Summary Information

California State University, Sacramento

Effects of structural enhancement on salmonid spawning

Amount sought: $188,776

Duration: 24 months

Lead investigator: Dr. Timothy Horner, CSU Sacramento Geology Department

Short Description

Due to the uncertainty of exactly how or why structure may attract spawning salmon or what benefits may be associated with spawning adjacent to objects, such as woody debris and boulders, this project will study the influence of structure on intergravel permeability, down−welling, sediment composition and behavior of spawning salmonids on known Chinook salmon and steelhead spawning habitat in the Central Valley of California, including existing enhanced spawning sites that have received AFRP and CALFED funding for either construction or monitoring.

Executive Summary

This project will examine the effects of woody debris and boulders on spawning behavior in Mokelumne River gravel restoration sites. These in−stream features create habitat diversity that is poorly understood and infrequently documented in restoration projects, so the proposed work will make a major contribution to future project design. Performance measures that deal with physical and behavioral changes near channel obstructions are linked to conceptual models, and the project is designed to be scalable to other restoration efforts on different rivers.

Gravel augmentation downstream of Central Valley dams began in the late 1960’s. At least 82 projects were conducted between 1968−2004, with at least 400,000 yd3 of gravel added for spawning habitat improvements. Many of these projects have been implemented by reconstructing spawning riffles and pool tails, and in some cases the incorporation of structure placement, including woody debris, boulder piles and wing dams, although the purpose or benefits of such placements is not well defined. Creation of spawning habitat is still the predominant rationale for gravel augmentation projects, with more sophisticated hydraulic models now being applied in an attempt to place gravel in a way that maximizes areas with preferred depths, velocities, and substrate for spawning salmonids. Although proposed, modeling of structure and its effects within spawning enhancement sites has not been accomplished to date. Due to the uncertainty of exactly how or why structure may attract spawning salmon or what benefits may be associated with spawning adjacent to objects, such as woody debris and boulders, we propose to study the influence of structure on intergravel permeability, down−welling, sediment composition and behavior of spawning salmonids on known Chinook salmon and steelhead spawning habitat in the Central Valley of California, including existing enhanced spawning sites that have received AFRP and CALFED funding for either construction or monitoring. This study will help state and federal agencies meet the CALFED main objective to Improve Ecosystem Quality. The study is focused on CALFED's Priority Topic Areas ii. Ecological Processes and Their Relationship to Water Management and Key Species Conservation and iii. Performance Assessment – Improving Tools and Implications for Future Changes. Furthermore, this project will meet key CALFED Ecosystem Restoration Program and Central Valley Project Improvement Act goals in the areas of continued habitat restoration (priority 1), improved geomorphic processes (priority 2), and enhanced salmonid spawning habitat (priority 3).

At present, California is rather ambiguous toward large woody debris within aquatic channels of the Central Valley. Future management of riparian corridors and river channels requires sound science to better weigh the needs of functional spawning channels and the role that debris and structure play in this habitat. Specifically, this study will help better define design and implementation of spawning gravel enhancement projects.

A) Project Description: Project goals and scope of work

A. 1) Problems, goals and objectives:

The Mokelumne River is a modified system that drains approximately 1,700 km^2 of the Central Sierra-Nevada (Figure 1). Similar to many other Central Valley river systems, the Mokelumne River has been affected by numerous human influences, including 16 major water projects and instream gravel and gold mining (CDC 1988). Camanche Dam, completed in 1964, is the lowest non-passable dam to migratory fishes and was constructed for flood control and river regulation. The subsequent altered flow regime stabilized active sediment and enabled survival of in-channel vegetation. According to Pasternack et al. (2004), changes are documented in historical aerial photos, with the active channel now incised and half its former width.

Mokelumne River Study Site Setting

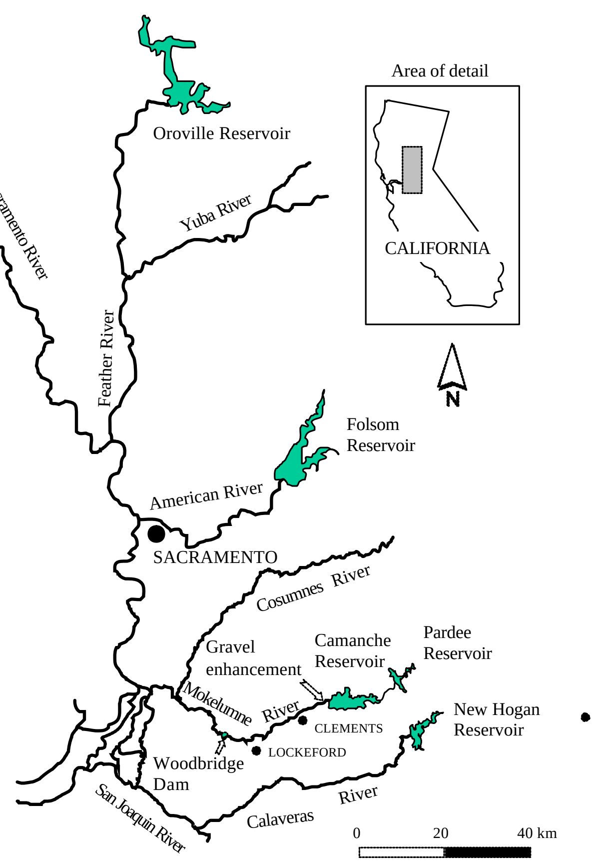

Figure 1: Location of the Mokelumne River in reference to the central Sacramento- San Joaquin River systems.

Prior to construction of Camanche Dam, annual peak flows exceeded 200 $m^3 s^{-1}$ for 21 of 57 years. Since 1964, annual peaks have never exceeded 200 $m^3 s^{-1}$. Pre-dam mean monthly flow had a typical snowmelt hydrograph with highest flow from May to June, after the peak in precipitation. The post-dam hydrograph shows significant reduction in late spring snowmelt runoff below the dam. A flood frequency analysis using annual extreme pre- and post-dam data shows a dramatic reduction in flow for all recurrence intervals after the dam was built. Estimated Q2, Q5, Q10, and Q100 flows decreased by 67, 59, 73, and 75 %, respectively. The statistical bankful discharge (Q1.5) prior to construction of Camanche Dam was 120 $m^3 s^{-1}$, but this flow is now released on average every five years (Pasternack et al. 2004). Flow out of Camanche Dam has a stepped hydrograph, with lows near the minimum (4.25 $m^3 s^{-1}$) prescribed in the Joint Settlement Agreement for re-licensing (FERC 1998). The maximum flood release rate (set by the Army Corp of Engineers for Camanche Dam) is 142 $m^3 s^{-1}$ (FERC 1993).

The lower Mokelumne River (LMR) is an approximately 54-km reach of regulated stream between Camanche Dam, the downstream non-passable barrier to anadromous fish, and its confluence with the Sacramento-San Joaquin Delta (Figure 1). The river between Camanche Dam and Lake Lodi, a seasonal reservoir with a fish passage facility at Woodbridge Irrigation District Dam (WIDD), is characterized by alternating bar complex and flatwater habitats with a gradient of 0.0017 (Merz and Setka 2004). The LMR flows through floodplains and alluvial fan deposit soils of the Valdez-Columbia and Hanford-Greenfield associations, which are both sandy-loams with good to poor drainage characteristics. Tailings from abandoned gravel mining operations are frequent along the upper one-third of the LMR. While many of the tailings are isolated from the river by berms and levees, several large pits are now incorporated into the main river channel. The LMR floodplain is dominated by agriculture, including walnut and winegrape production, livestock grazing and an increasing number of single-family dwellings. Riverbanks are characterized by 50 to 100-m sections of broken concrete and stone riprap with a thin ribbon of Fremont cottonwood *Populus fremonti*, valley oak *Quercus lobata*, willow *Salix* spp., and red alder *Alnus rubra*. Numerous non-native trees and shrubs such as black locust *Robinia pseudo-acacia*, Himalaya-berry *Rubus discolor*, and Giant Reed *Arundo donax* are also common (Merz and Setka 2004). At least 35 fish species occur in the LMR, including prickly sculpin *Cottus asper*, Sacramento sucker *Catostomus occidentalis*, and two anadromous salmonids, steelhead *O. mykiss*, and fall-run Chinook salmon (Merz 2001). Both salmonid populations are supplemented by fish reared in the Mokelumne River Hatchery or imported from the Feather River and Nimbus hatcheries (American River). Abundant non-native fish species include western mosquitofish *Gambusia affinis*, golden shiner *Notemigonus crysoleucas*, and spotted bass *Micropterus punctulatus*.

Records of historical Mokelumne River Chinook salmon runs are incomplete and conflicting (Clark 1929; Reynolds et al. 1990). Winery, cannery and mining pollution, along with water diversions and habitat blockage, periodically eliminated all LMR fish life, including whole year classes of salmon (CDFG 1959; Finlayson and Rectenwald 1978). From 1980 to 1988, over 90 percent of Mokelumne River Hatchery production originated from imported eggs and fry, all suggesting a run of questionable origin (Jewett 1982; Meyer 1982; Estey 1989). At present, Mokelumne River fall-run Chinook salmon are an ocean race; they typically emigrate to the ocean in the spring of their first year and spend two to four years in the ocean before returning to their natal stream to spawn (Healy 1991). Before completion of Camanche Dam, fall-run Chinook salmon spawned primarily between the town of Clements and an unnamed canyon about 4 km below Pardee Dam. Few fish spawned upstream of the canyon or downstream of Clements. The California Department of Fish and Game estimated that the river downstream of Pardee was capable of sustaining annual runs of 15,000 adult Chinook salmon

(CDFG 1959). However, runs for the 19-year period of record before Camanche Reservoir was impounded averaged 3,300 spawners, a period when instream mining was widespread.

The majority of salmon spawning now takes place in the 16-km reach between Camanche Dam (RKM 102.2) and Clements (RKM 86.9). The Revised Draft Restoration Plan for the Anadromous Fish Restoration Program (USFWS 1997) calls for a fall-run Chinook salmon production target of 9,300 for the Mokelumne River. Recent escapement in the Mokelumne River, based on counts at the WIDD, has ranged from 410 in 1991 to over 10,000 in 1997. The annual fall-run Chinook salmon migration into the Mokelumne River begins in September, peaks in November and tapers off in December and early January. Spawning generally occurs shortly after migration, primarily in late October through January. Fry emergence typically begins in late December and continues to the beginning of April (Merz and Setka 2004).

FERC (1993) ranked the various factors limiting the production of Chinook salmon in the LMR and determined that spawning habitat (quality and quantity) was the second-most important factor. Ocean harvest, which can account for 75-85% of adult Chinook salmon mortality, was identified as the most severe constraint on escapement of adults to the spawning grounds. From 1990 to present, East Bay Municipal Utility District (EBMUD), owner and operator of Camanche Dam, has partnered with the California Department of Fish and Game, United States Fish and Wildlife Service (AFRP funding) and the University of California, Davis (UCD) (CALFED funding), to perform annual Chinook salmon spawning habitat enhancement projects in the LMR. While the goal of the enhancement projects is to improve existing marginal habitat, a secondary goal is to increase total available spawning habitat. These projects typically consist of placing approximately 500–3,000 yd^3 (382-2,300 m^3) of washed river rock (25 – 150 mm diameter) in berms and staggered bar configurations, along with boulder clusters and LWD of various sizes, as a means to increase natural reproduction of these fish. Sites are typically 30 to 100 m long, spanning the river channel, with an average depth of 0.4 m for placed gravels. Cleaned gravel materials are purchased from an open floodplain quarry approximately 0.5 km from the river channel. Chinook salmon and steelhead typically begin spawning in the new gravels within 3-24 months of gravel placement.

CALFED has funded 3 demonstration projects for spawning gravel augmentation through UCD (Wheaton et al. 2004). EBMUD has funded monitoring of the benthic macroinvertebrate community within augmentation sites (Merz and Ochikubo Chan 2004), the effects of gravel augmentation on spawning use (Merz and Setka 2004), the effects of gravel augmentation on salmonid embryo survival (Merz et al. 2004) and a joint effort with UCD on estimating a coarse sediment budget for spawning gravel augmentation (Merz 2004). No work has been documented on the effects of structure, such as LWD and boulders, on spawning salmonids.

A. 2) Justification (including conceptual model and hypothesis):

Pacific salmonids (*Oncorhynchus* spp.) are an important ecological and economic component of California. The California Department of Fish and Game estimated that Pacific salmon generate between 28.8 and 50.6 million dollars annually to the state's economy (Barrow and Heisdorf 2001). Ecologically, Pacific salmon provide a nutrient subsidy for oligotrophic streams (O'keefe and Edwards 2003), an important energy source for numerous terrestrial and aquatic organisms (Cederholm et al. 1999; Hilderbrand et al. 1999; Chaloner et al. 2002) and an important component in the biofeedback between estuaries, oceans and streams (Larkin and Slaney 1997). The nutrient subsidy provided by salmon escapement results in an increase in the abundance and growth rates of aquatic invertebrates and fish (Wipfli et al. 2003) and riparian tree production (Helfield and Naiman 2001). In this context, salmon nutrients are part of a positive feedback loop, because juvenile salmon grow faster and have higher survival rates when their invertebrate prey are abundant in streams and riparian areas (Larkin and Slaney 1997). The complexity of stream habitat, important for both juvenile and spawning salmon, also increases when large, salmon-fertilized trees fall into the water. Salmonids also provide a mechanism for disturbance or modification of habitats via spawning and feeding that are only recently being quantified (Merz 2002; Merz 2004; Minakawa 1998).

California's Central Valley rivers historically supported runs of 1-3 million salmon per year. Chinook salmon were the most abundant anadromous salmon in these streams, but four other species, to much a lesser extent, were also present (Yoshiyama et al.1998; 2000). Over the past two centuries, human activity has greatly altered California's inland waterways. Development on aquatic systems and excessive harvest of natural resources, including gravel, timber and fish, have depleted native salmonids and their habitats, including a reduction in as much as 96% of historical riparian forests. Presently, less than 28% of historical Chinook salmon spawning habitat is available because of dams and diversions but 200,000 salmon still enter these rivers and their hatcheries each year (Yoshiyama et al. 2000; 2001). Concerns over the fate of California Central Valley steelhead (*Oncorhynchus mykiss*) and several runs of Chinook salmon (*O. tschawytscha*) resulted in the United States National Marine Fisheries Service (NOAA) listing these populations as threatened or endangered under the Endangered Species Act (NOAA 1994 and NOAA 1998).

Habitat condition is a key factor regulating salmonid production, and can limit the carrying capacity of streams for these fish (House and Boehne 1985). Thus, management programs are aimed at increasing naturally spawning wild stocks through rehabilitation of severely altered habitats (Farley 1993; AFRP 1997).

Habitat heterogeneity has long been associated with increased biotic production and species diversity in aquatic systems (House and Boehne 1986; Langler and Smith 2001). The formation of diverse habitats, such as gravel bars, pools and meanders, are important to spawning and rearing lifestages of anadromous salmonids and are intimately linked to structure, such as Large Woody Debris (LWD) and boulders. The influences of instream structure on juvenile salmonids have been extensively discussed in the literature (Ward and Slaney 1979, Ward and Slaney 1981, House and Boehne 1985, Fuller 1990). Woody debris is also an important energy source for benthic invertebrates (Anderson et al. 1978, Bisson et al. 1987), a principal food of juvenile salmonids (Mundie 1974). Woody debris provides cover for adult salmonids (Bjornn and Reiser 1991), and low gradient sediment deposits upstream of debris accumulation can provide suitable spawning substrate in sediment-poor drainages (Everest and Meehan 1981). Woody debris may create scour pools with tail-outs appropriate for redd construction in sediment-rich streams (Sedell et al. 1982). House and Boehne (1985) described the accumulation of superior salmon spawning material near gabion structures placed in East Fork Lobster Creek, Oregon to mimic large debris. House and Crispin (1990) evaluated the economic value of large woody debris in salmonid habitat, but only estimated numbers of adult salmonids from sampled juvenile populations.

Pacific salmon often make long migrations to spawning grounds which are energetically expensive. Adults stop feeding when they enter fresh water, creating a situation where energy conservation is essential to successful spawning (Hinch and Rand 2000). Heavily wooded streams of the Pacific West have supported genetically and morphologically distinct strains of salmonids (Beachham and Murray 1987, Beachham et al. 1988) and it is logical to assume that these fish have evolved to deal with and utilize flow vectors associated with debris. The amount and size of woody material that each forest contributes to stream habitats is directly linked to the vegetative composition of the riparian zone and, as some streams may lack the woody structure present in the old growth watersheds, they may also lack habitat structure for fish (Flebbe and Dolloff 1995).

Surveys in the lower Mokelumne River, California during 1994-1995 indicated that fall-run Chinook salmon, (*Oncorhynchus tshawytscha*) redds associated with LWD had smaller substrate, greater mean depths, and a negative relationship to stream gradient. Female Chinook salmon selected spawning sites containing LWD in some instances, suggesting that structure provides benefits to spawning salmonids (Merz 2001; Figures 2 and 3). The report suggests that LWD may make less desirable habitats more suitable for spawning, and may allow greater concentrations of redds on suitable sites. Furthermore, it has been hypothesized that LWD may increase intergravel water exchange through redds, benefiting developing eggs and embryos (Figures 4 and 5). These hypotheses have not been tested.

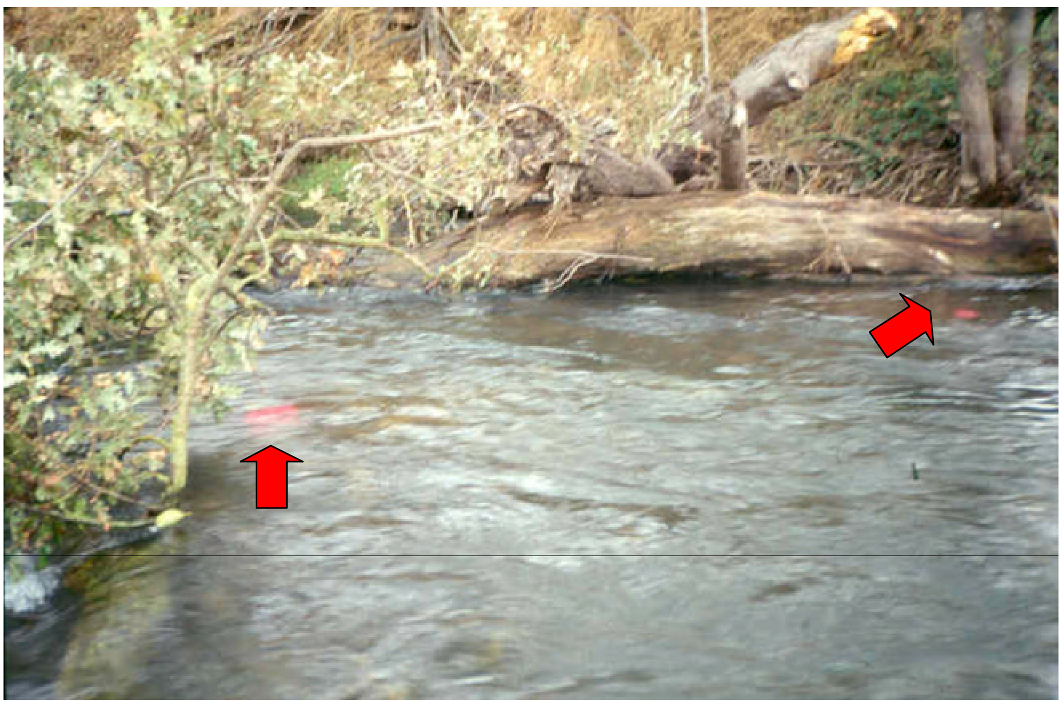

Figure 2: Chinook salmon redds associated with woody debris on the lower Mokelumne River, California. Red arrows point to colored markers placed at the tailspill of both redds.

Numerous salmonid habitat enhancement projects incorporate structure placement, including LWD, boulder piles and wing dams, although the purpose or benefits of such placements is not well defined (Schmetterling and Pierce 1999; Thompson 2002).

Unfortunately, the presence of LWD, and to a lesser extent, boulder clusters in streams, has been implicated as a potential source of log jams that could block river flow, impede navigation, reduce flood-control capacity, destabilize levees, and impair passage of migrating adult salmonids. As a consequence of these concerns, many maintenance programs historically were, and many still are, aimed at the removal of such structure from stream channels (Burns 1971; Bryant 1983; Harmon et al. 1986). Decreased availability of LWD is compounded by the severe reduction in Central Valley riparian forests and dams that block transport of this debris from historical watershed sources.

Figure 3. Steelhead redd associated with woody debris in the lower Mokelumne River, California.

We propose to examine the influence of in-stream structure on spawning salmon, and document benefits that may be associated with spawning adjacent to objects, such as LWD and boulders. We also propose to study the influence of structure on intergravel permeability, hyporheic flow (upwelling and down-welling in the stream bed), sediment composition, and behavior of spawning salmonids. Existing enhanced spawning sites that have received AFRP and CALFED funding for either construction or monitoring will be used for the study. Performance measures will be linked to hypothesis-driven field research, and the study will be driven by two theories:

Physical and behavioral benefits

Theory 1. Structure such as boulders and LWD influences hyporheic flow through gravel. The performance measure for this theory will be study of hyporheic flow (pressure, flow and temperature) near woody debris and in nearby background areas. If hyporheic flow is increased, survival and development of embryos should also increase. Female salmonids may be able to sense these pressure, flow or temperature changes, and seek out spawning sites adjacent to these structures. Therefore, a disproportional number of redds should be constructed adjacent to structures.

Theory 2. Water velocity changes in order to pass around structure such as LWD and boulders, which in turn affects the behavior of spawning salmonids. Performance measures for this theory will focus on behavioral observations near structure and in redds where no structure is present. Differences in hiding, time of redd construction, energy conservation, survival, and competition will be used as performance measures. These attributes could benefit spawning salmon in several ways:

a) Females may use structure as a hiding spot from predators. Therefore, females building redds adjacent to structure may move away from constructed redds less often than those not adjacent to structure;
b) Pre-segregated material within the relatively high shear zone adjacent to structure may be easier to manipulate for redd construction. Therefore, redds constructed adjacent to structure may be completed more quickly that those not adjacent to structure;
c) Females may be able to conserve energy by using the structure to rest, then dart out into faster water to dig during redd construction. Therefore, female salmon building redds adjacent to structure may survive longer than those constructing redds not adjacent to structure;
d) Visual obstruction may reduce conflict between competing females, reducing energy drain (adult salmon do not feed once they enter fresh water). Therefore, females constructing redds adjacent to structure may actually have fewer competitive interactions than those females that build redds in the open.

A conceptual model that links physical factors in embryo survival is shown in Figure 4.

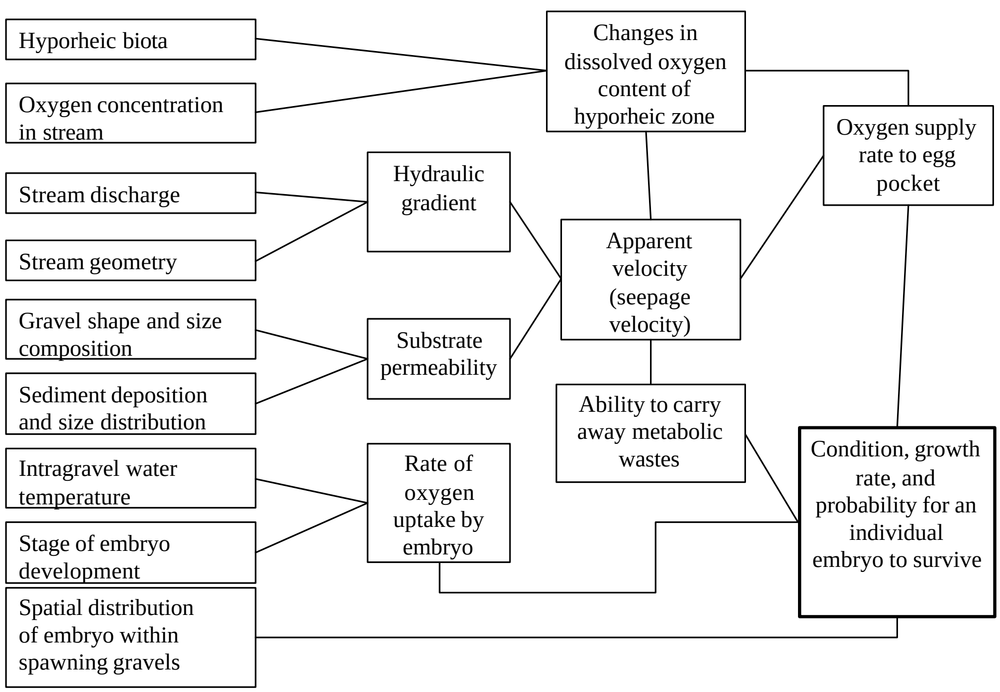

Figure 4: Conceptual model of factors influencing survival of salmonid embryos. Modified from Wu (2000) to include situations with groundwater upwelling that affect oxygen and nutrient supply to the egg pocket.

Physical factors from the conceptual model will be translated into performance measures that document the effects of flow near woody debris and boulders on spawning salmonids. Water velocity, water depth, dissolved oxygen, intergravel flow and sediment size will be used as direct measures of the importance of this little-known aspect of gravel restoration projects.

A more specific conceptual model that deals with woody debris is shown in Figure 5. Spawning behavior (resting, flight, hiding, aggression, survival) will be used as performance measures to evaluate the effects of cover for adult salmonids. This critical part of the model is unknown in restoration projects.

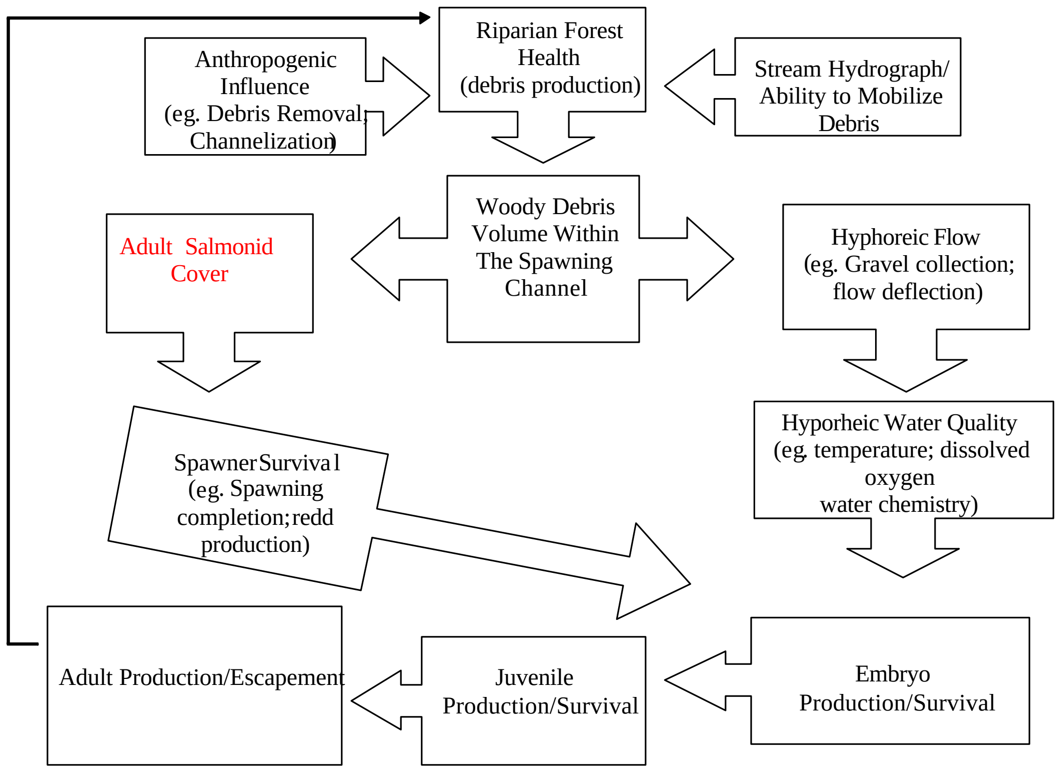

Figure 5: Conceptual model showing the effects of cover (woody debris and boulders) on salmon spawning. Behavioral performance measures will be used to assess the effectiveness of cover to spawning.

Elements of the conceptual model will be tested by several hypotheses. Each hypothesis has a physical or behavioral performance measure that will be used to evaluate the importance of in-stream structure to the conceptual model:

$1H_0$: There is no correlation between locations of boulders/LWD and redd construction.
$2H_0$: There is no increase in hyporheic flow around boulders and LWD.
$3H_0$: There is no difference in velocities measured immediately upstream, lateral and below structure.

$4H_0$: There are no differences in particle size categories of substrate collected immediately below and immediately lateral to structure.
$5H_0$: There is no difference in survival time for females constructing redds adjacent to and not adjacent to LWD/boulders.
$6H_0$: There is no difference in construction time for redds built adjacent to LWD/boulders and those not.
$7H_0$: There is no difference in the amount of time females spend away from redds constructed adjacent to structure and those not constructed adjacent to structure.
$8H_0$: There is no difference in the amount of time females fend off competitors when redds are constructed adjacent to and not adjacent to structure.

A. 3) Previously funded monitoring:

Since 1990, over 17,500 yards^3 of spawning-sized gravel has been placed at 16 spawning gravel augmentation sites (Figure 6). These projects have been funded by East Bay Municipal Utiltiy District, owner and operator of Pardee and Camanche reservoirs, as well as several federal and state funding sources (113328J200 Mokelumne River Spawning Habitat Improvement Project AFRP; 113329J014 Enhancement and Evaluation of spawning in the Mokelumne River AFRP; 113320G023 Mokelumne River Streambank Improvement Project AFRP). Monitoring of the spawning reach substrate characteristics, including channel configuration and gradient, substrate size, intergravel permeability, dissolved oxygen content, and temperature are one of the criteria developed to evaluate the effectiveness of East Bay Municipal Utility District's Mokelumne River Water Quality and Resource Management Program.

In 1990, East Bay Municipal Utility District (EBMUD) initiated an experimental spawning gravel project by placing approximately 500 yards^3 of suitable-sized gravel in the LMR just below the fish diversion fence below Camanche Dam (Figure 6). The objective was to enhance existing spawning areas as a means of increasing reproductive success of fall-run Chinook salmon. The project was continued over the next 7 years, except 1991, in cooperation with California's Department of Fish and Game and Department of Parks and Recreation and typically consisted of placing washed river gravel in known spawning areas.

Preliminary data collected by EBMUD between 1996 and 2000 show that the projects increased intergravel permeability and dissolved oxygen content, and reduced intergravel water temperatures in most situations. Adult Chinook salmon also used new gravel for spawning within three months of gravel placement (Merz and Setka 2004; Merz et al. 2004). Benthic macroinvertebrates began colonizing new gravel within three days and their numbers equaled or surpassed population densities at unenhanced areas within ten weeks after gravel placement (Merz and Chan 2004). A detailed analysis of effects of spawning habitat enhancement for Chinook salmon and steelhead on specific parameters associated with the spawning environment in a regulated California stream with a gravel deficit can be found in Merz (2004).

Existing monitoring work has focused on physical attributes of the gravel, and fish use of newly emplaced gravel. Work described in this proposal will add to existing monitoring projects, and provide new information about the importance of woody debris to salmonid behavior and spawning habitat.

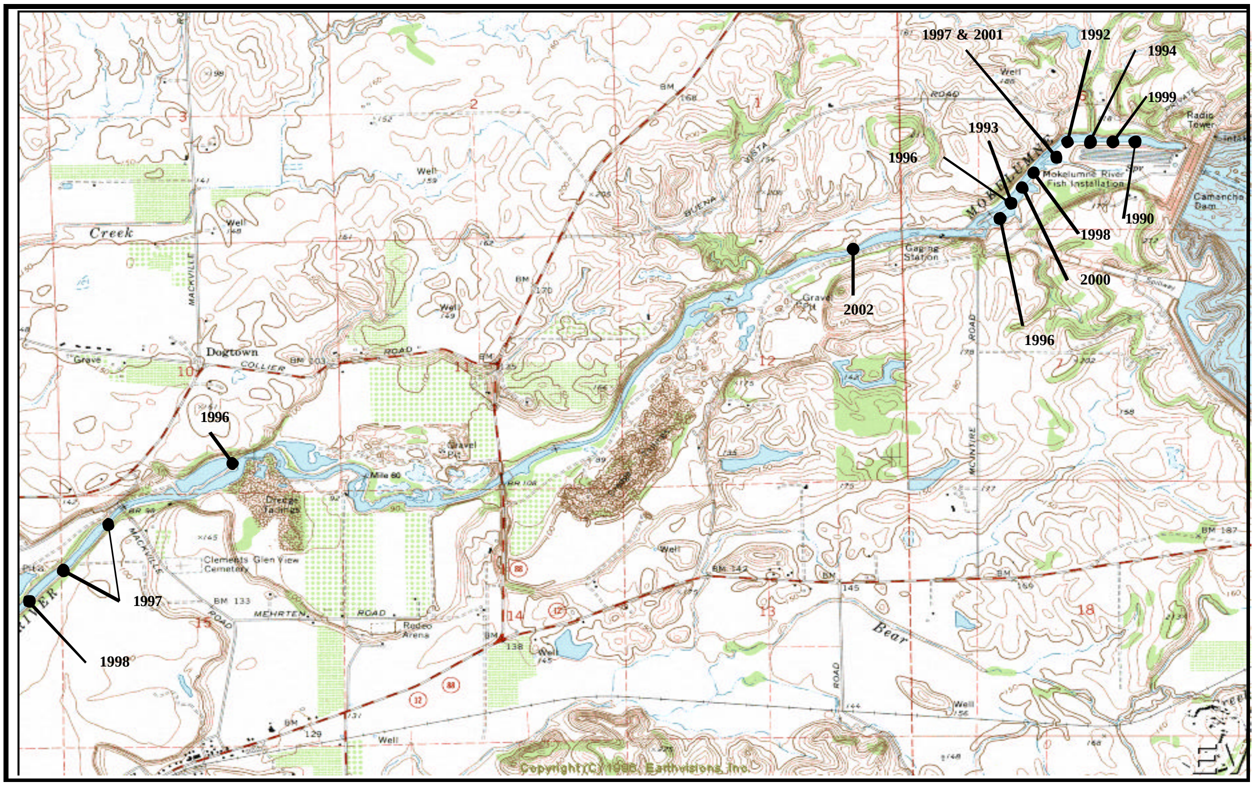

Figure 6: Lower Mokelumne River spawning gravel enhancement sites. These sites will be used to monitor the importance of in-stream structure to physical and behavioral performance measures in spawning salmonids.

A. 4) Approach and scope of work:

Task 1: Project management. – Project management will include student supervision in the lab and field, coordination between agencies, data management, accounting and budget details, equipment procurement, and periodic progress reports. Outreach to the general public, special interest groups, and technical/scientific groups will be included under project management. Costs billed under project management will be used to reduce the coarse load (teaching load) of Tim Horner, and will provide 1 month of summer salary for each project year (see budget justification).

Task 2: Conduct redd surveys. During September-January each year, salmonid spawning surveys will be conducted weekly by EBMUD along the 16-km reach, including all available spawning habitat below Camanche Dam. Two to three surveyors will canoe and walk downstream searching for signs of redd construction (Merz and Setka 2004). Redd locations will be recorded using a hand-held Global Positioning System (GPS) unit (Trimble Pro XR) and a laser range finder (Atlanta Advantage). Location of each redd will be downloaded from the GPS unit into an ArcView (ESRI) coverage. Data will be saved into an ASCII file and translated to the grid-based graphics program mentioned above. In addition to being mapped, individual redds will be marked with a 115-mm plastic tag. Tags will be numbered and anchored to the substrate at the peak of each redd tailspill with a 216mm steel bolt with a 40 mm drywall toggle wing anchor to differentiate old redds from new during subsequent surveys and monitor scour of individual redds. Tags will be recovered the first week of the following annual redd survey (Merz and Setka 2004).

Physical data recorded with redds will include: depth at the upstream edge of the redd (redd depth); water velocity at 6 cm above the upstream edge of the redd (nose velocity); stream velocity (average of 20% and 80% of depth below surface); and dominant substrate types. Dominant substrates will be divided into 5 classes: 1) small gravel (4 - 32 mm), 2) medium gravel (33 - 50 mm), 3) large gravel (51 - 64 mm), 4) small cobble (65 - 130 mm) and 5) medium cobble (131 - 250 mm) (modified from Bovee and Milhous 1978). Any redd constructed in a site where its shape, depth, view from terrestrial predators, or associated turbulence is altered by debris or a boulder will be considered associated with structure (Merz 2001).

Task 3: Map locations of structure (LWD and boulders). — LWD has been defined as material as large as 30.5 cm diameter by 1.8 m length (CDFG 1994). However, debris with diameter >10 cm is more commonly cited in the literature as LWD and material 1-9cm in diameter is classified as small woody debris (SWD)(Keller and Swanson 1979; Flebbe and Dolloff 1995; Baillie et al. 1999). Merz (2001) simply defined Woody Debris (WD) in the LMR as any vegetative material with a diameter greater than 5 cm and length greater than 30 cm because this was the minimum size visible from aerial photographs (1:4800). During redd surveys (described above) a CSUS graduate student will document the location of debris and boulders using a hand-held GPS unit (Trimble Pro XR) and a laser range finder (Atlanta Advantage). Each object will be classified as: boulder (>256 mm; Bunte and Abt 2001), SWD (1-9cm diameter) or LWD (>9cm diameter). Location of each object will be downloaded from the GPS unit into an ArcView (ESRI) coverage. Data will be saved into an ASCII file and translated to the grid-based graphics program mentioned above.

Approximately 8-10 spawning gravel enhancement sites within the LMR will be used to evaluate specific location of structure and Chinook salmon redds. Sites will be mapped by aerial photograph, GPS and ground crews. Woody debris, introduced boulders, and redds will be noted for each site. Because the average area of a Chinook salmon redd is approximately 9 m^2 (Bjornn and Reiser 1991, Merz 2004), sites will separated into grids of 9-m^2 squares. Each square will be categorized as containing 1 or more redds within its boundaries and containing structure (SWD; LWD; Boulder) within its boundaries. If a redd is located in more than 1 square, it will be counted in the square that contained the majority of the redd (Merz 2001).

Task 4: Conduct behavioral studies. — Field crews will monitor the behavior of female Chinook salmon constructing redds adjacent to structure and redds away from structure following the methods described in Keenleyside and Dupuis (1987) and Healey et al. (2003). These surveys will be done from a overhead observation points along the river. Length of time to redd completion, residence time and survival on redd, aggression (charge and chase), digging, spawning and flight behavior will be recorded. Total time for each behavior and number of times specific behaviors are made during each 10 min interval will be noted. A Student's t-test will be used to compare lengths of specific behavior times for fish constructing redds associated with and not associated with structure. A chi-square analysis will be performed to compare the rates of various behavior phases for fish constructing redds associated with and not associated with structure.

Task 5: Characterize surface water flow near woody debris and boulders. — Field measurements will be used to examine several aspects of surface water flow near obstructions. These measurements will be conducted independently from the redd survey data collection described in Task 1.

Surface water is deflected around obstructions (woody debris and boulders), resulting in pressure and velocity changes. Velocity tends to decrease on the upstream and downstream sides of obstructions as flow is diverted. Conservation of mass dictates concomitant increases in velocity elsewhere, so it is common to find increased velocity at the top and sides of obstructions. These changes will be documented using Price and Pygmy AA current meters on a topset wading rod (Wilde and Radtke, 1999), and velocity will be profiled from top to bottom of the stream near each obstruction. Spawning salmon prefer shallow, high velocity spawning sites, with water depth less than 2 m and current velocity ranging from 0.3 – 1 m/s (Bjorn and Reiser, 1991). Changes in water velocity associated with obstructions will be documented to determine effects on spawning. These will include identifying low velocity refugia where the female spawners conserve energy, high velocity zones where increased shear stress and scour aid in redd construction, and low velocity zones where fine sediment is deposite.

Task 6: Characterize hyporheic flow near woody debris and boulders. — Velocity changes are associated with pressure changes, and this creates intergravel flow near obstructions (Morita and Horner, 2004). The conceptual model proposed by Hendricks and White (2002) is scalable from river reach to individual bedforms (White, 1990), and channel obstructions produce a similar effect (Figure 2). Increased pressure on the upstream side of an obstruction diverts water around the obstruction, but there is also an increase in subsurface flow through shallow, permeable gravels. These shallow, short flow paths are largely unknown or undocumented near LWD and boulders, and will be described by installing nested piezometers near a variety of obstructions (Figure 2). At least ten to fifteen obstructions will be studied in detail, with objects selected to represent different sizes and shapes of LWD and boulders. Pressure differences will be compared between piezometers, and flow paths will be identified. Upwelling and downwelling conditions have been cited as an important factor in spawning site selection (Barnard and McBain, 1998; Geist and Dauble, 1998), and these conditions will be compared to fish behavior. Upwelling and downwelling conditions and vertical head gradients will be measured using a bubble manometer board (Horner and Bush, 2000). This compares hydraulic head between the river and shallow depths in the gravel bar.

Sensitive electronic pressure transducers and data loggers will also be used in a subset of the instrumented sites to identify eddies and flow pulses near obstructions. Habitat stability (or instability) may be a factor near channel obstructions, and this small-scale variability will be described, using sampling rates of up to 10 times per second. High frequency variability near channel obstructions will be compared to flow pulses in nearby surface water that is more representative of background turbulence levels in the stream.

Task 7: Measure field parameters. — Field parameters are an excellent indicator of inter-gravel conditions, and will be used to identify mixing between surface water and hyporheic water near channel obstructions. Surface water is essentially saturated with dissolved oxygen, and dissolved oxygen decreases along short flow paths in the subsurface as a result of interaction with organic matter and mineral constituents (Horner et al., in review; Head and Horner, 2004;

Horner and Bush, 2000). Dissolved oxygen is especially important for spawning salmonids, because low DO in pore waters may be a limiting factor for egg survivability (Sowden and Power, 1985). In addition to direct survival, DO levels affect the rate of development (Silver et al. 1963; Brannon 1965; Wells and McNeil 1970), growth rate of embryos (Silver et al. 1963), and the size at emergence of alevins or fry (Silver et al. 1963; Shumway et al. 1964; Mason 1969). Variability in pore water dissolved oxygen content near channel obstructions may be a major factor in the influence of these objects. Quarterly field sampling events will be used to characterize these subsurface reactions. Measurements will include dissolved oxygen, pH, electrical conductivity (EC), and intergravel temperature. Surface water DO will be recorded, and compared to subsurface (pore water) DO levels using a YSI field meter, peristaltic pump and flow-through chamber. This technique minimizes contamination from atmospheric oxygen, and maintains appropriate flow velocity past the DO probe tip. Temperature will be measured with a Fluke thermocouple meter and type "K" thermocouple wire, inserted into the mini-piezometers. This gives accurate inter-gravel temperature during field sampling events. Vertical temperature profiles will be used as an alternate method for estimating the vertical flux of water (Alexander and Caissie, 2003; Constantz, 1998; Constanz et al. 1999).

Task 8: Data analysis and statistical methods. — Cross-sections and diagrams will be used to illustrate subsurface flow patterns, and the proportion of redds associate with upwelling and downwelling will be assessed. The presence and significance of turbulence and vortices will be noted for each feature, and given a stability index. Redd construction will also be related to current velocity, dissolved oxygen content in pore water, and other field parameters.
A chi-square analysis will be used to assess these relationships and the relationship between 1) WD association and redd substrate size; 2) the frequencies of redds and WD within the 8 to 10 enhancement sites (Zar 1996). A simple linear regression will be used to assess the relationship between 1) the proportion of redds associated with structure classification and average gradient in each reach and 2) proportion of newly constructed redds associated with WD and average weekly discharge from Camanche Dam. A Student's *t* will also be used to assess the relationship between WD association and 1) redd nose velocity; 2) stream velocity and 3) redd depth.

A. 5) Feasibility:

The proposed work is both feasible and appropriate given the expertise of the principle investigators and the two year time line outlined in this proposal. Field studies will be conducted under EBMUD permits for monitoring and evaluation of stream gravel augmentation projects. All work described in this project comes under the heading of monitoring or evaluation, and does not involve sampling or "take" of biological specimens. Land and river access are available through EBMUD, and there are no additional landowners or affected third parties.

A. 6) Expected outcomes and products:

Expected outcomes from this project include two peer-reviewed manuscripts, a student thesis, and presentations by both co-investigators in appropriated venues.

Peer-reviewed manuscripts will be split between the principal investigators based on their expertise. Redd survey data, behavioral studies and relation to LWD will be summarized by Joe

Merz, with contributions from Tim Horner and at least one un-named graduate student. Inter-gravel flow, physical characteristics of the substrate, and surface water flow patterns will be submitted by Tim Horner, with contributions from Joe Merz and the graduate student. Examples of appropriate journals would be, but are not limited to: The San Francisco Estuary and Watershed Science Journal; Canadian Journal of Fisheries and Aquatic Sciences; North American Journal Fisheries Management; River Research and Applications.

The graduate student selected for this project must complete a peer-reviewed thesis, based on this study, to graduate from a California State University campus. The student will work with his/her advisor to publish aspects of the completed thesis in an accredited journal.

All of the participants will present their work in appropriate venues, ranging from CALFED (and other) symposia, to American Fisheries Society and Geological Society of America meetings.

A. 7) Data handling, storage, and dissemination:

Data will be archived in a M.S. thesis, available to the general public in the CSUS Library. Copies of all public-domain, peer-reviewed abstracts and publications (see below) will be available as PDF files on the world wide web through the CSUS faculty/staff server. The project will also result in EBMUD internal documents and project reports that contain summaries of field data. Data will also be stored and disseminated in the refereed publications and presentations described in section A.6 (above).

A. 8) Public involvement and outreach:

Communication is an important part of this research project, and will be accomplished through a series of non-technical talks in community forums, presentations at meetings and other outreach efforts. Potential venues include, but are not limited to: the Lodi Park Docent group; Stockton Sportsman Group; Delta Fly-fishers; The Granite Bay Flyfishers; The technical and scientific community will be involved with the project through data dissemination methods outlined in part A. 6 (above).

A. 9) Work schedule:

Year 1: Work conducted during year one will establish field sites and begin the data collection process. EBMUD biologists, along with at least one un-named CSUS graduate student, will assess spawning patterns, identify and classify channel obstruction features, and document spawning behavior. The CSUS Geology Department, including at least one graduate student, will measure surface flow near obstructions, instrument obstructions with mini-piezometers, document subsurface flow paths, and measure field parameters. Initial data will be compile and analyzed during the summer months. Project management and student supervision will be an on-going task through year one. Preliminary results will be reported at an IEP-sponsored symposium, or at the AFS or GSA national meetings. Work schedules for year one are as follows:

Task	Time schedule
Task 1: Project management. Student supervision (including field work), outreach and public contact, compilation and dissemination of preliminary results, budget and management.	September 2005 – August 2006
Task 2: Conduct redd surveys. Work with EBMUD biologists to identify locations of redds, mark redds, transfer information to ArcView GIS coverage.	September 2005 – January 2006
Task 3: Map locations of structure (woody debris and boulders). Use high resolution GPS to map locations of woody debris and boulders, transfer information to ArcView GIS coverage.	September – October 2005
Task 4: Conduct behavioral studies. Observe spawning behavior from high vantage points: time for redd construction, aggression, time on redd, digging, spawning, flight, survival on redd.	October 2005 – January, 2006
Task 5: Characterize surface water flow near woody debris and boulders. Measure surface water flow near obstructions when river flows are similar to spawning conditions. Limited flow measurements will also be made during the spawning season.	January – June 2007
Task 6: Characterize hyporheic flow near woody debris and boulders. Install piezometers, measure pressure differences and hydraulic head near obstructions, characterize intergravel flow.	January – June 2006
Task 7: Measure field parameters. Begin quarterly sampling when piezometers are installed. Measure dissolved oxygen, pH, EC, and temperature in intergravel pore water and surface water.	November, February, May, August, 2006
Task 8: Data analysis and statistical evaluation. Compile field data, construct database, plot preliminary results.	July – August 2006

Year 2: Work conducted during year two will assemble a more robust data set, and complete the studies outlined in year one. Field work with EBMUD biologists and graduate student(s) will include redd surveys, behavioral assessment, and classification of channel obstruction features (boulders and woody debris). Individual features identified in year one will be tracked where possible. Additional surface flow measurements and characterization of hyporheic flow and field parameters will benefit from lessons learned during year one. This adaptive management style will allow modification of the project design to address unexpected findings or data collection issues encountered during year one. Tasks and work schedule are as follows:

Task	Time Schedule
Task 1: Project management. Student supervision (including field work), public outreach and dissemination of final results, budget and management.	September 2006 – August 2007
Task 2: Conduct redd surveys. Work with EBMUD biologists to identify locations of redds, mark redds, transfer information to ArcView GIS coverage.	September 2006 – January 2007

Task 3: Map locations of structure (woody debris and boulders). Use high resolution GPS to map locations of woody debris and boulders, transfer information to ArcView GIS coverage. Previously identified features will be tracked where possible.	September – October 2006
Task 4: Conduct behavioral studies. Observe spawning behavior from high vantage points: time for redd construction, aggression, time on redd, digging, spawning, flight, survival on redd.	October 2006 – January, 2007
Task 5: Characterize surface water flow near woody debris and boulders. Measure surface water flow near obstructions (when river flows are similar to spawning conditions). Limited measurements will also be made during the spawning season.	January – June 2006
Task 6: Characterize hyporheic flow near woody debris and boulders. Repair or re-install piezometers as necessary, measure pressure differences and hydraulic head near obstructions, continue to characterize intergravel flow.	January – June 2007
Task 7: Measure field parameters. Continue quarterly sampling in piezometers located near channel obstructions. Measure dissolved oxygen, pH, EC, and temperature in intergravel pore water and surface water.	February, May, August, 2007
Task 8: Data analysis and statistical methods. Compile field data, add to database, plot final results, student will produce thesis.	July – August 2007

B. Applicability to CALFED Bay-Delta program ERP goals, ERP Draft Stage 1 implementation plan, and CVPIA priorities:

B. 1) Applicability to ERP and CVPIA priorities:

a. ERP: This project will be applicable to various ERP priorities by elucidating the effects of hyporheic habitat quality on salmonids:

The proposed project is directly relevant to the following specific goals of CALFED's Ecosystem Restoration Program:

? *Recover 19 at-risk native species and contribute to the recovery of 25 additional species.*

Fall-run Chinook salmon will be used to examine physical and behavioral performance measures near woody debris. This will transfer directly to Winter and Spring Chinook runs and Winter Steelhead runs. These at-risk species have almost identical spawning habits to the Fall-run population examined in this project, and the potential benefits of in-stream structure are the same. If significant benefits are found for in-stream structure, future projects that deal with the recovery of at-risk species can be designed to include appropriate woody debris and boulders.

? *Rehabilitate natural processes related to hydrology, stream channels, sediment, floodplains and ecosystem water quality.*

Woody debris and in-stream features were an important part of the ecosystem before humans altered the system. This ERP rehabilitation goal will be addressed by quantifying the importance of in-stream structure during spawning. Performance indicators will be identified, and will be transferable to other projects. Higher spawning use, physical measurements and behavioral differences will be used as performance indicators to evaluate the importance of channel obstructions in rehabilitation projects.

? *Protect and restore functional habitats, including aquatic, upland and riparian, to allow species to thrive.*

Functional spawning habitats should include appropriate structure and diversity. Objective evaluation of performance measures will evaluate the importance of channel obstructions, and this will be related to natural spawning densities in the Mokelumne river. Publication of the comprehensive interpretive reports planned as part of the proposed work will allow this understanding to be transferred to other Sierra Nevada watersheds.

? *Improve and maintain water and sediment quality to better support ecosystem health and allow species to flourish*

The additional data and data interpretation of the effects of in-stream structure that will result from this project will provide useful information to scientists responsible for improving and maintaining water and sediment quality in the ecosystem. Again, this has great transfer value to other watersheds of concern.

b. CVPIA: Several CVPIA goals are addressed by this project. The project is directly applicable to the doubling goal of CVPIA sections 3406(b)(1) and the gravel replenishment goal of 3406(b)(13). The CVPIA goal outlined in section 3402a also seeks to protect, restore and enhance fish, wildlife and associated habitats in the Central Valley. These goals will be met by identifying habitat issues associated with woody debris and in-stream boulders, and their effects on spawning.

B. 2) Relationship to other ecosystem restoration actions, monitoring programs, or system-wide ecosystem benefits:

Work described in this proposal will go beyond restoration actions that deal only with construction phase actions, and will add a new and critical piece of information about diversity of in-stream habitat in gravel enhancement projects. Simple performance measures from this project will be applicable to other restoration efforts that deal with in-stream habitat diversity, so there are important implications to ecosystem restoration projects outside of the Mokelumne River area.

Since the early 1970s, numerous projects have been undertaken to ameliorate anthropogenic impacts on indigenous salmonid populations and their habitats (House 1996; Scruton et al. 1997). Salmonid spawning habitat rehabilitation has received increasing attention as a tool to enhance dwindling California populations (Buer et al. 1981, Kondolf and Mathews 1993, CDWR 2002), but these rehabilitation projects are usually front-loaded to emphasize the design aspects of the project. In the Central Valley of California, 73 spawning habitat rehabilitation projects on 19 different rivers were conducted between 1976 and 1999, but their success has been poorly evaluated (Kondolf et al. 1996; Wheaton 2003). Wheaton (2003) developed a systematic approach to designing salmon spawning habitat rehabilitation projects using spawning bed enhancement, but this approach did not include detailed project evaluation and monitoring. Merz and Setka (2004) showed that spawning bed enhancement not only attracted spawning salmon to previously unused areas, but improved intergravel physical parameters associated with spawning and embryo development. Spawning bed enhancement has been shown to benefit non-target aquatic fauna as well (Merz and Chan 2004).

In spite of these studies of project construction and physical conditions, there is a scarcity of information about how well projects mitigate for degraded spawning habitat or improve survival of developing embryos (Roni et al. 2002). According to the University of California Berkeley (http://www.cnr.berkeley.edu/forestry/woody.html), lack of LWD may be the most critical limiting factor in restoring salmonid habitat in North Coast watersheds. Lack of large wood and its impact on the transport of sediment are items commonly raised in cumulative impact analyses in timber harvesting plans. Despite this recognition, there is no universally accepted work plan to provide for an overall strategy to determine the significance of and to restore and maintain LWD. To our knowledge, none of these projects have completed a detailed analysis of the small-scale effects of woody debris and boulders on salmonid spawning habitat. Benefits of woody debris and boulders in restoration projects are speculated but not documented, and additional project costs to add these features may be hard to justify given the navigational and flood conveyance hazards. We propose to address these questions, and make results available to future restoration projects.

C. Qualifications:

Joe Merz (EBMUD) and Tim Horner (CSUS Geology Department) will co-advise the graduate student funded by this project, and will share technical and management roles. Both principal investigators will be involved with field work. Fish behavior studies, river access, and review of gravel enhancement site data will be coordinated by Joe Merz, and surface water and hyporheic flow studies will be supervised by Tim Horner. Tim Horner will be responsible for fiscal reporting and budget management, with administrative and payroll assistance from the CSUS Foundation.

Tim Horner is an Associate Professor in the Geology Department at CSU Sacramento, and has been a member of the department since 1993. He graduated from The Ohio State University in 1992 with a Ph.D. in Geology, and specializes in ground water/surface water interaction, physical and geochemical conditions in salmonid spawning habitat, field instrumentation, and near-surface water geochemistry. He teaches undergraduate and graduate hydrogeology classes at CSUS, and has advised 34 senior thesis projects that deal with local hydrogeology and sedimentology. Tim currently has six M.S. students working on thesis projects that deal with ground water/ surface water interaction. He has taught portions of groundwater short courses for the US Army Corps of Engineers and US Forest Service, and has co-led field trips for the Association of Engineering Geologists, Lower American River Task Force, and National Research Council River Science Review Panel. His work for the past three years has focused on gravel restoration sites on the American River, with emphasis on physical and geochemical conditions that relate to salmon spawning habitat. These projects have been funded by the US Bureau of Reclamation and CVPIA. A draft report of the first year spawning gravel study is available at: http://www.csus.edu/indiv/h/hornert/, and is *in review* for the California Department of Fish and Game Stream Evaluation Program Technical Publication Series (Horner et al, in review). Relevant presentations on local ground water issues include Horner (2004), Head and Horner (2004), Morita and Horner (2004), Horner and Bush (2000), Bush and Horner (2000) and Horner and Fahning (1997). Tim Horner's experience extends to grant writing and project management, and he has conducted several relevant hydrogeology projects:

2004/2005: Research grant from US Bureau of Reclamation and CVPIA for $97,390 for *Habitat suitability of Spawning Gravels on the Lower American River*.

2003/2004: Research grant from US Bureau of Reclamation and CVPIA for $103,000 for *Evaluation of American River Spawning Gravels*.

2002/2003: Research grant from US Bureau of Reclamation and CVPIA, for $98,000 to evaluate *Gravel quality in recently restored salmon spawning gravels on the lower American River.*

2001/2003: Key participant and contributing author for $400,000 grant from W.M. Keck Foundation for *Proposal to establish the W.M. Keck Foundation Facilities for applied hydrogeology at California State University, Sacramento.*

1999/2001: Lead author on NSF CCLI A&I grant for $105,152 titled *Water quality and stream flow as teaching tools in geology*.

1996/97: Co-author on $221,000 grant from W.M. Keck Foundation to *Establish Laboratories for hydrogeologic studies.*

Joe Merz (EBMUD) is collaborator and advisor to this project. Joe is a Fisheries Biologist with East Bay Municipal Utility District and a part-time faculty member with the Environmental Studies Department at California State University, Sacramento. He received his Bachelor of Science in Environmental and Systematic Biology from California Polytechnic State University, San Luis Obispo in 1991, followed by an MS in Conservation Biology from California State University, Sacramento in 1994 and a Ph.D. in Conservation Ecology from the University of California, Davis in 2004. Joe has considerable experience as a freshwater fisheries and aquatic ecology specialist. He has taught professional courses in salmonid biology and spawning habitat restoration. In the past 10 years, he has performed fish and benthic macroinvertebrate community and fish dietary studies on several California streams, including the American and Mokelumne rivers. He has been responsible for Chinook salmon and steelhead spawning habitat enhancement on the lower Mokelumne River and has extensive local knowledge relating to the proposed project site. Joe has performed sediment transport and salmonid ecology experiments on gravel augmentation sites on several Central Valley streams.

Professional Experience
Fisheries Biologist II, East Bay Municipal Utility District (1996-)
Part-time Faculty, Environmental Studies, California State University, Sacramento (2001-)
Part-time Faculty, University of California, Davis Extension (2001-)
Pesticide Use Specialist, California Department of Pesticide Regulation (1995 – 1996)
Aquatic Ecologist, ENTRIX INC. (1993 – 1996)
Contract Biologist, California Department of Fish and Game (1991 – 1994)

PUBLICATIONS IN REFEREED JOURNALS

Merz, J.E. 2002. Seasonal feeding habits of steelhead trout in the lower Mokelumne River, California. California Fish and Game 88(3) 95-111.

________ 2002. Comparison of prickly sculpin and juvenile fall-run Chinook salmon diets in the lower Mokelumne River, California. South Western Naturalist 47(2):195-204.

________ 2001. Association of fall-run Chinook salmon redds and woody debris in the lower Mokelumne River, California. California Fish and Game 87(2).

________ 2001. Diet of juvenile fall-run Chinook salmon in the lower Mokelumne River, California. California Fish and Game 87(3).

________, and W. R. Merz. 2004. Morphological features used to identify Chinook salmon sex during fish passage. South Western Naturalist 49(2): 1-12.

________, and L.K. Ochicubo-Chan. 2004. Effects of Gravel Augmentation on Macroinvertebrate Assemblages in a Regulated California River. River Research and Applications 21:1-14.

________, and J. D. Setka. 2004. Evaluation of a spawning habitat enhancement site for Chinook salmon in a regulated California River. North American Journal of Fisheries Management 24:397-407.

________, J. D. Setka, G.B. Pasternack and J.M. Wheaton. 2004. Predicting benefits of spawning habitat rehabilitation to salmonid (*Oncorhynchus spp*.) fry production in a regulated California river. Canadian Journal of Fisheries & Aquatic Sciences 61:1433-1446.

________, and C. D. Vanicek. 1996. Comparative feeding habits of juvenile Chinook salmon, steelhead, and Sacramento squawfish in the lower American River, California. California Fish and Game 82(4):149-159.

Pasternack, G. B., C. L. Wang and J. E. Merz. 2004. Application of a 2D hydrodynamic model to design of reach-scale spawning gravel replenishment on the Mokelumne River, California. River Research and Applications 20(2):205-225.

Wheaton, J.M., G. B. Pasternack and J. E. Merz. 2004. Spawning habitat rehabilitation – II. Using hypothesis development and testing in design, Mokelumne River, California, U.S.A. International Journal of River Basin Management 1(4):1-17.

D. Cost:

1) Budget- Total cost for the two year project is $184, 716. See website budget forms for detail.

2) In-kind contributions: Support from CSUS and EBMUD will allow the project to proceed as planned, although this is not technically an “in-kind” contribution. Tim Horner and the un-named graduate student will use field equipment provided by CSUS. The CSUS contribution will include instruments that measure field parameters (pH, dissolved oxygen, turbidity and conductivity), current velocity meters, data loggers and pressure transducers, Terhune-style standpipes, high-resolution real-time GPS, and subsidized vehicle costs (0.30 per mile, as charged in budget). Joe Merz and EBMUD will provide project oversight and review, including instruction on observations that deal with fish monitoring behavior, water quality data, spawning escapement and redd enumeration and location. These contributions are part of on-going monitoring efforts at the gravel enhancement sites, and will not be billed to the project.

3) Long-term funding strategy: Not applicable. The two year study described in this proposal will provide baseline data about the influence of woody debris and obstructions on spawning behavior and hyporheic flow, and will be applicable to other restoration projects without additional work.

E. Compliance with standard terms and agreements:

CSU Sacramento is part of the California State University system, and will abide by previously negotiated standard terms and agreements at the state and federal level.

G. Literature cited:

Alexander, M.D., and F. Caissie. 2003. Variability and comparison of hyporheic water temperatures and seepage fluxes in a small Atlantic salmon stream. Ground water **41**(1):72-82.

Anderson, N.H., J.R. Sedell, L. M. Roberts, and F. J. Triska. 1978. The role of aquatic invertebrates in processing wood debris from coniferous forest streams. American Midland Naturalist **100**:64-82.

AFRP (Anadromous Fish Restoration Program). Revised Draft Restoration Plan for the Anadromous Fish Restoration Program. United States Fish and Wildlife Service. Sacramento, California, USA.

Baillie, B. R., T. L. Cummins, and M. O. Kimberley. 1999. Measuring woody debris in the small streams of New Zealand's pine plantations. New Zealand Journal of Marine and Freshwater Research **33**: 87-97.

Barrow, S., and M. Heisdorf. 2001. California Living Marine Resources: A Status Report. California Department of Fish and Game. Sacramento, California, USA.

Beacham, T.D., C.B. Murray, and R.E. Withler. 1988. Age, morphology, developmental biology, and biochemical genetic variation of Yukon River fall chum salmon, Oncorhynchus keta, and comparisons with British Columbia populations. Fishery Bulletin **86**:663-673.

Beacham, T.D. and C.B. Murray. 1987. Adaptive variation in body size, age, morphology, egg size, and developmental biology of chum salmon, Oncorhynchus keta, in British Columbia. Canadian Journal of Fisheries and Aquatic Science **44**:244-261.

Bisson, P.A. and 8 others. 1987. Large woody debris in forested streams in the Pacific Northwest: Past, present, and future. Contribution No. 57. Pages 143-190 *in*: E. Salo and T. Cundy, editors. Proceeding of a symposium on streamside management: Forestry and fisheries interactions. University of Washington, Seattle, Washington, USA.

Bjornn, T.C. and D.W. Reiser. 1991. Habitat requirements of salmonids in streams. Pages 83-138 *in*: W.R. Meehan, editor. Influences of forest and rangeland management on salmonid fisheries and their habitats. Special Publication 19, American Fisheries Society, Bethesda, Maryland, USA.

Bovee, K.D. and R. Milhous. 1978. Hydraulic simulation in instream flow studies: Theory and techniques. Instream Flow Information Paper No. 5, U.S. Fish and Wildlife Service, Fort Collins, Colorado, USA.

Brannon, E.L. 1965. The influence of physical factors on the development and weight of sockeye salmon embryos and alevins. International Pacific Salmon Fisheries Commission Progress Report. 1-12.

Bryant, M.D. 1983. The role and management of woody debris in west coast salmonid nursery streams. North American Journal of Fisheries Management **3**(3): 322-330.

Bush, N.J., and T. C. Horner. 2000. abs., Permeability and near-surface water chemistry of a salmon spawning gravel bar in the American River, Sacramento: CalFed Bay-Delta Science Conference 2000, Oct. 3-5, Sacramento Convention Center: 163.

Bunte, K. and S.R. Abt. 2001. Sampling surface and subsurface particle-size distributions in wadable gravel- and cobble-bed streams for analyses in sediment transport, hydraulics, and streambed monitoring. United States Department of Agriculture, Forest Service Rocky Mountain Research Station. General Technical Report RMRS-GTR-74.

Burns, J. W. 1971. The carrying capacity for juvenile salmonids in some northern California streams. California Fish Game **57**:44-57.

Cederholm, C. J., M. D. Kunze, T. Murota, and A. Sibatani. 1999. Pacific Salmon Carcasses: Essential Contributions of Nutrients and Energy for Aquatic and Terrestrial Ecosystems. Fisheries **24**:6-15.

CDC (California Department of Conservation). 1988. Mineral land classification of Portland cement concrete aggregate in the Stockton-Lodi production-consumption Region. Special Report 160. Division of Mines and Geology, Sacramento, California.

CDFG (California Department of Fish and Game) 1994. California salmonid stream habitat restoration manual. Second Edition. State of California Resources Agency. Department of Fish and Game. Sacramento, California, USA.

CDFG (California Department of Fish and Game). 1959. The Influences of Proposed Water Projects on the Fisheries of the Lower Mokelumne River; Amador, Calaveras, and San Joaquin counties. Sacramento, California.

Chaloner, D. T., K. M. Martin, M. S. Wipfli, P. H. Ostrom, and G. A. Lamberti. 2002. Marine carbon and nitrogen in southeastern Alaska food webs: evidence from artificial and natural streams. Canadian Journal of Fisheries and Aquatic Sciences **59**:1257-1265.

Clark, G. H. 1929. Sacramento River salmon fishery. California Fish and Game **15**:1-10.

Constantz, J. 1998. Interaction between stream temperature, streamflow, and groundwater exchanges in alpine streams. Water Resources Research. **34**:1609-1615.

Constantz, J., R. Niswonger, and A.E. Stewart. 1999. The use of heat as a tracer to estimate recharge beneath streams and artificial recharge ponds,pages 193-203. *in* R.D. Barlett, editor, Artificial recharge of groundwater. American Society of Civil Engineers.

Estey, D. F. 1989. Mokelumne River Hatchery Annual Report 1987-88. Inland Fisheries Administrative Report 89-3. California Department of Fish and Game, Sacramento, California.

Everest, F.H. and W.R. Meehan. 1981. Forest management and anadromous fish habitat productivity. Pages 521-530 *in*: Transactions of the 46th North American Wildlife and Natural Resources Conference. The Wildlife Management Institute, Washington, D.C. USA.

Farley, T. 1993. Restoring Central Valley Streams: A plan for action. California Department of Fish and Game. Sacramento, California, USA.

Finlayson, B. J., and H. J. Rectenwald. 1978. Toxicity of copper and zinc from the Penn Mine area on king salmon (Oncorhynchus tshawytscha) and steelhead trout (Salmo gairdneri) in the Mokelumne River Basin, California. Environmental Services Branch Report No. 78-1. California Department of Fish and Game, Rancho Cordova, California.

Flebbe, P. A. and C. A. Dolloff. 1995. Trout use of woody debris and habitat in Appalachian wilderness streams of North Carolina. North American Journal of Fisheries Management **15**:579-590.

Fuller, D.D. 1990. Seasonal utilization of instream boulder structures by anadromous salmonids in Hurdygurdy Creek, California. Fish Habitat Relationship Technical Bulletin No. 3, U.S. Department of Agriculture, Washington, D.C., USA.

Geist, D.R., and D.D. Dauble. 1998. Redd site selection and spawning habitat use by fall Chinook salmon: the importance of geomorphic features in large rivers. Environmental Management **22**:655-669.

Harmon, M. E., J. E. Franklin, F. J. Swanson, P. Sollins. S. V. Gregory, J. D. Lattin, N. H. Anderson, S. P. Cline, N. G. Aumen, J. R. Sedell, G. W. Lienkaemper. K. Cromack, Jr., and K. W. Cummins. 1986. Ecology of coarse woodv debris in temperate ecosystems. Adv.Ecol. Res. **15**:133-302.

Head, A.E., and T.C. Horner. 2004. abs., Steelhead redds and evolution of inter-gravel dissolved oxygen levels in the Lower American River. 3rd Biennial Calfed Bay-Delta Program, Science Conference Abstracts. 202.

Healey, M.C., R. Lake, and S.G. Hinch. 2003. Energy expenditures during reproduction by sockeye salmon (*Oncorhynchus nerka*). Behavior **140**:161-182.

Helfield, J. M., and R. J. Naiman. 2002. Salmon and alder nitrogen sources to riparian forests in a boreal Alaskan watershed. Oecologia **133**:573-582.

Helfield, J.M., and R.J. Naiman. 2001. Effects of salmon-derived nitrogen on riparian forest growth and implications for stream productivity. Ecology **82**:2403-2409.

Hendricks, S.P., and D.S. White. 2000. Stream and groundwater influences on phosphorus biogeochemistry. pages 221-235 *in:* J.B. Jones and P.J. Mullholland, editors, Streams and Ground Waters. Academic Press. San Diego, California, USA.

Hilderbrand, G. V., T. A. Hanley, C. T. Robbins, and C. C. Schwartz. 1999. Role of brown bears (*Ursus arctos*) in the flow of marine nitrogen into a terrestrial ecosystem. Oecologia **121**:546-550.

Hinch, S.G., and P.S. Rand. 2000. Optimal swimming speeds and forward-assisted propulsion: energy-conserving behaviours of upriver-migrating adult salmon. Canadian Journal of Fisheries and Aquatic Sciences **57**(12): 2470-2478.

Horner, T. C., R.Titus, and M. Brown. in review. Phase 3 Gravel Assessment on the Lower American River. California Department of Fish and Game, Stream Evaluation Program Technical Publication Series, 93 pp. available at: http://www.csus.edu/indiv/h/hornert/

Horner, T.C., 2004. abs., Hyporheic flow, pore water geochemistry and bar form influence on salmonid spawning in the American River, California. Geological Society of America Abstracts with Programs **36**(5): 565.

Horner, T.C., and Bush, N.J., 2000. abs., Small scale gain and loss and geochemical variability of pore water in the hyporheic zone of a gravel bar used for salmon spawning in the

American River, California. Geological Society of American Abstracts with Programs **32**(7): 141.

Horner, T.C., and R.M. Fahning. 1997. abs., Stream bed permeability and bank storage in the American River near Sacramento, California: Geological Society of America Abstracts with Programs **29**(6):334.

House, R. 1996: An Evaluation of Stream Restoration Structures in a Coastal Oregon Stream, 1981–1993. North American Journal of Fisheries Management **16**(2):272–281.

House, R.A., and P.L. Boehne. 1986. Effects of Instream structures on salmonid habitat and populations in Tobe Creek, Oregon. North American Journal of Fisheries Management **6**:38-46.

House, R. and V. Crispin. 1990. Economical analysis of the value of large woody debris as salmonid habitat in coastal Oregon streams. United States Department of Interior, Bureau of Land Management Technical Note OR-7, Portland, Oregon, USA.

Keenleyside, M.H.A., and H.M.C. Dupuis. 1988. Courtship and spawning competition in pink salmon (*Oncorhynchus gorbuscha*). Canadian Journal of Zoology **66**:262-265.

Keller, E. A. and F. J. Swanson. 1979. Effects of large organic material on channel form and fluvial processes. Earth Surface Processes and Landforms **4**:361-380.

Kondolf, G. M. 2000. Some suggested guidelines for geomorphic aspects of anadromous salmonid habitat restoration proposals. Restoration Ecology **8**(1):48-56.

Kondolf, G. M. 1997. Hungry water: Effects of dams and gravel mining on river channels. Environmental Management **21**:533-551.

Kondolf, G. M., M. Smeltzer, and L. Kimball. 2001. Freshwater Gravel Mining and Dredging Issues. Center for Environmental Design and Research. Washington Department of Fish and Wildlife. Washington Department of Ecology. Washington Department of Transportation, Berkeley, CA, pp. 130.

Kondolf, G. M., J. C. Vick, and T. M. Ramirez. 1996. Salmon spawning habitat rehabilitation on the Merced, Tuolumne, and Stanislaus Rivers, California: An evaluation of project planning and performance. University of California Water Resources Center. Report Number 90. ISBN 1-887192-04-2. 147 pages.

Kondolf, G. M., and M. G. Wolman. 1993. The Sizes of Salmonid Spawning Gravels. Water Resources Research **29**:2275-2285.

Langler, G.J., and C. Smith. 2001. Effects of habitat enhancement on 0-group fishes in a lowland river. Regulated Rivers: Research and Management **17**:677-686.

Larkin, G. A., and P. A. Slaney. 1997. Implications of trends in marine-derived nutrient influx to south coastal British Columbia salmonid production. Fisheries **22**:16-24.

Mason, J.C. 1969. Hypoxial stress prior to emergence and competition among coho salmon fry. Journal of the Fisheries Research Board of Canada. **26:**63-91.

Merz, J. E. 2004. Spawning Habitat Enhancement For Pacific Salmon (Oncorhynchus spp.) In A Regulated River. PhD. Dissertation. Department of Conservation Ecology, University of California, Davis.

Merz, J. E. 2002. Seasonal feeding habits, growth, and movement of steelhead trout in the lower Mokelumne River, California. California Fish and Game **88**(3):95-111.

Merz, J.E., and L. K. Chan. 2004. Effects of gravel augmentation on macroinvertebrate assemblages in a regulated California river. River Research and Applications. **21**:1-14.

Merz, J. E., and J. D. Setka, J. D. 2004. Evaluation of a spawning habitat enhancement site for Chinook salmon in a regulated California river. North American Journal of Fisheries Management.

Minakawa, N., and R. I. Gara. 2003. Effects of Chum Salmon Redd Excavation on Benthic Communities in a Stream in the Pacific Northwest. Transactions of the American Fisheries Society **132**(3): 598-604.

Morita, E.T., and T.C. Horner. 2004. abs., Streambed topography and its influence on hyporheic flow in salmon spawning gravels, American River. 3rd Biennial Calfed Bay-Delta Program, Science Conference Abstracts. 341.

Mundie, T.R. 1974. Optimization of the salmonid nursery stream. Journal of the Fisheries Research Board of Canada **31**:1827-1837.

O'Keefe, T.C., and R. T. Edwards. 2003. Evidence for hyporheic transfer and removal of marine-derived nutrients in a sockeye stream in southwest Alaska. American Fisheries Society Symposium **34**:99-107.

Pasternack, G. B., C. L. Wang, and J. E. Merz. 2004. Application of a 2D Hydrodynamic Model to Reach-Scale Spawning Gravel Replenishment on the lower Mokelumne River, California. River Research and Applications **20**:205-225.

Reynolds, F. L., R. L. Reavis and J. Schuyler. 1990. Central Valley salmon and steelhead restoration and enhancement plan. California Department of Fish and Game, Sacramento, California.

Roni, P., T. J. Beechie, R. E. Bilby, F. E. Leonetti, M. M. Pollock, and G. R. Pess. 2002. A Review of Stream Restoration Techniques and a Hierarchical Strategy for Prioritizing Restoration in Pacific Northwest Watersheds. North American Journal of Fisheries Management. **22**:1–20.

Schmetterling, D.A., and R.W. Pierce. 1999. Success of instream habitat structures after a 50-year flood in Gold Creek, Montana. Restoration Ecology **7**(4):369-375.

Sedell, J.R., P.A. Bisson, J.A. June, and R.W. Speaker. 1982. Ecology and habitat requirements of fish populations in South Fork Hoh River, Olympic National Park. Pages 47-63 *in*: E. Starkey, editor. Ecology research in national parks of the Pacific Northwest. Forest Research Laboratory, Oregon State University. Corvallis, Oregon, USA.

Silver, S.J., C.E. Warren, and P. Doudoroff. 1963. Dissolved oxygen requirements of developing steelhead trout and Chinook salmon embryos and different water velocities. Transactions of the American Fisheries Society. **92**:327-343.

Shumway, D.L, C.E. Warren, and P. Doudoroff. 1964. Influence of oxygen concentration and water movement on the growth of steelhead trout and coho salmon embryos. Transactions of the American Fisheries Society. **93:**342-356.

Sowden, T.K., and G. Power. 1985. Prediction of Rainbow Trout embryo survival in relation to groundwater seepage and particle size of spawning substrates. Transactions of the American Fisheries Society. **114**:804-812.

Thompson, D. M. 2002. Long-term effect of instream habitat-improvement structures on channel morphology along the Blackledge and Salmon rivers, Connecticut, USA. Environmental Manual.

Ward, B.R. and P.A. Slaney. 1979. Evaluation of instream enhancement structures for the production of juvenile steelhead trout and coho salmon in the Keogh River: progress 1977 and 1978. Fisheries Technical Circular 45, Ministry of the Environment, Fish and Wildlife Branch, Vancouver, British Columbia, Canada.

Ward, B.R. and P.A. Slaney. 1981. Further evaluations of structures for the improvement of salmonid rearing habitat in coastal streams of British Columbia, in: T. Hassler editor. Proceedings: Propagation, enhancement and rehabilitation of anadromous salmonid populations and habitat symposium. Humbolt State University, Arcata, California, USA.

Wells, R.A., and W. J. McNeil. 1970. Effect of quality of the spawning bed on the growth and development of pink salmon embryos and alevins. U.S. Fish and Wildlife Service Special Scientific Report-fisheries. 616 p.

Wheaton, J. M. and Pasternack, G. B. 2002. The integrated design approach to designing in-stream spawning habitat enhancement projects- a case study on the Mokelumne River. University of California. 100 pp.

Wheaton, J. M., G. B. Pasternack and J. E. Merz. 2004a. Spawning Habitat Rehabilitation - II. Hypothesis Testing in Design on the Mokelumne River, California, U.S.A. International Journal of River Basin Management, **2**(1), 21-37.

Wheaton, J. M., G. B. Pasternack and J. E. Merz. 2004b. Spawning Habitat Rehabilitation - I. Conceptual Approach and Methods, International Journal of River Basin Management, **2**(1), 3-20.

White, D.S., 1990. Biological relationships to convective flow patterns within stream beds. Hydrobiologia **196**:149-158.

Wilde, F.D., and Radtke, D.B., 1999, Chapter A6. Field Measurements, in Wilde, F.D., Radtke, D.B., Gibs, J., and Iwatsubo, R.T., eds., Techniques of Water Resources Investigations Handbook for Water Resources Investigations Book 9, National Field Manual for the Collection of Water Quality Data: Washington, U.S. Geological Survey, p. T1-T15.

Wipfli, M. S., J. P. Hudson, J. P. Caoette, and D. T. Chaloner. 2003. Marine subsidies in freshwater ecosystems: salmon carcasses increase the growth rates of stream-resident salmonids. Transactions of American Fisheries Society **132**:371-381.

Yoshiyama, R. M., F. W. Fisher, and P. B. Moyle. 1998. Historical abundance and decline of Chinook salmon in the Central Valley region of California. North American Journal of Fisheries Management **18**: 487-521.

Yoshiyama, R. M., E. R. Gerstung, F. W. Fisher, and P. B. Moyle. 2000. Chinook salmon in the California Central Valley: an assessment. Fisheries **25**:6-20.

Yoshiyama, R. M., E. R. Gerstung, F. W. Fisher, and P. B. Moyle. 2001. Historical and present distribution of Chinook salmon in the Central Valley drainage of California. Pages 71-176 *in* R. L. Brown Editor. Contributions to the biology of Central Valley salmonids. Fisheries Bulletin - California Department of Fish Game **179**:71-176.

Zar, J. H. 1996. Biostatistical analysis. Third ed. Prentice Hall, Upper Saddle River, New Jersey.

Tasks And Deliverables

Effects of structural enhancement on salmonid spawning

Task ID	Task Name	Start Month	End Month	Deliverables
1	Project Management	1	24	**Semiannual and final reports, outreach presentations, periodic invoices**
2	**Conduct redd surveys**	**1**	**17**	**Maps in GIS format showing distribution of redds. Similar surveys will be conducted in year 2.**
3	**Map locations of structure**	**1**	**14**	**GIS format maps of woody debris and boulder locations. Similar surveys will be conducted in year 2.**
4	**Conduct behavioral studies**	**2**	**17**	**Tables of time spent for redd construction, aggression, digging, spawning, time on redd, flight and time to mortality.**
5	**Characterize surface flow near woody debris and boulders**	**5**	**22**	**Maps and cross sections of stream velocity profiles and turbulence near channel**

				obstructions.
6	Characterize hyporheic flow near woody debris and boulders	5	22	Maps and tables of upwelling and downwelling conditions (vertical gradient)at instrumented sites.
7	Measure field paramters	3	24	Tables and maps of dissolved oxygen content in gravel near channel obstructions and nearby background areas.
8	Data analysis and statistical evaluation	11	24	Produce database and evaluate results (statistical comparisons)

Comments

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

"Start month" and "end month" for tasks and deliverables are described in more detail in the text (section A.9 Work schedule).

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
$90,774	**$16,602**	**$17,710**	**$9,510**	**$0**	**$9,400**	**$0**	**$0**	**$143,996**	**$44,780**	**$188,776**

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?

Effects of structural enhancement on salmonid spawning

Effects of structural enhancement on salmonid spawning

Year 1 (Months 1 To 12)

Task	Labor	Benefits	Travel	Supplies And Expendables	Services And Consultants	Equipment	Lands And Rights Of Way	Other Direct Costs	Direct Total	Indirect Costs	Total
	3106	1012	2400	300	0	0	0	0	$6,818	1533	$8,351

1: project management (12 months)											
2: Conduct redd surveys (12 months)	**5117**	**677**	**909**	**480**	**0**	**0**	**0**	**0**	$7,183	**2299**	$9,482
3: Map locations of structure (12 months)	**3033**	**491**	**432**	**0**	**0**	**0**	**0**	**0**	$3,956	**1266**	$5,222
4: Conduct behavioral studies (11 months)	**5117**	**677**	**717**	**0**	**0**	**0**	**0**	**0**	$6,511	**2083**	$8,594
5: Characterize surface flow near woody debris and boulders (8 months)	**3983**	**794**	**768**	**0**	**0**	**0**	**0**	**0**	$5,545	**1774**	$7,319
6: Characterize hyporheic flow near woody debris and boulders (8 months)	**12766**	**2165**	**2304**	**4050**	**0**	**6400**	**0**	**0**	$27,685	**8859**	$36,544
7: Measure field paramters (10 months)	**6699**	**1184**	**765**	**400**	**0**	**1500**	**0**	**0**	$10,548	**3375**	$13,923
8: Data analysis and statistical evaluation (2 months)	**5566**	**1301**	**560**	**800**	**0**	**0**	**0**	**0**	$8,227	**2633**	$10,860
Totals	**$45,387**	**$8,301**	**$8,855**	**$6,030**	**$0**	**$7,900**	**$0**	**$0**	**$76,473**	**$23,822**	**$100,295**

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
1: project management (12 months)	3106	1012	2400	300	0	0	0	0	$6,818	1533	$8,351
2: Conduct redd surveys (5 months)	5117	677	909	480	0	0	0	0	$7,183	2299	$9,482
3: Map locations of structure (2 months)	3033	491	432	0	0	0	0	0	$3,956	1266	$5,222
4: Conduct behavioral studies (5 months)	5117	677	717	0	0	0	0	0	$6,511	2083	$8,594
5: Characterize surface flow near woody debris and boulders (10 months)	3983	794	768	0	0	0	0	0	$5,545	1774	$7,319
6: Characterize hyporheic flow near woody debris and boulders (10 months)	12766	2165	2304	1500	0	0	0	0	$18,735	5995	$24,730
7: Measure field paramters	6699	1184	765	400	0	1500	0	0	$10,548	3375	$13,923

(12 months)												
8: Data analysis and statistical evaluation (12 months)	**5566**	**1301**	**560**	**800**	**0**	**0**	**0**	**0**	$8,227	**2633**	$10,860
Totals	**$45,387**	**$8,301**	**$8,855**	**$3,480**	**$0**	**$1,500**	**$0**	**$0**	**$67,523**	**$20,958**	**$88,481**

Budget Justification

Effects of structural enhancement on salmonid spawning

Labor

Year 1:

Task 1: Project Management Horner− 40 hours, $39.57 per hour Task 2: Conduct Redd Surveys Horner− 8 hours, $39.57 per hour 2 Graduate students− 160 hours each, $15.00 per hour Task 3: Map Locations of structure Horner− 16 hours, $39.57 per hour 2 Graduate students− 80 hours each, $15.00 per hour Task 4: Conduct behavioural studies Horner− 8 hours, $39.57 per hour 2 graduate students− 160 hours each, $15.00 per hour Task 5: Characterize flow near woody debris and boulders Horner− 40 hours, $39.57 per hour 2 graduate students− 80 hours each, at $15.00 per hour Task 6: Characterize hyporheic flow near woody debris and boulders Horner− 80 hours, $39.57 per hour 2 graduate students− 320 hours each, at $15.00 per hour Task 7: Measure field parameters Horner− 48 hours, $39.57 per hour 2 graduate students− 160 hours each Task 8: Data analyis and statistical methods Horner− 80 hours, $39.57 per hour 2 graduate students− 80 hours each at $15.00 per hour

Year 2:

Task 1: Project Management Horner− 40 hours, $39.57 per hour Task 2: Conduct Redd Surveys Horner− 8 hours, $39.57 per hour 2 Graduate students− 160 hours each, $15.00 per hour Task 3: Map Locations of structure Horner− 16 hours, $39.57 per hour 2 Graduate students− 80 hours each, $15.00 per hour Task 4: Conduct behavioural studies Horner− 8 hours, $39.57 per hour 2 graduate students− 160 hours each, $15.00 per hour Task 5: Characterize flow near woody debris and boulders Horner− 40 hours, $39.57 per hour 2 graduate students− 80 hours each, at $15.00 per hour Task 6: Characterize hyporheic flow near woody debris and boulders Horner− 80 hours, $39.57 per hour 2 graduate students− 320 hours each, at $15.00 per hour Task 7: Measure field parameters Horner− 48 hours, $39.57 per hour 2

graduate students− 160 hours each Task 8: Data analyis and statistical methods Horner− 80 hours, $39.57 per hour 2 graduate students− 80 hours each at $15.00 per hour

Benefits

Horner− Benefit rate = 32% Graduate students− Benefit rate = 12%

Travel

Year 1:

Task 1: Project Management Horner− $1200 non−local travel to present physical/hydrological results at National meeting. Merz− Collaborator and project advisor− $1200 non−local travel to present biological results at National meeting.

Task 2: Conduct redd surveys Horner and students: $909 travel for 140 mile round trips to Mokelumne river, at $0.30 per mile.

Task 3: Map locations of structure Horner and students: $432 travel for 140 mile round trips to Mokelumne river, at $0.30 per mile

Task 4: Conduct behavioral studies Horner and students: $717 travel for 140 mile round trips to Mokelumne river, at $0.30 per mile.

Task 5: Characterize surface water flow near woody debris Horner and students: $768 travel for 140 mile round trips to Mokelumne river, at $0.30 per mile.

Task 6: Characterize hyporheic flow near woody debris and boulders Horner and students: $2304 travel for 140 mile round trips to Mokelumne river, at $0.30 per mile.

Task 7: Measure field parameters Horner and students: $765 travel for 140 mile round trips to Mokelumne river, at $0.30 per mile.

Task 8: Data analysis and statistical methods Horner and students: $560 for travel to travel to Mokelumne river, confer with EBMUD biologists.

Year 2:

Task 1: Project Management Horner- $1200 non-local travel to present physical/hydrological results at National meeting. Merz- Collaborator and project advisor- $1200 non-local travel to present biological results at National meeting.

Task 2: Conduct redd surveys Horner and students: $909 travel for 140 mile round trips to Mokelumne river, at $0.30 per mile.

Task 3: Map locations of structure Horner and students: $432 travel for 140 mile round trips to Mokelumne river, at $0.30 per mile

Task 4: Conduct behavioral studies Horner and students: $717 travel for 140 mile round trips to Mokelumne river, at $0.30 per mile.

Task 5: Characterize surface water flow near woody debris Horner and students: $768 travel for 140 mile round trips to Mokelumne river, at $0.30 per mile.

Task 6: Characterize hyporheic flow near woody debris and boulders Horner and students: $2304 travel for 140 mile round trips to Mokelumne river, at $0.30 per mile.

Task 7: Measure field parameters Horner and students: $765 travel for 140 mile round trips to Mokelumne river, at $0.30 per mile.

Task 8: Data analysis and statistical methods Horner and students: $560 for travel to travel to Mokelumne river, confer with EBMUD biologists.

Supplies And Expendables

Year 1:

Task 1: Project Management $300 office supplies .

Task 2: Conduct redd surveys $480 field supplies: wading boots, wetsuits

Task 3: Map locations of structure No supplies or expendibles

Task 4: Conduct behavioral studies NO supplies or expendibles

Task 5: Characterize surface water flow near woody debris No supplies or expendibles

Task 6: Characterize hyporheic flow near woody debris and boulders $4050 supplies and expendible− piezometers, tubing, connectors to instrument woody debris and boulders for hyporheic flow study.

Task 7: Measure field parameters $400 supplies and expendibles− calibration fluids and batteries for meters

Task 8: Data analysis and statistical methods $800 supplies and expendibles− paper, mailing costs, computer supplies, copying.

Year 2:

Task 1: Project Management $300 office supplies .

Task 2: Conduct redd surveys $480 field supplies: wading boots, wetsuits

Task 3: Map locations of structure No supplies or expendibles

Task 4: Conduct behavioral studies NO supplies or expendibles

Task 5: Characterize surface water flow near woody debris No supplies or expendibles

Task 6: Characterize hyporheic flow near woody debris and boulders $1500 supplies and expendibles− replace piezometers, tubing, connectors to instrument woody debris and boulders for hyporheic flow study as needed.

Task 7: Measure field parameters $400 supplies and expendibles− calibration fluids and batteries for meters.

Task 8: Data analysis and statistical methods $800 supplies and expendibles− paper, mailing costs, computer supplies, copying.

Services And Consultants

No services or consultants.

Equipment

Purchase new data loggers and pressure transducers (4 total) capable of measuring pressure (flow) differences at a frequency of 10x per second. Multiple unts will allow 3−d flow mapping and tracking of pressure waves in surface water. Each set costs $1100 plus tax and shipping. This equipment will be used to characterize turbulence, heterogeneity and in−stream flow near channel obstructions.

Lands And Rights Of Way

No costs

Other Direct Costs

No other direct costs.

Indirect Costs/Overhead

CSUS indirect cost of 32% is added to all salary, benefits, supplies, expendibles and equipment, as required by the university for sponsored projects.

Comments

Environmental Compliance

Effects of structural enhancement on salmonid spawning

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	**–**	**–**	

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

Work will be conducted under existing permits to EBMUD.

Land Use

Effects of structural enhancement on salmonid spawning

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 will be through EBMUD sites, and the project will be conducted in cooperation with EBMUD biologists.

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.