Physical Habitat and Fish Use of Channel Rehabilitation Projects on the Trinity River

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Introduction

Construction and operation of the Trinity River Division (TRD) of the Central Valley Project dramatically changed the flow and sediment supply in the mainstem Trinity River below Lewiston Dam (USFWS 1994). With 90% of the historic water yield of the Trinity River above Lewiston diverted into the Central Valley from 1963 to 1985 (USFWS 1994), the very low flows released from the TRD (150 to 250 cfs) inhibited or eliminated the dynamic riverine processes that had historically created and maintained high quality salmonid habitat (McBain and Trush, In Press). As commonly occurs below dams (Bovee 1995), the wetted channel width decreased, forming a narrower, post-dam channel within the larger historic (pre-dam) channel. As the mainstem Trinity River below Lewiston Dam adjusted to a new flow and sediment regime, riparian vegetation encroached into the historic channel, establishing along the post-dam channel (McBain and Trush, In Press). The establishment of this riparian vegetation, coupled with the elimination of scouring high flows and the increased sediment input associated with logging practices led to the formation of sand berms, along much of the 40 miles of the Trinity River from Lewiston Dam downstream to the confluence with the North Fork Trinity River, and to a lesser extent below the North Fork confluence (Figure 1). The channel morphology below the TRD changed from wide, gently sloping point bars to a narrow trapezoidal channel contained within the berms (USFWS 1994). This change in channel morphology reduced the amount of chinook rearing habitat (USFWS 1994) and presumably reduced the amount of rearing habitat available for other salmonids.

Monitoring during the initial phases of the Trinity River Flow Evaluation (USFWS 1988) indicated that the gently sloping point bars of the pre-dam alluvial channel were critical habitat for salmonid fry. To rehabilitate the Trinity River, the U.S. Fish and Wildlife Service (Service) identified as necessary the rehabilitation of the river's historic alternate point bar morphology and the maintenance of this morphology with increased stream flows (USFWS 1988). In 1991, the Trinity River Restoration Program initiated a pilot feathered edge or channel rehabilitation program, mechanically removing the berms as a means of reshaping portions of the river channel to its historic configuration.

From 1991 to 1993, nine pilot channel rehabilitation projects were constructed by the Bureau of Reclamation (Reclamation) and the Service (Figure 2). Selection of project sites was based on survey data collected by Reclamation, and on historical and current aerial photography. Additional consideration was given to site access, required excavation quantities, available waste disposal areas, and land ownership. Projects were constructed along the inside bend of river meanders along historic gravel bar habitats, typically where the post-dam channel confinement had created monotypic "run" habitats. Heavy equipment was used to remove the berm down to the historic cobble surface and reshape the bank (typically 2-3 feet below the water surface elevation associated with a 300 cfs dam release (Gilroy 1997, personal communication)). The opposite bank of each site was left undisturbed. Project sites ranged from 395 to 1,200 feet in length.

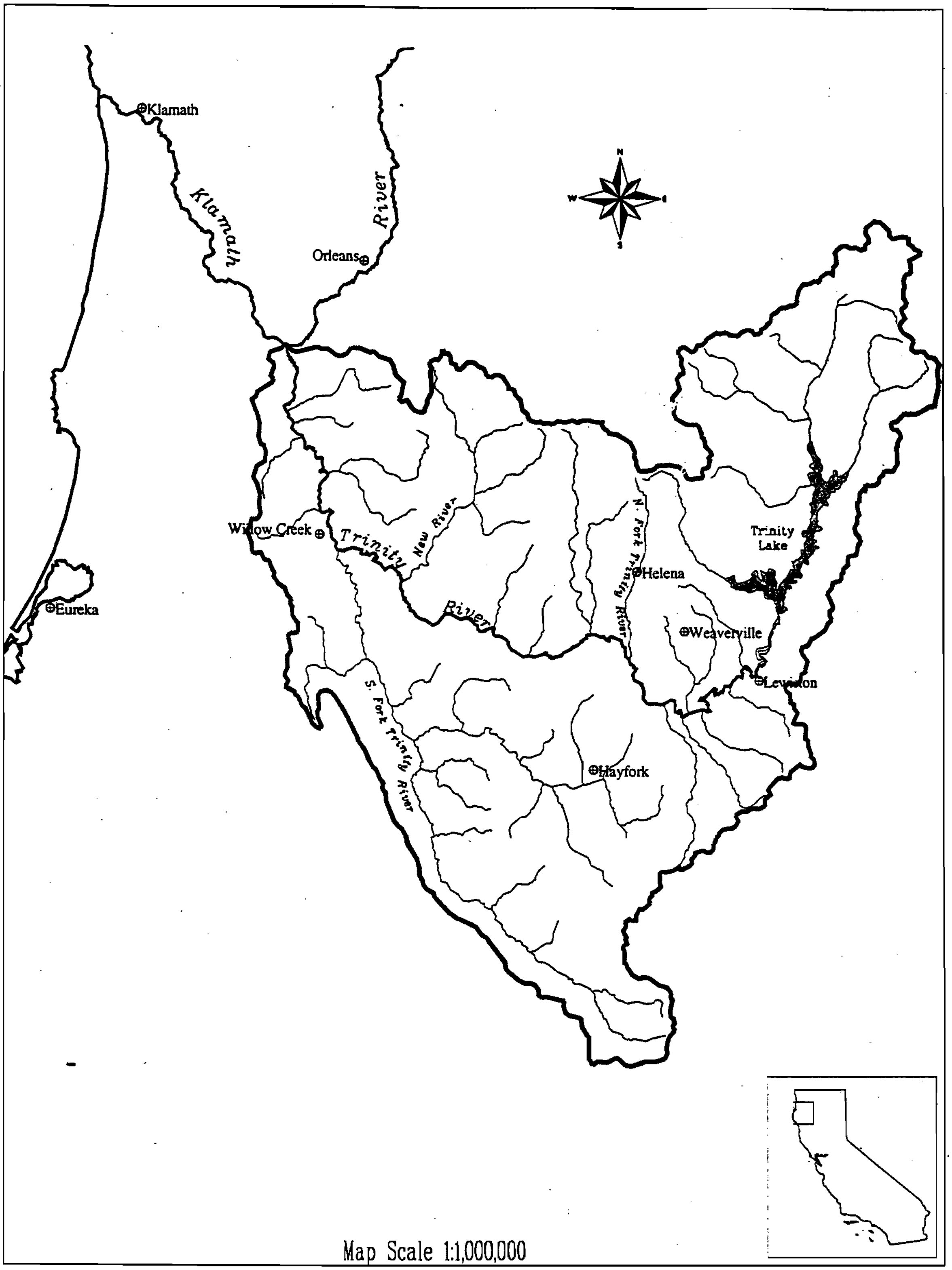
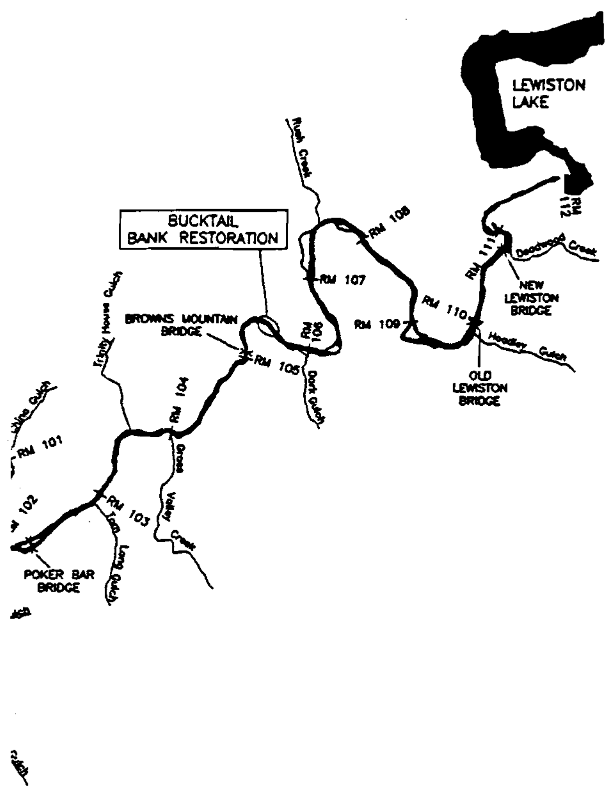


Figure 1. Location Map of the Trinity River Basin, California



TRINITY RIVER
-.OT BANK REHABILITATION PROJECT
SITE LOCATIONS

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To evaluate the effectiveness of the channel rehabilitation projects in providing increased salmonid fry rearing habitat, the Service initiated habitat and fish utilization assessments the pilot channel rehabilitation sites.

Methods

1. Physical Habitat Assessment

Two salmonid rearing habitat assessments of the channel rehabilitation projects were conducted using the Physical Habitat Simulation (PHABSIM) component of the Instream Flow Incremental Methodology (IFIM) (Bovee 1982). PHABSIM was used to relate changes in stream discharge to changes in weighted usable area (WUA), an index of habitat availability for selected species and life stages.

a. Pre- and Post-Rehabilitation Comparison

The first assessment was a site specific comparison of pre- and post-rehabilitation chinook fry rearing habitat. Pre-rehabilitation WUA estimates were available for only two sites: Steelbridge (RM 99) and Steiner Flat (RM 92). These sites were located within Trinity River Flow Evaluation PHABSIM sites and data were collected as part of the Trinity River Flow Evaluation (USFWS 1986, USFWS 1987, Appendix A). Post-construction WUA estimates for rearing chinook fry at these two sites were estimated using PHABSIM data collected in 1995 (USFWS 1996).

b. Projected Channel Analysis

The second assessment evaluated the effect of channel rehabilitation on the flow-habitat (WUA) relationships for a generalized channel rehabilitation project. Of the eight monitored rehabilitation sites, three sites (Bucktail (RM 105), Steiner Flat (RM 92), and Sheridan Creek (RM 81)) were identified as having created shallow, low velocity salmonid habitat within the study's time frame (McBain and Trush, In Press). These sites contained characteristics similar to natural gravel bars, mid-channel bars, backwaters, and other features typical of unregulated riverine systems (McBain and Trush, In Press). Using 1995 transect data (USFWS 1996), WUA was estimated for a combination of 15 transects (three from the Bucktail site, seven from the Steiner Flat site, and five from the Sheridan Creek site). Transect data were combined into a single data set, weighted equally, and calibrated for water surface elevation rating curves and velocity patterns. The resulting hydraulic models were then combined with habitat suitability criteria curves (depth and velocity variables only) for Trinity River salmonids (Hampton 1988) to produce estimates of WUA at various flow releases in the rehabilitated channel. All modeling was conducted using the Riverine Habitat Simulation System (RHABSIM) version of the PHABSIM system (Payne 1995). Based on calibrated water surface elevations for dam releases of 300 to 6000 cfs and site specific velocities measured at a 1000 cfs dam release flow, WUA were estimated for flows that ranged between 150 and 3000 cfs. For a full description of the methods used in the evaluation of the channel rehabilitation projects, refer to USFWS (1996).

WUA estimates for the non-rehabilitated channel were derived from data collected at 11 transects (equally weighted) representing run habitats from the Bucktail (four transects) and Steiner Flat (seven transects) study sites in 1985, 1986, 1989, and 1990. Run habitat transects at the Bucktail and Steiner Flat sites were selected to represent the non-rehabilitated channel because the channel rehabilitation sites were run habitats prior to construction (Gallagher 1995) and because these sites were in close proximity to the representative channel rehabilitation sites. WUA of the non-rehabilitated channel were estimated from velocity and depth measurements in conjunction with habitat suitability criteria at dam releases of 150, 350, 450, 800, 1500, 2000, and 3000 cfs. WUA values for intermediate flows were interpolated.

The absolute reliability of these calculations was limited by the relatively small number of appropriate transects, the narrow flow range for hydraulic modeling, and uncertainty regarding the ultimate configuration of the rehabilitated sites, as well as the adjacent reaches of the river. WUA were estimated for fry and juvenile chinook, coho, and steelhead for an idealized rehabilitated channel and the non-rehabilitated channel.

2. Chinook Use of Channel Rehabilitation Sites

Chinook salmon use of the eight monitored channel rehabilitation sites (Bucktail, Limekiln, Steelbridge, Steiner Flat, Bell Gulch, Deep Gulch, Sheridan Creek, and Jim Smith (Figure 2)) was assessed by direct observation (snorkel surveys) in the spring of 1994. Fish use data were not collected at the Peartree site and no fish use data were collected prior to construction at any of the sites. Counts of rearing chinook salmon were conducted along the same transects established for physical habitat assessments (Gallagher 1995). Sampling was conducted from mid-morning to late afternoon, which coincides with the peak activity levels of rearing chinook salmon (USFWS 1989).

Sample areas corresponding to physical habitat transect cells along each transect were marked with colored rocks so that fish counts for individual cells along the transect were accurately conducted (Gallagher 1995). An additional set of colored rocks were set six feet downstream of the transect to mark the lower boundary of the transect cell. Each diver made multiple (typically three) counts per cell and these counts were averaged to provide an estimate of the number of chinook using that cell. If multiple divers surveyed the same transect, the average count of each diver was averaged to provide an overall average number of fish per transect cell. Sampling design and implementation did not allow for statistical comparison of fish use of the rehabilitated and non-rehabilitated banks, nor the comparison of fish use between rehabilitation sites. Each transect was divided into a non-rehabilitated bank and the rehabilitated bank. The division of individual transects between the rehabilitated and non-rehabilitated banks was made in the area where fish were not observed, which was typically in the thalweg where depths and velocities were the greatest. Thirty-five transects were sampled at eight channel rehabilitation sites. Fish use sampling began March 28 and ended May 17, 1994 at Lewiston Dam releases of ~300 cfs (late March to early April) or ~1,600 cfs (late April to mid-May).

Results

1. Physical Habitat Assessment

a. Pre- and Post-Rehabilitation Habitat at the Steelbridge and Steiner Flat Sites

Comparisons of the chinook fry WUA estimates before and after construction of the Steel Bridge and Steiner Flat sites showed variable results. Construction of the Steel Bridge rehabilitation site had little effect on chinook fry WUA at low flows (≤450 cfs) and decreased chinook fry rearing habitat at higher flows (>450 cfs) (Figure 3A). At the rehabilitated Steiner Flat site, chinook fry WUA increased throughout the range of flows under 3000 cfs (Figure 3B).

b. Projected Channel Analysis

The flow-habitat relationships in the non-rehabilitated channel for fry and juvenile chinook, coho, and steelhead exhibited a similar pattern, with the largest WUA values at the lowest and highest flows (Figures 4, 5, 6). The greatest variability in WUA in the non-rehabilitated channel occurred for fry (Figure 4A, 5A, 6A). In contrast to the non-rehabilitated channel, WUA estimates for the rehabilitated channel were relatively stable throughout the range of flows modeled (Figures 4, 5, 6).

2. Fish Use of the Channel Rehabilitation Sites

The proportion of chinook observed along the rehabilitated bank and the opposing non-rehabilitated bank of each transect was variable between project sites and between

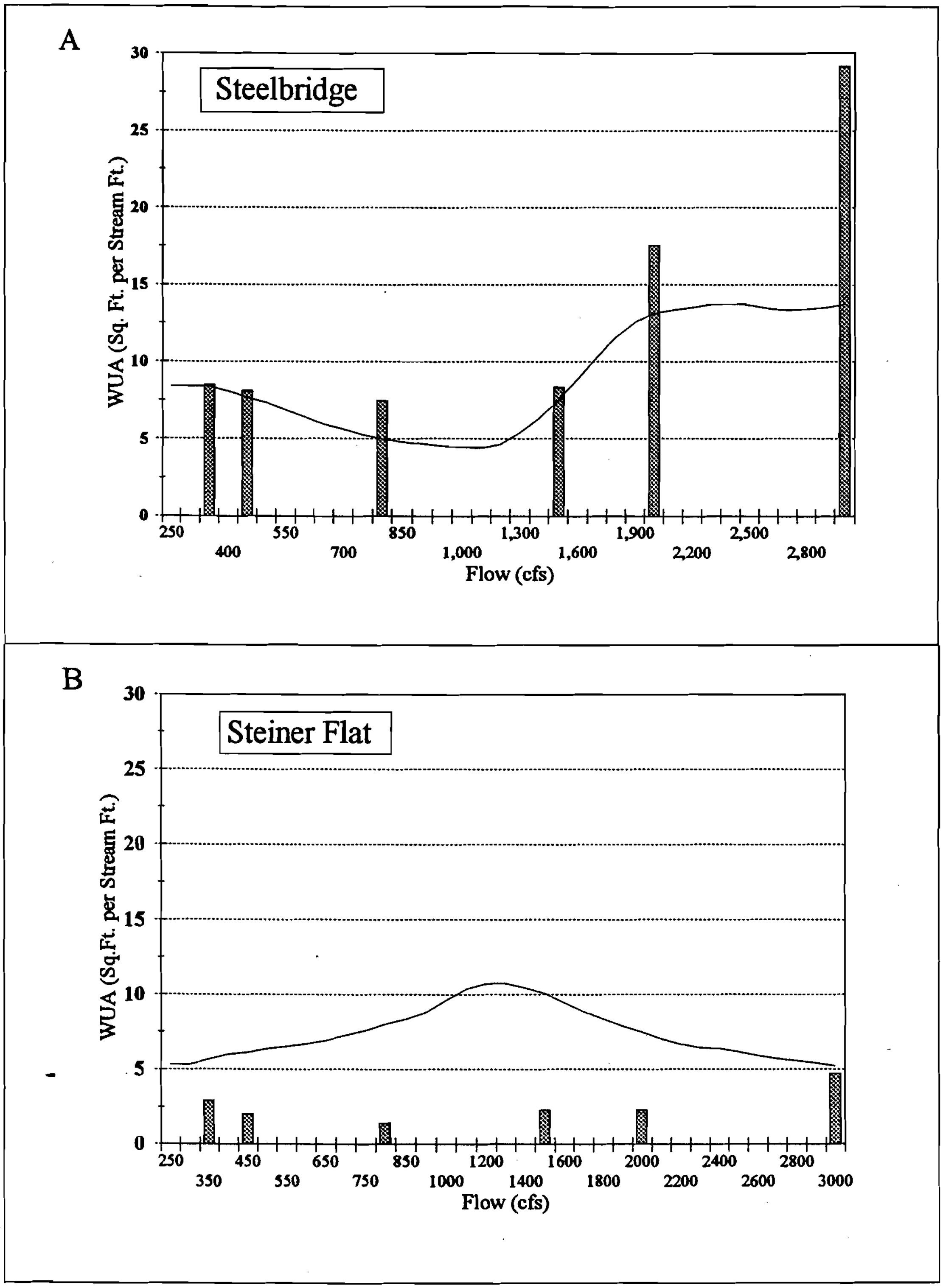

Figure 3. Comparison of chinook fry habitat before (bars) and after (line) construction of Steelbridge and Steiner Flat channel rehabilittion projects. Habitat estimates for "before" conditions were derived from direct measurement. Habitat estimates for "after" conditions were derived through modeling.

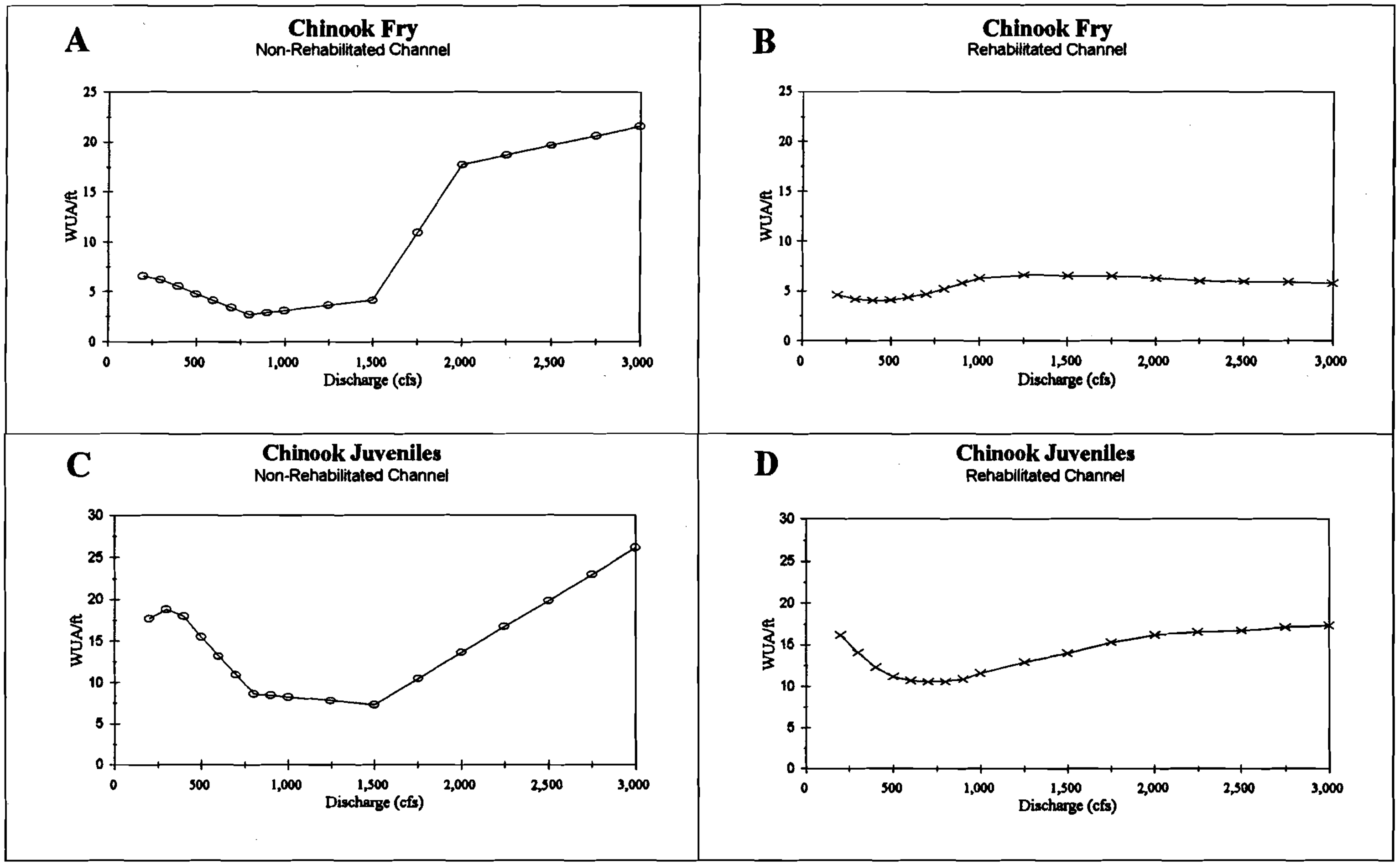

Figure 4. Flow-habitat relations for fry and juvenile chinook salmon in the non-rehabilitated and rehabilitated channel, Trinity River.

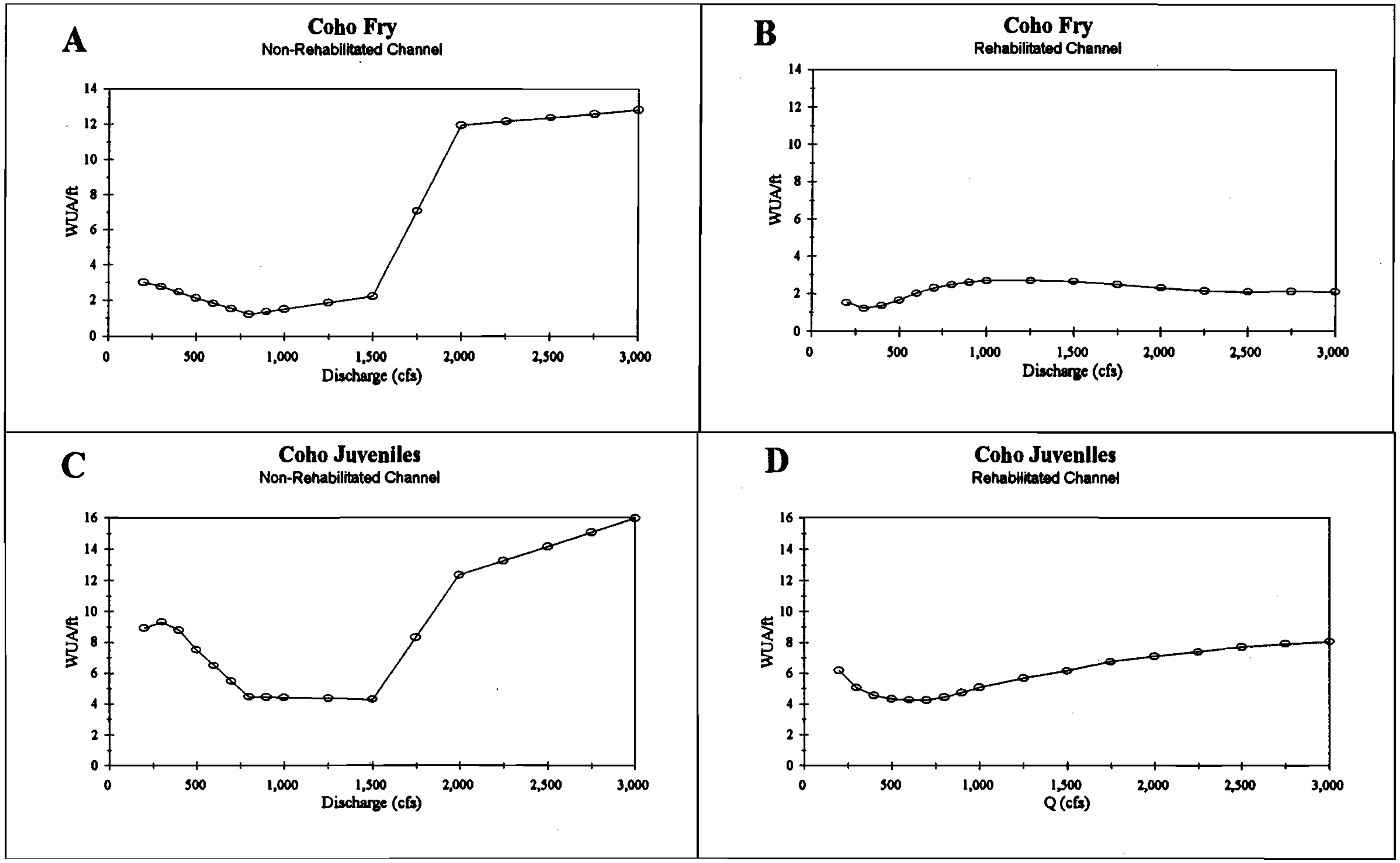

Figure 5 Flow-habitat relations for fry and juvenile coho salmon in the non-rehabilitated and rehabilitated channel, Trinity River.

surveys at the same site (Table 1). At the Bucktail site, rearing chinook were evenly distributed between the rehabilitated and non-rehabilitated banks during the first two surveys, which occurred during dam releases of ~300 cfs; however, more fish were observed on the rehabilitated bank during the last two surveys when dam releases were ~1,600 cfs. At the Limekiln site, more fish were observed on the non-rehabilitated bank during all three surveys. More fish were observed on the non-rehabilitated bank at the Steelbridge site when surveyed at ~1,600 cfs dam release, while chinook were equally distributed between both banks during the first survey at a dam release of ~300 cfs. At the Steiner Flat, Sheridan, and Jim Smith sites, more fish were observed on the rehabilitated bank during all three surveys. At the Bell Gulch and Deep Gulch sites, more fish were observed on the rehabilitated bank during the first survey at a dam release of ~300 cfs and more fish were observed on the non-rehabilitated bank during the surveys when dam releases were ~1,600 cfs.

During fish use surveys at dam releases of 300 cfs, more chinook were observed rearing on the rehabilitated bank at the five of the sites (Jim Smith, Sheridan Flat, Deep Gulch, Bell Gulch, Steiner Flat) (Figure 7). At the Steelbridge and Bucktail sites, chinook were distributed relatively equally on the rehabilitated and non-rehabilitated banks, while at the Limekiln site, more chinook were observed on the non-rehabilitated bank.

While chinook rearing along the non-rehabilitated bank were generally limited to a relatively narrow strip adjacent to the shoreline, the majority of chinook were generally distributed across greater areas along the rehabilitated bank, especially during the earlier surveys. Along transects that did not have a gently sloping bank (e.g. transect #1 of the Steelbridge site), chinook were only observed along the margins of the channel (Figure 8A). Along transects of the channel rehabilitation sites that provided gently sloping banks (e.g. transect #3 of the Sheridan site), chinook were observed across a greater area on the rehabilitated side of the channel, as well as along a narrow margin of the non-rehabilitated bank (Figure 8B).

Discussion

While channel rehabilitation is generally believed to provide benefits for rearing salmonids, proper design of projects is important. Assessments of salmonid rearing habitat before and after channel rehabilitation indicate that, when properly designed and constructed, these projects increase salmonid fry rearing habitat (Figure 3B). Prior to construction of the Steiner Flat channel rehabilitation project, the river was a long, channelized run that provided little rearing habitat; removal of the berms and re-creation of gently sloping point bars increased rearing habitat throughout the range of flows studied.

Table 1. Number of chinook per transect observed on rehabilitated bank (Rehab) and non-rehabilitated (Non-Rehab) bank during 1994 sampling.

Site	Date	Lewiston Release (cfs)	# Chinook Rehab	# Chinook Non-Rehab	% on Rehab
Bucktail (RM 105.5)	3/28/94	298	20.0	18.8	52%
	4/6/94	293	14.3	13.6	51%
	4/22/94	1,580	16.3	7.1	70%
	5/6/94	1,570	8.5	1.0	89%
Limekiln (RM 100.2)	3/31/94	291	5.7	29.7	16%
	4/28/94	1,560	0.8	8.9	8%
	5/9/94	1,590	0.7	10.7	6%
Steelbridge (RM 98.8)	3/30/94	291	22.6	25.3	47%
	4/26/94	1,570	0.6	28.5	2%
	5/10/94	1,610	2.2	34.2	6%
Steiner Flat (RM 92.0)	3/29/94	296	5.2	3.7	58%
	4/7/94	299	24.2	7.3	77%
	5/2/94	1,570	15.4	8.7	64%
	5/11/94	1,600	10.1	5.0	67%
Bell Gulch (RM 84.2)	3/31/94	291	70.6	41.7	63%
	4/29/94	1,570	2.2	30.5	7%
	5/12/94	1,580	4.2	23.2	15%
Deep Gulch (RM 82.0)	4/4/94	294	82.3	49.3	63%
	5/3/94	1,570	5.0	11.5	30%
Sheridan Creek (RM 81.7)	4/5/94	293	68.3	24.7	73%
	5/4/94	1,570	22.2	13.1	63%
	5/13/94	1,590	21.8	13.3	62%
Jim Smith (RM 78.5)	4/1/94	291	36.7	13.9	73%
	5/5/94	1,570	30.6	10.9	74%
	5/17/94	1,600	25.6	8.9	74%

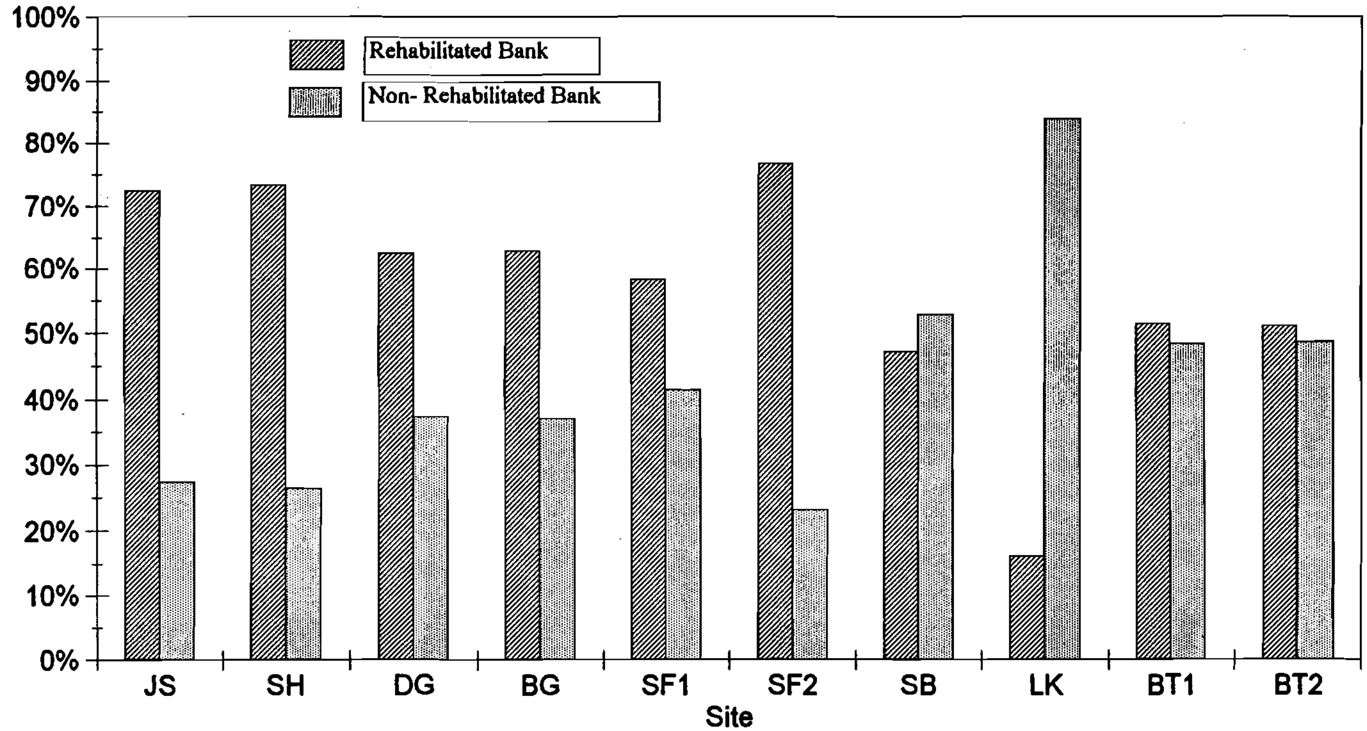

Figure 7. Percent of chinook per transect observed on the rehabilitated and non-rehabilitated bank of the channel rehabilitation projects at dam releases of approximately 300 cfs, Trinity River 1994. (JS=Jim Smith,SH=Sheridan, DG=Deep Gulch, BG=Bell Gulch, SF-1=Steiner Flat (1st Survey), SF-2= Steiner Flat (2nd survey), SB=Steelbridge, LK=Limekiln, BT1=Bucktail (1st Survey), BT2= Bucktail (2nd Survey)).

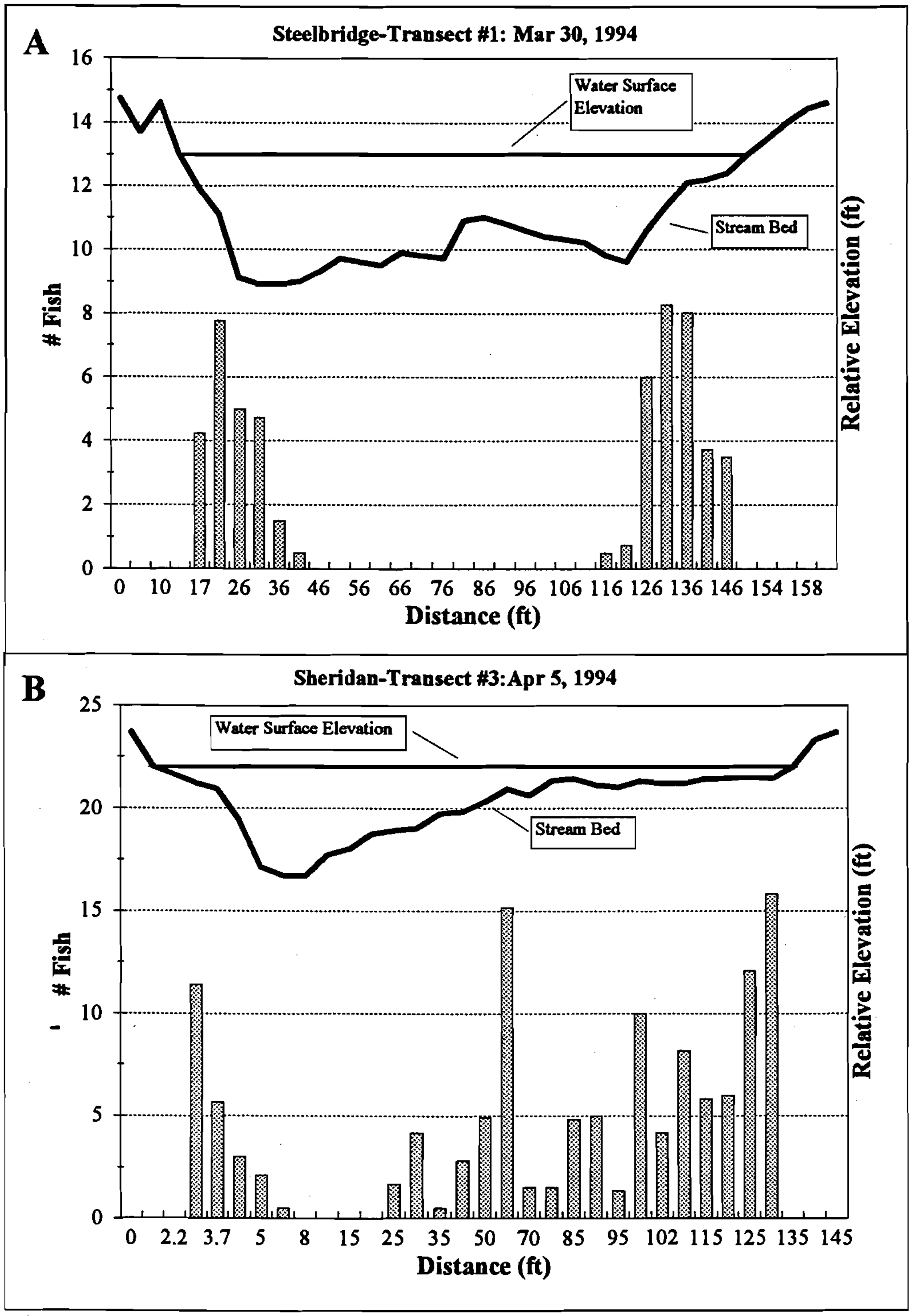

Figure 8. Channel profile (solid line), water surface elevation (dotted line) and distribution/abundance (bars) of chinook at two channel rehabilitation site transects at a dam release of ~300 cfs.

The importance of project design and construction was exemplified by the Steelbridge site, where the project failed to restore salmonid rearing habitat (Figure 3A). This lack of a beneficial response was attributed to the morphological characteristics of the site. The rehabilitation of the channel resulted in a steep bank that did not provide shallow, low velocity habitat when flow increased, while the opposing shoreline (the non-rehabilitated bank) was very diverse. With rocky outcroppings, small islands, and alcoves that created eddies and backwaters, the non-rehabilitated bank provided highly suitable habitat for rearing salmonids.

Restoration of gently sloping gravel bars changed the habitat-flow relationship from one in which there was great variability in habitat availability from low to high flows to one in which habitat availability was relatively stable throughout the range of flows studied. In the non-rehabilitated channel (Figures 4A, 4C, 5A, 5C, 6A, 6C), the large variability in habitat availability throughout the range of flows was due to the trapezoidal configuration of the channel. As flows increased up to ~1,500 cfs, water velocities and depths increased to levels that were less suitable for rearing salmonids. As flow increased above ~1,500 cfs, the areas behind the riparian berms became inundated and suitable depths and velocities were again provided. The peaks in the habitat (WUA) for the non-rehabilitated channel, which occurred at very high and low flows, do not represent quality rearing habitat (Figures 4A, 4C, 5A, 5C, 6A, 6C). The high WUA values at the lowest flows (150 cfs) were derived primarily from large areas of poor habitat (Habitat Suitability Criteria<0.20) over a broad area. The high WUA values at flows in excess of ~1,500 cfs are also misleading; the dense vegetation behind the berms, primarily berry vines and bushes, decreased velocities to levels suitable for salmonids, but this type of habitat (inundated vegetation) is not believed to be suitable rearing habitat for salmonid fry which prefer open, shallow, low velocity gravel bar habitats (Everest and Chapman 1972, Hampton 1988).

Changing the shape of the channel from a relatively narrow trapezoid to a gently sloping bank allowed the river to spread out along the sloping gravel bars, providing suitable salmonid rearing depths and velocities regardless of flow magnitude (Figures 4B, 4D, 5B, 5D, 6B, 6D). Bands of suitable habitat along the stream margin were relatively consistent at all flows, and migrated up and down the gently sloping bank relative to changes in flow (Figure 9).

Because the river often experiences substantial changes in flow due to winter storms, providing suitable habitat throughout a range of flows is desirable to prevent habitat bottlenecks. Stable amounts of suitable habitat throughout the rearing period are crucial to the survival of salmonids, especially fry that are highly sensitive and vulnerable to habitat changes (Healey 1991, Sandercock 1991). In the rehabilitated channel, stable amounts of suitable rearing habitat are maintained during these winter flow changes as regions of suitable habitat migrate in bands over the range of discharge (Figure 9), without

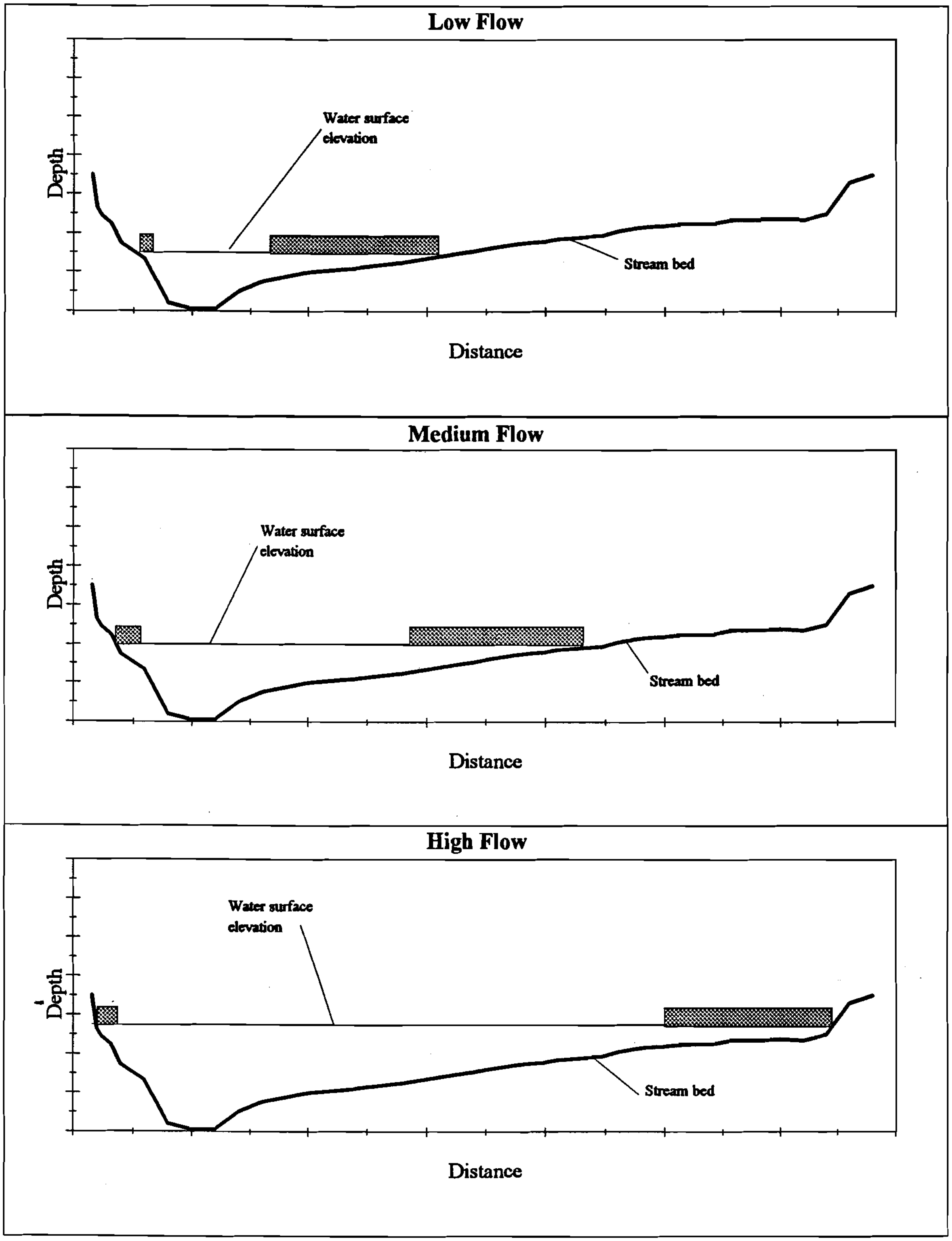

Figure 9. Representation of the historical and rehabilitated channel configurations with salmonid fry rearing habitat (represented by gray boxes) at low, medium, and high flow stages.

the distinct contrast in the amount of suitable habitat between low, medium, and high flows that occurs in the non-rehabilitated channel (Figures 4A, 4C, 5A, 5C, 6A, 6C).

Fish use data of the channel rehabilitation sites is limited. The most extensive surveys conducted were in 1994 and these surveys focused only on chinook and were conducted at a time when there were probably few chinook fry rearing in the mainstem. Because the primary purpose of the pilot channel rehabilitation program was to restore salmonid fry rearing habitat, fish use surveys must be conducted when the majority of the fry are rearing in the areas of the channel rehabilitation sites (typically January through March for chinook). To assess the use of the channel rehabilitation projects by coho and steelhead fry, surveys must be conducted later in the spring and early summer.

Chinook use data indicated that rehabilitated banks with gently sloping gravel bars were used by chinook and that rearing chinook were distributed along the shallow, low velocity habitat created by channel rehabilitation (Figure 8B). On non-rehabilitated banks and rehabilitation sites that did not provide the gently sloping gravel bars, chinook were mostly observed within a narrow area along the margin of the channel where velocity shelters were available (Figure 8A).

Evaluation of the pilot channel rehabilitation projects indicated that, when properly constructed, channel rehabilitation can effectively increase the amount of salmonid fry rearing habitat in the mainstem Trinity River. In addition to providing shallow, low velocity habitat for rearing salmonid fry, creating and maintaining gently sloping gravel bars sustains this rearing habitat over a wide range of flows.

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