Summary Information

University of California, Davis

Hypothesis−driven Monitoring of the CALFED/CVPIA Sponsored Gravel Augmentation on the Lower Mokelumne River

Amount sought: $705,052

Duration: 36 months

Lead investigator: Dr. Gregory Pasternack, University of California at Davis

Short Description

In this next−phase monitoring and hypothesis−testing project, the project goal is to test 3 sets of hypotheses nested into a multi−scalar framework that explicitly recognizes the diverse needs for hydrogeomorphic and biological monitoring at reach, geomorphic−unit, and hydraulic−unit scales. At the reach scale the key performance questions evaluate the extent to which coarse sediment addition has re−started self−sustainable sediment transport continuity and whether the fish community shows a response to rehabilitation over a decade (1997−2008). At the geomorphic−unit scale a sediment budget framework is used to evaluate performance and persistence of complex pool−riffle units designed using SHIRA. At the hydraulic−unit scale the key performance questions evaluate the large uncertainty surrounding the hydrogeomorphic and biological functionality as well as rehabilitation value of artificially placed boulders, woody debris, and other habitat heterogeneity features.

Executive Summary

Gravel augmentation is being implemented in the Central Valley in accordance with Draft Stage 1 PSP priorities to enhance salmon spawning habitat and restore in−stream geomorphic processes. With matching funding from CALFED and CVPIA, UC Davis and East Bay Municipal Utility District (EBMUD) have developed, implemented, and partially evaluated the Spawning Habitat Integrated Rehabilitation Approach (SHIRA) for use as a guiding framework for designing, implementing, and monitoring regulated river rehabilitation. While the approach employs empirical geomorphology and other heuristics to guide creative design of project alternatives, it also uses computer−aided−design and a 2D mechanistic model to quantify 0.1−1 m scale channel hydraulics, geomorphic complexity, sediment mobility, and spawning habitat quality. SHIRA has been implemented 4 times on the Lower Mokelumne River (LMR) 2001−2004, with one more demonstration project pending in 2005. These projects have generated a large monitoring and modeling database that is being used to test basic and applied scientific hypotheses about gravel augmentation and river rehabilitation as well as to assess LMR rehabilitation achievement. So far EBMUD and UC Davis have published 7 peer−reviewed journal articles based on this research assessing rehabilitation performance. Also, a comprehensive web portal for SHIRA (http://shira.lawr.ucdavis.edu) has been developed as a major public outreach component. In this next−phase monitoring and hypothesis−testing proposal, the project goal is to test 3 sets of hypotheses nested into a multi−scalar framework that explicitly recognizes the diverse needs for hydrogeomorphic and biological monitoring at reach, geomorphic−unit, and hydraulic−unit scales. At the reach scale the key performance questions evaluate the extent to which coarse sediment addition has re−started self−sustainable sediment transport continuity and whether the fish community shows a response to rehabilitation over a decade (1997−2008). At the geomorphic−unit scale a sediment budget framework is used to evaluate performance and persistence of complex pool−riffle units designed using SHIRA. At the hydraulic−unit scale the key performance questions evaluate the large uncertainty surrounding the hydrogeomorphic and biological functionality as well as rehabilitation value of artificially placed boulders, woody debris, and other habitat heterogeneity features. Whereas the first SHIRA proposal funded by CALFED focused on hydrogeomorphic concepts, this one provides an equal balance of monitoring actions for geomorphology and biology, because process mechanics and population outcomes are both important measures of rehabilitation performance. To aid assessment of future management alternatives and enable adaptive management, the proposed work applies 3 types of mechanistic computer models to a variety of hydrogeomorphic scenarios. This monitoring and data analysis project will meet key CALFED ERP and CVPIA goals in the areas of continued habitat restoration (priority 1), improved geomorphic processes (priority 2), enhanced spawning habitat (priority 3), and use of mechanistic models (priority 6).

A. Project Description
1. Problem Statement and Project Goals

Background

Four of the seven CALFED Ecosystem Restoration Program (ERP) Draft Stage 1 Implementation Plan priorities for the Sacramento and San Joaquin Valley Regions involve restoration planning and activities that require a hydrogeomorphic framework. To be of use to CALFED, any such framework needs to 1) have a transparent procedure that is documented in the open literature, 2) use the hypothesis-driven scientific method, 3) make specific, testable predictions over a range of scales relevant to natural processes, 4) provide for long-term monitoring and adaptive management, and 5) incorporate ecological linkages. Achieving these characteristics would provide CALFED and the scientific community with the data needed to evaluate alternative river restoration frameworks.

The Spawning Habitat Integrated Rehabilitation Approach (SHIRA) is a science-based framework for rehabilitating regulated rivers that was developed with funding from CALFED to have the above characteristics (Wheaton et al., 2004, a,b). What sets SHIRA apart from pre-existing schemes is that it integrates widely accepted concepts from hydrology, civil engineering, aquatic biology, riparian ecology, and geomorphology to design alternative river configurations for a degraded section of river and then it uses predictive computer models to evaluate the relative performance of the different configurations in their specific details *before* implementing a final design, thereby avoiding costly mistakes (Fig. 1). The approach is multi-scalar and even accounts for the 0.1-1 m^2 scale at which fish and cobbles experience a river. The transparent and documented inner-workings of SHIRA have been scientifically peer reviewed (Pasternack et al., 2004; Wheaton et al., 2004 a,b) and made available to the public (http://shira.lawr.ucdavis.edu). ***The inclusion of a comprehensive design development and testing phase makes SHIRA stand out in sharp contrast to single-design, prescriptive approaches based on empirical geomorphology*** (e.g. Rosgen, 1997).

SHIRA has been used as the guiding framework for 4 projects on the Lower Mokelumne River (LMR) (Figs. 2,3) and 1 on the Trinity River at Lewiston Dam. The LMR SHIRA projects have used 794-3,908 tons of coarse sediment and have been done in partnership among UC Davis, EBMUD, CALFED, and CVPIA. The Trinity River SHIRA project is being implemented jointly among UC Davis, USBR, and USFS and calls for 3,440-8257 m^3 of coarse sediment, depending on the design (see http://shira.lawr.ucdavis.edu/trinity.htm). Construction is planned for summer 2005. SHIRA's 5-cycle adaptive management history resulting from lessons learned in these efforts is documented at http://shira.lawr.ucdavis.edu/adaptivemgmt.htm.

Mokelumne Setting and River Rehabilitation Need

Snow-fed Mokelumne River drains 1624 km^2 of the central Sierra Nevada (Fig. 2). It has 16 major water impoundments, including Salt Springs (175 032 089 m^3), Pardee (258 909 341 m^3) and Camanche (531 387 061 m^3) reservoirs. Prior to Camanche Dam, annual peak flows 1904-1963 exceeded 200 cumecs for 21 of 57 years. Since 1964, releases are capped <142 cumecs. Pre-dam, the annual hydrograph was snowmelt-dominated, with highest flow May-June well after peak precipitation. Post-dam, snowmelt runoff was greatly reduced. Flood frequency analysis revealed a dramatic reduction in flow magnitude for all recurrence intervals (Pasternack et al. 2004). Since May 2000, flow has been near the 4.25 cumecs minimum prescribed in re-licensing (FERC, 1998) (Fig. 4).

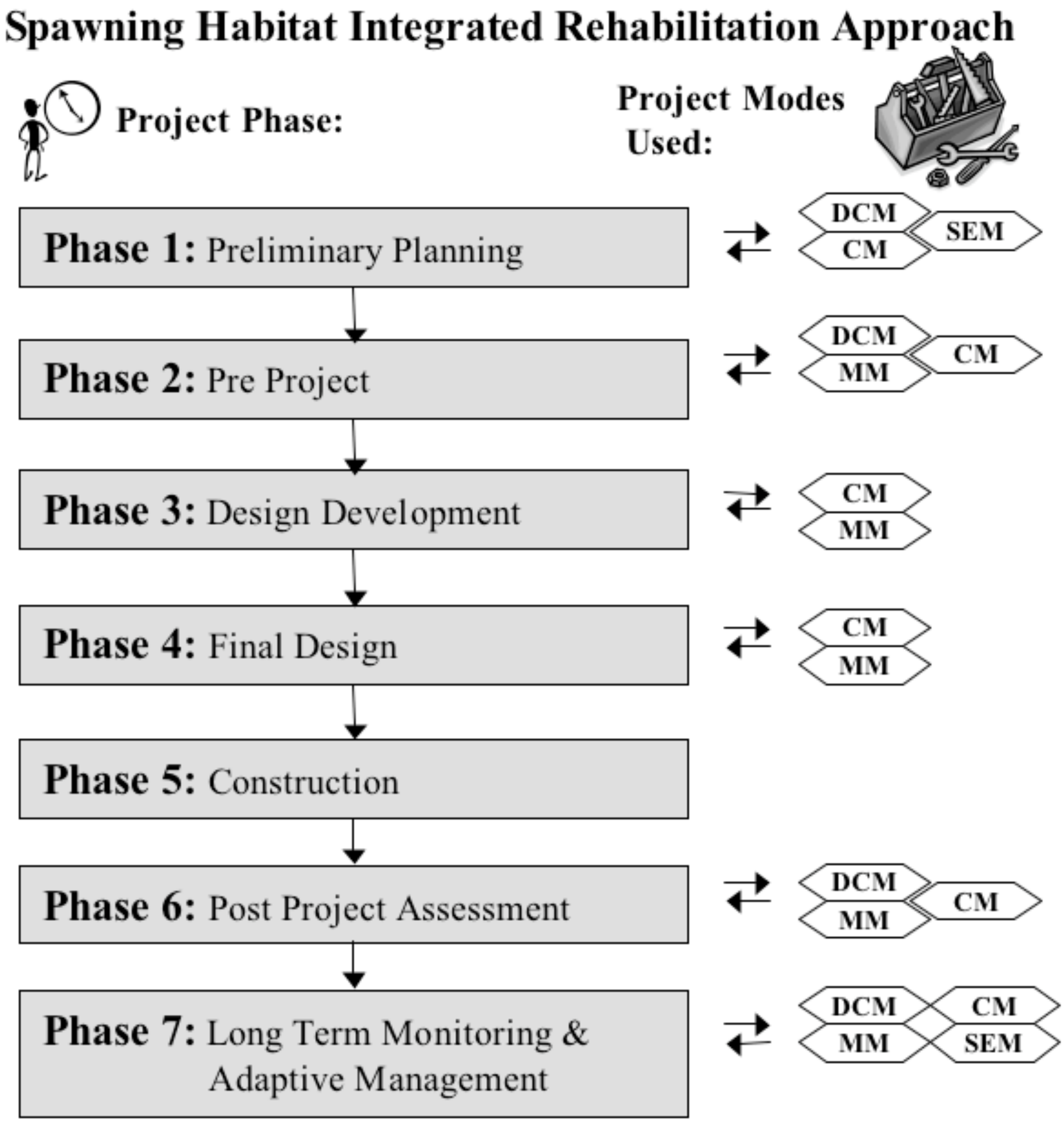


Figure 1. Using SHIRA, river rehabilitation projects progress chronologically through 7 phases (left side), in which various sets of analytical tools, called "modes" (right side), are used to guide decision making (Wheaton et al., 2004a). Modes span disciplines and include data collection (DCM), conceptualization (CM), modeling (MM), and scientific exploration (SEM). Concepts from multiple disciplines are brought together in the design development phase and then analytical tools are used to test design hypotheses prior to construction as a cost-saving measure. Monitoring checks compliance and tests hypotheses.

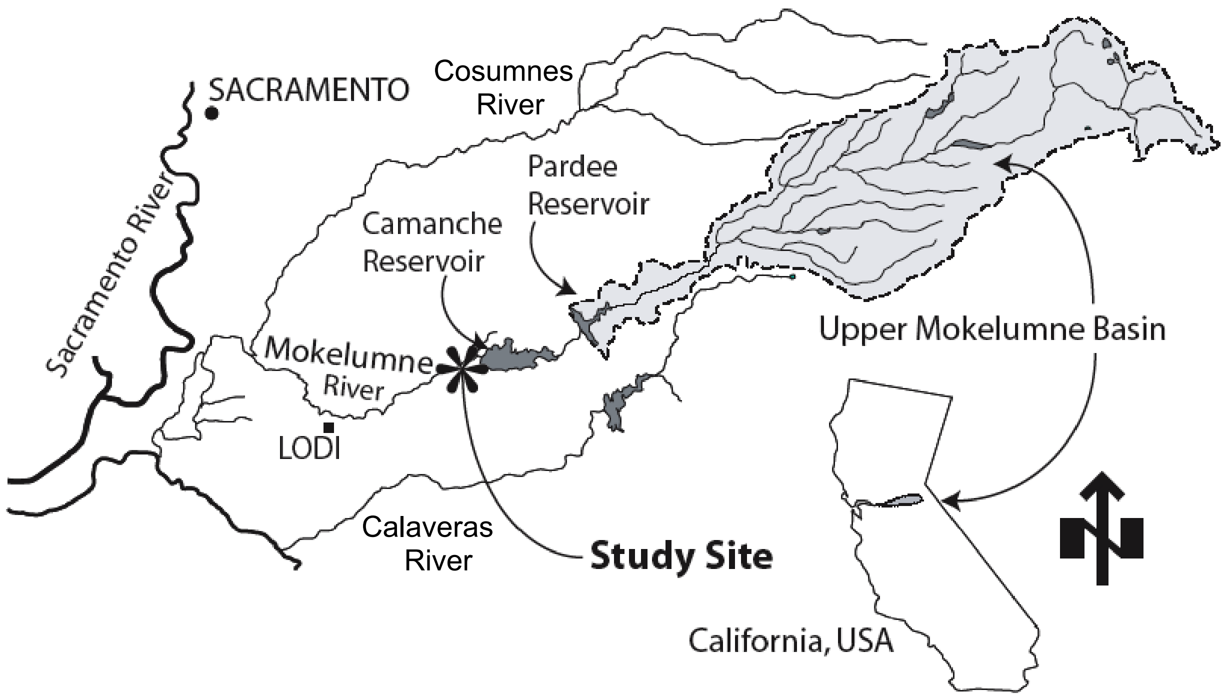


Figure 2. Regional maps showing the location of the Mokelumne basin in California, USA and the reach of the Mokelumne River below Camanche Dam where 4 river rehabilitation projects were designed using SHIRA with funding from CALFED. Monitoring is proposed for this reach.

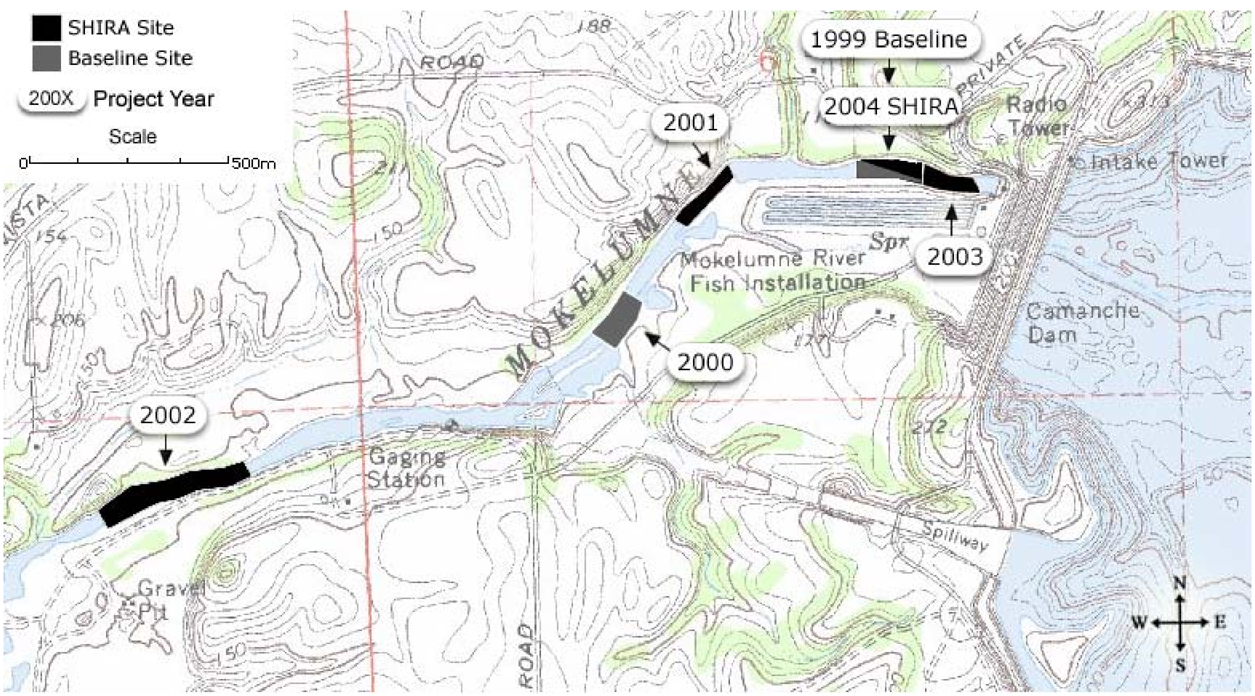


Figure 3. Local study area map showing SHIRA pilot project sites and baseline project sites as well as intervening degraded sections.

Because the LMR fish hatchery was built over the river, the channel below Camanche Dam is an excavated ditch. Beyond that alteration, most changes are due to an altered flow regime in which peaks have been eliminated. Geomorphically, this stabilized formerly active river deposits and permitted encroachment of vegetation into the channel (FERC, 1993). Now the LMR between Camanche Dam and I-5 has a low slope (0.0002-0.002), narrow width (19-43 m; < ½ of pre-dam width), and poor substrates (compacted coarse sediment partially overgrown with aquatic vegetation and organic-rich mud). Hydraulic mining, gravel extraction, dam construction, water diversion, altered flow regimes, deforestation, artificial bank protection, channelization and levee construction have resulted in depleted, degraded and otherwise, inaccessible gravel beds within the river. Camanche Dam blocks gravel delivery from upstream. Murphy Creek, a small tributary close to the dam, contributes little gravel. Downstream gravel mining not only depleted instream gravel storage, but also yielded deep pits that are barriers to bedload transport. Although mine tailings exist along the upper third of the LMR, these are isolated by levees. The channel and banks are not providing gravel recruitment.

The LMR supports >35 fish species, including five anadromous species: fall-run Chinook salmon, winter steelhead trout, American shad, striped bass and Pacific lamprey (Merz, 2004). Native Chinook salmon and steelhead trout populations are enhanced by hatchery fish produced at Camanche Dam. Prior to Camanche, spawning areas accommodated ~40,000 adults at 400 cfs (CDFG, 1955). Post-Camanche Dam, Chinook salmon runs have averaged ~3,800 spawners. USFWS (1997) called for a LMR fall-run Chinook salmon population target of 9,300. Average annual LMR salmon escapement has been monitored by video at Woodbridge Dam 1990-2004. Chinook escapement averages 5506 (min:280; max:10757). Steelhead escapement is < 100 (Workman, 2003). Most spawning occurs in the 15 km between Camanche and Elliott Road.

A scientific and political consensus reached for the LMR concluded that spawning habitat has been an important constraint on salmonid populations. FERC ranked factors limiting salmonid production in the LMR and determined that spawning habitat quality and quantity were the second most important factors (FERC 1993). The primary reason for this reality is that dams have blocked salmon from reaching a large fraction of their total historic spawning habitats (Moyle and Randall, 1998). Examples of the science supporting the theory that spawning habitat is limiting include Brown (2000), CDFG (1959,1991), FERC (1993), Moyle (1994), Fisher (1994), and Nehlsen et al. (1991). Fisher (1994) states, "All of the Central Valley salmon runs have incurred permanent habitat losses of varying amount." He then documents that spawning declines are directly attributable to habitat loses for all Chinook runs. Downstream spawning areas are now critical to the survival of seasonal runs. Examples of the numerous policy documents stating that habitat is degraded and prioritizing spawning habitat rehabilitation as an important goal include Flosi et al. (1995), USFWS (2001), DWR (1994), and CMARP (1999). CALFED's ERP Draft Stage 1 Implementation Plan specifically priorities spawning habitat restoration and gravel replenishment. USFWS (1997) recommends spawning gravel replenishment in the LMR. Thus, river rehabilitation efforts on the LMR have restored spawning habitat quantity and quality, while also accounting for other salmon lifestages (e.g. Merz et al., in press), the overall fish community (Merz et al., 2004), benthic macroinvertebrates (Ochikubo Chan, 2003), and aquatic vegetation.

River Rehabilitation Actions

With matching funds (~50%) from CALFED, CVPIA, and other sources, EBMUD has been performing spawning gravel replenishment below Camanche Dam since 1990. ***The overall***

goal of EBMUD's river rehabilitation program has been to replenish suitable-sized coarse sediment in the spawning reach of the LMR and provide immediate high-quality spawning habitat for Chinook salmon and steelhead, recognizing that placed gravels would not remain static over time. During the first 9 years of this effort, annual doses of 0-459 m^3 yr^{-1} were placed *ad hoc* to enhance existing spawning riffles. In 1999 and 2000, larger enhancements using 1,659 and 1,200 m^3, respectively, were built. In these cases, gravel placement involved creating boulder clusters, chutes, pools, and riffles *ad hoc* to match Chinook salmon-spawning depth and velocity preferences. An evaluation of pre- versus post- project conditions was made using a 2D hydrodynamic model and local habitat suitability curves to quantify the net habitat gain and assess the potential for hydrogeomorphic design by comparing the real conditions to 4 hypothetical designs (Pasternack et al., 2004). The study concluded that 1) *ad hoc* gravel replenishment yields highly patchy habitat conditions with some attractive patches susceptible to scour during spawning and incubation periods and 2) ***hydrogeomorphic design alternatives tested with a 2D model yield more high-quality habitat per unit of gravel added and have lower scour susceptibility during spawning and incubation periods than ad hoc designs***. Based on these peer-reviewed conclusions, EBMUD and UC Davis formed a collaboration to develop, test, and use SHIRA on the LMR. The pre-SHIRA 1999 and 2000 sites have served as baselines for comparing *ad hoc* versus science-based design.

During the last four years, one SHIRA-based project has been implemented each year (Figs. 3,4). In 2001 and 2002, sites were selected based on local hydrogeomorphic, engineering, and fish utilization criteria. The 2001 project used 794 tons of coarse sediment to build a final design selected among 12 thoroughly evaluated alternatives (Wheaton and Pasternack, 2002; Wheaton et al., 2004b). After a post-project appraisal and adaptive management, SHIRA was improved and used again in summer 2002 for a project further downstream (Fig. 3) that included hydrogeomorphic features designed at 3 spatial scales and using 2,100 tons of coarse sediment (Wheaton et al., 2004c). Post-project assessment found that the 2001 and 2002 projects increased the area of high-quality spawning-habitat by 175% and 145%, respectively (Figs. 6,7). A key lesson from these projects was that insufficient slope limits habitat creation on the LMR and might result in no net habitat gain (Wheaton et al., 2004a) (Fig 5). Consequently, a study scoped the problem, documented 1 m of bed incision below Camanche Dam, and hypothesized that "slope creation" was needed. In 2003 a new long-term phase of SHIRA-based rehabilitation began in which slope is being created at the dam by placing gravel across the channel to pond water. Subsequent projects are incrementally building a new bed downstream. Even where spawning habitat quality is high, slope rehabilitation is needed to promote the reach-scale fish utilization goal set by USFWS (1997). ***Had SHIRA's hydrogeomorphic framework not been used, this counter-intuitive need to adjust existing riffles would not have been identified and little net habitat gain would have been attainable.*** Furthermore, the ecological benefits of using a hydrogeomorphic framework are evident in the significant improvements predicted for Chinook salmon spawning habitat quality post- as compared with pre- rehabilitation (Figs. 6,7).

During 2003-2004, SHIRA was used for slope creation and downstream distribution. Design concepts for the 2003 and 2004 projects were coordinated, since limited gravel supply is available each year. In 2003, 2,300 tons of coarse sediment were placed and then in 2004 another 3,908 tons were placed (Fig. 3). The 2003 site was built with a high fill elevation yielding an intermediate condition with very low riffle crest depths and high chute velocities. Then in 2004 gravel fill was placed downstream to back water up and "soft land" conditions at the upstream 2003 site based on 2D model predictions. This turned the backwater problem

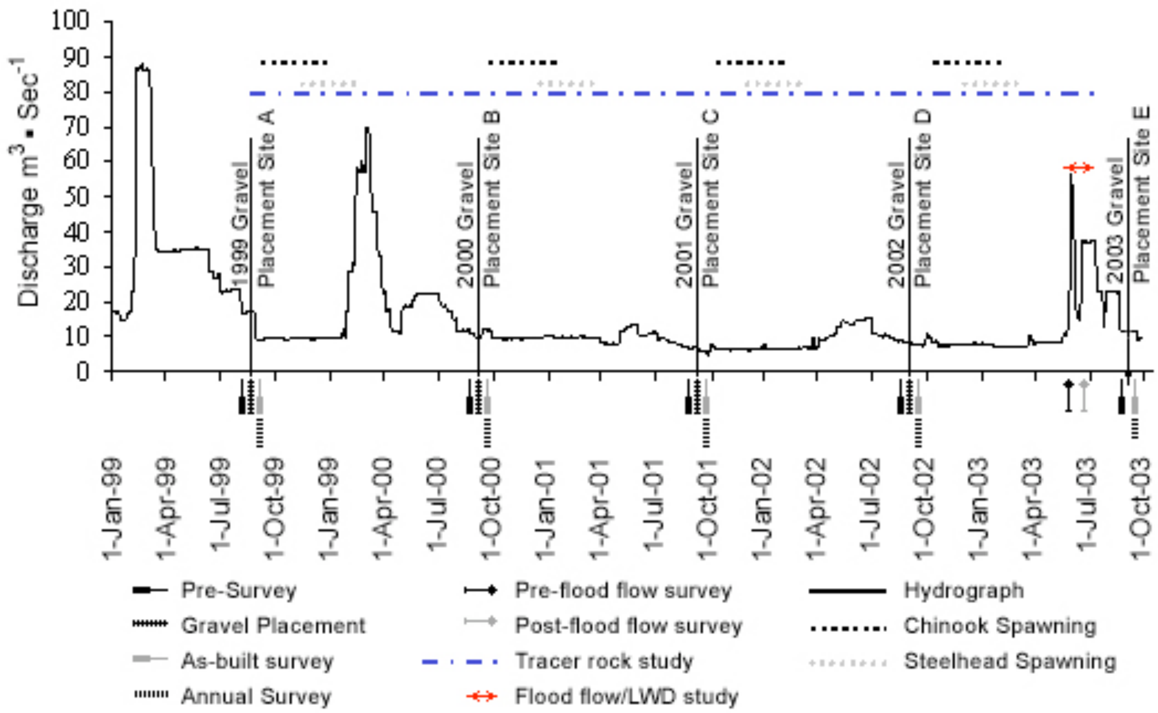


Figure 4. Hydrograph of the LMR at Camanche Dam showing gravel placement and topographic surveying times 1999-2003. Annual surveys covered all previous years' sites.

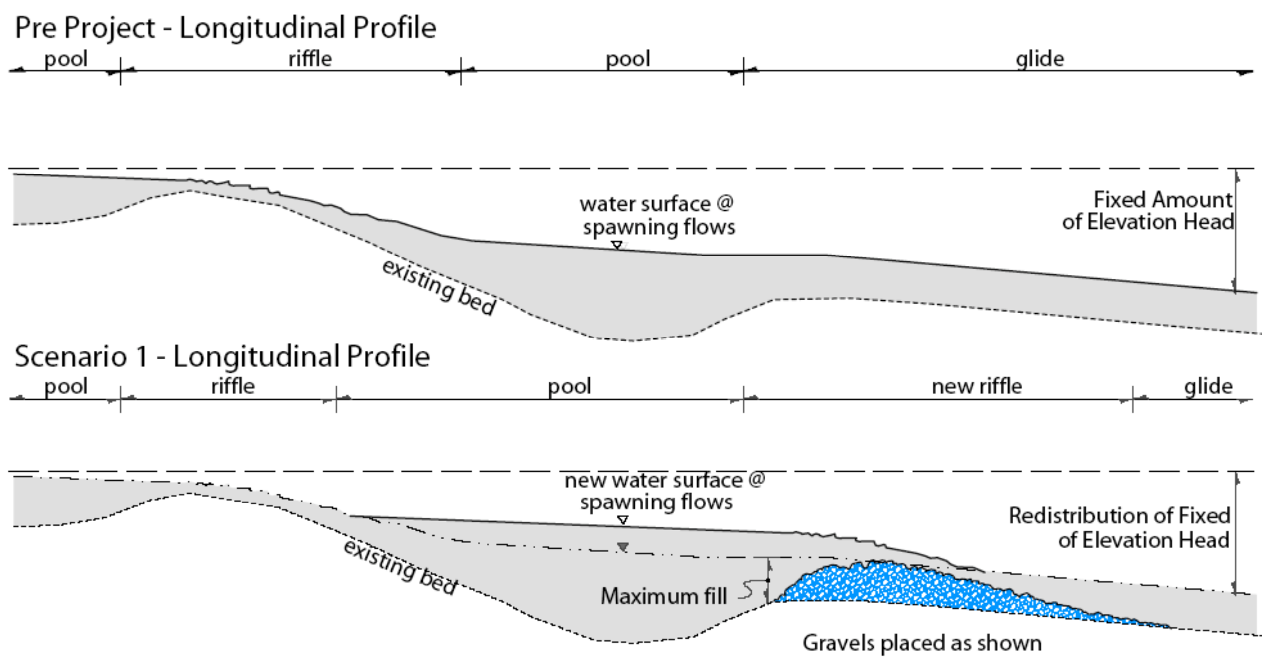


Figure 5. Gravel placement at one site backs water up and degrades habitat conditions at the next upstream site when slope is too low, possibly yielding no net habitat gain.

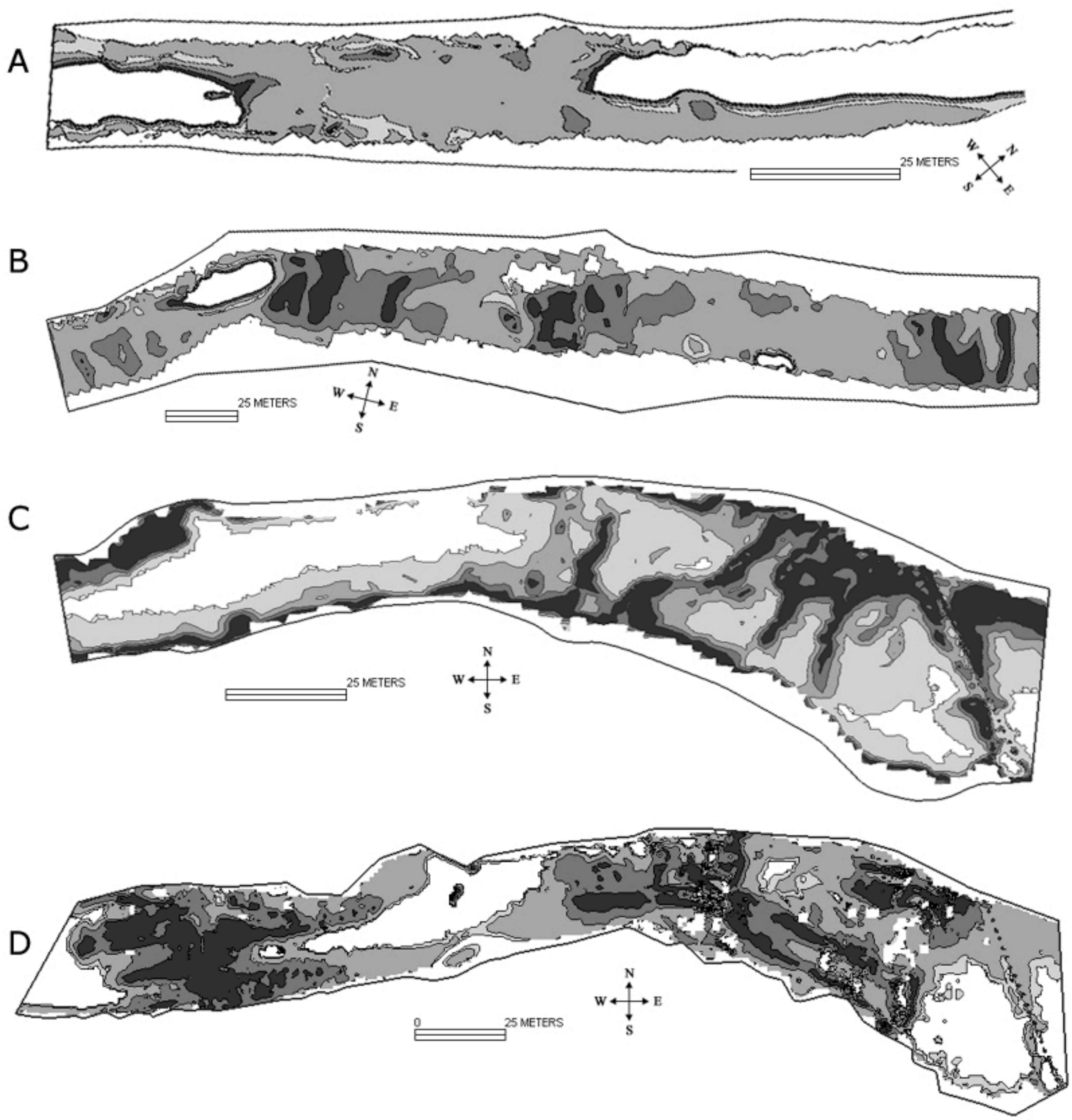


Figure 6. Pre-project Chinook salmon spawning habitat quality predictions for A) 2001, B) 2002, C) 2003, D) 2004. Flow is from right to left in all cases. Habitat quality is denoted as black=high, dark grey=medium, medium grey=low, light grey=very poor, white=non-habitat. The 2004 project spanned the areas of previous 1999 and 2003 projects.

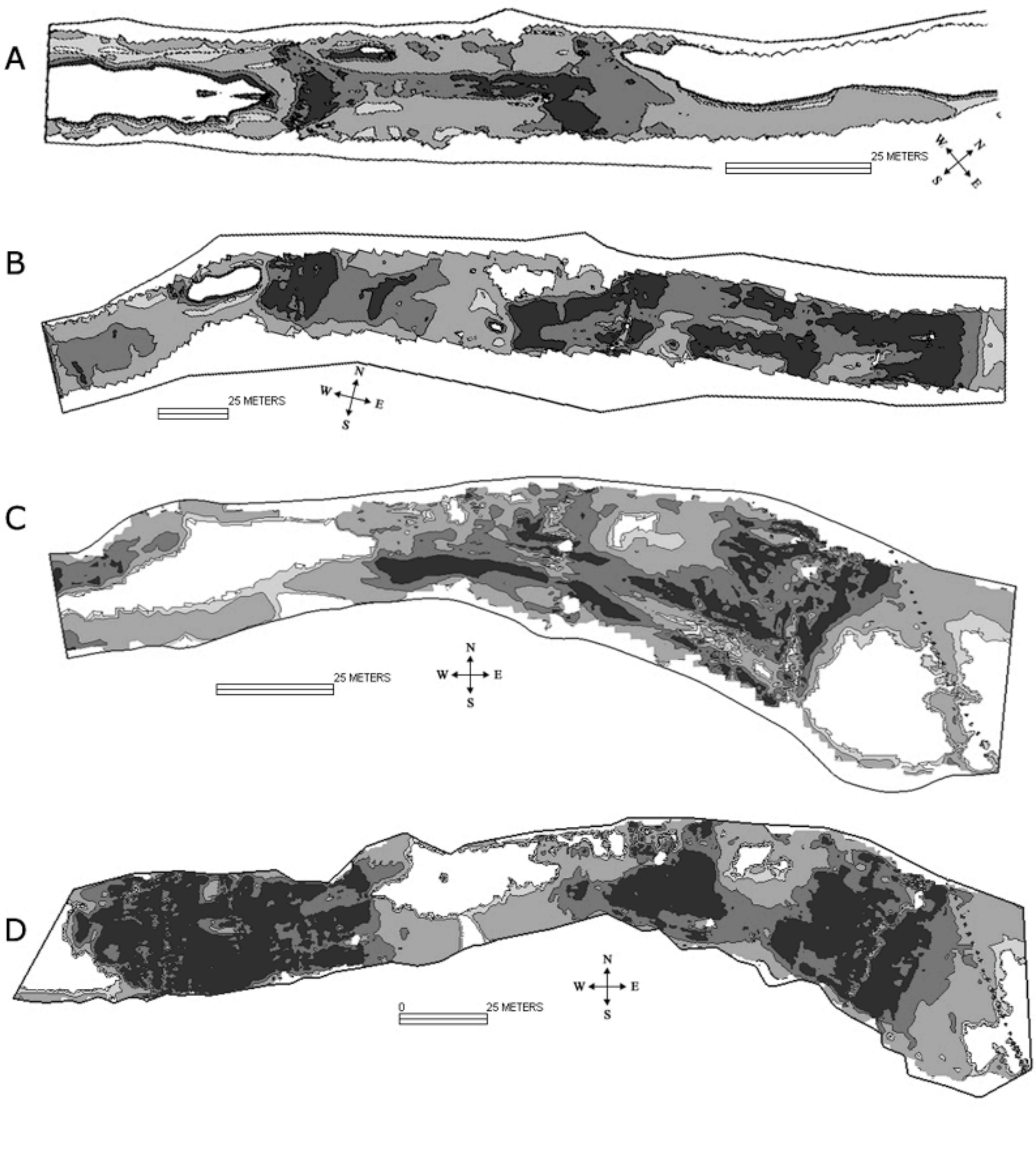


Figure 7. Post-project Chinook salmon spawning habitat quality predictions for A) 2001, B) 2002, C) 2003, D) 2004. Habitat quality is denoted same as in Fig. 6.

(Fig. 5) into a rehabilitation tool. Achieving this geomorphic change netted a habitat quality gain for the 2003 spawning season as a bonus, and after the 2004 project, an overall ***444% gain*** in high-quality habitat was achieved relative to before 2003 (Figs. 6,7). In 2005, the new slope will be distributed further downstream to rehabilitate a section where the channel is presently too deep, stagnant, and covered with aquatic weeds for spawning to occur.

In summary, the restoration actions on the LMR have had one specific management goal: to increase the area and quality of Chinook salmon spawning habitat below Camanche Dam. To achieve this goal, each project is broken down into a set of specific objectives, hypotheses, tests, and performance metrics associated with the key concepts and process-based tools used in SHIRA. For example, Table 2 of Wheaton et al. (2004b) presents each design objective for the 2001 site, a design hypothesis suggesting how the objective could be met, an implementation procedure for building an experiment to test each hypothesis, and the monitoring metrics used to corroborate or falsify each hypothesis. Along with EBMUD's management goal, ***CALFED has sponsored a higher goal of developing SHIRA for potential use on any regulated river, using the LMR as a field-scale testbed.*** SHIRA's key hypotheses also need monitoring to test quantitative 0.1-1 m^2 scale predictions from 2D models regarding flow, sediment scour, and habitat quality and test basic and applied scientific theories incorporated into designs by treating projects as adaptive management experiments. Thus, each project has included tests designed to evaluate underlying science, design concepts, rehabilitation procedures, and rehabilitation outcomes. Monitoring is now needed to determine the outcome of these tests.

2. Justification

Conceptual Models

California's decadal commercial landings for Chinook salmon have trended down from 33,621 metric tons (1950s) to 18,980 metric tons (1990s) (NMFS, 2001). A major factor has been that Pacific salmon spawning habitat has been depleted by instream and upland human activities (Nehlsen et al., 1991; Brown et al., 1994, Moyle and Randall, 1998; Yoshiyama et al., 1998). Dams (Kondolf, 1997; Brandt, 2000), gravel extraction (Clark, 1955; Kondolf et al., 1996b), historic gold mining (Harvey and Lisle, 1998), channelization (Nagasaka and Nakamura, 1999), water diversion (Carl Mesick Consultants, 1996; Douglas and Taylor, 1998), deforestation (Platts and Megahan, 1975; Marks and Rutt, 1997), and intensive agriculture (Soulsby et al., 2000) have disrupted stream ecology (Allan and Flecker, 1993; Poff et al., 1997).

SHIRA uses conceptual models that are organized by a guiding hierarchical framework. ***It is posited that regulated streams with no major tributaries below large valley-rim dams exhibit distinct dynamics at reach (10^2-10^3 W), geomorphic-unit (10^1 W), and hydraulic-unit (10^{-1}-10^0 W) spatial scales***, where W is channel width (e.g. Grant and Swanson, 1995). Reach dynamics relate to boundary conditions (e.g. channel/floodplain patterns and systemic sediment storage) and input regimes (e.g. flow, sediment, chemical, and biotic fluxes). Rehabilitation at this scale aims for self-sustainability, but systemic response takes decades to centuries. Such actions cannot sustain shrinking populations in need of short-term aid and could initially decrease habitat heterogeneity and increase frequencies and durations of disturbance. Geomorphic-unit dynamics relate to the process-morphology interactions that yield pools, riffles, glides, etc that serve as meso-scale habitats. Rehabilitation at this scale increases habitat quantity to yield measurable increases in population size, but is not sustainable beyond the recovery period for riparian vegetation re-encroachment that destroys width variability between geomorphic units, unless reach-scale input regimes are re-regulated. Hydraulic-unit dynamics govern local habitat conditions and drive bedform/bank adjustments. Rehabilitation at this scale improves habitat quality to sustain existing populations. These projects may be short-lived if the other scales are neglected, but they might stem the tide of further population declines. Ultimately, river restoration requires actions at all 3 scales, because there is large uncertainty regarding how actions at one scale cascade to impact other scales. Design, implementation, and monitoring must be nested and provide unique models and approaches appropriate for each scale.

SHIRA's primary conceptual model at the reach-scale addresses the systemic geomorphic impacts of dams on rivers (e.g. Williams and Wolman, 1984; Brandt, 2000; Grant et al., 2003). According to this model (Fig. 8), channels below dams are starved of flow and coarse sediment, while still receiving sand from tributaries and adjacent lands. Quantification of the spatial patterns of sediment storage/deficit using a sediment budget is needed to estimate how much coarse sediment addition and fine sediment removal is needed to re-initiate the system (Reid and Dunne, 2003). Historical flow regime analysis and sediment transport estimates are needed to evaluate alternative sediment-routing continuity options. In response to long-term water extraction and sediment blockage, the conceptual model predicts a cascading effect to smaller scales over decades to centuries in which geomorphic units experience bed incision and armoring, width constriction and vegetation encroachment, and loss of in-channel large woody debris (LWD) and gravel bars (Grams and Schmidt, 2002). Geomorphic analysis is needed to determine the extent to which channel units must be actively restored to overcome critical thresholds limiting a restored input regime from yielding self-sustainability. The aquatic biological consequences of damming include loss of access to the ~80% of upstream, pre-dam spawning area as well as incremental but steady loss of spawning and rearing habitat downstream over decades (Fisher, 1994). Macroinvertebrates that fish eat show a major decrease in diversity (Ochikubo Chan, 2003). Population surveys of migratory and resident fish as well as macroinvertebrates, aquatic vegetation, and riparian vegetation are used to estimate reach capacity with existing stressors and to track the response of populations to restoration-induced disturbances and eventual rehabilitated functionality (Merz, 2004; Merz et al., 2004).

Very large sources of uncertainty exist with rehabilitation actions at the reach scale. Sediment budgets do not exit for many streams, including the LMR, and where they do exist, different methods or data sets can yield estimates of a given component varying by 50-1000% or more (Reid and Dunne, 2004). The magnitude, duration, and rate of change of flow releases necessary to cross key thresholds, such as those related to channel migration and to removing pioneer vegetation from banks and active bars are poorly understood (Poff et al., 1997; Tickner et al., 2001). Flume studies of vegetated channel change using alfalfa sprouts, dowels, etc. have proven poor at addressing vegetation thresholds, because canopy cover and root cohesion have not been effectively downscaled. Similarly, a recent study of eradication methods in Utah was unsuccessful due to persistent inter-annual drought (Schmidt et al., 2002). Impacts of unnatural disturbances induced by restoration actions, such as rapid pool filling, riffle instability during low-flow spawning, poor timing of flood releases according to water demand schedules rather than biotic rhythms, and promotion of invasive species have not been addressed. In terms of population dynamics, challenges persist in detecting the signal of increases in numbers of species and population sizes relative to the noise of field methods uncertainty, ocean harvesting, hatchery take, and population cycles due to competition, predation, disease, and fertility.

At the geomorphic- and hydraulic- unit scales, external forces imposed on a channel yield morphodynamic processes controlling habitat conditions (Fig. 9). Pools and riffles are

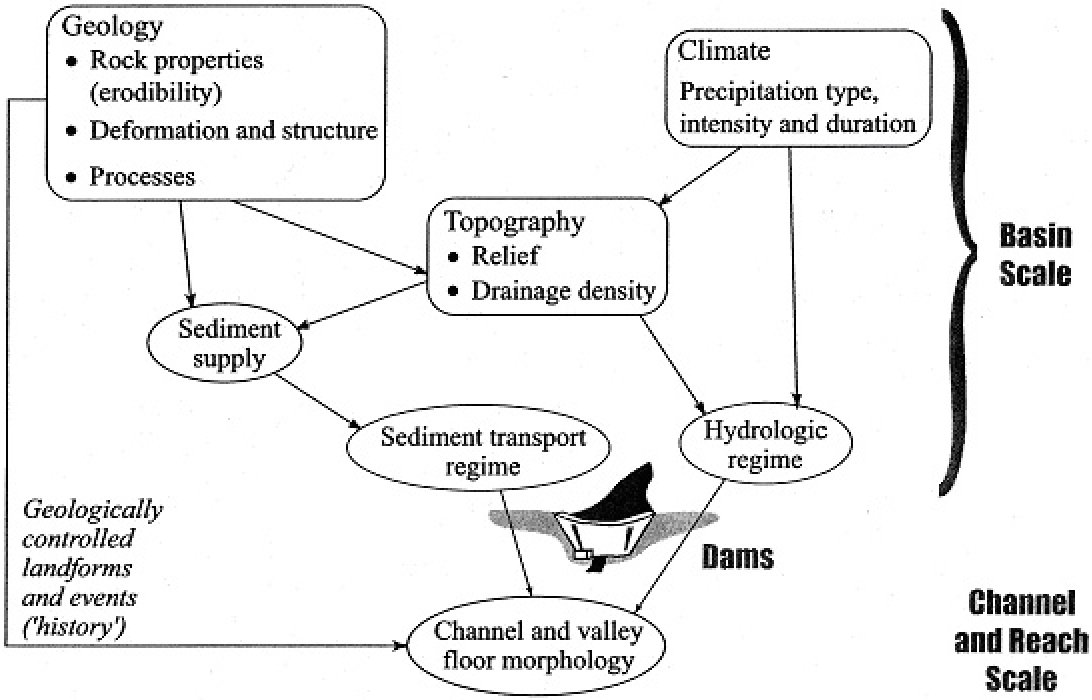


Figure. 8. Basin- and reach- scale conceptual models for geomorphic processes influencing the channel and valley floor downstream of a dam as a result of changes to the flow and sediment regimes (from Grant et al., 2003).

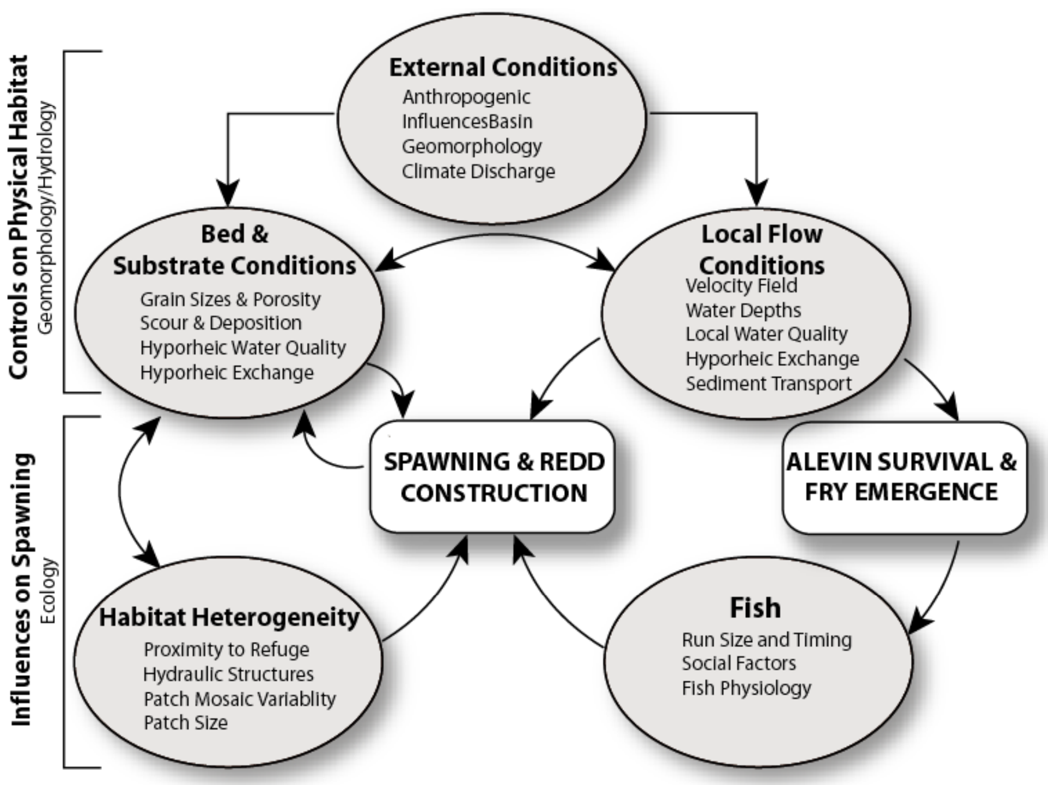


Figure. 9. Geomorphic- and hydraulic- unit scale linkages between physical processes, habitat, and fish populations (from Wheaton et al., 2004a).

naturally self-sustained primarily by large width differences between the two that drive dramatic shifts in convective accelerations as a function of discharge- not by variations in the depth-slope product as conceived by wrongly assuming steady, uniform flow (Carling, 1990). Geomorphic analysis is strongly needed to ascertain whether constructed units have the capacity for self-maintenance and passage of sediment, especially in light of the constraints provided by engineered structures such as bridges, levees, and bank protections. At the 0.1-1 m^2 scale at which fish experience the channel, depth, velocity, and substrate quality explain 85-95% of redd locations on the LMR (Pasternack, unpublished data). Increased sand/silt content in spawning gravels causes decreased salmonid embryo survival and alevin emergence (McNeil and Ahnell; Koski, 1966; Sear, 1993). Bedrock outcrops, boulders, gravel bars, and woody debris contribute local convective accelerations that yield habitat heterogeneities that are much more highly used by spawners than their relative availability (Wheaton et al., 2004c). They also provide traps in their lee that promote creation and retention of usable habitat, which can cascade upscale to provide long-term, systemic benefits. Hyporheic water quality can play a crucial role in embryo survival to emergence in rehabilitated riffles (Merz and Setka, 2004; Merz et al, in press).

Because of the large number of hypothesized mechanisms for geomorphic- and hydraulic- unit scales, there are many sources of uncertainty whose relative importance is itself unknown. Quantitative geomorphology has largely focused on transect-based tools (i.e. cross-sections and long profiles) and steady, uniform flow assumptions. These tools are highly predictive in sand channels that gradually vary downstream, but are poorly predictive when applied to rapidly varying bedrock and boulder streams (Valle and Pasternack, submitted). Gravel streams show some predictability (~10^0-10^2x errors), but 2D and 3D analysis is warranted. Also, conceptualizations of restored geomorphic units emphasize alternate bars based on textbook over-simplifications (e.g. Rosgen, 1997; Trush et al., 2000), even though many natural channel units do not exhibit this morphology. In terms of sediment transport, 1D models yield estimates accurate to within factors of 10^0-10^2 and cannot address spatio-temporal dynamics of gravel placed in complex channel morphologies. 2D and 3D hydrodynamic models can predict conditions more accurately and at much higher resolution (Leclerc et al., 1995; Gallagher and Gard, 1999; Crowlder and Diplas, 2000), but need more evaluation for predicting shear stress and bed scour (Pasternack et al., in prep), which are particularly crucial for embryo survival to emergence. A large uncertainty exists over whether gravels follow predicted 2D flow paths or whether grain momentum is sufficient to yield straighter trajectories, especially in the vicinity of boulders and other discrete roughness elements. On a practical level, there are large uncertainties regarding subsidence, consolidation, slope stability, and dispersion of placed gravel features as a function of construction method (Merz, 2004).

In terms of aquatic biology, use of 2D models dramatically reduces uncertainty in the major physical factors influencing gravel usage at geomorphic- and hydraulic- unit scales (Leclerc et al., 1995; Pasternack et al., 2004), but larger and longer term data sets are needed. Accounting for 0.1-10 m scale patterns of habitat heterogeneity remains the largest source of uncertainty in habitat predictions (Thomson et al., 2001; Wheaton et al., 2004c). Such patterns might relate to the distance spawners swim between a redd location and a resting location, distribution and quality of cover, and exchanges between surface and hyporheic waters. Also, differences in embryo survival to emergence due to habitat heterogeneity are unknown. Beyond salmon spawning, little is known about site functionality with regard to the resident aquatic community actually using rehabilitated units and how residents change over time as units change. Depending on their availability and residence time, in-channel and floodplain food sources- detritus, plant matter, zooplankton, macroinvertebrates, etc- could be important controls on fish populations. Assessment of the aquatic community would also reduce the uncertainty stemming from using spawners as *ecological indicators* of ecosystem health.

Hypothesis Testing

No one site, reach, or river system can be used to test all remaining uncertainties in regulated river rehabilitation. For example, some streams (e.g. Clear Creek) have high slopes and bedrock outcrops suitable for studying reach-scale dynamics associated with gravel injection using talus cones. Other streams (e.g. LMR) have low slopes and limited flow releases rendering talus cone gravel injections useless, but enabling long-term evaluation of predictive riffle construction. Also, some streams may show density-dependence in population dynamics while others do not, necessitating different emphasis on analyses of habitat quantity versus habitat quality. ***The key is to determine which uncertainties a particular project is best positioned to address***. This assessment depends on setting, rehabilitation framework used, design hypotheses used, and existing datasets. Similarly, one may prefer biological versus geomorphic, theoretical versus practical, and quantitative versus qualitative goals, methods, and conclusions. For example, an ecological statistician would prefer a p-value and r^2 assessment of the relation between fish locations and habitat types whereas a fluid biomechanicist would prefer a comparison of fish and sediment particle tracks between field-observed radio-tracking data and computational hydrodynamic predictions. Both perspectives are ultimately needed, even though no one project can span the full range of valid and valuable approaches.

In light of these practical constraints and based on the LMR setting, hypotheses already tested, usage of a mechanistic rehabilitation framework (SHIRA) with 0.1-1 m^2 scale predictions, and availability of a historical database of biological, chemical, and physical variables, this proposed LMR monitoring project aims to reduce the uncertainty associated with practical problems of gravel placement and improve the science of key linkages among spatial patterns of hydrodynamics, channel change, physical habitat, and community structure over a range of scales. Three sets of hypotheses that span and integrate aspects of hydrogeomorphology and ecology are proposed for testing on the LMR- one for each scale.

1) At the reach-scale it is hypothesized that
    a) Slope creation and distribution downstream on a regulated, low-slope gravel river promotes sediment dispersal to increase sediment conveyance while also yielding greater net increases in spawning habitat quantity and quality relative to noncontiguous, individual gravel placements throughout a reach.
    b) Because of the remaining gravel deficit and external factors (e.g. ocean harvesting, hatchery take, and natural cycles), time variations in the fish community 2005-2008 will not show a cause-effect response to 1999-2004 gravel augmentation. However, different sections of the LMR may be scaled to accommodate different flow processes, and thus the longitudinal distribution of the fish community may reflect specific values of non-dimensional variables (slope, Shield stress, depth to grain size ratio, width to depth ratio, and channel width to connected floodplain width ratio) characteristic of geomorphic controls.
2) At the geomorphic-unit scale it is hypothesized that
    a) Persistence of high-quality habitat at rehabilitated geomorphic units over years depends on spatial patterns of geomorphic change in response to local slope, discrete roughness elements, convective accelerations, and pool-riffle self-

maintenance with available upstream gravel sources. 2D models explain the mechanisms of discharge-dependent patterns of shear stress, sediment scour, and morphodynamic change associated with designed differences between rehabilitated pools and riffles, and can be used to assess rehabilitation persistence.

b) The volumetric yield of gravel placement, which governs the 1-10 yr geomorphic and ecologic potential of a constructed site, depends greater on the vertical force balance controlling *in situ* subsidence, landsliding, and compaction than on the streamwise force balance associated with hydraulic transport of placed gravels.

3) At the hydraulic-unit scale it is hypothesized that
   a) Direct manipulation of channel topography and substrate type significantly change riffle functionality to yield *immediate* improvements in habitat quality and spawner utilization of riffles (i.e. no "seasoning" required) when gravel placement is designed by iterative testing and improvement using 2D models.
   b) Whereas current numerical habitat predictors assume that each point in a stream is spatially independent, a key aspect of defining and analyzing habitat heterogeneity where aquatic organisms are located is to include effects of neighboring patches and transitional zones in predictions of habitat conditions.
   c) Types and amounts of spatially dependent habitat heterogeneity features are disproportionately important constraints on spawner utilization of rehabilitation sites relative to the amount of available homogeneous riffle habitat.
   d) The spatial distribution of benthic macroinvertebrate functional groups at a rehabilitation site reflects types/amounts of spatially dependent habitat heterogeneity features. Habitat suitability curves for these organisms would aid rehabilitation design and performance.
   e) As many juvenile salmonids use constructed hydraulic units as use pre-existing hydraulic units. The spatial distribution of juvenile salmonids reflects types/amounts of spatially dependent habitat heterogeneity features.
   f) Discrete roughness elements promote sediment retention on a riffle and 2D models can be used to predict the spatial patterns of sediment retention.

The above hypotheses illustrate and test key uncertain cause-effect mechanisms that relate hydrogeomorphic restoration actions, Chinook salmon spawning habitat quality and quantity, and biological utilization of rehabilitated features on the LMR over 3 scales. They take advantage of 4 types of geomorphic units present on the river: degraded, isolated rehabilitated, SHIRA-based isolated rehabilitated, and SHIRA-based slope-linked rehabilitated units. They also go beyond spawning assessment to consider broader biological effects of restoration. Finally, they are broad enough to be of general interest to CALFED, flexible enough to enable adaptive monitoring and hypothesis adjustment as collected data are analyzed, and quantitative enough to provide practical LMR management lessons for EBMUD.

3. Previously Funded Monitoring

The LMR has been monitored during pre-dam, post-dam, and post-rehabilitation periods for regulatory and scientific purposes, yielding an extensive database of hydrological, geomorphic, water quality, and, biological variables (Table 1). Analysis of historical data has guided goal setting, project design, and experimental monitoring. Direct comparisons of spawning habitat conditions pre- and post- rehabilitation have concluded that all sites have had an increase in spawning habitat quantity and dramatic improvements in habitat quality (Figs.

Table 1. LMR monitoring variables

Source	Variable
	Hydrological
EBMUD	Hourly Camanche Dam outflow
EBMUD	Long-term Q, V, depth measurements at XS network
UCD	Q-depth rating curves for rehab site flow boundaries
UCD	Q,V, depth measurements at rehab sites
UCD	Vertical velocity profiles at rehab sites
UCD	Eddy viscosity point estimates at rehab sites
UCD	Water surface elevation profiles
UCD	2D flow pattern sketches for rehab sites
	Geomorphic
UCD/EBMUD	DEMs of rehab sites surveyed annually
EBMUD	Floodplain DEM (aerial survey)
EBMUD	Long-term bed profiles at XS network
UCD/EBMUD	Long profile of gravel bed elevation (2 miles)
UCD/EBMUD	300 pebbles counted at rehab sites (pre and post)
UCD	~15,000 painted tracer rocks at rehab sites
UCD/EBMUD	Boulder positions and elevations
UCD	Bed roughness estimates
UCD/EBMUD	Bed material longitudinal survey
UCD/EBMUD	gravel porosity estimates
	Water quality
EBMUD	Hourly temp longitudinal survey
EBMUD	Hyporheic temp, DO, fines, permeability at points
EBMUD	Organic content of fine sediment
	Biological
EBMUD	Video surveillance of all migrating fish (count, species ID, fish length, sex id for salmonids)
EBMUD	Radio tracking of fish during pulse flow
EBMUD	Coded-wire tagging of juvenile Chinook salmon
EBMUD	Rotary screwtrap estimation of juvenile salmonids
EBMUD	Fish community surveys by electro-fishing/seining
EBMUD	Weekly redd surveys (> 8,000 GPS'd redd locations)
EBMUD	Redd habitat suitability measurements at ~1000 sites
EBMUD	Incubation success and fry production using embryo tubes
EBMUD	Macroinvertebrate counts and species id
EBMUD	Aquatic vegetation areal extent

6,7). Beyond evaluating management outcomes, monitoring data has recently been used to answer key scientific questions across all three spatial scales of interest.

At the reach scale, a survey was performed 1997-2004 to identify trends in spatial and temporal distributions of the LMR fish community in response to streamflow and water temperature regimes (Merz et al., 2004). Seining, backpack electrofishing, and boat electrofishing were used to characterize emergence, abundance, and growth of fish species at 16 locations. Reach and habitat classification as well as measurement of local physical habitat conditions (depth, velocity, substrate type, water temperature, dissolved oxygen content, and turbidity) were also done at fish survey sites. A total of 113,740 fish were captured. Juvenile Chinook salmon dominated the seine catch followed by western mosquitofish, prickly sculpin and Sacramento sucker. Prickly sculpin dominated the electrofishing catch followed by juvenile Chinook salmon, adult Sacramento suckers and threadfin shad. When sites were analyzed based on habitat type, glide and pool habitat catch per unit effort was highest in March, run habitat catch per unit effort peaked in May, and side channel riffle catch per unit effort peaked in February. Temperature change explained the absence of Chinook in backwaters after temperatures increased. Detailed analysis and reporting of this data is currently underway.

At the geomorphic-unit scale, hypothesis testing has been used to evaluate the roles of different geomorphic processes on temporal changes in placed gravel volume as well as to assess whether SHIRA's conceptual model of hydrogeomorphic-biologic links predicted changes in habitat quality and utilization. A 4-year site-scale volumetric sediment budget study using the 1999 baseline site tested the hypothesis that flow-induced scour is the primary mechanism causing volumetric change of placed gravels (Merz, 2004; Merz et al., in prep). Estimates of scour potential were made using 1D equations and 2D model predictions. Volumetric losses due to settling, compaction, and landsliding were estimated. A 20% change in placed-gravel volume was observed in the first year when flow was very low and no volumetric change occurred for the downstream pool. Over subsequent years, volumetric change continued but rapidly declined to a asymptote at ~5% loss per year. A net loss of 50% of volume was observed over 4 years. ***Based on sediment budget estimates, half of the net volumetric loss was attributable to settling and compaction***. Sediment tracer trajectories confirmed locations of lateral landsliding versus streamwise flow-based transport. As a result of this analysis, further studies regarding gravel settling and compaction are very important relative to further flow-based scour studies.

On a practical level, a monitoring study has been done on the practical challenges of using a front loader to place gravels and build bed features at the geomorphic-unit scale. DEM differencing of pre-project, design, and post-project DEMs shows that gravel placement using a front loader has a tendency to yield steeper riffle-tail slopes than designed, due to the depth-limit the machine can handle, thereby creating a localized risk. Furthermore, there is a tendency to place too much gravel at the starting point of placement, with decreasing fill depths being achieved towards the end of placement. The consequences of these practical problems require longer-term monitoring and thorough consideration with regard to detailed design.

In terms of habitat conditions, pre- versus post- project comparisons have found that ***spawning riffle enhancement does in fact significantly improve substrate quality, increase mean velocity, and decrease mean depth*** (Merz and Setka, 2004; Pasternack et al., 2004; Wheaton and Pasternack, 2002). Rehabilitated sites have reduced fine content, increased D_{50} and D_{90}, increased porosity and permeability, and decreased cover of aquatic weeds (Fig. 10). At the 1999 baseline site, mean depth decreased from 1.38 to 1.09 m, while mean velocity increased from 0.21 to 0.34 m/s. Also, the range of velocities increased from 0-0.6 to 0-2.07 m/s, which yielded more habitat niches for rearing, adult holding and macroinvertebrates. Persistence of these improvements for 1 year has been reported, but longer term monitoring is needed.

Some have hypothesized that gravel placement is a disturbance that could negatively impact aquatic organisms using geomorphic units. A LMR colonization study of benthic organisms at 7 placement sites found that they colonized new gravels quickly, equalling densities and biomass of unenhanced spawning sites within 4 weeks. Species richness equalled that of unenhanced sites within 4 weeks and diversity within 2 weeks. ***Standing crop, as indicated by densities and dry biomass, was significantly higher in enhancement sites after 12 weeks than in unenhanced sites and remained so over the following 10 weeks*** (Merz and Chan, in press).

Another hypothetical concern is that enhanced spawning riffles could serve as "attractive nuisances" by encouraging fish to spawn where hyporheic water quality is poor enough to inhibit embryo survival to emergence. To test this hypothesis, an egg-tube study was performed to compare embryo survival and growth between several enhanced and unenhanced sites (Merz et al., in press). ***Salmon embryos planted in placed gravels had an average of 35% higher survival rates to the swim-up stage than embryos planted in unenhanced gravels***, but no significant increase in growth was observed. Bed material (core-sampled) d_{50}, volatile suspended solids, and total temperature-hours accounted for 87% of the variability in embryo survival.

At the hydraulic-unit scale, the primary effort has been to test the accuracy and value of 2D models in predicting hydrodynamic, sediment scour, and physical habitat conditions at rehabilitation sites. Based on data from 35 cross-sections and 24 vertical-velocity profiles, ***2D hydrodynamic models were found to be accurate predictors of depth and velocity at the point scale in pools and riffles at rehabilitation sites, but poor predictors of these variables in very shallow water along dry boundarie***s. The degree of accuracy depends entirely on the accuracy of the digital elevation model (DEM) and the 2D model's mesh resolution along the dry boundary (Pasternack et al., 2004), which means that high-resolution, feature-based surveying is necessary (Wheaton et al., 2001a). Where depth prediction error is 0-20 %, velocity prediction error also randomly varies between 0-20 %. Sites with depth prediction error >25 % have velocity prediction errors varying randomly between 40-85%. A 1% increase in depth prediction error yields a 1.5% error in velocity prediction (Pasternack et al., in prep). 2D velocity patterns around boulders are well predicted (Fig. 11), while those near LWD are poorly predicted.

The hypothesis that 2D models can predict bed shear stress equally as well as field-based methods can estimate it was tested using vertical velocity profile data collected at the 2002 SHIRA site. A comparison of 5 field-based and 3 2D-model-based approaches for estimating bed shear stress found that 56% of model estimates were within the 95% confidence limits of the 2 best methods of field-based estimation (Pasternack et al., in prep). Those sites where field-based estimates and model predictions differed most were in very shallow water along dry boundaries where DEM and mesh resolution is very poor. At these boundaries, 90% of bed shear stress error in prediction was accounted for by velocity prediction error.

Given the accuracy of 2D models reported above, it was possible to use 2D models to test and falsify the hypothesis that enhanced riffles are inherently subject to significant scour even at spawning discharges, thereby making them attractive nuisances for fish (Fig. 12). For any depth > 0.1 m, the velocity required to induce gravel scour is significantly higher than that preferred by spawners for locating redds (Wheaton et al., 2001b). Observations and 2D models at the 2001 and 2002 sites confirm that scour of rehabilitated riffles is not a risk at spawning flows when sites are iteratively designed with the aid of a 2D model.

Figure 10. Comparison of pre-project (left) versus post-project (right) substrate quality. Persistence of high quality beyond 1 year has been observed to be spatially variable and controlled by riffle slope, but longer term monitoring is needed.

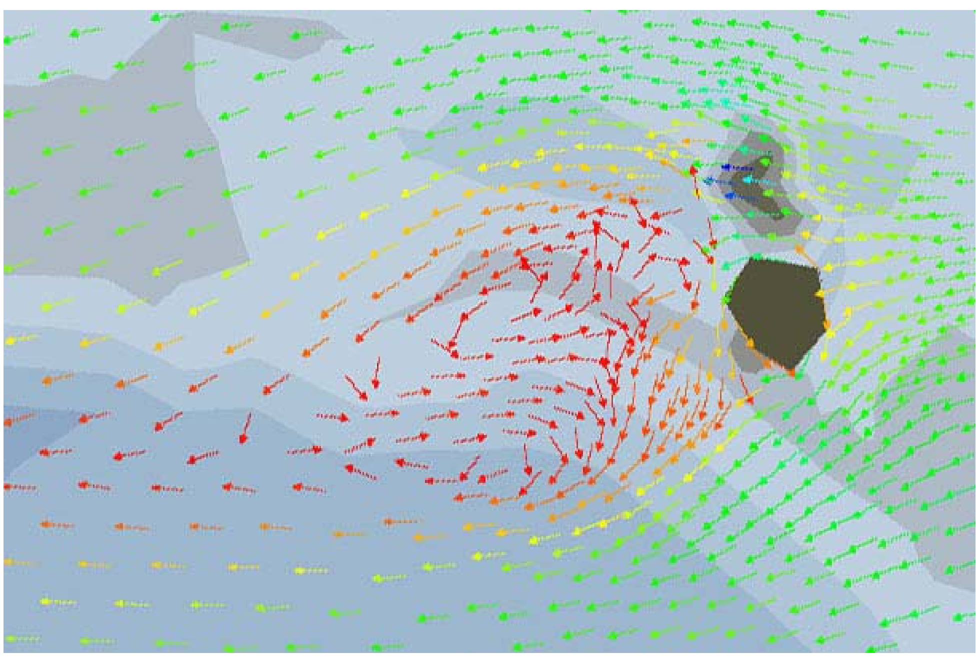
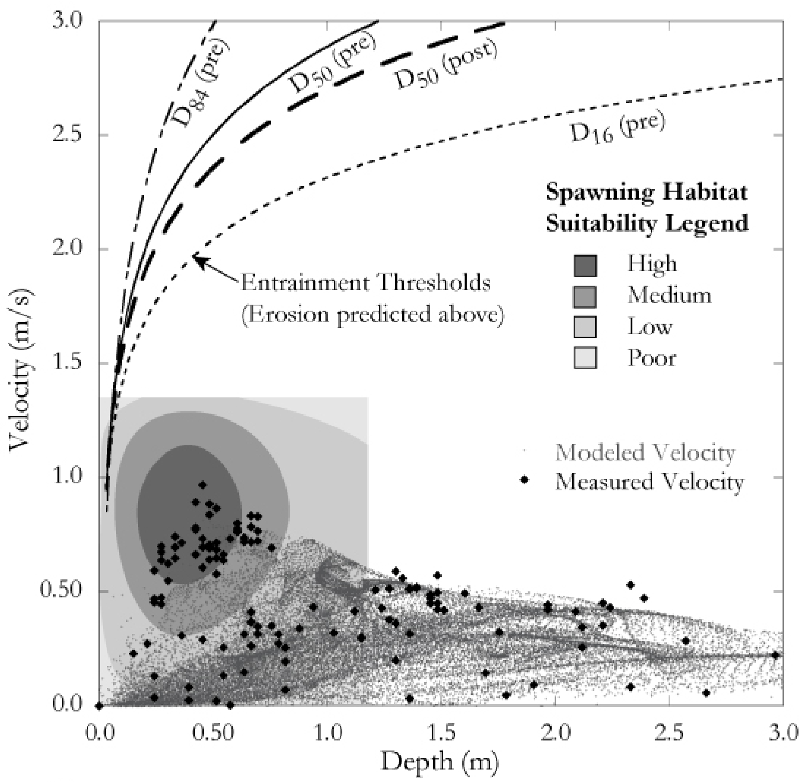


Figure 11. 2D model prediction of a double-vortex eddy downstream of a boulder cluster placed on a riffle at the 2002 rehabilitation site. Monitoring shows that gravel is accumulating in the eddy and that the accumulating gravel has higher substrate quality than surrounding gravels, but longer term observations are required to track the fate of this and similar features.



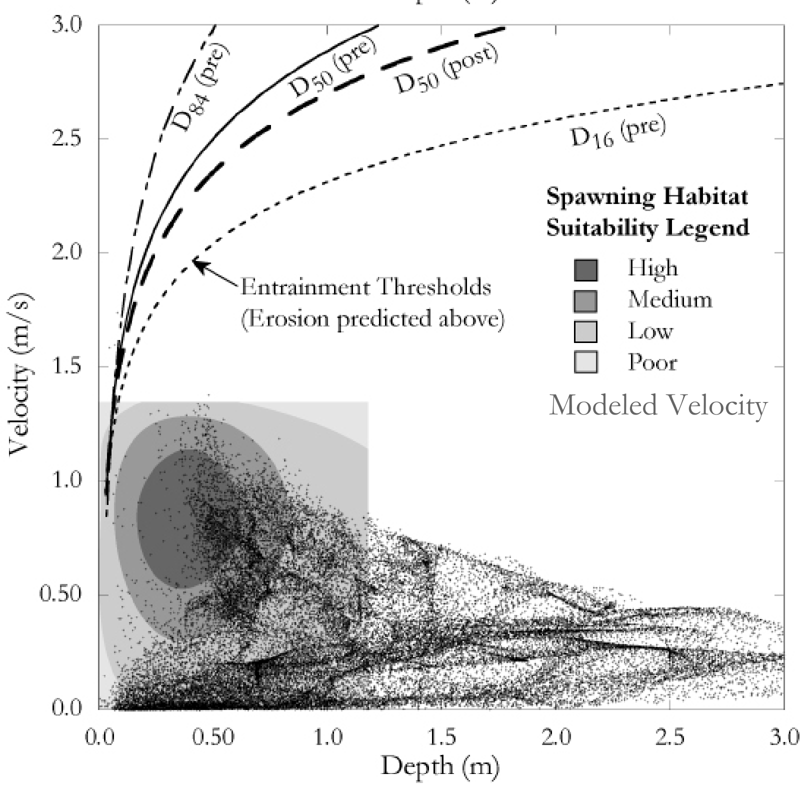


Figure 12. Comparison of D,V for the 2001 site pre- (top) and post- (bottom) project relative to Chinook salmon spawning habitat preference and gravel scour thresholds. There is no inherent scour risk at spawning Q, even though other projects report scour, evidently due to poor design.

The degree to which 2D model predictions of spawning habitat quality are sensitive to variability in depth and velocity habitat suitability curves is currently being assessed. EBMUD's 8000-redd database spanning 1994-2004 has been used to create multiple suitability curves using different assumptions, and these have been compared with the curves generated with 1980s data (CDFG, 1991). 1990s habitat suitability curves show systematic shifts in preference for higher depths and lower velocities relative to the older data (Fig. 13). However, the older data may represent a small sampling of high-quality habitat whereas the newer data represent a large sampling of all used sites in the LMR. Also, the differences may reflect local geomorphic context, decadal shifts in spawner-population preferences, and/or shifts in availability of habitat types. The sensitivity of 2D model predictions of habitat quality patterns to the observed habitat suitability curve shifts is being examined. Models have been run for the 2002, 2003, and 2004 projects using all available suitability curves and the results have been analyzed for the spatial patterns and summary statistics on the variation on predicted habitat quality. Patterns in sensitivity to different hydrogeomorphic features are being studied now.

Finally, 2D model predictions of spawning habitat quality for pre- and post- project conditions at all sites using all curves have been tested against actual redd locations. For example, at the 2002 site, ***85 of 88 post-project redds occurred on points predicted to be medium or high quality habitat*** and 50 of 60 redds had this result pre-project (Fig. 14). Also, the pattern of redd locations dramatically shifted, with redds aligned with the areal pattern of highest quality habitat. Thus, utilization was not an artifact of relative availability.

4. Approach and Scope of Work

Proposed monitoring is nested in a multi-scalar framework to test scale-dependent hypotheses (Table 2). Reconnaissance mapping, bedload monitoring, numerical models, and analysis of EBMUD's fish community data will address reach-scale questions about sediment dispersal and habitat creation over 1-10 years whereas high-resolution, intensive monitoring of specific mechanisms will be used to answer questions about geomorphic- and hydraulic- unit functionality and spatially heterogeneous ecological linkages. 2D models will be further tested to determine how far their results can be used to evaluate complex spatial dynamics.

Task 1- Reach-scale Monitoring and Analysis

The primary task at the reach-scale is to compare sediment export mass, fate of exported gravel, and downstream habitat quantity/quality changes between 3 areas: 1) an area subjected to slope creation (2003-2004 sites), 2) an area subjected to isolated gravel addition (2002 site), and 3) an unenhanced area (section upstream of 2002 site). Furthermore, as an adaptive management tool, historical flows and a bedload transport model will be used to test each area for its response to different flow re-regulation options, while a long-term sediment dispersal model will be used to help plan future sediment injections. EBMUD plans to continue its fish community survey 2005-2008, so baseline data collection of non-dimensional geomorphic variables will be performed to expand the analysis of longitudinal controls on community assemblage.

Subtask 1.1- Baseline mapping

To aid on-going and future hypothesis testing, more reach-scale baseline data must be collected for the LMR. These data include a high-resolution (~1 pt per 3 m) longitudinal profile for the gravel-bedded reach (by RTK GPS), a cross-sectional profile over each riffle crest and

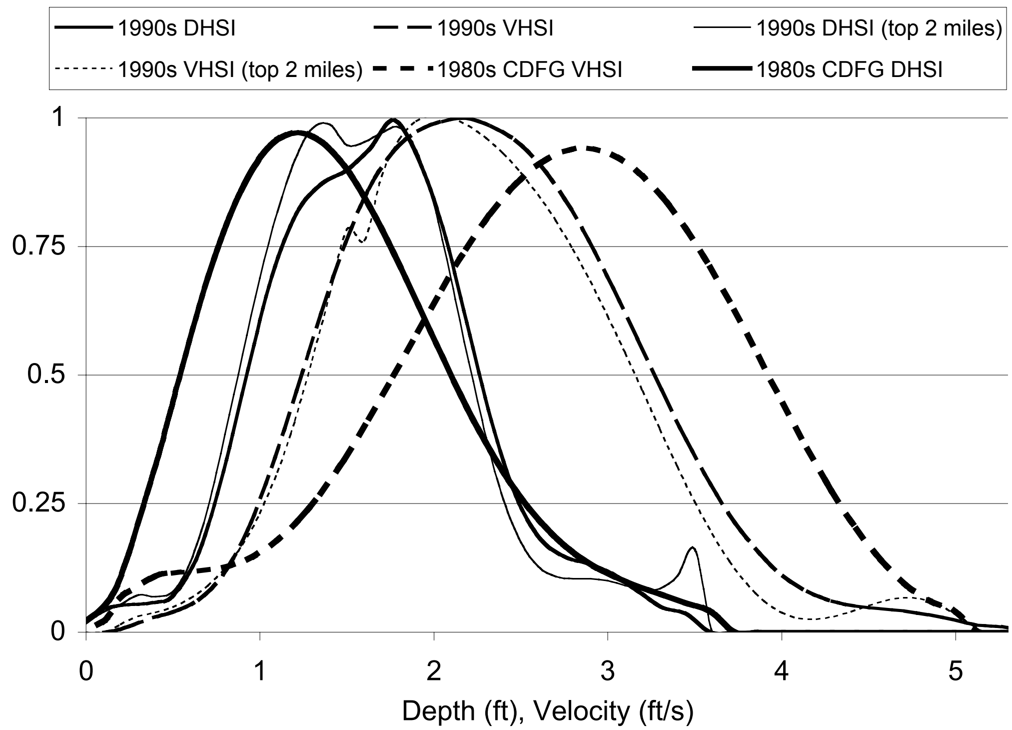


Figure 13. Depth (DHSI) and velocity (VHSI) spawning habitat suitability curves for the LMR using different datasets.

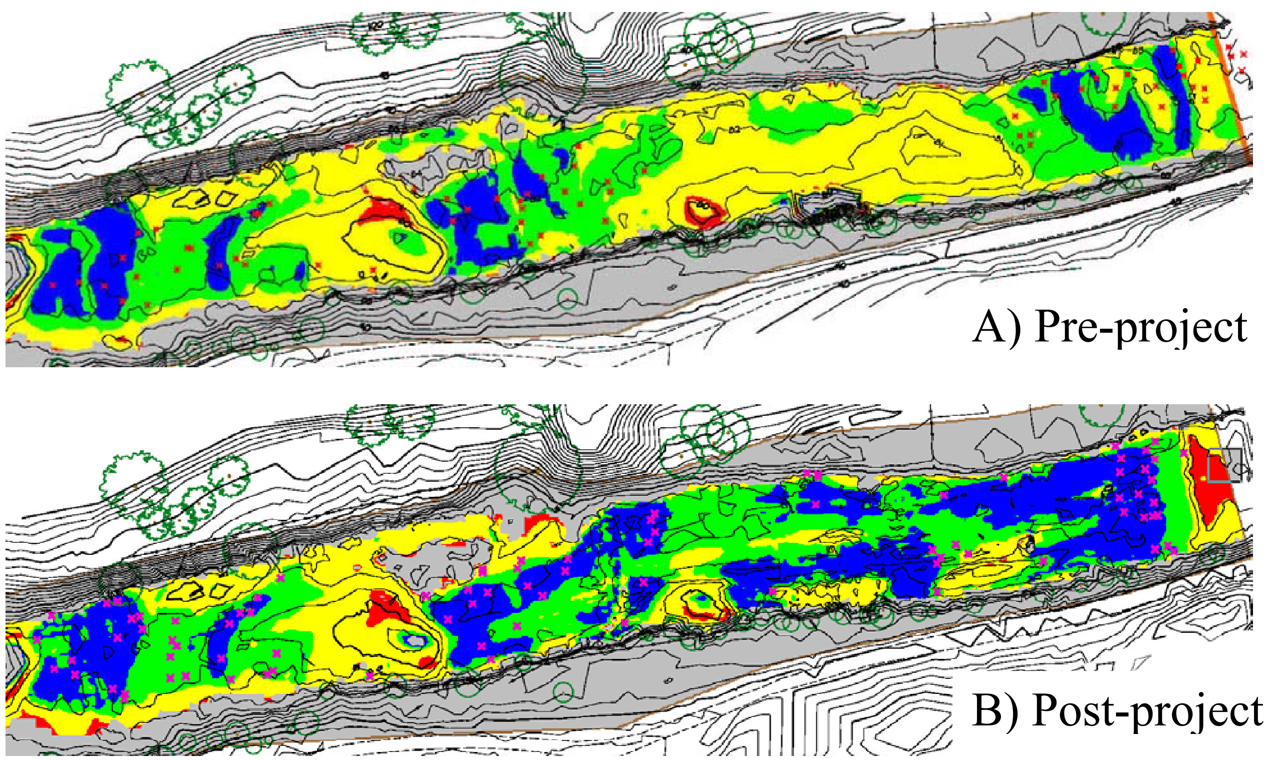


Figure 14. Comparison of predicted habitat quality and observed redds for the 2002 site's A) pre-project and B) post-project conditions. Habitat quality is denoted as blue=high, green=medium, yellow=low, red= very poor, white=non-habitat.

Table 2. Enumeration of tasks, responsibilities, and timeline

		|--------------------------Quarter*------------------------|											
Task #	Description	F1	W1	S1	S1	F2	W2	S2	S2	F3	W3	S3	S3
Task 1	**Reach-scale monitoring**												
subtask 1.1	*baseline mapping*												
	long profile	G											
	pool/riffle cross-sections	G											
	geomorphic data analysis		G										
subtask 1.2	*sediment export rates*												
	install/maintain 3 drum traps x 3 sites	G				G				G			
	install/maintain 3 net traps x 3 sites	G				G				G			
	monitor at designated intervals		G	G	G	G	G	G	G	G	G	G	
subtask 1.3	*sediment tracking*												
	collect rocks	G											
	embed magnets/paint/number			G									
	return rocks				G								
	monitor at designated intervals					G	G	G	G	G	G	G	
subtask 1.4	*habitat creation assessment*												
	map created habitat	B			B				B				B
subtask 1.5	*sediment transport modeling*												
	program ACRONYM model for sites			G									
	test flow regimes in model			G									
	program/use diffusion-based model							G					
subtask 1.6	*hypothesis testing*												
	1997-2004 geo-bio cross-analysis		GB										
	1997-2008 geo-bio cross-analysis										GB	GB	
	comparison of 3 reach types											G	G
Task 2	**Geomorphic-unit monitoring**												
subtask 2.1	*site volumetric changes*												
	annual site topo surveys				GB				GB				GB
	DEM generation		G				G				G		
	DEM differencing		G				G				G		
subtask 2.2	*1D vs 2D model comparisons*												
	program ACRONYM model for sites			G				G				G	
	program 2D model for sites			G				G				G	
subtask 2.3	*site-scale sediment budgets*					G				G			G
Task 3	**Hydraulic-unit monitoring**												
subtask 3.1	*2D model testing (pred. vs obs.)*			B				B				B	
subtask 3.2	*habitat heterogeneity*												
	export all 2D model data to ArcGIS	I	I							I			
	Arc spatial data processing			I							I		
	hierarchical cluster analysis				I							I	
	objective hydr-unit habitat het. map				I							I	
subtask 3.3	*spawner util. of habitat het.*						B						B
subtask 3.4	*macroinvert. util. of habitat het.*						B						B
	biweekly macroinvert. sampling	B			B	B			B	B			B
	macroinvert. lab analysis		B				B				B		
	macroinvert. data analysis			B				B				B	B
subtask 3.5	*juv. salmonid util. of habitat het.*												
	biweekly snorkel surveys		B	B			B	B			B	B	
	juv. salmond data analysis			B				B				B	B
subtask 3.6	*Discrete roughness elements*												
	feature-based 10 pt/m2 topo. survey				GB				GB				GB
	feature depth, velocity measurements	B				B				B			
	DEM differencing						G				G		
	2D model prediction testing						B				B		B
Task 4	**Project management**												
	science/management coordination	C	C	C	C	C	C	C	C	C	C	C	C
	budget management	$	$	$	$	$	$	$	$	$	$	$	$
	Data handling/processing	I	I	I	I	I	I	I	I	I	I	I	I
	overall management & outreach	P	P	P	P	P	P	P	P	P	P	P	P

*Letters correspond to the person responsible for each subtask (G=geomorphologist,B=biologist,I=GIS specialist,C=administrator,$=financial analyst,P-principal investigator) intervening pool up to the floodplain surface (by RTK GPS), and a characterization of the length, slope, and bed composition of the gravel-sand transitional zone (Knighton, 1999). Surfacial bed material will be characterized using Wolman pebble counts, while bulk samples of subsurface material will be analyzed by sieving (Bunte and Abt, 2001). At-a-station and downstream hydraulic geometry analyses will be performed using these data to obtain power-function parameters for relations between discharge and width, depth, and velocity (Leopold and Maddock, 1953; Wheaton and Pasternack 2002). Also, non-dimensional variables (slope, Shield stress, depth to grain size ratio, width to depth ratio, and channel width to connected floodplain width ratio) indicative of geomorphic controls on channel types will be calculated. These physical variables will be statistically analyzed along with EBMUD's fish community database using Principal Components Analysis to provide an explanation for the longitudinal distribution of fish and habitat types, which will help explain the amount of rehabilitation needed to yield a significant improvement to community size and structure.

Subtask 1.2- Sediment export rates

Monitoring sediment outfluxes will involve placing 2 kinds of bedload traps at each site's riffle tail. The 2 types include rectangular net traps with 6 mm openings fixed to the bed (Bunte, 2001) and half-cut 55-gallon drums buried flush with the bed surface (Hicks and Gomez, 2003). In a 1-month test of 3 net traps on the LMR, no fish were trapped. At each site's riffle tail, a drum (aka pit) trap will be placed in the thalweg with two net traps placed adjacent along the cross-section. Also, one net trap will be placed downstream in the thalweg at the pool tail to evaluate pool passage. These traps will be checked monthly, daily, or on an event basis, depending on whether the sediment transport regime is intermittent ($\tau^* < 0.03$), partial ($0.03 < \tau^* < 0.06$), or full ($\tau^* > 0.06$), respectively, where τ^* is the nondimensional Shields stress. No Camanche flow release has yielded full mobility since 1997. While large uncertainties exist in estimating transport rates when measuring over minutes, they are greatly reduced for daily and monthly measurements (Paintal, 1971). Weighed and measured sediment will be returned to the channel downstream of the trap from which it was obtained.

Subtask 1.3- Sediment tracking

Fate of exported sediment downstream of each study area will be tracked using 900 magnetic tracer rocks (300 per site). Rocks collected from each site will be taken to the lab, measured for density, sieve size, and axis lengths, painted a florescent color, numbered in black, drilled with a diamond-tip bit, and embedded with a high-strength magnet sealed with epoxy (Hassan and Ergenzinger, 2003). Rocks will then be returned to their sites and placed on a staggered grid using RTK GPS. For placement, a similar rock will be removed and the tracer put in its place to yield a natural starting condition. RTK GPS will be used to revisit site grids monthly (or after any event) and check for movement. If particles are missing from their original location, they will be searched for visually and with the aid of a magnetic locator (~90% recovery rate). Once located, each particle's new position will be surveyed with RTK GPS.

Subtask 1.4- Habitat creation assessment

On the LMR, gravel that is newly imported to a riffle (or re-distributed internally) is identifiable by its lack of biofilm, aquatic vegetation, and/or embedded fine sediment. The presence of tracers from upstream or cross-sectional changes to the riffle crest would also identify such features in this study. All of these indicators will be GPS'd at each downstream riffle each summer and after a high flow release . Visual indicators of fish utilization as well as physical habitat suitability metrics (GPS location, depth, substrate quality, and velocity) will be observed on any self-created sediment deposit.

Subtask 1.5- Sediment transport modeling

The ACRONYM series of gravel transport models will be used to estimate bedload transport rates for each riffle and pool cross-section in the 3 sites under different flow regimes (Parker, 1990a). This model uses the bedload transport relation of Parker (1990b), which is suitable because the test sites have gravel and cobbles with little fine sediment, so a two-fraction model is unnecessary (Wilcock and Kenworthy, 2002). Bed material metrics, channel data and hydrographs obtained during the first reconnaissance will be used to prepare the model. Camanche Dam historical flow data will be analyzed to obtain representative hydrographs for intermittent, partial, and full transport regimes pre- and post- dam conditions. Also, hydrographs for events during the study period will be obtained. All hydrographs will be used in the model to estimate bedload transport rates. Predicted rates for actual events during the study will be compared against observed rates to test the model. Sediment transport rates for riffles will be compared against each other and against those for downstream pools.

In a recent flume test, an analytical diffusion-based sediment-dispersal model (Pasternack et al., 2001) outperformed a computational sediment-dispersal model (Cui and Wilcox, 2004) for the case of dispersal in a uniform-width flume after a simulated dam removal releasing different bed mixtures (Wooster, 2003). Because the LMR has a low and uniform width, the model of Pasternack et al. (2001) is highly suitable for estimating the bulk sediment dispersal distance and sediment mass fluxes over longer time periods. To run this simple model, all that is needed is channel geometry data and an estimate of the sediment dispersal parameter, which can be obtained from previous studies or estimated using preliminary sediment transport observations or longitudinal profile re-surveys. This model will be used to compare the long-term fates of the 3 different riffle types and to evaluate the fates of different gravel volume additions.

Subtask 1.6- Hypothesis testing and performance assessment

Four monitoring and two modeling datasets obtained in subtasks 1.1-1.5 will be used to test the effectiveness of 3 riffle types in generating reach-scale sediment dispersal and relate the LMR fish community to geomorphic controls. Key metrics include relative sediment export mass fluxes, final resting place of tracer rocks, and relative amounts of usable downstream habitat. Variables explaining site differences, (e.g. slope, τ^*, width/depth ratio) will be tested using Principal Components Analysis to explain observed differences. To supplement the monitoring, a bedload transport model will be used to test the 3 riffle types for their response to observed and future potential hydrographs. In addition, a sediment dispersal model will be used to predict the long-term fate of sediment additions. ***The primary performance question at the reach-scale is whether LMR gravel augmentation has re-initiated a conveyor belt of coarse sediment transport. Bedload transport and habitat creation at downstream geomorphic units will serve as the performance measure to assess rehabilitation outcome***. The modeling subtask is important because it will provide guidance on adaptive management strategies in case negligible sediment dispersal is observed over the 3-year study. Empirical statistics and process-based modeling results will be combined to estimate future sediment-supplementation volumes needed to achieve reach-scale improvements.

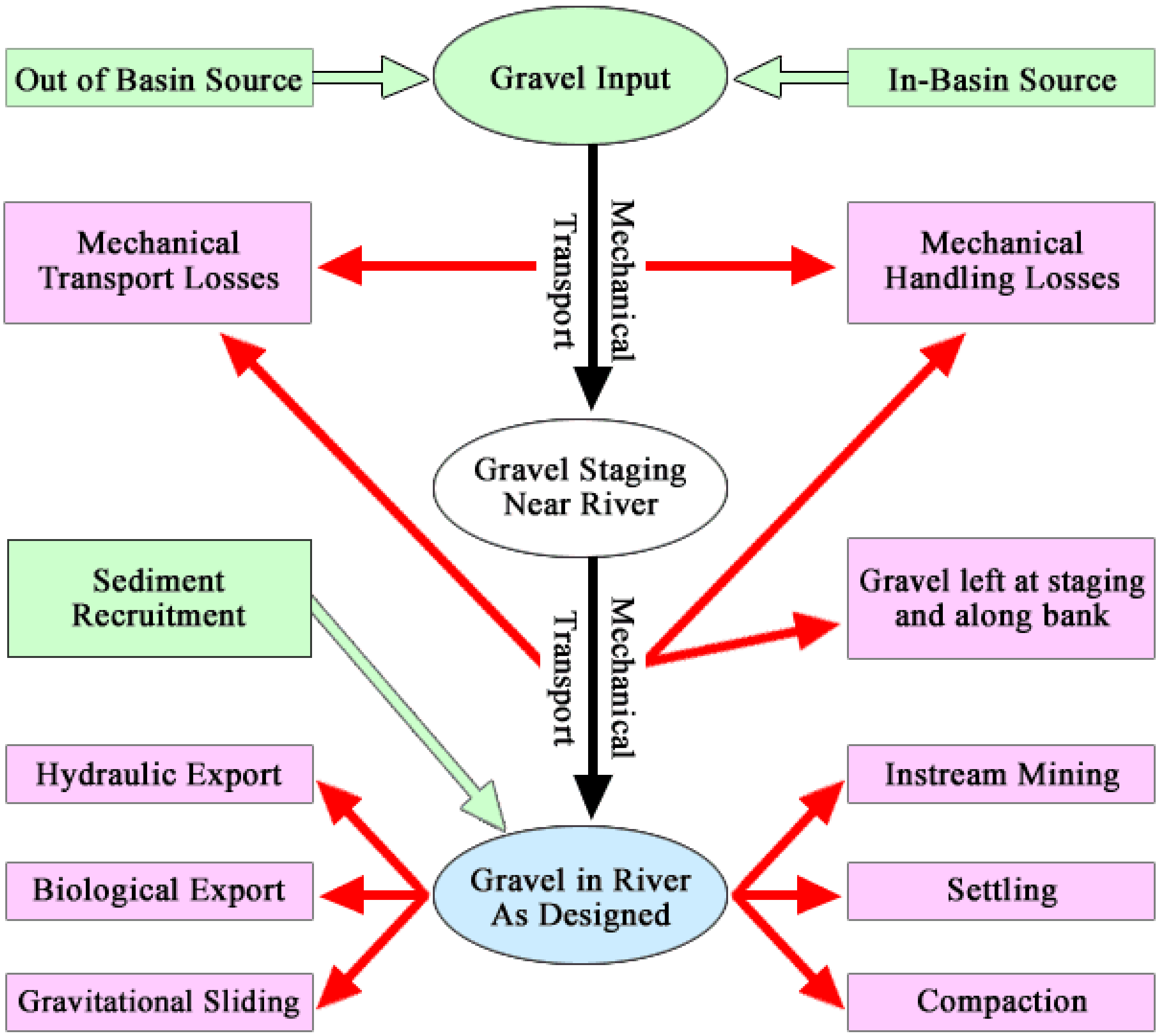


Figure 15. Site-scale sediment budget in use for tracking causes of volumetric change at each rehabilitation site. Fate of exported material will be studied separately in task using reach-scale tools.

Task 2- Geomorphic-unit monitoring and analysis

The goal of LMR monitoring at the geomorphic-unit scale is to ascertain the natural self-adjustments to a constructed riffle-pool unit over time to determine how long rehabilitated functionality persists and which gravel fill patterns worked best. The locations where this monitoring will occur are the 2000 baseline site as well as the 2001-2004 SHIRA sites. ***The primary monitoring tool proposed to track site changes is a site-scale volumetric sediment budget*** (Fig. 15). Preliminary budgets for all sites have been initiated and require tracking.

Subtask 2.1- Site volumetric changes

The overall volumetric change of each site will be monitored and analyzed by direct topographic surveying, DEM generation, and DEM differencing. Brasington *et al.* (2000) determined that a resolution of ~1 pt/m^2 is necessary to capture the key bed variations found in gravel-bed streams and to enable DEM differencing. Topographic surveying of each site with an RTK GPS system (X,Y,Z accuracies ~1-cm) will involve 5 steps: 1) siting a RTK GPS base station at one of our local benchmarks (CA State Plane coordinates), 2) wading into the channel in a dry suit with a rover RTK GPS to measure bed positions on a staggered grid with a sampling density of ~1 pt/m^2, 3) surveying and noting key breaklines (bank toes, boulders, slope breaks), 4) performing supplemental surveying of boulders, redds, and other features with a higher point density of ~10 pts/m^2, and 5) surveying unwadable pools by lowering the pole from a small rubber raft held in position by a rope system. Site surveying will be repeated annually as well as before and after any planned flow release expected to achieve t*>0.06.

Topographic data will be imported into Autodesk Civil 3D to create a DEM of each site for volumetric change assessment and for 2D modeling. French and Clifford (2000) describe 4 iterative stages of DEM development: interpolation, visualization, editing, and augmentation. First, survey data will be interpolated and a surface defined respecting breaklines. Linear Delaunay triangulation will be used for this, as data are non-uniformly distributed, boundaries are well delineated, and facet vertices honor survey data exactly. Next, the surface will be visualized as a map and edited to remove obvious interpolation errors. The revised surface will be visually verified in the field to check for poorly represented areas in the DEM. Further iteration will be done as needed. Once annual site surfaces are finalized, they will be inter-compared using DEM differencing to illustrate the spatial pattern of elevation change. ***Special attention will be paid to assessing whether riffle-pool relief is persistent or if geomorphic units tend toward a uniform depth (hypothesis 2a, part 1).*** DEM difference patterns will be compared to patterns of slope stability predicted using Autodesk Civil 3D and patterns of τ^* predicted with the 2D models. Volumetric changes between sites will be compared and related to hydrogeomorphic controls. ***Persistence or lack thereof will be used as a performance measure of the cost-benefit trade-off for creating complex topographic relief***.

Subtask 2.2- Model comparisons

Given a site DEM, a pre-established rating curve for the downstream boundary, and parameter estimates from past studies at each site, a 2D model of hydrodynamics, sediment scour potential, and Chinook salmon spawning habitat quality for each site for each year will be run for that year's spawning flow and the highest observed discharge for that year. SHIRA's modeling mode will be used to develop and run all models using standardized protocols that have been well validated (Pasternack et al., 2004; Wheaton et al., 2004a,b). Spawning flow habitat quality predictions will be compared against EBMUD's GPS survey of redd locations and used in other

subtasks. High-flow τ^* and scour predictions as a function of grain size will be used to assess hydraulic mechanisms and patterns of scour at sites and as described for other subtasks.
To further evaluate hydraulic mechanisms responsible for local adjustments, comparisons will be made between ACRONYM's annual bedload transport estimates for riffle and pool cross-sections and the 2D model's annual spatial sediment scour predictions. Cross-sections will be extracted from site DEMs for use with ACRONYM. ***Each approach provides different sets of metrics, but these sets can be tested against the observed site changes to see which is more useful at explaining them (hypothesis 2a, part 2)***. A key test is whether the spatial pattern in sediment mobility predicted by the 2D model matches with observed volumetric changes in DEMs. Also, fluid particle tracks predicted with the 2D model will be compared against observed on-site tracer-rock tracks from subtask 1.3 (for sites used in task 1).

Subtask 2.3- Site sediment budgets

Sediment budgets are used to explain and track causes of geomorphic change (Reid and Dunne, 2003). To quantify each site's sediment budget, an estimate of each budget term (Fig. 15) will be independently estimated annually and the net change compared to the measured net volumetric change. Methods for estimating each term have recently been tested using 5-years of data from the LMR 1999 baseline site (Merz, 2004). All terms associated with gravel placement and as-built conditions have been determined for all study sites, but post-project changes need tracking. Sediment recruitment will be estimated using one bedload net trap placed in the thalweg at each riffle entrance (same monitoring protocol as for subtask 1.2) and by analysis of DEM differencing volumetric surpluses. Hydraulic export will be estimated using 3 methods: ACRONYM model estimates of bedload export, DEM differencing volumetric losses aligned with 2D model predictions of spatial scour patterns, and observed export of tracer rocks monitored in subtask 1.3 (for sites used in task 1). Compaction will be estimated by making annual freeze-core measurements of sediment bulk density (Bunte and Abt, 2001) at 5 locations per site and comparing to the initial bulk density. Gravitational sliding export will be assessed using submerged slope stability analysis and by evaluating tracer tracks from subtask 1.3 relative to slope directions (for sites used in task 1). Biologically induced export may occur during redd construction and will be estimated by observing any redds near the downstream boundary at the end of the spawning season and measuring the tail spill pushed beyond the riffle tail. Settling of the pre-project bed beneath the placed gravel will be measured by digging down to that surface, as identified by its poor substrate quality, at 5 locations with different amounts of fill per site, surveying the elevation with RTK GPS, and comparing to the previous elevation of that location. All terms will be summed annually and the net volumetric change compared to the measured annual DEM difference. ***Settling+compaction will be compared against net hydraulic export to determine relative significance (hypothesis 2b)***. This will help CALFED assess resource allocation for studies of site settling/compaction versus those regarding sediment transport.

Task 3- Hydraulic-unit monitoring and analysis

The goal of hydraulic-unit monitoring is to tackle the large uncertainty regarding aquatic organism response to spatial dynamics and habitat heterogeneity. When placing gravels, managers may create diverse features, but there is no consensus on feature types and spatial patterns. Part of the problem stems from large variation in subjective classification and assessment of habitat types (Roper and Scarnecchia, 1995). Current objective 2D habitat-quality prediction schemes assume that aquatic organisms experience each point independently and don't use their memory and senses to assess spatial patterns (e.g. shear zone, eddies, and homogeneous patches). Task 3 will develop spatially dependent habitat evaluation metrics and test them on the different constructed hydraulic-units on the LMR. ***Spatial analysis of abiotc and biotic data will serve as a performance measure of the usage of complex topographic features in gravel placement on the LMR*** and to provide future design guidance to CALFED.

Subtask 3.1- Continued 2D model testing

2D models generated in subtask 2.2 will continue to be compared against EBMUD's redd surveys to test habitat quality predictions. ***Numbers of redds located in each type of predicted habitat quality will be compared directly and with adjustment to relative availability of each habitat quality (hypothesis 3a)***. Temporal trends in spawner utilization will be analyzed relative to observed changes in hydraulic-unit structure.

Subtask 3.2- Habitat heterogeneity mapping

To characterize the spatial patterns that hydraulic-unit features exhibit at rehabilitation sites, model predictions will be imported to ArcGIS where spatial gradients, curvatures, and autocorrelation functions for depth, velocity, shear stress, and habitat quality variables will be computed. These variables will be used to locate/characterize physical habitat heterogeneity features. Then all variables from all sites will be used in a hierarchical cluster analysis (e.g. Pasternack et al., 2000) to obtain a classification of spatial hydraulic patterns and associated habitat types. Next, each point at a site will be assigned to its class to yield a hydraulic-unit habitat map. This objective habitat map will be compared to an independent map obtained at the same hydraulic-unit scale using the expert-based approach of Thomson et al., (2001).

Subtask 3.3- Spawner utilization of habitat heterogeneity

To test whether spawners respond to hydraulic-scale spatial patterns at rehabilitation sites, redd locations (GPS'd by EBMUD) from each site will be overlaid on the corresponding hydraulic-unit habitat heterogeneity map in ArcGIS. The distribution of abundance of redds across feature types will be computed as a statistical test of niche exclusiveness. ***The overall biological density of utilization of each habitat type (#redds/unit area) will be computed as a metric of each habitat type's spawning value, which will test the disproportionate role of any habitat heterogeneity feature (hypothesis 3c)***.

Subtask 3.4- Benthic macroinvertebrates

Because many benthic macroinvertebrates have limited migration patterns or a sessile mode of life, their assemblages are good indicators of localized conditions and short-term environmental variations (Barbour et al., 1999). Further, macroinvertebrate assemblages are made up of species that constitute a broad range of trophic levels and pollution tolerances, thus indicating cumulative effects. ***To test the hypothesis that benthic macroinvertebrates (e.g. feeding groups, family classification, and common species) respond to hydraulic-scale spatial patterns at rehabilitation sites, macroinvertebrate abundance near complex hydraulic features will be surveyed and resulting metrics will be put through the same data analysis as described for redd data (hypothesis 2d)***. In addition, EBMUD's macroinvertebrate abundance and physical-habitat metrics database will be combined with the new data to test the potential for generating habitat suitability curves. Such curves will be applied to 2D model output to yield predictions of the spatial distribution of the macroinvertebrate community, which can be tested against the observed spatial patterns. These analyses will test the untapped potential of using benthic macroinvertebrates as indicators of hydrodynamic-ecologic linkages at the 0.1-1 m scale.

Macroinvertebrates will be sampled biweekly July-December each year at each site. Samples from habitat heterogeneity features will be taken using a stratified random scheme, with strata being boulders, LWD, channel margins, and velocity shear zones. Each site has 8-12 boulders and 3-5 pieces of LWD, so biweekly random points will not repeat too frequently to impact local assemblage. Collections will be made with a 34-cm dia. Hess sampler in depths <60 cm or else with a 1-m kicknet ((Merz and Ochikubo Chan, 2004; Hauer and Resh, 1996). Samples will be washed through a net and placed in 250-ml bottles along with 80% ethyl alcohol for preservation. Taxonomic ID to the family or lowest practical level, life stage separation, and size classification will be performed after sorting. Dry biomass will be determined by oven drying a subsample of 20-50 organisms of a particular taxon at 70° C for 24h to constant weight, weighing subsamples, and adjusting the weight to reflect the total number of organisms in the sample. Richness, composition, tolerance, feeding, and habit metrics will be calculated (Barbour et al., 1999), assessed, and used in the spatial analyses described earlier.

Subtask 3.5- Juvenile salmonids

Juvenile salmonids require shallow water habitat free of vegetation and fines for feeding and rearing (Zimmerman, and Rasmussen, 1981; Power, 2003). The population of juvenile salmonids using LMR rehabilitated sites and their microhabitat preferences for constructed features are unknown, so the purpose of this subtask is to observe and compare the fish assemblage and features of project sites with those of unenhanced sites already sampled by EBMUD. Using the habitat maps generated in subtask 3.2 and snorkel surveying, estimates of the habitat type-specific densities of juvenile salmonids will be made biweekly at each hydraulic unit at all rehabilitation sites January-June (or when flows are safe for snorkeling). Two people will snorkel each sample area working upstream, each observing an equal portion of the hydraulic unit's width using standardized underwater observation techniques (Thurow, 1994). Species and size of fish will be recorded on underwater slates. Markers will be placed where fish are first observed. After snorkeling, the crew will measure depths, substrates, and velocities as well as distance from bank, type of cover and water temperature for each marker. Depths, velocities, and other metrics will also be obtained from 2D models. To evaluate snorkel survey quality and test the potential for rapid population assessment (e.g. Jones and Stockwell, 1995), backpack electrofishing into a block net may be performed with EBMUD. ***To test the hypothesis that juvenile salmonids respond to hydraulic-scale habitat heterogeneity patterns at rehabilitation sites, the spatial pattern in juvenile abundance will be put through the same data analysis as described for redd and benthic macroinvertebrate data (hypothesis 2e)***.

Subtask 3.6- Discrete roughness element functionality

Boulders, LWD, and gravel bars built at LMR rehabilitation sites (~10-15 per site) serve as discrete roughness elements whose dynamics are poorly understood. The topography of all such elements will be surveyed with RTK GPS using a point density of ~10 pts/m^2 and with breaklines as needed (Valle and Pasternack, submitted). ***DEM differencing will directly reveal whether more sediment accumulates in the lee of such elements than is lost by the scour they induce (hypothesis 3f, part 1)***. Annual trends in DEM differencing will quantify persistence of roughness elements. Although all nuances of such features cannot be captured in a 2D model, a nodal density of 9 pts per /m^2 is commonly achieved in LMR models. The models will be used predict convective accelerations around elements. Vertical velocity profiles will be collected and used to assess and improve model functionality around these elements. Also, ***2D model scour predictions will be tested against DEM differences (hypothesis 3f, part 2)***.

Task 4- Project Management

The PI will be responsible for all aspects of project management. An administrative coordinator and a financial analyst will provide support to meet CALFED's expected budget and project oversight requirements. The coordinator will also act as an administrative liaison between UC Davis and EBMUD as well as between UC Davis and CALFED. A computer programmer with training in ArcGIS, AutoDesk Civil 3D, and 2D modeling will aid researchers with data processing, handling, and storage on the SHIRA central server. That person will also maintain the SHIRA website and make information available as quickly as possible. These primary participants will hire and work with UC Davis undergraduate students who will help with all areas of data collection, analysis, and project logistics.

5. Feasibility

No one monitoring project can assess all remaining uncertainties across all relevant disciplines. This proposal identifies key management goals and scientific questions regarding abiotic-biologic linkages to be assessed by testing 3 sets of scale-dependent hypothesis with 3 years of post-project monitoring. Under an agreement between EBMUD and UC Davis, EBMUD has built 4 projects (with 1 more in 2005) according to specifications generated in the CALFED-sponsored SHIRA design-development project. EBMUD and UC Davis have collaborated in all phases of these efforts. In addition, EBMUD has an extensive database of LMR data that they have been sharing with UC Davis. Our collaboration will continue through this project. As in the past, field work will be coordinated with EBMUD, CDFG, and CALFED.

The PI has worked intensively on the LMR for 5 years. Proposed field methods have been tested and can be implemented in the allotted time regardless of weather. Access to field sites is obtained via the Mokelumne River Day Use Area, which is open to the public daily. The PI has access to drive on gated roads to bring supplies/equipment as close to sites as possible. The CDFG staff at the fish hatchery and patrolling the area are aware of our activities and are supportive of our efforts. No third parties will be impacted by our activities.

The primary constraint on the project is the essential need for purchase of an RTK GPS system, because the three major monitoring components (high-resolution topographic surveying, sediment tracer tracking, and biological community surveys) and 2D modeling all require it. Previously EBMUD donated surveyors for our work, but the large amount of surveying needed now is beyond their ability to provide. The PI has all other required facilities and equipment at UC Davis. The PI has experience using all of the major modeling components (DEM generation, 2D process modeling, ACRONYM bedload transport modeling, and diffusion-based sediment dispersal modeling). Statistical, process-based, and GIS-based analyses have already been utilized by the PI for LMR studies and are appropriate for the proposed hypothesis testing. A postdoctoral scholar in aquatic ecology will add disciplinary breadth to the effort.

6. Expected Products/Outcomes

Table 2 enumerates all project tasks and subtasks, key performance metrics, and the project personnel responsible for achieving each subtask. Table 3 lists project deliverables. In addition, quarterly reports, conference presentations at CALFED, American Geophysical Union,

Table 3. Major project deliverables.

Task	Anticipated Deliverables	Time
Task 1. Reach-scale monitoring and analysis	Report: Effectiveness of 3 riffle types in generating reach-scale sediment dispersal and creating downstream habitat.	36 months
	Report: Non-dimensional geomorphic controls on the LMR fish community.	24 months
Task 2. Geomorphic-unit monitoring and analysis	Report: Natural self-adjustment and topographic persistence of constructed riffle-pool units	36 months
	Report: Utility of 2D models in predicting persistence of riffle-pool units	36 months
	Report: Relative roles of settling, compaction, landsliding, and bedload transport in changing constructed geomorphic units.	36 months
Task 3. Hydraulic-unit monitoring and analysis	Report: Predictability of redd locations using 2D models and standard habitat suitability curves	12 months
	Report: Objective analysis of the spatial patterns and gradients of rehabilitated hydraulic units.	24 months
	Report: Relative importance of habitat heterogeneity versus habitat abundance for salmon spawning	24 months
	Report: Benthic macroinvertebrate utilization of spatially dependent habitat heterogeneity features	36 months
	Report: Juvenile salmonid utilization of spatially dependent habitat heterogeneity features	36 months
	Report: Deposition and scour of coarse sediment around discrete roughness elements constructed at rehabilitation sites	24 months
Task 4. Project management	Quarterly reports	36 months
	Invoices	36 months
	Database: ArcGIS spatial database of all monitoring and modeling datasets	36 months
	Website: further development of the SHIRA website at http://shira.lawr/ucdavis.edu to include all findings, reports, and general rehabilitation lessons	36 months

and American Fisheries Society meetings, and peer-reviewed journal articles will be produced. So far we have produced 2 MS theses, 1 PhD thesis, 2 technical reports, and 7 peer-reviewed journal articles (4 more in prep) based on our LMR research. In addition, many college students have been educated in field, laboratory, and modeling methods. The SHIRA website (http://shira.lawr.ucdavis.edu) serves as the primary public outlet of all of SHIRA-based research and will be updated quarterly. Upon completion of peer-review of the results of a subtask, the new information will be added to the SHIRA website in a highly understandable, graphical form.

7. Data Handling and Storage

The proposed project will generate/integrate large amounts of new and historical field data, data analyses, and computer simulations. Field data will be stored by EBMUD and UC Davis. Currently there are 25,630 files (28.2 GB) stored on a UC Davis server with quarterly back-up. Because many analyses require specific software, one dataset will be stored in native format and a second will be exported to ArcGIS format for long-term comparisons. Included in the database work will be engineering drafting and plotting, GIS analysis, data management, and web serving. Reports and appropriate data will be made available through the SHIRA website. A new server will be obtained in the final year to replace the existing server when it is retired.

8. Public Involvement and Outreach

Public outreach will be performed for scientific and regulatory communities, college students, and the public-at-large. Scientific presentations will be made at American Geophysical Union, American Fisheries Society, and CALFED conferences. Invited lectures will continue to be given to universities (~ 3/yr). The PI will participate in CALFED-sponsored workshops related to river rehabilitation. Students taking Field Methods in Hydrology (HYD151) at UC Davis will go on a Saturday field trip annually to the LMR to practice collecting stream measurements. The primary outreach tool for the public-at-large is the SHIRA website, which includes an educational streaming video and detailed documentation. Through the on-going efforts of the UC-Davis Cosumnes Research Group the PI has routinely collaborated with local planning groups and state, federal and private agencies active in the Cosumnes-Mokelumne region. This includes participating in discussions with the Mokelumne/Cosumnes Watershed Alliance, the Cosumnes River Task Force, and the CALFED North Delta Improvements Group. We are partnering on restoration activities with EBMUD, CA DWR, USFWS, USBR, and the Nature Conservancy's Cosumnes and Delta Project. These partnerships and collaborations not only assure coordination; they also serve as a means to share expertise and transmit the results of University research to local restoration managers and practitioners.

9. Work Schedule

Table 2 presents the work schedule by subtask. Table 3 presents key deliverable dates. All tasks require persistent monitoring over years. It is expected that some reach-scale and geomorphic-unit dynamics will be observable during the study while others would require longer term monitoring. Hydraulic-unit dynamics should be fully apparent within 3 years.

B. Applicability to CALFED ERP Goals, Implement Plan, CVPIA Priorities

1. ERP and CVPIA Priorities

Priorities 1, 2, and 3 of the draft Stage 1 plan for the San Joaquin region in which the LMR is located call for continued habitat restoration (with special emphasis on gravel augmentation projects), restoration of geomorphic processes in streams, and improved salmonid spawning habitat. This project follows-up on exactly these priorities by using hypothesis testing within an integrated monitoring-modeling-data analysis framework to evaluate the linkages between hydrogeomorphic processes and biological communities over 3 scales at gravel-augmentation sites designed to rehabilitate spawning habitat and restore geomorphic processes. Usage of annual high-resolution mapping and 2D modeling enables a detailed spatial analysis of temporal changes to rehabilitation sites. Priority 6 calls for adaptive management experiments with regard to modified flow regimes, with special consideration for mechanistic models as restoration tools and for instream flow programs. The SHIRA framework has gone through 5 cycles of adaptive management. LMR river rehabilitation has been changed from isolated augmentations to linked augmentations promoting slope-creation through adaptive management. The proposed study will utilize 3 mechanistic models to aid future management planning.

2. Relationship to Other Ecosystem Restoration Projects

This project follows up on 5 years of rehabilitation design development and monitoring work on the LMR performed jointly by EBMUD and UC Davis with matching funds from CALFED and CVPIA. A key factor for consideration is that this project has been integrated with a SHIRA project funded by USBR on the Trinity River and one funded by USFWS on the Yuba River to provide a comprehensive test of SHIRA across widely differing regulated rivers. ***There would be a strong synergistic effect produced by continued cross-comparison***. The primary system-wide benefit of the proposed project is that it will further test and improve SHIRA, which has been demonstrated to be suitable for all streams in the Central Valley, which would be highly useful for CALFED's ERP. The design approach is universal in nature due to its incorporation of a mechanistic model based on the fundamental laws of physics. Where local data are required, specific empirical equations developed for the LMR could easily be replaced with similar equations from other Central Valley streams. Much of that data already exists.

C. Qualifications

The PI for the proposed project will be Dr. Gregory Pasternack, an Associate Professor of Watershed Hydrology at UC Davis. Professor Pasternack has considerable experience as a fluvial geomorphologist and sediment transport expert. In the last 6 years he has performed sediment transport experiments and computer models on the Mokelumne, Trinity, and Yuba Rivers, and thus has extensive local knowledge relating to the proposed project site. He is also an associate editor for the journal Water Resources Research.

In terms of ecology and biology, Pasternack trained under an ecologist for his Ph.D. (Dr. Grace Brush) and has published scientific articles on wetland ecology and biogeomorphology. In addition he has taught a course “Hydrological Processes in Ecosystems” (HYD143) since 1999 in which he explains hydrology-ecology linkages to students. For the last 5 years, he has worked with fisheries biologists at UC Davis and at EBMUD. In 2002 he participated in the American Fisheries Society conference and gave an invited presentation on salmon spawning habitat research there.

The PI will hire a postdoctoral scholar with a Ph.D. in aquatic ecology as well as a specialist with training in geomorphology to work with him on the project and to add depth and breadth. In addition, project participants will collaborate with EBMUD fisheries biologists and hydrographers for additional breadth. Undergraduates will be hired to aid project participants in field data collection, data analysis, and computer modeling. To assist with project management an administrative coordinator and a budget analyst will be available. These staff have already been involved in existing CALFED-sponsored projects for UC Davis faculty, including the PI. Jess Phalen is the UC Davis Office of Research official responsible for this contract. Kim Lamar is a UC Daviss Office of Research official with the authority to sign the proposal’s signature page prior to submission.

Key links in the organizational structure of the project are the UCD-EBMUD link, which is commonly between the PI and Joe Merz, and the UCD-CALFED link, which is commonly between the PI and the assigned CALFED oversight staff. The postdoctoral scholar and geomorphology specialist will coordinate field work directly with Joe Merz of EBMUD. Past graduate students who have worked with the PI on studying the LMR for their MS degrees will serve as outside contacts and collaborators on aspects of the research related to their previous activities.

A detailed CV for the PI follows:

EDUCATION
Ph.D., Environmental Engineering, The Johns Hopkins University, Baltimore, MD, 1998
M.S., Env. Water Resources Engineering, University of California, Berkeley, CA, 1994
B.A., Earth Science; Science in Society, Wesleyan University, Middletown, CT, 1993.

PROFESSIONAL EXPERIENCE
Associate Professor, Land, Air, Water Resources, University of California, Davis (2002-)
Assistant Professor, Land, Air, Water Resources, University of California, Davis (1998-2002)
Geomorphologist subcontractor, TRC Garrow Associates, Inc., Chapel Hill, NC (1997-1998)

PUBLICATIONS IN REFEREED JOURNALS

29. Pasternack, G. B. submitted. Wind induced sediment resuspension on a Chesapeake Bay subestuarine delta and its management implications. Estuaries.
28. Pasternack, G. B. and Brown, K. J. submitted. Natural and anthropogenic geochemical signatures of floodplain and deltaic sedimentary strata, Sacramento Delta, CA. Environmental Pollution.
27. Brown, K. J. and Pasternack, G. B. submitted. A paleoenvironmental reconstruction to aid in the restoration of floodplain and wetland habitat on an upper deltaic plain, California, USA. Environmental Conservation.
26. Valle, B. L. and Pasternack, G. B. submitted. Meso-scale bed and flow spatial heterogeneity for two hydraulic jump regions in a step-pool mountain channel. Geomorphology.
25. Valle, B. L. and Pasternack, G. B. submitted. Spatial heterogeneity of surface air concentration for two hydraulic jump regions in a step-pool mountain channel. Journal of Geophysical Reseearch- Earth Surface.
24. Valle, B. L. and Pasternack, G. B. submitted. Field mapping and digital elevation models of two hydraulic jump regions in a step-pool mountain channel. Earth Surface Processes and Landforms.
23. Pasternack, G.B., Ellis, C. Leier, K.A., Valle, B.L., Marr, J.D. in press. Convergent hydraulics at horseshoe steps in bedrock rivers. Geomorphology.
22. Constantine, J. C., Pasternack, G. B., and Johnson, M. B. in press. Logging effects on sediment flux observed in a pollen-based record of overbank deposition. Earth Surface Processes and Landforms.
21. Merz, J. E., Setka, J., Pasternack, G. B., Wheaton, J. M. in press. Predicting benefits of spawning habitat rehabilitation to salmonid fry production in a regulated California river. Canadian Journal of Fisheries and Aquatic Science.
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16. Pasternack, G. B. and Hinnov, L. A. 2003. Hydro meteorological controls on water level in the upper reaches of a Chesapeake Bay tidal freshwater tributary. Estuarine, Coastal, and Shelf Science 58:2:373-393.
15. Constantine, J. C., Pasternack, G. B., and Johnson, M. B. 2003. Floodplain evolution in a small, tectonically active basin of northern California. Earth Surface Processes and Landforms 28:869-888.
14. Pasternack, G. B. and G. S. Brush. 2002. Biogeomorphic controls on sedimentation and substrate on a vegetated tidal freshwater delta in upper Chesapeake Bay. Geomorphology 43:293-311.
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the South Fork of the American River, CA. Geomorphology 42:153-165.
12. Pasternack, G. B. 2001. Animal Response to River Evolution in the Tidal Freshwater Zone. In (J. M. Dorava, D. R. Montgomery, B. B. Palcsak, and F. A. Fitzpatrick, Eds) Geomorphic Processes and Riverine Habitat. American Geophysical Union, Water Science and Application Volume 4, p. 139-157.
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9. Pasternack, G. B. 2001. Reply to "Comment on 'Does the river run wild? Assessing chaos in hydrological systems' by G. B. Pasternack". Advances in Water Resources 24:5:578-580.
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2. Wheaton, J. M., Pasternack, G. B. and Merz, J. E. 2004. Use of habitat heterogeneity in salmonid spawning habitat rehabilitation design. in Fifth International Symposium on Ecohydraulics: Aquatic Habitats: Anlalysis and Restoration, IAHR-AIRH: Madrid, Spain. p. 791-796.
1. Yick, J., Bharathidasan, A., Pasternack, G. B., Mukherjee, B, and Ghosal, D. 2004. Optimizing Placement of Beacons and Data Loggers in a Sensor Network – A Case Study. IEEE Wireless Communications and Networking Conference 2004.

NON-REFEREED REPORTS, PROCEEDINGS, AND ARTICLES

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7. Pasternack, G. B. 1997. How scientists use mud to understand the Chesapeake Bay. Otter Point Creek National Estuarine Research Reserve Newsletter, p. 1-2.
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3. Pasternack, G. B. 1994. Foundations of urban river management. Master's project.

University of California, Berkeley, 75 pp, 3 appendices.
2. Varekamp, J. C. and Pasternack, G. B. 1994. Crater lakes in eastern Indonesia. Newsletter of the IAVCEI Commission on Volcanic Lakes 7:19.
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ABSTRACTS (45 total, but not listed)

E. Compliance with Standard Terms and Conditions

University of California, Davis takes exception to the following proposed "standard" clauses:

Exhibit A – Scope of Work Section III, Project Officials (add Administrative Contact)
Exhibit B – Attachment 3 – State Travel & Per Diem Expenses Guidelines (Delete)
Exhibit C – General Terms and Conditions for ERP Grants (Replace with GIA 101)
Exhibit D – Special Terms and Conditions for ERP Grants (Replace with UC IP Clause)

Please note with the exception of Exhibit A the above has previously been negotiated with CALFED/GCAPS on behalf of the University of California and agreeable language has been included in the following current ERP agreements with UC Davis (ERP-02D-P31, ERP-02D-P32, ERP-02D-P33, ERP-02D-P35, and ERP-02D-P51).

Exhibit A – Scope of Work, Section III, Project Officials. We request that a third individual be added as the administrative contact and will act on behalf of the Grantee in lieu of the Project Director.

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EAST BAY
MUNICIPAL UTILITY DISTRICT

November 16, 2004

The East Bay Municipal Utility District wishes to confirm its support of the Hypothesis-driven Monitoring of the CALFED/CVPIA Sponsored Gravel Augmentation on the Lower Mokelumne River proposed by Dr. Gregory Pasternack of the University of California, Davis.

On an ongoing basis we are pursuing opportunities for specific restoration projects along the lower Mokelumne River that will have significant fisheries benefits. We continue to work with the University of California, Davis to implement ecological restoration projects in the lower Mokelumne River including the Spawning Habitat Integrated Rehabilitation Approach.

We anticipate sharing fisheries data and providing access to East Bay Municipal Utility District properties in support of the Study. This letter of support is not binding upon the East Bay Municipal Utility District or its Directors.

Sincerely,

James R. Smith
Supervising Fisheries and Wildlife Biologist

1 WINEMASTERS WAY . UNIT K2 . LODI . CA 95240 . (209) 333-2095 . FAX (209) 334-3795

Tasks And Deliverables

Hypothesis−driven Monitoring of the CALFED/CVPIA Sponsored Gravel Augmentation on the Lower Mokelumne River

Task ID	Task Name	Start Month	End Month	Deliverables
4	Project Management	1	36	Semiannual and final reports. Periodic invoices. Database: ArcGIS spatial database of all monitoring and modeling datasets. Website: further development of the SHIRA website at http://shira.lawr/ucdavis.edu to include all findings, reports, and general rehabilitation lessons.
1	Reach−scale Monitoring and Analysis	1	36	Report: Effectiveness of 3 riffle types in generating reach−scale sediment dispersal and creating downstream habitat. Report: Non−dimensional geomorphic controls on the LMR fish community.
2	Geomorphic−unit Monitoring and Analysis	1	36	Report: Natural self−adjustment and topographic persistence of constructed riffle−pool units. Report: Utility of 2D models in predicting persistence of riffle−pool units.
3	Hydraulic−unit Monitoring and Analysis	1	36	Report: Predictability of redd locations using 2D models and standard habitat suitability

				curves. Report: Objective analysis of the spatial patterns and gradients of rehabilitated hydraulic units. Report: Relative importance of habitat heterogeneity versus habitat abundance for salmon spawning. Report: Benthic macroinvertebrate utilization of spatially dependent habitat heterogeneity features. Report: Juvenile salmonid utilization of spatially dependent habitat heterogeneity features. Report: Deposition and scour of coarse sediment around discrete roughness elements constructed at rehabilitation sites

Comments

If you have comments about budget justification that do not fit elsewhere, enter them here.

Budget Summary

Project Totals

Labor	Benefits	Travel	Supplies And Expendables	Services And Consultants	Equipment	Lands And Rights Of Way	Other Direct Costs	Direct Total	Indirect Costs	Total
$353,462	$73,814	$13,800	$71,766	$0	$64,000	$0	$0	$576,842	$128,210	$705,052

Do you have cost share partners already identified?
No.

If yes, list partners and amount contributed by each:

Do you have potential cost share partners?
No.

If yes, list partners and amount contributed by each:

Are you specifically seeking non−federal cost share funds through this solicitation?
No.

Hypothesis−driven Monitoring of the CALFED/CVPIA Sponsored Gravel Augmentation on the Lower Mokelumne River

Hypothesis−driven Monitoring of the CALFED/CVPIA Sponsored Gravel Augmentation on the Lower Mokelumne River

Year 1 (Months 1 To 12)

Task	Labor	Benefits	Travel	Supplies And Expendables	Services And Consultants	Equipment	Lands And Rights Of	Other Direct Costs	Direct Total	Indirect Costs	Total

Task	Labor	Benefits	Travel	Supplies And Expendables	Services And Consultants	Equipment	Lands And Rights Of Way	Other Direct Costs	Direct Total	Indirect Costs	Total
4: project management (12 months)	20987	4596	4600	1320	0	0	0	0	$31,503	7876	$39,379
1: Reach−scale Monitoring and Analysis (12 months)	29014	6398	0	10326	0	23750	0	0	$69,488	11434	$80,922
2: Geomorphic−unit Monitoring and Analysis (12 months)	18763	3836	0	7576	0	23750	0	0	$53,925	7544	$61,469
3: Hydraulic−unit Monitoring and Analysis (12 months)	47800	8947	0	6996	0	9500	0	0	$73,243	15936	$89,179
Totals	**$116,564**	**$23,777**	**$4,600**	**$26,218**	**$0**	**$57,000**	**$0**	**$0**	**$228,159**	**$42,790**	**$270,949**

Year 2 (Months 13 To 24)

Task	Labor	Benefits	Travel	Supplies And Expendables	Services And Consultants	Equipment	Lands And Rights Of Way	Other Direct Costs	Direct Total	Indirect Costs	Total
4: project management (12 months)	16646	4377	4600	3420	0	0	0	0	$29,043	7261	$36,304
1: Reach−scale Monitoring and Analysis (12 months)	30464	6718	0	5225	0	0	0	0	$42,407	10602	$53,009

2: Geomorphic−unit Monitoring and Analysis (12 months)	**19701**	**4028**	**0**	**8425**	**0**	**0**	**0**	**0**	$32,154	**8038**	$40,192
3: Hydraulic−unit Monitoring and Analysis (12 months)	**43046**	**8966**	**0**	**9495**	**0**	**0**	**0**	**0**	$61,507	**15377**	$76,884
Totals	**$109,857**	**$24,089**	**$4,600**	**$26,565**	**$0**	**$0**	**$0**	**$0**	**$165,111**	**$41,278**	**$206,389**

Year 3 (Months 25 To 36)

Task	Labor	Benefits	Travel	Supplies And Expendables	Services And Consultants	Equipment	Lands And Rights Of Way	Other Direct Costs	Direct Total	Indirect Costs	Total
4: project management (12 months)	**22026**	**4822**	**4600**	**920**	**0**	**7000**	**0**	**0**	$39,368	**8091**	$47,459
1: Reach−scale Monitoring and Analysis (12 months)	**31987**	**7054**	**0**	**5631**	**0**	**0**	**0**	**0**	$44,672	**11168**	$55,840
2: Geomorphic−unit Monitoring and Analysis (12 months)	**20686**	**4229**	**0**	**6481**	**0**	**0**	**0**	**0**	$31,396	**7849**	$39,245
3: Hydraulic−unit Monitoring and Analysis (12 months)	**52342**	**9843**	**0**	**5951**	**0**	**0**	**0**	**0**	$68,136	**17034**	$85,170

Totals	**$127,041**	**$25,948**	**$4,600**	**$18,983**	**$0**	**$7,000**	**$0**	**$0**	**$183,572**	**$44,142**	**$227,714**

Budget Justification

Hypothesis−driven Monitoring of the CALFED/CVPIA Sponsored Gravel Augmentation on the Lower Mokelumne River

Labor

YEAR 1

Task 1− The primary effort will be to perform baseline geomorphic data collection and install sediment transport traps and magnetic tracer rocks. This will require 48%−time of a junior specialist 1 (JS1) ($31,044 annual salary) with an MS degree in hydrology or related field along with an undergraduate student field assistant (SR3) paid $7.50 per hour and working 20hrs/wk * 18 wks during the academic year and 20hrs/wk * 12 wks during the summer (hereafter denoted as 50%−time SR3). Secondarily, a postdoctoral scholar (PDS) in aquatic biology will work 10%−time ($36,912 annual salary) to coordinate with EBMUD to obtain, organize, and analyze fish community data previously collected 1997−2004 and aid the junior specialist with habitat creation field assessment. Sediment transport model usage for reach−scale study sites will require 10%−time JS1.

Task 2− Topographic surveying and DEM generation/analysis will require 25%−time JS1 along with 30%−time SR3 and 5%−time PDS. Mechanistic model usage and intercomparisons will require 15%−time JS1 and 20%−time SR3 (coupled with PDS time allotted in task 3).

Task 3− Biological monitoring will require 60%−time PDS and 100%−time SR3 (defined as $7.50 per hour and working 20hrs/wk * 36 wks during the academic year and 40hrs/wk * 12 wks during the summer). 2D modeling of rehabilitation sites will require 15%−time PDS (coupled with JR1 and SR3 time allotted in task 2). High−resolution surveying and analysis of discrete roughness elements will require 5%−time PDS and 2%−time JS1. GIS spatial data analysis and habitat heterogeneity assessment will be performed by an undergraduate computer programmer

working full-time during the summer ($13.5/hr * 40hr/wk * 12.6wks) (denoted as summer-time SR4). Report writing will require 5%-time PDS.

Task 4- Project management will require 8.33%-time associate professor 3 (PI), 8.33%-time budget analyst, and 8.33%-time coordinator. The PI will use this time to do QA/QC on monitoring and modeling, participate in outreach, and co-author the first report with PDS. Database management, data analysis, and web programming will require an undergraduate computer programmer working part-time during the academic year ($13.5/hr * 20 hr/wk * 16.8 wks) (denoted as school-time SR4)

YEAR 2

PDS, JS1, and SR3 salaries increased by 5% and budget analyst, coordinator salaries adjusted by 2% for projected cost-of-living salary increases.

Task 1- Monitoring sediment transport and tracking sediment tracers will require 48%-time JS1 and 50%-time SR3. Sediment dispersal model usage for reach-scale study sites will require 5%-time JS1. EBMUD data sharing, data analysis, and habitat creation mapping will require 5%-time PDS. Report writing will require 5%-time PDS and 5%-time JS1.

Task 2- Topographic surveying and DEM generation/analysis will require 25%-time JS1 along with 30%-time SR3 and 5%-time PDS. Mechanistic model usage and intercomparisons will require 15%-time JS1 and 20%-time SR3.

Task 3- Biological monitoring will require 60%-time PDS and 100%-time SR3 (defined as $7.50 per hour and working 20hrs/wk * 36 wks during the academic year and 40hrs/wk * 12 wks during the summer). 2D modeling of rehabilitation sites will require 15%-time PDS (coupled with JR1 and SR3 time allotted in task 2). High-resolution surveying and analysis of discrete roughness elements will require 5%-time PDS and 2%-time JS1. Report writing will require 5%-time PDS.

Task 4- Project management will require 8.33%-time associate

professor 3 (PI), 8.33%−time budget analyst, and 8.33%−time coordinator. The PI will use this time to do QA/QC on monitoring and modeling, participate in outreach, and co−author 4 reports with PDS and JS1.

YEAR 3

PDS, JS1, and SR3 salaries increased by 5% and budget analyst, coordinator salaries adjusted by 2% for projected cost−of−living salary increases. PI salary increased from step 3 to step 4 level based on projected merit−based salary increase.

Task 1− Monitoring sediment transport and tracking sediment tracers will require 48%−time JS1 and 50%−time SR3. EBMUD data sharing, data analysis, and habitat creation mapping will require 5%−time PDS. Final analysis of relations between hydrogeomorphic and biologic data will require 5%−time JS1. Report writing will require 5%−time PDS and 5%−time JS1.

Task 2− Topographic surveying and DEM generation/analysis will require 25%−time JS1 along with 30%−time SR3. Mechanistic model usage and intercomparisons for rehabilitation sites will require 10%−time JS1 and 20%−time SR3. Report writing will require 5%−time PDS and 5%−time JS1.

Task 3− Biological monitoring will require 60%−time PDS and 100%−time SR3 (defined as $7.50 per hour and working 20hrs/wk * 36 wks during the academic year and 40hrs/wk * 12 wks during the summer). 2D modeling of rehabilitation sites will require 15%−time PDS (coupled with JR1 and SR3 time allotted in task 2). High−resolution surveying and analysis of discrete roughness elements will require 5%−time PDS and 2%−time JS1. GIS spatial data analysis and habitat heterogeneity assessment will be performed by an undergraduate computer programmer working full−time during the summer ($13.5/hr * 40hr/wk * 12.6wks) (denoted as summer−time SR4). Report writing will require 5%−time PDS.

Task 4− Project management will require 8.33%−time associate professor 4 (PI), 8.33%−time budget analyst, and 8.33%−time

coordinator. The PI will use this time to do QA/QC on monitoring and modeling, participate in outreach, and co−author 7 reports with PDS and JS1. Database management, data analysis, and web programming will require a school−time SR4.

Benefits

Associate Professor −> 25%,

Budget Analyst −> 30%,

Coordinator −> 25%,

PostDoctoral Scholar −> 25%,

Jr Specialist 1 −> 25%,

Student Researcher 4 −> 6%,

Student Researcher 3 −> 6%

Travel

Note that UC Davis accounts for our leasing of a 4x4 truck from UCD Fleet Services for use in travel to field sites and other locations as supplies and expenses, not travel. Consequently, travel costs are only budgeted for Task 4 for outreach and continuing education. Travel costs for the PI, JS1, and PDS to submit oral and poster abstracts, register, park, and eat meals at the CALFED science conference in Sacramento each year is $300. These same people will attend the annual fall conference of the American Geophysical Union in San Francisco where many sessions deal with gravel bed rivers, regulated rivers, salmon spawning habitat, and hydrogemorphology. The cost of abstract submission ($50/person*3), registration (~$350/person*3), parking ($150), a hotel room ($121/night*7), meals ($30*7) and the extra day of the Gilbert Club geomorphic meeting ($30/person*3) is $2500 per year. It is also important for the PDS in aquatic biology to have an opportunity to do outreach and receive peer review

and feedback at the annual American Fisheries Society meeting, which may not be local. The cost of attending this meeting depends on where it is held, but is estimated as $1200 ($300 registration, $400 airfare, $300 hotel room, and $200 meals). Each year the PI will give outreach seminars explaining the overall SHIRA framework to potential user groups, agencies, local communities, and universities in the US western region. A cost of $600 is budgeted per year to cover $100 of meals, hotel, and travel to 6 different locations for presenting such seminars.

Supplies And Expendables

YEAR 1

Task 1−topography/habitat surveying supplies ($500), bedload transport traps ($2000), sediment tracing supplies ($2000), grain size analysis supplies ($600), flow/sediment modeling software licenses ($200), statistics/math software licenses ($300), river safety supplies ($250), drysuit/wader supplies ($1500), truck lease/usage ($2976=3mo * $800/mo + 160mi * $0.15/mi * 24trips).

Task 2− topography/habitat surveying supplies ($1500), flow/sediment modeling software licenses ($300), statistics/math software licenses ($300), truck lease/usage ($2976=3mo * $800/mo + 160mi * $0.15/mi * 24trips), 1 desktop computer ($2500 UC Davis considers all items under $5000 to be supplies/expenses).

Task 3−DEM software licenses ($800), flow/sediment modeling software licenses ($300), statistics/math software licenses ($300), benthic macroinvertebrate survey supplies ($970), snorkel survey supplies ($300), river safety supplies ($250), drysuit/wader supplies ($1100), truck lease/usage ($2976=3mo * $800/mo + 160mi * $0.15/mi * 24trips).

Task 4− digital camera ($400), office supplies/charges ($700), photocopy cards ($120), CDs and other computer supplies ($100).

YEAR 2

Task 1– bedload transport traps replace/repair ($500),sediment tracing supplies ($500), grain size analysis supplies ($600), flow/sediment modeling software licenses ($200), statistics/math software licenses ($300), truck lease/usage ($3125=YR1*1.05 projected cost increase).

Task 2– topography/habitat surveying supplies ($1500), DEM software upgrade/license ($3200), flow/sediment modeling software licenses ($300), statistics/math software licenses ($300), truck lease/usage ($3125=YR1*1.05 projected cost increase).

Task 3– DEM software licenses ($800), flow/sediment modeling software licenses ($300), statistics/math software licenses ($300), benthic macroinvertebrate survey supplies ($970), snorkel survey supplies ($300), Marsh–McBirney current meter ($3700 UC Davis counts items under $5000 as supplies/expenses), truck lease/usage ($3125=YR1*1.05 projected cost increase).

Task 4– office supplies/charges ($700), photocopy cards ($120), CDs and other computer supplies ($100).

YEAR 3

Task 1– bedload transport traps replace/repair ($500),sediment tracing supplies ($500), grain size analysis supplies ($600), flow/sediment modeling software licenses ($200), statistics/math software licenses ($300), river safety supplies ($250), truck lease/usage ($3281=YR2*1.05 projected cost increase).

Task 2– topography/habitat surveying supplies ($1500), flow/sediment modeling software licenses ($300), statistics/math software licenses ($300), drysuit/wader supplies ($1100), truck lease/usage ($3281=YR2*1.05 projected cost increase).

Task 3– DEM software licenses ($800), flow/sediment modeling

software licenses ($300), statistics/math software licenses ($300), benthic macroinvertebrate survey supplies ($970), snorkel survey supplies ($300), truck lease/usage ($3281=YR2*1.05 projected cost increase).

Task 4– office supplies/charges ($700), photocopy cards ($120), CDs and other computer supplies ($100).

Services And Consultants

n/a

Equipment

YEAR 1

Task 1– 41.67% Trimble R7/R8 RTK GPS System with data collector and accessories ($23,750).

Task 2– 41.67 % Trimble R7/R8 RTK GPS System with data collector and accessories ($23,750).

Task 3–16.66 % Trimble R7/R8 RTK GPS System with data collector and accessories ($9,500).

YEAR 3

Task 4– Database and web server computer system ($7000).

Lands And Rights Of Way

n/a

Other Direct Costs

n/a

Indirect Costs/Overhead

Rates. For contracts with Federal agencies, the University of California uses rates based on OMB Circular A−21; the research rate in effect until June 30, 2005 is 48.5%, after which it increases to 51.5 until June 30, 2007, and then to 52% until June 30, 2008. For contracts with all State Agencies except the Department of Food and Agriculture, the University applies a rate of 25%. (A special 10% rate for State Resources agencies which has been in effect in recent years was revoked by the Office of the President on May 9,2003 via Operating Guidance memo No. 03−02.)

Application. These rates are applied to modified total direct costs (MTDC), which consists of all salaries and wages, fringe benefits, materials and supplies, services, travel, subgrants and subcontracts up to the first $25,000 of each subgrant or subcontract. Equipment and student fee remissions are excluded from the MTDC.

Comments

Environmental Compliance

Hypothesis−driven Monitoring of the CALFED/CVPIA Sponsored Gravel Augmentation on the Lower Mokelumne River

CEQA Compliance

Which type of CEQA documentation do you anticipate?
X none
− negative declaration or mitigated negative declaration
− EIR
− categorical exemption

If you are using a categorical exemption, choose all of the applicable classes below.
− Class 1. Operation, repair, maintenance, permitting, leasing, licensing, or minor alteration of existing public or private structures, facilities, mechanical equipment, or topographical features, involving negligible or no expansion of use beyond that existing at the time of the lead agency's determination. The types of "existing facilities" itemized above are not intended to be all−inclusive of the types of projects which might fall within Class 1. The key consideration is whether the project involves negligible or no expansion of an existing use.
− Class 2. Replacement or reconstruction of existing structures and facilities where the new structure will be located on the same site as the structure replaced and will have substantially the same purpose and capacity as the structure replaced.
− Class 3. Construction and location of limited numbers of new, small facilities or structures; installation of small new equipment and facilities in small structures; and the conversion of existing small structures from one use to another where only minor modifications are made in the exterior of the structure. The numbers of structures described in this section are the maximum allowable on any legal parcel, except where the project may impact on an environmental resource of hazardous or critical concern where designated, precisely mapped, and officially adopted pursuant to law by federal, state, or local agencies.
− Class 4. Minor public or private alterations in the condition of land, water, and/or vegetation which do not involve removal of healthy, mature, scenic trees except for forestry or agricultural purposes, except where the project may impact on an environmental resource of hazardous or critical concern where designated, precisely mapped, and officially adopted pursuant to law by federal, state, or local agencies.
− Class 6. Basic data collection, research, experimental management, and resource evaluation activities which do not result in a serious or major disturbance to an environmental resource, except where the project may impact on an environmental resource of hazardous or critical concern where designated, precisely mapped, and officially adopted pursuant to law by federal, state, or local agencies. These may be strictly for information

gathering purposes, or as part of a study leading to an action which a public agency has not yet approved, adopted, or funded.
− Class 11. Construction, or placement of minor structures accessory to (appurtenant to) existing commercial, industrial, or institutional facilities, except where the project may impact on an environmental resource of hazardous or critical concern where designated, precisely mapped, and officially adopted pursuant to law by federal, state, or local agencies.

Identify the lead agency.

Is the CEQA environmental impact assessment complete?

If the CEQA environmental impact assessment process is complete, provide the following information about the resulting document.

Document Name
State Clearinghouse Number

If the CEQA environmental impact assessment process is not complete, describe the plan for completing draft and/or final CEQA documents.

NEPA Compliance

Which type of NEPA documentation do you anticipate?
X none
− environmental assessment/FONSI
− EIS
− categorical exclusion

Identify the lead agency or agencies.

If the NEPA environmental impact assessment process is complete, provide the name of the resulting document.

If the NEPA environmental impact assessment process is not complete, describe the plan for completing draft and/or final NEPA documents.

Successful applicants must tier their project's permitting from the CALFED Record of Decision and attachments providing programmatic guidance on complying with the state and federal endangered species acts, the Coastal Zone Management Act, and sections 404 and 401 of the Clean Water Act.

Please indicate what permits or other approvals may be required for the activities contained in your proposal and also which have already been obtained. Please check all that apply. If a permit is *not* required, leave both Required? and Obtained? check boxes blank.

Local Permits And Approvals	Required?	Obtained?	Permit Number (If Applicable)
conditional Use Permit	–	–	
variance	–	–	
Subdivision Map Act	–	–	
grading Permit	–	–	
general Plan Amendment	–	–	
specific Plan Approval	–	–	
rezone	–	–	
Williamson Act Contract Cancellation	–	–	
other	–	–	

State Permits And Approvals	Required?	Obtained?	Permit Number (If Applicable)
scientific Collecting Permit	–	–	
CESA Compliance: 2081	–	–	
CESA Complance: NCCP	–	–	
1602	–	–	
CWA 401 Certification	–	–	
Bay Conservation And Development Commission Permit	–	–	
reclamation Board Approval	–	–	
Delta Protection Commission Notification	–	–	
state Lands Commission Lease Or Permit	–	–	

action Specific Implementation Plan	–	–	
other	–	–	

Federal Permits And Approvals	Required?	Obtained?	Permit Number (If Applicable)
ESA Compliance Section 7 Consultation	–	–	
ESA Compliance Section 10 Permit	–	–	
Rivers And Harbors Act	–	–	
CWA 404	–	–	
other	–	–	

Permission To Access Property	Required?	Obtained?	Permit Number (If Applicable)
permission To Access City, County Or Other Local Agency Land Agency Name	–	–	
permission To Access State Land Agency Name	–	–	
permission To Access Federal Land Agency Name	–	–	
permission To Access Private Land Landowner Name East Bay Municipal Utility District	X	X	

If you have comments about any of these questions, enter them here.

EBMUD has a DFG 1600 (Streambed Alteration Agreement), currently in place allowing the gravel injection and associated work to be completed through 2008. Our activities have been covered under this agreement. We report our activities to CALFED and CDFG.

Land Use

Hypothesis−driven Monitoring of the CALFED/CVPIA Sponsored Gravel Augmentation on the Lower Mokelumne River

Does the project involve land acquisition, either in fee or through easements, to secure sites for monitoring?
X No.
− Yes.

How many acres will be acquired by fee?

How many acres will be acquired by easement?

Describe the entity or organization that will manage the property and provide operations and maintenance services.

Is there an existing plan describing how the land and water will be managed?
− No.
− Yes.

Will the applicant require access across public or private property that the applicant does not own to accomplish the activities in the proposal?
− No.
X Yes.

Describe briefly the provisions made to secure this access.

Access to all sites is possible from the Mokelumne River Day Use Area at the base of Camanche Dam, which is an area open to the public. EBMUD has been cooperating in facilitating acces by providing a gate key to allow us to drive along a road along th channel to bring equipment and supplies right to each enhancement site. We have also coordinated with CDFG and the Mokelumne Fish Hatchery regarding our field activities.

Do the actions in the proposal involve physical changes in the current land use?
X No.

− Yes.

Describe the current zoning, including the zoning designation and the principal permitted uses permitted in the zone.

Describe the general plan land use element designation, including the purpose and uses allowed in the designation.

Describe relevant provisions in other general plan elements affecting the site, if any.

Is the land mapped as Prime Farmland, Farmland of Statewide Importance, Unique Farmland, or Farmland of Local Importance under the California Department of Conservation's Farmland Mapping and Monitoring Program?
X No.
− Yes.

Land Designation	Acres	Currently In Production?
Prime Farmland		−
Farmland Of Statewide Importance		−
Unique Farmland		−
Farmland Of Local Importance		−

Is the land affected by the project currently in an agricultural preserve established under the Williamson Act?
X No.
− Yes.

Is the land affected by the project currently under a Williamson Act contract?
X No.
− Yes.

Why is the land use proposed consistent with the contract's terms?

Describe any additional comments you have about the projects land use.