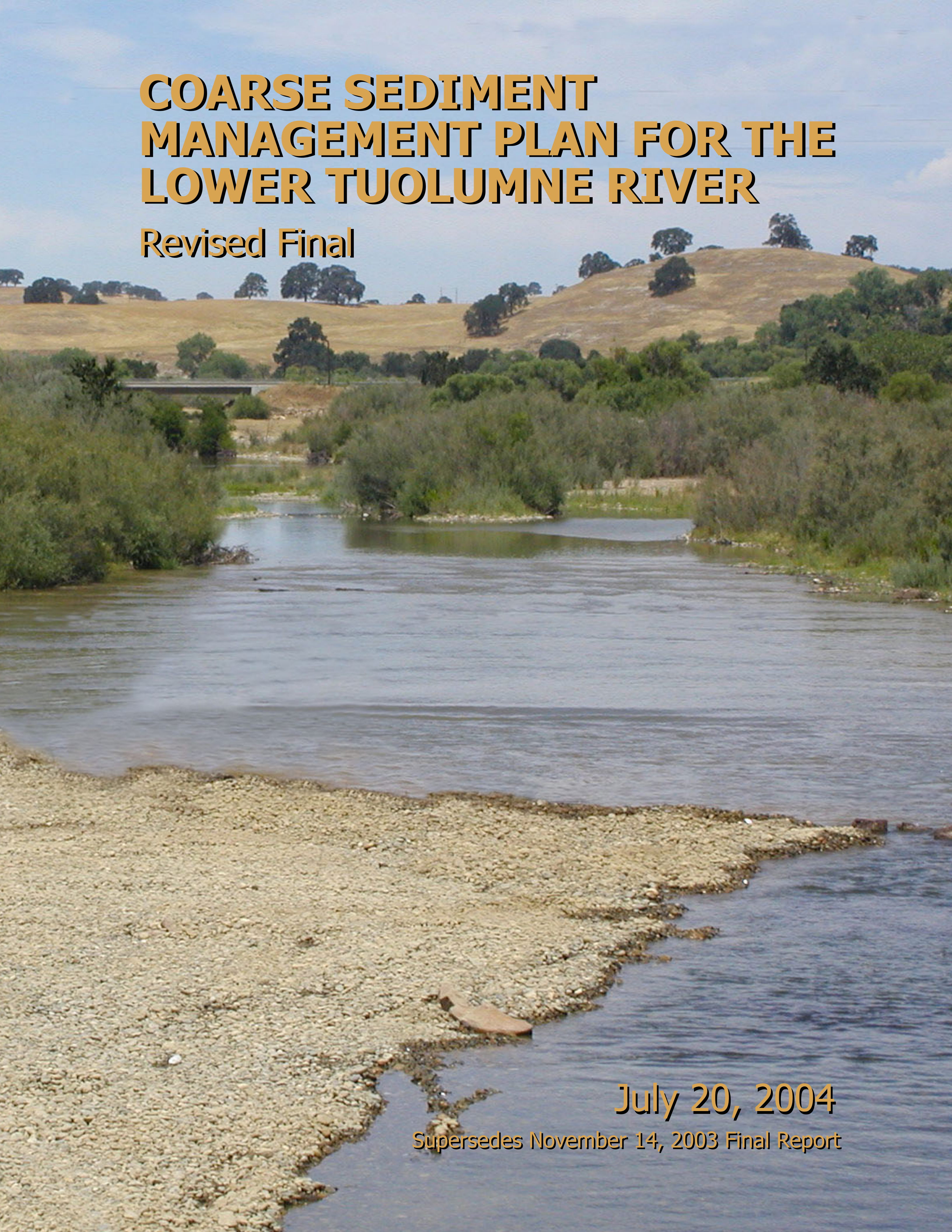
COARSE SEDIMENT MANAGEMENT PLAN FOR THE LOWER TUOLUMNE RIVER

Revised Final



July 20, 2004

Supersedes November 14, 2003 Final Report

Cover photograph: Constructed point bar as part of 2002 coarse sediment introduction on the Tuolumne River immediately downstream of Old La Grange Bridge (RM 50.5).

COARSE SEDIMENT MANAGEMENT PLAN FOR THE LOWER TUOLUMNE RIVER

(REVISED FINAL)

Prepared for:

TUOLUMNE RIVER TECHNICAL ADVISORY COMMITTEE
TURLOCK AND MODESTO IRRIGATION DISTRICTS
USFWS ANADROMOUS FISH RESTORATION PROGRAM
CALIFORNIA BAY-DELTA AUTHORITY

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NOTE:
This report supersedes a previous version of the Coarse Sediment Management Plan for the Lower Tuolumne River dated November 14, 2003. This report includes significant revisions to the November 2003 report that are intended to increase benefits for and reduce potential adverse impacts to *O. mykiss* in the Tuolumne River resulting from coarse sediment augmentation implemented to improve habitat for salmonids.

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ACKNOWLEDGEMENTS

This Report is the result of contributions from numerous individuals, all with a stake in helping the restoration and management of the Tuolumne River move forward. Several components of this plan were researched and developed independently, including:

- the EASI Bedload Transport Model described in Section 4.3 was developed by Yantao Cui with assistance from Noah Hume of Stillwater Sciences;
- the update of the EACH and Stock Recruitment Models of Chinook Salmon in the San Joaquin River System described in Section 4.5 was performed by Peter Baker with assistance from Noah Hume of Stillwater Sciences;
- the surveys and quantification of fine sediment deposits in the upper spawning reaches presented in Appendix E were conducted by Noah Hume and Martin Trso of Stillwater Sciences;
- the technical study evaluating fine sediment removal methods for use in the Tuolumne River presented in Appendix F was prepared jointly by Noah Hume, Peter Baker, and Jay Stallman of Stillwater Sciences;
- the bedload transport measurements at Riffle 4B and Basso Bridge were conducted by Graham Matthews and Cort Pryor of Graham Matthews and Associates (GMA) and John O'Brien of Stillwater Sciences;
- coarse sediment augmentation site surveys were prepared by Keith Barnard of GMA;
- the Regulatory Compliance Issues section of the report (Section 8) was researched and compiled by Aldaron Laird of Trinity Associates;
- mapping of existing *O. mykiss* habitat presented in Appendix I was conducted by Carl Mesick and Steve Walser of the California Rivers Restoration Fund; and
- Stillwater Sciences contributed to the descriptions of Chinook salmon and *O. mykiss* spawning habitat suitability information presented in Sections 3.1 and 3.2.

The Department of Fish and Game and Department of Water Resources are currently leading the effort in on-the-ground coarse sediment augmentation work in the Tuolumne River and have placed over 30,000 cu yds of coarse sediment in the river in the last five years. The departments also contributed extremely valuable data and technical review to the development of this Coarse Sediment Management Plan.

Finally, we wish to acknowledge the funding support provided by the USFWS Anadromous Fish Restoration Program and project administration provided by Wilton Fryer of the Turlock Irrigation District.

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EXECUTIVE SUMMARY

I. INTRODUCTION AND BACKGROUND

The Tuolumne River is one of the largest rivers in California's Central Valley. The largest tributary of the San Joaquin River, the Tuolumne River supplies valuable agricultural and municipal water, hydroelectric power, commercial aggregate, and recreational opportunities to the region. The Tuolumne River also provides riparian and aquatic habitats that sustain numerous plant and animal species, including fall-run Chinook salmon (*Oncorhynchus tshawytscha*) and steelhead/rainbow trout (*O. mykiss*). Despite recent declines in abundance, the Chinook salmon population in the Tuolumne River has been the largest naturally reproducing salmon population in the San Joaquin Valley over most recent years.

Since 1971, the Turlock and Modesto Irrigation Districts (the Districts), in cooperation with the California Department of Fish and Game (CDFG) and the U.S. Fish and Wildlife Service (USFWS), have conducted extensive studies of Chinook salmon population dynamics and habitat in the lower Tuolumne River as part of the Don Pedro Project FERC Study Program. The objective of these studies was to identify potential management actions for increasing Chinook population abundance and improving Chinook salmon habitat in the Tuolumne River. In 1995, through the FERC licensing process for the New Don Pedro Project, the Districts and the City and County of San Francisco (CCSF) entered into a FERC Settlement Agreement (FSA) with the USFWS, CDFG, and several environmental and recreational groups. The FSA established minimum instream flow requirements for the Tuolumne River downstream of the New Don Pedro Project and set forth a strategy for recovery of the lower Tuolumne River Chinook salmon population.

O. mykiss are also known to occur in the Tuolumne River. Steelhead and rainbow trout represent two life history strategies of the same species, *O. mykiss,* with steelhead being the anadromous life history form and rainbow trout being the resident life history form. *O. mykiss* have been recorded in the Tuolumne River as an incidental species during Chinook salmon monitoring in the lower Tuolumne River, but no efforts have been made thus far to quantify their abundance. The Districts began more intensive *O. mykiss* monitoring in 2004.

Convened under the FSA, the Tuolumne River Technical Advisory Committee (TRTAC) contributes to planning and implementation of restoration projects on the river. To guide these restoration efforts, the TRTAC has developed a Habitat Restoration Plan for the Lower Tuolumne River Corridor (Restoration Plan) (McBain and Trush 2000). The Restoration Plan identifies several large-scale restoration projects for the river. Several of these projects have been implemented, and others are underway. These large-scale restoration efforts are in response to the severity of impacts that cumulatively have degraded the Tuolumne River ecosystem during the past 150 years. Beginning with the Gold Rush, the Tuolumne River has been extensively modified by land use practices (e.g., agriculture, ranching, and urbanization) and resource extraction (e.g., water diversion, gold mining, and aggregate mining). Streamflow regulation began with construction of Wheaton Dam (1871) and La Grange Dam (1893), intensified in the 1920s with the construction of several large reservoirs in the basin, and culminated in 1971 with construction of the New Don Pedro Project (NDPP), which more than tripled reservoir storage capacity in the basin and stores 106% of the average annual basin outflow of 1.9 million acre-feet. In addition to regulating streamflow, the dams also trap coarse sediment from the upper watershed, eliminating coarse sediment supply below La Grange Dam. Small tributaries and bank erosion contribute a small supply of coarse sediment, but this volume is inadequate to mitigate for dam-related impacts.

During the early twentieth century, the Tuolumne River channel and floodplain were dredged for gold. The gold dredges excavated channel and floodplain alluvial deposits to the depth of bedrock and often realigned the river channel. After recovering the gold, the dredges deposited the remaining tailings back onto the floodplain, creating large, cobble-armored windrows that replaced the alluvial deposits and floodplain soils. By the end of the gold mining era, the majority of the floodplain adjacent to 14.5 miles of the river had been converted to dredger tailing deposits. In the 1960's much of the tailings were excavated to provide construction aggregate for New Don Pedro Dam. Much of this floodplain remains today as barren, unproductive surfaces, with exposed gravel/cobble and little or no soil layer and little or no native, riparian vegetation.

The Tuolumne River has also been extensively mined for aggregate. Large-scale aggregate mining began in the 1940s and continues today. Historically, aggregate mines extracted sand and gravel directly from the active river channel, creating large, in-channel pits. Contemporary mining operations excavate sand and gravel from floodplains and terraces adjacent to the river channel. These operations create large pits that are poorly separated from the river by narrow dikes that often fail during even moderate flows

II. PURPOSE OF THE COARSE SEDIMENT MANAGEMENT PLAN

Many factors govern the productivity and capacity of the Tuolumne River to produce salmonids, and factors vary from year-to-year depending on the water yield, escapement, and other variables. Past studies of Chinook salmon population dynamics in the Tuolumne River concluded that poor spawning substrate quality and redd superimposition in heavily used spawning areas were primary factors limiting Chinook salmon production in this river. *O. mykiss* population dynamics have not been studied in the Tuolumne River, but reproduction for this species could be expected to be affected by similar factors as Chinook salmon.

Coarse sediment augmentation is expected to provide immediate and long-term benefits for both salmonid habitat and geomorphic conditions and processes in the river. Coarse sediment augmentation is expected to increase the area and quality of available spawning habitat for both Chinook salmon and *O. mykiss*, thus increasing fry production and, potentially, recruitment to these salmonid populations. Augmentation is also expected to improve fry and juvenile rearing habitat. In addition to improving habitat conditions for salmonids, coarse sediment augmentation is expected to improve sediment routing, channel morphology, and geomorphic processes in the river by increasing sediment supply to the channel (to make up for past and future deficits) and eliminating bedload impedance reaches.

The purpose of this Plan is to:

- identify and prioritize sites and alternative methods to augment coarse sediment (and salmon spawning gravel) in the gravel-bedded reaches below La Grange Dam;
- identify and prioritize sediment sources that can be acquired and developed that minimize competition for commercial aggregate reserves;
- evaluate varying options and strategies for complying with regulations that govern gravel augmentation and other large-scale restoration projects; and
- establish monitoring and adaptive management programs that evaluate: (1) long-term coarse sediment augmentation needs, and (2) the success of the Plan in restoring sediment supply, geomorphic processes, and spawning habitat.

III. CONCEPTUAL MODEL: FLUVIAL PROCESSES, SEDIMENT SUPPLY AND TRANSPORT, SALMONID HABITAT

The Coarse Sediment Management Plan is based on a simple conceptual model linking fluvial processes, sediment supply and transport, and salmonid habitat. In this model, an alluvial river ecosystem is created and maintained by geomorphic and hydrologic processes that result from energy and material interactions between flowing water and sediment supply and from secondary influences of riparian vegetation (Trush et al. 2000). Water, sediment, geology, riparian vegetation, and human influences interact to define the river channel form (morphology). The channel morphology, in turn, provides aquatic and terrestrial habitat within the river corridor, and thus influences the abundance and distribution of riverine biota. This Plan attempts to increase sediment supply, balance sediment texture and supply with contemporary flow conditions, and improve sediment routing in an effort to improve fluvial geomorphic processes and, thus, increase the area and quality of suitable salmonid spawning, incubation, and rearing habitat.

IV. ANADROMOUS SALMONID POPULATIONS IN THE LOWER TUOLUMNE RIVER

In recent decades, the Tuolumne River has supported the largest population of fall-run Chinook salmon in the San Joaquin Basin. Since completion of the New Don Pedro Dam in 1971, Chinook salmon escapement has ranged from a low of less than 100 adults to a high of 40,300 adults. Major population declines have been associated with the droughts of 1959-1961, 1976-1977, and 1987-1992. Almost all Chinook salmon spawning occurs upstream of Hickman Bridge (at Waterford) and is most heavily concentrated in the reach between La Grange Dam and Basso Bridge. The longitudinal distribution of salmon in selecting spawning sites is poorly understood but has been identified as a factor contributing to redd superimposition, which is a key source of density-dependent Chinook salmon mortality in the Tuolumne River (TID/MID 1992c).

Historical and current *O. mykiss* population abundance in the Tuolumne River is not known. *O. mykiss* have been recorded as an incidental species during Chinook salmon monitoring in the lower Tuolumne River, but no efforts have been made thus far to quantify their abundance. For this Plan, the California Rivers Restoration Fund (CRRF) identified *O. mykiss* holding, foraging, and spawning habitat distribution in the Tuolumne River based on 10 years of hook-and-line and snorkel surveys for use in the coarse sediment management planning effort (CRRF 2004).

V. INVESTIGATIONS AND ANALYSES CONDUCTED FOR THE COARSE SEDIMENT MANAGEMENT PLAN

Several field investigations, modeling efforts, and other analyses were conducted for this Plan. The objectives of these analysis were to quantify or describe: (1) pre- and post-dam coarse sediment supply to the lower river, (2) existing channel morphology and bed texture, (3) bedload transport rates under existing and post-augmentation conditions, (4) existing fine sediment storage in the mainstem channel bed, (5) existing habitat conditions for salmonid spawning, (6) salmonid spawning distribution and habitat utilization, and (7) potential Chinook salmon population-level effects from coarse sediment augmentation. Investigations and analyses conducted to support this Plan included are shown in Table A. The results of these analyses are briefly summarized below.

Table A. Investigations and analyses conducted for the Coarse Sediment Management Plan

Parameter	Method(s)
Pre- and post-dam coarse sediment supply	• Analysis of reservoir survey data • Analysis of 1997 spillway erosion • Channel and watershed analyses reported in McBain and Trush (2000)
Channel morphology and bed texture	• Field reconnaissance • Channel cross sections (n=41) and profiles • Pebble counts (Wolman 1954)
Sediment transport rates and thresholds	• Helley-Smith sampling of bedload transport • Numerical modeling based on Parker (1990) • Tracer rock experiments
Sand and fine sediment storage	• Field reconnaissance and mapping
Salmonid spawning habitat quality, distribution, and utilization	• Habitat mapping • Redd mapping • Detailed physical surveys at reference spawning sites • Analysis of CDFG spawning survey data
Population-level effects	• Population modeling (EACH and Stock Recruitment)

<u>Pre- and post-dam coarse sediment supply</u>

The historical source of coarse sediment to the Tuolumne River was primarily erosion and hillslope processes in the upper watershed in the Sierra Nevada Range. Based on reservoir sediment surveys, Brown and Thorp (1947) estimated a sediment yield of 303 tons/mi^2/yr. Assuming that 10% of the total yield was bedload, we estimated that the unimpaired coarse sediment supply was 18,800 cu yds/yr from the watershed upstream of NDPP. Since construction of large storage reservoirs on the Tuolumne River, the majority of sediment supply from the upper watershed has been completely lost. The primary exception to this was the January 1997 flood spill, which accessed the New Don Pedro Dam spillway. Erosion in the spillway delivered approximately 500,000 cu yds of topsoil mixed with crushed and scoured bedrock to La Grange Reservoir and over the dam into the lower Tuolumne River (McBain and Trush 2000). Small tributaries downstream of La Grange Dam do not supply significant volumes of coarse sediment to the mainstem river.

<u>Channel morphology</u>

Existing channel morphology was documented using channel cross section surveys (n=42) and longitudinal profiles. Several indicators, based on the contemporary channel morphology, suggest that the channel downstream of La Grange Dam is in severe sediment supply deficit and that this condition is affecting both the productivity and capacity of salmonid spawning habitat. First, channel cross section surveys indicate that the channel is overly wide in many reaches, lacks adequate bankfull channel confinement, and has not readjusted its cross sectional dimensions to the contemporary high flow regime. Second, field surveys conducted by McBain and Trush have identified numerous sites where lateral bars, riffles, or other sediment storage features have been depleted of sediment. Third, long scour pools and in-channel mining pits known as "Special Run Pools" cumulatively comprise nearly five miles of river channel in the dominant spawning reaches upstream of Roberts Ferry Bridge. These sections of channel trap all sediment routed to them, provide little or no high quality salmonid habitat, and provide suitable habitat for non-native piscivores that prey on juvenile salmonids. Finally, a large number of riffles throughout the gravel-bedded zone has been progressively reduced in size or completely eliminated by a single or numerous large floods. Between 1988 and 1999-2001 (following the 1997 flood), riffle area in the study reach was reduced by 16% from 1.57 million ft^2 to 1.32 million ft^2.

Sediment transport rates and thresholds

Tracer rock experiments and numerical modeling were used to estimate the flow required to mobilize the river bed in the spawning reach. Three tracer rock monitoring sites were established in April 2001, and a fourth was added in 2002. Additional tracer rock monitoring sites were established in the 7/11 Mining Reach as part of the post-construction monitoring for the 7/11 Mining Reach restoration project. Based on these tracer rock experiments, coarse bed particles in most reaches do not appear to be significantly mobilized by flows up to 6,880 cfs. Bed mobility modeling conducted in the past at the Ruddy 4-Pumps Restoration site and predicted bed mobility at discharges of 9,800 cfs, 7,050 cfs, and 8,250 cfs for each of three cross sections.

Bedload transport rates were measured in March 2000 at Riffle 4B (XS 2685+00) at flows of 4,020 cfs, 4,960 cfs, 5,980 cfs, and 6,700 cfs. Data points from the two lower discharges (4,020 and 4,960 cfs) were nearly identical (i.e., there was no increase in transport between those two discharges). An empirically derived bedload transport rating curve was developed from these monitoring data. With the few data points available, however, this rating curve should be considered very preliminary. Applying the rating curve to the regulated flow record at La Grange (USGS 11-289650) for the post-New Don Pedro period (WY 1972-2001) resulted in an average annual sediment transport rate (for sediment > 8 mm) of 8,600 tons/yr (5,400 cu yds/yr), with rates as high as 200,000 tons/yr (126,000 cu yds/yr) in WY 1997. Excluding the 1997 water year, the average annual bedload transport rate (for sediment > 8 mm) was 1,930 tons/yr (1,211 cu yds/yr). During this same period, if flood control recommendations from the Restoration Plan are applied to the hydrograph, average annual bedload transport rates would have been from 1,930 to 2,240 tons/yr (1,200 to 1,400 cu yds/yr) (for sediment > 8 mm), or 15% greater than under real conditions.

The EASI model (Enhanced Acronym Series 1 & 2 with Interface) was used to predict contemporary bedload transport rates in the primary spawning reach and to evaluate the benefits and/or potential impacts of alternative sediment augmentation approaches. The model focused on the 2,000 ft reach from Riffle 5A to Riffle 4A and included the bedload transport measurement site at Riffle 4B. The model integrated survey data from eight cross sections in this reach and the bedload transport data collected at Riffle 4B. The model predicted that long-term average bedload sediment transport rates (for sediment >8 mm) in the modeling reach is 1,670 ton/yr. This estimate is similar to the estimate derived from bedload measurements at R4B (1,930 tons/yr) based on the post-NDPP flow records.

Part of the strategy for coarse sediment management is to progressively reduce the overall particle size distribution so that bed sediments are mobilized more frequently by the contemporary regulated flow regime. The EASI model was used to evaluate the effect of varying the surface grain size on particle size distribution by using the finest and coarsest of available pebble counts as model input, which resulted in a predicted long-term coarse sediment transport rate of 4,010 tons/year for the finest bed texture and 490 tons/year for the coarsest bed texture.

Sand and fine sediment storage

Stillwater Sciences conducted a three-day reconnaissance-level snorkel survey from Riffle A3/4 (RM 52.0) to Roberts Ferry Bridge (RM 39.5) to estimate the volume of fine sediment accumulation in pools and other discrete fine sediment deposits (within the bankfull channel) and to assess the contribution of fine sediment from small tributary inputs. In general, the survey noted that all streambed surface and subsurface substrates contained a large volume of sand stored in the channel. Only limited sand deposits were observed in pools in the reach upstream of Basso Bridge (RM 47.5); moderate amounts of sand storage were observed from Basso Bridge to Peasley Creek (RM 45.3). The highest volumes of sand were observed in the Dredger Reach from Peasley Creek to Roberts Ferry Bridge (RM 39.5). Gasburg Creek and Peasley Creek appeared to be the largest contributors of fine sediment in the survey reach.

Salmonid spawning habitat quality, distribution, and utilization

Within the approximately 23-mile-long gravel-bedded reach, Chinook salmon spawning habitat was assessed in 1988 and 1999-2001. The 1988 assessment, which estimated spawning habitat area by digitizing riffle area from aerial photos taken during flows of 100 cfs and 230 cfs, assumed that the entire riffle area provided suitable spawning habitat. Because the actual area of suitable habitat is influenced by substrate texture, site-specific hydraulic characteristics, and other factors, this estimate likely over-represents available Chinook salmon spawning habitat (TID/MID 1991, Appendix 6). Between September 1999 and February 2001, spawning habitat in the 16-mile reach from La Grange Dam (RM 52.0) to the Santa Fe Aggregates haul road bridge (RM 36.3) was resurveyed to document changes in riffle area since 1988 (including the effects of the 1997 flood) and to provide a more detailed assessment of spawning habitat extent that reflects the effects of substrate texture and local hydraulics during spawning flows. During these surveys, riffle area and suitable spawning area were plotted onto aerial photographs in the field, digitized, and added to the Tuolumne River GIS.

To estimate the amount of Chinook salmon spawning habitat that historically was available in this 15-mile reach, spawning habitat density obtained from 1999-01 mapping surveys in the reach between New La Grange Bridge and Basso Bridge was extrapolated to the entire gravel-bedded zone (with similar channel slopes). This reach, including riffles 2 to 5B, contained an estimated 323,000 ft^2 of spawning habitat, or approximately 30 ft^2 of spawning habitat per linear foot of channel. Based on this extrapolation, the area of spawning habitat historically available (i.e., pre-dam and pre-mining) from La Grange Dam to the Santa Fe Aggregates bridge was estimated to be 2.4 million ft^2. Riffle area mapped in 1988 was 1.6 million ft^2, or 823,000 ft^2 (34%) less than the historical estimate for the reach. Riffle area mapped in 1999-2001 was 1.3 million ft^2, or 269,000 ft^2 (17%) less than in 1988. Loss of riffle area between 1988 and 1999-2001 for the dominant spawning reach, dredger reach, and mining reach was 128,000 ft^2 (17%), 46,000 ft^2 (11%), and 52,000 ft^2 (13%), respectively. Comparing 1999-2001 spawning habitat area to historical estimates indicates a potential loss of 1.8 million ft^2 (73%) of Chinook salmon spawning habitat compared to historical conditions.

To provide preliminary documentation of potentially suitable adult *O. mykiss* foraging, holding, and spawning habitat, the CRRF mapped locations where they routinely catch adult *O. mykiss* that weigh between 2 and 12 pounds using hook-and-line methods in the lower Tuolumne River between La Grange Dam and the Roberts Ferry Bridge. The mapping surveys were conducted January and February, 2004. Forty-seven sites were identified as adult *O. mykiss* habitat between the La Grange Dam and Roberts Ferry Bridge. The locations of these sites, site numbers, GPS coordinates, habitat features are presented in Appendix D. CRRF also reports that some *O. mykiss* habitat occurs downstream to the Reeds property just above Waterford (approximately RM 33). In May 2004, CRRF and CDFG collected adult *O. mykiss* as far downstream as Riffle 36A (RM 36.5).

Poor spawning and incubation gravel quality resulting from accumulation of sand in the channel bed is also an issue in the Tuolunme River. The fisheries studies conducted by the Districts in the 1980s (TID/MID 1992d) predicted that mean survival to emergence in the river ranged was 15.7% for riffles sampled in 1987 and 34.1% for riffles sampled in 1988. A 1997 study conducted for the TRTAC (and using different methods than the 1988 study) predicted survival-to-emergence ranging from 34% (95% CI: 27-41%) at Riffle 7 to 51% (95% CI: 34-68%) at Riffle 2 (Stillwater Sciences 2001a).

Population-level effects

Two population models were used to test potential Chinook salmon population-level effects resulting from coarse sediment augmentation. The EACH model is a deterministic simulation that represents the dynamics of populations from each of the three salmon-bearing tributaries to the San Joaquin River (the Merced, Tuolumne, and Stanislaus rivers). The model consists of a set of finite difference equations describing changes in the numbers of Chinook salmon at various geographical locations and developmental stages as functions of these numbers, and of environmental parameters. The model uses streamflow to represent environmental conditions, and mortality at each life stage is assumed to be either constant or linearly related to flow. The Stock Recruitment Model (TID/MID 1992b) was developed to support understanding of management implications on the behavior of the fluctuating population of the San Joaquin River basin. This model uses statistical analysis of the time-series of historical escapements to the San Joaquin basin in relation to flow and Delta exports. More specifically, the model attempts to capture how density-independent mortality, as influenced by spring flow, combines with density-dependent mortality to affect the rate and magnitude of changes in population of the San Joaquin system's Chinook salmon. The population modeling conclusions were as follows:

- The EACH and Stock Recruitment models use different assumptions and methodologies, but both predict significant benefits of the planned management actions. Increases in spawning habitat availability is expected to reduce a significant source of density-dependent mortality in years of peak escapement, and improvements in gravel quality are expected to reduce a source of density independent mortality in all years causing a fundamental shift in the stock production relationship for the lower Tuolumne River.
- The updated population models track general trends in escapement very well but tend to overestimate escapement in peak years.
- Although the EACH model appears to predict slightly greater production benefits from increased gravel availability than the Stock Recruitment model, both models suggest that significant production benefits may be realized from planned sediment augmentation actions to the upper three spawning reaches in the Tuolumne River.
- Gravel cleaning can be expected to reduce a source of density independent mortality.

VI. RECOMMENDED AUGMENTATION PROGRAM

The overall coarse sediment management approach presented in this Plan includes three basic elements:

- a short-term transfusion of large volumes of coarse sediment to restore instream coarse sediment storage and increase spawning habitat area for Chinook salmon and *O. mykiss*, while protecting existing habitat features for these species;
- long-term, periodic augmentation of smaller volumes of coarse sediment at selected sites to maintain in-channel storage and sediment supply as sediment is mobilized and transported downstream by high flow releases; and
- adaptive management and monitoring to evaluate the program and improve the benefits of introduced coarse sediment (e.g., salmon use, particle size distribution, method of sediment placement, augmentation locations, etc.), and reduce costs.

These three program elements are described in the following sections.

Short-term Sediment Transfusion

The first recommendation in the Sediment Management Plan is to implement a short-term "transfusion" of large volumes of coarse sediment to immediately replenish instream coarse sediment storage, resupply alluvial features, and create salmonid spawning areas. The primary task for planning the sediment transfusion phase was to determine how much sediment to place into the river, where to place it, and what implementation time-frame would be suitable. Laminated aerial photos were used in the field to sketch zones where sediment could be placed into the river channel. These zones included areas such as the surface of lateral bars and pool-tails where sediment storage has been depleted, or the main body of riffles where the slope could be decreased by adding gravel. These discrete zones were digitized to estimate sediment volumes, then grouped into larger transfusion "sites" and prioritized to determine which sites should be implemented in the first phases of gravel transfusion. The site prioritization was intended to select sites for early implementation where the project benefits could be maximized. A total of 29 coarse sediment transfusion sites were identified between La Grange Dam (RM 52.2) and Roberts Ferry Bridge (RM 39.5).

Based on their priority, the 29 projects were grouped into six phases. The CDFG projects at Riffle 1A/B and Riffle A7 constitute Phases I and II, which began in 1999 and were completed in 2003. Phase III includes six high priority projects and one medium priority project, as follows: Riffle A5/6 La Grange Pool (site 2), Basso Pool (site 10), Riffle A3/4 (site 1), Riffle 3A Complex (site 6), Riffle 12 Complex (site 14), FOT RM 43 (Bobcat Flat) (site 22), and Riffle 24 (TLSRA) (site 26). Phase IV includes three high priority projects and six medium priority projects, as follows: Riffle 28B/Roberts Ferry Bridge Pool (site 29), Zanker Pool (site 13), SRP 4 (site 27), New La Grange Bridge Backwater (Riffle 1C) (site 5), Riffle 5A Complex (site 8), Riffle 5B Complex (site 9), Riffle 8 (site 12), FOT RM 44.5 Site (Riffles 16, 17A, 17D) (site 18), and Riffle 7 Complex (site 11). Phase V includes seven medium priority projects, as follows: RM 44 Pool (site 19), SRP 3 (site 20), Riffle 18 (site 21), Riffle A7 Complex (site 3), Riffle 1A/B Complex (site 4), Riffle 13 A/B Complex (site 15), and Riffle 14/15 Complex (site 17). Phase VI includes six low priority projects, as follows: Riffle 4A Complex (site 7), RM 40.5 Pool/Riffle 27 (site 28), Riffle 13C and Backwaters (site 16), Riffle 23A (site 23), RM 42.4 (site 24), and Riffle 23B (site 25).

Four sediment augmentation methods are recommended, each having unique benefits and limitations. The fourth method (Method 2C) was added after review of the November 2003 version of this Plan. The High Flow Recruitment Pile Method (Method 1) places a quantity of coarse sediment at or near the channel margin or to supplement a gravel bar where it is then available for downstream transport by high flows. The main benefit of this method is that it reduces the need for heavy equipment working in the low-flow channel and thus minimizes the risk of adverse impacts to existing salmonid habitat. The primary drawback is that it is indirect, such that in the absence of high flow releases at La Grange a lengthy period of time may pass before the sediment is recruited and redeposited downstream as usable habitat. The In-river Gravel Placement Method (Method 2) places coarse sediment directly into the channel to augment or create riffles, pools tails, and point bars, thus creating or improving habitat features immediately usable for salmonids and introducing coarse sediment into the channel for future routing. Three variations of this method are proposed: riffle-pool tail supplementation (Method 2A), point bar supplementation (Method 2B), and riffle-pool tail-point bar creation in long pool reaches (Method 2C). The primary advantage of direct in-river placement is that it simultaneously increases sediment supply to the river, while immediately providing usable habitat for salmonids and other biota. The potential drawback of this method is that it is difficult to construct or preserve all of the important habitat features required by salmonids, such as deep water, surface turbulence, and/or bankside riparian vegetation, at highly manipulated construction sites.

Conceptual designs were developed for five transfusion sites that were considered to be high priority. These sites were as follows: (1) Riffle A3/4 at the top of the spawning reach below La Grange Dam, (2) Riffle 1C under the New La Grange Bridge, (3) Riffle 3A just downstream of New La Grange Bridge at the site of the former haul road crossing, (4) Riffle 12 near the Zanker Ranch that was heavily altered by the 1997 flood, and (6) Riffle 24A at Turlock Lake State Recreation Area. As part of a previously funded restoration project, conceptual designs were also developed for the FOT RM 43 site (Bobcat Flat). Of sites for which conceptual designs have been developed, Riffle A3/4, Riffle 3A, Riffle 12, and Riffle 24A remain high priority. The FOT RM 43 project was ranked as medium priority but is included in Phase III because it is funded for implementation and offers important opportunities for learning and experimentation. Riffle 1C was ranked as medium priority and is included in Phase IV.

Conceptual designs are intended to identify potential fill placement locations, potential access routes, fill placement methods, and preliminary fill volume estimates. Prior to project implementation, final designs must be developed for each site and approved by the TRTAC and property owner. These final designs should include experimental treatments to test the effectiveness of different restoration methods and the importance of various habitat features. The designs should also provide detailed information on existing habitat conditions at each site, final fill placement methods and locations, detailed microhabitat conditions to be created at the site, and final access and other construction features. Moreover, during implementation, we strongly recommend that a highly qualified fisheries biologist familiar with Chinook salmon and *O. mykiss* habitat requirements and reproductive behavior and approved by the TRTAC be present on-site and work with the construction managers to direct equipment operators to ensure that impacts to existing habitat features are avoided and habitat improvements resulting from the augmentation project are realized. Implementation should be consistent with designs and specifications but could include additional micro-topographic features, avoidance of specific cover features, protection of pools downstream of existing and constructed riffles, and other measures.

Long-term Sediment Maintenance

Once coarse sediment storage is replenished in the upper Tuolumne River, long-term coarse sediment additions will be required to maintain coarse sediment supply as sediment is transported downstream by high flow releases. The volume of periodic augmentation will be smaller than the transfusion and should be approximately equivalent, on average, to the volume transported downstream during high flows. This long-term strategy is essential to maintain alluvial features and spawning habitat downstream of the dam. The estimated average annual long-term augmentation volume is 1,000 – 2,500 cu yds/yr. The following locations are recommended as long-term augmentation sites: Riffle A3/4, Riffle A7, Riffle 7, Bobcat Flat (RM 44), Turlock Lake State Recreation Area, and Roberts Ferry Bridge.

VII. TOTAL SEDIMENT NEEDS FOR RESTORING THE LOWER TUOLUMNE RIVER

The volume of coarse sediment needed for complete restoration of the Tuolumne River is considerable. We have estimated the short-term needs for coarse sediment transfusion to be approximately 372,000 cu yds to complete Phases III and IV, 167,000 cu yds to complete Phases V and VI, and approximately 1,000-2,500 cu yds/yr for long-term coarse sediment maintenance (Table 17). In addition, the Gravel Mining Reach channel restoration project, which is currently underway, will require additional coarse sediment to complete. Phase I (7/11 Materials) of this 4-phased project was completed in 2002, and Phase II (MJ Ruddy) is scheduled to be implemented in 2004-2005. The sediment source for Phase II has already been identified. The Phase III (Warner-Deardorff) project will require approximately 500,000 cu yds of material. The sediment source for this phase has not yet been identified. Volume estimates for Phase IV (Reed) are not available at this time. The Restoration Plan also identifies two additional channel reconstruction projects that will require coarse sediment as follows: SRP 5 (108,000 cu yds), SRP 6 (159,000 cu yds). The total volume of sediment needed for restoration of the river, including coarse sediment transfusion phases and completing projects identified in the Restoration Plan, therefore, is approximately 1.3 million cu yds plus 1,000-2,500 cu yds/yr for long-term coarse sediment maintenance. Additional channel reconstruction projects may be identified in the future based on the outcome of projects completed over the next several years. Such projects could include filling and channel reconstruction at SRP's 3, 4, 7, and 8, which would require an estimated 1.3 million cubic yards of coarse sediment.

VIII. SEDIMENT COMPOSITION

Sediment placed into the channel is intended to be "used" for many purposes, such as to rebuild alternate bars, supplement spawning gravels, or change the slope or confinement of a particular section of river. The sediment composition, therefore, may vary according to several factors, including the specific site conditions, site objectives, and placement methods. We recommend two different sediment compositions be used in coarse sediment augmentation projects. Sediment intended for rebuilding geomorphic features such as lateral bars and banks can utilize a coarse, screened, unwashed mix of gravel and cobble in the size range of ½ to 6 inches (13 to 150 mm). This mixture can be ungraded within this size range (i.e., relative proportions of gravel/cobble does not matter) and may contain small amounts of fine sediment that cling to gravel and cobble during processing. This coarse sediment mix may also occasionally contain a few larger cobble particles in the size range of 6–10 inches (150 to 254 mm) (less than 5% of the total), if this minimizes the costs of processing the material.

For spawning habitat supplementation, a more refined or "processed" sediment composition should be used defined by preferred spawning substrate textures for Chinook salmon and *O. mykiss* and textures documented at Chinook salmon spawning sites in the Tuolumne River. Suitable substrates for Chinook salmon range from 0.1 inches to six inches (3-150 mm) in diameter with a D_{50} of 1.6-2.3 inches (40-58 mm), and suitable substrates for *O. mykiss* range up to four inches (102 mm) in diameter and have a D_{50} of 0.5-1.8 inches (10-46 mm). Data from the Stanislaus River (CMC 2002a) suggest that sediment between 1/4-inch (7 mm) and 1/2-inches (10 mm) may be an important component of preferred Chinook salmon spawning substrates.

IX. SEDIMENT SOURCES

The Coarse Sediment Management Plan builds on the sediment source inventory conducted in the Restoration Plan by prioritizing sources, refining volume estimates, and linking sources to different augmentation sites. The recommended strategy is to purchase materials from commercial suppliers or acquire mineral rights to undeveloped coarse sediment sources (e.g., dredger tailings) that can be developed for future restoration projects. The benefits of this approach are considerable. First, this strategy reduces the potential conflict with the use of commercially- permitted aggregate reserves. Second, these source sites can often be restored to higher quality habitat (e.g., revegetated floodplain and wetland habitat) while simultaneously avoiding additional floodplain pit mining. Lastly, purchasing and developing a source of sediment dedicated to restoration can substantially lower the cost of the sediment and make restoration much more cost effective.

Four high priority sediment sources are identified: (1) the Zanker/Domecq properties, (2) the Reeves Coarse Sediment piles, (3) the Bobcat Flat Dredger Tailings, and (4) Stanislaus County Floodplain

Properties. The estimated volume of coarse sediment suitable for restoration available at these sites is 750,000 cu yds, 76,000 cu yds, 215,000 cu yds, and 100,000 cu yds, respectively, or a total of approximately 1.14 million cu yds. One of these sites, the Bobcat Flat property, has been purchased by FOT. The Crooker Dredger Tailings and Cree Dredger Tailings are identified as medium priority sites due to their high cost and their commercial demand; the Merced River Dredger Tailings are considered to be low priority due to their distance from the Tuolumne River and the potential that they may be needed for restoration projects on the Merced River.

X. ADAPTIVE MANAGEMENT AND MONITORING.

While the sediment management approach described in this report is relatively simple in concept, the proposed scale will require adaptive management and monitoring to ensure that project benefits are achieved. The fundamental steps to adaptive management are: (1) define goals and objectives in measurable terms, (2) develop hypotheses, build models, compare alternatives, design system manipulations and monitoring programs, (3) propose modifications to operations that protect, conserve, and enhance resources, (4) implement monitoring and research programs to examine how selected management actions meet resource management objectives, and (5) use the results of steps 1-4 to further refine ecosystem management to meet the stated objectives (Hollings 1978). The CBDA Strategic Plan (CBDA 1999) describes some of the critical elements of CBDA's adaptive management approach, and a step-wise procedure for implementing adaptive management.

This Plan developed a set of quantitative objectives and hypotheses related to coarse sediment management and a set of monitoring methods that should be implemented. Specific experimental components are recommended to be implemented during the sediment transfusion phase to increase the opportunity to learn from these projects.

The goal of adaptive management is to evaluate alternative project designs, objectives, and hypotheses, and obtain information that will allow refinement of subsequent project phases or during implementation in other river systems. For this Plan, the monitoring objectives are to:

- observe and quantify trends in bed aggradation/degradation to determine volumetric and geomorphic changes in sediment storage;
- refine estimates of the sediment volume necessary to maintain sediment storage over the long term;
- assess mobility thresholds, frequency of bed mobilization, and transport rates as coarse sediment augmentation proceeds;
- evaluate changes in spawning habitat availability and habitat use by fall-run Chinook salmon (particularly in response to varying baseflows) that result from sediment management actions;
- evaluate salmon egg survival longitudinally throughout the entire salmon spawning reach and across water year types resulting from sediment management actions;
- evaluate sediment routing to determine when long-term augmentation sites can be discontinued; and
- measure smolt production, and compare the ratio of adult escapement to smolt production

[1] These monitoring elements combine both project-related and broader river-wide objectives.

estimates [1].

To meet these objectives, our recommended monitoring elements are:

- topographic surveys, including cross sections, longitudinal thalweg surveys, and planform surveys with total station;
- bed mobility experiments (tracer rocks, scour cores, pebble counts) and bedload transport empirical measurements and transport model development;
- reach-wide spawning habitat surveys and redd surveys and site-specific spawning habitat vs. streamflow relationship;
- spawning gravel quality measurements (including permeability, sediment composition, dissolved oxygen, and intra-gravel temperature)[1]; and
- rotary screw trap (or other comparable methods) monitoring to quantify smolt production from the Tuolumne River[1].

Monitoring activities should initially be concentrated in the upper 4.2 mile reach from Basso Bridge (RM 47.5) to Riffle A3/4 (RM 51.7). The Riffle 4B reach (RM 48.5) can serve as a reference condition for sediment augmentation since it will not receive any mechanical coarse sediment input. The reach is also bounded at both upper and lower ends by deep pools that functionally capture all bedload routing into them.

XI. REGULATORY COMPLIANCE REQUIREMENTS

Implementing large-scale restoration projects is a complex process. Project proponents must obtain adequate funding, set attainable goals and objectives, develop designs that incorporate adaptive management components, and interpret monitoring results to evaluate project objectives and maximize learning. In addition, project proponents must also meet permitting and environmental compliance requirements; address local, state, and federal regulatory agencies with jurisdiction over project components; and provide the opportunity for public involvement. Numerous regulatory agency permits are required for restoration projects of this scale. All this must be accomplished in the face of time constraints, overburdened regulatory agency staff, finite duration of funding, annual cost inflations, and more.

Regulatory compliance issues were evaluated that pertain specifically to: (1) purchasing and developing material sources for coarse sediment restoration, (2) placing sediment into the river for habitat improvement, and (3) developing strategies for complying with land use and resource protection regulations and environmental laws which have jurisdiction over the implementation of this Plan.

The Coarse Sediment Management Plan recommends the District (and/or the TRTAC) implement coarse sediment management as three separate projects, each addressing a different purpose: (1) identification and/or development of suitable sediment sources, (2) short-term transfusion, and (3) long-term maintenance augmentation. The District is a state agency under the Water Code and acts as the implementation agency for the TRTAC. The District will often the project proponent, as well the project manager and construction manager, for coarse sediment management projects in the Tuolumne River and could act as state lead agency for CEQA for all three project types. The USFWS could be

1 INTRODUCTION

1.1 Overview

The Tuolumne River is one of the largest rivers in California's Central Valley. The largest tributary of the San Joaquin River, the Tuolumne River supplies valuable agricultural and municipal water, hydro-electric power, commercial aggregate, and recreational opportunities to the region. The Tuolumne River also provides riparian and aquatic habitats that sustain numerous plant and animal species, including fall-run Chinook salmon (*Oncorhynchus tshawytscha*) and steelhead/rainbow trout (*O. mykiss*). Despite recent declines in abundance, the Chinook salmon population in the Tuolumne River has been the largest naturally reproducing salmon population in the San Joaquin Valley over most recent years.

The Tuolumne River drains a 1,960-square-mile watershed on the western slope of the Sierra Nevada Range and is the largest of three major tributaries to the San Joaquin River (Figure 1). The river originates in Yosemite National Park and flows west to its confluence with the San Joaquin River, approximately 10 miles west of the city of Modesto. As the Tuolumne River emerges from the Sierra Nevada foothills into the Central Valley, the river transitions into a gently sloping alluvial valley. Within the alluvial valley, the river can be divided into two geomorphic reaches defined by channel slope and bed composition. The gravel-bedded zone extends from La Grange Dam (RM 52) to Geer Road Bridge (RM 24); the sand-bedded zone extends from Geer Road Bridge to the confluence with the San Joaquin River. The gravel-bedded zone, the focus of the Coarse Sediment Management Plan, provides spawning and rearing habitat for fall-run Chinook salmon and steelhead/rainbow trout populations.

Since 1971, the Turlock and Modesto Irrigation Districts (the Districts), in cooperation with the California Department of Fish and Game (CDFG) and the U.S. Fish and Wildlife Service (USFWS), have conducted extensive studies of Chinook salmon population dynamics and habitat in the lower Tuolumne River as part of the Don Pedro Project FERC Study Program. The objective of these studies was to identify potential management actions for increasing Chinook population abundance and improving Chinook salmon habitat in the Tuolumne River. In 1995, through the FERC licensing process for the New Don Pedro Project, the Districts and the City and County of San Francisco (CCSF) entered into a FERC Settlement Agreement (FSA) with the USFWS, CDFG, and several environmental and recreational groups. The FSA established minimum instream flow requirements for the Tuolumne River downstream of the New Don Pedro Project and set forth a strategy for recovery of the lower Tuolumne River Chinook salmon population. Using adaptive management, the FSA goals are to: (1) increase the abundance of wild Chinook salmon in the Tuolumne River, (2) protect any remaining genetic characteristics unique to the Tuolumne River Chinook salmon population, and (3) improve salmon habitat in the Tuolumne River.

Steelhead/rainbow trout are also known to occur in the Tuolumne River. Steelhead and rainbow trout represent two life history strategies of the same species, *O. mykiss,* with steelhead being the anadromous life history form and rainbow trout being the resident life history form. This species exhibits considerable plasticity in selection of life history strategy. While new technology has made it possible to determine the maternal origin of juvenile *O. mykiss* (i.e., whether the mother was anadromous or resident), it is not possible to predict whether juveniles will mature to be anadromous or resident (Zimmerman and Reeves 2000). Due to this flexibility in selection of life history strategy and the lack of ability to predict whether juveniles will mature into anadromous or resident life forms, steelhead and rainbow trout are collectively referred to as "*O. mykiss*" in this report.

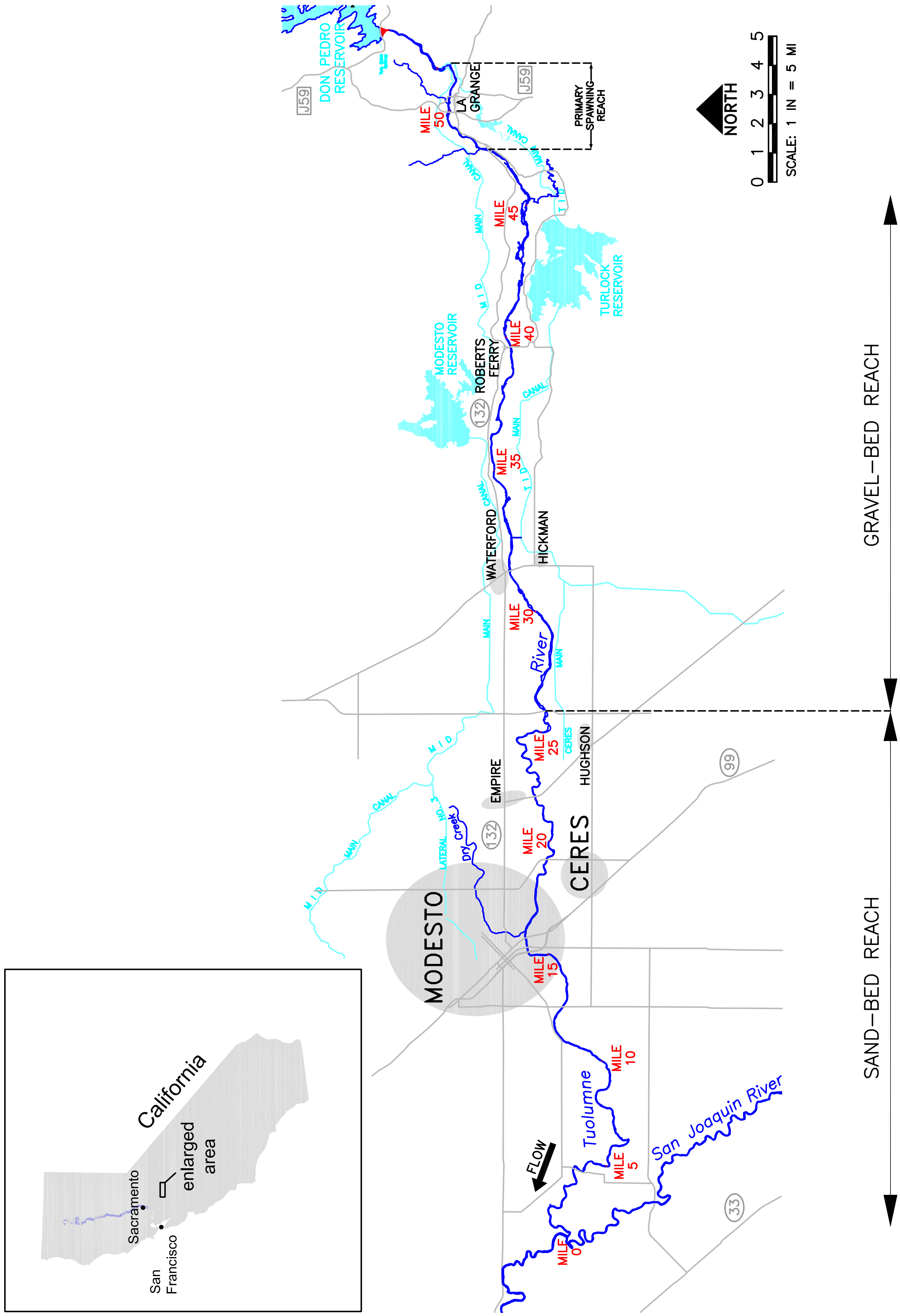


Figure 1. The lower Tuolumne River study area in the San Joaquin Valley, CA.

While the Chinook salmon population has been the subject of many years of study in the Tuolumne River, *O. mykiss* have received much less attention. In fact, until adoption of the FSA, the Tuolumne River was managed to suppress *O. mykiss* population abundance to reduce their predation pressure on Chinook salmon. With the recent listing of anadromous *O. mykiss* under the Federal Endangered Species Act, fisheries agencies have begun to increase their focus on *O. mykiss* in the Tuolumne River, and the Districts have begun to monitor *O. mykiss* distribution and abundance.

Since the completion of the FSA, the Tuolumne River Technical Advisory Committee (TRTAC) has worked to develop and implement studies of specific aspects of salmon biology and habitat required by the FSA. To guide this effort, the TRTAC developed a Habitat Restoration Plan for the Lower Tuolumne River Corridor (McBain and Trush 2000) (Restoration Plan) that integrates Chinook salmon biology, fluvial geomorphic processes, and mechanical channel and floodplain reconstruction as a strategy for ecosystem recovery and Chinook salmon restoration. Several large-scale channel reconstruction projects are identified in the Restoration Plan. Several of these projects have been implemented; others are underway.

The Lower Tuolumne River is also a central focus in the broader restoration efforts underway in the Central Valley of California. From top (La Grange Dam) to bottom (San Joaquin River confluence), there are approximately 17 different restoration projects in various stages of planning and implementation, including several multi-million dollar channel reconstruction projects funded by the California Bay-Delta Authority (CBDA) (formerly CALFED) and the USFWS Anadromous Fish Restoration Program (AFRP). Two main factors, the success of the TRTAC in promoting river-wide restoration goals and implementing restoration projects and the tremendous opportunity for significant improvements in the river, have prompted the CBDA to designate the Tuolumne River as one of three Demonstration Streams in the Central Valley and the only one in the San Joaquin basin (CBDA 2001). The CBDA and AFRP also selected the Tuolumne River and the TRTAC as the first stakeholder group to present their restoration planning and monitoring programs during the first Adaptive Management Forum held in June 2001.

These large-scale restoration efforts are in response to the severity of impacts that cumulatively have degraded the Tuolumne River ecosystem during the past 150 years. Beginning with the Gold Rush, the Tuolumne River has been extensively modified by land use practices (e.g., agriculture, ranching, and urbanization) and resource extraction (e.g., water diversion, gold mining, and aggregate mining). Streamflow regulation began with construction of Wheaton Dam (1871) and La Grange Dam (1893), intensified in the 1920s with the construction of several large reservoirs in the basin, and culminated in 1971 with construction of the New Don Pedro Project (NDPP), which more than tripled reservoir storage capacity in the basin and stores 106% of the average annual basin outflow of 1.9 million acre-feet. During the early twentieth century, the Tuolumne River channel and floodplain were dredged for gold. The gold dredges excavated channel and floodplain alluvial deposits to the depth of bedrock (approximately 25 feet) and often realigned the river channel. After recovering the gold, the dredges deposited the remaining tailings back onto the floodplain, creating large, cobble-armored windrows that replaced the alluvial deposits and floodplain soils. By the end of the gold mining era, the majority of the floodplain adjacent to 14.5 miles of the river had been converted to dredger tailing deposits (Figure 2). In the 1960's much of the tailings were excavated to provide construction aggregate for New Don Pedro Dam. Much of this floodplain remains today as barren, unproductive surfaces, with exposed gravel/cobble and little or no soil layer (Figure 3).

Figure 2. The lower Tuolumne River's dominant spawning reach from 1950 showing an example of the extent of gold dredging in the gravel-bedded reaches.

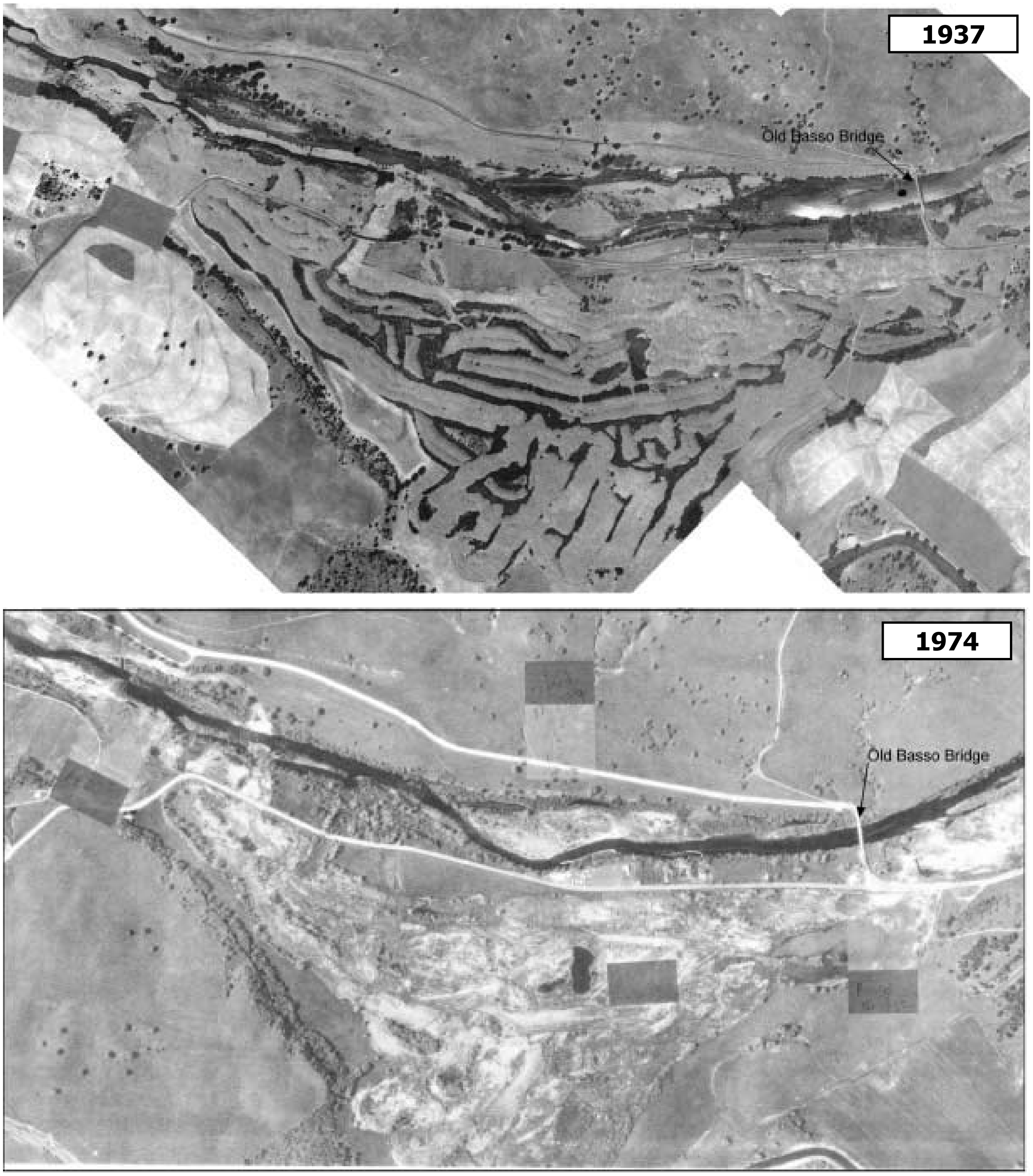


Figure 3. The former Delaney Ranch property now owned by Stanislaus County and the Zanker family. The land was first dredged for gold, then later the dredger tailings were removed and used to construct New Don Pedro Dam.

The Tuolumne River has also been extensively mined for aggregate[1]. Large-scale aggregate mining began in the 1940s and continues today. Historically, aggregate mines extracted sand and gravel directly from the active river channel, creating large, in-channel pits. More recent mining operations have excavated sand and gravel from floodplains and terraces directly adjacent to the river channel. These floodplain and terrace pits are often poorly separated from the river by narrow dikes (Figure 4), which often fail during even moderate flows allowing these large pits to connect to the river channel. The January 1997 flood, which peaked at nearly 60,000 cfs in Modesto, caused extensive damage to gravel mine dikes along the river, breaching or overtopping nearly every dike along the 6-mile-long mining reach.

Additional degradation has resulted from the lack of sediment recruitment from the upper Tuolumne River watershed that historically maintained sediment supply in the gravel-bedded zone (DWR 1994). More than a century of reduced coarse sediment supply has caused channel downcutting and widening, armored the channel bed, impaired geomorphic processes, and slowly diminished the available Chinook salmon and *O. mykiss* spawning habitat in the Tuolumne River.

Figure 4. The Tuolumne River (in the foreground of photo) in the Gravel Mining Reach showing commercial aggregate mining operations near Waterford, which create huge floodplain pits adjacent to the low-water channel.

1.2 Need for a Sediment Management Plan

The Tuolumne River has the largest naturally reproducing population of fall-run Chinook salmon in the San Joaquin Valley, despite extremely low escapements in the early 1990s that resulted from the prolonged drought of 1987-1992, and also supports *O. mykiss*. Many factors govern the productivity and capacity of the Tuolumne River to produce salmonids, and factors vary from year-to-year depending on the water yield, escapement, and other variables. Past studies of Chinook salmon population dynamics in the Tuolumne River concluded that poor spawning substrate quality and redd superimposition in heavily used spawning areas were primary factors limiting Chinook salmon production in this river. *O. mykiss* population dynamics have not been studied in the Tuolumne River, but reproduction for this species could be expected to be affected by similar factors as Chinook salmon. Coarse sediment augmentation is expected to provide immediate and long-term increases in

[1] In this report 'aggregate' refers to sand, gravel, and crushed stone mined commercially for construction material such as concrete and road base. 'Sediment' refers to alluvium transported and deposited by the river and includes silt, sand, gravel, and cobble-sized particles. 'Coarse sediment' refers to the gravel and cobble sediment components and ranges in size between approximately ¼ inch and 6 inches (Table 1). The term 'spawning gravel' is often used to describe gravel and cobble mixtures ranging in size from approximately ¼ inch to 5 inches, the range suitable for Chinook salmon and steelhead spawning. Also, the conversion factor of 1 cubic yard = 1.6 tons is used in this report.

Table 1. Coarse sediment size gradation chart showing particle size class descriptions and sizes. Particle sizes less than 2 mm are classified as sand (0.063–2 mm), silt (0.0093–0.063 mm), and clay (<0.0039 mm).

Particle size class		***Particle size (mm)***	***Particle size (in)***
	---------------------	4,096	161.2
	Very large	2,896	114
	---------------------	2,048	80.6
	Large	1,448	57
Boulder	---------------------	1,024	40.3
	Medium	724	28.5
	---------------------	512	20.1
	Small	362	14.2
---------------------	---------------------	256	10.1
	Large	181	7.1
Cobble	---------------------	128	5
	Small	90.5	3.6
---------------------	---------------------	64	2.5
	Very coarse	45.3	1.8
	---------------------	32	1.2
	Coarse	22.6	0.9
	---------------------	16	0.6
Gravel	Medium	11.3	0.4
	---------------------	8	0.3
	Fine	5.66	0.2
	---------------------	4	0.16
	Very fine	2.83	0.11
---------------------	---------------------	2	0.08

the area and quality of available spawning habitat for both species, thus increasing fry production and, potentially, recruitment to these salmonid populations. Augmentation is also expected to improve fry and juvenile rearing habitat, sediment routing, channel morphology, and geomorphic processes in the river.

Another fundamental purpose for coarse sediment augmentation is to provide the river with a sediment supply that will improve the geomorphic function of the channel. The strategy proposed in the Restoration Plan is to restore channel morphology and sediment supply conditions as a means to improve salmonid habitat conditions. Currently the sediment-depleted condition of the channel, sediment transport discontinuity, and the coarsened and embedded substrates collectively constrain channel dynamics. Coarse sediment augmentation will improve this condition. According to Stanford (et. al 1996) the goal of restoration should be to minimize human-mediated constraints, thereby allowing natural re-expression of the productive capacity of the river. Constraints imposed by lack of sediment supply cannot generally be mitigated, but the constraint can be removed by sediment augmentation.

The Restoration Plan developed restoration goals and strategies for each of the seven reaches of the Tuolumne River. These goals are broad and comprehensive and do not specify quantitative targets. Below we present the goals as developed in the Restoration Plan that are relevant to coarse sediment and spawning gravel management. In Section 7.3 we provide a list of quantitative objectives that will allow managers (the TRTAC) to monitor progress toward attaining these goals. Specific goals for coarse sediment and spawning gravel management identified in the Restoration Plan are:

- Increase the volume of coarse sediment storage and spawning gravel supply throughout the gravel-bedded zone to achieve an equilibrium between sediment input and transport volumes;
- Manage flood control releases to promote surface particle mobility, sediment transport, floodplain inundation, and other channel processes;
- Reduce fine sediment input into the river and fine sediment storage in coarse sediments (especially in spawning gravels);
- Restore riffles to increase salmon spawning and rearing habitats;
- Re-grade floodplains to reduce salmon stranding, increase the frequency of inundation, and promote riparian regeneration, [specifically targeting areas where sediment supplies could be attained];
- Secure coarse sediment supplies (remnant dredger tailings or other sources) for channel and floodplain restoration projects;

This history of extensive gravel/cobble manipulation by gold dredging and aggregate mining combined with the need to fill damaged sections of river channel and re-supply spawning gravels has created a large demand for coarse sediment for use in river and floodplain restoration projects. The Tuolumne River is in immediate need of large volumes of coarse sediment to restore and maintain salmonid spawning habitat and improve geomorphic processes. This Plan recommends large-scale coarse sediment "transfusion" to immediately provide needed sediment in the river combined with smaller-scale, longer-term coarse sediment maintenance to provide coarse sediment supply over future decades. Large volumes of sediment are also needed to implement channel and floodplain reconstruction projects in the Mining Reach, the Special-Run-Pools, and the Dredger Reach (McBain and Trush 2000).

Restoration projects that consume large volumes of coarse sediment must compete for the limited commercial aggregate reserves that have been permitted and developed to supply Stanislaus County's growth and development. This utilization of commercial aggregate for restoration and the competition for limited aggregate supplies jeopardizes the availability of aggregate for commercial development projects. This conflict was expressed in comments provided to the CEQA/NEPA environmental document for the Gravel Mining Reach Restoration Project by the Central Valley Rock, Sand & Gravel Association (CVRS&GA), which stated that "Since the Tuolumne River is a major aggregate resource area serving Stanislaus County, the proposed restoration project will have an impact on the continued availability of these resources." The CVRS&GA also noted that, based on the most current information available (in 1997), the permitted aggregate reserves in Stanislaus County would have been depleted by 2002. In other words, the demand for coarse sediment for restoration has increased consumption of the finite amount of commercial aggregate reserves and could accelerate depletion of those reserves.

To avoid conflicts with commercial aggregate markets, this Plan recommends obtaining permits for and purchasing a coarse sediment supply to be set aside for restoration projects. This supply should be sufficiently large to preclude any future demand for the region's commercial reserves, in close proximity to the upper river where restoration is focused, and commercially less desirable than other regionally available aggregate sources. This strategy of securing a long-term sediment source for restoration projects avoids the need to obtain coarse sediment from the commercial market and has been implemented on the Merced River (Merced River Ranch) and Clear Creek (Reading Bar and Former Shooting Gallery).

1.3 Purpose of the Report

The purpose of this report is to present a Coarse Sediment Management Plan to:

- restore coarse sediment supply and Chinook salmon and *O. mykiss* spawning gravels to the gravel-bedded reaches below La Grange Dam in a manner that protects existing habitat values for both salmon and *O. mykiss*;
- introduce coarse sediment to create immediately usable spawning habitat for both Chinook salmon and *O. mykiss* to supplement existing degraded habitat and/or create new habitat where none currently exists;
- prioritize potential coarse sediment supplies for sediment augmentation, as well as channel/floodplain reconstruction projects, to minimize additional demands on commercial aggregate supplies;
- identify alternative strategies for the environmental compliance process for coarse sediment management and other large-scale restoration projects;
- establish monitoring and adaptive management guidelines for evaluating the long-term coarse sediment management needs and the success of this program in restoring coarse sediment supply equilibrium, geomorphic processes, spawning gravel availability, and spawning habitat quality.

This report is divided into nine major sections. Sections 2 and 3 describe the conceptual model underlying this Plan and provide relevant information on salmonid populations in the lower Tuolumne River and salmonid habitat needs. Section 4 describes analyses and field investigations conducted as part of the Plan. Sections 5 and 6 describe recommended sediment augmentation actions and sediment source development. Section 7 provides recommendations for adaptive management and monitoring. Section 8 addresses regulatory compliance.

2 CONCEPTUAL MODEL: FLUVIAL PROCESSES, SEDIMENT SUPPLY AND TRANSPORT, SALMONID HABITAT

In this section we present a conceptual model of river ecosystem processes that influence sediment supply and transport and describe how river channel and floodplain morphology provides suitable conditions for riparian vegetation as well as salmonid habitat. Within the context of this conceptual model, we then describe historical and contemporary sediment supply conditions. We then present results of field investigations that evaluated how regulated conditions have depleted coarse sediment storage and spawning gravels that are critical to Chinook salmon and *O. mykiss*. The Restoration Plan (McBain and Trush 2000) provides a broader description of historical and current conditions.

2.1 Overview

An alluvial river ecosystem is created and maintained by geomorphic and hydrologic processes that result from energy and material interactions between flowing water and sediment supply, and from secondary influences of riparian vegetation (Trush et al. 2000). Water, sediment, geology, riparian vegetation, and human influences interact to define the river channel form (morphology). The channel morphology, in turn, provides aquatic and terrestrial habitat within the river corridor, and thus influences the abundance and distribution of riverine biota. The generalized hierarchical model of alluvial river ecosystems is depicted in Figure 5.

The primary WATERSHED INPUTS are water and sediment, with some influence by large wood (depending on the river), energy, nutrients, geology, and chemical pollutants. Changes to the input variables in this conceptual system usually cascade down to plant and animal communities, but this cascading effect is often not adequately considered before a change is imposed on the system. The primary natural components of the FLUVIAL PROCESSES tier are sediment transport and deposition, channel migration, channel avulsion, floodplain construction and inundation, and streamflow–groundwater exchange. Sediment transport processes create the geomorphic features of the channel, such as alternate bar sequences and floodplain surfaces. In turn, these channel and floodplain features provide the physical location and suitable conditions that define habitat for native species. Channel morphology is thus a critical linkage between fluvial processes and the native biota that use the river corridor. The Tuolumne River, as many rivers in the Central Valley, exhibits a gradient of habitat types from headwaters to confluence. Salmonids, their habitats, and other aquatic flora and fauna are distributed in predictable ways along that gradient, according to their specific life history requirements.

2.2 Sediment Supply and Transport

Sediment is supplied to rivers by erosional processes in headwater streams and tributaries and from the river bed and banks. Sediment is a general term that describes the solid rock and soil material that passes through the system. The term bedload applies to the sediment size fraction that moves on or near the bed, in contrast to the suspended load, which is transported primarily in the water column (Figure 6). Channel bed "scour" and "fill" describe bed erosion and redeposition during relatively short periods of time. The channel bed tends to scour during high flows due to the increase in velocity and shear stress (force per unit area) on the bed and local sediment imbalances. Conversely, as the shear stress decreases with the fall in stage, sediment arriving from upstream tends to deposit on the bed, and the bed "fills" when there is adequate sediment supply. Scour and fill are beneficial processes that form and maintain channel morphology, prevent riparian encroachment into the active channel, and maintain aquatic habitat, including clean spawning gravels for salmonids. In contrast, channel aggradation and degradation describe processes that occur over a longer time period, or when an imbalance occurs in sediment supply and transport capacity (Leopold et al. 1964).

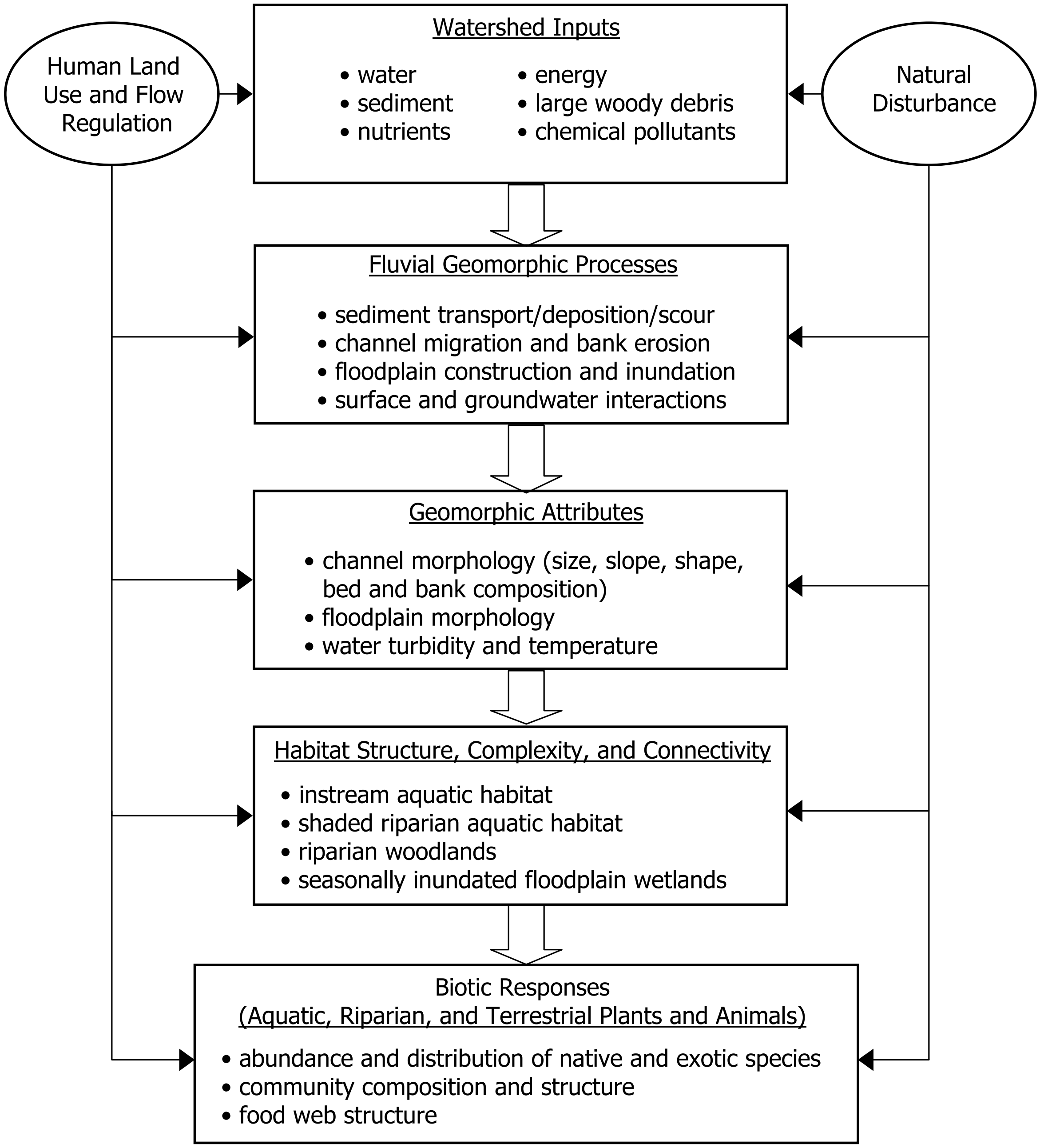


Figure 5. A simplified conceptual model of the physical and ecological linkages in alluvial river–floodplain systems. SOURCE: Stillwater Sciences.

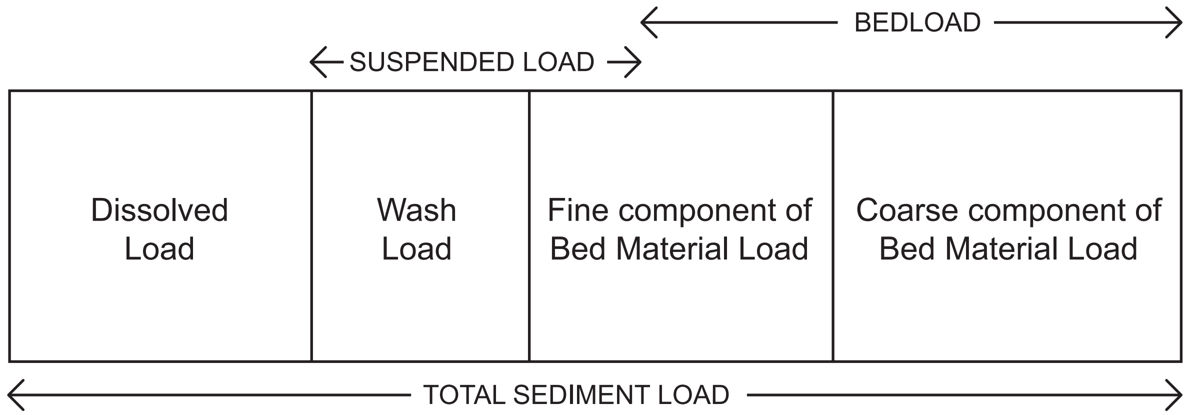


Figure 6. Delineation of total sediment load generated from a given watershed. The coarse component of bed material load is typically beneficial to salmon (e.g., spawning gravel, point bars), while the fine component of bed material load is typically harmful to salmon (e.g., clogging of spawning gravels, embeddedness). The proportions of the total sediment load in each box are unique to each watershed.

Aggradation and degradation frequently have detrimental impacts on the river channel and ecosystem. For example, many regulated rivers receive elevated rates of fine sediment (silt and sand) to the channel, and combined with a reduced magnitude and frequency of floods, fine sediments accumulate in the channel bed, filling interstitial spaces among larger gravel and cobble particles. Increased substrate embeddedness renders the channel bed more resistant to mobilization, reduces invertebrate production, and reduces the quality of salmonid spawning gravels.

Many alluvial channels are maintained in a "dynamic quasi-equilibrium" by transporting sediment load downstream at a rate approximately equal to the sediment supply (Leopold et al. 1964; Schumm 1977). This process maintains the channel in a generally constant form (or "morphology") over time, despite the continual routing of material through the system that produces local variations in the channel bed topography. Sediment moving through the system is stored in depositional features such as gravel and cobble point bars, or on floodplains and terraces, and becomes mobilized and routed downstream during high flow events. During such high flows, particles from the surface of the channel bed are constantly being traded for new particles arriving from upstream. Therefore, the channel form remains relatively constant as sediment is routed through the system.

2.3 Channel Morphology

In many alluvial rivers, the relationship between the bankfull channel and floodplain is important to allow mobilization of the channel bed while maintaining the channel's morphology. Bedload transport initiates at discharges slightly less than bankfull discharge. With continuing increase in discharge, bedload transport increases rapidly. When the bankfull capacity is exceeded, flow spills onto the floodplain, shifting the zone of transport onto point bar surfaces. Although the highest discharges carry the most sediment during their passage, they are less frequent, such that over time, they do not accomplish as much work (sediment transport, bank erosion, fine sediment deposition, etc.) as the more frequent, smaller magnitude flood events (Wolman et al. 1960). Thus, the bankfull discharge transports a large portion of the total sediment load, and is important in scaling and maintaining the channel width, depth, velocity, meander wavelength, particle sizes, and other morphological features.

Alternating bars are considered basic units of alluvial rivers (Dietrich 1987). This conceptual framework is useful in describing linkages between alluvial river form and aquatic habitat (Trush et al. 2000). Each alternate bar is composed of an aggradational lobe (lateral bar) and scour hole (pool) connected by a riffle (Figure 7). A variable flow regime causes spatial and temporal differences in sediment transport, scour, and deposition to create morphologically and hydraulically complex alternate bars, which in turn provide:

- adult salmonid holding habitat in pools;
- preferred hydraulic conditions and substrates for salmonid spawning in riffles and pool tails;
- high quality salmonid egg incubation environment in water-permeable, frequently mobilized spawning gravels;
- winter and spring salmonid rearing habitat in cobble substrates along slack-water bar surfaces and in shallow backwater zones behind point bars;
- salmonid fry and juvenile velocity refugia and ephemeral rearing habitat on inundated bar and floodplain surfaces during high flows;
- abundant primary and secondary (food) production areas on the surface of gravels and cobbles, on woody debris, and on floodplains (terrestrial invertebrates); and
- large organic debris and nutrient input (logs, root-wads, leaf litter, and salmon carcasses) that provide structural diversity as well as a primary source of nutrients for lower trophic levels.

A dynamic alternating bar morphology is only one indicator of a properly functioning alluvial channel. Floodplains, terrace complexes, and side channel networks are also key morphological indicators. These features may not be the direct consequence of alternate bar formation, but all are interdependent. As the channel migrates (over a time span of years to decades), large wood is contributed into the channel, cobbles and gravels are deposited on the inside of the bend in the gravel bedded reaches, sand bars are deposited on the inside bend in the sand-bedded reaches, and fine sediment is deposited on developing floodplains at the backside of alternate bars (Figure 8). Riparian vegetation initiates on these new floodplain surfaces, and as the vegetation matures and the channel eventually migrates again, this mature riparian vegetation can again be eroded into the river.

During low flows, the streamflow meanders around the alternating point bars, but during high flows the bars become submerged and the flow pattern straightens. During these periods of high energy, bedload is transported primarily across the face of these alternating point bars rather than along the thalweg (the deepest portion of channel) (Figures 7 and 8). *In unregulated alluvial rivers, alternate bar surfaces are frequently mobilized, but channel morphology is retained between floods. This process results in the channel form remaining relatively constant as sediment routes through the system.*

This last concept is at the core of the INPUTS ➔ FLUVIAL PROCESSES ➔ CHANNEL MORPHOLOGY➔ HABITAT concept of a healthy alluvial river (Figure 5). The topographic diversity provided by an alternate bar sequence is extremely important to aquatic organisms, particularly as habitat for anadromous salmonids. For example, at typical baseflows, an alternate bar sequence provides adult holding areas, preferred spawning substrates, early-emergence slack water, and winter/summer juvenile rearing habitats (Figures 7). In the initial stages of flow increases (above baseflows), the different micro-habitats remain available but in differing proportions and locations. Suitable spawning habitat in pool tails shifts downstream deeper into the riffle and laterally up the bar face as flow stage increases. Similarly, juvenile rearing habitat along the shallow margins of point bars also shifts laterally onto the bar surface, then onto the floodplain. The floodplain thus provides refugia (and high quality food resources) for juvenile salmonids during high flow events.

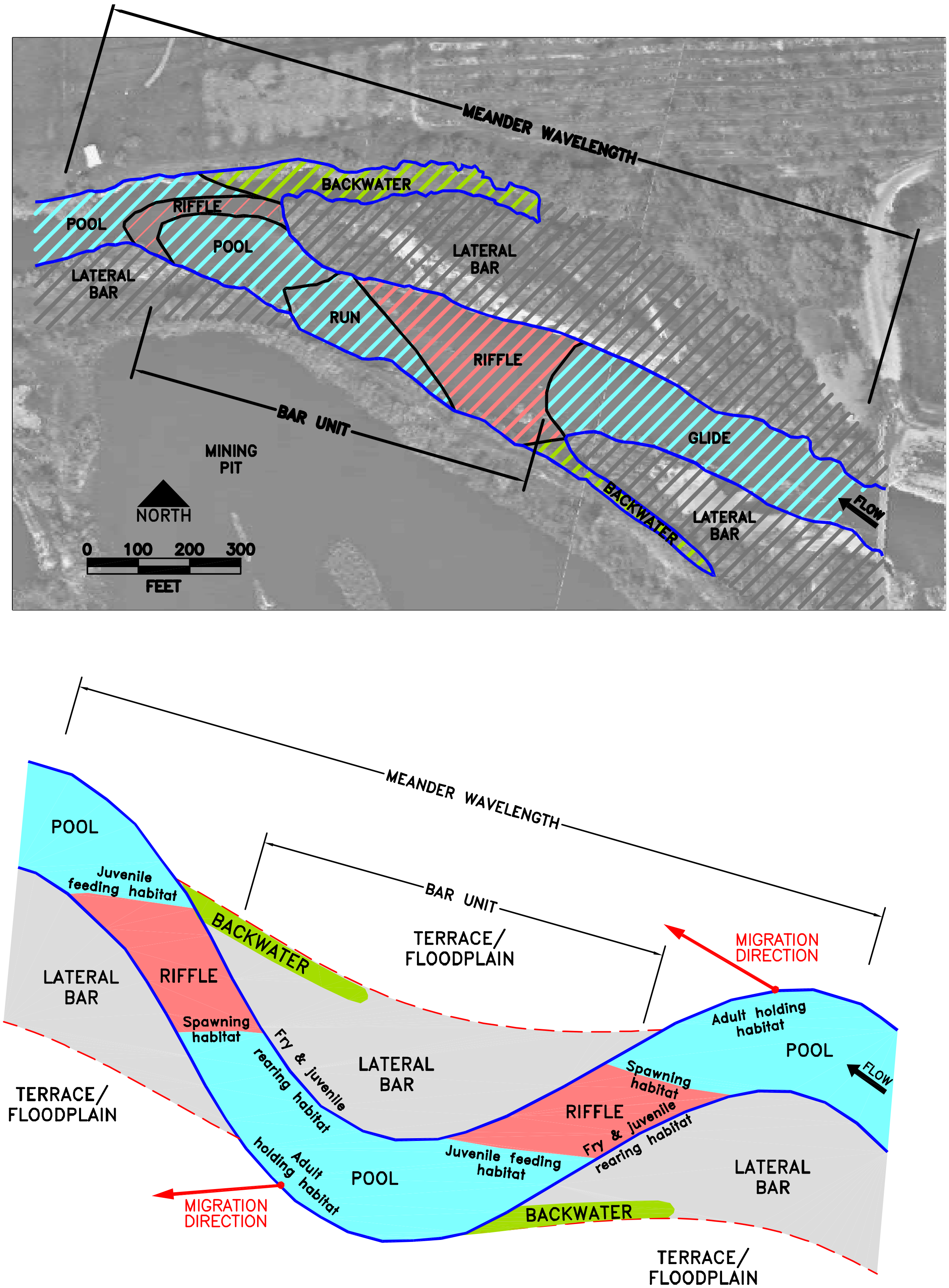
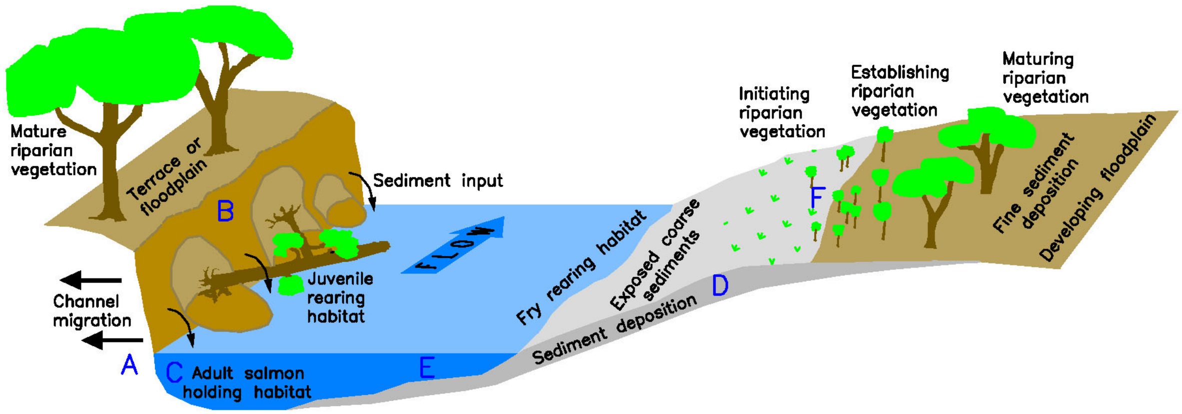


Figure 7. Idealized alternate bar sequence showing location of habitat features used by chinook salmon. The aerial photograph shows Riffles 33A and B in the 7/11 Mining Reach (RM 31.8).



An example of the dynamics of natural rivers is depicted above. (A) A channel with adequate space to migrate (Attribute 6) erodes the channel bank on the outside of the meander bend during high flows (Attribute 2), (B) encouraging aged riparian trees to topple into the channel (Attribute 9). (C) A deep pool also forms here, which provides structural complexity (Attribute 1) for good fish habitat. As bank erosion continues, the pool "migrates" downstream (Attribute 6), but high quality habitat is maintained. (D) On the opposite bank, high flows (Attribute 2) scour and redeposit coarse sediments (Attributes 4 and 5), forming a shallow bar on the inside of the meander bend (Attribute 1), and providing clean spawning gravels. (E) This area, in turn, provides ideal slow-water rearing conditions for juvenile chinook salmon, as well as habitat for aquatic insects (fish food), amphibians and reptiles. (F) Progressively higher up the gravel bar surface, a dynamic interplay occurs between receding water levels during the spring snowmelt (Attribute 2), and the presence of riparian tree seeds (Attribute 7). These woody riparian trees are sporadically scoured out (Attribute 8), and those established high enough on the bank are toppled into the channel as the channel migrates back across the valley (A).

Figure 8. Conceptualized channel cross section illustrating the importance of active channel processes and a variable flow regime in forming complex habitat and areas for riparian vegetation to establish.

2.4 Channel Migration and Avulsion

The channel bed and banks within the bankfull channel are dynamic features, subject to frequent physical disturbance. On a longer temporal scale, the river planform is also dynamic, controlled by similar processes of scour and fill, bank erosion, and deposition. Channel migration and channel avulsion describe processes that change the planform location of a river channel. In general, channels formed in alluvium move laterally (migrate) by eroding the banks on the outside of a meander bend and concurrently depositing material (transported from upstream) on the inside of the meander bend. This spatial imbalance between erosion and deposition is the driving force behind lateral channel migration.

Over time, the channel migrates across the entire valley floor, depositing fresh floodplains in its wake. Therefore, the flat floor of a valley is constructed by lateral migration and the deposition of sediment (Dunne and Leopold, 1978). As channels migrate laterally, they erode their own floodplain and terrace deposits formed in the past. In addition, migrating channels frequently erode into mature vegetation, toppling trees and dense shrubby vegetation into the channel.

Two forms of channel avulsion, or catastrophic relocation of the channel planform, are common to alluvial channels. In the first, lateral migration of the channel over time tends to increase the sinuosity and reduce the channel slope. As the channel becomes increasingly more sinuous, convergent points of meander bends come increasingly close together to a point where the meander bend pinches off, usually during a high flow event. The meander cut-off forms oxbow lakes and sloughs, which provide rich and productive habitat for establishment of riparian vegetation, and the channel migration process begins again. This process is common to the lower gradient sand-bedded reaches of the Tuolumne River. The second type of avulsion typically occurs in steeper semi-braided streams, and causes a rapid relocation of the channel during a very large flood (e.g., 10 to 50 year flood). This process was likely historically common to the higher gradient gravel-bedded reaches of the Tuolumne River.

2.5 Floodplain Processes

Adjacent to the active channel and frequently covered in thick patches of riparian vegetation, floodplains are often viewed as a morphological feature distinct from the bankfull channel. Floodplains, however, are integral parts of a functioning river channel (Leopold et al. 1964). Not only do fluvial processes form floodplains, but floodplains also influence geomorphic processes in the adjacent river channel. By definition, the floodplain is the relatively flat area adjoining the river channel and *constructed by the river in the present climate and overflowed at times of high discharge* (Dunne and Leopold 1978). During floods, the floodplain provides a large storage reservoir that can dampen the downstream propagation of floodwaters. On the floodplain surface, vegetation slows water velocities, allowing fine sediment (silts and sand) to settle out and deposit. These deposits maintain the floodplain elevation and create rich, fertile soils characteristic of river valley floors. Floodplains often have variable topography, high flow scour channels, and large woody material.

The change in elevation of a river channel is the net effect of complex processes, but if the river channel incises into the valley floor over time, floodplains become inaccessible to contemporary flood stages and are abandoned. An abandoned floodplain is called a terrace (Dunne and Leopold 1978). Over geologic time scales, an alluvial river often adjusts its channel and floodplain morphology through channel migration and deposition of new floodplains, avulsion and scouring of new channels, erosion into old terrace deposits, and abandonment of old floodplains. These processes create a mosaic of landscape forms in a river valley.

The stored alluvial material composing floodplain and terrace deposits is the material generally targeted by commercial aggregate mining operations.

2.6 Fluvial Processes, Habitat, and Salmonid Abundance

Fluvial processes — described above as the processes of flowing water, sediment supply and transport, and the formation and maintenance of geomorphic features in the river channel —play a critical role in forming and maintaining aquatic habitats used by juvenile and adult salmonids. Salmonids have adapted over millennia to the physical disturbances caused by high flows and to morphologic and habitat characteristics provided by the natural flow and sediment regimes, and are thus vulnerable to changes to these conditions. Stanford et al. (1996) describe this as the "propensity for riverine biodiversity and bioproduction to be largely controlled by habitat maintenance processes, such as cut and fill alluviation mediated by catchment water yield."

Life history links salmonids to their habitat. A salmonid life history *pathway* can be viewed as the selection of a sequence of habitats with favorable spatial-temporal distributions (i.e., habitats available to the organism at the appropriate time and place) (Thompson 1959). Salmonid survival along a particular life history pathway is determined by the quantity and quality of those habitats. Mobrand et al. (1997) suggest a useful way to link habitat quantity and quality to salmon population dynamics, using the concepts of *productivity* and *capacity*. They define productivity as the component of survival that operates independently of population density and is primarily determined by environmental quality. For example, spawning gravel quality incorporates the coarse particle size distribution, the percentage of fine sediment in the spawning gravels, the degree of embeddedness, and the permeability of the gravels. These variables collectively determine the relative survival-to-emergence of incubating salmonid eggs. The better the gravel quality, the higher the productivity of that habitat component. Capacity refers to the amount of space available, or the quantity of preferred habitat. Using the above example of spawning gravel, if gravel quality regulates productivity, then gravel abundance (quantity) regulates capacity. Twenty miles of gravel-bedded river with associated alluvial features and spawning gravels has a higher capacity to produce salmon than do ten miles of river, given that all other conditions are equal. This fact is independent of the productivity of the gravels (assuming productivity is not zero).

These three components - life history, productivity, and capacity - are the cornerstones to understanding salmonid populations and an important linkage to their environment. They measure ecosystem performance and suggest that a useful approach to managing salmonid populations is to consider each life history pathway and associated habitats as the primary management unit(s). Thus, to increase salmonid production from the river (not the same as productivity), we can implement activities to increase habitat productivity and capacity. This strategy encourages a broader perspective on restoration and management, incorporating the important material supplies and the processes that shape them into habitat (INPUTS ➔ PROCESS ➔ FORM) and helps avoid focusing on only a single limiting factor or other variables. It is important to note that anadromous salmonids are also affected by environmental conditions, harvest, and other factors beyond their natal streams. This conceptual model focuses only on in-river factors potentially affecting Tuolumne River salmonid populations and does not consider factors in the San Joaquin River, Sacramento-San Joaquin Delta and estuary, or Pacific Ocean.

3 ANADROMOUS SALMONID POPULATIONS IN THE LOWER TUOLUMNE RIVER

Prior to construction of La Grange Dam, the Tuolumne River supported populations of spring-run Chinook salmon, fall-run Chinook salmon, and probably steelhead. Spring-run Chinook salmon were extirpated from this watershed when dam construction eliminated access to upstream habitats (Yoshiyama et al. 1998). The number and distribution of *O. mykiss* in the watershed is not currently known, but *O. mykiss* are known to occur in the river both upstream and downstream of the dams. Fall-run Chinook salmon occur downstream of La Grange Dam. The abundance, distribution, life history, and spawning habitat needs for fall-run Chinook salmon and *O. mykiss* are discussed in Sections 3.1 and 3.2 below.

3.1 Chinook Salmon

3.1.1 Population Abundance

In recent decades, the Tuolumne River has supported the largest population of fall-run Chinook salmon in the San Joaquin Basin. Estimates of adult escapement (returning spawners) to the Tuolumne River and San Joaquin basin are available since 1940. Since completion of the New Don Pedro Dam in 1971 through 2003, salmon escapement ranged from a low of less than 100 adults (1963, 1990, 1991) to a high of 40,300 adults (1985) (Figure 9). Major population declines have been associated with the droughts of 1959-1961, 1976-1977, and 1987-1992. In 2003, estimated adult escapement in the Tuolumne River was 2,854 (CDFG preliminary data), the lowest since 1995 and unusually low compared to the Merced and Stanislaus rivers. The AFRP has established escapement targets for anadromous fish in all rivers of the Central Valley. The AFRP Chinook salmon escapement target for the Tuolumne River is 38,000 returning adults (USFWS 1997).

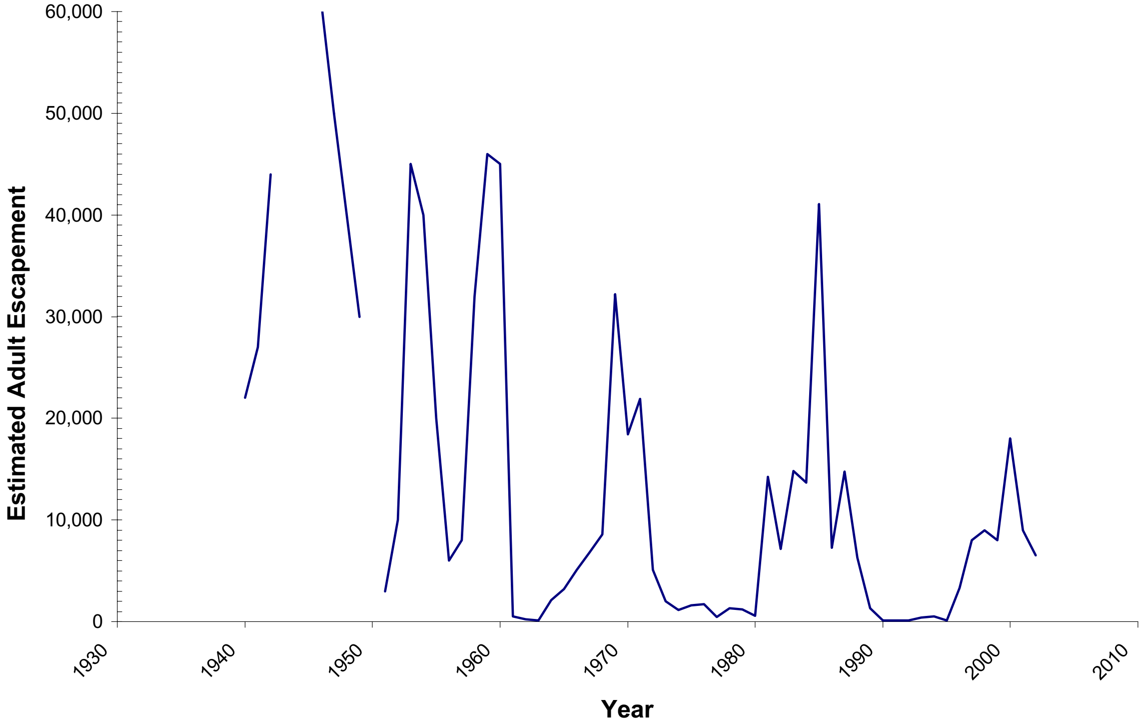


Figure 9. Adult spawning escapement estimates for the fall-run Chinook salmon returning to the lower Tuolumne River.

Adult Chinook salmon arrive to the Tuolumne River to spawn from September through December, with arrivals typically peaking in November. The age of return for adult salmon generally ranges from 2 to 4 years and abundance varies by year-class depending on juvenile survival and ocean harvest. The percentage of females in the adult escapement ranges from 25 to 67 percent and is lowest in years dominated by 2-year-old adults. The period of fry emergence varies depending upon the timing of adult arrival and incubation temperature but typically extends from January through March. Young salmon leave the river as fry, subyearlings, or yearlings. Subyearlings emigrate in late spring.

3.1.2 Spawning Habitat Requirements

Chinook salmon typically spawn in the mainstem and lower reaches of large rivers or tributaries, although spawning has been observed over a broad range of stream sizes, from small tributaries 6–10 feet wide (Vronskiy 1972) to very large mainstem reaches (Healey 1991). Preferred spawning reaches are low gradient (< 3%) but higher gradient areas are occasionally used (Kostow 1995).

Spawning sites (redds) are typically located near pool tailouts, heads of riffles, the upstream side of gravel dunes, and below log jams (Healey 1991). It is believed that they select these sites because, for salmonids, they have relatively large eggs that require high concentrations of dissolved oxygen, and these sites promote the downwelling of oxygen-rich water into the gravel beds (Bjornn and Reiser 1991, Healey 1991, Mesick 2001). These areas also typically offer nearby cover in the form of deep water, large woody debris, or overhanging vegetation (Bjornn and Reiser 1991). It is possible that the lack of cover at the large artificial spawning beds created in the Central valley during the 1990s is the main reason that they were so poorly used by spawners (Mesick, pers. comm., 2004).

Chinook salmon spawn over a wide range of water depths, varying from 2 inches to 22 feet (Burner 1951, Vronskiy 1972, Chapman et al. 1986, Healey 1991). Because of their larger size, Chinook salmon can spawn in deeper water with higher velocities than other salmonids (Healey 1991). Typical spawning depths range from 12–22 inches (Healey 1991). Nine inches has been cited as the minimum preferred depth for spawning (Russell et al. 1983; Thompson 1972, as cited in Bjornn and Reiser 1991). Average water velocities in spawning areas range from 1 ft/s to over 3 ft/s, with an observed range of 0.3–6.2 ft/s (Healey 1991, Thompson 1972, as cited in Bjornn and Reiser 1991).

Considerable research indicates that Chinook salmon spawn in a wide range of sediment sizes in natural gravel beds (Healey 1991). Descriptions of suitable substrate sizes for Chinook salmon spawning found in the literature are summarized in Table 2. These data indicate that suitable spawning substrates range in size from 0.1 inches (3 mm) to 5.9 inches (150 mm), with wide variability in the D_{50} particle size (ranging from 0.8 inches [21 mm] to 2.8 inches [70 mm]).

Table 2. Suitable Substrates for Chinook salmon spawning.

Sediment Size	Comment	Source
0.5–4 in (13–102 mm), <25% fines less than 2 mm	"preferred"	Platts et al. 1979; Bell 1986, as cited in Bjornn and Reiser 1991
0.8-4.2 in (20-106 mm)	"optimal"	Raleigh et al. 1986
21% 0.1-0.5 in (3-12.5 mm) 41% 0.5-2.4 in (12.5-60 mm) 24% 2.4-3.9 in (60-100 mm) 14% 2.4-5.9 in (60-150 mm)	"suitable"	Chambers 1956
80% 0.5-4 in (13-51 mm) 20% 2-4.1 in (51-103 mm)	"optimal"	Bell 1973
84% 0.4-3 in (10-76 mm) 16% >3 in (76 mm)	South Fork Salmon River, Idaho	Platts et al. 1979
Mean D_{50}: 0.8 in (21 mm) Mean D_{50}: 0.4 in (11 mm) Mean D_{50}: 2.8 in (70 mm)	Compilation of data from the western United States, Siberia, and New Zealand	Kondolf and Wolman 1993

The availability of well oxygenated intragravel flow appears to be one of the most important requirements for successful salmonid spawning and incubation (Healy 1991). Chinook salmon have frequently been observed spawning in poor quality gravel with low permeability in Central Valley rivers, including the Merced, Tuolumne, and Stanislaus. During excavation of the redd, some portion of the fine sediment in the spawning gravel is removed and transported downstream to the tailspill, thus improving permeability and intragravel flow conditions in the redd to some degree (Kondolf et al. 1993, CMC 2002b). Nevertheless, spawning may not be successful in gravel beds with high concentrations of fine sediment because the degree of removal of fine sediment may be insufficient to adequately improve intragravel flow conditions and/or excavation of redds by later arriving females may disperse fines over pre-existing redds, thereby reducing permeability and entombing alevins (CMC 2002b).

In addition to the factors described above, there may be additional cues or habitat requirements for spawning salmonids that are poorly understood. Many factors could contribute to low utilization of created spawning areas, such as local hydraulics, substrate texture, available cover, or other more subtle features. Carl Mesick Consultants (2002a) suggests that poor use of some constructed spawning beds may be due to spawner avoidance of gravel imported from other nearby watersheds rather than from the river in which the project was constructed or the lack of cover provided at reconstructed sites. Mesick's suggestion, however, is based on limited data and has not been compared to projects in other watersheds throughout the Central Valley that have utilized non-local sediment sources. Additional analysis of constructed spawning sites and their utilization is needed to address these issues.

3.1.3 Spawning Distribution in the Tuolumne River

Yoshiyama et al. (1998) describe the historical distribution of salmonids within the Tuolumne River basin. Their research concluded that the historical spring-run Chinook salmon likely reached as far as Preston Falls, approximately 50 miles upstream of the present New Don Pedro Dam. La Grange Dam now blocks access to these upper reaches. Steve Walser, a local angling guide and co-founder of the California Rivers Restoration Fund, reports catching adult Chinook salmon in the Tuolumne River during summer months, which he believes could be spring-run. The potential occurrence of spring-run Chinook salmon in the Tuolumne River, however, has not been verified (S. Walser, pers. comm., 2004). The historical fall-run Chinook salmon distribution was likely similar to the present distribution, ranging from La Grange Dam downstream approximately 20 miles to Waterford (Yoshiyama et al. 1998), with additional limited spawning habitat downstream to Hughson at RM 23. The channel gradient remains relatively constant downstream to approximately RM 30 (below Hickman Bridge near Waterford), and historically would have been gravel-bedded with an alternate bar morphology and high quality spawning and rearing habitats throughout this reach.

While spawning may occur throughout the gravel-bedded zone of the river, almost all spawning occurs upstream of Hickman Bridge (at Waterford). Spawning is most heavily concentrated in the reach between La Grange Dam and Basso Bridge (the "Primary Spawning Reach") (Figure 10). Maximum redd count data compiled annually by CDFG were analyzed to assess the distribution of spawning within the gravel-bedded reaches. Maximum redd count is simply the highest number of redds counted within a single riffle during one of the 10-15 weekly CDFG redd surveys and thus represents the highest annual spawning density or maximum habitat utilization at that site. The 21-year mean and 5-year mean from 1997-2002 of the annual maximum redd count for each riffle was computed and ranked by riffle number (and river mile) then plotted to assess the distribution of spawning habitat use (Figure 10). This evaluation indicates that between 1981 and 2001 approximately 86% of all spawning occurred upstream of the Santa Fe Haul Bridge (RM 36.3) (Table 3), and almost half (46%) of all spawning activity occurred in the 4.2-mile reach upstream of Basso Bridge (RM 47.5). Data for the past 5 years show the relative proportion of spawning may have increased in the upper river, indicating that Chinook salmon may be relying on an increasingly smaller portion of the river to sustain the bulk of their reproductive activities.

The longitudinal distribution of salmon in selecting spawning sites is also poorly understood. As has been reported for the Tuolumne River (TID/MID 1992c), spawners typically bypass apparently suitable spawning sites during their upstream migration and concentrate spawning in upstream reaches. The cues and behavioral mechanisms used by the fish to select spawning sites are not well understood. This concentration of spawners in the upstream portion of the spawning reach may be related to water quality conditions (such as dissolved oxygen and water temperature), a behavioral trait of fall-run Chinook salmon, or other factors. Additional analysis of available data and/or further experimentation are required to better understand factors driving the uneven spawning distribution in the river and to identify management actions that could increase the utilization of downstream spawning sites.

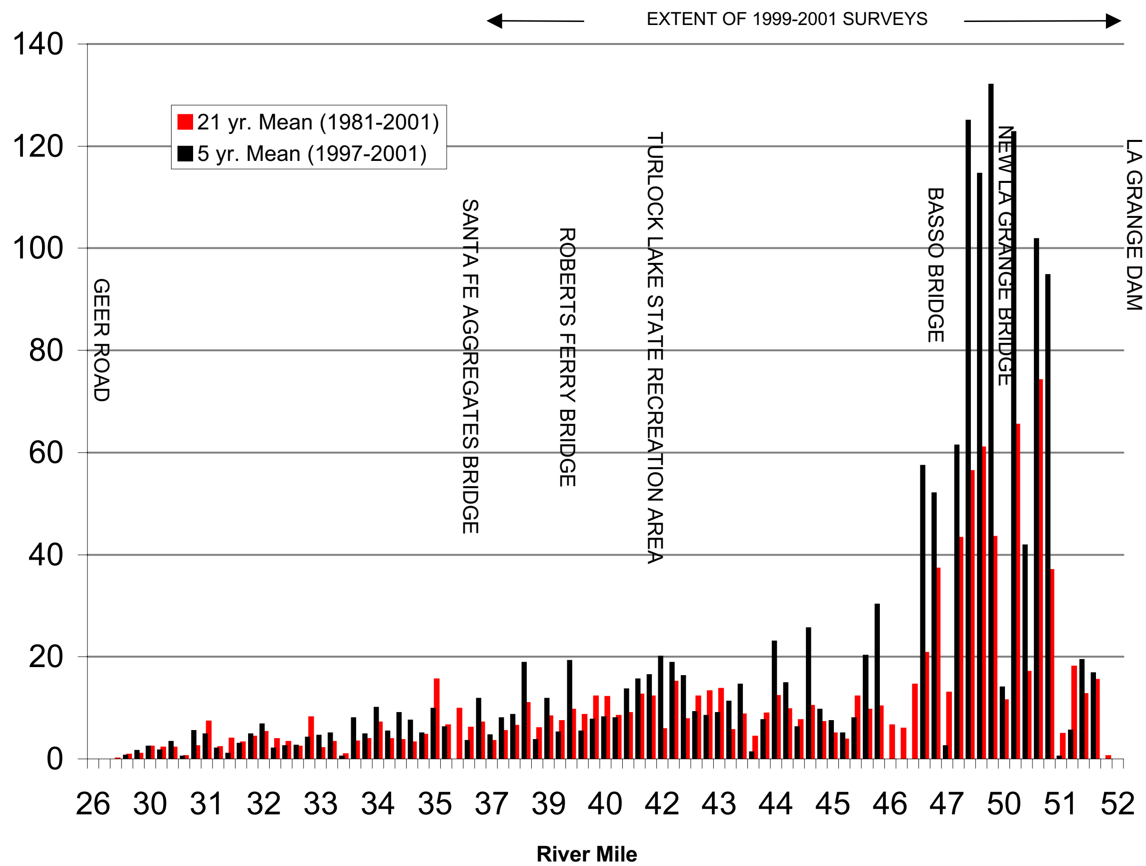


Figure 10. Distribution of fall-run Chinook spawning along the entire spawning reaches, as indicated by the CDFG annual "high redd count data", which is the annual maximum number of redds counted at each riffle during weekly carcass surveys.

Table 3 Comparison of the river-wide distribution of Chinook salmon spawners in the gravel-bedded reaches using "high redd count data" for the 21 year period of data collection and data from the five post-1997 flood spawning seasons. High redd count is the annual maximum number of redds observed at each riffle during weekly carcass and redd surveys. Data Source: CDFG La Grange, CA.

	1981-2001	**1997-2001**
Average number of redds observed in the spawning reaches (RM 29-52) during the fall-run Chinook spawning season	1,014	1,524
Percentage of the total high redd counts observed upstream of Santa Fe Aggregates bridge (RM 37-52)	86%	90%
Percentage of the total high redd counts observed upstream of Basso Bridge (RM 37-52)	46%	56%

3.2 Steelhead/Rainbow Trout

Historical and current *O. mykiss* population abundance in the Tuolumne River is not known. *O. mykiss* have been recorded as an incidental species during Chinook salmon monitoring in the lower Tuolumne River, but no efforts have been made thus far to quantify their abundance. The Districts began more intensive *O. mykiss* monitoring in 2004.

Steelhead is the term used for the anadromous life history form of rainbow trout, *O. mykiss*. *O. mykiss* exhibit highly variable life history patterns throughout their range, but are broadly categorized into winter- and summer-run reproductive ecotypes. McEwan and Jackson (1996) report that only winter-run steelhead stocks are currently present in Central Valley streams. Anglers, however, report catching what appear to be summer-run steelhead (large *O. mykiss* with a bright silvery body) in the Tuolumne, Merced, and Stanislaus rivers between April and July (S. Walser, pers. comm. 2004). Winter steelhead become sexually mature in the ocean, enter spawning streams in fall or winter, and spawn a few months later in winter or late spring (Meehan and Bjornn 1991, Behnke 1992). Adults may return to the ocean after spawning and return to freshwater to spawn in subsequent years. Juveniles remain in fresh water for 2–4 years before emigrating to the ocean. Juvenile emigration typically occurs from April through June, but have been captured in outmigrant traps on the Stanislaus River from January through June, implying that O. mykiss may emigrate from the San Joaquin River tributaries throughout the winter and spring. Emigration appears to be more closely associated with size than age, with 6–8 inches being the size of most downstream migrants. Downstream migration in unregulated streams has been correlated with spring snowmelt freshets (Reynolds et al. 1993). Because O. mykiss, unlike most fall-run Chinook salmon, rear in fresh water for a year or more, suitable summer flows and water temperatures are an important factor in ensuring their rearing success.

Habitat requirements for steelhead and Chinook salmon are similar, with the important exceptions that steelhead over-summer in fresh water (and thus are affected by summer flow and water temperature conditions) and steelhead prefer slightly finer spawning substrates than Chinook salmon. Water depths ranging from approximately 7 to 54 inches are reported as being used for spawning, with depths of approximately 14 inches being preferred (Moyle et al. 1989, Barnhart 1991). Velocities from 2.0 to 3.8 ft/s are typically preferred for redd locations (Moyle et al. 1989, Barnhart 1991). Smith (1973, as cited in Bjornn and Reiser 1991) suggests a gravel mixture ranging from 6-102 mm for steelhead spawning but does not specify the size proportions within this range. Kondolf and Wolman (1993) reported values for the D_{50} of spawning gravels for steelhead ranging from 10-46 mm and averaging 25 mm. Deep pools provide important resting and holding habitat during upstream migration (Puckett 1975, Roelofs 1983, as cited in Moyle et al. 1989).

The California Rivers Restoration Fund (CRRF) identified *O. mykiss* holding, foraging, and spawning habitat distribution in the Tuolumne River based on 10 years of hook-and-line and snorkel surveys (CRRF 2004). From these data and similar surveys on the Stanislaus and Merced rivers, the CRRF concluded that adult *O. mykiss* typically utilize short riffle-pool sequences where surface turbulence is present over the riffle and downstream pool habitat. Adults usually feed and hold downstream in pool habitat that is within 150 feet of the upstream riffle and spawn under surface turbulence in the riffle habitat. Juvenile *O. mykiss* typically rear in riffle and run habitats with surface turbulence. CRRF noted that preferred *O. mykiss* habitat typically was found at pool tails that were usually narrow or constricted, creating the surface turbulence. The riffles were also steep and quickly transitioned into pools that were at least four feet deep at low flows (100-300 cfs). Riffle substrates were typically coarse, with small patches suitable for *O. mykiss* spawning and juvenile rearing, but frequently were too steep or coarse for Chinook salmon spawning. The bed topography was complex at the best used sites, consisting of multiple rows of ridges formed by Chinook salmon tailspills. *O. mykiss* were also associated with overhead cover provided low, branching riparian vegetation near the bank.

4 INVESTIGATIONS AND ANALYSES CONDUCTED FOR THE COARSE SEDIMENT MANAGEMENT PLAN

4.1 Coarse Sediment Supply

4.1.1 Historical Coarse Sediment Supply

The historical source of coarse sediment to the Tuolumne River was primarily erosion and hillslope processes in the upper watershed in the Sierra Nevada Range. As with most rivers and streams of the Central Valley, historical information describing rates of sediment supply from the upper watershed and information describing past and present spawning habitat quantity and quality in the Tuolumne River is limited. Some information does exist, however. Brown and Thorp (1947) estimated the Tuolumne River basin-wide sediment yield by comparing the original capacity of the Old Don Pedro Reservoir surveyed 10 years prior to the dam's closure in 1923 with re-surveys conducted in 1946 (22.7 years later). They estimated 4,734 acre-feet of sediment had accumulated behind Don Pedro Dam, indicating a sediment yield of 303 tons/mi^2/yr.

$$(303 \text{ tons/mi}^2\text{/yr}) \times (996 \text{ mi}^2)^{2} = 301{,}800 \text{ tons/yr}$$

We assume this estimate includes gravel and cobble as well as fine sediment. Fine sediment is a much larger proportion of the total sediment yield (Jones et al. 1972). The coarse sediment component is generally estimated to be 10-15% of the total sediment budget (Reid and Dunne 1992). Based on these very general estimates and using 10% as an approximation of the coarse sediment fraction, we estimated the unimpaired coarse sediment supply as:

$$(301{,}800 \text{ tons/yr}) \times (10\%) = 30{,}000 \text{ tons/yr}$$

Applying the standard conversion factor of 1.6 tons/cu yd results in an estimated coarse sediment yield of 18,800 cu yds/yr:

$$(30{,}000 \text{ tons/yr}) \div (1.6 \text{ tons/cy}) = 18{,}800 \text{ cu yds/yr}$$

Using data from the La Grange Reservoir, Brown and Thorpe report a similar sedimentation rate (303 tons/mi^2/yr) but a slightly different average annual yield of 24,700 tons/yr (15,400 cu yds/yr) due to a different estimate of the sediment-yielding drainage area. Brown and Thorp's calculations of sediment yield are within the range of other long-term calculations of non-glacial erosion rates for large rivers in the Sierra Nevada (Kirchner et al. 2001, Riebe et al. 2001). The estimate of annual yield for the Tuolumne River based on the Old Don Pedro estimate, if extrapolated over the 109-year period of record since La Grange Dam was constructed in 1893, provides a very rough estimate of approximately 2 million cubic yards of coarse sediment trapped behind dams and therefore not delivered to the lower Tuolumne River.

For the Exchequer Reservoir on the Merced River, Brown and Thorpe estimated a sedimentation rate of 242 tons/mi^2/yr, which equates to approximately 24,700 tons/yr (15,400 cu yds/yr). The Merced River Corridor Restoration Plan estimated the unimpaired coarse sediment yield from the upper watershed to be approximately 11,000-21,000 tons/yr (Stillwater Sciences 2001b). These estimates provide a useful comparison because the two adjacent watersheds – the Merced and Tuolumne –are similar in geology, climate, vegetation, and land uses. Their sediment supply rates, therefore, should be similar.

[2] Brown and Thorpe define the drainage area as 996 square miles, which is the "effective" drainage area yielding sediment supply

4.1.2 Contemporary Coarse Sediment Supply

Since construction of large storage reservoirs on the Tuolumne River, the majority of sediment supply from the upper watershed has been completely lost. La Grange Dam was constructed in 1893 and likely trapped all sediment larger than 1-2 mm behind the dam. The original Don Pedro Dam was completed in 1923, providing 289,000 acre-feet of storage. This capacity was probably large enough to trap most of fine sediment load in addition to trapping all coarse sediment. New Don Pedro Dam, completed in 1971, has eliminated any sediment delivery – both coarse and fine - to the lower Tuolumne River. The primary exception to this was the January 1997 flood spill, which accessed the New Don Pedro Dam spillway for the first time in its history, releasing approximately 45,000 cfs down Twin Gulch. This event delivered an estimated 500,000 cu yds of topsoil mixed with crushed and scoured bedrock to La Grange Reservoir and over the dam into the lower Tuolumne River (McBain and Trush 2000). The Restoration Plan also identified several small tributaries downstream of La Grange Dam as sources of fine sediment and sand to the gravel-bedded zone of the lower Tuolumne River.

4.2 Channel Morphology

4.2.1 Baseline Channel Conditions

Existing channel morphology was documented using channel cross section surveys and longitudinal profiles. Forty-two cross sections were established in the gravel-bedded zone of the river (Table 4 and Figure 11). Each cross section is referenced in the Tuolumne River Geographic Information System (GIS) and named according to its longitudinal stationing in feet upstream of the San Joaquin River. For example, cross section XS 2847+00 is located approximately 284,700 feet upstream from the confluence with the San Joaquin River. The endpoints for each cross section were monumented with rebar pins, and GPS coordinates were recorded (where site conditions allowed) with an RTK GPS unit. Cross section plots are presented in Appendix A.

Table 4. Distribution of cross sections by river reach.

Reach Name	No. of Cross Sections Established
Primary Spawning Reach (Riffle A3/4 to Basso Bridge)	21
Turlock Lake State Recreation Area	4
7/11 Mining Reach	10
Ruddy Mining Reach	6

Several indicators, based on the contemporary channel morphology, suggest that the channel downstream of La Grange Dam is in severe sediment supply deficit and that this condition is affecting both the productivity and capacity of salmonid spawning habitat. First, channel cross section surveys indicate that the channel is overly wide in many reaches, lacks adequate bankfull channel confinement, and has not readjusted its cross sectional dimensions to the contemporary high flow regime. McBain and Trush established 21 cross sections in the gravel-bedded reach of the river between La Grange Dam and Basso Bridge, four cross sections at Turlock Lake State Recreation Area (TLSRA), and 16 cross sections in the 7/11 and MJ Ruddy mining reaches. These cross sections show an overly wide and/or deepened channel in many locations, a condition which impairs sediment transport processes, encourages deposition and storage of fine sediment, and degrades salmonid spawning habitat.

Second, field surveys conducted by McBain and Trush have identified numerous sites where lateral bars, riffles, or other sediment storage features have been depleted of sediment. For example, at the upper end of the left bank gravel bar at Riffle A7, the cumulative effects of scour and lack of sediment replenishment have successively lowered the bar surface elevation, reduced channel confinement at the pool tail, exposed the underlying bedrock, scoured away riparian vegetation, and caused water to pond on the surface of the bar at low flows (Figure 12). Another example is a 300–foot length of the right bank between riffles 3A and 3B that was severely scoured and eroded by the January 1997 flood. The right bank migrated approximately 25 feet to the north, but the lack of sediment supply has prevented a new gravel bar from depositing along the adjacent left bank (Figure 13).

Third, long scour pools and in-channel mining pits known as "Special Run Pools" have been well documented in the Tuolumne River and cumulatively represent nearly five miles of river channel in the dominant spawning reaches upstream of Roberts Ferry Bridge. These sections of channel trap all sediment routed to them, provide little or no high quality salmonid habitat and provide suitable habitat for non-native piscivores that prey on juvenile salmonids.

Finally, a large number of riffles throughout the gravel-bedded zone have been progressively reduced in size or completely eliminated by a single or numerous large floods (Figure 14). Riffle area was mapped in 1988 and remapped in 1999-2001 (following the 1997 flood). During that period, riffle area in the study reach was reduced by 16% from 1.57 million ft^2 to 1.32 million ft^2. Reduction in riffle area is discussed in more detail in Section 4.4.

4.2.2 Reference Spawning Sites

Riffles 3B and 4A exhibit some of the best spawning conditions in the upper river. These riffles have well-formed lateral bars and cross section profiles that appear to have adjusted their dimensions to the post-NDPP flow regime. We surveyed two cross sections to model sediment augmentation designs and established bed mobility and scour experiments on the lateral bar margins.

In addition to cross section surveys, we surveyed several short longitudinal profile sections to document the range of channel bed and water surface slopes at spawning riffles. Riffle slope is an important criterion in the design of coarse sediment augmentation sites because it influences water depth and velocity and, therefore, habitat suitability for spawning salmonids. We plotted riffle slopes on common coordinates for comparison (Appendix A). Our riffle construction designs targeted riffle slopes in the range of 0.0010 to 0.0020.

We performed surface pebble counts (Wolman 1954, Leopold 1970) in several locations between New La Grange Bridge and Basso Bridge at locations with good spawning gravel (Table 5). Based on these pebble counts, Chinook salmon were observed spawning in substrates with a D_{50} ranging from 40-58 mm and a D_{84} ranging from 68-106 mm.

Table 5. Particle sizes from reference spawning riffles on the Tuolumne River.

Pebble Count Location	D_{50} (mm)	D_{84} (mm)	Type of Facies
Riffle 3B	52	83	Low water margin of lateral bar
Riffle 4A	40	70	Low water margin of lateral bar
Riffle 4B	45	68	Surface of shallowly inundated medial bar surrounded by numerous redds
Riffle 5A	58	106	Coarser facies representative of riffle and run thalweg

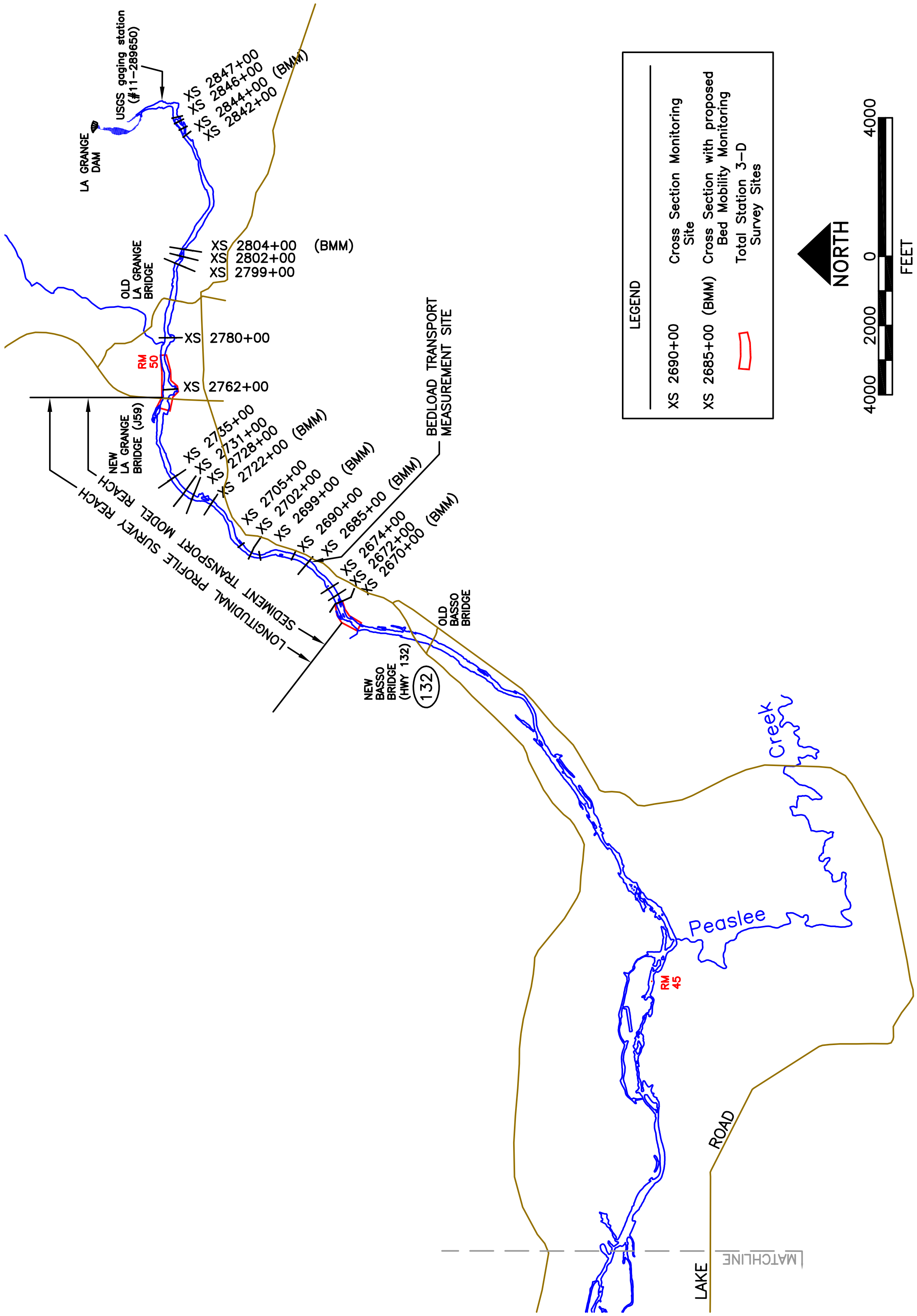


Figure 11. Location of established monitoring cross sections, long profile reaches, bedload transport measurement site, marked rock and scour core locations, and 3D survey sites. Cross section stationing refers to distance upstream of the San Joaquin River confluence. (BMM) indicates recommended 'bed mobility monitoring' sites.

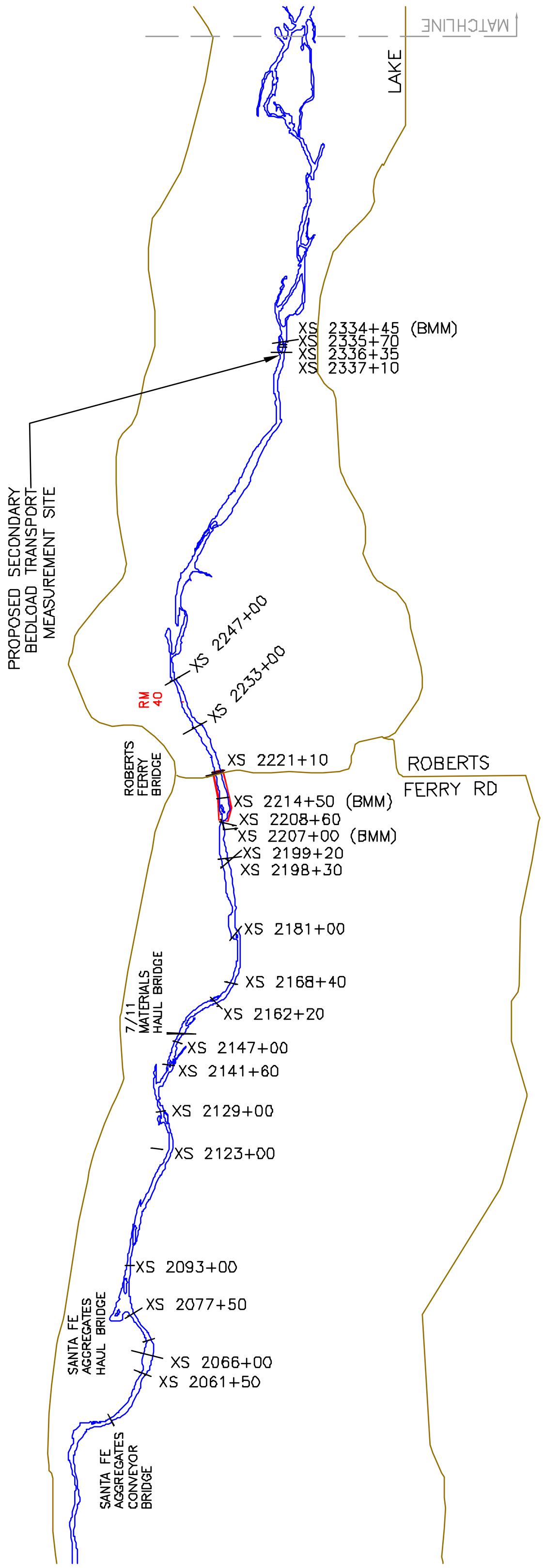


Figure 11. Continued.

Figure 12. Aerial photograph from 1999 of Riffle A7 (RM 50.7). Successive floods and the lack of coarse sediment supply have slowly depleted the volume of coarse sediment stored in lateral bars.

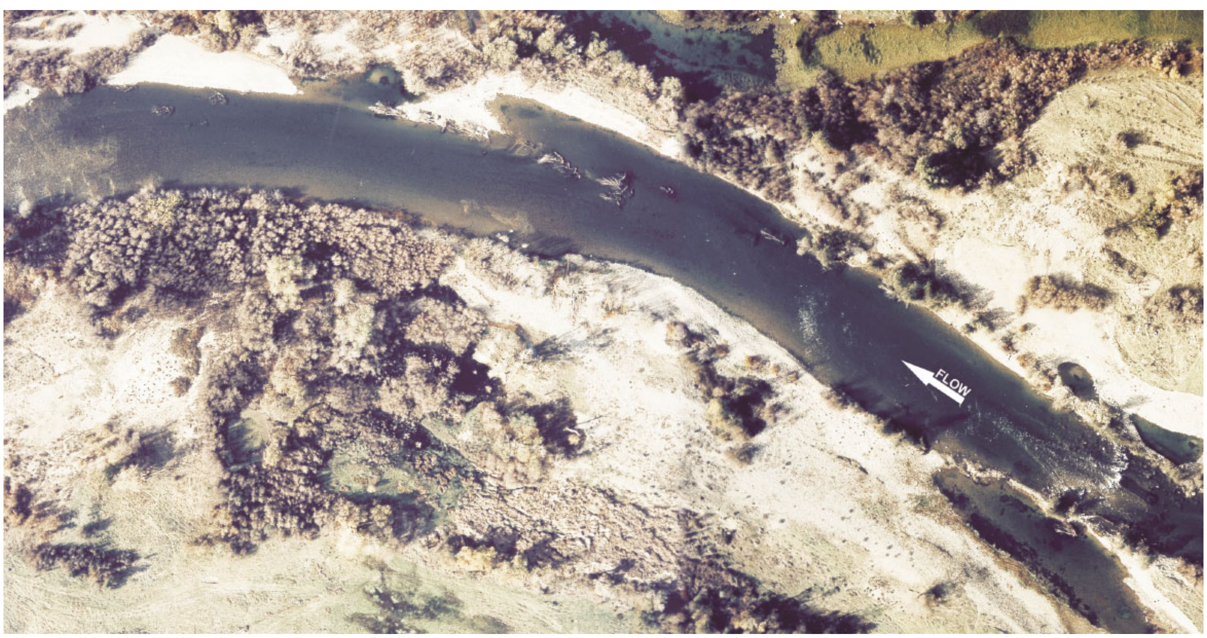


Figure 13. Aerial photograph from 1999 showing the right bank along the downstream end of Riffle 3A that was heavily eroded during the 1997 flood. The lack of sediment supply prevented material from redepositing here, and instead a long, wide pool has formed.

4.2.3 Conceptual Design Sites

For coarse sediment augmentation design purposes, we surveyed the channel and bank topography, and bathymetry at four sites in February 2002, using a combination of total station, Acoustic Doppler Profiler (ADP), and Real Time Kinematic (RTK) GPS unit. These sites included Riffle A3/4 (RM 51.6), Riffle 1B/C (RM 50.3), Riffle 3A (RM 49.6), and the Zanker site (RM 45.8). These surveys were used to produce digital terrain models (DTM) of existing topography for each site at one-foot contour intervals. The DTM was then used as the basis for developing the proposed design contours and estimating coarse sediment augmentation volumes for these sites. The DTMs provide detailed topographic information, useful for monitoring short-term trends in bed aggradation and degradation. Site topography is shown in the site design drawings in Appendix B.

4.3 Sediment Transport and Storage

4.3.1 Mobility Thresholds

As described in Section 2.6, salmonid habitat quantity and quality are controlled by fluvial processes, including bed mobility and scour. Tracer rocks were used to document channel bed surface mobility on alluvial features (e.g., point bars, medial bars, pool tails, etc.) during high flow events. Data from these experiments can be used to evaluate the differential mobility of these features, estimate the frequency of bed mobilization, determine flow magnitude that initiates bed mobility, determine at which flows full sediment mobility is achieved, and compare predicted mobility thresholds from sediment transport modeling to thresholds observed in the field. The goal of tracer rock experiments was to document bed surface mobility resulting from a broad range of high flow events so that the results bracket the range of peak flows that generates incipient mobility of each size class of tracer rock and type of alluvial feature. During the study period, however, only a relatively narrow range of flows could be tested.

Tracer rocks are grouped into "sets", with each set consisting of a specific particle size (e.g., the D_{84}, D_{50}, and D_{31} are particle sizes in a cumulative distribution for which 84, 50, and 31 percent are finer, respectively). We used the D_{31}, D_{50}, and D_{84} because they provide a good statistical representation of the channel bed particle size distribution. The D_{84} is also an idealized representation of the bed framework particles (Church et al. 1987). These particular size classes were determined using a modified Wolman pebble count (Wolman 1954, Leopold 1970) to determine the particle size distribution, from which approximately 10-20 rocks from the size classes are selected. These particle size classes representing the area to be monitored were painted a bright color, such as fluorescent orange, and placed along a cross section (Figure 15). Rocks were placed into the bed surface to simulate the surrounding particle embeddedness. Following a discrete high flow, the cross section was revisited to document whether mobility of the tracer rocks occurred and, if so, how many tracers moved and how far they moved. The tracer rocks were then re-set for the next high flow event. "Significant" particle mobilization occurs when more than 80% of the D_{84} clasts is mobilized from the cross section. Theoretically, enough monitoring events will provide sufficient data points to identify the flow range at which bed mobility occurs, as illustrated conceptually in Figure 16.

Three tracer rock monitoring sites were established in April 2001, and a fourth was added in 2002 to monitor particle mobility during the spring pulse flow releases of 2001 and 2002. Additional tracer rock monitoring sites were also established in the 7/11 Mining Reach as part of the post-construction monitoring for the 7/11 Mining Reach restoration project. Sets of D_{84} and D_{50} tracer rocks were placed on cross sections at riffles 3B, 4A, 4B, and 5A, at two-foot intervals across the cross section. Tracer rocks were then monitored and mobility data recorded following the peak flow release of 1,460 cfs on April 19, 2001. During the 2001 experiment only rocks at XS 2690+00 at Riffle 4B were mobilized, with 5 of 25 D_{50} particles (43 mm particle size) moving an average of 5-6 ft. None of the D_{84} particles moved. No mobility was observed at riffles 3B or 4A. Rock sets were reset in February 2002, then monitored a second time following the peak spring pulse flow of 1,200 cfs in April 2002. Tracer rock recovery following the 2002 spring pulse flow failed to relocate several rocks at riffles 3B, 4A, and 4B. The spring pulse flow release of 1,200 cfs is not considered a "bed-mobilizing flow," and we suspect that tracer rocks were either buried by sand, had the paint abraded off, or were moved by humans or spawning salmon. No tracer particles were moved at Riffle 5A, and no movement of particles occurred at other sites during 2002.

Observations from 2001 and 2002 were similar to tracer rock experiments reported in the Restoration Plan. Those previous experiments were implemented at six sites between Old La Grange Bridge and Geer Road Bridge at flows up to 6,880 cfs. Of the six sites monitored, the only location with

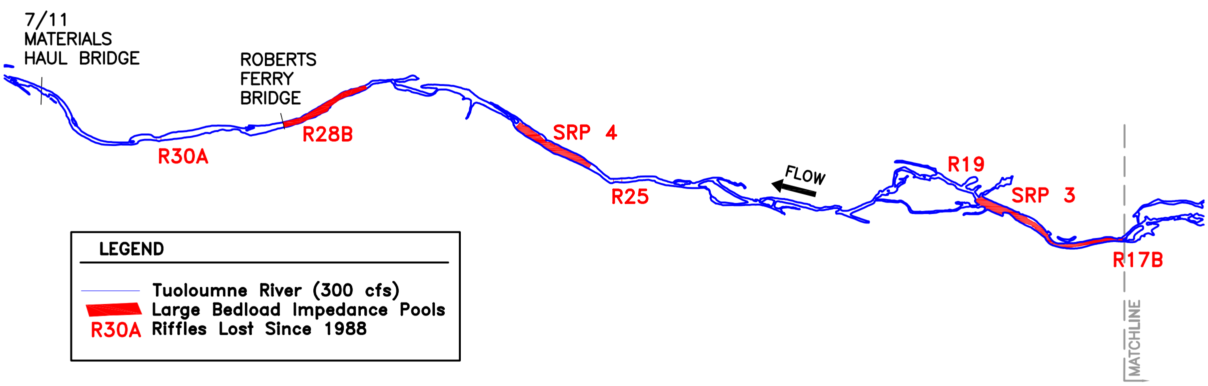


Figure 14. Location of major coarse sediment deficit sites along the upper spawning reaches. The riffles indicated (red) were mapped in 1988 and contained suitable spawning habitat, but were no longer present in our 2000 mapping efforts.

significant transport distances was Riffle 4B (RM 48.5). Based on these tracer rock experiments, the Restoration Plan concluded that the coarse bed particles in most reaches are not significantly mobilized by flows up to 6,880 cfs. Results of bed mobility modeling at three cross sections within the Ruddy 4-Pumps Restoration site also supported this conclusion, predicting bed mobility at discharges of 9,800 cfs, 7,050 cfs, and 8,250 cfs.

4.3.2 Bed Scour Depth

Scour cores are used to document the depth of bed scour and redeposition on alluvial features during high flows (e.g., point bars, medial bars, riffles, pool tails). To measure this, a "core", or sample of channel bed substrate, is removed and backfilled with brightly painted, uniformly sized gravels (or rock with uniform color lithology such as quartzite or dolomite) (Figure 17). The elevation of the pre-disturbed bed surface and the surface of the installed scour core are surveyed, and the precise location of the core is determined either on a cross section station or by triangulation from two permanent reference points. When discharge increases and scours the surrounding bed, the painted gravels become entrained and are transported downstream. As flows recede, bed material from upstream can then deposit at the scour core site, replacing the sediment transported downstream. Following high flows capable of causing scour, the scour core location is relocated to document scour and redeposition depths. Typically two to three scour cores are installed at a site where scour is to be measured. Scour cores have not yet been installed at potential augmentation sites in the Tuolumne River. Scour cores should be installed in association with tracer rocks during future bed mobility experiments.

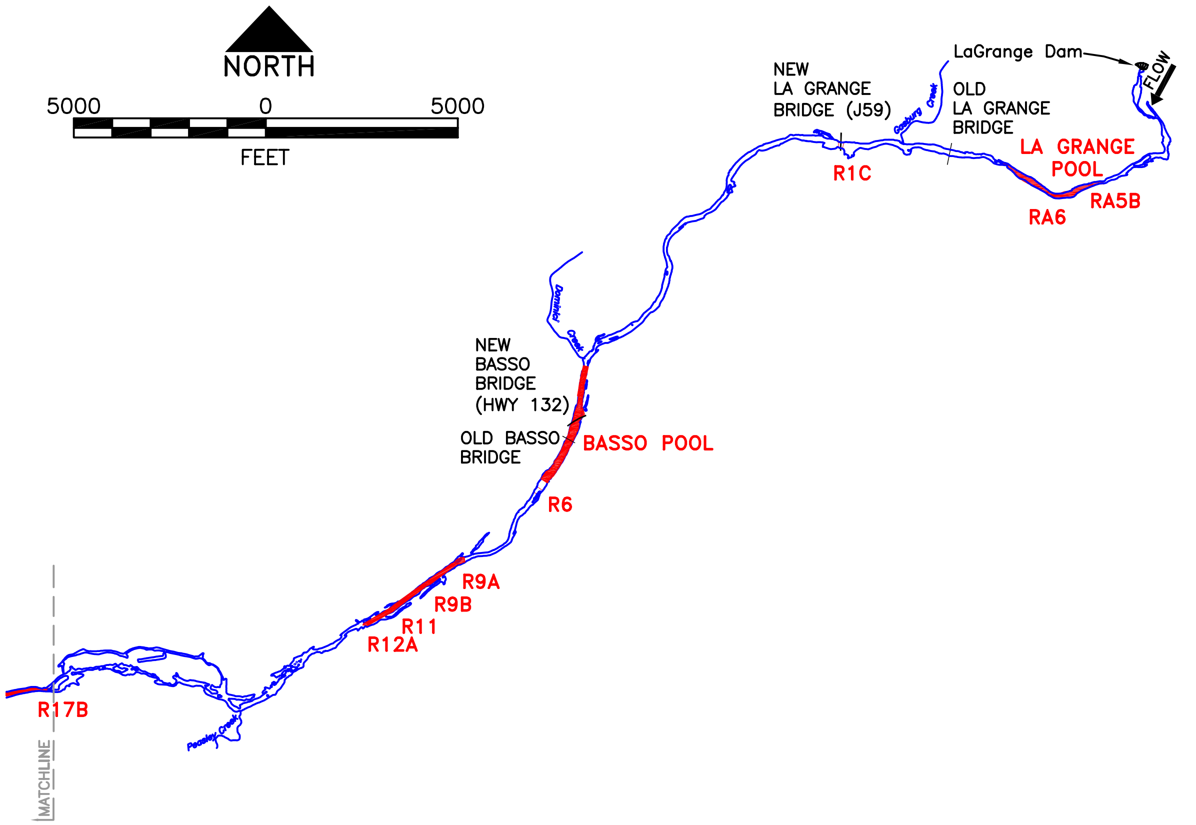


Figure 14, Continued.

4.3.3 Bedload Transport Rates

Annual sediment transport flux is a function of the magnitude and duration of peak flows released below the La Grange Dam during the water year. In most water years (approximately 60% between WY 1972–2001), peak flow magnitudes do not exceed bed mobility thresholds (assumed to be 5,500 cfs) and no sediment is transported. During years with high flow releases, typically wetter water year types, bed mobility thresholds are exceeded, and sediment transport occurs. For the long-term sediment augmentation program, the volume of sediment introduced into the river each year should be based on this estimate of sediment transported downstream each year.

"Bedload transport rate" describes the volume of sediment that is transported by given flows over a certain time period. Transport rates can be measured in the field and can be predicted using available sediment transport models. Both field and modeling methods have limitations. The utility of field sampling of sediment transport rates can be limited by the availability of high flows during the monitoring period. That is, sampling can be conducted only for observed flow conditions and for existing bed texture and channel geometry. Field measurements are also labor-intensive and, depending on the method used, can include substantial error. Transport modeling can augment field sampling because models can be used to predict bed mobility for a broader range of flows than observed in the field and for a range of bed textures (such as existing bed textures and finer textures achieved through sediment augmentation) and channel geometries. The primary drawback to bedload transport modeling is that the potential error is large, with predictions up to an order of magnitude different than the actual bedload transport rates (Gomez and Church 1989). Field experiments, therefore, are useful and necessary for testing and improving model predictions. For this Plan, bedload transport rates were measured in the field and predicted using transport models.

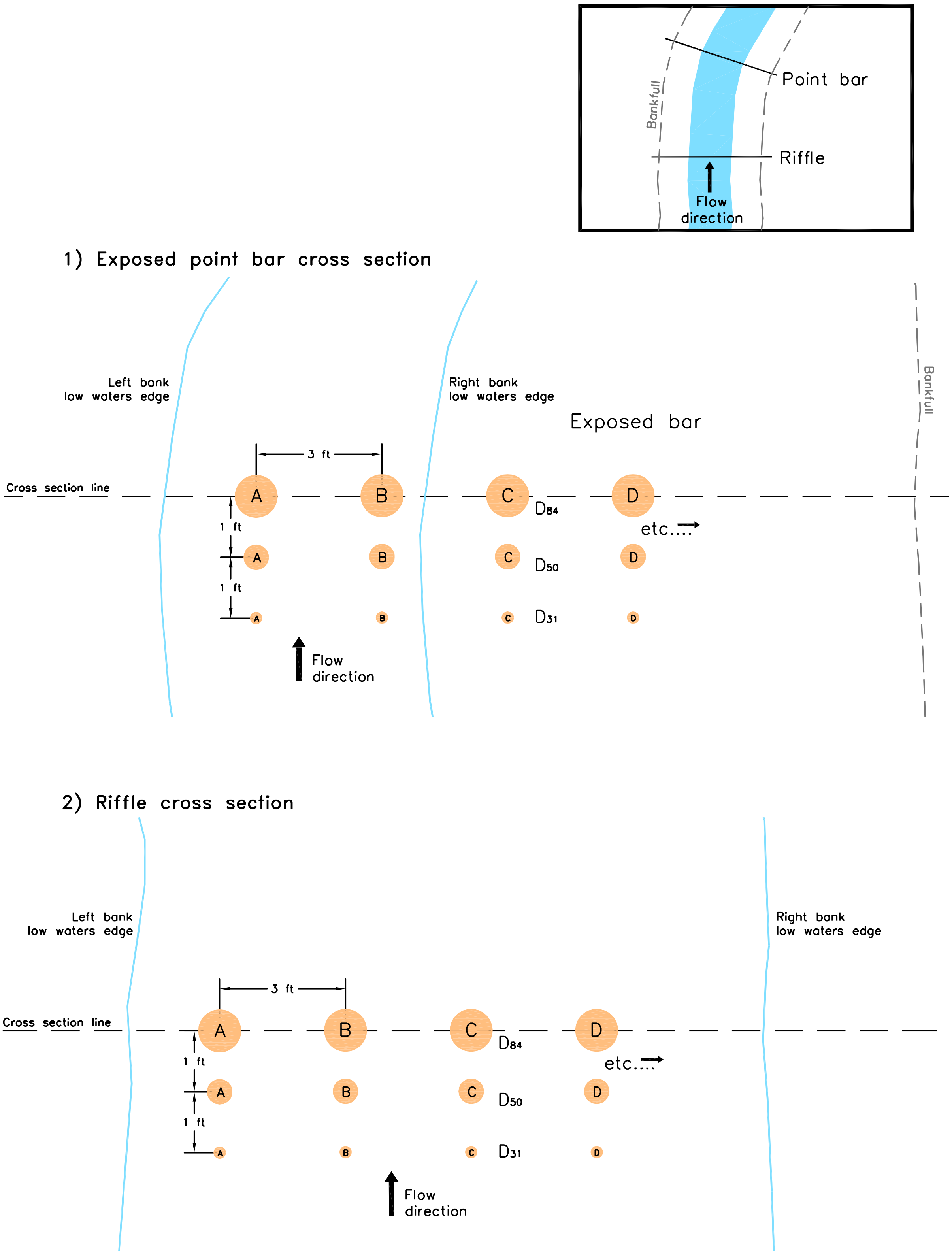


Figure 15. Typical tracer rock placement along a cross section. The D_{84}, D_{50}, and D_{31} are the sizes at which 84%, 50%, and 31% of the sediments are finer, measured along the intermediate axis. The D_{84} and D_{31} represent one standard deviation from the mean.

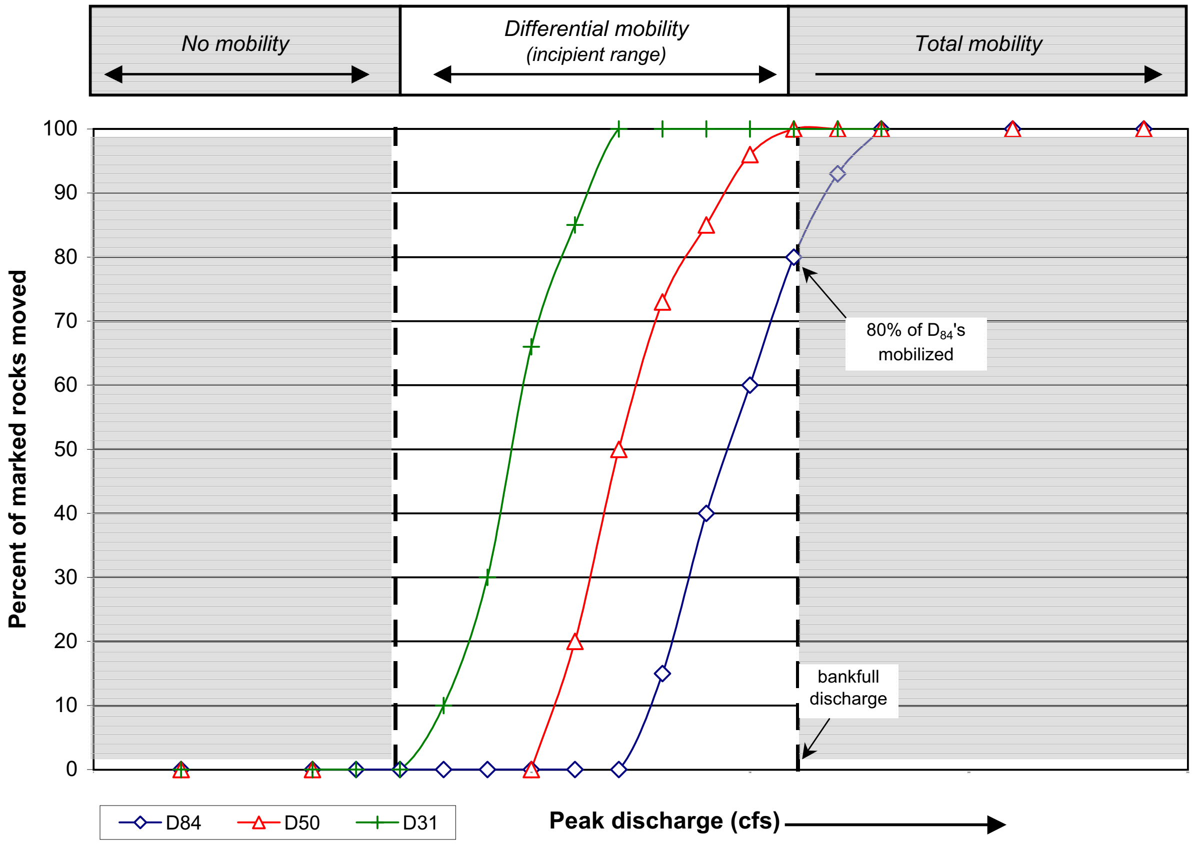


Figure 16. Illustration of the relationship between discharge and bed mobility targeted by tracer rock experiments. Tracer rock mobility occurs over a range of peak flows at a given alluvial feature. Each point represents a peak flow event mobilizing a percentage of tracer rocks. The range of differential mobility varies by alluvial feature. Complete bed mobilization occurs when mobilization of approximately 80% of the D_{84} *occurs.*

4.3.3.1 Field Measurements of Bedload Transport Rates

Estimates of the average annual sediment transport *volume* are based on integration of sediment transport *rates* and the annual hydrograph or flow duration curve. While hydrologic data are typically more readily available, measurements of bedload transport rates are difficult to obtain. The overall goal of collecting bedload transport measurements is to develop a rating curve relationship between discharge and bedload transport that allows prediction of coarse sediment transported over a range of flows. Using this rating curve, annual sediment yield (total volume of sediment transported annually) can be estimated for an annual hydrograph.

The best estimates of bedload transport are derived by measuring the volume change in a sediment trap over discrete periods of time (e.g., measuring how much bedload is deposited in a sedimentation basin with 100% trap efficiency over a storm hydrograph). This method quantifies bedload transported over numerous storm hydrographs of varying magnitudes and integrates bedload as it moves in “waves” through the system. The resulting rating curve is a good representation of bedload transport rates.

When sediment traps cannot be installed, bedload transport can be measured by sampling during specific flow events using a Helley-Smith bedload sampler. This approach, however, is limited by short sampling times (often 60 seconds per station), and samples are usually collected at a small

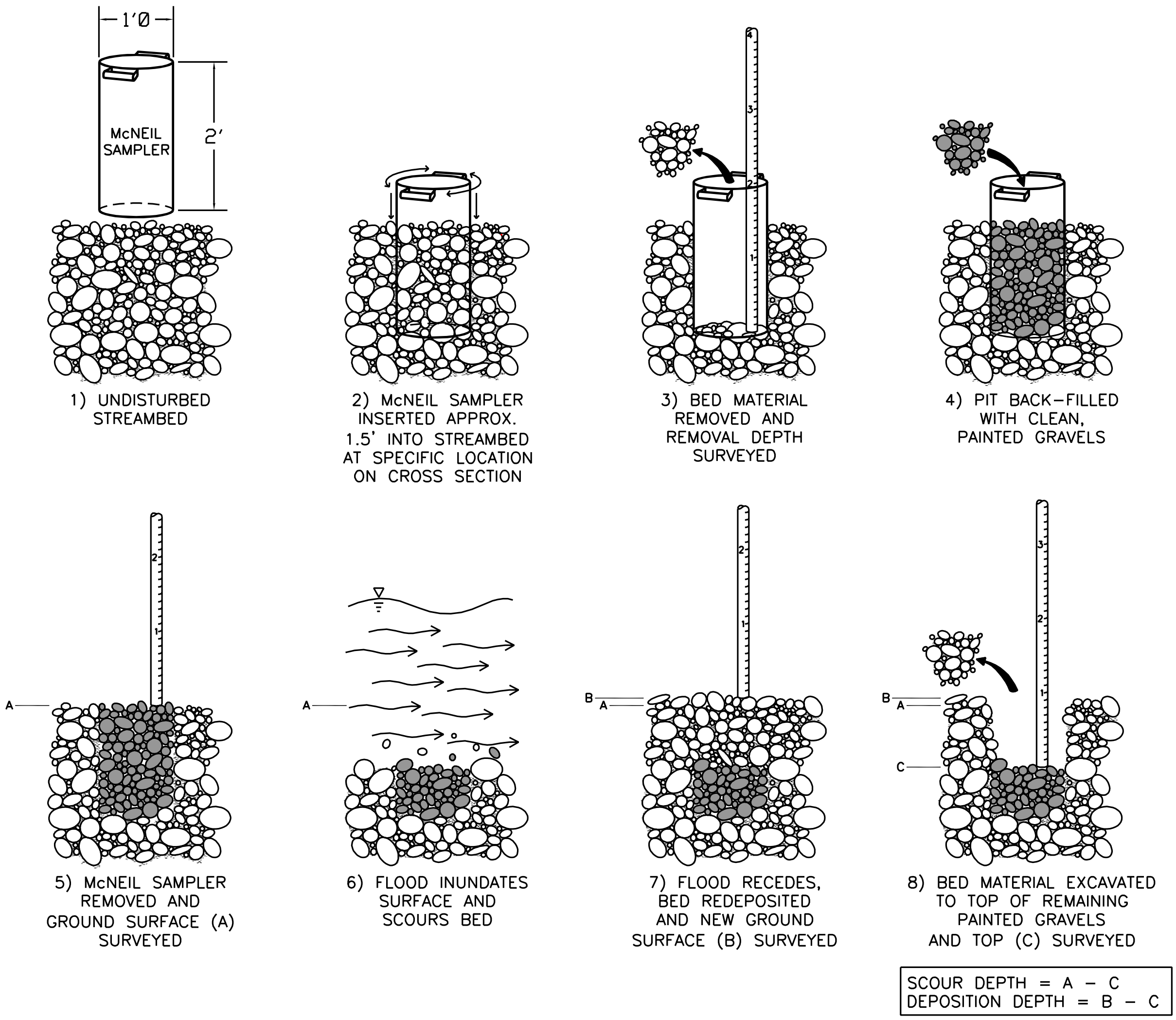


Figure 17. Scour core installation and monitoring procedure.

number of points on the storm hydrograph. The Helley-Smith bedload sampler is prone to sampling error from selective capture of different particle sizes if not deployed properly, and spatial and temporal variability resulting in sampling bias has been shown (Carey 1980, Gray 1991). Also, because sampling must occur during high flows when river conditions are challenging, field sampling of transport rates can be difficult to implement.

A suitable empirical bedload transport relationship typically requires several winter high flow periods to opportunistically sample a broad range of flows capable of transporting coarse sediment, unless controlled flow releases can be provided by the dam. In general, bedload transport measurements are collected repeatedly at an established site to reduce the variability observed between different sites (Edwards and Glysson 1999). Ideal site conditions include a relatively straight reach with rectangular channel cross section (resembling a flume) that provides uniform hydraulic conditions, and well-distributed bedload transport across the channel width. Long-term streamflow gaging records are also necessary for obtaining hydrograph data during the measurements as well as for long-term flow records.

In March 2000, a bedload transport measurement site was established at Riffle 4B at XS 2685+00 (Figure 11). In addition to possessing the conditions described above (e.g., straight reach, uniform cross section,), this site was chosen because it is at the downstream end of the dominant spawning reach targeted by sediment augmentation, thus allowing measurement of the sediment volume being transported out of this reach. Prior bedload transport measurements were collected at Old Basso Bridge using a Helley-Smith bedload sampler and portable, hand-operated crane (McBain and Trush 2000). Conditions at Old Basso Bridge are not ideal, however, and this site was abandoned. In March 2000, four discharges were sampled at the Riffle 4B site during a modified flood control release from New Don Pedro Dam. Releases from La Grange Dam during the sampling period were ramped up and held at 4,020 cfs, 4,960 cfs, 5,980 cfs, and 6,700 cfs (Figure 18) over the 2 day sampling period. For each discharge, bedload measurements were collected at 27 stations on XS 2685+00. Two sample passes were made from a cataraft (Figure 19) for each flow (except at 4,020 cfs), with sampling verticals spaced five feet apart. For each vertical station, the Helley-Smith sampler was lowered to the bed surface for 60 seconds to collect the bedload in transport. The sampler was then raised, and the sediment sample was removed and stored for later weighing and particle size analysis. Samples from each vertical station were lumped together to produce a single sediment sample for each pass. Samples were oven-dried, sieved, and weighed by half-phi size classes to determine the particle size distribution for each sample. The total sample weight of each individual pass was then averaged to obtain an estimate of transport rates for each flow. Transport rates for the fractions larger than 8 mm, smaller than 8 mm, and smaller than 2 mm were also computed to compare with predictions from bedload transport equations.

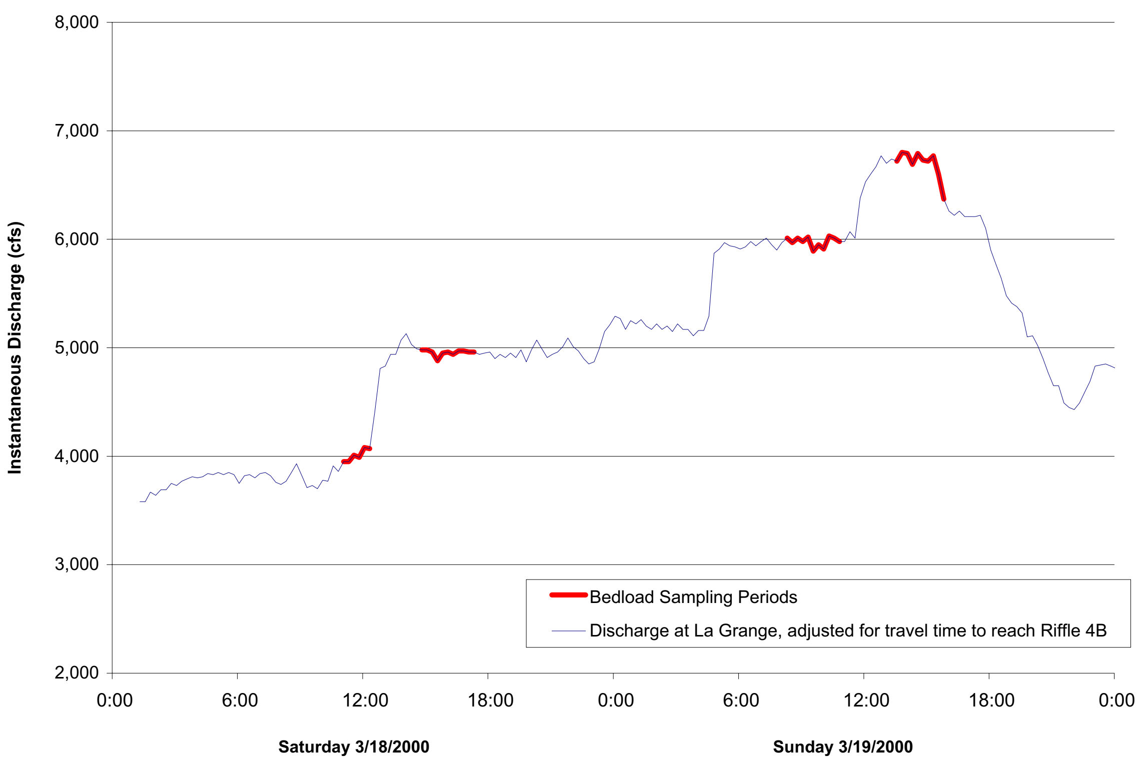


Figure 18. Discharge at La Grange (USGS 11-289650) during the March 2001 bedload transport measurements.

Figure 19. Bedload sampling at Riffle 4B on the Tuolumne River during a controlled flow release of 6,700 cfs. The Helley-Smith bedload sampler is lowered to the riverbed on the boom and collects sediment in transport for 60 seconds at multiple stations along the cross section.

Transport rates for the coarse sediment fraction larger than 8 mm (average of the two passes) were plotted as a function of discharge at La Grange (USGS 11-289650) on log-log axes and fitted with a straight line (Figure 20). Data points from the two lower discharges (4,020 and 4,960 cfs) were nearly identical, (i.e., there was no increase in transport between those two discharges). We assumed that the low transport rates at 4,020 cfs and 4,960 cfs were below the threshold for general bed mobilization; sediment caught in the sampler was presumably derived from the disturbance caused by the bedload sampler coming to rest on the substrate. The rating curve, therefore, was fitted to the three data points collected at 5,980 and 6,700 cfs, and the threshold for transport was estimated to be 5,500 cfs. Estimates of sediment transport based on extrapolation from a line fit to the two data points are preliminary. The threshold for bed mobility provided by this curve-fit (5,500 cfs), however, corresponds reasonably well with previous estimates of sediment transport thresholds at Riffle 4B (McBain and Trush 2000), in which initial mobility of tracer particles was observed from peak flows of 5,400 and 6,880 cfs (March-May, 1996). Additional information describing bed mobility and bedload transport experiments (at Old Basso Bridge) and results are presented in the Restoration Plan (McBain and Trush 2000).

The empirically derived bedload transport rating curve was developed from estimates of sediment transport measured at Riffle 4B, using measurements at 4,000 cfs, 4,900 cfs, 5,980 cfs, and 6,700 cfs. With few points on the curve (assuming a mobility threshold at approximately 5,500 cfs), this rating curve for coarse sediment larger than 8 mm should be considered very preliminary; transport estimates derived from this curve are first approximations. The rating curve was applied to the regulated flow record at La Grange (USGS 11-289650) for the post-New Don Pedro period (WY 1972-2001) to

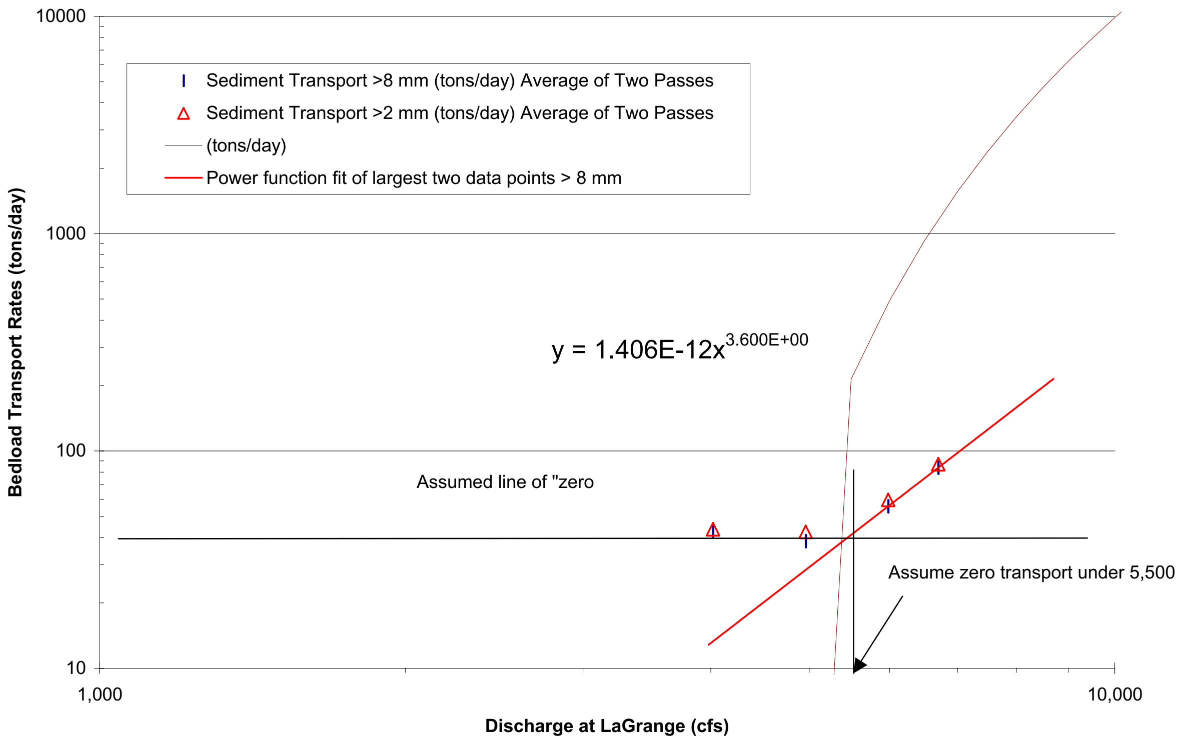


Figure 20. Bedload transport rating curve developed from data collected at Riffle 4B in March 2001.

estimate annual sediment transport volumes. The annual sediment transport volume for this period averaged 8,600 tons/yr (5,400 cu yds/yr), and ranged as high as 200,000 tons (126,000 cu yds/yr) in WY 1997, when peak discharge reached 60,000 cfs on January 4, 1997. Excluding the 1997 water year, the annual bedload transport volume was significantly less, averaging 1,930 tons/yr (1,211 cu yds/yr). The lack of sediment transport data from flows higher than 7,000 cfs renders sediment transport estimates at higher flows very tenuous. We altered the January1997 flood data to fit the assumption of a hypothetical maximum flood release of 15,000 cfs. In place of the one-day 60,000 cfs peak and accompanying ascending/descending limbs, the January 1997 hydrograph would have had 23 days of 15,000 cfs at La Grange, and had a sediment transport estimate of 43,000 tons/year instead of 202,000 tons/year. Efforts are currently underway to improve flood control management on the lower Tuolumne River to reduce the risk of uncontrolled flood releases. Assuming future flood releases do not exceed the maximum controlled release discharge of 15,000 cfs, we estimate the post-NDPP average annual bedload transport (>8 mm) is approximately 1,930 tons/yr (1,211 cu yds/yr).

The Restoration Plan also recommended evaluating opportunities to revise flood control operating criteria to provide short duration, larger magnitude pulse flows during flood control releases. The Restoration Plan evaluated post-NDPP water years with regulated flood releases exceeding 5,500 cfs, and suggested that higher magnitude flood control releases could be released in all flood control years with no impact to reservoir storage volume and small changes to power generation. Flood control releases occur in approximately 30–40% of water years. We evaluated the effect of higher peak flow releases on sediment transport rates, using the re-operated flood control hydrographs presented in the Restoration Plan (p. 110–113). Water years 1980, 1982–84, 1986, and 1995–2000 had higher flow releases capable of mobilizing the channel bed (Table 6). Water year 1997 was excluded

Table 6. Preliminary estimates of sediment transport rates for regulated discharge at La Grange, using the rating curve developed from bedload transport measurements at Riffle 4B. Hypothetical re-operated flood control releases were also evaluated to estimate potential increases in sediment transport by increasing high flows, during flood control releases.

	Annual Maximum Discharge at La Grange		Empirically Derived Transport Rate (from March 2000 sampling)		
Water Year	Actual Flood Release (cfs)	Hypothetical Re-Operated Flood Release (cfs)	Annual Transport Volume (tons/yr)	Annual Transport Volume (tons/yr) (w/out 1997)	Annual Transport Volume (tons/yr) with Hypothetical Flood Releases
1972	1,450	1,450	0	0	0
1973	1,370	1,370	0	0	0
1974	1,940	1,940	0	0	0
1975	3,080	3,080	0	0	0
1976	2,730	2,730	0	0	0
1977	224	224	0	0	0
1978	4,570	4,570	0	0	0
1979	3,650	3,650	0	0	0
1980	7,280	10,000	3,995	3,995	4,286
1981	2,980	2,980	0	0	0
1982	8,150	10,000	5,963	5,963	6,290
1983	10,400	12,000	22,300	22,300	22,631
1984	8,010	10,000	1,921	1,921	3,378
1985	2,820	2,820	0	0	0
1986	6,870	10,000	2,733	2,733	3,161
1987	2,980	2,980	0	0	0
1988	588	588	0	0	0
1989	767	767	0	0	0
1990	861	861	0	0	0
1991	1,190	1,190	0	0	0
1992	1,150	1,150	0	0	0
1993	1,740	1,740	0	0	0
1994	3,080	3,080	0	0	0
1995	8,710	12,000	12,528	12,528	13,202
1996	6,790	8,000	537	537	1,166
1997	50,100	50,100	202,952		
1998	8,010	12,000	4,232	4,232	4,950
1999	7,580	10,000	1,104	1,104	2,540
2000	6,610	8,000	864	864	1,111
2001	3,400	3,400	0	0	0
	Average Annual Sediment Transport Volume		8,630 tons/yr	1,930 tons/yr	2,240 tons/yr

from analyses. Compared to the actual regulated peak flows and consequent transport rates, the hypothetical flood releases increased bedload transport from 1,930 to 2,240 tons/yr (1,200 to 1,400 cu yds/yr), a 15% increase in bedload transport.

4.3.3.2 Bedload Transport Modeling

The EASI model (Enhanced Acronym Series 1 & 2 with Interface) was used to predict contemporary bedload transport rates in the primary spawning reach and to evaluate the benefits and/or potential impacts of alternative sediment augmentation approaches. The model focused on the 2,000 ft reach from Riffle 5A to Riffle 4A and included the bedload transport measurement site at Riffle 4B. The model integrated survey data from eight cross sections in this reach and the bedload transport data collected at Riffle 4B.

The EASI model (Enhanced Acronym Series 1 & 2 with Interface) is the implementation of the surface based bedload transport equation of Parker (1990a, b), modified to apply to natural gravel-bedded rivers. The model calculates sediment transport capacity for a given cross section, friction slope, water discharge, and bedload grain size distribution. The model also calculates normalized Shields stress, which provides a site-specific estimate of bed mobility threshold. The sediment transport capacity is the maximum possible sediment transport rate in the reach in the case of unlimited sediment supply. In a supply-limited case, the actual sediment transport rate in the river reach is smaller than the model-calculated transport capacity. During development of the model for the Tuolumne River, the model was updated so it could accommodate floodplains on both left and right bank, in addition to the main channel. The current model version is 4.3. A technical memorandum describing the EASI Model application on the Tuolumne River is presented in Appendix C. Long-term average transport rates for sediment larger than 8 mm and bed mobility thresholds were calculated for six cross sections in the Riffle 5A-4A reach (Figure 21). Based on model predictions, the long-term sediment transport rate in the modeling reach is 1,670 ton/yr (Table 7). This estimate is similar to the estimate derived from bedload measurements at R4B (1,930 tons/yr) based on the post-NDPP flow records. Estimates of the threshold for coarse sediment transport were slightly higher from the model (6,510 to 10,670 cfs) than from our estimate based on the empirical bedload measurements (5,500 cfs) (Table 7). These modeled estimates, however, are similar to empirical marked rock observations and bed mobility models that suggest flows in the range of 7,000 to 8,000 are required to fully mobilize the bed in most reaches (McBain and Trush 2000).

Table 7. Predicted long-term average sediment transport rates and discharges for bed mobility threshold with different cross sections as model input. Cross section locations are shown in Figure 11.

Cross section used for simulation	Long-term average sediment transport rate (tons/yr)	Discharge for bed mobility threshold (cfs)
XS 2702+00	1,690	6,950
XS 2699+00	2,110	6,510
XS 2690+00	940	10,670
XS 2685+00	820	9,520
XS 2674+00	2,430	8,770
XS 2672+00	1,760	9,620
Average	1,670	8,670

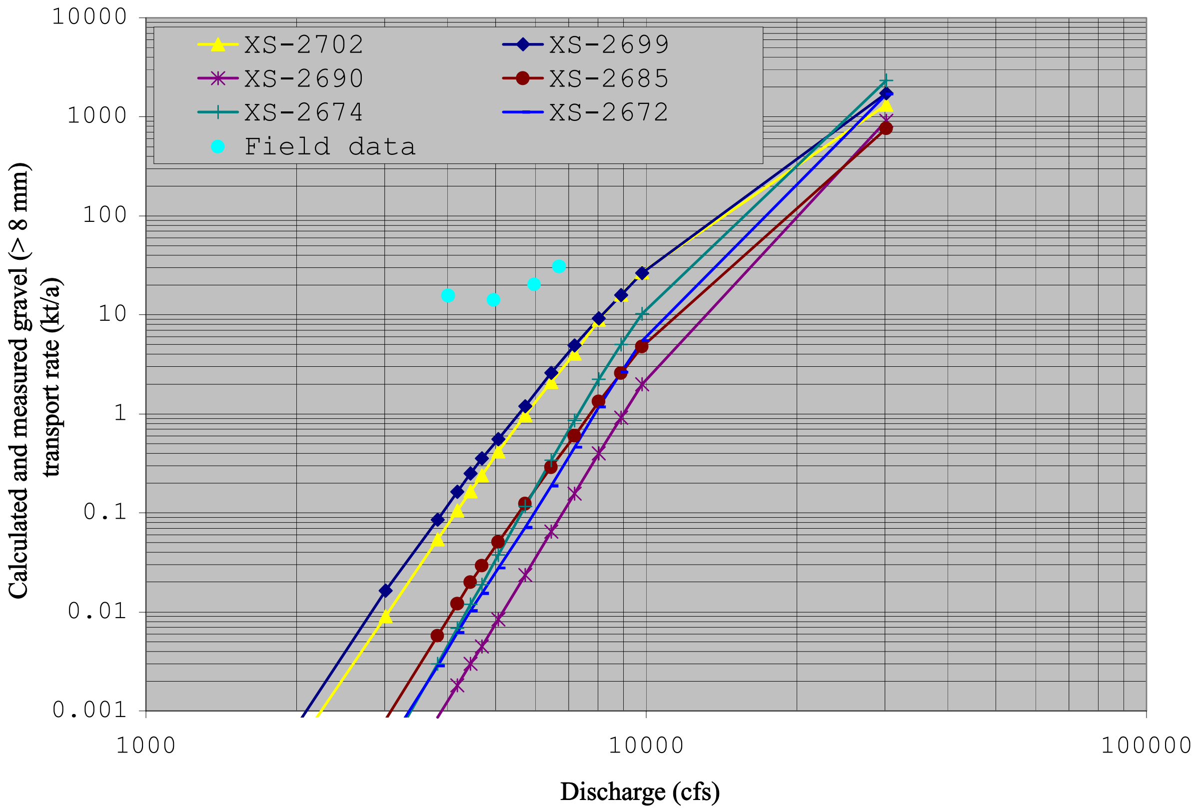


Figure 21. Bedload transport rating curves developed from the EASI Model for the dominant spawning reach between Riffles 3A and 5A.

Part of the strategy for coarse sediment management is to progressively reduce the overall particle size distribution so that bed sediments are mobilized more frequently by the contemporary regulated flow regime. Evaluating this strategy empirically will require many years of sediment augmentation and additional bedload transport measurement to develop a new bedload transport rating curve. The EASI model was used to evaluate the effect of varying the surface grain size on particle size distribution by using the finest and coarsest of available pebble counts as model input, which resulted in a predicted long-term coarse sediment transport rate of 4,010 tons/year for the finest bed texture and 490 tons/year for the coarsest bed texture (Table 8). Reducing the particle size distribution therefore would increase the rate of sediment transport and increase the average volume of sediment augmentation required to maintain equilibrium in sediment supply.

The potential benefits of increased sediment storage, combined with re-operated flood hydrographs to increase sediment transport and re-distribute coarse sediment, are critically important to this sediment management strategy and habitat maintenance processes. We have not evaluated the combined effects of increased flood releases *and* reduced particle size distribution on sediment transport rates, but the anticipated effects are likely minor.

Table 8. Predicted minimum and maximum annual sediment transport rate (tons/year) by varying input within a reasonable range

	Variation in Cross Section	Floodplain Assumption[3]	Varying water surface slope by ±20%	Varying surface grain size distribution
Minimum Prediction	820	1,690	480	490
Maximum Prediction	2,430	5,430	4,360	4,010
Average[1]	1,412	3,029	1,447	1,447
Deviation Factor[2]	1.72	1.79	3.01	3.01

[1] Geometric average of the minimum and maximum predictions;
[2] Ratio of maximum prediction to geometric average, which equals the ratio of geometric average to minimum prediction.
[3] Assumes that flow is confined to the active channel (maximum prediction) or the available flood (minimum prediction).

4.3.4 Sand and Fine Sediment Storage

In 2001, Stillwater Sciences conducted a three-day reconnaissance-level snorkel survey from Riffle A3/4 (RM 52.0) to Roberts Ferry Bridge (RM 39.5) to estimate the volume of fine sediment accumulation in pools and other discrete fine sediment deposits (within the bankfull channel), and to assess the contribution of fine sediment from small tributary inputs. Aerial photos were used in the field to delineate planform boundaries of sand deposits in pools, gravel and sand bars, and on floodplain surfaces. An approximate depth of sand was then assigned to each deposit to estimate the volume. A technical memorandum describing this survey is provided in Appendix E.

In general, the survey noted that all streambed surface and subsurface substrates contained a large volume of sand stored in the channel. Only limited sand deposits were observed in pools in the reach upstream of Basso Bridge (RM 47.5), and moderate amounts of sand storage were observed from Basso Bridge to Peasley Creek (RM 45.3). The highest volumes of sand were observed in the Dredger Reach from Peasley Creek to Roberts Ferry Bridge (RM 39.5). The survey estimated approximately 102,000 cu yds of sand within the bankfull channel in the reach upstream of Roberts Ferry Bridge, with about 77% of this material deposited in pools within the low flow channel. Gasburg Creek and Peasley Creek appeared to be the largest contributors of fine sediment in the survey reach.

4.4 Salmonid Spawning Habitat Area, Distribution, and Quality

4.4.1 Chinook Salmon Spawning Habitat Area and Distribution

Within the approximately 23-mile-long gravel-bedded reach, several surveys have documented Chinook salmon spawning gravel quality and availability. In 1988, spawning area was estimated by digitizing riffle area from aerial photos taken during flows of 100 cfs and 230 cfs. This assessment assumed that the entire riffle area provides suitable spawning habitat. Because the actual area of suitable habitat is influenced by substrate texture, site-specific hydraulic characteristics, and other factors, this estimate likely over-represents available Chinook salmon spawning habitat (TID/MID 1992c).

Between September 1999 and February 2001, spawning habitat in the 16-mile reach from La Grange Dam (RM 52.0) to the Santa Fe Aggregates haul road bridge (RM 36.3) was resurveyed to document changes in riffle area since 1988 (including the effects of the 1997 flood) and to provide a more detailed assessment of spawning habitat extent that reflects the effects of substrate texture and local hydraulics during spawning flows. Surveys were conducted from Roberts Ferry Bridge (RM 39.5) to the Santa Fe Aggregates haul bridge (RM 36.3) in summer 1999, from La Grange Dam (RM 52.0) to Basso Bridge (RM 47.5) in December 2000, and from Basso Bridge to Roberts Ferry Bridge in February 2001. Flow during the 1999 surveys (Roberts Ferry Bridge to the Santa Fe Aggregates haul bridge) was 250–300 cfs. Flow during the December 2000 surveys (La Grange Dam to Basso Bridge) was 361 cfs and during February 2001 survey (Basso Bridge to Roberts Ferry Bridge) was 1,010 cfs. Flow during the 2000 spawning season for which spawning utilization was observed during the 2000 and 2001 surveys averaged 342 cfs (October 20 through December 31, 2000). The portion of the gravel-bedded reach from the MJ Ruddy Bridge downstream to Hughson was not included in these recent surveys and has not been re-mapped since 1988.

During these surveys, riffle area and suitable spawning area were plotted onto aerial photographs in the field, digitized, and added to the Tuolumne River GIS. Riffles and spawning habitat areas from these surveys are shown in the habitat maps presented in Appendix D. The December 2000 surveys were conducted during spawning and during a high escapement year. Chinook salmon escapement in 2000 was estimated to be 17,870 adults, the highest since 1985. During this survey, Chinook salmon utilized all of the available spawning habitat in the survey reach (i.e., from La Grange Dam to Basso Bridge). During the surveys downstream of Basso Bridge, where riffles are patchy and spawning habitat is limited, CDFG personnel accompanied the survey to help identify areas of potential habitat where spawning has been observed in recent years. The results of the 1988 and 1999-2001 surveys for each riffle are shown in Table 9.

To estimate the amount of spawning habitat that historically was available in this 15-mile reach, we used the spawning habitat density obtained from 1999-01 mapping surveys in the reach between New La Grange Bridge and Basso Bridge and extrapolated this density to the entire gravel-bedded zone (with similar channel slopes). We assumed this reach was the best representation available of a healthy alternate bar morphology and spawning habitat conditions. This portion of river has recovered better than other reaches from mining and dredging impacts and has not shown the same degree of coarse sediment depletion and channel degradation documented in other reaches. This reach, including riffles 2 to 5B, contained an estimated 323,000 ft^2 of spawning habitat, or approximately 30 ft^2 of spawning habitat per linear foot of channel.

While extrapolating data from one discrete reach of river to the entire gravel-bedded river may be tenuous, we believe that, absent empirical data describing historical conditions, this evaluation is useful. The gravel-bedded reaches have similar longitudinal gradient and flow/sediment conditions and, therefore, should display a similar alluvial morphology under natural conditions. The pool-riffle sequences in the reach between New La Grange and Basso bridges appear to maintain a more natural morphology than other, more degraded reaches. We, therefore, could expect similar riffle habitat densities in other river reaches under less degraded (natural or historical) conditions.

Based on this extrapolation, the area of spawning habitat historically available (i.e., pre-dam and pre-mining) from La Grange Dam to the Santa Fe Aggregates bridge was estimated to be 2.4 million ft^2 (Table 10, Figure 22). Riffle area mapped in 1988 was 1.6 million ft^2, or 823,000 ft^2 (34%) less than the historical estimate for the reach. Riffle area mapped in 1999-2001 was 1.3 million ft^2, or 269,000 ft^2 (17%) less than in 1988 due to riffle scour during the 1997 flood. Loss of riffle area between 1988 and 1999-2001 for the dominant spawning reach, dredger reach, and mining reach was 128,000 ft^2 (17%), 46,000 ft^2 (11%), and 52,000 ft^2 (13%), respectively. Comparing 1999-2001 spawning habitat area to historical estimates indicates a potential loss of 1.8 million ft^2 (73%) of Chinook salmon spawning habitat compared to historical conditions.

Table 9. Estimates of spawning habitat availability for different reaches for surveys conducted in 1988 (EA 1992) and surveys conducted in 1999-2001. Riffle areas indicated in green are those used to estimate a relatively healthy spawning habitat density of 30 ft² per linear foot of channel.

DOMINANT SPAWNING REACH (La Grange Dam to Basso Bridge)

RIFFLE	1988 RIFFLE ESTIMATE (ft^2)	2000 RIFFLE ESTIMATE (ft^2)	2000 SPAWNING ESTIMATE (ft^2)	CHANGE IN RIFFLE AREA	% CHANGE IN RIFFLE AREA
RA1	7,603		not surveyed		
RA2	2,965	3,989	not surveyed		
RA3/4	22,475	11,762	3,702	-10,713	-48%
RA5A	16,277	0	0	-16,277	-100%
RA5B	8,336	0	0	-8,336	-100%
RA6	10,147	0	0	-10,147	-100%
RA7A	7,596	33,099	16,740	25,503	336%
R1A	92,257	23,559	31,989	-68,698	-74%
R1B	27,269	19,735	13,150	-7,534	-28%
R2	86,867	103,766	76,072	16,899	19%
R3A	38,268	15,622	7,076	-22,646	-59%
R3B	44,135	77,606	70,137	33,471	76%
R4A	125,523	94,827	57,821	-30,696	-24%
R4B	178,077	171,421	108,810	-6,656	-4%
R5A	64,395	31,773	18,140	-32,622	-51%
R5B	9,167	19,407	6,936	10,240	112%
TOTAL	**741,357**	**606,566**	**410,573**	**-128,212**	**-17%**

DREDGER REACH (Basso Bridge to Turlock Lake State Rec Area)

RIFFLE	1988 RIFFLE ESTIMATE (ft^2)	2000 RIFFLE ESTIMATE (ft^2)	2000 SPAWNING ESTIMATE (ft^2)	RIFFLE AREA REDUCTION	RIFFLE AREA % REDUCTION
R6	26,050	0	0	-26,050	-100%
R7	67,747	76,643	34,489	8,896	13%
R8	22,023	8,536	5,449	-13,487	-61%
R9	34,862	0	0	-34,862	-100%
R10	7,458	0	0	-7,458	-100%
R11	23,206	0	0	-23,206	-100%
R12	5,959	52,321	12,627	46,362	778%
R13A	10,550	10,116	779	-434	-4%
R13B	10,151	6,494	3,103	-3,657	-36%
R13C	12,283	6,335	1,357	-5,948	-48%
R14	9,478	7,847	1,064	-1,631	-17%
R15/16	26,598	24,167	4,456	-2,431	-9%
R17A	4,431	14,099	1,354	9,668	218%
R17B	11,272	0	1,148	-11,272	-100%
R17C	18,315	0	0	-18,315	-100%
R17D	2,072	0	0	-2,072	-100%
R18	17,421	12,129	2,181	-5,292	-30%
R19	9,736	0	0	-9,736	-100%
R20	19,203	26,321	1,766	7,118	37%
R21	5,974	18,900	2,469	12,926	216%
R22	4,037	17,978	2,954	13,941	345%
R23A	6,933	12,110	1,016	5,177	75%
R23B	9,091	4,693	612	-4,398	-48%
R23C	14,088	18,062	3,454	3,974	28%
R23D	22,698	36,229	7,627	13,531	60%
R24	18,175	20,935	11,348	2,760	15%
TOTAL	**419,811**	**373,915**	**99,252**	**-45,896**	**-11%**

Table 9. Continued.

MINING REACH (Turlock Lake State Rec Area to Ruddy Bridge)					
RIFFLE	*1988 RIFFLE ESTIMATE (ft²)*	*2000 RIFFLE ESTIMATE (ft²)*	*2000 SPAWNING ESTIMATE (ft²)*	*RIFFLE AREA REDUCTION*	*RIFFLE AREA % REDUCTION*
R25	18,785	19,104	0	319	2%
R26	21,214	26,726	7,246	5,512	26%
R27	4,003	6,747	518	2,744	69%
R28A	29,887	15,126	0	-14,761	-49%
R28B	10,381	11,795	9,060	1,414	14%
R29	43,994	9,421	5,262	-34,573	-79%
R30A	11,268	8,772	4,158	-2,496	-22%
R30B	13,496	8,311	2,757	-5,185	-38%
R30C	21,326	0	0	-21,326	-100%
R31	25,033	32,902	13,692	7,869	31%
R32	3,628	6,605	6,605	2,977	82%
R33	29,472	13,934	25,662	-15,538	-53%
R34A	16,667	8,704	10,823	-7,963	-48%
R34B	8,005	0	0	-8,005	-100%
R35A/B	66,792	94,316	38,686	27,524	41%
R36A	34,954	44,690	1,910	9,736	28%
R36B	53,974	17,312		-36,662	-68%
TOTAL	**412,879**	**324,465**	**126,379**	**-51,752**	**-13%**
TOTAL	**1,574,047**	**1,304,946**	**636,205**	**-225,860**	**-14%**

Table 10. Summary of riffle and spawning habitat surveys by reach.

Reach	**Est. Historic Spawning Area (ft²)**	**1988 Riffle Area (ft²)**	**2000 Riffle Area (ft²)**	**2000 Spawning Area (ft²)**
Dominant Spawning Reach	660,000	741,357	606,566	410,573
Dredger Reach	936,000	419,811	373,915	99,252
Mining Reach	801,000	412,879	324,465	126,379
Total	**2,397,000**	**1,574,047**	**1,304,946**	**636,205**

As discussed in Section 3.1.3, Chinook salmon in the Tuolumne River spawn primarily upstream of Basso Bridge (i.e., in the "Dominant Spawning Reach"), which could be driven by habitat availability, behavioral mechanisms, or a combination of the these factors. Comparing redd density in the reaches by riffle area, spawning in the Dominant Spawning Reach is 1.4 redds/1,000 ft² of riffle and is denser than in the other two reaches surveyed (Table 11). Comparing redd density by spawning habitat area, however, spawning density is highest in the Dredger Reach, at 3.8 redds/1,000 ft² of spawning habitat (Table 11), suggesting that increasing spawning habitat in the Dredger Reach may increase spawning utilization in this reach and potentially reduce redd superimposition in the Dominant Spawning Reach. One caution is that the peak read counts presented in Table 11 simply represent the highest number of redds counted at a riffle during the spawning season. The peak redd count, therefore, does not represent the total number of redds constructed at each riffle, which can be much higher especially in riffles where substantial redd superimposition occurs.

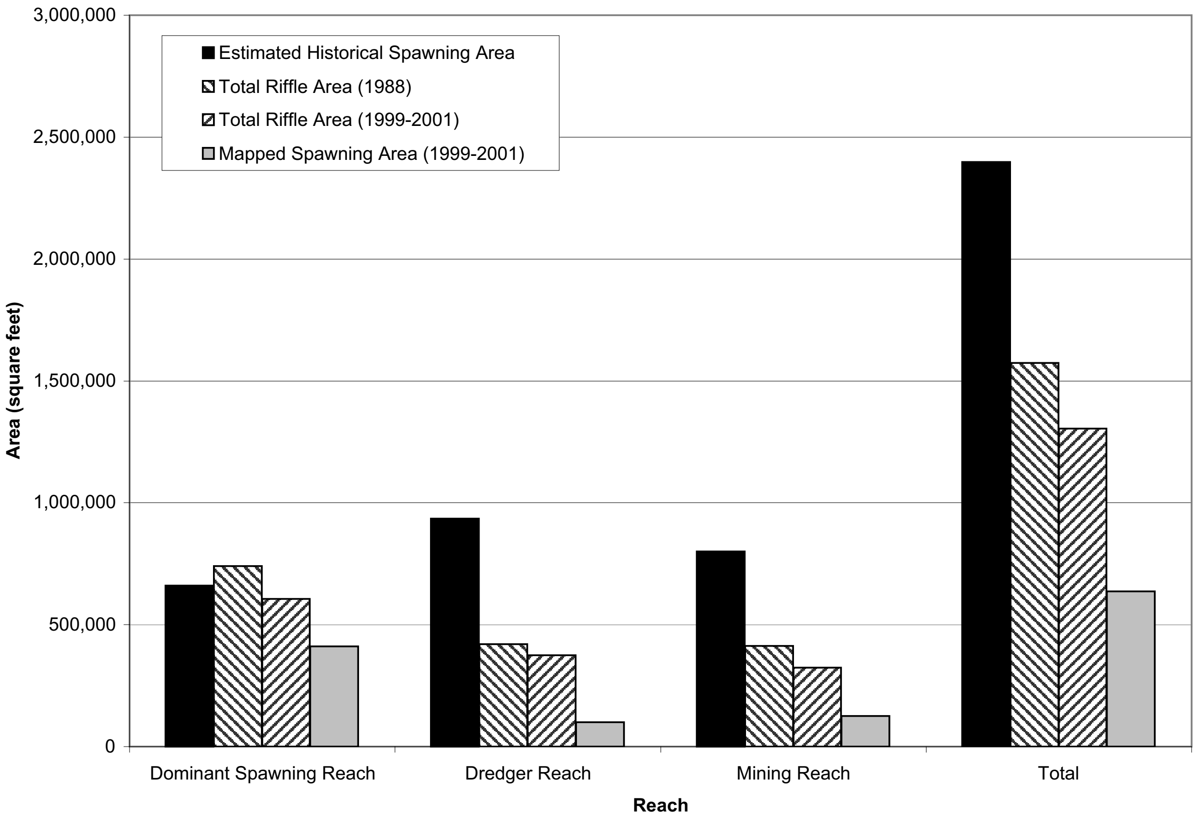


Figure 22. Spawning habitat area estimates for the lower Tuolumne River between La Grange Dam and the Santa Fe Aggregates bridge (RM 36.4). Data are derived from: (A) historical estimate obtained by extrapolating relatively healthy conditions in the upper river to the entire river, (B) estimates from 1988 habitat mapping conducted by the Districts, and (C) estimates from 2000 habitat mapping conducted during preparation of this Plan.

Table 11. Fall-run Chinook salmon spawning density by reach (1997-2001).

Reach	Total Peak Redd Count (1997-2001)	2000 Riffle Area (ft^2)	2000 Spawning Habitat Area (ft^2)	Redd density (no./1,000 ft^2)	
				by riffle area	by spawning habitat area
Dominant Spawning Reach (Riffle A1 - Riffle 5B)	851	606,566	410,573	1.4	2.1
Dredger Reach (Riffle 6 - Riffle 24)	378	373,915	99,252	1.0	3.8
Mining Reach (Riffle 25 - Riffle 36)	189	324,465	126,379	0.6	1.5

4.4.2 O. mykiss Spawning Habitat Area and Distribution

As discussed in Section 3, prior studies of salmonid habitat and populations in the Tuolumne River focused exclusively on Chinook salmon. With the listing of *O. mykiss* under the Federal Endangered Species Act and the increasing observations of *O. mykiss* reported in the Tuolumne River, it has become increasingly important to gather information on *O. mykiss* distribution, abundance, and habitat. To provide preliminary documentation potentially suitable adult *O. mykiss* foraging, holding, and spawning habitat, the CRRF mapped locations in the lower Tuolumne River between La Grange Dam and the Roberts Ferry Bridge where they routinely catch adult *O. mykiss* that weigh between 2 and 12 pounds using hook-and-line methods. Some of the fish caught by the CRRF were bright silver, which is typical of Central Valley steelhead (CRRF 2004).

The mapping surveys were conducted January 21, 2004 and February 23, 2004. Most of the study area was surveyed from a raft; areas upstream of the Old La Grange Bridge were surveyed by foot. Site locations were identified with hand-held GPS units and by marking the locations on habitat maps produced by McBain and Trush in 2002. A digital photo was taken at most sites. Forty-seven sites were identified as adult *O. mykiss* habitat between the La Grange Dam and Roberts Ferry Bridge. The locations of these sites, site numbers, GPS coordinates, habitat features are presented in Appendix D. CRRF also reports that some *O. mykiss* habitat occurs downstream to the Reed property just above Waterford (approximately RM 33). In May 2004, CRRF and CDFG collected adult *O. mykiss* as far downstream as Riffle 36A (RM 36.5).

4.4.3 Salmonid Spawning Habitat Quality

Historical information describing spawning gravel quality in the Tuolumne River is limited. Large-scale alterations to the river channel and sediment composition (and therefore spawning gravel) have been ongoing and increasing in degree of impact since the beginning of the gold rush in 1848 and culminated with the January 1997 flood, which deposited a large volume of fine sediment into the river channel. The fisheries studies conducted by the Districts in the 1980s (TID/MID 1992d) evaluated the quality of spawning gravel in the Tuolumne River in relation to Chinook salmon egg and alevin survival, including: (1) assessment of the size distribution of gravels in spawning riffles with McNeil samples, (2) estimates of egg survival-to-emergence with redd capping experiments, and (3) estimates of sediment intrusion into redds. The results of these studies presented an overall picture of poor spawning gravel quality in the Tuolumne River in 1988. For example, the cumulative percentage of fine sediment smaller than 0.85 mm, a frequently used indicator of fine sediment impairment, averaged 17% (range = 11.1% to 28.6 %) in riffles sampled in 1987 and 11% (range = 5.0% to 24.0%) in riffles sampled in 1988 (TID/MID 1992d). Mean survival predicted by the Tappel-Bjornn survival-to-emergence model (Tappel and Bjornn 1983) was 15.7% for riffles sampled in 1987 and 34.1% for riffles sampled in 1988. Observed survival-to-emergence from the redd capping experiments ranged from an estimated 0% to 68% and averaged 34% (TID/MID 1992d).

In 1997, additional gravel quality monitoring studies were initiated using substrate composition and permeability as assessment tools. These studies were conducted to test several hypotheses linking permeability to survival-to-emergence. The mean permeability (per riffle) documented throughout the river ranged from 2,497 to 8,024 cm/hr, and predicted survival-to-emergence ranged from 34% (95% CI: 27-41%) at Riffle 7 to 51% (95% CI: 34-68%) at Riffle 2 (Stillwater Sciences 2001a). Permeability and survival-to-emergence did not exhibit an upstream-downstream trend, as had been observed in previous pilot studies of permeability, and there was no detectable difference in permeability among the riffles sampled.

4.5 Chinook Salmon Population Models

This section summarizes recent refinements to two Chinook salmon population models developed by Stillwater Sciences for the Districts and the TRTAC. The models were originally developed as part of the District's 1988 study plan, and were updated with recent hydrologic and habitat data (where available). The models are useful as predictive tools to evaluate potential outcomes of different restoration scenarios. Following updates to the models, we applied them to different coarse and fine sediment restoration actions to evaluate the effects these proposed or planned restoration actions would have on the salmon population. No population models have been developed for *O. mykiss* in the Tuolumne River.

4.5.1 Model Descriptions and Application

4.5.1.1 San Joaquin River System Chinook Salmon Population Model (EACH).

The EACH model is a deterministic simulation that represents the dynamics of populations from each of the three salmon-bearing tributaries to the San Joaquin River (the Merced, Tuolumne, and Stanislaus rivers). The Districts originally developed the EACH model in 1986–1987 as a way to conceptualize individual Chinook salmon life-stages and geographical locations in a life-history context, and to provide a tool for studying the multigenerational dynamics of the populations in the presence of constantly changing environmental conditions. The model consists of a set of finite difference equations describing changes in the numbers of Chinook salmon at various geographical locations and developmental stages as functions of these numbers, and of environmental parameters. The development and structure of EACH have been described in detail previous reports (TID/MID 1992b).

The model uses streamflow to represent environmental conditions, and mortality at each life stage is assumed to be either constant or linearly related to flow. In a time series analysis, the flow is allowed to vary weekly based on flow data in the upper and lower reaches of each tributary. Although the model considers a great many factors, such as mortality and migration rates, these are usually taken to be linear functions of flow or export. Flow serves as a surrogate for all factors related to flow, such as temperature or turbidity.

The ocean population is represented by six "state variables," representing the numbers of individuals aged 0 to 5 years respectively. In the ocean, the fish are subjected to harvest, hook-and-release mortality, and natural mortality. The model operates as a time series in which once each year, a fraction of the adult population is separated into a spawning class, which is then divided among the three tributaries. The number of spawners of each age class and available spawning habitat determines the production of eggs in each tributary, and the total number of spawning sites is determined by flow.

The model distinguishes three populations of eggs. In each tributary, the total egg production is obtained by summing the contributions from all spawning adults. Eggs are subject to superimposition by incoming spawners. The amount of habitat available, the amount in use, and the numbers of spawners determine superimposition rates. An egg development submodel keeps track of weekly cohorts of eggs through their development period. Individuals surviving this period become alevins (sac fry).

The three tributary populations of alevins are subject to flow-related mortality. An alevin development submodel follows weekly cohorts of alevins through their development period until they become fry. Fry can either remain in their natal tributary or migrate to the San Joaquin River or the Delta. Natural mortality rates and migration fractions are determined by flows in the appropriate parts of the system, and fry in the Delta are subject to pumping-related mortality at the State and Federal Water Project export facilities. Most individuals residing in the tributaries at the end of their development period become smolts, with the remainder becoming yearlings.

Five populations of smolts are distinguished: one in each tributary, one in the Delta, and one in San Francisco Bay. Smolts from hatcheries can be introduced into any of these populations. Natural mortality rates are determined by flows in the appropriate parts of the system, and smolts in the Delta are subject to pumping-related mortality at the Export Facilities. Survivors make up the age-zero ocean population.

Yearlings remain in the tributaries until the following fall, when they migrate downstream to the ocean. Five populations of yearlings are distinguished: one in each tributary, one in the Delta, and one in the Bay. Yearlings from hatcheries can be introduced into any of these populations. Natural mortality rates are determined by flows in the appropriate parts of the system, and yearlings in the Delta are subject to pumping-related mortality at the export facilities. Survivors are added to the age-1 ocean population.

4.5.1.2 Stock Recruitment Model for Chinook Salmon in the San Joaquin River System.

The Stock Recruitment Model (TID/MID 1992b) differs from the EACH Model described above in several ways. In an effort to understand management implications on the behavior of the fluctuating population of the San Joaquin River basin, the Stock Recruitment Model uses statistical analysis of the time-series of historical escapements to the San Joaquin basin in relation to flow and Delta exports. More specifically, the model attempts to capture how density independent mortality, as influenced by spring flow, combines with density dependent mortality to affect the rate and magnitude of changes in population of the San Joaquin system's Chinook salmon.

Development of the Stock Recruitment Model. The development of the stock recruitment model essentially used the inland component of the state-space model (Rein 1993). The resulting stock-recruitment relationship arising from the initial model development is well described by one of a family of Ricker-type curves that may be modeled by the state-space model (TID/MID 1997a). The state-space model statistically represents the time series evolution of a system of unobserved quantities R_t^2, R_t^3, R_t^4, S_t, representing ocean populations of two year olds, three year olds, and four year olds, and the total number of spawners, in year *t*, and observed quantities E_t, C_t representing the escapement and harvest in year *t*:

(*System equations*)

$$R_{t+1}^2 = f(Q_t, S_{t-1}) + \varepsilon_t$$

$$R_{t+1}^3 = (1-\mu)(1-\omega)(1-\rho_2)R_t^2$$

$$R_{t+1}^4 = (1-\mu)(1-\gamma)(1-\rho_3)R_t^2$$

$$S_t = (1-\mu)(1-\omega)\rho_2 R_t^2 + 1-\mu)(1-\gamma)(\rho_3 R_t^3 + R_t^4)$$

(*Observation equations*)

$$E_t = (1-\mu)(1-\omega)\rho_2 R_t^2 + 1-\mu)(1-\gamma)(\rho_3 R_t^3 + R_t^4) + \delta_{1t}$$

$$C_t = (1-\mu)\gamma(R_t^3 + R_t^4) + \delta_{2t}$$

The parameters describe various aspects of ocean life-history; they are assigned the values estimated by R.G. Kope (1987):

$$\mu = 0.2,\ \omega = 0.18,\ \gamma = 0.60,\ \rho_2 = 0.17,\ \rho_3 = 0.65$$

The variables ε_t, δ_{1t}, δ_{2t} are independent gaussian deviates with mean 0 and variances var $\varepsilon_t = \sigma_\varepsilon^2$, var$\delta_{1t}$ = varδ_{2t} = ε_δ^2. The function *f(Q,S)* is the spawner-to-recruit stock production relationship.

The first step in the Stock Recruitment Model development used the R^3 and R^4 system equations to rewrite the observation equations (without the error terms) as higher-order recurrences for escapement and harvest in terms of only the recruitment series for R^2. A preliminary estimate of the recruitment series was then found by minimizing the sum-of-squares error in the predicted escapements and harvests over all series of non-negative recruits. These were plotted against escapements in order to suggest a reasonable functional form for the stock-recruit relationship; on the basis of this analysis, it was determined that the data were consistent with a Ricker (1954) relationship, with errors related to flow, so *f(Q, S)* was chosen to have the form $\alpha QSexp(-\beta S)$. The second step in the model development used an extended Kalman filter on the full set of both the system and observation equations above to re-estimate the time-series of ocean populations. The remaining model parameters α, β, σ_ε^2, σ_δ^2 below were chosen by maximum likelihood:

$\alpha = 2.58$, $\beta = 0.068$, $\sigma_\varepsilon = 59$, $\sigma_\delta = 10$

It should be noted that although other forms (*e.g.,* Beverton Holt) of the spawner-recruit relationship may apply to the Stock Recruitment Model for the San Joaquin River system, the form and parameters of this relationship are based on empirical data.

4.5.1.3 Model Operation

Operation of the Stock Recruitment Model. The current version of the Stock-Recruitment model for the San Joaquin River Chinook salmon population is not a stand-alone model in an executable program form. Modeling various river management scenarios requires a sequential statistical analysis of the model structure and parameters described above as a series of scripts written for S-PLUS. The analysis also requires historical flows, exports, escapements and harvest data; these have been updated to July 2001.

Operation of the EACH Model. The EACH model (v 8.5.5) is an executable program written in C for Windows that uses a number of linked (.dat) files that describe historical conditions (*e.g.,* escapement and flow) for the period from 7/29/40 through 7/01/01. We have attached a disk containing the program and the following data files:

- **hydro.dat** The historical hydrology and export data.
- **harvest.dat** The historical fishing harvest efforts, in the form of ratios of 3-year-olds in the catch to 3-year-olds in the escapement
- **spawn.dat** The number of spawners which are taken by the Merced River Fish Facility (MRFF). Note the model deducts these from the spawning population after they are counted towards the total escapement.
- **release.dat** Historical hatchery release numbers (which the model adds to the appropriate smolt and yearling populations).
- **nopulse.dat** Specifies the model weeks in which the model assumes that "pulse flow" conditions are in effect.
- **histesc.dat** Historical escapement data.

Although the data in the attached files are arranged in columns, the names of .dat files, and the distribution of variables among files, are fairly arbitrary so long as the variables are in the header row (see example files). After selecting which data files to use (using the "Tables..." dialog under the "Setup" menu); the model will scan these files to determine which variables they contain. For example, to evaluate alternative flow regimes, just replace "hydro.dat" with a new file.

This program package also contains an "each.ini" file. When you create "scenarios" for differing harvests, flows or gaming future conditions, they are saved. A "scenario" consists of a list of .dat files, and a list of changes to parameters. A scenario with the name "startup", if present, is loaded automatically when EACH is first launched. The "each.ini" file on this disk assumes that the default .dat files are in EACHv855\baseline, but you can change this by using the "Tables..." dialog (or by changing "each.ini" directly with a text editor).

Running the model often requires the data files to be modified to capture differing flow regimes or conditions (*e.g.,* Set barriers switch to 0 or 1 to simulate presence/absence of Delta barriers). From the "Report" dialog, select a population variable of interest (*e.g.,* Adlt2_Hvst_Frc for 2-year old mortality due to ocean harvest), report frequency (*e.g.,* weekly) and period of analysis (*e.g.,* 1950–1997). The model output is both an on-screen graphic representation and a report text file that may be saved as comma separated values (.csv) for use in other software.

4.5.2 Evaluation of Potential Restoration Actions

In contrast to the EACH model, the Stock-Recruit model is a statistical population model of the entire San Joaquin Chinook salmon population and is less suited for predictive analysis of changes in productivity of the individual tributary rivers within the system under a particular management scenario. A deterministic population model can be associated to this model. However, in order to use this model effectively as a predictive tool, it was first necessary to determine how the underlying stock production relationship had changed since the original model development.

Changes in the underlying stock production relationship for the Tuolumne River. One of the largest changes in the habitat conditions for the Tuolumne River Chinook salmon run in recent years corresponds with the losses in available spawning area due to the January 1997 flood, which scoured away many riffles in the primary spawning reach below La Grange Dam. In order to predict population consequences of this event or planned changes in habitat quantity (sediment augmentation) and quality (gravel cleaning), it was necessary to determine how this underlying stock production relationship would change under a number of scenarios. Below we describe the integration of recent habitat surveys with spawning habitat use assessments using CDFG spawner surveys to assign spawning preferences and a refined stock production relationship for the lower Tuolumne River.

Changes in spawning habitat were recently assessed in a baseline survey conducted in 2000 (Section 4.4.1) to compare with the next most recent surveys conducted in 1988. The 1988 habitat mapping surveys divided the lower Tuolumne River into six reaches using GIS analysis of aerial photographs at 230 cfs (TID/MID 1992c). Using the most recent spawning habitat assessment, Table 11 suggests that reduction in riffle area combined with more refined field mapping of potential spawning habitat reduced estimates of available spawning area by 40% compared to the 1988 estimates. Downstream in the Gravel Mining Reach, conditions appeared to have degraded but these areas were not mapped.

Using the reported areas common to both surveys in 1988 and 2000, the areas in Table 10 corresponded to reductions of 94%, 33% and 77% of the spawnable area in the upper three reaches, or nearly 600,000 ft^2 combined. Extending these habitat estimates to determine whether planned restoration actions (*e.g.,* sediment transfusions) will have measurable population benefits, we ran several model simulations using these data from the recent habitat mapping effort.

Redd superimposition modeling. The reductions of spawning habitat in the reaches shown in Table 10 can be shown to have a significant impact in the numbers of emergent fry for a given number of spawners. To assess these effects of the underlying stock-production relationship for the lower Tuolumne River, we used an individual-based mode, *escape4*, originally developed to assess density dependent mortality effects on the Tuolumne River Chinook salmon due to redd superimposition by late arriving spawners (TID/MID 1997b). However, to counter the spawning habitat reductions shown in Table 10, planned restoration actions include sediment transfusions which we estimate could increase spawnable area to the upper three reaches (A, 1A, and 1B) of 84,100 ft^2, 267,950 ft^2 and 74,800 ft^2, respectively. On the basis of CDFG spawner surveys conducted during the 1980s, assigning a spawning habitat preference as a fixed fraction of the total run to each of the six reaches (Table 12), reach 1A appears to account for almost half of the spawning activity in the lower Tuolumne River over this period.

Table 12. Spawning preference estimated from 1981–1989 spawner surveys.

Reach	A	1A	1B	2	3	4
Percent of run	5	45	25	20	4	1

Data Sources: CDFG, LaGrange CA.

Using the habitat preferences shown in Table 12, we used the *escape4* model to estimate the effects of superimposition on subsequent smolt production. The model results are reported in units of "equivalent females," or the number of females needed to produce the same number of successful smolts in the complete absence of superimposition effects. From these results, smooth curves were fitted through the first part of the resulting stock-production relationships, and used to estimate the number of spawners yielding the maximum production. There were two base scenarios evaluated:

- Populations levels using spawnable area declines shown in Table 10.
- Population levels with coarse sediment augmentation to the upper three reaches of 84,100 ft^2, 267,950 ft^2 and 74,800 ft^2, respectively.

On the basis of this analysis, we concluded that the stock production curves maximizing escapement predicted for 2001 conditions is 48% of that for 1988 conditions. With sediment augmentation, the maximizing escapement predicted for 2001 conditions is 131% of that for 2001 conditions without augmentation, or a long term increase in 30% over current conditions. The exact value of the production-maximizing escapement is dependent on a number of assumptions whose accuracy is difficult to assess, such as the size of a typical redd, the fraction of mapped gravels which salmon will deem usable, and the date beyond which spawning is futile because the resulting fry will not attain smolt size in time to join the spring outmigration. However, the relative changes to these maximizing escapements can be expected to be a more robust measure of planned restoration actions.

Assessment of Changes in Spawning Area. The two population models were used to translate changes to spawning habitat conditions into expected changes to overall population levels, taking population dynamics and varying environmental conditions into account. The EACH model distinguishes between the individual tributary river sub-populations of the San Joaquin basin and it is possible to assess changes from individual management actions by a parameter governing each tributary's spawning habitat availability. Although spawning habitat quality, egg or alevin survival parameters are not accessible to the user, gravel quality can be represented by altering the female fecundities (since egg/alevin survival is not density-dependent in the model, increasing egg/alevin survival is equivalent to increasing fecundities by the same factor). Although the Stock Recruit model represents the fall run of the entire San Joaquin basin, we were able to use this model to evaluate Tuolumne-specific measures by assuming that the Tuolumne River is a reasonable surrogate for the basin as a whole. That is, if we scale the quality and quantity of spawning habitat for the entire basin, the basin-wide population should respond in the same way that the Tuolumne River population would respond to corresponding changes to the Tuolumne River alone.

4.5.3 Model Results

Calibration Performance of the Updated Models. Although the EACH model was updated for more recent escapement and flow data, it only uses flow to predict escapement. Using the most recent data, the model appears to over-predict San Joaquin basin tributary escapement (*e.g.,* 79,000 predicted vs. 18,000 observed for the Tuolumne River in 2001) with the exception of the Merced River.

In contrast to the EACH model, the Stock Recruit model uses historical escapement updates to continuously update and re-calibrate (*i.e.,* track) the escapement. The escapements that would have been predicted using only the pre-1990 input data were higher than observed than those developed from more recent data, perhaps reflecting the loss in available spawning habitat. In contrast to the EACH Model, the Stock Recruit Model is more dependent upon the self-correction of the time series of recent escapement data. The uncertainty in the model prediction grows with time. However, the model appears to predict the recent population rebound based upon the increased number of above average water yields during the 1990's.

Results of Restoration Actions to Increase Spawning Area. Sediment augmentation is one of several planned restoration actions considered by the TRTAC (McBain and Trush 2000). By rescaling the adjustable parameters in the two population models, we were able to assess the long term effects of sediment augmentation to the upper three reaches of 84,100 ft^2, 267,950 ft^2 and 74,800 ft^2, respectively. Table 13 shows the two models make similar predictions in the changes in overall population levels. Because the models may fail to predict run size in any particular year, the analyses were conducted over the entire modeled period (1950-2000) to predict population responses. If analyzed over this entire period, both population models predict that the loss of usable spawning gravel suggested by the changes between the 1988 and 2001 coarse sediment surveys should correspond to a reduction to general escapement levels of 40% to 50%. Sediment augmentation should increase general escapement levels by 35% to 50% over current conditions.

Table 13. Population changes under sediment augmentation and gravel cleaning scenarios.

Scenario Evaluated	EACH model	Stock-Recruit model
Mean escapement over period of record (1950-2000) under current gravel conditions (2000)	56% of 1988 gravel conditions	52% of 1988 gravel conditions
Mean escapement over period of record (1950-2001) with sediment augmentation to the upper three reaches.	135% of 2001 gravel conditions without sediment augmentation	150% of 2001 gravel conditions without sediment augmentation
Mean escapement over period of record (1950-2001) with sediment augmentation to the upper three reaches and gravel cleaning of all reaches	154% of that for 2001 gravel conditions without augmentation or cleaning.	182% of that for 2001 gravel conditions without augmentation or cleaning.

Results of Improvements in Spawning Gravel Quality. In addition to sediment augmentation, gravel cleaning has been considered as a means to improve survival to emergence in the Tuolumne River and is one of the potential management actions being evaluated under the Tuolumne River Sediment Management Plan. Although prior spawning gravel quality analyses on the Tuolumne River predicted survival to emergence on the order of 30 percent (TID/MID 1992d) using the Tappel-Bjornn Index (Tappel and Bjornn 1983), on the basis of data collected in the 1993 Tuolumne River gravel cleaning experiments, we estimated that it was possible to increase egg and alevin survival by a factor of 1.187 through gravel cleaning. Although this value is based on the best results obtained during the gravel cleaning experiments, sediment augmentation and gravel cleaning together could increase general escapement levels by 50% to 80% (Table 13).

4.5.4 Model Discussion

Calibration Performance of the Updated Models. In general, the updated population models appear to track general trends in escapement very well but tend to overestimate escapement in peak years. It is not clear whether discrepancies in predicted Tuolumne River escapement (79,000 predicted vs. 18,000 observed in 2001) are due to changes in the underlying calibration parameters arising from fundamental changes in ocean or spawning conditions in the Tuolumne River. Year-to-year population levels also vary widely, with periodic “crashes” in the San Joaquin system, making model predictions very difficult to evaluate over the short term. For this reason, the model results were represented as long term mean escapement levels. Under both models, that the percent changes to geometric or harmonic mean population levels for the various scenarios were almost identical to the percent changes in the arithmetic mean escapement. In particular, conclusions about the benefits of sediment augmentation and cleaning relative to average population levels also apply to effective population levels (as used in calculations of inbreeding depression and other genetic issues).

Evaluation of Recent and Planned Changes in Spawning Habitat Availability. Although adjustable parameters (*e.g.,* spawning areas, egg, fry or smolt survival, etc.) in both the EACH and Stock Recruit models allow various management options to be evaluated, the models differ in their ability to provide the spatial resolution of reach-specific restoration and management measures. In general, the population models do not have a fine enough resolution, in space or time, to represent typical management actions directly. The required resolution is obtained by factoring the empirical escapement-to-recruitment relationship into lifestage-to-lifestage relationships, until it is possible to make reasonable predictions about the effects of a proposed management action on one or more of these relationships. The most significant of these relates to spawning and egg-to-alevin survival, which were then propagated forward through the life history to determine the implications of the action for overall population levels.

Both population models predict that the loss of usable spawning gravel suggested by the changes between the 1988 and 2001 gravel surveys should correspond to a reduction to general escapement levels of 40% to 50%. Although sediment augmentation should increase general escapement levels by 35% to 50% over current conditions, this only corresponds to 70% to 80% of the long term escapement estimates under 1988 conditions. The EACH model predicts somewhat larger benefits from sediment augmentation than does the Stock-Recruit model. However, it also predicts somewhat larger losses from the change from 1988 gravel area to 2001 area. Although the EACH model appears to be a little more sensitive to gravel abundance than the Stock-Recruit model, both models suggest significant production benefits may be realized from planned sediment augmentation actions.

Evaluation of Improvements in Spawning Gravel Quality. Although the long-term benefits to gravel quality will relate to both the area and frequency of planned gravel cleaning, gravel cleaning could increase general escapement levels by 20% to 30% over current conditions. Sediment augmentation and gravel cleaning together could increase general escapement levels by 50% to 80%, approaching the long-term escapement levels represented by the 1988 spawning habitat conditions.

4.5.5 Model Conclusions

- Because the EACH and Stock Recruit models use different assumptions and methodologies but similarly both predict significant benefits of the planned management actions, our confidence of the benefits of planned management actions is increased. In prior sensitivity analyses during the development of the Stock Recruit model (TID/MID 1997a) the most important factor affecting production of Chinook salmon was the number of spawners and the environmental conditions in the spring when smolts were outmigrating. However, increases in spawning habitat availability reduces a significant source of density dependent mortality in years of peak escapement, and improvements in gravel quality reduces a source of density independent mortality in all years causing a fundamental shift in the stock production relationship for the lower Tuolumne River.
- The updated population models track general trends in escapement very well but tend to overestimate escapement in peak years. The Stock Recruit model appears to predict the recent population rebound based upon the increased number of above average water years during the late 1990s.
- Although the EACH model appears to predict slightly greater production benefits from increased gravel availability than the Stock-Recruit model, both models suggest that significant production benefits may be realized from planned sediment augmentation actions to the upper three spawning reaches in the Tuolumne River.
- Gravel cleaning can be expected to reduce a source of density independent mortality. The population models suggest overall population level increases as high as 80% over current escapements with a combination of sediment augmentation and gravel cleaning.

5 RECOMMENDED SEDIMENT AUGMENTATION PROGRAM

5.1 General Strategy

The overarching goal of this approach to restoration is to restore coarse sediment supply to a state of dynamic equilibrium similar to the natural, unaltered sediment storage and routing condition, but at a smaller scale so that sediment input and downstream transport is balanced, bedload transport continuity is achieved, and sediment augmentation will eventually be required only in one location below La Grange Dam. The overall approach to coarse sediment management therefore includes three basic elements:

- a short-term transfusion of large volumes of coarse sediment to restore instream coarse sediment storage to increase spawning habitat area for Chinook salmon and *O. mykiss*, while protecting existing habitat features for these species;
- long-term, periodic augmentation of smaller volumes of coarse sediment at selected sites to maintain in-channel storage and supply as sediment is mobilized and transported downstream by high flow releases; the volume of periodic augmentation is approximately equivalent to the rate of downstream transport over the long-term;
- adaptive management and monitoring to evaluate the program and improve the benefits of introduced coarse sediment (e.g., salmon use, particle size distribution, method of sediment placement, augmentation locations, etc.), and reduce costs.
- These three program elements are described in the following sections.

A useful analogy to illustrate differences in coarse sediment storage and routing, as well as how flow and sediment regulation and coarse sediment management approaches change these conditions, views the river as a long conveyor belt coated with sediment (the channel bed) and with discrete sediment deposits (lateral gravel/cobble bars) stored along the belt (Figure 23-A). The downstream transport of coarse sediment, caused by the force of flowing water, is analogous to the conveyor being turned on and off periodically. The downstream transport "switch" is turned on only during infrequent high flow events, on average approximately once every year under unimpaired conditions. During periods of downstream sediment transport, sediment moves from one depositional site to the next downstream depositional site, for example, from alternate bar to alternate bar. Construction of the dam in the middle of the conveyor belt (Figure 23-B) eliminated the sediment supplied to the conveyor by the watershed, and also reduced the frequency of downstream sediment transport due to the reduced high flow regime. Periodic high flows still continue to move the sediment, just less frequently and at smaller discharge magnitude and duration than during unimpaired conditions. Over the course of a century of sediment impairment, sediment storage has steadily been depleted (Figure 23-B), sediment traps (bedload impedance reaches) have been created by gold dredging and gravel mining, and sediment has coarsened as finer gravel particles have been selectively transported downstream. Through either gradual sediment attrition, or during catastrophic floods like January 1997, entire sediment deposits (gravel bars and riffles) have completely disappeared, unreplenished by upstream supplies (McBain and Trush 2000).

The recommended coarse sediment management approach would first replenish existing storage deposits and restore lost ones by mechanical introductions (sediment transfusion) (Figure 23-C), then maintain sediment storage equilibrium by periodically adding sediment (long-term management) (Figure 23-D). The annual maintenance volume is determined by the rate of downstream transport estimated by bedload transport modeling and monitoring. We hypothesize that placement of large quantities of coarse sediment into the channel, in combination with periodic high flows to redistribute and reshape those supplies, will significantly improve salmonid habitat conditions and channel dynamics.

5.2 Short-term Sediment "Transfusion"

5.2.1 Overview

The term "transfusion" is used to express the critical need to replenish coarse sediment and spawning gravel storage as soon as possible to quickly improve the health and function of fluvial processes as well as salmonid habitat. The primary tasks of our planning and preparation for sediment transfusion were to determine how much sediment to place into the river, where to place it, and what time-frame would be required to implement the transfusion phase. There are no tried-and-true methods for assessing a 20-mile stretch of alluvial river channel and accurately and objectively quantifying the volume of sediment deficit caused by a century of lack of supply. This lack of method is further compounded by the broader objective of trying to scale down the river channel dimensions and the particle size distribution so that the contemporary regulated flow regime can still promote dynamic geomorphic processes and improve habitat conditions for salmonids and other native species. Given these challenges, we identified suitable locations and volumes for sediment augmentation using the following criteria:

- riffles with coarsened surface layer (armoring), riffle gradient too steep to provide high quality Chinook salmon or *O. mykiss* spawning habitat, and/or overall reduction in riffle size (some riffles were completely scoured away by the 1997 flood and previous high flows);

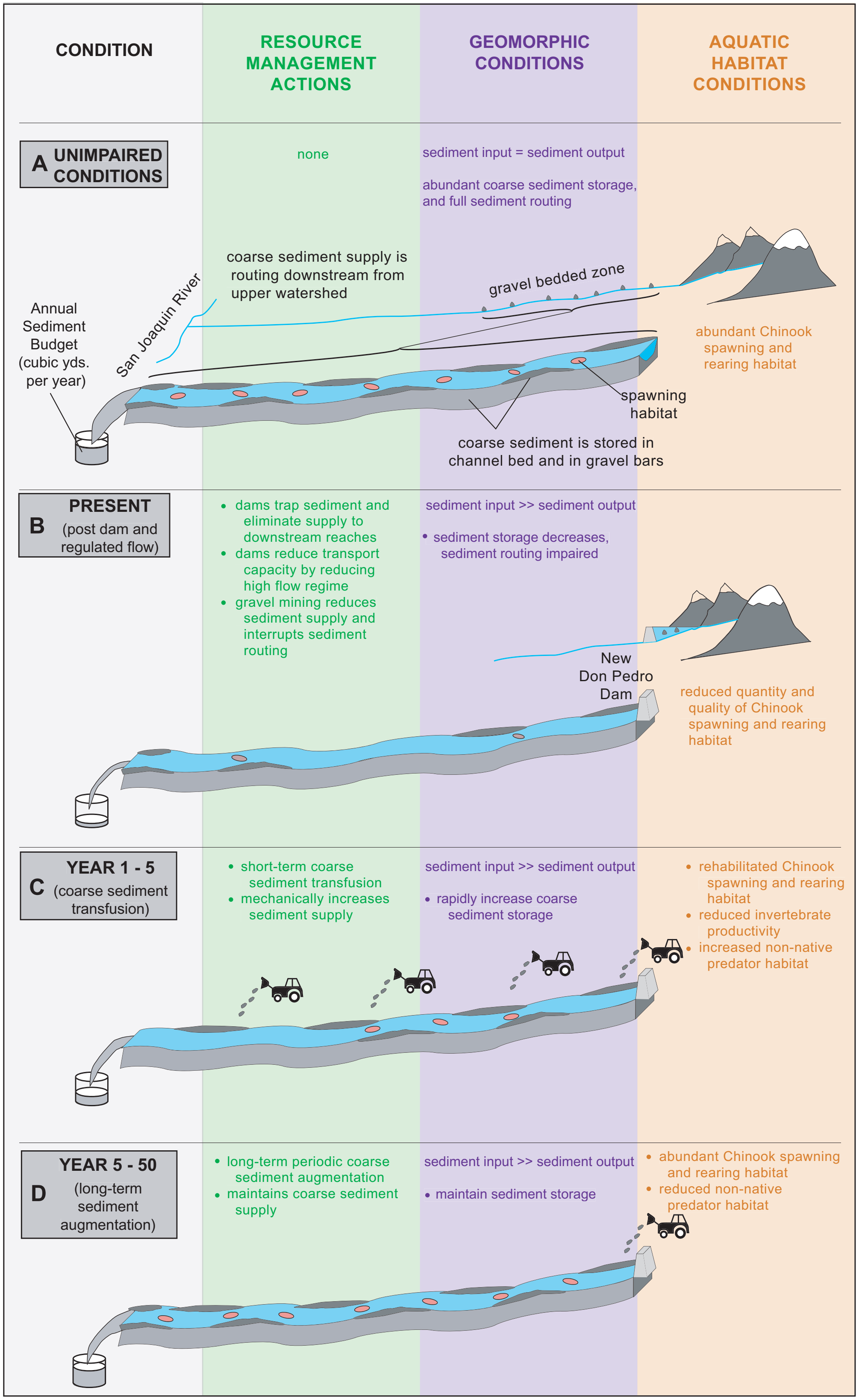


Figure 23. Conceptual illustration of coarse sediment storage and transport processes, the response to the regulated flow and sediment regimes, and the proposed coarse sediment management approach to remedy the sediment supply deficit.

- long pools and Special Run Pools that currently lack riffles and alternate bars and do not presently provide salmonid spawning habitat;
- inside of meander bends with subtle or non-existent point bars;
- pool-tails with overly steep riffle crests and substrates embedded with fine sediments that do not presently provide *O. mykiss* habitat;
- lateral gravel bars that showed signs of erosion, steady depletion of the coarse sediment storage, and overwidening of the channel;
- channel banks that had been eroded during high flows and not re-supplied via deposition on the inside of the bend, causing channel widening;
- backwater features that were remnant of historic dredging and other channel manipulations; and
- former riffle sites that have been lost by channel bed scour and lack of sediment supply to replenish the riffle.

These locations were mapped in the field onto aerial photographs as numerous discrete polygons (planform boundaries) with an estimated depth of sediment augmentation. These polygons are shown on the maps presented in Appendix D and are listed in Table 14. Depths of proposed sediment introduction facies were determined by field reconnaissance and/or by surveyed cross sections, using guidelines for channel dimensions developed in the Restoration Plan (p. 155). Once digitized, the area and volume of sediment augmentation was determined for each polygon. The sediment augmentation polygons were grouped into 29 discrete sediment transfusion sites (Figure 24).

Site prioritization reflects several iterations. An initial prioritization was presented to the TRTAC, which offered the following suggestions:

- no sediment transfusion should occur in the 1.2 mile reach between riffles 3B and 4B to preserve an unaltered “spawning refugia” at these intensively used and relatively healthy riffles;
- augmentation at the long pool between riffles A3/4 and A7 (i.e., the Riffle A5/6 site) would be difficult to implement due to its relative inaccessibility and the large volume of sediment needed to re-create Riffles A5 and A6;
- the Riffle 12 site should be a high priority largely because of channel adjustments that occurred during the 1997 flood and because of the large potential to restore spawning riffles at this site;
- Riffle 24A at TLSRA could provide a project demonstration site where the public could view spawning gravel augmentation (this site also has good access and fills a void in the lower portion of the Dredger Reach; and
- The Friends of the Tuolumne (FOT) Bobcat Flat sites have already been funded or proposed for funding, conceptual designs have been prepared, and coarse sediment is available on-site; these sites were recommended as high priority sites.

The resulting site prioritization was published in the November 2003 version of this Plan. Subsequent review of that version of the Plan, however, identified concerns that proposed methods and site selection could adversely impact existing *O. mykiss* habitat by altering riffles and filling pools currently or potentially used by adult *O. mykiss* for holding, foraging, and spawning, and that the proposed implementation methods and sites may not provide a sufficient immediate benefit to Chinook salmon and *O. mykiss* spawning habitat. In response, the CRRF produced a map of *O. mykiss*

Table 14. Coarse sediment transfusion sites between La Grange Dam and Roberts Ferry Bridge, with prioritization and implementation phase.

Site No.[1]	Site Name[1]	Polygon Number(s)[2]	Approx. Corse Sediment Augmentation Volume (yd^3)	Revised Plan Priority	Recommended Phase	Prioritization Criteria: Increase in Chinook salmon and *O. mykiss* spawning area	Avoidance of impacts to existing *O. mykiss* habitat	Proximity to La Grange Dam	Potential to improve bedload transport continuity	Site access, logistics, and landowner willingness	Value for experimentation and learning
2	Riffle A5/6 La Grange Pool	5, 6, 7	17,284	High	III	●	●	●	●	●	●
10	Basso Pool	30, 31, 32, 33, 34, 35, 36	47,737	High	III	●	●	●/◉	●	●/◉	●
1	Riffle A3/4 Complex (*)	1, 2, 3, 4	8,300	High	III	●	◉	●	◉	●	●
6	Riffle 3A Complex (*)	21, 22, 23	20,000	High	III	●	◉	●	◉	●	●
14	Riffle 12 Complex (*)	46, 47, 48, 49	65,000	High	III	●	○	◉	●	●	●
22	FOT RM 43 Site (Bobcat Flat) (*4)	73, 74, 75, 76, 77, 78	15,350	Medium	III	●	◉	◉	○	●	◉
26	Riffle 24 (TLSRA) (*6)	82	2,000	High[5]	III	◉	◉	◉	○	●	●
29	Riffle 28B/Roberts Ferry Bridge Pool	88, 89, 90, 91, 92	44,443	High	IV	●	●	◉	●	●	●
13	Zanker Pool	42, 43, 44, 45	37,110	High	IV	●	◉	◉	●	●	●
27	SRP 4	83, 84, 85, 86	32,891	High	IV	●	●	◉	●	○	●
5	New La Grange Bridge Backwater (Riffle 1C) (*)	17, 18, 19, 20	27,000	Medium	IV	◉	◉	●	◉	●	●
8	Riffle 5A Complex[6]	26, 27	4,761	Medium	IV	●	◉	●	◉	●	◉
9	Riffle 5B Complex	28, 29	3,557	Medium	IV	●	◉	●	◉	●	◉
12	Riffle 8[6]	38, 39, 40, 41	9,369	Medium	IV	●	◉	◉	●	◉	●
18	FOT RM 44.5 Site (Riffles 16, 17A, 17D)6	58, 59, 60, 61, 62	34,656	Medium	IV	◉	◉	◉	○	●	◉
11	Riffle 7 Complex	37	2,878	Medium	IV	◉	◉	◉	○	◉	◉
19	RM 44 Pool	63, 64, 65, 66	15,505	Medium	V	●	●	◉	◉	◉	●
20	SRP 3	67, 68	20,912	Medium	V	●	●	◉	●	◉	◉
21	Riffle 18[6]	69, 70, 71, 72	20,802	Medium	V	●	◉	◉	◉	●	●
3	Riffle A7 Complex[3]	proposed: 8; completed: 9, 10, 11	3,774	Medium	V	○	●	●	◉	●	○
4	Riffle 1A/B Complex[3]	proposed: 12, 15; completed: 13, 14, 16	16,109	Medium	V	○	●	●	◉	●	○
15	Riffle 13 A/B Complex	50, 51	19,625	Medium	V	●	◉	◉	◉	◉	●
17	Riffle 14/15 Complex	53, 54, 55, 56, 57	28,709	Medium	V	●	◉	◉	◉	○	●
7	Riffle 4A Complex	24, 25	3,215	Low	VI	○	●	●	○	●	○
24	RM 42.4	80	5,004	Low	VI	●	◉	◉	◉	○	○
28	RM 40.5 Pool/Riffle 27	87	9,688	Low	VI	○	●	◉	◉	○	○
16	Riffle 13C and Backwaters	52	8,996	Low	VI	◉	◉	◉	○	○	○
23	Riffle 23A	79	5,163	Low	VI	○	◉	◉	◉	○	○
25	Riffle 23B	81	9,636	Low	VI	○	◉	◉	◉	○	○

LEGEND
● = high; ◉ = Medium; ○ = low

(*) Sites for which conceptual designs have been prepared (see Appendix B).

[1] See Figure 25 for site names and numbers.

[2] See Appendix D for polygon numbers.

[3] Sediment augmentation at these sites is partially complete. Priority ranking is for new work at these sites only.

[4] Conceptual designs for this site were developed under a separate contract with the Friends of the Tuolumne funded by the California Department of Water Resources.

[5] This project was elevated to high priority for the opportunity it provides for public education regarding coarse sediment augmentation and the need for such educational opportunities early in the implementation process.

[6] These projects occur in areas that have been identified as *O. mykiss* habitat (CRRF 2004). Project designs should include measures to protect cover features and pools downstream of

habitat in the lower Tuolumne River based on 10 years of hook-and-line and snorkel surveys (CRRF 2004). Site prioritization and augmentation methods were revised to avoid impacts to potential *O. mykiss* habitat identified by the survey and to increase the immediate benefit to Chinook salmon and *O. mykiss* by emphasizing creation of bars and riffles in long pool reaches. Prioritization criteria and their application to the projects are described in Table 15. The revised prioritization is shown in Table 14.

Table 15. Application of ranking criteria for coarse sediment transfusion sites.

Criterion	Ranking Definitions
Magnitude of increase in area of Chinook salmon and *O. mykiss* spawning habitat.	High: Creation of new pool tail-riffles in long pools, SRPs, and severely degraded riffles. Medium: Coarse sediment addition to existing riffles and pool tails. Low: Coarse sediment addition as point bars.
▪ Avoidance of impacts to existing *O. mykiss* habitat	High: No work in the "red boxes" identified by the CRRF (2004) survey. Medium: Work in the "red boxes" identified by the CRRF (2004) survey that preserves existing spawning riffles and downstream pools. Low: Work in the "red boxes" identified by the CRRF (2004) survey that substantially disturbs or eliminates existing spawning riffles and/or downstream pools and thus may result in short-term adverse impacts to *O. mykiss*.
Proximity to La Grange Dam	High: Upstream of Basso Bridge Medium: Between Basso Bridge and Roberts Ferry Bridge Low: Downstream of Roberts Ferry Bridge
Potential to improve bedload transport continuity	High: Construction of point bars and/or riffles through the entire length or a portion of the length of an identified bedload impedance reach (see Table 16). Medium: Construction of point bars and/or riffles in large pools, but not in identified bedload impedance reaches. Low: Expected to have a minor or no effect on sediment routing through existing pools and SRPs.
Site access, logistics, and landowner willingness	High: Access routes available with minor grading; agency landowner or landowner has expressed willingness to provide access and or other rights of way needed for project construction. Medium: Access routes available with moderate grading; private landowner willingness is not known. Low: Access difficult and requires major disturbance to existing resources; private landowner willingness not known and/or unlikely.
▪ The value of the site for experimentation and learning. ▪ [Note: This prioritization criterion addresses single sites only. It does not address combinations of sites.]	High: Provides potential to test physical and biological response hypotheses, such as hypotheses describing redd superimposition; spawning use of gravel placed through different methods, in different configurations, or having different textures; and sediment transport rates and thresholds. Provides good opportunity for public education. Medium: Provides limited capacity to test biological-response hypotheses due to low salmonid spawner utilization or other factors but provides opportunities to test physical-response hypotheses. Provides no or limited opportunity for public education. Low: Within the individual project, provides limited opportunity to test biological- or physical-response hypotheses due to limited size, poor location, or other factors. Provides no or limited opportunity for public education.

From the list of prioritized sites, we grouped all projects into a series of implementation phases (Tables 14 and 15, Figure 24). The CDFG projects at Riffle 1A/B and Riffle A7 constitute Phases I and II, which began in 1999 and were completed in 2003. Phase III includes six high priority projects and one medium priority project, as follows: Riffle A5/6 La Grange Pool (site 2), Basso Pool (site 10), Riffle A3/4 (site 1), Riffle 3A Complex (site 6), Riffle 12 Complex (site 14), FOT RM 43 (Bobcat Flat) (site 22), and Riffle 24 (TLSRA) (site 26). Phase IV includes three high priority projects and six medium priority projects, as follows: Riffle 28B/Roberts Ferry Bridge Pool (site 29), Zanker Pool (site 13), SRP 4 (site 27), New La Grange Bridge Backwater (Riffle 1C) (site 5), Riffle 5A Complex (site 8), Riffle 5B Complex (site 9), Riffle 8 (site 12), FOT RM 44.5 Site (Riffles 16, 17A, 17D) (site 18), and Riffle 7 Complex (site 11). Phase V includes seven medium priority projects, as follows: RM 44 Pool (site 19), SRP 3 (site 20), Riffle 18 (site 21), Riffle A7 Complex (site 3), Riffle 1A/B Complex (site 4), Riffle 13 A/B Complex (site 15), and Riffle 14/15 Complex (site 17). Phase

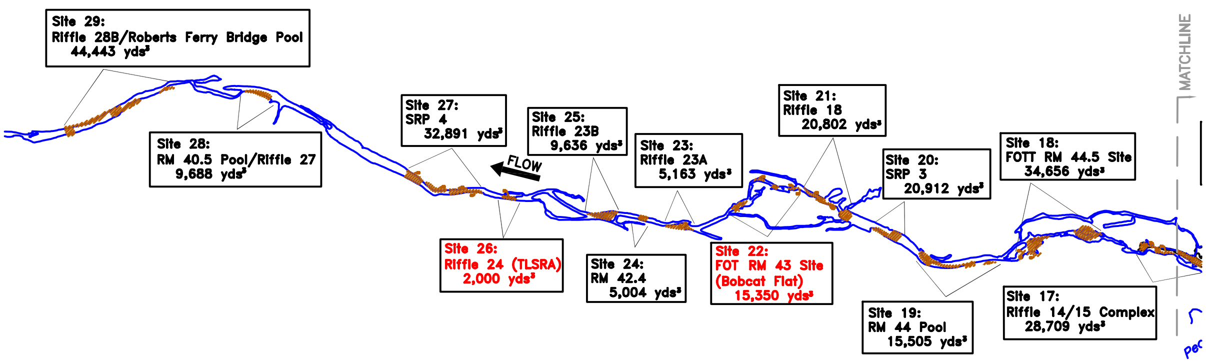


Figure 24. Proposed coarse sediment transfusion sites in the upper spawning reaches of the Tuolumne River. Sites in red are high priority sites proposed for the Phase III of sediment transfusion. All volumes are approximate.

VI includes six low priority projects, as follows: Riffle 4A Complex (site 7), RM 40.5 Pool/Riffle 27 (site 28), Riffle 13C and Backwaters (site 16), Riffle 23A (site 23), RM 42.4 (site 24), and Riffle 23B (site 25).

5.2.2 Coarse Sediment Augmentation Methods

Several different methods for sediment placement are proposed, the selection of which depends on the augmentation site morphology and site objectives. Augmentation sites were selected based on their initial spawning habitat suitability, as described in the previous section, but because each site has its own unique hydraulic and geomorphic setting, sediment should be placed in the channel in a manner consistent with the site's unique setting. Four sediment augmentation methods are recommended, each having unique benefits and limitations. The fourth method (Method 2C) was added after review of the November 2003 version of this Plan.

5.2.2.1 Method 1: High Flow Recruitment Pile

This method places a quantity of coarse sediment at or near the channel margin or to supplement a gravel bar where it is then available for downstream transport by high flows (Figure 25). The primary advantage to this method is the relative ease to implement annual augmentation. This method can be implemented any time of the year. Where the recruitment pile location is readily accessible, placing a recruitment stockpile can reduce project costs and vegetation removal for access. The main benefit of this method is that it reduces the need for heavy equipment working in the low-flow channel and thus minimizes the risk of adverse impacts to existing salmonid habitat.

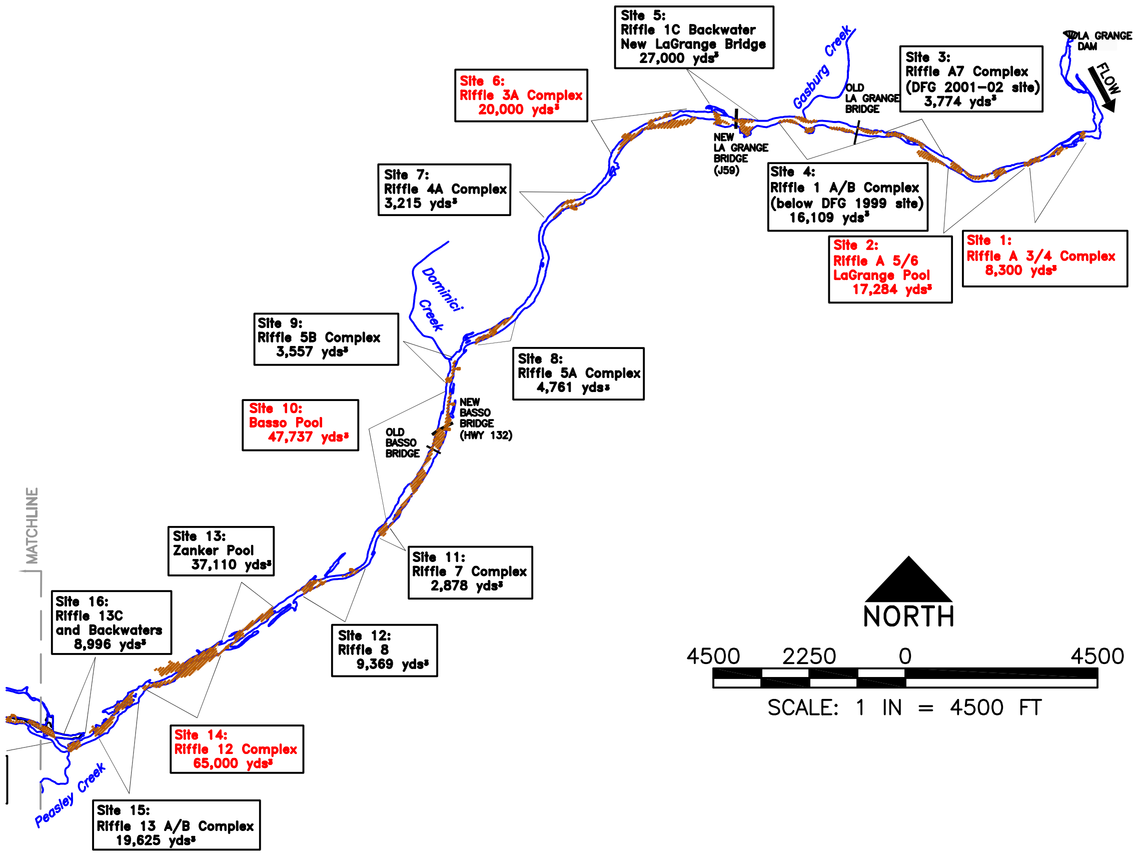


Figure 24. Continued.

The primary drawback to this method is that it is indirect, such that in the absence of high flow releases at La Grange a lengthy period of time may pass before the sediment is recruited and redeposited downstream as usable habitat. Additionally, flows exceeding bed mobility thresholds generally occur during events of short duration (days), followed by long periods (months or years) in which bedload transport thresholds are not exceeded. Although the recruitment stockpile method provides some benefit in the long-term once it is distributed into the stream by high flows, it often does not maximize the benefits of coarse sediment augmentation in the short-term, potentially requiring several years before providing usable salmonid habitat. The Western Shasta Resource Conservation District (2000) has been implementing this method for several years below Whiskeytown Dam on Clear Creek, near Redding CA (Figure 26). If funding is limited, implementation during Phase III should focus on sites upstream of Basso Bridge, with the exception of the FOT RM 43 (Bobcat Flat) (site 22) project which will be implemented in 2004 and/or 2005.

5.2.2.2 Method 2: In-river Gravel Placement

This approach places coarse sediment directly into the channel to augment or create riffles, pools tails, and point bars, thus creating or improving habitat features immediately usable for salmonids and introducing coarse sediment into the channel for future routing (Figures 26 and 27). Three in-river augmentation methods are proposed: riffle-pool tail supplementation (Method 2A), point bar supplementation (Method 2B), and riffle-pool tail-point bar creation in long pool reaches (Method 2C). During implementation of these methods, existing habitat features that support salmonid spawning (such as spawning substrates and in-channel and overhead cover) will be either preserved or reconstructed so that habitat benefits are realized as expeditiously as possible and to avoid adverse impact to existing habitat.

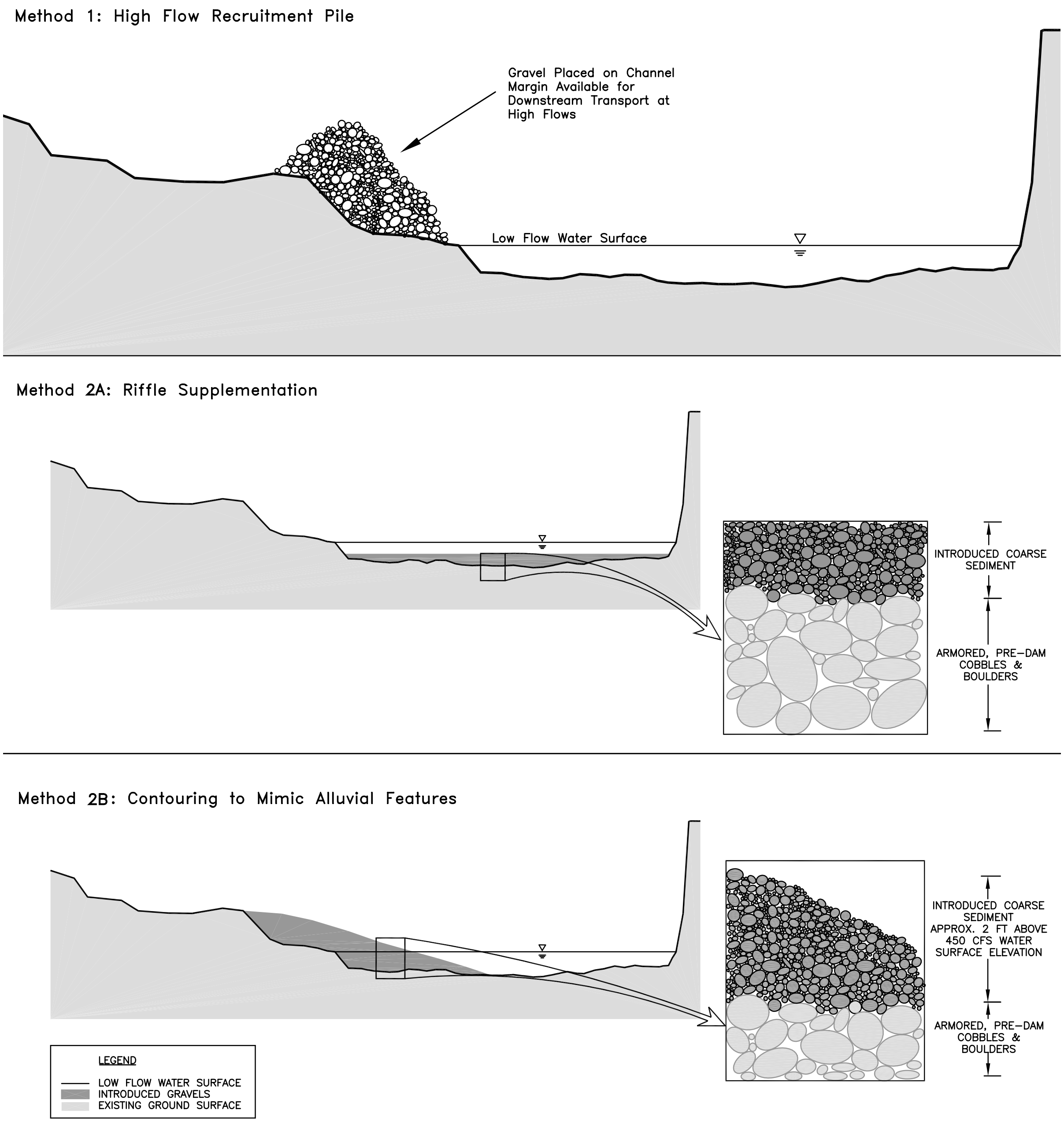


Figure 25. Suggested coarse sediment augmentation methods to address different channel conditions, Methods 1, 2A, and 2B.

Figure 26. Coarse sediment introduction below Whiskeytown Dam on Clear Creek, near Redding CA, using the high-flow recruitment method, with gravel end-dumped from the hillside above. The top photo is from April 2000. The bottom photo, from May 2003, shows most coarse sediment having been mobilized during intervening high flow releases from Whiskeytown Dam.

The primary advantage of direct in-river placement is that it simultaneously increases sediment supply to the river, while immediately providing usable habitat for salmonids and other biota. The potential drawback of this method is that it is difficult to construct or preserve all of the important habitat features required by salmonids, such as deep water, surface turbulence, and/or bankside riparian vegetation, at highly manipulated construction sites. For example, bankside vegetation often must be removed to access the channel, existing spawning substrates may be compacted or buried during construction, or newly added substrates may require time to "season" before they become attractive to spawning salmon.

Method 2A: Riffle-Pool Tail Supplementation

Riffle-pool tail supplementation places coarse sediment directly over existing riffle-pool tail units to increase their length and restore sediment to a more suitable size for spawning (Figure 25). This method assumes that the river will transport and reshape the sediment, particularly from the riffle tails, into other alluvial deposits (e.g., building alternate bars, riffles, and pools) during high flow events while temporarily providing usable habitat for salmonids at the pool tailouts and riffle heads. The primary advantage of this method is that adding a relatively small volume of gravel can greatly increase the quantity and quality of immediately usable habitat. Moreover, instead of requiring time for introduced sediment to route downstream, the coarse sediment storage in the channel is immediately replenished at spawning depositional features and is usable to spawning salmonids. As stated above, however, this method presents a risk of degrading existing habitat if: (1) the newly added substrate is an unsuitable source or size for spawning, or (2) cover is reduced by filling of pools or removal of bankside vegetation.

Method 2B: Point Bar Supplementation

This method would contour the bed using the introduced coarse sediments to augment or create point bars in sediment-depleted reaches to mimic or enhance natural alluvial features (Figure 25). Augmentation would be accomplished using site-specific low-flow and bankfull channel dimensions measured from sites that have re-adjusted their channel dimensions to contemporary flow conditions. This method provides the benefit of creating a more functional channel morphology that immediately enhances habitat suitability for aquatic biota. It also poses minimal risk to the existing habitat.

Coarse sediment introduction at point bars could potentially be done in a way that prevents heavy equipment from entering the low-flow channel but must be evaluated at each site. Additionally, the volume of sediment introduced could be slightly exaggerated (oversupplied) because excess coarse sediment can be routed to downstream sites to improve storage. A final benefit is in the aesthetic appearance of the channel at these introduction sites, which would be designed to resemble a natural alluvial channel. An excellent example of this method is the sediment placed as a left bank bar at Riffle 1A below Old La Grange Bridge by CDFG in 2002.

Method 2C: Riffle-Pool Tail-Point Bar Creation in Long Pool Reaches

This method is similar to Methods 2A and 2B but would introduce coarse sediment to create riffles, pool tails, and point bars in long pool reaches where salmonid habitat is currently very limited (Figure 27). This method could be implemented by recreating riffle-pool tail units alone or in combination with point bars to recreate an appropriately scaled alternate bar morphology in the augmentation reach using site-specific low-flow and bankfull channel dimensions measured from sites that have re-adjusted their channel dimensions to contemporary flow conditions. This method would greatly increase habitat immediately usable by salmonids in areas with little to no salmonid habitat, while avoiding potential adverse impacts to existing habitat. Additionally, by recreating a more natural pool-riffle sequence within the long pool, coarse sediment routing continuity between reaches

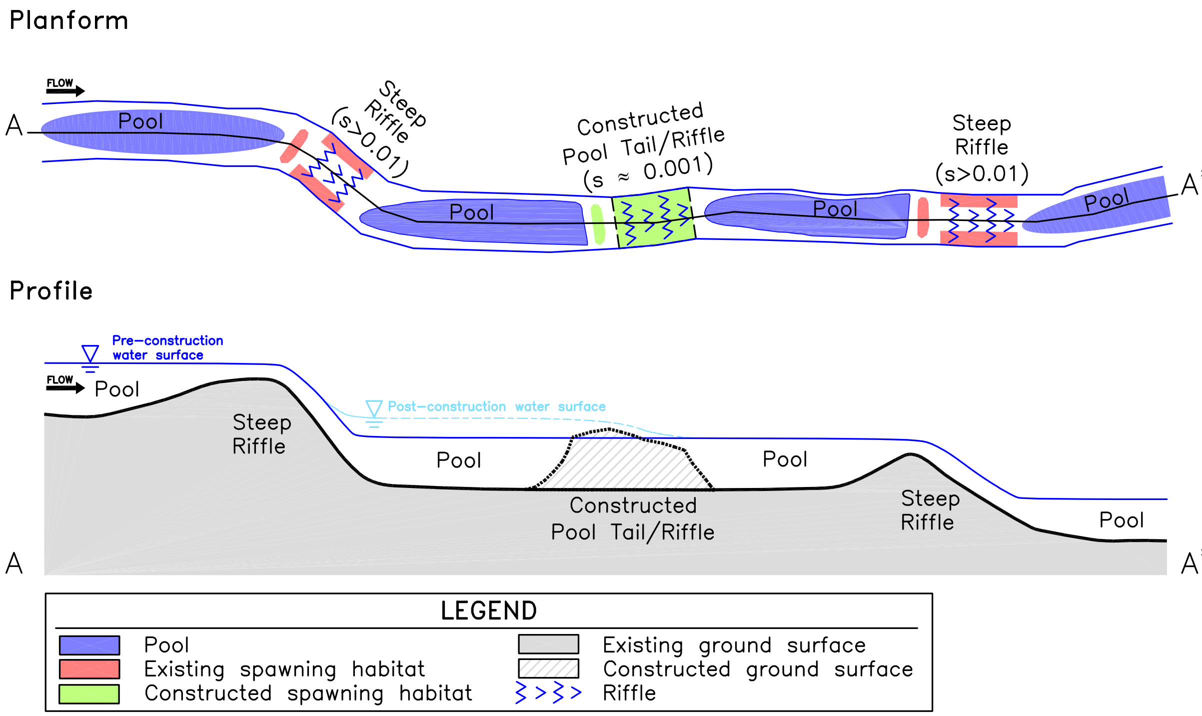


Figure 27. Suggested coarse sediment augmentation methods to address different channel conditions, Method 2C.

would be quickly restored. The primary drawback is that a large volume of coarse sediment would be required to construct these projects, which may be difficult to locate and/or transport to the project site and which greatly increases project costs.

5.2.3 Conceptual Designs for Five Transfusion Sites

Based on feedback received from the TRTAC and included in the November 2003 version of this Plan, conceptual designs were developed for five sites that, at the time, were considered to be high priority. These sites were as follows:

- Riffle A3/4 at the top of the spawning reach below La Grange Dam;
- Riffle 1C under the New La Grange Bridge;
- Riffle 3A just downstream of New La Grange Bridge at the site of the former haul road crossing;
- Riffle 12 near the Zanker Ranch that was heavily altered by the 1997 flood; and
- Riffle 24A at Turlock Lake State Recreation Area.

As part of a previously funded restoration project, conceptual designs were also developed for the FOT RM 43 site (Bobcat Flat). Of sites for which conceptual designs have been developed, Riffle A3/4, Riffle 3A, Riffle 12, and Riffle 24A remain high priority. The FOT RM 43 project was ranked as medium priority but is included in Phase III because it is funded for implementation and offers important opportunities for learning and experimentation. Riffle 1C was ranked as medium priority and is included in Phase IV.

Conceptual designs are presented in Appendix B, and the sites and designs are described below. These designs are conceptual only. The intent of the conceptual designs is to depict locations and methods of coarse sediment augmentation, identify potential access routes, and provide preliminary estimates of the volume of coarse sediment needed to complete each project. Two-dimensional designs, three-dimensional grading plans, final access routes, and final excavation and fill volumes will be developed during the final design phase. The final design process is described in Section 5.2.4. Descriptions of riffles, sediment augmentation sites, coarse sediment introduction polygons, and longitudinal stationing refer to Figure 11, maps presented in Appendix D, and the site designs presented in Appendix B.

Site 1: Riffle A3/4 Complex (RM 51.3 – 51.8): This riffle/bar complex is the upstream limit of the sediment management program; the large corner pool farther upstream of this site (Stn 2850+00) is more than 25 ft deep, would require enormous volumes of sediment to fill, and would capture all coarse sediment placed upstream and routed down to this pool during high flows. We recommend that coarse sediment not be placed upstream of this pool. Spawning habitat has been severely depleted at Riffle A3/4 in recent years. The 1988 riffle survey estimated approximately 22,500 ft^2 of riffle area at this site. The 2000 survey documented 11,800 ft^2 of riffle area (a 48% reduction), of which 3,700 ft^2 were estimated to be suitable for Chinook salmon spawning. Riffle A3/4 is recommended as a high priority site for short-term and long-term coarse sediment augmentation.

We recommend placing approximately 19,300 cu yds of coarse sediment along this 1,600-ft reach as part of the short-term transfusion, as follows:

- add 1,600 cu yds of coarse sediment to augment the existing pool tail at the upstream end of the site (Stn 2847+75 to Stn 2846+75);
- stockpile 300 cu yds of coarse sediment at the upstream end of the medial bar (Stn 2847+00 to Stn 2846+00);
- add 2,000 cu yds of coarse sediment to create a point bar on the left (south) bank (Stn 2842+00 to Stn 2837+00);
- add 4,400 cu yds of coarse sediment to create pool tail and riffle (Stn 2386 +00 to Stn 2382+00);
- 9,000 cu yds of coarse sediment for additional stockpile material; and
- 2,000 cu yds of coarse sediment for a 25% contingency.

The surrounding property belongs to the Turlock Irrigation District (TID); the site could be developed to create a large coarse sediment stockpile area on the south hillside next to the road. Access to the site could be provided via an existing access road on the south bank. The existing road would require minor grading and vegetation removal for trucks and coarse sediment placement equipment to access the river. Sediment augmentation would increase spawning habitat in the upstream pool-tail (at XS 2847+00) and would provide coarse sediment that would route to the downstream portion of the riffle in both north and south split channels..

Site 5: Riffle 1C (RM 49.9 – RM 50.1): Riffle 1C, formerly directly under the New La Grange Bridge, was scoured and depleted of most coarse sediment during the 1997 flood. Very little spawning habitat remains. We recommend placing approximately 33,700 cu yds of coarse sediment at this site, as follows:

- add 11,000 cu yds of sediment to fill a mining pit on the south bank of the channel (Stn 2764+00 to Stn 2760+00);

- add 14,000 cu yds of coarse sediment to create alternate point bars on the north bank upstream of the New La Grange Bridge and on the south bank downstream of the bridge (Stn 2765+00 to Stn 2754+00);
- add 2,000 cu yds coarse sediment to create one pool tail at Stn 2761+50 to Stn 2760+50 and augment one pool tail at the upstream end of Riffle 2 (Stn 2755+25 to Stn 2753+50); and
- 6,400 cu yds of coarse sediment for a 25% contingency.

The point bars created upstream and downstream of New La Grange Bridge will provide fry rearing habitat, as well as a future source of coarse sediment for downstream routing. The pool tails would provide area for salmonid spawning. The project would preserve the much of pool under the bridge, as well as Riffle 1B located upstream. The overall channel gradient at this site, measured by water surface slope, limited the amount of spawning habitat that could be created here. Slope could be improved by lowering the riffle crest at Riffle 2, but this is not recommended. Site access is good via State and County owned properties on north and south banks.

Site 6: Riffle 3A Complex (RM 49.2 – RM 49.6): The Riffle 3A area contains in-channel rip-rap, grade control boulders, and remnant bridge abutments (concrete and metal debris) that were part of the gravel haul road and bridge used to transport reclaimed dredge tailings to the New Don Pedro Dam construction site in the late 1960s. This material has caused a deep pool to scour upstream of Riffle 3A, degraded Riffle 3As morphology, and reduced the spawning habitat availability at this riffle. In addition, the left bank floodplain has a low-flow scour channel that reduces channel confinement and may contribute to fry and juvenile salmon stranding. Downstream of Riffle 3A, 300 feet of the right bank were severely eroded during the 1997 flood, leaving an overly-wide channel cross section (Figure 12). In general, bank erosion should be encouraged as a natural process, but without adequate coarse sediment to deposit and maintain low-flow confinement, the resulting channel has become a large pool with no spawning habitat. This site is also the only significant bedload impedance site between the Old La Grange Bridge and Riffle 5B. Restoring sediment storage at this site would restore bedload transport continuity for 2.9 miles from Old La Grange Bridge nearly to Basso Bridge.

We recommend removing the concrete rubble, the old bridge sheet-piling abutments, and other debris, then placing approximately 25,000 cu yds of coarse sediment at this site, as follows:

- add 5,000 cu yds of coarse sediment to create two pool tails and riffles (Stn 2740+00 to Stn 2732+00);
- add 15,000 cu yds coarse sediment to create alternate point bars on the north and south banks (Stn 2745+00 to Stn 2734+00;
- (potentially) add coarse sediment to fill the left bank scour channel at the upstream end of the site (polygon 22); and
- 5,000 cu yds of coarse sediment for a 25% contingency.

The project would preserve the majority of the long pool located between Riffle 3A and Riffle 3B. The south bank parcel belongs to Stanislaus County. Access to the site is good from J59 near the Hwy 132 intersection. Riparian vegetation on the south bank of the project site provides important cover for salmonids (Steve Walser, pers. comm. 2004). Impacts to riparian vegetation should be avoided and minimized during construction of this project.

Site 14: Riffle 12 Complex (RM 45.7 - 46.0): This site is the most complex of the coarse sediment augmentation sites due to the large-scale channel alterations caused by the January 1997 flood. During the flood, a new channel was cut behind the left bank bar, forming a medial bar. The right bank bar was also scoured, and a large 5-6-foot deep backwater area formed. The prior location of the channel is plugged by a large lobe of sediment, and flow now passes through thick vegetation and a steep run that provides no usable spawning habitat. This project would require on-site excavation of approximately 10,000 cu yds, followed by a large volume of coarse sediment fill.

We recommend the alternate bar morphology be reconstructed by placing approximately 65,000 cu yds of coarse sediment (plus a 16,000 cu yd contingency) at this site, as follows:

- excavate fluvial deposits and place fill to re-create the pre-1997 channel alignment;
- add fill to create a point bars; and
- 16,000 cu yds of coarse sediment for a 25% contingency.

Construction impacts to riparian vegetation at the site should be avoided and minimized, and the restored floodplains should be re-vegetated with native riparian vegetation. This project will restore approximately 1,000 linear feet of new riffle by redistributing the existing slope.

Site 22: FOT Bobcat Flat Site (RM 43): This project is one of ten priority projects developed for the Tuolumne River by the TRTAC under Article 12 of the 1995 FSA. The project has been funded by the Department of Water Resources Delta Fish Protection Agreement and is administered by TID. The 300-acre floodplain parcel adjacent to the project site is owned by FOT, which plans to restore floodplain and riparian habitat functions at the site.

The in-channel coarse sediment augmentation portion of the project includes 15,300 cu yds of coarse sediment be added to this site, as follows:

- add 400 cu yds of coarse sediment to create a riffle and 800 cu yds of coarse sediment to create a point bar on the right bank at Riffle 20;
- add 2,000 cu yds of coarse sediment to create new riffle between Riffles 20 and 21;
- add 4,400 cu yds of coarse sediment to create point bar on the right bank downstream of Riffle 20;
- add 5,000 cu yds of coarse sediment to create point bar on the right bank downstream of Riffle 21;
- add 2,750 cu yds of coarse sediment to create new riffle downstream of Riffle 20;

Additional floodplain restoration would include grading of a high flow scour channel, floodplain, and terrace, which would require 37,900 cu yds of excavation and 7,500 cu yds of fill. The 25% fill contingency for the project would be 5,650 cu yds.

This project would rehabilitate salmonid spawning and rearing habitat by adding coarse sediment at six locations at Riffles 20 and 21. Specific objectives of the project are to: (1) add approximately 10,000-15,000 cu yds of coarse sediment at several location in the 2,000-foot project reach to reduce riffle slope and particle size within spawning riffles, and thus increase the quality and quantity of a variety of habitats available for salmonids; (2) implement experiments comparing different methods of coarse sediment placement to evaluate relative use of salmonid spawning, rearing, and holding habitats created by the project and to compare this project to upstream coarse sediment augmentation sites; and (3) demonstrate the feasibility, benefits, and cost-savings of producing coarse sediment augmentation material on-site. Access to this site would be via the FOT property. Minor grading and vegetation removal would be required to construct the access road.

Site 26: Riffle 24 (RM 41.8): Riffle 24 was selected because it has public access within a relatively long reach (RM 39.4–43.0) that otherwise would not receive coarse sediment augmentation in the near future. Access is via Turlock Lake State Recreation Area. Coarse sediment augmentation at this site would not only increase spawning gravel availability and quality but would also route sediment downstream to the next augmentation site at Roberts Ferry Bridge. This site was also suggested by the TRTAC as an interpretive site to allow public access to view spawning gravel restoration methods.

We recommend that 2,000 cu yds of coarse sediment be added to this site at polygon 81 to enhance existing run habitat at Riffle 24 and provide coarse sediment supply for downstream transport. The 25% coarse sediment contingency is 500 cu yds.

5.2.4 Developing Final Designs

Designs presented in Appendix B and coarse sediment augmentation locations presented in Appendix D are conceptual only and are intended to identify potential fill placement locations, potential access routes, fill placement methods, and preliminary fill volume estimates. Prior to project implementation, final designs must be developed for each site and approved by the TRTAC and property owner. These final designs should include experimental treatments to test the effectiveness of different restoration methods and the importance of various habitat features. The designs should also provide detailed information on existing habitat conditions at each site, final fill placement methods and locations, detailed microhabitat conditions to be created at the site, and final access and other construction features. Moreover, during implementation, we strongly recommend that a highly qualified fisheries biologist familiar with Chinook salmon and *O. mykiss* habitat requirements and reproductive behavior, as well as construction management and heavy equipment operation, and approved by the TRTAC be present on-site and work with the construction managers to direct equipment operators to ensure that impacts to existing habitat features are avoided and habitat improvements resulting from the augmentation project are realized. Implementation should be consistent with designs and specifications but could include additional micro-topographic features, avoidance of specific cover features, protection of pools downstream of existing and constructed riffles, and other measures. The protective actions will be particularly important at riffles 5A, 8, 17A, 18, and 24 where important existing habitat for *O. mykiss* was identified by CRRF (2004).

Creating final designs for coarse sediment augmentation projects requires a collaborative approval process with the TRTAC and property owners of the project site and access routes. Steps that should be followed for developing final designs are as follows:

(1) survey the project site topography to obtain a DTM of the existing channel bed and floodplain conditions and conduct detailed habitat mapping to identify or confirm existing Chinook salmon and *O. mykiss* spawning, holding, and foraging habitat conditions;

(2) develop a 2-dimensional planform conceptual design superimposed over an aerial photograph that specifies existing meso-habitat units and microhabitat features; locates cross sections, access roads, and other essential features of the project; and delineates coarse sediment sources and areas where placement is recommended;

(3) submit this 2-dimensional conceptual design along with a technical memorandum describing the project and design analyses to the TRTAC, the site property owner(s), and other appropriate parties for review;

(4) based on review comments, make necessary revisions and adjustments to the proposed design, until approved by the TRTAC and property owner;

(5) develop the final project design, including floodplains and scour channels appropriate to the overall project, with channel design contours (3-dimensional), coarse sediment placement methods, particle composition specifications, coarse sediment sources, access, and final coarse sediment cut and fill estimates.

Final designs should include efforts to create surface turbulence at *O. mykiss* spawning areas. Where possible, projects should include provisions for providing cover through preservation and planting of riparian vegetation and other methods approved by the regulatory agencies. Final designs should also include measures to avoid or minimize impacts to riparian vegetation at the project sites and along access routes to the maximum extent possible while accomplishing project objectives. Particular care should be given to protecting large trees that provide shade, cover, or other habitat values. On-site supervision by a qualified biologist should also help ensure that impacts to riparian vegetation are avoided or minimized.

5.3 Long-term Sediment Augmentation

5.3.1 Overview

One of the highest priority strategies for restoring and managing coarse sediment storage on the Tuolumne River will be to establish a program to routinely add sediment to the river to maintain coarse sediment supply as sediment is routed downstream during future high flows. This long-term strategy is essential to compensate for the sediment trapped by dams (and therefore prevented from routing downstream) and to maintain alluvial features and spawning habitat downstream of the dam. Equally important, this strategy will promote dynamic fluvial processes.

The primary objective of long-term sediment augmentation is to maintain coarse sediment storage by adding a volume of coarse sediment that is equivalent to the volume transported downstream during high flows. An example of this strategy would be to place a known volume of sediment (e.g., 10,000 cu yds) as a recruitment pile at the low water edge. Subsequent high flows would mobilize and transport some or all of this supply downstream, depositing the sediment as new gravel bars and riffles. The following year, the recruitment pile would be replenished up to the pre-existing 10,000 cu yds. Downstream cross section and longitudinal profile surveys would monitor trends in bed aggradation and degradation to best assure that equilibrium is maintained (i.e., too much or too little gravel isn't being placed into the channel).

In addition to periodically adding coarse sediment, another important objective of long-term augmentation is to gradually reduce the particle size distribution and re-size the bankfull channel to that appropriate to the post-dam flow regime. This would mobilize sediment more frequently and at slightly lower peak flows. Restoring coarse sediment supply and reducing particle size would help recover fluvial processes (sediment transport, channel migration, floodplain inundation). Recommended particle size mixtures are discussed in Section 5.5.

Introducing coarse sediment with a smaller diameter than the existing particle size distribution will increase the frequency of bed mobilization and sediment transport rates. Sediment modeling suggests that fining of the bed texture could increase transport rates by an order of magnitude, based on model runs using the finest bed texture observed in the field (which is slightly coarse than the recommended augmentation texture) (Table 8). While this may initially require more sediment introduction, we hypothesize that this process will reach equilibrium, imposed by the transport capacity of the regulated flow regime. In other words, while the particle size may be smaller, the introduced coarse sediment will still require high flows (exceeding at least 4,500 cfs) to mobilize, and these flows have a relatively predictable frequency under the regulated flow regime. Currently, the threshold for bed mobility is between 5,500 and 8,000 cfs, which have recurrence intervals of 3 to 5 years. The goal developed in the Restoration Plan is to reduce the particle size distribution, increase sediment supply, and reduce the bankfull channel dimension so coarse sediment is mobilized at flows ranging from 4,500 to 5,500 cfs. If periodic flood control releases were modified to achieve slightly higher peak magnitudes, as recommended in the Restoration Plan (pp. 110-112), the recurrence interval for this flow range would be 1.8 to 2.6 years.

An important long-term goal of the sediment augmentation program is to restore bedload transport continuity to large sections of the gravel-bedded reach below La Grange Dam until only augmentation at the top of the gravel-bedded reach at Riffle A3/4 is needed. Long-term coarse sediment augmentation should initially include several locations where coarse sediment is introduced periodically to re-supply discrete reaches isolated by large bedload impedance reaches. There are nearly five miles of pool habitat between La Grange Dam and Roberts Ferry Bridge (Table 16). These bedload sinks capture coarse sediment transported from upstream reaches and inhibit transport continuity to downstream reaches until storage in the entire sink is filled. Sediment sinks in the river will require considerable time to fill to allow full sediment routing throughout the Tuolumne River corridor. With an average width of 150 ft and an estimated depth of fill of 6 ft, these pools would require as much as 860,000 cu yds of sediment to fill in and begin routing sediment. This length of channel has a potential capacity of as much as 770,000 ft^2 of spawning habitat, using the average of 30 ft^2/linear foot of channel. As continuity is restored, intermediate sites of long-term sediment augmentation would be discontinued. This goal will likely require 10–20 years, depending on the availability of funding and the time required to construct individual projects.

Table 16. Bedload impedance reaches identified in the gravel-bedded zone between La Grange Dam and Roberts Ferry Bridge. Stationing refers to habitat maps in Appendix D.

Pool Location	Downstream Station	Upstream Station	Length (ft)	Potential Spawning Habitat (based on 30 ft^2/ft)
La Grange Pool	2804+00	2842+00	3,800	114,000
Basso Bridge Pool	2618+00	2660+00	4,200	126,000
Zanker Pool (Riffle 12)	2555+00	2600+00	4,500	135,000
Peasley Creek Pool	2505+00	2536+00	3,100	93,000
SRP-3	2425+00	2447+00	2,200	66,000
SRP-4	2289+00	2328+00	3,900	117,000
Roberts Ferry Bridge Pool	2208+00	2250+00	4,200	126,000
SRP-5	RM 32.9	RM 33.4	2,640	79,200
SRP-6	RM 30.2	RM 30.9	3,696	110,880
SRP-7	RM 27.9	RM 29.4	7,920	237,600
SRP-8	RM 26.1	RM 27.5	7,392	221,760
SRP-9	RM 25.7	RM 25.9	1,056	31,680
SRP-10	RM 25.2	RM 25.5	1,584	47,520
TOTAL			50,188 [9.5 MILES]	1,505,640

5.3.2 Long-term sediment augmentation sites

Several sites are recommended for long-term coarse sediment augmentation (Figure 28). These sites are preliminary, and may be revised as the sediment transfusion phase is implemented and the results of monitoring suggest better strategies and locations for periodic coarse sediment augmentation.

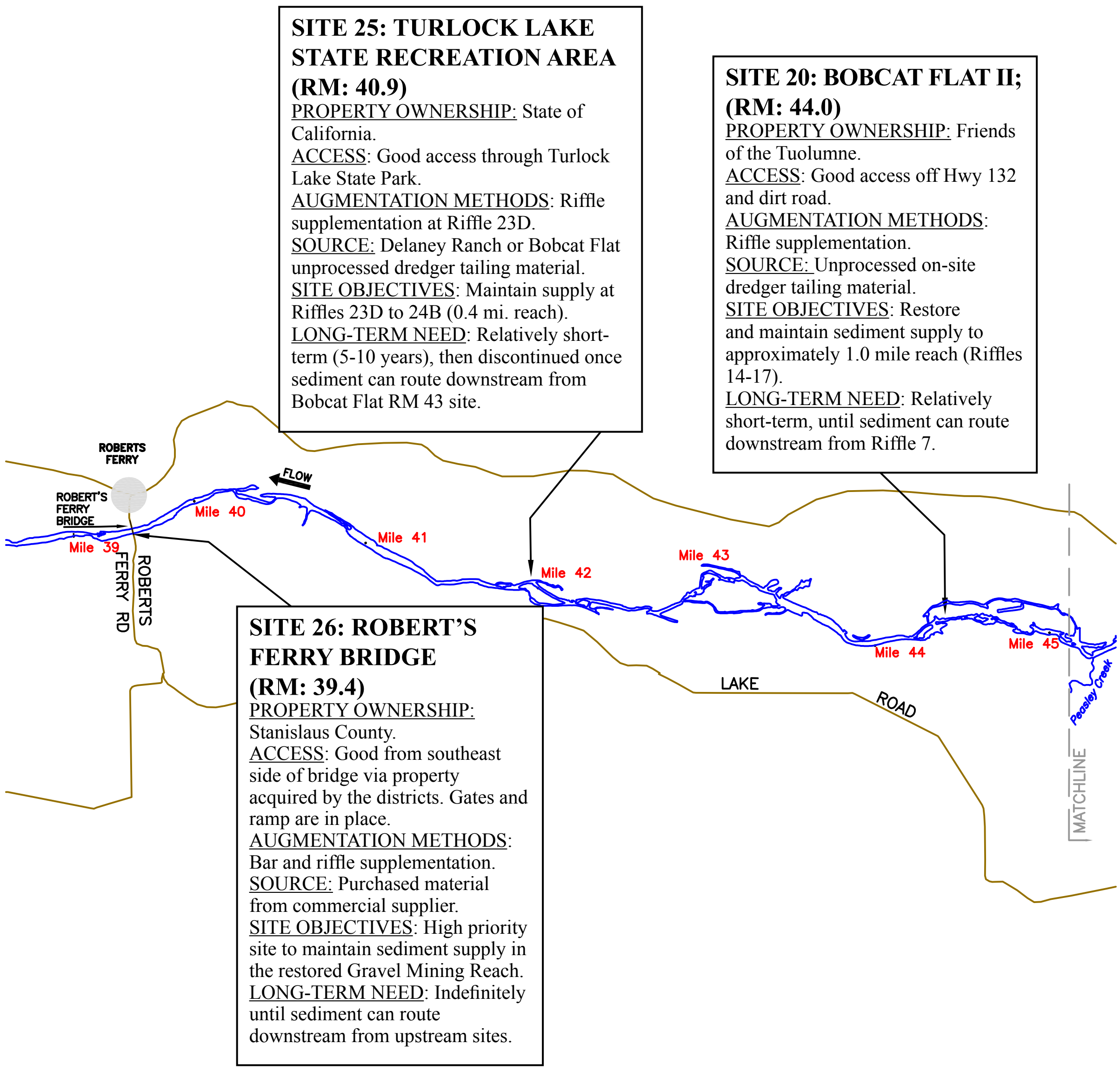


Figure 28. Coarse sediment augmentation sites along the upper spawning reaches of the Tuolumne River proposed for periodic augmentation on a long-term basis.

<u>Site 1: Riffle A3/4 and A5/A6 (RM 49.8)</u>: These sites provide ideal conditions for implementing long-term sediment augmentation, with adequate space to stockpile large volumes of sediment, relatively good access to the river, property ownership by TID and/or Modesto Irrigation District (MID), and an ideal location near the top of the river. The pool downstream of Riffle A3/4 will continue to be a substantial bedload sink. As a long-term augmentation site, we recommend sediment be placed at the upstream pool-tail at the head of Riffles A3/4 to be available as immediately usable spawning gravels. The upstream insertion site can be accessed by crossing the river onto the

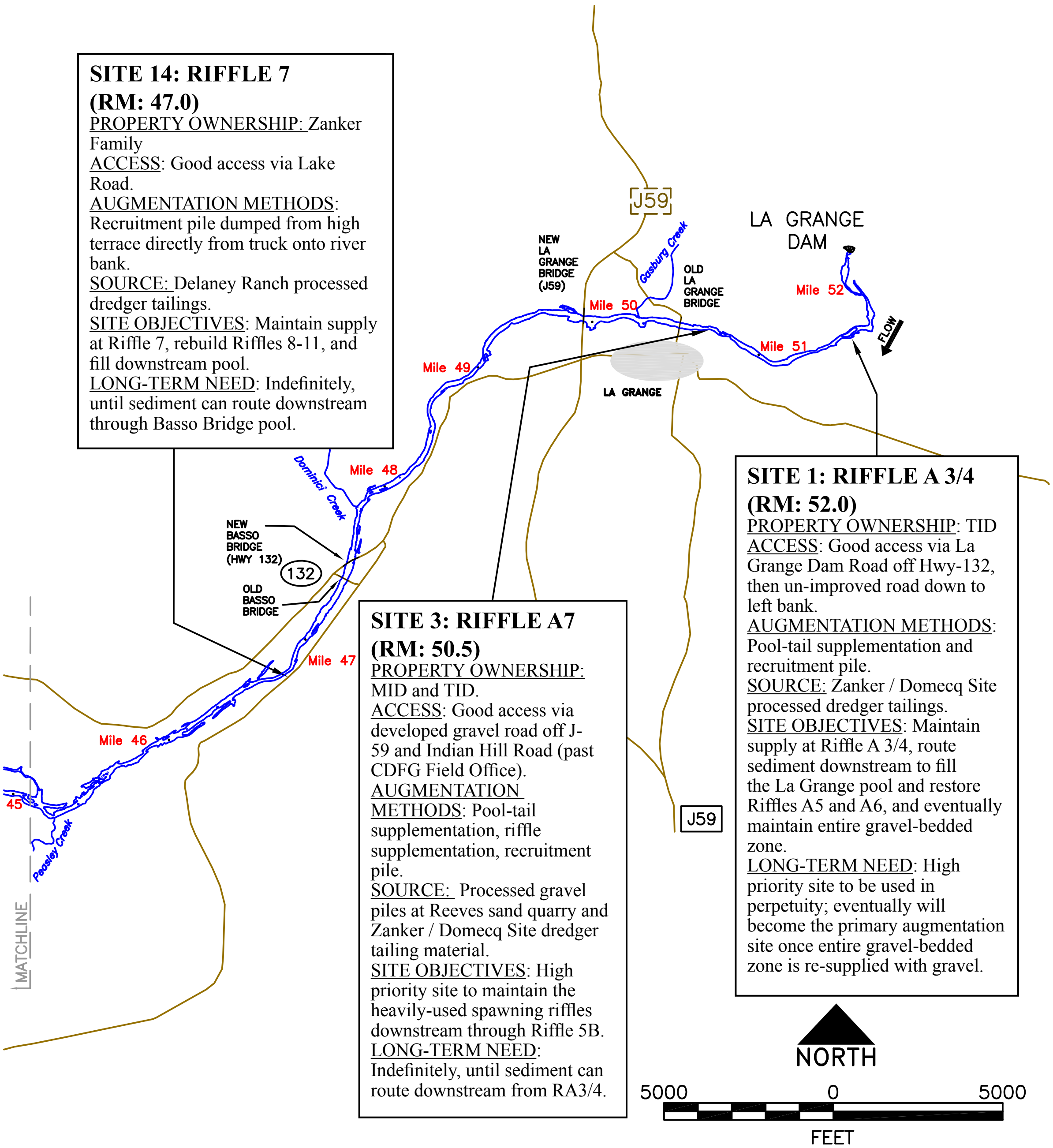


Figure 28. Continued.

medial bar at low streamflows by tractor-loader. The ultimate goal of coarse sediment management is to restore coarse sediment supply until only this site is needed for sediment augmentation (i.e., coarse sediment inserted here can route downstream). This goal necessitates planning for periodic augmentation in perpetuity by stockpiling cleaned spawning gravels and maintaining access from stockpile to insertion points. This site will be required in perpetuity. As an alternative, this long-term augmentation site could be shifted downstream to Riffle A5/6 once the A5/6 project is constructed. The Riffle A5/6 site can be accessed by improving an existing road on the north side of the channel. Use of the Riffle A5/6 site could reduce transport costs for the long-term sediment augmentation stock pile. Periodic augmentation on a smaller scale would continue to be required at Riffle A3/4.

Site 3: Riffle A7 (RM 50.7): In the next five to ten years, this site will be the most important sediment augmentation site due to its strategic location at the upstream end of the dominant spawning reach. This reach (from Riffle A7 to 5B) still has relatively good bedload transport continuity. Insertion at this site will therefore supply coarse sediment to the most highly used and best quality spawning riffles from Riffle A7 to 5B (2.8 miles). Augmentation at this site will be necessary until the Riffle A5/6 project is constructed. Several methods can be implemented here, including supplementing the large left bank gravel bar, inserting spawning gravel onto the pool-tail at the upstream end of the riffle, and placing a recruitment pile on the right bank bedrock.

Site 11: Riffle 7 (RM 46.5-47.0): This high priority site is located just downstream of the large Basso Bridge pool that will effectively trap all bedload transported from upstream for many years, until projects to improve sediment routing are constructed. This site will therefore maintain sediment supply to the upstream portion of the Dredger Reach, contribute to rebuilding Riffles 9 through 11 that were scoured away in the 1997 flood, and eventually provide sediment supply to Riffles 12 and 13 down to RM 45.5 near Peasley Creek. The best location for this site is at the upstream end of Riffle 7, though this location may be difficult to access. An alternative site is at the downstream end of Riffle 7 where the river is only approximately 100 ft from Lake Road. With direct access off Lake Road, coarse sediment could be end-dumped from the terrace to form a coarse sediment recruitment pile down the bank and into the channel. Coarse sediment placed here would be readily mobilized because of the high gradient along this bank. Augmentation at this site will be necessary until the upstream Basso Bridge pool allows sediment to route through Riffle 5B. Access to this site is via private property.

Site 22: Bobcat Flat Restoration Site (RM 43.0): The Bobcat Flat RM 43 site is a proposed restoration project site, with FOT as the project proponent. This reach provides limited but valuable spawning habitat in a 4,000-ft reach from Riffles 14 through 17D, and has enormous potential for improving spawning by sediment augmentation. The best location for a long-term sediment augmentation site is at the head of Riffle 14, where coarse sediment can be placed onto the pool-tail to increase spawning habitat and be mobilized downstream. The south bank bluff precludes access from this side, but the north bank floodplain has access through private property. If landowners allow access, we recommend placing coarse sediment as a recruitment pile and on the right bank at Riffle 16. Coarse sediment placed here would be readily mobilized downstream due to the steep slope in this reach. This site could be used for a shorter duration of 10-15 years.

Site 26: TLSRA (RM 41.8): The Turlock Lake State Recreation Area was suggested by CDFG as a site for sediment augmentation that is accessible to the public as a demonstration site. Cross sections were placed at Riffles 24-25 to estimate the sediment volume to be placed during coarse sediment transfusion to improve spawning habitat and sediment storage. We recommend sediment be placed at the head of Riffle 23D along the left bank and in the pool tail. This site is a good long-term site to supply coarse sediment to several downstream riffles upstream of SRP 4. Coarse sediment placed at this site and transported downstream will deposit into SRP 4. Road access would need to be constructed from the campground to Riffle 23D, but this would require only minor grading and vegetation removal. This site will also likely be needed for only 10-15 years.

Site 29: Roberts Ferry Bridge (RM 39.4): The four-phased Mining Reach restoration projects will import several hundred thousand cubic yards of coarse sediment to restore the floodway and Chinook salmon habitat in this 7-mile-long reach. An objective of these projects is to create conditions for a dynamic channel that allows sediments to mobilize frequently (4,500 cfs) to maintain habitat conditions. These restoration sites, therefore, will require long-term sediment augmentation to maintain the restored sediment supply and allow the project reaches to function as designed (scour bars, encourage some lateral movement, discourage riparian encroachment, clean spawning gravels, inundate floodplains, etc.) . The upstream boundary of the completed restoration project at the 7/11 Mining Reach was at Riffle 28C directly under Roberts Ferry Bridge. We recommend periodic sediment introduction at the head of Riffle 28C. Sediment should be placed to supplement the riffle, supplement the pool-tail, and extend the pool-tail farther upstream. The Mining Reach projects will be monitored to observe trends in channel bed aggradation/degradation, and this information will be incorporated into the assessment of the volume of sediment placed at this site. Cross section and long profile monitoring sites are shown in Figure 11. This site will be required for approximately 10-15 years, until significant portions of the upstream reach receive sediment augmentation.

5.4 Total Sediment Needs for Restoring the Lower Tuolumne River

Coarse sediment is the primary ingredient in many on-going and future river channel and floodplain reconstruction projects. The purchase, transport, and placement of coarse sediment are also the single most costly project component. The availability of coarse sediment for use as fill material in these projects, therefore, drives cost and greatly influences the implementability of these projects.

The volume of coarse sediment needed for complete restoration of the Tuolumne River is considerable. We have estimated the short-term needs for coarse sediment transfusion to be approximately 372,000 cu yds to complete Phases III and IV, 167,000 cu yds to complete Phases V and VI, and approximately 1,000-2,500 cu yds/yr for long-term coarse sediment maintenance (Table 17). In addition, the Gravel Mining Reach channel restoration project, which is currently underway, will require additional coarse sediment to complete. Phase I (7/11 Materials) of this 4-phased project was completed in 2002, and Phase II (MJ Ruddy) is scheduled to be implemented in 2004-2005. The sediment source for Phase II has already been identified. The Phase III (Warner-Deardorff) project will require approximately 500,000 cu yds of material. The sediment source for this phase has not yet been identified. Volume estimates for Phase IV (Reed) are not available at this time. The Restoration Plan also identifies two additional channel reconstruction projects that will require coarse sediment as follows: SRP 5 (108,000 cu yds), SRP 6 (159,000 cu yds). The total volume of sediment needed for restoration of the river, including coarse sediment transfusion phases and completing projects identified in the Restoration Plan, therefore, is approximately 1.3 million cu yds plus 1,000-2,500 cu yds/yr for long-term coarse sediment maintenance. Additional channel reconstruction projects may be identified in the future based on the outcome of projects completed over the next several years. Such projects could include filling and channel reconstruction at SRP's 3, 4, 7, and 8, which would require an estimated 1.3 million cu yds of coarse sediment.

5.5 Sediment Composition

Sediment placed into the channel is intended to be "used" for many purposes, such as to rebuild alternate bars, supplement spawning gravels, or change the slope or confinement of a particular section of river. The sediment composition, therefore, may vary according to several factors, including the specific site conditions, site objectives, and placement methods. We recommend two different sediment compositions be used in coarse sediment augmentation projects. Sediment intended for rebuilding geomorphic features such as lateral bars and banks can utilize a coarse, screened, unwashed mix of gravel and cobble in the size range of ½ to 6 inches (13 to 150 mm). This mixture can be ungraded within this size range (i.e., relative proportions of gravel/cobble does not matter) and may contain small amounts of fine sediment that cling to gravel and cobble during processing. This coarse sediment mix may also occasionally contain a few larger cobble particles in the size range of 6–10 inches (150 to 254 mm) (less than 5% of the total), if this minimizes the costs of processing the material.

Table 17. List of coarse sediment augmentation sites, with estimated volumes, suggested implementation phases, and the estimated total coarse sediment volume needed for complete sediment supplementation of the gravel-bedded reaches.

Site No.	**Site Name**	**Approx. Fill Total (cu yd)**
PHASE 3		
1	Riffle A3/4 Complex (*)	8,300
2	Riffle A5/6 La Grange Pool	17,284
6	Riffle 3A Complex (*)	20,000
10	Basso Pool	47,737
14	Riffle 12 Complex (*)	65,000
22	FOTT RM 43 Site (Bobcat Flat) (*4)	15,350
26	Riffle 24 (TLSRA) (*)	2,000
	Phase 3 Total =	**175,671**
PHASE 4		
5	New La Grange Bridge Backwater (Riffle 1C) (*)	27,000
8	Riffle 5A Complex	4,761
9	Riffle 5B Complex	3,557
11	Riffle 7 Complex	2,878
12	Riffle 8	9,369
13	Zanker Pool	37,110
18	FOTT RM 44.5 Site (Riffles 16, 17A, 17D)	34,656
27	SRP 4	32,891
29	Riffle 28B/Roberts Ferry Bridge Pool	44,443
	Phase 4 Total =	**196,663**
PHASE 5		
3	Riffle A7 Complex3	3,774
4	Riffle 1A/B Complex3	16,109
15	Riffle 13 A/B Complex	19,625
17	Riffle 14/15 Complex	28,709
19	RM 44 Pool	15,505
20	SRP 3	20,912
21	Riffle 18	20,802
	Phase 5 Total =	**125,435**
PHASE 6		
7	Riffle 4A Complex	3,215
16	Riffle 13C and Backwaters	8,996
23	Riffle 23A	5,163
24	RM 42.4	5,004
25	Riffle 23B	9,636
28	RM 40.5 Pool/Riffle 27	9,688
	Phase 6 Total =	**41,702**
	TOTAL =	**539,471**

For spawning habitat supplementation, a more refined or "processed" sediment composition should be used. Preferred spawning substrate textures for Chinook salmon and *O. mykiss* are reported in Sections 3.1 and 3.2, respectively, and textures documented at Chinook salmon spawning sites in the Tuolumne River are reported in Section 4.2.2. These data suggest that suitable substrates for Chinook salmon range from 0.1 inches to six inches (3-150 mm) in diameter with a D_{50} of 1.6-2.3 inches (40-58 mm), and suitable substrates for *O. mykiss* range up to four inches (102 mm) in diameter and have a D_{50} of 0.5-1.8 inches (10-46 mm). Because there is significant overlap in the size distribution of suitable spawning substrates for these species, a single spawning mixture with reasonable processing requirements could be used to benefit both species.

Information on sediment composition can also be obtained from similar projects constructed on the Tuolumne and other rivers. Previous spawning gravel projects implemented at Riffle 36A in the Santa Fe Aggregates (formerly MJ Ruddy) Mining Reach on the Tuolumne River used information from available literature to develop a coarse sediment composition suitable for Chinook salmon spawning riffles specifically for the Tuolumne River (TFC 1990). This coarse sediment mixture ranged in size from 0.3 to 5 inches (8-128 mm). Mesick (CMC 2002a) tested Chinook salmon spawner preference for two similarly sized sediment compositions: one 0.25 to 5 inches (7-128 mm) with a D_{50} of 28 mm and the other 0.375 to 5 inches (10-128 mm) with a D_{50} of 40 mm in the Stanislaus River. He observed that salmon redd densities were higher in either of these gravel mixtures than in nearby non-restored spawning sites. We recommend using a coarse sediment mixture that conforms as closely as is practical to the "standard" mixture used at the Santa Fe Aggregates Mining Reach (Table 18) but that specifically does not exceed the 20% larger than 2-5 inches (50-130 mm). This gravel mixture equates to approximately 80% finer than 2.5 inches (64 mm) and has a with D_{50} of 1.4 inches (35 mm) and a D_{84} of 2.8 inches (72 mm) and is very similar to material specifications recommended by CDFG/DWR for the La Grange projects.

Table 18. Recommended particle size distributions for salmonid spawning coarse sediment augmentation.

PARTICLE SIZE (mm)		*PERCENT OF TOTAL COMPOSITION*	
(mm)	*(inches)*	*Standard Mix*	*Finer Mix*
64 to 128	2.5 to 5	20%	20%
32 to 64	1 1/4 to 2 1/2	35%	30%
16 to 32	5/8 to 1 1/4	30%	30%
8 to 16	5/16 to 5/8	15%	12%
2 to 8	1/8 to 5/16	0%	8%
	D_{84} =	74	74
	D_{50} =	35	32

We also developed a coarse sediment mixture that is slightly finer. Literature reviewed for this project indicates that the finer range of sediment suitable for Chinook salmon is also suitable for *O. mykiss*. In other words, there is significant overlap in the particle size distributions for each species preference curves. The recommended mixture is truncated at 4 inches (102 mm) instead of 5 inches (128 mm) and includes 8% in the size fraction from 0.1-0.3 inches (2-8 mm). The D_{50} is 1.3 inches (32 mm); the D_{84} is 2.4 inches (60 mm). This mixture is expected to be suitable for both Chinook salmon and *O. mykiss* and may reduce production costs or result in a larger volume of coarse sediment production in cases where on-site coarse sediment processing occurs.

We emphasize the importance of the fraction of the composition smaller than one inch (25 mm) for several reasons. First, Mesick (CMC 2002a) found that salmon spawning on the Stanislaus River preferred to construct redds in the gravel washed with a 1/4-inch (7 mm) screen than in gravel washed with a 3/8-inch (10 mm) screen (CMC 2001), and it was noticeably easier to dig artificial redds with hoes and shovels in the gravel washed with the smaller screen. Mesick noted that substrate particles between 7 and 10 mm may act as a "lubricant" during redd construction (CMC 2001). If true, then seasoning of freshly introduced gravels may also involve the intrusion of fine sediment (sand and fine gravel) that aids in the digging of redds. Second, a smaller particle size distribution will also be mobilized more frequently under the present flow regime, helping restore a more natural channel morphology and spawning gravel quality.

As mentioned above, we also emphasize that dredger tailings should be the primary source of material for spawning gravel enhancement. Unprocessed material purchased for use in sediment augmentation projects should be tested for its particle size distribution, and if the ¼ – 5 inch (6-128 mm) fraction is found to correspond reasonably well to the recommended mixture, then no additional material sorting may be needed. The material would still need to be washed.

In addition to substrate texture, specifications should be included to ensure that the sediment is free of pollutants, not angular, and from local sources. The following specifications, which were developed by CDFG for their coarse sediment augmentation projects, should be followed and included in all project bid packages:

- material must be free from all deleterious material, fine sediment, oils, clay, debris, organic material, rock dust;
- only smooth river rock is acceptable, crushed rock is not acceptable;
- preference is given to rock derived from within the Tuolumne River basin.

6 COARSE SEDIMENT SOURCES

6.1 Overview

The Restoration Plan conducted a reconnaissance-level aggregate source inventory (Restoration Plan pg. 114) that summarized the location and rough volumes of aggregate potentially available for restoration projects, and the most cost-effective sources (based on haul distances, etc.). This aggregate inventory focused on dredger tailings in the Merced River corridor, remaining dredger tailings in the Tuolumne River corridor, and remnant material left after dredger tailings were removed for construction of NDPP.

The Coarse Sediment Management Plan builds on the sediment source inventory conducted in the Restoration Plan by prioritizing sources, refining volume estimates, and linking sources to different augmentation sites. The Bobcat Flat sediment source site has already been acquired. Potential coarse sediment sources are described in more detail below.

6.2 Regional Aggregate Supplies and Special Report 173

The Surface Mining and Reclamation Act of 1975 (SMARA) required the State Geologist to classify land based on known or inferred mineral resource potential of that land. The Stanislaus County study, *Mineral Land Classification of Stanislaus County, California, Special Report 173* (Higgins and Dupras 1993) was published in 1993 to meet this requirement. The mineral classification process entailed six distinct steps: (1) determination of study area, (2) establishment of Mineral Resource Zones (MRZ), (3) identification of Aggregate Resource Areas (ARA), (3) calculation of resource volumes within ARAs, (4) forecast of 50-year needs and the life expectancy of current reserves, and (6) identification of alternative resources. Aggregate mineral resources in Stanislaus County are classified as:

- Aggregate Resources, which include all potentially useable aggregate materials that may be mined in the future, but for which no mining permit has been granted, or for which marketability has not been established.
- Aggregate Reserves, which are aggregate resources determined to be acceptable for commercial use, that exist within properties owned or leased by aggregate producing companies, and for which permits have been granted to allow mining and processing.

For purposes of coarse sediment management, Mineral Resource Zones classified as MRZ-2a and 2b are relevant. MRZ-2a zones are *known* to contain PCC (Portland Cement Concrete) or AC (Asphalt Concrete) grade aggregate, whereas MRZ-2b zones are *inferred* to contain PCC or AC grade aggregates. These aggregates are the rarest and most commercially valuable of aggregate resources. An ARA is an area that has been classified as MRZ-2a or MRZ-2b for concrete aggregate by the State Geologist and is deemed to be available for mining based upon criteria for compatibility provided by the State Mining and Geology Board (SMGB). ARAs are divided into three categories: IS (Immediately Significant), HS (Highly Significant), and S (Significant).

Special Report 173 indicated that aggregate resources are located in six different geographic areas of Stanislaus County, and contain an estimated 540 million tons (338 million cu yds) of aggregate resources (Higgins and Dupras 1993). The Tuolumne River floodway corridor is the largest of the six aggregate resources, containing an estimated 217 million tons (135 million cu yds) (Higgins and Dupras 1993). Special Report 173 identified 14 Aggregate Resource Areas (ARAs) that include the Tuolumne River channel and terraces (ARA-42 through ARA-55) (Figure 29). The Gravel Mining Reach delineated by the Restoration Plan (RM 34.4-40.3) includes ARAs 47-49, which are currently the focus of development by commercial aggregate producers (Figure 29).

To put the supply and demand into a regional perspective, Special Report 173 noted that, based on information available in 1993, the permitted aggregate reserves in Stanislaus County would have been depleted by 2002. As of 1993, permitted reserves in Stanislaus County totaled 27.7 million tons (17.3 million cu yds). An additional 16 million tons of reserves were added in 1996, and near-term aggregate reserves are therefore secure. Special Report 173 estimated a total projected consumption in Stanislaus County of 244 million tons (153 million cu yds) of aggregate through 2040 (Higgins and Dupras 1993), based on present per capita aggregate consumption and future population growth projections. Additional permitted reserves will therefore be required to maintain the reserve base and to meet the regional aggregate demand.

Aggregate producers in Stanislaus County have found that pit-run aggregate from the Tuolumne River is superior in quality to aggregates found in the west side of the County. Discussions with producers in the Stanislaus County area also indicate that reserves of sand are being exhausted. As a result, demand for sand in the area is likely to remain strong. Although not considered the optimum source of construction aggregate, dredger tailing deposits have become increasingly more important as alternative sources of aggregate are depleted. Dredger tailing material is not generally considered high grade construction aggregate because:

- the overburden was not removed, so dredge material is a heterogeneous mix including clay, sand, and gravel;

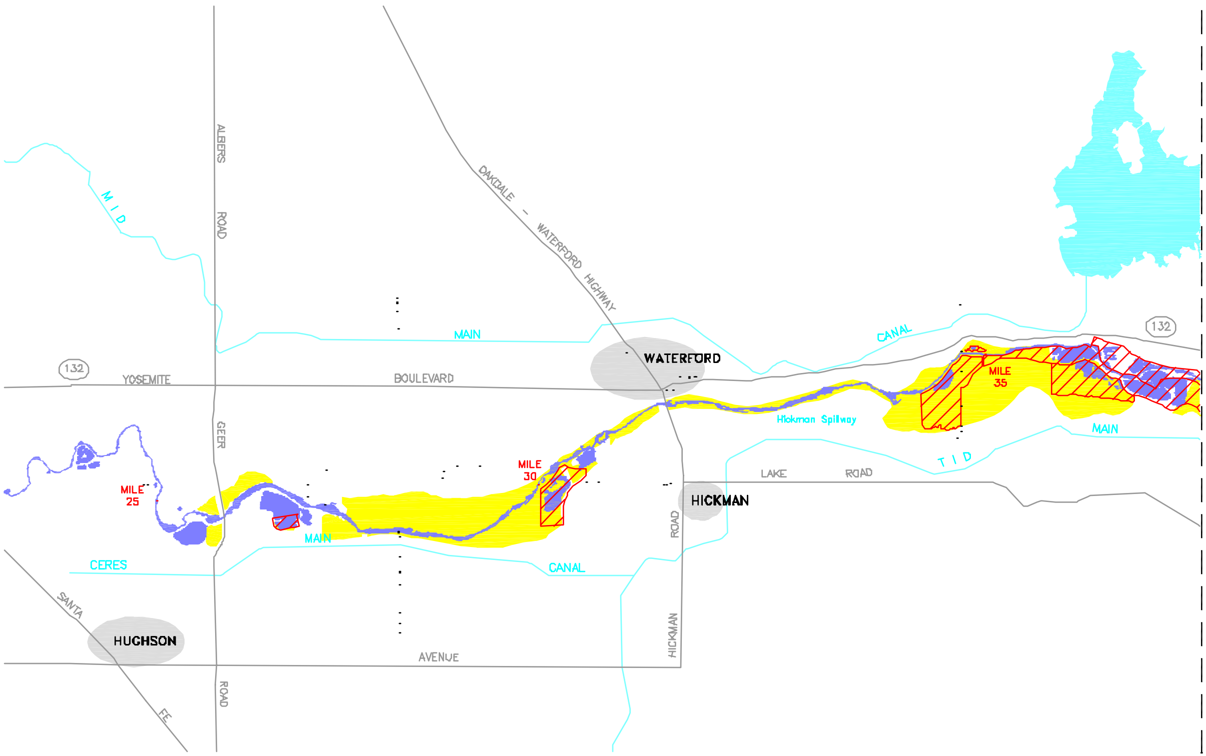


Figure 29. Location of Aggregate Resource Areas (ARA's) along the Tuolumne River identified in Special Report 173. Also shown are Aggregate Reserves with existing mining permits from Stanislaus County, and priority coarse sediment sources recommended to be developed for use in restoration projects.

- they may contain organic material, are often a mix of older and younger alluvial deposits, and may contain metal debris from the dredger equipment;
- dredger material may be contaminated with bedrock excavated during dredging;

Because the dredging process and subsequent scraping of a portion of the tailings may have impacted the quality of the aggregate, dredger tailing sources are of lower commercial value. Their lower commercial value makes the dredger tailings an ideal source of material for sediment augmentation projects.

6.3 General Strategy for Sediment Acquisition and Development

The enormous demand for sediment for large-scale restoration activities may conflict with the regional demand for permitted aggregate reserves, particularly in the Stanislaus County region currently experiencing rapid population growth. This growing conflict was expressed in comments provided to the CEQA/NEPA environmental document for the Gravel Mining Reach Restoration Project by the Central Valley Rock, Sand & Gravel Association (CVRS&GA), which stated that "Since the Tuolumne River is a major aggregate resource area serving Stanislaus County, the proposed restoration project will have an impact on the continued availability of these resources." As the previous section indicated, the demand for additional sediment supplies for restoration purposes will increase as coarse sediment augmentation and other channel reconstruction projects proceed.

Several options are available to meet the sediment demands of restoration projects. On one extreme, the task of obtaining sediment for a particular project can be accomplished on a project-by-project basis. This strategy has been employed at the 7/11 Mining Reach, SRP-9, and the CDFG Phase I and

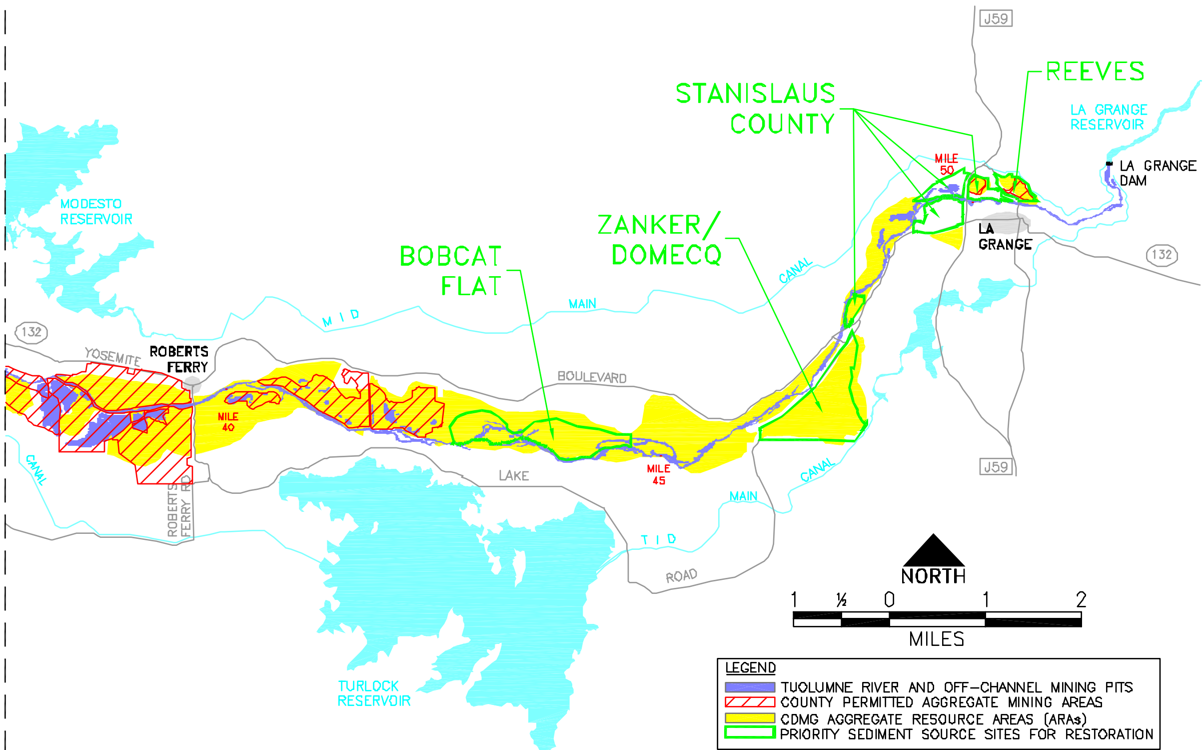


Figure 29. Continued.

II Coarse Sediment Augmentation. These projects have solicited bids for project implementation, and contractors then acquired material from the commercial market. This strategy creates at least three significant issues: (1) obtaining commercial aggregate for restoration increases the regional demand for the limited (and finite) permitted aggregate reserves, (2) obtaining commercial aggregate may ultimately contribute to creating additional floodplain pits or other ecological damage that river restoration proponents are trying to fix, and (3) commercial aggregate is expensive, significantly driving up the costs of restoration projects.

A recommended alternative is for TID/MID, the TRTAC, CDFG, or another "restoration proponent" to acquire mineral rights to a large source of undeveloped coarse sediment (e.g., dredger tailings) and implement a process to develop this material for long-term use in various restoration projects. This latter strategy was recommended in the Habitat Restoration Plan, and has also been implemented in various degrees on Clear Creek and the Merced River. The benefits of this approach are considerable. First, this strategy of purchasing and developing a separate source of sediment for restoration reduces the potential conflict with the use of commercially permitted aggregate reserves. Second, using dredger tailings or formerly-mined areas for river restoration also allows these sediment source sites to be restored to higher quality habitat (e.g., revegetated floodplain and wetland habitat) as opposed to contributing to the creation of additional floodplain mining pits. Lastly, purchasing and developing an independent source of sediment for restoration can substantially lower the cost of obtaining and transporting the coarse sediment. Given the already substantial costs of the large restoration projects, these cost savings are significant in long term restoration planning.

To carry this strategy forward on the Tuolumne River, the Restoration Plan (McBain and Trush 2000) conducted a preliminary sediment source inventory based on the following set of criteria:

- the material was lower in commercial quality than pit-run aggregate, to avoid removing a high quality aggregate reserve from commercial/infrastructure use;
- the material could be extracted without creating a pit adjacent to the river to avoid perpetuating the same situation the restoration project(s) were attempting to remedy;
- the material could be extracted and the extraction or "borrow" site could be restored to better conditions (e.g., creating shallow off-channel wetlands, restoring floodplain adjacent to the river, or replacing a xeric surface with native riparian vegetation);
- the source was within 20 miles one-way of most of the channel restoration projects planned for the Tuolumne River;

Several coarse sediment sources could potentially become available in the near future. The Bobcat Flat land acquisition (RM 42.7–44.3) by FOT included purchase of the dredger tailing materials on the property, which will provide a coarse sediment source. The Zanker family has begun the process of obtaining permits to mine coarse sediment from their property for restoration. There is also a small supply of coarse sediment on CDFG property near La Grange, and CDFG may acquire more at this site. These three sources (discussed in more detail below) are high priority sediment sources and together could meet a large portion of the long-term sediment demand for river restoration. In addition to obtaining local sediment sources to be used for restoration, we also recommend linking specific restoration projects to specific sources based on local, unique circumstances. The best example of this strategy is the coarse sediment at the CDFG property near La Grange. Riffle A7 is recommended to be used as a site for long-term, periodic coarse sediment augmentation. The coarse sediment located at the CDFG property is ideal for this site. No highway hauling is required, the north bank road access leading down to Riffle A7 is directly adjacent to the large coarse sediment piles, and coarse sediment is easily transported to the site. Eliminating transportation costs and impacts from on-highway hauling would significantly reduce the total cost of implementing sediment augmentation projects at this site. This strategy fits several other sites along the river, and is discussed in more detail below.

6.4 Potential Sources for Sediment Augmentation and Channel Restoration

The following descriptions build on the sediment source inventory conducted in the Restoration Plan by prioritizing sources, refining volume estimates, and linking sources to different augmentation sites. We retained the same criteria presented in the Habitat Restoration Plan to help prioritize sediment sources. The sediment sources listed below are presented in three tiers of priority: high, medium, and low. Location of high priority sites are shown in Figure 29.

6.4.1 High priority sources

Zanker/Domecq properties: The Joe Domecq County Park (approximately 208 acres) and the Zanker family property (approximately 100 acres) are located between river miles 46.5 and 47.5, south of Lake Road near Basso Bridge. These parcels were historically floodplain and terrace alluvial deposits that were dredged for gold in the 1930s, then partially re-excavated in the 1960s to provide aggregate for constructing New Don Pedro Dam (Figure 3). Some coarse sediment was left in place, and these parcels now exist as barren surface that provide little wildlife habitat or recreational uses. The Zanker/Domecq parcels contain an estimated 2.4 million tons of usable sediment (1.5

million cu yds) and meet all the above criteria. First, they are of lower quality than commercial pit-run aggregate. Using this material would preclude using commercial aggregate that contributes to additional pit excavation along the river. Second, purchasing mineral rights to this material would allow a portion of the material to be used for restoration while leaving some material on-site for reclamation purposes that would substantially improve the overall quality of the property. The restoration design (reclamation plan) for these properties could include restoring the xeric, dredged and scraped surfaces to better quality habitat, including perennial wetlands, riparian habitat, and woodland habitat. Last, the Domecq/Zanker parcels are approximately 20 miles from the furthest downstream project (SRP 10), are as close as possible to the spawning reaches proposed for sediment transfusion, and are farther away from the commercial market than downstream commercial reserves. This is the ideal location to supply the high priority sediment augmentation projects (Figure 29).

These parcels are listed in Special Report 173 as ARA-51, classified as a "significant" resource. The report states that the "uppermost 15-20 feet over nearly 80 percent of this area was scalped for aggregate…and used in the Don Pedro Dam. Available data indicate that remaining sand and gravel resources within this area range in thickness between 5–15 ft."

The Zanker family has begun efforts to acquire a SMARA permit to mine their property near Basso (RM 46.5–47.5) and set aside this material exclusively for river restoration projects. No SMARA permit is currently being pursued for the Domecq property. A resource analysis report commissioned by the Zanker family reported a <u>gross</u> volume of 2 million tons (1.25 million cu yds) of coarse sediment contained on their property. This report also analyzed sediment composition from 12 test pits and determined approximately 50% of the gross sediment volume was fine sediment smaller than 3/8 inch. This fine sediment portion of the material would be screened and removed from the coarse sediment component. Sand would either be left on-site and used in reclamation or sold commercially to offset costs of producing the introduced coarse sediment. We assumed a maximum of only 60% of the gross material volume would be mined to meet restoration goals and reclamation plan requirements (mining only 6 ft deep where 10 ft of aggregate are available). These assumptions yielded a net maximum usable volume of 1.2 million tons of coarse sediment (750,000 cu yds).

<u>Reeves Coarse Sediment piles:</u> The Reeves Sand Quarry is located on the north side of the river adjacent to Old La Grange Bridge (Figure 29). Gasburg Creek runs through this site. The original Reeves parcel was split; the western half was sold to DWR and is currently used by CDFG as a field office. The eastern half is leased to a mining company. The eastern parcel contains the majority of the sand quarry site, as well as four large piles of coarse gravel and cobble that were a byproduct of sand mining. Rough volume estimates reported in the Restoration Plan totaled 74,000 cu yds of gravel and cobble. We evaluated the particle size of the sediment by sieving approximately 50 kg of material from two different piles. All processed material passed through the 100 mm (4 inch) sieve and was retained on the 32 mm (1 inch) sieve. This size distribution of 1–4 inches is ideal for sediment augmentation. Another smaller coarse sediment pile is located on the DWR parcel, has an estimated volume of 2,000 cu yds, and is composed of coarse sediment ranging from 1–2 inches.

<u>Bobcat Flat Dredger Tailings:</u> CBDA recently funded the acquisition of approximately 303 acres of riparian floodplain on the Tuolumne River from river mile 42.7 to 44.3 (approximately 1.6 miles of riverfront property). This property is located 12 miles east of Waterford and 8 miles downstream of La Grange Dam, in the Dredger Reach. The property is contained within the larger 1,979 acre ARA-50 (north of Lake Road, south of State Route 132, east of Roberts Ferry, west of Basso Bridge) categorized as immediately significant due to the presence of commercial aggregate producers (7/11 Materials, Santa Fe Aggregates, Western Stone). Most of the Bobcat Flat parcel was dredged for gold, and then scraped to remove aggregate for construction of New Don Pedro Dam. Similar to the

Zanker/Domecq properties, much of the area has not regenerated riparian vegetation, and has lower ecological value. Other areas have regenerated healthy riparian vegetation, mostly closer to the river channel and in depressions between the old dredger tailings. A land and mineral appraisal prepared for the Bobcat Flat land purchase estimated the total recoverable aggregate reserves at 10.9 million tons (Griffin 2001), which equates to approximately 6.8 million cu yds. This volume estimate included typical mining setback requirements and the assumption of recoverable material to a depth of 30 ft. The Restoration Plan originally estimated approximately 215,000 cu yds of dredged material remain on the site available for restoration purposes (Figure 29). This estimate assumed tailings would be excavated only to the surrounding ground surface elevation and all vegetation would be avoided. Considerably more sediment volume would be available if the reclaimed (scraped) dredger tailing areas were re-excavated to rehabilitate the xeric cobble surfaces into wetlands and lower floodplain elevations.

Stanislaus County Floodplain Properties: Stanislaus County owns several parcels in the reach between Basso Bridge and Old La Grange Bridge that contain dredged/scraped surfaces similar to those described in the Zanker, Domecq, and Bobcat Flat parcels. These areas are relic floodplain surfaces that were dredged and reclaimed, but in many areas were left at elevations too high to be inundated by the present flow regime, and have not appreciably recovered riparian vegetation. If excavated and processed, these materials would meet the basic criteria presented above: they are of lower quality than pit-run aggregate, the extraction site could be reclaimed to more functional floodplain revegetated with riparian hardwood species, and the reclaimed material could be used on-site to avoid hauling costs and impacts. We have identified five parcels that fit this description (Figure 29). Three parcels surrounding the New La Grange Bridge were subject of a 2000 CBDA proposal submitted by the Tuolumne River Preservation Trust, and contain as much as 100,000 cu yds of reclaimable material. The wildlife habitats could be significantly improved and recreational opportunities such as hiking, wildlife viewing, boating, and fishing could be developed.

6.4.2 Medium priority sources

Crooker Dredger Tailings (RM 41), Cree Dredger Tailings (RM 42): Collectively, these sites represent medium priority material that should be considered for restoration only if other sources are not available, or if they become for sale at a reasonable cost. Given the availability of sediment in the medium and high priority categories discussed above, and the assumption that regulatory compliance requirements can be met (CEQA/NEPA and mining permits), neither of these factors is likely true for the next several decades. These sites are medium priority only because of their high cost due to their commercial demand. The primary benefit of this source is its location between the Dredger Reach and the Gravel Mining Reach where much sediment augmentation and channel restoration are needed. If the mineral rights or land containing these supplies could be purchased, allowing control over the extent of excavation and subsequent reclamation, these sources would be a high priority for long-term use.

6.4.3 Low priority sources

Merced River Dredger Tailings: The Merced River dredger tailings are an enormously important source of sediment for long-term river restoration on both the Tuolumne and Merced rivers. These materials meet several important criteria: they are lower quality than the commercial pit-run aggregate, extraction could avoid creating additional mining pits, and the borrow site could be reclaimed to higher quality land. Several large parcels containing dredger tailings are owned publicly, either by Merced County, Merced Irrigation District, or by CDFG. The 318 acre Merced River Ranch parcel is the most significant Merced River source. This parcel was purchased by CDFG using funding provided by CBDA from a 1997 grant proposal. Eventually the site will be developed to produce sediment available for river restoration projects. Presumably the minimal costs of the material would be for permitting, excavation, and processing. The largest cost component associated with using this material on the Tuolumne River would result from transportation costs. The Restoration Plan (McBain and Trush 2000) reported round trip haul distances of 32 miles to La Grange, 58 miles to Waterford, and 66 miles to Geer Road Bridge at Fox Grove. These distances presently add considerable costs to the use of this material. In addition to the Merced River Ranch, there are several private landowners along the Merced with dredger tailing material available for purchase commercially. The Restoration Plan provided a conservative estimate of 3,644,000 cu yds of coarse sediment available from just the publicly owned parcels containing undisturbed dredger tailings. The material is considered a low priority for use on the Tuolumne River until it can be determined that this entire source will not be needed for restoration on the Merced River, and until it can be shown that all other available sources on the Tuolumne River are less feasible, more expensive, depleted, etc.

La Grange Reservoir Delta: This sediment source, if used by TID/MID, has the virtue of being available at no purchase cost, and would meet other criteria of reducing pressure on commercial aggregate reserves. The Restoration Plan estimated approximately 500,000 cu yds of sediment were available, but recommended this material be used only for pit filling because of the angularity of the rock and the heterogeneous mix of sand and coarse sediment. The primary disadvantage of this source is the haul distance from the reservoir to downstream restoration sites, which is approximately 8–10 miles just to Basso Bridge. Accessing the material down in the La Grange reservoir canyon would also require construction of a road, and dredging the material might also be technically difficult and therefore costly. As more readily available material along the lower river becomes scarce, however, using this material may become more feasible.

7 ADAPTIVE MANAGEMENT AND MONITORING PROGRAM

7.1 Overview

This Coarse Sediment Management Plan recommends introducing large volumes of coarse sediment into the channel during the next several decades to increase sediment storage, facilitate fluvial geomorphic processes and complex channel morphology, and replenish spawning habitat. This approach to restoration, while relatively simple in concept, is still untested at the proposed scale. It is therefore imperative that sediment management actions be accompanied by clearly defined goals, measurable objectives, testable hypotheses, and the appropriate monitoring methods to maximize the information obtained from these proposed actions. This *adaptive management* approach (Holling 1978; Walters 1986) encourages managers to treat management actions as experiments, the results of which are used to guide future decisions.

To increase the information gained from restoration projects, both AFRP and CBDA have required that project proponents use adaptive management in planning, design, and implementation (CBDA 2001). So far this process has produced mixed results. To realize the benefits of adaptive management, the AFRP, with assistance from CBDA's Ecosystem Restoration Program and the Information Center for the Environment (ICE) at U.C. Davis, established an Adaptive Management Forum (Forum) to assist with the planning and implementation of habitat restoration projects. The Tuolumne River program was selected as the first program for review of its restoration, adaptive management, and monitoring programs. The forum provided several important conclusions regarding the adaptive management process and program on the Tuolumne River, including:

- restructuring of channel and floodplain morphology and its evolution under the specified flow regime is not linked to any quantitative expectations for species recovery;
- at present there appears to be no established criteria for determining either project success or improvement in ecosystem function at the tributary scale relative to the Restoration Plan objective of restoring "a natural river and floodplain morphology";
- the restoration team does not appear to have agreed upon a comprehensive set of monitoring methods;
- a hydraulic model for the lower Tuolumne River should be completed to assist in sediment transport analyses and other evaluations;
- the evidence that superimposition is a serious problem appears to be rather weak, although it is a reasonable conjecture based on spawner distributions and evidence from the lower Tuolumne River and elsewhere; adult spawner distribution and superimposition represents an important area of uncertainty that could be explored with suitable experiments.

7.2 Tuolumne River Adaptive Management Framework

The Restoration Plan recommended a framework for adaptive management based on Hollings' (1978) Adaptive Environmental Assessment and Management (AEAM). This approach emphasizes the inherent uncertainties that accompany management and restoration actions, as well as the need to incorporate hypothesis testing into management actions to explain causative processes instead of simply monitoring trends. This is the difficult step in the AEAM process. Walters and Holling (1990) note that defining testable hypotheses is trivial, but generating hypotheses sensitive to changes in the function or processes of the ecosystem is much more complex.

The fundamental steps to adaptive management are: (1) define goals and objectives in measurable terms; (2) develop hypotheses, build models, compare alternatives, design system manipulations and monitoring programs; (3) propose modifications to operations that protect, conserve, and enhance resources; (4) implement monitoring and research programs to examine how selected management actions meet resource management objectives; and (5) use the results of steps 1-4 to further refine ecosystem management to meet the stated objectives (Hollings 1978). The CBDA Strategic Plan (CBDA 1999) describes some of the critical elements of CBDA's adaptive management approach, and a step-wise procedure for implementing adaptive management (Figure 30).

The Tuolumne River Technical Advisory Committee is the appropriate entity to oversee the design and implementation of an adaptive management program on the Tuolumne River. The FERC Settlement Agreement (Section 7) states: "The participants to the settlement agree to an adaptive management strategy that would initially employ measures considered feasible and have a high chance of success. The success of these initial measures would be evaluated and, based on the results of evaluation, the measures would either be fine-tuned to improve success or alternative measures would be taken." In this management role, the TRTAC must perform the dual tasks of first requiring that projects for which it (or the Districts or agencies independently) takes a lead role have a suitable experimental design and appropriate monitoring metrics that will provide the necessary feedback information, and second, conducting the post-project management evaluation, drawing the appropriate conclusions, and making the necessary recommendations for future projects or management actions based on these conclusions. This feedback and review process must also be documented so relevant information is transferable to other projects and restoration programs.

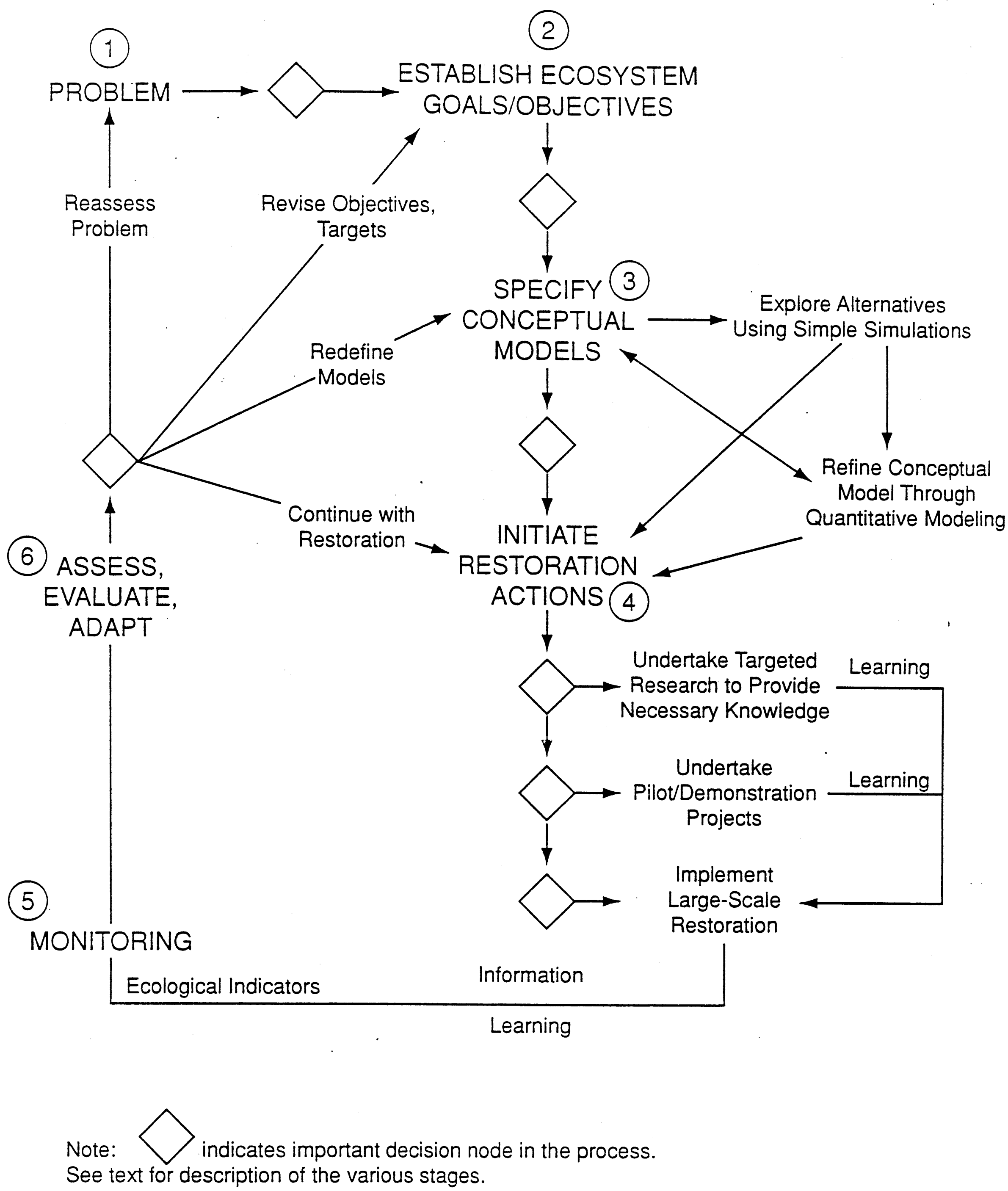


Figure 30. Diagram showing the organization of Adaptive Management and Monitoring. SOURCE: CBDA 1999.

In the following sections we present a set of quantitative objectives and hypotheses related to coarse sediment and spawning gravel management, and monitoring methods that should be implemented as part of the coarse sediment management plan. We follow this by describing specific experimental components that should be implemented during the sediment transfusion phase to increase the opportunity to learn from these projects.

7.3 Quantitative Objectives and Hypotheses

7.3.1 Quantitative Objectives for Coarse Sediment Management

The basis for monitoring the success of the sediment management program and the broader Restoration Plan implementation should be specific, well-defined quantitative targets for the key components of the program. These targets should include parameters assessing salmon population abundance and habitat characteristics, measurements of material inputs and geomorphic processes, invertebrate production, and riparian habitat characteristics. As a starting point to developing these quantitative objectives, we have summarized the following initial objectives:

- Sufficient spawning habitat is available to support the AFRP target escapement for the Tuolumne River of 38,000 adult spawners (USFWS 1997).
- Coarse sediment storage and spawning gravel supplies are increased each year until coarse sediment storage is restored and full sediment routing through the gravel-bedded reaches is achieved. During the short-term sediment TRANSFUSION phase implemented over the next 5-10 years, approximately 372,000 cubic yards of coarse sediment is added to the river (Section 5.2).
- Water surface slope is redistributed (by sediment augmentation and channel maintenance releases) so that average riffle slopes fall between 0.0010 and 0.0015.
- Approximately 1,000 to 2,500 cu yds of coarse sediment are added to the river each year during the long-term sediment MAINTENANCE phase to maintain equilibrium based on empirical and modeled (post NDPP) sediment transport rates (see Section 5.3).
- Spawning habitat (total spawning area per river mile) reaches a density of approximately 150,000 ft^2/mile (based on 30 ft^2/ft estimated from the Riffle 2-5B reach) (see Section 4.4). The total amount of spawning habitat for subreaches of the gravel-bedded zone should approach targets shown in Table 19.

Table 19. Target spawning habitat area by reach

River Reach	Reach Length (ft)	Present Habitat Area (ft^2)	Targeted Habitat Availability Area (ft^2)
La Grange Dam to New La Grange Bridge	10,600	112,300	371,000
New La Grange Bridge to Basso Bridge	11,500	345,000	402,500
Basso Bridge to Roberts Ferry Bridge	42,500	106,000	1,487,500
Roberts Ferry Bridge to Hickman Bridge	41,800	NA[1]	1,463,000
Hickman Bridge to Gear Road Bridge	29,500	NA[1]	1,032,500

[1]Spawning habitat in these sections of river has not been assessed recently.

- The particle size distribution of spawning gravels gradually becomes finer, resulting in a bed particle size of D_{100} = 128 mm; D_{84} = 60 mm; D_{50} = 28 mm in spawning riffles (see Section 5.5).
- The percentage of fine sediments stored in spawning gravels is reduced and maintained below 10% finer than 0.85mm, with optimal target of 5% finer than 0.85mm (Tappel and Bjornn 1983). Average permeability of spawning gravels exceeds 10,000 cm/hr (based Stillwater Sciences 2001a).
- By reducing fine sediment and increasing interstitial spacing among sediment substrate, maintaining low temperatures, and frequently mobilizing the channel bed surface, benthic macroinvertebrate productivity, abundance, and diversity increases (Hershey and Lamberti 1998). No quantitative target for invertebrate production is presently available, but should be based on biomass per unit substrate area.
- Thresholds for mobility of surface particles are lowered, with coarse sediment particle facies becoming fully mobilized at flows ranging between 4,500 and 5,500 cfs (D100 < 128 mm) (McBain and Trush 2000). Channel bed (riffle and pool-tail) particle facies are mobilized annually on average; gravel bar particle facies should be mobilized approximately every 1–2 years on average (McBain and Trush 2000).
- The channel is scaled to convey to 1.5 to 2-year flood, with larger floods spilling over the channel banks and inundating adjacent floodplains (McBain and Trush 2000).

7.3.2 Hypotheses Regarding Sediment Augmentation and Salmonid Spawning Habitat

We have developed a set of hypotheses that relate coarse sediment and spawning gravel management to fluvial processes, salmon population, invertebrate production, and riparian habitat. These hypotheses should be expanded/supplemented by the TRTAC and incorporated into river-wide goals and objectives. Section 7.5 presents monitoring protocols that will be useful for evaluating the success of the coarse sediment management program.

Geomorphic Processes:

- Bedload supply can be restored to a state of dynamic equilibrium similar to the natural unaltered sediment storage and routing condition, so that sediment input and downstream transport is balanced (but on a smaller scale than unimpaired conditions), bedload transport continuity is achieved, and sediment introduction will eventually be required only in one location below La Grange Dam.
- An increase in coarse sediment supply will increase low-flow and bankfull channel confinement and reduce the particle size distribution of the channel bed substrates, thereby lowering bed mobility thresholds and increasing the frequency of bed mobility.
- An increase in coarse sediment supply will encourage channel migration, floodplain formation, lateral bar formation important for sediment storage and fry rearing, and inundation and fine sediment deposition on floodplains.
- An increase in coarse sediment supply, reduction in particle size distribution, and an increase in the frequency of bed mobilization will increase (over existing conditions) the volume of sediment augmentation needed to maintain equilibrium of in-channel sediment storage and downstream transport.
- Adding riffles and bars in long pools and runs will reduce the time required to restore sediment routing continuity.

Salmonid Populations:

- Current spawning habitat availability is a limiting factor during years of moderate and higher escapements, influencing the size of the Tuolumne River Chinook salmon population by causing redd superimposition, which in turn leads to density-dependent mortality (TID/MID 1992c).
- Increasing sediment supply (in conjunction with periodic high flows) will increase salmonid spawning habitat availability in the gravel-bedded zone to habitat quantities approaching the density in the reach between New La Grange Bridge and Basso Bridge.
- The density of fall-run Chinook salmon redds will be higher in unconsolidated introduced coarse sediment than at unrestored, embedded spawning gravels (from CMC 2002a).
- Chinook salmon and *O. mykiss* will utilize introduced coarse sediment immediately following insertion (i.e., in the first spawning season following insertion) and will continue to use inserted and mobilized coarse sediment in the years following insertion.
- Backing water upstream into steep riffles (as a result of riffle creation in long pool reaches) will not reduce *O. mykiss* rearing and holding habitat associated with the upstream riffles as long as cover remains as either surface turbulence, instream woody debris, or overhanging vegetation.
- Riffle and point bar creation in long pools and SRPs will speed restoration of coarse sediment routing through the augmentation reach.
- *O. mykiss* will preferentially use constructed riffles associated with downstream pools with a residual pool depth of at least four feet and available overhead and in-channel cover.
- *O. mykiss* will spawn in sediment that is finer than that utilized by Chinook salmon.
- Spawning areas utilized by *O. mykiss* will be spatially discreet from areas utilized by Chinook salmon, with Chinook salmon utilizing primarily pool tails and riffle heads and *O. mykiss* utilizing riffles and riffle tails associated with downstream pools > 4 feet deep and with available overhead and/or in-channel cover.
- Sediment introduced and transported downstream by high flows will eventually improve salmonid spawning habitat and channel geomorphic conditions in un-restored downstream riffles.
- Salmonid spawning gravel without fine sediment added to the channel will increase intragravel flow of water in redds (from CMC 2001).
- Increasing spawning habitat availability through sediment augmentation will alter the stock-recruitment model in the long term, thereby reducing or eliminating density-dependent mortality associated with redd superimposition.
- Increasing spawning habitat availability in the gravel-bedded zone will directly increase the average high redd count (defined in Section 3.1.3) in proportion to the annual escapement level (i.e., will allow broader distribution of spawning and reduce redd superimposition, assuming other habitat suitability requirements are similar).
- Improving gravel quality (particle size distribution, percentage of fine sediment, permeability, DO, and intragravel temperature) will improve the survival and emergence success of salmon eggs deposited by spawning adults (from TID/MID 1992c).

- Increasing the frequency and duration of bed mobilization will improves spawning gravel quality by flushing fine sediments from spawning gravels, reducing fine sediment storage in the channel, increasing hyphorheic flows, reducing intragravel temperatures, and increasing dissolved oxygen (DO) in salmon egg pockets.
- Introduced gravels containing a higher percentage of "fine gravels" (1/4 inch to 1/2 inch) will be preferentially used by spawning salmonids relative to introduced gravels that lack fine gravels (based on CMC 2002a).
- Adding coarse sediment and improving channel morphology in long pools and SRPs will improve the survival of juvenile salmonids by reducing habitat for predators, particularly Sacramento pikeminnow (*Ptychocheilus grandis*) and striped bass (*Morone saxatilis*), and providing refuge for juvenile salmonids.
- Increasing the quantity of side channel, high flow scour channel, and floodplain habitats will increase the growth rates and survival of juvenile salmonids by providing high flow refuge habitat and rearing habitat at a wide range of flows.

Invertebrate Production

- Sediment augmentation, combined with fine sediment reduction, will increase the abundance and diversity of the macro-invertebrate food base for rearing juvenile salmonids.
- Floodplain inundation, particularly over organic, vegetated soils, will increase the abundance and diversity of the macro-invertebrate food base for rearing juvenile salmonids.

Riparian Habitat

- Increased coarse sediment supply and channel confinement will encourage channel migration and floodplain formation, which in turn will promote natural regeneration of riparian vegetation.
- Increased coarse sediment storage in lateral gravel bars, and increased frequency of floodplain inundation, will reduce riparian encroachment along lateral bar margins and encourage establishment at more appropriate locations (e.g., on floodplain surfaces).

7.4 Experimental Components of Coarse Sediment Augmentation

In addition to testing explicit within-site variables such as habitat use, redd density, and gravel quality, the most basic evaluation of the success of coarse sediment augmentation is to compare spawning use of unrestored riffles to restored riffles and to compare benefits of different methods of gravel augmentation (particularly between riffles constructed in long pools vs. coarse sediment addition to existing riffles). This test is difficult because many confounding variables can obfuscate a direct comparison. To minimize uncontrolled variables, control and treatment sites should be (1) close to each other and the sediment introduction site, (2) riffle slopes and gravel particle size distribution should be similar, and (3) the zone of riffles evaluated (riffle crest, main riffle, etc.) should be the same. We recommend paired evaluations of control vs. experimental sites at Riffle 2 (control) and 3A (experimental), Riffle 7 (control) and Riffle 12 (experimental), Riffle 18 (control) and 19 (experimental) at Bobcat Flat, and at 24A (experimental) and 24B (control). Several years of monitoring may be required for this evaluation.

Sediment augmentation projects should include explicit evaluation of differential habitat use in upstream vs. downstream locations. The CDFG redd count data indicate that salmon preferentially spawn in higher concentrations in riffles upstream of Basso Bridge. Several alternative hypotheses may explain this difference, such as more favorable riffle morphology and gravel composition upstream, colder water temperatures and higher dissolved oxygen concentrations upstream, and the salmon's general propensity to migrate as far upstream as possible then select the highest quality available habitat in which to spawn. The Tuolumne River restoration program must investigate the factors causing this uneven distribution in spawning habitat use, and then develop alternative management scenarios to re-distribute spawning and reduce superimposition losses. We recommend implementing paired upstream-downstream evaluations of spawning habitat use, using projects at Riffle A5/6, Riffle A7, Riffle 1A/B, and Riffle 3A as the upstream sites and Riffle 24, the Mining Reach, and the FOT RM 43 (Bobcat Flat) project as the downstream sites. The project at Basso Pool could also be used in this evaluation. We also recommend experimenting within or between sites with the micro-topography of restored riffles to achieve the maximum spawning habitat benefits, as measured by redd densities. Spawning riffle restoration projects implemented on the Stanislaus River (CMC 2001) were constructed in a succession of "dunes", each dune approximately 60–80 ft long, with a pool between each dune. This morphology was potentially more attractive to spawning salmonids than a single, long riffle (Carl Mesick, personal communication).

We also recommend experimenting with different coarse sediment mixtures and placement methods to determine the most inexpensive and best-used coarse sediment composition and placement approach. This evaluation should be conducted by within-site, side-by-side experiments at a single riffle to control for other potential variables and should also compare riffles constructed in long pools to existing riffles that are augmented or expanded. Section 5.5 describes our initial recommendation for an "ideal" coarse sediment mixture; Section 5.2.2 describes placement methods. The proposed sediment mixture should be tested against mixtures with a higher proportion of coarse gravel and with a higher proportion of smaller gravel. Also, unprocessed (unscreened) coarse sediment mixtures should be evaluated, since this would be the least expensive way to import coarse sediment that meet spawning substrate composition recommendations (i.e., are not too coarse and do no contain large quantities of fine sediment). The various augmentation methods and micro-topographic or other features that might be added to those methods should also be tested against one another.

Hypothesis 15 states that "sediment introduced and transported downstream by high flows will eventually improve salmonid spawning habitat and channel geomorphic conditions in un-restored downstream riffles." Evaluating riffle morphology improvements at Riffle 13 that result from sediment augmentation at Riffle 12 should test this hypothesis. This evaluation would include surveying cross sections and longitudinal profile (or a complete total station survey of the bed topography) at Riffle 13, and then monitoring changes after high flows capable of mobilizing the channel bed. Other sites may be selected to evaluate this hypothesis.

Finally, redd superimposition has been identified as a potential limiting factor on the Tuolumne River. Coarse sediment augmentation has the potential to reduce superimposition by increasing the area of available habitat and by redistributing spawners further downstream. Observed spawning distribution patterns, however, suggest that Chinook salmon may continue to concentrate spawning in upstream reaches (upstream of Basso Bridge), and the potential for distributing spawners further downstream is not known. Two monitoring approaches are recommended. First, salmon redd surveys throughout the spawning reach and detailed mapping of redd construction within newly constructed riffles should be a high priority for the monitoring program, during years with low as well as high escapement, and should compare use of upstream riffles (where utilization and imposition are high) to downstream riffles. We recommend this monitoring component be included in all riffle supplementation sites. This monitoring should compare redd densities and superimposition in upstream and downstream riffles. Second, the relationship between the annual abundance of juveniles migrating from the spawning reach and the annual abundance of spawners should be monitored with calibrated screw trapping and carcass surveys. This monitoring would provide the data to evaluate the effects of coarse sediment augmentation on the stock-recruitment relationship. The analysis, however, could be confounded by other factors affecting juvenile survival in the river after emergence from incubation substrates. Monitoring efforts in the Stanislaus River have indicated that gravel augmentation at 18 sites substantially improved the stock-juvenile production relationship for the first four years following sediment augmentation (CMC 2004). Moreover, these data suggest that redd superimposition continues to limit juvenile production, although to a lesser degree, and so further sediment augmentation is warranted. Conversely, an evaluation of stock-recruitment solely based on estimates of escapement and ocean harvest may not be as useful due to the confounding effects of Delta and ocean conditions on juvenile and adult survival.

7.5 Monitoring Recommendations

In general, the goal of monitoring is to evaluate project design, objectives, and hypotheses, and obtain information that will allow refinement of subsequent project phases or during implementation in other river systems. For the Coarse Sediment Management Plan, the monitoring objectives are:

- observe and quantify trends in bed aggradation/degradation to determine volumetric changes in sediment storage;
- estimate the periodic sediment augmentation volume necessary to maintain sediment storage over the long term;
- assess rates and frequency of bed mobilization in relation to the volume of coarse sediment augmentation;
- evaluate trends in spawning habitat availability and habitat use by fall-run Chinook salmon and *O. mykiss*, including measures of microhabitat, grain texture, and substrate permeability;
- evaluate trends in salmon egg survival-to-emergence longitudinally throughout the entire salmon spawning reach and across water year types;
- determine when sediment routes through impedance reaches so that long-term augmentation sites can be discontinued;
- compare the ratio of adult escapement to smolt outmigration estimates;
- evaluate trends in adult *O. mykiss* abundance relative to area and quality of available spawning habitat; and
- compare placement methods and micro-topographic features that are added to any coarse sediment augmentation site.

These monitoring goals will be discussed in more detail in the following section. To meet these objectives, our recommended monitoring elements are:

- Channel bed topography surveys, including cross section surveys with engineers level, longitudinal thalweg surveys at selected sub-reaches, and planform surveys with total station at three sites;
- Bed mobility experiments (tracer rocks, scour cores, pebble counts);
- Bedload transport empirical measurements and transport model development;
- Reach-wide spawning habitat and redd surveys;
- Site-specific spawning habitat vs. streamflow relationship;

- Spawning gravel quality measurements (including permeability, sediment composition, dissolved oxygen, and intra-gravel temperature).
- Annual calibrated screw trapping and escapement surveys or counting weir.

We recommend that monitoring activities initially be concentrated in the upper 4.2 mile reach from Basso Bridge (RM 47.5) to Riffle A3/4 (RM 51.7). The Riffle 4B reach (RM 48.5) will serve as a reference condition for sediment augmentation since it will not receive any mechanical sediment input. In the following sections, we provide an overview describing the monitoring activities recommended for the Tuolumne River, then follow with our recommendations for monitoring activities to be implemented along with the sediment transfusion and the long-term sediment maintenance program.

7.5.1 Topographic Surveys

Surveying the topography of the channel bed is one of the most important monitoring tools available for the sediment augmentation program. These surveys provide a quantitative evaluation of the general reach-wide trends in bed aggradation/degradation that result from sediment augmentation; they provide a means for estimating the volume of sediment augmentation needed periodically to maintain sediment storage equilibrium; and in combination with planform mapping, cross section surveys will allow us to observe the evolution of channel morphology that contributes to salmonid habitat (e.g., spawning riffle slopes, pool depths, margins of alternate bars). Surveys can be accomplished by several methods, including cross sections, longitudinal profiles, and total station surveys.

We recommend a combination of cross sections, long profiles, and 3D topographic surveys for monitoring different locations and site characteristics. All channel surveying, including new and existing cross sections and longitudinal profiles should be re-surveyed routinely, particularly following years with high flow events capable of causing topographic change. Longitudinal profiles should be established to document the existing (pre-transfusion) conditions for the reaches between Old and New La Grange bridges (Stn 2759+00 to 2789+00), as well as between New Basso Bridge and Riffle 5A (Stn 2645+00 to 2670+00). These surveys are best accomplished either with a total station or with RTK GPS (Real Time Kinematic GPS). Finally, we recommend two sites – Riffle 1B/C and Riffle 5A – for 3-dimensional total station surveys of the bed topography. These surveys will provide more detailed information describing changes in bed topography, sediment storage, and habitat conditions. Both sites are strategically located, one at the downstream end of the reach slated to receive the first phase of sediment transfusion (La Grange Dam to New La Grange Bridge), the other at the downstream end of the most heavily used spawning reach (Riffles 4B/5A) where the bedload measurement station and transport models are focused.

7.5.2 Bed Mobility and Scour Experiments

The long-term goal of bed mobility monitoring is to document long-term changes in bed mobility thresholds that result from sediment augmentation. We recommend continuing bed mobility and scour monitoring to document particle mobility thresholds and depth of scour in relation to discharge magnitude. We have established 4 bed mobility monitoring sites and recommend an additional 2 sites in the reach from La Grange to Basso Bridge (Figure 11). These sites incorporate a range of conditions and habitat types, including pool-tail, riffle, and lateral bar sediment facies. In addition, we have established 3 sites in the 7/11 Mining Reach for monitoring bed mobility (Figure 11). Each site should include (at a minimum) a set of 20 D_{84}, D_{50}, and D_{31} tracer rock particles, based on on-site pebble counts, and set on the cross section spaced 1–2 ft apart, traversing a defined coarse sediment facies, as shown in Figure 15. Each site should also include several (2–4) scour cores excavated at least 1.0 ft into the substrate and surveyed to a known benchmark. As sediment transfusion sites are implemented, additional sites can be established to supplement particle mobility data.

Field mobility experiments should be set up prior to the spring pulse flow release, and data collection should proceed immediately following the peak flow release. During years in which New Don Pedro reservoir is fuller and flood control releases are possible, experiments should be set up soon after the spawning season is over, and data collected as soon as possible following a spill event. If controlled flow releases are planned for collecting bedload transport data or other purposes, then bed mobility experiments should also be set out for these releases. Data should be collected in as consistent a manner as possible, using the same cross section sites and stations. A bed mobility–discharge relationship should be developed for each mobility site, as shown in Figure 16. Empirical data on bed mobility should continually be compared with predicted thresholds from sediment transport models, and used to improve model output.

7.5.3 Bedload Transport Estimates

Bedload transport measurement should continue to be conducted at Riffle 4B. This monitoring effort depends on the occurrence of high flows that generally occur only during wet water year cycles. We recommend conducting bedload transport measurements only at discharges that exceed 5,500 cfs (measured at La Grange), especially targeting flows in the 7,000 to 10,000 cfs range. Monitoring must therefore be opportunistic to take advantage of these events. During periods of extended flood control releases below the 5,500 cfs threshold, we recommend exploring opportunities to conduct controlled flow releases similar to the March 2000 experiments, such that numerous bedload samples can be collected during a single sampling effort. This should reduce overall monitoring costs and improve data quality.

During bedload transport measurements, water surface elevation profiles should also be collected for use in hydraulic model calibration. Water surface profiles should extend a minimum of 500 ft upstream and downstream of the bedload measurement cross section. Bed mobility tracer particles should also be placed on this cross section routinely to refine our estimates of mobility thresholds.

7.5.4 Spawning Habitat Evaluations

7.5.4.1 Quantify Spawning Habitat Availability

The objectives of planform mapping (relative to sediment management) are: (1) record habitat conditions at a specified time (e.g., during spawning season), (2) record the spatial boundaries of meso-habitat units (pools, riffles, runs) and other reach-scale geomorphic conditions (e.g., sediment storage, bank erosion), (3) document the extent of Chinook salmon and *O. mykiss* spawning habitat. This third objective can be completed using either pre-determined habitat suitability criteria to delineate habitat boundaries on the aerial photos, or by delineating habitat based on the area used by spawning Chinook salmon and *O. mykiss*. Each approach has advantages and disadvantages. Mapping with suitability criteria (usually depth, velocity, and substrate) ignores other variables that may determine if the habitat is selected for use by adult salmon, whereas allowing the adult fish to delineate habitat boundaries assumes that all suitable habitat is used. This latter assumption may be true in high escapement years, but not in lower escapement years or in riffles downstream of Basso Bridge. The preferred approach, therefore, would be to employ both methods, at least initially.

The basis for habitat mapping is a digitally orthorectified aerial photograph set. Photos should be flown at relatively low flow conditions (200-500 cfs), and should include the reach from La Grange Dam to at least Fox Grove (entire river is preferable). For field use, photographs should be scaled to at least 1”=100’, printed and laminated. All mapping should be done in the field. Riffles should be mapped by wading with maps in hand, but other sections generally require a boat for access. Within each spawning riffle, the boundaries surrounding suitable spawning habitat can be traced onto the aerial photos using permanent ink markers (different colors are useful), depending on the mapping approach selected (using suitability criteria or fish use of habitat, or both). At this scale of habitat assessment, boundaries can be drawn roughly (±3-5 ft) and should be more inclusive (i.e., don't micro-map). An area of contiguous spawning gravels with intermittent redds or zones of unsuitable hydraulics can be mapped as a single unit, acknowledging that spawners defend a broader area than the redd. During the mapping, occasional pebble counts (Wolman 1954, Leopold 1970) can be collected within areas identified as spawning habitat, to assess the gravel size suitability. Other features to be mapped should include the proximity of cover (e.g., pool habitat, surface turbulence, and overhanging vegetation) to gravel beds, mean depth, and mean column velocity.

When field mapping is complete, photos are then digitized to determine the area of spawning habitat at each flow inventoried. Areas should be determined at least for each individual riffle, and riffles with multiple large contiguous areas can be divided into sub-areas. This will allow more detailed comparisons in subsequent years. Areas can be summarized for reaches that correspond to the CDFG surveys, and riffle/reach area quantities should correspond to the original spawning habitat assessment from 1988 for comparison to this "baseline" condition.

7.5.4.2 Quantify Spawning Gravel Quality

We recommend several parameters for assessing gravel quality. The standard (but relatively more costly) method is bulk sampling of the substrate at selected sites to determine the particle size distribution. This allows an assessment of the relative proportion of fine sediment in the substrate, as well as the size range and proportion of spawning-sized gravels. Bulk sampling should be implemented periodically, in association with specific projects such as installation of the Gasburg Creek sedimentation basin or successive phases of sediment augmentation. Permeability techniques have been developed for monitoring spawning gravel quality on the Tuolumne River, and should be continued. Stillwater Sciences has developed and implemented a pilot assessment and first year of monitoring using permeability. Their methods, site selection, and recommendations should be implemented in conjunction with the Coarse Sediment Management Plan. Finally, methods to assess intra-gravel temperature, dissolved oxygen concentration, and apparent velocity have been implemented successfully on the Stanislaus River (CMC 2001, 2002a) to monitor sediment augmentation projects, and should be explored for use on the Tuolumne River, particularly measurement of intragravel temperature, as this factor is suspected to potentially decrease egg viability on the Tuolumne River.

7.5.4.3 Develop Flow vs. Habitat Relationship

The 1995 FERC flow schedule provides minimum flows for the Chinook salmon spawning season based on the flow vs. habitat relationship developed by the 1995 PHABSIM study (Figure 31) (USFWS 1995). Spawning baseflows are prescribed for the period Oct 1 to May 31 by the minimum flow schedule, and range between 100 cfs and 200 cfs for the drier 50% exceedance water year types and 300 cfs for the wetter 50% exceedance conditions. The effect of minimum flow releases during the spawning season is evident in most annual hydrographs, which shows all flow variability eliminated during the spawning season. As suggested above, streamflow variability is a key to ecosystem health and full utilization of available spawning habitat, can help reduce the risk of redd scour, and should be restored to the Tuolumne River during the spawning season. Variable spawning flows should not require too much, if any, additional water allocation, but should not be implemented randomly. We recommend the following approach to developing an empirical relationship between streamflow and spawning habitat availability.

The main assumption of this method of streamflow allocation is that different areas of the channel provide suitable habitat at different flows, so varying flows during the spawning season will provide the maximum amount of habitat. The approach is to develop a cumulative spawning curve that indicates the incremental increases in spawning habitat made available as streamflow is progressively

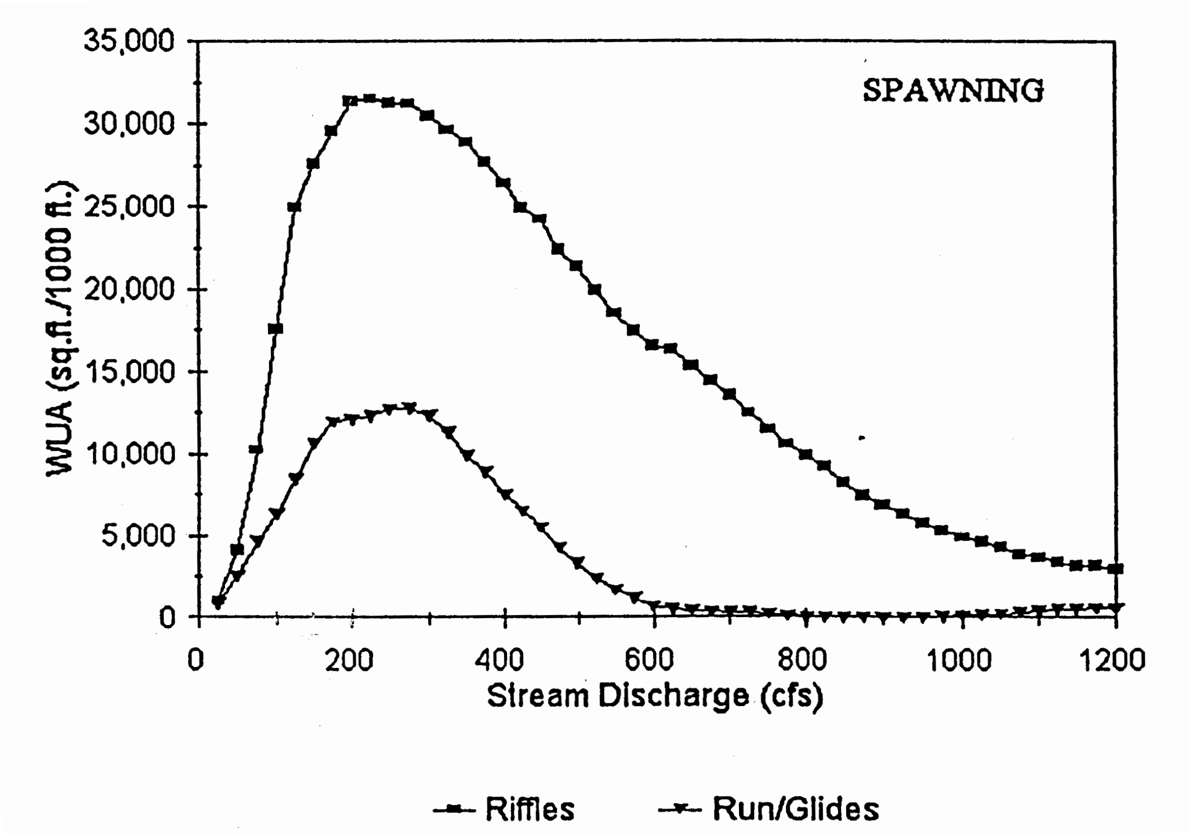


Figure 31. Relationship between discharge and Weighted Usable Area (WUA) for Chinook salmon spawning, developed from the Tuolumne River PHABSIM study (USFWS 1995).

increased. This curve is developed by measuring the amount of habitat available (or used) over a range of flows, then cumulatively adding additional habitat made available at each incrementally higher flow (McBain and Trush 2000). This cumulative habitat is then plotted in relation to discharge. As flows approach the higher end of the range, less habitat is added with each additional flow increment and the cumulative spawning curve will reach an asymptote. Selection of the range of flows and the pattern of flow increases that will provide the best use of habitat during the spawning season is a subjective management decision based on the empirical flow habitat relationship. Dry water years may only provide the lower range of spawning flows, whereas wetter water years may be able to provide spawning flows that maximize spawning habitat availability. The key is that different portions of the channel are made available at different times during the spawning season, which redistributes spawners and minimizes superimposition.

The potential benefits of this approach are numerous. On many river systems that receive unregulated winter floods, distributing spawning to different areas of channel significantly reduces the risks associated with flood scour of egg pockets if all spawning is artificially concentrated in the middle portion of the channel. In these infrequent years, the relatively small proportion of spawners that use marginal habitat made available by higher spawning flows may be the savior of those years' spawning cohort. This is likely less of an issue on the Tuolumne River because of regulation of winter floods. Another significant benefit is in maximizing use of spawning habitat, by distributing spawning activity to several different areas of the channel. Low flows during spawning season will allow fish to use the center of the channel, moderate flows (give range) will allow fish to use different portions of pool-tails and margins of gravel bars, high flows may allow fish to spawn on bar surfaces or other high elevation features. This strategy not only encourages spawning in different locations with different potential productivities, but also may reduce superimposition by reducing the suitability of habitat used early in the season. Finally, staged increases in flows during the spawning season would provide lower temperatures progressively downstream later in the year (from ambient and from higher releases), encouraging spawning farther downstream as the spawning season progresses.

Our recommendation is to implement detailed spawning habitat and redd mapping surveys both river-wide and at selected locations during a broad range of flow conditions. This activity should target flows ranging from the current 150 cfs minimum up to at least 1,000 cfs. Flows up to 1,000 cfs still provide 15% of the peak of the WUA curve (Figure 31) and should not be excluded from analysis. Monitoring should occur on an opportunistic basis when these flows are available. We recommend these methods be applied to several riffles in the upper spawning reaches, on a trial basis, potentially including the following sites: Riffles 3B, 4A, 5A, 7, 24, and 34A. These sites are relatively homogenous riffles, several are associated with lateral gravel bars that would potentially provide spawning habitat when inundated by higher flows. Different methods are available for redd mapping at each riffle. One approach would use larger scale aerial photos (1"=10' or 20'), with reference cross sections established at each site to aid in orienting features onto the photos. An alternative approach would employ a total station survey, with low flow channel features mapped as reference, then spawning habitat polygons surveyed at different flows. River-wide redd counts currently conducted by CDFG should continue.

8 REGULATORY COMPLIANCE

8.1 Overview

Implementing large-scale restoration projects is a complex process. Projects must obtain adequate funding, set attainable goals and objectives, develop designs that incorporate adaptive management guidelines, and interpret monitoring results to maximize learning. In addition, projects must also navigate the complex waters of permitting and environmental compliance. Project implementation is made even more difficult by the local, state, and federal regulatory agencies with jurisdiction over project components, the opportunity for public involvement, the need to justify using public funds, and time constraints (overburdened regulatory staff, finite duration of funding, annual cost inflations, etc.). In this section we discuss the regulatory compliance issues that pertain specifically to (1) purchasing and developing material sources for coarse sediment restoration, and (2) placing sediment into the river as river channel features and spawning gravel. We explore strategies for complying with land use and resource protection regulations and environmental laws, which have jurisdiction over the implementation of the Coarse Sediment Management Plan. Naturally, there are pros and cons when pursuing any strategy to expedite regulatory compliance.

This section addresses coarse sediment management as two separate projects, a surface mining operation (source development), and the restoration of salmonid habitat (sediment augmentation). All local, state, and federal land use, resource protection statutes, and procedural environmental laws that have jurisdiction over either project will be described. Issues that may arise while developing the projects and complying with these statutes are identified as they apply to each project, followed by a discussion of options that are available to address each issue. The section concludes with discussion of several alternative regulatory compliance strategies, and a recommended strategy.

8.2 Coarse Sediment Development Project

The purpose of the coarse sediment development project is to acquire and develop coarse sediment for channel restoration and spawning gravel augmentation projects. As discussed above, sediment augmentation is an accepted restoration approach to increase and maintain Chinook salmon spawning and rearing habitats and geomorphic features below dams. The purchase (or lease), excavation, and processing of sediment deposits for use in river restoration is similar to surface mining and processing of sediment to produce commercial aggregate products, which is a locally regulated land use activity along the Tuolumne River. Unlike aggregate mining, however, habitat restoration is generally funded and implemented by public entities rather than private business. During implementation of the Coarse Sediment Management Plan, either Stanislaus County, TID or CDFG would likely be the Local or State project lead agencies.

Section 6.4 recommended using dredger tailing materials from several sites along the Tuolumne River (and Merced River) as coarse sediment material for restoration and spawning gravel augmentation projects. These materials are the highest priority because they may be more economical than commercially purchased aggregate, and their use would reduce the demand for regionally valued and supply-limited commercial aggregate. In the 1930s, gold dredging along the Tuolumne River ceased, leaving behind dredger tailings as mine waste. This mine waste formed an abandoned landscape that was never reclaimed for beneficial uses as is now required. Later in the 1960s, most dredger tailings areas were re-excavated to supply aggregate for the construction of New Don Pedro Dam. The proposed excavation and processing of dredger tailings for use in restoration projects *could* therefore be considered deferred reclamation and habitat enhancement, instead of mining, as it will convert mining waste into riparian, wetland, and woodland habitats for wildlife, while developing a coarse sediment supply for river restoration. However, under today's statutes, this activity is still similar to commercial aggregate mining, which is regulated by Stanislaus County and California. In terms of regulatory compliance, we therefore recommend treating the source acquisition and development component as a commercial mining operation. Other reasons for this recommendation are given in the following sections.

8.2.1 Land use and resource protection agencies and statutes

Permitting for the coarse sediment development project will involve several activities, including mining, reclamation, hauling, stockpiling, and processing, as well as any secondary activities necessary for its implementation. The primary statutes that regulate the coarse sediment development project are Stanislaus County's General Plan and its implementing ordinances, and California's Surface Mining and Reclamation Act (SMARA). Secondary statutes would address mosquito abatement, water quality, air quality, stream-wetland protection, endangered or threatened species, and flood protection. Compliance with the California Environmental Quality Act (CEQA) is the principal procedural statute needed to support the permit approval process. The National Environmental Policy Act (NEPA) would also be required if a federal agency is involved. The following sections identify agencies that may have jurisdiction over this project, and describes numerous issues that must be addressed for regulatory compliance (Figure 32).

8.2.1.1 Local Agencies

Stanislaus County General Plan: Goals, Policies, and Implementation Measures

The Stanislaus County General Plan (General Plan) governs land use in Stanislaus County. The General Plan incorporates three important statutes: (1) California's 1975 Surface Mining and Reclamation Act (SMARA) as amended (Public Resource Code Section 2710 et seq.), (2) State Policy (California Code of Regulations Section 3500 et seq.), which can be found at http://www.ceres.ca.gov/ceqa and (3) Special Report 173: Mineral Land Classification of Stanislaus County (Higgins and Dupras 1993), discussed in Section 6.2. Goal 9 in the Conservation/Open Space Element of the General Plan specifically addresses extracting mineral resources such as coarse

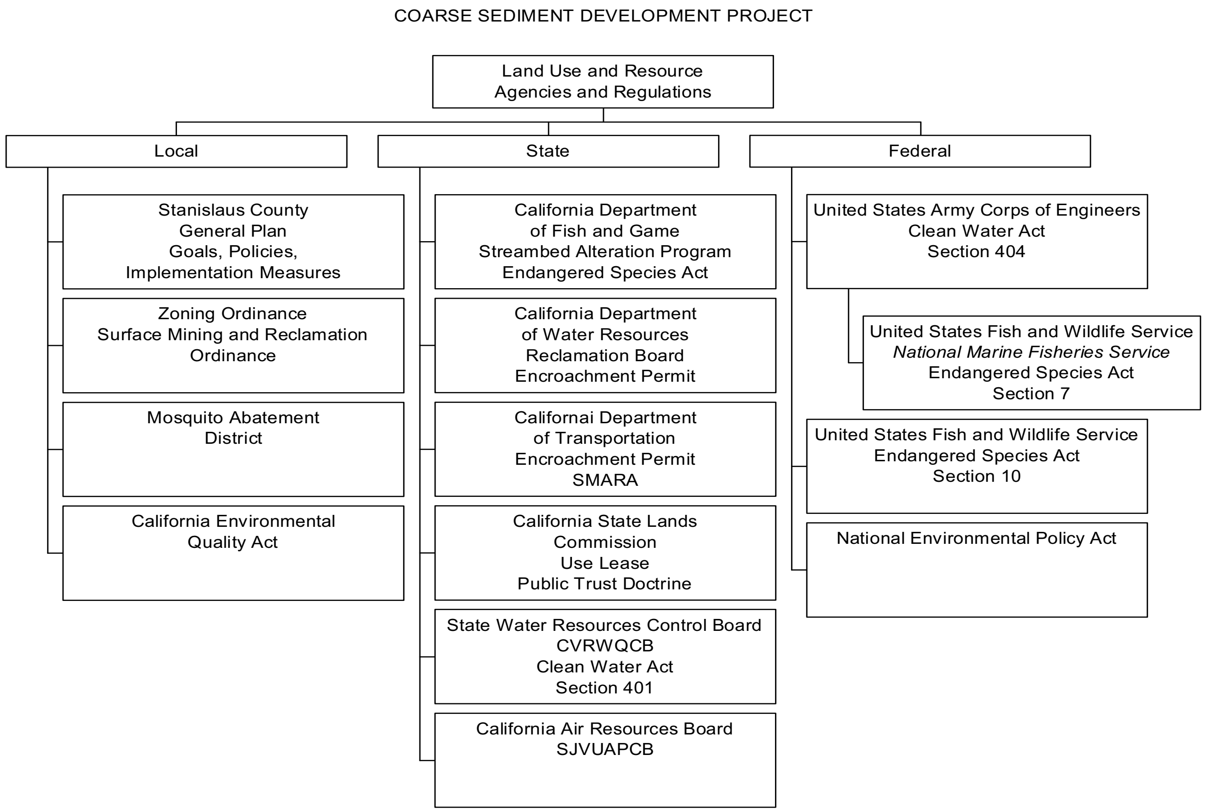


Figure 32. Organizational flowchart of the local, state, and federal agencies with jurisdiction over the proposed sediment development project.

sediment. Policy 26 of Goal 9 states that surface mining shall be encouraged in areas classified by the State Division of Mines and Geology. Based on the State's classification in Report 173, "Significant" Aggregate Resource Areas are designated on General Plan maps as ARAs (Figure 29). Most of the ARAs are located in terraces and floodplain along the Tuolumne River, which are currently zoned for either Agricultural or Open Space land uses.

The Stanislaus County Zoning Code contains the 1984 Surface Mining and Reclamation Ordinance (SMRO) (SCC, Title 21 Zoning, Chapter 21.88), which can be found at http://www.co.stanislaus.ca.us/board/ch21-88.htm. This ordinance designates Stanislaus County as the local lead agency under SMARA to authorize surface mining operations and approve mine reclamation plans and financial assurances. In Stanislaus County, surface mining means "processes for the commercial removal of minerals from the surface of the earth (SCC 21.12.600)." The SMRO applies to "all lands within the County, public and private" (SCC 21.88.040). Surface mining is a land use that requires a County Use Permit, because this activity may potentially be harmful to people and property in the county. The purpose of a use permit is to allow public review of a proposed use, and placement of conditions necessary to protect the rights of other citizens. When County decision-makers, such as the Planning Commission or Board of Supervisors, seek to approve a project like the proposed Coarse Sediment Development project, they are required to determine if the project conforms to the General Plan, and that they (i.e. decision-makers) have complied with CEQA before approving the project. The specific General Plan finding is:

> *The establishment, maintenance, and operation of the proposed use or building applied for is consistent with the General Plan and will not, under the circumstances of the particular case, be detrimental to the health, safety, and general welfare of persons residing or working in the neighborhood of the use, and that it will not be detrimental or injurious to property and improvements in the neighborhood or to the general welfare of the County.*

If that finding cannot be made then the project cannot be approved.

In addition to the County's SMRO, there are General Plan Elements that can affect a surface mining operation and reclamation plan, and that protect the County's mineral resources from non-compatible uses so they can be excavated. These General Plan Elements include the Land Use, Open Space, and Safety. Each Element contains *Goal*s, *Policies* and *Implementation Measures*, and are presented below as they appear in the County General Plan.

Land Use Element: Goals, Policies, and Implementation Measures

One-provide for diverse land use needs by designating patterns which are responsive to the physical characteristics of the land as well as to environmental, economic and social concerns of the residents of Stanislaus County.

Policy Two; Land designated Agriculture shall be restricted to uses that are compatible with agricultural practices, including natural resources management, open space, outdoor recreation and enjoyment of scenic beauty.

Policy Seven; Riparian habitat along the rivers and natural waterways of Stanislaus County shall to the extent possible be protected.
Implementation Measure-All requests for development which require discretionary approval and include lands adjacent to or within riparian habitat shall include measures for protecting that habitat.

Policy Eight; The County will continue to provide proper ordinances to ensure that flood insurance can be made available to qualified property owners through state and federal programs.
Implementation Measure-Development within the 100-year flood boundary shall meet the requirements of Chapter 16.40 (Flood Damage Protection) of the County Code and within the designated floodway shall obtain Reclamation Board approval

Policy Nine; The Land Use Element shall be maintained so that it is responsive to change.
Implementation Measure-Emphasize the conservation and development of significant mineral resources as identified by the State Division of Mines and Geology in its report entitled Mineral Land Classification of Stanislaus County, California (Higgins and Dupras 1993) by implementing the policies and implementation measures specified under Goal Nine of the Conservation/Open Space Element.

Conservation/Open Space Element: Goals, Policies, and Implementation Measures

In Stanislaus County, open space lands are defined as any parcel or area of land or water, which are essentially unimproved.

One-encourage the protection and preservation of natural and scenic areas throughout the County.

Policy Three; Areas of sensitive wildlife habitat and plant life (riparian habitats, waterfowl habitats, etc.) including those habitats and plant species listed in the General Plan Support Document, or by state or federal agencies, shall be protected from development.
Implementation Measure-Review all development requests to ensure that sensitive areas are left undisturbed or that mitigation measures acceptable to appropriate state and federal agencies are included in the project.

Implementation Measure-In known sensitive areas, the State Department of Fish and Game shall be notified as required by the California Native Plant Protection Act; the U.S. Fish and Wildlife Service also shall be notified.
Implementation Measure-All discretionary projects that will potentially impact riparian habitat or other sensitive areas shall include mitigation measures for protecting that habitat.

Two-conserve water resources and protect water quality in the County.

<u>Policy Six</u>; Preserve vegetation to protect waterways from bank erosion and siltation.
Implementation Measure-Development proposals including or in the vicinity of waterways and/or wetlands shall be closely reviewed to ensure that destruction of riparian habitat and vegetation is minimized. This shall include referral to the U.S. Army Corps of Engineers, the U.S. Fish and Wildlife Service, and the State Department of Fish and Game.

Three-provide for the long-term conservation and use of agricultural lands.

<u>Policy Eleven</u>; In areas designated "Agriculture" on the land Use Element, discourage land uses which are incompatible with agriculture.
Implementation Measure-All development proposals that require discretionary approval shall be reviewed to ensure that the project will not adversely affect an existing agricultural area.

Four-provide for the open-space recreational needs of the residents of the County.

<u>Policy Fourteen</u>; Provide for diverse recreational opportunities such as horseback riding trails, hiking trails, and bikeways.

Five-reserve, as open space, lands subject to natural disaster in order to minimize loss of life and property of residents of Stanislaus County.

<u>Policy Sixteen</u>; Discourage development on lands that are subject to flooding, landslide, faulting or any natural disaster to minimize loss of life and property.
Implementation Measure-Development will not be permitted in floodways unless it meets the requirements of Chapter 16.40 of the County Code and is approved by the State Reclamation Board.
Implementation Measure-The County shall utilize CEQA process to ensure that development does not occur that would be subject to natural disasters.

Six-improve air quality

<u>Policy Eighteen</u>; The County will promote effective communication, cooperation and coordination among agencies involved in developing and operating local and regional air quality programs.
Implementation Measure-Refer discretionary projects under CEQA to the San Joaquin Valley Unified Air Pollution Control District.

<u>Policy-Twenty</u>; The County shall strive to reduce motor vehicle emissions by reducing vehicle trips and vehicle miles traveled and increasing average vehicle ridership.

Eight-preserve areas of national, state, regional and local historical importance.

<u>Policy-Twenty-Four</u>; The County will support the preservation of Stanislaus County's cultural legacy of historical and archeological resources for future generations.
Implementation Measure-The County shall make referrals to the Office of Historic Preservation and the Central California Information Center as required to meet CEQA requirements.
Implementation Measure-The County will work with all interested individuals and organizations to protect and preserve the mining heritage of Stanislaus County.

Nine-manage extractive mineral resources to ensure an adequate supply without degradation of the environment.

Policy-Twenty-Six; Surface mining in areas classified by the State Division of Mines and Geology as having significant deposits of extractive mineral resources shall be encouraged.
Implementation Measure-The County shall utilize the CEQA process to protect mineral resources as well as the environment. The Legislature declares that in the event specific economic, social, or other conditions make infeasible such project alternatives or such mitigation measures, individual projects may be approved in spite of one or more significant effects.
Implementation Measure-The County shall adopt the Mineral Resources land use designation for those areas designated by the state as significant deposits.

Policy-Twenty-Seven; The County shall emphasize the conservation and development of lands having significant deposits of extractive mineral resources by not permitting uses that threaten the potential to extract the minerals.
Implementation Measure-The classification maps and mineral information contained in the Mineral Land Classification of Stanislaus County, California (Higgins and Dupras 1993), together with Public Resource Code Section 2710 et seq., SMARA and state policy, are hereby incorporated in this General Plan by reference.

Policy-Twenty-Eight; Lands used for the extraction of mineral resources shall be reclaimed as required by SMARA to minimize undesirable impacts.
Implementation Measure-Approval of any excavation permits shall include requirements for reclamation of the land consistent with the land use designation.
Implementation Measure-Mineral excavation on productive agricultural land should have a reclamation plan that retains or restores a maximum amount of agricultural or open space land.

Ten-protect fish and wildlife species of the County.

Policy-Twenty-Nine; Adequate water flows should be maintained in the County's rivers to allow salmon migration.
Implementation Measure-The County should continue to lobby the federal government to provide adequate water flow in the County's rivers to allow salmon migration.

Policy-Thirty; Habitats of rare and endangered fish and wildlife species shall be protected.
Implementation Measure-The County shall utilize CEQA process to ensure that development does not occur that would be detrimental to fish, plant life, or wildlife species.
Implementation Measure-The County shall protect sensitive wildlife habitat and plant life through the strategies identified under Policy Three of this element.

Safety Element: Goals

One-prevent loss of life and reduce property damage as a result of natural disasters.

Policy-Two; Development should not be allowed in areas that are within the designated floodway.
Implementation Measure-Development within the 100-year flood boundary shall meet the requirements of Chapter 16.40 [50] (Flood Damage Protection [Prevention]) of the County Code and within the designated floodway shall obtain Reclamation Board approval.
Implementation Measure-The County shall utilize CEQA process to ensure that development does not occur that would be especially susceptible to flooding.

California Environmental Quality Act

The California Environmental Quality Act (CEQA) is the principal procedural statute needed to support the permit approval process. The CEQA and the State's administrative guidelines are exhaustive, but the intent of the Act is simply to disclose and avoid, or reduce, potentially significant adverse environmental effects of the project, where possible, before the project is approved. In the case of a surface mining operation, certain categories of effects can be anticipated, and there might also be additional site-specific effects that must be addressed once a project location has been selected.

Stanislaus County has determined that new surface mining projects may have significant effects on the environment, and therefore require an Environmental Impact Report (EIR) for CEQA compliance. Significant impacts are those which are substantial or potentially substantial changes that may adversely affect the physical conditions within the area affected by the project, including land, air, water, minerals, flora, fauna, ambient noise, and objects of historic or aesthetic significance. The EIR must assess off-site and on-site actions, cumulative and project-level impacts, indirect and direct impacts, and construction and operational impacts. Those categories of environmental factors that are likely to be address in an EIR for the proposed project are discussed below. The significance thresholds, mitigation measures, and monitoring methods are not discussed in this report, as those issues are more suited for discussion in an EIR. Before it can approve a project, however, the Stanislaus County Planning Commission must support its decision by making the following findings (supported by substantial evidence in the record, for each potentially significant impact):

- the project has been changed to avoid or substantially reduce the magnitude of the impact to less than significant.
- there is no alternative to the project, while meeting the purpose of the project, that has less adverse environmental affects.
- changes to the project are within the jurisdiction of another agency and have been adopted or should be adopted.
- specific economic, social, legal, technical, or other considerations make mitigation measures or alternatives infeasible.

Some of the potentially significant environmental factors that may be associated with a surface mining operation are listed below.

Land Use and Planning

- Conflict with general plan designation, policy, or zoning? Conflict with applicable environmental plans or policies adopted for the purpose of avoiding or mitigating an environmental effect by agencies with jurisdiction over the project? Be incompatible with existing land use in the vicinity? Affect agricultural resources or operations (e.g., impacts to soils or farmlands, or impacts from incompatible land uses)?

Hydrology and Water Quality

- Change absorption rates, drainage patterns, or the rate and amount of surface runoff? Change the amount of surface water in any water body? Change the quantity of ground waters, either through direct additions or withdrawals, or through interception of an aquifer by cuts or excavations, or through substantial loss of groundwater recharge capability? Alter the direction or rate of flow of groundwater? Impact groundwater quality?

- Discharge into surface waters or other alteration of surface water quality (e.g., temperature, dissolved oxygen or turbidity)? Violate any water quality standards or waste discharge requirements?
- Place within 100-year flood hazard area structures, which would impede or redirect flood flows?

Air Quality

- Violate any air quality standard or contribute to an existing or projected air quality violation?
- Expose sensitive receptors to pollutants?
- Alter air movement, moisture, or temperature, or cause any change in climate?
- Mining above groundwater, operation of heavy equipment, trucks hauling aggregate from the mine site to the processing facility, stockpiling and screening of materials can generate dust and diesel exhaust that can contribute to the San Joaquin Valley Air Quality Management District's non-attainment condition.

Transportation/Circulation

- Increased vehicle trips or traffic congestion?

Biological Resources

- There may be riparian habitat dispersed throughout areas proposed for mining. This sensitive habitat could potentially be adversely affected by the proposed project. Stanislaus County, California Dept. of Fish and Game, and the Army Corps of Engineers protect riparian habitat from adverse effects.
- If endangered, threatened, or rare species or their habitats are present in the area proposed for mining they could be adversely affected by the mining operation. Stanislaus County, California Dept. of Fish and Game, and the U.S. Fish and Wildlife Service protect these sensitive and or special status species and their habitats from adverse effects.
- There may be federally protected wetlands dispersed throughout areas proposed for mining. Stanislaus County and the Army Corps of Engineers protect these wetlands from adverse effects.

Mineral Resources

- Use non-renewable resources in a wasteful and inefficient manner?
- Result in the loss of availability of a known mineral resource that would be of value to the region and the residents of the state?
- Result in the loss of availability of a locally important aggregate resource area delineated in the local general plan, specific plan, or other land use plan?

Noise

- Increases in existing noise levels?
- Exposure of people to severe noise levels?

Aesthetics

- Affect a scenic vista or scenic highway?
- Have a demonstrable negative aesthetic effect?
- The Tuolumne River below La Grange is confined between bluffs that are less than a mile apart; locating the processing facility so that it is not visible to the public will be challenging. Depending on the volume of sediment to be placed in the pre- and post- processing stockpiles, they also may be visible to the public.

Cultural Resources

- Cause a substantial adverse change in the significance of a historical resource as defined in §15064.5?

Recreation

- Affect existing recreational opportunities?

Mandatory Findings of Significance

- A potentially significant impact on any of the following questions requires preparation of an Environmental Impact Report (EIR).
- Does the project have the potential to degrade the quality of the environment substantially, reduce the habitat of a fish or wildlife species, cause a fish or wildlife population to drop below self-sustaining levels, threaten to eliminate a plant or animal community, reduce the number or restrict the range of a rare or endangered plant or animal, or eliminate important examples of the major periods of California history or prehistory?
- Does the project have impacts that are individually limited, but cumulatively considerable? ("Cumulatively considerable" means that the incremental effects of a project are considerable when viewed in connection with the effects of past projects, the effects of other current projects, and the effects of probable future projects).

Stanislaus County Mosquito Abatement District

State law now codified in the Stanislaus County Health and Safety Code (HSC Section 2200, et seq.) governs local Mosquito Abatement Districts. Districts protect the public's health, safety, and welfare from the spread of diseases carried by mosquitoes. Mosquitoes carry pathogens that cause malaria, encephalitis, and other vector borne diseases. In 2002 the Governor signed into law SB 1588 to toughen California's mosquito abatement and vector control laws, in response to new health hazards from the spread of the West Nile Virus and Asian tiger mosquitoes. The proposed project could result in the creation of sensitive riparian and wetlands habitats, which also may support populations of mosquitoes. Some District's claim populations of mosquitoes are increasing with the creation of more wetlands. The principal vector control technique employed by the District is spraying mosquito-breeding areas with insecticides, which they charge to the landowner.

8.2.1.2 State Agencies

California Department of Fish and Game

The California Department of Fish and Game (CDFG) administers its 'Lake and Streambed Alteration Program' pursuant to Fish and Game Code Sections 1600-1607. The coarse sediment development project will affect lands that have dredger tailings outside of the bed and bank of the Tuolumne River.

Within the dredger tailings are isolated ponds, wetlands, and riparian areas that may be incorporated into the coarse sediment development project's mining-reclamation designs. Consequently, these areas could be impacted by the proposed project. CDFG must be notified of such activity. If CDFG finds that the proposed project will not substantially adversely affect existing fish or wildlife resources, then it will not be necessary for the project proponent to enter into a Lake or Streambed Alteration Agreement (Agreement) with CDFG. If substantial adverse impacts to fish and wildlife resources are expected, then mitigation measures will be required as a condition of operation under the Agreement. Monitoring and reporting will also be required to document compliance with the conditions of operation and to determine the success of the mitigation measures.

CDFG also administers California's Endangered Species Act (CESA) pursuant to Fish and Game Codes 2080 to 2090. Because the coarse sediment development project is subject to SMARA, Stanislaus County will be the local lead agency under CEQA. CDFG consults with state lead agencies pursuant to Fish and Game Code Section 2090 and provides a Biological Opinion on a proposed projects' likelihood to jeopardize the continued existence of any listed species or adversely modify "essential habitat" necessary to the species. For species that are listed both under the federal and state endangered species acts, securing a federal 'Incidental Take Permit' for the proposed project will not require further state action pursuant to Section 2080.1 of the Fish and Game Code. The take of a species that is listed only under the CESA can be authorized under Fish and Game Code Section 2081, with an Incidental Take Permit from CDFG.

Pursuant to Stanislaus County General Plan Goal 1 Policy 3 and Goal 10 Policy 30, existing sensitive wildlife habitats, such as wetlands and riparian areas, are to be protected from development. This protection should avoid the taking of any listed species and ensure the protection of sensitive species and their habitats. The goal of the proposed reclamation plan for the coarse sediment development project would be to create riparian, wetland, and woodland habitats. The proposed project would therefore result in a net gain in beneficial habitats.

Environmental assessment surveys and subsequent project designs prepared for use by the local lead agency should be sufficient to notify DFG, and for them to determine if an Agreement will be required. Entering into an Agreement is a project as defined by CEQA, and DFG as a responsible and trust agency under CEQA can rely on prior compliance with CEQA attained by the local lead agency, Stanislaus County.

California Department of Water Resources

In the Sacramento-San Joaquin River Basin, the Department of Water Resources (DWR) Reclamation Board regulates encroachment within their 'Designated Floodways'. The Reclamation Board (Board) can also regulate activities outside of a designated floodway that could adversely affect a flood control project under their jurisdiction (Figure 33). The coarse sediment development project proposes to retain and create riparian habitat. If this were to occur within the designated floodway, both the Board and DWR would be concerned. Planting vegetation in the designated floodway can increase resistance to flood flows, resulting in a higher flood stage. One of the criteria that DWR uses when reviewing any proposed excavation, construction, or vegetation plans is that flood conveyance not be impaired (i.e., reduced). HEC modeling for the proposed project area may therefore be required to assist DWR in their evaluation of the project's effect on flood stage. The proposed project's riparian vegetation plans may need to be modified to satisfy DWR's concerns. Environmental assessment surveys and subsequent project designs prepared for use by the local lead agency, as well as HEC modeling, should be sufficient for DWR to process an application for an Encroachment Permit. Other projects similar to the proposed Coarse Sediment Project have had the following conditions included in their Encroachment Permit.

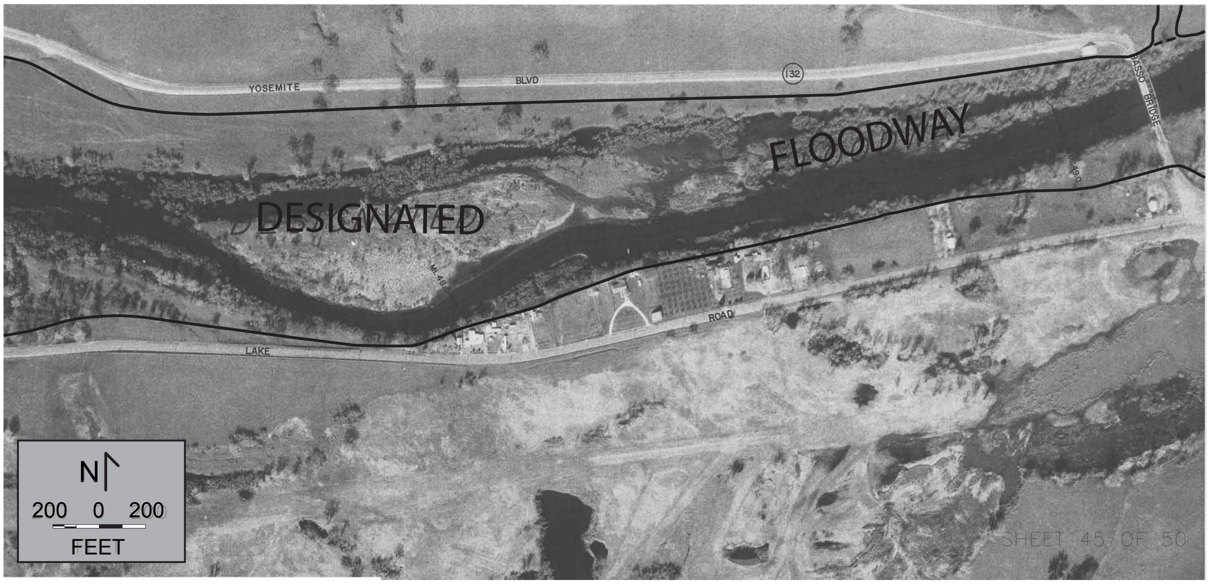


Figure 33. Tuolumne River Designated Floodway (based on 44,000 cfs). SOURCE: California Department of Water Resources. Adopted by State of California Reclamation Board, Nov. 25, 1975. Imagery acquired Feb., 21, 1975.

General and Special Conditions of Approval-Operation

- A key caveat of the Encroachment Permit is that the permittee is liable for any and all damages resulting from the encroachment, and liability insurance may be required.
- A pre-construction conference with DWR is required.
- The permittee shall maintain the permitted encroachment(s) and project works in the manner required by DWR.
- The permittee shall be responsible for repair of any damages to the floodway due to the construction, operation, or maintenance of the proposed project.
- From November 1st through July 15th no material stockpiles, temporary buildings, or equipment shall remain in the floodway.
- Cleared trees and brush shall be completely burned or removed from the floodway, and downed trees or brush shall not remain in the floodway during the flood season from November 1st through July 15th.
- The channel capacity of the Tuolumne River Designated Floodway shall not be adversely affected by the proposed project.
- If the proposed project results in an adverse hydraulic impact, the permittee will provide appropriate mitigation.
- If the project, or any portion thereof, is to be abandoned in the future, the permittee shall abandon the project under direction of the Board and DWR, at the permittee's expense.
- The permittee may be required, at permittee's cost and expense, to remove, alter, relocate, or reconstruct all of any part of the permitted encroachment(s) if required by the Board. If the permittee does not comply, the Board may remove the encroachment(s) at the permittee's expense.

- Environmental assessments, and subsequent project designs prepared for use by the local lead agency and HEC modeling should be sufficient to support the issuance of an Encroachment Permit. Issuance of this permit is a project as defined by CEQA, and the Board as a responsible agency under CEQA can rely on prior compliance with CEQA attained by the local lead agency, Stanislaus County.

California Department of Transportation

PRC Section 2770.5 in SMARA requires the lead agency to notify the California Department of Transportation (CALTRANS) whenever surface mining operations are proposed within the 100-year floodplain and one mile up or downriver of a state highway bridge (such as J-59 Bridge). The project proponent may be required to provide CALTRANS with field surveys and HEC modeling to support CALTRANS' hydraulic review of the project's affect on its bridge structures. Additionally, an Encroachment Permit may be required if the proposed project will occur on lands within CALTRANS' rights-of-way. A CALTRANS permit engineer will determine if the proposed encroachment will threaten the integrity of its highway. Environmental assessments and subsequent project designs prepared for use by the local lead agency as well as HEC modeling should be sufficient for CALTRANS to process an application for an Encroachment Permit. Issuance of an Encroachment Permit is a project as defined by CEQA, and CALTRANS as a responsible agency under CEQA can rely on prior compliance with CEQA attained by the local lead agency, (e.g., Stanislaus County).

California State Lands Commission

In 1850 California acquired the lands beneath the Tuolumne River's ordinary "high water mark". These are known as Sovereign lands and they are encumbered with public property rights as described under the Public Trust Doctrine. Today California retains a fee simple title in the riverbed that was inundated under natural conditions by "ordinary low water". The California State Lands Commission (SLC) administers these Sovereign lands and protects their Public Trust uses and resources. The coarse sediment development project will involve the extraction and processing of minerals from historic Tuolumne River bottomlands. Historically, the river migrated across these lands, and during major flood events the river abandoned some meanders and formed new channels (referred to as avulsion). Therefore, the last natural location of the river free of avulsion may not be the present river location, and the last natural location will need to be agreed upon by the SLC in order to determine whether a State Lands Lease will be required for the project (Figure 34). The State Lands Commission generally does not issue a lease that may result in any net adverse impact to wetlands or riparian habitat.

The SLC has issued leases on the Tuolumne River for salmon habitat restoration projects that did not involve the removal of mineral assets from State Lands. But the coarse sediment development project may involve the extraction of minerals from State Lands if a former channel is located in the dredger tailing deposits. Minerals removed from such lands would be used for habitat restoration in the Tuolumne River. The sand and silt that are screened and washed from the coarse sediment would be an exception. If these fines are sold, a royalty may become due the State. The Environmental Assessment and subsequent project designs prepared for use by the local lead agency should be sufficient for SLC to process a lease application for this project. Entering into a lease is a project as defined by CEQA, and SLC as a responsible and trust agency under CEQA can rely on prior compliance with CEQA attained by the local lead agency, Stanislaus County.

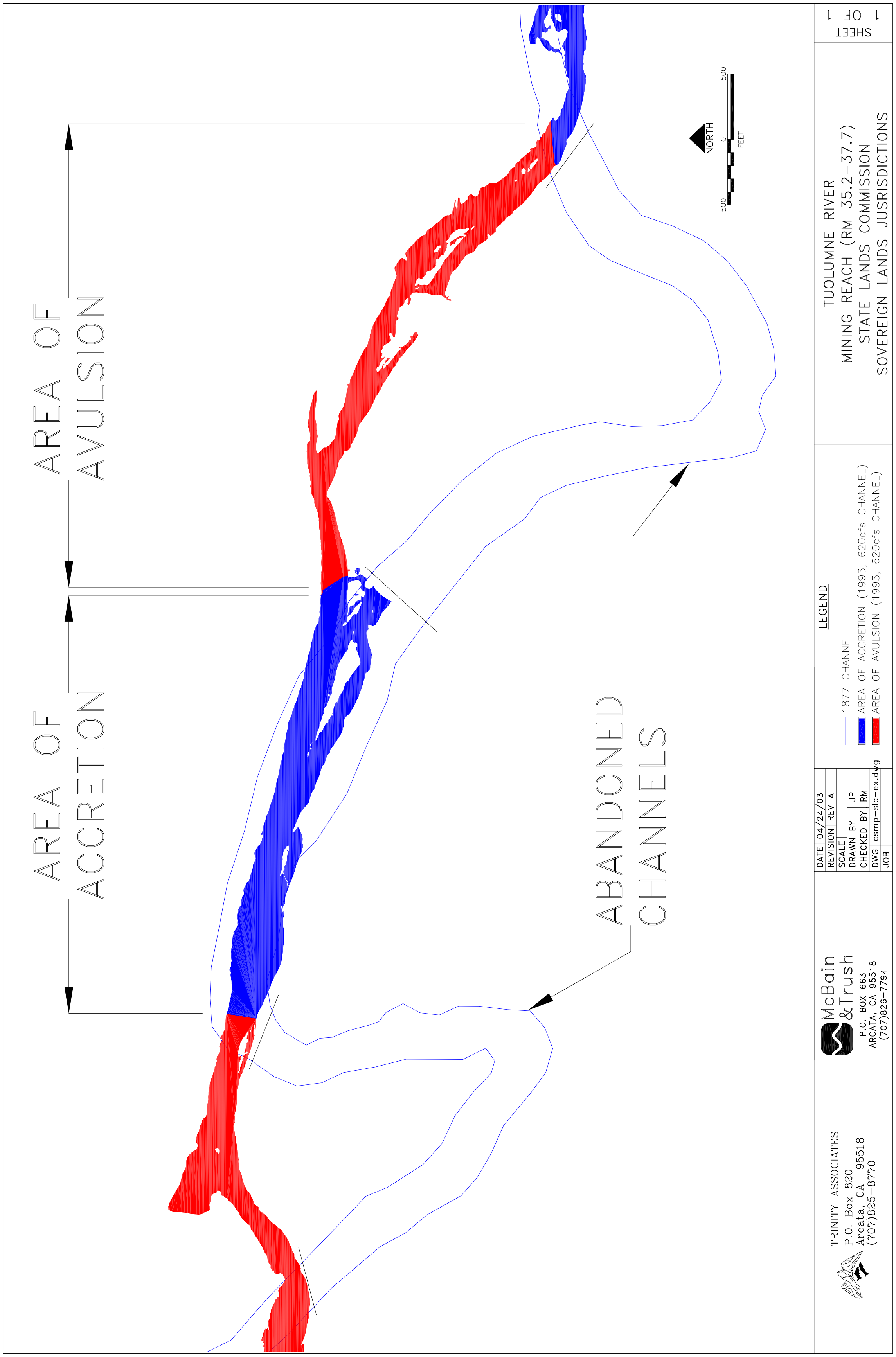


Figure 34. Example of mapping required to locate and identify CA State Sovereign Lands, for which the State Lands Commission has jurisdiction.

California State Water Resources Control Board (SWRCB) and Central Valley Regional Water Quality Control Board (CVRWQCB)

The federal Clean Water Act (CWA) requires that applicants for federal permits to conduct activities that may result in a discharge of a pollutant into waters of the U.S., such as the discharge of fill or dredged materials that could affect state water quality, must obtain a certification or waiver of certification from the state in which the discharge would originate. The SWRCB, through the CVRWQCB on the Tuolumne River, is responsible for issuing water quality certifications pursuant to the CWA. If the proposed action is determined to have minimal effect on water quality, certification may be waived by the CVRWQCB. If certification is necessary, the CVRWQCB will forward the application to the SWRCB with its recommendations for certification, with conditions of approval (if appropriate) or recommendation for denial. The Environmental Assessment and subsequent project designs prepared for use by the local lead agency should be sufficient for the CVRWQCB to process an application for certification. The Army Corps of Engineers will not issue a Fill Permit under Section 404 of the CWA for a project until a certificate or a waiver of certification has been issued.

In addition to possibly filling or dredging an existing water of the U.S., which is regulated by the ACOE under Section 404 of the CWA, the proposed coarse sediment development project may have a potential for both point source and non-point source discharges to such waters. The federal CWA authorizes states to issue National Pollution Discharge Elimination System Permits (NPDESP). The SWRCB and CVRWQCB regulate both types of discharges, and issue NPDESP. The Coarse Sediment Development project will involve surface mining and reclamation activities affecting greater than 5 acres, and there is a potential for stormwater runoff from the site discharging into a water of the U.S. If a general permit has been developed for surface mining and aggregate processing in California, it may be applicable to this project. A general permit authorizing the discharge of stormwater from construction may be applicable for surface mining sites. The General Permit prohibits discharges that contain a hazardous substance in excess of reportable quantities established by the U.S. Environmental Protection Agency, and requires preparation of a Storm Water Pollution Prevention Plan and monitoring program.

The SWRCB has approved ‘Basin Plans’ that establish water quality standards, objectives, and beneficial uses of rivers and streams. The CVRWQCB enforces those standards on the Tuolumne River. The CVRWQCB regulates discharges that could contaminate surface water or groundwater quality. The proposed project will involve washing sediment mined from dredger tailings. The wash water will be routed to a settling basin. While the proposed project does not propose to discharge wash water to the Tuolumne River, inundation during large floods could potentially result in discharge. A Waste Discharge Requirement (WDR) Permit will therefore be required, and will include a description of the activity, the type of potential discharge, and source of water that contributes to or transports the wastes.

Certification or issuance of a waiver from certification of water quality, or issuance of a NPDESP, WDR Permit are projects as defined by CEQA, and SWRCB and CVRWQCB are responsible agencies under CEQA and can rely on prior compliance with CEQA attained by the local lead agency, Stanislaus County.

California Air Resources Board and San Joaquin Valley Unified Air Pollution Control District

The California Air Resources Board (CARB) has adopted ambient air quality standards. The San Joaquin Valley Unified Air Pollution Control District (SJVUAPCD) can issue an ‘Authority to Construct’ for project activities, which may affect the attainment or maintenance of ambient air quality standards. These activities include construction and perhaps similarly mining and reclamation, and the operation of equipment (trucks, excavators, graders, generators, and pumps), which may emit any regulated air pollutant. The Coarse Sediment Development project application to the SJVUAPCD will need to describe the process used to extract, stockpile, screen and wash sediment, as well as the periodic dredging of the settling basin. Stanislaus County also refers its discretionary projects under CEQA to the SJVUAPCD for comment.

8.2.1.3 Federal Agencies

United States Army Corps of Engineers (ACOE)

The ACOE regulates the placement of fill or dredged materials into waters of the U.S. pursuant to Section 404 of the CWA (33 USC 1344). Because there are aquatic, wetland and riparian habitats (collectively referred to as wetlands) among unreclaimed dredger tailings, and some dredger tailings bordering the Tuolumne River, the ACOE's jurisdiction under Section 404 would likely include these wetlands and dredger tailing areas that are below "ordinary high water" (bankfull discharge) elevation. The proposed project's surface mining and reclamation plans in dredger tailings will involve cut and fill activities, which could affect existing jurisdictional wetlands or areas inundated during ordinary high water. The EPA has issued guidelines under Section 404 that the ACOE applies to determine whether there are practicable alternatives to the proposed discharge of fill in waters of the U.S. which would have less adverse impact on the aquatic ecosystem. The obvious alternative to the proposed sediment development project would be to purchase commercial aggregate. Additionally, one of the coarse sediment development project's objectives is the reclamation of abandoned dredger tailings that historically supported riverine habitats. The proposed creation of aquatic, wetland, and riparian habitats during reclamation is a water-dependent activity that could not be achieved by purchasing commercial aggregate. Pursuant to Section 7 of the Federal Endangered Species Act (ESA) the ACOE would consult with the United States Fish and Wildlife Service (USFWS) before issuing a Section 404 Permit if the proposed activity could jeopardize a federally listed species or its habitat. The USFWS would provide the ACOE with its Biological Opinion on the risk of jeopardy posed to any federally listed species by the proposed fill project, or its potential to adversely affect any designated Critical Habitat. After consultation with the USFWS, the ACOE could issue a Section 404 Permit. In providing a Biological Opinion and rendering a Jeopardy Decision, the USFWS must also comply with the National Environmental Policy Act (NEPA).

The ACOE issues two types of Section 404 Permits; General and Individual. The ACOE has adopted numerous Nationwide Permits, which are a type of General Permit. The activities covered under these Nationwide Permits authorize certain activities without the need for a permit that complies with general and specific conditions. The processing time to determine that a Nationwide Permit's conditions are met and receive these permits is greatly expedited compared to securing an individual permit. Nationwide Permit 27, *Wetland and Riparian Restoration and Creation Activities*, allows discharge activities associated with the restoration of former non-tidal wetlands and riparian areas in accordance with a binding agreement with the USFWS. Nationwide Permit 27 also covers the reclamation of surface coal mined lands that create wetland and riparian habitats. Nationwide Permit 27 could similarly apply to surface aggregate mined lands that are reclaimed as wetland and riparian habitats, although this is not certain. Individual Districts of the ACOE may issue Regional Permits for certain activities that are not national in scope, which is another type of General Permit. Regardless of the type of permit the ACOE issues, the permit will require reasonable and practicable mitigation measures of unavoidable impacts will be accepted.

Issuance of a Section 404 Permit is based on the following findings:

- the relative public and private need for the proposed actions.

- consideration of whether a proposed action is dependent on being located in, or in proximity to, the aquatic environment and whether practicable alternatives sites are available.
- where there are unresolved conflicts regarding resource use, the practicability of using reasonable alternative locations and methods to accomplish the objective of the proposed action.
- the extent and permanence of the beneficial and/or detrimental effects that the proposed action may have on public and private uses to which the area is suited.
- the ACOE as lead agency must comply with NEPA at the time it issues a permit. Project designs, environmental assessments, mitigation measures, and monitoring/report plans prepared for use by the local CEQA lead agency should greatly assist the ACOE in complying with NEPA and the issuance of a Section 404 Permit. The local and federal lead agencies also could prepare a joint CEQA/NEPA document.

In addition, under Section 401 of the CWA, the ACOE must ensure that the discharge it authorizes will not violate the state's water quality standards. As discussed previously, the applicant must secure and present the ACOE with either certification from the SWRCB or a waiver of certification from the CVRWQCB.

United States Fish and Wildlife Service and National Marine Fisheries Service

The Federal Endangered Species Act of 1973 (16 USC 1531), as amended, requires that actions not jeopardize the continued existence of federally listed species or result in adverse modification of the critical habitat of these species. The USFWS has jurisdiction over those species that are not anadromous (with the exception of Coastal Cutthroat Trout, Lamprey, and Sturgeon) or marine mammals. The National Marine Fisheries Service (NMFS) has jurisdiction over all other anadromous fish such as Chinook, coho, steelhead, and marine mammals. There are two ways to comply with the ESA if a federally listed species or its critical habitat may be affected by a project; one is via Section 7 when there is a federal nexus with the project, and the other is Section 10 when there is no federal nexus or the federal jurisdiction does not cover the whole of the action. If the coarse sediment development project affects wetland, riparian habitats or the floodplain of the Tuolumne River and requires a Section 404 Permit from the ACOE, then pursuant to Section 7, the ACOE would consult with the USFWS and possibly with NMFS. Even if all of the existing wetland, riparian and floodplain habitat areas are avoided, a Section 10 Incidental Take Permit may be needed if a federally listed species such as Valley Elderberry Longhorn Beetle or its critical habitat, Elderberry plants, could be affected by the project. Generally, avoidance of critical habitat and interference with the life cycle of a federally listed species is prudent. A Section 7 consultation using a federal agency is the most expedient alternative for compliance with the ESA.

Section 7 requires all federal agencies to consult with USFWS and NMFS (Services), depending on the species affected, to ensure that their actions do not jeopardize the continued existence of federally listed species or result in the adverse modification of the critical habitat of those species. Section 9 of the ESA prohibits the "taking" of any federally listed species without an authorized 'Incidental Take Permit'. Under Section 7, 'take' would be authorized in a Biological Opinion provided by either USFWS or NMFS to the federal action agency, such as the ACOE issuing a Section 404 permit. Under Section 10 of the ESA, the Services can also issue an Incidental Take Permit directly to a project proponent when no federal agency is involved.

Pursuant to Section 7 either USFWS or NMFS, whichever is applicable, will receive a request from the federal lead agency for information on whether any federally listed species or their critical habitat occupies the proposed project area. In response, the lead agency will prepare a biological assessment describing whether federally listed species or their critical habitat identified by the Services are likely to be affected by the proposed project. The Services must concur with the findings of the biological assessment. The Services will then enter into formal consultation with the lead agency and prepare a Biological Opinion on whether the proposed project or action would jeopardize the continued existence of listed species or adversely modify their critical habitat. If the Services makes a finding that either jeopardy or adverse modification could occur, then they will recommend reasonable and prudent alternatives that would avoid jeopardy, and the lead agency must modify the project approval conditions to ensure neither jeopardy nor adverse modification will occur. If mitigation measures or alternatives are not sufficient to protect the continued existence of a listed species the Services may issue a jeopardy opinion that the continued existence of the species would be jeopardized by the proposed project, and incidental take would be prohibited.

Pursuant to Section 10, either USFWS or NMFS (depending on the affected species) may issue an Incidental Take Permit for the proposed activity. An Incidental Take Permit can be issued if the Services can find that:

- The taking will be incidental to otherwise legal land use activities.
- The applicant will, to the maximum extent practicable, minimize and mitigate the impacts of such taking.
- The applicant will ensure that adequate funding for the plan and procedures to deal with the unforeseen circumstances will be provided.
- The taking will not appreciably reduce the likelihood of the survival and recovery of the species in the wild.
- The additional measures required by the Services, if any, will be met, and the Services have received assurances that the plan will be implemented.

Either USFWS or NMFS will be the lead agency for a Section 10 Incidental Take Permit. Issuing an Incidental Take Permit involves two federal actions that require compliance with NEPA: the Section 7 Consultation/Biological Opinion on issuing the Section 10 Incidental Take Permit, and the determination to issue the Incidental Take Permit. Depending on the complexity of the proposed project, the number of listed species involved, and the environmental effects of implementing the mitigation measures, an Environmental Impact Statement (EIS) may be required. Simpler projects and Incidental Take Permits may be able to comply with NEPA via an Environmental Assessment (EA) and by making a Finding of No Significant Impact (FONSI).

8.2.2 Coarse Sediment Development Issues

Issues for consideration are numbered and described first, followed by a bulleted list of possible options to address the issue.

1. If the proposed activity is a surface mining operation, then Stanislaus County would be the local Lead Agency under SMARA. If the project is a restoration project on the same property then it would be exempt from SMARA and the project proponent could be the local lead agency. Is there any advantage to seeking an exemption from SMARA as opposed to proceeding as a surface mine operation?
    - Stanislaus County requires that processing facilities not part of a SMRP be sited on industrial or commercially zoned property.
    - Stanislaus County requires that all material received by a processing facility be from sources with approved reclamation plans.

- Having Stanislaus County as the Lead Agency under SMARA may facilitate their support for the project if County properties are involved.
- As a surface mining operation, there would be no limits placed on where the mined material could be used, such as off site restoration projects, as there would be for a construction project under an exemption.
- If the project is treated as a surface mine then it would be possible to exercise options to sell the gold that is recovered as the fine sediment is separated from the coarse sediment.
- Treating the project as a surface mine would avoid third party appeals of a County decision to exempt this project from SMARA.
- Exempting the project from SMARA as a construction project would negate the need to assign responsibility to the project lead agency (mine operator) to implement the approved reclamation plan or to provide financial assurance to the County.
- Exemption from SMARA would also preclude the need to develop and secure approval of an Interim Management Plan if the excavation of the properties proceeds in phases with no mining occurring for greater than 90 days.
- Stanislaus County regulates surface mining and reclamation on all lands, public and private, so there is no advantage to having the sediment development project on public versus private lands from a regulatory perspective.

2. Permitting for the proposed sediment development project may exceed the period when funding is available to implement the project.
    - Use permits run with the land, and convey a property right to the underlying fee owner, which has value.
    - If the project lead agency were not able to complete the mining project, public funds would have been used to enrich the value of private property by securing a long-term use permit.
3. Permitting of a surface mining operation may contain conditions of approval.
    - Protecting existing riparian, wetland and sensitive species habitats from development will reduce the area and volume available to be mined.
    - Mining, stockpiling, and processing facilities within the 100-year flood boundary will need to meet conditions of the County's Flood Damage Protection Code.
    - Development on lands subject to flooding will require approval of the State Reclamation Board.
    - The proposed project's reclamation designs involve the creation of riparian and wetland habitats. The Mosquito Abatement District may require vector control measures.
4. If the project lead is a public agency, then the mine operator, the party responsibility for reclamation, and the party providing financial assurances to the County need to be identified.
    - Suitable properties for procuring the coarse sediment needed for the project are either privately or publicly owned. The underlying fee title holder of the mined property will most likely want the project lead agency to assume responsibility for reclaiming the mined lands.

- The project lead agency could select different contractors to excavate or process the alluvium versus being responsible for reclaiming the mined lands to wetlands, riparian and upland oak habitats.
- If one SMRP is submitted for all of the project area, then one financial assurance will be needed for the life of the Plan until all of the project area is reclaimed, including the processing yard and stockpile areas.
- If the SMRP is to be implemented in phases, then financial assurance may also be able to be phased.
- The County and State may accept conservation easement or covenant language in lieu of financial assurances if a public agency is the responsible entity for reclamation.

5. Identification of the owners in fee title as well as mineral rights of the properties that will be affected by the proposed mine operations is needed, and property boundaries established.
    - Delineation of State Sovereign land boundaries will be necessary to determine if the proposed mine areas affects State lands.
    - A decision will need to be made on whether to include State lands in the SMRP, if any are present within the project area.
    - If boundary monuments of the properties affected by the proposed mine operations do not exist, a survey will be necessary in order to establish the County's required 20-foot property setback to negotiate leases, right-of-way agreements and establish the distribution of royalties for minerals extracted.
    - Title searches will be necessary to verify who has a possessory interest in the surface and minerals of all areas affected by the project.
    - Leases and right-of-way agreements will be needed from all affected property owners.
6. If hauling of clean coarse aggregate or other products will traverse other property then identification of the owners of those properties that will be affected will be needed.
    - Leases and right-of-way agreements will be needed from all affected property owners.
    - If public roads are to be used then maintenance agreements or mitigation may be required for their use.
7. Baseline documentation is needed in order to proceed with planning, design, and permit acquisition.
    - A Digital Terrain Model (DTM) of the surface topography shall be developed of the areas affected by the SMRP.
    - Habitat delineation of the proposed SMRP areas should also be prepared.
    - Pre-existing sensitive species surveys should be conducted to determine if the presence of such species is likely.
    - If such species are likely to occupy the area affected by the SMRP and surveys have not been conducted, then time sensitive surveys by qualified biologists will be needed before designs can be developed and permits acquired.

8. A potential supply of coarse sediment for restoration totaling approximately 2 million cubic yards has been identified on public and private properties near Basso Bridge (at Joe Domecq County Park and the Zanker family property). For material from these sites to become available, permits must be obtained by the property owners and the site must be developed for mining. Average rates of surface mining of alluvial deposits in the region range from 100 to 300 tons per day. Utilizing a rate of 150 tons per day would generate approximately 195,000 cu yds per year, indicating that mining and processing of this material might require, at a minimum, approximately 10 years to complete.
   - The timing, rate, duration, and frequency of mining will affect the cost of mining and reclamation, the permitting strategy, and the ability to reclaim areas to functional habitats and provide for recreational uses.
   - Sediment test pits will be needed in the proposed excavation areas to discern the depth and quantity of coarse sediment reserves and to develop SMRP designs.
   - Regulatory constraints need to be identified that will affect the excavation footprint, and any constraints need to be delineated on the DTM to facilitate quantifying the SMRP area and the amount of available sediment.
   - The manner in which mining will occur (frequency and duration) will be either independent or dependent of the sediment input needs of the restoration projects requiring alluvial fill.
   - One strategy would develop all of the available alluvium deposit in a continuous operation, process and stockpile that material for use as needed later, and complete reclamation in one continuous operation in approximately 10 years.
   - A second strategy would excavate and process only the volume of material necessary for pending sediment introduction or other funded habitat restoration projects requiring fill. This strategy would require additional permits, an interim management plan, and multiple contracts with mine operators. This would be a less economical or efficient strategy than mining continuously.
   - Approval of an interim mining plan will be required if mining is not continuous and reclamation is not done on an annual basis.
   - If a phased approach is selected, then the minimum area to be mined and thus reclaimed will need to be of sufficient size to support a functional habitat unit.
9. What mineral commodities will be produced?
   - The excavation of former dredger tailing deposits is to generate coarse sediment, the project's preferred mineral commodity.
   - The project will screen and wash the sediment excavated for use in the sediment introduction project; sand will be a by-product of this operation. Sand is a valuable but limited commercial aggregate product. The value of sand would be included in the purchase of mineral rights. The value of sand could be used in negotiations with the mine operator to offset the cost of producing clean coarse sediment.
   - Commercial aggregate operations in the region engage in gold recovery during the processing of aggregate deposits along the Tuolumne River. Therefore this is another commercially valuable mineral commodity that could be produced by this operation. When mineral rights are purchased from either private or public entities, the issue of gold recovery and royalties for that mineral will need to be resolved separately from the acquisition of aggregate minerals. The production of this mineral commodity could help offset the cost of producing clean coarse sediment.

- Fine sediments that precipitate out of the wash water also have potential commercial value locally as a soil additive used in landscaping.
- If overburden is present and not utilized in reclamation, it would have value as fill or as a landscaping material.

10. Will the approved SMRP impose restrictions on future land use?
    - Areas that are mined must be reclaimed for whatever beneficial use(s) are identified in the approved reclamation plan.
    - Stanislaus County is the local lead agency regulating land use, and if uses other than those contained in the reclamation plan are proposed, it has the authority to amend the plan if reclamation has not been completed. Once the plan has been implemented, any other land uses that are allowed in that land use zone would be permissible. If the proposed future use is a conditional use, a permit would be necessary from the County. If the use is principally permitted, no permit would be necessary for that use.
    - The reclamation plan could serve as the foundation governing future land use restrictions contained in a conservation easement.
    - A conservation easement provides the benefits to the property owner of monetary compensation and to the purchasing agency of assurance that the habitat areas created and enhanced during reclamation will be perpetuated.
    - Without conservation easements, the private property owner could at some future time convert the lands that were reclaimed as habitat to other uses, such as agriculture or for commercial use such as a private hunting club.
11. The layout of the surface mining-reclamation operations may have numerous constraints and regulatory requirements.
    - A mining-reclamation plan can be prepared for each individual property owner, or, if contiguous properties are involved, one plan can be developed regardless of ownership.
    - The mining-reclamation layout can be constrained by property boundaries, topography, existing vegetation, regulatory jurisdictions, or the extent of the deposit.
    - A conceptual reclamation-habitat plan needs to be developed to direct the layout of the mining plan and reclamation to capitalize on those natural features present, as well as dictate the ability to implement the project in phases.
    - Proceeding with mining in phases over a ten-year period would provide for the establishment of habitat, which might include the presence of sensitive species on reclaimed lands. If reclamation is not designed with such restrictions in mind, that could constrain future mine entry into adjacent areas.
    - Some of the areas where mining is proposed could occur within the existing 11,000 cfs floodway established by Stanislaus County. Mining below groundwater elevation in those areas would be prohibited unless a levee was constructed with freeboard above that discharge. Mining in the 11,000 cfs floodway may be permissible if the area is reclaimed to riverine habitats, such as floodplain riparian habitat or shallow sloughs etc.

- There are two methods of mining that can affect the success of reclamation to wetland and riparian habitats. One involves the excavation of pits with vertical walls, and reclamation utilizes overburden that was removed previously to back fill to create desired slopes. The other method excavates the pit, leaving original ground at the desired slopes, and overburden, if available, can be used as surface dressing. Backfilled slopes that will be inundated are prone to erosion from wind fetch and bank failure during flood draw down.
- The layout of access roads and haul roads needs to consider the phased mining and reclamation design over the ten-year period to avoid unnecessary disturbance to wildlife or recreational uses. Road layout and reclamation needs to be described in the Conditional Use Permit application or a separate Grading Permit will be needed.
- Measurable biological and physical habitat goals will need to be developed to guide monitoring plans necessary to document success of reclamation.

12. Sediment sources that require multiple years to mine and reclaim the site will need to determine where to site the processing facility.
    - A lease, rental payment, and right-of-way agreement will be needed to site the processing facility on private or public property.
    - The processing facility could be located on the property that is presently being mined, and then moved to the next property to be mined, while reclamation occurs on the former site.
    - One centrally located processing site could be established to minimize haul time.
    - If, after mining and reclamation are completed but the aggregate products are to be stockpiled on site, then another lease, rental payment, and right-of-way agreement will be needed to secure the use of that property.
13. The layout and operation of the aggregate processing facilities may have numerous constraints and regulatory requirements.
    - The processing facilities should be located outside of the Reclamation Board's Tuolumne River designated floodway boundary
    - The processing facilities should be sited where they will have the least affect on neighboring properties or other uses.
    - Water and electrical sources may need to be developed.
    - A settling basin will need to be constructed to retain wash water. The settling basin will need to be located outside of any floodways and not discharge to any waterway.
    - The settling basin will need to be periodically excavated to restore its holding capacity.
    - The settling basin may need to be sprayed with an insecticide to control mosquitoes.
    - A scale house and turn-around area will be needed for haul trucks.
14. The County's General Plan requires that riparian habitat be protected from development.
    - What setback distance is adequate to protect existing riparian habitat from the effects of pit excavations?
    - What slope will be adequate for the pit walls adjacent to riparian habitat?

- Are Elderberry plants present in the proposed project areas, and how much area would be removed from extraction to protect these plants?
- Is there a suitable area to establish riparian or Elderberry vegetation to mitigate project impacts to such vegetation?
- Will excavation intercept surface or groundwater sources that maintain riparian vegetation?

15. The County's General Plan requires compliance with its Flood Protection standards for development within the 100-year flood zone as mapped by FEMA's FIRMs.
    - Development should not be susceptible to flooding, such as locating processing and stockpiles in the 100-year flood zone, which maybe restricted.
16. The County's General Plan requires that Aggregate Resource Areas (ARAs) be set aside for extraction of aggregate.
    - Surface mining is encouraged in ARAs. The proposed project is a surface mining operation, and therefore it fulfills the purpose for creating ARAs. The ARAs did not specify how the aggregate was to be utilized, just that it was to be protected from incompatible uses that would preclude its future extraction.
    - The proposed reclamation will be creating Open Space Areas, which is a desired land use in the County's General Plan.
17. The County's General Plan requires that a surface mine be reclaimed to a beneficial use. The proposed reclamation use is for Open Space, specifically wildlife habitat.
    - The reclamation habitat that will be created has the potential to support listed species and protected habitats such as riparian and wetlands, which may preclude future uses that would affect those habitats or species.
    - The result of the proposed reclamation could restrict neighboring land uses if they were to affect listed species or protected habitats.
18. The County's General Plan requires that the application for a use permit be referred to other regulatory agencies.
    - Some of these agencies; CDFG, DWR-RB, CVRWQCB, SJVUAPCD, ACOE and USFWS may require their own permits for the project, which can increase the time, effort and expense to secure all of the permits necessary.
    - Some of these agencies may recommend that conditions of approval be adopted in the County' CUP permit to protect: natural resources, flood conveyance capacity, cultural-historic resources and listed species.
19. The County's General Plan requires that its cultural and historical legacy be protected.
    - Dredger tailings are part of the County's cultural and historical legacy, and either the County or the State Office of Historic Preservation may require their protection. Other dredger tailing areas in County or State parks may already be adequately preserved.

- To some people the dredger tailings are an important example of a major period of California history. The County has chosen not to designate the dredger tailings along the Tuolumne River as a historic or culturally important landscape. On the contrary, Stanislaus County General Plan Policy 27 specifically states "*The County shall emphasize the conservation and development of lands having significant deposits of extractive mineral resources by not permitting uses that threaten the potential to extract the minerals.*" These dredger tailings are mine waste from the 1930s, forming an abandoned landscape that was never reclaimed for beneficial uses. The conversion of this mine waste into wildlife-wetland habitats and a clean coarse sediment supply for spawning and rearing habitats could be considered deferred reclamation and importantly as habitat restoration and enhancement. The use of the dredger tailings along the Tuolumne River will not eliminate an important example of a major period of California history, as examples are still common along other rivers in the region.

20. The County's General Plan requires that reclamation of mined land be consistent with the underlying land use designation.
    - The proposed project will create Open Space to foster wildlife and recreation uses, which are allowable uses in Agricultural and Natural Resource lands where the majority of the dredger tailings are located on the Tuolumne River.
21. The County's General Plan requires that fish and wildlife species be protected.
    - The wetlands being created through reclamation may provide habitat for exotic or predatory species that would affect the distribution or abundance of protected fish and wildlife species
    - Restored wetland and riparian habitats may increase mosquito populations.
22. To support approval of the sediment development project, the County must comply with CEQA, most likely by preparing an Environmental Impact Report.
    - CEQA requires that project alternatives be included in an EIR. One possible alternative that could meet some of the project's objectives with less environmental effects at the proposed project locations would be to purchase coarse sediment from existing mine operations.
    - CEQA requires that a project not be fragmented; compliance may require that both the coarse sediment development and sediment introduction projects be treated as two phases of one project. However, this would make an EIR more complicated to review and certify.
23. The proposed sediment development project could be construed to be in conflict with Stanislaus County's General Plan (as per CEQA Guidelines) policies emphasizing the conservation of its Mineral Resource Zone lands for the extraction of aggregate resources,
    - These aggregate resources are necessary to support future growth in the County (see discussion in Section 6.2).
    - Obtaining commercial aggregate for restoration projects may (1) increase demand from the limited number of permitted operations, possibly increasing the cost of aggregate products for the region as a whole, (2) contribute to creating additional floodplain pits on agriculturally productive lands, and (3) contribute to other ecological damage that is contrary to the restoration of the County's General Plan policies that protect fish and wildlife habitats, agriculture, and open space.

- Developing dredger tailings not available for commercial use, but instead for river restoration eliminates the potential conflict with the use of permitted aggregate reserves. Further, mining dredger tailings allows these sites to be reclaimed to higher quality habitat as opposed to contributing to the creation of additional floodplain mining pits.
- By obtaining coarse sediment closer to the sites where they are needed, the proposed sediment development project will involve fewer vehicle trips and miles than would the purchase of material that has to be transported to the sediment introduction sites. This would have a significantly less impact on air quality and road maintenance.
- The proposed project would mine an Aggregate Resource Area (ARA) that is less economically viable for existing commercial operations due to the longer distance to commercial markets.

24. One of the issues of concern (as per CEQA Guidelines) is the project's affect on hydrology and water quality. The mining of the dredger tailing areas will occur by excavating pits to secure sediment.
    - These pits will penetrate the groundwater table and be reclaimed to open water, wetlands, and riparian habitats. Depending on the source of groundwater, these water bodies could intercept or separate groundwater connectivity to the Tuolumne River or to other wetlands in the area.
25. Another issue of concern (as per CEQA Guidelines) is the affect of the project on air quality.
    - The excavation of dredger tailings can expose underlying fine sediments to wind, resulting in the transport of particulate matter off-site. This could be a long term impact if mining is continual, rather than in stages followed by reclamation that would reduce the exposure of these fine sediments.
    - Long-term storage of sediment in stockpiles that have not been screened could also result in airborne transmission of fine matter.
    - Locating the sediment development project near the sites that will receive the spawning gravels will reduce the distance that trucks haul material to the site compared to purchasing commercial aggregate from downriver sites.
26. Project effects on biological resources are an area of concern (as per CEQA Guidelines).
    - Avoiding existing aquatic, wetland, riparian, and listed species habitats in the sediment development project will greatly facilitate compliance with CEQA and other regulations.
    - If the project areas have not been previously surveyed, then sensitive species presence/absence surveys will need to be conducted.
    - Wetland delineations and vegetation-habitat mapping will also be necessary to assist project designs and to address regulatory concerns.
    - Groundwater investigations may be necessary in order to understand the source of water that is supporting existing aquatic, wetland, and riparian habitats to assure that water supplies are not interrupted by proposed mining activities.
    - Setback distances and slopes will need to be negotiated with the appropriate regulatory agencies before a mining footprint can be established and the volume of sediment that would be purchased and available for use in restoration projects.

27. Project effects on the availability of mineral resources are an area of concern (as per CEQA Guidelines).
    - The state has designated numerous Aggregate Resource Areas in Stanislaus County, which have been incorporated into the County General Plan. The proposed project will involve extraction of aggregate resources in ARAs. The use of the mined material is for the restoration of the Tuolumne River and its anadromous salmonid fisheries. Such restoration is in furtherance of the health, safety, and public welfare of local residents and for those who reside in the Central Valley region and California as a whole. There must be a balance in the use of these important mineral resources between the needs for natural resource restoration and to support urban growth. The Public Trust Doctrine calls for such a balance of uses to protect the Public's Trust uses and resources in the Tuolumne River.
28. Project effects on cultural resources are also an area of concern (as per CEQA Guidelines).
29. One of the Findings required under CEQA is whether the project could reduce the number or restrict the range of a rare or endangered plant or animal?
    - Elderberry plants provide habitat for the federally listed Valley Elderberry Longhorn Beetle, found in the Tuolumne River bottomlands. The proposed project has the potential to reduce the number or restrict the range of these plants and thus the listed species.
    - Individual or clumps of such plants, if present, could be removed and transplanted during mining and reclamation to the riparian and upland habitat areas being created. Additional Elderberry plants could be planted in suitable areas to increase the number and range of the species and its habitat.
30. The proposed project would result in the creation of sensitive riparian and wetlands habitats, which may also support populations of mosquitoes. Local Abatement Districts are concerned about the spread of vector diseases like the West Nile Virus.
    - Monitoring may be necessary to determine if mosquito populations increase with the creation of the project's riparian and wetlands habitats.
    - If mosquitoes population do occur in the wetlands then abatement efforts may be needed, which will result in an ongoing expense, and possibly having deleterious effects on protected habitats.
    - Alternative vector control techniques may also be needed.
31. DFG administers the CESA, and can authorize incidental take of a listed species.
    - The environmental analysis in Stanislaus County's CEQA document should include habitat mapping as well as the results of presence or absence surveys for sensitive species.
    - DFG could determine if an incidental take permit is necessary, during its review of Stanislaus County's CEQA document that will be prepared for the proposed project, as well as provide its findings on jeopardy.
32. California as Sovereign has a fee title interest and Public Trust interests in the Tuolumne River. However, in the proposed project reach the exact location of the state's interests have not been ascertained. The State's Sovereign lands fee title interest and Public Trust interests are normally associated with the last natural channel location absent avulsion. However, the present day location of the Tuolumne River in the proposed project reach may be an artifact of where past mining operations ceased dredging for gold, and not its natural location.

- A boundary study could determine if an abandoned channel, which would be claimed as Sovereign lands, exists in the proposed project area.
- A boundary study could determine if the present day channel's location is a result of artificial manipulations, and determine if the last natural channel location resides in the proposed project area.

33. The coarse sediment development project may involve the extraction of minerals from State Lands if a former channel is located in the dredger tailing deposits, which normally requires a Lease and payment of royalties.
    - The SLC could find that the proposed use of such state assets for the restoration of anadromous fisheries is beneficial and would further the Public's Trust uses and resources in the Tuolumne River.
34. The SWRCB and CVRWQCB pursuant to the CWA regulate the discharge of pollutants into waters of the U.S.
    - The isolated aquatic, wetland and riparian areas in the dredger tailings could be avoided to prevent the proposed project' activities from discharging pollutants into the waters of the U.S., except possibly during flood events.
    - Screening and washing the mined aggregate would remove any mercury from the coarse sediment.
    - The settling basin could be lined with an impervious layer to prevent possible contamination of ground water.
    - The settling basin could be dredged each year and the waste material removed to avoid discharge to surface or groundwater.
35. The SJVUAPCD will require air pollution control measures to protect air quality during mining, reclamation, processing and stockpiling.
    - Dust abatement measures can be applied on roadways and on exposed mine areas.
    - Unscreened stockpiles could occupy a larger footprint to reduce overall height.
    - Watering of unscreened stockpiles may be necessary.
    - Screening of stockpiles could occur as the material is mined.
36. The ACOE regulates the placement of fill or dredged materials into waters of the U.S. pursuant to Section 404 of the CWA.
    - Projects should determine whether the ACOE will have jurisdiction over the excavation of isolated wetlands if there is no discharge of fill (incidental fall-back) in these small wetlands.
    - If excavation occurred in dredger tailings along the Tuolumne River in such a manner that the material is transported above the "ordinary high water" elevation, the ACOE may not have jurisdiction of this activity under CWA Section 404.
    - If the ACOE has jurisdiction over these areas, the proposed reclamation plan would significantly increase the acreage of wetlands and riparian habitat areas.
37. Reclamation of the mined areas proposes to create wetland, riparian, and woodland habitats. Placing these reclaimed areas under a conservation easements could prevent future land use conflicts.

38. The ACOE must comply with NEPA before issuing a Section 404 permit. To streamline compliance with NEPA the local and federal lead agencies could have a joint CEQA/NEPA document prepared.
39. If Section 10 applies to the proposed project activities, a HCP will need to be prepared, and an Incidental Take Permit acquired.
    - A HCP could be prepared in conjunction with an EIR/EIS if they are required.
    - The HCP and Incidental Take Permit could be expanded to cover both the sediment development and coarse sediment augmentation activities.
40. Section 10 requires that the project proponent demonstrate that funds are available to implement HCP mitigation and monitoring measures. How could this be demonstrated?
    - Similar to providing financial assurances for the reclamation of the mined area, a letter of credit, or certificate of deposit or a MOA could be used by the project lead agency.

8.3 Coarse sediment Augmentation Project

The coarse sediment augmentation project proposes to introduce clean coarse sediment into a channel to restore and maintain bedload supply and spawning habitat downstream of La Grange Dam. Coarse sediment augmentation will involve several phases, including: (1) a short-term transfusion of large volumes of coarse sediment at numerous sites to re-supply alluvial features (alternate bars, riffles, pool-tails, etc.), provide spawning gravels, and to create immediately usable spawning and rearing habitat, (2) long-term periodic augmentation of small volumes of coarse sediment at several sites to maintain in-channel supply as sediment is mobilized and transported downstream, and (3) filling of in-channel mining pits and other bedload impedance sites with sediment to restore bedload transport continuity throughout the gravel-bedded reaches. The initial tasks of the Coarse Sediment Management Plan included estimating coarse sediment volumes, locations, methods, and timing of augmentation. Conceptual designs were developed for five sites (Appendix B). Four different methods for coarse sediment placement are proposed (Section 5.2.2), depending on site morphology and site objectives.

The implementation of different phases of coarse sediment augmentation, including delivery and stockpiling coarse sediment, and coarse sediment insertion and contouring at the multiple coarse sediment transfusion sites, will all require the same permits. Depending on the length of time between each phase or between construction at each site, it may not be possible to secure one set of long-term permits for all phases. The environmental compliance process discussed below may need to be repeated several times if time extensions or amendments cannot be secured for the initial permits. The following sections identify agencies that may have jurisdiction over this project, and describes numerous issues that must be addressed for regulatory compliance (Figure 35). The evaluation of land use laws and regulations that apply to coarse sediment augmentation projects will be reviewed, considering all of the phases and methods described above.

8.3.1 Land use and resource protection agencies and statutes

8.3.1.1 Local Agencies

Stanislaus County General Plan: Goals, Policies, and Implementation Measures

This section describes Stanislaus County's General Plan goals and policies that govern land use in the County that are relevant to the proposed coarse sediment augmentation project, as well as describing relevant aspects of CEQA not covered in Section 8.1.1. Goal 1 of the Safety Element in Stanislaus

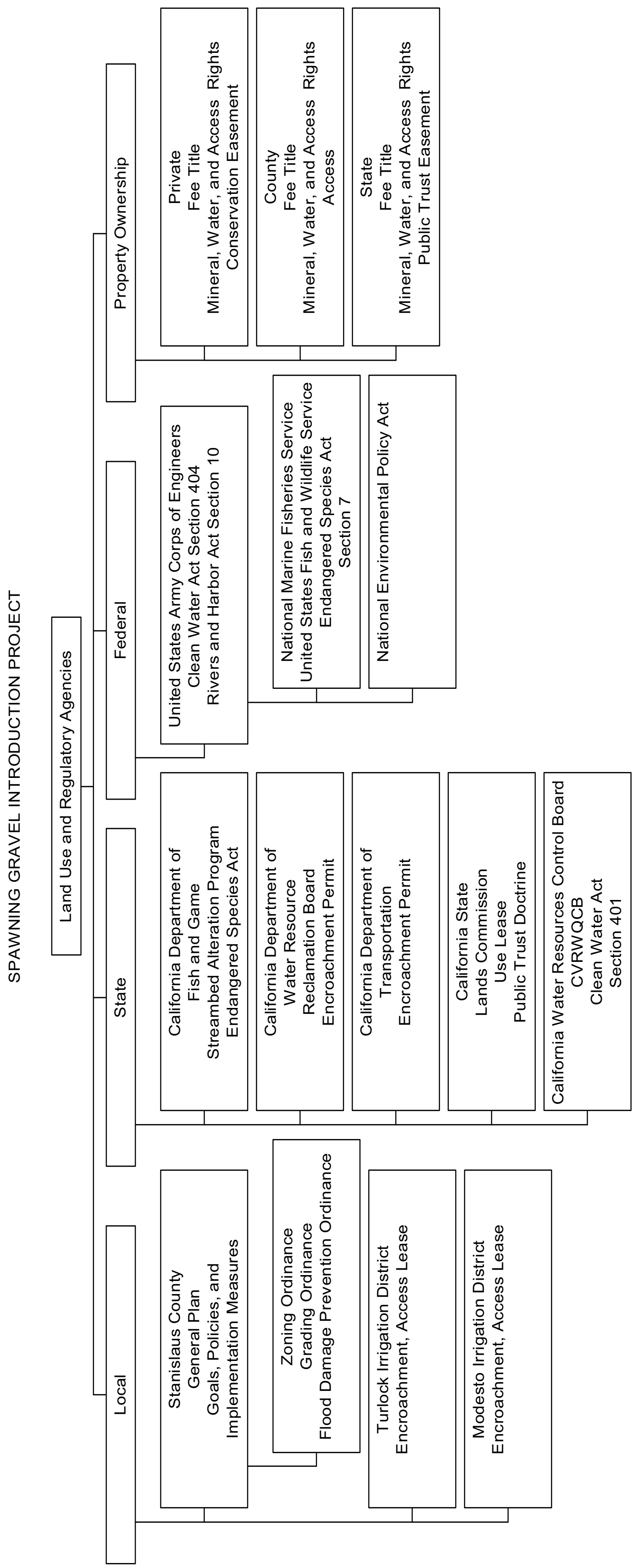


Figure 35. Organizational flowchart of the local, state, and federal agencies with jurisdiction over the proposed sediment augmentation project.

County's General Plan states (under Policy 2) that development within the 100-year flood boundary shall meet the requirements of Chapter 16. 50 *Flood Damage Prevention* of the County Code, (which can be found at http://www.co.stanislaus.ca.us/board/ch16-50.htm). One method identified by the County to reduce flood losses is to control alterations of natural floodplains and stream channels which help accommodate or channel flood waters (SCC 16.50.040.C). A Development Permit is required for any *encroachment* or *obstruction* (as defined in SCC 16.50.120) such as the proposed coarse sediment augmentation project(s) within areas of special flood hazard established in SCC 16.50.060. Development permits are obtained from the Floodplain Administrator, who is the Public Works Director for the County. Normally a grading permit would be sufficient for the type of work proposed if it did not involve special flood hazard areas. One condition of receiving the Development Permit is that all required federal, state, and local government agency permits or approvals have been obtained before approving the permit. Another condition of approval is that a registered professional engineer certifies that the encroachment shall not result in any increase in the base flood elevation during the occurrence of the base flood discharge (100 year flood). As described in Section 8.2, there are General Plan goals and policies that can affect the proposed coarse sediment augmentation project. These goals, policies, and implementation measures are listed below.

Land Use Element: Goals, Policies, and Implementation Measures

One-provide for diverse land use needs by designating patterns which are responsive to the physical characteristics of the land, as well as to environmental, economic, and social concerns of the residents of Stanislaus County.

<u>Policy Two</u>; Land designated Agriculture shall be restricted to uses that are compatible with agricultural practices, including natural resources management, open space, outdoor recreation, and enjoyment of scenic beauty.

<u>Policy Seven</u>; Riparian habitat along the rivers and natural waterways of Stanislaus County shall to the extent possible be protected.
Implementation Measure-All requests for development, which require discretionary approval and include lands adjacent to or within riparian habitat, shall include measures for protecting that habitat.

<u>Policy Eight</u>; The County will continue to provide proper ordinances to ensure that flood insurance can be made available to qualified property owners through state and federal programs.
Implementation Measure-Development within the 100-year flood boundary shall meet the requirements of Chapter 16.40 (Flood Damage Protection) of the County Code and within the designated floodway shall obtain Reclamation Board approval

Conservation/Open Space Element: Goals, Policies, and Implementation Measures

In the County, Open Space Lands are defined as any parcel or area of land or water which is essentially unimproved.

One-encourage the protection and preservation of natural and scenic areas throughout the County.

<u>Policy One</u>; Maintain the natural environment in areas dedicated as parks and open space.

<u>Policy Three</u>; Areas of sensitive wildlife habitat and plant life (riparian habitats, waterfowl habitats, etc.), including those habitats and plant species listed in the General Plan Support Document or by state or federal agencies, shall be protected from development.
Implementation Measure-Review all development requests to ensure that sensitive areas are left undisturbed or that mitigation measures acceptable to appropriate state and federal agencies are included in the project.

Implementation Measure-In known sensitive areas, the State Department of Fish and Game shall be notified as required by the California Native Plant Protection Act; the U.S. Fish and Wildlife Service also shall be notified.
Implementation Measure-All discretionary projects that will potentially impact riparian habitat or other sensitive areas shall include mitigation measures for protecting that habitat.

Two-conserve water resources and protect water quality in the County.

<u>Policy Six</u>; Preserve vegetation to protect waterways from bank erosion and siltation.
Implementation Measure-Development proposals including or in the vicinity of waterways and/or wetlands shall be closely reviewed to ensure that destruction of riparian habitat and vegetation is minimized. This shall include referral to the U.S. Army Corps of Engineers, the U.S. Fish and Wildlife Service, and the State Department of Fish and Game.

Four-provide for the open-space recreational needs of the residents of the County.

<u>Policy Fourteen</u>; Provide for diverse recreational opportunities such as horseback riding trails, hiking trails, and bikeways.

<u>Policy Fifteen</u>; Coordinate the provision of recreation needs with other providers such as the ACOE, the State Resources Agency, school districts, river rafters, horse stable operators, and private organizations such as the Sierra Club and Audubon Society.
Implementation Measure-The County will pursue various funding options for providing recreational opportunities.

Five-reserve, as open space, lands subject to natural disaster in order to minimize loss of life and property of residents of Stanislaus County.

<u>Policy Sixteen</u>; Discourage development on lands that are subject to flooding, landslide, faulting or any natural disaster to minimize loss of life and property.
Implementation Measure-Development will not be permitted in floodways unless it meets the requirements of Chapter 16.40 of the County Code and is approved by the State Reclamation Board.
Implementation Measure-The County shall utilize the CEQA process to ensure that development does not occur that would be subject to natural disasters.

Ten-protect fish and wildlife species of the County

<u>Policy-Twenty-Nine</u>; Adequate water flows should be maintained in the County's rivers to allow salmon migration.
Implementation Measure-The County should continue to lobby the federal government to provide adequate water flow in the County's rivers to allow salmon migration.

<u>Policy-Thirty</u>; Habitats of rare and endangered fish and wildlife species shall be protected.
Implementation Measure-The County shall utilize the CEQA process to ensure that development does not occur that would be detrimental to fish, plant life, or wildlife species.
Implementation Measure-The County shall protect sensitive wildlife habitat and plant life through the strategies identified under Policy Three of this element.

Safety Element: Goals

One-prevent loss of life and reduce property damage as a result of natural disasters

<u>Policy-Two</u>; Development should not be allowed in areas that are within the designated floodway.
Implementation Measure-Development within the 100-year flood boundary shall meet the requirements of Chapter 16. [50] (Flood Damage [Prevention]) of the County Code and within the designated floodway shall obtain Reclamation Board approval.

Implementation Measure-The County shall utilize the CEQA process to ensure that development does not occur that would be especially susceptible to flooding.

California Environmental Quality Act

The Lead Agency pursuant to CEQA (PRC Section 21067) should be the "public agency which has the principal responsibility for carrying out or approving a project which may have a significant effect upon the environment." In the past, CDFG has acted as lead agency for projects similar to the proposed coarse sediment augmentation project on both the Tuolumne and Merced Rivers that it implemented. Pursuant to its Flood Damage Prevention Program as discussed above, Stanislaus County has jurisdiction over any alteration of channels in the Special Flood Hazard Zone, and requires that a Development Permit be acquired before any work occurs. However, it appears that the County could want CDFG to be the lead agency on this type of project because one of the County's conditions of receiving the Development Permit is that all required federal, state, and local government agency permits or approvals have been obtained before approving the permit (SCC 16.50.150 A.2). CDFG could not enter into an agreement for the proposed coarse sediment augmentation project without first complying with CEQA.

Some of the primary purposes for the proposed coarse sediment augmentation project are enhancement of fluvial processes and restoration of spawning habitat in the Tuolumne River. Those categories of environmental factors that are likely to be addressed in an Initial Study and/or EIR for the proposed project will be listed below. The significance thresholds, mitigation measures and monitoring methods will not be discussed (but would be included in an EIR).

Land Use and Planning

- Conflict with any applicable land use plan, policy, or regulation of an agency with jurisdiction over the project, adopted for the purpose of avoiding or mitigating an environmental effect?

Aesthetics

- Have a substantial adverse effect on a scenic vista?
- Substantially degrade the existing visual character or quality of the site and its surroundings?

Recreation

- Conflict with any recreational uses on the Tuolumne River?

Hydrology and Water Quality

- Substantially alter the existing drainage patter of the site or area, including the alteration of the course of a stream or river, in a manner which would result in substantial erosion or siltation on or off-site?
- Discharge into surface waters or other alteration (degradation) of surface water quality (e.g., temperature, dissolved oxygen or turbidity)? Violate any water quality standards or waste discharge requirements?
- Place within 100-year flood hazard area structures, which would impede or redirect flood flows?

Biological Resources

- Have a substantial adverse effect, either directly or through habitat modifications, on any species identified as a candidate, sensitive, or special status species in local or regional plans, policies, or regulation, or by the California Department of Fish and Game or U.S. Fish and Wildlife Service?

- Have a substantial adverse effect on any riparian habitat or other sensitive natural community identified in local or regional plans, policies, or regulation, or by the California Department of Fish and Game or U.S. Fish and Wildlife Service?
- Have a substantial adverse effect on federally protected wetlands as defined by Section 404 of the Clean Water Act through direct removal, filling, hydrological interruption, or other means?
- Conflict with any local policies or ordinances protecting biological resources, such as a tree preservation policy or ordinance?

Mandatory Findings of Significance

- A potentially significant impact on any of the following questions requires preparation of an Environmental Impact Report (EIR).
- Does the project have the potential to degrade the quality of the environment substantially reduce the habitat of a fish or wildlife species, cause a fish or wildlife population to drop below self-sustaining levels, threaten to eliminate a plant or animal community, reduce the number or restrict the range of a rare or endangered plant or animal, or eliminate important examples of the major periods of California history or prehistory?
- Does the project have impacts that are individually limited, but cumulatively considerable? ("Cumulatively considerable" means that the incremental effects of a project are considerable when viewed in connection with the effects of past projects, the effects of other current projects, and the effects of probable future projects.)

8.3.1.2 State Agencies

California Department of Fish and Game

CDFG administers its Lake and Streambed Alteration Program, the elements of which were described in the preceding section 6.2. CDFG has engaged in, and issued Agreements for work similar to the proposed coarse sediment augmentation project (CDFG La Grange Phase I (1999) and II (2001)) as part of the Tuolumne River Coarse Sediment Program. The proposed coarse sediment augmentation project is expected to result in a net benefit to the environment by increasing salmonid spawning habitat in the lower Tuolumne River.

Because the coarse sediment augmentation project is subject to Stanislaus County's Flood Damage Prevention Ordinance and a Development Permit may be required, the County could become the local lead agency under CEQA. While CDFG, pursuant Fish and Game Code Section 2090, consults with state lead agencies, it could provide its opinions on jeopardy during its review of the CEQA document that will be prepared for the proposed project. If CDFG were the lead agency under CEQA it could provide consultation pursuant to Section 2090. Pre-activity inspections by biologists would enable impacts to any sensitive species and their habitats near project sites to be avoided. Pre-project surveys should be conducted to observe if species of concern are present at project sites. Measures to avoid impacts can be developed for each species that may be present at project sites. For example, a primary adverse impact may occur if riparian vegetation needs to be cleared to provide access to the project sites. If riparian vegetation removal were necessary, then mitigation measures would be needed to offset that impact. While sensitive species may occur near the project area, conditions to avoid jeopardy can be implemented to ensure protection of sensitive species and their habitat. The Department has determined that similar projects as proposed would not jeopardize the continued existence of any of the identified species of concern and no significant adverse environmental impacts were expected.

Environmental assessment surveys and subsequent project designs prepared for use by Stanislaus County as lead agency should be sufficient to notify DFG, and to determine if an Agreement will be required, and render any opinion on jeopardy posed by the proposed coarse sediment augmentation project. Entering into an Agreement is a project as defined by CEQA, and DFG as a responsible and trust agency under CEQA can rely on prior compliance with CEQA attained by the local lead agency, Stanislaus County.

California Department of Water Resources

The Reclamation Board regulates encroachment within the Designated Floodway of the Lower Tuolumne River pursuant to California Water Code (CWC) Section 8710. The coarse sediment augmentation project proposes to both introduce clean coarse sediment and to restore abandoned instream mining pits. The proposed coarse sediment augmentation project has both a short and long term phase involving numerous sites. The proposed project also involves filling abandoned instream mining pits. The proposed coarse sediment infusion project includes three different methods for introducing sediment; including stockpiling coarse sediment adjacent to the channel to be recruited during high flows, and uniform filling of the channel.[the contouring of fill was the third method] All of these activities will occur within the Tuolumne River's Designated Floodway. One of the criteria DWR uses when evaluating any proposed construction, stockpiling, or fill proposal is whether the floodway's conveyance will be impaired or structures/property threatened by flood-induced erosion. HEC modeling for the proposed project area may be required to assist DWR in their evaluation of the project's effect on flood stage.

Environmental assessment surveys and subsequent project designs prepared for use by the local lead agency, as well as HEC modeling, should be sufficient for DWR to process an application for an Encroachment Permit. Other projects (CDFG La Grange Phase I (1999) and II (2001)) similar to the proposed coarse sediment augmentation project have had the following general and special conditions included in their Encroachment Permit.

General Conditions of Approval-Operation

- Work is to be accomplished under the direction and supervision of DWR, and the permittee shall conform to all requirements of DWR and the RB.
- Unless work contemplated shall have been commenced within one year after issuance of this permit, the Board reserves the right to change any conditions in this permit as may be consistent with current flood control standards and policies of the RB.
- The permittee is responsible for all personal liability and property damages which may arise out of failure of the permittee's part to perform the obligations under this permit, and the permittee shall defend and hold each of them (Public Agencies, etc) harmless from each claim. A Certificate of Insurance may be required.

Special Conditions of Approval-Operation

- The permittee shall maintain the permitted encroachment(s) and project works in the manner required by DWR.
- A pre-construction conference with DWR is required.
- The permittee shall be responsible for repair of any damages to the floodway due to the construction, operation, or maintenance of the proposed project.

- From November 1st through July 15th no material stockpiles, temporary buildings, or equipment shall remain in the floodway.
- Cleared trees and brush shall be completely burned or removed from the floodway, and downed trees or brush shall not remain in the floodway during the flood season from November 1st through July 15th.
- The channel capacity of the Tuolumne River Designated Floodway shall not be adversely affected by the proposed project.
- If the proposed project results in an adverse hydraulic impact, the permittee will provide appropriate mitigation.
- If the project, or any portion thereof, is to be abandoned in the future, the permittee shall abandon the project under direction of the Board and DWR, at the permittee's expense.
- The permittee may be required, at permittee's cost and expense, to remove, alter, relocate, or reconstruct all of any part of the permitted encroachment(s) if required by the Board. If the permittee does not comply, the Board may remove the encroachment(s) at the permittee's expense.
- The permittee is responsible for all liability associated with the placement of spawning gravel and shall defend and hold harmless the RB and DWR from any liability or claims of liability associated therewith.
- Environmental assessments, and subsequent project designs prepared for use by the local lead agency and HEC modeling should be sufficient to support the issuance of an Encroachment Permit. Issuance of this permit is a project as defined by CEQA, and the Board as a responsible agency under CEQA can rely on prior compliance with CEQA attained by the local lead agency, Stanislaus County.

California Department of Transportation

CALTRANS may conduct a hydraulic review if any of the proposed coarse sediment augmentation project sites are within one mile up or downriver of a state highway bridge, such as J-59 Bridge. The project proponent may be required to provide CALTRANS with field surveys and HEC modeling to support CALTRANS' hydraulic review of the project's affect on its bridge structures.

California State Lands Commission

The SLC administers Sovereign lands and protects their Public's Trust uses and resources. The coarse sediment augmentation project will involve the placement of clean coarse sediment to restore anadromous salmonid spawning and rearing habitat, as well as fluvial processes. Several instream mining pits may also be filled with sediment mined from dredger tailings to eliminate non-native piscivore habitat and restore fluvial processes. As described in Section 8.2.1, the last natural location of the river free of avulsion may not be the present river location. The proposed coarse sediment augmentation project does not involve the removal of any bed material or state assets; material mined and processed from dredger tailings will be used as fill to restore the Tuolumne River. The proposed project will enhance the Public's Trust uses and its resources in the Tuolumne River. The SLC has previously waived the need for a Lease (M.J. Ruddy 4 Pumps Restoration Project) as well as required a Lease for instream restoration work (TID Gravel Mining Reach Restoration Projects Phases I and II), both types of projects did not involve the removal of mineral assets from State Lands. A Lease from the SLC could become necessary if temporary bridges need to be installed across the Tuolumne

River to access work sites. SLC's primary concern with temporary bridges is that they not impede the public's right of navigation. The Environmental Assessment and subsequent project designs prepared for use by the local lead agency should be sufficient for SLC to process a lease application for this project. Entering into a lease is a project as defined by CEQA, and SLC as a responsible and trust agency under CEQA can rely on prior compliance with CEQA attained by the local lead agency, Stanislaus County.

California State Water Resources Control Board (SWRCB) and Central Valley Regional Water Quality Control Board (CVRWQCB)

As described in Section 8.1.1, the SWRCB, through the CVRWQCB on the Tuolumne River is responsible for issuing water quality certifications and waste discharge permits pursuant to the Clean Water Act. If the proposed action is determined to have minimal effect on water quality, certification may be waived by the CVRWQCB. The coarse sediment augmentation project proposes to place two types of fill into the Tuolumne River: one type will be dredger tailings screened and washed to remove any fines so that only clean coarse sediment is placed in the channel; the second type of fill is unsorted sediment mined from dredger tailings to be placed into abandoned instream mining pits. The purposes and objectives of the coarse sediment augmentation project were described in detail in Chapter 3. The first type of fill will restore anadromous salmonid spawning habitat and as bedload will be transported and sorted downriver where it will continue to provide spawning as well as rearing habitat. The second form of fill is being proposed as the most economical means to reclaim instream mining pits, eliminate salmonid predator habitat, and restore channel form and processes.

The CVRWQCB has issued water quality certifications, as well as waivers of waste discharge requirements and water quality certification for similar projects (CDFG La Grange Phase I (1999) and II (2001)) that proposed to use coarse sediment for spawning habitat restoration. However, the CVRWQCB initially denied water quality certification for the CDFG Phase II project that did not propose to use clean coarse alluvium as fill in the Tuolumne River. The reason for CVRWQCB denial was to protect water quality from possible mercury pollution from gold mining dredger tailings. Currently there is uncertainty regarding concentrations and distribution of mercury in dredger tailings. CDFG and CVRWQCB are cooperating in a study to characterize mercury contamination in dredger tailings on the Merced River. Recently the CVRWQCB has accepted the use of fill material derived from dredger tailing alluvium if it is free of fines and has been washed, as the coarse sediment augmentation project proposes.

Best Management Practices should be employed during and after construction-fill to minimize potential indirect adverse impacts to waters of the U.S., as well as timing fill placement with low flow to reduce and limit turbidity from the proposed coarse sediment augmentation project.

The Environmental assessment and subsequent project designs prepared for use by the local lead agency should be sufficient for the CVRWQCB to process an application for certification. Certification or issuance of a waiver from certification of water quality, are projects as defined by CEQA, and SWRCB and CVRWQCB are responsible agencies under CEQA and can rely on prior compliance with CEQA attained by the local lead agency, Stanislaus County. The Army Corps of Engineers will not issue a Fill Permit under Section 404 of the CWA for a project until a certificate or a waiver of certification has been issued.

8.3.1.3 Federal Agencies

United States Army Corps of Engineers

As described in Section 8.2, the ACOE regulates the placement of pollutants such as fill materials into waters of the U.S. pursuant to Section 404 of the Clean Water Act. Because the proposed coarse sediment augmentation project will involve placing fill into the Tuolumne River channel, the ACOE could have jurisdiction over the entire proposed action, except for placement of stockpiles and grading/construction of access routes that are above ordinary high water (unless those activities affect a jurisdictional wetland). The Sacramento District of the ACOE has issued a General Permit 008 that authorizes placement of fill material below the ordinary high water elevation for rehabilitation of salmon spawning areas in the Sacramento-San Joaquin River system by CDFG or its representative. That General Permit (GP) was issued for five years, and expires September 21, 2003, unless renewed. The ACOE Nationwide Permit 27, which involves the enhancement and restoration of riffle and pool stream structure, could also authorize the proposed coarse sediment augmentation project. If the ACOE determines that neither GP 008 or NWP 27 are applicable to the proposed coarse sediment augmentation project then an Individual Permit will be required. As discussed previously, the SWRCB through the CVRWQCB would have to issue a water quality certification or a waiver from certification for the proposed coarse sediment augmentation project before the ACOE can issue a Section 404 permit pursuant to the CWA. Section 10 of the 1899 Rivers and Harbor Act (33 USC 403) (RHA) also prohibits the obstruction or alteration of any navigable waters of the U.S. without a permit from the ACOE. The ACOE recognizes the lower 47 miles up to Basso Bridge as navigable for purposes of applying the RHA.

General Permit 008

General Permit 008 authorizes CDFG to construct low level berms to retain spawning gravels, add gravels to spawning sites, remove unsuitable habitat, loosen compacted gravel, and modify or restore side channels that have historically maintained a salmon and/or steelhead population. Excluded from this Permit are activities that would impact critical habitat for any listed species. Issuance of GP 008 is authorized both pursuant to Section 404 of the CWA and Section 10 of the RHA. The ACOE has issued permits for actions (DFG La Grange Phase I (1999) and II (2001)) similar to the proposed coarse sediment augmentation project on the Tuolumne River, which contained the following special conditions:

- Project must attain CVRWQCB's Basin Plan objectives for turbidity and sedimentation.
- Permittee shall obtain approval from DWR-RB prior to commencing work.
- Complete project designs and channel cross sections and profiles must be submitted to the ACOE.
- Best management practices must be followed during and after construction to protect from pollution and to minimize turbidity and siltation or other potential indirect adverse impacts to waters of the U.S. and adjacent wetlands.
- Rehabilitation projects shall not impede navigation; any decreases in channel depth will be indicated on project location maps and designs.
- Instream excavation activities at critical periods of fish spawning will be isolated from spawning areas to prevent sediment deposition on active nests, and all fill materials shall be sufficiently washed and added in a manner that prevents sediment deposition on active nests.
- Prior to initiation of any project the permittee shall consult with NMFS to determine the allowable construction period and any other procedures needed to avoid adverse impacts to anadromous fish that are listed pursuant to the ESA. The permittee shall insure that all measures recommended for the protection of these species are implemented.
- Prior to initiation of work, all stream banks and riparian areas to be crossed or utilized during the project activity shall be inspected to insure no habitat for Longhorn Elderberry Beetle or Giant Garter Snake is present. If habitat or the species are present no work shall

be conducted in these areas unless the work is approved by the USFWS. If such work is approved, the permittee shall ensure that all measures recommended for protection of the species are implemented.

- Regarding the bridges in La Grange, the permittee must directly contact and update CALTRANS of the work schedule and volume of fill for this project annually. The results of the contact were to be reported the ACOE.

Of particular note is that GP 008 does not authorize the "take" of any listed species pursuant to the ESA, or any work which is likely to jeopardize the continued existence of a listed species or which is likely to destroy or adversely modify critical habitat of such species. Similar to DWR-RB encroachment permit conditions, the Federal government is not liable for personal and property damage resulting from the permitted activity. NEPA compliance occurred at the time that the ACOE adopted GP 008, further compliance for separate project actions authorized under that GP is not required.

<u>Nationwide Permit 27</u>

Stream and wetland restoration activities located on non-federal lands may be authorized pursuant to Nationwide Permit 27 (NWP) in accordance with the terms and conditions of a binding wetland enhancement, restoration, or creation agreement between the landowner and USFWS/NMFS. Compensatory mitigation is not required for activities authorized by the NWP, provided the authorized work results in a net increase in aquatic resource functions and values in the project area. NWP 27 contains the following general conditions:

- No activity may cause more than a minimal adverse effect on navigation.
- Permittees are encouraged to perform work within waters of the U.S. during periods of low flow to control soil erosion and sedimentation.
- No activity is authorized that is likely to jeopardize the continued existence of a listed species or adversely modify critical habitat for such species. Non-federal permittees shall notify the ACOE Sacramento District if any listed species or designated critical habitat might be affected or is in the vicinity of the project. Work is not authorized until the requirements of the ESA have been satisfied.
- Authorization of an activity by a NWP does not authorize the "take" of a listed species. Separate authorization (Section 10 Permit or Biological Opinion with incidental take provisions) is required from USFWS and/or NMFS. The ACOE must initiate consultation with USFWS and/or NMFS pursuant to Section 7 of the ESA.
- The permittee must comply with any applicable FEMA-approved state or local floodplain management requirements.

<u>Rivers and Harbor Act Section 10</u>

If the ACOE's jurisdiction under Section 404 of the CWA covers the same area subject to Section 10 jurisdiction under the Rivers and Harbor Act, it generally will process and issue one permit pursuant to both Acts. The RHA applies to any action that alters the course, location, condition, or capacity of a navigable water as defined for the RHA.

<u>ESA Section 7 Consultation</u>

Pursuant to Section 7 of the ESA, the ACOE will prepare a biological assessment of the proposed action, which would address all listed and proposed species found in the action area, not just those species to be affected. The ACOE would then seek consultation with either USFWS or NMFS or both before issuing a Section 404 Permit if the proposed coarse sediment augmentation project could jeopardize a federally listed species or its critical habitat. Alternatively, after preparing its biological assessment, the ACOE could determine that the proposed action is not likely to adversely affect listed species or designated critical habitat. The ACOE could then request a letter of concurrence from the Services that the proposed action has no likelihood of adverse effect on listed species or critical habitat. This approach is justifiable when the proposed actions' effects on listed species are expected to be discountable, or insignificant, or completely beneficial. The Services could either provide the ACOE with a letter of concurrence or initiate formal consultation and issue their Biological Opinion on the risk of jeopardy posed to any federally listed species by the proposed fill project, or its potential to adversely affect any designated Critical Habitat. However, the concurrence letter does not provide incidental take authorization pursuant to Section 7 of the ESA. After consultation with the Services the ACOE could issue a Section 404 Permit.

In addition to compliance with the ESA, the proposed project area (the lower Tuolumne River below La Grange Dam) has been identified as Essential Fish Habitat (EFH) for Chinook salmon in Amendment 14 of the Pacific Salmon Fishery Management Plan pursuant to provisions of the Magnuson-Stevens Fishery Conservation and Management Act (MSA). Federal action agencies such as the ACOE are mandated by the MSA (Section 305[b][2]) to consult with NMFS on all actions that may adversely affect EFH, and NMFS must provide EFH Conservation Recommendations (Section 305[b][4][A]).

As lead agency, the ACOE must comply with NEPA at the time it issues a permit, unless it has done so previously. Project designs, environmental assessments, mitigation measures, and monitoring/report plans prepared for use by the local CEQA lead agency should greatly assist the ACOE in complying with NEPA and the issuance of a Section 404 and Section 10 Permits. The local and federal lead agencies also could prepare a joint CEQA/NEPA document.

United States Fish and Wildlife Service and National Marine Fisheries Service

The USFWS has been charged with implementing the Anadromous Fish Restoration Program (AFRP), which has made USFWS the lead federal action agency in similar projects implemented by CDFG in 1999 and 2001. As the federal lead agency, USFWS would comply with NEPA and several other laws (Clean Water Act, Rivers and Harbors Act, Endangered Species Act, Magnuson-Stevens Fishery Conservation and Management Act, Fish and Wildlife Coordination Act, National Historic Preservation Act, and American Indian Religious Freedom Act) and Executive Orders (Protection of Wetlands, Floodplain Management, and Indian Trust Assets) relevant to the proposed project.

USFWS has ESA jurisdiction over those listed fish species that are not anadromous (with the exception of Coastal Cutthroat Trout, Lamprey, and Sturgeon). Pursuant to the ESA, NMFS has jurisdiction over all other anadromous fish such as Chinook, Coho, and Steelhead. USFWS is also a federal action agency for the proposed coarse sediment augmentation project, and would therefore need to prepare a biological assessment for this project (unless one is prepared jointly with the ACOE as discussed above). Section 7 requires all federal agencies to consult with one or both Services, depending on the species affected, to ensure that their actions do not jeopardize the continued existence of federally listed species or result in the adverse modification of the critical habitat of those species. USFWS could also make a determination that its action will not likely adversely affect listed species such as threatened Central Valley Steelhead or its critical habitat, and request a letter of concurrence from NMFS. In 2001, NMFS provided USFWS with such a letter of concurrence that the USFWS's determination that funding CDFG's La Grange Gravel Addition Project Phase II (2001) on the Tuolumne River was not likely to adversely affect federally threatened Central Valley Steelhead or its critical habitat. NMFS noted the project's benefits to anadromous salmonids in the

Central Valley Rivers. Again, the concurrence letter did not provide incidental take authorization pursuant to Section 7 of the ESA. Section 9 of the ESA prohibits the "taking" of any federally listed species without an authorized Incidental Take Permit. Under Section 7, take would be authorized in a Biological Opinion provided by NMFS to the federal action agency, the USFWS.

USFWS is also an action agency under the MSA and will therefore need to consult with NMFS on all of its actions that may adversely affect Chinook salmon EFH, and NMFS must provide the USFWS with EFH conservation recommendations. In 2001, NMFS reported that it had reviewed the potential effects of CDFG's proposed project on Central Valley Steelhead, under provisions of the ESA, and Chinook salmon under provisions of the MSA. Provided that all avoidance and conservation measures built into the proposed project were adhered to, NMFS concurred with USFWS' determination that CDFG's project was not likely to adversely affect threatened Central Valley Steelhead or adversely modify designated critical habitat. NMFS found that EFH Conservation Recommendations were not required at that time, pursuant to the MSA, because the CDFG project was not likely to adversely affect species listed under the ESA or adversely modify designated critical habitat, and the habitat requirements of Chinook salmon in the project area are similar to ESA listed species,. If there were substantial revisions to the action, USFWS would need to re-initiate EFH consultation.

8.3.2 Coarse sediment Augmentation Project Issues

Issues for consideration are numbered and described first, followed by a bulleted list of discussion items.

1. The proposed coarse sediment augmentation project includes short-term and long-term coarse sediment transfusion at different locations.
    - Acquiring permits for the short-term phase could facilitate amendments or time extensions at those same sites, for the long-term phase.
    - Including all sites in the initial permit documentation and environmental documents may enable future amendments and time extensions as needed, unless project designs or environmental conditions change. Supplemental environmental documents may be required in processing future amendments and time extensions.
2. The proposed filling of abandoned instream mining sites appears to be a different project than coarse sediment transfusion, in purpose, location, method, and materials to be used, and potential impacts i.e. mercury pollution and benefits.
    - Acquiring permits for this project may be more difficult and time consuming than the coarse sediment transfusion phases, and may need to be processed separately.
    - Permitting for the pit-filling project may also need to proceed separately for each pit location.
3. The coarse sediment augmentation project transfusion phases propose four different methods.
    - One method proposed is to stockpile clean coarse sediment adjacent to the low flow channel. The material would be recruited when high flows occur. The timing of recruitment and the volume to be recruited during each occurrence is unknown. Without greater certainty, the environmental review will be speculative, which may make it more difficult to permit this method of coarse sediment transfusion.

- The other three methods of coarse sediment transfusion are similar in placing fill in the active channel, thus there would be very little difference between these methods from a regulatory compliance perspective.

4. The proposed coarse sediment augmentation project will occur on lands designated as Agricultural in the County General Plan and Zoning Ordinance.
   - Natural resources management, open space, and recreation are compatible uses with the Agricultural designation. The proposed project will help restore natural resources, maintain open space, and provide for recreational uses.
5. The proposed coarse sediment augmentation project will require access to the banks and bed of the river, which will likely entail traversing the riparian corridor along the Tuolumne River.
   - Existing access to the proposed project locations will be used when ever possible. If access does not exist, then any riparian vegetation affected will need to be replaced.
   - Stockpile of clean coarse sediments will be located away from riparian vegetation.
6. The proposed coarse sediment augmentation project will affect sensitive wildlife habitats including federally listed critical habitat and EFH in the Tuolumne River.
   - The purpose of the proposed project is to restore fluvial processes, critical habitat, and EFH; the net effect of the project will be beneficial to such habitats and the species they support.
7. The County General Plan seeks to provide for the open-space recreational needs of the residents of the County.
   - The proposed project seeks to restore habitat and populations of Chinook salmon and Steelhead in the Tuolumne River, for the benefit of people in the County and State.
8. The County General Plan and Flood Damage Prevention Ordinance seek to discourage development within the 100-year flood boundary on lands that are subject to flooding.
   - The proposed project is not a development activity or use, but is instead intended to help restore fluvial geomorphic processes in the Tuolumne River.
   - HEC modeling will be prepared for the project to document that an increase in the base flood elevation will not result from the actions of this project.
9. Which agency will be the lead agency pursuant to CEQA?
   - The Stanislaus County Flood Damage Prevention Program (SCC 16.50.150 A.2) requires that all other permits be secured <u>prior</u> to it issuing a Development Permit. This would defer lead agency status to other local or state permitting authorities.
   - CDFG is the only other local or state public agency that has principal responsibility for carrying out or approving the proposed project in its entirety. CDFG has acted as lead agency for similar projects on both the Tuolumne and Merced Rivers that it has implemented.
   - Stanislaus County could issue its Development Permit and comply with CEQA by tiering its approval to the document prepared and certified by DFG.

10. It would appear that the proposed fill in the Tuolumne River would be contrary to County, State and Federal policy and regulations protecting property and people from flood damage or degradation of sensitive habitat.
    - The proposed project is not a development activity or use, but instead is intended to help restore fluvial geomorphic processes in the Tuolumne River for the benefit of sensitive and listed species and their habitats.
11. The proposed project potentially could conflict with certain recreational uses on the Tuolumne River.
    - The filling of abandoned instream mining pits could impair or eliminate some recreation uses such as swimming, fishing and boating at these sites. Authorizing the proposed project is an act of balancing competing uses. The restoration of Central Valley and Tuolumne River Chinook salmon and steelhead populations is a local, state, and national priority. While there are alternative sites for such recreational uses that could be affected by the proposed project at these sites, there are no alternatives rivers available to replace the Tuolumne River for these native salmon and steelhead populations.
12. The use of dredger tailings to supply the fill to be used in the coarse sediment augmentation project has the potential to introduce mercury in the surface water and groundwater in and along the Tuolumne River.
    - All sediment that will be used as fill during coarse sediment transfusions will have been screened and washed of all fines at the mining site. The CVRWQCB has issued waivers of water quality certification in the past when clean gravels are used as fill for the restoration of the Tuolumne River for anadromous salmonids.
    - Monitoring for mercury could occur when proposed fill sediments are in stockpiles at the mining processing site. If these materials are free of mercury they could be used as fill, unscreened or washed at the abandoned instream mining pits that are to be restored.
    - Several entities within the Central Valley (USGS, CBDA, private research) are investigating the distribution and concentration of mercury in dredger tailings, as well as developing recommendations for using dredger tailings as restoration material.
13. CDFG must enter into a Streambed Alteration Agreement for the proposed coarse sediment augmentation project.
    - CDFG could enter into one Agreement for the entire project, subject to extensions, or treat the major components of the project separately: short-term coarse sediment transfusion, long-term coarse sediment augmentation, and filling instream mining pits.
    - If only one site a year will be affected, CDFG may want to enter into separate Agreements for each site as needed.
14. Pursuant to CESA and the ESA, CDFG, USFWS and NMFS personnel will need to be consulted.
    - Biological assessment surveys will be necessary unless pre-existing documentation of the sites affected by the project are available. Such surveys would need to cover all sensitive and listed species as well as their habitats that could occur at these sites. The timing of presence or absence surveys is dependent on the life cycles of the species suspected of occurring at the sites. Habitat mapping of the action areas should be sufficient for use in consultation as well as for the CEQA, NEPA, ESA and MSA documents that will be prepared for the project.

- Additional surveys and mapping may become necessary if site conditions change over the life of the project (short and long term coarse sediment transfusions).

15. One of the special conditions contained in the Reclamation Board's encroachment permit requires no stockpiles be within the designated floodway from November 1st through July 15th.
    - This special condition may eliminate one of the proposed coarse sediment transfusion methods, involving stockpiling material for recruitment adjacent to the active channel.
    - It may be possible to have the Reclamation Board waive this condition if it could be documented that the stockpiles do not affect design or base flood elevations or have the potential to damage property or deflect flood flows.
16. A condition of approval from the Reclamation Board is that the work be accomplished under the direction and supervision of DWR.
    - Coordination between all of the regulatory agencies, landowners, and project proponents during permitting and construction will be very important if implementation of the proposed project is to be expedited.
17. Most permits contain a condition that the work shall commence within one year of the issuance of the permit.
    - Permits that are issued for the proposed project may need to be amended if environmental conditions change before work at a particular site begins.
18. The permittee may be liable for damages resulting from the proposed project's construction and fill activities in the designated floodway and special flood hazard zone.
    - [?]
19. HEC modeling will be necessary to secure some permits.
    - Will HEC modeling be needed both at the time permits are secured, and, if construction is to occur more than one winter season later, at the time of construction?
20. Will temporary bridges be needed across the Tuolumne River to access coarse sediment transfusion sites?
    - Low water crossing with sufficient fill placed for the approaches to the bridge can be elevated to not impede the public's navigation of the river.
    - Temporary bridges may have to be removed from November 1st through July 15th.
21. Will the proposed fill activities increase turbidity?
    - If coarse sediment transfusion is conducted during low flow, any turbidity caused by that activity could be limited to the immediate area.
    - If at all possible when filling abandoned instream mining pits, filter fences or similar barriers could be employed to isolate the work area from the low flow channel.

8.4 Regulatory Compliance Strategies

The complexity of a proposed project affects the effort, expense, and time necessary to secure authorizations to implement the project. The Coarse Sediment Management Plan proposes to acquire large quantities of sediment and place it into the river to improve geomorphic processes and salmonid spawning habitat. The prior sections outlined the numerous regulatory issues for which compliance is necessary to implement this Plan. Because there are different components to this plan that will require many years to complete, and because funding is not presently allocated for complete implementation, there are consequently several different possible strategies for packaging the proposed project(s). This section presents several alternative strategies, and then presents a recommended strategy that would meet all regulatory requirements and streamline implementation of the Sediment Management Plan.

8.4.1 Alternative Strategies

- Proceed with three separate projects each addressing a different component of the Plan: (1) sediment acquisition and development (material processing), (2) coarse sediment augmentation, and (3) filling abandoned instream mining pits.
- Combine two of the projects above, which in sequence could make one project with a common goal: sediment acquisition/development and coarse sediment augmentation, or sediment acquisition/development and filling abandoned instream mining pits.
- Consider each action as an individual project requiring its own permits: for example, mining at each sediment development site, coarse sediment augmentation at each individual short-term transfusion site, periodic augmentation at each long-term coarse sediment maintenance site, and filling at each abandoned instream mining pit sites.
- Develop and permit as one project one sediment source site and use the materials to implement several coarse sediment transfusion sites and long-term maintenance sites; the number of sites is dependent on the volume of sediment available at the source site.
- Develop and permit as one project one sediment source site and use the materials to implement several coarse sediment transfusion and long-term maintenance sites and several abandoned instream mining pit sites; this strategy assumes a large volume of sediment is available.
- Develop and permit as one project one sediment source site specifically to be set aside for use at long-term coarse sediment maintenance sites.
- Develop and permit as one project the purchase of clean spawning gravels from commercial aggregate sources and obtain permits for the short-term transfusion sites.
- Develop and permit as one project the purchase of either unscreened or washed sediment from commercial aggregate sources and obtain permits for filling abandoned instream mining pit sites.
- Develop and permit as one project the purchase of clean spawning gravels from commercial aggregate sources and obtain permits for the long-term coarse sediment maintenance sites.

8.4.2 Preferred Compliance Strategy

In addition to the regulatory issues described in the previous sections, the preferred regulatory compliance strategy must account for the length of time (10–20 years) expected to implement the Coarse Sediment Management Plan, the total volume of sediment needed to complete the Plan, and the longitudinal distribution of coarse sediment augmentation sites along the gravel-bedded reaches of the Tuolumne River.

We recommend the District (and/or the TRTAC) implement the Sediment Management Plan as three separate projects, each addressing a different purpose: sediment source development, coarse sediment augmentation, and filling of abandoned instream mining pits. The District, as project proponent, construction contractor, overall project manager, and effectively a state agency under the Water Code, should act as state lead agency for CEQA for all three project types. The USFWS should be federal lead agency for NEPA for all three project types. Numerous regulatory agency permits are required for restoration projects of this scale (Table 20).

Table 20. Permits required for the different components of coarse sediment augmentation. X = permit required; ? = permit may be required; O = permit not required.

PERMITS	SEDIMENT SOURCE DEVELOPMENT	SEDIMENT TRANSFUSION	PIT FILLING
Stanislaus County-Conditional Use Permit	X	O	O
Stanislaus County-Approval of Reclamation Plan	X	O	O
Stanislaus County-Grading/Development Permit	O	X	X
East Side or Turlock Mosquito Abatement Districts	X	O	?
California Department Fish & Game-Streambed Alteration Agreement	O	X	X
California Department Fish & Game -Endangered Species Act Incidental Take Permit	?	?	O
California Department Water Resources-Reclamation Board Encroachment Permit	?	X	X
California Department of Transportation-Encroachment Permit	O	?	?
California State Lands Commission-Lease	?	X	X
California State Water Resources Control Board (CVRWQCB)-Water Quality Certification	O	X	X
California State Water Resources Control Board (CVRWQCB)-National Pollution Discharge Elimination System Permit	X	?	?
California State Water Resources Control Board (CVRWQCB)-Waste Discharge Permit	?	X	X
California Air Resources Board (SJVUAPCD)-Authority to Construct	X	X	X
United States Army Corps of Engineers Clean Water Act-Dredging & Fill Permit	?	X	X
United States Army Corps of Engineers Rivers & Harbor Act-Dredging & Fill Permit	O	X	X
United States Fish & Wildlife Service Endangered Species Act-Jeopardy Decision	?	?	?
United States Fish & Wildlife Service Endangered Species Act-Incidental Take Permit	?	O	O
United States National Marine Fisheries Service Endangered Species Act-Jeopardy Decision	?	X	X
United States National Marine Fisheries Service Essential Fish Habitat -Consultation	O	O	O
California Environmental Quality Act	X	X	X
National Environmental Policy Act	?	X	X

Developing sediment sources (rather than purchasing commercial aggregate) is more beneficial to the environment because it allows the opportunity to implement reclamation plans that simultaneously address SMARA and County regulations and also improve habitat conditions at material source sites. This strategy also provides more certainty regarding the cost and availability of sediment for use in restoration projects and coarse sediment management. Treating the coarse sediment augmentation and filling of instream mining pits separately is more logical in terms of regulatory compliance for several reasons. First, unwashed and unscreened dredger tailing materials may be preferred to fill the pits, which may therefore require a different water quality certification. Also the spawning gravel work is entirely beneficial while the pit filling eliminates certain types of private and public recreational uses.

Additionally, filling pits creates new or reclaimed land which then triggers issues regarding ownership of the land, since private property extends to ordinary low water. And finally, depending on the location of abandoned instream mining pits, several of which are several miles downstream of most sediment source sites, purchasing commercial aggregate for those sites might be more economical than transporting fill from one of the upstream dredger tailing source sites. The short-term and long-term phases of the coarse sediment augmentation could be permitted as one project. Coarse sediment augmentation extending beyond ten years may require time extensions or amendments, but those could be tiered to the original permits depending on the length of time involved and future environmental conditions (e.g., changes that result from future flood events).

Implementing the preferred regulatory compliance strategy will still involve assessing CEQA/NEPA compliance needs, conducting a regulatory and environmental constraints analysis, identifying relevant environmental laws and regulations, initiating the scoping process, finalizing the project description(s), prioritizing permit acquisitions, preparing permit application and the relevant supporting documents, circulating administrative environmental documents, revising project description-environmental documents, circulating project description and draft environmental documents, holding public hearings, revising project description-environmental documents, finalizing documents and seeking project authorizations, and finally, implementing the projects and mitigation monitoring.

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10 GLOSSARY OF TERMS

TERM	DEFINITION
Accretion	Accumulation of groundwater seeping into a stream or river, that increases the surface discharge.
Aggradation	Raising of the channel bed elevation on a reach-wide scale, due to sediment deposition and accumulation.
Aggregate	Commercially mined river-run rock (sand and gravel) extracted and used for road-base, concrete, etc.
Alluvium/Alluvial	Sediment transported and deposited by running water. An alluvial river has bed, banks, and floodplain composed of alluvium. An alluvial deposit is composed of unconsolidated or partially consolidated river-laid material in a stream valley.
Alternate bar	Fundamental geomorphic unit of alluvial rivers, composed of an aggradational lobe or point bar, and a scour hole or pool. A submerged transverse bar connects adjacent point bars to form a riffle. An alternate bar sequence, composed of two alternate bar units, is a single meander wavelength, usually 9-11 bankfull channel widths long.
Anadromous	Typical life cycle of salmon, in which fish spawn in freshwater streams and migrate early in their life cycle to the ocean where they grow and mature. Anadromous fish return to freshwater as adults to spawn in the stream or river of their origin, then typically die.
Ascending limb	Component of a winter or spring snowmelt hydrograph in which the discharge rapidly ramps up from a baseflow level to the peak flow magnitude.
Avulsion	Large-scale channel abandonment and planform readjustment resulting from large floods.
Bankfull channel	Channel of an alluvial river that contains without overflow approximately the discharge that occurs, on average, once every 1.5 to 2 years.
Bankfull discharge	Flood discharge that exceeds the capacity of the bankfull channel and begins to spill onto the floodplain. Bankfull discharge occurs with a frequency ranging between 1.5 and 2 years.
Bar face	Portion of point bar that is downward - sloped from the floodplain towards the low water edge.
Bedload	Coarse component of sediment transported by a stream. During transport, particles are in constant or frequent contact with the stream bottom. Bedload makes up most of the channel bed and banks of alluvial rivers, but typically represents only 5-15 percent of the total sediment yield (excluding dissolved component).
Boundary shear stress	Force exerted on the channel bed by flowing water. When boundary shear stress (force) exceeds the forces of a particle resisting motion (e.g., particle size and density), the particle may become mobilized and transported downstream.
Braided channel	Channel form having multiple low-flow threads.

Capacity (channel)	Volume of flow a channel can convey before overflowing the channel and spilling onto the floodplain.
Capacity (flow)	Maximum amount of sediment a river can transport, for a given flow condition.
Capillary fringe	Zone in which water is drawn into soil pores above the water table by surface tension (capillarity).
Channelization	Straightening of a river channel or containment between levees.
Channel morphology	The shape, size, and particle size of a channel created by the interaction of fluvial, biological, and geomorphic processes.
Channel slope	Longitudinal slope or gradient of the channel, measured, for example, by the water surface elevation or from the crest of successive riffles.
Competence	A measure of overall stream power, determined by the largest grain size the river can transport, for a given flow condition.
Constriction	Significant narrowing of the channel width, forcing flow between banks.
Conveyance	Ability of a channel to pass water downstream.
Critical Habitat	(1) Specific areas within the geographic area occupied by a species at the time it is listed in accordance with the Federal Endangered Species Act (ESA); (2) Specific areas outside the geographical area occupied by a species at the time it is listed under ESA if there is a determination that such areas are essential for conservation of the species.
Critical rooting depth	Minimum root depth that is capable of anchoring a plant firmly enough to withstand channelbed scour.
Descending Limb	Component of a winter or spring snowmelt hydrograph in which the discharge rapidly ramps down (descends) from a peak flow magnitude to a lower flow.
Degradation	Downcutting of the channelbed elevation on a reach-wide scale, caused by an imbalance in sediment supply and transport processes.
Deposition	Process in which a sediment particle in transport comes to rest on the stream bottom, point bar, floodplain, etc., when the competence and transport capacity of a stream are exceeded by the particle's resisting forces.
Designated Floodway	River channel and adjoining floodplains and terraces that together provide the necessary lateral space (valley width) to convey floods of a specified (designed) magnitude.
Drainage basin	Area of land that drains water, sediment, and dissolved materials to a common outlet along the stream channel. Synonymous with "watershed" and "catchment."
Encroachment	(see Riparian encroachment)
Entrainment	The initiation of motion of sedimentary particles, leading to sediment transport and deposition.
Entrenchment	Ratio of flood-prone channel width to the bankfull channel width.

Exceedance probability (P)	Statistical estimate of the likelihood or probability that a certain discharge will be equaled or exceeded in any given year.
Flood Frequency Curve	The statistical distribution of the annual peak flood discharge for a period of record for a gauging station, typically plotted as discharge verses exceedance probability on a log-probability scale.
Floodplain	Geomorphic surfaces bordering a river channel constructed by the deposition of alluvial material, and inundated by discharges equaling or exceeding bankfull discharge. Floodplains often provide habitat for riparian vegetation.
Floodway	River channel and adjoining floodplains and terraces that together provide the necessary lateral space (valley width) to convey floods of a range of magnitudes.
Fluvial	Processes involving the physical properties of flowing water.
Flushing flows	High-flow dam releases intended to “flush” fine sediments stored in the bed of rivers and transport them downstream, thus cleaning the riverbed. Flushing flows rarely achieve their goal, as most fine sediments are simply redeposited in the downstream channel bed.
GIS	Geographical Information System. A specialized form of computerized, geographically-referenced data bases that provide for manipulation and summation of geographic data. A GIS may also be defined as a system of hardware, software, data, and personnel for collecting, storing, analyzing, and disseminating information about geographical areas.
Groundwater	The saturated subsurface or phreatic zone of water, constituting 21% of the world’s fresh water and 97% of all the unfrozen fresh water on earth.
Headward erosion	Process of channelbed erosion or migration upstream from an abrupt drop in the longitudinal profile of a stream.
Hydraulic geometry	The relationship between a given discharge and the physical dimensions of channel, including width, depth, velocity, and slope.
Hydraulic Radius (R)	Hydraulic mean depth, expressed as the ratio of cross-sectional area to wetted perimeter of the channel (A/p).
Hydrograph	Streamflow (discharge) plotted as a function of time. Annual hydrographs show streamflow during and entire year, typically with daily flow averaged, while flood hydrographs may use time increments of 15 minutes or 1 hour for the duration of the flood.
Incision	Vertical erosion or downcutting of the channelbed.
Knickpoints	Abrupt changes or local perturbations in the longitudinal gradient of a river or stream, caused by accumulation of coarse debris or sharp change in the erosional resistance of the bedrock.
Levee	An engineered berm or dike designed and constructed to confine floodwaters to a specified river corridor, thus protecting adjacent lands from flood inundation.
Longitudinal Profile	The morphology and gradient of a river or stream channel, viewed longitudinally from upstream to downstream.

Meander	The approximately sinusoidal planform pattern of a river or stream channel in which the ratio of channel length to down-valley distance exceeds 1.5.
Meander Belt	River corridor within which channel migration occurs, indicated by abandoned channels, oxbow lakes, and accretion topography.
Migration (channel)	The process in which rivers change their planform location by the gradual erosion of banks, floodplains, and terraces on the steep, outside portion of the meander bend, with concurrent deposition on the inside portion or point bar.
Mitigation	Activities designed to avoid, minimize, rectify, reduce, or compensate for project or land-use impacts.
Morphology	(see Channel morphology)
Particle facies	A discrete patch or zone of homogenously-sized sediments resulting from natural segregation of particle grain sizes within depositional sites.
Phenology	Biological periodicity (e.g. flowering, seed dispersal, etc.) related to climate, especially seasonal changes.
Planform	Allignment or location of a river viewed from directly above, such as a map view.
Plant assemblage	Group of plant species that form a distinct unit, called a stand, in the vegetation mosaic.
Plant recruitment	Plants that have survived through establishment to reach sexual maturity.
Plant stand	A plant assemblage defined by the presence of one dominant species or co-dominance between a few species
Pools	Geomorphic channel forms (or habitat units) characterized by deep water and flat water surface, formed by scouring of the channel bed.
Rating Curve	Graph plotting discharge verses the water surface elevation, to establish a linear or power regression relationship, then used to predict discharge at any given water surface stage height.
Riparian	The zone adjacent to water bodies, watercourses, and surface-emergent aquifers (springs, seeps, and oases) whose water provides soil moisture significantly in excess of that otherwise available through local precipitation. Vegetation characteristic of this zone depends on the availability of excess water.
Riparian Corridor/Zone	The zone of interaction along a river or stream containing moisture-dependent vegetation, trees, brush, grasses, sedges, etc., that affect the channel and are affected by it.
Receding limb	Component of storm, snowmelt, or dam-release hydrograph that is ramping down from a peak flow magnitude to a lower flow.
Recurrence Interval (T)	The average interval (in years) between flood events equaling or exceeding a given magnitude. Defined as the inverse of the exceedance probability (1/P)

Riffles	Shallow, steep, coarse section of river channel, or topographic high in the longitudinal profile, formed at the cross-over of the sediment transport path (transverse bar) and the water flow path.
Riparian berm	Dune of sand deposited along the edge of the low water channel caused by, then anchored by, encroached riparian vegetation. Riparian berms constrict the channel, isolating the channel from adjacent floodplains, often causing the channel to downcut.
Riparian encroachment	The process of riparian initiation, establishment, and maturity progressing toward the low water channel. Reduction in high flow regime reduces natural flood - induced riparian mortality, which allows riparian vegetation to initiate and survive in channel locations that would normally be scoured by floods.
Riparian establishment	Begins at the end of the first summer and extends through several growing seasons as the plant increases energy reserves and strengthens roots and shoots.
Ramping	Flow reduction by either natural or dam control means.
Riparian initiation	Begins at seed germination and extends through the first summer.
Riparian maturity	Period of life-cycle when a plant first expends energy on sexual reproduction and continues through its maximum reproductive period.
Rooting depth	The maximum depth that a plant's roots grow every year.
Sapling	A young tree with a trunk less than 4 inches in diameter at breast height (4.5 feet above the ground surface).
Sediment budget	Quantification of sediment yield to a river channel from different contributing sources, including overland flow and gullying, landsliding, bed and bank erosion.
Sediment deposition	The termination of motion or settling-out of sedimentary particles, usually as result of a decrease in flow capacity and competence in the recession stage of a storm hygrograph.
Sediment load	The rate of sediment transported by a river, expressed in tons per day.
Sediment transport	Process or rate of movement of sedimentary particles downstream by entrainment resulting from physical forces of water acting on the channel bed.
Sediment yield	Annual production of bedload and suspended load contributed to, and transported by a stream or river as result of erosional processes, expressed as tons per year
Seedling	A plant shortly after seed germination, includes the first plumuoles.
Sinuosity	The irregular, meandering planform pattern of a river, strictly defined as a ratio of the length of the channel axis or thalweg to the straight-line length of the river valley (Sinuosity Index).
Slough	Portion of abandoned channel or meander cutoff that continues to receive flow from the main channel
Snowmelt hydrograph	The annual spring flood (long duration, moderate magnitude) resulting from the seasonal melting of snow at higher elevations.

Special Status Species	Generally refers to species with declining populations, including, but not limited to species listed or proposed for listing as threatened or endangered under the state and federal Endangered Species Acts.
Stage (height)	Elevation of the water surface at a particular discharge.
Subsurface particles	Particles found in the gravel column deeper than one D_{84} diameter below the bed surface.
Surface particles	Particles found in the gravel column from the bed surface to a depth of one D_{84} diameter.
Suspended load	The finer portion of the annual sediment load, transported in suspension above the bed surface
Thalweg	The deepest portion of the channel.
Threatened species	Any species of plant or animal likely to become endangered within the foreseeable future throughout all or a significant portion of its natural range.
Transverse bar	Depositional channel feature representing the path of sediment transport connectivity between two alternating point bars, and location of a riffle.
Turbidity	Cloudiness in water produced by presence of suspended sediments.
Vegetation	Mosaic of different assemblages of plants across a landscape, and wide range of environmental conditions and gradients.
Water yield	Total volume of runoff generated by a watershed over a water year, usually expressed in acre-feet.
Wetlands	A zone periodically or continuously submerged or having high soil moisture that has aquatic and /or riparian vegetation components and is maintained by water supplies significantly in excess of those otherwise available through local precipitation.
Wetted perimeter	Distance from the left edge to right edge of water surface measured along the channel sides and bottom, perpendicular to the flow direction, i.e., along a cross section.

Appendix A

Cross Sections Established in the Upper Spawning Reach and Gravel Mining Reach for Monitoring Channel Bed Topography.

(see figure 11, page 26 for planform location of cross sections)

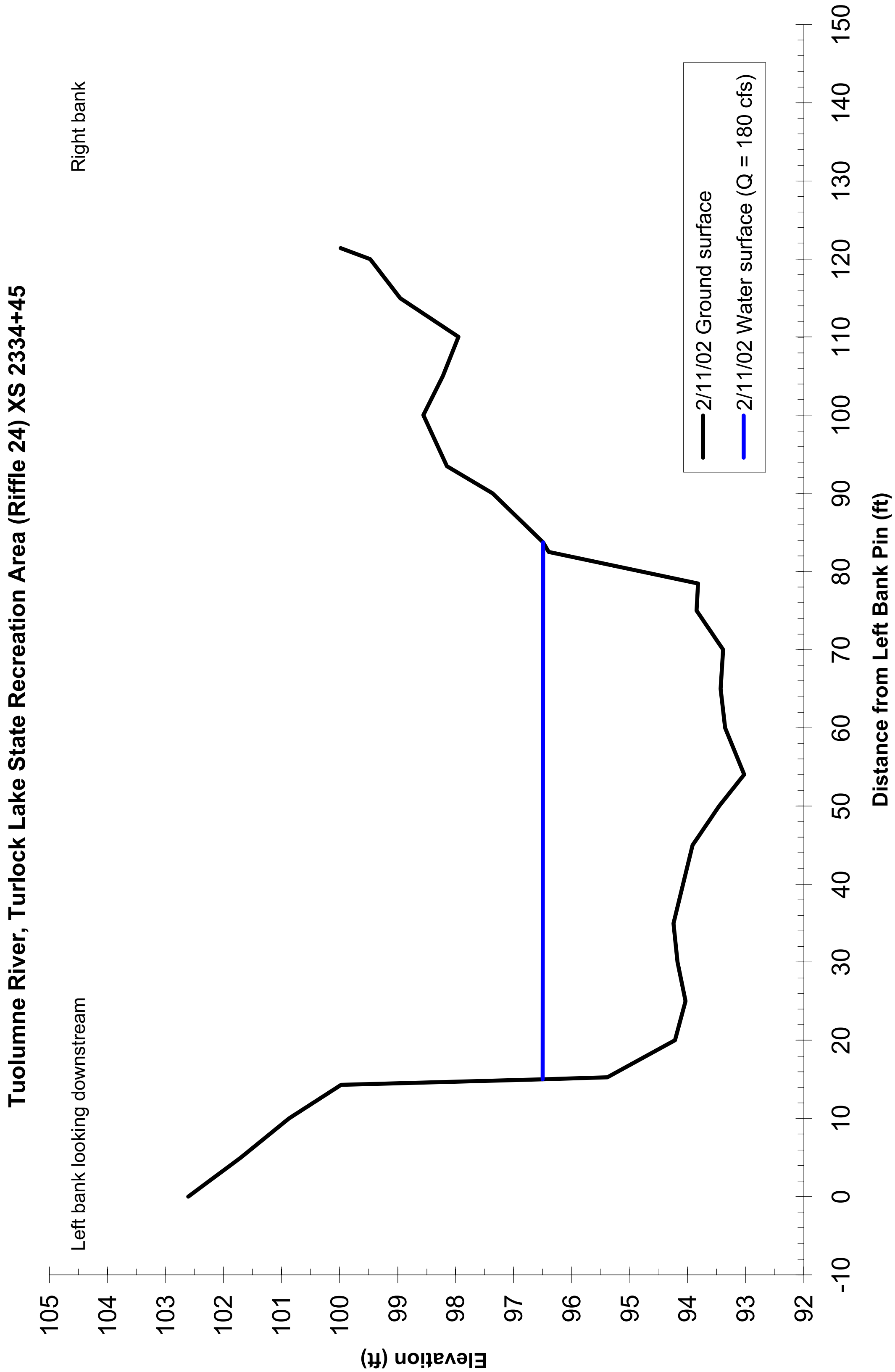
Tuolumne River Cross Section Pin Elevation Summary Sheet

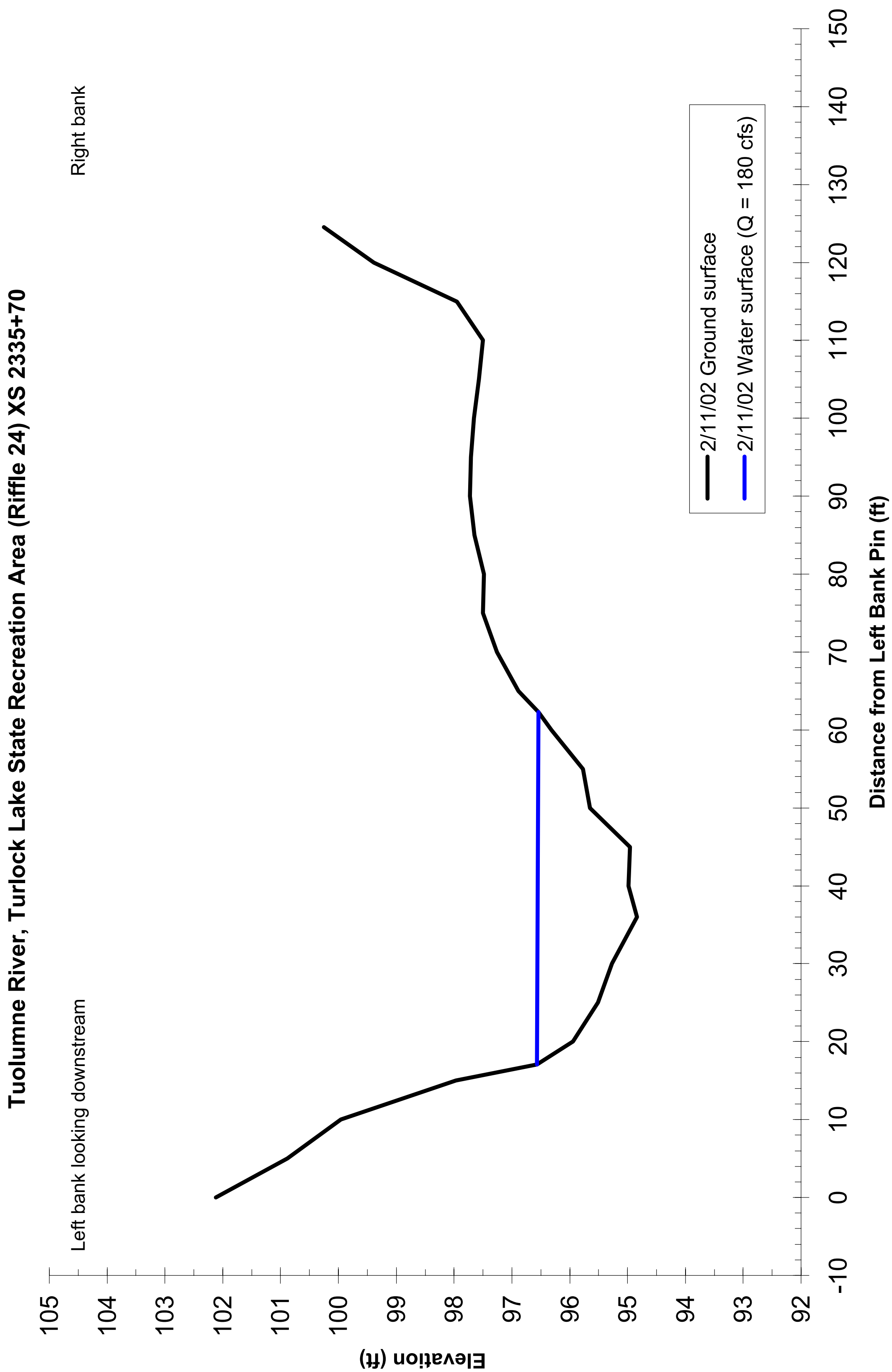
Site Name	Current Cross Section Label	Old Cross Section Label	BM Elevation (ft)	Top Upper Left Bank Pin Elev. (ft)	Top Left Bank Pin Elev. (ft)	Top Right Bank Pin Elev. (ft)	Total cross section length (ft)	Fieldbook # and Page #'s	Notes
TLRSA	2334+45				102.97	100.0		Fieldbook 9, page 104	
	2335+70				102.54	100.25		Fieldbook 9, page 104	
	2336+35				101.73	100.78		Fieldbook 9, page 104	
	2337+10				105.18	99.42		Fieldbook 9, page 104	
			175.61						Old basso bridge brass benchmark
Riffle 4B			165.81						5/8 inch rebar pin at Riffle 4B next to concrete block
	2670+00	A			158.64	161.16	654.70	Fieldbook #10, page #46-57	
	2672+00	B			159.08	158.35	218.20	Fieldbook #10, page #38-41	
Riffle 5A	2674+00	C			160.52	163.32	255.30	Fieldbook #10, page #38-41	
	2685+00	D		169.15	159.38	158.86	700.10	Fieldbook #10, page #58-63	
	2690+00	E		163.96	160.15	160.20	288.30	Fieldbook #10, page #64-67	
Riffle 4A	2699+00	F			164.19	161.91	255.40	Fieldbook 10, page 88-91	
	2702+00	G		166.09	164.39	165.07	762.00	Fieldbook 10, page 80-87	
	2705+00	H			164.59	165.77	191.10	Fieldbook 10, page 92-95	
	2722+00	J			176.02	165.33	328.10	Fieldbook 10, page 96-99	
Riffle 3B	2728+00	K			172.50	166.22	193.60	Fieldbook 10, page 108-111	
	2731+00	L		174.87	166.71	167.76	664.60	Fieldbook 10, page 112-115	
	2735+00	M			173.08	174.70	308.50	Fieldbook 10, page 112-115	
	2799+00	R			181.59	180.32	369.70	Fieldbook # 9, page 54-56	Elevation based on back calculation from XS 2802+00
	2802+00	S			182.57	182.32	361.50	Fieldbook 9, page 42-51	
	2804+00	T			178.35	182.70	357.10	Fieldbook 9, page 42-51	
	2842+00	W			183.89	187.90	260.90	Fieldbook 10, page 146-149	
	2844+00	X			182.51	177.09	259.60	Fieldbook 10, page 140-143	
	2846+00	Y			182.49	184.61	272.30	Fieldbook 10, page 134-139	
	2847+00	Z			184.71	184.33	260.20	Fieldbook 10, page 130-133	

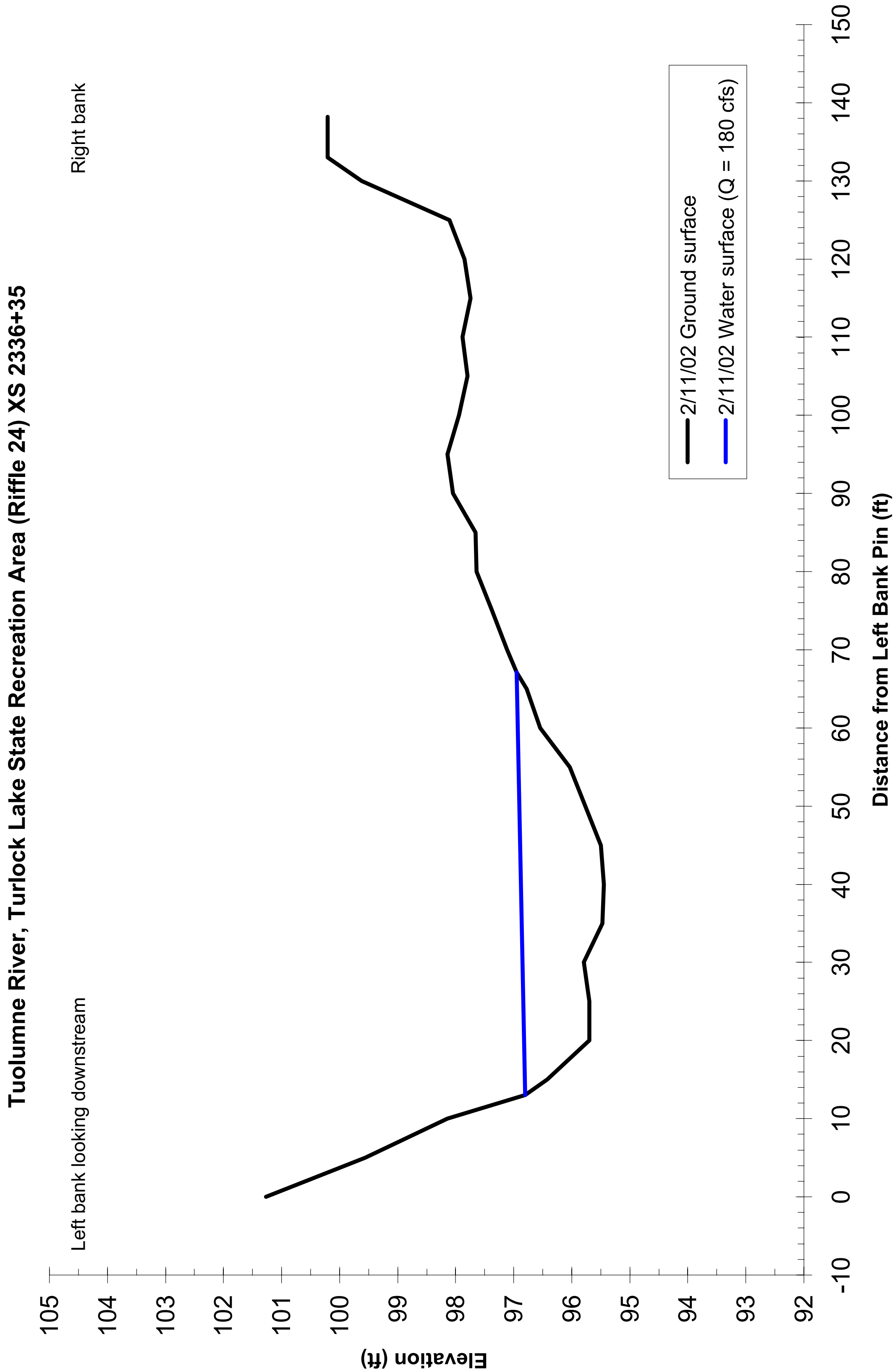
Tuolumne River Sediment Management Reach, Turlock Lake State Recreation Area to La Grange Dam. Benchmark and Cross Section Pin Elevation Summary Sheet.

Name	Northing	Easting	XS Letter Code	XS Feature Code
1	2066126.84	6572356.54		REBAR10
2	2064452.41	6577609.73		SPIKE
3	2064946.56	6573796.43	R	RB2799+00
4	2064835.40	6574053.97	S	RB2802+00
5	2064767.23	6574251.11	T	RB2804+00
6	2064433.91	6574122.76	T	LB2804+00
7	2064601.42	6573662.97	R	LB2799+00
8	2064599.16	6573732.97		ORANGEREBAR
9	2061435.30	6565513.33	E	ULB2690+00
10	2061510.23	6565247.11	E	RB2690+00
12	2063092.28	6565850.96		STILLWATERORANGEREBAR
13	2062924.83	6565700.29	H	LB2705+00
14	2063052.09	6565557.98	H	RB2705+00
15	2062687.39	6565473.73	G	LB2702+00
16	2062774.89	6565254.53	G	RB2702+00
18	2062433.18	6565237.48	F	RB2699+00
19	2062488.92	6565486.21	F	LB2699+00
20	2062447.21	6565937.91	G	ULB2702+00
21	2063617.52	6566946.22	J	LB2722+00
23	2063838.84	6566705.08	J	RB2722+00
25	2064420.56	6566982.76	K	RB2728+00
26	2064754.79	6567157.36	L	RB2731+00
27	2065125.05	6567570.06	M	RB2735+00
28	2064860.98	6567728.54	M	LB2735+00
29	2064618.68	6567306.96	L	LB273100
30	2064362.45	6567165.79	K	LB2728+00
32	2064296.87	6567636.64	L	ULB2731+00
33	2063783.06	6566765.96	J	REBAR
34	2063849.22	6566827.57		REBAR
35	2061016.29	6565240.30	D	LLB2685+00
36	2060959.78	6565345.45	D	ULB2685+00
37	2061137.44	6565054.18	D	RB2685+00
38	2060308.29	6564483.53	C	LB2674+00
39	2060208.19	6564346.28	B	LB2672+00
41	2060084.85	6564086.51	A	LLB2670+00
42	2060317.26	6564015.22	A	RB2670+00
43	2060448.81	6563896.52	A	RBFPON2670+00
44	2060398.19	6564239.12	B	RB2672+00
45	2060540.06	6564376.93	C	RB2674+00
50	2065196.59	6570447.11		REBAR
52	2065240.42	6569987.82		REBAR
53	2065129.03	6569604.70		REBAR
54	2065049.18	6568354.81		REBAR
55	2065052.77	6567883.21		REBAR
56	2064932.21	6577839.71	Y	RB2846+00
57	2064840.94	6577916.70		REBAR
58	2064679.66	6577443.19	W	RB2842+00
59	2064460.15	6577581.68	W	LB2842+00
60	2064730.72	6578064.10	Z	LB2847+00
61	2064696.60	6577975.54	Y	LB2846+00
62	2064981.44	6577997.19	Z	RB2847+00
63	2064823.87	6577703.67	X	RB2844+00
64	2064576.83	6577782.41	X	LB2844+00
65	2057433.40	6563006.83		USGSLBOLDBASSO

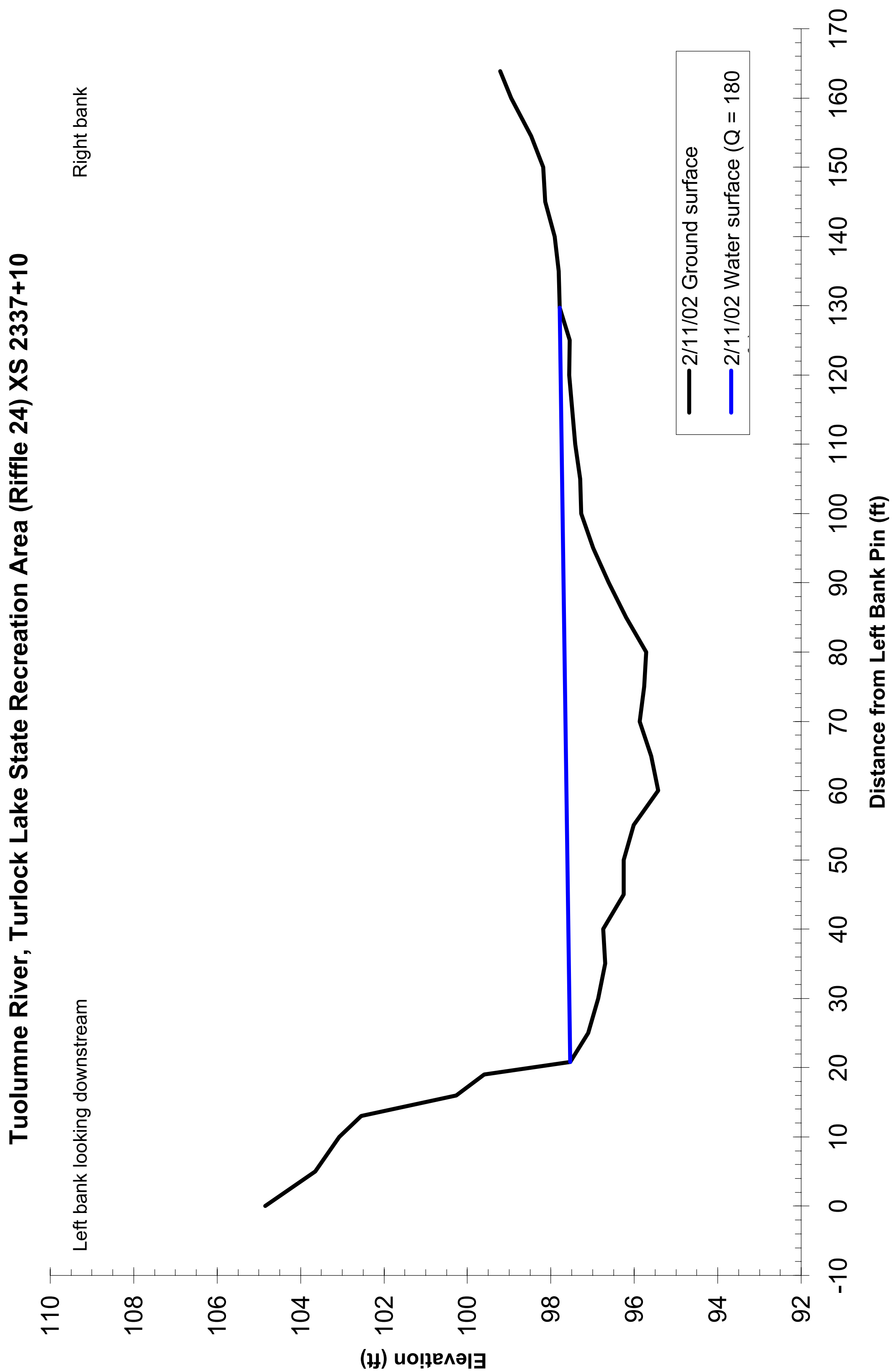
Tuolumne River Sediment Management Reach, Turlock Lake State Recreation Area to La Grange Dam. Benchmark and cross section pin coordinate summary (northing and easting). Note: Use pin elevations from ‘pin elevation summary sheet’ in conjunction with coordinates (northing and easting).

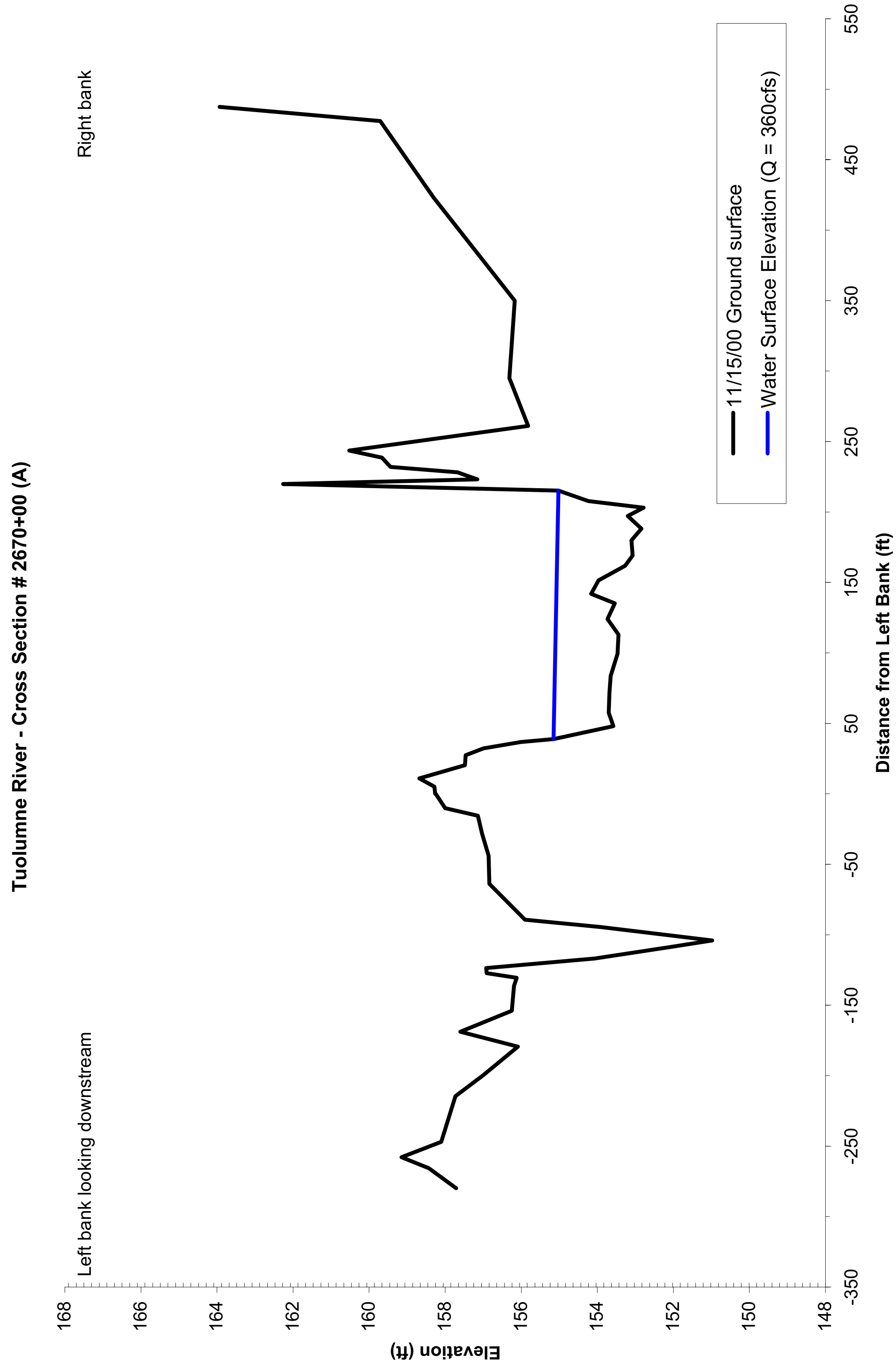

Tuolumne River, Turlock Lake State Recreation Area (Riffle 24) XS 2334+45
Left bank looking downstream
Right bank
2/11/02 Ground surface
2/11/02 Water surface (Q = 180 cfs)
Elevation (ft)
Distance from Left Bank Pin (ft)
105
104
103
102
101
100
99
98
97
96
95
94
93
92
-10
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150

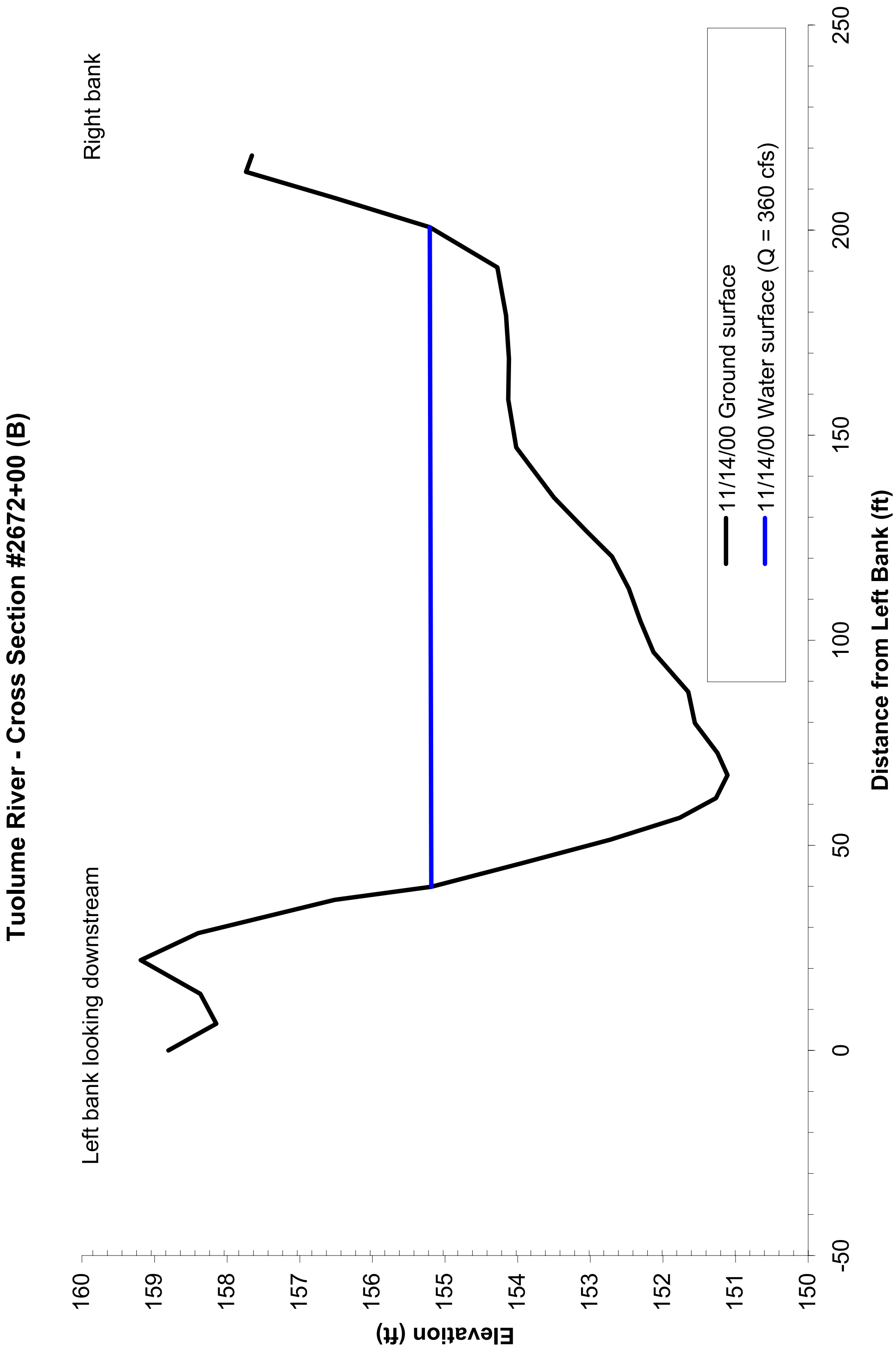

Tuolumne River, Turlock Lake State Recreation Area (Riffle 24) XS 2335+70
Left bank looking downstream
Right bank
2/11/02 Ground surface
2/11/02 Water surface (Q = 180 cfs)
Elevation (ft)
105
104
103
102
101
100
99
98
97
96
95
94
93
92
-10
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
Distance from Left Bank Pin (ft)

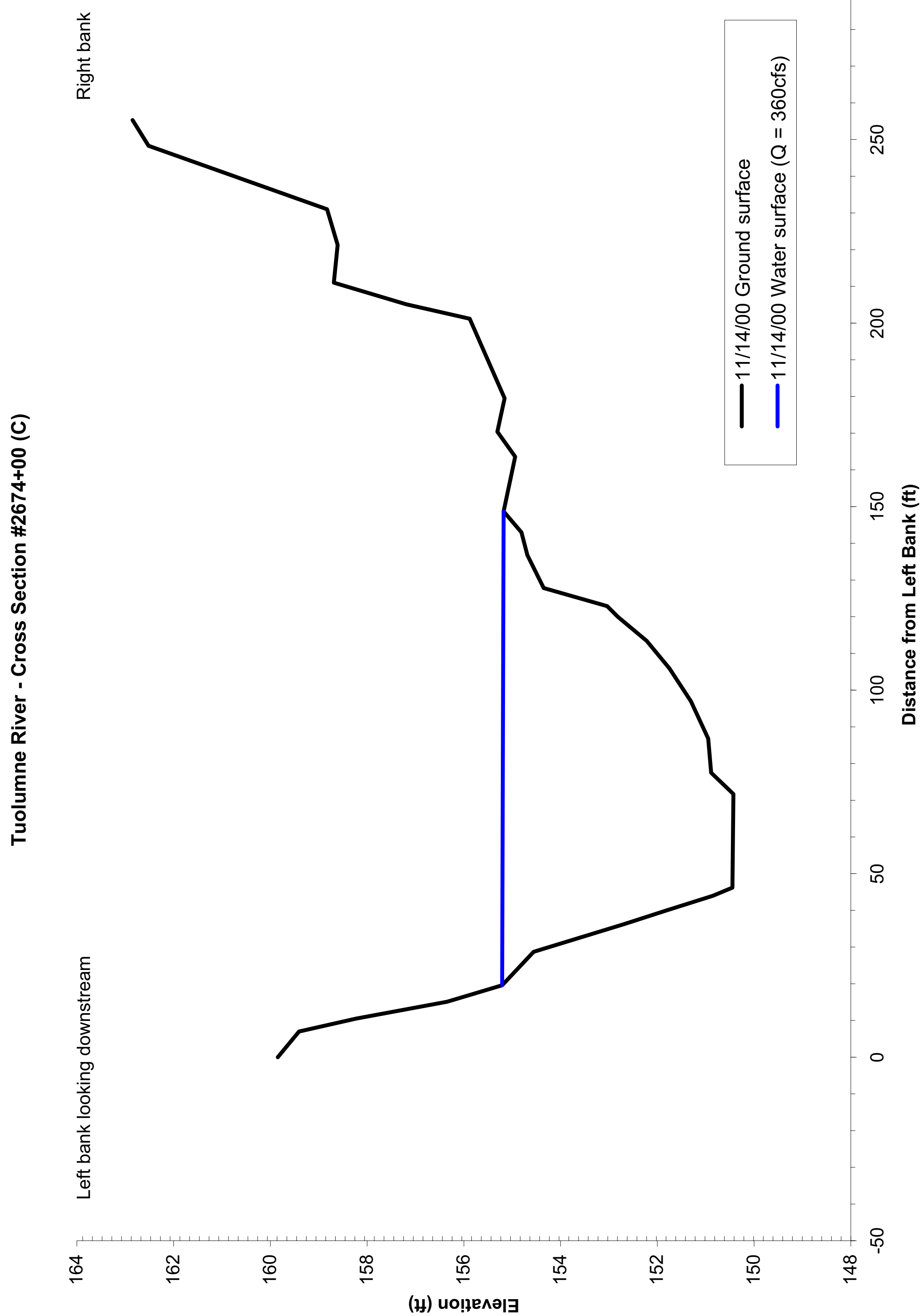


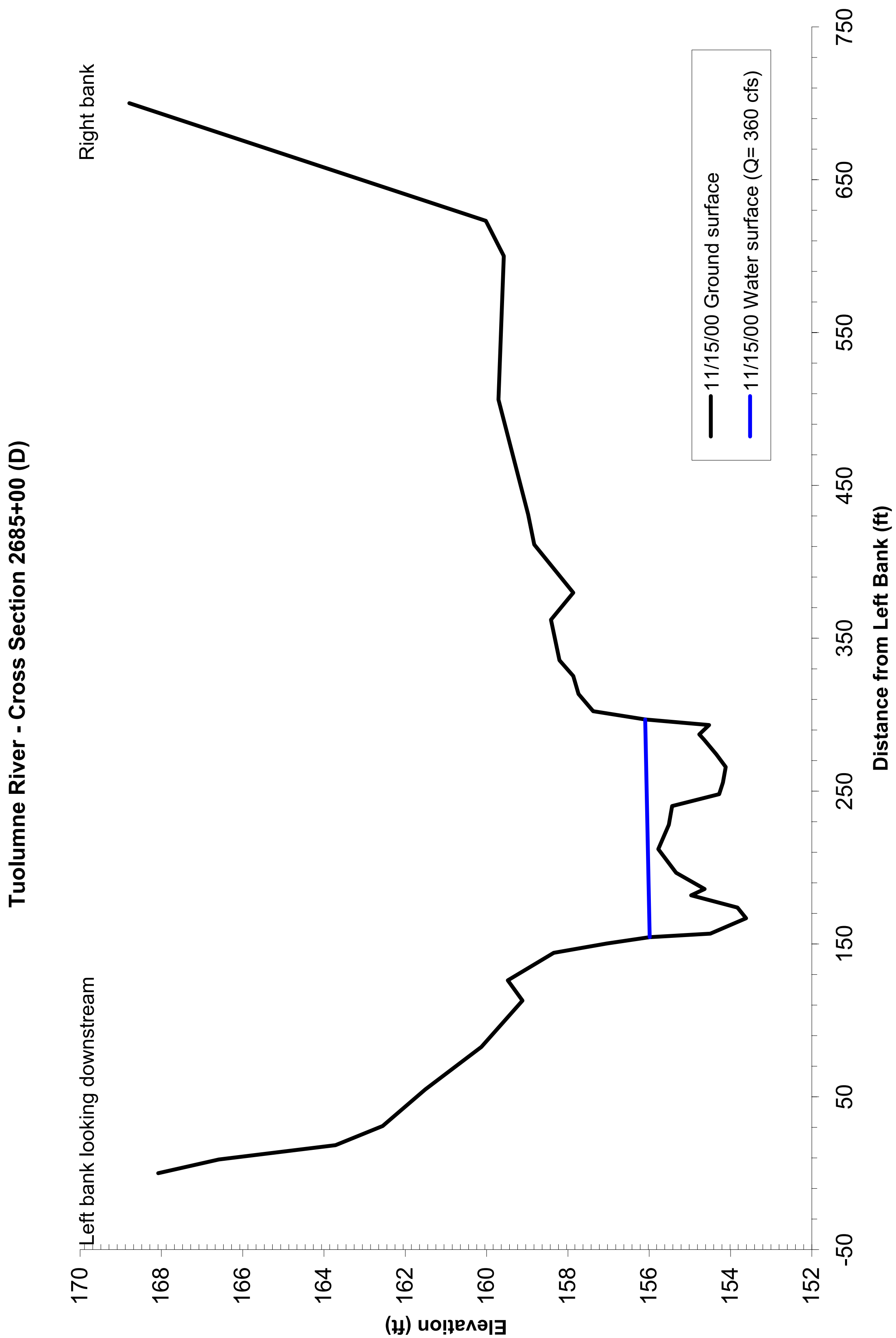
Tuolumne River, Turlock Lake State Recreation Area (Riffle 24) XS 2336+35
Left bank looking downstream
Right bank
2/11/02 Ground surface
2/11/02 Water surface (Q = 180 cfs)
Elevation (ft)
Distance from Left Bank Pin (ft)
105
104
103
102
101
100
99
98
97
96
95
94
93
92
-10
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150

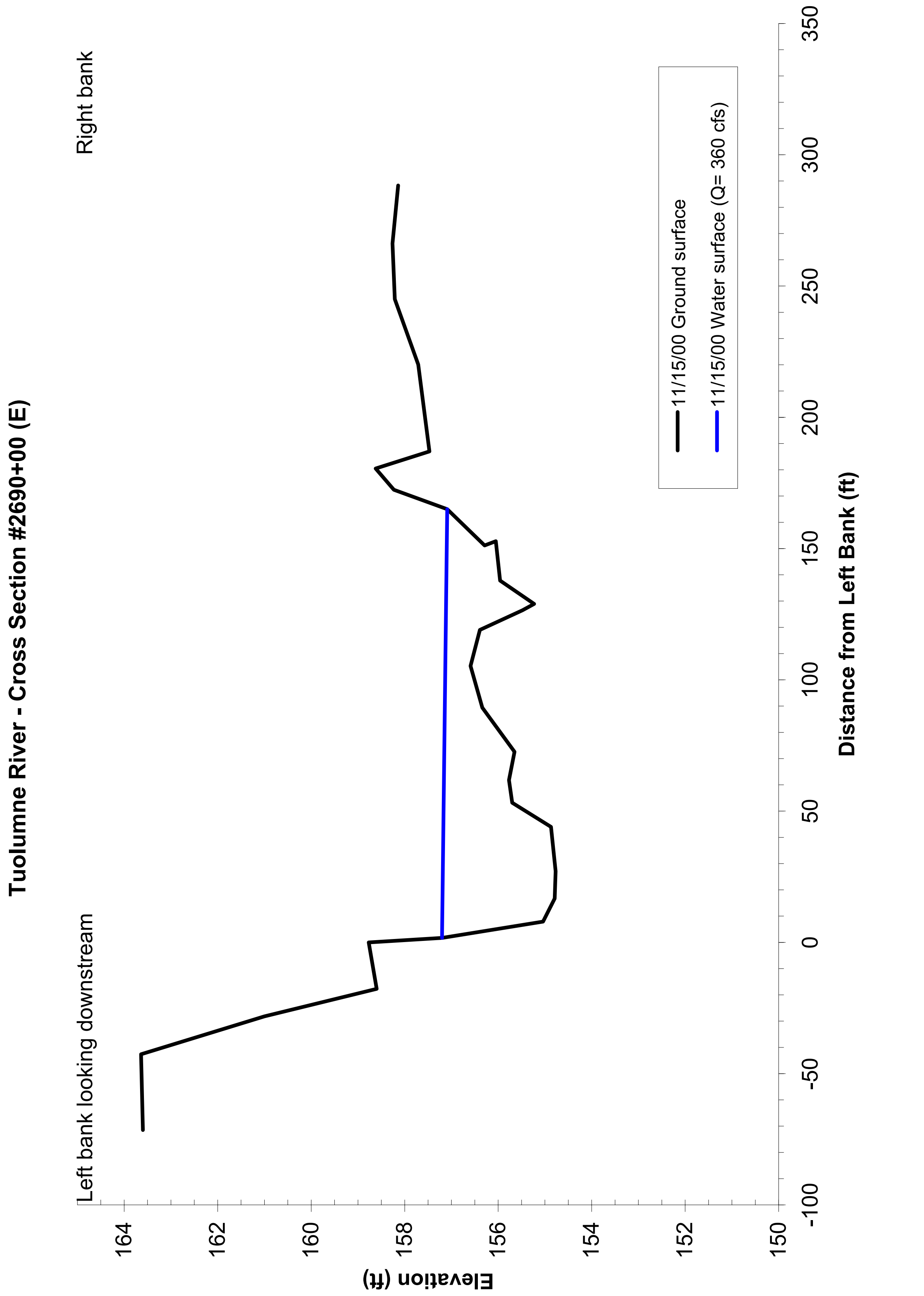

Tuolumne River, Turlock Lake State Recreation Area (Riffle 24) XS 2337+10
Left bank looking downstream
Right bank
2/11/02 Ground surface
2/11/02 Water surface (Q = 180
Elevation (ft)
Distance from Left Bank Pin (ft)

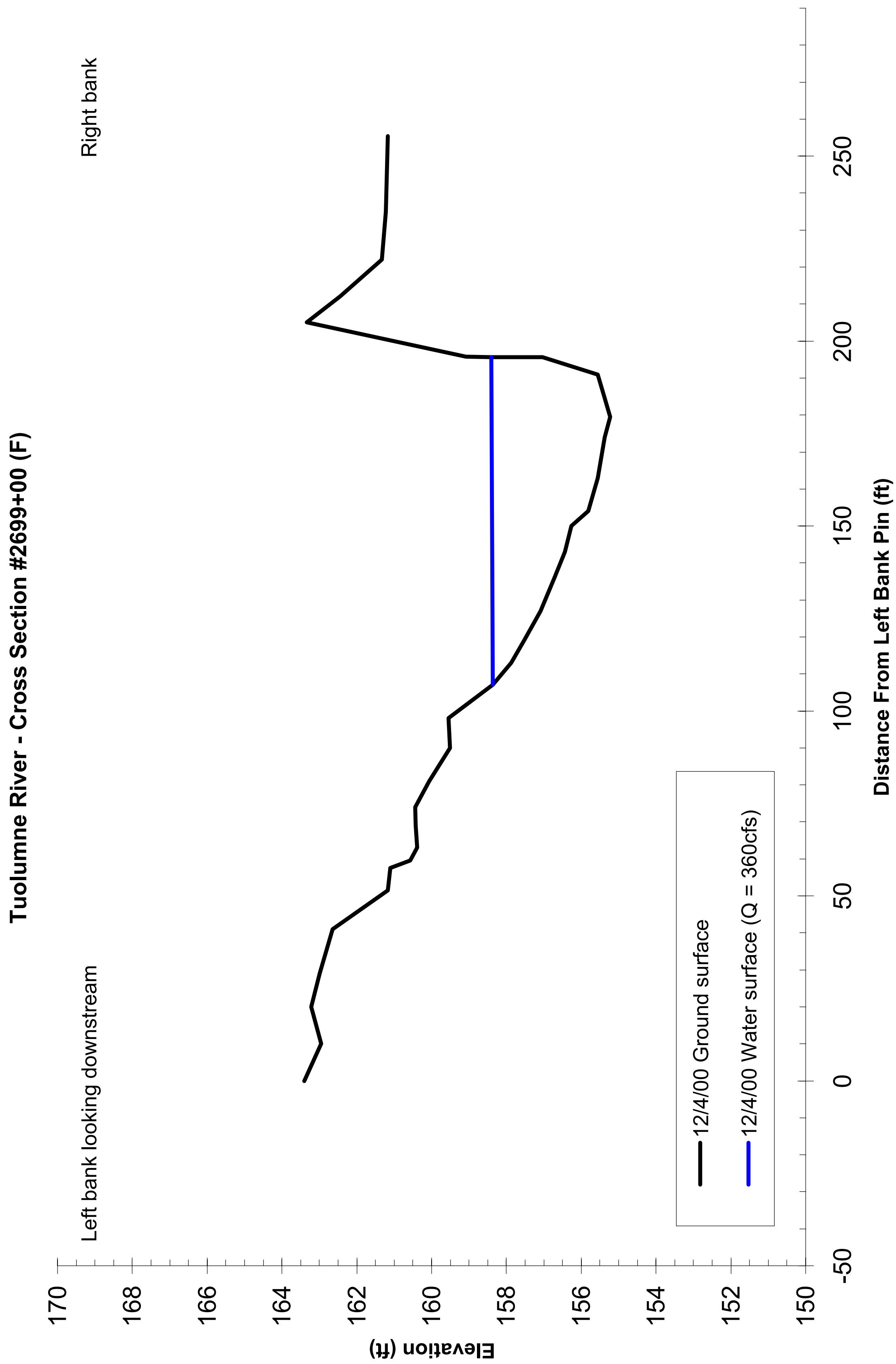

Tuolumne River - Cross Section # 2670+00 (A)
Left bank looking downstream
Right bank
11/15/00 Ground surface
Water Surface Elevation (Q = 360cfs)
Elevation (ft)
168
166
164
162
160
158
156
154
152
150
148
Distance from Left Bank (ft)
-350
-250
-150
-50
50
150
250
350
450
550

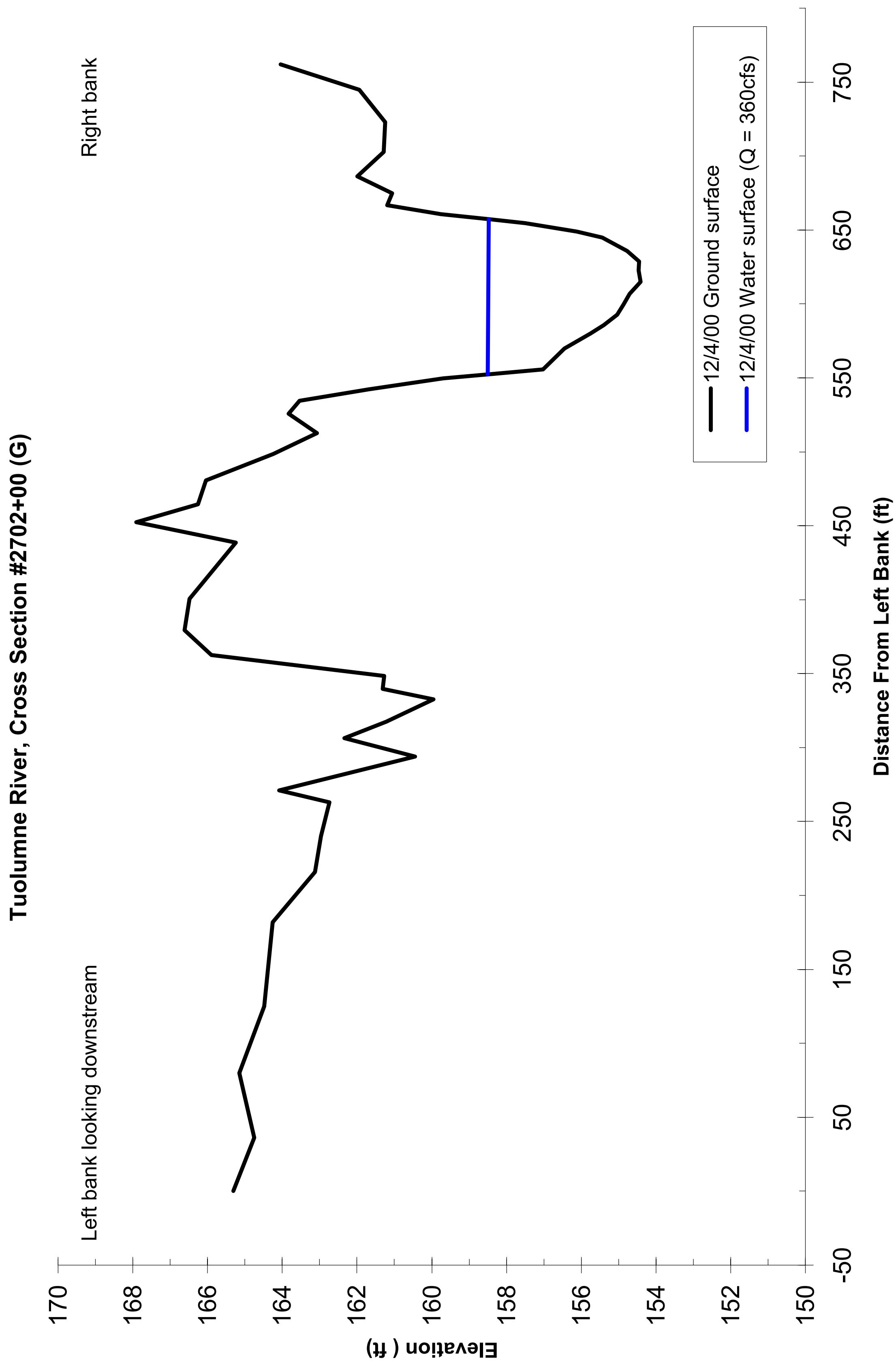

Tuolume River - Cross Section #2672+00 (B)
Left bank looking downstream
Right bank
11/14/00 Ground surface
11/14/00 Water surface (Q = 360 cfs)
Elevation (ft)
Distance from Left Bank (ft)
160
159
158
157
156
155
154
153
152
151
150
-50
0
50
100
150
200
250

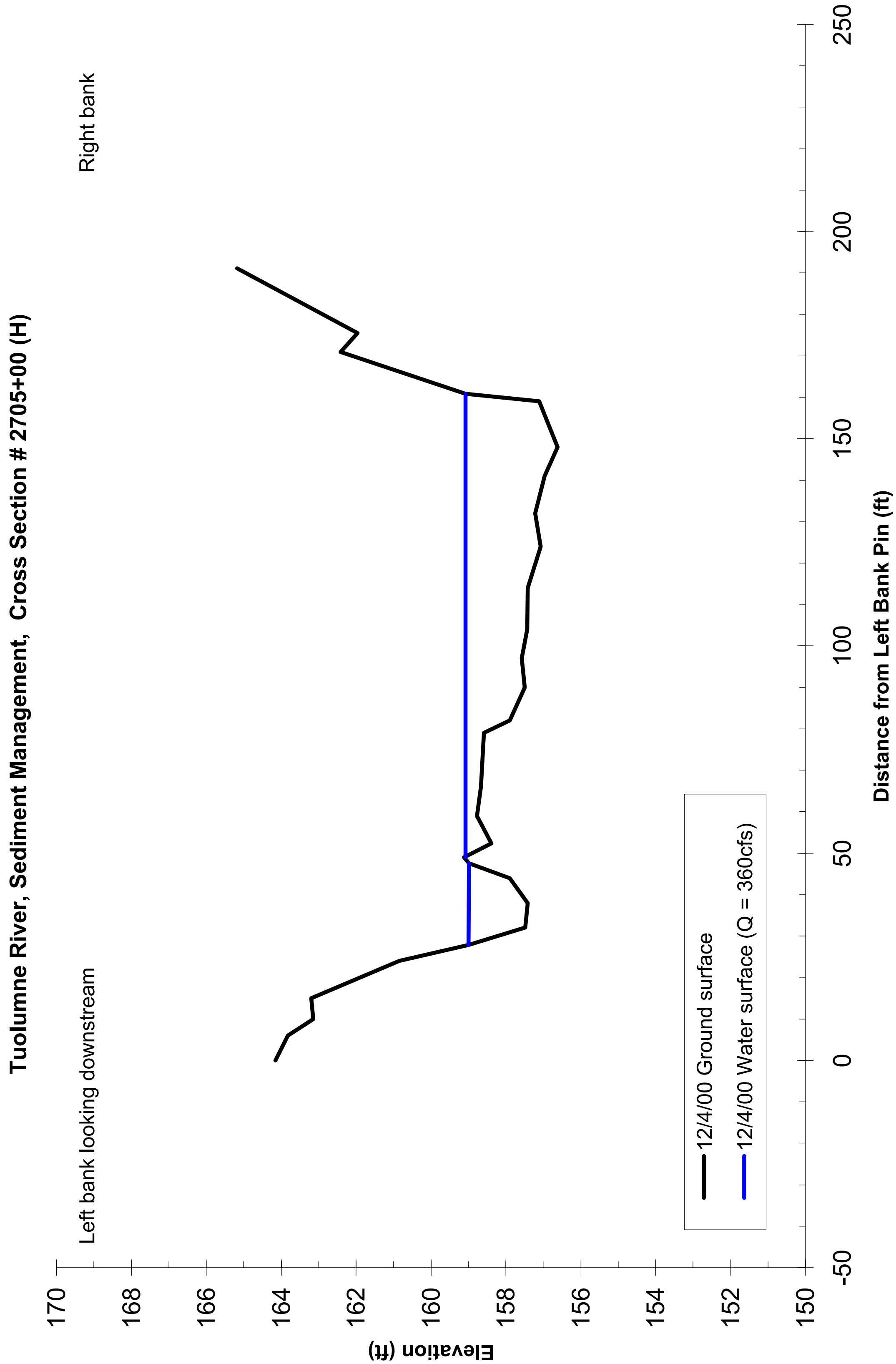

Tuolumne River - Cross Section #2674+00 (C)
Left bank looking downstream
Right bank
11/14/00 Ground surface
11/14/00 Water surface (Q = 360cfs)
Elevation (ft)
Distance from Left Bank (ft)
164
162
160
158
156
154
152
150
148
-50
0
50
100
150
200
250
300

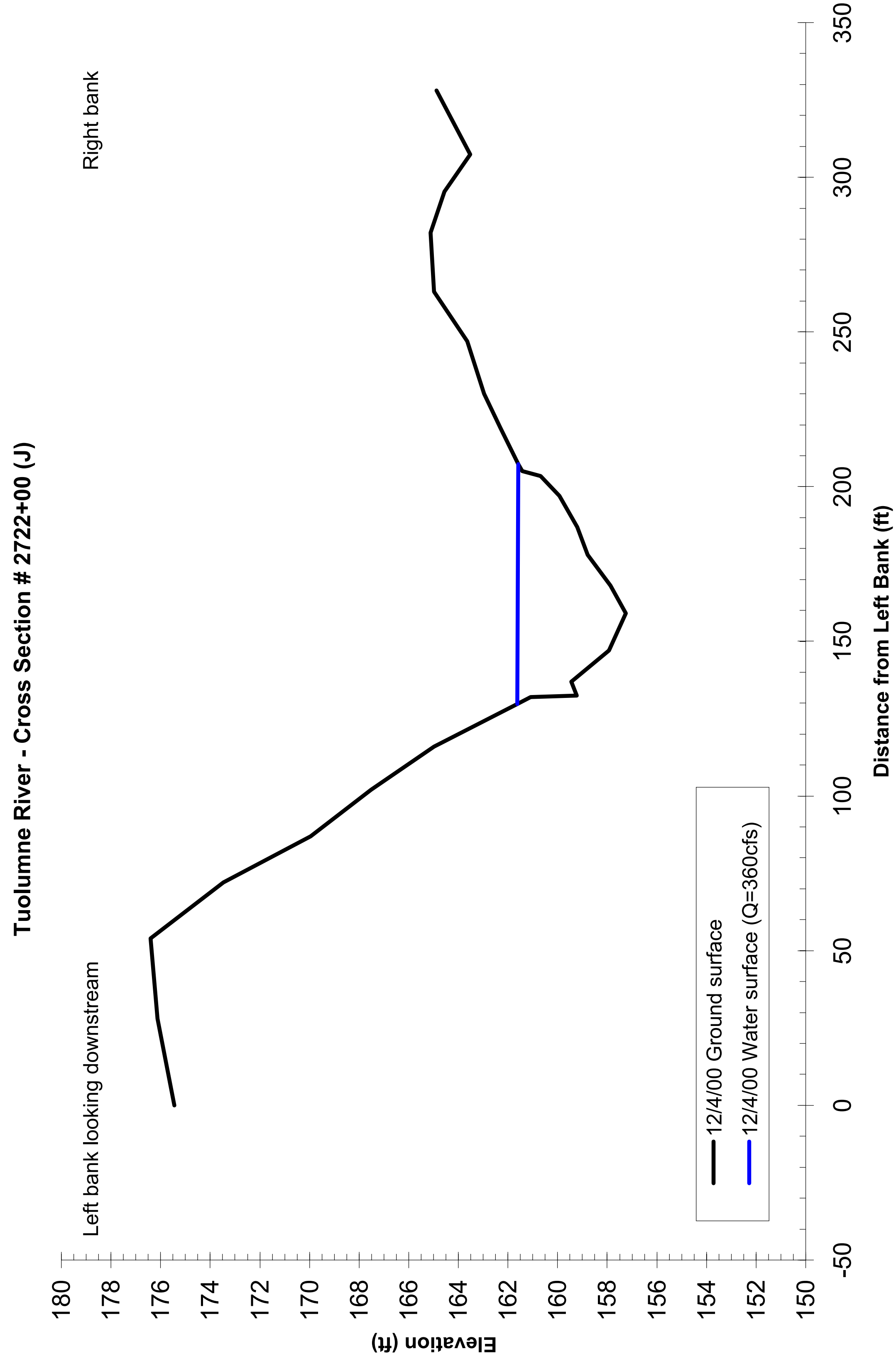

Tuolumne River - Cross Section 2685+00 (D)
Left bank looking downstream
Right bank
11/15/00 Ground surface
11/15/00 Water surface (Q= 360 cfs)
Elevation (ft)
Distance from Left Bank (ft)
170
168
166
164
162
160
158
156
154
152
-50
50
150
250
350
450
550
650
750

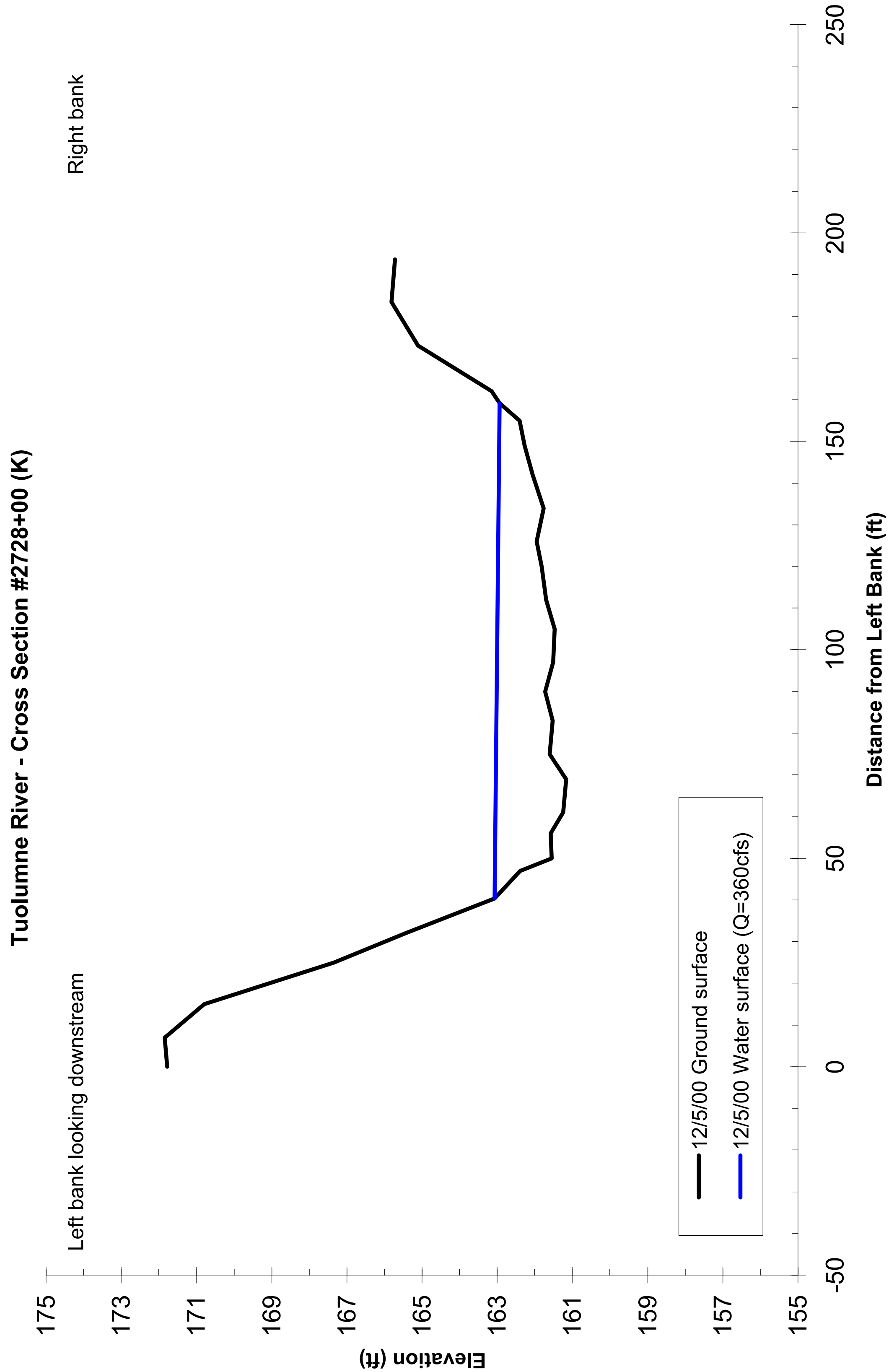

Tuolumne River - Cross Section #2690+00 (E)
Left bank looking downstream
Right bank
11/15/00 Ground surface
11/15/00 Water surface (Q= 360 cfs)
Elevation (ft)
164
162
160
158
156
154
152
150
Distance from Left Bank (ft)
-100
-50
0
50
100
150
200
250
300
350

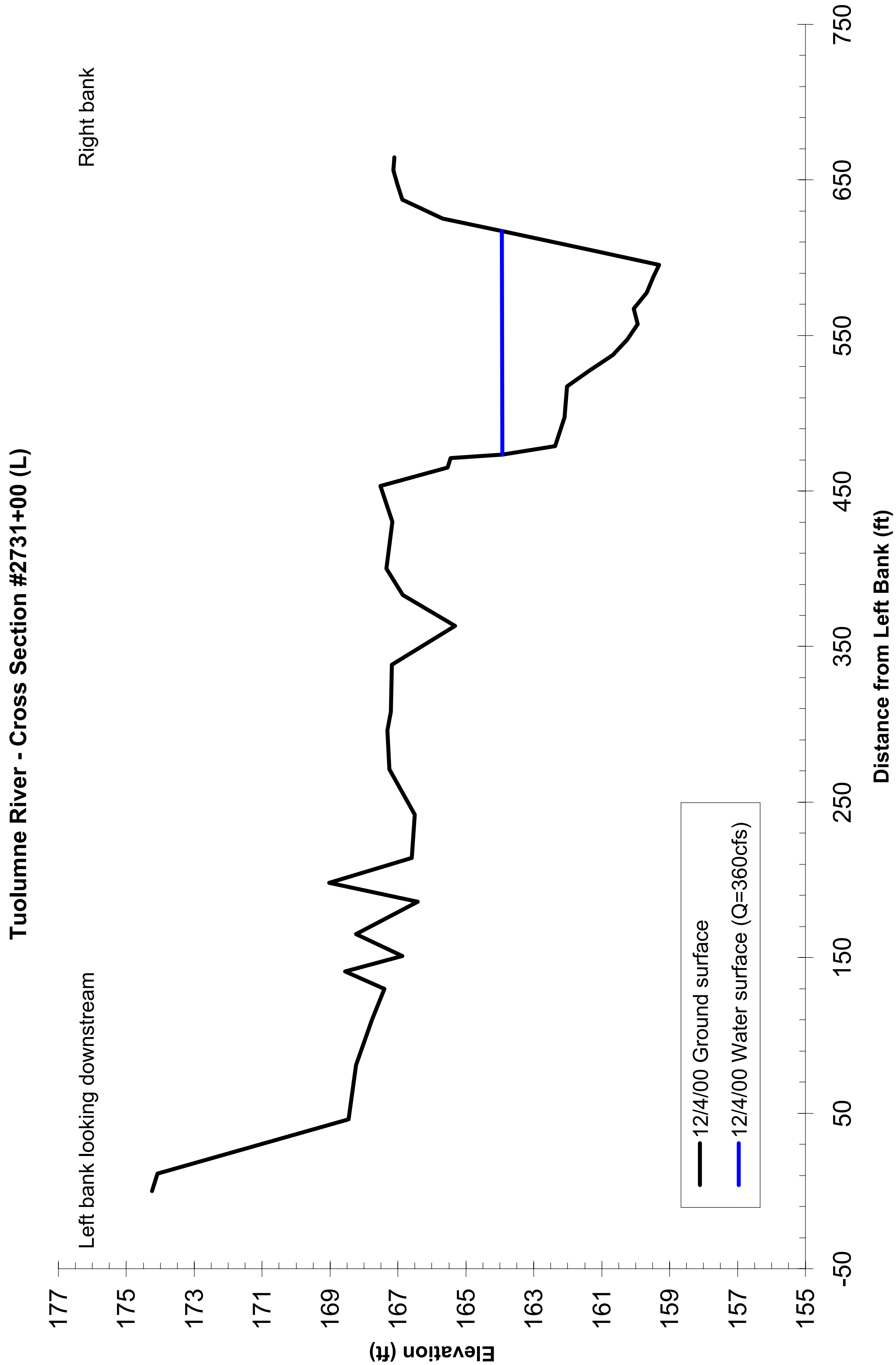

Tuolumne River - Cross Section #2699+00 (F)
Left bank looking downstream
Right bank
12/4/00 Ground surface
12/4/00 Water surface (Q = 360cfs)
Elevation (ft)
170
168
166
164
162
160
158
156
154
152
150
Distance From Left Bank Pin (ft)
-50
0
50
100
150
200
250

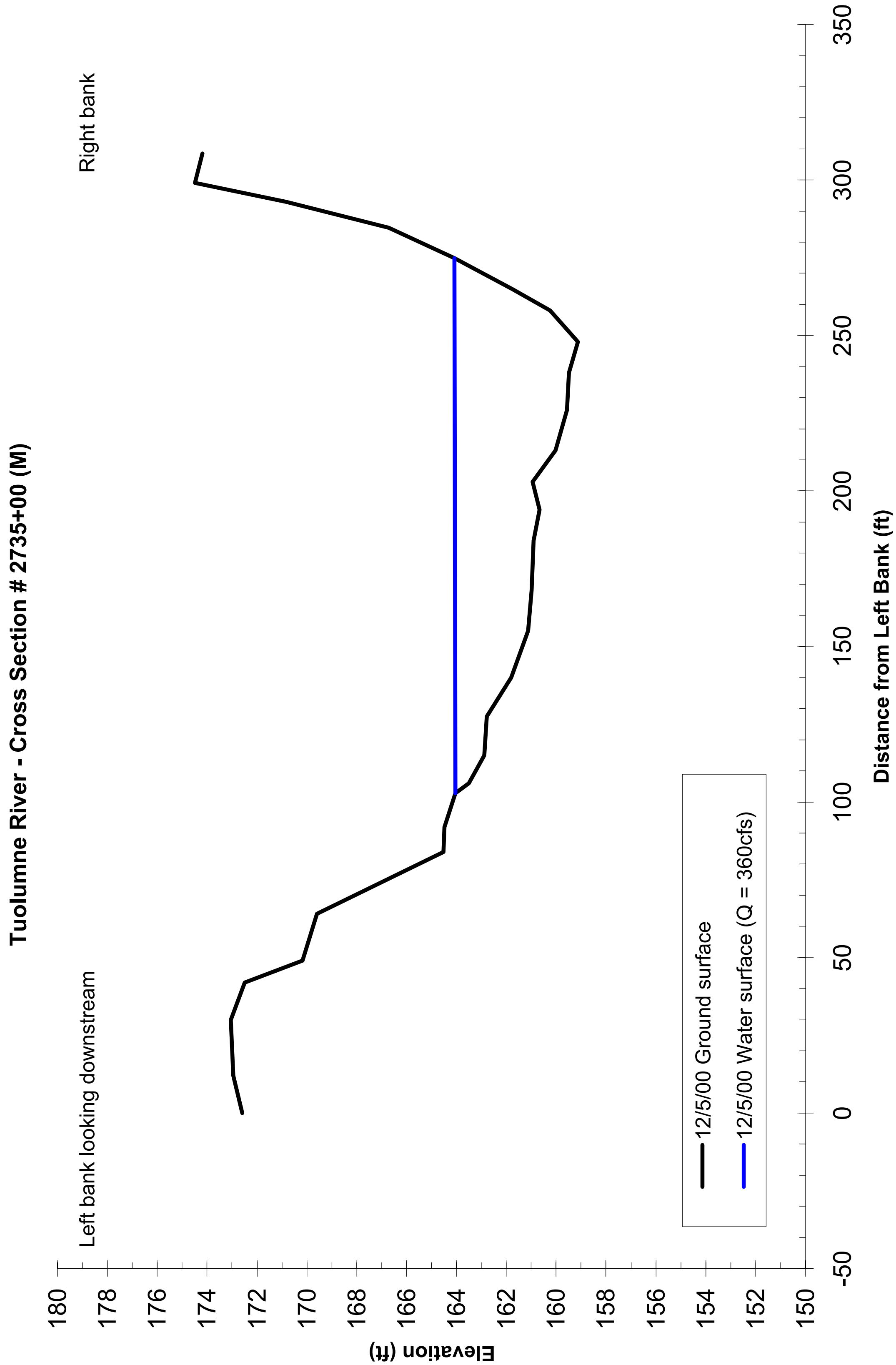

Tuolumne River, Cross Section #2702+00 (G)
Left bank looking downstream
Right bank
12/4/00 Ground surface
12/4/00 Water surface (Q = 360cfs)
Elevation (ft)
Distance From Left Bank (ft)
170
168
166
164
162
160
158
156
154
152
150
-50
50
150
250
350
450
550
650
750

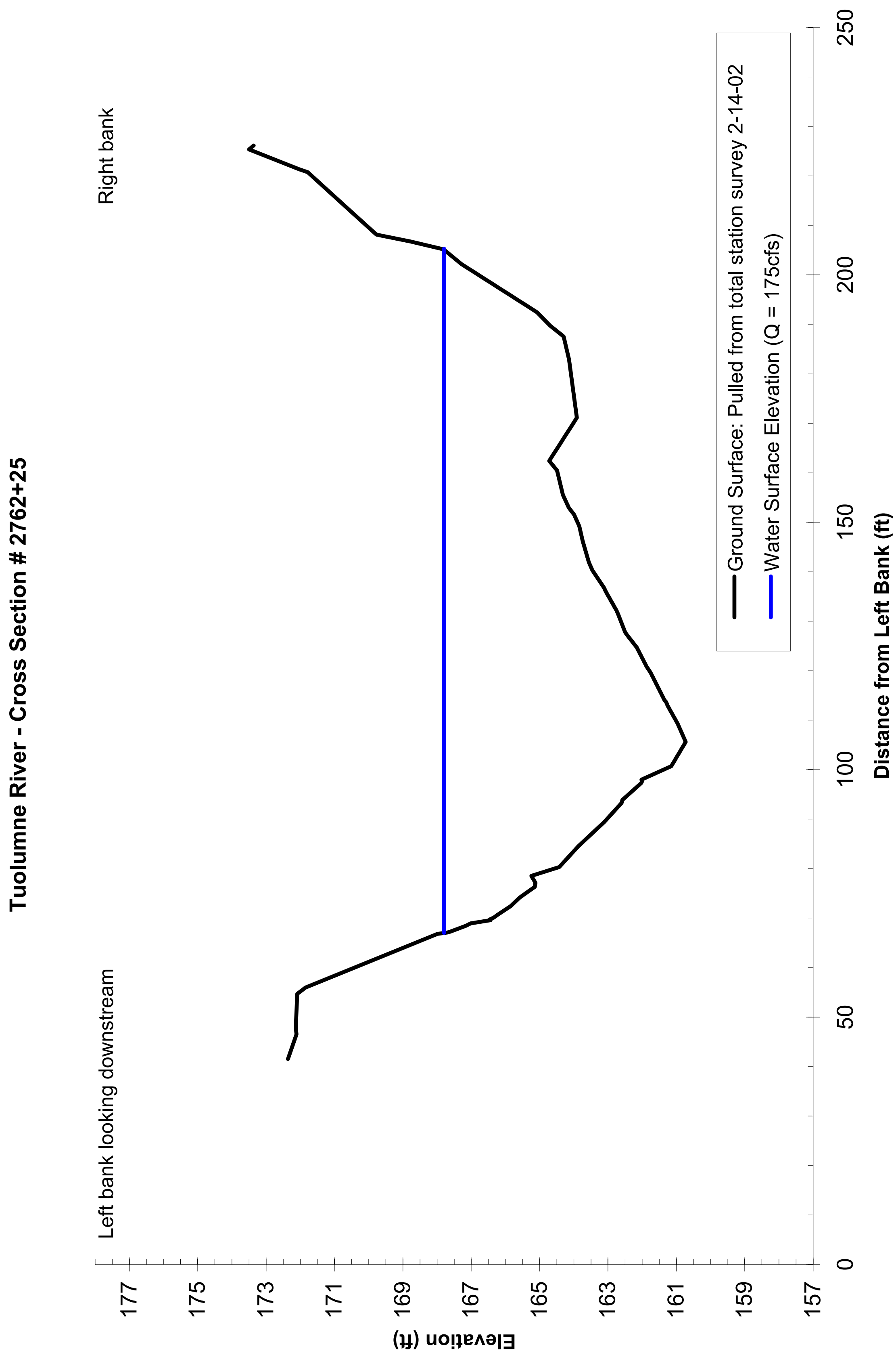

Tuolumne River, Sediment Management, Cross Section # 2705+00 (H)
Left bank looking downstream
Right bank
12/4/00 Ground surface
12/4/00 Water surface (Q = 360cfs)
Elevation (ft)
170
168
166
164
162
160
158
156
154
152
150
Distance from Left Bank Pin (ft)
-50
0
50
100
150
200
250

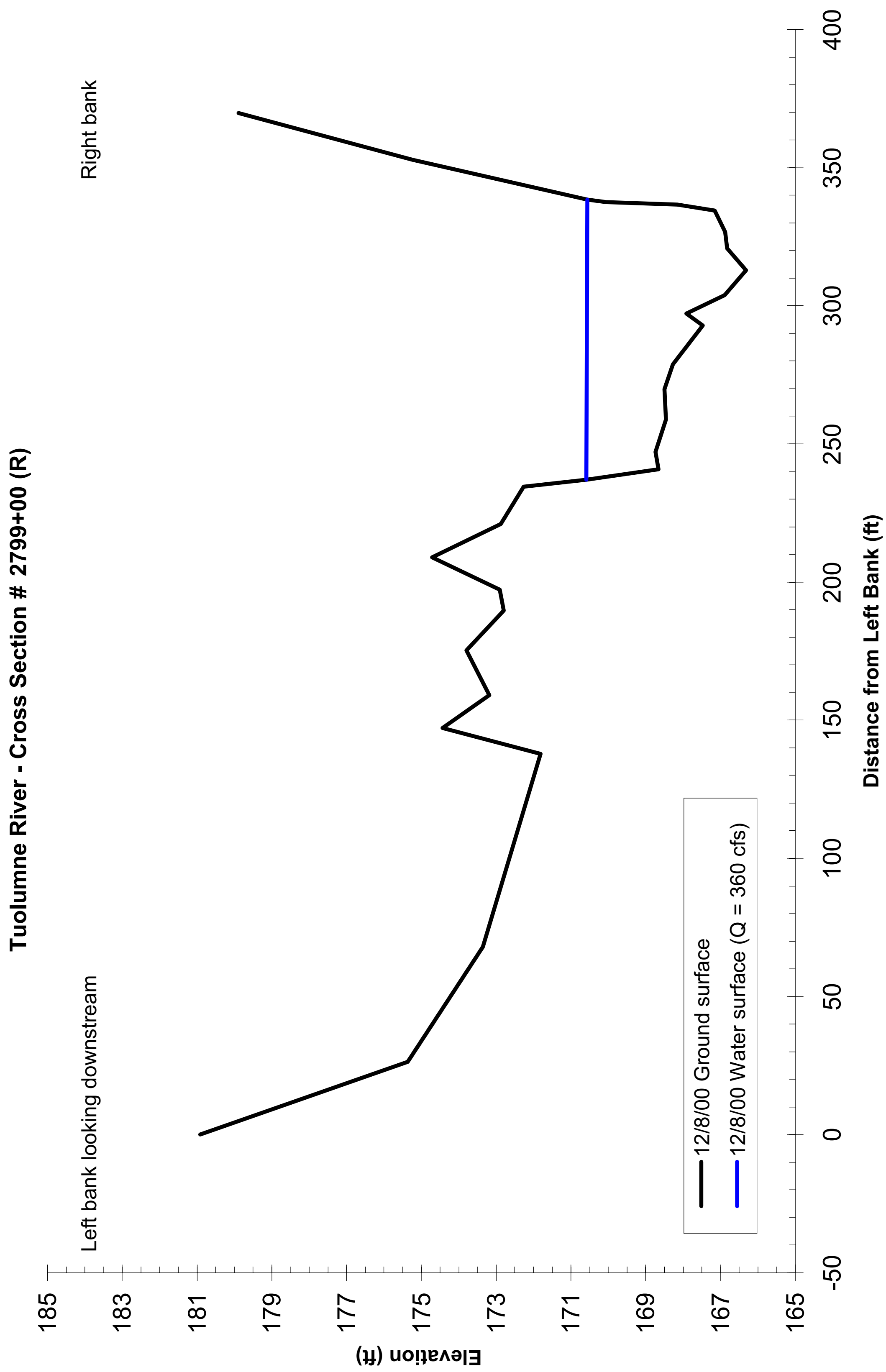

Tuolumne River - Cross Section # 2722+00 (J)
Left bank looking downstream
Right bank
12/4/00 Ground surface
12/4/00 Water surface (Q=360cfs)
Elevation (ft)
Distance from Left Bank (ft)
180
178
176
174
172
170
168
166
164
162
160
158
156
154
152
150
-50
0
50
100
150
200
250
300
350

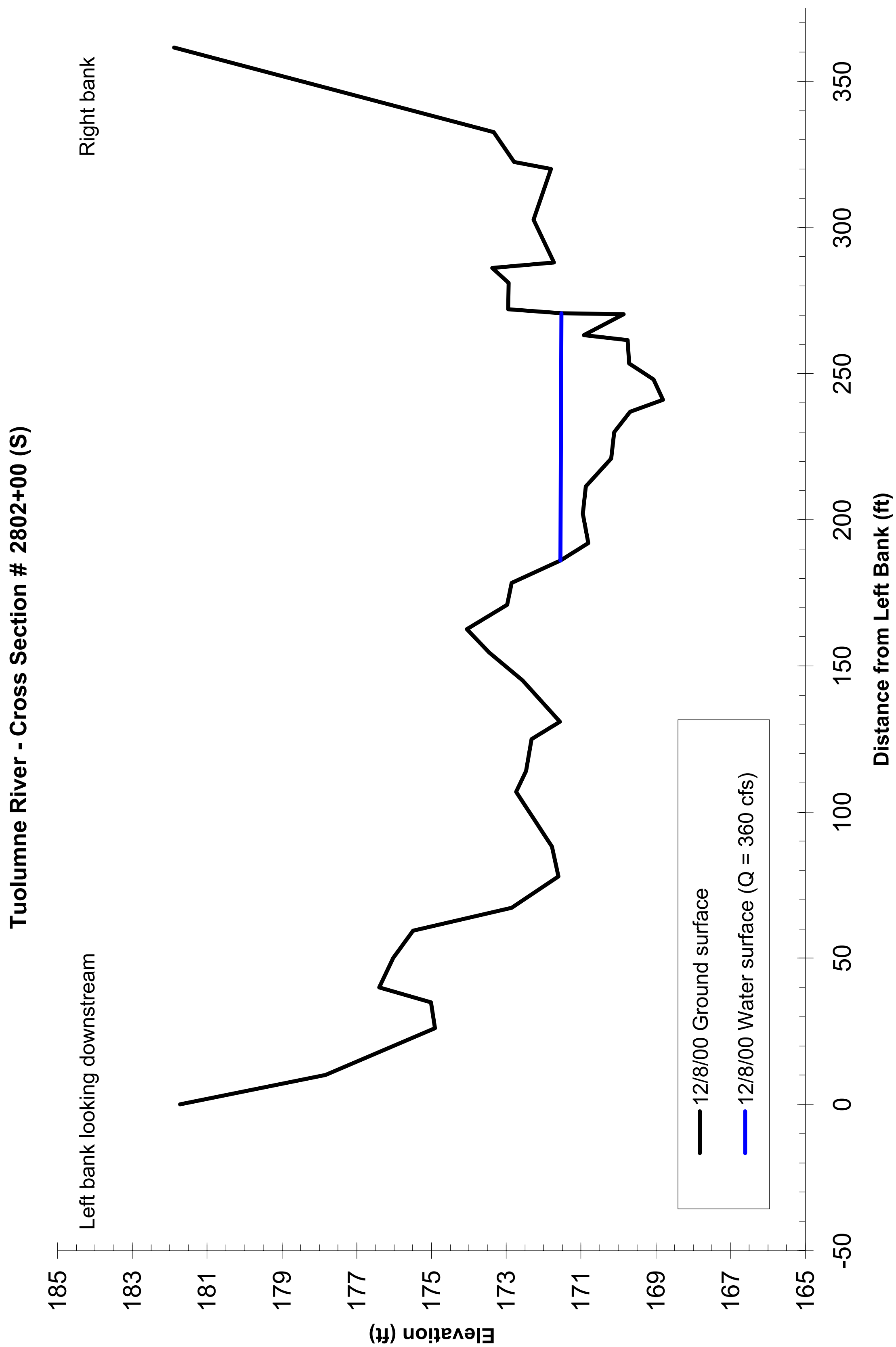

Tuolumne River - Cross Section #2728+00 (K)
Left bank looking downstream
Right bank
12/5/00 Ground surface
12/5/00 Water surface (Q=360cfs)
Elevation (ft)
Distance from Left Bank (ft)
175
173
171
169
167
165
163
161
159
157
155
-50
0
50
100
150
200
250

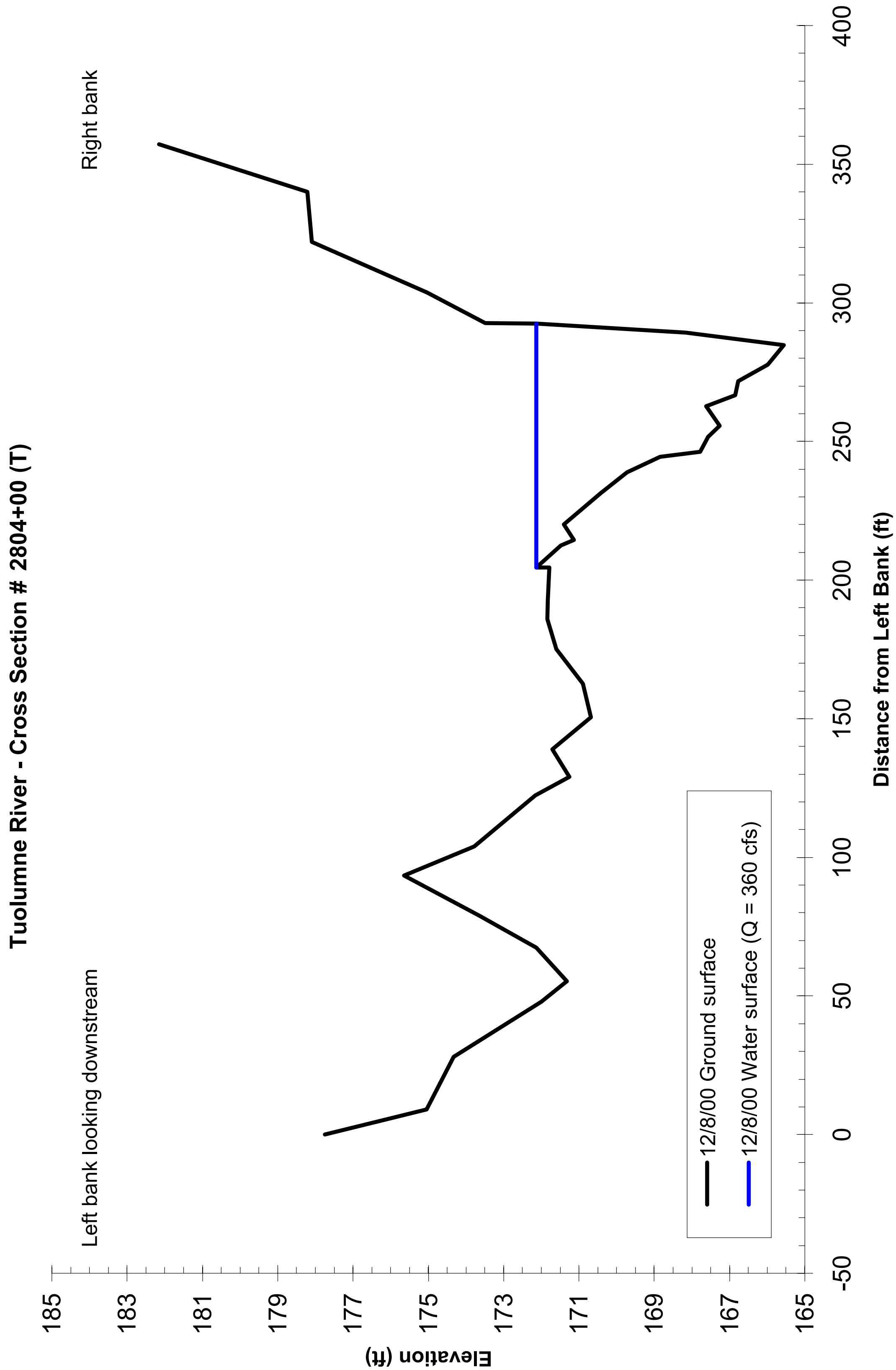

Tuolumne River - Cross Section #2731+00 (L)
Left bank looking downstream
Right bank
12/4/00 Ground surface
12/4/00 Water surface (Q=360cfs)
Elevation (ft)
Distance from Left Bank (ft)
177
175
173
171
169
167
165
163
161
159
157
155
-50
50
150
250
350
450
550
650
750

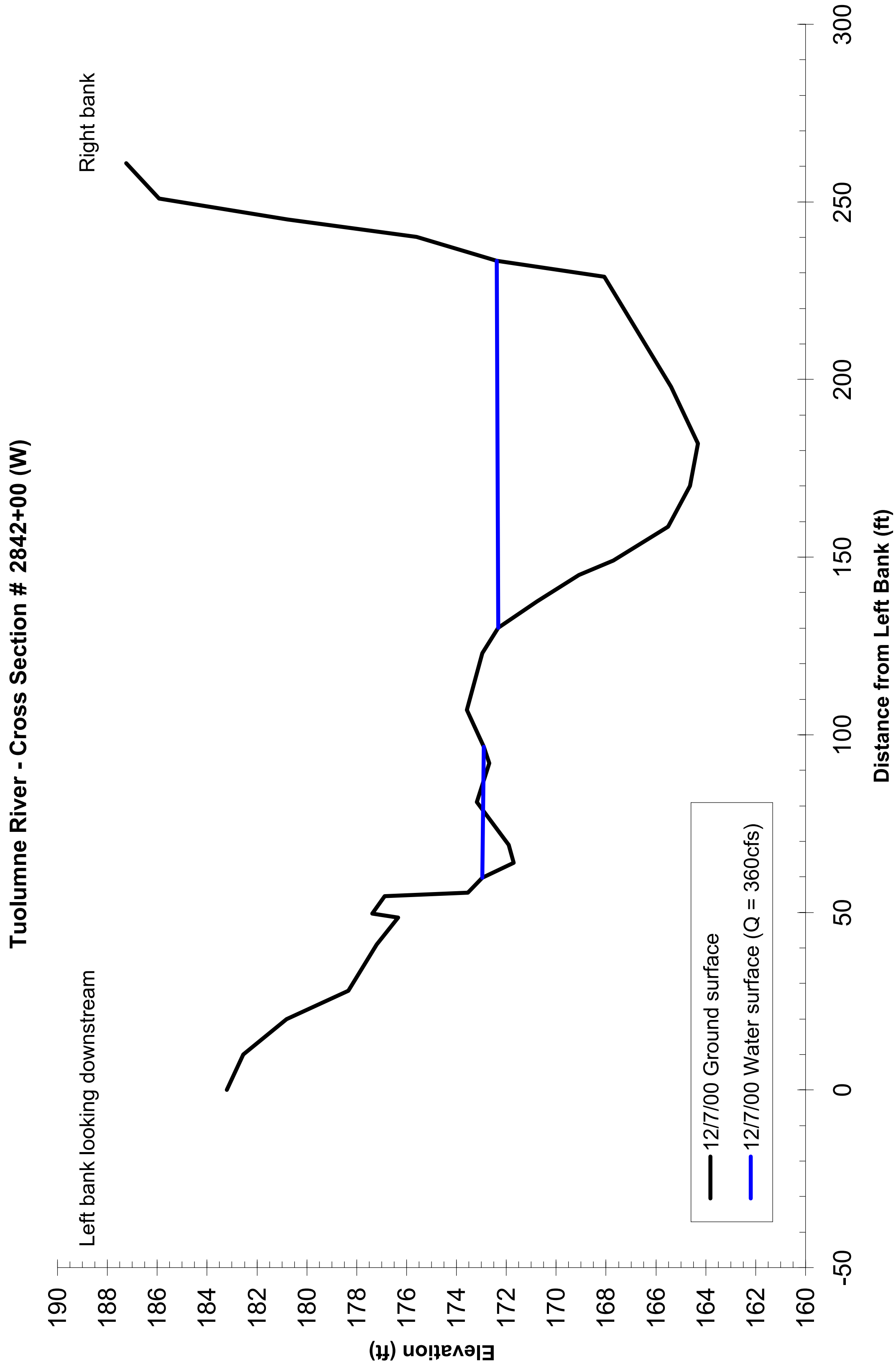

Tuolumne River - Cross Section # 2735+00 (M)
Left bank looking downstream
Right bank
12/5/00 Ground surface
12/5/00 Water surface (Q = 360cfs)
Elevation (ft)
Distance from Left Bank (ft)
180
178
176
174
172
170
168
166
164
162
160
158
156
154
152
150
-50
0
50
100
150
200
250
300
350

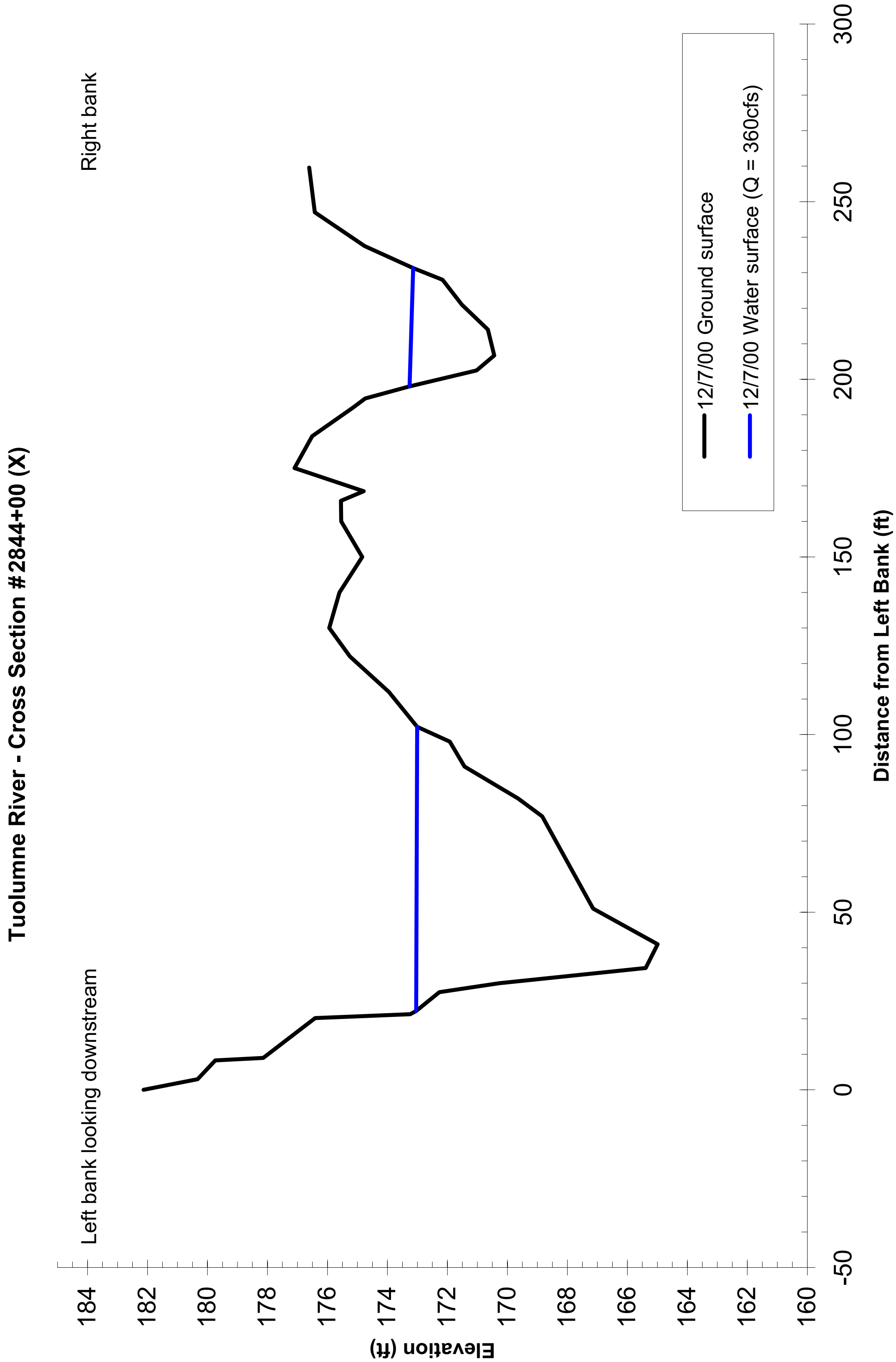

Tuolumne River - Cross Section # 2762+25
Left bank looking downstream
Right bank
Ground Surface: Pulled from total station survey 2-14-02
Water Surface Elevation (Q = 175cfs)
Elevation (ft)
177
175
173
171
169
167
165
163
161
159
157
Distance from Left Bank (ft)
0
50
100
150
200
250

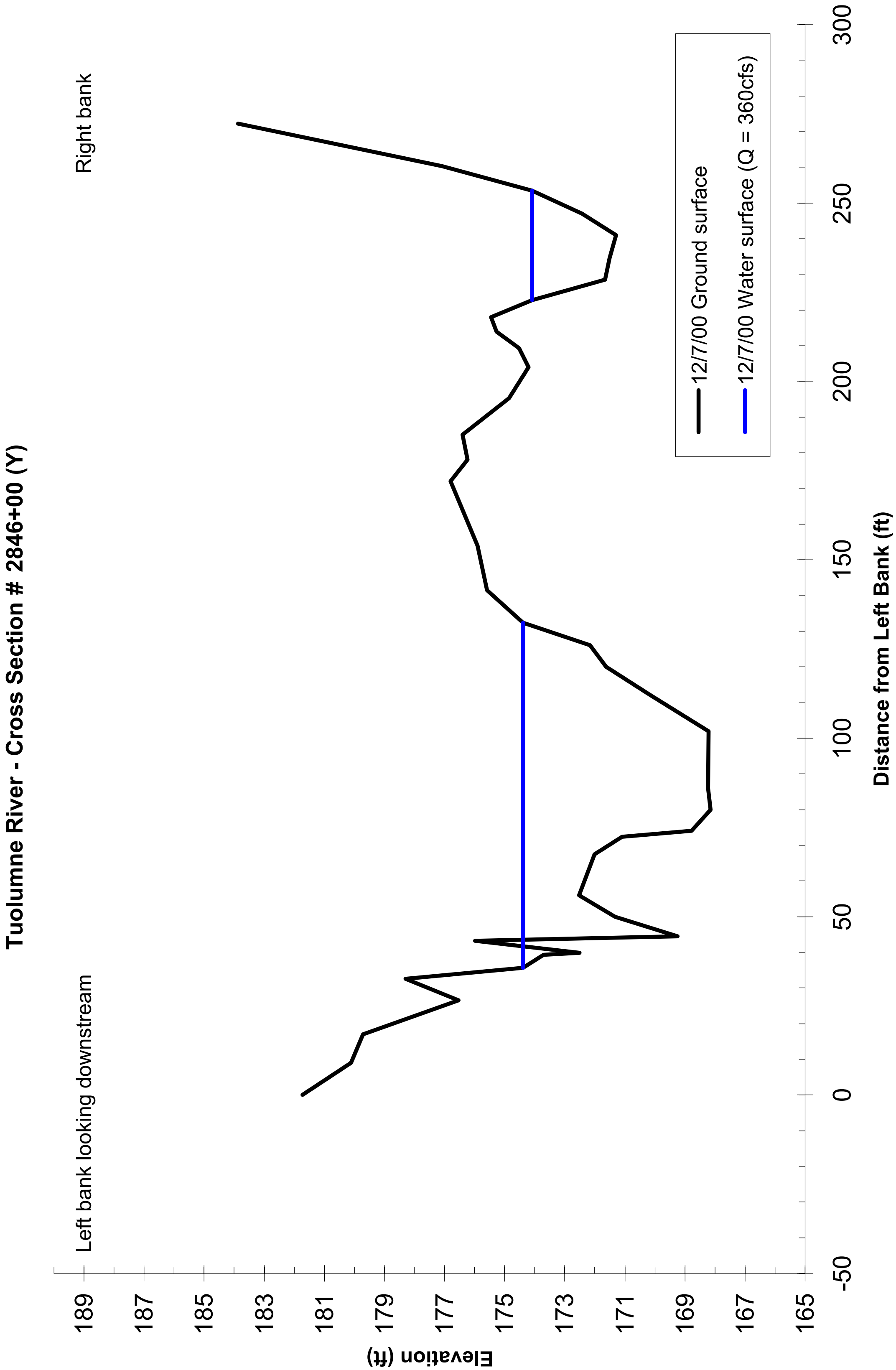

Tuolumne River - Cross Section # 2799+00 (R)
Left bank looking downstream
Right bank
12/8/00 Ground surface
12/8/00 Water surface (Q = 360 cfs)
Elevation (ft)
185
183
181
179
177
175
173
171
169
167
165
Distance from Left Bank (ft)
-50
0
50
100
150
200
250
300
350
400

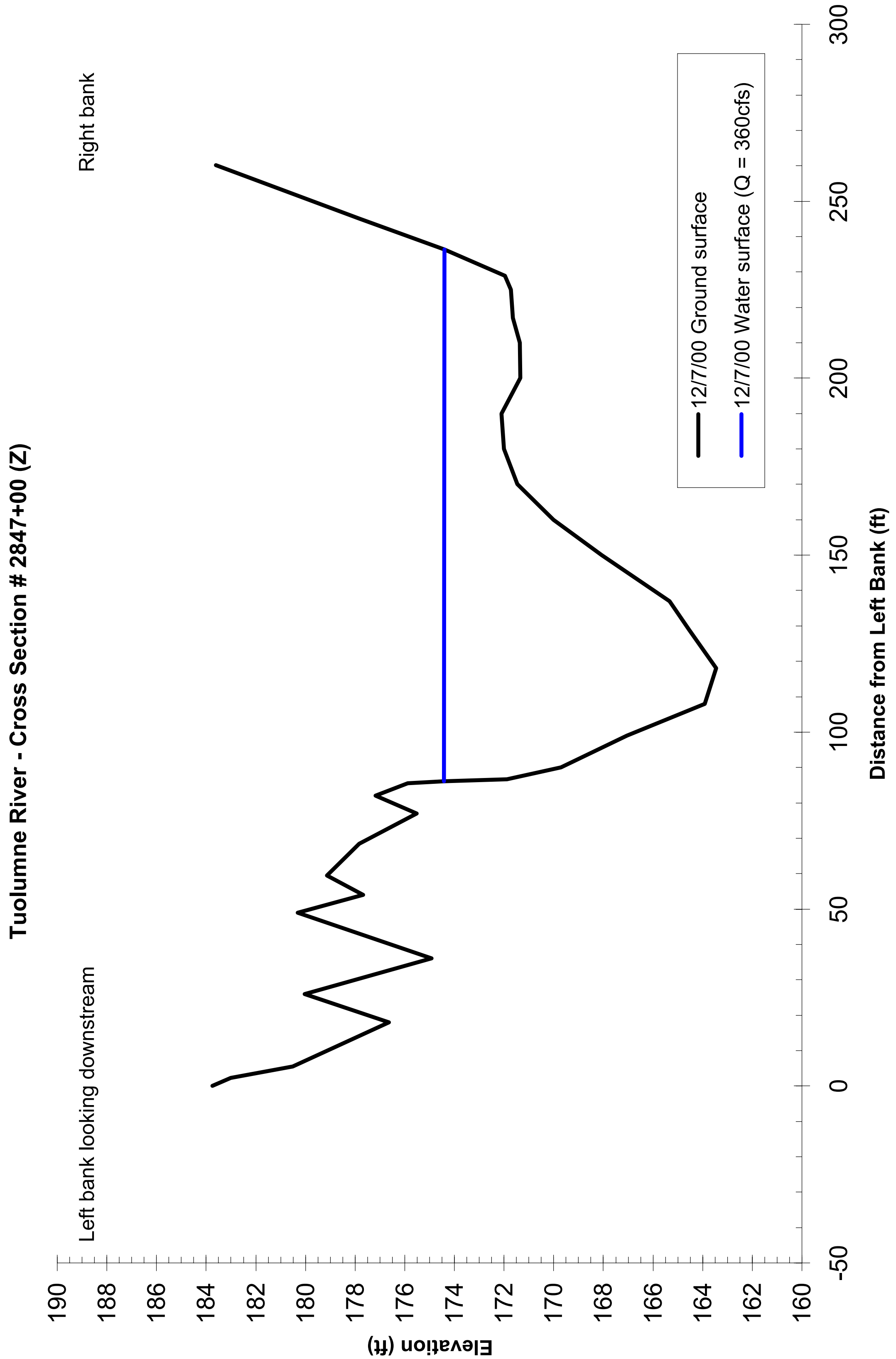

Tuolumne River - Cross Section # 2802+00 (S)
Left bank looking downstream
Right bank
12/8/00 Ground surface
12/8/00 Water surface (Q = 360 cfs)
Elevation (ft)
185
183
181
179
177
175
173
171
169
167
165
Distance from Left Bank (ft)
-50
0
50
100
150
200
250
300
350

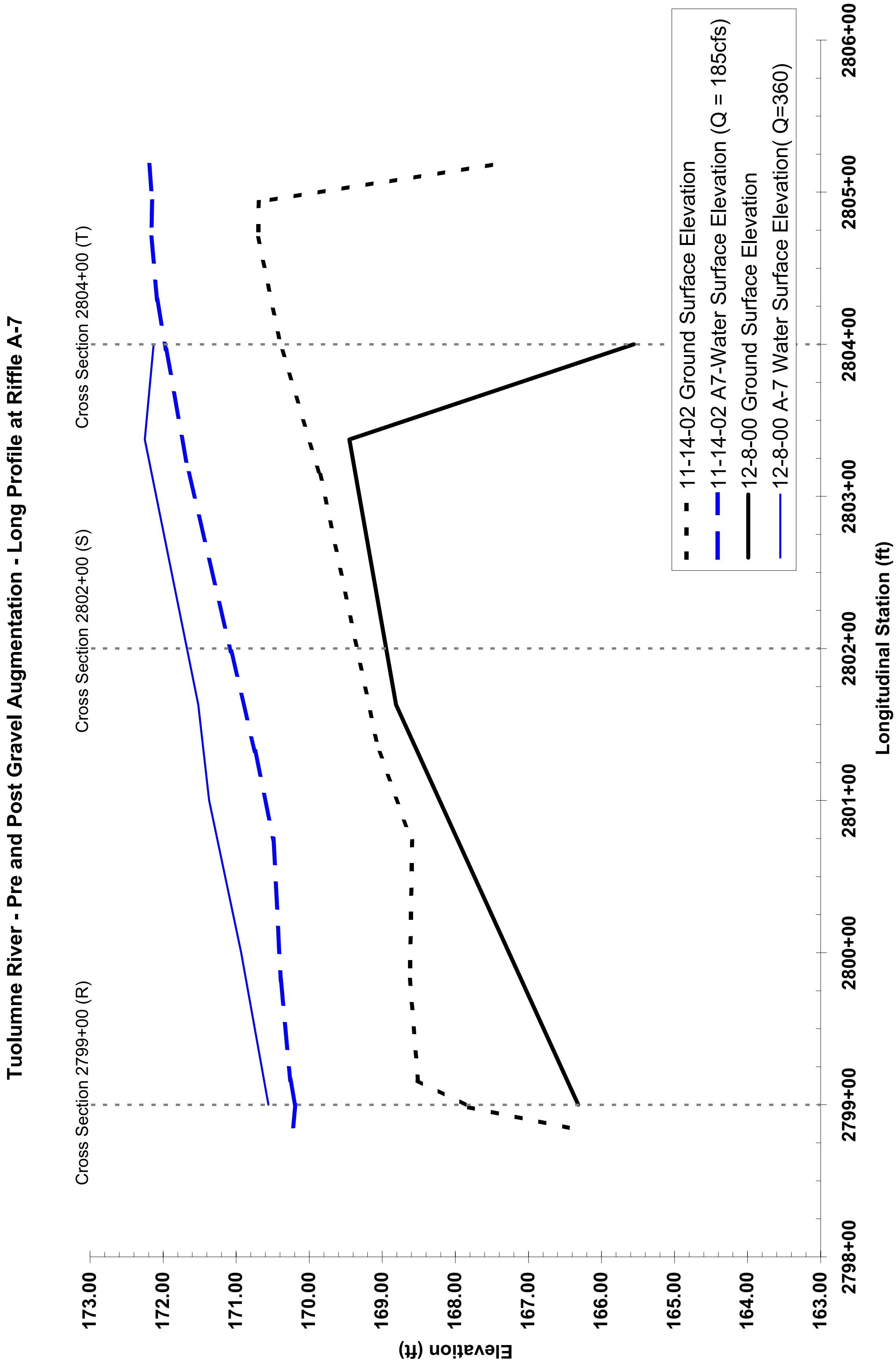

Tuolumne River - Cross Section # 2804+00 (T)
Left bank looking downstream
Right bank
12/8/00 Ground surface
12/8/00 Water surface (Q = 360 cfs)
Elevation (ft)
Distance from Left Bank (ft)
185
183
181
179
177
175
173
171
169
167
165
-50
0
50
100
150
200
250
300
350
400

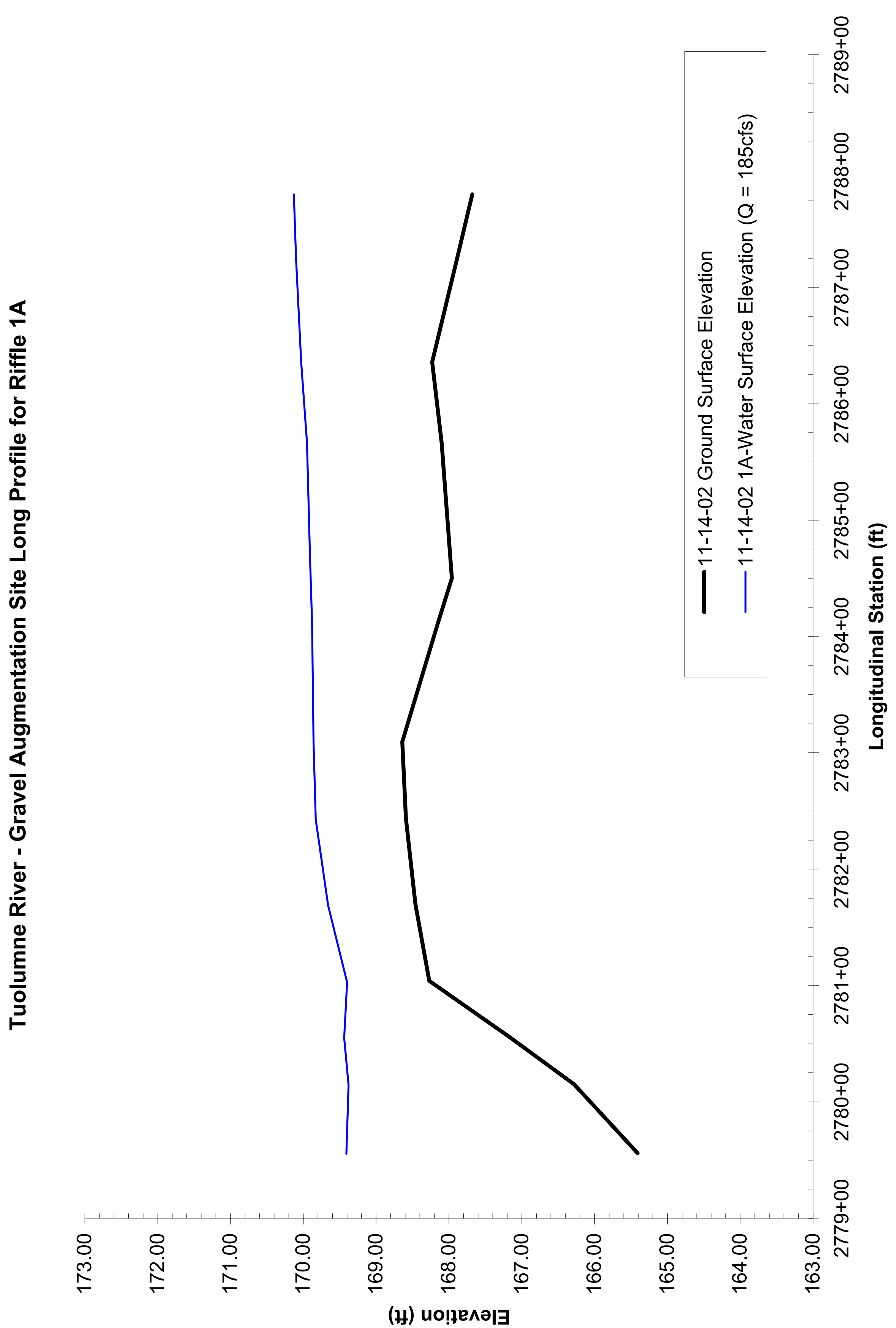

Tuolumne River - Cross Section # 2842+00 (W)
Left bank looking downstream
Right bank
12/7/00 Ground surface
12/7/00 Water surface (Q = 360cfs)
Elevation (ft)
190
188
186
184
182
180
178
176
174
172
170
168
166
164
162
160
Distance from Left Bank (ft)
-50
0
50
100
150
200
250
300

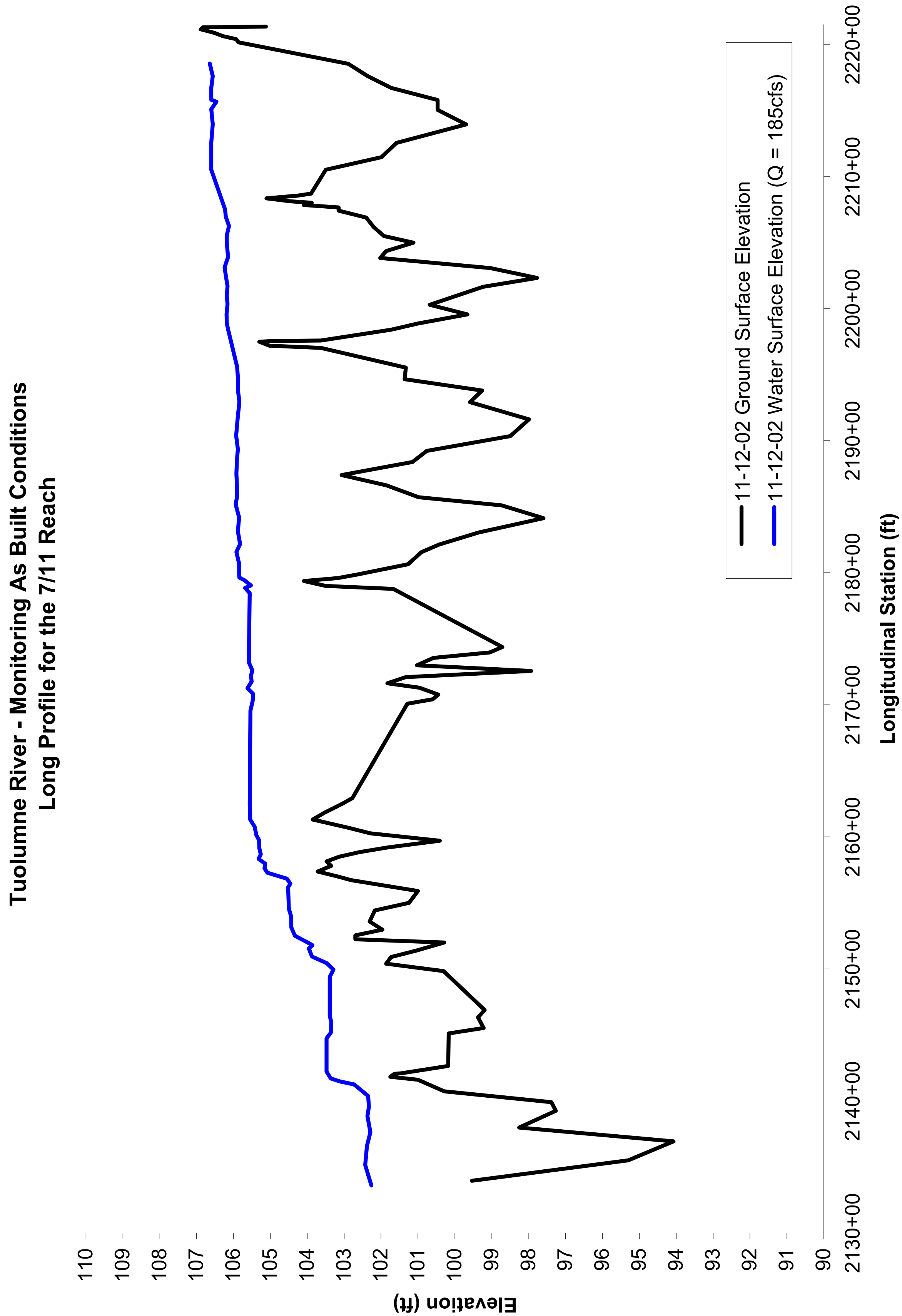

Tuolumne River - Cross Section #2844+00 (X)
Left bank looking downstream
Right bank
12/7/00 Ground surface
12/7/00 Water surface (Q = 360cfs)
Elevation (ft)
Distance from Left Bank (ft)
184
182
180
178
176
174
172
170
168
166
164
162
160
-50
0
50
100
150
200
250
300


Tuolumne River - Cross Section # 2846+00 (Y)
Left bank looking downstream
Right bank
Elevation (ft)
189
187
185
183
181
179
177
175
173
171
169
167
165
Distance from Left Bank (ft)
-50
0
50
100
150
200
250
300
12/7/00 Ground surface
12/7/00 Water surface (Q = 360cfs)


Tuolumne River - Cross Section # 2847+00 (Z)
Left bank looking downstream
Right bank
12/7/00 Ground surface
12/7/00 Water surface (Q = 360cfs)
Distance from Left Bank (ft)
Elevation (ft)
-50
0
50
100
150
200
250
300
160
162
164
166
168
170
172
174
176
178
180
182
184
186
188
190


Tuolumne River - Pre and Post Gravel Augmentation - Long Profile at Riffle A-7
Cross Section 2799+00 (R)
Cross Section 2802+00 (S)
Cross Section 2804+00 (T)
11-14-02 Ground Surface Elevation
11-14-02 A7-Water Surface Elevation (Q = 185cfs)
12-8-00 Ground Surface Elevation
12-8-00 A-7 Water Surface Elevation(Q=360)
Elevation (ft)
173.00
172.00
171.00
170.00
169.00
168.00
167.00
166.00
165.00
164.00
163.00
Longitudinal Station (ft)
2798+00
2799+00
2800+00
2801+00
2802+00
2803+00
2804+00
2805+00
2806+00

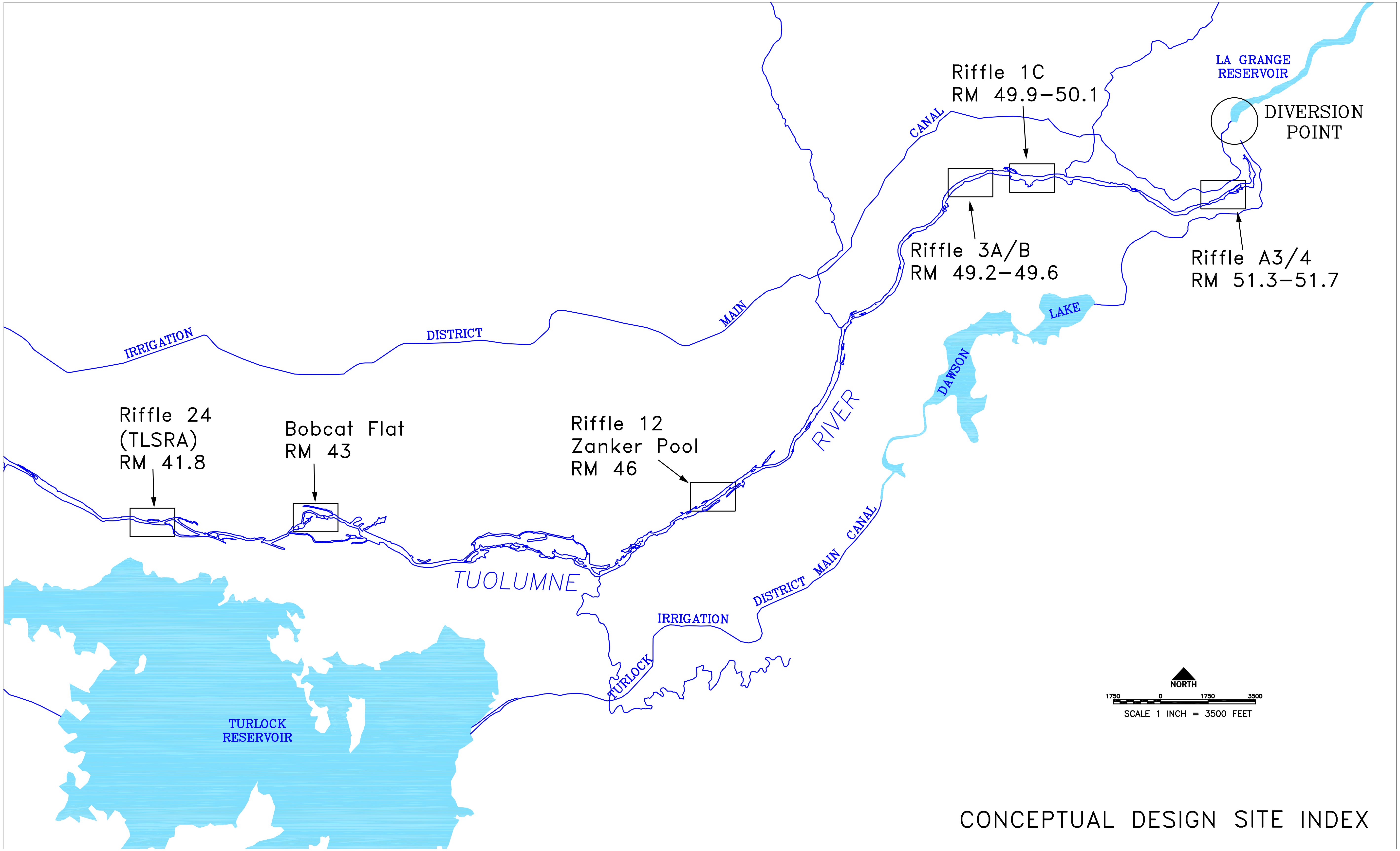

Tuolumne River - Gravel Augmentation Site Long Profile for Riffle 1A
Elevation (ft)
173.00
172.00
171.00
170.00
169.00
168.00
167.00
166.00
165.00
164.00
163.00
2779+00
2780+00
2781+00
2782+00
2783+00
2784+00
2785+00
2786+00
2787+00
2788+00
2789+00
Longitudinal Station (ft)
11-14-02 Ground Surface Elevation
11-14-02 1A-Water Surface Elevation (Q = 185cfs)


Tuolumne River - Monitoring As Built Conditions
Long Profile for the 7/11 Reach
Elevation (ft)
Longitudinal Station (ft)
11-12-02 Ground Surface Elevation
11-12-02 Water Surface Elevation (Q = 185cfs)
90
91
92
93
94
95
96
97
98
99
100
101
102
103
104
105
106
107
108
109
110
2130+00
2140+00
2150+00
2160+00
2170+00
2180+00
2190+00
2200+00
2210+00
2220+00

Appendix B

Conceptual Designs Developed for High Priority Sediment Augmentation Sites.

Riffle A 3/4
Riffle 1C
Riffle 3 A/B
Zanker Site
Bobcat Flat
Turlock Lake State Recreation Area


LA GRANGE RESERVOIR
DIVERSION POINT
Riffle 1C
RM 49.9–50.1
Riffle 3A/B
RM 49.2–49.6
Riffle A3/4
RM 51.3–51.7
CANAL
MAIN
DISTRICT
IRRIGATION
DAWSON
LAKE
RIVER
TUOLUMNE
Riffle 24
(TLSRA)
RM 41.8
Bobcat Flat
RM 43
Riffle 12
Zanker Pool
RM 46
TURLOCK
IRRIGATION
DISTRICT
MAIN
CANAL
TURLOCK RESERVOIR
NORTH
1750 0 1750 3500
SCALE 1 INCH = 3500 FEET
CONCEPTUAL DESIGN SITE INDEX

Coarse Sediment Augmentation Volume Estimates

1) Extend pool tail and riffle between stations 2847+75 and 2846+75.
   Approximate Coarse Sediment 1,600 cu. yds.

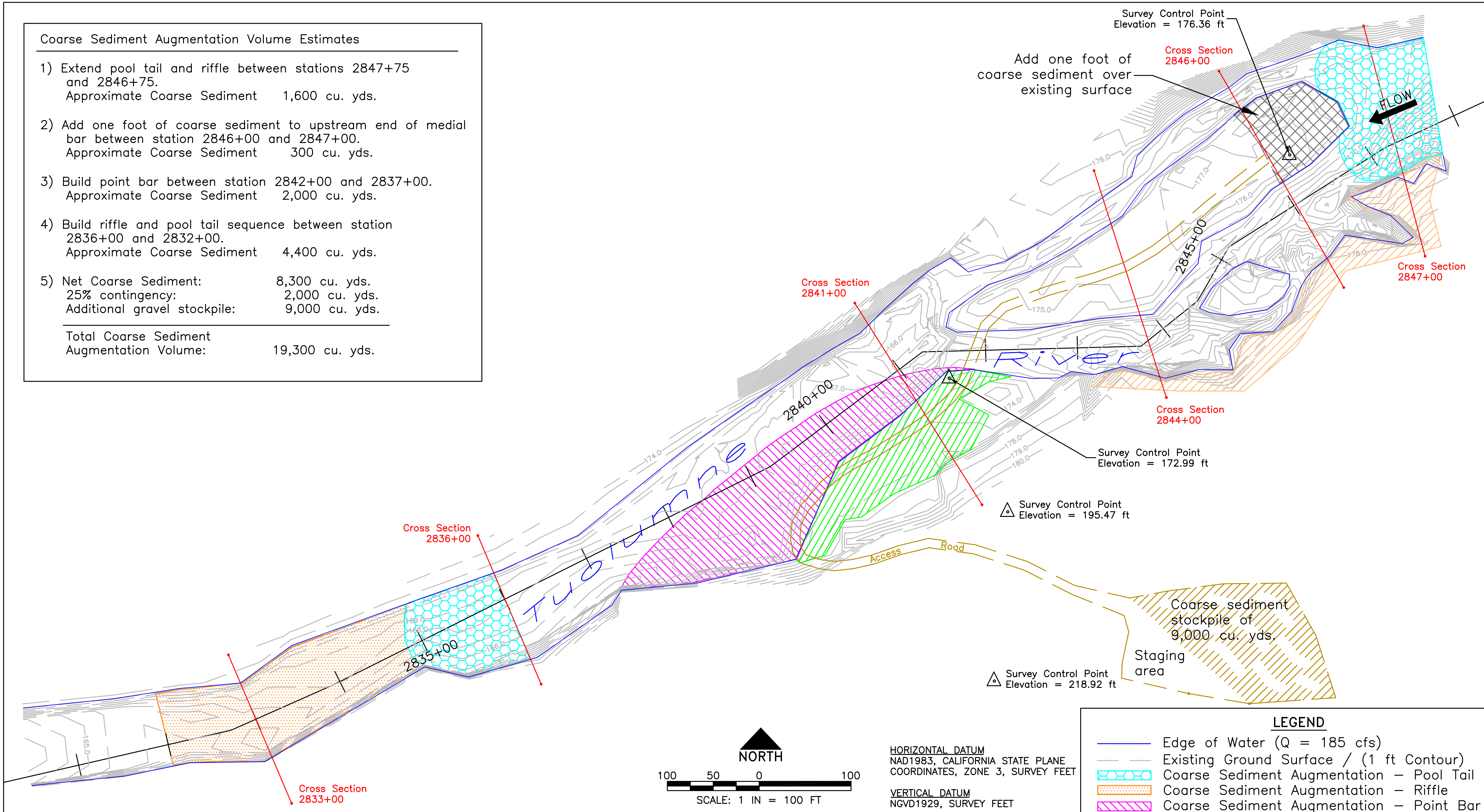
2) Add one foot of coarse sediment to upstream end of medial bar between station 2846+00 and 2847+00.
   Approximate Coarse Sediment 300 cu. yds.

3) Build point bar between station 2842+00 and 2837+00.
   Approximate Coarse Sediment 2,000 cu. yds.

4) Build riffle and pool tail sequence between station 2836+00 and 2832+00.
   Approximate Coarse Sediment 4,400 cu. yds.

5) Net Coarse Sediment: 8,300 cu. yds.
   25% contingency: 2,000 cu. yds.
   Additional gravel stockpile: 9,000 cu. yds.

   Total Coarse Sediment Augmentation Volume: 19,300 cu. yds.



HORIZONTAL DATUM
NAD1983, CALIFORNIA STATE PLANE COORDINATES, ZONE 3, SURVEY FEET

VERTICAL DATUM
NGVD1929, SURVEY FEET

LEGEND

- Edge of Water (Q = 185 cfs)
- Existing Ground Surface / (1 ft Contour)
- Coarse Sediment Augmentation – Pool Tail
- Coarse Sediment Augmentation – Riffle
- Coarse Sediment Augmentation – Point Bar
- Coarse Sediment Recruitment Area
- Grubbing / Vegetation Removal
- Sensitive Area
- Existing Cross Sections
- Longitudinal Stationing
- Access Road

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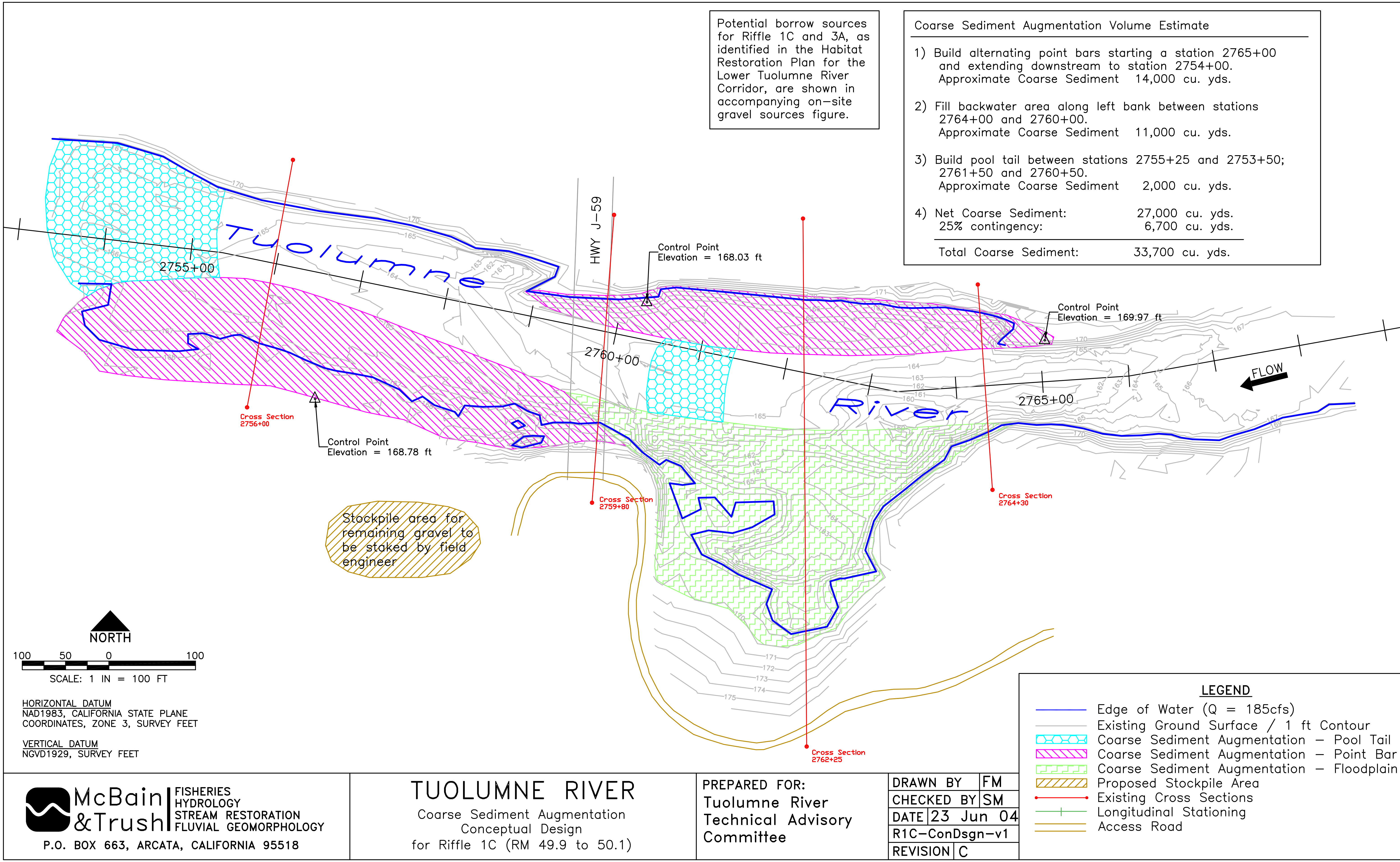
TUOLUMNE RIVER
Coarse Sediment Augmentation Conceptual Design for Riffle A 3/4 (RM 51.3 to 51.7)

PREPARED FOR:
Tuolumne River Technical Advisory Committee

DRAWN BY	FM
CHECKED BY	SM
DATE	23 Jun 04
RA3–4ConDsgn–v1	
REVISION	C


Potential borrow sources for Riffle 1C and 3A, as identified in the Habitat Restoration Plan for the Lower Tuolumne River Corridor, are shown in accompanying on-site gravel sources figure.
Coarse Sediment Augmentation Volume Estimate
1) Build alternating point bars starting a station 2765+00 and extending downstream to station 2754+00.
Approximate Coarse Sediment 14,000 cu. yds.
2) Fill backwater area along left bank between stations 2764+00 and 2760+00.
Approximate Coarse Sediment 11,000 cu. yds.
3) Build pool tail between stations 2755+25 and 2753+50; 2761+50 and 2760+50.
Approximate Coarse Sediment 2,000 cu. yds.
4) Net Coarse Sediment: 27,000 cu. yds.
25% contingency: 6,700 cu. yds.
Total Coarse Sediment: 33,700 cu. yds.
Tuolumne
River
HWY J-59
2755+00
2760+00
2765+00
FLOW
Control Point Elevation = 168.03 ft
Control Point Elevation = 169.97 ft
Control Point Elevation = 168.78 ft
Cross Section 2756+00
Cross Section 2759+80
Cross Section 2764+30
Cross Section 2762+25
Stockpile area for remaining gravel to be staked by field engineer
NORTH
100 50 0 100
SCALE: 1 IN = 100 FT
HORIZONTAL DATUM
NAD1983, CALIFORNIA STATE PLANE COORDINATES, ZONE 3, SURVEY FEET
VERTICAL DATUM
NGVD1929, SURVEY FEET
LEGEND
Edge of Water (Q = 185cfs)
Existing Ground Surface / 1 ft Contour
Coarse Sediment Augmentation – Pool Tail
Coarse Sediment Augmentation – Point Bar
Coarse Sediment Augmentation – Floodplain
Proposed Stockpile Area
Existing Cross Sections
Longitudinal Stationing
Access Road
McBain & Trush
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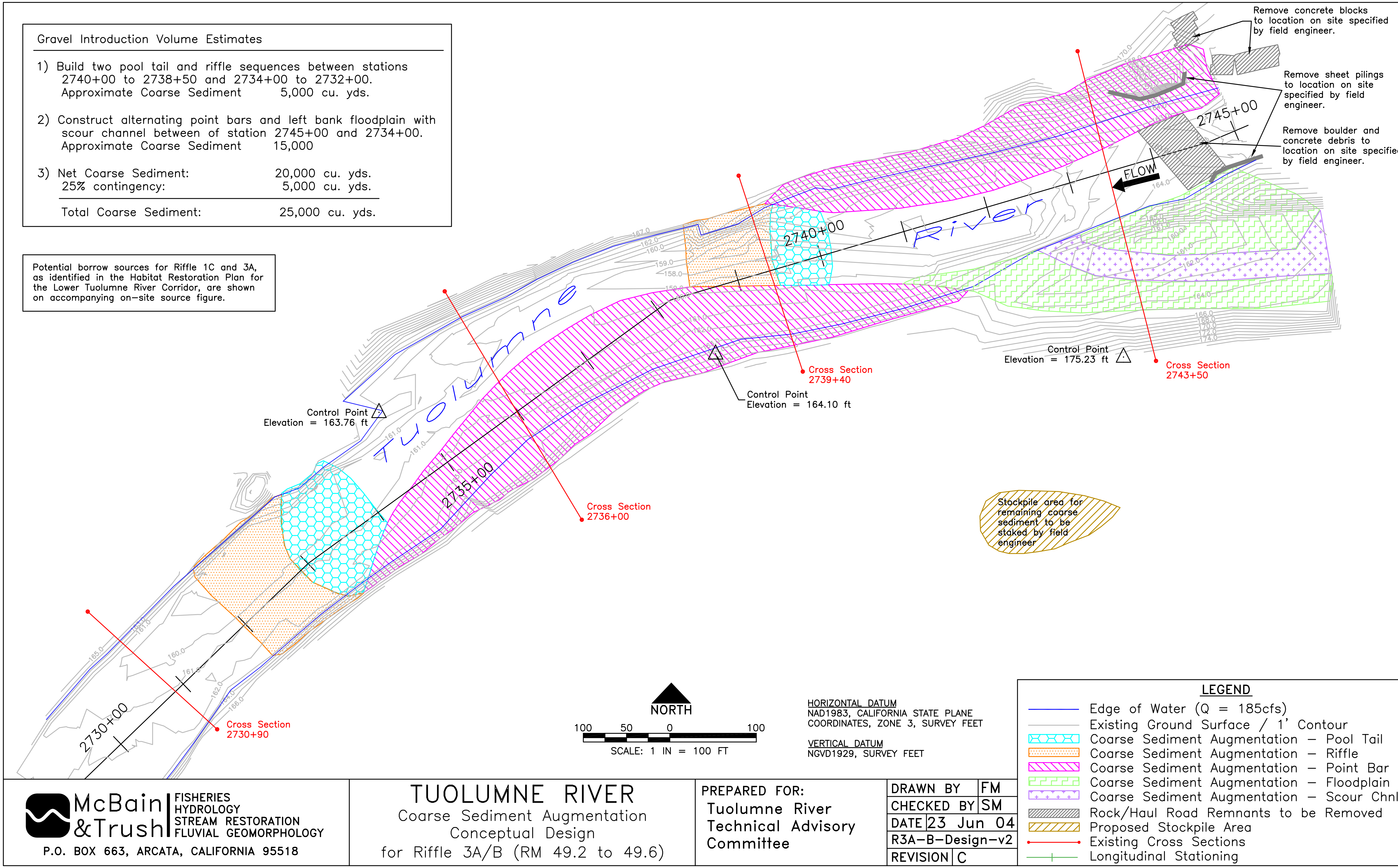
TUOLUMNE RIVER
Coarse Sediment Augmentation Conceptual Design for Riffle 1C (RM 49.9 to 50.1)
PREPARED FOR:
Tuolumne River Technical Advisory Committee
DRAWN BY FM
CHECKED BY SM
DATE 23 Jun 04
R1C-ConDsgn-v1
REVISION C


Gravel Introduction Volume Estimates
1) Build two pool tail and riffle sequences between stations 2740+00 to 2738+50 and 2734+00 to 2732+00.
Approximate Coarse Sediment 5,000 cu. yds.
2) Construct alternating point bars and left bank floodplain with scour channel between of station 2745+00 and 2734+00.
Approximate Coarse Sediment 15,000
3) Net Coarse Sediment: 20,000 cu. yds.
25% contingency: 5,000 cu. yds.
Total Coarse Sediment: 25,000 cu. yds.
Potential borrow sources for Riffle 1C and 3A, as identified in the Habitat Restoration Plan for the Lower Tuolumne River Corridor, are shown on accompanying on-site source figure.
Remove concrete blocks to location on site specified by field engineer.
Remove sheet pilings to location on site specified by field engineer.
Remove boulder and concrete debris to location on site specified by field engineer.
FLOW
Tuolumne River
2730+00
2735+00
2740+00
2745+00
Control Point Elevation = 163.76 ft
Control Point Elevation = 164.10 ft
Control Point Elevation = 175.23 ft
Cross Section 2730+90
Cross Section 2736+00
Cross Section 2739+40
Cross Section 2743+50
Stockpile area for remaining coarse sediment to be staked by field engineer
NORTH
100 50 0 100
SCALE: 1 IN = 100 FT
HORIZONTAL DATUM
NAD1983, CALIFORNIA STATE PLANE COORDINATES, ZONE 3, SURVEY FEET
VERTICAL DATUM
NGVD1929, SURVEY FEET
LEGEND
Edge of Water (Q = 185cfs)
Existing Ground Surface / 1' Contour
Coarse Sediment Augmentation – Pool Tail
Coarse Sediment Augmentation – Riffle
Coarse Sediment Augmentation – Point Bar
Coarse Sediment Augmentation – Floodplain
Coarse Sediment Augmentation – Scour Chnl.
Rock/Haul Road Remnants to be Removed
Proposed Stockpile Area
Existing Cross Sections
Longitudinal Stationing
McBain & Trush
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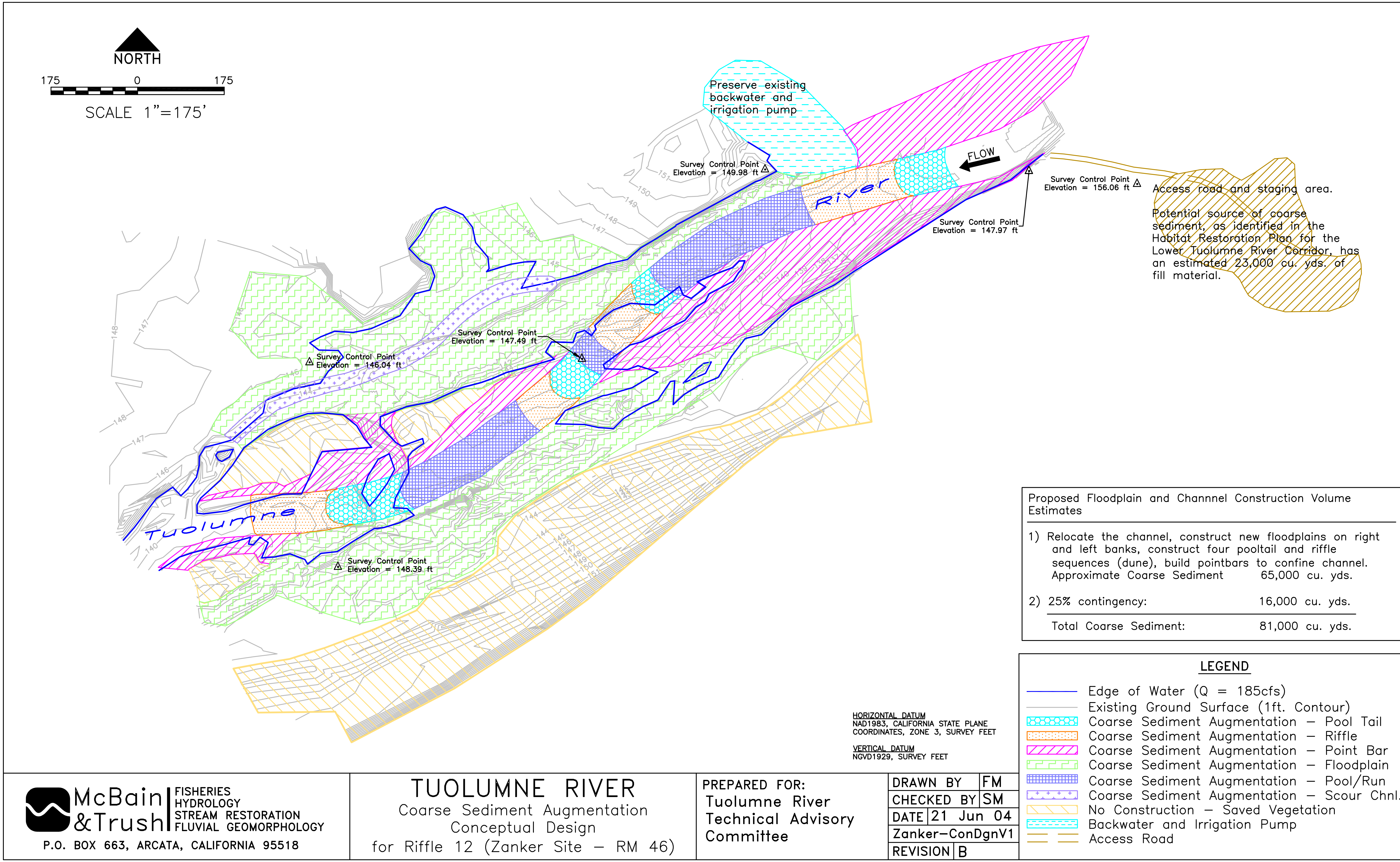
P.O. BOX 663, ARCATA, CALIFORNIA 95518
TUOLUMNE RIVER
Coarse Sediment Augmentation
Conceptual Design
for Riffle 3A/B (RM 49.2 to 49.6)
PREPARED FOR:
Tuolumne River
Technical Advisory
Committee
DRAWN BY FM
CHECKED BY SM
DATE 23 Jun 04
R3A-B-Design-v2
REVISION C


NORTH
175 0 175
SCALE 1"=175'
Preserve existing backwater and irrigation pump
FLOW
Tuolumne River
Survey Control Point Elevation = 149.98 ft
Survey Control Point Elevation = 156.06 ft
Survey Control Point Elevation = 147.97 ft
Survey Control Point Elevation = 147.49 ft
Survey Control Point Elevation = 146.04 ft
Survey Control Point Elevation = 148.39 ft
Access road and staging area.
Potential source of coarse sediment, as identified in the Habitat Restoration Plan for the Lower Tuolumne River Corridor, has an estimated 23,000 cu. yds. of fill material.
Proposed Floodplain and Channel Construction Volume Estimates
1) Relocate the channel, construct new floodplains on right and left banks, construct four pooltail and riffle sequences (dune), build pointbars to confine channel.
Approximate Coarse Sediment 65,000 cu. yds.
2) 25% contingency: 16,000 cu. yds.
Total Coarse Sediment: 81,000 cu. yds.
HORIZONTAL DATUM
NAD1983, CALIFORNIA STATE PLANE COORDINATES, ZONE 3, SURVEY FEET
VERTICAL DATUM
NGVD1929, SURVEY FEET
LEGEND
Edge of Water (Q = 185cfs)
Existing Ground Surface (1ft. Contour)
Coarse Sediment Augmentation – Pool Tail
Coarse Sediment Augmentation – Riffle
Coarse Sediment Augmentation – Point Bar
Coarse Sediment Augmentation – Floodplain
Coarse Sediment Augmentation – Pool/Run
Coarse Sediment Augmentation – Scour Chnl.
No Construction – Saved Vegetation
Backwater and Irrigation Pump
Access Road
McBain &Trush
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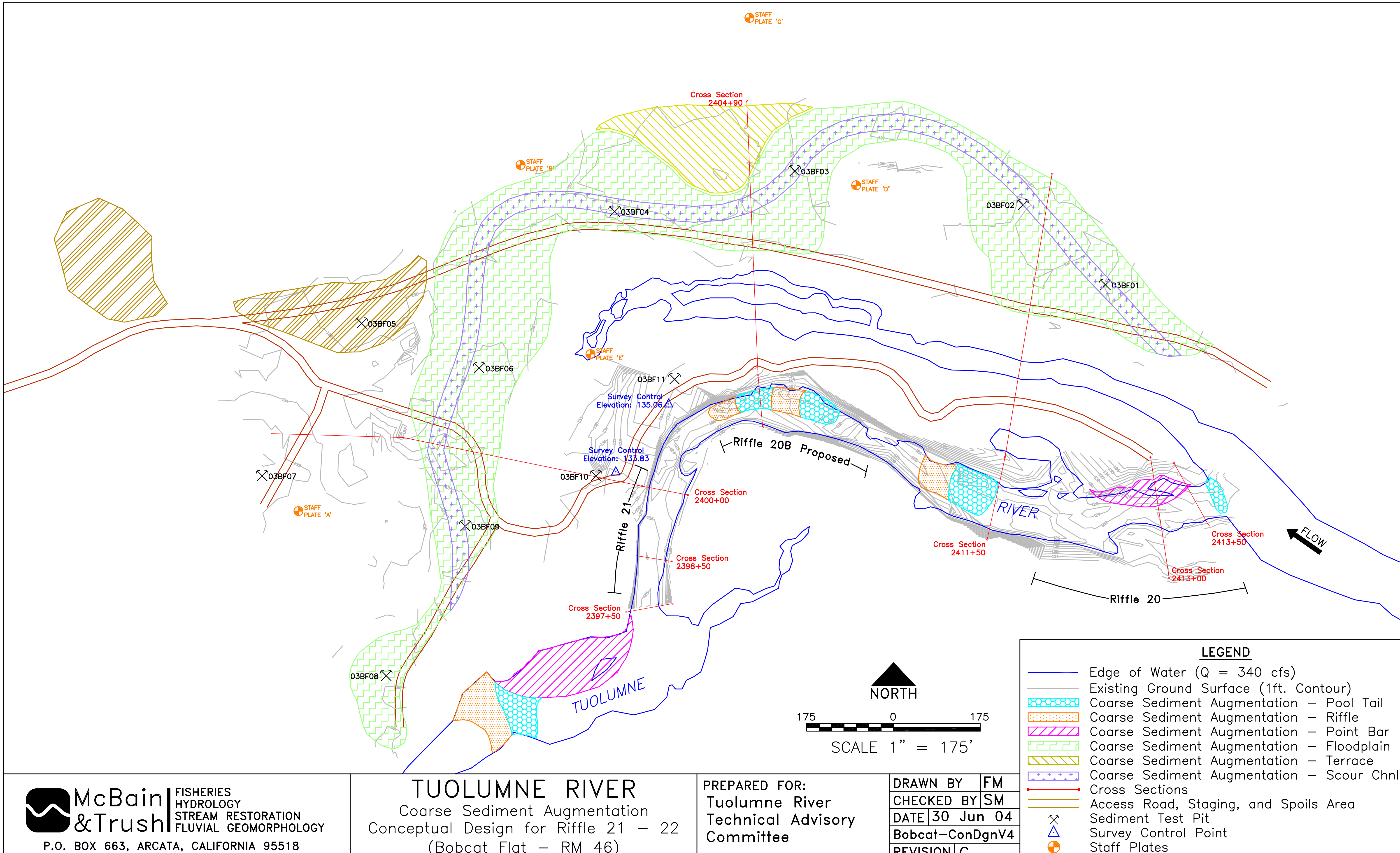
P.O. BOX 663, ARCATA, CALIFORNIA 95518
TUOLUMNE RIVER
Coarse Sediment Augmentation Conceptual Design for Riffle 12 (Zanker Site – RM 46)
PREPARED FOR:
Tuolumne River Technical Advisory Committee
DRAWN BY FM
CHECKED BY SM
DATE 21 Jun 04
Zanker–ConDgnV1
REVISION B


STAFF PLATE 'C'
STAFF PLATE 'B'
STAFF PLATE 'D'
STAFF PLATE 'E'
STAFF PLATE 'A'
Cross Section 2404+90
Cross Section 2400+00
Cross Section 2398+50
Cross Section 2397+50
Cross Section 2411+50
Cross Section 2413+50
Cross Section 2413+00
03BF01
03BF02
03BF03
03BFC4
03BF05
03BF06
03BF07
03BF08
03BF09
03BF10
03BF11
Survey Control Elevation: 135.06
Survey Control Elevation: 133.83
Riffle 20B Proposed
Riffle 21
Riffle 20
RIVER
TUOLUMNE
FLOW
NORTH
175 0 175
SCALE 1" = 175'
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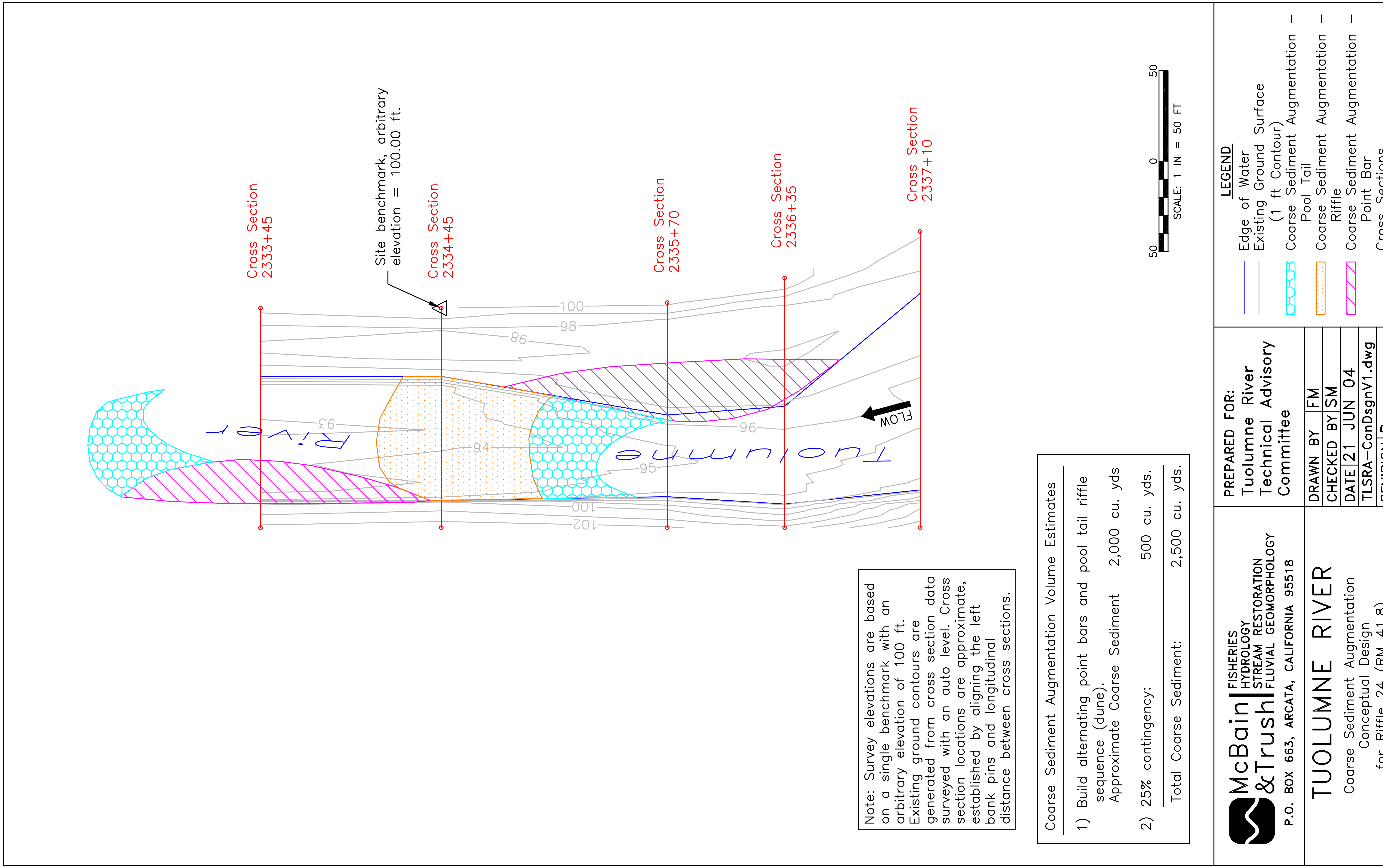
TUOLUMNE RIVER
Coarse Sediment Augmentation
Conceptual Design for Riffle 21 – 22
(Bobcat Flat – RM 46)
PREPARED FOR:
Tuolumne River
Technical Advisory
Committee
DRAWN BY FM
CHECKED BY SM
DATE 30 Jun 04
Bobcat–ConDgnV4
REVISION C
LEGEND
Edge of Water (Q = 340 cfs)
Existing Ground Surface (1ft. Contour)
Coarse Sediment Augmentation – Pool Tail
Coarse Sediment Augmentation – Riffle
Coarse Sediment Augmentation – Point Bar
Coarse Sediment Augmentation – Floodplain
Coarse Sediment Augmentation – Terrace
Coarse Sediment Augmentation – Scour Chnl.
Cross Sections
Access Road, Staging, and Spoils Area
Sediment Test Pit
Survey Control Point
Staff Plates


Cross Section 2333+45
Site benchmark, arbitrary elevation = 100.00 ft.
Cross Section 2334+45
Cross Section 2335+70
Cross Section 2336+35
Cross Section 2337+10
100
98
98
96
95
94
93
100
102
FLOW
Tuolumne
River
50 0 50
SCALE: 1 IN = 50 FT
LEGEND
Edge of Water
Existing Ground Surface (1 ft Contour)
Coarse Sediment Augmentation – Pool Tail
Coarse Sediment Augmentation – Riffle
Coarse Sediment Augmentation – Point Bar
Cross Sections
Note: Survey elevations are based on a single benchmark with an arbitrary elevation of 100 ft. Existing ground contours are generated from cross section data surveyed with an auto level. Cross section locations are approximate, established by aligning the left bank pins and longitudinal distance between cross sections.
Coarse Sediment Augmentation Volume Estimates
1) Build alternating point bars and pool tail riffle sequence (dune). Approximate Coarse Sediment 2,000 cu. yds
2) 25% contingency: 500 cu. yds.
Total Coarse Sediment: 2,500 cu. yds.
PREPARED FOR: Tuolumne River Technical Advisory Committee
DRAWN BY FM
CHECKED BY SM
DATE 21 JUN 04
TLSRA-ConDsgnV1.dwg
REVISION B
McBain & Trush
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P.O. BOX 663, ARCATA, CALIFORNIA 95518
TUOLUMNE RIVER
Coarse Sediment Augmentation Conceptual Design for Riffle 24 (RM 41.8)

Appendix C

Reach-Scale Bedload Transport Model Results on the Tuolumne River Downstream Riffle 4B - Stillwater Sciences Technical Memorandum

Stillwater Sciences

2532 Durant Avenue, Suite 201 Berkeley, CA 94704 Phone (510) 848-8098 Fax (510) 848-8398

TECHNICAL MEMORANDUM

DATE: July 10, 2001

TO: McBain & Trush

FROM: Yantao Cui and Noah Hume

SUBJECT: Reach-Scale Bedload Transport Model Results on the Tuolumne River Downstream Riffle 4B

INTRODUCTION

As a component of McBain & Trush's coarse sediment management plan being developed for the Tuolumne River Technical Advisory Committee (TRTAC), Stillwater Sciences integrated recent survey and bedload transport data into the *EASI* (Enhanced Acronym Series 1 & 2 with Interface) sediment transport model to assess gravel transport at the Tuolumne River downstream of Riffle 4B. The objective of this task is to understand the gravel transport rate through the system and to guide the ongoing and future gravel introduction projects in the reach. This report summarizes the results of modeling and sensitivity tests performed to provide information on planned gravel augmentation projects in the Tuolumne River.

The *EASI* sediment transport model is the implementation of the surface-based bedload transport equation of Parker (1990a, b) modified to apply to natural gravel-bedded rivers. The model calculates gravel transport capacity for a given cross section, friction slope, water discharge, and surface or bedload grain size distribution. The model also calculates normalized Shields stress, which provides an estimate of bed mobility threshold. The gravel transport capacity is the maximum possible gravel transport rate in a reach in the case of unlimited gravel supply. In a supply-limited case, the actual gravel transport rate in the river reach is smaller than the model-calculated gravel transport capacity. If the channel is not supply-limited, the sediment transport rate in the reach is equal to transport capacity. Whether the channel is supply-limited is best assessed by field observations.

METHODS

Prior to the current modeling effort, the most recent version of *EASI* model (Version 4.2) allowed for the delineation of the cross section into a main channel and a floodplain. Gravel transport was assumed to occur only in the main channel and the floodplain was assumed to function only as flood passage during high flow events. During the current modeling exercise, it became necessary to update the model so that it could accommodate both left and right bank floodplains in addition to the main channel. The current model is Version 4.3.

The relevant data provided by McBain & Trush are as follows:

- Eight cross sections given in river-feet upstream of the confluence with the San Joaquin River: XS-2670+00, XS-2672+00, XS 2674+00, XS-2685+00, XS-2690+00, XS-2699+00, XS-2702+00 and XS-2705+00.
- Thalweg profile in a 5,500-ft reach downstream of the Old Basso Bridge between 2585+00 and 2640+00; water surface profile at various discharges in the same reach; and water surface profile between 2647+40 and 2760+00 at 5,400 cfs discharge.
- Pebble counts at cross sections XS-2670+00, XS-2690+00, XS-2699+00 and a cross section further upstream.
- Bedload measurement at Riffle 4B (XS 2690+00) on March 19 and March 20, 2000 with estimated discharges of 4,020 cfs, 4,960 cfs, 5,980 cfs and 6,700 cfs.

One of the necessary parameters of the model is the friction slope of the modeled reach, which was approximated by the water surface slope calculated from the 1996 water surface survey data supplied. Other necessary information for running the model includes the discharge record from water year (WY) 1971 to WY 1999 from the USGS gauge Tuolumne River below La Grange Dam near La Grange (11289650).

During the modeling exercises, the Stillwater Sciences performed a reconnaissance field trip to the model reach. Field observations indicated that the reach is typical pool-riffle morphology void of bedrock outcrops and large boulder pavements. It was judged that sediment transport in this reach is at capacity. The floodplain was characterized with a Manning's n value of 0.07 based on the observation that the edge of the main channel is lined with medium-sized trees.

RESULTS

EASI Model Results: Results of the model runs are presented in the attached MS-Excel files. Because the *EASI* model is a reach-scale gravel transport model, its application requires the selection of a typical cross section to represent the reach. In order to test the sensitivity of the model results to selection of a representative cross section, all the cross sections provided by McBain & Trush except those at the upstream end (XS-2705+00) and downstream end (XS-2670+00) of the reach were used in the simulation. The main channel portion of each cross section is shown in Figure 1.

The water surface survey data between 2761+75 and 2872+60 at 5,400 cfs discharge (Figure 2) provided by McBain & Trush were used to estimate water surface slope and a value of 0.0014 was obtained for input in the calculation.

The surface grain size distributions from the four pebble-counts were all within a relatively narrow band as shown in Figure 3. The representative of the four sets of data used for model input was the average of the maximum and minimum cumulative percent finer values of the given grain sizes. This representative grain size distribution is also shown in Figure 3.

Daily average discharge from USGS gauge Tuolumne River below La Grange Dam near La Grange (11289650) from WY 1971 to WY 1999 (post-New Don Pedro Reservoir period) were used to calculate the long-term flow duration curve. The duration curve, shown in Figure 4, was used in the model to calculate long-term average annual gravel transport rate.

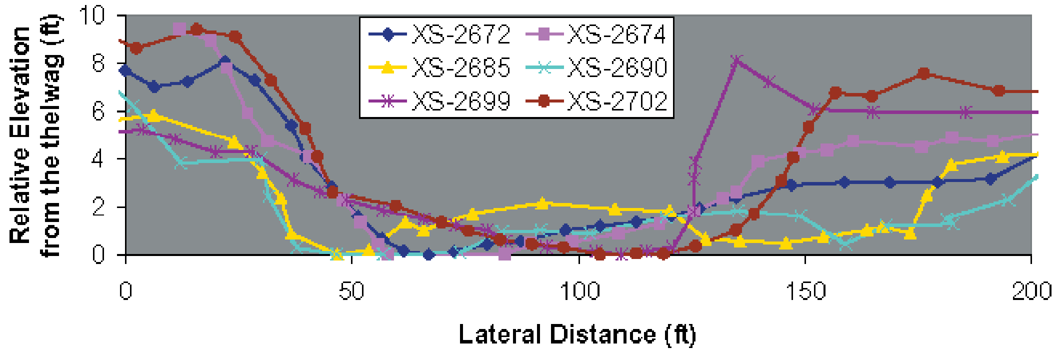


Figure 1. Cross sections in the modeling reach

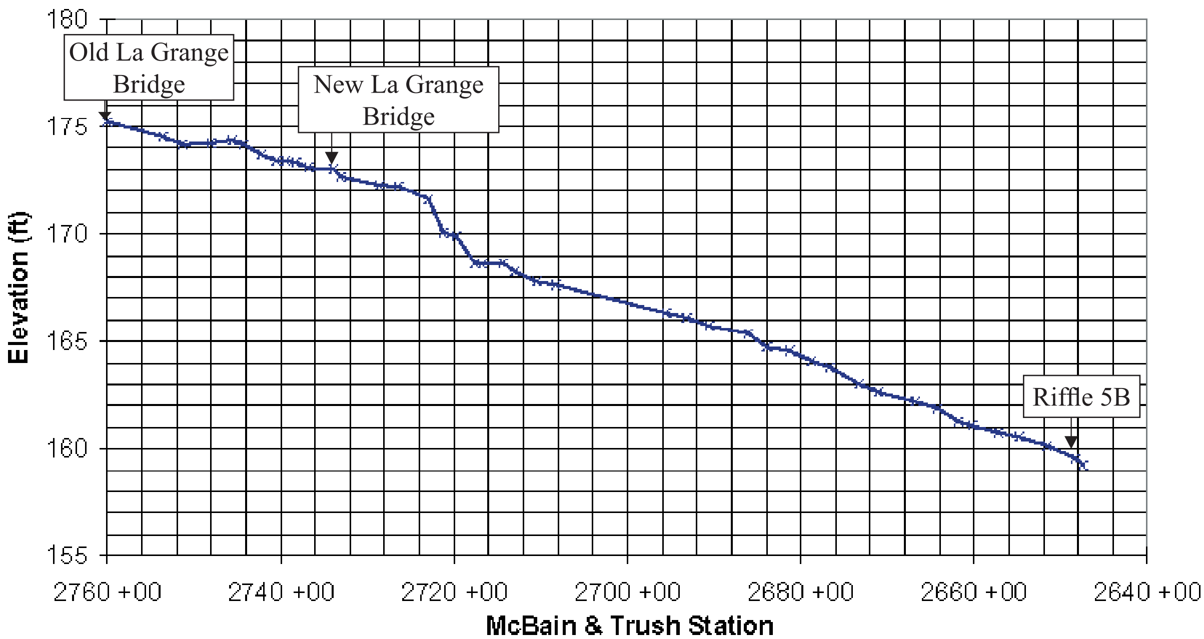


Figure 2. Tuolumne River water surface profile surveyed at a discharge of 5,400 cfs on March 26, 1996 by McBain & Trush

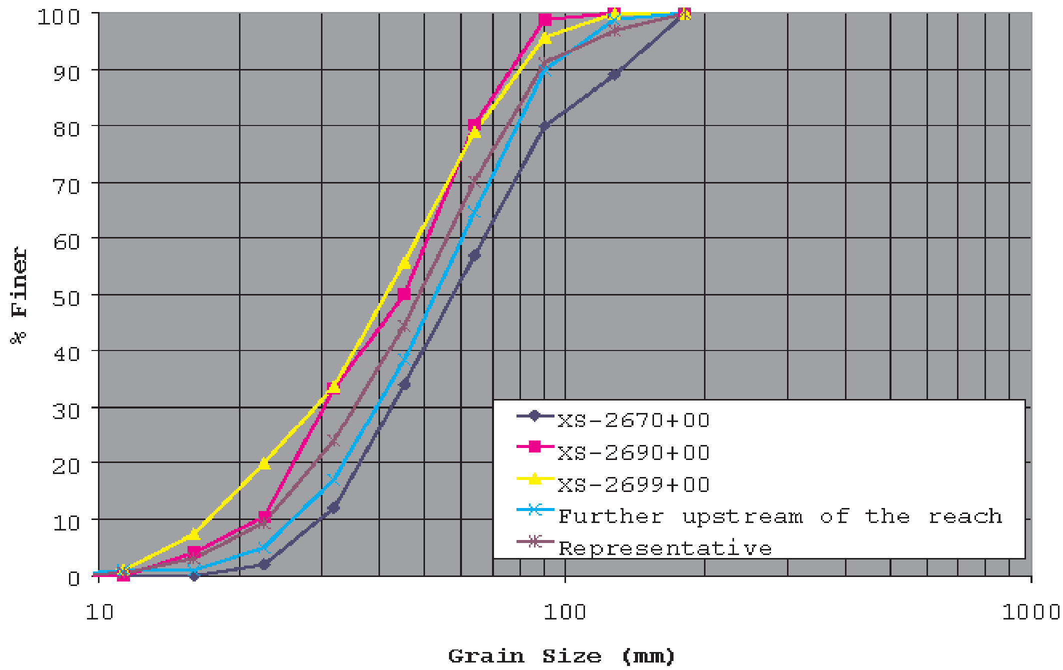


Figure 3. Grain size distributions on channel surface from McBain & Trush pebble counts. A representative grain size distribution was constructed for model input.

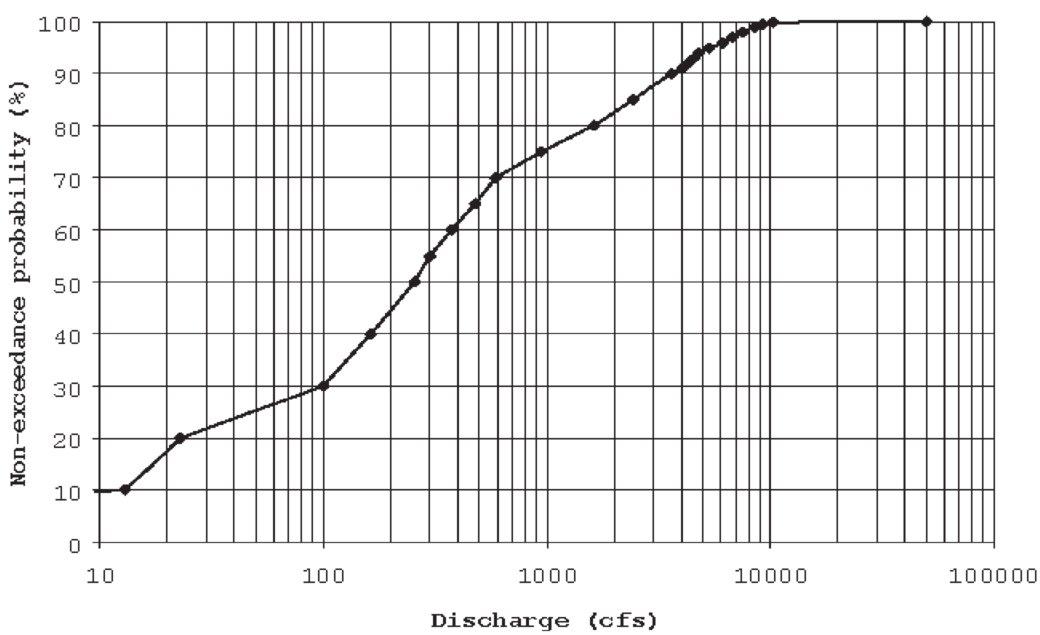


Figure 4. Flow duration curve based on post-New Don Pedro Reservoir (WY 1971 – WY 1999) daily discharge records at USGS gauge Tuolumne River below La Grange Dam near La Grange (station no. 11289650)

The calculated transport rates of gravel (> 8 mm) are shown in Figure 5 along with the field data provided by McBain & Trush. The calculated normalized Shields stresses, which are the ratio between surface-geometric-mean-based Shields stresses and a reference Shield stress, are shown in Figure 6. Note that the reference Shield stress can be viewed as a surrogate for the critical Shields stress, and thus a normalized Shields stress of unity is equivalent to thresholds for bed mobility. The long-term average annual gravel transport rates and the discharges corresponding to normalized Shields stress of unity for the simulated cross sections are shown in Table 1.

Table 1. Predicted long-term average gravel transport rate and discharge for bed mobility threshold with different cross sections as model input

Cross section used for simulation	Long-term average gravel transport rate (kt/a)	Discharge for bed mobility threshold (cfs)
XS 2702+00	1.69	6,950
XS 2699+00	2.11	6,510
XS 2690+00	0.94	10,670
XS 2685+00	0.82	9,520
XS 2674+00	2.43	8,770
XS 2672+00	1.76	9,620
Average	1.67	8,670

The calculated gravel transport rates range between 1–10 kt/a and are systematically lower than the measured bedload transport data by more than an order of magnitude (Figure 5). The calculated normalized Shields stresses shown in Figure 6 and Table 1 suggest that the threshold for gravel transport is between 6,510 cfs and 10,670 cfs. This result only partially confirms the McBain & Trush observations at Riffle 4B that flows of 6,880 cfs are capable of mobilizing cobbles and gravels. It, however, does support McBain & Trush conclusion that the bed will not be mobilized by flows less than 7,000 to 8,000 cfs in most reaches (McBain & Trush 2000, p.79-84).

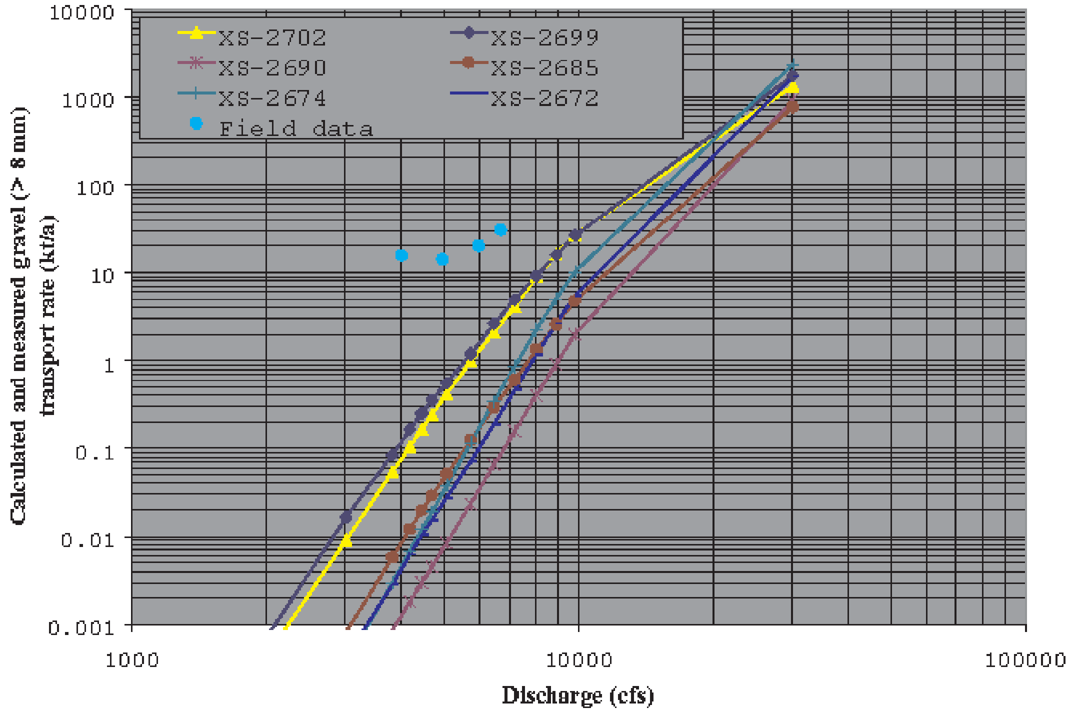


Figure 5. Calculated and measured gravel transport rates

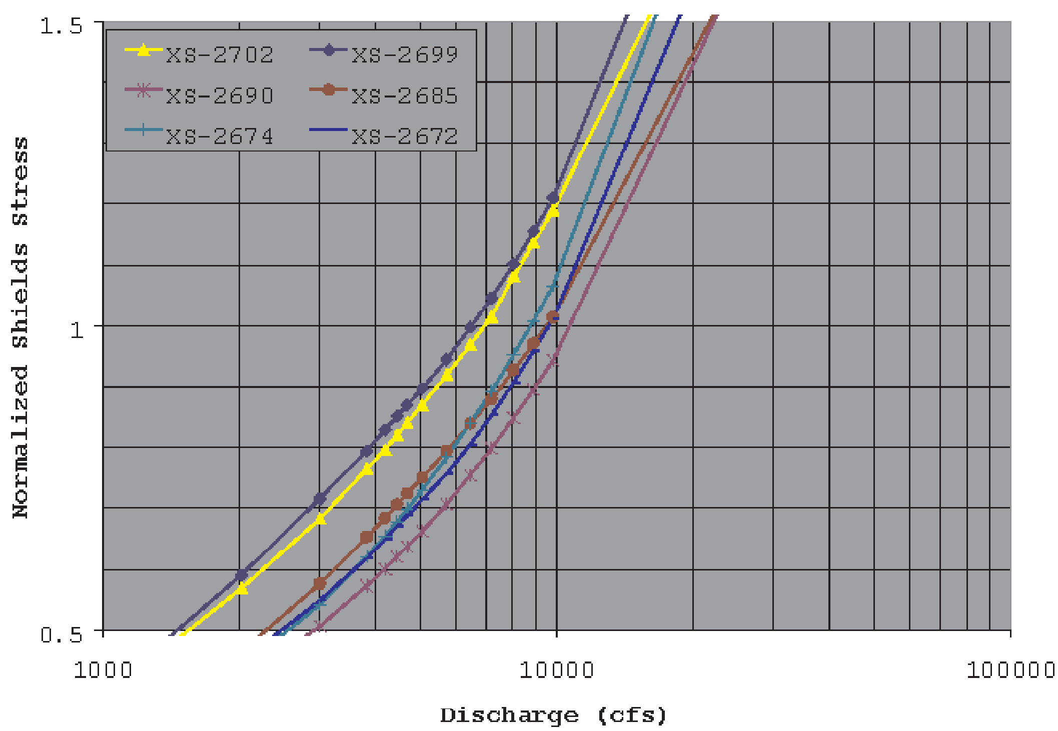


Figure 6. Calculated normalized Shields stress

Sensitivity test of floodplain assumptions: The bedload transport model results (Figure 5) indicate that the difference between the highest and lowest gravel transport rate predictions calculated with different cross sections as input data varied over an order of magnitude for low flow conditions and by a factor of two for high flow conditions. The difference between the highest and lowest long-term average gravel transport rate predictions is within a factor of three, which falls within the estimated general range of accuracy of the model. Arbitrarily selecting XS-2702+00 as the representative cross section, an additional run was performed by assuming that flow is confined in the main channel. The complete cross section XS 2702+00 and the delineation of the main channel and floodplains are given in Figure 7.

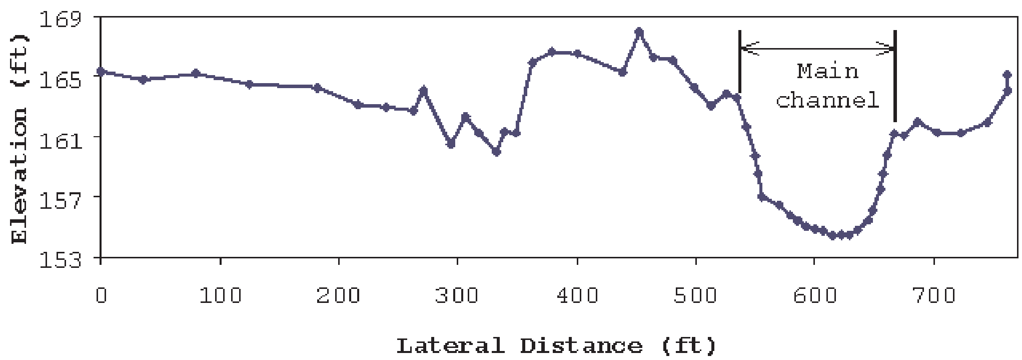


Figure 7. Cross section XS-2702+00, showing floodplains and the main channel

The predicted long-term average gravel transport rate increased from 1,690 ton/year to 5,340 ton/year, a change of a factor of about 3. Comparison of gravel transport rating curve and normalized Shields stresses is shown in Figures 8 and 9, respectively. Note that there is no difference between the two runs for low flow conditions. The differences in predicted gravel transport rates and normalized Shields stresses begin to appear at bankfull flow and increase as discharge increases.

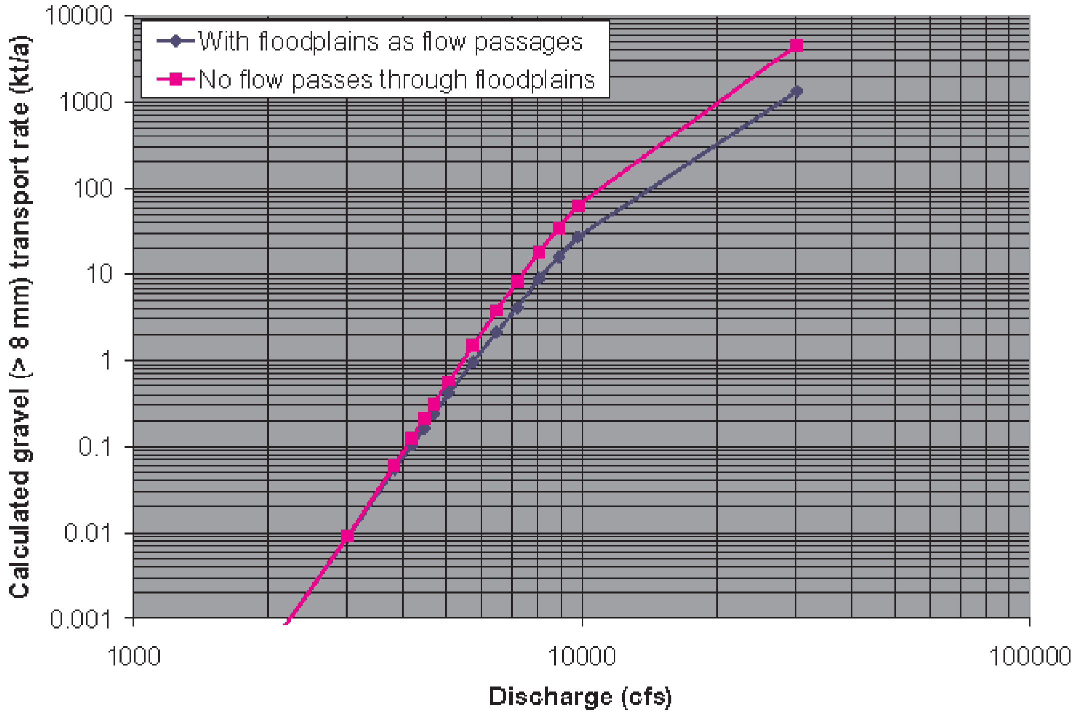


Figure 8. Calculated gravel transport rate with XS-2702+00 as representative cross section and different assumptions on flow passages

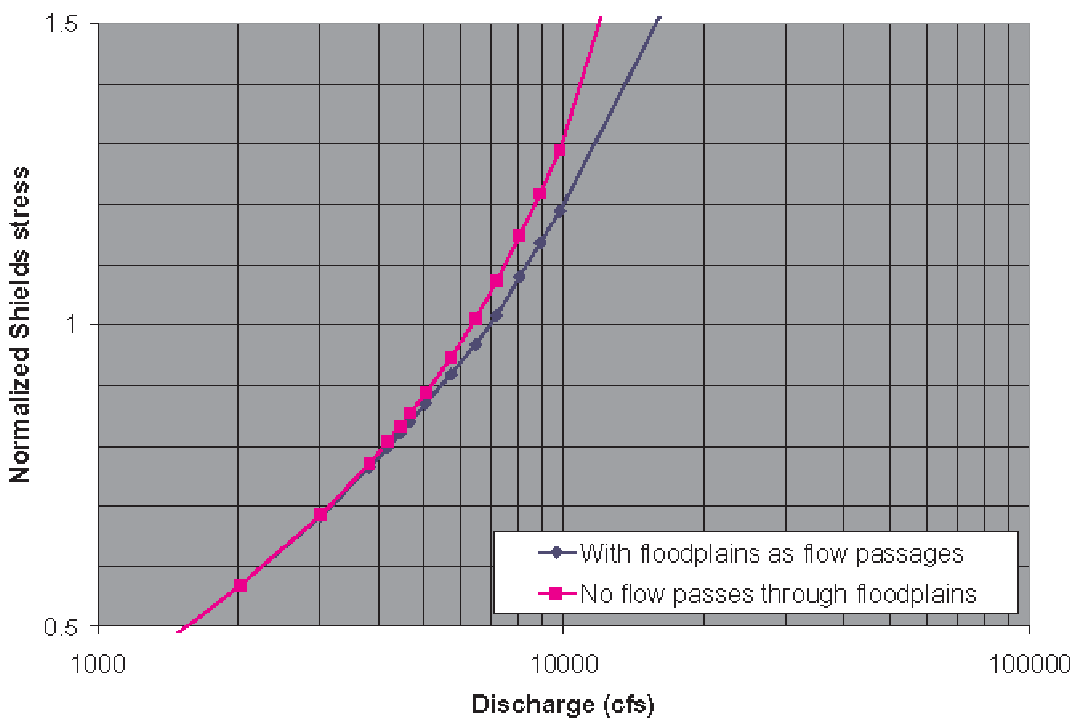


Figure 9. Calculated normalized Shields stress with XS-2702+00 as representative cross section and different assumptions on flow passages

Sensitivity test of water surface slope: Cross section XS-2702+00 was selected arbitrarily as a representative cross section for the sensitivity test on water surface slope. In addition to the calculation reported in earlier, two additional runs were performed using water surface slopes changed by ±20%. The predicted gravel transport rating curves and normalized Shields stresses are shown in Figures 10 and 11. Varying water surface slope by ±20% resulted in a change in gravel transport rate by a factor of 9 for low flow conditions and by a factor of less than 3 for high flow conditions. Decreasing water surface slope by 20% resulted in a decrease in long-term gravel transport rate from 1,690 ton/year to 480 ton/year. Increasing water surface slope by 20% resulted in an increase in long-term gravel transport rate from 1,690 ton/year to 4,360 ton/year.

Sensitivity test of surface grain size distribution: Two runs were performed by varying surface grain size distribution. These two runs used pebble counts at XS-2699+00 and XS-2670+00, the finest and coaresest of all pebble counts available, respectively, as model input. Using pebble count at XS-2699+00 and XS-2670+00 as surface grain size input changed the long-term gravel transport rate prediction to 4,010 ton/year and 490 ton/year, respectively, from the original 1,690 ton/year, or factors of 2.4 and 3.4, respectively. The predicted gravel transport rating curves and normalized Shields stresses are shown in Figures 12 and 13.

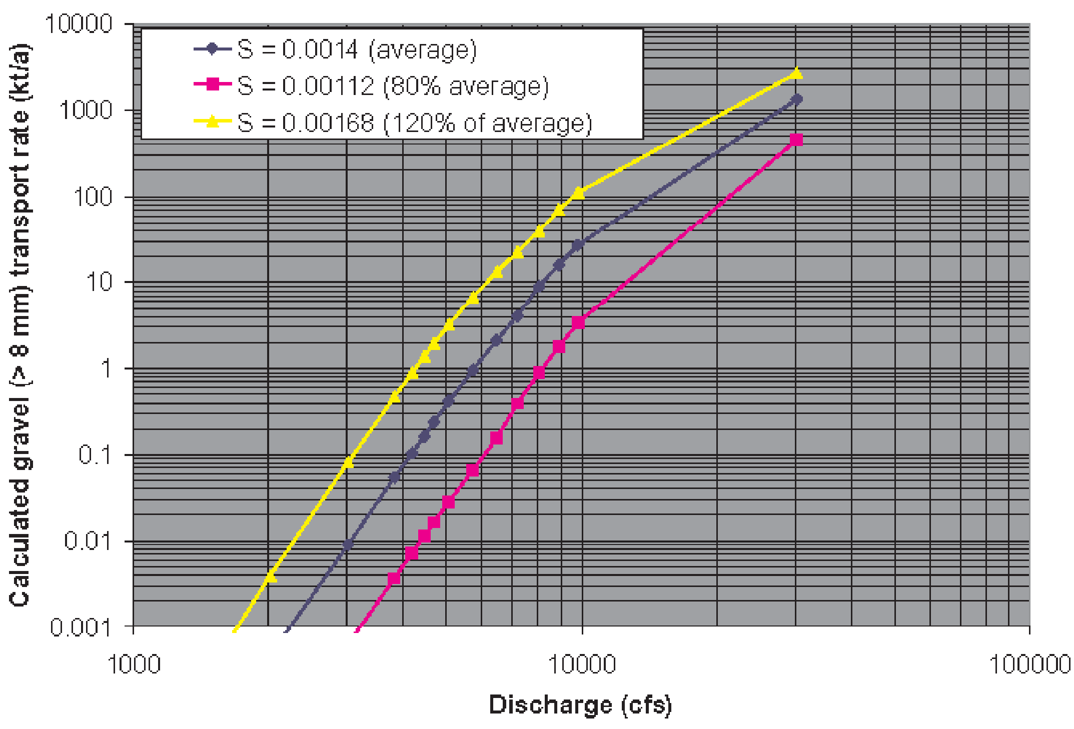


Figure 10. Predicted gravel transport rating curve with XS-2702+00 and different water surface slope as input

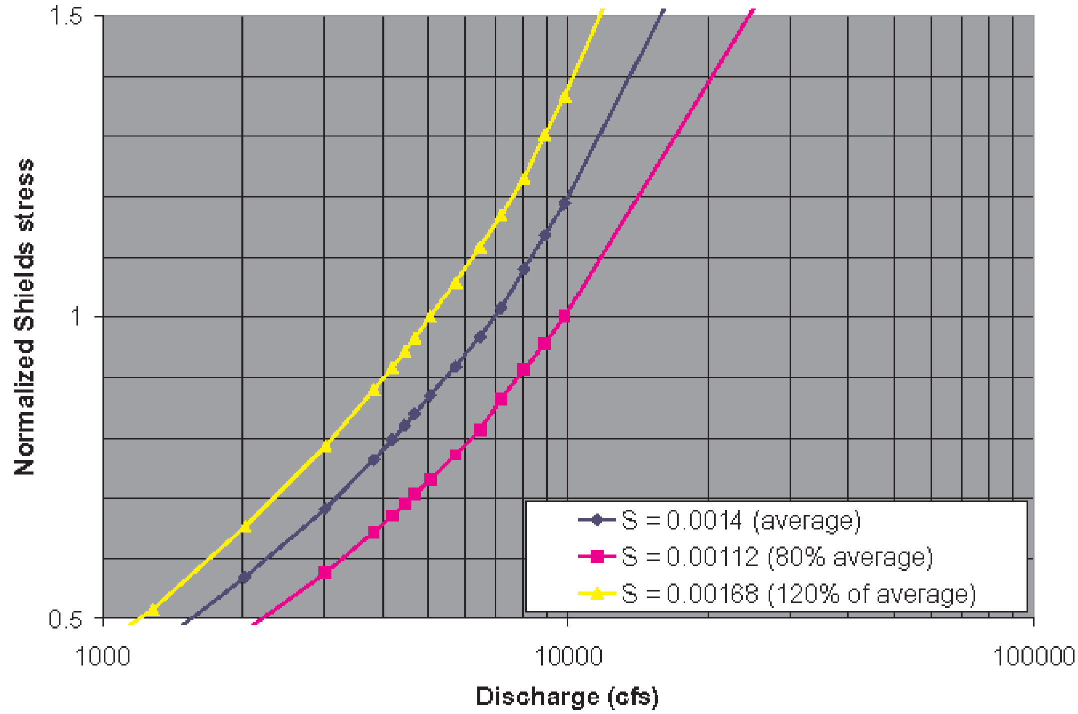


Figure 11. Predicted normalized Shields stress with XS-2702+00 and different water surface slope as input

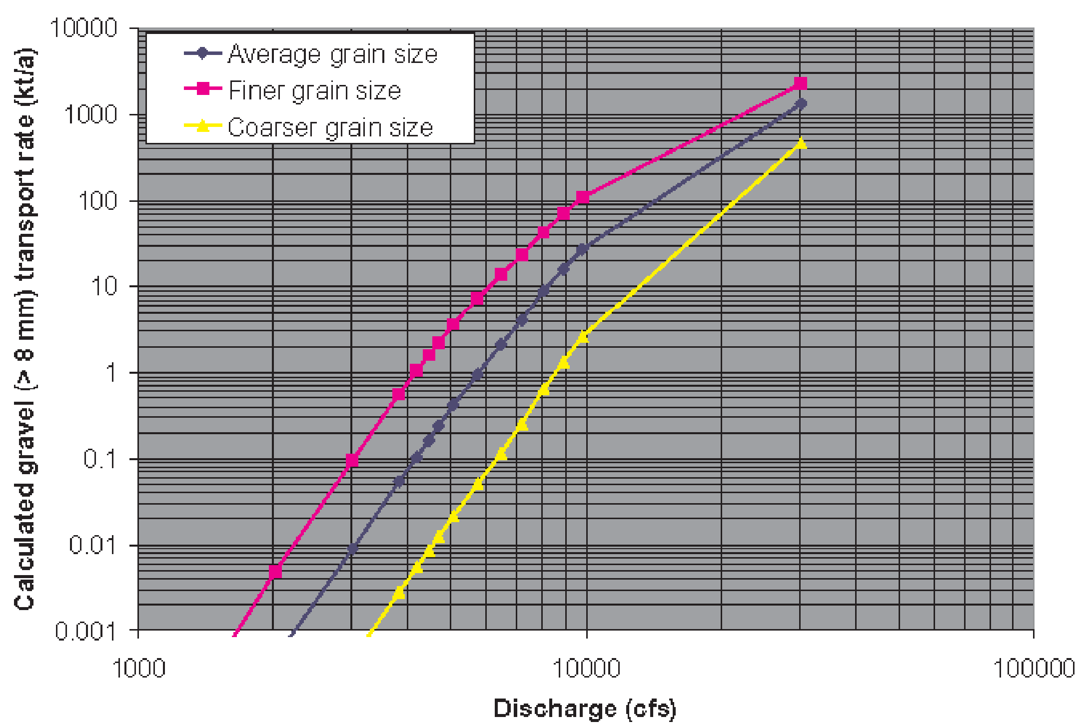


Figure 12. Predicted gravel transport rating curve with XS-2702+00 and different surface grain size distributions as input

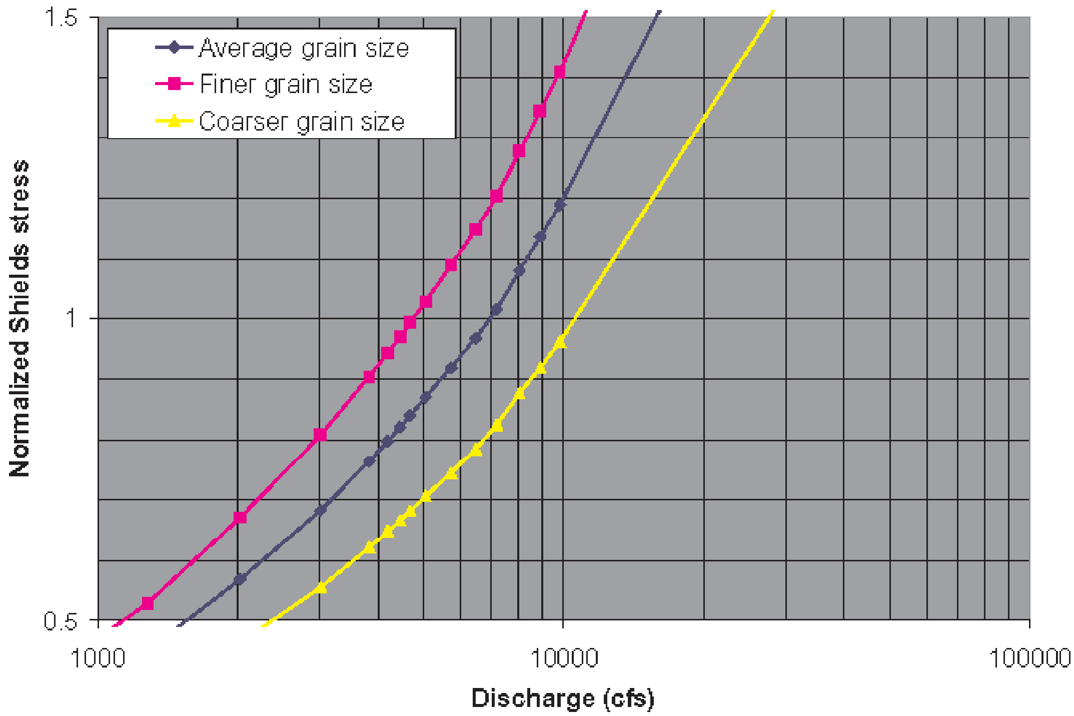


Figure 13. Predicted normalized Shields stress with XS-2702+00 and different surface grain size distributions as input

DISCUSSION

The sensitivity tests illustrated that the model results are sensitive to many input parameters. Among them, reasonable variations in cross section, surface grain size distribution, or water surface slope can result in a change in predicted gravel transport rate by a factor of 2 to 3 (Table 2). The predicted gravel transport rates are significantly lower than rates measured with a cable-held Helley-Smith bedload sampler as shown in Figure 5. Adjusting the input parameters within the ranges tested did not appreciably reduce the discrepancy. We believe that the discrepancy between the model results and field measurements could be a result of the following factors:

- The model could under-predict the gravel transport rate by a factor of 2 to 3. Field observation indicates that the reach has relatively simple morphology and channel geometry, reducing the probability of less accurate predictions.
- The measurement of water surface slope was performed in March 1996, and other input data were collected in March 2000. The channel may have experienced significant change in bed slope during that period of time considering that there was a flow event of more than 60,000 cfs on January 3, 1997.
- The model predicts reach-average sediment transport rate for a quasi-equilibrium state. The introduction of gravel upstream of the modeling reach may have resulted in non-equilibrium conditions, which is supported by McBain & Trush (2000) observation that the bed mobility is discontinuous with the neighboring reaches. This non-equilibrium state downstream of the gravel introduction site might have resulted in significant increase in sediment transport

rates in the modeling reach. Cui et al. (2001) demonstrated that sediment transport rate could increase from the equilibrium value by 2 orders of magnitude downstream of an introduced sediment pulse for certain period of time.

- Sampling error in the field measurement of bedload transport rate could occur due to the short duration of the sampling and small number of samples. Ryan (1998) reported that annual sediment accumulation predicted using historical gauge records are often within a factor of 2 compare with measurement in a weir pond. Sampling accuracy at an individual cross section for a single event, however, is not known.

Table 2. Predicted minimum and maximum annual gravel transport rate (ton/year) by varying input within a reasonable range

	Variation in Cross Section	Floodplain Assumption[c]	Varying water surface slope by ±20%	Varying surface grain size distribution
Minimum Prediction	820	1,690	480	490
Maximum Prediction	2,430	5,430	4,360	4,010
Average[a]	1,412	3,029	1,447	1,447
Deviation Factor[b]	1.72	1.79	3.01	3.01

a. Geometric average of the minimum and maximum predictions;

b. Ratio of maximum prediction to geometric average, which equals to the ratio of geometric average to minimum prediction.

c. Assumes that flow is confined to the active channel (maximum prediction) or the available flood (minimum prediction).

CONCLUSIONS AND RECOMMENDATIONS

We believe that the predicted gravel transport rating curve should be used as the long-term restoration guidance for future gravel introduction projects. The bedload measurements at Riffle 4B should not be used as the basis for estimates of long-term gravel transport rate because of the high possibility of non-equilibrium sediment transport at the reach during the measurement. Based on model predictions, long-term gravel transport rate in the modeling reach is about 820 to 2,430 ton/yr, which can be used as an estimate of future gravel augmentation rate. New model runs should be performed to improve the predictions if additional data are collected in the future.

REFERENCES

Cui, Y., Parker, G., Lisle, T.E., Gott, J., Hansler, M.E., Pizzuto, J.E., Allmendinger, N.E., and Reed, J.M. (2001) Sediment pulses in mountain rivers. Part 1. Experiments. *Water Resources Research*, in press.

McBain & Trush (2000) Habitat restoration plan for the lower Tuolumne River corridor. March.

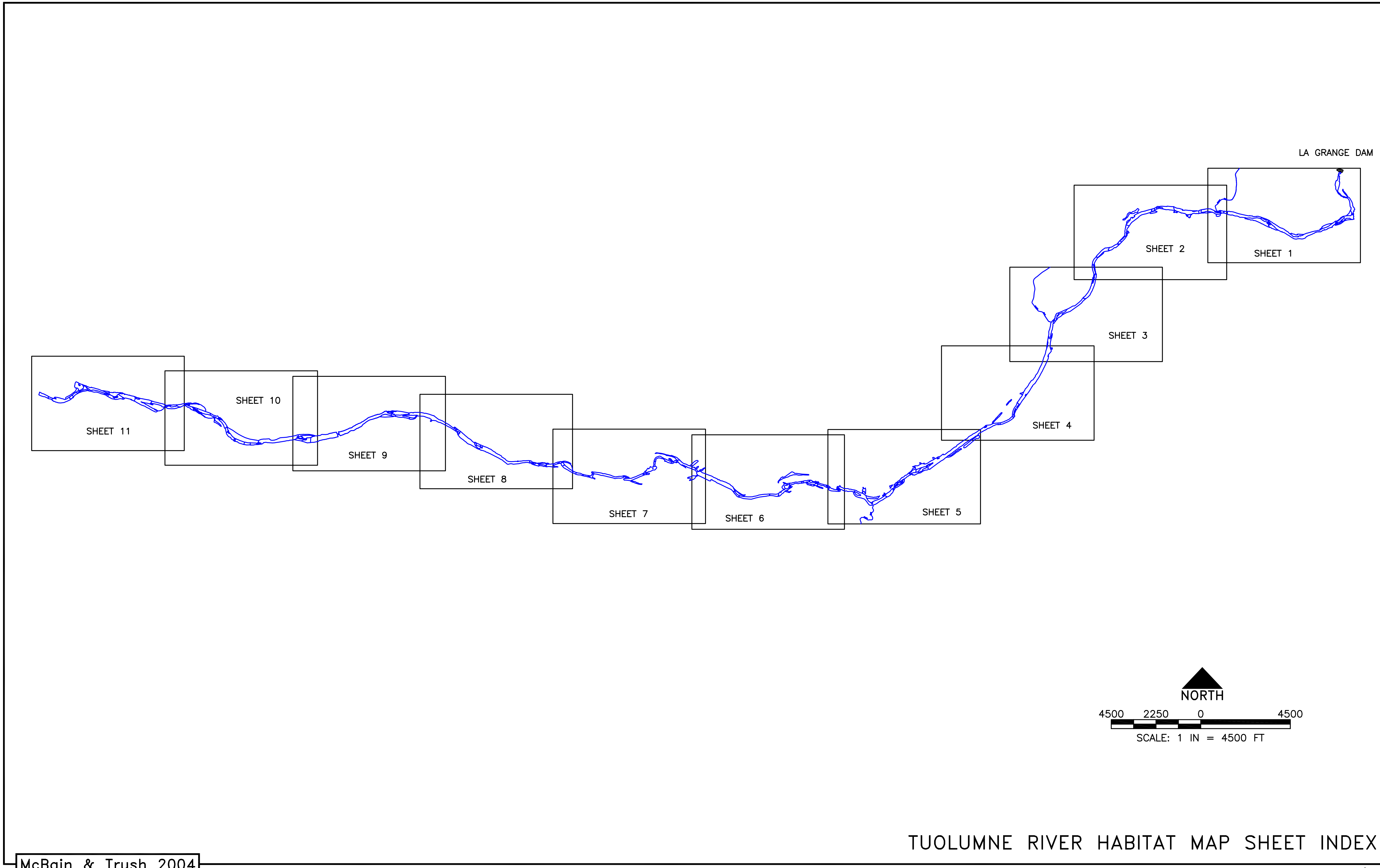
Parker, G. (1990a) Surface-based bedload transport relation for gravel rivers. *Journal of Hydraulic Research*, 28(4), 417-436.

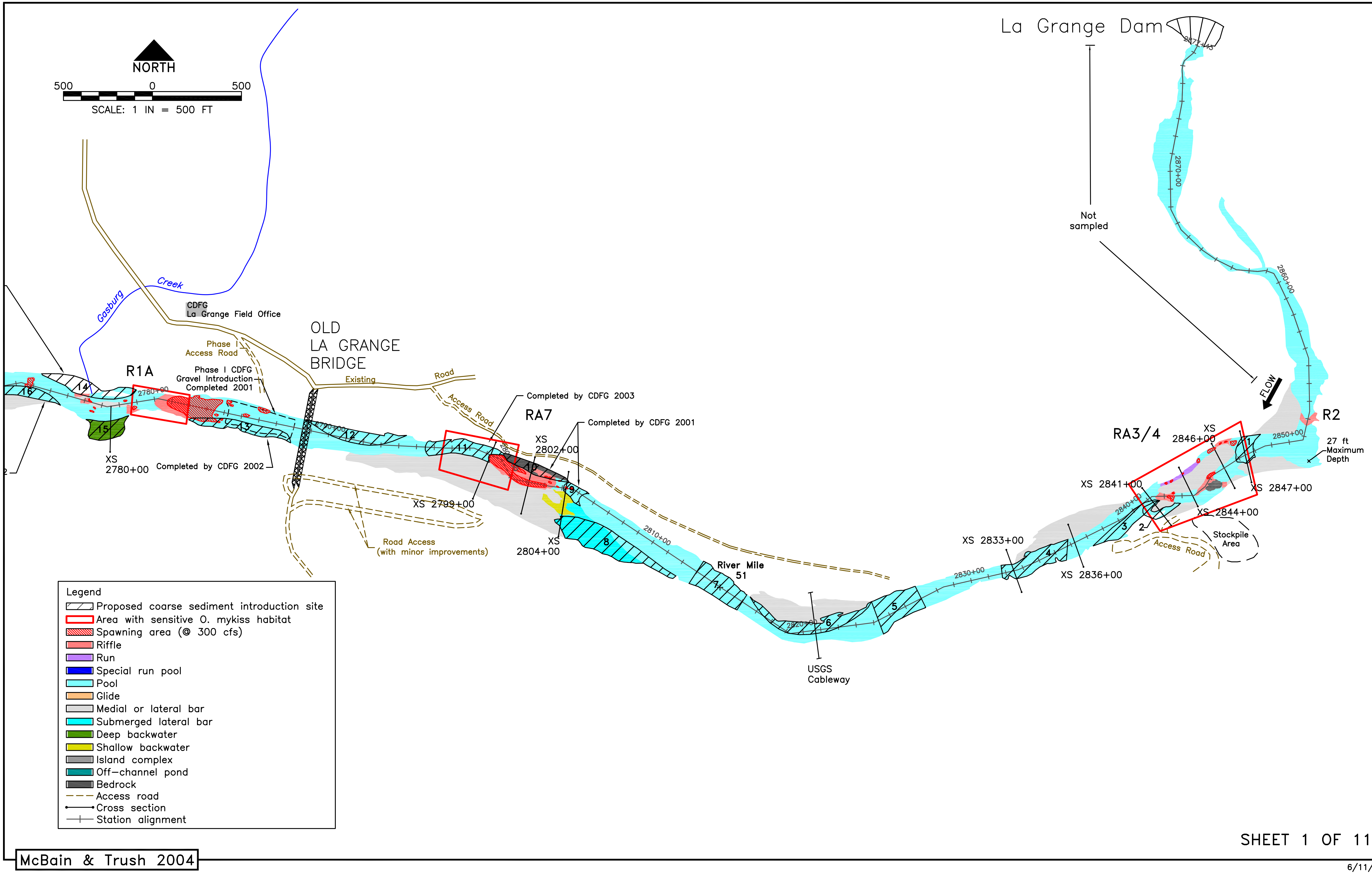
Parker, G. (1990b) The "ACRONYM" series of PASCAL programs for computing bedload transport in gravel rivers. External Memorandum No. M-220, St. Anthony Falls Laboratory, University of Minnesota, Minneapolis. February. 124p.

Ryan, S.E. (1998) Sampling bedload transport in coarse-grained mountain channels using portable samplers. *Proceedings of the Federal Interagency Workshop: Sediment Technology for the 21'st Century*. St. Petersberg, FL, February 17-19. (http://water.usgs.gov/osw/techniques/sedtech21/ryan.html)

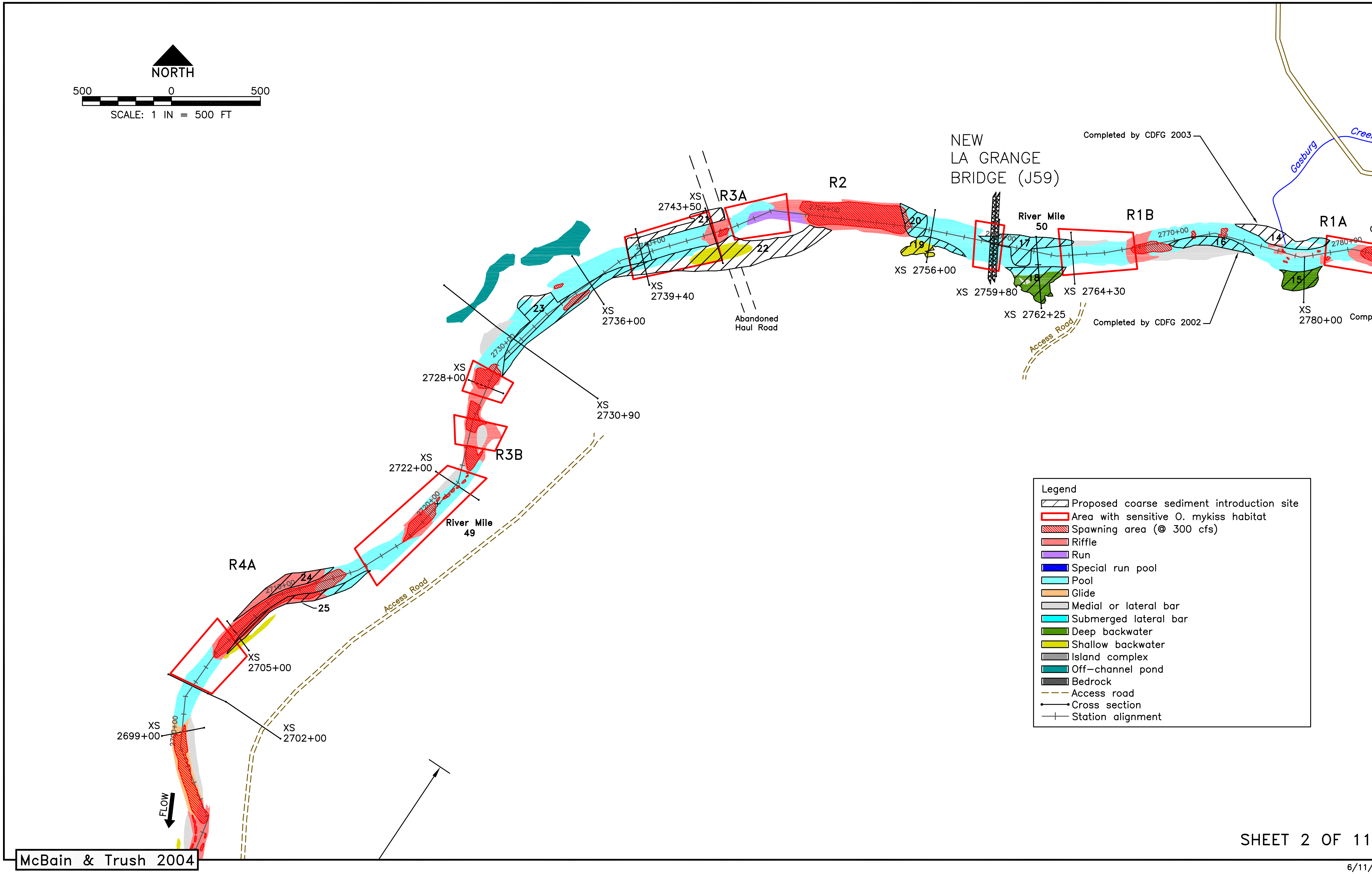
Appendix D

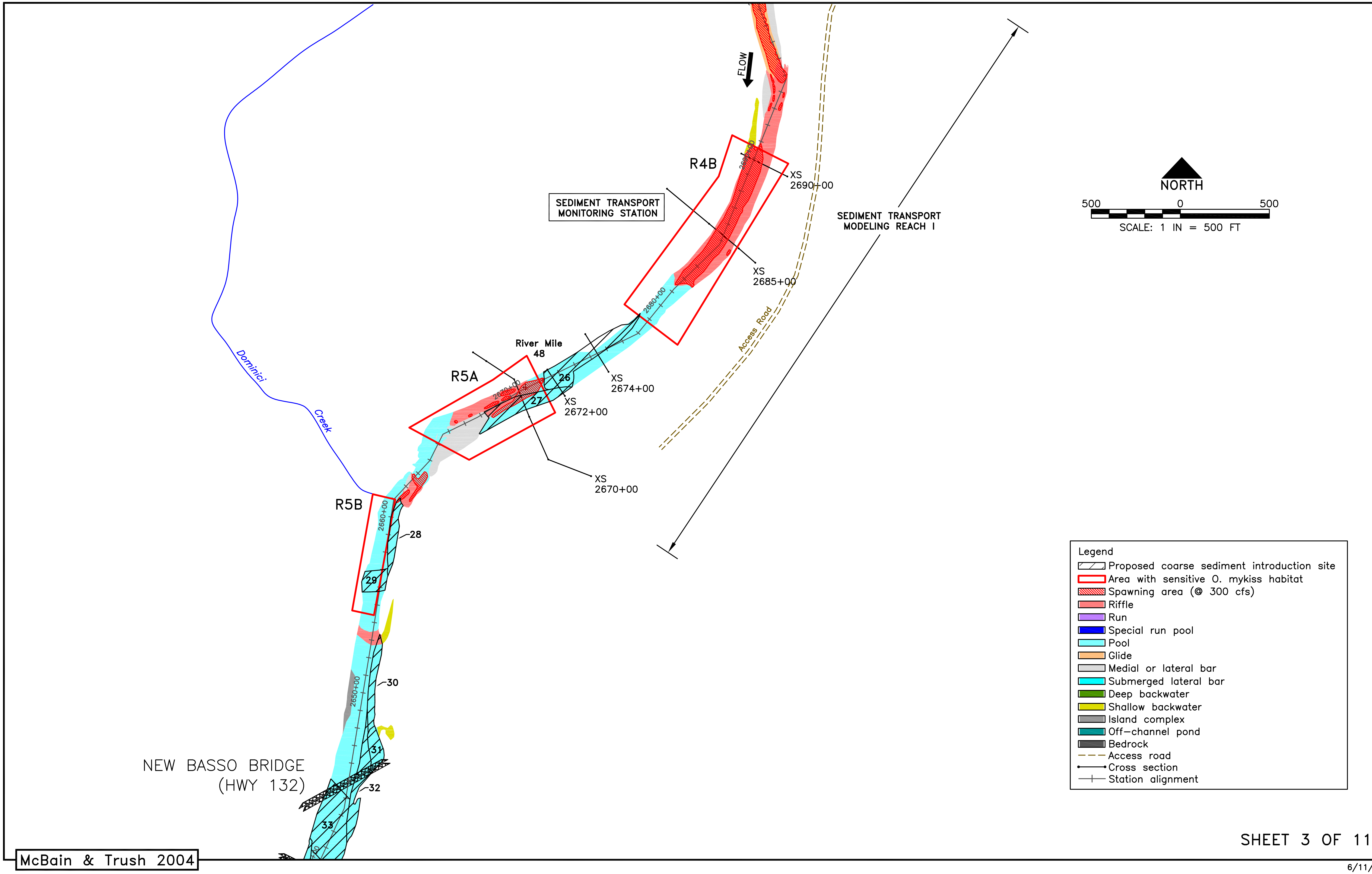
Habitat Maps and Coarse Sediment Augmentation Sites Developed for the Upper 15.8 Miles of Gravel-Bedded Reach.

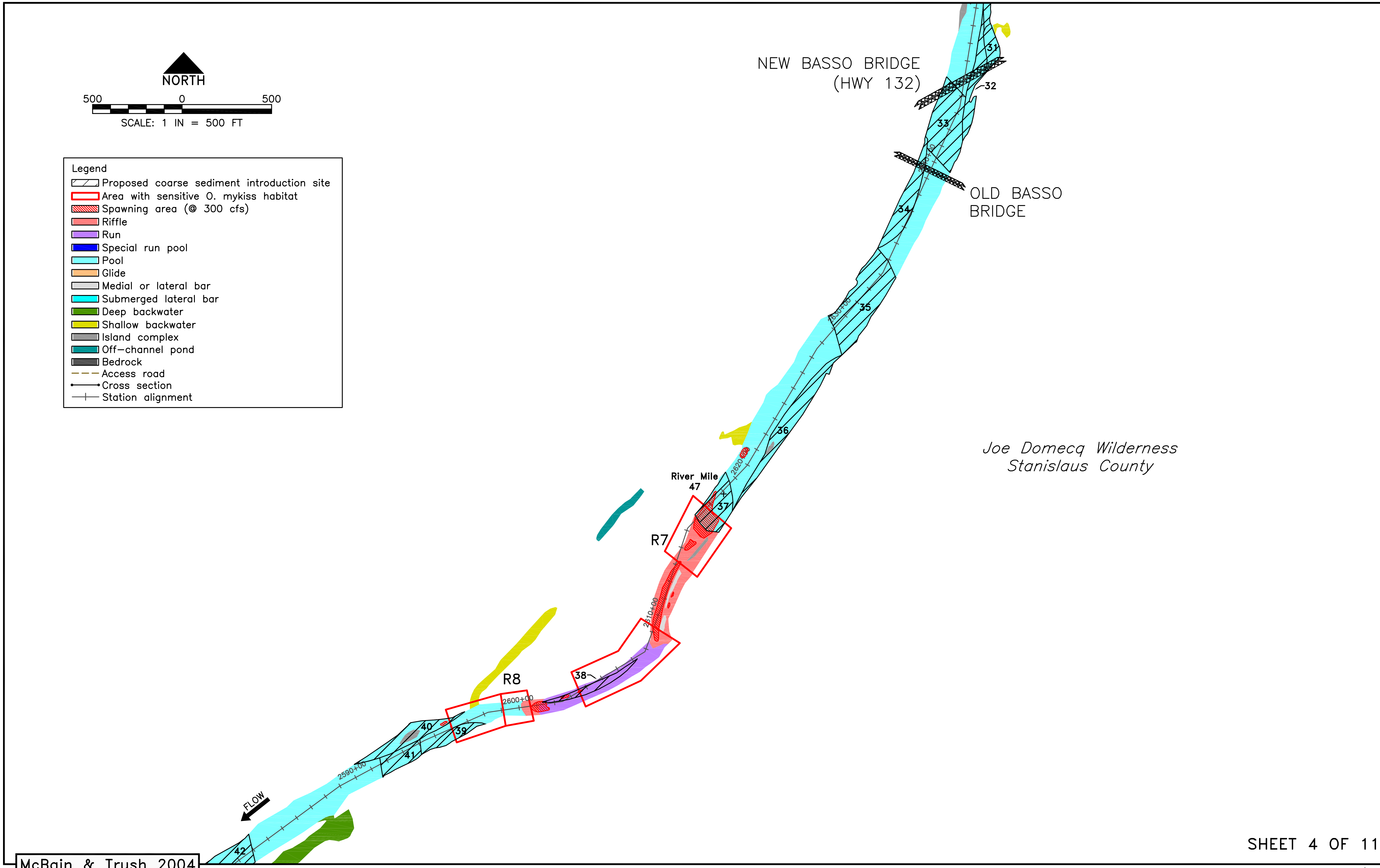

LA GRANGE DAM
SHEET 1
SHEET 2
SHEET 3
SHEET 4
SHEET 5
SHEET 6
SHEET 7
SHEET 8
SHEET 9
SHEET 10
SHEET 11
NORTH
4500 2250 0 4500
SCALE: 1 IN = 4500 FT
TUOLUMNE RIVER HABITAT MAP SHEET INDEX
McBain & Trush 2004
6/11/04

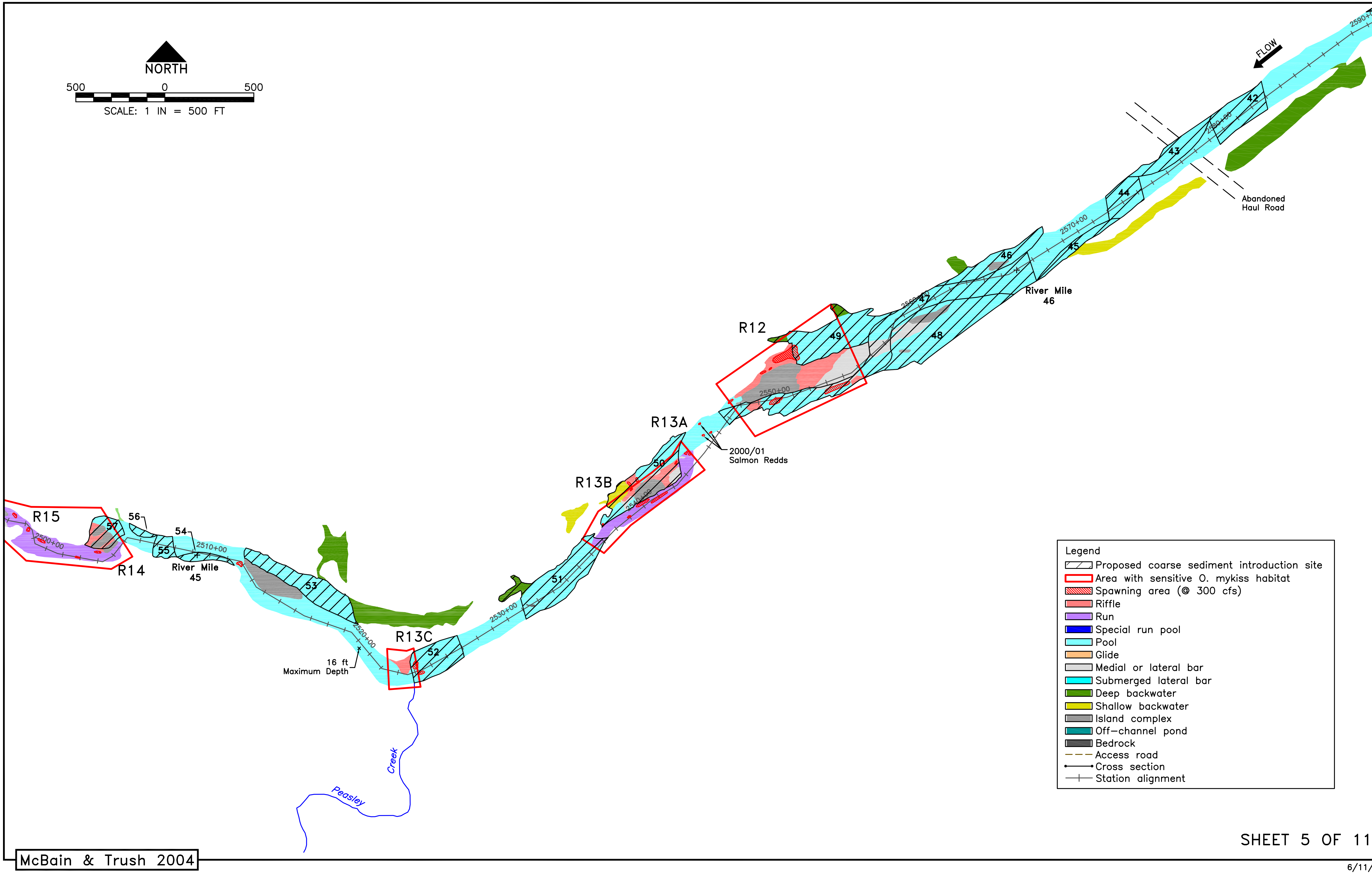


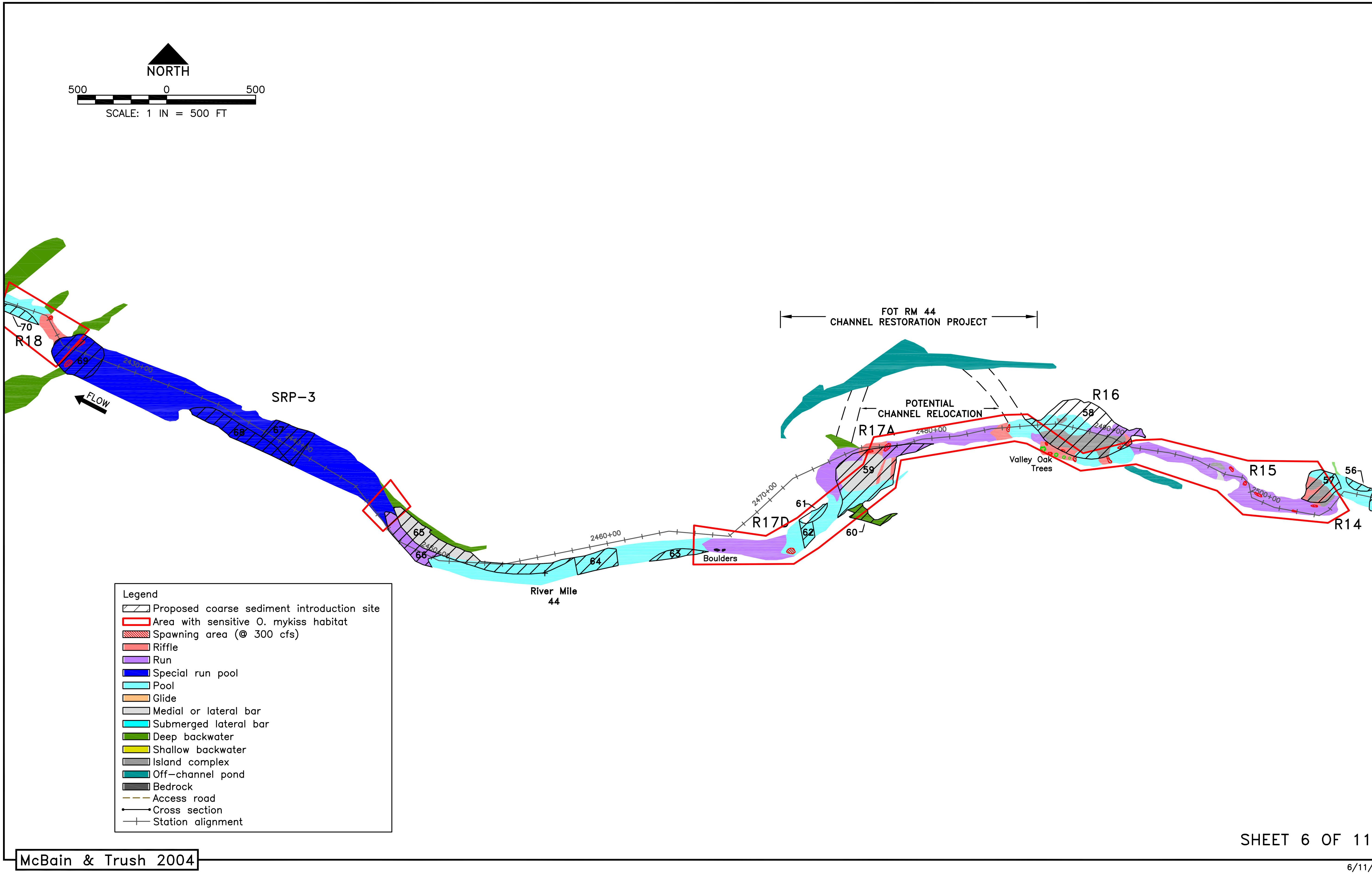
La Grange Dam
NORTH
500 0 500
SCALE: 1 IN = 500 FT
Not sampled
FLOW
R2
27 ft Maximum Depth
RA3/4
XS 2846+00
XS 2841+00
XS 2847+00
XS 2844+00
Stockpile Area
Access Road
XS 2833+00
XS 2836+00
River Mile 51
USGS Cableway
RA7
Completed by CDFG 2003
Completed by CDFG 2001
XS 2802+00
XS 2799+00
XS 2804+00
Road Access (with minor improvements)
OLD LA GRANGE BRIDGE
Existing Road
Access Road
CDFG La Grange Field Office
Gasburg Creek
Phase I Access Road
Phase I CDFG Gravel Introduction Completed 2001
R1A
XS 2780+00
Completed by CDFG 2002
Legend
Proposed coarse sediment introduction site
Area with sensitive O. mykiss habitat
Spawning area (@ 300 cfs)
Riffle
Run
Special run pool
Pool
Glide
Medial or lateral bar
Submerged lateral bar
Deep backwater
Shallow backwater
Island complex
Off–channel pond
Bedrock
Access road
Cross section
Station alignment
SHEET 1 OF 11
McBain & Trush 2004
6/11/04

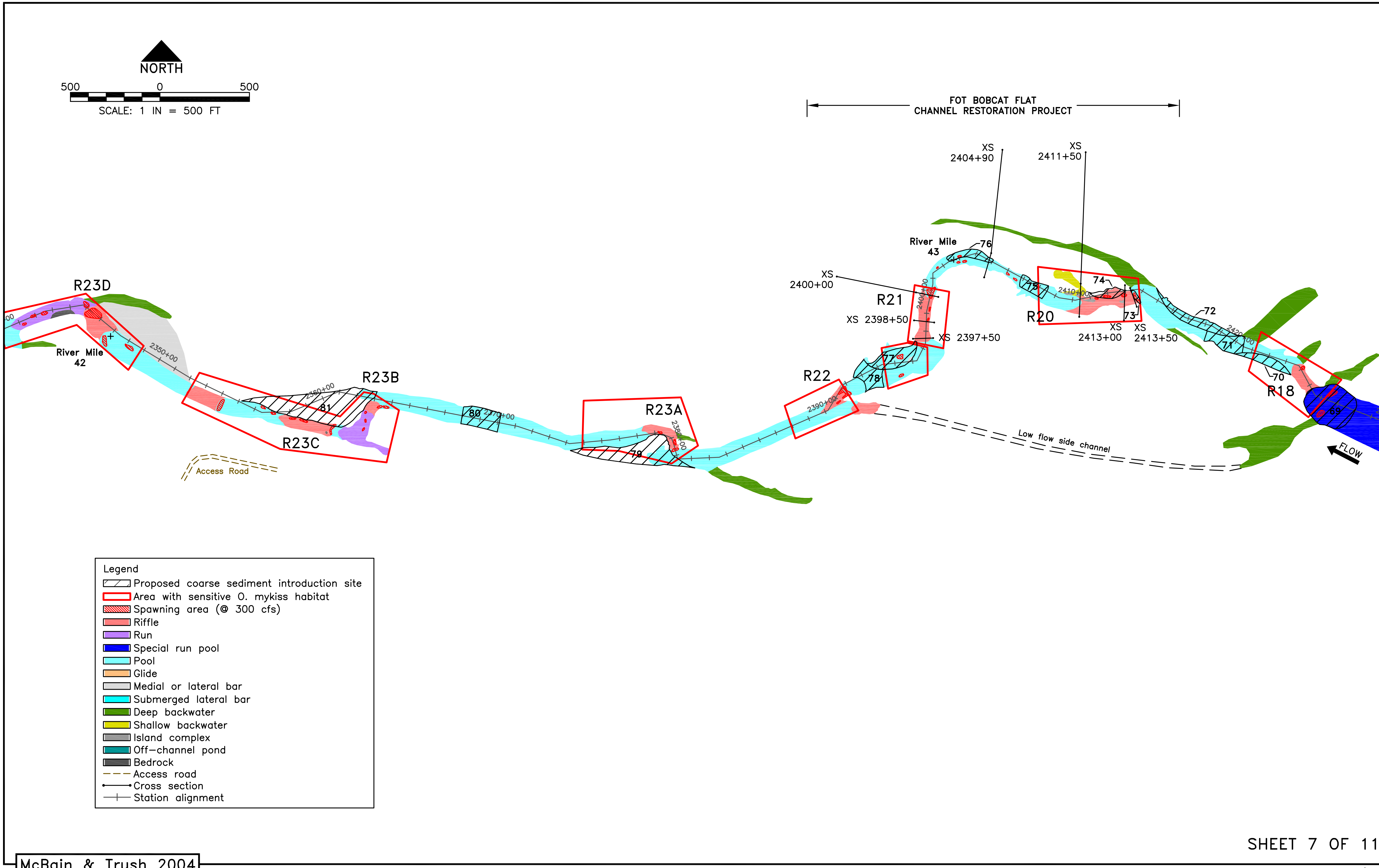

NORTH
500
0
500
SCALE: 1 IN = 500 FT
NEW
LA GRANGE
BRIDGE (J59)
Completed by CDFG 2003
Completed by CDFG 2002
Gasburg Creek
R3A
R2
R1B
R1A
R3B
R4A
River Mile
50
River Mile
49
XS 2743+50
XS 2739+40
XS 2736+00
XS 2730+90
XS 2728+00
XS 2722+00
XS 2705+00
XS 2702+00
XS 2699+00
XS 2756+00
XS 2759+80
XS 2762+25
XS 2764+30
XS 2780+00
Abandoned
Haul Road
Access Road
Access Road
FLOW
Legend
Proposed coarse sediment introduction site
Area with sensitive O. mykiss habitat
Spawning area (@ 300 cfs)
Riffle
Run
Special run pool
Pool
Glide
Medial or lateral bar
Submerged lateral bar
Deep backwater
Shallow backwater
Island complex
Off-channel pond
Bedrock
Access road
Cross section
Station alignment
SHEET 2 OF 11
McBain & Trush 2004
6/11/04

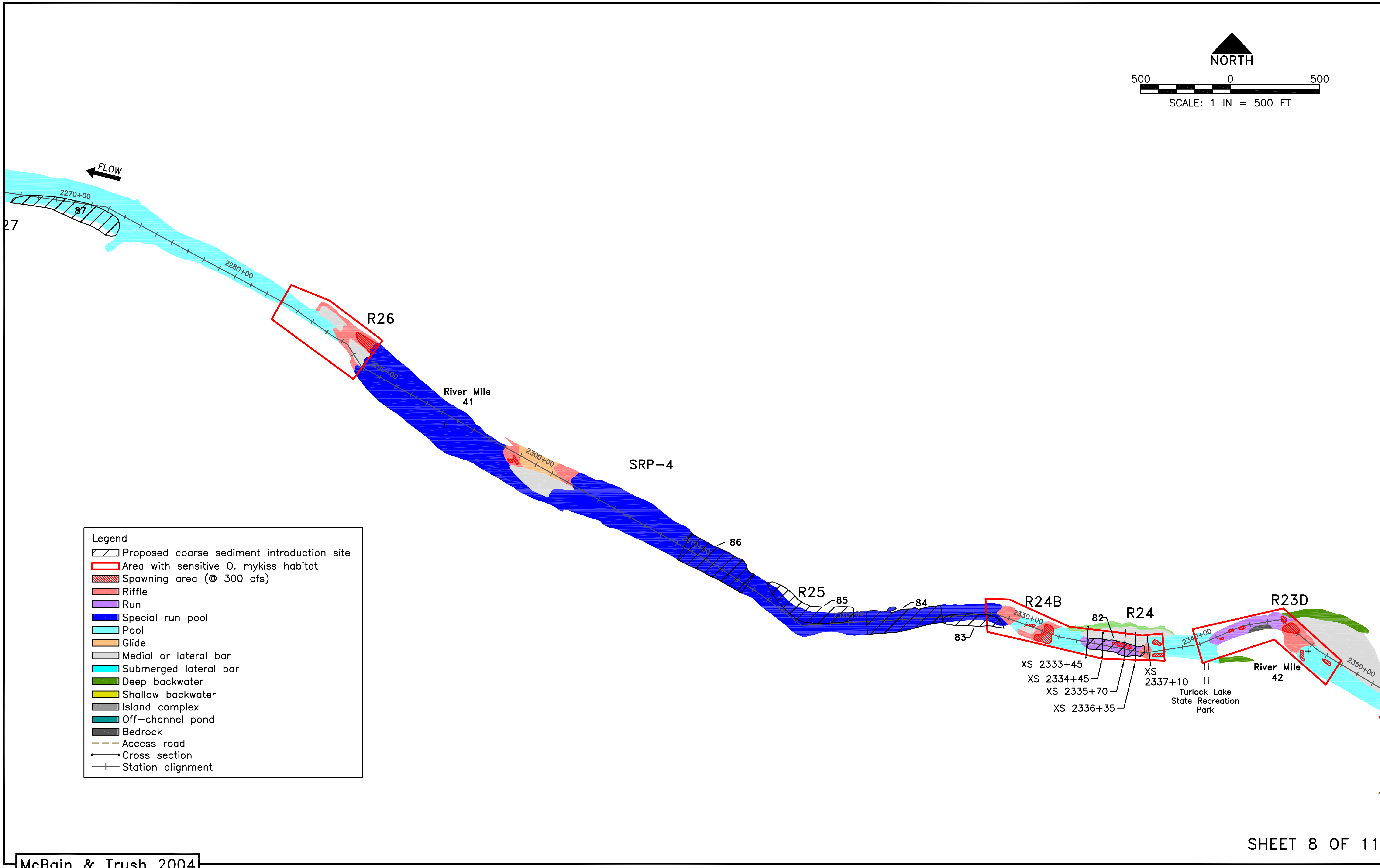

FLOW
R4B
XS
2690+00
SEDIMENT TRANSPORT
MONITORING STATION
XS
2685+00
2680+00
SEDIMENT TRANSPORT
MODELING REACH I
NORTH
500 0 500
SCALE: 1 IN = 500 FT
Access Road
Dominici Creek
River Mile
48
R5A
26
27
XS
2674+00
XS
2672+00
XS
2670+00
R5B
2660+00
28
29
30
2650+00
31
32
33
NEW BASSO BRIDGE
(HWY 132)
Legend
Proposed coarse sediment introduction site
Area with sensitive O. mykiss habitat
Spawning area (@ 300 cfs)
Riffle
Run
Special run pool
Pool
Glide
Medial or lateral bar
Submerged lateral bar
Deep backwater
Shallow backwater
Island complex
Off–channel pond
Bedrock
Access road
Cross section
Station alignment
SHEET 3 OF 11
McBain & Trush 2004
6/11/04

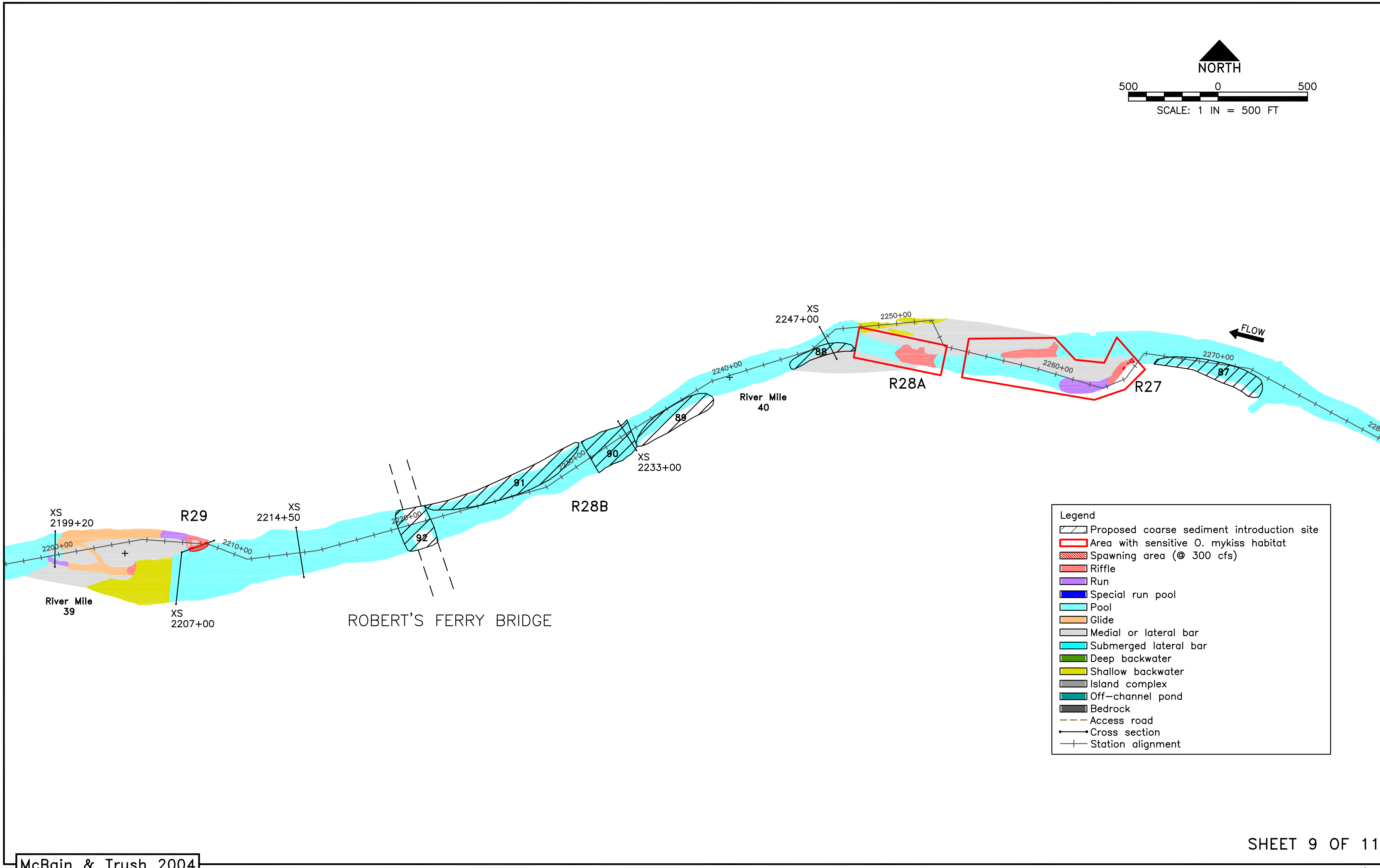

NORTH
500 0 500
SCALE: 1 IN = 500 FT
Legend
Proposed coarse sediment introduction site
Area with sensitive O. mykiss habitat
Spawning area (@ 300 cfs)
Riffle
Run
Special run pool
Pool
Glide
Medial or lateral bar
Submerged lateral bar
Deep backwater
Shallow backwater
Island complex
Off–channel pond
Bedrock
Access road
Cross section
Station alignment
NEW BASSO BRIDGE
(HWY 132)
OLD BASSO
BRIDGE
Joe Domecq Wilderness
Stanislaus County
River Mile
47
R7
R8
FLOW
2590+00
2600+00
2610+00
2620+00
31
32
33
34
35
36
37
38
39
40
41
42
SHEET 4 OF 11
McBain & Trush 2004
6/11/04


NORTH
500
0
500
SCALE: 1 IN = 500 FT
FLOW
Abandoned Haul Road
River Mile 46
River Mile 45
R12
R13A
R13B
R13C
R14
R15
2000/01 Salmon Redds
16 ft Maximum Depth
Peasley Creek
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
2590+00
2570+00
2550+00
2530+00
2520+00
2510+00
2500+00
Legend
Proposed coarse sediment introduction site
Area with sensitive O. mykiss habitat
Spawning area (@ 300 cfs)
Riffle
Run
Special run pool
Pool
Glide
Medial or lateral bar
Submerged lateral bar
Deep backwater
Shallow backwater
Island complex
Off–channel pond
Bedrock
Access road
Cross section
Station alignment
SHEET 5 OF 11
McBain & Trush 2004
6/11/04


NORTH
500
0
500
SCALE: 1 IN = 500 FT
FOT RM 44
CHANNEL RESTORATION PROJECT
POTENTIAL
CHANNEL RELOCATION
R18
70
69
2430+00
FLOW
SRP-3
68
67
65
66
64
63
River Mile
44
2460+00
Boulders
R17D
2470+00
61
62
60
59
R17A
2480+00
Valley Oak
Trees
R16
58
R15
2500+00
56
57
R14
Legend
Proposed coarse sediment introduction site
Area with sensitive O. mykiss habitat
Spawning area (@ 300 cfs)
Riffle
Run
Special run pool
Pool
Glide
Medial or lateral bar
Submerged lateral bar
Deep backwater
Shallow backwater
Island complex
Off-channel pond
Bedrock
Access road
Cross section
Station alignment
SHEET 6 OF 11
McBain & Trush 2004
6/11/04


NORTH
500 0 500
SCALE: 1 IN = 500 FT
FOT BOBCAT FLAT
CHANNEL RESTORATION PROJECT
XS 2404+90
XS 2411+50
XS 2400+00
River Mile 43
R21
XS 2398+50
XS 2397+50
R20
XS 2413+00
XS 2413+50
R23D
River Mile 42
R23B
R23C
R23A
R22
R18
Low flow side channel
FLOW
Access Road
Legend
Proposed coarse sediment introduction site
Area with sensitive O. mykiss habitat
Spawning area (@ 300 cfs)
Riffle
Run
Special run pool
Pool
Glide
Medial or lateral bar
Submerged lateral bar
Deep backwater
Shallow backwater
Island complex
Off–channel pond
Bedrock
Access road
Cross section
Station alignment
SHEET 7 OF 11
McBain & Trush 2004
6/11/04


NORTH
500
0
500
SCALE: 1 IN = 500 FT
FLOW
2270+00
87
27
2280+00
R26
River Mile
41
2300+00
SRP-4
86
R25
85
84
83
R24B
2330+00
82
R24
R23D
2340+00
2350+00
XS 2333+45
XS 2334+45
XS 2335+70
XS 2336+35
XS
2337+10
Turlock Lake
State Recreation
Park
River Mile
42
Legend
Proposed coarse sediment introduction site
Area with sensitive O. mykiss habitat
Spawning area (@ 300 cfs)
Riffle
Run
Special run pool
Pool
Glide
Medial or lateral bar
Submerged lateral bar
Deep backwater
Shallow backwater
Island complex
Off-channel pond
Bedrock
Access road
Cross section
Station alignment
SHEET 8 OF 11
McBain & Trush 2004
6/11/04


NORTH
500
0
500
SCALE: 1 IN = 500 FT
FLOW
XS
2199+20
R29
XS
2214+50
XS
2207+00
River Mile
39
ROBERT'S FERRY BRIDGE
R28B
XS
2233+00
River Mile
40
XS
2247+00
R28A
R27
92
91
90
89
88
87
2200+00
2210+00
2220+00
2230+00
2240+00
2250+00
2260+00
2270+00
Legend
Proposed coarse sediment introduction site
Area with sensitive O. mykiss habitat
Spawning area (@ 300 cfs)
Riffle
Run
Special run pool
Pool
Glide
Medial or lateral bar
Submerged lateral bar
Deep backwater
Shallow backwater
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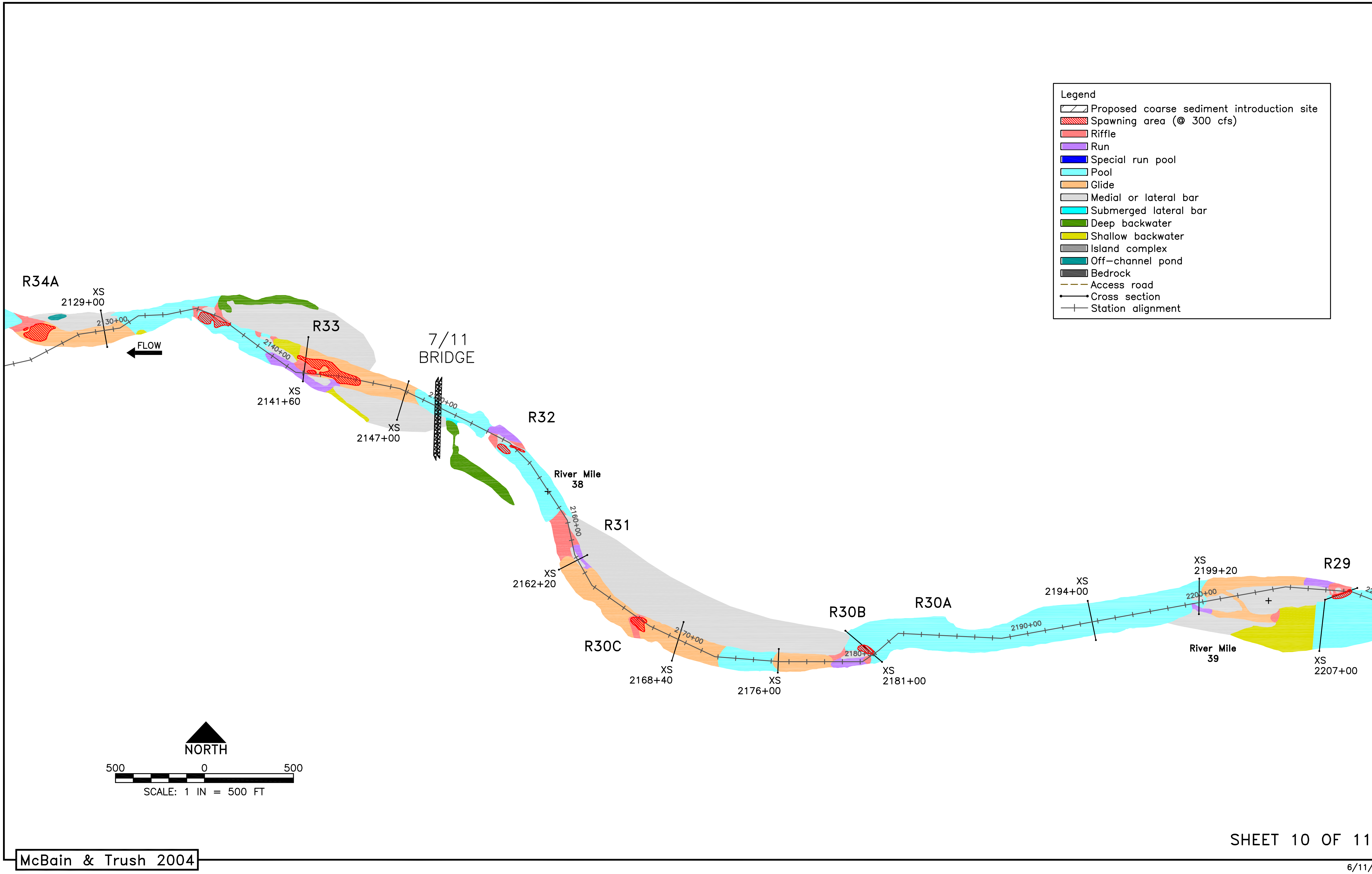
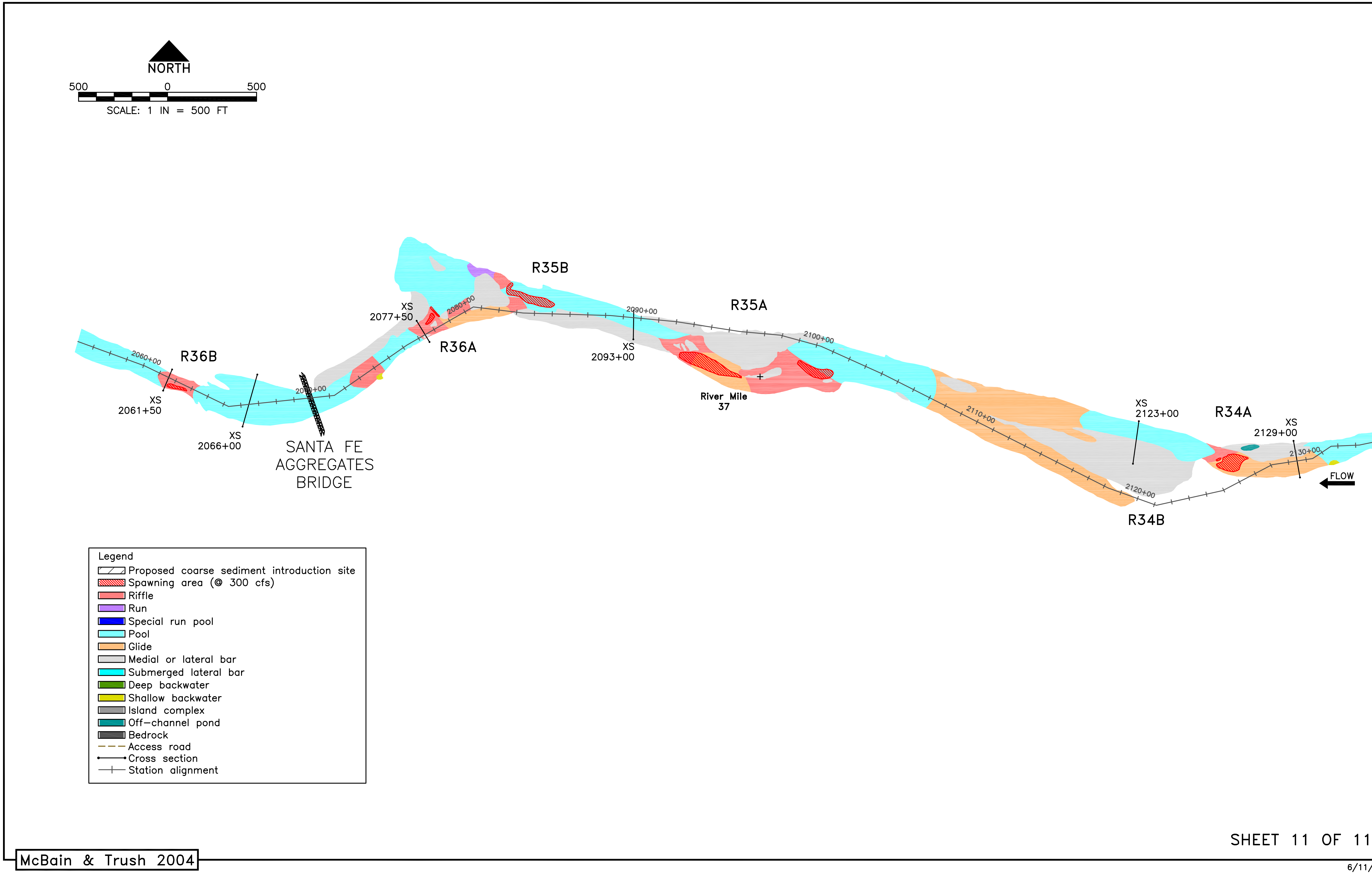
Off–channel pond
Bedrock
Access road
Cross section
Station alignment
SHEET 9 OF 11
McBain & Trush 2004
6/11/04


Legend
Proposed coarse sediment introduction site
Spawning area (@ 300 cfs)
Riffle
Run
Special run pool
Pool
Glide
Medial or lateral bar
Submerged lateral bar
Deep backwater
Shallow backwater
Island complex
Off–channel pond
Bedrock
Access road
Cross section
Station alignment
R34A
XS 2129+00
FLOW
R33
XS 2141+60
7/11 BRIDGE
XS 2147+00
R32
River Mile 38
R31
XS 2162+20
R30C
XS 2168+40
XS 2176+00
R30B
XS 2181+00
R30A
XS 2194+00
XS 2199+20
R29
River Mile 39
XS 2207+00
NORTH
500 0 500
SCALE: 1 IN = 500 FT
SHEET 10 OF 11
McBain & Trush 2004
6/11/04


NORTH
500
0
500
SCALE: 1 IN = 500 FT
R35B
R35A
XS
2077+50
R36A
XS
2093+00
R36B
XS
2061+50
XS
2066+00
SANTA FE
AGGREGATES
BRIDGE
River Mile
37
XS
2123+00
R34A
XS
2129+00
FLOW
R34B
2060+00
2080+00
2090+00
2100+00
2110+00
2120+00
Legend
Proposed coarse sediment introduction site
Spawning area (@ 300 cfs)
Riffle
Run
Special run pool
Pool
Glide
Medial or lateral bar
Submerged lateral bar
Deep backwater
Shallow backwater
Island complex
Off-channel pond
Bedrock
Access road
Cross section
Station alignment
SHEET 11 OF 11
McBain & Trush 2004
6/11/04

Appendix E

Results of Summer 2001 Snorkel Surveys of Fine Sediment Deposits in the Lower Tuolumne River - Stillwater Sciences Technical Memorandum

Stillwater Sciences

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TECHNICAL MEMORANDUM

DATE: July 10, 2001

TO: McBain & Trush

FROM: Martin Trso and Noah Hume

SUBJECT: Results of Summer 2001 Snorkel Surveys of Fine Sediment Deposits in the Lower Tuolumne River

INTRODUCTION

As a component of McBain & Trush's coarse sediment management plan being developed for the Tuolumne River Technical Advisory Committee (TRTAC), Stillwater Sciences conducted a three-day reconnaissance-level snorkel survey of fine sediment deposits of the lower Tuolumne River from the USGS gaging station below La Grange Dam (RM 52) to Roberts Ferry Bridge (RM 39.6). The purpose of this investigation was to provide estimates of fine sediment accumulation in pools and to assess the relative contribution of in-channel sand and finer grain sources relative to tributary creeks (*i.e.,* Gasburg, Dominici and Peasley creeks). This interim memorandum will be integrated with prior spawning gravel quality reports in conjunction with a literature review on gravel cleaning methods to provide an assessment of the effectiveness of various gravel cleaning methods in improving spawning gravels within the lower Tuolumne River.

METHODS

On June 19–21, 2001, Stillwater Sciences surveyed the entire river reach from above the Old La Grange Bridge (RM 51.7) to Roberts Ferry Bridge (RM 39.6). River flows were approximately 90 cfs. The surveys were conducted by canoe and on foot using snorkel and Silvey rod to assess all fine sediment deposits for boundaries, type, average depth, textures, and geomorphic association in pools delineated in 1997 by EA (the pool habitat units comprised runs, side channels, bedrock chutes and backwater areas under flow conditions of 620 cfs) and adjacent areas within the bankfull-flow channel. Additionally, substrate characteristics and maximum depth in all pools were investigated. Locations of current riffles were checked against the 1997 locations. The confluences of Gasburg, Dominici, and Peasley creeks were briefly investigated for signs of sediment loading relative to transport capacity.

To help guide the field reconnaissance, all 1999 1:1,200 scale aerial photos (stored on a CD ROM) were examined in the office for preliminary identification of fine sediment deposits. In the field, all fine sediment deposits located within river's active channel were identified and sketched on the maps. The active channel was defined as a "bankfull" channel under the current post-dam hydraulic regime (approx. 3,000 cfs). Due to the nearly rectangular low-flow channel bank sections, the location of the 90-cfs low-flow channel boundaries approximated the 620-cfs wetted perimeter on the 1997 inundation maps for the purpose of mapping in the field during the surveys. The areas that lay between the 1,000-cfs to 3,000-cfs wetted perimeters adjacent to the low-flow channel were investigated to a limited extent and no further than 150 meters (500 feet) away from the low-flow channel boundary.

Maps: Two sets of maps were used for the field surveys. From the USGS gauge station (RM 52) downstream to New Basso Bridge, fine sediment deposit boundaries were mapped onto recent (1997) 1:6,000-scale aerial photos (Aerial Photgraphs 1–4) and their attributes recorded on Tables 1 and 2. The 1:6,000-scale photos were generated from the original 1:24,000-scale aerial photos (TID 1997 [KAV]?). From the New Basso Bridge to Roberts Ferry Bridge, fine sediment deposits were mapped onto laminated maps featuring channel habitat type and various inundation surfaces made prior to the 1997 floods (Aerial Photgraphs 5-9, TID 1997; Tables 1 and 2).

Pool Habitat Units: All pools were numbered consecutively (Aerial Photgraphs 1-9; Tables 1 and 2) and located by the upstream and downstream riffle or pool designations on the 1997 inundation maps (except for the relict Special Run Pools of mining origin). Data collected in each pool included: maximum depth (using depth sounder); visual estimate of percent area alluvium/bedrock (100% alluvium assumed, unless noted otherwise); visual assessment of substrate characteristics (by texture and presence of sand in the substrate matrix and on the surface of the bed substrate in the form of veneer); a photograph of the streambed substrate, and assessment of discreet fine sediment deposits. Due to summer low flow conditions during the June 19-21, 2001 surveys, the measured maximum pools depths reasonably approximated the maximum residual pool depths. The substrate texture was classified by a visually estimated areal coverage of each size fraction (*e.g.,* gravel and cobble (or cobble and gravel)=50/50; gravel (cobble) with cobble (gravel) =70/30; gravel and/with cobble and some boulder = 40/40/20; mossy substrate). The substrate sand veneer was characterized as follows: no or thin veneer; 0.5–1 inch thick veneer, and 1–2 inch thick veneer. Sometimes embeddedness estimates were made to give a sense of degree of mantling of gravel substrate with sand or silt (generally embededdness did not exceed 50% for 0.5–1 inch thick veneer). Assessment of discreet fine sediment deposits is described further below.

Discreet Fine Sediment Deposits: All discreet fine sediment deposits were noted and sketched on the field maps (Aerial Photgraphs 1-9). The discreet fine sediment deposits surveyed included those located within the low-flow channel (in the form of mainstem or side channel pool bottom sand/silt deposit, or mainstem or side channel in-stream wetland deposit), on top of gravel bars (vegetated or unvegetated), in sand bars (vegetated or unvegetated), and overbank sand deposits (unvegetated deposits on 1,000–3,000-cfs surfaces adjacent to the mainstem river channel). Extensive side channels or pits were not thoroughly investigated due to time constraints; extent of fine sediment deposits in these areas was roughly estimated, as indicated by question marks on the photos and maps (Aerial Photgraphs 1–9).

All fine sediment deposits were associated with a habitat type (*e.g.,* riffle, pool, bar) and categorized by the percentage of their areal extent within and outside the low-flow channel (Tables 1 and 2). Deposit textures (Table 1) were classified as follows: SA=sand, SI=silt, MUD=mud. The first component implies dominance (*e.g.,* SISA implies dominant silt mixed with sand). Deposit depths were measured with a Silvey rod. Fine sediment depth was determined by probing with the rod through sand or silt until the rod stroke coarser streambed material. When deposits appeared variably thick or irregular in shape, several depth measurements were taken for averaging. Otherwise only a few measurements of depth were taken. Degree of consolidation was not systematically assessed due to time constraints, but the conditions for unvegetated deposits ranged from loose to compacted. On that basis, a range of dry bulk densities from 1.14 to 1.86 t/m^3 reported for reservoir sediment in northern California (Anderson 1975) were used to convert from bulk volume to mass.

Tributaries: All three confluences (*i.e.,* Gasburg, Peasley, and Dominici creeks) were inspected from the river and by walking a short reach upstream of their confluence with the mainstem Tuolumne River. At each tributary, channel dimensions and geomorphic association were noted to assess relative contributions of fine sediment to the mainstem river.

RESULTS

General Observations: To help guide the field reconnaissance, all 1999 1:1,200 scale aerial photos (stored on a CD ROM) were examined in the office for preliminary identification of fine sediment deposits. Only a few deposits identified from these turned out to be substantial discreet fine sediment deposits. The majority was found to be approximately 1-inch thick veneer of sand on the pool streambed substrate. Interestingly, comparison between the pre-1997 inundation and habitat maps and the most recent (McBain & Trush) habitat maps suggests only minor changes in riffle areas and locations only, and the changes were generally limited to changes in shape of the riffles. The greatest changes have occurred between Old La Grange Bridge and Basso Bridge, where some riffles have been substantially re-formed in this reach. In the lower reach from New Basso Bridge to Roberts Ferry Bridge, most of the riffle locations and sizes have remained unchanged since 1997, except for a few which either have been broken down to a series of pool-riffle short segments or have actually increased in length (noted on maps). A number of submerged riffles, generally less than one channel width long but at least 1-meter below the water surface, were identified in the middle of long and deep pool runs.

Pool Substrates: Most of the mainstem pools have surface substrates of sand-rich (even sand matrix-supported) mixed gravel and cobble. Most of the pools have a sand veneer (veneer thickness varied from 0.5 to 2 inches, thicker veneers were sketched on the habitat maps as dashed blue polygons). Upon visual inspection of the surface bed (involving partial removal of the pavement layer in several pools), the sand content in the surface substrate appeared high in all pools. In several cases the gravel interstitial space was fully infilled with sand, implying a sand content of at least 40% of the gravel if a typical porosity is assumed.

No spatial distribution or pattern in the degree of mantling was apparent in the field. Often, ‘dirty’ substrate pools were abruptly followed by ‘clean’ substrate pools, and vice versa, etc. Further inspection of the field maps may reveal associations between potential sediment source areas (*e.g.,* pits, side channels) and observed sand conditions in the mainstem channel. Observations in the sub-reach below SRP 4 and above Roberts Ferry Bridge showed the pool substrates that were generally mossy.

Discreet Fine Sediment Deposits: Discreet fine sediment deposits identified in the field are summarized in Tables 1 and 2. These deposits were mapped as blue infill polygons on Aerial Photgraphs 1–9 of the survey maps for GIS entry. Information regarding the pool substrate fine sediment veneer has not been mapped on the survey maps except for veneers thicker than 2 inches (such appear as dashed blue polygons). In general, all alluvial stream banks outside the bankfull-flow channel appeared relatively stable, and no substantial streamside cliff sources of sediment were observed. As noted above, all streambed surface and subsurface substrates investigated appeared rich in sand, implying a large storage of sand in the subsurface.

Overall, only limited fine sediment deposits were identified in pools in the reach above Dominici Creek. Moderate storage was identified between Dominici and Peasley creeks, with the first substantial deposit located downstream of Basso Bridge below Peasley Creek. There was higher sediment storage between Peasley Creek and Roberts Ferry Bridge (one of the largest deposits was located immediately downstream of Peasley Creek) with other substantial deposits located in abandoned pits and side channels.

Table 1 shows that about 78,000 m^3 of fine sediment deposits was identified within the active channel in the study reach from the USGS gauge station to the Roberts Ferry Bridge. Assuming dry bulk density ranging from 1.14 to 1.86 t/m^3 (Anderson 1975), this volume amounts to an estimated total mass ranging from 89,000 to 145,000 tons. About 60,000 m^3 of fine sediment (77% of the total), ranging from 68,300 to 111,000 tons, is deposited in pools within the low-flow mainstem and side channels. Approximately 3,200 m^3 of sediment is stored in pools outside the low flow channel with the remaining fine deposits (15,079 m^3, or 17,000-28,000 tons) stored on top of gravel bars and in overbank sand deposits outside of the low-flow channel.

Side channel pools and wetlands store about 32,000 m^3, or 36,000-59,000 tons, approximately 40% of the total surveyed. The largest of these deposits is a wetland area just downstream of Peasley Creek with over 14,000 m^3 located at SRP 2 (Table 1). Several side channels were infilled with wetland-type fine sediment to capacity, likely concealing pool topography.

Tributaries: For the three tributaries surveyed, Peasley Creek appeared to be the largest contributor of fine sediment downstream of Basso Bridge. The first deposit downstream of Gasburg Creek Deposit 4 on Table 1) was estimated at 4,050 m^3 of fine sediment, with approximately 1,200 m^3 deposited in Pool 16 below Dominici Creek (Table 2). However, the largest single deposit associated with tributary input lies within a wetland area just downstream of Peasley Creek with over 14,000 m^3 located at SRP 2 (Table 1). The three tributaries are summarized below:

Gasburg Creek: The 5-meter (16 feet) wide creek gently cuts across the mainstem's gravel pre-dam 10-yr (estimate) floodplain for about 200 meters before it exits into pool No.7, located between riffles R1A and R1B (Aerial Photgraphs 1 and 2). A brief inspection of the upland reach of the creek did not reveal evidence of recent downcutting (the creek banks are composed of alluvium and appear stable). The streambed was comprised of sand-matrix-supported gravel with no evidence of sand loading beyond river's transport capacity (no recent sand bars or overbank sand deposits). Most overbank sand deposits located on the mainstem's pre-dam 10-yr floodplain appear to be of 1997 origin based on vegetation. A three-meter-high (10 feet) gravel delta/bar located at the confluence between low-flow channels of the Tuolumne River and Gasburg Creek appears to be of 1997 origin based on vegetation.

Dominici Creek: The 5-meter (16 feet) wide creek exits in pool No. 16 located between riffles R5B and R6 (Aerial Photgraph 3). Comparison of aerial photos and maps shows that the generalized floodplain delineation in the 1997 inundation maps in this area needs field verification. No delta deposit was associated with the confluence was observed, suggesting only moderate sediment supply. The creek channel appeared historically entrenched.; The streamside banks exhibited moderate erosion. The streambed characteristics were not investigated due to access constraints, but signs of high sediment supply (gravel bars, thick streambed) were observed.

Peasley Creek: The 3-5 meter (10-16 feet) wide creek exits in pool No. 28, located between the riffle R13B and pool SRP2 (Aerial Photgraph 5). Comparison of aerial photos and maps shows that the generalized floodplain delineation in the 1997 inundation maps in this area needs field verification. A 20 m^2 (200 ft^2) sand delta was observed at the confluence with the mainstem Tuolumne River. A two-meter (6-feet) high bedrock knickpoint in the streambed is located at 70 meters (230 feet) upstream of the confluence. Upstream of the knickpoint the channel appeared historically entrenched by 1–1.5 meters (3–5 feet) and the streambed was sand-matrix-supported medium gravel. Downstream of the knickpoint, the streambed consisted of 0.3–1-meter (1- to 3-feet) thick sand. Although the streamside banks appeared relatively stable (showing only ravel and minor slumps), this creek appeared to be the highest contributor of fine sediment of all three tributaries. At least two irrigation canal crossings on this creek possibly contribute to local erosion and sediment supply downstream.

DISCUSSION

Removal of Existing Fine Sediment Storage: Assessing the feasibility of mechanical or suction dredging removal of pool deposits of fine sediment in terms of the existing sediment inventory suggest that dredging of pools above Basso Bridge (where most useable spawning area occurs) is probably not warranted. The majority of pools in the upper river reaches above Basso Bridge were “clean”, exhibiting only a veneer of sand over sand-rich mixed gravel and cobble. However, fine sediment deposition increases markedly in pools below Basso Bridge (Table 2) and attaining improved in spawning gravels in riffles in the lower reaches may require some removal of these deposits.

Quantifying Rates of Fine Sediment Supply: Both the effectiveness of any proposal for dredging pool deposits or riffle cleaning requires an assessment of re-supply from upstream sources. Based on inspection of tributary junctions none of the three tributaries appeared to be delivering large amounts of sediment to the mainstem river at present, suggesting that the current sand-rich conditions on the mainstem Tuolumne River may either be a legacy of the 1997 flood event, which transported approximately 200,000 yd^3 of sand to the lower Tuolumne River (McBain & Trush 2000), and/or are related to other sources of sediment (bleeding pits or side channels). The observed sand-rich conditions may also be related to long-term immobility of the channel bed as a result of decreased peak flows. However, all three tributaries exhibited evidence of historic entrenchment and sediment-rich conditions in the streambed substrate, implying a need for sediment source analysis to quantify sediment delivery to the mainstem river.

Although fine sediment transport generally exceeds coarse sediment transport rates by an order of magnitude, fine sediment transport is limited by the rate of upstream supply. Without further knowledge of characteristics of the alluvial river mantle (average total depth to bedrock or inactive valley fill, and overall sand content; active sand deposits on the floodplains, etc.) and sediment supply from upstream of the La Grange Dam and main tributaries, we cannot adequately answer whether dredging the fine sediment deposits located within the low-flow channel pools will lead to reduction of in-channel fine sediment transport and thus sand re-infiltration in downstream riffles that may be cleaned.

CONCLUSIONS

Estimated total mass of fine sediment deposits within the active channel in the study reach from RM 51.7 (d/s USGS gauge station) to RM 39.6 (Roberts Ferry Bridge) ranges from 89,000 to 146,000 tons. Approximately 66% (or 59,000–97,000 tons) of the total fine sediment storage inventoried was associated with low-flow channel pools, with an additional 4% (or 3,700-6,000 tons) in side channel pools and wetland habitats. Although the majority of pools in the upper reaches above Basso Bridge had little or no discreet fine sediment deposits, nearly all pool substrates were filled with sand in the interstitial spaces. Sand deposition in pools increased markedly below Basso Bridge.

Although none of the three main tributaries (*i.e.,* Gasburg, Dominici, and Peasley Creeks) appeared to be delivering large amounts of sediment to the mainstem river at present, we cannot make confident conclusions without a more thorough sediment source analysis. The 20 m^2 sand delta and 14,400 m^3 deposit below Peasley Creek suggests that this is the largest tributary source of fine sediment to the lower Tuolumne River. Other sources, such as bars, riffles and overbank sand deposits within the low flow channel (10% of the inventoried total or 9,000–15,000 tons) and in the 1,000-3,100 cfs floodplain (19% of the total or 17,000–28,000 tons) could be transported downstream under high flow conditions and deposit in the tributary confluences or other areas. These latter sources and fine sediment deposits located between the low-flow and bankfull-flow channel boundaries should be considered carefully because they may exceed fine sediment delivery from all three tributaries below La Grange Dam.

Although removal of stored sediment in pools above Basso Bridge may not be warranted at this time, the feasibility of gravel cleaning methods has not yet been evaluated. Because fine sediment transport rates directly determine the rates of re-deposition in pools and riffle interstices, a separate sediment source analysis may be required to adequately quantify the rates of re-supply of fine sediment in the lower Tuolumne River.

REFERENCES

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McBain & Trush (2000). Habitat restoration plan for the lower Tuolumne River corridor. March.

Table 1 - Fine Sediment Deposits Surveyed in the lower Tuolumne River, June 19-21, 2000.

Discreet Fine Sediment Deposit No.	1997 location (up/ downstream)	Habitat unit	Pool No.	Ave. Deposit depth, m	% above low-flow LF channel	% in low-flow LF channel	Texture	Est. area, m2	Est. volume, m3	Est. volume within LC, m3	GIS area, m2	GIS-based volume, m3	Comment
1	RA3B-RA5A	LF mainstem pool	1	0.13	0	100	SA	80	10.4	10.4			
2	RA5A-RA5B	LF mainstem pool	2	0.15	0	100	SA	15	2.25	2.3			
	RA5B-RA6	LF mainstem pool	3										
	SRP1	LF mainstem pool	4										
	SRP1-RA7B	LF mainstem pool	5										
3	RA7B-R1A	LF mainstem pool	6	0.14	0	100	SA	60	8.4	8.4			
	R1A-R1B	LF mainstem pool	7										
4	R1B-R1C	LF mainstem pool	8	0.75	0	100	SA	5400	4050	4050			
	R1C-R2	LF mainstem pool	9										
	R2-R3A	LF mainstem pool	10										
	R3A-R3B	LF mainstem pool	11										
5	R3B-R4A	LF mainstem pool	12	0.4	20	80	SA	2700	1080	864			
	R4A-R4B	LF mainstem pool	13										
	R4B-R5A	LF mainstem pool	14										
6	R5A	OLF sand bar	n/a	0.6	100	0	SA	3300	1980	0			overbank sand deposit (OSD), sand bar
	R5A-R5B	LF mainstem pool	15										
7	R5B	OLF sand bar	n/a	0.75	100	0	SA	1800	1350	0			OSD, sand bar
8	R5B-R6	LF mainstem pool	16	0.15	0	100	SASI	240	36	36			
9	R5B-R6	LF mainstem pool	16	0.3	0	100	SASIMUD	1300	390	390			
10	R5B-R6	OLF sand bar	n/a	0.3	100	0	SA	300	90	0			OSD, sand bar
11	R5B-R6	LF mainstem pool	16	0.11	0	100	SASIMUD	5400	594	594			could be Dominici Cr related
12	R5B-R6	OLF lateral bar	n/a	0.5	100	0	SA	3000	1500	0			vegetated OSD, sand bar
13	R5B-R6	LF mainstem pool	16	0.5	0	100	SA	450	225	225			deep riffle, part of pool
	R6-R7	LF mainstem pool	17										
	R7-R8	LF mainstem pool	18										
14	R8-R9A	OLF sand bar	n/a	0.6	100	0	SASI	6000	3600	0			vegetated sand bar
15	R9A-R9B	LF riffle	n/a	0.6	0	100	SA	2400	1440	1440			in-stream side channel (SC) wetland; deep riffle
16	R9A-R9B	LF side channel pool	19	0.6	0	100	SASI	130	78	78			sand deposit at the mouth of the side channel
17	R9A-R9B	LF side channel pool	19	0.15	0	100	SASIMUD	6400	960	960			SC wetland/pond
18	R9A-R9B	LF sand bar	n/a	0.6	100	0	SA	200	120	0			vegetated sand bar
19	R9B-R11	LF mainstem pool	20	0.6	0	100	SISA	200	120	120			
20	R11-R12A	LF mainstem pool	21	0.9	0	100	SA	140	126	126			
21	R11-R12A	LF side channel pool	21	0.15	0	100	SA	1000	150	150			SC pool deposit, as long as SC
22	R11-R12A	LF SC and mainstem pool	21	0.75	0	100	SISA	4800	3600	3600			wetland located in both main and side channel (50%)
23	R12A-R12B	LF mainstem pool	22	0.75	0	100	SASI	1200	900	900			
24	R12A-R12B	LF mainstem pool	22	0.9	50	50	SA	1500	1350	675			
25	R12A-R12B	LF mainstem pool	22	0.11	0	100	SASI	1000	110	110			
26	R12B-R13A	LF sand bar	n/a	0.9	50	50	SA	300	270	135			unvegetated sand bar
27	R12B-R13A	LF sand bar	n/a	0.9	50	50	SA	300	270	135			unvegetated sand bar
28	R13A-R13B	LF riffle	n/a	0.15	0	100	SA	300	45	45			former pool
29	R13B	LF riffle	n/a	0.6	50	50	SA	130	78	39			vegetated sand bar
30	R13B	LF riffle	n/a	0.6	50	50	SA	100	60	30			unvegetated sand deposit
31	R13B	OLF mid-channel gr. bar	n/a	1.5	100	0	SA	150	225	0			vegetated sand mantle on top of GR bar
32	R13B-SRP2	LF mainstem pool	23	0.6	20	80	SASI	3600	2160	1728			
33	R13B-SRP2	LF mainstem pool	23	0.9	0	100	SA	1800	1620	1620			
34	SRP2	LF mainstem pool	24	0.6	0	100	SA	150	90	90			
35	SRP2	OLF gravel bar	n/a	1.7	100	0	SA	150	255	0			gravel bar with sand deposit
36	SRP2	LF mainstem pool	24	0.9	0	100	SASI	16000	14400	14400			in-stream mainstem wetland, major deposit
	R14-R15	LF mainstem pool	25										

Table 1 - Fine Sediment Deposits Surveyed in the lower Tuolumne River, June 19-21, 2000.

Discreet Fine Sediment Deposit No.	1997 location (up/ downstream)	Habitat unit	Pool No.	Ave. Deposit depth, m	% above low-flow LF channel	% in low-flow LF channel	Texture	Est. area, m2	Est. volume, m3	Est. volume within LC, m3	GIS area, m2	GIS-based volume, m3	Comment
	R15-R16A	LF mainstem pool	26										
37	R16A-R16B	LF mainstem pool	27	1.2	0	100	SASI	800	960	960			
38	R16B-R16C	LF mainstem pool	28	0.6	0	100	SASI	200	120	120			
39	R16B-R16C	OLF mid-channel gravel bar	n/a	1.1	100	0	SASI	200	220	0			vegetated gravel bar with sand deposit
40	R16C-R17A1	LF mainstem pool	29	0.75	0	100	SA	100	75	75			
41	R17A1-R17A2	LF riffle	n/a	1.2	0	100	SASI	600	720	720			former pool
42	R17A1-R17A2	LF riffle area & OLFsand bars	n/a	1.5	50	50	SASI	7000	10500	5250			OSD, sand bars (50% area)
43	R17A2-R17B	LF pool & OLF sand bar	n/a	0.75	50	50	SA	400	300	150			OSD, sand bars (50% area)
44	R17A2-R17B	LF mainstem pool	30	1.2	50	50	SA	400	480	240			wetland
45	SRP3	LF mainstem pool	31	0.9	0	100	SIMUD	5300	4770	4770			
46	SRP3	OLF?/LF? side channel pool	31	0.9	0	100	SIMUD	5000	4500	4500			wetland is formerly LF pool infilled to capacity now
47A	SRP3	LF mainstem pool	31	0.3	50	50	SA	700	210	105			
47B	R18-R19	LF mainstem pool	32	0.9	50	50	SASI	2400	2160	1080			
48	R18-R19	LF mainstem pool	32	0.3	0	100	SISA	120	36	36			
49	R19-R20	LF side channel pool	33	1.2	0	100	SASI	5800	6960	6960			wetland; need to investigate the extent of deposit
50	R20-R21	LF mainstem pool	34	0.15	50	50	SA	600	90	45			
51	R21-R22S	LF mainstem pool	35	0.75	50	50	SASI	1000	750	375			
	R22S-R23A1	LF mainstem pool	36										
52	R23A1-R23A2	LF mainstem pool	37	0.45	50	50	SIMUD	250	112.5	56			
	R23A2-R23C1S	LF mainstem pool	38										
	R23C1S-R23C2	LF mainstem pool	39										
53	R23D	LF side channel pool	40	0.6	0	100	SASIMUD	1000	600	600			in-stream SC wetland
	R23D-R24S	LF mainstem pool	41										
	R24S--R25	LF mainstem pool	42										
54	R25	LF riffle	n/a	0.15	0	100	SIMUD	250	37.5	38			vegetated sand deposit
	R25-SRP4	LF mainstem pool	43										
55	SRP4	LF mainstem pool	44	0.3	0	100	SA	4000	1200	1200			
56	SRP4	LF mainstem pool	45	0.11	0	100	SIMUD	900	99	99			
	R26-R27A	LF mainstem pool	45										
	R27A-R27B	LF mainstem pool	46										
	R27B-R28A	LF mainstem pool	47										
	R28A-R28B	LF mainstem pool	48										
					23%	77%			**78243**	59940	Total within Low flow		
									31728	31488			
									55183	51958	Total Mass in Low Flow Pools		
										3224	Pool Deposits between 1,000-3,000 cfs wetted Perimeter		
					1.14 to 1.86 t/m3 (Anderson 1975)				20680	5670	Bars within Low Flow		
Est. total within the bankfull-flow channel surveyed: 78,243 m^3, or					**89,197**	**145,532 tons**				15010	Overbank Sand Deposits and Bars between 1000-3100 cfs wetted Perimeter		
Est. total within the low-flow channel: 59,940 m^3, or					**68,331**	**111,488 tons**			2381	2312	Riffles within Low Flow		
Est. total in Pools outside Low Flow Channel: 3,224 m^3 , or					**3,676**	**5,997 tons**				69	Riffles Between 1,000-3100 cfs Wetted PerimeterOutside Low Flow		
Est. total in Bars, Riffles and Overbank Dep. Within Low Flow: 7,982 m^3, or					**9,099**	**14,846**							
Est. total in Bars, Riffles and Overbank Dep. Outside Low Flow: 15,079 m^3, or					**17,190**	**28,047 tons**							

Table 2 - Fine Sediment Deposits in Pools Surveyed in the Lower Tuolumne River, June 19-21, 2001

1997 pool No.	1997 location (up/ downstream)	Habitat unit	Max Water Depth, m	Pool Substrate	Predominant Sand Cover	Discreet Fine Sediment Deposit No.	Deposit Texture	Avg depth of deposit, m	est. area, m^2	Tot est. volume, m^3	GIS area, m^2	Tot Volume, m^3	% outside low-flow channel	% in low-flow channel	Total Mass, t	Mass in LF pools, ton
1	RA3B-RA5A	LF mainstem pool	3	GR-CO	0.5-1" veneer	1	SA	0.13	80	10.4			0	100	10.4	10
2	RA5A-RA5B	LF mainstem pool	3	GR	0.5-1" veneer	2	SA	0.15	15	2.25			0	100	2.25	2
3	RA5B-RA6	LF mainstem pool	3	CO	clean											
4	SRP1	LF mainstem pool	5	BO-GR-CO	0.5-1" veneer											
5	SRP1-RA7B	LF mainstem pool	n/a	GR-CO	clean											
6	RA7B-R1A	LF mainstem pool	3	GR-CO	clean	3	SA	0.14	60	8.4			0	100	8.4	8
7	R1A-R1B	LF mainstem pool	4	GR	0.5-1" veneer											
8	R1B-R1C	LF mainstem pool	3	GR	n/a	4	SA	0.75	5400	4050			0	100	4050	4050
9	R1C-R2	LF mainstem pool	2	GR-CO	clean											
10	R2-R3A	LF mainstem pool	4	GR-BDR (20%)	clean											
11	R3A-R3B	LF mainstem pool	3	GR	0.5-1" veneer											
12	R3B-R4A	LF mainstem pool	2	GR-CO	clean	5	SA	0.40	2700	1080			20	80	1080	864
13	R4A-R4B	LF mainstem pool	1.3	CO-GR	clean											
14	R4B-R5A	LF mainstem pool	1.2	CO-GR, wBO	clean											
15	R5A-R5B	LF mainstem pool	1.6	GR wBDR (10%), CO	clean											
16	R5B-R6	LF mainstem pool	2.3	CO wGR	0.5-1" veneer	8-9,11,13	SASIMUD	0.17	7390	1245			0	100	1245	1245
17	R6-R7	LF mainstem pool	n/a	CO-GR	0.5-1" veneer											
18	R7-R8	LF mainstem pool	1.8	GR wCO	clean											
19	R9A-R9B	LF mainstem&side channel pool	2.3	GR wCO	0.5-1" veneer	16-18	SASIMUD	0.17	6730	1158			0	100	1038	1038
20	R9B-R11	LF mainstem pool	2.3	GR-CO	0.5-1" veneer	19	SISA	0.60	200	120			0	100	120	120
21	R11-R12A	LF mainstem&side channel pool	2.5	FiGR	clean	20-22	SASI	0.65	5940	3876			0	100	3876	3876
22	R12A-R12B	LF mainstem pool	1.5	GR	1-2" veneer	23-25	SASI	0.64	3700	2360			29	71	2360	1685
23	R13B-SRP2	LF mainstem pool	1.3	GR wCO	1-2" veneer	32-33	SASI	0.70	5400	3780			11	89	3780	3348
24	SRP2	LF mainstem pool	3.4	GR wCO	0.5-1" veneer	34, 36	SASI	0.90	16150	14490.02			0	100	14490.02	14490.02
25	R14-R15	LF mainstem pool	1.2	GR	clean											
26	R15-R16A	LF mainstem pool	2	GR	clean											
27	R16A-R16B	LF mainstem pool	0.5	GR	clean	37	SASI	1.20	800	960			0	100	960	960
28	R16B-R16C	LF mainstem pool	1.5	GR	0.5-1" veneer	38	SASI	0.60	200	120			0	100	120	120
29	R16C-R17A1	LF mainstem pool	1	CO wGR	clean	40	SA	0.75	100	75			0	100	75	75
30	R17A2-R17B	LF mainstem pool&bar	1.3	GR	1-2" veneer	44	SA	1.20	400	480			50	50	480	240
31	SRP3	LF mainstem&SC pool	2.3	CO wGR, BDR (30%)	1-2" veneer	45,46,47A	SIMUD	0.86	11000	9480			1	99	9480	9375
32	R18-R19	LF mainstem pool	2.5	CO wGR	1-2" veneer	47B-48	SASI	0.87	2520	2196			49	51	2196	1116
33	R19-R20	LF side channel pool	1.5	CO-GR	0.5-1" veneer	49	SASI	1.20	5800	6960			0	100	6960	6960
34	R20-R21	LF mainstem pool	2	GR wCO	clean	50	SA	0.15	600	90			50	50	90	45
35	R21-R22S	LF mainstem pool	2.1	CO wGR	0.5-1" veneer	51	SASI	0.75	1000	750			50	50	750	375
36	R22S-R23A1	LF mainstem pool	2.1	CO wGR	0.5-1" veneer											
37	R23A1-R23A2	LF mainstem pool	n/a	n/a	n/a	52	SIMUD	0.45	250	112.5			50	50	112.5	56.25
38	R23A2-R23C1S	LF mainstem pool	1	CO-GR	clean											
39	R23C1S-R23C2	LF mainstem pool	0.9	GR wCO	clean											
40	R23C2-R23D	LF side channel pool	0.6	CO wGR	clean	53	SASIMUD	0.60	1000	600			0	100	600	600
41	R23D-R24S	LF mainstem pool	1	CO wGR	0.5-1" veneer											
42	R24S-R25	LF mainstem pool	2.3	CO wGR	0.5-1" veneer											
43	R25-SRP4	LF mainstem pool	1	GR, BDR (50%)	clean											
44	SRP4	LF mainstem pool	4.3	CO wGR	0.5-1" veneer	55-56	SASIMUD	0.27	4900	1299			0	100	1299	1299
45	R26-R27A	LF mainstem pool	2.1	GR	algae											
46	R27A-R27B	LF mainstem pool	n/a	n/a	n/a											
47	R27B-R28A	LF mainstem pool	0.5	GR wCO	algae											
48	R28A-R28B	LF mainstem pool	2	GR wCO, BDR (20-30%)	some algae											
													6%	94%	55183	51959
																3224

Est. total within the Low Flow Channel Pools: 51,959 m^3, or 59,000 to 97,000 tons

Est. total in Pools outside Low Flow Channel: 3,224 m^3 , or 3,700 to 6,000 tons

Aerial Photographs 1 - 4: Fine sediment deposit boundaries were mapped onto recent (1997) 1:6,000-scale aerial photos from the USGS gauge station (RM 52) downstream to New Basso Bridge. The 1:6,000-scale photos were generated from the original 1:24,000-scale aerial photos (TID 1997).

Aerial Photographs 5 - 9: Fine sediment deposits from the New Basso Bridge to Roberts Ferry Bridge, were mapped onto laminated maps featuring channel habitat type and various inundation surfaces made prior to the 1997 floods.

Aerial photograph sets are available upon request.

Appendix F

Evaluation of Fine Sediment Removal Methods for use in the Tuolumne River - Stillwater Sciences Technical Memorandum

Stillwater Sciences

2532 Durant Avenue, Suite 201 Berkeley, CA 94704 Phone (510) 848-8098 Fax (510) 848-8398

TECHNICAL MEMORANDUM

DATE: November 18, 2002

TO: McBain & Trush

FROM: Noah Hume, Peter Baker and Jay Stallman

SUBJECT: Evaluation of Fine Sediment Removal Methods for use in the Tuolumne River

INTRODUCTION

Previous studies of the quality of spawning gravels in the lower Tuolumne River in 1988 and 1989 attributed low salmonid survival-to-emergence rates to poor riffle quality, which has resulted from the deposition of fine sediment in the gravel substrate (TID/MID 1992a). Recent gravel permeability studies have reinforced this supposition (Stillwater Sciences 2001). Gravel quality is a key factor influencing the success of incubation and emergence of salmonid eggs and alevins. Accumulation of fine sediment in spawning gravel reduces salmonid survival-to-emergence through two mechanisms: (1) reduction of intragravel flow, and (2) entombment of emerging fry. The intrusion of fine sediment into gravel interstices reduces intragravel flow by reducing gravel permeability (Cooper 1965, Lotspeich and Everest 1981, McNeil 1960, Platts et al. 1979) and results in reduced rates of oxygen delivery to and removal of metabolic wastes (carbon dioxide and ammonia) from the eggs and alevins (Coble 1961, Silver et al. 1963, McNeil 1960, Wickett 1958). Fine sediments in the gravel interstices can also physically impair the ability of alevins to emerge through the gravel layer, trapping (or entombing) them within the gravel (Philips et al. 1975, Hausle and Coble 1976).

The Habitat Restoration Plan for the Lower Tuolumne River Corridor (McBain and Trush 2000) recommended that coarse sediment supply be increased and fine sediment supply be reduced, with the overall goal of improving spawning habitat conditions for salmon. The Tuolumne River Technical Advisory Committee (TRTAC) is preparing overall sediment management and implementation plans to address these issues. The Turlock and Modesto Irrigation Districts (the Districts) contracted McBain and Trush to develop a Coarse Sediment Management Plan for the lower Tuolumne River (funded by the implement an Anadromous Fisheries Restoration Program (AFRP) funded Coarse Sediment Management Plan for the lower Tuolumne River. The Districts have also received funding to develop a Fine Sediment Management Plan for the lower Tuolumne River, and have retained Stillwater Sciences to complete this work. As a component of the Coarse Sediment project, Stillwater Sciences recently completed two tasks to summarize existing information regarding potential fine sediment removal:

1) A literature review and evaluation of fine sediment removal methods from similar alluvial rivers used by salmonids in California (Feather and Trinity Rivers), Idaho (Palouse River) and Washington (Cedar, Nadina, and Horsefly Rivers), among others.
2) An evaluation of the cost and effectiveness of mechanical gravel cleaning methods used by the Turlock and Modesto (TID/MID) Irrigation Districts in the early 1990s.

REVIEW OF FINE SEDIMENT SOURCE CONTROL METHODS

Several non-flow source control measures may reduce the rate of introduction of fine sediments in the primary spawning reach of the lower Tuolumne River, including changes in upstream land use and a number of-instream control measures. Although the LaGrange and Don Pedro dams act as highly efficient sediment traps, they are located above several sediment sources (*e.g.,* Gasburg Creek, Dominici Creek, etc.) to the Tuolumne River. For dams located above major fine sediment sources, substantial deposition of sediments is likely to occur (Reider et. al. 1989), particularly given the generally lowered hydrograph peaks and flushing capacities under natural flow conditions. Einstein (1968) found that the rate of accumulation of fine sediment in spawning gravels is dependent of the concentration of suspended sediment, but is independent of either the flow velocity or the amount of material already present in interstices. This reinforces the need for a fine sediment source control program prior to the implementation of a gravel cleaning program. Below we describe several methods for reducing fine sediment inputs into the Tuolumne River.

Land Use Changes. Although the sediment contribution to streams from roads is often much greater than that of other land management use activities (Gibbons and Salo, 1973, Reid 1981) a number of historical land uses (e.g., sand mining, road and canal cuts, etc.) have resulted in soil instability with the potential for landslides and erosion (Stillwater Sciences 2002a). With the exception of large flood events such as the 1997 floods, recent field surveys have identified Gasburg and Dominici Creeks as chronic sources of fine sediment to the lower Tuolumne River. The most effective means for controlling fine sediment inputs is to eliminate the sediment sources by stabilizing disturbed lands. In the absence of soil stabilization techniques for past construction activities or long term changes in land use, perhaps the most effective means of fine sediment source control from the tributary watersheds in the near term is the use of sedimentation basins.

Sedimentation Basins. The current Fine Sediment Management Project Plan includes the design and construction of a sedimentation basin on Gasburg Creek, which is the furthest upstream tributary in the spawning reach of the Tuolumne River. Sedimentation basins provide a passive means of reducing or eliminating input of the coarser sand component of fine sediment from flowing water. Although gravity settling of solids that have a specific gravity greater than water is well understood, sedimentation basins are ineffective in the removal of silts and clays with low settling velocities. In general, sedimentation basin effectiveness will depend upon the size of the basin, the upstream sediment load, and the frequency of cleaning.

Suction Dredge Removal of Pool Deposits. As part of the overall Coarse Sediment Management Plan, in June 2001 Stillwater Sciences conducted a three day snorkel survey of fine sediment deposits of the lower Tuolumne River from the USGS gauging station below La Grange Dam (RM 52.0) to Robert's Ferry Bridge (RM 39.6). Approximately 65,000 m^3 (104,000 tons, assuming a bulk density of 1.6 tons/m^3) were mapped, and about 70 % of the total volume was deposited in low-flow pools, with about 5 % in pools outside the low-flow channel, and the remainder deposited on top of gravel bars and as overbank deposits. One question arises is whether removal of these deposits using suction dredges will reduce the rate of downstream transport and affect re-infiltration of fine sediments into recently cleaned gravels. Although suction dredging in spawning gravels for gold mining has a number of short-term impacts on invertebrate communities and spawning use (Harvey and Lisle 1999), dredging in pools is not considered to represent a major impact provided the materials are not discharged onto downstream gravels. Suction dredging methods for removal of sand from pools will be evaluated under the Tuolumne River Fine Sediment Project.

Mechanical Removal from Riparian Berms and Floodplain. The primary spawning reach of the Tuolumne River below La Grange and Don Pedro dams is characterized as a low gradient, meandering alluvial river by relatively low gradients than those historically used by the anadromous fishes of the Tuolumne River. Because the upstream dams interrupt the sediment supply from the watershed, the resupply of spawning gravels is largely limited to bank erosion of the relict floodplain deposits. The current regulated flow regime mobilizes these materials much less frequently than the natural flow regime and consequently, there has been a significant accumulation of fine sediments both within the bankfull channel, and on floodplain surfaces. These floodplain deposits are prone to remobilization during infrequent overbank flows. One solution to reducing the rates of fine sediment re-introduction into the spawning reach into the channel is mechanical excavation, sorting, and removal of fines and replacement. Although the costs of this strategy are high due to the vast magnitude of floodplain deposits (on the order of hundreds of thousands of cubic yards), these should be addressed in comparison to the costs of coarse sediment importation from long distances. There is potential for cost reduction by prioritizing for excavation large deposits closer to the channel. The primary question that we sought to address in our literature review is how the fine sediment currently stored in the spawning gravels of the lower Tuolumne River can be removed most economically, either by mechanical or hydraulic means.

REVIEW OF FINE SEDIMENT REMOVAL METHODS

In addition to the source control measures discussed above, other approaches (i.e., engineered, mechanical) have been proposed to reduce the impact of fine sediments on spawning and incubation conditions in the lower Tuolumne River. The primary question that we sought to address in our literature review is how the fine sediment currently stored in the spawning gravels of the lower Tuolumne River can be removed most economically, either by mechanical or hydraulic means. We evaluated several mechanical and hydraulic methods for fine sediment removal from the spawning reach, including suction dredging from pools, disruption of the coarse armor layer by gravel ripping, gravel excavation and replacement, hydraulic disturbance, and other gravel cleaning methods. This review supplements and extensive review of existing gravel cleaning methodologies completed for the District’s in 1991 (TID/MID 1992b) and is separated into mechanical and hydraulic methodologies, summarized in Tables 1 and 2.

Suction Dredge Removal of Pool Deposits. As part of the Coarse Sediment Management Plan, in June 2001 Stillwater Sciences conducted a three day snorkel survey to identify fine sediment deposits in the lower Tuolumne River from the USGS gauging station below La Grange Dam (RM 52.0) to Robert’s Ferry Bridge (RM 39.6). Approximately 65,000 m^3 (104,000 tons, assuming a bulk density of 1.6 tons/m^3) were mapped. About 70 % of the total volume was deposited in low-flow pools, with about 5 % in pools outside the low-flow channel. The remainder was deposited on top of gravel bars and as overbank deposits. We have formulated two hypotheses regarding fine sediment reduction from pool sources. First, removal of these deposits using a suction dredge may reduce the rate of downstream transport and therefore reduce re-infiltration of fine sediments into recently cleaned gravels. Second, the annual rate of fine sediment transport may be much larger than the accumulated pool deposits and dredging effects may only last a season or more. The Tuolumne River Fine Sediment Project includes a pilot investigation of suction dredging from pools to answer these questions. Although suction dredging in spawning gravels for gold mining has a number of short-term impacts on invertebrate communities and spawning use (Harvey and Lisle 1999), dredging in pools is not considered to represent a major impact provided the materials are not discharged onto downstream gravels.

Hydraulic Gravel Cleaning Methods. In order to operate within the constraints of the current (*i.e.,* post New Don Pedro Project) flow and sediment transport regime of the lower Tuolumne River, the hydraulic methods evaluated involved inducing localized disturbance of the channel bed to mobilize fines, which allows for either suction removal or allows river flows below the bed mobilization threshold to wash them further downstream. Table 1 provides a summary of our review of available studies on hydraulic gravel cleaning methods. The simplest hydraulic methods involves baffles or gates (Einstein 1965, Mih, 1978) to use the river flows create high local velocities and shear stresses sufficient to mobilize fine sediments. A second set of techniques uses water jets from pumped water (Mundie and Mounce 1978; Mih 1979; Mih and Bailey 1981; Allen et al. 1981; Andrew 1981; Shackle et al. 1999; Shields 1968) to disrupt the armor layer of the bed and mobilize fines. However, in addition to difficulties in achieving adequate penetration of the bed, all of these methods rely on river flow to carry the fines downstream. Since, redeposition of fines in downstream spawning areas is generally considered a serious drawback, higher effectiveness rankings were assigned to these methods when used in conjunction with sedimentation ponds or other means to prevent the re-introduction of fines into the channel bed (Shields 1968, Meehan 1971, Mih 1979).

Mechanical Methods. The most common mechanical method used in removing fines from spawning gravels is a using a bulldozer to disturb the sediment and release the fines (Hall and Baker 1982). Table 2 summarizes other mechanical methods, including raking and ripping (EA 1989; Gerke 1990; Hampton 1990; Painter 1990; Shackle et al. 1999; Stemple 1990; West 1984), and gravel removal and replacement with cleaned or newly supplied gravels (Andrew 1981; Heiser 1971; Mih 1978; Wilson 1976). In cleaned areas that had an armored surface substrate, incomplete removal of the underlying sand was identified as a potential source of fine sediment load to downstream spawning areas (Mih 1978). With the exception of complete excavation and replacement with clean gravels, all of these methods, especially raking and ripping, release turbidity and suspended sediments to the water column that may deposit further downstream. In armored stream beds, disruption of the armor layer may increase bed erosion rates following cleaning and this bed instability may be have been associated with observations of spawner avoidance of gravels on the Trinity River (Hampton 1990).

High Flow Releases. The simple recreation of natural hydraulic conditions capable of mobilizing fine sediments offers promise in removal of fine sediments from the mainstem Tuolumne River. Natural flushing flows in headwater streams are the primary means of gravel sorting and maintaining spawning gravel quality for stream fishes (Kondolf et. al. 1987; Kondolf and Wilcock 1996). In laboratory studies, Einstein (1968) found that once fines are deposited in the gravel bed there is minimal upward or horizontal movement of the particles within the interstices until shear stresses are large enough to mobilize the majority of the larger particles that make up the bed. Under unimpaired conditions, high river flows mobilize coarse sediments, liberating fine sediments stored in the channel bed for downstream transport.

In contrast to headwater streams, because dams act as nearly perfect sediment traps, high flow releases should maintain lower deposition of fines in downstream spawning gravels. As a management tool, because the Tuolumne River dams are located above major several sediment sources (*e.g.,* Gasburg Creek, Dominici Creek, etc.), substantial deposition of sediments is likely to occur (Reiser et. al. 1989), particularly given the generally lowered hydrograph peaks and flushing capacities under natural flow conditions. The absence of a natural upstream coarse sediment supply means that flushing flows of sufficient magnitude to mobilize the channel bed may also deplete available spawning habitat unless the gravels are replaced by a long-term coarse sediment augmentation program.

Results. We attempted to evaluate the relative costs vs. benefits of these gravel cleaning methods by comparing the costs per unit area of coarse gravel cleaned, and the effectiveness of each technique in removing fines. Only limited cost data was available from published reports (Tables 1 and 2). In general, costs ranges very broadly, from less than $1.00 per square meter cleaned, to more than $47/m^2 cleaned. The level of effectiveness of different techniques also ranged quite broadly, from complete removal of all fine sediments (e.g., excavation-sieving-replacement techniques) to only surficial removal of fines in one location and relocation of those fines to downstream riffles (gravel ripping and bulldozing techniques). Table 3 ranks the available data as a qualitative rank from 0–1. These rankings were developed by multiplication of individual scores assessed for each of the following factors: Cost (1 = High Cost, 3 = Low Cost), Effectiveness (1 = Low, 3 = High) and Ecological impact (1 = High, 3 = Low). When all data was available, rankings were expressed as the quotient of the three score product (*i.e.,* from 1 to 9 divided by 9), using a maximum score of six when cost data was unavailable. The biggest differences in methodologies related to secondary ecological impacts.

EFFECTIVENESS OF PRIOR GRAVEL CLEANING STUDIES ON THE LOWER TUOLUMNE RIVER, 1991-1993

Between 1988 and 1993, the Districts experimented with several gravel cleaning methodologies to improve gravel quality (TID/MID 1992b), including: (1) a bulldozer with its blade angled to plow furrows through the riffle bed; (2) an excavator that lifted up buckets full of gravel and sifted them back into place allowing fines to be winnowed out and transported away as the gravels fell through the water column; (3) hydraulic back flushing using a small pump and single nozzle; and (4) a small suction pump and nozzle tested in conjunction with the back-flushing.

Gravel samples taken before and after the 1991 tests indicated that the back-flushing method offered the most uniform cleaning of fines from the gravels (EA 1991). The gravel cleaning machine developed for the Tuolumne River included ripper bars to break up the armor layer at the gravel surface, nozzles to inject high velocity streams of water into the gravels and suction nozzles to remove fine particles flushed from the gravels. In order to test the concepts of the design, a prototype was built. The prototype consisted of one of the five cells intended for inclusion in the final cleaning machine shown in Figure 1. Each cell included ripper bars, two ¾ inch jets, and 3-inch suction nozzles (these were later modified during the 1993 tests) (Figure 2a).

In May 1992 the gravel cleaning machine was tested, but the flows (550 cfs at La Grange) were too high to permit a quantitative assessment of the cleaner's effectiveness. The high velocity jets did appear to backflush fines from the gravels, but the suction configuration was inadequately designed to remove the amount of fines flushed into the water column. Based on these observations, several modifications were implemented for the 1993 Tuolumne River Gravel Cleaning Experiments.

1993 Equipment Modifications. The primary modification made to the prototype gravel-cleaning machine was the suction nozzle configuration. The previous configuration included splitting the suction line into two between the pump and the cleaner. Two lines went into the cleaner and were adjustable from side to side and front to back in the cleaner's central box (Figure 2a). The lines were open-ended pipes with no nozzle to facilitate flow of water into them. This configuration was determined to be a significant source of head loss in the suction system. No advantage was seen in having two suction lines, and there appeared to be a disadvantage to having no nozzles to direct flow into the suction hose.

In the new configuration, the alignment of the single vertical four-inch suction pipe was swept forward and flared to a rectangular opening which covered the entire cross-section of the downstream end of the cleaner box (Figure 2). The heavy mesh screens of the cleaner box were replaced by a single flat bar screen (3/8 inch). The front part of the screen sloped back at approximately 45 degrees from the top to the bottom of the box. At the bottom it ran parallel to the bottom edge of the box. This screen design was used to alleviate the problem of organic material building up on the mesh screens (particularly the front screen) and impeding the flow of water and fine particles into the box for removal. The angled flat bar design screened heavy materials as well as the mesh screens did, but also allowed lighter materials such as plant material that easily became impinged on mesh screens, to be washed away by the flow across it.

The 1992 tests showed that a cloud of fine particles often escaped from the front of the cleaner (rebounding forward from the jets), and flowed out around the side of the machine. In 1993, a hood was designed to funnel water and entrained fine particles from in front of the machine back into the suction nozzle for removal (Figure 2). It would also serve to create a venturi effect in low velocity water to accelerate the flow of water into the machine. The hood was 48 inches wide and 24 inches high at the front end and narrowed back to the same outer dimensions of the front of the cleaner box (approximately 26 x 10 inches). The sides of the hood had doors that were hinged at the front and could be opened toward the rear so that excess flow could be spilled along the side of the machine in situations when the flow entering the hood overwhelmed the capacity of the machine to remove or pass water, and a "bow wave" effect was created at the front of the machine. The doors could also be removed completely if necessary. At the bottom of the sides of the hood were permanent deflector wings that directed flow inward and toward the front of the cleaner box even when the doors were opened or removed.

Site Location. The study area was established in Riffle 5A, approximately 3/4 mile upstream of Basso Bridge on the Tuolumne River. The general location is the same site used in 1992, but the actual treatment and control areas were different from the area cleaned in 1992. The treatment area was established in the thalweg of the riffle. It was 30 feet wide by 100 feet long. A rebar benchmark was established on the river-left side of the treatment site. A control area was established upstream of the treatment area, to avoid disturbance from the tractor or incidental disturbance during the cleaning tests.

Visual Assessment of Cleaning Effectiveness. After the gravel cleaning tests were completed, ten sites in the treatment area were selected at random to determine the effective depth of cleaning. At each site the initial depth of water was measured. The site was then excavated by hand until interstitial deposits were encountered. When plumes of fine sediment could be seen washing out of the substrate a depth measurement was taken and subtracted from the initial depth to calculate the depth of effective cleaning. In addition to the estimates of cleaning depth, photographs and video tapes were also taken of all aspects of the gravel cleaning and data collection processes for general documentation. Although the major substrate facies were traced onto clear acetates for future digitization, gravel composition was estimated by the gravel sampling methods below.

Gravel Sampling Methods. Four sets of gravel-composition samples were taken in Riffle 5A during July 1993 prior to gravel cleaning. Two sets of fifty randomly selected samples each were collected before and after the cleaning experiment using a modified McNeil sampler (EA 1991, McNeil and Ahnell 1960). Two additional sets of five samples each were taken from the upstream control area before and after the cleaning experiment.

Each bulk sample that was collected before the cleaning was divided into top and bottom sub-samples. The top portion was the armor layer at the surface: the coarse and discolored substrate overlaying the generally finer material below. The separation of the portions was done to allow separate, as well as combined, analyses of the samples. Separate analyses are done because the purpose of the study was to look at the effects of gravel cleaning on the particle sizes of the gravel where salmon eggs would be deposited. This egg deposition zone is between six and 18 inches below the surface. Because the surface layer of gravel tends to become coarse and armored over time, the inclusion of this layer in the analysis can skew the particle size estimates upward, reducing estimates of the effects of the fine particle sizes in the subsurface gravels.

Following the gravel cleaning, another 50 McNeil samples were taken from the pre-test locations within the treatment area. This was permissible because the cleaning process is so disruptive to the substrate that there was no possibility of biasing the results by sampling at the pre-test sampling activity locations. For the same reasons, the post-cleaning McNeil samples did not include an armor layer since the particles were completely redistributed from the surface down to the depth of effective cleaning.

Control Sampling. Five McNeil samples were taken in the control area before sampling, using the same methods described above for pre-test sampling. McNeill samples were also collected in the control area after cleaning was completed to document the depths at which fines sediments appeared in uncleaned gravels and compare these to the effective cleaning depths in the treatment area. The samples were collected from undisturbed locations immediately adjacent to the original control samples to minimize the effect of spatial variability of the particle size distributions of the spawning gravels, and attempted to reduce the need to collect large numbers of control samples.

Sample Processing and Analysis. Processing and analysis of both the McNeil samples was done in a step-wise fashion by analyzing the least number of samples that are expected to show a discernable difference in gravel composition, if one exists. Pre-treatment and control samples were separated into surface and sub-surface samples as they were collected. In all, only 64 of the 100 samples from the cleaning test area were dried and sieved (32 randomly selected from each set). The remaining 36 samples were dried but not sieved.

All samples from the control area were dried and sieved. Processing the McNeil samples involved separating the sample material into different size categories and determining the weight of material in each. After drying (80 ^{o}C) the samples were transferred to a set of sieves of geometrically decreasing size from 128 mm down to 0.0625 mm. The weight of the material retained by each sieve was recorded.

Gravel Sample Analysis. To assess the quality of the gravel samples the particle size distribution of the entire sample should be characterized, rather than just the percentage of a sample that falls below an arbitrarily defined limit of “fine” particles. Research on the effect of gravel quality on survival to emergence (Chapman 1988, Tappel and Bjornn 1983, Milhous 1982) has indicated that the effect of fine sediments on intergravel flow depends in part on the size distribution of the coarser particles. A heterogeneous mixture of coarse gravels would likely have better intergravel flow and provide better quality spawning habitat than a homogeneous mixture of smaller gravels that contained the same percentage of fine sediments.

Tappel and Bjornn (1983) suggested that ideal quality spawning gravel size composition for chinook salmon (*Onchorhyncus tshawytscha*) and steelhead trout (*O. mykiss*) is adequately characterized by the cumulative percentage by weight of gravel finer than 0.85 mm diameter, in combination with the percentage by weight of gravel finer than 9.5 mm diameter. Tappel and Bjornn related those percentages to survival of chinook salmon eggs with the following equation:

$$\text{Survival} = 0.934 - 17.1 q_{9.5} q_{0.85} + 3.87 q_{0.85}$$

where q_d is the fraction by weight of the sample less than d mm in diameter. To characterize the quality of the gravel samples, the weights of the material retained in each of the standard sieves are recorded. The entire sample was used for these calculations (that is, the data were not “truncated” at 25.4mm, as in other analyses). The sieve set used did not include sieves of 0.85 and 9.5mm; the values used to compute the index were found by interpolation from the particle size distribution.

In addition to the Tappel and Bjornn index, we also calculated several other gravel quality indices:

- *Fraction Fines*. This was simply defined as $q_{2.0}$, the fraction by weight of the sample less than 2mm in diameter.
- *Geometric Mean Diameter*. This was calculated as $(d_{0.84}d_{0.16})^{1/2}$, where d_q is such that q% of the sample by weight is less than d_q in diameter (Shirazi and Siem 1981). The values of $d_{0.16}$, $d_{0.84}$ were estimated by interpolation from a log-probit linearization of the particle size distribution.
- *Fredle Index*. This was calculated as $(d_{0.84}d_{0.16})^{1/2} / (d_{0.75} / d_{0.25})^{1/2}$ (Lotspeich and Everest 1981). the values of $d_{0.16}$, $d_{0.25}$, $d_{0.75}$, $d_{0.84}$ were estimated by interpolation from a log-probit linearization of the particle size distribution.

Cleaning Test Results. The values of the gravel quality indices were calculated using the combined (surface and sub-surface) samples to account for mixing of the surface and subsurface layer during cleaning. Table 4 shows the Tappel-Bjornn Index, Fraction of Fines, Geometric Mean Diameter and Fredle Indices and Figure 3 summarizes these in box-plot form. For the cleaning test samples, with the exception of the Tappel-Bjornn Index, all gravel quality indices improved as a result of cleaning (Table 5). Using two-sided two-sample heteroscedastic t-tests, the first set of results reported (all samples combined) show the fraction of fines and Fredle index decreased and differed very significantly ($p < 10^{-3}$, $p = 0.03$) from the pre-test samples. However, the increase in geometric mean diameter was not found to be significant ($p = 0.06$) by this test.

To improve the lower power of parametric tests (i.e., t-test) to demonstrate statistical differences between the treatment and control samples, Figure 4 shows a graphical representation of non-parametric analyses of the gravel cleaning results. Figure 2 shows that non-parametric estimates for the distribution of index values among samples in the treatment area were generally non-normal, especially the distributions of the Tappel-Bjornn index and geometric mean diameter.

This explains the disagreement between the different forms of the t-test shown in Figure 1 and Table 5. Figure 4 shows that for all samples combined, bootstrap tests for equality of the before- and after-cleaning index distributions shown in Figure 3 are significantly different ($p < 0.01$).

Because of reported problems with the gravel cleaner operation, a number of downstream cleaning locations were apparently contaminated by a front of fines swept ahead of the gravel cleaner by the high-pressure jets. Figure 5 shows that somewhere near 50 feet from the upstream end of test area, the cleaner began to lose effectiveness and in some cases more fine sediments were found in the post cleaning samples. In an attempt to improve the pre- and post-test comparisons, Table 5 separates the pooled results into upstream and downstream portions of the test area, showing some improvements in the prior indices, but no significant increase in the Tappel-Bjornn index.

Control Site Results. Interestingly, significant changes were detected in the four gravel quality indices for samples from the control area (Table 5). The 95% confidence interval for the changes control area gravel quality indices included those observed in the treatment area, so that the t-tests do not rule out the possibility that the increases seen in the treatment area did not result from some systematic changes over time unrelated to the cleaning. However, because the number of control samples was small, the power of the test to rule out this possibility was very poor. The changes in the control area gravel quality were in all cases much smaller than those of the treatment area.

DISCUSSION

Review of Gravel Cleaning Methodologies. All of the gravel cleaning methods evaluated in this memorandum depended upon the separation of sediment fines by some mechanical disturbance, followed by a variety of sediment removal methods (*e.g.,* hydraulic flushing, mechanical sorting, etc.). Hydraulic cleaning methods generally ranked highest in terms of cleaning effectiveness. Although improvement in survival to emergence has been demonstrated in several gravel cleaning studies, subsequent use by spawners was often delayed (Wilson 1976), suggesting that some disturbance of the invertebrate community or other factors may be responsible for an initial decline in spawning use. For this reason, our analysis tended to favor hydraulic methodologies that showed lower impacts on the re-establishment of invertebrate populations (Allen et al. 1981; Meehan 1971; Mih 1979; Mih and Bailey 1981; Shields 1968; Shields 1999; TID/MID 1992). In-situ mechanical methods (*i.e.,* bulldozing and tilling) generally ranked slightly below hydraulic methods in effectiveness and disturbance (Hall and Baker 1982, Gerke 1990; Mih 1979; Shackle et al. 1999). Although intuitively simple, excavation, cleaning, and replacement of spawning gravels (Andrew 1981; Mih 1978; Wilson 1976) ranked among the lowest of the methods evaluated due to high energy costs, moderate effectiveness and high ecological impact (Table 3).

Implementation of the 1993 Gravel Cleaning Experiments. The prototype gravel cleaning machine developed by the Districts was designed to break up the armor layer by mechanically ripping the gravel, break up interstitial deposits using high pressure jets, and then vacuum the fine sediments for their removal (TID/MID 1992b). Although the initial conceptual design of the cleaner was intended to take advantage of differential settling velocities of fine and coarse sediment, a number of field modification were made to accommodate low suction velocities. Implementation of the single-cell prototype tests were most affected by use of a back-hoe, which affected the use of the ripper bars and also required separating the pumping assembly from the cleaner shown in Figure 1.

Mounting the cleaner to the backhoe appeared logical: the backhoe could imitate the linear motions of the bulldozer through the water and would permit closer and safer examination of the machine and its operation in the stream than would a bulldozer. However, the prototype gravel cleaner was designed for use on a bulldozer that would drag it in one direction and orientation in the river. Placement of the ripper teeth and the jetting and suction nozzles was designed to use the unidirectional flow to backflush, suspend, and direct the fine sediments back into the suction nozzle for removal. Use of the cleaner in a radial pattern changed the orientation of the cleaner relative to the river flow, causing the back-flushed sediment to be washed past the mouth of the machine instead of being swept back into the suction nozzle. Lastly, the separation of the suction pump from the cleaner during the 1993 prototype tests created large suction losses that prevented the cleaner from developing its design hydraulic capacity and large amounts of fine sediments escaped the cleaner hood. Interestingly, removal of the narrow-bore jet nozzles increase jetting effectiveness noticeably and the final tests were conducted without the ripper bars.

Results of the 1993 Gravel Cleaning Experiments. Past estimates of probability of survival of salmonid eggs in uncleaned gravels, based on particle size distributions of the gravels (Tappel and Bjornn 1983) have ranged from 0 to less than 30 percent in the Tuolumne (TID/MID 1992a). Although the prior Tuolumne River studies indicated that survival-to-emergence was low, the 1993 gravel-cleaning results showed much higher Tappel & Bjornn indices in both treatment and control gravels. Some of the results were low, but the mean survival-to-emergence for treatment and controls was near 90% (Table 4). Recent permeability studies in the spawning reach predicted survival-to-emergence ranged from 34 percent (95% Confidence Interval (CI): 31–37 percent) at Riffle 7 to 51 percent (95% CI: 35–67 percent) at Riffle 2 (TID/MID 2000). This discrepancy may either be due differing methodologies in that the recent studies developed Tappel Bjornn indices from permeability measurements. These differences may also be due to the 1993 test within riffles area with particularly clean substrate, followed by large volumes of fine sediment deposited in from the 1997 flood, and possibly some sampling artifact that under-represented the fines present in the bulk samples. In any case, the analysis of the 1993 gravel cleaning data do show a significant difference between pre- and post-cleaning and controls.

CONCLUSIONS AND RECOMMENDATIONS

Source Control Measures. A coarse sediment augmentation program in conjunction with managed high flow releases was suggested as an important component of the overall restoration of the lower Tuolumne River (McBain &Trush 2000). Limitations on long-term coarse sediment supplies and available water may also natural sorting processes to re-establish high quality spawning gravels. In the near term, fine sediment source control (*e.g.,* Gasburg Creek sedimentation basin, changes in land uses) and cleaning of the existing interstitial deposits may be the most effective means of improving productivity of the available spawning habitat in the lower Tuolumne River.

Relative Costs of Gravel Cleaning Methods. The costs and effectiveness of gravel cleaning methodologies reviewed appear to depend on the size of the area to be cleaned. However, the available cost data was variable and this could not be explained by economies of scale. For example, of the six mechanical cleaning citations reviewed that provided cost data, the highest inflation-adjusted cost was over \$47/m^2 for a large excavation and gravel replacement projects, whereas another large scale excavation and replacement project was among the lowest in cost (\$0.72/m^2). Of the in-situ methods, ripping and tilling were among the least expensive (0.3/m^2 and \$0.42/m^2), but were largely ineffective at low river flows. For the hydraulic methods reviewed, only two studies provided cost data (\$0.6/m^2 and \$3.2/m^2).

Recommended Cleaning Methodologies. The methods reviewed for this evaluation were largely demonstration studies not yet developed as long-term sediment management tools. All methods were effective to some degree, with varying ecological impacts due to the disruption of the spawning gravels (*i.e.,* impacts to the invertebrate community). Impacts increased due to turbidity or disruption of the ecological community as the hydraulic methods increased in energy intensity from vacuum methods, to hydraulic jets to mechanical removal and cleaning. Based on our review of gravel cleaning methods, we recommend the following fine sediment removal methods be considered for additional experimentation and implementation:

1. *High Flow Releases.* A combination of upstream gravel augmentation and high flow releases in excess of the bed-mobilizing thresholds offers the simplest approach to creating and maintaining large areas of high quality spawning habitat. This strategy requires implementation of a gravel augmentation program in combination with fine sediment reduction program to eliminate inputs from tributary watersheds (Gasburg Creek, Dominici Creek) and floodplain deposits.
2. *Hydraulic Methods.* Although the top five methods reviewed were hydraulic, none of these studies provided cost data. A modified form of the gravel cleaning machine offers a viable means for removing fine sediment from spawning gravels. Creation of localized shear stresses by use of weirs or baffles was one of the simplest methods reviewed and may be also an effective strategy of fine sediment removal in the relatively uniform spawning riffles of the lower Tuolumne River.

3. *Mechanical Methods.* Mechanical methods ranked below hydraulic methods, but they may be suitable to the large pools of the spawning reaches in the lower Tuolumne River that tend to trap and store large volumes of sand. A program combining mechanical displacement of fines by high flow releases followed by suction dredging of sand accumulated in pools may offer a relatively effective, low-cost approach.

The prototype gravel-cleaning machine developed by the Districts appeared to improve all gravel quality indices, with an expected improvement in survival to emergence of cleaned areas. We recommend the 2003 pilot scale gravel cleaning tests be conducted using the same approach as the prior experiments. This will employ either ripper bars and/or hydraulic jets to disrupt the armor layer and mobilize fines followed by vacuum removal of suspended sediments.

1. Given the corrosion damage to the Districts gravel cleaning machine since its last use in May 1993 and its relatively small size, it may be unsuitable for large scale gravel cleaning in its present condition. We recommend the rehabilitation of the existing unit or the fabrication of a new cleaner with a careful re-examination of pump selections, jet and suction velocities.
2. Each suction nozzle should be supplied with an independent venturi-type (*e.g.,* wye-inlet) suction nozzle. This design would allow remote pumping and also remote location of sand separators, while reducing nozzle suction losses to a minimum.
3. Separation of the suspended sediments can be accomplished by settling ponds constructed on the floodplains or by cyclone separator with recycling of the supernatant water back to the river. Stockpiled sands should be removed or deposited on the back of floodplains to reduce the risks of future re-infiltration into the spawning gravels.

In summary, the feasibility of gravel cleaning as a long-term management tool for enhanced salmonid production relates to the sensitivity of the streambed to disturbance (*i.e.,* ESA limitation on in-stream activities at certain times of the year) and the rate of re-introduction of new fines from upstream and the mobilization of relict floodplain deposits. Two questions remain as to whether a gravel-cleaning machine can be employed as an effective tool to manage fine sediment accumulation in the Tuolumne River. First is the costs and feasibility of employing such a device on a large scale in the spawning reach. The second question is how long the benefits of cleaned gravel will last. The Fine Sediment Management Plan will address both these questions, and includes implementation and monitoring of gravel cleaning experiments in 2003. Following an initial gravel cleaning program, a fine sediment source control program coupled with coarse sediment augmentation may be the most cost effective sediment management tool for maintenance of high spawning gravel quality in the Tuolumne River.

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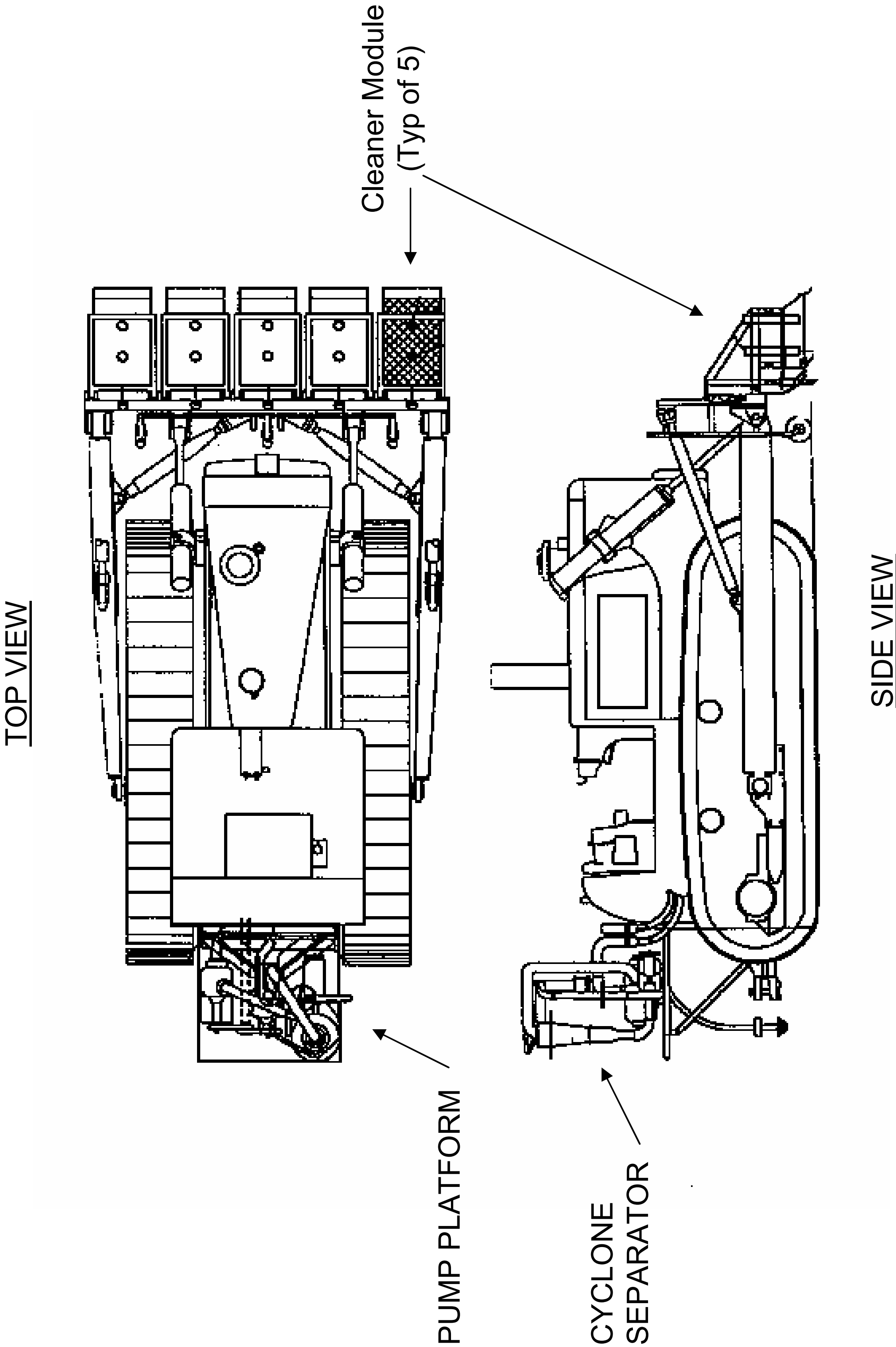
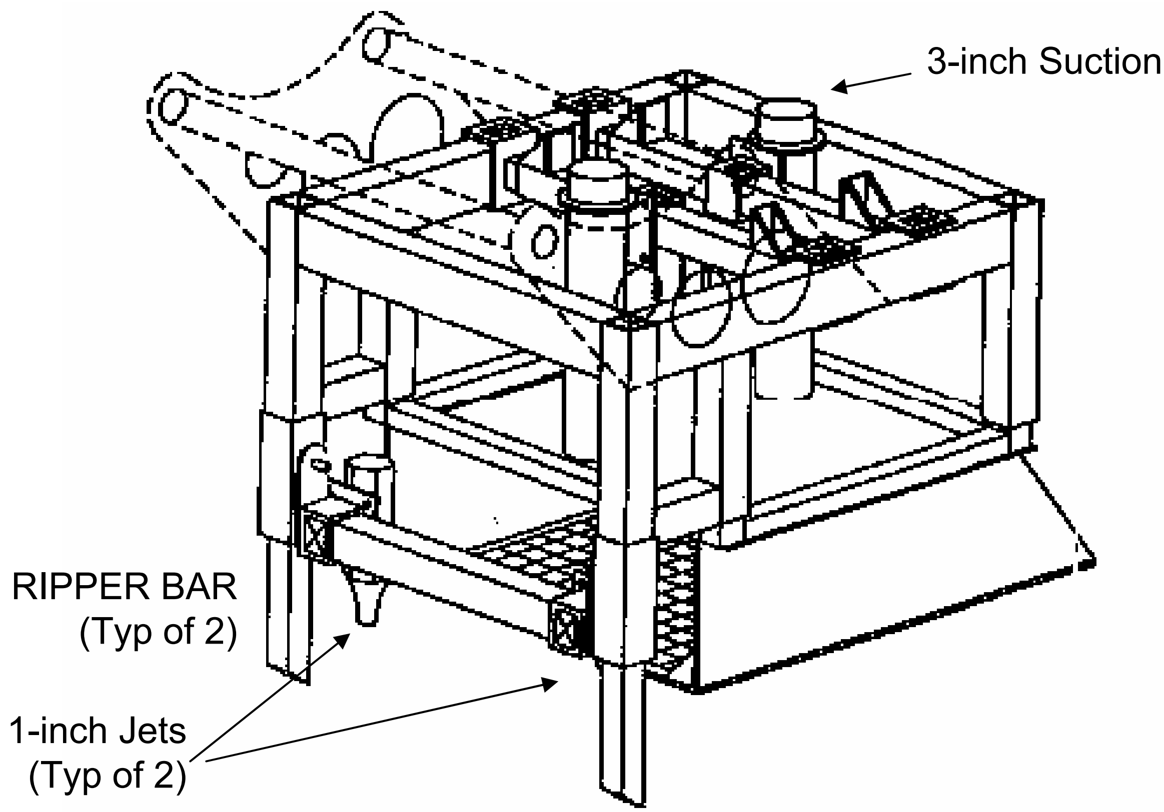


Figure 1. Conceptual Design for self-contained spawning gravel cleaner (EA 1991)



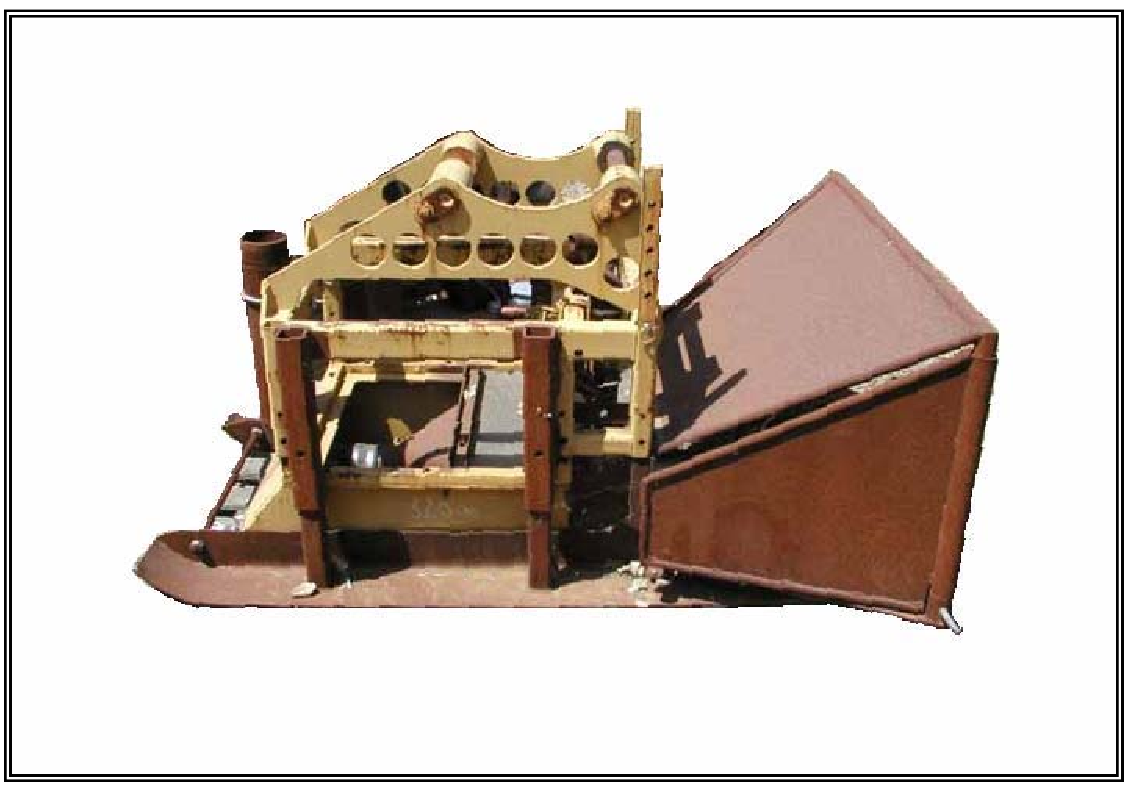


Figure 2. 1991 Cleaner Module Design (Top) and 1993 Inlet Baffle Modifications (Bottom)

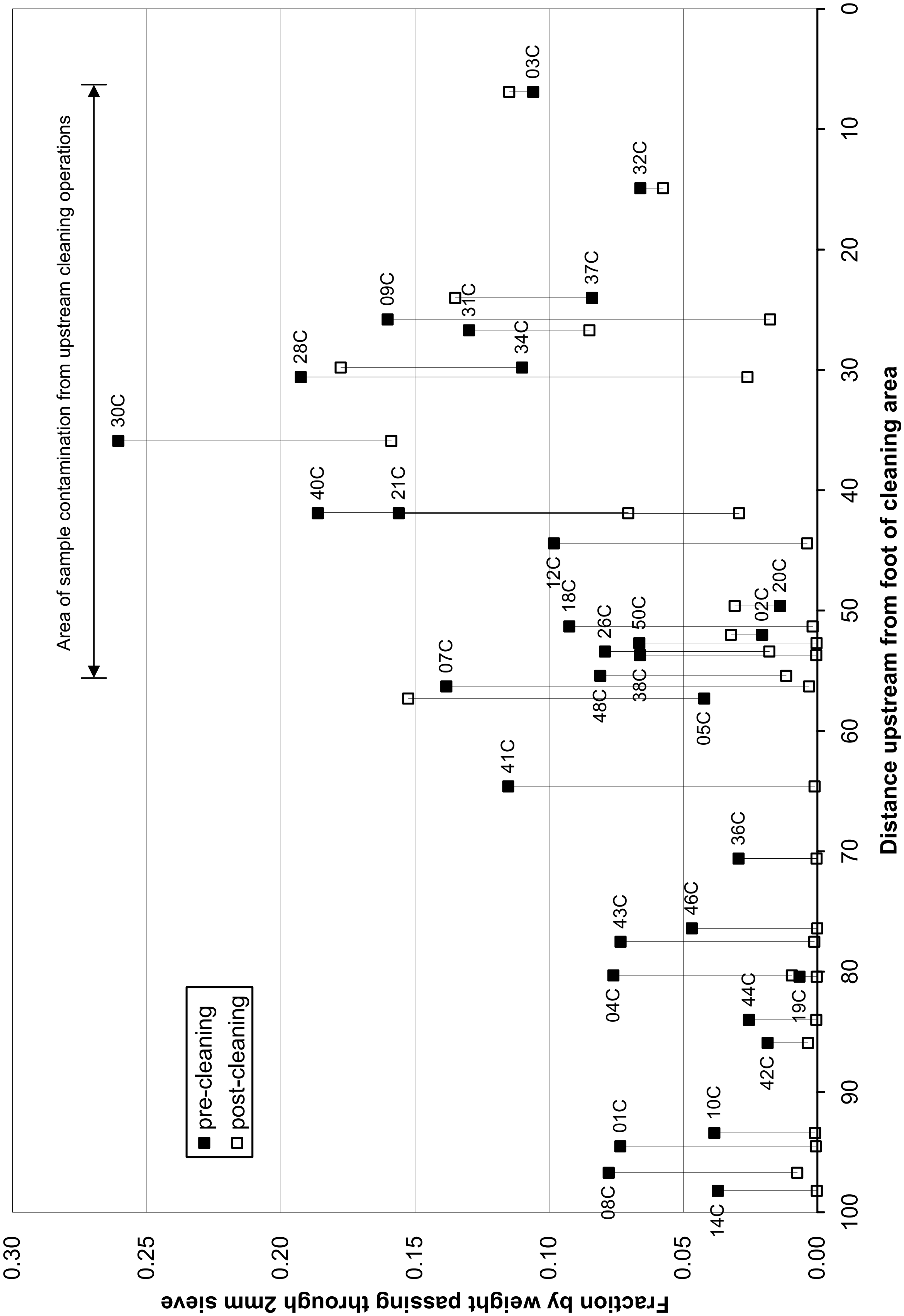
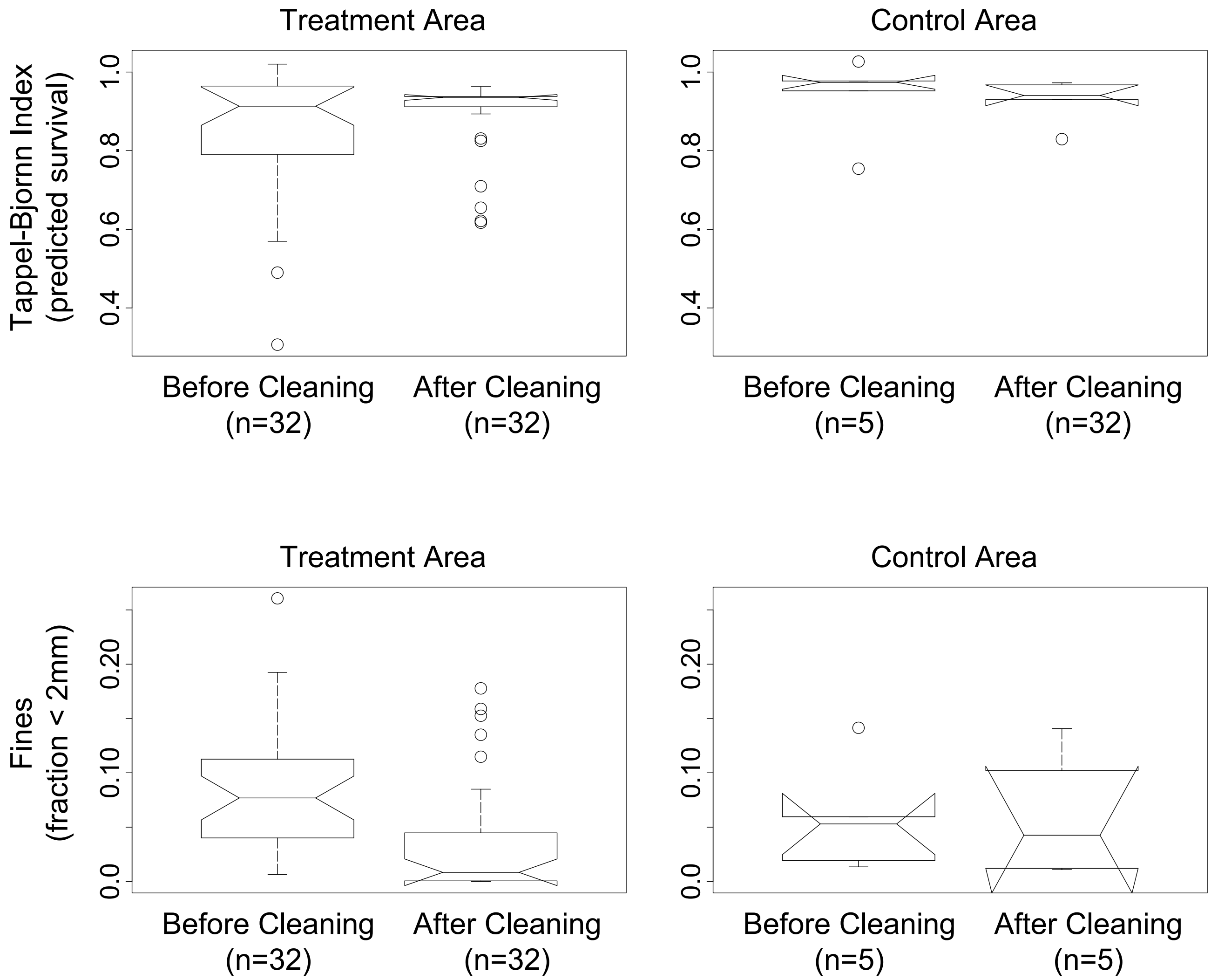


Figure 3. Pre- and Post-Cleaning Comparisons of Fraction Fines in 1993 Treatment Areas.



Notes on Box and Whisker Plots:

1. The basic box extends from the first to the third quartile of the data values, the horizontal central line in each box marks the median.
2. Vertical central lines extend from the median by 1.5 times the inter-quartile range towards the minimum to maximum, with values in excess of this range shown individually.
3. V-"notches" in the boxes show the approximate 95% tests for equality of medians, using an order-statistic-based version of the standard two-sample t-test (note that notches may extend above or below the boxes).

Figure 4. Summary of gravel quality index values for gravel samples collected as part of 1993 gravel cleaning experiments.

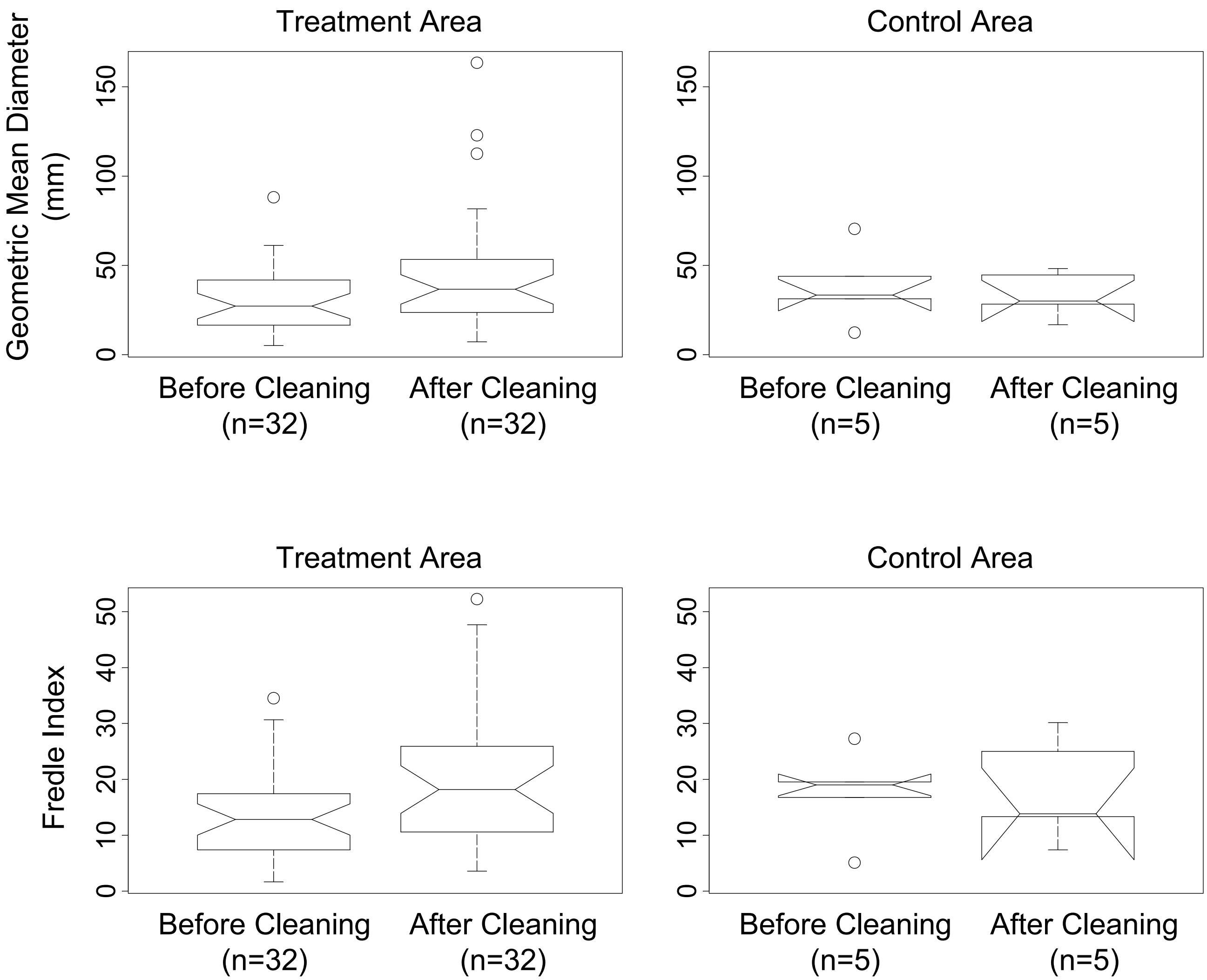
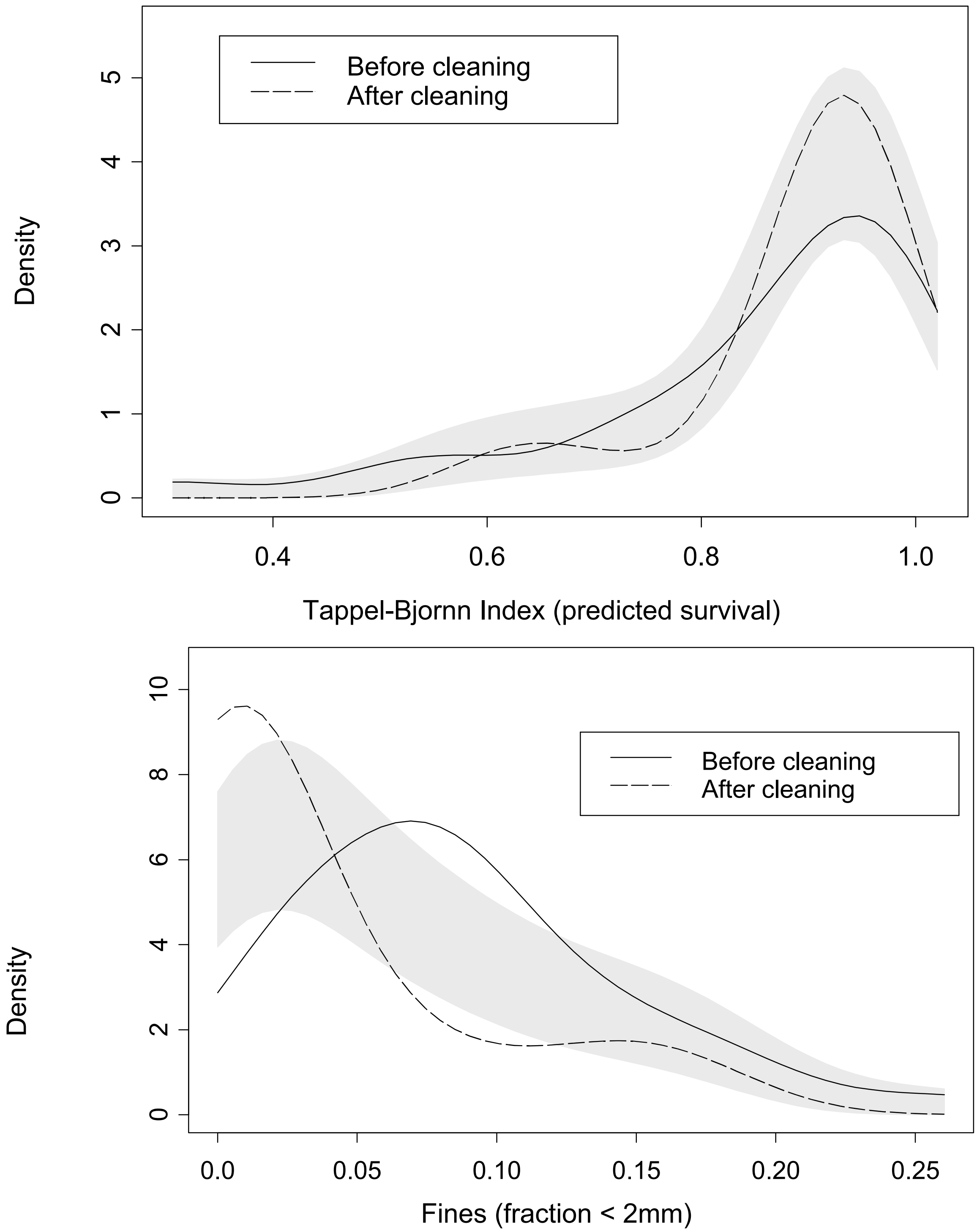
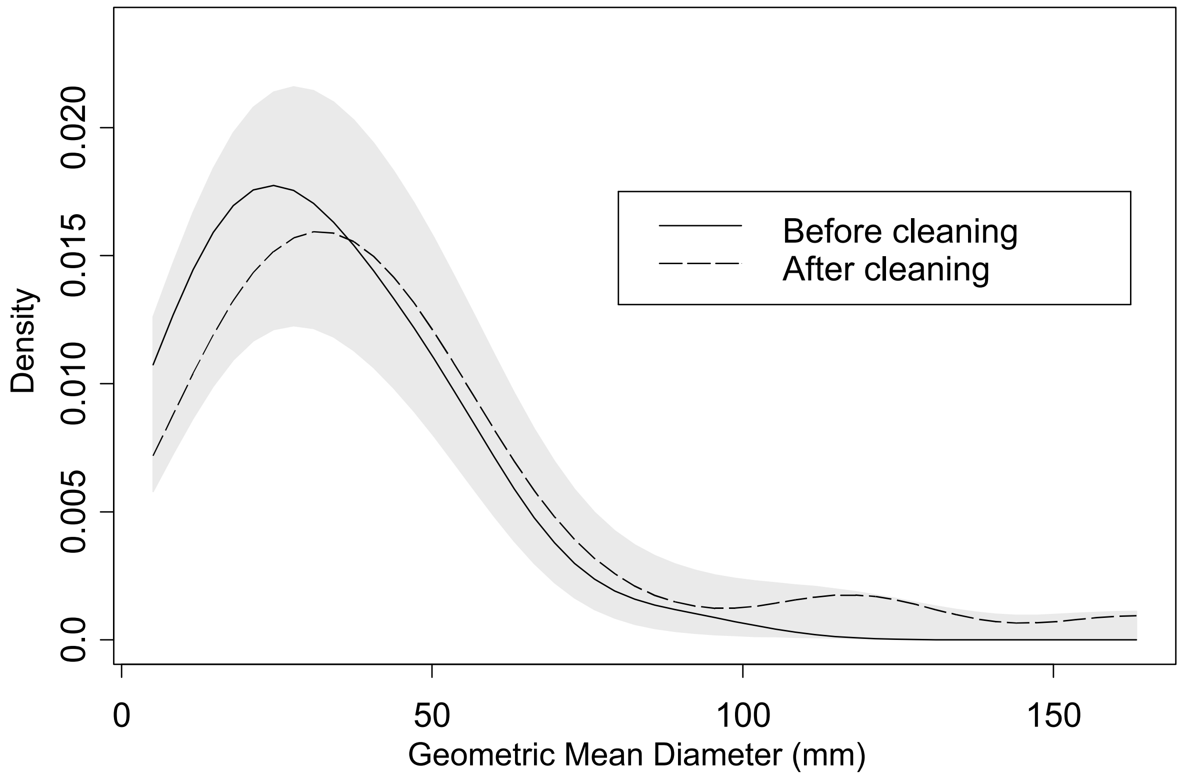


Figure 4 (continued). Summary of gravel quality index values for gravel samples collected as part of 1993 gravel cleaning experiments.



Notes: Assuming the before- and after-cleaning samples are from the same underlying distribution (null hypothesis), both curves should lie within the 95% confidence band (shaded). Places at which the curves approach or cross the boundaries of the reference band are therefore places at which the before- and after-cleaning distributions are most different.

Figure 5. Non-parametric gravel quality index distributions, determined after Bownan and Azzalani (1997).



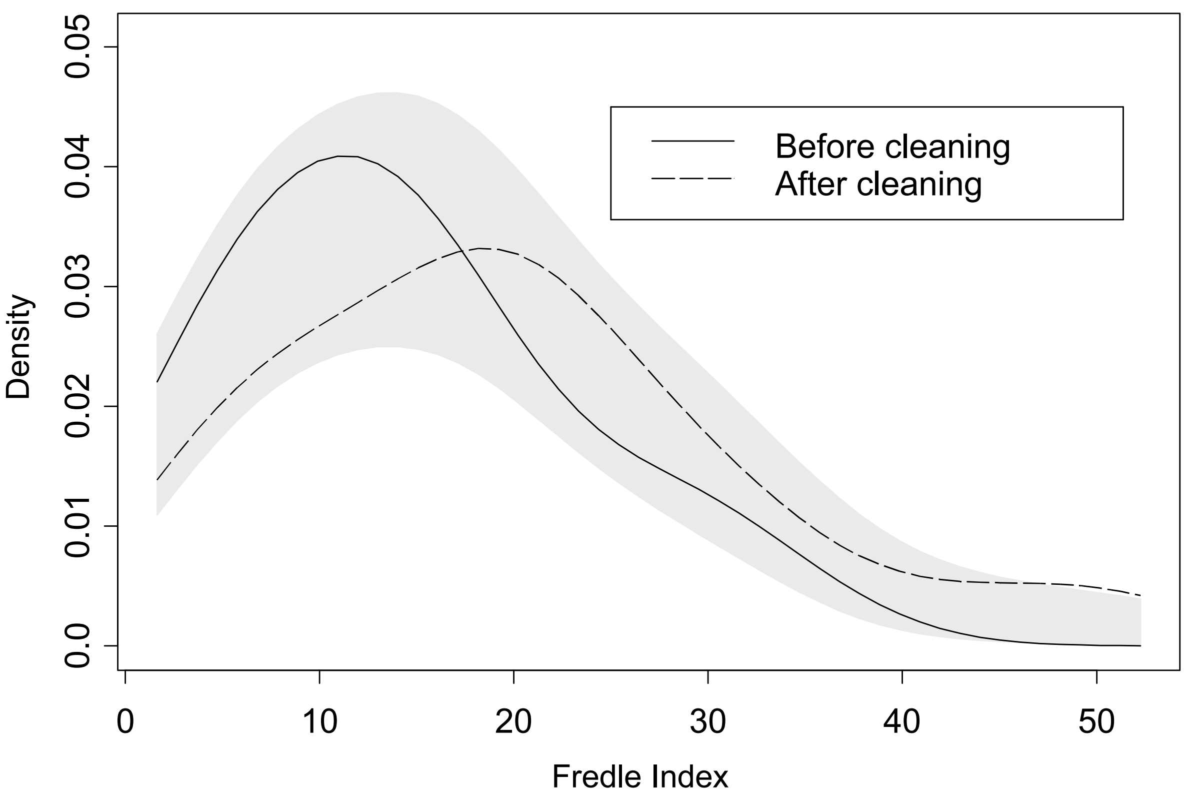


Figure 5 (continued). Non-parametric gravel quality index distributions, determined after Bownan and Azzalani (1997).

Table 1 - A Literature Review Summary of Hydraulic Gravel Cleaning Methods and Applications

reference	location	method	corrected cost $\$/m^2$	effectiveness	secondary effects/impacts	ranking
Andrew 1981	Gates Creek spawning channel, Horsefly River, McKinley River	Two rows of 5.1 cm (2 in) diameter pipes, mounted 31-46 cm (12-18 in) on center, extended 23 cm (9 in) into the gravel bed. Water was pumped at 20 psi through each of the 21 pipes to wash the gravel. Suspended fine sediments were pumped to the surface and allowed to flush downstream. The machine was towed downstream by a track-mounted G-600 Warner-Swasey Gradall at about 1.5 cm/s.	0.61	Cleaning on Gates Creek removed all material finer than approximately 1.3 cm (0.5 inches) to a depth of 40.6 cm (16 in). Cleaning on the Horsefly and McKinley Rivers removed all material less than 2 mm and some of the material up to 10 mm. However, much of the material coarser than 1mm accumulated on the gravel surface to a depth of 2.5-15 cm (1-6 in). Large in-stream boulders interferred with passage of the cleaner and prohibited adequate penetration. Gravel sampling of cleaned sites 2 months after spawning indicated a significant reduction in survival to emergence survival rates, while sampling 8.5 months after cleaning indicated survival was substantially increased by cleaning.	Coarser bed material that accumulated in front of the cleaner had to be periodically removed. Reduced survival may have resulted from the deposition of coarse material on the gravel surface during cleaning followed by redistribution of this material to redd sites during spawning. Short-term increases in turbidity and suspended sediment occurred downstream of cleaning operations.	0.50
TID/MID 1992	Riffle 5A -- Tuolumne River, CA	The design included a mechanism to break up the armor layer at the gravel surface, jetting nozzles to inject high velocity streams of water into the gravels, and suction nozzles to remove fine particles suspended in the water column. The machine was mounted on the articulating arm of a backhoe that worked in the downstream direction. After testing in 1992, modifications were made to the suction line and the cleaner box, a hood was added to funnel water and entrained sediments into the suction nozzle for removal, and skids were added to better control the position of the cleaner above the stream bottom.	3.26	Effective cleaning depth was18-inches. Mean egg survival rates, calculated from particle size distributions of bulk gravel samples before and after treatment (Tappel and Bjornn 1983), increased from 29.4 % (pre-treatment) to 63.7 % (post-tretament). Photographs and videotape indicat that some of the sand flushed from the substrate was mobilized downstream by the river instead of being picked up by the suction nozzle.		0.33
Einstein 1965	flume experiments	A movable gate was placed above the streambed perpendicular to flow, causing increased hydraulic pressure to be exerted on the silted gravels.	N/A	The cleaning process was slow and created a force sufficient to remove only superficial fines.		0.67
Mih 1978	Tehama-Colusa Canal (artificial spawning channel)	A carriage-mounted baffle gate was lowered into the flow to create a hydraulic force sufficient to scour spawning gravels.	N/A	Gravels were scoured to a depth of 0.76 m (2.5 feet). The technique is limited to highly regulated, trapezoidal channels.		0.67
Mundie and Mounce 1978	small unknown channel	A small pump and firehose was used to direct a jet of water into spawning gravels.	N/A	The small size of the machine resulted in uneven cleaning.	Short-term increases in turbidity and suspended sediment can be expected downstream of cleaning operations.	0.67
Mih 1979	flume experiments	Jet nozzles positioned above the streambed were directed into a gravel bed to flush fines. Jet diameters, angles, elevations, and water velocities were varied to derermine the optimum cleaning effect.	N/A	Cleaning depth increased as jet velocity and jet diameter increased, jet angles of 60 and 90 degrees resulted in deeper cleaning than those at 45-degree angles, and cleaning depth increased with increased jet elevation up to approximately 40.6 cm for a 2.5 cm jet diameter. All particles smaller than 3 mm were removed from the cleaned layer.		0.56
Mih and Bailey 1981, Allen et al. 1981	Palouse River, Idaho; Kennedy Creek and Cedar River, Washington	A hydraulic gravel cleaner, referred to as the "Gravel Gertie," was mounted on a trailer and towed through the riffle. Design specification included a 19 mm (3/4 in) jet diameter, a jet velocity of 24.4 m/s, a jet elevation of 30.5 cm (12 in) above the bed, a 90 degree angle of impingement, and a machine speed of 1.83 cm/s. A rectangular collection hood and suction system removed fines from the streamflow.	N/A	Average cleaning depths were 15-30 cm.	Samples taken downstream before and after cleaning showed an increase in total suspended solids from 5 to 140 ppm and an increase in turbidity from 2 to 60 NTU after 30 minutes of operation. Reduced downstream transport rates of spawning gravels was observed in the years folowing cleaning operations.	0.56

reference	location	method	corrected cost $/m^2$	effectiveness	secondary effects/impacts	ranking
Shackle et al. 1990	Kennet River, Coln River, Windrush River, and Leach River in southern England	The first method involved high-pressure jet washing using a KEW 5203 KD pressure washer. River water was pumped at 150 bar through a hand-held lance with jets of 5 mm and 1 mm in diameter. A second method involved pump washing, using a Pacer pump with a 3 Hp Briggs and Stratton engine. River water was pumped through a lance formed from 1 m of 22 mm copper tubing.	N/A	Gravel treated by both methods was noticeably looser than adjacent uncleaned gravels. The pump washer disturbed a shallower, wider area of gravel (2 to 3 cm depth, 10 to 15 cm diameter), forcing a greater volume of water horizontally through the bed. Freeze core samples taken before and after treatment indicated a 1.5% to 3.5% reduction (by weight) in silt content. Significant increases in the number of living eggs recovered from egg boxes in control and treated reaches were found in 3 of 5 pump-washed reaches and 1 of 5 pressure-washed reaches.	Fine sediments released during cleaning were carried downstream to other potential spawning sites.	0.50
Shields 1968, Meehan 1971, Mih 1979	Several Alaskan streams including Fish Creek, Slocum Creek, and an artificial spawning channel at Lover's Cove Creek; Trinitiy River, CA	The design included pipes inserted 30.5 cm into the bed to hydraulically flush fines from the gravel. Suspended fines were directed back toward the surface where they were suctioned from the water column and jetted onto the streambank. An amphibious vehicle carrying the machine was drawn downstream at a rate of 3 cm/s by a cable attached to a winch anchored downstream.	N/A	The method removed up to 65 % of particles less than 0.4 mm. Mechanical problems occurred that were related to the inability of the flushing pipes to adequately penetrate the gravels, and detachment of the anchor due to a large drag force on the machine.	Unquantified decreases in aquatic invertebrates occurred following cleaning. Aquatic invertebrate populations returned to pretreatment levels after 1 year.	0.50

Notes:
N/A = not applicable or not available

Table 2 - A Literature Review Summary of Mechanical Gravel Cleaning Methods and Applications

reference	location	method	corrected cost $/m^2	effectiveness	secondary effects/impacts	ranking
Heiser 1971	Lower Dungeness River, WA	A D-5 Caterpiller tractor pushing a blade angled at 45 degrees upstream to expose and clean spawning gravels to a depth of 0.25-0.36 m.	0.72	Sediment sampling before and after treatment indicated a 2% to 8% reduction in fine sediments less than 0.8 mm. One-fourth of all spawning Pink salmon in the lower Dungeness River were attracted to the cleaned areas. Pink salmon fry survival was 90% in treated areas and 47.5% in adjacent untreated areas. Fry survival increased by 89% in treated areas.	Increased bed erosion and spawner avoidance may occur in cleaned areas where stream gravels are placed in locations out of equilibrium with streamflow conditions. Short-term increases in turbidity and suspended sediment can be expected downstream of cleaning operations.	0.8
Wilson 1976	Cleaning occurred on the Entiat River, WA; replacement occurred on the Nisqually River, Tarboo Creek, Dogfish Creek, East Fork Satsop River, McLane Creek, and Swift Creek in Washington	A bulldozer with a tilt-and-angle blade worked across the stream at about a 15 degree angle into the current. Passes were made 1.5 - 2.5 m apart progressing downstream. At gravel replacement sites, existing gravels were removed to a depth of 0.3 m by a bulldozer and replaced with clean gravels. Gabion weirs were constructed to contain the new gravels, and riprap was placed to protect banks from erosion	47.57	Spawner utilization was generally low in gravel replacement sites. Some of these sites experienced a significant loss of the new gravel.	Increased bed erosion and spawner avoidance may occur in cleaned areas where stream gravels are out of equilibrium with streamflow conditions. Short-term increases in turbidity and suspended sediment can be expected downstream of cleaning operations.	0.8
Mih 1978	Palouse River, ID; Kennedy Creek and Cedar River, WA	A Gradall, carrying a modified 2.1 m digging bucket with a screened bottom constructed of 3.2 mm (1/8-inch) wire mesh, scooped gravel to a depth of approximately 0.61 m and vibrated the bucket in the water to remove fines through the screened bottom. The cleaned gravel in the bucket was then returned to the hole.	4.10	Fines were removed from the upper 30.5 cm of the bed, under which a layer of concentrated fines was left.	Cleaned areas experienced twice the erosion rate of uncleaned areas. Subsurface fines created a potential source of fine sediment when the surface gravels are mobilized.	0.8
Andrew 1981	Nadina and Horsefly rivers, WA	A 1.5 m-wide digging bucket was mounted on a G-600 Gradall. Moving downstream, the Gradall excavated to a depth of 30-60 cm. Excavated gravel was then poured back onto the stream bed, allowing flow to entrain the suspended fines.	1.44	Cleaning resulted in a 12 % reduction in material less than 0.5 mm and complete removal of fines less than 0.3 mm. Areas cleaned on the Nadina River showed significant increases in permeability but were not used by subsequent spawners. Areas cleaned on the Horsefly River were heavily used by subsequent spawners but showed no improvement ir gravel permeability or egg survival to emergence.	Fines removed during cleaning were swept downstream and deposited in pools. Erosion in cleaned areas was double that in uncleaned areas.	0.8
Hall and Baker 1982, Gerke 1990	Entail River, WA	A bulldozer moved up and across the stream at a 45-degree angle to flow with its blade angled upstream. Gravels were turned to a depth of 25-36 cm and pushed up into the flow. After each pass the bulldozer crossed the river and began another pass 1.5 -2.5 m downstream of the last pass.	N/A	Gravel sampling indicated decreased fines and increased spawning in treated areas compared to untreated areas. The method was most effective when executed during high flows to allow maximum flushing of gravels.	Increased bed erosion and spawner avoidance may occur in cleaned areas where stream gravels are out of equilibrium with streamflow conditions. Short-term increases in turbidity and suspended sediment can be expected downstream of cleaning operations.	0.8
West 1984	Scott River, CA	A Caterpillar D-6 tractor equiped with tilt-and-angle blade was used to rip spawning gravels. Gravels were repeatedly ripped until it became visually evident that further treatment would not reduce fines.	0.30	Gravel manipulation successfully loosened embedded gravels. McNeil samples taken before and after treatment indicated a reduction in the concentration of sand from 16.9% to 12.0% and the concentration of fines (<3.3 mm) from 24.3% to 6.1%. Treatment was followed by moderate to heavy spawner use.	Increased bed erosion and spawner avoidance may occur in cleaned areas where stream gravels are out of equilibrium with streamflow conditions. Short-term increases in turbidity and suspended sediment can be expected downstream of cleaning operations.	0.8
EA 1989	Tuolumne River, CA	Steel tongs mounted on a bulldozer were raked through gravels during low flow. Gravels were raked perpendicular to flow, parallel to flow, and in a combination of directions.	N/A	Ripping appeared to remove clay and silt from the subsurface but not sand. There was no significant change in the ammount or distribution of fine sediments on the bed surface. No significant change in subsequent spawning was observed.	Increased bed erosion and spawner avoidance may occur in cleaned areas where stream gravels are out of equilibrium with streamflow conditions. Short-term increases in turbidity and suspended sediment can be expected downstream of cleaning operations.	0.8

reference	location	method	corrected cost $/m^2	effectiveness	secondary effects/impacts	ranking
Hampton 1990	Trinity River, CA	Gravels were ripped to a depth of approximately 0.6 m during low flow (1/3 bankfull discharge, average point velocities were 0.46-0.61 m/s) using a rip bar mounted on a crawl tractor.	N/A	Surface embeddedness decreased by approximately 20 percent, but fines likely settled during ripping rather than being removed.	Increased bed erosion and spawner avoidance may occur in cleaned areas where stream gravels are out of equilibrium with streamflow conditions. Short-term increases in turbidity and suspended sediment can be expected downstream of cleaning operations.	0.8
Stemple 1990	Trinity River, CA	A ripping bar mounted to a bulldozer was drawn through the gravel.	N/A	McNeil samples before and after ripping showed no significant decrease in fines. A slight increase in spawning was observed in ripped areas.	Deep ripping brought large material to the surface that was not conducive to spawning. Reducing the ripping depth from 24 to 18 inches decreased the number of large cobbles and boulders brought to the surface.	0.8
Painter 1990	Feather River, CA	A ripping bar mounted to a bulldozer was drawn through the gravel. Treatment occurred during summer low-flow conditions (1/2 bankfull discharge, 11.3 cms)	N/A	Ripping appeared to increase subsequent spawning activity.	Treatment increased turbidity for 40-50 miles downstream.	0.7
Shackle et al. 1999	Kennet River, Coln River, Windrush River, and Leach River in southern England	The treatment involved rotovating with a Dowdeswell Powervator 35 (rotary tiller) pulled behind a Ford 1220 four wheel drive tractor.	0.42	Freeze core samples taken before and after treatment indicated a 1.5% to 3.5% reduction (by weight) in silt content. Significant increases in the number of living eggs recovered from egg boxes were found in 2 of 5 treated reaches compared to untreated reaches . Treated gravel was noticeably looser than adjacent uncleaned reaches.	Increased bed erosion and spawner avoidance may occur in cleaned areas where stream gravels are out of equilibrium with streamflow conditions. Short-term increases in turbidity and suspended sediment can be expected downstream of cleaning operations.	0.7

Notes:
N/A = not applicable or not available

Table 3 - Ranking of Gravel Cleaning Methods Reviewed by Cost, Effectiveness and Ecological Disturbance

Reference	Method	cost[2]			effectiveness		impact		ranking[1]
		$/m²	rating	Score	rating	Score	rating	Score	
Mih and Bailey 1981, Allen et al. 1981	Hydraulic (water jet/vaccuum)	N/A	N/A	N/A	moderate	2	low	3	0.83
Shields 1968, Meehan 1971, Mih 1979	Hydraulic (water jet/vaccuum)	N/A	N/A	N/A	moderate	2	low	3	0.83
Mih 1979	Hydraulic (water jet)	N/A	N/A	N/A	high	3	moderate	2	0.83
Shackle et al. 1999	Hydraulic (water jet)	N/A	N/A	N/A	high	3	moderate	2	0.83
Hall and Baker 1982, Gerke 1990	Mechanical (ripping, tilling)	N/A	N/A	1	moderate	2	moderate	2	0.83
West 1984	Mechanical (ripping, tilling)	$ 0.30	low	3	moderate	2	moderate	2	0.78
Andrew 1981	Hydraulic (water jet)	$ 0.61	low	3	moderate	2	moderate	2	0.78
Heiser 1971	Mechanical (excavation/replacement)	$ 0.72	low	3	moderate	2	moderate	2	0.78
TID/MID 1992	Mechanical (ripping); Hydraulic (jet/vaccuum)	$ 3.26	moderate	2	high	3	moderate	2	0.78
Shackle et al. 1999	Mechanical (tilling)	$ 0.42	N/A	N/A	high	3	high	1	0.67
Einstein 1965	Hydraulic (weir/baffle gate)	N/A	N/A	N/A	low	1	low	3	0.67
Mih 1978	Hydraulic (weir/baffle gate)	N/A	N/A	N/A	low	1	low	3	0.67
Hampton 1990	Mechanical (ripping)	N/A	N/A	N/A	moderate	2	moderate	2	0.67
Painter 1990	Mechanical (ripping)	N/A	N/A	N/A	moderate	2	moderate	2	0.67
Andrew 1981	Mechanical (excavation/cleaning)	$ 1.44	moderate	2	moderate	2	high	1	0.56
Mih 1978	Mechanical (excavation/cleaning)	$ 4.10	moderate	2	moderate	2	high	1	0.56
EA 1989	Mechanical (ripping)	N/A	N/A	N/A	low	1	moderate	2	0.50
Stemple 1990	Mechanical (ripping)	N/A	N/A	N/A	low	1	moderate	2	0.50
Mundie and Mounce 1978	Hydraulic (water jet)	N/A	N/A	N/A	low	1	moderate	2	0.50
Wilson 1976	Mechanical (excavation/replacement)	$ 47.57	high	1	low	1	high	1	0.33

notes:

1. Ranking is based on the fraction of the points received over the total score available (9 where units costs are identified, 6 where N/A). Scores are assigned as follows:

cost: low=3, moderate=2, high=1
effectiveness: high=3, moderate=2, low=1
impacts: low=3, moderate=2, high=1

2. Costs adjusted for inflation to year 2001 basis and normalized to unit area cleaned.

N/A = not applicable or not available

Table 4. Gravel quality statistics for all processed gravel-quality samples from 1993 Tuolumne River gravel-cleaning test.

Samples From Upstream Fifty Feet Of Cleaning Test Area

Pre-Cleaning Samples					Post-Cleaning Samples				
Sample	Tappel-Bjornn	Fraction Fines	dG (mm)	Fredle	Sample	Tappel-Bjornn	Fraction Fines	dG (mm)	Fredle
91-01C	0.88	0.073	17	8.1	92-01C	0.94	0.001	43	22.7
91-02C	1.02	0.021	88	34.5	92-01C	0.94	0.032	24	12.1
91-04C	0.81	0.076	57	15.8	92-01C	0.95	0.010	66	26.2
91-05C	0.98	0.042	27	15.5	92-01C	0.65	0.153	13	4.3
91-07C	0.85	0.138	15	7.3	92-01C	0.94	0.003	112	32.6
91-08C	0.96	0.078	30	14.8	92-01C	0.94	0.007	28	17.5
91-10C	0.98	0.038	27	16.6	92-01C	0.94	0.001	36	18.6
91-14C	1.02	0.037	61	27.4	92-01C	0.93	$< 5x10^{-4}$	56	41.3
91-18C	0.92	0.092	20	10.4	92-01C	0.94	0.002	82	25.6
91-19C	0.96	0.007	53	30.7	92-01C	0.94	$< 5x10^{-4}$	123	52.3
91-26C	0.93	0.079	26	12.1	92-01C	0.92	0.018	163	28.0
91-36C	0.95	0.029	41	16.7	92-01C	0.94	$< 5x10^{-4}$	50	32.1
91-38C	0.88	0.066	49	15.7	92-01C	0.94	$< 5x10^{-4}$	47	23.3
91-41C	0.84	0.115	16	6.5	92-01C	0.94	0.001	48	21.0
91-42C	0.98	0.019	36	23.2	92-01C	0.94	0.003	32	17.8
91-43C	0.94	0.073	29	13.6	92-01C	0.93	0.001	26	15.6
91-44C	0.98	0.025	51	28.6	92-01C	0.94	$< 5x10^{-4}$	57	31.8
91-46C	0.98	0.047	40	18.2	92-01C	0.93	$< 5x10^{-4}$	59	47.7
91-48C	0.96	0.081	22	11.9	92-01C	0.94	0.012	41	16.7
91-50C	0.89	0.066	22	9.7	92-01C	0.94	$< 5x10^{-4}$	35	20.9

Samples From Downstream Fifty Feet Of Cleaning Test Area

Pre-Cleaning Samples					Post-Cleaning Samples				
Sample	Tappel-Bjornn	Fraction Fines	dG (mm)	Fredle	Sample	Tappel-Bjornn	Fraction Fines	dG (mm)	Fredle
91-03C	0.57	0.106	42	9.9	92-01C	0.83	0.115	13	5.3
91-09C	0.71	0.160	10	3.7	92-01C	0.94	0.018	40	17.7
91-12C	0.85	0.098	54	20.2	92-01C	0.94	0.004	43	21.8
91-20C	0.97	0.014	42	28.0	92-01C	0.95	0.031	30	14.7
91-21C	0.72	0.156	11	4.2	92-01C	0.94	0.029	21	11.4
91-28C	0.49	0.192	9	3.0	92-01C	0.96	0.026	37	20.2
91-30C	0.31	0.260	5	1.6	92-01C	0.62	0.159	7	3.6
91-31C	0.77	0.130	12	6.0	92-01C	0.82	0.085	26	9.1
91-32C	0.95	0.066	37	15.7	92-01C	0.91	0.057	23	9.8
91-34C	0.73	0.110	22	7.5	92-01C	0.62	0.178	11	3.6
91-37C	0.91	0.084	24	10.9	92-01C	0.71	0.135	17	5.8
91-40C	0.57	0.186	9	3.0	92-01C	0.89	0.071	15	8.1

Samples From Control Area

Pre-Cleaning Samples					Post-Cleaning Samples				
Sample	Tappel-Bjornn	Fraction Fines	dG (mm)	Fredle	Sample	Tappel-Bjornn	Fraction Fines	dG (mm)	Fredle
93-01C	0.98	0.060	44	19.0	92-01C	0.97	0.011	48	30.1
93-02C	0.95	0.014	33	16.8	92-01C	0.93	0.043	30	13.3
93-03C	0.75	0.141	12	5.1	92-01C	0.94	0.102	28	13.8
93-04C	0.97	0.019	70	27.3	92-01C	0.83	0.141	17	7.4
93-05C	1.03	0.053	31	19.5	92-01C	0.97	0.012	45	25

Table 5. Two-sample two-sided heteroscedastic t-tests for changes to gravel quality parameters.

Samples From Cleaning Test Area (All Samples)

	Change in mean index value				95% confidence interval for increase	
	before	**after**	**increase**	**p**	**lower**	**upper**
Tappel-Bjornn	0.85	0.89	0.04	0.24	-0.11	0.03
Fines	0.086	0.036	-0.05	$<10^{-3}$	0.022	0.079
dG	31	45	13	0.061	-27	1
Fredle	14	20	6	0.031	-11	-1

Samples From Cleaning Test Area (Upstream Samples)

	Change in mean index value				95% confidence interval for increase	
	before	**after**	**increase**	**p**	**lower**	**upper**
Tappel-Bjornn	0.94	0.92	-0.01	0.48	-0.03	0.05
Fines	0.060	0.012	-0.048	$<10^{-4}$	0.026	0.070
dG	36	57	21	0.035	-40	-2
Fredle	17	25	9	0.011	-15	-2

Samples From Cleaning Test Area (Downstream Samples)

	Change in mean index value				95% confidence interval for increase	
	before	**after**	**increase**	**p**	**lower**	**upper**
Tappel-Bjornn	0.71	0.84	0.13	0.066	-0.28	0.01
Fines	0.130	0.076	-0.055	0.043	0.002	0.107
dG	23	24	1	0.91	-13	12
Fredle	9	11	1	0.63	-8	5

Samples From Control Area

	Change in mean index value				95% confidence interval for increase	
	before	**after**	**increase**	**p**	**lower**	**upper**
Tappel-Bjornn	0.94	0.93	-0.01	0.88	-0.12	0.14
Fines	0.057	0.062	0.004	0.90	-0.084	0.075
dG	38	34	-5	0.69	-22	31
Fredle	18	18	0	0.94	-13	12

Appendix G

Tuolumne River Phase II Gravel Introduction Technical Memorandum (Draft)

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TUOLUMNE RIVER PHASE II GRAVEL INTRODUCTION TECHNICAL MEMORANDUM

Prepared on Behalf of
Tuolumne River Technical Advisory Committee

for

Department of Water Resources
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and

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February 28, 2001

Background

The Tuolumne River Technical Advisory Committee developed the *Habitat Restoration Plan for the Lower Tuolumne River Corridor* (McBain and Trush 2000) to guide restoration activities on the river. A primary recommendation in the Restoration Plan was to restore coarse sediment conditions in the Gravel-bedded Zone, first by adding large volumes of gravel and cobble to rapidly improve the coarse sediment storage in the channel, then by periodically adding coarse sediment approximately at the rate it is transported downstream during high flows. This gravel introduction program began in 1999 with implementation of the DFG/DWR Phase I Gravel Addition Project at La Grange, which introduced approximately 12,500 cubic yards of gravel at riffle 1A below La Grange Bridge. Phase II of the Spawning Gravel Introduction Project was funded by AFRP and the Tracy Mitigation Program to continue spawning gravel introduction in the upper reaches of the Tuolumne River. The AFRP program also funded McBain and Trush to prepare a Coarse Sediment Management Plan that would provide additional detail on high priority gravel introduction sites, refined volume estimates, methods for gravel introduction, and specific monitoring guidelines. Because the Sediment Management Plan will not be complete before the DFG/DWR Phase II project is implemented, McBain and Trush have prepared this technical memorandum to help guide the implementation of the Phase II project.

Data Collection

To date, we have collected the following information for the Sediment Management Plan:

- habitat mapped, using recent aerial photos (Dec 1999) and methods developed for other Tuolumne River projects; mapping includes pool-riffle-run units, gravel bars, and chinook spawning habitat as indicated by recent redd construction;
- surveyed several potential sites that would benefit from spawning gravel or coarse sediment augmentation, and assessed logistical opportunities/constraints (road construction needs, land ownership, etc.);
- installed and surveyed 19 new cross sections between La Grange Dam and Basso, monumented with rebar pins and tied to real elevation control where possible; cross sections are numbered according to longitudinal stationing from the San Joaquin River, similar to other Tuolumne River project reaches; cross sections and other survey data were used to estimate gravel volumes at specific proposed sites;
- performed pebble counts of existing and proposed sediment conditions;
- compared pre-1990's habitat data with recent data to document spawning habitat attrition at specific riffles, in order to aid in prioritizing the selection of gravel introduction sites for 2001 and for future projects;
- assessed historical conditions at selected sites from early aerial photo sequences;

The primary focus of the Sediment Management Plan is in the reach between La Grange Dam and Basso Bridge. We mapped the available spawning habitat in this reach in December 2000, to compare to previous spawning habitat assessments conducted by the Districts in 1988 (EA 1992). Our assessment in the upper reach indicates that spawning habitat has decreased by as much as 44% compared to the 1988 data, likely a result of steady gravel attrition from annual bedload transport and lack of upstream supply, as well as from the catastrophic degradation from the January 1997 flood. Based on spawning habitat availability, channel widening and downcutting, and chinook spawning preferences (redd densities), the most evident impacts are generally in the riffles upstream of New La Grange Bridge (NLGB), compared to riffles between NLGB and Basso Bridge. For example, spawning habitat at riffle A3/4 has been reduced from 22,000 ft2 in 1988 to approximately 3,700 ft2 in 2000; Riffle A5 is nearly completely scoured away, with water depths of 5 to 6 ft, coarse substrate, and very little velocity; Riffle A6 supported only one or two redds in 2000/01 spawning season.

Site Selection, Methods, and Volumes

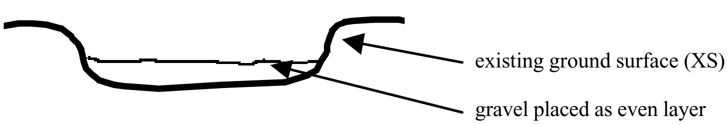
During the Feb 13 meeting, the TRTAC agreed that sites upstream of New La Grange Bridge were highest priority. This reach receives the highest concentration of spawners, and gravel placed here will not only provide immediate benefit to salmon, but will continue to benefit salmon in future years as the gravel is routed downstream. Our selection of preferred sites for 2001 implementation was therefore prioritized as follows (see Figure 1 for site locations):

- the section of channel between riffles A7 and 1B (upstream and downstream of the Phase I project site) was recommended as a preferred site for implementation in 2001. In addition, the TRTAC discussed supplementing the riffle 1A Phase I site with a gravel bar extending from the left bank, with the objective of increasing channel confinement, providing better velocities in the riffle, and introducing a somewhat finer gravel mixture.

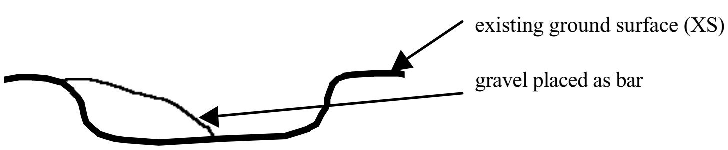
- riffles A1 and A2 were not recommended because of the limited long-term benefits to be gained at these sites, both located upstream of a deep pool that would prevent gravel from routing downstream in future events;
- riffle A3/4 would require construction of a new access road on TID property, and was recommended as a project for implementation by the Districts;
- riffles A5 and A6 are high priority, but access is limited to a single location at the USGS Cableway;

Early implementation of gravel introduction (prior to completion of the Coarse Sediment Management Plan) provides an excellent opportunity to experiment with gravel placement techniques to maximize . We propose several different techniques for gravel placement (Figure 3):

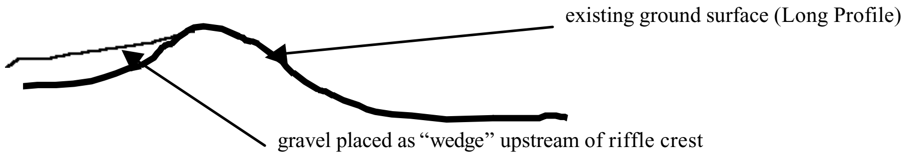
1. Riffle supplementation: this method entails placing clean, well-sorted gravel onto the existing channelbed in an even layer of specified depth;



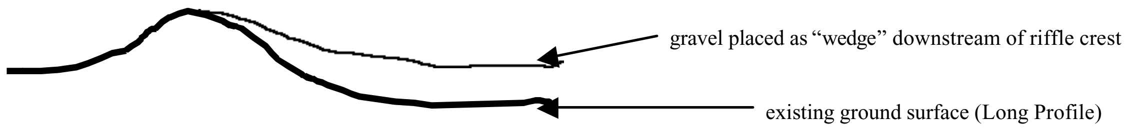
2. Point bar supplementation: this method would place gravel as a lateral bar to increase confinement and provide long-term supply;



3. Pool tail supplementation: this method would increase spawning habitat area on overly-steep pool-tails;



4. Riffle wedge: this method would layer gravel increasing in depth moving downstream to reduce the riffle slope and increase spawning habitat;



5. Recruitment pile: this method would place a quantity of gravel on or near the channel margin, available for downstream transport at high flows; long-term recruitment locations could be identified for routine (annual) supplementation;

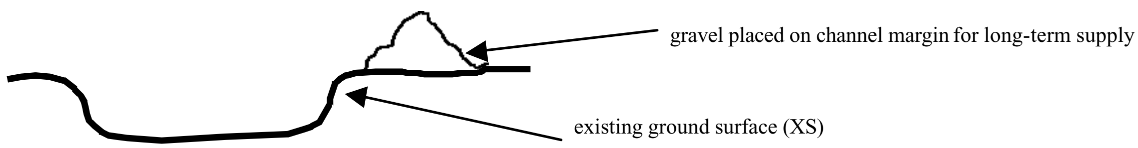


Figure 3. Suggested gravel introduction methods that can be used to address different channel conditions.

In addition to placement of large quantities of gravel directly in the channel for immediate spawning habitat supplementation, our assessment of coarse sediment storage conditions below La Grange Dam concluded that gravel could be placed in a natural gravel bar morphology in several locations to increase coarse sediment storage for eventual downstream transport, to improve channel confinement, and to increase water velocities during spawning flows. Restoring a more natural alternate bar morphology will improve bedload transport continuity, and therefore better downstream routing of introduced gravels during high flows. Importantly, this strategy will discourage future riffle loss by providing instream sediment storage to replace gravels transported from riffles during high flows. In addition, the large backwater dredging pit should be filled to reconstruct bankfull channel confinement. A coarser (unprocessed) gravel composition can potentially be used to construct bars and fill backwaters.

Figure 1 shows recommended spawning gravel and coarse sediment introduction sites from riffle A7 to riffle 1B. We delineated discrete gravel introduction polygons (numbered 10 to 18) to provide gravel volume estimates and flexibility in gravel addition methods and particle size composition. These polygons were digitized to estimate the surface area, and combined with the recommended depth of gravel placement, yielded the estimated gravel volumes. We used cross section surveys to estimate the appropriate depth of gravel placement in the riffle A7 section. We have not installed cross sections in the portion of channel below riffle 1A, and estimates of gravel depth should be refined with additional surveys.

In addition to the planview map of the gravel introduction sites (Figure 1), we provide the 1999 aerial photo of the proposed gravel introduction reach upstream and downstream of Old La Grange Bridge (Figure 2),cross sections with "proposed channel contours" sketched onto cross section plots. These contour lines were used to estimate recommended gravel depths/volumes. Placement of gravel into the channel during implementation may be simplified, with less topographic detail than is reflected in the sketched contour lines.

Below we describe each gravel introduction polygon, the main objective for gravel placement, and provide a rough volume estimate.

Polygon 10: Impacts of bank scour and lack of supply from upstream sources are clearly evident in recent air photos and field visits. Spawning habitat in adjacent portions of the channel will benefit from increased confinement in the upper portion of the riffle, by increasing velocities in the pool tail spawning areas at spawning flows (~300 cfs). Additionally, this material will be available for transport at high flows to maintain spawning gravel supply at downstream riffles. Recommended gravel introduction volume at polygon 10 is approximately 4,300 yd^3. A coarser, heterogeneous mix of unwashed gravel and cobble could be used here. Figure 4 (XS-2804+00) shows the proposed gravel introduction morphology on the left bank bar.

Polygon 11: The pool tail at the head of riffle A7 emerges from a deep pool, and has an unnaturally steep longitudinal morphology (Figure 4), and bedrock has become exposed within the channel. Introducing gravel in the pool tail downstream to the riffle crest will increase available spawning habitat. Gravel should be placed so the riffle crest elevation is not increased at this site. Recommended volume = 700 yd^3. Figure 4 (XS-2804+00) shows the proposed pool tail morphology.

Polygon 12: The direction of flow entering the riffle causes frequent scour of the bedrock outcropping on the right bank. We recommend placing a small volume of gravel on this bedrock ledge for future transport during high flows to maintain spawning gravel at downstream riffles. Recommended volume = 600 yd^3. This material should be relatively clean, fine gravel (1-4 inch) to facilitate mobilization and downstream transport. Figure 5 shows the proposed right bank bar morphology.

Polygon 13: The main portion of the riffle provides usable spawning habitat, but the spawning area could be improved and increased by reducing the riffle slope. Measured slope from the riffle crest to XS-R is 0.0070. Raising the channelbed approximately 2.0 ft at XS 2802+00 would reduce slope to 0.0020. Gravel should be placed so the riffle crest elevation is not increased at this site. This would require a gravel "wedge" of increasing depth from 0.0 ft at the upstream riffle crest to 2.0 ft at XS 2802+00. Recommended volume = 1,200 yd^3. Figure 5 shows the proposed riffle cross section contour.

Polygon 14a,b: The riffle ends abruptly into a pool with depths increasing in the downstream direction up to 11 ft. By adding gravel at the downstream end of the riffle, the entire riffle length can be extended and substantially increase the available spawning habitat. Gravel should be placed contiguous with polygon 13 and extend approximately 300-500 ft downstream (depending on the volume of material available), with constant slope of approximately 0.0020. Recommended volume = 5,200 yd^3. Figure 5 shows the proposed cross section contour extending downstream from the riffle tail.

Subtotal gravel volume for introduction at riffle A7 = 12,000 yd^3

Polygon 15a: The CDFG Phase I gravel addition at riffle 1A below the Old La Grange Bridge substantially increased the volume of coarse sediment in this portion of channel, replacing much of the material scoured downstream during the 1997 flood. The channel is over-widened in this reach, however, contributes to water velocities below the usable range for salmonid spawning. Additionally, the material appears somewhat coarser than the preference range for chinook salmon. The TRTAC Subcommittee agreed that the Phase I project would likely be improved by further supplementing riffle 1A with gravel placed as a left bank bar to slightly increase confinement and velocities during spawning flows, and with finer gravels sprinkled throughout the riffle. Recommended volume = 3,500 yd^3. Figure 1 shows the proposed location and extent of gravel placement.

Polygon 15b: The section of channel between riffles 1A and 1B was extensively altered during the 1997 flood. The large right bank bar opposite the left bank backwater was nearly entirely scoured away, and a small side-channel formed. Very little spawning was observed in this reach in 2000-01. This gravel introduction polygon would extend riffle 1A further downstream and eliminate the small scour pool. Recommended volume = 1,500 yd^3. Figure 1 shows the proposed location and extent of gravel placement.

Polygon 16: The former right bank bar that was scoured during the 1997 flood should be replaced to restore high flow (<5,000 cfs) confinement through this section of channel. Replacing the bar would eliminate the right side channel and backwater areas where velocities were too low for salmon spawning. This bar will also provide in-channel gravel storage available to maintain downstream spawning riffles and reduce/prevent future losses. Recommended volume = 4,000 yd^3. Figure 1 shows the proposed location and extent of gravel placement.

Polygon 17: The large backwater pond on the left bank is a remnant dredger mining pit. Backwater areas provide habitat for bass during summer when water temperatures are higher, trap and store fine sediments (sand), and eliminate the bankfull channel confinement that allows bedload transport continuity through the reach. Filling in this backwater pond (Figure 7) will significantly improve spawning habitat and geomorphic conditions in this reach. A coarser, heterogeneous mix of gravel and cobble could be used here. Recommended volume = 6,000 yd^3. Figure 1 shows the proposed location and extent of gravel placement.

Polygon 18a: The section of channel between the backwater pond and right bank bar was also significantly scoured during the 1997 flood. Water depths exceed 6-8 ft. By placing gravel back into this portion of the channel, riffle 1A could be extended further downstream to increase the amount of spawning habitat available. Additional surveying would be necessary here to refine the estimate of gravel depths appropriate to restore a suitable riffle slope. Recommended volume = 3,000 yd^3. Figure 1 shows the proposed location and extent of gravel placement.

Polygon 18b: If enough gravel is available (within funding constraints) during Phase II, then riffle 1A can be extended further downstream by supplementing the channel between polygon 18a and riffle 1B with approximately 2 ft of clean spawning gravel. Additional surveying would be necessary here to refine the estimate of gravel depths appropriate to restore a suitable riffle slope. Recommended volume = 5,000 yd^3. Figure 1 shows the proposed location and extent of gravel placement.

Subtotal gravel volume for introduction at riffle 1A/B (including 18b) = 23,000 yd^3

Total gravel volume recommended for Phase II introduction = 35,000 yd^3

Site Access

During the Feb 13th TRTAC meeting, we discussed access to the riffle A7 and 1A/B sites. Access to riffle A7 from the south bank would require trucks passing through downtown La Grange, then down the Old La Grange Bridge road and onto the floodplain via a steep, unimproved dirt road on the west (downstream) side of the bridge. Trucks would then pass under the bridge and upstream on the floodplain where access is relatively straightforward. Access to riffles 1A/B would be relatively easy here. An abandoned dirt road leads from the Old La Grange Bridge road to riffle A7, but this road would require substantial improvements (grading and brush/tree limb clearing) to provide access for dump trucks. This property is owned by Stanislaus County.

Access from the north bank appears preferable. Haul trucks would avoid having to pass through downtown La Grange, and very little road improvement would be necessary. The existing improved dirt road leading past the DFG La Grange Field Office, past La Grange Bridge, then up-river along the hillside would provide access to riffle A7. A small section of road grading and placement of a temporary culvert to cross the small swale would be required to descend the hill to the introduction site. Improving this access would also provide a future long-term gravel introduction site for routine maintenance (by placing small quantities of gravel on the right bank bedrock bar). Access to the sites downstream of Old La Grange Bridge already exists along the north bank from the Phase I project. All property on the north bank is owned either by Stanislaus County or the State of California.

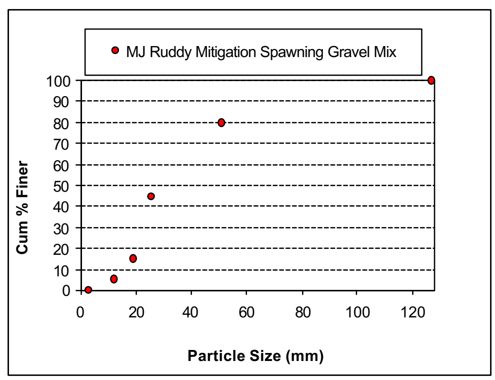
Gravel Composition

Gravel size requirements vary with a fish's life stage. For spawning adult chinook salmon, considerable research has been conducted to describe suitable spawning gravel size compositions. For example, Raleigh (et al. 1986) reported the optimal mix for chinook salmon ranging from 20 to 106 mm. Chambers (1956) reported suitable gravel mixes of: 21% for 3 to 12.5 mm; 41% for 12.5 to 60 mm; 24% for 60 to 100 mm; and 14% for 60 to 150 mm. Allen and Hassler (1986) developed profiles of habitat requirements for chinook salmon in the Pacific Southwest, and site Bell's (1973) findings that optimal gravels range from 13 to 102 mm, and that 80% of the particles should range from 13 to 51 mm, and the remaining 20% from 51 to 103 mm. This size range also agrees with Thompson (1972) as cited in Bjornn and Reiser for fall chinook salmon. Platts et al. (1979) reported spawning gravel mixes from the South Fork Salmon River, Idaho containing 84% of 10 to 76 mm, and the remaining greater than 76 mm. Finally, Kondolf and Wolman (1993) compiled published and original reports containing spawning gravel size distribution data for salmonids, and noted a large range of spawning gravel sizes used by chinook salmon. Describing the ideal or definitive spawning gravel mixture is thus not possible.

Previous spawning gravel improvement projects on the Tuolumne River (TFC 1990) used literature information to develop a gravel composition suitable for chinook salmon spawning riffles specifically for the Tuolumne River. They recommended (and used) the following gravel mixture at riffle 36A in the Santa Fe Aggregates (formerly MJ Ruddy) Mining Reach:

Table 1. Gravel composition used at MJ Ruddy (riffle 36A) for spawning gravel mitigation in 1989.

Percent of Total	*Particle Size (mm)*	*Particle Size (inches)*
5%	3 to 12.5 mm	1/8 " to 1/2"
10%	12.5 to 19.1 mm	1/2" to3/4"
30%	19.1 to 25.4 mm	3/4" to 1"
35%	25.4 to 51 mm	1" to 2"
20%	51 to 127 mm	2" to 5"



This gravel mixture equates to approximately 80% finer than 51 mm (2 inches), with D_{50} = 28 mm and D_{84} = 60 mm. We recommend using a spawning gravel mixture that conforms as closely as is practical to the above mixture, but that does not exceed the 20% recommended for the larger 2" to 5" component.

We performed surface pebble counts at several riffle sites in the reach between New La Grange Bridge and Basso Bridge, at locations with good spawning gravel-sized gravel distributions. Table 2 shows the particle sizes of the most recent pebble count data. This data conforms well with the recommended gravel mixture above, since the surface particle composition is generally coarser than the subsurface bulk sample.

Table 2. Particle sizes from recent pebble count data.

Pebble Ct Location	D_{50}	D_{84}	*Type of Facies*
Riffle 3B	52	83	Low water margin of lateral bar
Riffle 4A	40	70	Low water margin of lateral bar
Riffle 4B	45	68	Surface of shallowly inundated medial bar surrounded by numerous redds
Riffle 5A	58	106	Coarser facies representative of riffle and run thalweg

Literature Cited

Allen, M.A., and T.J. Hassler. 1986. Species profiles: life histories and environmental requirements of coastal fishes and invertebrates (Pacific Southwest) –chinook salmon. U.S. Fish and Wildlife Service Biological Report 82(11.49). US Army Corp of Engineers, Tuolumne River EL-82-4. 26 p.

Bell, M.C. 1973. Fisheries handbook of fisheries requirements and biological criteria. U.S. Army Corp of Engineers, Fish Eng. Res. Program. Portland Oregon.

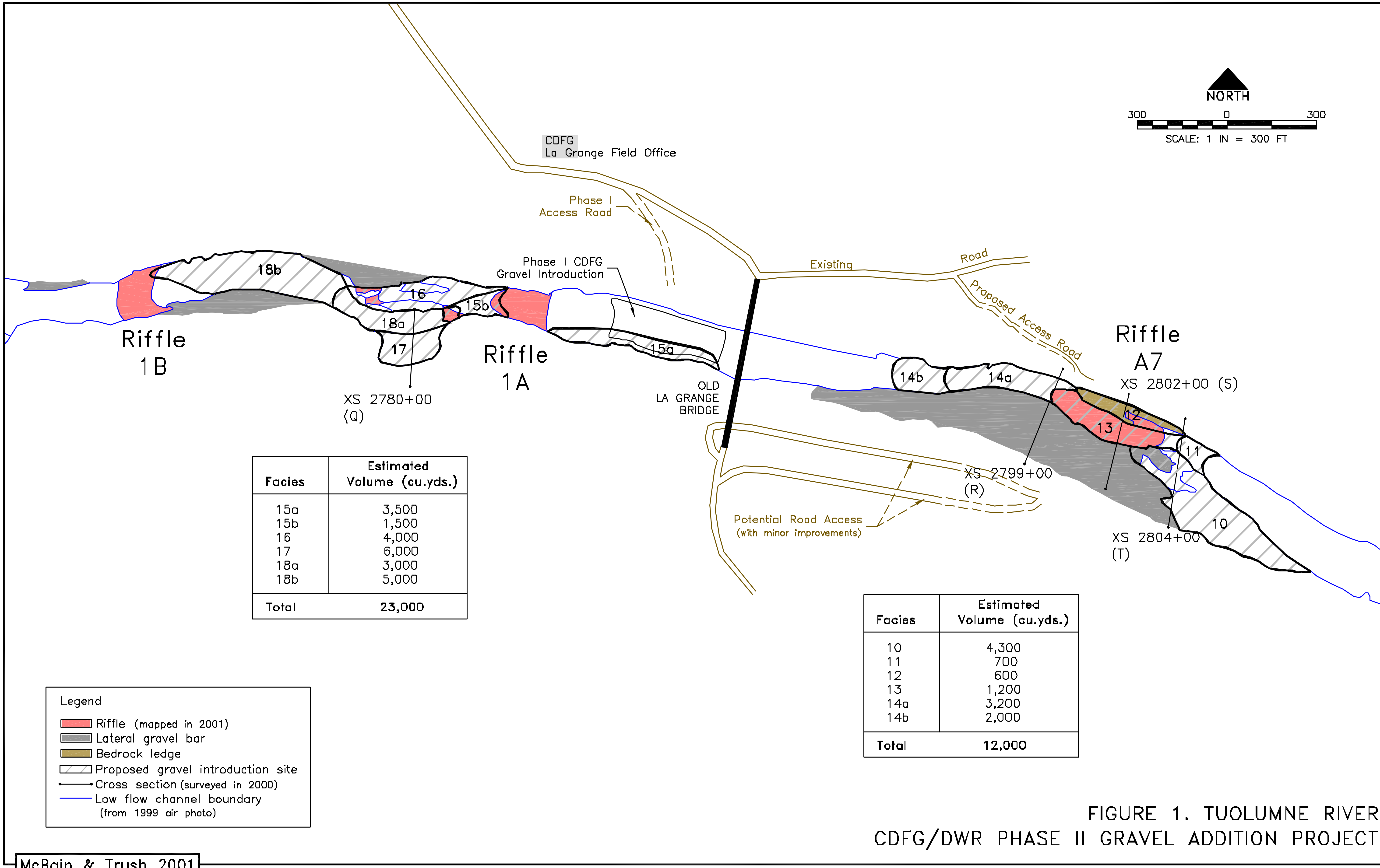
Chambers, J.S. 1956. Research relating to study of spawning grounds in natural areas. U.S. Army Corp of Engineers, North Pacific Division, Fish Eng. Res. Program. p 88-94.

Kondolf, G.M., and M.G. Wolman. 1993. The sizes of salmonid spawning gravels. Water Resources Research, 29(7): 2275-2285.

Platts, W.S., W.F. Megahan, and G.W. Minshall. 1983. Methods for evaluating stream, riparian, and biotic conditions. USDA Forest Service, Intermountain Forest and Range Experimental Station, General Technical Report INT-138

Raleigh, R.F., W.J. Miller, and P.C. Nelson. 1986. Habitat suitability index models and instream flow suitability curves: chinook salmon. U.S. Fish and Wildlife Service Biological Report 82(10.122). 64 p.

Trinity Fisheries Consulting: Anadromous Fisheries Restoration. 1990. Draft Report on gravel quality monitoring of MJ Ruddy, Inc. 1989 salmon spawning restoration projects on the Tuolumne River. Arcata Ca.



Facies	Estimated Volume (cu.yds.)
15a	3,500
15b	1,500
16	4,000
17	6,000
18a	3,000
18b	5,000
Total	23,000

Facies	Estimated Volume (cu.yds.)
10	4,300
11	700
12	600
13	1,200
14a	3,200
14b	2,000
Total	12,000

FIGURE 1. TUOLUMNE RIVER
CDFG/DWR PHASE II GRAVEL ADDITION PROJECT

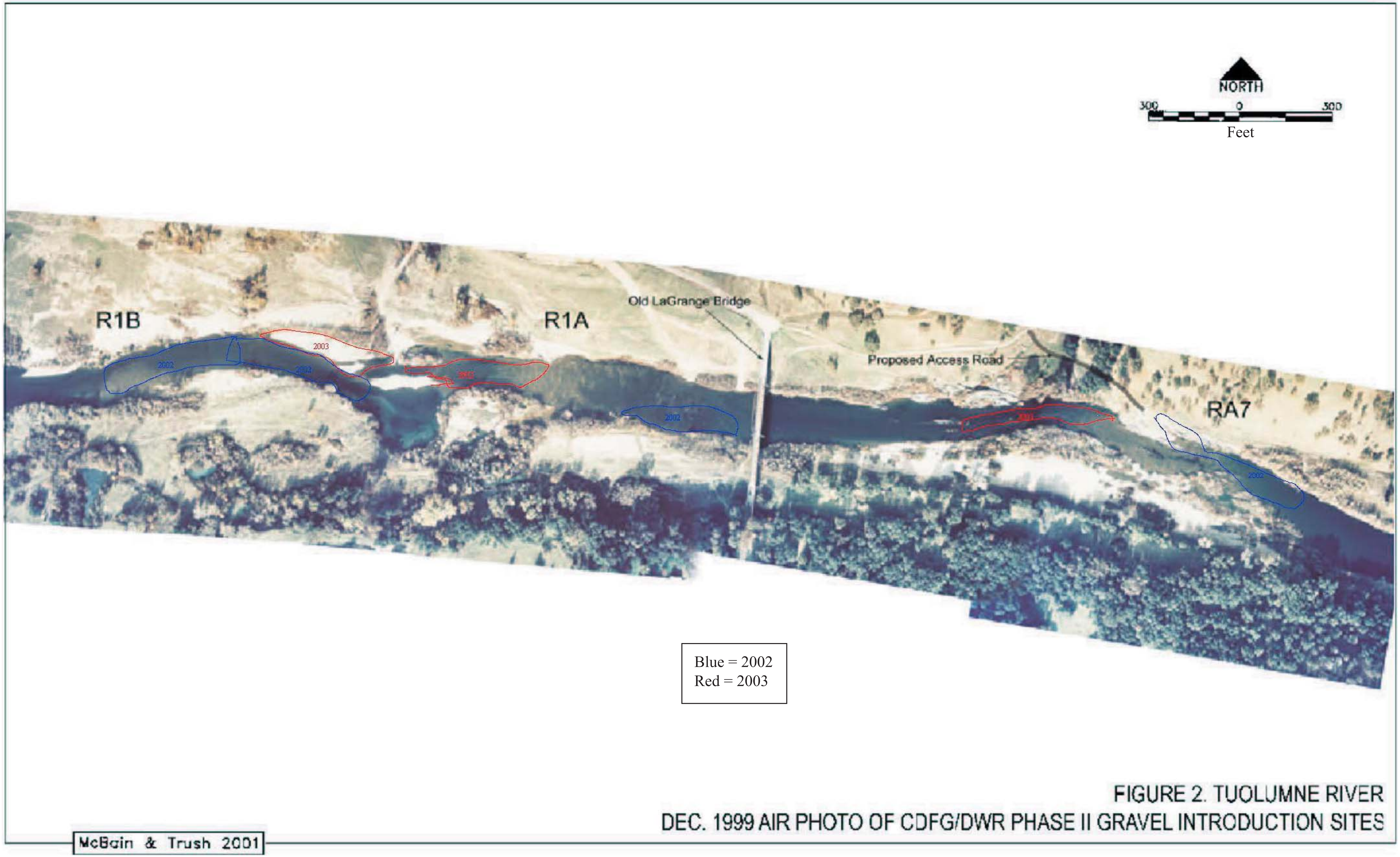


FIGURE 2. TUOLUMNE RIVER
DEC. 1999 AIR PHOTO OF CDFG/DWR PHASE II GRAVEL INTRODUCTION SITES

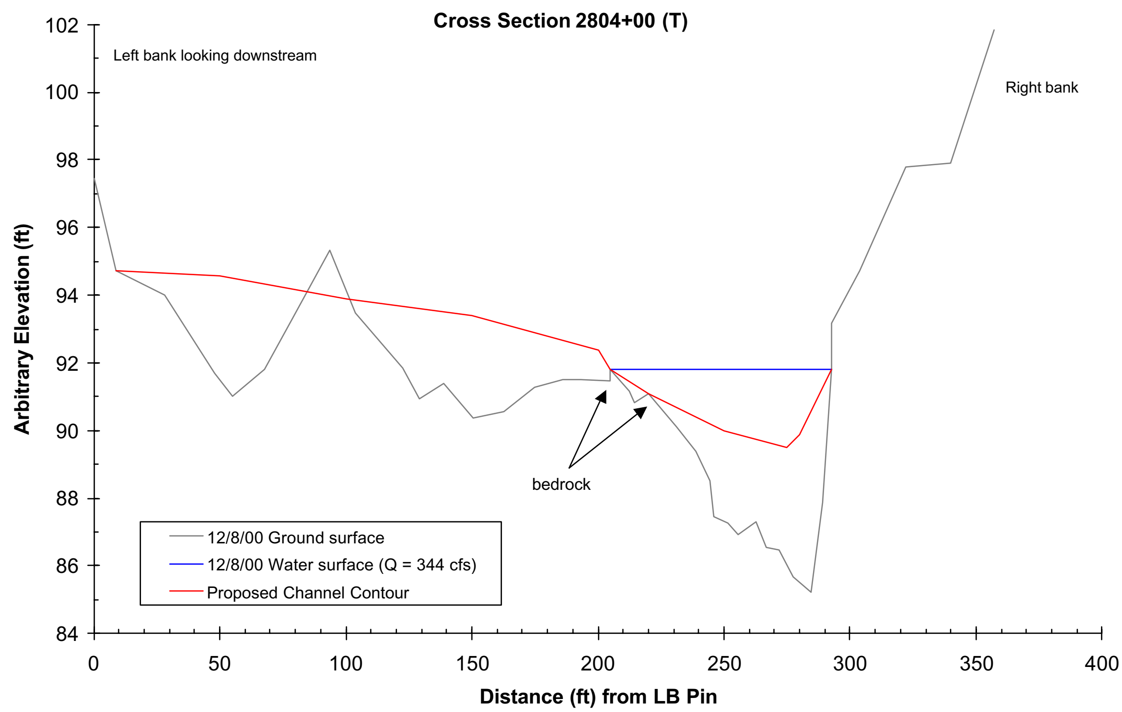


Figure 4. Cross Section 2804+00 traversing pool-tail at the head of riffle A7. The left bank lateral bar has been scoured and depleted of most coarse sediment stored on the bank. The right bank has become incised to bedrock, and the face of the pool-tail steepened.

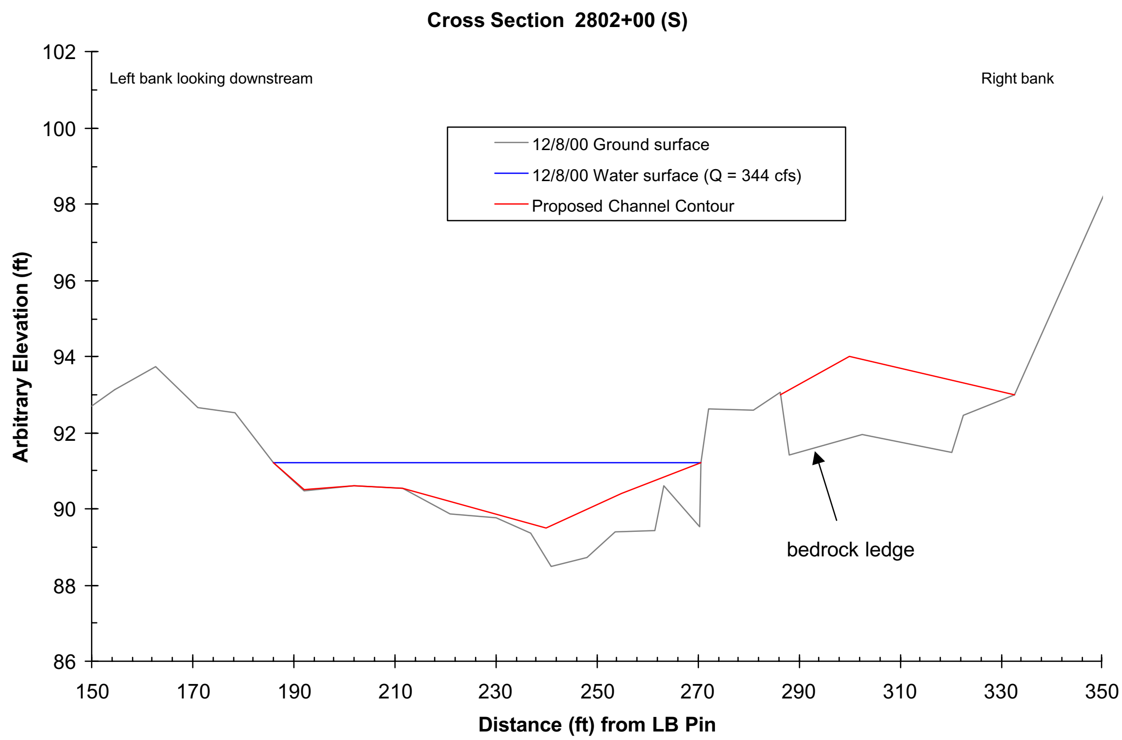


Figure 5. Cross Section 2802+00 traversing the middle portion of riffle A7. The left side of the riffle provides good spawning habitat, but the right half has higher velocities that exceed the suitable range for chinook spawning. Additionally, the right bank bedrock ledge is an ideal site to re-supply gravel storage.

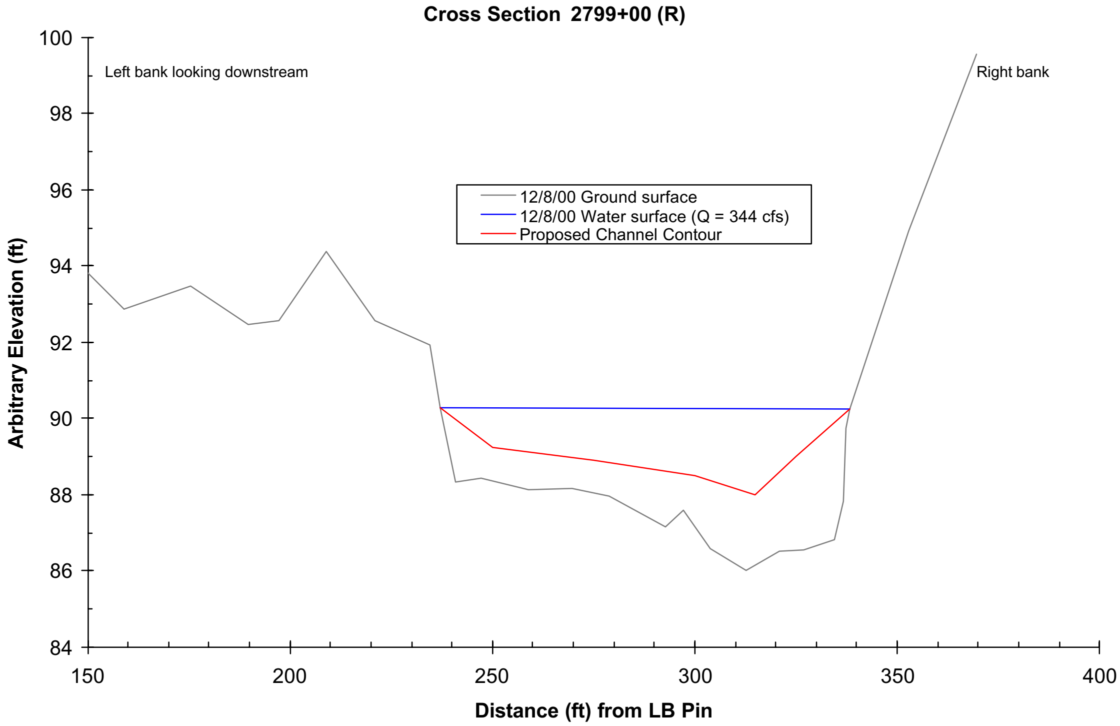


Figure 6. Cross Section 2799+00 traversing the downstream end of riffle A7. beyond this cross section the channel deepens to 6-8 ft.

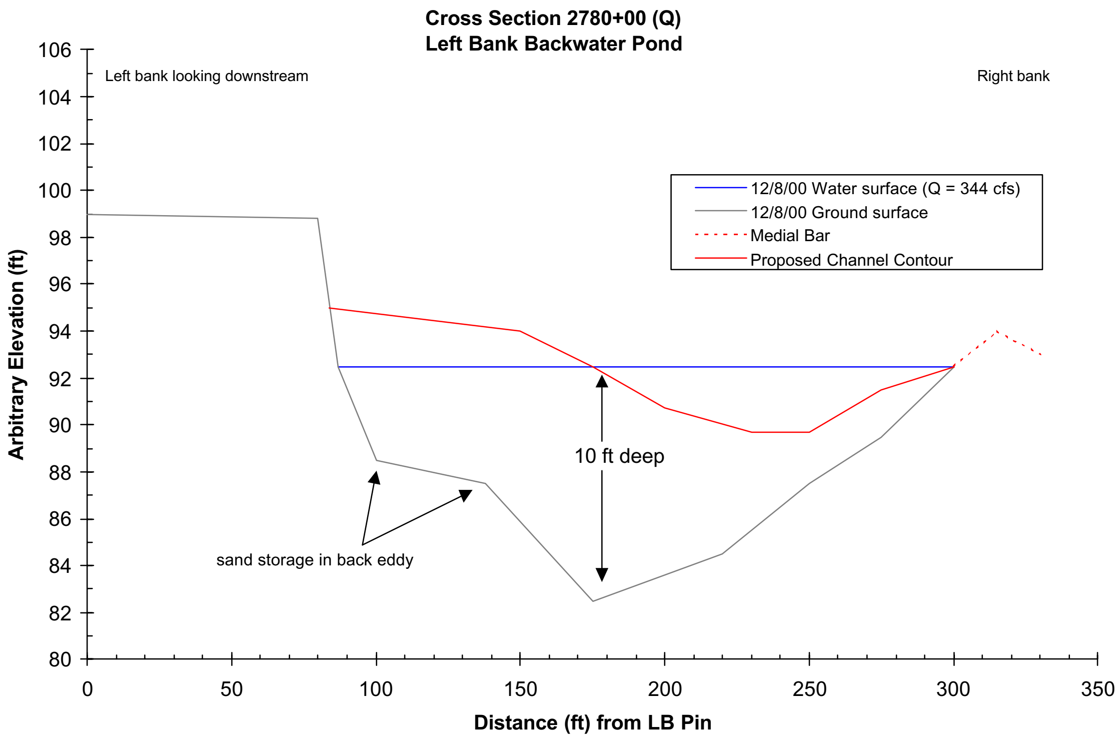


Figure 7. Cross Section 2780+00 traversing the left bank backwater pit that was left from dredger mining operations. Filling the pit would reconfine the low water channel.

Appendix H

Informal Consultation with regards to Steelhead for Phase II Gravel Introduction at La Grange on the Tuolumne River, CA.

United States Department of the Interior
FISH AND WILDLIFE SERVICE
Stockton Fish and Wildlife Office
4001 North Wilson Way, Stockton, CA 95205-2486
209-946-6400 (Voice) 209-946-6355 (Fax)

July 7, 2003

To: Madelyn Martinez, NOAA Fisheries

From: Jeff McLain, Anadromous Fish Restoration Program

Subject: Informal Consultation with regards to Steelhead for Phase II Gravel Introduction at La Grange on the Tuolumne River, CA.

Dear Madelyn,

I am sending this letter to you, at your request, to summarize the meeting on June 25, 2003, in La Grange to discuss the impacts of gravel additions for salmon spawning enhancement on ESA listed steelhead/trout habitat. As you know, The Anadromous Fish Restoration Program (AFRP) has contracted a portion of this work to the La Grange habitat improvement shop and feels it fulfills a vital role in restoring Chinook salmon populations on the Tuolumne River. The AFRP wants to ensure steelhead/trout habitat is not adversely effected during this process. The meeting which took place on site was attended by representatives of the Tuolumne River Technical Advisory Committee. The following people attended the meeting:

Doug Ridgeway, California Department of Fish and Game
Dave and Allison Boucher, Friends of Tuolumne River
Dennis Blakeman, California Department of Fish and Game
Jeff McLain, U.S. Fish and Wildlife Service
Madelyn Martinez, NOAA Fisheries
Patrick Koepele, Tuolumne River Preservation Trust
Tim Heyne, California Department of Fish and Game
Wilton Fryer, Turlock Irrigation District

The group visited gravel augmentation sites utilized by the California Department of Fish and Game La Grange office. Dave Boucher, among others present pointed out the favorable steelhead/trout habitat adjacent to these sites and we discussed methods to avoiding impacts to these habitats as well as potential enhancements. Following, is a summary of our discussion at these sites and recommendations for gravel augmentation during 2003.

Introduction Site 15a (Riffle 1A)

The group observed introduction site 15a, which appeared to have good salmon spawning habitat. Previous years gravel introductions at this site have been successful (Figure 1).

Introduction Site 15b (Riffle 1A)

This site had a good steelhead/trout pool on the south bank with good depth, velocity and overhanging vegetation (Figure 2). Previous gravel introductions have remained upstream of this pool, and the group agreed to continue to avoid disturbing this pool that is at the lower end of the riffle. Any introductions in the future should stay at least 20'-30' from the bank.

Figure 1. Gravel introduction site 15a, La Grange.

Figure 2. South bank pool (left) at lower end of gravel introduction site 15b, La Grange.

Introduction Site 16

Introduction site 16 was on a riffle just below a large pool and appeared to have moderate steelhead/trout habitat adjacent to the south bank (Figure 3). The group recommended pushing gravel from the north bank, restricting the channel and concentrating the flow on the south bank.

Figure 3. Gravel introduction site 16, La Grange.

Introduction Site 18b (Riffle 1B)

Site 18b appeared to have good gravel on the slightly large side for both Chinook and steelhead/trout (Figure 4). Top dressing may be beneficial in the future. There were some good pools just downstream of this gravel introduction site on the north side that should be preserved (Figure 5). The group recommended filling the south site of the channel upstream of the bridge to keep the thalweg on the north bank.

Figure 4. Gravel introduction site 18b, La Grange

Figure 5. Pools just below gravel introduction site 18b, La Grange.

Introduction Sites 14a and 14b

Introduction sites 14a and 14b are upstream of the Old La Grange bridge just downstream of Riffle A7 (Figure 6). These sites contained small pools with overhanging vegetation along the north bank but did not have the required topographical heterogeneity for steelhead/trout usage. The suggestion of the group was to add gravel in “bumps” upstream of the pools.

Figure 6. Gravel introduction sites 14a and 14b, La Grange.

Recommendations

Due to increasing gravel costs, only 5,300 cubic yards of gravel will be available for placement during 2003 (see attached letter from Doug Ridgeway, California Department of Fish and Game). In light of the limited gravel supply, the group made the following recommendations:

1) Build new riffles downstream of Riffle A7 in sites 14a and 14b,
2) Create a new gravel bar at site 16 by narrowing the channel,
3) Add contours running diagonally to the rivers flow at 18a,
4) Stay 20' to 30' from banks with valuable steelhead habitat, and
5) Conduct pre and post project evaluations.

The group agreed that these actions should be taken to ensure no damage to steelhead/trout habitat. In addition, it appears the existing steelhead habitat could be improved with small adjustments in gravel introduction methods. Please call me if you have any questions.

Sincerely,

Jeff McLain
Fishery Biologist

Attachments

Appendix I

Adult *O. mykiss* Habitat in the Lower Tuolumne River: California Rivers Restoration Fund (2004)

CALIFORNIA RIVERS RESTORATION FUND

Adult *O. mykiss* Habitat in the Lower Tuolumne River

Produced for

Tuolumne River Technical Advisory Committee

Prepared by

California Rivers Restoration Fund
P.O. Box 236
Soulsbyville, California 95372
Phone (209) 532-7146

Funded by

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and

Friends of the Tuolumne, Inc.
7523 Meadow Avenue
Stockton, CA 95207
(209) 477-9033

8 March 2004

INTRODUCTION

The California Rivers Restoration Fund (CRRF) mapped the locations where they routinely catch adult *Oncorhynchus mykiss* that weigh between 2 and 12 pounds using hook-and-line tackle in the lower Tuolumne River between La Grange Dam and the Robert's Ferry Bridge. Some of these fish are bright silver, which is typical of Central Valley steelhead that have recently migrated into the river (Photo 34, Appendix A).

Adult *O. mykiss* typically utilize short riffle-pool sequences where surface turbulence is present over the riffle and downstream pool habitat (Appendix A). The channels at the pool-tails are usually narrow or constricted, which creates the surface turbulence. The riffles are also steep, quickly transitioning into pool habitat that is at least 4 feet deep. Riffle substrates are typically coarse, but suitable for spawning and juvenile rearing. The bed topography is complex at the best used sites, consisting of multiple rows of ridges formed by Chinook salmon tailspills. These habitats typically occur in narrow sections of the channel that have not been mined for gravel. Riparian vegetation is usually dense along one or both sides of the channel.

The fish usually feed and hold downstream in pool habitat that is within 150 feet of the upstream riffle. They primarily spawn under surface turbulence in the riffle habitat. Juvenile *O. mykiss* typically rear in riffle and run habitats with surface turbulence. In contrast, Chinook salmon, *O. tshawytscha*, primarily spawn in pool tails and infrequently in riffle habitats.

METHODS

The mapping surveys were conducted 21 January 2004 and 23 February 2004 by Dr. Carl Mesick and Mr. Steve Walser. Most of the study area was surveyed from a raft, whereas the areas upstream of the Old La Grange Bridge were surveyed by foot. Site locations were identified with hand-held GPS units and by marking the locations on habitat maps produced by McBain and Trush in 2002. A digital photo was taken at most sites.

RESULTS

A total of 47 sites were identified as adult *O. mykiss* habitat between the La Grange Dam and Robert's Ferry Bridge. Photos of 40 of these sites are presented in Appendix A and the location of all 47 sites are shown on the McBain and Trush (2002) maps in Appendix B. Table 1 provides the site numbers, GPS coordinates, habitat features, and photo number in Appendix A.

Table 1. Map site number and DFG Site # shown on the McBain and Trush (2002) maps in Appendix B, the GPS coordinates (UTM, NAD 27 Datum), Habitat Features, and Photo number shown in Appendix A.

Site #	DFG Site #	Zone	Easting	Northing	Habitat Features	Photo #
1	RA3/4	10S	725545	4171558	Spawning, Feeding, Holding	None
2	RA7	10S	724228	4171556	Degraded by Gravel Augmentation 2003	1
3	R1A UPPER	10S	723715	4171649	Spawning, Feeding, Holding	3
4	R1A LOWER	10S	723586	4171624	Spawning, Feeding, Holding	None
5	PHASE II GRAVEL AUGMENTATION	10S	723334	4171655	Degraded by Gravel Augmentation 2002	None
6	R1B	10S	723274	4171626	Spawning, Feeding, Holding	4
7	J59 BRIDGE	10S	723028	4171619	Holding, Feeding	5
8	R2	10S	722687	4171691	Spawning, Feeding, Holding	6
9	R3A	10S	722560	4171654	Spawning, Feeding, Holding	7
10	R3B UPPER	10S	722162	4171401	Spawning, Feeding, Holding	8
11	R3B MIDDLE	10S	722117	4171219	Spawning, Feeding, Holding	9
12	R3B LOWER	10S	722061	4171136	Spawning, Feeding, Holding	10
13	R4A	10S	721697	4170885	Spawning, Feeding, Holding	11
14	R4B UPPER	10S	721684	4170611	Spawning, Feeding, Holding	12
15	R4B MIDDLE	10S	721604	4170313	Spawning, Feeding, Holding	13
16	R5A	10S	721285	4170071	Spawning, Feeding, Holding	14
17	R5B	10S	721092	4169903	Spawning, Feeding, Holding	15
18	R7 UPPER	10S	720730	4168703	Spawning, Feeding, Holding	16
19	R7 LOWER	10S	720467	4168409	Spawning, Feeding, Holding	17
20	R8	10S	720190	4168296	Spawning, Feeding, Holding	18
21	R8A	10S	720034	4168215	Spawning, Feeding, Holding	19
22	R12	10S	719038	4167563	Spawning, Feeding, Holding	20

Table 1. Continued.

Site #	DFG Site #	Zone	Easting	Northing	Habitat Features	Photo #
23	R13A	10S	718843	4167433	Spawning, Feeding, Holding	21
24	R13C	10S	718342	4167019	Spawning, Feeding, Holding	22
25	R14	10S	717985	4167236	Spawning, Feeding, Holding	None
26	R16	10S	717839	4167200	Spawning, Feeding, Holding	23
27	RUN DOWNSTREAM R16	10S	717683	4167262	Spawning, Feeding	24
28	R17A	10S	717310	4167338	Spawning, Feeding, Holding	25
29	DOWNSTREAM R17A	10S	717252	4167323	Spawning, Feeding, Holding	26
30	R17D NEAR BOULDERS	10S	716790	4167137	Spawning, Feeding, Holding	27
31	FEEDING HABITAT AT SRP-3	10S	716339	4167169	Holding, Feeding	None
32	R18	10S	715986	4167341	Spawning, Feeding, Holding	None
33	R20	10S	715280	4167673	Spawning, Feeding, Holding	28
34	R21 UPPER	10S	715031	4167528	Spawning, Feeding, Holding	29
35	R21 LOWER	10S	715019	4167433	Spawning, Feeding, Holding	30
36	R22	10S	714923	4167386	Spawning, Feeding, Holding	31
37	R23A	10S	714680	4167378	Spawning, Feeding, Holding	32
38	R23B	10S	714105	4167433	Spawning, Feeding, Holding	33
39	R23C UPPER	10S	714048	4167273	Spawning, Feeding, Holding	35
40	R23C LOWER	10S	713635	4167449	Spawning, Feeding, Holding	36
41	R23D	10S	713586	4167570	Spawning, Feeding, Holding	37 & 38
42	R24	10S	713403	4167523	Spawning, Feeding, Holding	39
43	R24B UPPER	10S	713204	4167538	Spawning, Feeding, Holding	40
44	R24B LOWER	10S	713076	4167575	Spawning, Feeding, Holding	41
45	R26	10S	711990	4167981	Spawning, Feeding, Holding	42
46	R27	10S	711386	4168250	Spawning, Feeding, Holding	None
47	R28A	10S	711052	4168223	Holding, Feeding	None

APPENDIX A

Site Photos of *Oncorhynchus mykiss* Habitat
in the lower Tuolumne River
between La Grange Dam and Robert's Ferry Bridge

Photos of Sites 1 through 30 were taken on 21 January 2004
Photos of Sites 32 through 47 were taken on 23 February 2004

Prepared by

California Rivers Restoration Fund
P.O. Box 236
Soulsbyville, California 95372
Phone (209) 532-7146

Photo 1. Site #2 (RA7) Phase II Gravel Augmentation 2003

Photo 2. Gravel added at Site #2 (RA7) in 2003

Photo 3. Site #3 (R1A upper)

Photo 4. Site #6 (R1B)

Photo 5. Site #7 (J59 Bridge)

Photo 6. Site #8 (R2)


Photo 7. Site #9 (R3A)


Photo 8. Site #10 (R3B Upper)

Photo 9. Site #11 (R3B Middle)

Photo 10. Site #12 (R3B Lower)

Photo 11. Site #13 (R4A)

Photo 12. Site #14 (R4B Upper)

Photo 13. Site #15 (R4B Middle)

Photo 14. Site #16 (R5A)

Photo 15. Site #17 (R5B)

Photo 16. Site #18 (R7 Upper)

Photo 17. Site #19 (R7 Lower)

Photo 18. Site #20 (R8)

Photo 19. Site #21 (R8A)

Photo 20. Site #22 (R12)


Photo 21. Site #23 (R13A)


Photo 22. Site #24 (R13C)


Photo 23. Site #26 (R16)


Photo 24. Site #27 (Run Downstream of R16)

Photo 25. Site #28 (R17A)

Photo 26. Site #29 (Run Downstream of R17A)


Photo 27. Site #30 (R17D)


Photo 28. Site #33 (R20 Upper)

Photo 29. Site #34 (R21 Upper)

Photo 30. Site #35 (R21 Lower)

Photo 31. Site #36 (R22)

Photo 32. Site #37 (R23A)


Photo 33. Site #38 (R23B)


Photo 34. Fish (~15 inches FL) caught at site #38 (R23B) on 2/23/04


Photo 35. Site #39 (R23C Upper)


Photo 36. Site #40 (R23C Lower)


Photo 37. Site #41 (R23D Upper)


Photo 38. Site #41 (R23D Lower)

Photo 39. Site #42 (R24)

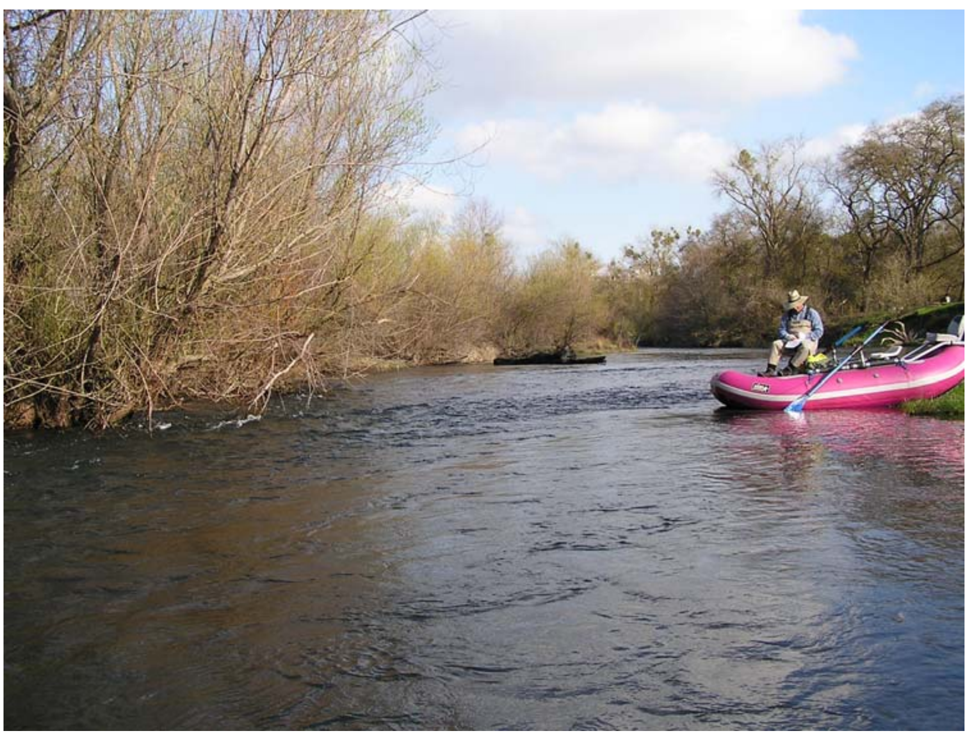

Photo 40. Site #43 (R24B Upper)

Photo 41. Site #44 (R24B Lower)

Photo 42. Site #45 (R26)

APPENDIX B

Oncorhynchus mykiss Habitat
in the lower Tuolumne River
between La Grange Dam and Robert's Ferry Bridge
overlain on the McBain and Trush 2002 maps

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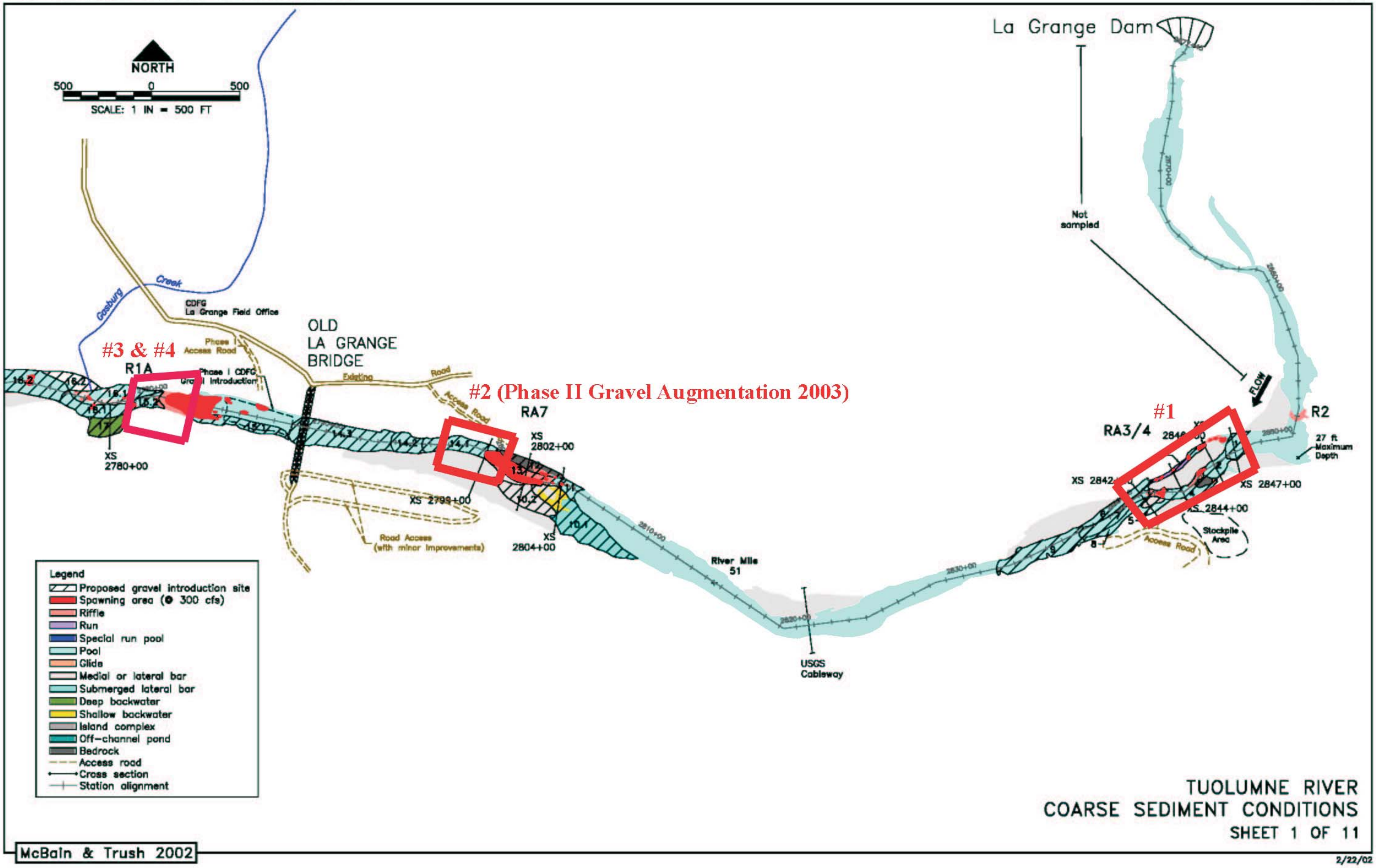
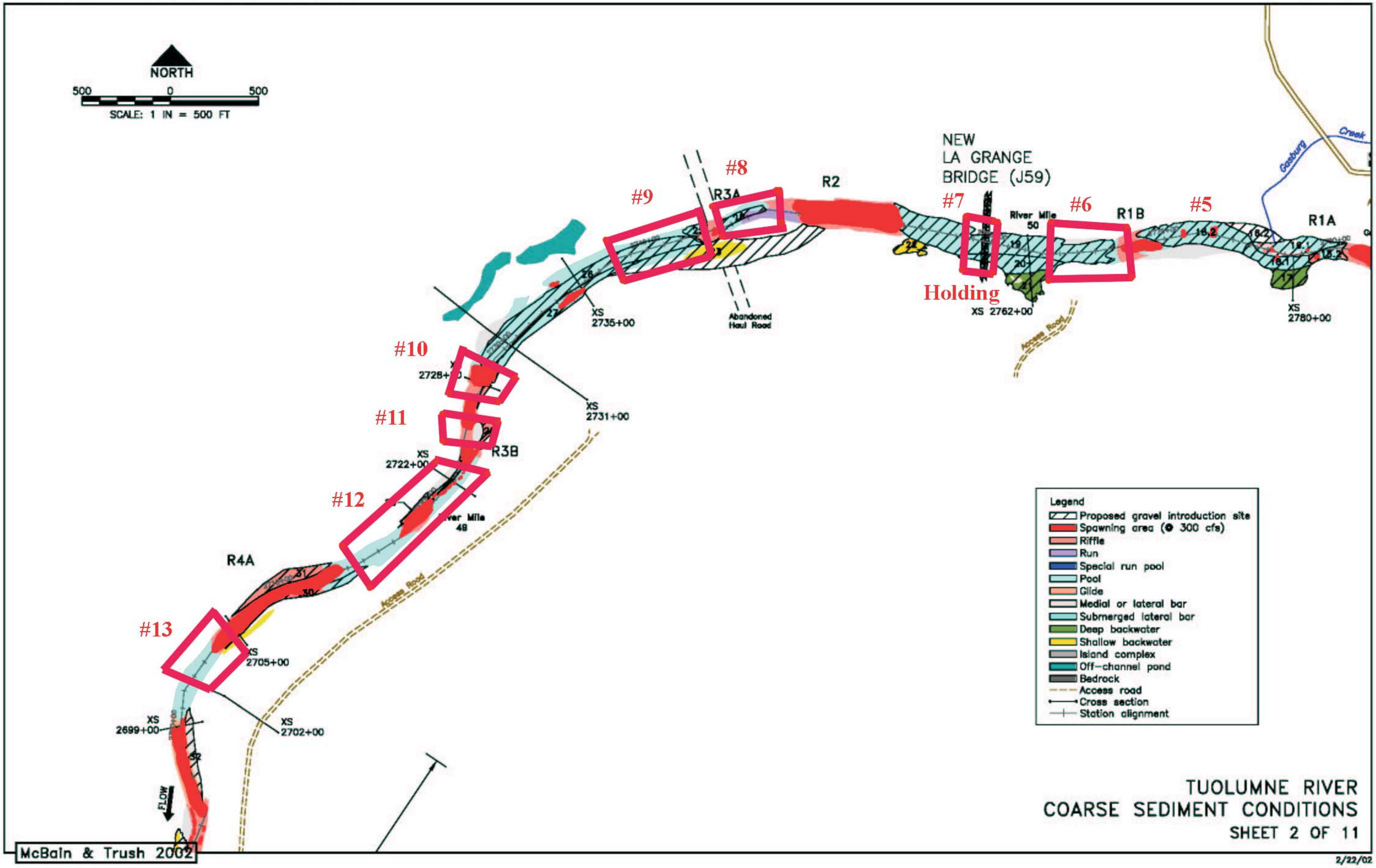
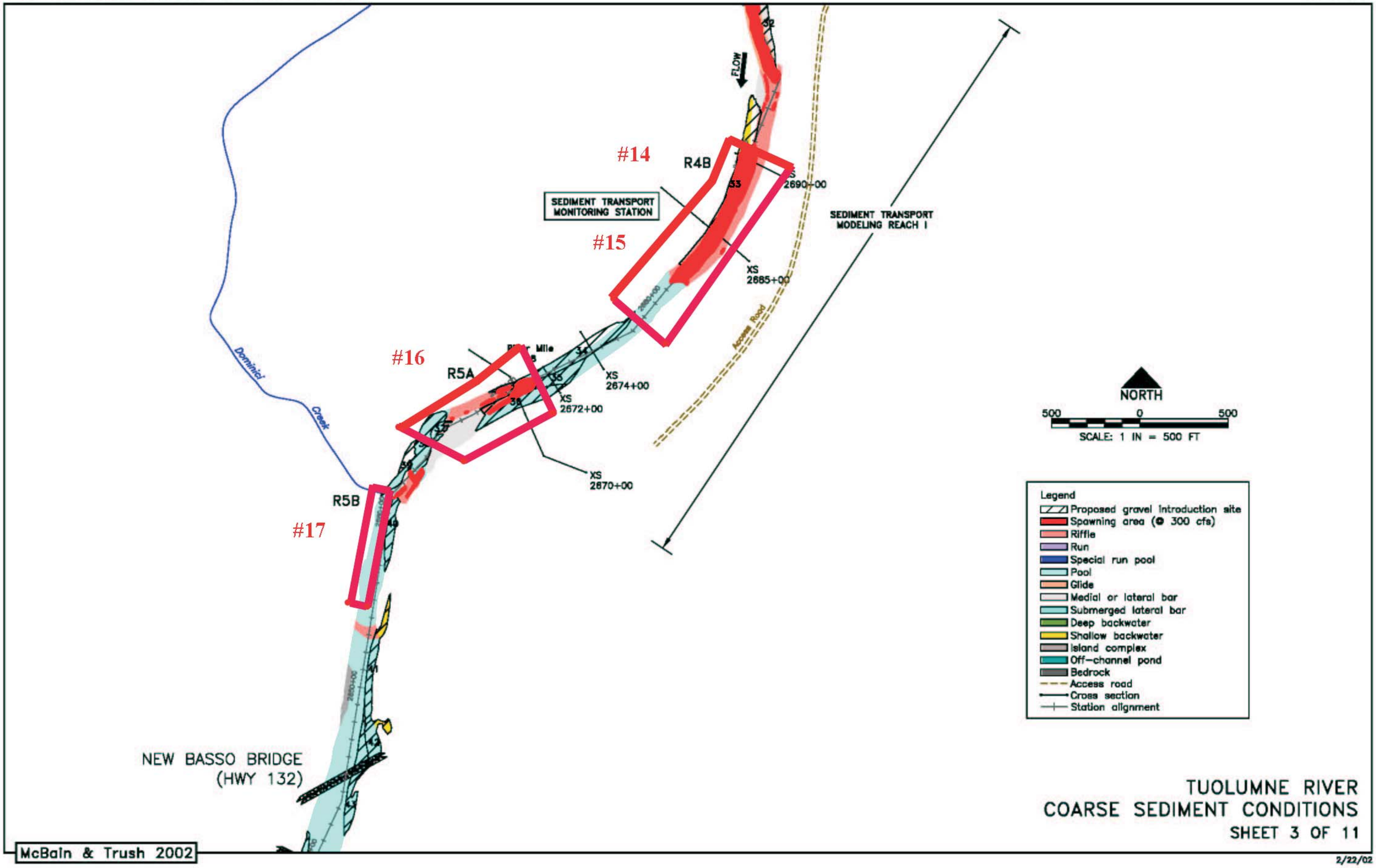
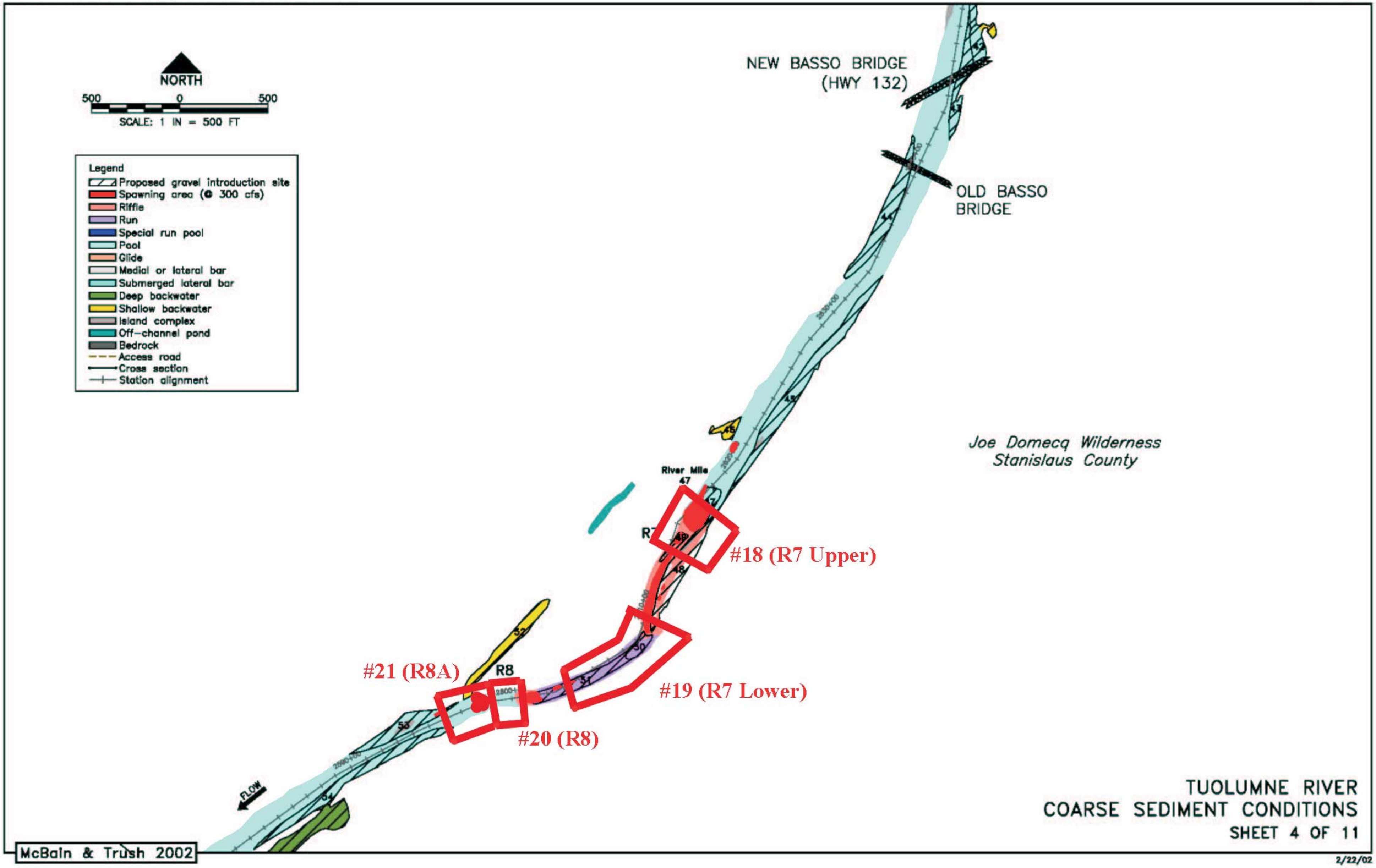
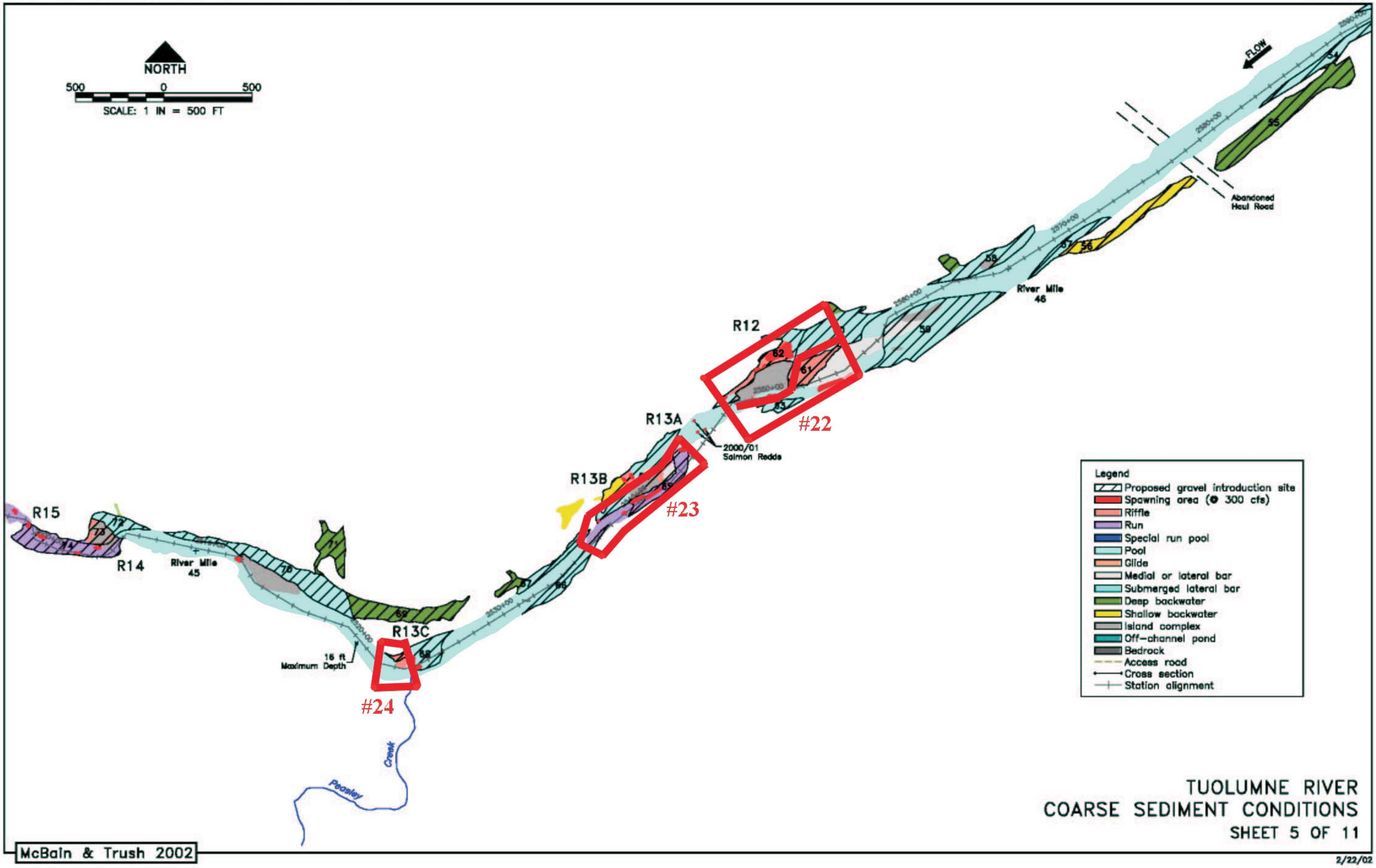
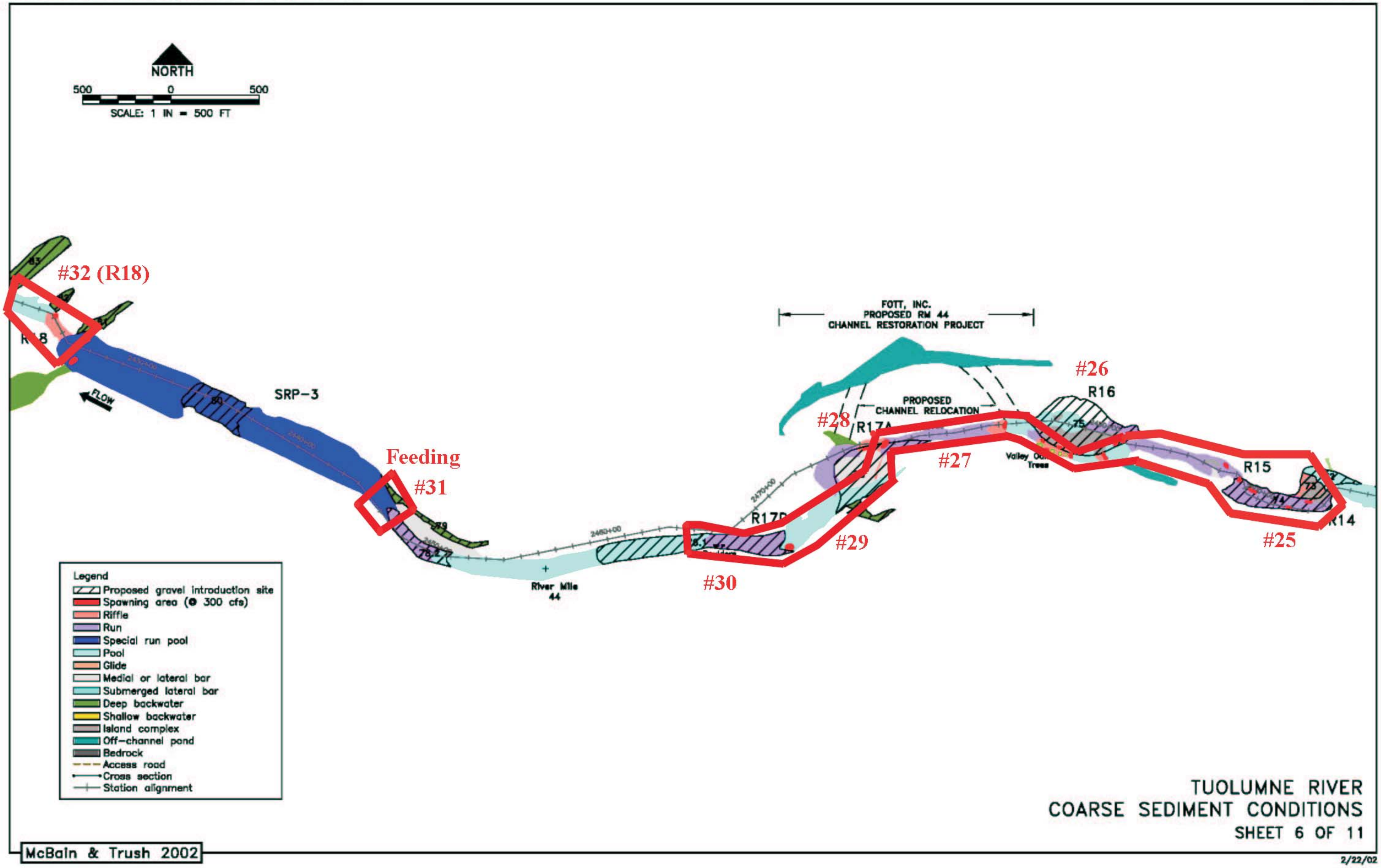

La Grange Dam
NORTH
500 0 500
SCALE: 1 IN = 500 FT
Not sampled
FLOW
R2
27 ft Maximum Depth
#1
RA3/4
XS 2842
XS 2847+00
XS 2844+00
Stockpile Area
Access Road
River Mile 51
USGS Cableway
#2 (Phase II Gravel Augmentation 2003)
RA7
XS 2802+00
XS 2799+00
XS 2804+00
Road Access (with minor improvements)
OLD LA GRANGE BRIDGE
Existing Road
Access Road
CDFG La Grange Field Office
Gasburg Creek
Phase I Access Road
Phase I CDFG Gravel Introduction
#3 & #4
R1A
XS 2780+00
Legend
Proposed gravel introduction site
Spawning area (@ 300 cfs)
Riffle
Run
Special run pool
Pool
Glide
Medial or lateral bar
Submerged lateral bar
Deep backwater
Shallow backwater
Island complex
Off-channel pond
Bedrock
Access road
Cross section
Station alignment
TUOLUMNE RIVER
COARSE SEDIMENT CONDITIONS
SHEET 1 OF 11
McBain & Trush 2002
2/22/02

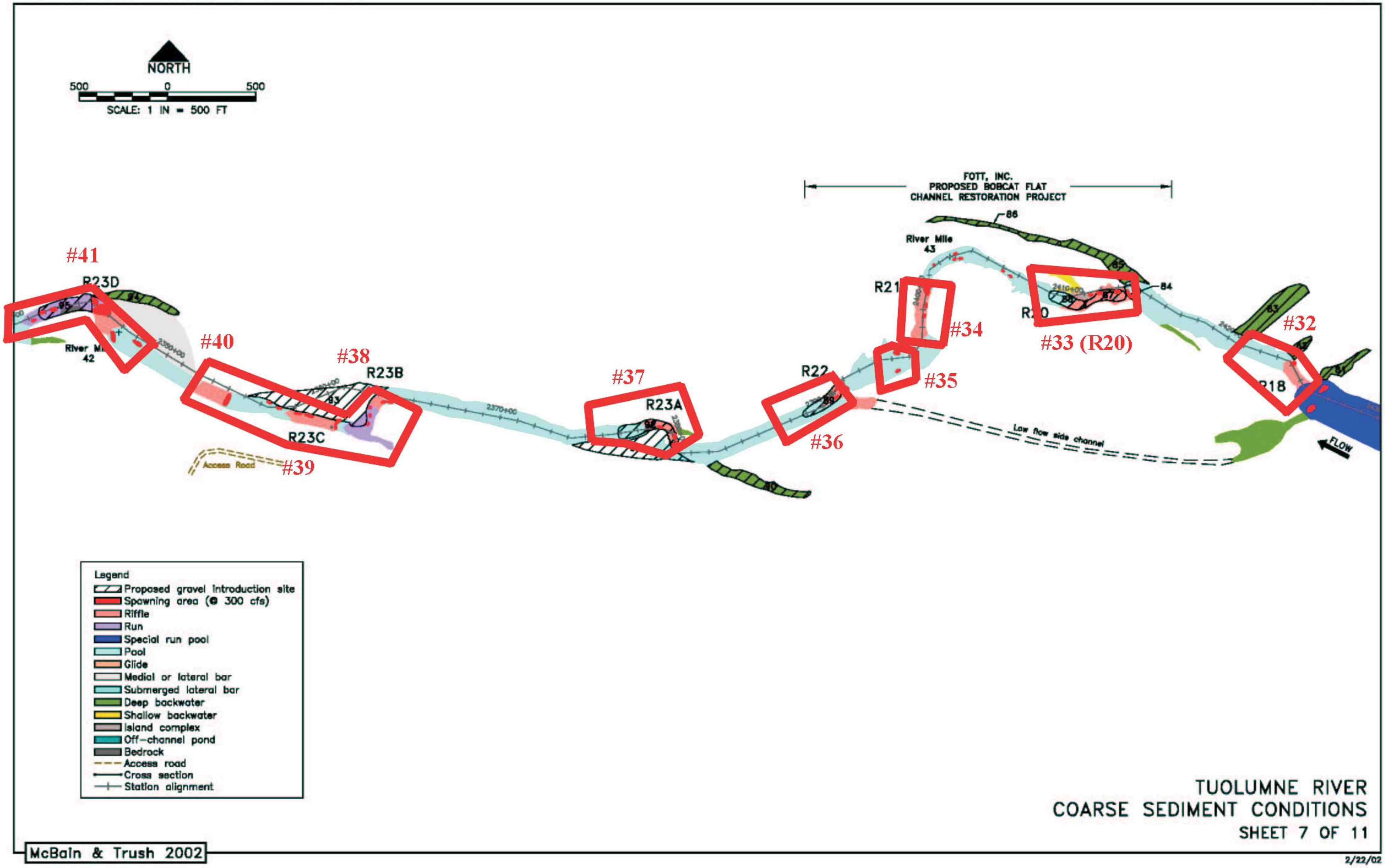

NORTH
500 0 500
SCALE: 1 IN = 500 FT
NEW LA GRANGE BRIDGE (J59)
#5
#6
#7
#8
#9
#10
#11
#12
#13
Holding
R1A
R1B
R2
R3A
R3B
R4A
River Mile 50
River Mile 49
Abandoned Haul Road
Access Road
XS 2780+00
XS 2762+00
XS 2735+00
XS 2731+00
XS 2728+00
XS 2722+00
XS 2705+00
XS 2702+00
XS 2699+00
FLOW
Legend
Proposed gravel introduction site
Spawning area (@ 300 cfs)
Riffle
Run
Special run pool
Pool
Glide
Medial or lateral bar
Submerged lateral bar
Deep backwater
Shallow backwater
Island complex
Off-channel pond
Bedrock
Access road
Cross section
Station alignment
TUOLUMNE RIVER
COARSE SEDIMENT CONDITIONS
SHEET 2 OF 11
McBain & Trush 2002
2/22/02

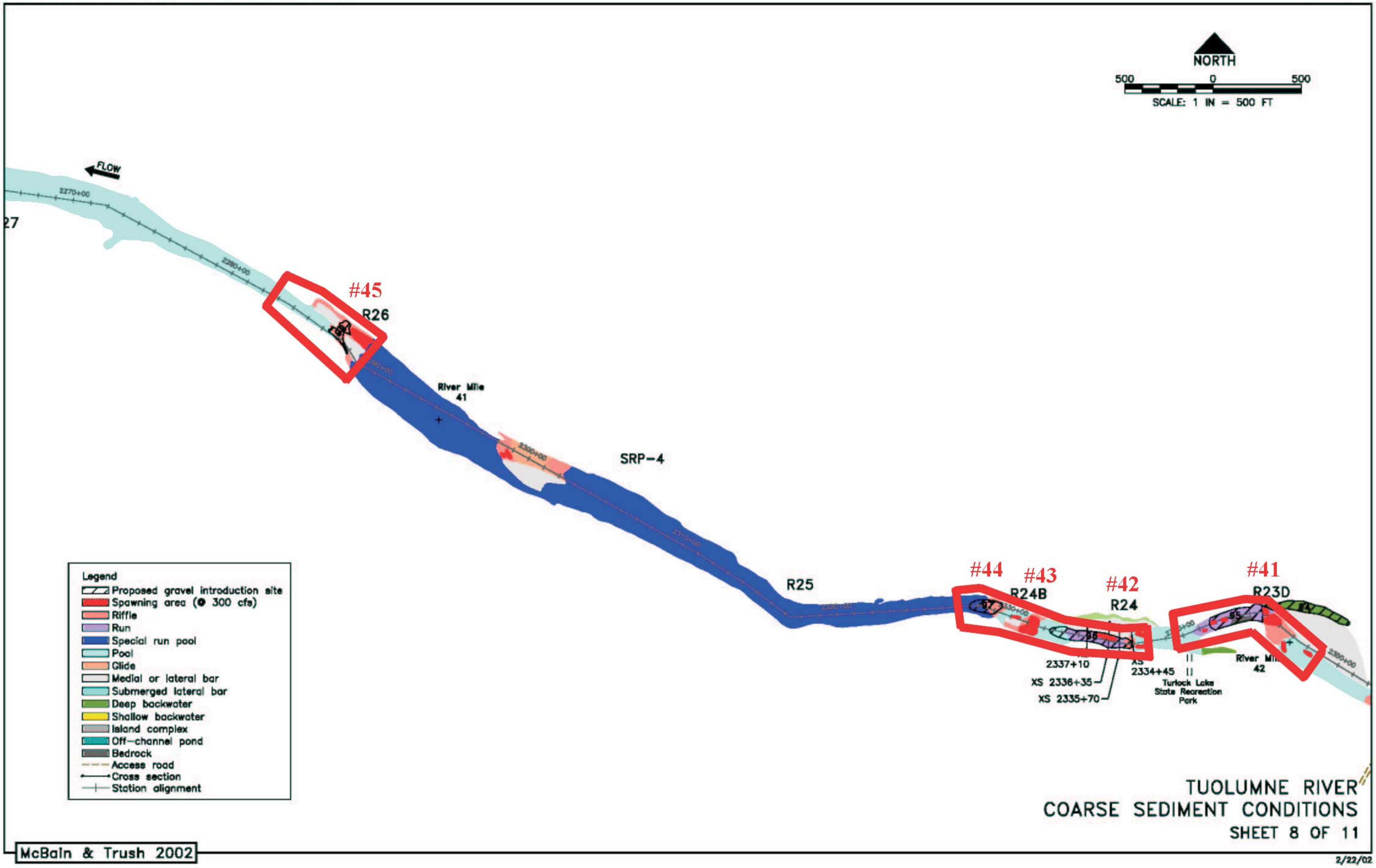

FLOW
#14
R4B
SEDIMENT TRANSPORT MONITORING STATION
XS 2690+00
#15
XS 2685+00
SEDIMENT TRANSPORT MODELING REACH I
Access Road
#16
R5A
XS 2674+00
XS 2672+00
XS 2670+00
Dominici Creek
R5B
#17
NORTH
500 0 500
SCALE: 1 IN = 500 FT
Legend
Proposed gravel introduction site
Spawning area (@ 300 cfs)
Riffle
Run
Special run pool
Pool
Glide
Medial or lateral bar
Submerged lateral bar
Deep backwater
Shallow backwater
Island complex
Off-channel pond
Bedrock
Access road
Cross section
Station alignment
NEW BASSO BRIDGE (HWY 132)
TUOLUMNE RIVER
COARSE SEDIMENT CONDITIONS
SHEET 3 OF 11
McBain & Trush 2002
2/22/02

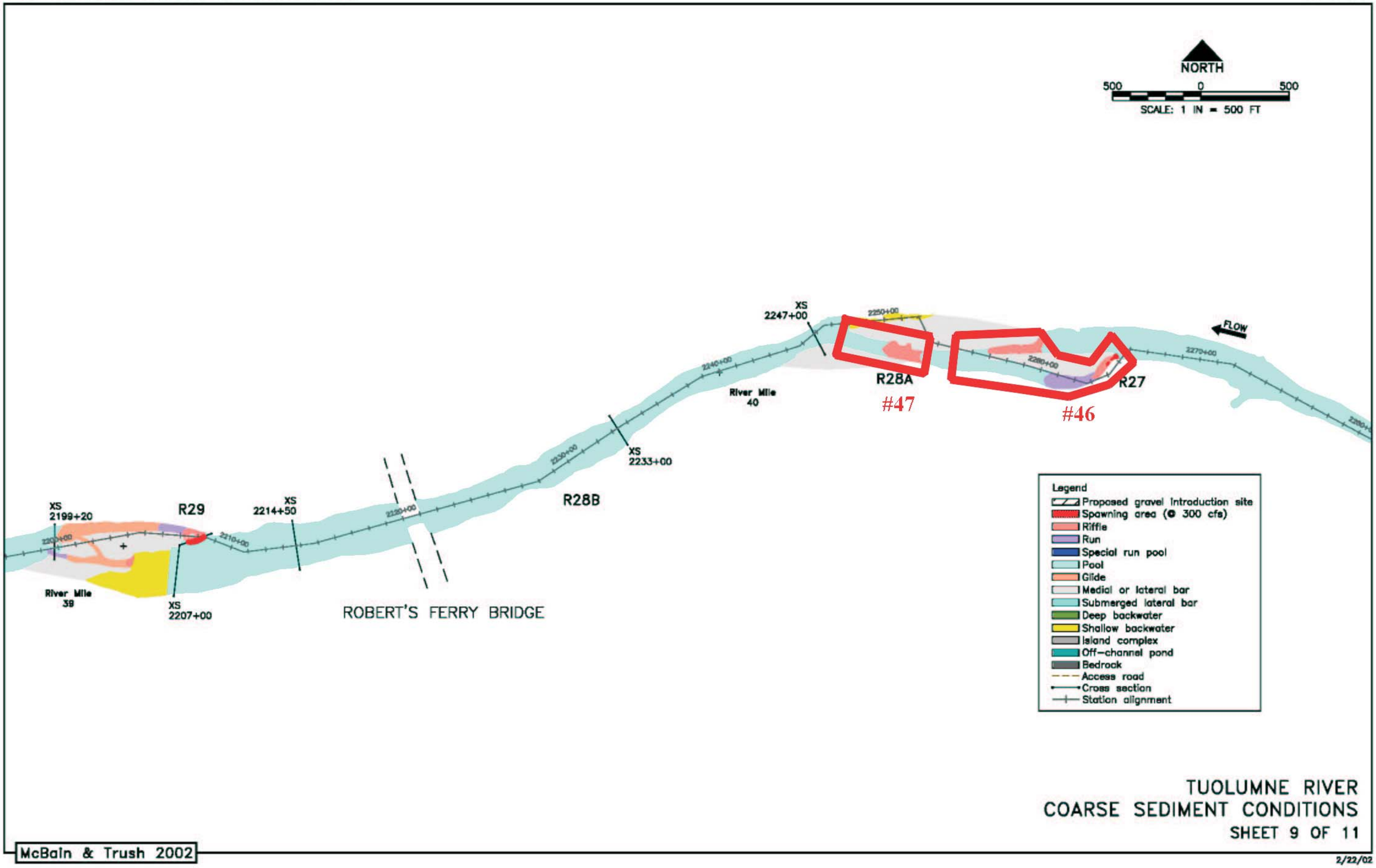

NORTH
500 0 500
SCALE: 1 IN = 500 FT
Legend
Proposed gravel introduction site
Spawning area (@ 300 cfs)
Riffle
Run
Special run pool
Pool
Glide
Medial or lateral bar
Submerged lateral bar
Deep backwater
Shallow backwater
Island complex
Off-channel pond
Bedrock
Access road
Cross section
Station alignment
NEW BASSO BRIDGE
(HWY 132)
OLD BASSO BRIDGE
Joe Domecq Wilderness
Stanislaus County
River Mile
47
R7
#18 (R7 Upper)
#19 (R7 Lower)
#21 (R8A)
R8
#20 (R8)
FLOW
TUOLUMNE RIVER
COARSE SEDIMENT CONDITIONS
SHEET 4 OF 11
McBain & Trush 2002
2/22/02


NORTH
500 0 500
SCALE: 1 IN = 500 FT
FLOW
Abandoned Haul Road
River Mile 46
R12
#22
R13A
2000/01 Salmon Redds
R13B
#23
R15
R14
River Mile 45
R13C
16 ft Maximum Depth
#24
Peasley Creek
Legend
Proposed gravel introduction site
Spawning area (@ 300 cfs)
Riffle
Run
Special run pool
Pool
Glide
Medial or lateral bar
Submerged lateral bar
Deep backwater
Shallow backwater
Island complex
Off-channel pond
Bedrock
Access road
Cross section
Station alignment
TUOLUMNE RIVER
COARSE SEDIMENT CONDITIONS
SHEET 5 OF 11
McBain & Trush 2002
2/22/02


NORTH
500 0 500
SCALE: 1 IN = 500 FT
#32 (R18)
R18
FLOW
SRP-3
Feeding
#31
FOTT, INC.
PROPOSED RM 44
CHANNEL RESTORATION PROJECT
PROPOSED
CHANNEL RELOCATION
#28
R17A
#27
#26
R16
Valley Oak Trees
R15
#25
R14
R17B
#29
#30
River Mile 44
Legend
Proposed gravel introduction site
Spawning area (@ 300 cfs)
Riffle
Run
Special run pool
Pool
Glide
Medial or lateral bar
Submerged lateral bar
Deep backwater
Shallow backwater
Island complex
Off-channel pond
Bedrock
Access road
Cross section
Station alignment
TUOLUMNE RIVER
COARSE SEDIMENT CONDITIONS
SHEET 6 OF 11
McBain & Trush 2002
2/22/02


NORTH
500 0 500
SCALE: 1 IN = 500 FT
FOTT, INC.
PROPOSED BOBCAT FLAT
CHANNEL RESTORATION PROJECT
River Mile 43
River Mile 42
#41
R23D
#40
#38
R23B
R23C
#39
Access Road
#37
R23A
R22
#36
#35
R21
#34
R20
#33 (R20)
#32
R18
Low flow side channel
FLOW
2370+00
Legend
Proposed gravel introduction site
Spawning area (@ 300 cfs)
Riffle
Run
Special run pool
Pool
Glide
Medial or lateral bar
Submerged lateral bar
Deep backwater
Shallow backwater
Island complex
Off-channel pond
Bedrock
Access road
Cross section
Station alignment
TUOLUMNE RIVER
COARSE SEDIMENT CONDITIONS
SHEET 7 OF 11
McBain & Trush 2002
2/22/02


NORTH
500 0 500
SCALE: 1 IN = 500 FT
FLOW
27
#45
R26
River Mile 41
SRP-4
R25
#44
#43
#42
#41
R24B
R24
R23D
2337+10
XS 2336+35
XS 2335+70
XS 2334+45
Turlock Lake State Recreation Park
River Mile 42
Legend
Proposed gravel introduction site
Spawning area (@ 300 cfs)
Riffle
Run
Special run pool
Pool
Glide
Medial or lateral bar
Submerged lateral bar
Deep backwater
Shallow backwater
Island complex
Off-channel pond
Bedrock
Access road
Cross section
Station alignment
TUOLUMNE RIVER
COARSE SEDIMENT CONDITIONS
SHEET 8 OF 11
McBain & Trush 2002
2/22/02


NORTH
500 0 500
SCALE: 1 IN = 500 FT
FLOW
XS 2199+20
R29
XS 2214+50
River Mile 39
XS 2207+00
ROBERT'S FERRY BRIDGE
R28B
XS 2233+00
River Mile 40
XS 2247+00
R28A
#47
#46
R27
Legend
Proposed gravel introduction site
Spawning area (@ 300 cfs)
Riffle
Run
Special run pool
Pool
Glide
Medial or lateral bar
Submerged lateral bar
Deep backwater
Shallow backwater
Island complex
Off-channel pond
Bedrock
Access road
Cross section
Station alignment
TUOLUMNE RIVER
COARSE SEDIMENT CONDITIONS
SHEET 9 OF 11
McBain & Trush 2002
2/22/02