Demonstration Project to Test a New Interdisciplinary Approach to Rehabilitating Salmon Spawning Habitat in the Central Valley

Spring 2005

This was the eleventh quarter of this CALFED project to demonstrate the utility of the Spawning Habitat Integrated Design Approach (SHIRA). In the previous quarter, all activity focused on data analysis, report writing and outreach. This quarter, more data analysis and report writing was conducted as described below. Several new areas of analysis, including new design considerations, were evaluated. Preliminary planning for the 2005 gravel augmentation was performed. The plan is to continue to use SHIRA's slope creation methodology (described below) to continue to rehabilitate the Mokelumne River's longitudinal profile for another ~500' of channel length using ~3000 tons of gravel. Because Camanche Dam flow releases have been >1,500 cfs since January and will not be lowered until construction, the pre-project characterization phase will be done using data collected in previous years. This is not a major constraint, since the section to be rehabilitated has a deep hole from historic gravel mining right in the primary spawning reach, so that will need to be filled in before any significant habitat heterogeneity may be considered.

A manuscript presenting and testing SHIRA's new slope creation methodology was completed during this quarter and it is undergoing informal review prior to journal submission shortly. Incised channels below dams can lack adequate slope to enable spawning habitat enhancement for anadromous fish. The purpose of this study was to test a new approach for rehabilitating bed slope and salmonid spawning habitat in regulated, rivers with degraded habitat where habitat quality is a limiting factor. This approach, an extension of the Spawning Habitat Integrated Rehabilitation Approach, calls for a staged gravel augmentation process including iterative design development and assessment using 2-D depth-averaged models to predict flow, habitat quality, and substrate entrainment risk. To test specific predictions regarding the viability of this approach, a 2-year manipulative experiment was carried out on the Mokelumne River below Camanche Dam. In summer 2003, 2,300 tons of gravel and cobble were added to a 180 m channel reach increasing the slope from 0.002 to 0.008. In summer 2004, 3,908 tons of gravel and cobble were added to the channel at and downstream of the first augmentation site, spreading the initial increase in slope over riffles 76 m further downstream resulting in a final channel slope of 0.004. Channel features were structured such that habitat quality was maintained after the first manipulation and significantly improved after the second. The experiment was also designed to increase habitat heterogeneity and distribute slope downstream effectively without resulting in partial transport of sediment at spawning flows. The quantity of high-quality spawning habitat increased by 2,540 $m^2$ (471 %) after slope creation. The staged approach provided the opportunity for the downstream manipulation to create new habitat without drowning upstream habitat. Slope creation using the new design methodology did not increase the extent and rate of entrainment beyond the critical threshold during the sensitive spawning and embryo-incubation periods. Spawning fall-run Chinook salmon created 67 redds in 2002 prior to gravel augmentation, 90 redds in 2003 after the first stage, and 151 in 2004 after the conclusion of the second stage. Of all redds 88%were located in high and medium quality habitat as predicted by the model. Given the positive outcome of the experiment, SHIRA-based slope creation using the framework provided in this study is recommended for widespread use.

Another manuscript analyzing the hydraulic, habitat, and scour implications of different downstream riffle crest elevations on the upstream riffle conditions was prepared based on a suite of 18 numereical modeling experiments and is currently being edited in preparation for journal submission. Two-Dimensional Hydrodynamic Modeling (2D) has proven to be effective in predicting depths, velocities, and variables derived from them that govern the spatial distribution of physical habitat for spawning Pacific salmon populations at the 0.1-10 m scale. In this study, the effects of riffle configuration on flow conditions, channel stability, and physical habitat were analyzed for 9 combinations of the independent controlling variables, downstream water surface elevation and discharge for two different riffle configurations, notched riffle and diagonal bar riffle (18 experiments total). Downstream water surface elevations were selected to mimic backwater, uniform, and accelerating flow conditions as controlled by downstream riffle morphology. Discharges included a spawning low flow (300 cfs), a fish-attraction moderate summer flow (2500 cfs), and a winter flood release (6000 cfs). Findings suggest that a change from the backwater to uniform flow for 300 cfs dramatically reduces the habitat for spawning by 22 percent for the notched riffle configuration. The diagonal bar didn't show a decrease in the high quality habitat but the there was an overall deterioration in the region suitable for spawning. The study also shows that a change from uniform to accelerating flow has little effect on the habitat patterns. The notched riffle was found to be more stable for all flow rates and flow types when compared to the diagonal bar. As a result, backwater effects were discovered as a critical requirement for channel stability and high quality habitat, and the notched riffle is recommended over the bar as a tool for river habitat restoration.

Another numerical experiment was completed this quarter in which an assessment was made of the "velocity reversal" mechanism thought to be needed for post-project self-sustainability. Although this conventional hypothesis is based on the magnitude of mean flow parameters, recent studies have suggested that mean parameters are not sufficient to explain the dominant processes in many pool-riffle sequences. In this study, two- and three-dimensional models were applied to simulate flow in the classic pool-riffle sequence on Dry Creek, CA, where the velocity reversal hypothesis was first proposed. This work was not done on the Mokelumne, because there was no known self-sustainable riffle there. The goal was to determine if the concept behind the self-sustianing mechanism could be fully understood and then applied to the Mokelumne River using SHIRA. These simulations provided an opportunity to evaluate the hydrodynamic mechanics underlying the observed reversals in near-bed and section-averaged velocity, and were used to investigate the influence of secondary currents, the advection of momentum, and cross-stream flow variability. The simulation results supported the occurrence of a reversal in mean velocity and mean shear stress with increasing discharge. However, the results indicated that the effects of flow convergence due to an upstream constriction and the routing of flow through the system were more significant in influencing pool-riffle morphology than the occurrence of a mean velocity reversal. The hypothesis of flow convergence-routing was introduced as a more meaningful explanation of the mechanisms acting to maintain pool-riffle morphology. Even though the analyses and manuscript were only just finalized this year, the concepts form this on-going work have been used in all Mokelumne SHIRA designs to the extent possible lacking the approval to widen the channel. This manuscript has been submitted to the journal Water Resources Research.

Another analysis was continued in which we are assessing the relative potential of flow re-regulation versus channel manipulation for rehabilitating regulated rivers. Alluvial rivers consist of a channel boundary over which water and sediment inputs pass creating a suite of physical processes. The physical controls on river behavior may be grouped as boundary or input related, where the category implies the effect of the control on the system. Each of these groups of controls can be further subdivided into natural or anthropogenic. Preliminary results suggest that many rivers including the Mokelumne have enough anthropogenic boundary controls that merely re-regulating flow will not yield rehabilitation by itself. Thus, nature cannot restore itself under the current conditions. A manuscript evaluating this problem is being prepared.

An analysis of the capability of 2D models to predict annual channel change under low slope, regulated flow conditions was begun. In this study, 7 years of monitoring data will be modeled to see if predictions match observed channel changes.

A previously reported manuscript presenting and evaluating a site-scale sediment budget for gravel augmentation was reviewed informally and further edited. It is pending submission to the journal Geomorphology shortly.

Another previously reported manuscript comparing and contrasting the utility of empirical geomorphology versus 2D modeling for use in river rehabilitation is continuing to be edited in preparation for journal submission shortly.

A previously reported manuscript on 2D model validation of depth, velocity, and shear stress prediction was submitted to the Journal of Hydrology.

Finally, long-term monitoring of the SHIRA demonstration projects is an important necessity in order to see their cost-effectiveness and self-sustainability. At this time there is no apparent funding for continuing our independent monitoring beyond September 2005.

All CALFED quarterly reports for this project are available to the public at
http://shira.lawr.ucdavis.edu/publications_calfed.htm