LOWER MOKELUMNE RIVER SALMONID REARING HABITAT RESTORATION PROJECT

SUMMARY REPORT

June 28, 2007

Prepared for:
CVPIA Anadromous Fish Restoration Program

By:

Walter Heady
Department of Ecology and Evolutionary Biology
University California Santa Cruz
Santa Cruz, California
heady@biology.ucsc.edu

and

Joseph Merz
East Bay Municipal Utility District
Fisheries and Wildlife Office
1 Winemasters Way Suite K2
Lodi, CA 95240
jmerz@ebmud.com

LOWER MOKELUMNE RIVER SALMONID REARING HABITAT RESTORATION PROJECT
SUMMARY REPORT

Executive Summary

This report presents the results of monitoring conducted by East Bay Municipal Utility District (EBMUD) of physical parameters, fish utilization and macroinvertebrate community structure of two side channel enhancement projects designed to increase juvenile salmonid rearing habitat. The following questions and hypotheses were posed in proposal reports to be evaluated by monitoring the created side channel habitats: 1) Does the project as implemented meet the design criteria for juvenile rearing habitat? and 2) Does the project, as designed, provide suitable rearing habitat for juvenile salmonids? Monitoring results show that the resulting restored side channel habitats do indeed meet juvenile salmonid rearing habitat criteria (USACE 2002; Anderson 2002). Aquatic macroinvertebrates quickly colonize the habitats when wetted, and seem to follow a successional pattern across time. Much of this change through time was in relation to chironomids, a preferred diet item for juvenile salmonids (Merz 2002a; 2002b), increasing in abundance through the monitoring period. Macroinvertebrate abundance and taxonomic richness both increased through the monitoring period. A suite of fish species were also found utilizing the side channel habitats, including juvenile steelhead *Oncorhynchus mykiss* and Chinook salmon *O. tschawytscha*. Diet samples from salmonids captured within the side channels indicate the fish foraged on benthic macroinvertebrates that colonized the side channels. The created side channel habitats not only meet design criteria, but a natural colonization and successional pattern can be observed that provides excellent foraging and rearing habitat for juvenile salmonids.

Background

The Mokelumne River is a tributary to the Sacramento-San Joaquin Delta (Fig. 1). Five species of anadromous fishes including Chinook salmon (*Oncorhynchus tshawytscha*) and steelhead trout (*O. mykiss*) are present in the lower Mokelumne River. The riparian areas of the lower river (below Camanche Dam) historically supported a diverse and dynamic ecosystem of oxbow lakes, seasonal wetlands, secondary channels and extensive, forested floodplains. Since the onset of California's gold rush in the mid 19th century, the river has been modified by mining, agriculture, forestry, levee and dam construction, and water diversion. Since 1927, approximately 190,000 m^2 of secondary channels have been eliminated in the 14.5 km section from Camanche Dam downstream to the Elliott Road Bridge (Edwards et al. 2004), the extent of the remaining salmonid spawning reach in the lower Mokelumne River. These secondary channels provided high-quality rearing habitat for juvenile Chinook salmon and steelhead.

The California Department of Fish and Game (CDFG) has determined that the lower Mokelumne River between Camanche Dam and its confluence with the Delta is of considerable importance for restoration and maintenance of Chinook salmon and steelhead (CDFG 1991). FERC (1993) concluded that much more Chinook salmon rearing habitat could be created by management of the adjacent gravel pit ponds – interconnected and provided with Mokelumne River water – than could be attained in the existing river channel through flow manipulations. They also recommended rearing habitat improvement for steelhead by installation of coarse substrate of boulders and large woody debris in high-gradient riffles and runs not used for spawning.

The Anadromous Fish Restoration Program (AFRP) lists two action items for Chinook salmon and steelhead restoration on the Mokelumne River: evaluate the feasibility of increasing available rearing habitat to maximize suitable rearing habitat in the lower Mokelumne River; and, enhance and maintain the riparian corridor to improve streambank and channel rearing habitat for juvenile salmonids. The Final Restoration Plan for the Anadromous Fish Restoration Program (USFWS 2001) lists enhancing and maintaining the riparian corridor to improve streambank and channel rearing habitat for juvenile salmonids as a high priority action in the Mokelumne River.

Justification - East Bay Municipal Utility District (EBMUD) is implementing several flow and non-flow measures designed to enhance the anadromous fishery and improve the Mokelumne River ecosystem. One measure to improve the anadromous fishery is to increase rearing habitat for fall-run Chinook salmon and steelhead by restoring secondary channels. As a result of river regulation and extensive gold and gravel mining in the lower Mokelumne River, the main channel was degraded, secondary channels were eliminated, and numerous dredge sites were left isolated from the river channel.

Fisheries habitat improvement frequently entails the exploitation of existing features of stream channels and floodplains (Richards et al 1992). This project proposes to re-establish off-channel juvenile salmonid rearing habitat by reconnecting and enhancing existing secondary channels that were isolated from the main channel of the lower Mokelumne River.

Successful rearing of juvenile Chinook salmon in off-channel habitats has been reported in other river systems (Richards et al 1992). Murray and Rosenau (1989) suggest that the dispersal and migratory patterns of young Chinook salmon increase the use of available rearing areas, and that movements of young salmonids from spawning areas to rearing areas consist of complex local migrations (upstream, downstream, or both) that are genetically and environmentally controlled. Juvenile Chinook salmon may migrate into off-channel habitats to exploit food resources, seek optimal temperatures, and to escape unfavorable environmental conditions in the main channel such as predators and high turbidities (USRFRHAC 1989). Components of high quality juvenile salmonid rearing habitat typically include appropriate water temperatures, suitable concentrations of dissolved oxygen, overhanging vegetation for shade and source of terrestrial insects for food, in-water natural woody debris, decreased water velocity, and suitable substrate for benthic macroinvertebrate production.

This project was designed to create about 1,915 m^2 of high quality off-channel rearing habitat for juvenile steelhead and Chinook salmon in two isolated secondary channels of the lower Mokelumne River (Fig. 2).

Since 1990, EBMUD, in cooperation with the California Department of Fish and Game and the U.S. Fish and Wildlife Service has placed over 11,500 m^3 of spawning gravel in the lower Mokelumne River. Merz and Setka (2004) determined that the gravel placement significantly increased channel water velocities, intergravel permeability, and dissolved oxygen; reduced channel depths; and, equilibrated intergravel and ambient temperatures. Benthic macroinvertebrates begin colonizing new gravel within three days and their numbers equal or surpass population densities at unenhanced areas within ten weeks after gravel placement (Merz and Chan 2005). Adult Chinook salmon also use new gravel for spawning within three months of gravel placement.

To compliment the improvement of spawning habitat in the lower Mokelumne River, the Lower Mokelumne River Salmonid Rearing Habitat Improvement Project was designed to provide additional rearing habitat for Chinook salmon and steelhead produced naturally in the river.

Approach

Aerial photographs were used to identify potential sites for potential restoration of isolated side channels within the vicinity of Chinook salmon and steelhead spawning areas. Then ground topographic surveys were conducted on-site to incorporate natural features and properly design the hydrodynamics of the restoration side channels. The side channels were cut and filled with approximately 1,401 yds^3 of gravel. Boulders and logs were also placed to provide structure and habitat.

The side channels were designed and created to have water at Camanche Dam discharges of 14.15 m^3/sec (500cfs) or greater. This design criteria was engineered to provide suitable rearing habitat for juvenile Chinook and steelhead while not stranding fish if flows recede. Figure 3 shows a hydrograph of the Mokelumne River during the monitoring period. When wetted the two side channels met physical parameter design criteria.

Physical goals for the side channels as presented in prior proposal reports were as follows: substrate size (2.6 – 15cm); water depth (>15cm); water velocity (mean water column velocities <40 cm/sec); water temperature (<15°C); dissolved oxygen (>75% saturation); bank slope (<40%) and instream cover (>20% of wetted area) (USACE 2002; Anderson 2002).

Performance Measures

This report evaluates the performance of two side channel habitats created in September 2005 as rearing habitat for juvenile Chinook salmon and steelhead. Performance evaluation includes measures of physical parameters, macroinvertebrate community structure, fish use, and diet samples from juvenile Chinook salmon and steelhead.

Monitoring of physical parameters

Pebble counts.—Pebble counts were conducted at two randomly selected transects (about 100 samples per transect) at each site immediately following project completion using methods similar to those of Bauer and Burton (1993). Two 30-m longitudinal transects were randomly placed at each site. Surveyors collected substrate samples by hand every 0.3 m along the transect and used a template to measure size. Substrate from pebble counts were categorized into 15 classes (vegetation, woody debris, 8.0, 8.0, 16.0, 22.2, 31.8, 44.5, 63.5, 89.0, 127.0, 177.8, 254.0, >254.0 mm, and Bedrock). The diameter categorization was based on the largest slot (round hole with specified diameter) through which an individual pebble could not be passed. Measurements were repeated 12 months after gravel placement.

Hydrologic data.—During various releases from Camanche Dam (Fig. 3), we measured velocities and depths with a Marsh-McBirney Flo-Mate model 2000 flowmeter and a depth-setting wading rod at every ~0.6 m along five evenly-spaced cross-sections over each site.

Macroinvertebrates. — Following site construction, macroinvertebrate samples were collected every 2 -4 weeks while channels were wetted to assess rates of colonization and changes in community structure based on colonization rates of previous studies (Waters, 1964; Shaw and Minshall, 1980). Samples were collected until flows became too high to wade the channel or channels were dry (Fig. 4). Benthic macroinvertebrates were collected with a 330mm i.d.x 400mm high, stainless steel 363 μm Nitex Hess Stream Sampler (bottom open area = 0.086m^2) with an attached 368 μm dolphin bucket. Samples were taken to ~15 cm depth within the substrate. Macroinvertebrates collections were made at four random points within a site at the entrance, middle and bottom of each channel. Collected samples were placed in 500 ml Nalgene bottles in 95% ethyl alcohol. In order to maximize sampling efficiency, all samples were taken in substrates dominated by gravel, in depths less than 60 cm and velocities between 0.1 and 1.00m x s^{-1}.

Concurrently, two drift macroinvertebrate samples were collected at the entrance and exit of each channel using a ~318 x 457 mm 363 μm Nitex drift nets. Nets were set for 15 minutes and velocities within each net opening were measured at the beginning and ending of each set to calculate catch efficiency.

Samples were transported to the laboratory and hand sorted using a 60x dissecting scope and macroinvertebrates were identified to family, placed into size classes and enumerated. Multivariate statistical analysis was performed using Primer6 software. Analyses of similarity (ANOSIM) were calculated for different levels of data.

Fish samples—*Seining procedures*- A 50 ft x 6 ft -1/16 inch mesh (15.25 m x 1.8 m - 0.16 cm) beach seine with 1.5 inch (38 mm) diameter wooden support poles was used to make one to three hauls (typically two) during daylight within each sample site. Depth of seining was less than 6 ft (1.8 m), velocities less than 3 ft/s (0.92 m/s) and we attempted to seine areas with substrates free of large obstructions that would hinder the movement of the seine. A 50 ft (15.25 m) rope was attached to each support pole at the ends of the seine. Two people walked the seine out into the river while two people held the ropes from the bank. The net was deployed at the end of the 50 ft (15.25 m) ropes or at a depth of 6 ft (1.8 m) and the distance was noted. One person began moving downstream to deploy the seine as the upstream member remained stationary. The two crew members on the bank did the same. The two people on shore assisted by pulling in the net as the two people in the river began moving the net toward shore. Two markers were placed where the two ends of the seine first reached the bank. The measurement of site length multiplied by the distance out from shore provides an estimate of area seined. The two people holding the poles continued to pull the ends of the seine in while the two rope handlers assisted in keeping the lead line down and pulling the net on shore. When the net was completely retrieved, captured fish were removed from the net and placed in a large container of river water. Captured fish were enumerated and released live to the river.

Backpack electrofishing surveys- Shallow riffles and runs (<0.61 m depth; >0.6 m $\cdot$ sec^{-1}) were electrofished monthly. A 25 ft x 6 ft -1/16 inch mesh (7.6 m x 1.8 m - 0.16 cm) beach seine with 1.5 inch (38 mm) diameter wooden support poles was deployed perpendicular to stream flow by two people. Markers were placed on the substrate, at the corner of each seine pole. A third person used a Smith - Root Model 12 backpack electrofisher to sample the area approximately 15 ft (4.6 m) upstream of the seine and within the seine area. A marker was placed where the third person began sampling. After the area was sampled, the lead line of the seine was immediately raised to prevent the loss of fish captured in the seine. Captured fish were enumerated, measured, weighed and released live in the river. For seining and backpack electrofishing, depth, velocity and area (sq. meters) within the markers were recorded. These data were used to estimate total area sample as a means to calculate a catch-per-unit effort (CPUE) (e.g. number of fish per m^3 of water sampled).

Boat electrofishing survey- On 4 May 2006, we were able to access the two side channels with a Smith-Root SR-18E electrofishing boat to sample the fish community following the methods described in Meador et al. (1993). An automatic timer was used to measure the total length of time a specific site was sampled to calculate a CPUE (e.g. number of fish per second). After enumeration, fish were immediately released at the sample site except for those kept and preserved for diet analysis studies (see Merz 2002a; Merz 2002b). Diet analysis specimens were immediately preserved in an 80-85% ethyl-alcohol solution, packed in ice, and transported to the laboratory for analysis.

Fish diets- Stomach contents were removed and hand-sorted in the lab under a dissecting microscope and magnifying illuminator. Food items were identified to family for aquatic organisms and order for terrestrial organisms; life stages (larva, pupa, or adult) were determined. Adult Ephemeroptera, Trichoptera, and Diptera were classified as terrestrial.

Results

Channel 1 has a length of approximately 300 ft, a mean width of 17 ft, with a mean depth and velocity of 1.38ft and 0.9 ft · sec^{-1} when the mainstem Mokelumne River is at a discharge of 1500cfs (Fig. 3). Channel 2 has a length of 200 feet, a mean width of 27 feet, with a mean depth and velocity of 0.6 ft and 0.6 ft · sec^{-1} when the mainstem Mokelumne River is at a discharge of 1500cfs.

Mean substrate size for the 2 side channels is: 6.4 cm (2.5 inches). Range: 0.8 - 64 cm (0.3 – 25 inches) (Fig. 5). This includes the addition of LWD and boulders.

Macroinvertebrate community structure

Data from aquatic macroinvertebrate samples collected from three sites within each of the two side channels during the monitoring period show aquatic macroinvertebrate colonization of the created habitats and their utilization by juvenile Chinook salmon and steelhead (Figs. 6-10). Multidimensional scalar plots show spatial and temporal patterns observable from data from benthic, drift and diet data (Fig. 6). There were no difference between the entrance, middle and exit sites within side channels for benthic or drift samples ($p = 0.99$; $p = 0.43$, respectively). There were also no statistical differences in aquatic macroinvertebrate community structure between side channels for benthic or drift samples ($p = 0.14$; $p = 0.41$, respectively). It is interesting to note that side channels were more similar in regards to drift samples ($p = 0.41$) than in regards to benthic samples ($p = 0.14$), telling that while drift supply may be very similar, benthic production within habitats is more channel specific. There were distinct statistical differences across time for both benthic and drift samples (Figs.7 and 8). Months were distinctly different for drift samples at a level of $p = 0.01$, with the largest distinction being seen in February (Fig. 8). Seasonal increases in drift organisms, especially, daphinids, cyclopids and chironomids were responsible for drift differences over time (Fig. 8). Benthic samples were extremely different across months with a significance of $p = 0.001$. Patterns visible in Figure 7 suggest a successional pattern across time in benthic community structure. In general, benthic invertebrate abundance and taxon richness both increased across time (Figs. 9 & 10). The pattern of succession observed in benthic macroinvertebrate community structure over such a short time period suggests that habitats were self rehabilitating after creation and providing ecosystem services such as food supply to fish. A large part of the community structure change was in relation to a dramatic increase in chironomid abundance through time, a preferred diet item for juvenile salmonids (Merz 2002a; 2002b).

Fish Use

The two channels were sampled by beach seine and backpack electrofishinig in February, March, and April 2006 and boat electrofishing in May 2006 for fish community structure (Fig. 4). Species observed include Chinook salmon, Sacramento suckers, prickly sculpin *Cottus asper*, and western mosquitofish *Gambusia affinis*. One adult largemouth bass *Micropterus salmoides* was captured during May flood flows. In February water temperatures ranged from 10.0-10.1 ^{o}C. Chinook salmon captured in February ranged in size from 34-73mm fork length. Chinook salmon densities in February were calculated at 0.008-0.031 · ft^{-2}. In March water temperatures were from 10.2-10.9 ^{o}C. In March Chinook salmon captured ranged in size from 33-42mm fork length. Densities were estimated to be 0.03-0.21 · ft^{-2} in March. During the monitoring period it was calculated that side channels may have contained 45 -1134 Chinook salmon juveniles per channel. In May, the two side channels had overflowed there banks and could only be sampled by electrofishing boat. Water temperature was 11.2 ^{o}C and dissolved oxygen was 11.5 ppm. Steelhead were the most prevalent fish, followed by Chinook salmon and Sacramento sucker.

Diet samples from Chinook salmon and steelhead

The most numerically abundant diet item for juvenile salmonids in the side channels was the water flea *Daphnia pulex* with up to 1708 daphnid individuals in one stomach. For steelhead within the side channel the second most numerically abundant diet item was fish eggs and larvae (primarily cottids), followed by chironomid midge pupae, hydroptilid caddisfly pupae and terrestrial homoptera. However, for Chinook salmon nematodes were the second most abundant diet item, followed by chironomid and hydroptilid pupae, and cottid eggs. This suggests some forage partitioning for juvenile Chinook salmon and steelhead within the side channels. Daphnids and chironimids, both numeric dominants in juvenile salmonid diet samples are also two of the highest numeric dominants in both benthic and drift aquatic macroinvertebrate samples.

Conclusions

The following questions and hypotheses were posed in proposal reports to be evaluated by monitoring the created side channel habitats: 1) Does the project as implemented meet the design criteria for juvenile rearing habitat? and 2) Does the project, as designed, provide suitable rearing habitat for juvenile salmonids? Results from the side channel monitoring programs show positive answers to both of these questions. The two side channels when wetted (at mainstem Mokelumne River discharges above 14.15 m^3/sec (500cfs) or greater indeed meet the design criteria and physical parameters recommended for juvenile salmonid rearing habitat (USACE 2002; Anderson 2002). Monitoring results also show the two created side channels providing suitable and beneficial habitat to juvenile Chinook salmon and steelhead as well as habitat for a community of other fish and aquatic invertebrates. Macroinvertebrates colonized the side channel habitats quickly upon creation and quickly when wetted after a long dry period. There seems to be a pattern of succession across sampling periods within aquatic macroinvertebrate community structure in both numeric abundance and taxonomic richness for the two side channels. Juvenile salmonid diet samples consisted primarily of *Daphnia* sp. and chironomid midges. Daphnids and chironomids, preferred diet items for juvenile salmonids (Merz 2002a; 2002b), were also numerically dominant in benthic and drift aquatic macroinvertebrate samples, showing the habitats provide excellent foraging and rearing habitat for juvenile salmonids.

Acknowledgements

We thank R. Bilski, L. Chan, C. Hunter, E. Rible, M. Saldate, J. Shillam, J. Smith, and M. Workman, for field sampling. This project was funded by the CVPIA Anadromous Fish Restoration Program, East Bay Municipal Utility District and the California Sea Grant CALFED Science Fellows Program. George Reed, Inc. D.H. Winn Trucking, and Ford Construction provided materials, transportation and construction of the project.

Literature Cited:

Anderson, J.W. 2002. Physical habitat and water quality criteria for fall chinook salmon associated with the Hells Canyon complex. Cold Stream Consulting. Baker City, OR.

Bjornn, T.C., and D.W. Reiser. 1991. Habitat requirements of salmonids in streams. American Fisheries Society Special Publication 19:139-179.

California Bay-Delta Authority (CBDA). 2003. California Bay-Delta Program, Ecosystem Restoration Multi-Year Program Plan (Years 4-7). August 2003.

Edwards, B.R., C.H. Perry, S.J. Steinberg, and K.A. Reeves. 2004. A century of riparian change in the lower Mokelumne River. American Water Resources Association, 2004 Spring Specialty Conference, Nashville, TN.

Healey, M.C. 1991. Life history of chinook salmon. Pages 311-394 in C. Groot and L. Magolis (eds.), Pacific salmon life histories. University of British Columbia Press. Vancouver, BC.

Jackson, T.A. 1992. Microhabitat utilization by juvenile chinook salmon (Oncorhynchus tshawytscha) in relation to stream discharges in the lower American River of California. M.S. Thesis, Oregon State University.

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

Merz, J.E. 2002b. Comparison of prickly sculpin and juvenile fall-run Chinook salmon diets in the lower Mokelumne River, California. Southwestern Naturalist 47(2):195-204.

Merz, J.E., and L.K. Chan. 2005. Effects of Gravel Augmentation on Macroinvertebrate Assemblages in a Regulated California River. River Research and Applications 21:61-74

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

Murray, C.B., and M.L. Rosenau. 1989. Rearing of juvenile Chinook salmon in non-natal tributaries of the lower Fraser River, British Columbia. Transactions of the American Fisheries Society 118:284-289.

Richards, C., P.J. Cernera, M.P. Ramey, and D.W. Reiser. 1992. Development of off-channel habitats for use by juvenile Chinook salmon. North American Journal of Fisheries Management 12:721-727.

Upper Sacramento Fisheries and Riparian Habitat Advisory Council (USFRHAC). 1989. Upper Sacramento River fisheries and riparian habitat management plan. State of California, Resources Agency. Sacramento, CA.

U.S. Fish and Wildlife Service (USFWS). 2001. Final Restoration Plan for the Anadromous Fish Restoration Program. A Plan to increase Natural Production of Anadromous Fish in the Central Valley of California. Prepared for the Secretary of the Interior by the United States Fish and Wildlife Service with assistance from the Anadromous Fish Restoration Program Core Group under authority of the Central Valley Project Improvement Act. Stockton, CA.

U.S. Army Corps of Engineers (USACE). 2002. Lower Snake River juvenile salmon migration feasibility report/Final Environmental Impact Statement. Walla Walla District. Walla Walla, WA.

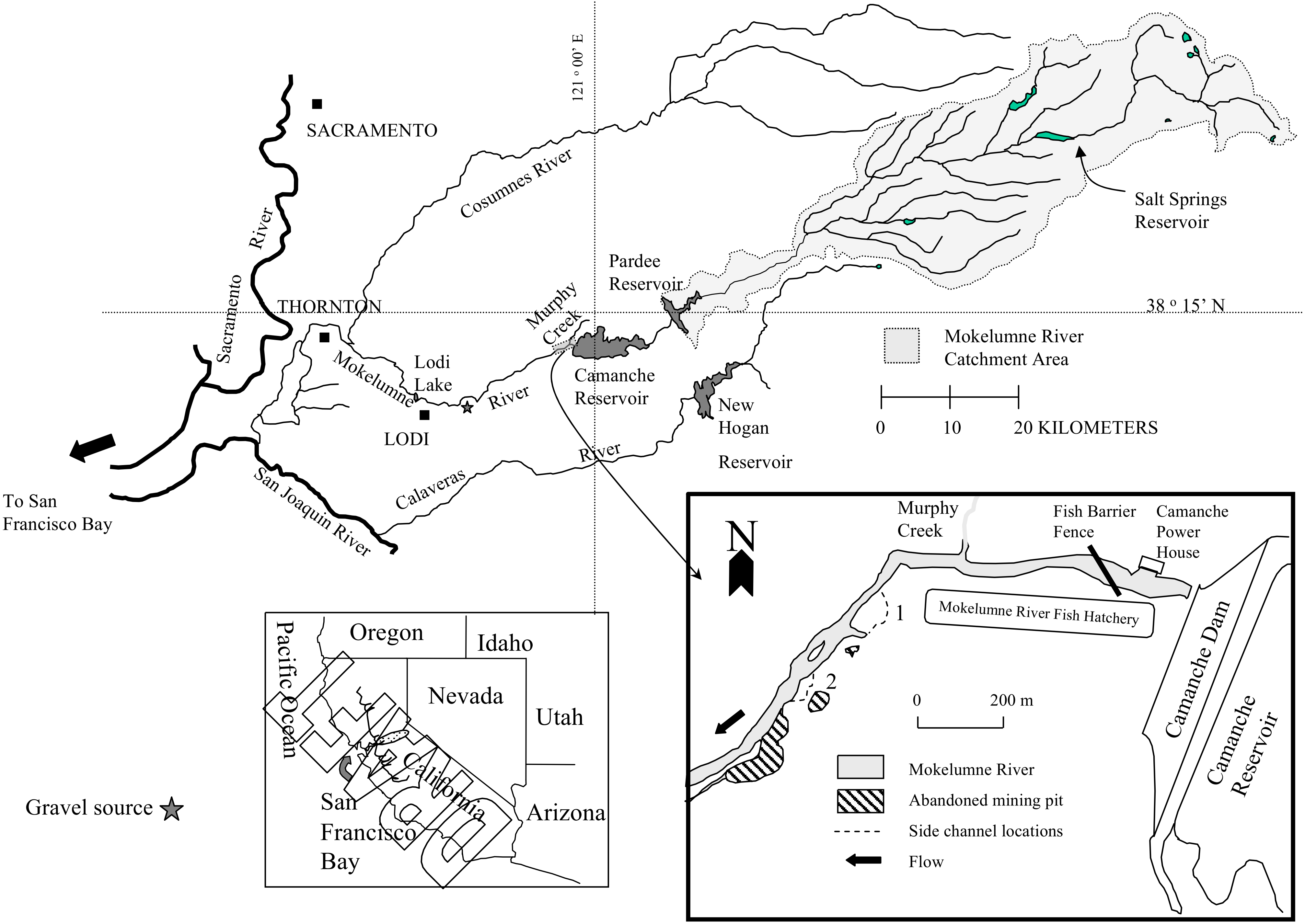

Figure 1. Location of two side channel enhancement projects in relationship to the lower Mokelumne River, California.

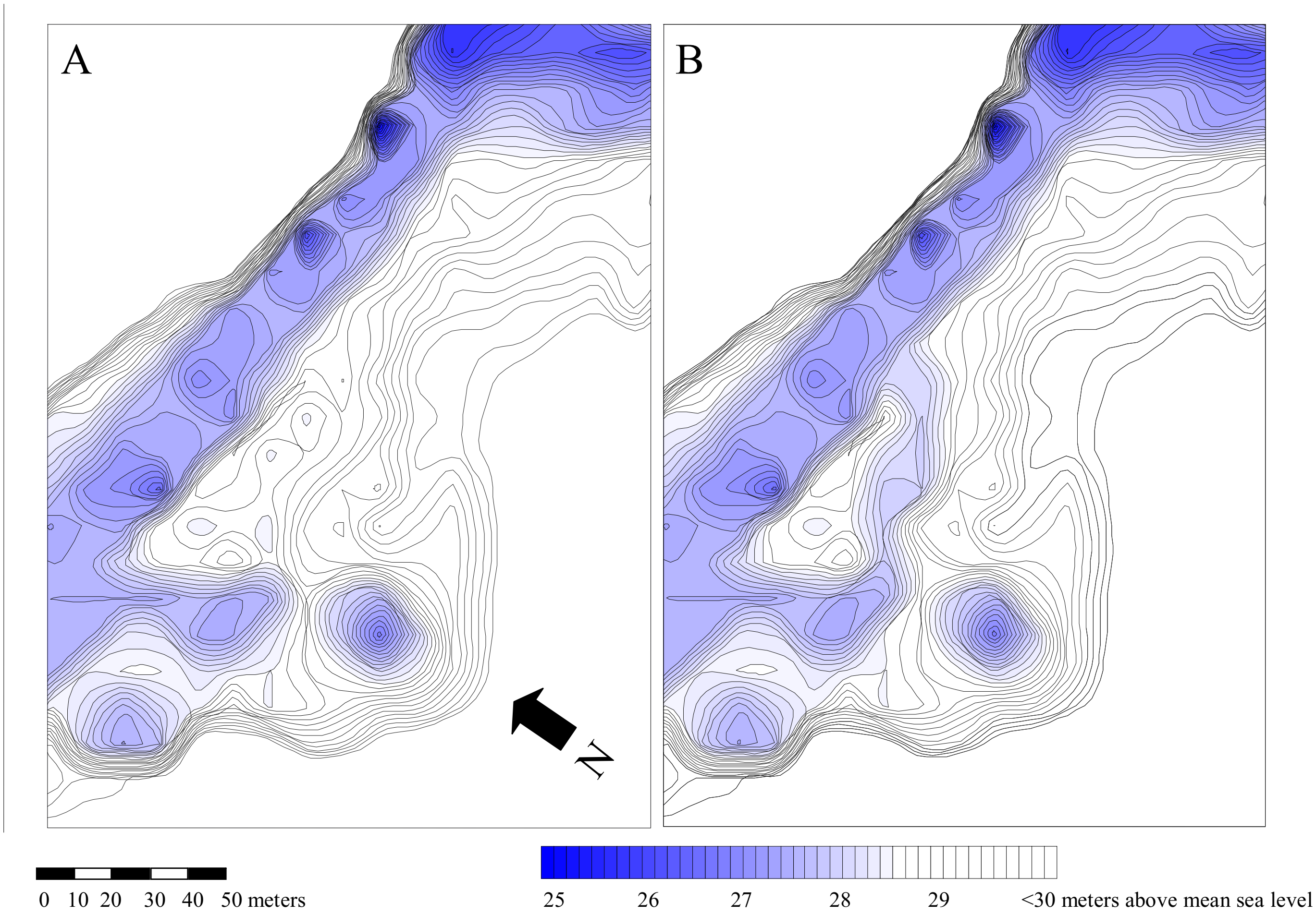

Figure 2a. Topographical survey of Site 1 under present condition (A) and proposed reconnected secondary channel (B).

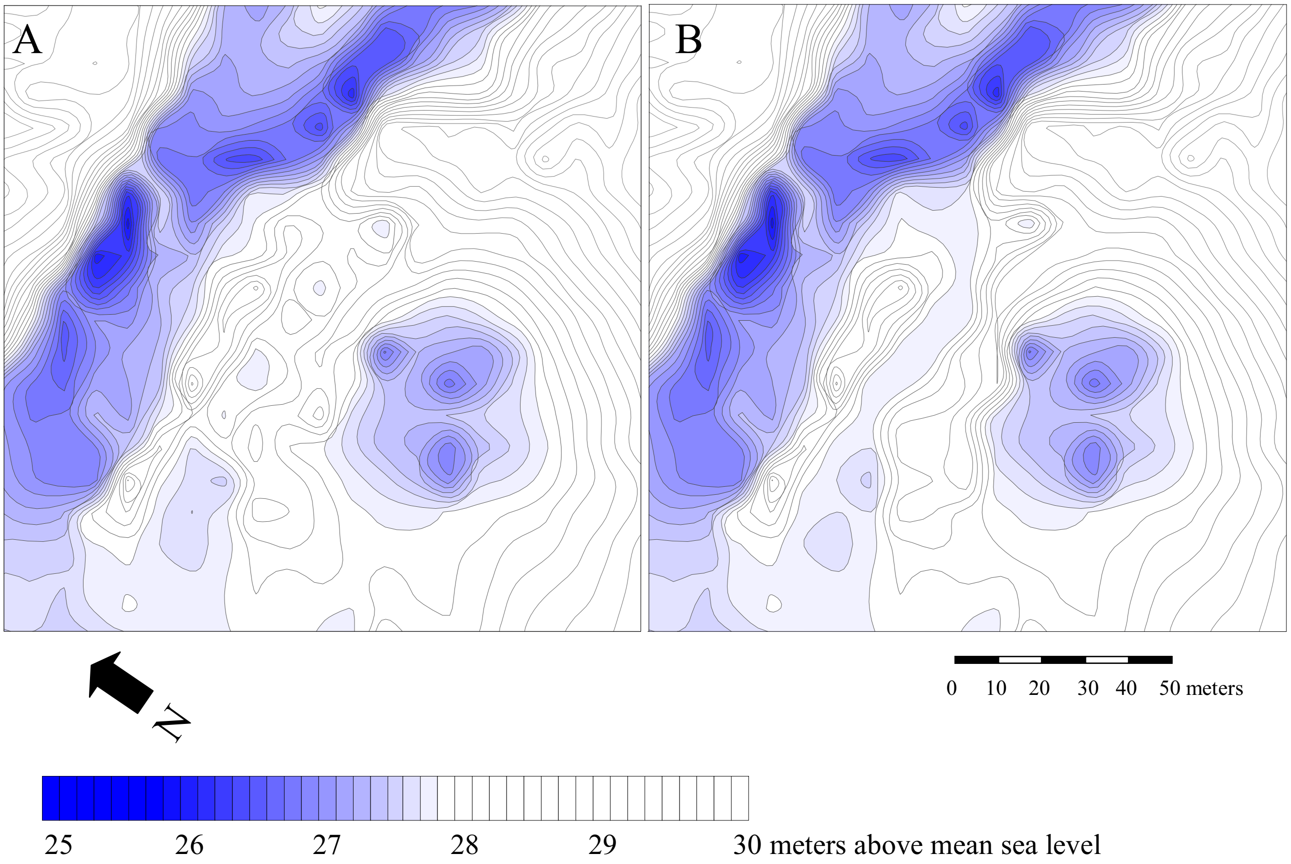

Figure 2b. Topographical survey of Site 2 under present condition (A) and proposed reconnected secondary channel (B).

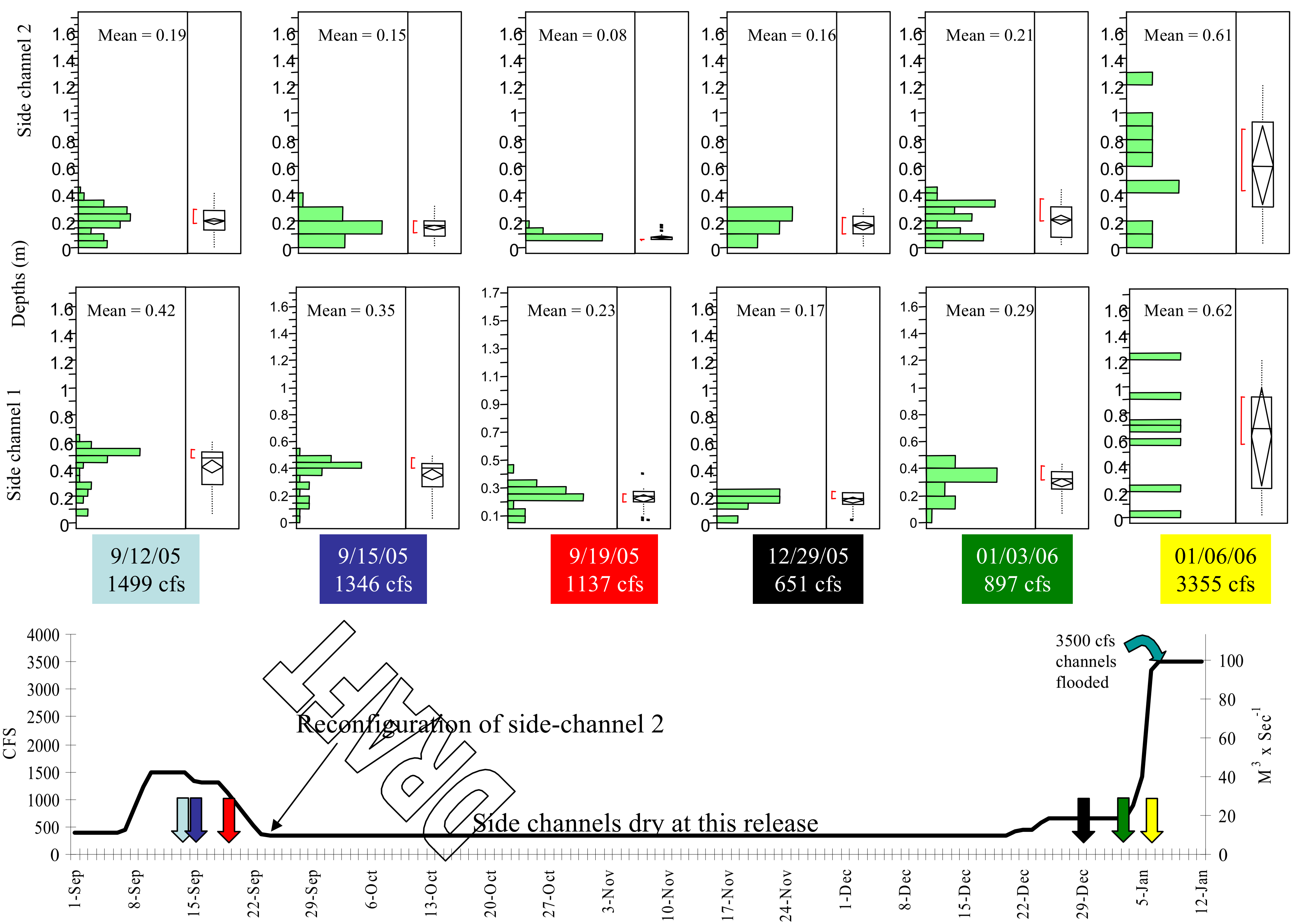

Figure 3a. Depths Collected by transect within two side channels created in the lower Mokelumne River, California. August – September, 2005. Measurements were taken at 6 flow schemes. Water left the channel at flows above ~3500 cfs.

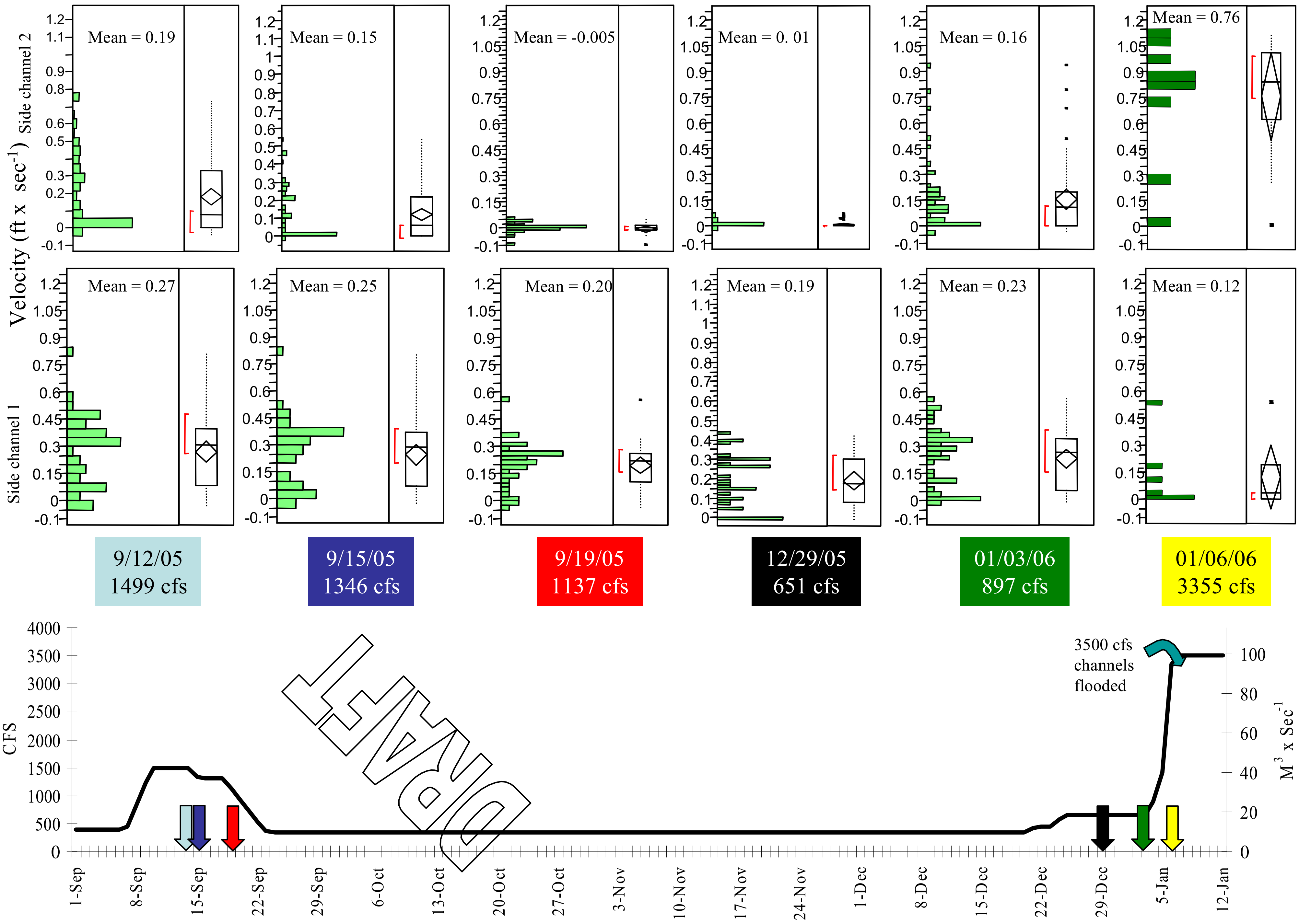

Figure 3b. Velocities collected by transect within two side channels created in the lower Mokelumne River, California. August – September, 2005. Measurements were taken at 6 flow schemes. Water left the channel at flows above ~3500 cfs.

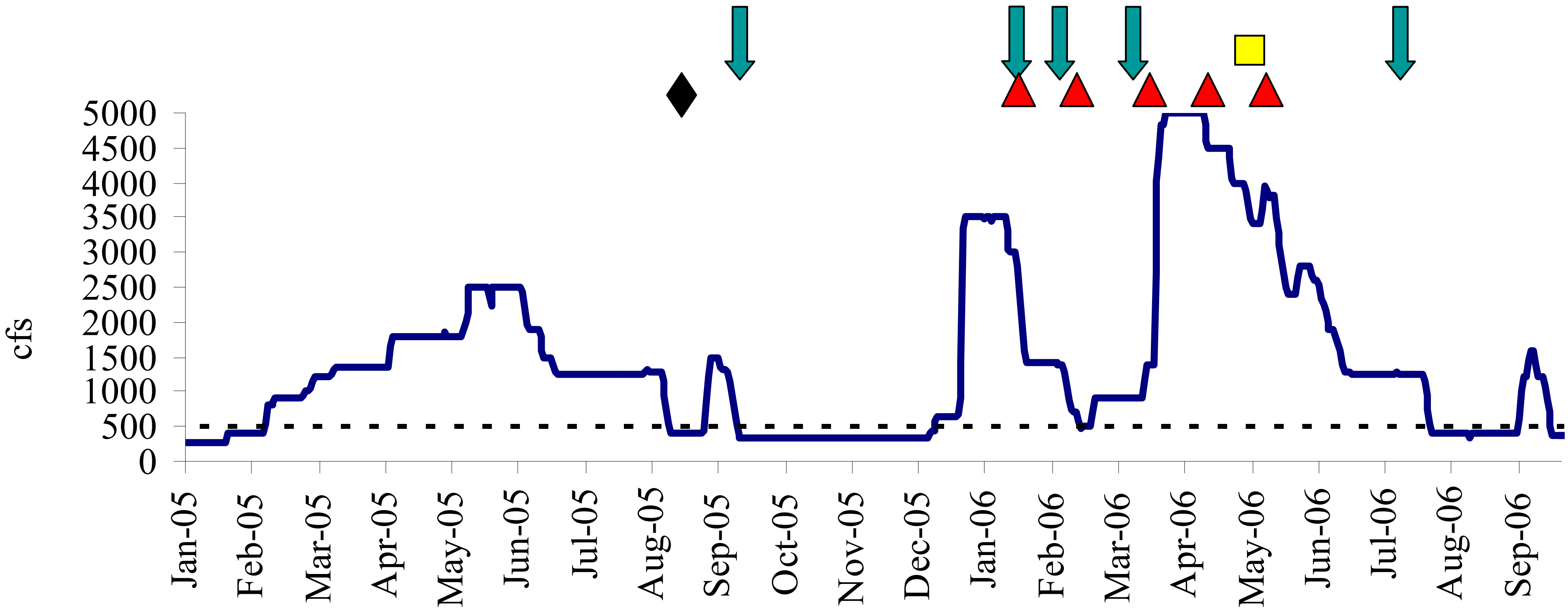

Figure 4. Camanche Dam discharge (solid line) in relation to 500 cfs target flow to wet the side channels (dashed line), and construction (diamond) and sampling periods. Arrow: benthic and drift samples; Triangle: seine samples; Square: boat electrofishing

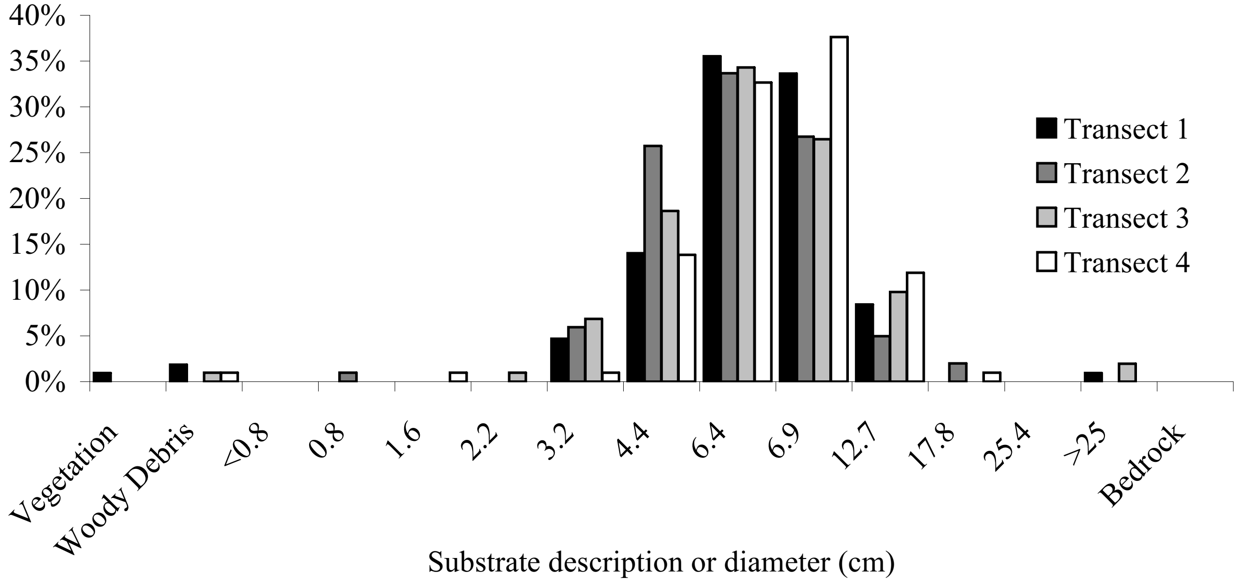

Figure 5. Substrate data from 4 transects within the two constructed side channel habitats, September 2005.

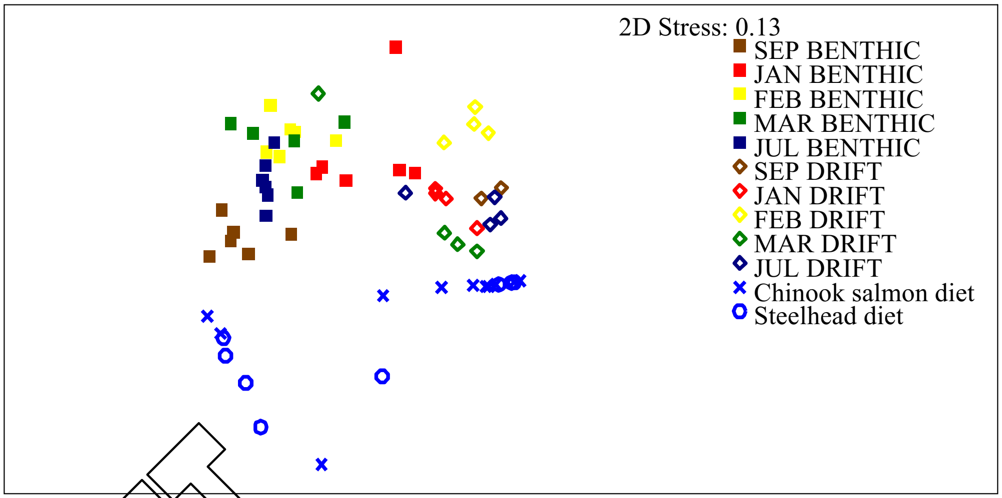

Figure 6. A multi-dimensional scalar plot from a Bray Curtis similarity index of the aquatic macroinvertebrate community structure and diet samples during the monitoring period. Samples coincide with schedule provided in Figure 4.

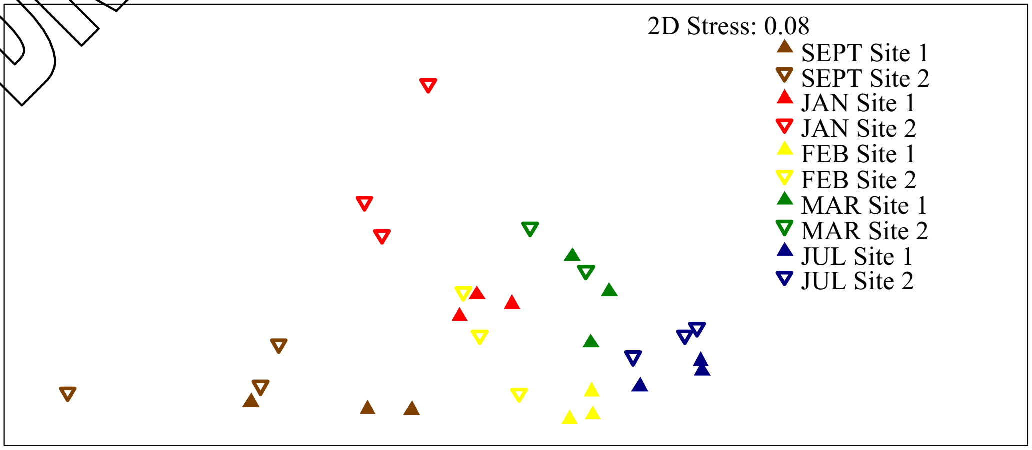

Figure 7. A multi-dimensional scalar plot from a Bray Curtis similarity index of the benthic aquatic macroinvertebrate community structure during the monitoring period. Samples coincide with schedule provided in Figure 4.

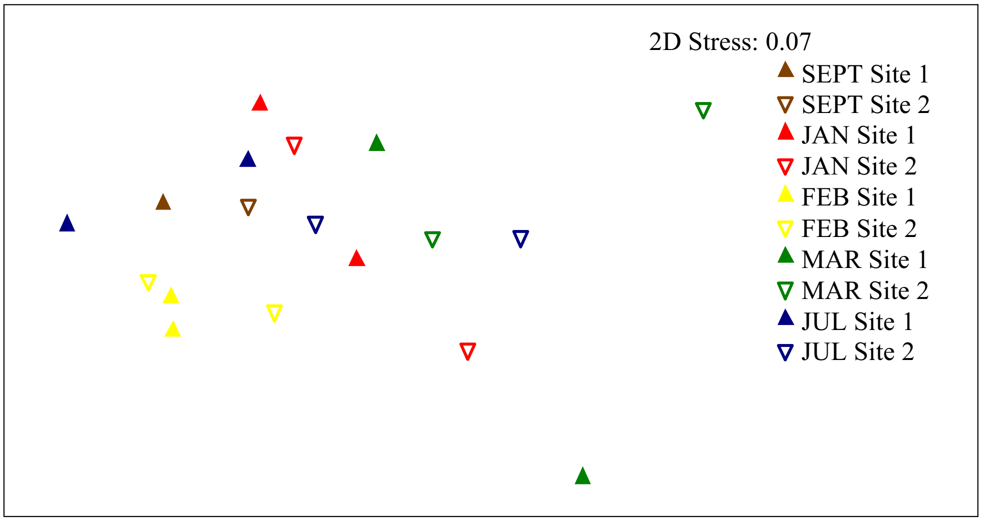

Figure 8. A multi-dimensional scalar plot from a Bray Curtis similarity index of the drift aquatic macro-invertebrate community structure during the monitoring period. Samples coincide with schedule provided in Figure 4.

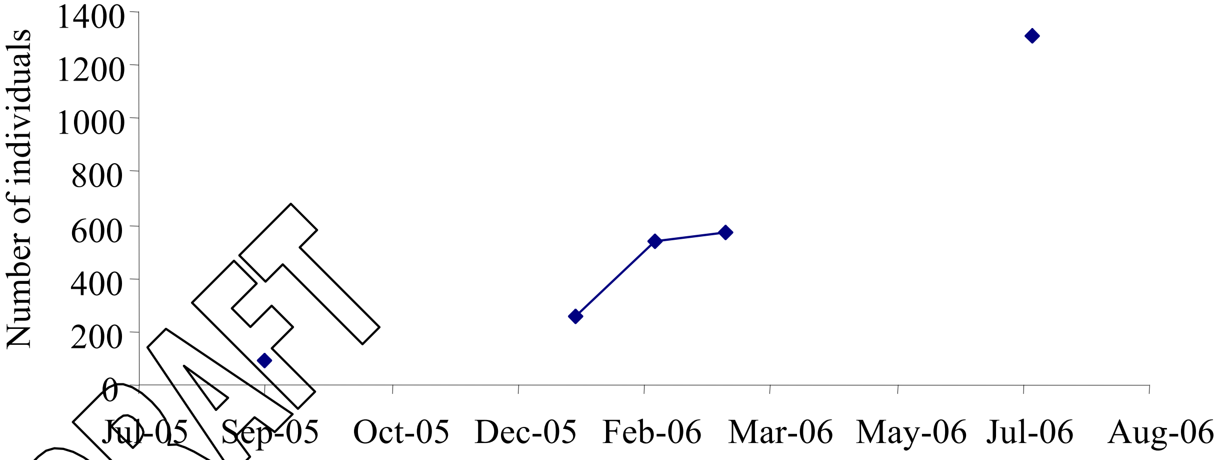

Figure 9: The total number of macroinvertebrate individuals observed during each sampling of the side channel benthos. Samples coincide with schedule provided in Figure 4.

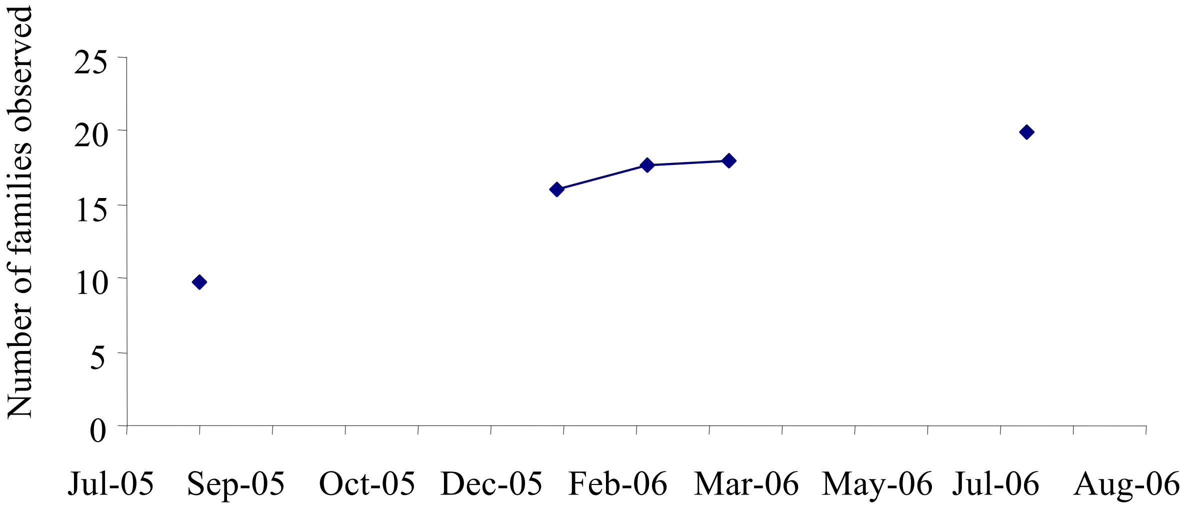

Figure 10: Total number of macroinvertebrate families observed during each sampling of the side channel benthos. Samples coincide with schedule provided in Figure 4.