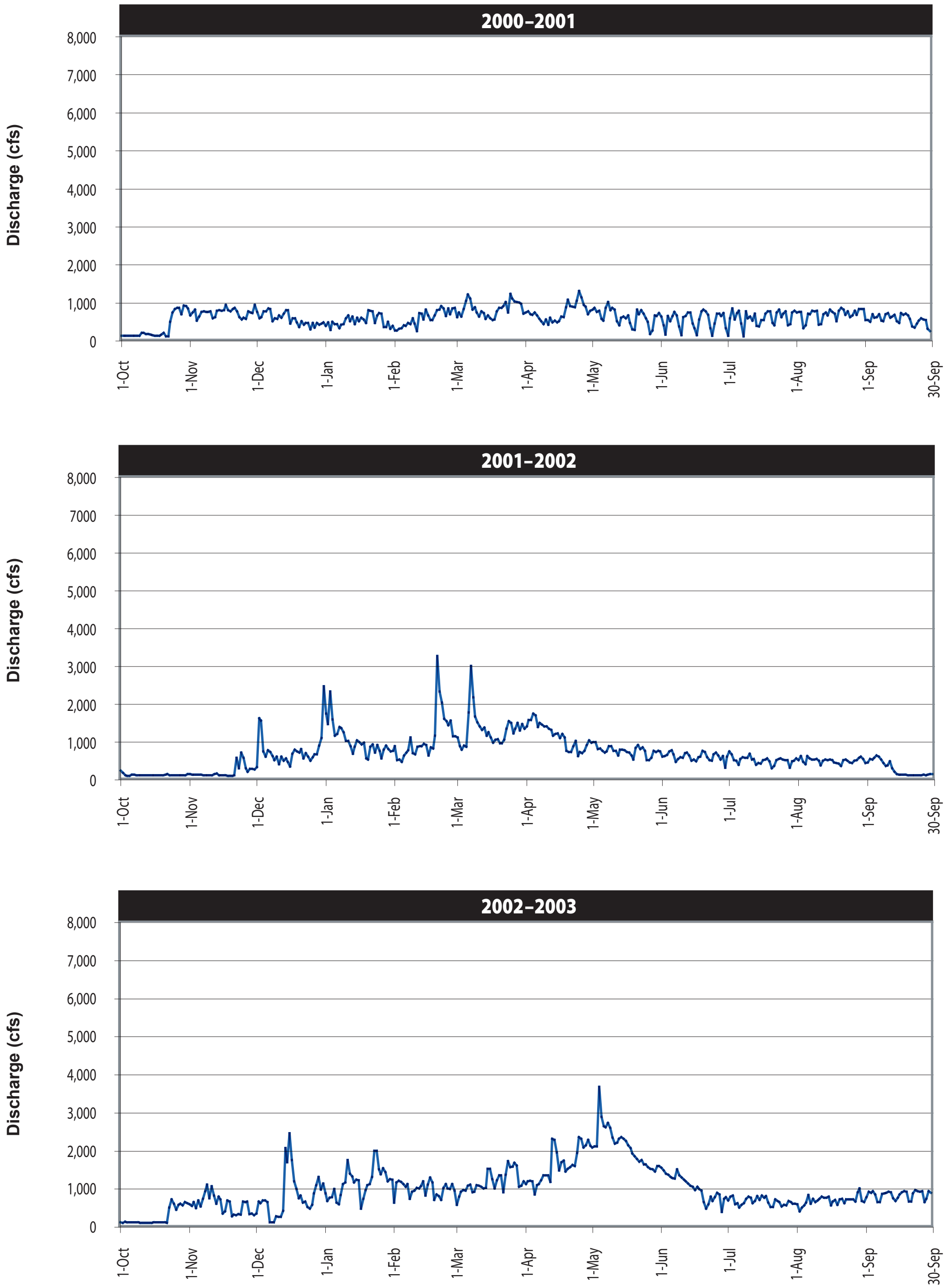


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Figure 2
Daily Flows (Cubic Feet per Second) in the MFAR at the Foresthill Gage in Water Years 2001–2005

serve as benchmarks for evaluating potential project effects during the postproject monitoring period. This report also includes a review of the status of special-status fish, amphibians, and aquatic reptiles and their habitat in the project area. The result of preproject water quality monitoring will be presented in a separate memorandum following analysis of all water quality data collected through spring 2006.

Methods

Aquatic Habitat

Substrate Size Composition and Embeddedness

Substrate size composition and embeddedness were measured at all monitoring sites (transect locations) used in previous years (2001, 2002, and 2004) to characterize preproject substrate conditions and BMI communities in each monitoring reach (Table 1). All monitoring sites are located at the heads of natural riffles and shallow tails of pools. A total of five to nine transects (one to three transects per monitoring site) were used to characterize substrate conditions in each monitoring reach. This year, an additional transect (19b) was added to Reach 3 to increase sample size to levels comparable to other reaches below Ralston Dam. No pebble count data were collected at the Indian Bar Sediment Disposal Site in 2005.

Pebble counts were conducted at all monitoring sites between October 4 and October 14, 2005. Pebble counts were conducted in the reaches below Oxbow Powerhouse (Reaches 1–3) during low flows when pebble counts could be safely performed across the entire channel width.

Table 1. Aquatic Habitat and Benthic Macroinvertebrate (BMI) Monitoring Reach Locations

Reach	Location	Primary Purpose	Substrate Transects	BMI Transects
Reach 1	MFAR above Otter Creek	Treatment	1–8	1, 3, 7
Reach 2	MFAR above Volcano Creek	Treatment	9–15	9, 11, 13
Reach 3	MFAR at Junction Bar	Treatment	16–19b*	16, 18
Reach 4	MFAR at Indian Bar	Treatment	20–24	20, 23
Reach 5	MFAR above Ralston Afterbay	Control	25–30	25, 27, 29
Reach 6	North Fork MFAR	Control	31–35	31, 33, 35
Reach 7	Rubicon River above Ralston Afterbay	Control	36–44	36, 40, 43

* see text for description

In 2001, substrate size composition and embeddedness were measured using the methods described by Bain (1999). In 2002, at the request of the California Department of Fish and Game (CDFG), the pebble count method (Bunte and Abt 2001) was evaluated as an alternative method for characterizing riffle substrates. It was concluded that pebble counts provide a more objective, repeatable method that is more sensitive to changes in fine sediment than the Bain method (Jones & Stokes 2003). Therefore, the pebble count method was used in 2002, 2004, and 2005 to measures substrate size composition and embeddedness in the monitoring riffles.

Pebble counts were conducted according the methods described by Bunte and Abt (2001). Individual particles were sampled at regular intervals along fixed transects extending the width of the active channel on or immediately upstream of the crest of each riffle. The spacing between sampling points was set at the longest diameter (a axis) of the largest particle to avoid double-counting large particles. A metal pin, held vertically at each sampling point, was lowered until it contacted the substrate. The first particle touched by the metal pin was selected. In areas where the bed was submerged, a facemask was used to identify particles that could not be clearly seen from above the water's surface. The selected particle was picked up and measured using a template with square holes ranging from 2 to 181 millimeters (mm) on a side (Wentworth scale). The particle's sieve diameter was recorded as the largest hole size through which the particle could not pass. If the particle could not be dislodged from the bed, a ruler was used to measure or approximate the length of the b axis (the axis that defines sieve diameter). Embeddedness was determined by examining each selected particle and recording the extent to which the particle was buried by fine sediment (measured as a percentage of the total vertical height of the particle). Embeddedness was scored as negligible (<5%), low (5–25%), moderate (25–50%), high (50–75%), or very high (>75%).

Substrate size composition was described quantitatively using particle-size frequency distributions and percentile values (D_{16}, D_{25}, D_{50}, D_{75}, and D_{84}). The percentile values are the particle sieve diameters for which a certain percentage of the sample is finer. For example, in a sample with a D_{50} of 10 millimeter (mm), 50% of the sample is finer and 50% is coarser than 10 mm. Percentile values were calculated using linear interpolation methods (Bunte and Abt 2001). Embeddedness was described and compared using frequency distributions of embeddedness scores.

Channel Cross Sections

Between October 4 and October 14, 2005, standard surveying techniques were used to survey channel cross sections previously surveyed in 2002 and 2004. Measurements were taken with an auto level and stadia rod. Measurements were first taken above the active channel at an average horizontal distance of approximately 10 feet and average vertical distance of approximately 5 feet from the water surface. Bed elevations were measured every 2 feet along the transect to produce a detailed cross section of the channel at each location. In some cases, measurements were taken at more frequent intervals to accurately define changes in channel contours associated with bedrock ledges, large rocks, and other significant features. Site maps were updated for each transect location.

Water Temperature

Since July 2001, automated water temperature loggers (Onset Corporation Optic StowAway) have been operating in the MFAR below Ralston Dam (at the Foresthill gage), the MFAR above Ralston Afterbay (approximately 0.5 mile upstream of its confluence with the Rubicon River), the North Fork MFAR (approximately 2.2 miles above its confluence with the MFAR), and the Rubicon River (approximately 0.5 mile upstream of Ralston Powerhouse). The hourly data from these loggers are retrieved every 3 to 6 months. Additional temperature loggers were installed in the Otter Creek, Volcano Creek, and Indian Bar reaches (Reaches 1, 2, and 4) in August 2004.

In 2005, five of the seven loggers were lost as a result of high spring flows. Water temperature data extending from October 2004 through September 2005 were successfully retrieved from the two loggers in the MFAR at the Foresthill gage and in the North Fork MFAR. New temperature loggers were installed below Ralston Afterbay in the Otter Creek, Volcano Creek, and Indian Bar reaches, and above the afterbay in the MFAR and Rubicon River reaches in October 2005.

Benthic Macroinvertebrates

BMI monitoring was conducted in October 2005 according to the sampling and laboratory procedures described in the monitoring plan (Appendix). BMI monitoring was not conducted in June or August because of high flows and unsafe sampling conditions.

Field Methods

BMI samples were collected in the field according to the CSBP non-point source sampling design (California Department of Fish and Game 1999, 2003a). Samples were collected from the same riffles (transect locations) that were used in previous monitoring years (Table 1). High spring and summer flows in 2005 precluded sampling in June and August. BMI sampling was conducted only in October.

A square-frame kick net with 500-micrometer Nitex mesh was used to collect benthic invertebrates from three 1-by-1-foot areas along each transect. Samples were placed in sealable plastic containers containing 90% ethanol. Labels indicating the reach, site, stream, and date were placed in each sample jar and on each lid. Samples were then transferred to the Jones & Stokes laboratory in Sacramento, California. A standardized chain-of-custody form was used to document each sample transfer.

Laboratory Methods

Each BMI sample was processed in the Jones & Stokes laboratory according to the CSBP Professional (Level 1) Laboratory Procedures. Invertebrates were distributed evenly in a tray marked with a 1-by-1-inch-square grid. Invertebrates were then removed from randomly selected grids and counted until 300 individuals were removed. Each 300-count subsample was stored in 70% ethanol and labeled with the original sample data and subsample size (number of grids). Each invertebrate in the 300-count subsamples was identified to the required standard taxonomic level as described in the revised CSBP (California Department of Fish and Game 2003). Differences in the procedures from previous monitoring years included identifying non-biting midges to family (Chironomidae) and identifying segmented worms to order (Oligochaeta). Taxonomic data were recorded on standardized data sheets along with the date subsampled, date identified, total number of grids in tray, number of grids selected, and number of invertebrates removed from each grid. Standardized sample-tracking logs were used to track the progress of each sample through the laboratory process.

BMI Metrics

The following metrics were used to characterize BMI communities in 2001, 2002, 2004, and 2005. These metrics were compared between monitoring reaches, seasons, and years to describe longitudinal trends, seasonal patterns, and annual variation in community attributes and habitat conditions. A summary of the metrics used and their expected response to habitat change or environmental disturbance is provided in Table 2.

BMI Density

BMI density is calculated by dividing the total number of invertebrates in a sample by the area of streambed sampled (number of individuals per square meter). Although BMI density can be highly variable and difficult to interpret (Karr and Chu 1999), this metric may be helpful in interpreting trends or changes in other variables (e.g., California tolerance values). This metric was calculated using the procedure described in the CSBP (California Department of Fish and Game 1999, 2003).

EPT Index

EPT stands for the insect orders Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddisflies). The EPT index is calculated by dividing the combined number of individuals in these three orders by the total number of individuals in the sample. The orders included in the EPT index were selected because of their relative intolerance of human disturbance. Two common genera, *Hydropsyche* (Trichoptera) and *Baetis* (Ephemeroptera),

Table 2. Summary of Benthic Macroinvertebrate Metrics

BMI Metric	Description	Response to Impairment
Richness Measure		
Taxa Richness	Total number of individual taxa	Decrease
Composition Measures		
EPT Index	Percent of mayfly, stonefly, and caddisfly larvae in sample	Decrease
Percent Chironomidae	Percent of midge larvae in sample	Increase
Tolerance/Intolerance Measures		
Tolerance Value (TV)	Value between 0 and 10 weighted by abundance of taxa designated as pollution-tolerant (higher values) or -intolerant (lower values)	Increase
Functional Feeding Groups (FFG)		
Percent Collectors	Percent of individuals that collect fine particulate matter	Increase
Percent Filterers	Percent of individuals that filter fine particulate matter	Increase
Percent Scrapers	Percent of individuals that graze on periphyton	Variable
Percent Predators	Percent of individuals that feed on other organisms	Variable
Percent Shredders	Percent of individuals that shred coarse particulate matter	Decrease
Abundance Measure		
BMI Density	Estimated number of BMI per sample	Variable

demonstrate a high tolerance of human influence that is uncharacteristic of their respective orders. *Hydropsyche* and *Baetis* are therefore not included in the calculation of the EPT Index metric.

Taxa Richness

Taxa richness describes the number of distinct taxonomic groups (family, genus, etc.) in a sample and is a measure of community structure. It is commonly used in bioassessment monitoring because it has been found to vary consistently and systematically with human influence (Karr and Chu 1999). For comparability with 2004 and 2005, taxa richness values for 2001 and 2002 were recalculated using a revised methodology based on CAMLnet recommendations (California Department of Fish and Game 2003).

California Tolerance Values

The California tolerance value is a metric based on the Hilsenhoff Biotic Index, which uses a set of taxon-specific tolerance values to characterize community-level tolerance (California Department of Fish and Game 2003). The tolerance value is used as a general index of tolerance of pollution and other forms of environmental disturbance. Tolerance values range from 0 (highly intolerant) to 10 (highly tolerant); higher tolerance values indicate a greater amount of environmental disturbance. Like taxa richness, the percentages of tolerant and intolerant individuals in a sample have been found to vary consistently and systematically with human influence (Karr and Chu 1999). The tolerance value metric is found by calculating a weighted average of the known tolerance values based on the relative abundance of each taxon.

Dominant Taxa

Dominant taxa are taxonomic groups (family, genus, etc.) that are highly abundant in a community relative to other taxa. Dominant taxa are typically generalists that occur in great abundance throughout their range. The level of dominance of these taxa can be an indicator of the level of disturbance in aquatic systems. The abundance of the dominant taxon in a habitat is expected to increase in response to environmental disturbance or impairment. A relatively undisturbed environment would be expected to have a more even distribution of taxa in the community. The relative abundance of the dominant taxon, calculated by dividing the number of individuals of each taxon by the total number of individuals in the sample, was calculated for each monitoring reach.

Functional Feeding Groups

Functional feeding groups are groups of invertebrates that are similar in the way they obtain food. The relative abundance of each functional feeding group is an indicator of community trophic structure. CDFG developed a list of California taxa and grouped them into the following functional feeding group categories: predator, collector-gatherer, collector-filterer, scraper, shredder, and others. The category *others* includes parasites, macrophyte herbivores, piercing herbivores, omnivores, and wood eaters.

Quality Assurance Procedures

In 2005, the Jones & Stokes laboratory performed quality assurance measures throughout the field and laboratory processes to ensure a high level of data quality and integrity. Each Jones & Stokes employee who contributed to the collection or processing effort was trained by the project supervisor on CSBP methods, sampling techniques, and laboratory techniques. The laboratory supervisor performed routine checks during the sorting and identification process to ensure CSBP procedures were implemented accurately and appropriately. Approximately 10% of the samples collected were checked by the laboratory supervisor for taxonomic and enumeration accuracy.

Following completion of the taxonomic identification in 2005, approximately 10% of the samples collected were transported to the CDFG laboratory in Chico, California, for an independent taxonomic inventory. As in previous years, the results from this independent effort were used to validate the taxonomic determinations and enumeration conducted by Jones & Stokes. Jones & Stokes' taxonomists discussed the results of the taxonomic validations with the participating taxonomists to identify and correct discrepancies.

Results

Aquatic Habitat

Substrate Size Composition and Embeddedness

Substrate Size Composition

Figure 3 presents the substrate size composition (percent of particles in each Wentworth size class) for each monitoring reach in 2002, 2004, and 2005 and the Indian Bar sediment disposal site in 2002 and 2004. These data were also consolidated into broader size classes corresponding to those used in 2001 (Bain method) to allow comparison of substrate size composition among all years (Figure 4). It is important to note that the differences in particle size distributions between 2001 and 2002 were caused largely by differences in the Bain and pebble count methods (Jones & Stokes 2003). The actual differences in particle size distributions between 2001 and 2002 are smaller than those shown in Figure 4, indicating little or no change in substrate size composition between 2001 and 2002. However, the 2002, 2004, and 2005 results are directly comparable.

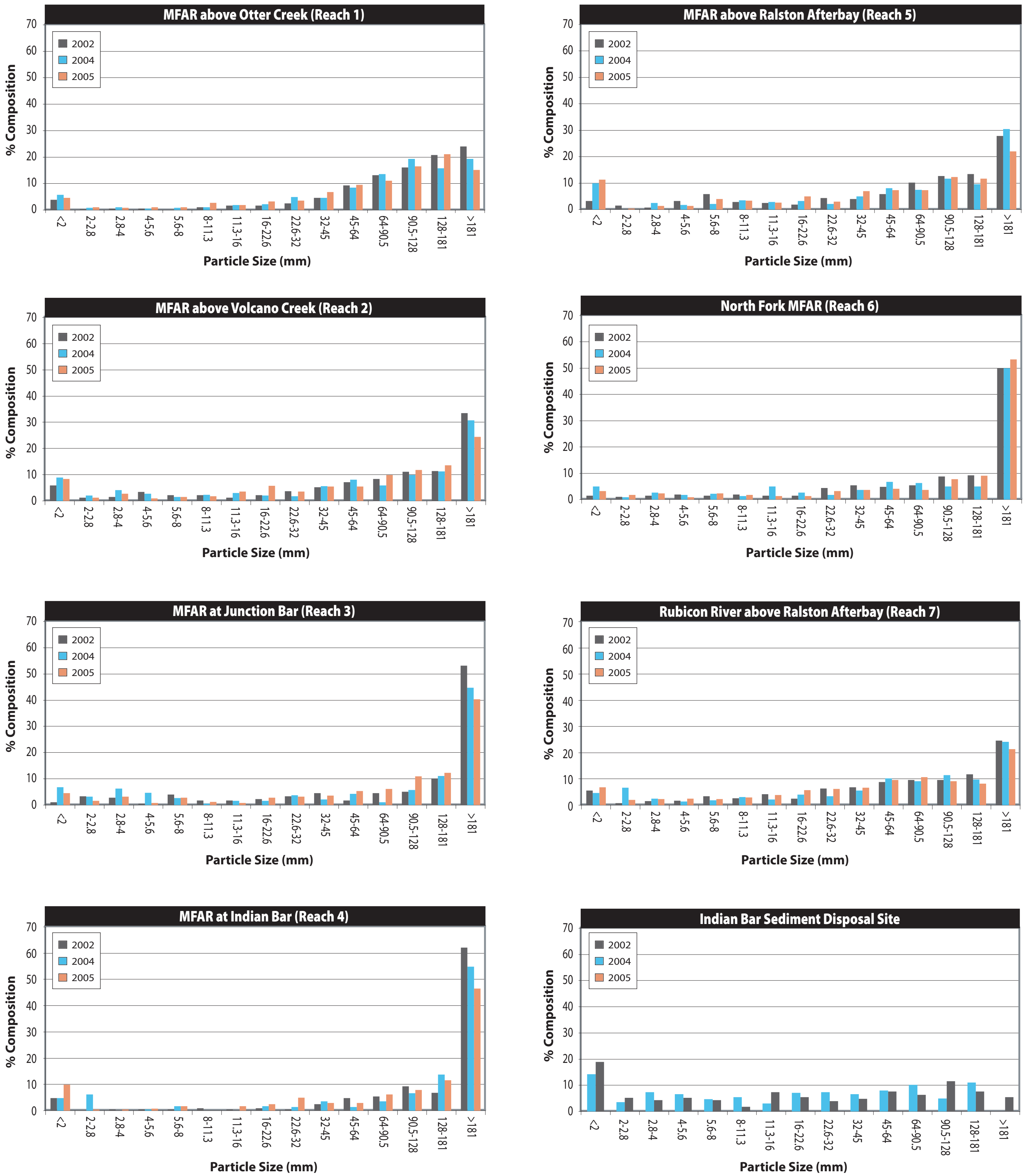

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Figure 3
Substrate Size Composition (Wentworth Size Classes) in Each Monitoring Reach and the Indian Bar Sediment Disposal Site in 2002, 2004, and 2005

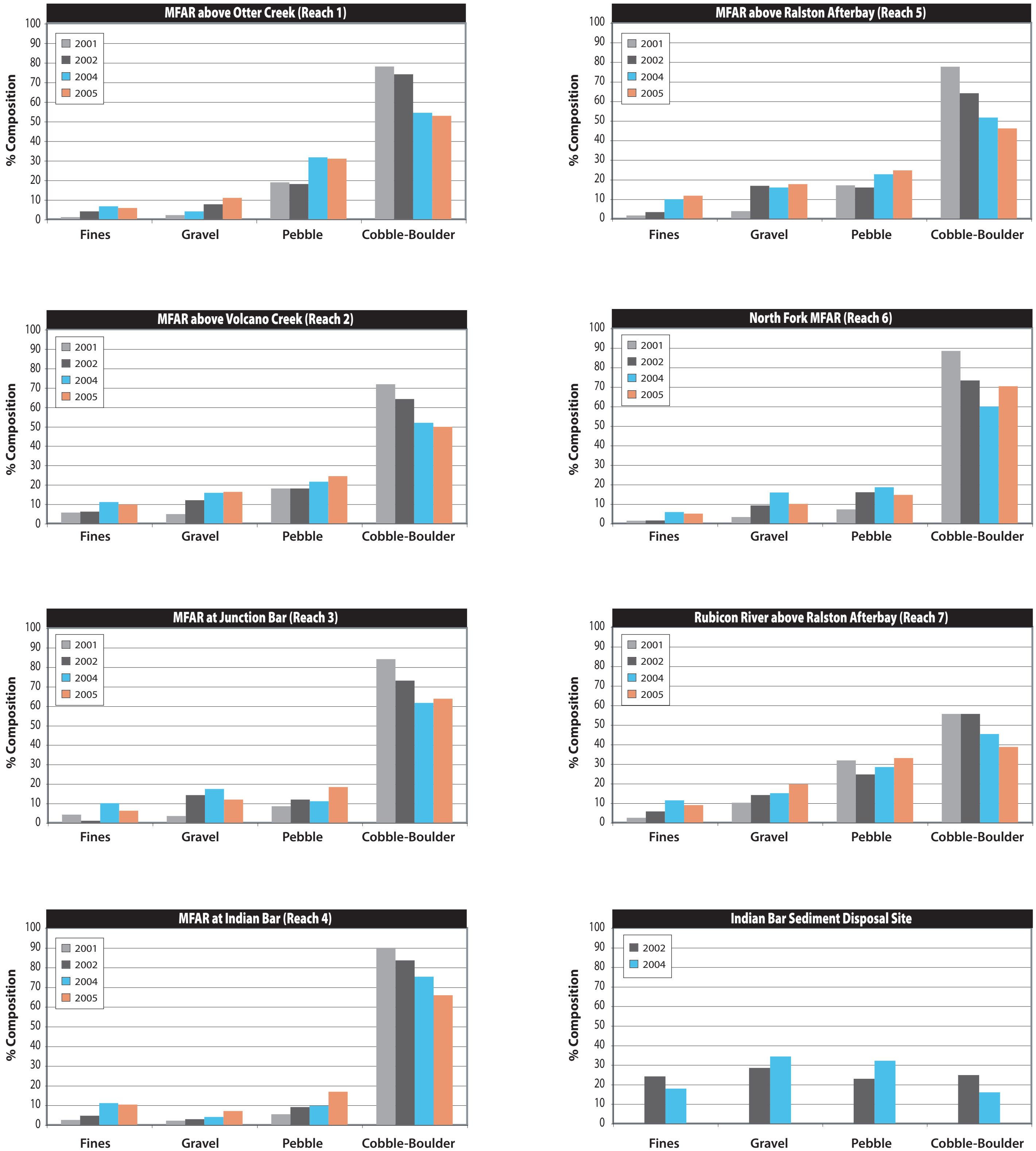

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Figure 4
Substrate Size Composition (Bain Size Classes) in Each Monitoring Reach in 2001, 2002, 2004, and 2005 and the Indian Bar Sediment Disposal Site in 2002 and 2004

Figure 5 presents an overall comparison of the substrate composition between the treatment and control reaches.

Gradation curves, showing the cumulative percentage of particles finer than a given diameter, for each reach are presented in Figure 6. The corresponding D_{16}, D_{25}, D_{50}, D_{75}, and D_{84} particle sizes (particle sizes for which a certain percentage of the sample is finer) are presented in Table 3. Monitoring year 2001 is not included because the results from the Bain method are not directly comparable to the results for subsequent years. For 2002, the gradation curve does not extend beyond 181 mm because only a single size class (>181 mm) was used to classify particles greater than 181 mm diameter.

Riffle Substrates

Riffle substrates in the project area continue to be dominated by cobbles and boulders (Figures 3 and 4). Among the treatment reaches, the highest proportion of large cobble and boulder substrates (>181 mm) was observed in the MFAR at Indian Bar (Reach 4) (Figure 3). As in previous years, pebble counts in 2005 detected higher proportions of large cobbles and boulders in the reaches immediately below Ralston Dam (Reaches 3 and 4) than in the reaches near Otter and Volcano Creek (Reaches 1 and 2). The proportions of large cobbles and boulders in Reaches 1, 2, 3, and 4 were 15%, 24%, 40%, and 46%, respectively. The coarser nature of the streambed in the reaches near the dam is also reflected by the gradation curves; median particle size (D_{50}) in Reaches 1, 2, 3, and 4 were 96 mm, 90 mm, 138 mm, and 163 mm, respectively (Figure 6). Among the control reaches, the highest proportions of large cobble and boulder substrates (>181 mm) were observed in the North Fork MFAR reach (Reach 6) (Figure 3). The proportions of large cobble and boulders (>181 mm diameter) in Reaches 5, 6, and 7 were 22%, 53%, and 21%, respectively.

While riffle substrates in the project area continue to be dominated by cobbles and boulders, there has been a general decrease in the proportion of cobbles and boulders (>64 mm) and a corresponding increase in the proportion of finer sediments (<64 mm) since 2002 (Figures 3 and 4). The shift toward smaller substrate sizes was first detected in 2004 in both the control and treatment reaches (Figure 5). Between 2002 and 2004, the proportion of cobble and boulder substrates decreased by 12–13%, and the individual contributions of fines, gravel, and pebble substrates increased by 3–5%. The D_{16}, D_{25}, D_{50}, D_{75}, and D_{84} particle sizes (particle sizes for which a certain percentage of the sample is finer) and gradation curves also reflect the general shift toward smaller particle sizes since 2002 (Table 3, Figure 6).

Indian Bar Sediment Disposal Site

Pebble counts were not conducted at the Indian Bar Sediment Disposal Site in 2005 because no significant changes in sediment volume had occurred since October 2004. The particle size distribution and associated percentile values of the surface layer of deposited material in 2002 and 2004 are shown in Table 3 and Figures 3, 4, and 6. Fines, gravel, pebble, and cobble-boulder substrates made up 18%, 34%, 32%, and 16%, respectively, of the total pebble count in 2004, indicating a slightly higher proportion of gravel and pebble substrates and a lower proportion of fines and cobble-boulder substrates since 2002.

Table 3. D_{16}, D_{25}, D_{50}, D_{75}, and D_{84} Particle Sizes (Particle Diameters for which a Certain Percentage of the Sample is Finer) in Each Monitoring Reach and the Indian Bar Sediment Disposal Site

2002

Reach	D16	D25	D50	D75	D84
1	42.9	61.7	114.5	178.1	*
2	10.8	35.6	109.2	*	*
3	17.9	43.6	184.7	*	*
4	61.7	101.9	193.7	*	*
5	9.6	29.3	100.9	*	*
6	30.7	56.6	181.0	*	*
7	11.6	26.1	78.2	178.7	*
Indian Bar	2.0	3.0	19.4	89.0	117.4

2004

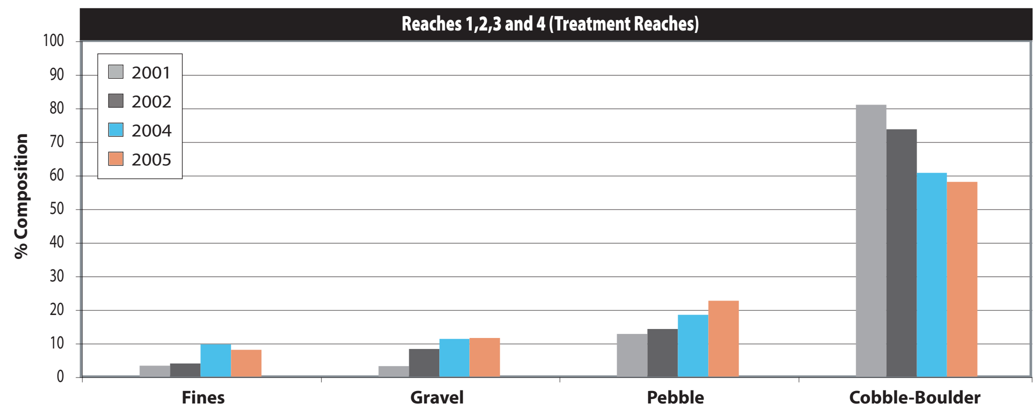
Reach	D16	D25	D50	D75	D84
1	25.8	47.6	97.9	159.7	198.7
2	4.4	16.8	96.4	217.3	303.4
3	3.9	13.4	153.5	327.0	420.2
4	29.0	91.6	208.5	430.5	570.2
5	7.7	20.7	94.9	220.1	307.4
6	13.0	37.1	181.0	402.2	516.3
7	6.6	20.1	75.8	175.4	254.4
Indian Bar	2.4	4.0	20.5	66.3	89.8

2005

Reach	D16	D25	D50	D75	D84
1	21.5	42.2	95.8	153.9	178.4
2	10.1	21.4	89.6	178.2	252.6
3	17.8	45.3	138.0	274.8	346.4
4	18.9	44.5	162.9	371.2	474.1
5	6.5	16.8	74.9	165.6	247.3
6	25.0	58.6	210.9	419.8	528.8
7	8.1	18.4	62.4	155.2	259.3
Indian Bar**					

* Values larger than 181 mm cannot be calculated because only a single size class (>181 mm) was used to classify particles greater than 181 mm diameter in 2002.

** not surveyed in 2005



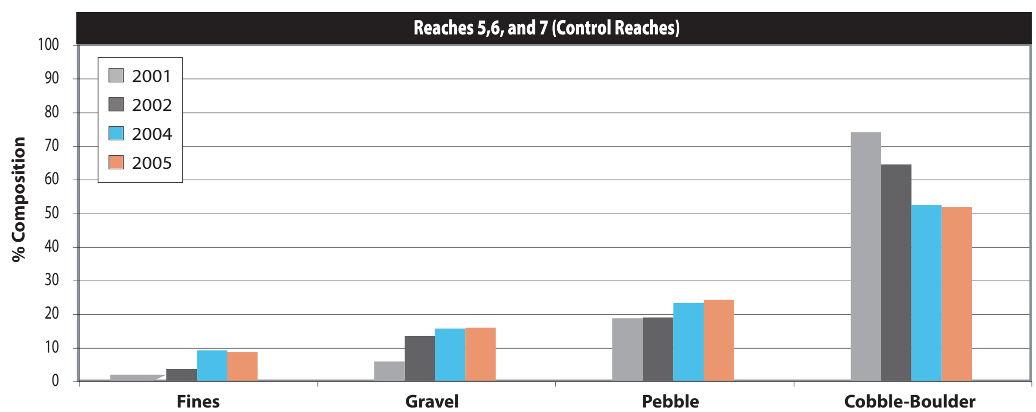


Figure 5
Combined Substrate Size Composition in the Treatment and Control Reaches in 2001, 2002, 2004, and 2005

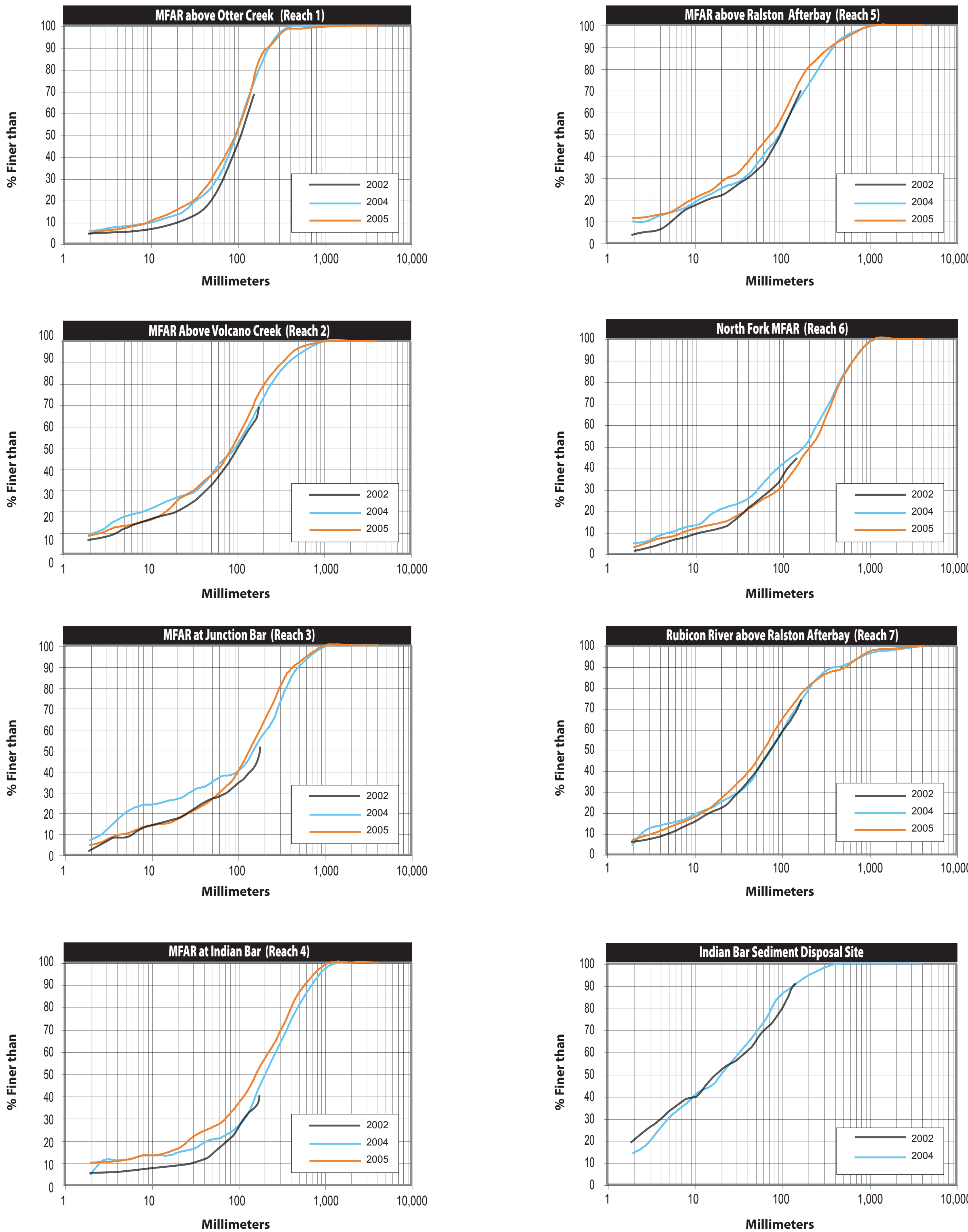


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Figure 6
Cumulative Particle Size Distribution in Each Montitoring Reach in 2002, 2004, and 2005 and the Indian Sediment Disposal Site in 2002 and 2004

Substrate Embeddedness

Figure 7 presents the proportion of particles exhibiting different levels of embeddedness in each monitoring reach in 2002, 2004, and 2005. In general, riffles in the project area are characterized predominantly by negligible (<5%) to low (5–25%) embeddedness levels. However, a distinct increase in embeddedness was observed in 2004 followed in 2005 by a return to the levels observed in 2002.

Decreased embeddedness of riffle substrates was evident throughout the project area in 2005. Between 2004 and 2005, both the control and treatment riffles exhibited a decrease in the proportion of particles embedded by 5–25% (low levels) and an increase in the proportion of particles embedded by less than 5% (negligible levels). This change was most pronounced in the treatment reaches where embeddedness levels shifted from predominantly low values (5–25% embedded) in 2004 to predominantly negligible values (<5% embedded) in 2005. The proportion of highly embedded particles (>75% embedded) also decreased in 2005. These changes resulted in embeddedness levels that were very similar to those observed in 2002.

Pool Cross Sections

No significant changes in channel contours or bed elevations were evident in pools in the MFAR near Otter Creek, MFAR near Volcano Creek, and Rubicon River reaches in 2005 (Figure 8). Minor mid-channel and near-bank aggradation and degradation were apparent based on comparison with the 2002 and 2004 channel cross sections; however, overall changes were negligible, as little or no change in average bed elevations occurred (Table 4). Additionally, survey error from year to year may have contributed to the differences in average channel bed elevations (e.g., transects may have been slightly off in any given year).

No survey of the MFAR at the Foresthill gage was conducted in 2005. Surveys of the MFAR at the Foresthill gage before (March 4 and June 9, 2004) and after (August 11, 2004) the August 5 spill event detected no significant change in channel contours and bed elevations at this location (Jones pers. comm.).

Water Temperatures

Hourly water temperatures in the MFAR below Ralston Dam (at the Foresthill gage) and the North Fork MFAR (approximately 2.2 miles above its confluence with the MFAR) from October 2004 to September 2005 are presented in Figure 9.

Table 4. Change in Average Channel Bottom Elevation between 2002 and 2005

Pool	Average Bed Elevation in 2002	Average Bed Elevation in 2004	Average Bed Elevation in 2005	Change in Average Bed Elevation between 2002 and 2004	Change in Average Bed Elevation between 2004 and 2005	Change in Average Bed Elevation between 2002 and 2005
1 (MFAR near Otter Creek)	n/a	-9.91	-10.15	n/a	-0.24	n/a
2 (MFAR near Otter Creek)	-11.83	-12.46	-12.32	-0.63	+0.14	-0.49
3 (MFAR near Volcano Creek)	-13.95	-13.67	-13.33	+0.28	+0.34	+0.62
4 (MFAR near Volcano Creek)	-12.88	-12.77	-11.86	+0.11	+0.91	+1.02
5 (Rubicon River)	-18.05	-17.78	-17.93	+0.27	-0.15	+0.12
6 (Rubicon River)	-11.56	-11.03	-10.70	+0.53	+0.33	+0.86

Note: Average channel bottom elevations were calculated between left and right edges of water.

* Baseline monitoring year for Pool 1 is 2004; baseline monitoring year for Pools 2-6 is 2002.

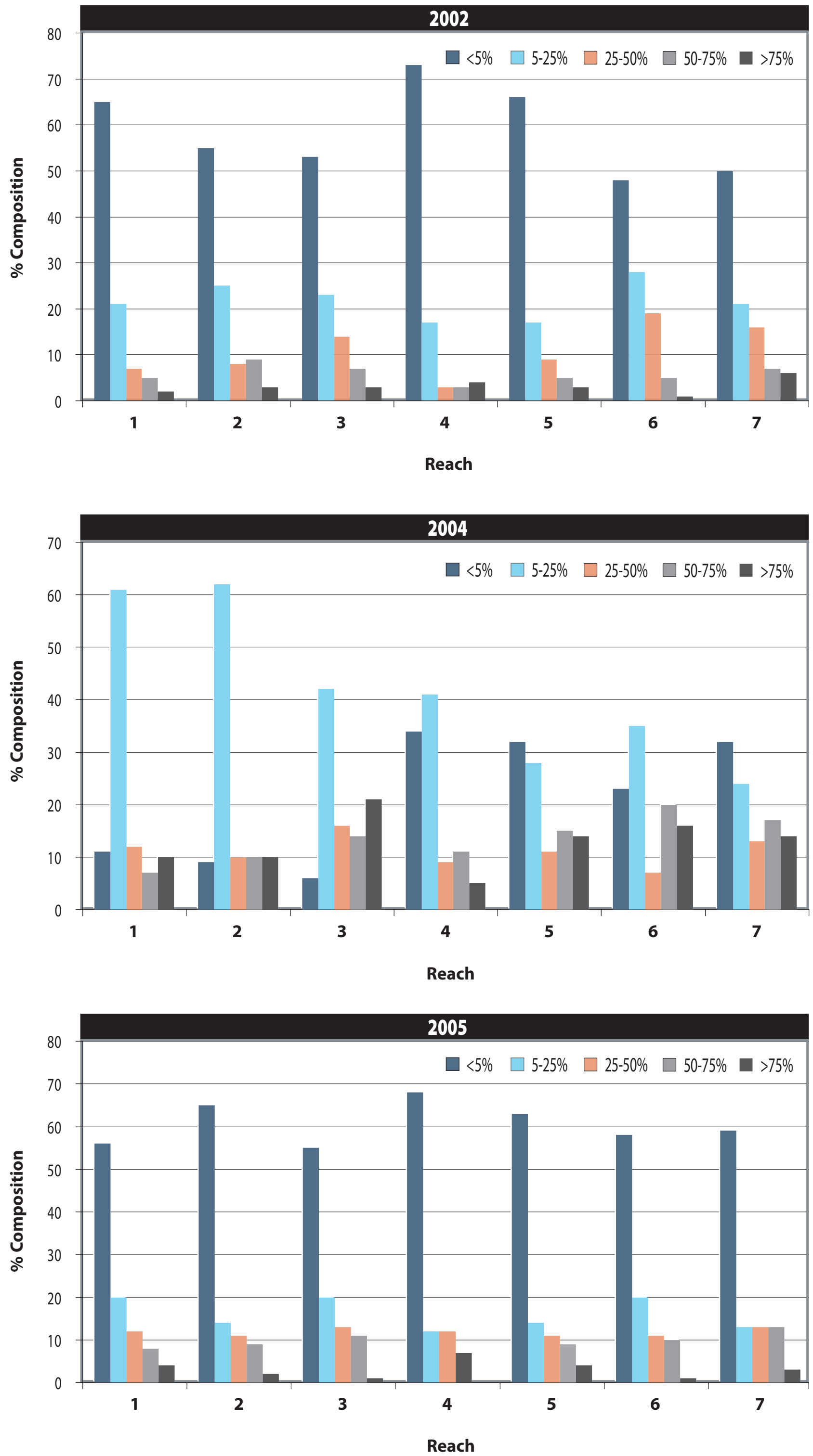

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Figure 7
Particle Embeddedness in Each Monitoring Reach in 2002, 2004, 2005

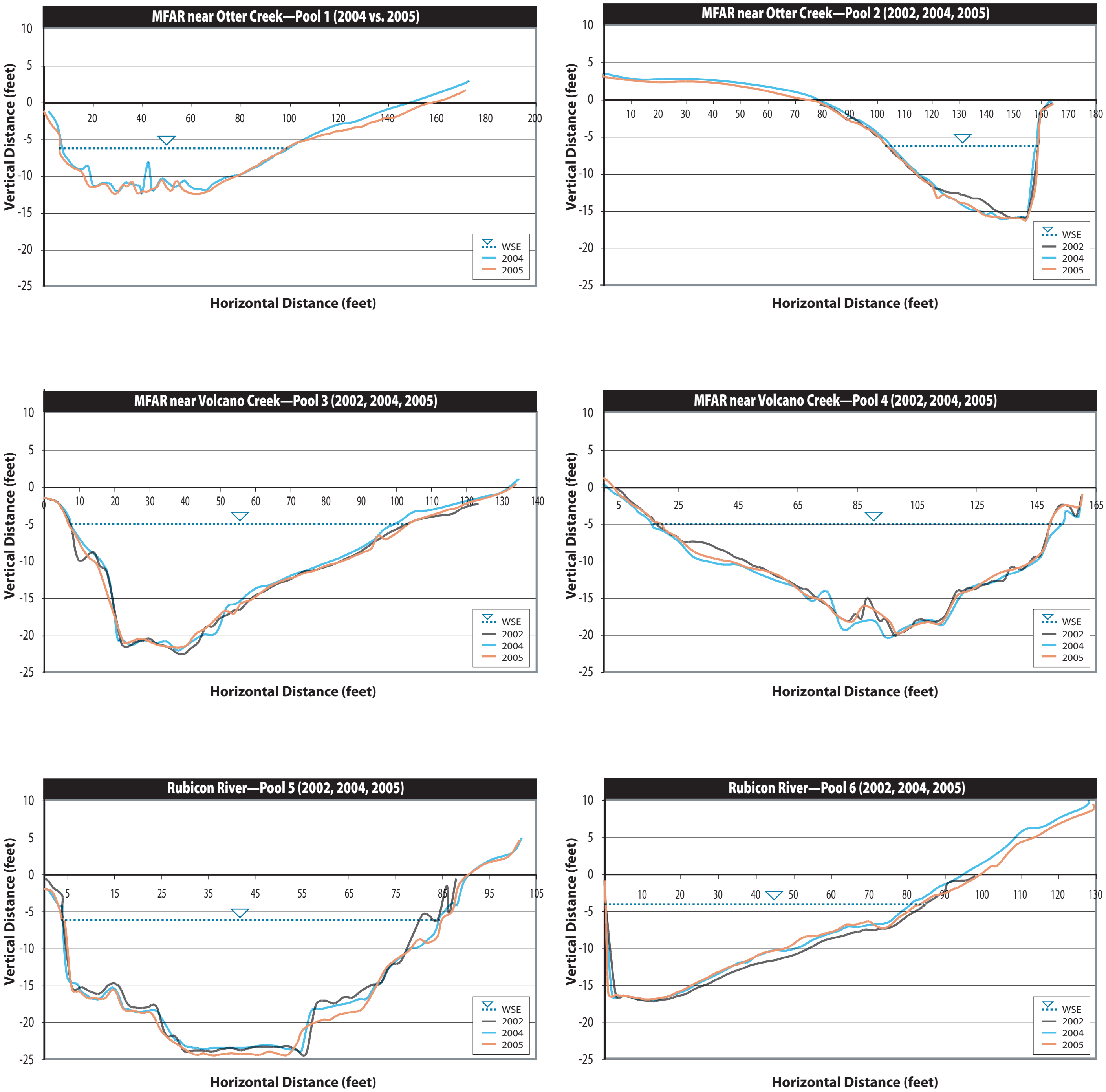

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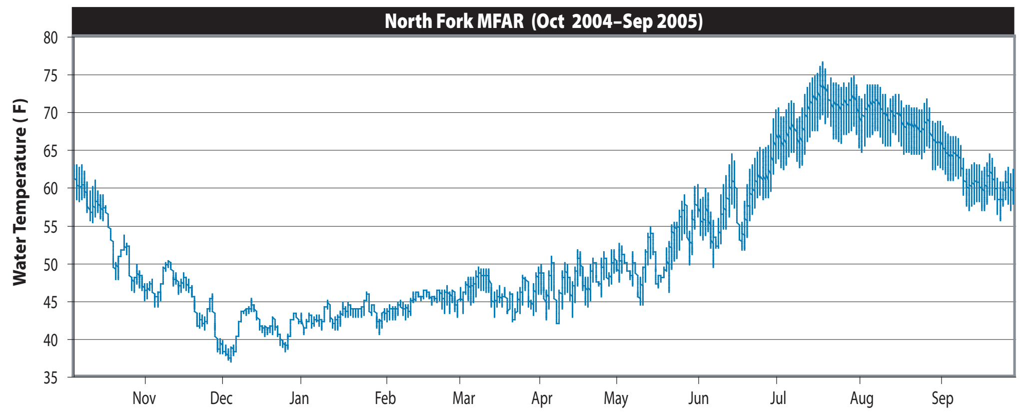
Figure 8
Channel Cross Sections in Monitoring Pools in 2002, 2004, 2005



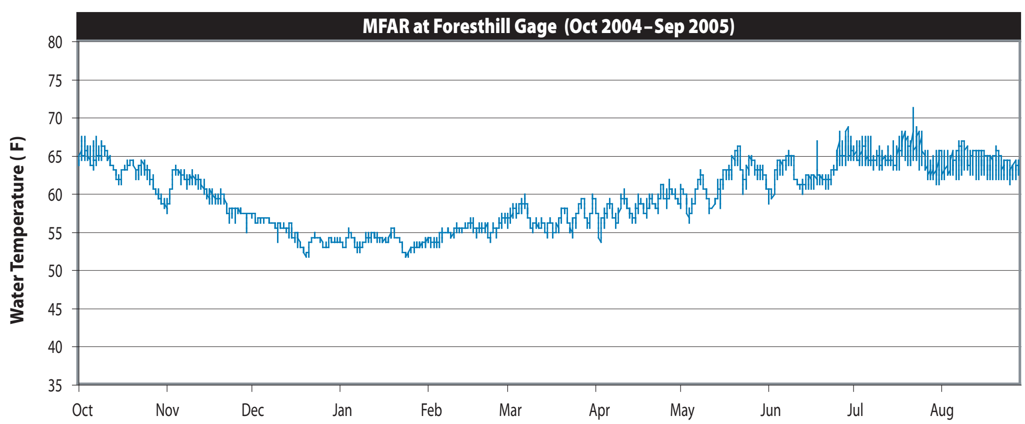


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Figure 9
Temperature Summaries for
North Fork MFAR and MFAR at Foresthill Gage
October 2004 thru September 2005

Benthic Macroinvertebrates

In 2005, BMI monitoring was conducted only in October because high spring and summer flows precluded sampling in June and August. Consequently, the following results focus on reach and annual differences and trends in BMI metrics based on samples collected in October 2001, 2002, 2004, and 2005.

BMI Metrics

BMI Densities

In October 2005, BMI densities ranged from 3,472 invertebrates per square meter in Reach 7 to 12,865 invertebrates per square meter in Reach 4 (Figure 10). In general, annual variability in BMI density has been higher in the treatment reaches than in the control reaches. The highest variability in BMI density occurred in the reach immediately below Ralston Dam (Reach 4)..

EPT Index

In October 2005, EPT index values ranged from 8% in Reach 4 to 56% in Reach 2 (Figure 10). As in previous years, the monitoring reach immediately below Ralston Dam (Reach 4) had the lowest EPT values of any reach. With the exception of Reach 4, EPT values in October 2005 were the highest observed since monitoring began. This increase occurred in both the treatment and control reaches but was most pronounced in Reaches 1 and 2 where EPT values more than doubled relative to 2004 values.

Reach difference and longitudinal trends in EPT values were similar among the monitoring years (Figure 10). Downstream of Ralston Dam, EPT values have generally been lowest in Reach 4 (3–16%), intermediate in Reach 3 (14–28%), and highest in Reaches 1 and 2 (20–57%). EPT values in the control reaches have been relatively high (23–50%) and similar to those observed in the lowermost treatment reaches (Reaches 1 and 2).

Taxa Richness

In October 2005, taxa richness ranged from 20 in Reach 1 to 31 in Reach 5 (Figure 10). These values were consistent with the range of values observed in previous monitoring years. Since 2001, taxa richness has been higher and less variable than in the treatment reaches.

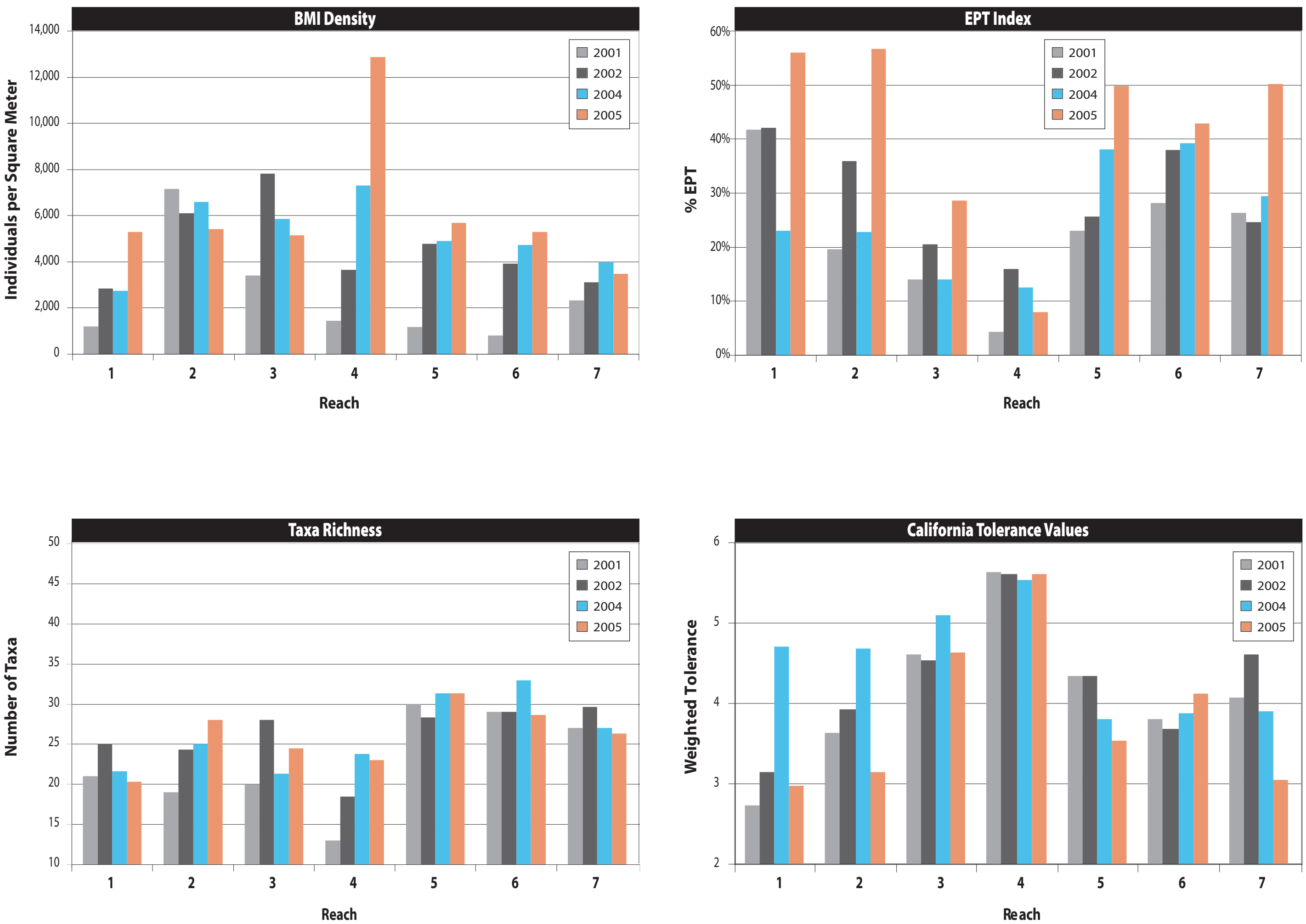

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Figure 10
BMI Metrics for Each Monitoring Reach in October 2001, 2002, 2004, and 2005

California Tolerance Values

In October 2005, California tolerance values ranged from 3.0 in Reach 1 to 5.6 in Reach 4 (Figure 10). As in previous years, the monitoring reach immediately below Ralston Dam (Reach 4) had the highest California tolerance values (5.5-5.6) of any reach.

Reach differences and longitudinal trends in California tolerance values were similar among the monitoring years. Downstream of Ralston Dam , California tolerance values have generally been highest in Reach 4 (5.5–5.6), intermediate in Reach 3 (4.5–5.1), and lowest in Reaches 1 and 2 (2.7–4.7). California tolerance values in the control reaches have been relatively low (3.0–4.6) and similar to those observed in the lowermost treatment reaches (Reaches 1 and 2).

Dominant Taxa

Dominant taxa in October 2005 included chironomid midges (Chironomidae), *Baetis* mayflies, *Rhithrogena* mayflies, and black flies (Simuliidae). Chironomidae was again the most common and widely distributed taxon in the project area (Table 5). As in previous years, the relative abundance of chironomids was highest in the reaches immediately downstream of Ralston Dam (Reaches 3 and 4), where they composed about half of the samples. *Baetis* mayflies also exhibited the same general pattern of abundance observed in previous years with the highest proportions (12–19%) occurring in the control reaches (Reaches 5, 6, and 7). As in previous years, Simuliidae was dominant only in Reaches 1 and 4 (24% and 25%). *Rhithrogena* mayflies, which were present in relatively low numbers in 2004, were a dominant taxon in 2005 in most of the monitoring reaches (8–30%).

Functional Feeding Groups

In October 2005, collector-gatherers were the dominant feeding group in most of the monitoring reaches (Figure 11). The dominance of collector-gathers was attributable primarily to the relatively large numbers of chironomid midges and *Baetis* mayflies in most samples. As in previous years, a general longitudinal trend in collector-gatherers was evident downstream of Ralston Dam; the relative abundance of collector-gatherers was highest in the reach at Junction Bar (Reach 3), intermediate near Volcano Creek (Reach 2), and lowest near Otter Creek (Reach 1). The relative abundance of collector-gatherers in the control reaches (Reaches 5–7) was intermediate to that of the treatment reaches.

In October 2005, the relative abundance of collector-filterers was highest in Reaches 1 and 4, lowest in Reaches 2 and 3, and intermediate in Reaches 5–7 (Figure 11). Black flies (Simuliidae) were the dominant collector-filterer in the treatment reaches (Reaches 1–4), and *Hydropsyche* caddisflies were the dominant collector-filterer in the control reaches (Reaches 5–7).

Table 5. Percent Composition of Dominant Taxa in each Monitoring Reach in October 2001, 2002, 2004, and 2005

	2001		2002		2004		2005	
Reach 1								
1	*Hydropsyche*	34.0%	*Hydropsyche*	28.2%	*Simulium*	31.2%	*Rhithrogena*	29.7%
2	*Rhithrogena*	18.5%	*Rhithrogena*	16.9%	*Baetis*	18.2%	Simuliidae	23.6%
3	*Glossosoma*	17.6%	Chironomidae	11.5%	Chironomidae	6.0%	*Baetis*	8.6%
4	Chironomidae	5.0%	*Baetis*	7.2%	Oligochaeta	5.9%	*Calineuria californica*	6.3%
5	*Cheumatopsyche*	3.9%	*Isoperla*	4.6%	*Sweltsa*	5.4%	Chironomidae	5.5%
Reach 2								
1	Oligochaeta	37.9%	Chironomidae	27.8%	Chironomidae	28.6%	Chironomidae	22.8%
2	Ephemerellidae	14.9%	*Hydropsyche*	11.2%	Oligochaeta	16.9%	*Rhithrogena*	17.3%
3	Chironomidae	6.9%	*Baetis*	9.6%	*Baetis*	16.0%	Ephemerellidae	13.7%
4	*Baetis*	6.9%	*Rhithrogena*	8.8%	*Serratella*	7.7%	*Calineuria californica*	6.0%
5	*Serratella*	6.9%	*Isoperla*	8.6%	*Simulium*	4.7%	*Baetis*	5.2%
Reach 3								
1	Oligochaeta	47.6%	Oligochaeta	28.5%	Chironomidae	37.2%	Chironomidae	58.0%
2	*Simulium*	10.3%	Chironomidae	22.6%	*Baetis*	17.7%	*Rhithrogena*	7.5%
3	*Ephemerella*	6.7%	*Baetis*	7.4%	Oligochaeta	12.9%	Ephemerellidae	6.2%
4	Chironomidae	5.0%	*Serratella*	7.1%	*Simulium*	6.4%	Oligochaeta	4.3%
5	*Baetis*	5.0%	*Antocha*	6.2%	*Antocha*	5.5%	*Leucrocuta/Nixe*	3.0%
Reach 4								
1	*Simulium*	32.9%	Chironomidae	43.4%	Chironomidae	31.8%	Chironomidae	47.9%
2	Chironomidae	23.8%	*Simulium*	9.1%	*Simulium*	20.8%	Simuliidae	25.1%
3	*Acentrella*	4.4%	*Acentrella*	8.9%	Oligochaeta	7.2%	*Baetis*	6.7%
4	*Antocha*	2.3%	Oligochaeta	6.7%	*Baetis*	5.5%	Plecoptera	2.3%
5	*Gyraulus*	2.3%	*Gyraulus*	6.6%	*Hydroptila*	3.8%	Oligochaeta	2.2%

	2001		2002		2004		2005	
Reach 5								
1	Chironomidae	18.8%	*Baetis*	21.4%	*Baetis*	26.3%	Chironomidae	25.4%
2	*Baetis*	16.3%	Chironomidae	18.9%	*Epeorus*	15.3%	*Baetis*	15.6%
3	*Hydropsyche*	11.1%	*Hydropsyche*	12.2%	Chironomidae	7.7%	*Epeorus*	11.9%
4	*Cheumatopsyche*	8.1%	*Epeorus*	4.5%	*Paraleptophlebia*	5.4%	*Rhithrogena*	11.4%
5	*Optiocervus*	6.2%	*Cheumatopsyche*	4.3%	*Simulium*	5.1%	Ephemerellidae	3.6%
Reach 6								
1	*Hydropsyche*	20.1%	Chironomidae	18.9%	Chironomidae	17.3%	Chironomidae	31.8%
2	Chironomidae	15.5%	*Rhithrogena*	18.3%	*Rhithrogena*	10.6%	*Baetis*	11.7%
3	*Baetis*	8.8%	*Baetis*	12.0%	*Optioservus*	7.8%	*Rhithrogena*	10.1%
4	*Cheumatopsyche*	8.2%	*Hydropsyche*	7.2%	*Baetis*	7.7%	*Hydropsyche*	9.6%
5	*Rhithrogena*	8.2%	Hydroptilidae	5.5%	*Hydropsyche*	5.7%	*Lepidostoma*	6.4%
Reach 7								
1	*Hydropsyche*	30.8%	Chironomidae	25.9%	*Baetis*	13.7%	*Rhithrogena*	20.4%
2	*Baetis*	13.2%	*Baetis*	12.5%	Chironomidae	13.3%	*Baetis*	18.8%
3	Chironomidae	9.2%	*Hydropsyche*	7.1%	*Psephenus falli*	13.1%	Chironomidae	14.7%
4	*Optiocervus*	8.4%	*Psephenus falli*	7.0%	*Hydropsyche*	10.2%	*Epeorus*	10.7%
5	*Cheumatopsyche*	6.6%	*Argia*	5.5%	*Epeorus*	7.9%	*Psephenus falli*	5.7%

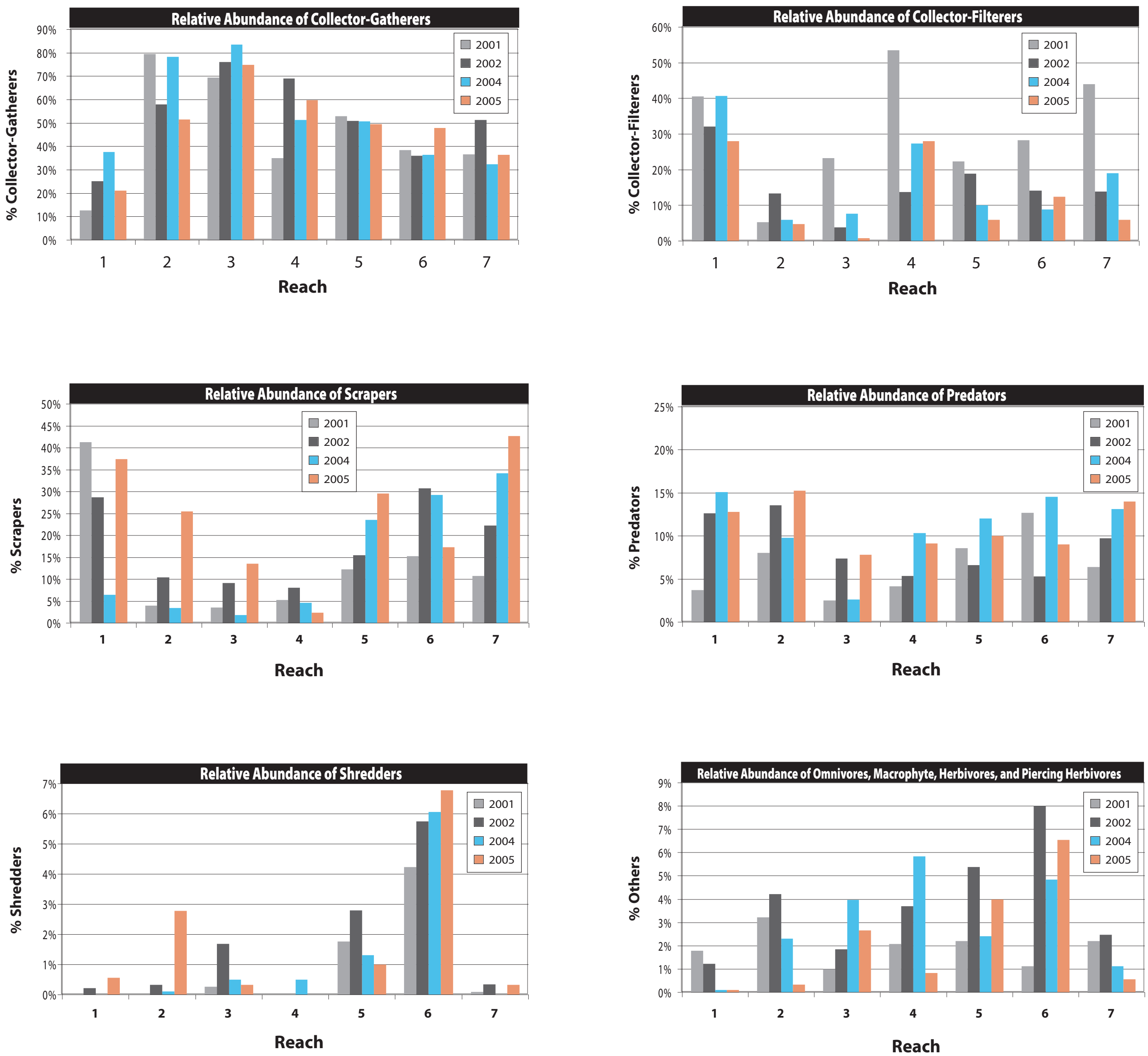

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Figure 11
Relative Abundance of Functional Feeding Groups in Each Monitoring Reach in October 2001, 2002, 2004, and 2005

In October 2005, scrapers were a dominant component in most of the monitoring reaches largely because of increases in the relative abundance of *Rhithrogena* mayflies since 2004 (Figure 11). The exception was Reach 4 where scrapers have been absent or present in relatively low numbers since monitoring began.

The relative abundance of predators in October 2005 was generally within the range observed in previous years (Figure 11). No distinct trends or patterns in predator abundance were evident.

Shredders are a relatively small component of the riffle communities sampled in the project area (Figure 11). The relative abundance of shredders has consistently been highest in the North Fork MFAR (Reach 6) and the MFAR above Ralston Afterbay (Reach 5).

Other functional feeding groups—macrophyte herbivores, piercing herbivores, and omnivores—have been a relatively small, variable component of riffle communities in the project area.

Discussion

Aquatic Habitat

Preproject monitoring since 2001 continues to support the general predictions regarding the geomorphic processes and sediment dynamics that influence the distribution and quality of aquatic habitat in the project area. The MFAR, Rubicon River, and North Fork MFAR in the project area are dominated by stable channels and coarse-grained substrates characteristic of steep, canyon-bound streams where sediment transport capacity exceeds sediment supply. Large materials (boulders and cobble) move only during relatively high and infrequent flow events, while finer materials are effectively transported during most events. Variation in channel form and substrate composition is generally related to channel gradient and confinement; steeper, more confined reaches act to transport sediment during peak flows, and lower-gradient, less confined reaches act to temporarily store sediment between such flows. Alluvial channel features (pool-riffle-bar sequences) are most developed above major channel constrictions (e.g., alluvial fans, landslides, bedrock outputs) where water backs up, slows down, and deposits sediment during high flow events.

Preproject monitoring of channel cross sections, substrate conditions, and sediment dynamics since 2001 confirmed that the MFAR downstream of Ralston Afterbay is inherently stable and therefore relatively insensitive to changes in discharge and sediment supply. Despite year-to-year variation in the magnitude and duration of winter and spring flows, no significant trends in channel cross section or substrate size composition have been detected since monitoring began in 2001. Annual variation in the proportion of small, mobile sediments (fines, gravel, and pebbles) was detected, but general reach differences and longitudinal trends in substrate size composition below Ralston Dam and in the control reaches have persisted through the monitoring period.

The spill event at Ralston Dam on August 5, 2004, provided a unique opportunity to examine the response of the river to a relatively large discharge of flow and sediment from Ralston Afterbay and the Indian Bar Sediment Disposal Pile. The effects of the spill on bed conditions downstream of Ralston Dam were most pronounced in the reaches immediately below the dam. The most obvious effects were extensive scour and mobilization of sediment from the Indian Bar Sediment Disposal Site and adjacent channel (Reach 4) and deposition of fine sediment (predominantly coarse sand) in the Junction Bar reach (Reach 3). Consistent with the observed effects of the spill event, pebble counts in October 2004 detected small but measurable increases in substrate embeddedness and the proportion of fines, gravel, and pebbles in riffles relative to 2002 levels.

In October 2004, similar increases in fine sediments and embeddedness were detected in the control reaches upstream of Ralston Afterbay and in the North Fork MFAR, suggesting that the observed increases below Ralston Dam may have been caused, at least in part, by increases in sediment inputs from other watershed sources since 2002. Possible sources include the Star Fire, which burned approximately 17,500 acres of the MFAR and Rubicon River watersheds above Ralston Afterbay in 2001. Increases in erosion and sediment input from these watersheds may have been triggered by the relatively large runoff events that occurred in winter and spring of 2003 and 2004. However, following high flows in spring 2005, embeddedness and fine sediment levels in all monitoring reaches had decreased or returned to the levels observed in 2002.

Another source of channel disturbance and fine sediment in the project area is suction dredge mining. Since 2001, suction dredge mining has been an ongoing activity in the North Fork MFAR and Rubicon River monitoring reaches (Reach 6 and 7). Consequently, some of the observed variation in substrate composition and embeddedness may be attributable to this activity.

Benthic Macroinvertebrates

Preproject monitoring of BMI communities in the project area since 2001 has revealed general similarities to communities in other regulated rivers at similar elevations in the Sierra Nevada (Pacific Gas and Electric Company 2002; Garcia and Associates 2000). Although channel and bed conditions in the MFAR, North Fork American River, and Rubicon River are inherently stable, the hydrology of these watersheds is strongly influenced by the Mediterranean climate, resulting in substantial annual and seasonal variation in streamflow. In steep Sierra Nevada streams like the MFAR, BMI are adapted to the periodic scouring effects of high winter and spring flows, recovering from such events through rapid recolonization of the streambed and development of stable, diverse communities by summer and fall.

Since 2001, BMI communities downstream of Ralston Dam have exhibited relatively high spatial and temporal variability compared to the control reaches. Reach differences have been marked by a general longitudinal trend in metric values, indicating a decreasing trend in habitat quality from Indian Bar (Reach 4) to Otter Creek (Reach 1). For example, California tolerance values, an index of human influence on stream habitat, have consistently exhibited a decreasing trend from Indian Bar to Otter Creek. This trend reflects the higher proportions of relatively tolerant taxa (e.g., Chironomidae) and lower proportions of relatively intolerant taxa (e.g., *Rhithrogena*) near the dam. Reach 4 appears to the most modified reach based on the dominance of just two taxa (Chironomidae, Simuliidae) in all monitoring years. These metrics continue to support the conclusion that existing habitat conditions vary significantly among the treatment reaches, with the lowest habitat values immediately below Ralston Dam and the highest habitat values in the lowermost reaches. By comparison, habitat values in the control reaches (Reaches 5–7) have been relatively high and stable based on EPT index, taxa richness, California tolerance values, and functional feeding group composition.

The observed spatial and temporal patterns and trends in BMI metrics among the monitoring reaches likely reflect differences in habitat conditions that exist naturally as well as the effects of long- and short-term human influences on the aquatic environment. For example, longitudinal trends in BMI metrics and median particle size (D_{50}) downstream of Ralston Dam indicate a general negative correlation between degree of channel armoring (proportion of large cobbles and boulders) and habitat quality. This relationship is consistent with the general observation that streambeds dominated by mostly coarse or fine sediment are less productive than streambeds with a broad range of small to intermediate-size substrates (sand, gravels, pebble, and small cobbles) (Minshall 1984). Steeper, coarser stream reaches like those nearest the dam would also tend to retain smaller quantities of organic detritus, which is known to have a major effect on benthic community structure and function in streams (Culp et al. 1983).

Other factors that potentially contribute to variation in BMI communities among the monitoring reaches include flow regime, water temperature, light (extent of shading by streamside vegetation), food availability, water velocities, and biological interactions (e.g., predation, competition). For example, hydroelectric operations typically result in higher, colder, and more variable flows in the reaches downstream of Oxbow Powerhouse (Reaches 1, 2, and 3) than in the control reaches. Between Ralston Dam and confluence of North Fork MFAR (Reach 4), habitat conditions are often distinctly different because flows are maintained by minimal discharge from the dam (during non-spill periods) and are not subject to discharges from Oxbow Powerhouse. Compared to the treatment reaches, the control reaches are characterized by smaller channels, lower flows, greater riparian influence, and higher summer and fall water temperatures. The relatively large number of taxa and functional feeding groups in the control reaches indicate greater diversity in physical habitat and food resources than the reaches below Ralston Dam.

Since 2001, the most notable change in habitat conditions and BMI communities in the project area occurred as a result of the gate malfunction and spill event at Ralston Dam on August 5, 2004. This event, while unforeseen and not representative of normal operations, provided a unique opportunity to examine the response of the BMI community to a large discharge event and associated effects on aquatic habitat below the dam. Field observations and sampling immediately after the event detected substantial reductions in BMI densities and diversity in the reaches immediately below Ralston Dam (Reaches 3 and 4) where the effects of scour, sediment transport, and deposition were most apparent. Subsequent sampling in October 2004 revealed that BMI abundance had increased substantially, reaching or exceeding the levels measured in 2001 and 2002. However, the effects of the spill on certain taxa were still evident based on reductions in EPT values, increases in California tolerance values, and reductions in the relative abundance of scrapers. These effects were temporary as BMI metrics measured in October 2005 indicated that the community had fully recovered.

Amphibians and Aquatic Reptiles

Previous amphibian surveys have documented the presence of significant populations of yellow-legged frogs (*Rana boylii*) in the Rubicon River and the MFAR above Ralston Afterbay (Jones & Stokes 2002c). A federal and state species of concern and Forest Service sensitive species, foothill yellow-legged frogs have also been observed in the reaches immediately above Ralston Afterbay and the North Fork MFAR (Reaches 5, 6, and 7) during BMI monitoring activities. Since 2001, the greatest numbers of adult frogs have been observed along the Rubicon River above Ralston Afterbay (Reach 7). A single subadult was found in the MFAR below Ralston Dam, near the confluence with the North Fork MFAR, during surveys of Junction and Indian Bars in June 2002. However, no evidence of foothill yellow-legged frog breeding has been found below Ralston Dam during either previous amphibian surveys or monitoring activities.

In October 2005, adult foothill yellow-legged frogs were observed in the MFAR above Ralston Afterbay (Reach 5), the North Fork MFAR (Reach 6), and the Rubicon River (Reach 7). Because BMI monitoring activities were conducted in October only, egg masses and larval frogs were not observed. Several pools that provide suitable breeding habitat for foothill yellow-legged frogs occur in these reaches. No foothill yellow-legged frogs were observed below Ralston Dam.

Other amphibians and reptiles that have been observed in the project area are western toad (*Bufo boreas*), bullfrog (*Rana catesbeiana*), aquatic garter snake (*Thamnophis couchii*), and western pond turtle (*Clemmys marmorata*). The western pond turtle is a federal and state species of concern and Forest Service sensitive species. Western toads have been observed below Ralston Dam near Indian Bar. Garter snakes have been observed in MFAR above Ralston Afterbay, MFAR below Ralston Dam, North Fork of MFAR, and Rubicon River. Bullfrog and western pond turtle have been observed in the perennial wetland occurring in the historic channel of the MFAR below American Bar, which today is bypassed by the tunnel chute.

Fish

Fish species known to occur in the project area include rainbow trout, brown trout, Sacramento sucker, speckled dace, riffle sculpin, Sacramento pikeminnow, and hardhead. The hardhead is a state species of concern and a Forest Service sensitive species (Moyle et al. 1995).

Little information is available on existing fish populations in the project area. Ralston Afterbay may provide habitat for native suckers and minnows (including hardhead) and possibly overwintering habitat for trout. The project area is immediately downstream of the state-designated wild trout section of the Rubicon River, which extends 30 miles from Hell Hole Dam to the confluence of the MFAR. Angler surveys in the late 1970s indicate that the abundance of trout is relatively low in the Rubicon River immediately upstream of Ralston Powerhouse and increases at higher elevations and in areas where angler access is restricted. Relatively high summer water temperatures (typically ranging between 70ºF and 80ºF in July and August) may also limit the downstream extent and abundance of trout in the Rubicon River immediately above Ralston Afterbay.

No angling or fish population data are available for the MFAR downstream of Ralston Dam. Preproject monitoring of aquatic habitat and BMI communities in the MFAR between Ralston Dam and Otter Creek since 2001 indicate that channel morphology, substrate conditions, water temperatures, and food availability are generally suitable for the above fish species. The spill event that occurred in August 2004 caused adverse effects on food availability (decreases in BMI diversity and abundance) in the reaches immediately below Ralston Dam. However, recolonization of these reaches led to nearly complete recovery of the benthic community by October 2005 based on several key BMI metrics measured in previous years (Jones & Stokes 2004, 2005). Pools, which provide important habitat for a number of species in the project area (e.g., hardhead), were largely unaffected by the spill event. No significant changes in the bed profile, volume, or depth of pools were detected during the preproject monitoring period.

Since 2001, channel and substrate monitoring in the reaches below Ralston Dam have revealed relatively stable channel and bed conditions and continued dominance of large cobble and boulder substrate, consistent with the geomorphic character of the MFAR and the effects of Ralston Dam on sediment transport. Consequently, most of the riffle substrates in the MFAR below Ralston Dam remain unsuitable for trout spawning and suboptimal for BMI production because of their large, uniform size (Jones & Stokes 2002b). Therefore, the potential benefits of reintroducing smaller sediments (gravel, pebble, and small cobbles) that have been trapped in the reservoir by placing them on Indian Bar will continue to be evaluated during the postproject monitoring phase.

Conclusions and Recommendations

Water year 2005 was an important preproject year because, for the first time since monitoring began, spring flows fell within the target range for SPT operations (>3,000 cfs at Ralston Dam), allowing an assessment of the effects of such flows on aquatic habitat and BMI under preproject conditions (i.e., in the absence of SPT operations). In addition, monitoring in 2005 provided an opportunity to further evaluate the condition of aquatic habitat and BMI communities in the MFAR below Ralston Dam following the spill event that occurred at Ralston Dam in August 2004.

As discussed in the monitoring plan (Appendix), this monitoring program employs an optimum design for impact assessment based on its success in distinguishing potential project effects from background variation in natural systems (Green 1979). In this design, detecting project effects requires the monitoring of key parameters in locations both within and outside the project's influence (treatment and control locations) during pre- and postproject periods. The effectiveness of this design depends on adequate characterization of the range of variability in these parameters, and the ways in which the monitoring reaches vary in relation to each other under preproject conditions. Since 2001, preproject monitoring of substrate conditions and BMI communities in natural riffles upstream and downstream of Ralston Afterbay (as well as in the North Fork MFAR) has detected several important preproject patterns and trends that will serve as benchmarks for evaluating potential project effects during the postproject monitoring period.

- The channels of the MFAR, Rubicon River, and North Fork MFAR are inherently stable; despite substantial variation in the magnitude and duration of annual peak flows, no significant changes or trends in channel profiles or substrate size composition have been detected since 2001.
- The stability and high sediment transport capacity of these reaches are reflected by the dominance of coarse-grained substrates (cobbles and boulders) and the transient nature of fine sediments resulting from local inputs (August 2004 spill event) and other watershed sources.
- Reach differences in substrate size composition reflect differences in channel gradient, confinement, and sediment supply, which is best illustrated by the general longitudinal gradient in substrate size composition between Ralston Dam and Otter Creek.
- Slight increases in the proportion of small to intermediate-sized sediments (fines, gravel, and pebbles) throughout the project area since 2002 suggest a potential short-term increase in sediment loads from upstream sources in recent years.
- BMI communities in the project area, which appear to be highly resilient to natural and human-caused disturbances, are generally similar to the communities found in other regulated, mid-elevation rivers in the Sierra Nevada.

- Although exhibiting high spatial and temporal variability, several BMI metrics indicate general reach differences and longitudinal patterns in habitat quality related to channel gradient, substrate size composition, and degree of flow modification associated with hydropower operations.
- Several key BMI metrics and taxa have shown consistent relationships and responses to habitat alteration, including changes in substrate size composition and embeddedness.

Water year 2006 will mark the first year of postproject monitoring following significant entrainment of sediment from the Indian Bar Sediment Disposal Site in late December and early January 2005–2006. Extremely high flows resulting from the New Year's storm (>50,000 cfs peak flows at the Foresthill gage on December 31, 2005) resulted in an estimated loss of 13,782 cubic yards or approximately 31% of the deposited sediment on Indian Bar. Consequently, a major focus of 2006 monitoring will be to document any changes in channel geometry, substrate conditions, and BMI communities below Ralston Dam as a result of this event. Because of high spring and summer flows, aquatic habitat and BMI monitoring will be conducted in October 2006.

Recommendations for future monitoring are:

- conduct the first year of postproject aquatic habitat and BMI monitoring in October 2006 to evaluate the effects of the high winter flows and Indian Bar sediment inputs in winter 2005–2006, and
- conduct 2 to 3 years of postproject water quality, aquatic habitat, and BMI monitoring following each occurrence of SPT operations in accordance with the flow conditions identified in the CDFG's streambed alteration agreement.

Additional recommendations for future water quality monitoring may be identified following analysis of the data collected to date.

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Appendix

Appendix

Water Quality and Aquatic Habitat Monitoring Plan for the Ralston Afterbay Sediment Management Project Indian Bar Pilot Project

Executive Summary

Placer County Water Agency (PCWA) is proposing to initiate a pilot sediment management project at Ralston Afterbay Reservoir (Ralston Afterbay), a component of the American River Hydroelectric Project on the Middle Fork American River (MFAR). The primary purpose of the sediment management project is to create sediment storage capacity in Ralston Afterbay, maintain operational flexibility of Ralston Dam and Oxbow Powerhouse, and delay the complete sedimentation of Ralston Afterbay.

The sediment management project consists of 2 components. The first component consists of dredging approximately 75,000 cubic yards (yds) of sediment from the upstream end of the reservoir and placing approximately 48,000 yds of this material downstream of the Ralston Dam on Indian Bar. The sediment will be configured to allow high flows to mobilize and transport the sediment to reaches downstream of the dam. The second component, termed sediment-pass-through (SPT), consists of reoperating Ralston Dam during high flow events to pass greater quantities of fine sediment past the dam than passes under current operations.

A secondary objective of the project is to restore the natural migration of coarse and fine sediment that occurred in the project area before dam construction. This sediment, especially the intermediate-sized material (gravel, pebbles, and cobbles), is critically important for maintaining suitable stream habitat for fish and benthic macroinvertebrates (BMI) (insects and other aquatic organisms that live in or on the streambed). Since the construction of Ralston Dam in 1966, a portion of the total sediment load transported by high flows from the MFAR and Rubicon River above Ralston Afterbay has accumulated in the reservoir, requiring periodic dredging of the reservoir to maintain the reliability of Ralston and Oxbow Powerhouses. As documented for other rivers, the retention of sediment by dams and corresponding reductions in sediment supply to downstream reaches can lead to a reduction in habitat quality in these reaches as high flows continue to transport cobble and finer materials that are not replaced by upstream sources.

SPT operations and sediment placement on Indian Bar constitute an effective and economic approach for managing sediment at Ralston Afterbay while compensating for the long-term effects of sediment retention on aquatic habitat in potentially sensitive reaches of the MFAR downstream of the dam. The proposed sediment management activities will allow the river to mobilize sediments and carry them downstream as they did naturally before dam construction. The placement of reservoir sediment, composed largely of gravel and larger materials, is expected to have beneficial effects on aquatic habitat downstream of the dam. Analyses of the hydraulic and sediment transport characteristics of the MFAR indicate that increases in the amount of fine sediment resulting from SPT operations and sediment placement will not cause adverse effects on water quality and aquatic resources because the amount of fine sediment affected by the project is small compared to the total amount of fine sediment transported by the MFAR.

In 2001, PCWA initiated a monitoring program to ensure project compliance with established water quality objectives and monitor the effects of the project on aquatic habitat and BMI in the MFAR downstream of Ralston Dam. Potential project effects will be evaluated by collecting a minimum of 1 year of water quality data and 2–3 years of aquatic habitat and BMI data before project activities begin and a minimum of 2–3 years of water quality, aquatic habitat, and BMI data after project activities begin. Key water quality, aquatic habitat, and BMI parameters will be monitored at treatment sites below Ralston Afterbay and at control sites above the reservoir. These parameters will include turbidity, total suspended solids, substrate size composition, embeddedness, and several BMI community and population attributes. Because of the high degree of variability of natural systems and lack of baseline data, an adaptive monitoring approach will be used to regularly evaluate the monitoring program and determine whether modifications are warranted to improve its performance. Evidence for project effects will be a significant postproject change (adverse or beneficial) in water quality and aquatic habitat conditions in the treatment reaches relative to changes in the control reaches. If these changes constitute an adverse effect on water quality and aquatic habitat conditions downstream of the dam, the magnitude of these changes will be compared with established water quality and habitat thresholds to evaluate project performance and determine whether corrective actions are warranted. The need for corrective actions will also be based on the results of BMI monitoring, which will serve as a key indicator of the biological effects of observed water quality and habitat changes. In addition, these changes will be evaluated in the context of other watershed events and trends that may influence the monitoring results and conclusions.

Introduction

PCWA operates a series of reservoirs and powerhouses as part of the American River Hydroelectric Project on the MFAR and Rubicon Rivers (Middle Fork Project) in the central Sierra Nevada (Figure 1). The Middle Fork Project includes Ralston Afterbay, created by the construction of Ralston Dam in 1966

(Photo 1). The dam and reservoir are located on the MFAR on the border of Placer and El Dorado Counties, California.

Ralston Afterbay serves 3 primary purposes. First, it protects public safety and fisheries by regulating the rate of river stage change downstream. Second, it allows the 2 largest powerhouses of the Middle Fork Project—Middle Fork and Ralston Powerhouses—to quickly respond to system electrical needs. Third, it impounds water for power generation at Oxbow Powerhouse.

PCWA is proposing to initiate sediment management at Ralston Afterbay to address continuing sedimentation of the reservoir that threatens the reliability of power generation at Ralston and Oxbow Powerhouses. PCWA issued and adopted an initial study/mitigated negative declaration for the Ralston Afterbay Sediment Management Project in August 2001. The primary purposes of the sediment management project are to create sediment storage capacity within Ralston Afterbay, maintain operational flexibility of Ralston Dam and Oxbow Powerhouse, and delay the complete sedimentation of Ralston Afterbay.

The sediment management project consists of 2 independent components. The first component consists of dredging approximately 75,000 cubic yds of sediment from the upstream end of the reservoir and placing this material downstream of the dam on a 1.96-acre portion of Indian Bar (Photo 2). The sediment will be configured to allow high flows to mobilize and transport it to the river downstream of the dam. The second component of the project will consist of reoperating the dam during high flow events to pass greater quantities of fine sediment beyond the dam. SPT operations will be conducted whenever river flows exceed approximately 3,500 cubic feet per second (cfs).

PCWA is proposing an initial placement of 48,000 cubic yds of sediment on Indian Bar to evaluate the project at a pilot level and to address concerns regarding recreational uses at Indian Bar (Jones & Stokes 2002). This evaluation will include consideration of potential strategies for increasing the sediment volume while maintaining or enhancing recreational opportunities at Indian Bar. Other sediment placement locations (e.g., Junction Bar) may also be considered.

A secondary objective of the project is to restore the natural migration of coarse and fine sediment that occurred in the project area before dam construction. This sediment, especially the intermediate-sized material (gravel, pebble, and cobble), is critically important for maintaining suitable stream habitat for fish and BMI (Waters 1995). Following construction of dams, these materials continue to be transported from the reaches below dams but without replacement from upstream sources, resulting in loss of important habitat (Kondolf and Matthews 1993). Other effects include scouring and deepening of the channel and associated increases in substrate size (i.e., channel armoring), a process that has been occurring below Afterbay Dam since its construction (Stiehr, pers. comm.). Efforts to mitigate these effects on salmon and trout streams in California have focused primarily on augmenting the supply of spawning-size gravels (Parfitt and Buer 1980). These efforts, which include placing gravel on bars and riffles and installing artificial and natural gravel-retaining structures downstream of dams, can be costly and ineffective over the long term. A more satisfactory alternative is to attempt to maintain natural channel features below dams by managing water releases and sediment in ways that preserve, as much as possible, the predam geomorphic processes (Ligon et al. 1995).

SPT operations and placement of sediment on Indian Bar constitute a viable and economic approach for managing sediment at Ralston Afterbay while mitigating for the long-term effects of sediment trapping on aquatic habitat downstream of the dam. The proposed sediment management activities will allow the river to mobilize sediments and carry them downstream as occurred naturally before dam construction. Preliminary analyses indicate that these activities will not cause adverse effects on aquatic resources. For reasons cited above, the reintroduction of sediment below the dam is expected to have beneficial effects on stream habitat and aquatic resources downstream of the dam. Both SPT operations and sediment disposal at Indian Bar are expected to result in relatively small, temporary increases in turbidity and suspended sediment above ambient levels during high flow events. In addition, past analyses and modeling of the hydraulic and sediment transport characteristics of the MFAR indicate that the channel is inherently stable and therefore relatively insensitive to changes in discharge and sediment supply (Harvey pers. comm.).

In 2001, PCWA initiated a monitoring program to test these predictions and ensure compliance of the project with established water quality objectives. The following report presents the monitoring plan and the results of the first year of baseline monitoring activities.

Purpose and Objectives

The purpose of the monitoring program is to evaluate the potential effects of the Ralston Afterbay Sediment Management Project on water quality, aquatic habitat, and BMI in the MFAR downstream of Ralston Dam. The primary objectives of the monitoring program are to:

- quantitatively evaluate project compliance with the water quality objectives established by the Central Valley Regional Water Quality Control Board (RWQCB) in the Water Quality Control Plan (Basin Plan) (Regional Water Quality Control Board 1998), and
- quantitatively evaluate project effects on aquatic habitat based on changes or trends in streambed and BMI populations downstream of the reservoir (treatment area) relative to changes or trends in unaffected areas (control areas), and

PCWA will use the results of annual monitoring to evaluate project effects and implement appropriate corrective measures if the data indicate that the project is adversely affecting water quality and aquatic resources in the MFAR.

Project Area

Ralston Afterbay is located at the confluence of the MFAR and Rubicon Rivers at an elevation of approximately 1,200 feet (ft). Indian Bar is located immediately downstream of Ralston Dam. The project area includes the MFAR watershed from French Meadows Reservoir (5,200 ft elevation) to the confluence the NFAR (600 ft elevation), the Rubicon River watershed from Hell Hole Reservoir (4,600 ft elevation) to Ralston Afterbay, and the North Fork of the MFAR watershed from its headwaters (6,000 ft elevation) to its confluence with the MFAR (1,000 ft elevation). The North Fork of the MFAR enters immediately downstream of Ralston Dam and Oxbow Powerhouse (Figure 1).

Climate

The MFAR watershed is dominated by a Mediterranean-like climate (warm, dry summers and cool to cold, wet winters). Air temperatures vary widely during the year and there is no appreciable precipitation in the summer except for scattered thunderstorms. Average annual precipitation in the form of rain and snow ranges from 60 to 65 inches per year with the majority of it falling between November and April (El Dorado National Forest 2001a). A portion of the watershed lies in the transient rain-on-snow zone, which occurs at elevations between 3,500 and 6,000 ft. Areas experiencing rain-on-snow events are considered to have a higher sensitivity to watershed disturbance than areas with rain- or snow-dominated climates (El Dorado National Forest 2001a and b).

Geology

The MFAR and North Fork of the MFAR watersheds include 2 different geologic units: the Shoo Fly Complex and the Mehrten formation (California Department of Conservation 1992). The rocks of the Shoo Fly geologic unit, comprising approximately 90% of the watershed, are relatively impermeable (El Dorado National Forest 2001a, b, and c). The Mehrten formation comprises approximately 10% of the watershed.

The Rubicon River watershed includes 5 different geologic units: Paleozoic metasedimentary undifferentiated rocks, the Mehrten formation, Mesozoic granitic rocks, Cretaceous-Jurassic plutonic rocks (gabbro), and glacial moraine deposits (California Department of Conservation 1981 and 1982). Paleozoic metasedimentary undifferentiated rocks, comprising approximately 60% of the watershed, are relatively erodible, and are especially erodible when unvegetated. The Mehrten formation comprises approximately 20% of the watershed. The contact zones between the Mehrten formation and adjacent units are often locations where landslides occur (El Dorado National Forest 2001c). Mesozoic granitic rocks, Cretaceous-Jurassic plutonic rocks, and glacial moraine deposits comprise the remaining 20%.

Soils

The MFAR and North Fork MFAR watersheds contain a diverse set of soils with 6 different soil map units described. The major soils in the watershed are the Hurlbut, Rock Outcrop, and Deadwood series associated with the Shoo Fly Complex and the Waca, Ledmount, and McCarthy series associated with the Mehrten formation. With the exception of Rock Outcrop, these soils have a moderate to very high erosion hazard, depending on the slope.

The Rubicon River watershed contains 7 different soil map units. Major soils in the watershed are the Hurlbut and Deadwood series associated with the Shoo Fly Complex; the Waca, Ledmount, and McCarthy series associated with the Mehrten formation; and the Chaix and Zeibright series associated with the granitic rocks and glacial deposits. These soils have a moderate to very high erosion hazard, depending on the slope.

Vegetation

Vegetation within the MFAR, Rubicon River, and North Fork of the MFAR watersheds consists mostly of mixed conifers with true firs at higher elevations. Major species of mixed conifer include ponderosa pine, sugar pine, incense cedar, white fir, Douglas-fir, big leaf maple, California black oak, and interior live oak. Shrub species include deerbrush, mountain whitehorn, Sierra mountain misery, green leaf manzanita, thimble berry, and Sierra currant.

Hydrology

The MFAR watershed upstream of Ralston Afterbay covers approximately 115 square miles. The nearest U.S. Geological Survey (USGS) flow gage, 10 miles upstream at Interbay Dam, represents flow from 90 square miles of the watershed. Flows in the MFAR are substantially attenuated by upstream reservoir storage facilities, including French Meadows Reservoir. A full-range gaging station was in service 500 feet downstream from Interbay Dam from October 1965 until the February 1986 flood, which destroyed the gaging station. According to the 1985 USGS yearbook, the maximum discharge was 9,900 cfs on January 13, 1980. USGS flow records indicate that the average daily flow in the MFAR is about 50 cfs (Hydrosphere Data Products 2000).

The Rubicon River watershed covers about 315 square miles and provides the majority of flow to Ralston Afterbay with an average daily flow of 332 cfs. The unregulated portion of the Rubicon River watershed extends 32 miles upstream to Hell Hole Reservoir. Flows in this reach exhibit large annual and seasonal variation. An historical peak flow of approximately 300,000 cfs occurred when Hell Hole dam failed in December 1964. The North Fork MFAR has a 92-square-mile watershed and enters immediately downstream of Ralston Dam and Oxbow Powerhouse. The North Fork MFAR is unregulated by reservoirs and contributes a substantial amount of flow to the MFAR with an average daily flow of 285 cfs, a 1% exceedance flow of 2,400 cfs, and a peak flow of 30,100 cfs recorded in 1980.

PCWA operates a flow gage on the MFAR immediately downstream of the North Fork MFAR confluence and upstream of Horseshoe Bar. The flow records for this site indicate that the average daily flow is 1,150 cfs and the 1% exceedance flow is 6,900 cfs. The January 1997 storm was considered to generate peak flows in the American River basin and its tributaries that were nearly as large as the projected 100-year flood event; however, peak flows were not recorded for the Rubicon River, North Fork MFAR, or MFAR at the Horseshoe Bar gage. PCWA estimated the peak 1997 flow passing Ralston Dam to be about 100,000 cfs. The highest recorded peak flow at the Horseshoe Bar gage, excluding the peak caused by the December 1964 Hell Hole Dam failure, was 123,000 cfs on January 2, 1997.

Geomorphology

The MFAR, Rubicon River, and North Fork MFAR are characterize primarily by steep, canyon-bound channels with a step-pool morphology. Average stream gradient ranges from <1% in the lower reaches of the MFAR to 2% in the MFAR and Rubicon River above Ralston Afterbay. Sediment transport capacity in these systems generally exceeds sediment supplied by eroded canyon walls and upper portions of the watershed. Consequently, fine sediments are easily transported through the system even during relatively small storm events. The channel bed consists largely of bedrock, boulders, and cobbles. The presence of these larger bed materials indicates that transport of larger material occurs only during large storm events (Bechtel Corporation 1997). The sediment transport and geomorphic characteristics of the MFAR watershed are further described below.

Sediment Transport and Geomorphic Characteristics of the Middle Fork American River

For large river basins like the MFAR basin, the amount of suspended sediment carried in the river will depend on a number of hydrologic and hydraulic characteristics as well as the source of sediment. Particles larger than 1.0 millimeter (mm) typically travel as bedload sediment close to or on the bottom; particles less than 0.1 mm generally travel suspended in the water as total suspended solids (TSS); particles between 0.1 mm and 1.0 mm may travel as either bedload or TSS. Sediment sources include organic litter on the soil surface, soil erosion, landslides, and other mass wasting of debris, as well as scouring of existing channel substrate. Sediment transport will vary during a storm in relation to rainfall, runoff, and streamflow conditions. As streamflow increases during a storm, the TSS load and associated turbidity carried in the flow will rise and then typically decrease as the storm passes and streamflow starts to recede (Environmental Protection Agency 1991). Bedload sediment may be mobilized and transported only during extremely high and infrequent flows. The MFAR has sufficient gradient and hydraulic energy to transport sediment at a faster rate than the natural rate of sediment input from watershed sources (Harvey pers. comm.). Consequently, there is very little deposition of sediment in the high gradient reaches of the river.

Potential sources of sediment transport to Ralston Afterbay vary in space and time and include the Rubicon Rivers and MFAR, upstream of the reservoir. The project area that may be affected by the proposed project also includes the MFAR downstream of Ralston Dam. Additional sources of sediment to the project area include sediments residing in Ralston Afterbay, the North Fork MFAR, smaller tributaries downstream of the North Fork MFAR, and the downstream slopes of the MFAR canyon. Given the large watershed area and variability in flows and erosion rates, background variation in sediment transport is expected to be large. Bathymetric surveys of Afterbay indicate that about 1,205,000 yds of course and fine sediments currently reside in the reservoir (Bechtel Corporation 1997). The estimated annual rate of accumulation since 1966 was estimated at 56,000 yds annually (EA Engineering, Science, and Technology 1990); however, a more recent evaluation indicates that the annual rate between 1987 and 1995 was only 36,250 yds (Bechtel Corporation 1997). It was presumed that the higher rate in previous years was a result of residual contribution of sediments to MFAR from the 1964 failure of Hell Hole Dam, which released large quantities of sediment to the river (Bechtel Corporation 1997). Current estimates of annual sediment transport in the MFAR downstream of Ralston Afterbay from natural sources are about 11,000 cubic yds of bedload sediment and 18,000 cubic yds of suspended sediment annually (Ayres Associates 1997). Field observations indicate that there is no accumulation of sediment upstream of the tunnel at Horseshoe Bar, suggesting that the existing sediment load passes through the tunnel (Mussetter Engineering 2001).

The quantity of material proposed to be placed at Indian Bar is approximately 48,000 yds. It is unknown how much fine sediment will be transported downstream during SPT operations; however, only about 20% of the total amount of suspended sediment reaching Ralston Afterbay is currently estimated to be deposited in the reservoir (Ayres Associates 1997). Consequently, the amount of sediment affected by the proposed project is a relatively small amount of the total amount transported in the river. Additionally, not all of the sediment stored in Ralston Afterbay or placed at Indian Bar will be transported in any 1 year, so the potential for project-related effects will most likely be further reduced relative to the existing annual sediment transport rates in the river.

The MFAR downstream of Ralston Afterbay is characterized by a steep, canyon-bound channel that is inherently stable and therefore relatively insensitive to changes in discharge and sediment supply (Harvey pers. comm.). In general, the channel form and processes of such rivers are related to infrequent flood events (50-year or greater recurrence interval), structural controls, landslides, human-induced impacts (e.g., hydraulic and placer mining), and discharges that occurred under different climatic regimes. The MFAR exhibits significant bedrock control of channel position, geometry, and gradient. Landslides, rock falls, and tributary-derived debris flows have placed materials with a wide range of sizes in the channel. In addition, mining practices and failure of Hell Hole Dam on the Rubicon River in 1964 (Resource Consultants and Engineers 1993) have modified the terraces and high-elevation boulder bars between Ralston Dam and the North Fork American River (NFAR) confluence.

The MFAR has a step-pool morphology composed of steep, coarse-grained (predominantly bedrock and boulder) reaches interspersed with lower-gradient, alluvial reaches associated with tributary alluvial fans, landslide debris, and bedrock outcrops. These features form localized constrictions that create upstream zones of sediment deposition during flood events. The steeper reaches act as conduits that convey most of the supplied sediment to downstream reaches during floods while the lower-gradient reaches act to temporarily store sediments between flood events. These lower-gradient, alluvial reaches generally exhibit a pool-riffle morphology (alternating pools, riffles, and bars) formed by fine- to coarse-grained alluvial deposits.

Monitoring Approach

The proposed monitoring approach is based on general principles and design of environmental impact studies (e.g., Bernstein and Zalinski 1983, Green 1979). Potential project effects are evaluated by collecting preproject and postproject water quality, aquatic habitat, and BMI data at monitoring sites located upstream and downstream of Ralston Afterbay. The downstream locations serve as treatment sites (areas potentially affected by the project) and the upstream locations serve as control sites (areas unaffected by the project). In this design, preproject (baseline) monitoring of the parameters of interest is conducted to characterize differences or relationships between these parameters in the treatment and control sites before the project begins. After the baseline monitoring period, the project is initiated and monitoring will continue to determine whether the differences or relationships between the treatment and control sites significantly change relative to those measured during the baseline period. Such a change will be evidence of a project effect. This is considered an effective design for detecting environmental impacts because it offers, with proper pairing of treatment and control reaches, a means of separating the effect of a given action from other extraneous sources of variation (e.g., climatic factors).

The monitoring plan proposes acquiring a minimum of 1 year of preproject water quality data and 1–2 years of preproject aquatic habitat and BMI data, followed by 2–3 years of postproject water quality, aquatic habitat, and BMI data. The potential effects of SPT operations and Indian Bar sediment disposal will be monitored concurrently, although the sequence of project activities may permit independent evaluations of these project components. The schedule for postproject monitoring will be subject to the occurrence of SPT operations, significant entrainment of sediment from the Indian Bar disposal site, and an appropriate range of flows for evaluating the performance of sediment disposal relative to model predictions. Accordingly, the target flows for postproject monitoring are 3,500 cfs, 5,000 cfs, and 8,000 cfs. These flows are expected to occur within a reasonable time frame (statistically, every 1 to 3 years), are sufficient to meet the flow threshold for SPT operations (3,500 cfs), and correspond to the flows used to model sediment entrainment from Indian Bar. Because hydrologic conditions needed to achieve these flows cannot be predicted or controlled from year to year, the minimum requirement for postproject monitoring will be the occurrence of at least one year in which flows reach or exceed 3,500 cfs (and SPT operations occur) and at least one year in which flows reach or exceed 8,000 cfs (and SPT operations occur). No post-project habitat or BMI monitoring will be conducted in years following runoff seasons when such events do not occur (e.g., dry years or extended droughts).

The decision to conduct postproject aquatic habitat and BMI monitoring in any given year will also be based on the magnitude of sediment entrainment (i.e., volume of entrained sediment) from Indian Bar following flow events large enough to cause spills over Ralston Dam. Using ground-based surveying techniques, PCWA will survey the Indian Bar sediment disposal site after initial sediment placement (fall 2002) and after each subsequent flow event capable of mobilizing significant quantities of sediment from the site (or after re-grading or moving sediment into the entrainment zone following such an event). The magnitude of sediment entrainment will be determined by PCWA and DFG based on comparisons of photographs of the Indian Bar disposal site (taken at a fixed location) before and after major spill events. If it is concluded that significant entrainment has occurred, the disposal site will be surveyed to document changes in area and cross-section of the site, and to estimate the volume of entrained sediment. Pebble counts (following the methods described in Section 4.1.1 of Bunte and Abt [2001]) will be conducted at the Indian Bar disposal site at the time of surveys to monitor particle size distributions over time.

Monitoring will be terminated after 2–3 sampling events (triggered by the occurrence of the target flows [as described above] necessary to evaluate the performance of sediment disposal relative to model predictions, and following the occurrence of SPT operations and significant entrainment of sediment from Indian Bar) if no significant adverse project effects on water quality, aquatic habitat, and BMI are detected. If such effects are detected, monitoring will be continued for a period of time mutually agreed to by PCWA and DFG to evaluate corrective measures to be implemented by PCWA.

An adaptive monitoring strategy is proposed to address the uncertainties related to the complex behavior of natural river systems. Factors that increase uncertainty and affect the ability of the monitoring program to detect project effects include:

- large natural variability (both spatial and temporal) in water quality, aquatic habitat, and BMI populations and communities;
- lack of sufficient baseline data and limited time frame in which to characterize preproject variability in the monitoring parameters; and

- local variation in flows, sediment loads, and sediment transport capacity that may differentially affect the monitoring parameters in the treatment and control areas.

Detecting the effect of a given management activity on water quality and aquatic habitat requires a demonstration that the change lies outside the normal range of the variable and that the change is attributable to the management activity. Thus, sufficient preproject data are required to adequately characterize preproject conditions and provide a meaningful basis for detecting project effects. In addition, because habitat monitoring sites will be located downstream of the project area and will be influenced by other sediment sources (North Fork MFAR and smaller tributaries), establishing a link between observed changes and the project may be difficult. Accordingly, monitoring data will be analyzed regularly to evaluate the monitoring program and determine whether any modifications can be made to improve its overall effectiveness.

A primary objective in developing the monitoring approach was to maximize the ability of the monitoring program to detect project effects. Accordingly, knowledge of hydraulic, sediment transport, and channel characteristics of the MFAR watershed will be used to select monitoring sites that are most sensitive to changes in sediment loads. Concurrent monitoring of several key water quality, aquatic habitat, and BMI parameters will also provide a more comprehensive and reliable indicator of overall trends in sediment and habitat conditions than 1 or 2 parameters alone. To further address uncertainty, the relative effects of the sediment management program will be evaluated in the context of other management activities or disturbances in the watershed. This task will involve continued coordination with federal, state, and local resource agencies to gather and update information on land management activities and watershed events (e.g., fires, landslides) that may significantly affect sediment loads in the MFAR, North Fork MFAR, and Rubicon Rivers.

After project activities begin, evidence for project effects will consist of significant changes (adverse or beneficial) in the relationships or differences between key water quality and aquatic habitat parameters established between treatment and control sites before project activities begin. If these changes constitute an adverse effect on water quality and aquatic habitat conditions downstream of Ralston Dam, the magnitude of these changes will be compared with established water quality and habitat thresholds to evaluate project performance and determine whether corrective actions are warranted. The need for corrective actions will also be based on the results of BMI monitoring, which will serve as a key indicator of the biological effects of observed water quality and habitat changes. In addition, these changes will continue to be evaluated in light of other watershed events and trends that may influence the monitoring results and conclusions.

A current limitation in determining an optimum sampling design and appropriate statistical model for detecting project effects is the lack of sufficient baseline data to adequately characterize natural variability in water quality, aquatic habitat, and BMI communities in the project area. Therefore, as more data become available, the monitoring program will continue to be evaluated to determine whether any changes in the sampling design or methods are warranted to improve the program's ability to achieve the objectives.

Water Quality and Aquatic Resources Monitoring Plan

Water Quality Monitoring

Objectives

The water quality monitoring program is designed to monitor project compliance with the water quality objectives established by the RWQCB in the Basin Plan (Regional Water Quality Control Board 1998). The Basin Plan objectives constitute allowable changes in water quality from project-related disturbances. Therefore, the main objectives of the monitoring program include quantifying water quality differences between sampling stations located upstream and downstream of Ralston Afterbay and ensuring that project-related changes in TSS and turbidity do not exceed the applicable Basin Plan water quality objectives. The water quality monitoring program will be most useful for evaluating project-related effects from SPT operations. SPT operations have a greater likelihood of affecting fine sediment transport that travels as suspended material because coarse material settles out at the upper end of the reservoir. Placement of reservoir sediments at Indian Bar is presumed to have little effect on background concentrations of suspended sediment because excavated reservoir sediments will consist mostly of coarse material that will be transported as bedload. The effects of the project on the coarser material traveling as bedload sediment will be addressed by the habitat monitoring program.

The RWQCB Basin Plan includes numerical water quality objectives for turbidity; however, there are no numerical standards for TSS. The narrative water quality objective for suspended sediment states that the load and discharge rate shall not be altered in such a manner as to cause nuisance or adversely affect beneficial uses. The turbidity water quality objectives vary in relation to the background levels as follows:

- where natural turbidity is between 5 and 50 nephelometric turbidity units (NTUs), increases shall not exceed 20%;
- where natural turbidity is between 50 and 100 NTUs, increases shall not exceed 10 NTUs; and
- where natural turbidity is greater than 100 NTUs, increases shall not exceed 10%.

These objectives will serve as thresholds for evaluating project performance. Accordingly, the water quality monitoring results will be used to test the following null hypotheses.

- **H_o:** During SPT operations, increases in turbidity downstream of Ralston Dam do not exceed 20% of ambient levels when natural turbidity is between 5 and 50 NTUs.
- **H_o:** During SPT operations, increases in turbidity downstream of Ralston Dam do not exceed 10 NTUs of ambient levels when natural turbidity is between 50 and 100 NTUs.
- **H_o:** During SPT operations, increases in turbidity downstream of Ralston Dam do not exceed 10% of ambient levels when natural turbidity is greater than 100 NTUs.

Based on limited TSS data available for the MFAR, background conditions may vary considerably during storm events and all 3 ranges of the numerical turbidity objectives may apply to the proposed project. Preproject monitoring will be conducted to establish this range and determine the relationship between turbidity and TSS at stations upstream and downstream of Ralston Afterbay.

Monitoring Parameters

Turbidity levels are generally correlated to the TSS concentrations, typically accounting for roughly 80% of the variability observed in simultaneous TSS measurements (Environmental Protection Agency 1991). The relationship between turbidity and TSS values is not typically linear and must be determined on a site-specific basis because the relationship can vary as a result of storm size, water color, organic matter, and algae growth. Collecting TSS samples that accurately represent average river conditions depends on hydraulic characteristics such as current patterns, flow velocity, and eddies. A composite sample collected over vertical and lateral intervals in the channel will typically provide a better representation of the average river TSS concentration than a single sample (Environmental Protection Agency 1985).

Turbidity measurements are less sensitive to the sampling location because turbidity is primarily a function of finer materials (silt and clay) that are more readily held in suspension and evenly distributed throughout the water. The time required to transport samples to a lab and conduct the analytical procedures for TSS effectively precludes its use as a real-time monitoring tool. Given the practical limitations of TSS sampling methods, need for correlation analysis with turbidity, and lack of regulatory objectives, this monitoring program will be focused on intensive automated turbidity monitoring; TSS data will be collected on a supplemental basis. The site-specific relationship between turbidity and TSS will be determined after sufficient monitoring data have been collected.

Few water quality data are available for the MFAR downstream of Ralston Dam. Simultaneous grab sample data for TSS are available from the MFAR at Foresthill and Auburn (47 miles downstream) for 25 scattered dates, collected during high flow periods between the years 1956 and 1962 (EarthInfo 1993). Other scattered grab samples are available up to 1985. Given that flow and TSS data are available for a variety of years with differing precipitation patterns, the available data may provide a reasonable estimate of the range of conditions that will be observed under current conditions and when the proposed project is implemented. The data represent sediment transport that is affected by several primary watersheds within the project area, including the Rubicon River (315 square miles), MFAR above Ralston Afterbay (94 square miles), and NMFAR (92 square miles) watersheds. Streamflow and TSS values at Foresthill and Auburn are reasonably correlated with each other (Figure 2). TSS values range up to a maximum of about 120 milligrams per liter (mg/l), and values at Auburn are generally lower than at Foresthill. Table 1 presents descriptive statistics for TSS data from all MFAR sample dates. The maximum value recorded at Foresthill and Auburn of 397 mg/l and 537 mg/l, respectively, are considerably larger than the paired data in Figure 2. The coefficient of variation (i.e., standard deviation/mean) is large and indicates that variability in the values is high.

Table 1. Summary Descriptive Statistics for TSS Data in MFAR

Statistic	MFAR at Foresthill (mg/l)	MFAR at Auburn (mg/l)
Mean	54.6	45.6
Median	30.0	12.0
Standard deviation	71.3	85.5
Minimum	2	1
Maximum	367	537
95% confidence interval of mean	± 25.3	± 19.7
Sample Size	33	75

Real-time automated turbidity monitoring data will serve as the primary tool for evaluating water quality conditions during SPT operations. Appropriate numerical turbidity objectives for long-term evaluation of water quality conditions during SPT were estimated from the variability in existing TSS data for the MFAR. Numerical data quality objectives are generally stated in terms of a specific level of precision and confidence that is desired in the collected data. Based on the Basin Plan objectives for allowable project-related increases in turbidity and lack of existing turbidity values for the MFAR, the monitoring program may need to be able to detect differences between upstream and downstream samples as low as 5 NTUs. Consequently, turbidity monitoring is designed to produce data capable of detecting differences of 5 NTUs with a 95% confidence level. Data will be collected that are sufficient to identify differences in TSS with a precision of 30 mg/l at a 95% confidence interval. Approximately 70–100 samples per year for the range of flows shown in table 1 may be needed to detect significant annual differences between upstream and downstream samples at this recommended level of precision.

Sampling Design

Table 2 presents sampling locations and protocols for the water quality monitoring program, including collection schedule and sampling methods. Figure 3 shows the location of the water quality monitoring stations. It is hypothesized that during SPT operations, water quality conditions will not differ appreciably between upstream and downstream monitoring stations. Therefore, this monitoring program is designed to evaluate the proposed sediment management activities and ensure that adverse water quality effects do not occur. An initial 3-year monitoring period is recommended, consisting of 1 year of preproject monitoring followed by 2 years of monitoring to evaluate the water quality effects of SPT operations. The need for follow-on monitoring after year 3 will be evaluated after the initial data are collected and evaluated. Preproject monitoring data will be used to develop relationships between turbidity and TSS concentrations at stations upstream and downstream of Ralston Afterbay.

To obtain as many data values as possible during storm events and SPT operations, turbidity will be monitored on a real-time basis with automated sensors that can collect data at any desired time interval and relay the data by telemetry to the Ralston Powerhouse and PCWA's Foresthill office. Two sampling locations were selected for installation of automated turbidity monitoring probes to provide the primary compliance monitoring data. The Rubicon River, approximately 200 feet upstream from the Ralston Powerhouse (which is generally discharging about 1,000 cfs to the river), will serve as the primary upstream sample site. The Rubicon River has the largest contributing watershed and generates most of the sediment input to the reservoir (Bechtel Corporation 1997). PCWA's river-gaging station immediately upstream of Horseshoe Bar will serve as the principal downstream compliance monitoring location. The Horseshoe Bar gaging station records river stage and has a telemetry unit with radio link to Ralston Powerhouse. The gage can also be monitored from PCWA's Foresthill office.

Supplemental grab samples will be collected for both turbidity and TSS in the MFAR upstream of Ralston Afterbay at the bridge crossing, MFAR bridge crossing, and in the MFAR between Ralston Dam and the Oxbow Powerhouse tailrace. Samples for TSS will be collected manually by field personnel. Grab sample locations will serve as additional indicators of water quality conditions during the initial years of monitoring and allow site-specific correlation between turbidity and TSS values.

Table 2. Summary of Water Quality Monitoring Locations, Schedule, and Methods

Monitoring Locations	Schedule of Sampling Activities	Constituents Monitored & Frequency of Activity		
		Total Suspended Solids (Grab Samples Only[1])	Turbidity	
			Grab Samples[1]	Automated[2]
Rubicon River	Year 1 preproject monitoring	X		X
Upstream from Ralston Powerhouse	Years 2 & 3 monitoring	X		X
	After year 3 follow-on monitoring	X (as needed)		X (as needed)
MFAR Upstream from reservoir at bridge	Year 1 preproject monitoring	X	X	
	Years 2 & 3 monitoring	X (as needed)	X (as needed)	
MFAR Upstream from Oxbow Powerhouse tailrace	Year 1 preproject monitoring	X	X	
	Years 2 & 3 monitoring	X (as needed)	X (as needed)	
North Fork of the MFAR at bridge	Year 1 preproject monitoring	X		X
	Years 2 & 3 monitoring	X (as needed)		X (as needed)
MFAR at Downstream gage house	Year 1 preproject monitoring	X		X
	Years 2 & 3 monitoring	X		X
	After year 3 follow-on monitoring	X (as needed)		X (as needed)

Notes:

1 Grab samples for turbidity and total suspended solids (TSS) will be collected at a minimum of 4-hour intervals during storm events when water level is rising and starting when streamflow is 3,000 cfs or greater. Sampling should be targeted to include sufficient storm events that provide data from as wide a range of high streamflows as possible. Sampling in successive years should be targeted at storm events that generate flow conditions similar to those sampled during the pre-project monitoring.

2 Automated turbidity probe and telemetry system can be adjusted as needed based on available battery power. Data will be monitored during storm events and downloaded by telemetry at a minimum of 4-hour intervals. Turbidity recorders need be used only during storm events and at a frequency sufficient to generate at least 70 samples per year. Sampling should be targeted to include sufficient storm events that provide data from as wide a range of streamflows in excess of 3,000 cfs as possible. Sampling in successive years should be targeted at storm events that generate similar flow conditions similar to those sampled during the pre-project monitoring.

If the initial monitoring data indicate that turbidity and TSS data are closely correlated and turbidity measurements are effective for monitoring compliance of SPT operations, compliance monitoring for TSS will be discontinued and the real-time turbidity data will be used as the primary indicator for SPT operations compliance. The TSS data will be used primarily for long-term evaluation of SPT operations and for additional confirmation of real-time water quality conditions as indicated with the automated turbidity sensors.

SPT operations will commence when river flows exceed 3,500 cfs. Therefore, preproject monitoring of turbidity and TSS will be conducted when storms generate river flow rates that exceed 3,000 cfs. Preproject data for low flow events will not be conducted because natural variability in TSS and turbidity will be much lower and not representative of conditions during SPT operations. Both automated turbidity and grab sample data will be collected at a minimum of 4-hour intervals during storm events commencing when streamflows begin to rise and ceasing when the hydrograph has begun to recede or SPT operations are discontinued, whichever occurs first. The trigger for commencing sample collection can be water level in the reservoir or flow at the Horseshoe Bar gage. An additional automated water level recorder is recommended for the Rubicon River site to determine when streamflow starts to increase during storm events and provide time to prepare for the necessary manual sampling activities. This gage does not have to be an approved USGS-type stilling well. The system can be a simple enclosure with a pressure transducer for monitoring water level. A flow-rating curve does not need to be calculated. For monitored storm-flow events, sampling should be targeted to include data from as wide a range of streamflows as possible that exceed 3,000 cfs. Sampling in successive years should be targeted to storm events that generate flow conditions similar to those sampled during the preproject monitoring.

During SPT operations, PCWA staff will monitor the real-time upstream and downstream turbidity monitoring data to evaluate compliance of operations with Basin Plan water quality objectives. All grab sample data collected at field sites will be recorded on a field data form. TSS and turbidity samples will be collected by hand using an appropriate bottle sampling device (e.g., Van Dorn, Kemmerer). Sample bottles will be specified by the laboratory performing the analyses. Samples will be analyzed to provide the lowest practical detection limit for TSS (less than or equal to 5 mg/l) and turbidity (less than or equal to 1 NTU). Field samples will be refrigerated for sample preservation and shipped to a commercial laboratory after each sampling event. A field blank of deionized water and field duplicate samples should be collected once for every 20 samples, with a minimum of 1 replicate per storm event. Automated turbidity probes installed at the Rubicon River and Horseshoe Bar sites will have a minimum detection limit of 1% of full-scale reading. The probe should be capable of measuring a range of turbidity measurements up to 500 NTU.

Data Analysis

Standard data control charting methods will be used to identify the rate and direction of change in real-time turbidity concentrations in the river and detect significant excursions from the Basin Plan water quality objectives. Supplemental information regarding TSS concentration conditions will be evaluated from the grab sample data. The long-term performance of SPT operations with respect to water quality objectives will be evaluated with standard statistical testing of the mean differences between preproject and postproject conditions. Linear regression analysis will also be used for year-to-year evaluations of project-related effects on water quality based on the relationship between values collected at the primary upstream and downstream sample sites. If routine patterns of turbidity and TSS in the tributary streams are constant over the duration of the monitoring program, regression analysis will allow the detection of changes between the Rubicon and the Horseshoe Bar gaging site attributable to the project without explicitly evaluating changes in the tributaries. Consequently, until the initial data collected from the tributaries prove otherwise, it is assumed that the automated turbidity data will be sufficient to establish a statistically significant relationship reflecting differences in water quality conditions between the upstream and downstream sites.

Following collection of the first year of pre-project data, results will be evaluated for statistical variability in turbidity and TSS concentrations. Descriptive and exploratory analysis of the data will be necessary to ensure that the proper statistical tools are applied to the analyses. Issues that may need to be addressed include transformation of data to approximate a normal data distribution and evaluation for autocorrelation among the data points. The estimated number of samples necessary to achieve the desired data quality objectives will be confirmed. Following the second and third years of data collection, means testing and linear regression analysis of turbidity and TSS data will be conducted to identify the differences between preproject and postproject data and the statistical significance of the differences. Adjustments to the data based on related variables such as background TSS and turbidity concentrations or streamflow may be used to improve the sensitivity of the data analyses.

The procedures for determining water quality conditions necessitating corrective actions will be defined in advance in coordination with RWQCB and California Department of Fish and Game (DFG). When the data indicate that downstream turbidity values exceed the water quality objectives, possible corrective actions may include immediately taking additional samples for both turbidity and TSS to provide additional data on the water quality conditions. If SPT operations are presumed to be causing a water quality compliance problem, other possible corrective actions may include reducing the flow through the gates, increasing flow through the spillway gates, or both. As a final action, the low level outlet gate may be closed to cease SPT until more favorable conditions occur. The procedure for ceasing and restarting SPT operations will also be defined before starting SPT.

Two issues described below merit consideration when interpreting project-related water quality monitoring data for SPT operations and to avoid taking corrective actions when they are not necessarily warranted: (a) evaluating effects of water residence time in the reservoir at varying levels of streamflow; and, (b) evaluating the direction of change in turbidity and TSS concentrations.

- **Hydraulic residence time:** Based on the volume of the reservoir, the residence time of a slug of water passing from the upper end of the reservoir to the downstream end will be short at high flows (approximately 40 minutes at 50,000 cfs) and samples collected simultaneously at upstream and downstream locations will presumably be adequately comparable to each other. When SPT operations first begin at a flow of 3,500 cfs, however, the residence time will be approximately 10 hours. TSS values typically rise and fall in correlation with streamflow. Therefore, it is likely that when upstream turbidity concentrations start to decrease as the stormflows recede, simultaneous measurement made downstream may indicate continued increasing concentrations and regulatory exceedances because of the time delay of previously high turbidity water moving downstream. In order to account for water residence time in the reservoir, data charting procedures should account for the time delay at varying flow rates to establish whether an exceedance in the thresholds is truly occurring. The transport time can be reasonably predicted with empirical calculations from bathymetric profile data of the reservoir. In addition, dye tracer tests can be conducted to more accurately characterize flow through the reservoir. The need for dye tracing will be evaluated after the first year of monitoring to determine whether such precision is necessary for the program.

- **Direction of changes in monitored constituents:** As noted above, TSS will typically rise and fall with the streamflow pattern. Following the passage of peak flows and corresponding TSS and turbidity transport during storm events, high variability in upstream and downstream TSS and turbidity may continue despite an overall decreasing trend in their values. Consequently, the absolute differences between upstream and downstream values during the receding period of a storm event may exceed the numerical water quality objectives. Compliance evaluations should account for whether the concentrations at upstream and downstream locations are rising or falling when interpreting the data with respect to this criteria. If concentrations are decreasing overall, yet downstream values are higher, it will indicate that the flush of sediment resulting from initial mobilization and transport is nearing completion. Concentrations at this point in the storm may be relatively low compared to the higher peak values occurring earlier in the storm and should not constitute a violation of the water quality objectives.

Aquatic Habitat Monitoring

Objectives

The primary objective of aquatic habitat monitoring is to quantitatively evaluate project effects on aquatic habitat based on changes or trends in key substrate and BMI parameters upstream and downstream of Ralston Afterbay. The results will be used to test the following null hypothesis:

- **Ho:** Differences between mean substrate size in the treatment reaches and that in the control reaches during preproject years do not change during postproject years.

This hypothesis also may be stated as follows:

- **Ho:** The relationship between mean substrate size in the treatment reaches and that in the control reaches during preproject years does not change during postproject years.

Rejection of either hypothesis will be evidence of significant project effects (adverse or beneficial). The biological significance of these changes will be evaluated based on the general trout- and BMI-substrate relationships and observed changes in BMI population or community attributes measured in the treatment and control reaches.

Stream and laboratory studies have shown that excessive amounts of fine sediments can adversely affect aquatic habitat and the capacity of that habitat to support trout and aquatic invertebrates. Although the results vary with species, life stage, and season, significant declines in fish and aquatic invertebrates were generally associated with riffles in which 50% or more of the coarse particles (gravels and larger materials) were covered or surrounded by fine sediment (embeddedness). This level will serve as a preliminary threshold for evaluating habitat quality during the preproject monitoring period. Additional years of preproject data will be necessary to adequately characterize annual variation in substrate conditions and establish an impact threshold (i.e., change in substrate conditions) that would trigger the need for corrective actions. This impact threshold will also be based on the results of BMI monitoring and any observed relationships between the BMI parameters and substrate conditions during the preproject monitoring period.

The BMI monitoring data will indicate seasonal and annual patterns of abundance, composition, and diversity associated with the ecology and natural history of BMI communities. These patterns will be compared from year to year to detect any change or shift that would indicate a response to an environmental change. More importantly, BMI monitoring will be useful in evaluating the biological effects (beneficial or adverse) of any changes in water quality and substrate conditions observed during the monitoring program.

In addition to monitoring the size composition of riffle substrates, the U.S. Forest Service and DFG requested monitoring of channel cross sections downstream of Ralston Afterbay to detect potential deposition of sediment in pools during the postproject monitoring period. The U.S. Forest Service also requested that water temperature loggers be installed upstream and downstream of Ralston Afterbay.

Monitoring Parameters

Substrate size composition and embeddedness will be used as key monitoring parameters for assessing project effects on aquatic habitat. These parameters were selected because they are sensitive indicators of changes in sediment loads, can be rapidly measured in the field, and provide a direct or indirect measure of factors known to affect the abundance and production of fish and invertebrates in streams.

Substrate Size Composition

The size composition of streambed substrates is a major factor determining the quality of stream habitat for trout and aquatic invertebrates. Changes in substrate size can affect the productive capacity of trout streams by affecting the suitability of substrate for spawning, the availability of suitable cover and shelter for juvenile and adult trout, and the amount of living space for aquatic invertebrates (Waters 1995, Bjornn and Reiser 1991).

Substrate Embeddedness

Embeddedness is the percentage to which coarse sediments (gravel and larger particles) are surrounded or covered by fine sediment (silt/clay and sand). This parameter provides a measure of the amount of interstitial space between coarse sediments and thus reflects the suitability of the streambed for incubation, emergence, and overwintering of trout, and the amount of living space for BMI. Excessive amounts of fine sediments and embeddedness have been shown to affect the abundance of juvenile salmonids and aquatic invertebrates in laboratory and natural streams (Hillman et al. 1987, Bustard and Narver 1975, Bjornn et al. 1977). Although the results vary depending on species, life stage, and season, a general observation was that significant declines in fish and invertebrate abundance were generally associated with embeddedness levels of 50% or more.

Sampling Design

Because of the high degree of spatial and temporal variability in habitat conditions in natural river systems, several criteria were developed to guide selection of monitoring sites. These criteria were based on the need to minimize differences between treatment and control sites, increase sampling efficiency, and maximize the ability of the monitoring program to detect potential project effects. Foremost among these criteria is the need for all monitoring sites, especially those that serve as primary treatment and control reaches, to be equally sensitive to changes in sediment loads and respond similarly to these changes. Second, monitoring sites should have similar channel and substrate characteristics that provide important aquatic habitat for trout and aquatic invertebrates. Third, monitoring sites should be located as close as possible to Ralston Afterbay to reduce the confounding effects of other sediment sources (e.g., tributaries). Finally, as a practical consideration, all sites should be accessible and provide safe conditions for field measurements.

Based on the hydraulic and sediment transport characteristics of the river, these criteria appear to best be met by localized alluvial portions of the river where sediment deposition occurs in response to local channel and valley constrictions that include tributary alluvial fans, landslide debris, and bedrock constrictions (Mussetter Engineering 2001). Mussetter Engineering identified 5 such reaches between the Ralston Dam and the North Fork of the American River confluence (Table 3).

Before selecting monitoring sites, a Jones & Stokes fisheries biologist will conduct an aerial survey of the MFAR by helicopter to examine the 5 reaches identified by Mussetter Engineering and identify other potential treatment and control reaches upstream and downstream of Ralston Afterbay. The aerial survey will include the first 5 miles of the MFAR and Rubicon River upstream of Ralston Afterbay, the MFAR from Ralston Dam to Louisiana Bar, and the lowermost 5 miles of the North Fork MFAR. The goal of this initial survey is to evaluate the suitability of potential treatment and control reaches based on the criteria presented above. Preference will be given to those reaches that are closest to the project area and are reasonably accessible by foot. All potential monitoring reaches will be delineated on 7.5-minute topographic maps. Photographs will be taken of representative portions of the potential monitoring reaches.

Table 3. Locations and Characteristics of Hydraulic Controls for Sediment Transport in the Middle Fork of the American River

Location	River Mile	Comments
Louisiana Bar	50.4	Pool and riffle upstream of bedrock control; road accessible
Mammoth Bar	52.4	Pool and riffle upstream of bedrock constriction at Murderer's Gulch; road accessible
Cherokee Bar	59.0	Head of alluvial reach that extends from Greenwood Bridge to Mammoth Bar; pools and riffles; road accessible
Canyon Creek	61.44	Pool formed by alluvial fan constriction and backwater from Ruck-A-Chucky landslide; not road accessible but can be reached by track in about 20 minutes
Other sites:		
Otter Creek	64.65	Pools and riffles upstream of alluvial fan-induced contractions; neither site is readily accessible but they are closer to Ralston Dam.
Volcano Creek	71.4	

Note: River mile 50.37 is the confluence with the North Fork of the American River.

Table 4 presents the proposed locations and schedule for aquatic habitat and BMI monitoring. Two reaches will be established immediately downstream of Ralston Afterbay between the dam and the confluence of the North Fork MFAR and between the confluence of the North Form MFAR and Horseshoe Bar. These reaches will be used primarily to evaluate changes in substrate composition associated with coarse sediment input from the Indian Bar disposal site. One or more treatment reaches will be established on the MFAR downstream of Horseshoe Bar to evaluate potential changes in fine and coarse sediment associated with SPT operations and Indian Bar sediment disposal. One or more control areas will be established on the Rubicon River upstream of Ralston Afterbay, the MFAR upstream of the reservoir, and on the North Fork MFAR.

Table 4. Summary of Aquatic Habitat and BMI Monitoring Locations, Activities, and Schedules

Monitoring Reach	Purpose	Aerial Survey and Monitoring Reach Selection	Monitoring Site Selection	Field Measurements
Rubicon River upstream of Ralston Powerhouse	Control for SPT operations	Conduct in first year of preproject monitoring period and in subsequent years only if warranted	Conduct in first year of preproject monitoring period and in subsequent years only if warranted	Sample in 2–3 preproject years and 2–3 postproject years following each occurrence of SPT operations. Schedule subject to change depending on project schedule, the occurrence of SPT-triggering flows, and the occurrence of significant sediment entrainment from Indian Bar.
MFAR upstream of Ralston Afterbay	Control for SPT operations			
MFAR between Ralston Dam and North Fork of the MFAR	Treatment for Indian Bar sediment disposal			
MFAR between North Fork of the MFAR and Horseshoe Bar	Treatment for SPT operations and Indian Bar sediment disposal			
North Fork of the MFAR	Control for SPT operations and Indian Bar sediment disposal			
MFAR downstream of Horseshoe Bar	Treatment for SPT operations and Indian Bar sediment disposal			

Following selection of monitoring reaches, ground surveys will be conducted to more closely examine the reaches and identify specific habitats that meet the selection criteria above. Riffles will likely be key habitats because they are considered relatively sensitive indicators of bed conditions, provide important habitat for trout and invertebrates, and allow safe conditions for collecting substrate data across the entire channel.

Aerial surveys and monitoring site selection will be conducted in the first year of preproject monitoring. Substrate sampling will be conducted in the first year of preproject monitoring and in subsequent preproject and postproject years. Because substrate conditions are not expected to change significantly after winter and spring storm events, substrate sampling will be conducted once a year during the summer or fall when flows are low enough to permit sampling. Sampling will be conducted at the same time each year to minimize the effects of possible seasonal changes in fine sediments.

Preproject monitoring should begin as soon as possible and be conducted in selected years during the preproject monitoring period to characterize baseline variation in substrate conditions among and within reaches. Ideally, preproject data should include measurements of streambed conditions following flow events equal in magnitude and duration to those that will trigger SPT operations. A minimum of 2–3 years of preproject monitoring may be necessary to provide a meaningful basis for evaluating potential changes in substrate conditions during postproject years.

Monitoring of project effects will be conducted in 2–3 sampling events triggered by the occurrence of the target flows necessary to evaluate the performance of sediment disposal relative to model predictions, and following the occurrence of SPT operations and significant entrainment of sediment from Indian Bar (see Monitoring Approach).

Substrate Composition and Embeddedness

Five to 10 riffles will be established as monitoring sites in each reach. All riffles or a random sample of riffles in each reach will be selected for monitoring. Two transects will be established at each riffle. One transect will be established at a random location in the upstream third of the riffle, and the other transect will be established in the riffle crest or pool tail (immediately upstream of the head of the riffle) in an area equal in length to one-third the riffle length.

Field measurements of substrate composition and embeddedness will follow the methods described by Bain (1999). The location of each transect will be marked with paint and flagging above the high-water mark. Cloth or metal measuring tapes will be suspended above the wetted channel (perpendicular to the channel) between 2 metal stakes secured at the edge of the low-flow channel. Substrate composition will be measured with a 1-meter (m) metal ruler, divided into ten 10-centimeter (cm) sections painted contrasting colors. The first sampling location along each transect will be selected randomly and subsequent locations selected at regular intervals from the first. Sampling locations will be separated by at least 1 m. A maximum of 15 sampling locations will be evenly distributed across the transect, depending on channel width.

At each sampling location, the ruler will be lowered across the stream substrate (perpendicular to the current) and the dominant substrate class under each 10-cm segment will be recorded using the modified Wentworth scale (Table 5).

Table 5. Modified Wentworth Classification of Substrate Types by Size

Substrate Type	Particle Size Range (millimeters)	Code
Silt and clay	<0.059	0
Sand	0.06–1	1
Gravel	2–15	2
Pebble	16–63	3
Cobble	64–256	4
Boulder	>256	5

Embeddedness will be visually determined at each transect by examining the coarse sediments (gravel, pebble, cobble, boulder) in the deepest portion of the channel and recording the dominant level of embeddedness (Table 6).

Table 6. Embeddedness Rating for Stream Channel Materials*

Level of Embeddedness	Description	Code
Negligible	Gravel, pebble, cobble, and boulder particles have <5% of their surface covered by sediment.	0
Low	Gravel, pebble, cobble, and boulder particles have 5–25% of their surface covered by sediment.	1
Moderate	Gravel, pebble, cobble, and boulder particles have 25–35% of their surface covered by sediment.	2
High	Gravel, cobble, and boulder particles have 50–75% of their surface covered by sediment.	3
Very High	Gravel, pebble, cobble, and boulder particles have >75% of their surface covered by sediment.	4

* Fine sediment includes materials less than 2 mm in diameter: sand, silt, and clay.

As requested by DFG, pebble counts will be evaluated as an alternative method for assessing the size composition of riffle substrates. In fall 2002, pebble counts (following the methods described in Section 4.1.1 of Bunte and Abt [2001]) will be conducted at existing transects in addition to the Bain method. A squareholed template will be used to measure substrate particles based on the standard Wentworth scale (rather than the modified scale used in 2001). The embeddedness of gravel and larger material will be measured as the percentage of the total vertical extent of a particle below the bed surface. Following data collection, Jones & Stokes and DFG will compare the particle size distributions resulting from the two methods. If the particle size distributions produced by the Bain method are reasonably consistent with those produced by the pebble count method, the Bain method will continue to be used to characterize riffle substrates.

Otherwise, the pebble count method will be used for the remainder of the monitoring program.

Channel Cross-Sections

Standard surveying techniques will be used to measure channel cross-sections at several pools upstream and downstream of Ralston Afterbay during pre- and postproject monitoring years to detect potential changes in pool habitat that may occur following project activities. Pool cross-sections will be measured at three representative pools downstream of Ralston Dam (in Reaches 1 and 2) and three representative pools above Ralston Afterbay in the Rubicon River (Reach 7). Two to three transect locations will be established in each pool depending on the variability in channel profile along the length of the pool. All transect locations will be marked in the field with permanent markers and recorded with global positioning system unit. Channel cross sections will be measured in October when flows are at minimum levels (100 cfs, approximately).

Water Temperature

Automated water temperature loggers will be installed above and below Ralston Afterbay near the proposed water quality monitoring stations (MFAR at Horseshoe Bar gage, MFAR above Ralston Afterbay, North Fork MFAR, and Rubicon River. The loggers will be programmed to continuously record water temperatures at hourly intervals. The loggers will be installed in July 2002 and the data will be downloaded in the field every three months.

Data Analysis

Substrate composition and embeddedness data will be analyzed quantitatively using statistical techniques developed for control-treatment designs (e.g., Bernstein and Zalinski 1983). As discussed earlier, the applicability of the proposed design depends on proper pairing of the treatment and control reaches and sufficient preproject data to characterize the differences or relationship between streambed conditions in these reaches. Alternatively, the data can be analyzed graphically using descriptive statistics (e.g., means, confidence intervals) and/or regression techniques to characterize trends in streambed parameters over time (e.g., Adams and Beschta 1980).

Because the sampling design may not be able to effectively discern project effects from those of other sediment sources in the MFAR watershed, it will be necessary to complement the monitoring program with additional information to assess the relative magnitude of effects related to SPT and other sources. For example, bathymetric surveys of Ralston Afterbay before and after SPT operations will provide valuable information on the preproject and postproject quantities of fine sediment in the reservoir. In the event that a large amount of sedimentation is detected downstream of Ralston Dam, bathymetric surveys will provide a measure of net changes in reservoir sediment conditions, which will help assess the extent to which SPT operations contributed to the supply of fine sediment. The data then may help in the assessment of whether any net contribution to fine sediment supply in the river is attributable to the reservoir. Other sources of information include ongoing watershed monitoring programs and assessments being conducted by the U.S. Forest Service (Forest Service), U.S. Geological Survey, and other federal and state agencies responsible for resource and land management in the MFAR, Rubicon, and North Fork MFAR watersheds.

In addition, annual reports, maps, and interviews with resource managers will be used to monitor the occurrences of major events (e.g., fires, landslides, intense land use activities) that could influence erosion and sedimentation processes in these watersheds. This information will be used to further evaluate the relative effects of these sediment sources on habitat conditions in the monitoring reaches. The interpretation of monitoring results will also include an analysis of hydrologic parameters that may differentially affect geomorphic conditions in the monitoring reaches from year to year.

Benthic Macroinvertebrate Monitoring

Objectives

The primary objective of BMI monitoring is to provide biological indicators of aquatic habitat health and functionality to be used in conjunction with the water quality and substrate data to evaluate potential project effects on aquatic habitat. Quantitative bioassessment based on BMI was developed by the Environmental Protection Agency (EPA) as a tool for monitoring and assessing the impacts of watershed management activities on water quality, fish, and stream productivity. Quantitative bioassessment has become the legal standard in most states for mitigation and restoration projects. Justifications for the use of BMI as indicators of water and habitat quality have been described by Hutchinson (1993), Resh and Jackson (1993), Rosenburg and Resh (1993), and others. Additional advantages of BMI-based biological assessment include long storage life for preserved samples and the establishment of BMI voucher collections. Voucher collections may be evaluated by other investigators and serve as a source of information for taxonomists and resource managers.

Monitoring Parameters

The following parameters will be used to monitor the overall health and functionality of aquatic habitat in the treatment and control reaches during preproject and postproject periods.

Invertebrate Density

Invertebrate density is the number of individual invertebrates per square meter. This is a measure of overall habitat utilization by BMI, as well as a measure of forage available to fish. Typically, BMI density remains fairly stable. Sudden BMI density fluctuations are indicative of impacts on habitats and water quality. Disturbed systems also may exhibit high BMI densities attributed mainly to opportunistic species. Some opportunistic species include Philippine clam, some crawdad species, chironomid midges (e.g., Chironomus), culicids, and some worms.

Taxa Richness

Taxa richness is the total number of individual taxa and is used as a means of determining the overall health of an aquatic habitat (Plafkin et al. 1989). In general, the higher the water quality, habitat suitability, and variety, the higher the taxa richness. Similarly, sudden drops in taxa richness will indicate a negative impact within the system.

BMI Productivity

BMI productivity is defined as the grams of living invertebrates per square meter within the study area. This measurement yields the biomass per unit area that the habitat is able to support. Diverse, highly functional habitats typically produce higher biomass than is produced by impaired systems. Alternately, disturbed systems that are overrun by opportunistic species may have abnormally high biomass.

Ephemeroptera, Plecoptera, Trichoptera Ratios

By measuring the abundance of invertebrate families most sensitive to changes in water quality and habitat suitability, the relative habitat health can be examined. The Ephemeroptera, Plecoptera, Trichoptera (EPT) index examines nymphal Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddisflies), which as a group are generally considered to be pollution sensitive. The abundance index of these families increases with increasing water quality (Plafkin et al. 1989).

Jaccard Coefficient of Community Similarity

Jaccard Coefficient of Community Similarity and Community Loss indices (Barbour et. al. 1999) will be used to determine similarities between the treatment and control reaches and between preproject and postproject years.

$$\text{Jaccard Coefficient of Community Similarity} = \frac{\text{\# of taxa common to both samples}}{\text{\# of taxa in both samples}}$$

The Jaccard Coefficient of Community Similarity estimates the degree of similarity between samples, based on presence or absence of taxa. The coefficient values range from 0 to 1.0. The higher the coefficient, the greater the similarity between the samples.

Community Loss Index

The Community Loss index estimates the loss of taxa between comparison samples and reference samples.

$$\text{Community Loss} = \frac{[\text{\# of taxa in reference sample}] - [\text{\# of taxa common to both samples}]}{\text{\# of taxa in comparative sample}}$$

The index identifies the differences in sample composition. The higher the index value, the greater the dissimilarity between the comparison sample and the reference sample.

Sampling Design

The sampling design for BMI monitoring was based on EPA's quanititative bioassessment protocols for streams and wadeable rivers (Barbour et al. 1999). BMI populations will be sampled in the same pre- and postproject years as substrate monitoring and in 3 of the same riffle transects used for substrate sampling in each monitoring reach. (Table 4). Samples will be collected in the late spring (June), midsummer (August), and fall (October). Sampling 3 times per year is a standard protocol to adequately characterize seasonal changes and assess potential seasonal impacts on species and life stage composition of BMI communities. Littoral sampling from Ralston Afterbay will not be necessary because the water in the reservoir fluctuates sufficiently during normal yearly maintenance practices to limit colonization of the littoral zone by BMI.

A standard kick seine will be used to sample BMI at 3 locations along selected transects. These locations were selected to provide samples from a representative range of velocities along each transect. A kick is accomplished by placing the kick net in a stationary position and disturbing 0.33 square meter of substrate immediately upstream of the net. Large cobble and boulders will be dislodged and cleaned by hand to remove attached organisms. Sand, gravel, and pebble substrates will be disturbed by hand and with the toe or heel of a boot and the current will carry dislodged organisms into the net. Sample material from each kick will be combined into a single composite sample, which represents one square meter of substrate area. The material will be placed in an airtight container and preserved immediately in 95% ethanol. All samples will be labeled with the collection number, station, date, and collector. The samples will then be transported to the Jones & Stokes laboratory for analysis. After 24 hours, the ethanol in each sample will be replaced with fresh 95% ethanol.

In the laboratory, chain of custody forms will be used to track the samples. The contents of each sample will be placed into a 300-micrometer (µm) sieve, gently rinsed, and then placed in a Pyrex pan with 30% ethanol. The sample contents will then be examined for BMI by a technician using illuminated magnifying glasses. All BMI will be removed from debris with forceps and placed in containers filled with 70% ethanol. Once a sample presumably has all BMI removed, a second technician will then review the sample to ensure that all BMI are removed. After 2 technicians have searched the sample and found no more BMI, all debris will be discarded. If the second technician finds 4 or more BMI remaining in the sample, the original sorter will repeat the search of the entire sample.

Invertebrate biomass will be estimated using volumetric displacement. BMI specimens from all samples will be dried at room temperature for 15 minutes on size 613 qualitative filter paper and then placed in a 25 ml graduated cylinder with 15 ml of 15ºC deionized water. The volumetric displacement will then be determined and recorded.

Specimens collected from each sample will be identified by taxonomists to the lowest justifiable taxon using an Olympus SZ-ST40 zoom stereo scope and the appropriate taxonomic references (Arnett 1968; Edmunds et al. 1976; McAlpine et al. 1981; Merritt and Cummins 1984; Pennak 1978; Usinger 1956; Wiggins 1977) in order to establish diversity, EPT ratios, opportunistic taxa ratios, taxa richness, and abundance, and to develop community indexes.

Starting in 2002, modifications and additions will be made to BMI sampling protocols to ensure consistency with the California Stream Bioassessment Procedure (www.dfg.ca.gov). These modifications include subsampling 300 organisms from each sample for identification purposes and complete counts of the remaining organisms, sending at least 10% of the samples to an independent quality assurance taxonomist to ensure taxonomic accuracy and enumeration, and using the California Bioassessment Worksheet.

Data Analysis

All data analyses will be conducted following the protocols for quantitative bioassessment established by EPA and the scientific community (Plafkin et al. 1989; Resh and Rosenberg 1984; Merritt and Cummins 1984; Hutchinson 1993; Resh and Jackson 1993; Rosenburg and Resh 1993).

Data Management and Reporting

Successful implementation of the water quality and aquatic resource monitoring program requires proper data reduction and analysis procedures, routine quality control checks during sampling and data processing, and annual reporting of results for permit compliance, impact assessment, and performance evaluation. The chain of custody for data handling, storage, and processing will be clearly established. It is best to have a single person responsible for the monitoring program to ensure that all field and laboratory techniques, data entry, quality control and assurance methods, and analytical methods are coordinated and follow established protocols.

Standard field and laboratory data forms will be prepared for each monitoring component. All completed field and laboratory data forms will be kept in a central location or logbook. Duplicates will be made and stored in a separate location. The lead technician will proof all data forms at the end of each day of field or laboratory work. All data will be entered into Microsoft Excel spreadsheets (or equivalent) and maintained in a central database. The original spreadsheets will be checked for errors by comparing all entries in the electronic spreadsheets with the raw field and laboratory entries. The central database will be write-protected and maintained on a main computer server. Working copies of the spreadsheets will be used for data reduction, analysis, and reporting. The results of the preproject and project operation monitoring will be presented in annual reports prepared at the end of each annual monitoring period. The reports will summarize the methods and results of the current and previous years' monitoring activities. Data and statistical analyses will be presented in summary graphs and tables. The reports will present and update conclusions regarding permit compliance, impact assessment, and monitoring performance and will include recommendations for modifications of sampling design and other program elements, if warranted.

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