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**PHYSICAL AND BIOLOGICAL MONITORING AND EVALUATION OF
THE LOST MAN CREEK DAM REMOVAL**

Final Report

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I. INTRODUCTION

The upper dam on Lost Man Creek was built in 1936 to serve as a water source for the Prairie Creek Fish Hatchery. The concrete dam structure was approximately 7.3 meters long, 17.4 meters wide, and 2.1 meters high. Cement wing walls were located adjacent to the dam face on each stream bank. Following a large flood event in 1955, the pool upstream of the upper dam filled in with sediment. The dam and delivery pipe were no longer functional. In 1955, the upper dam was replaced by another dam lower on Lost Man Creek to divert water for hatchery operations (Redwood National Park, 1988). Later, this water source was replaced and the hatchery was supplied by water pumped from a well.

In August 1989, Redwood National Park removed the upper hatchery dam on Lost Man Creek. About half of the sediment stored behind the dam was excavated and the spoils were deposited in a stable location in the middle of the right bank terrace. The excavated materials were recontoured and replanted.

Several factors led to the decision to remove the dam. First, the dam structure posed a safety hazard to park visitors. Second, National Park Service Guidelines for Dams and Appurtenant Structures (NPS-40) requires removal of dams which are not essential for environmental preservation, management or operation of parks and do not have any purpose. Third, The dam was a partial barrier to migrating adult salmonids, in particular chinook salmon (Redwood National Park, 1988). Removing the dam assisted the natural recovery of the stream and helped restore 2.9 km of stream for salmonid spawning and rearing habitat.

Concern was raised about potential effects of dam removal releasing sediment into the lower reaches of Lost Man Creek and impacting the aquatic habitat and the operation of the county fish hatchery. Redwood National Park initiated a monitoring program in 1988 to evaluate effects of dam removal on lower Lost Man Creek.

II. STUDY OBJECTIVE

The objective of this study was to monitor and evaluate physical and biological changes in channel geometry, morphology, fish habitat, and fish distribution as a result of removing the upper hatchery dam on Lost Man Creek.

III. STUDY AREA

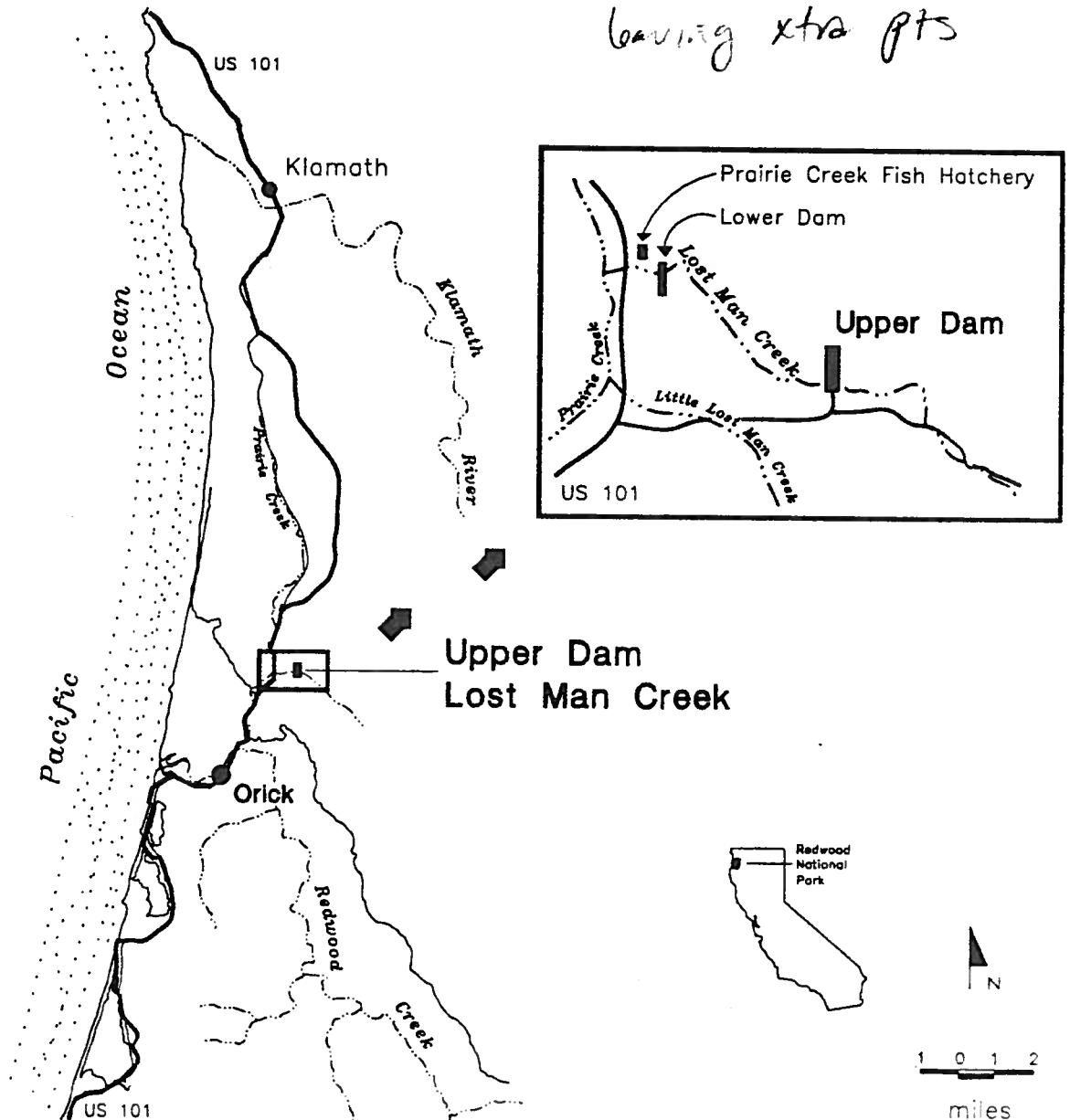
The 32.1 km² Lost Man Creek basin is located in north coastal California four miles north of Orick, California (Fig. 1). Lost Man Creek is a tributary of Prairie Creek in the Redwood Creek watershed. The upper hatchery dam was located 0.5 km upstream of the confluence of Lost Man Creek with Prairie Creek.

Average annual rainfall in the Prairie Creek basin is 170 cm (67 in) measured at the Prairie Creek Redwood State Park (Fig. 2; 41 years of record). At least 80% of the rainfall occurs

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during moderately intense winter storms between October and March. Rainfall during summer months is uncommon. Since 1985, the Prairie Creek watershed has experienced below normal rainfall.

Bedload transport rates in Lost Man Creek from 1973 to 1975 were measured at a station located in the upper one-third of the Lost Man Creek basin. Annual bedload transport rates of 153 m³ per year (318 tons/year) were measured at the gaging station, or about 460 m³ per year (adjusted by drainage area from gaging station data) at the dam site. This represents an estimate of bedload transport for Lost Man Creek during two high flow years. More recently, winter flows have been lower. Peak flows at a nearby gaging station were less than a two-year recurrence interval during the study period. Consequently, bedload transport has probably been much less (less than 229 m³/year).

Lost Man Creek supports runs of chinook and coho salmon along with steelhead trout. Cutthroat trout were probably more numerous at one time in Lost Man Creek, however land use and stream modifications have significantly reduced their number (Redwood National Park, 1988). Lamprey (also anadromous species) and sculpin are found in the creek.

Prior to dam removal, salmonid spawning and rearing primarily occurred in the lower 1.3 km of Lost Man Creek below the upper dam. Removal of the dam increased fish access to the upper portions of Lost Man Creek. The upper limit of spawning and rearing in the creek is an impassable log jam 2.0 km upstream of the Lost Man Creek picnic area bridge. In addition, a short stretch of Larry Damm Creek (a tributary of Lost Man Creek upstream of the upper Lost Man Creek dam) is utilized.

In the past, the dam's configuration was a partial barrier to fish passage and passage was dependent on stream flows. Salmon need both a plunge pool and standing wave at the base of a structure which are large enough for the fish to gain the necessary momentum to jump over the structure. The larger the fish and higher the structure, the more substantial a wave is required. At the upper Lost Man Creek dam, the relatively long and low angled dam face, shallow plunge pool, and lack of standing wave at the dam bottom all contributed to preventing fish from gaining the momentum necessary to pass the structure. Under lower flow conditions, the standing wave at the bottom of the dam was too small and the depth of water flow across the face of the dam was too shallow for use by salmon, especially the larger Chinook salmon. As a result during periods of low winter flows, fish were trapped below the dam.

IV. METHODS

A channel marker system was set up along the length of Lost Man Creek between the confluence with Prairie Creek upstream to the Lost Man Creek picnic grounds bridge. Every 50 meters a marker was nailed into a stream bank tree. The markers were referred to by the following numbering system: 00+00 is the distance in meters from the mouth of Lost Man Creek where the "+" sign separates the hundreds place from the tens place. For example, station 2+10 was 210 meters upstream of Prairie Creek. Physical and biological monitoring sites were referenced to the channel marker system.

ANNUAL PRECIPITATION PRAIRIE CREEK STATE PARK

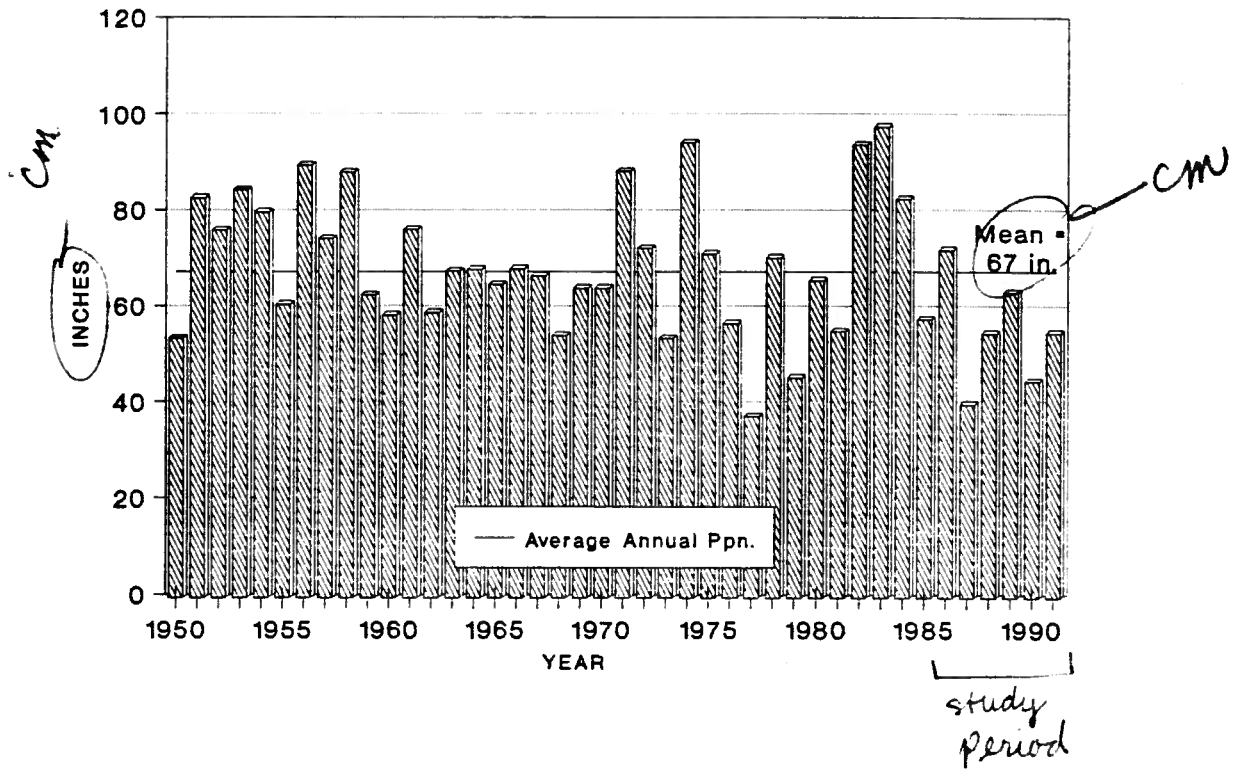


Figure 2

A. Physical Methods

Fourteen cross sections (X/S) were monumented on Lost Man Creek and extend from station 4+50 (X/S 1) to station 16+65 (X/S 14). Figure 3 shows the location of channel cross sections. Ten cross sections were monitored in the vicinity of the dam. Two additional cross sections were located upstream of the dam site and two downstream.

To determine the volume of material excavated from behind the dam, cross sections were surveyed pre- and post-dam removal in the summer of 1989. The double end method was used to calculate the total volumes extracted in the reach above the dam. Cross sections were also surveyed in spring 1990 and summer 1991 to document channel response to dam removal. Cross section channel changes were evaluated by Water Year (WY). A water year extends from September 30 to October 1 and groups the high flow months into the same year; for example WY 90 extends from September 30, 1989 to October 1, 1990.

To document changes in the surface sediment size distribution due to dam removal, pebble counts (Wolman, 1954) were measured at selected cross sections in the summer of 1989 and at all cross sections in the summers of 1990 and 1991. Particle size was measured along five transects perpendicular to the stream channel and spaced a quarter-channel width apart. A total of 100 rocks were chosen at random and the median axis measured. The D_{50} was determined for each cross section. The D_{50} is the particle size diameter in millimeters at which 50 percent of the sample is smaller.

Longitudinal streambed profiles of the lower 2.2 km of Lost Man Creek were surveyed in 1987 and 1990 to document changes in the channel gradient and bed morphology. The streambed profile extended from the Lost Man Creek picnic grounds bridge downstream to the confluence with Prairie Creek. In addition, local adjustments in channel gradient following dam removal were monitored throughout the winter of 1989-90 by repeating longitudinal profile surveys along a 440 meter long reach in the immediate vicinity of the dam. The streambed profile extended from a large redwood log spanning the channel downstream of X/S 13 (station 14+91) downstream to a riffle crest 120 m downstream of the dam site at X/S 3 (station 10+50).

Pool locations and residual pool depths were measured from the 1987 and 1990 longitudinal profile surveys. Residual pool depth is defined by the difference in elevation between the deepest point of a pool and the downstream riffle crest controlling pool depth. Pools were defined by a residual depth of 0.46 m (1.5 ft) or greater. The stream was divided into two reaches: the lower 1433 meter reach which could be impacted by removal of the dam and the upper 617 meter reach above the influence of the dam. For each reach, the two-sample t -test with an $\alpha = 0.05$ was used to determine if there was a difference in the mean residual pool depths between 1987 and 1990. The F-statistic with $\alpha = 0.05$ was used to determine if the sample variances were equal. Although the total number of sample pools were low ($n=9$ in the upper reach and $n=17$ in the lower reach), the total population of pools were measured in both reaches.

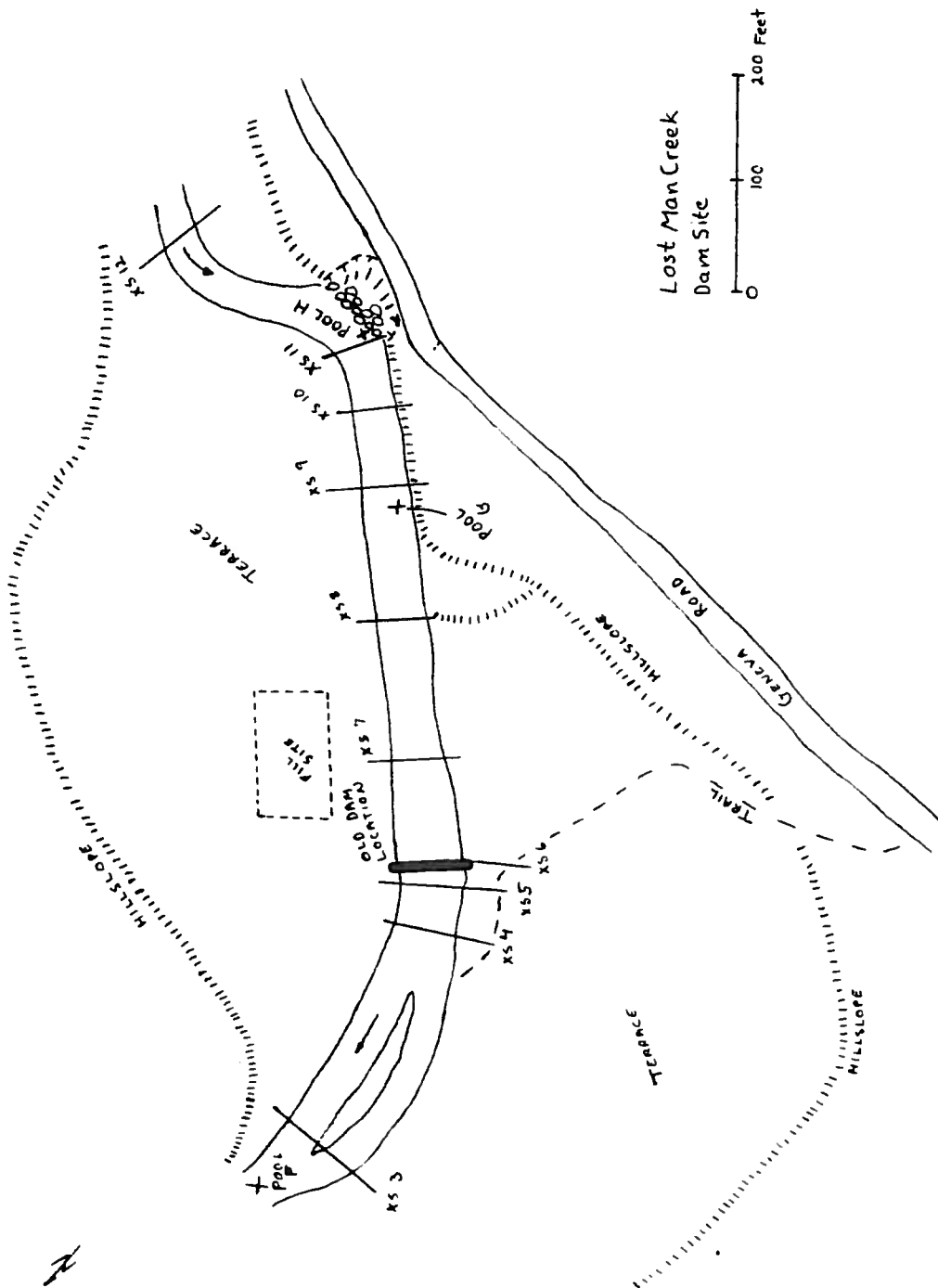


Figure 3

B. Biological Methods

Habitat typing. The aquatic habitat of lower Lost Man Creek was inventoried using the habitat typing method of Bisson and others (1981). Trinity Restoration Associates conducted winter and summer surveys to establish baseline data and to document changes in fish habitat due to the dam removal. Habitat surveys were performed pre- and post-dam removal. Winter habitat typing surveys were performed at a discharge of about 25 cubic feet per second (cfs) and summer surveys conducted at a baseflow discharge of about 2 cfs. A discharge of 25 cfs is equal or exceeded about 30% of the time and a discharge of 2 cfs is equal or exceeded about 75% of the time (Fig. 4).

Fish habitat was surveyed from the confluence with Prairie Creek upstream to the Lost Man Creek picnic grounds bridge. The stream was separated into three reaches: a 1,050 m lower reach which extended from the confluence with Prairie Creek to X/S 3 (about a 120 m downstream of the dam), a 400 m dam reach in the immediate vicinity of the dam (X/S 3 - X/S 13), and a 580 m upper reach which extended from X/S 13 upstream to the Lost Man Creek picnic grounds bridge. Individual habitat types were measured and described within the designated stream reaches. The description of each habitat unit included habitat type, length, average width, surface area, average depth and maximum depth, and volume. Measurements were made using a range finder, tape and stadia rod.

Spawner Surveys. Winter surveys were conducted in Lost Man Creek to determine the distribution of salmonid spawners, carcasses, and redds in relation to the dam before and after its removal in August 1989. Chinook and coho salmon and steelhead trout were surveyed.

Spawner survey data collected prior to the winter of 1988-1989 was part of another study to determine if the Prairie Creek Hatchery weir (located 150 m upstream of the confluence with Prairie Creek) blocked fish access to the upper reaches of the creek, and if interception of returning fish by the hatchery caused low spawning numbers above the weir. The first survey in February 1985 counted only carcasses and live salmonids. During the winters of 1985-86 and 1987-88, surveys were continued to evaluate the passage of fish beyond the weir, and live salmonids, carcasses and redds were counted. Carcasses were flagged to prevent double counting.

When dam removal on Lost Man Creek was proposed in 1988, the number of winter surveys were increased to monitor the effects of dam removal on the distribution of returning adults. Multiple winter surveys were conducted during the winter of 1988-89 to the present.

During the 1991-92 winter surveys, all redds were flagged to prevent double counting in subsequent surveys. Redds were flagged since redd features are sometimes flattened by flows, or superimposed upon by subsequent spawning fish. Since live fish eventually end up as carcasses or, in the case of steelhead trout, migrate downstream after spawning, spawning surveys were spaced at least ten days apart. The spacing of fish surveys insured that live fish would have died or migrated out of the creek before the next survey and minimized double counting.

LM X/S 6

— Pre-Dam Removal 1989
- - - Post-Dam Removal 1989
- - - December 1989
- - - February 1990

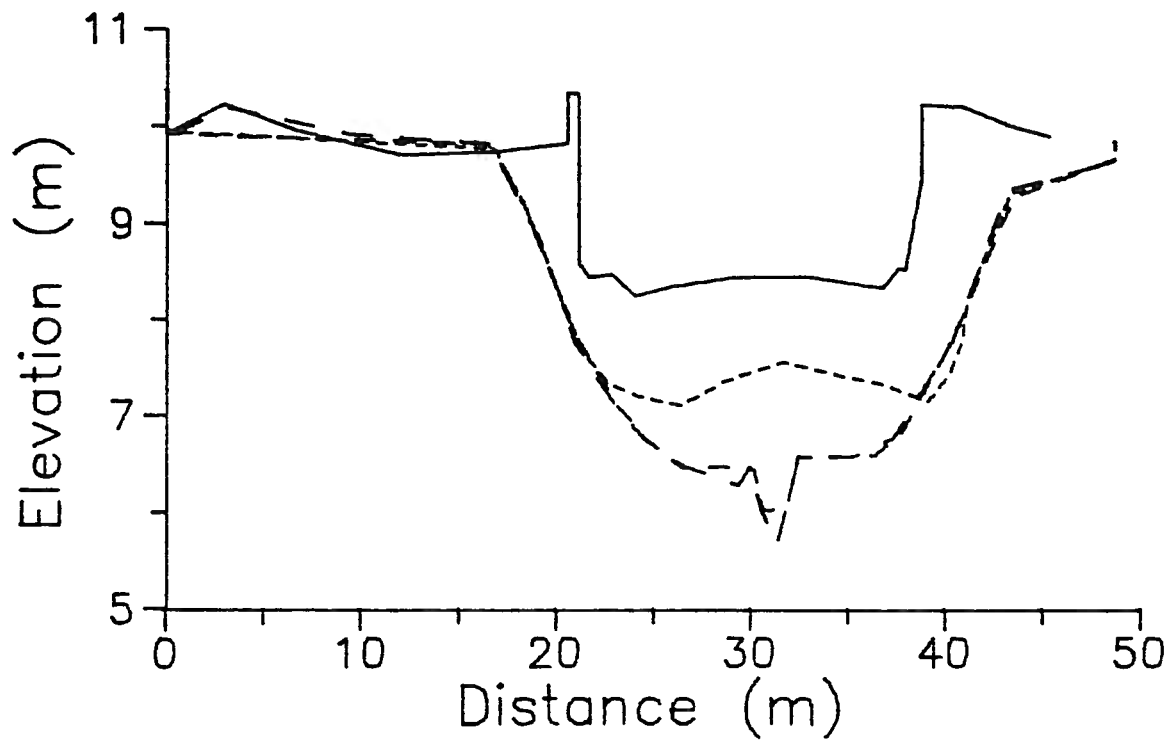
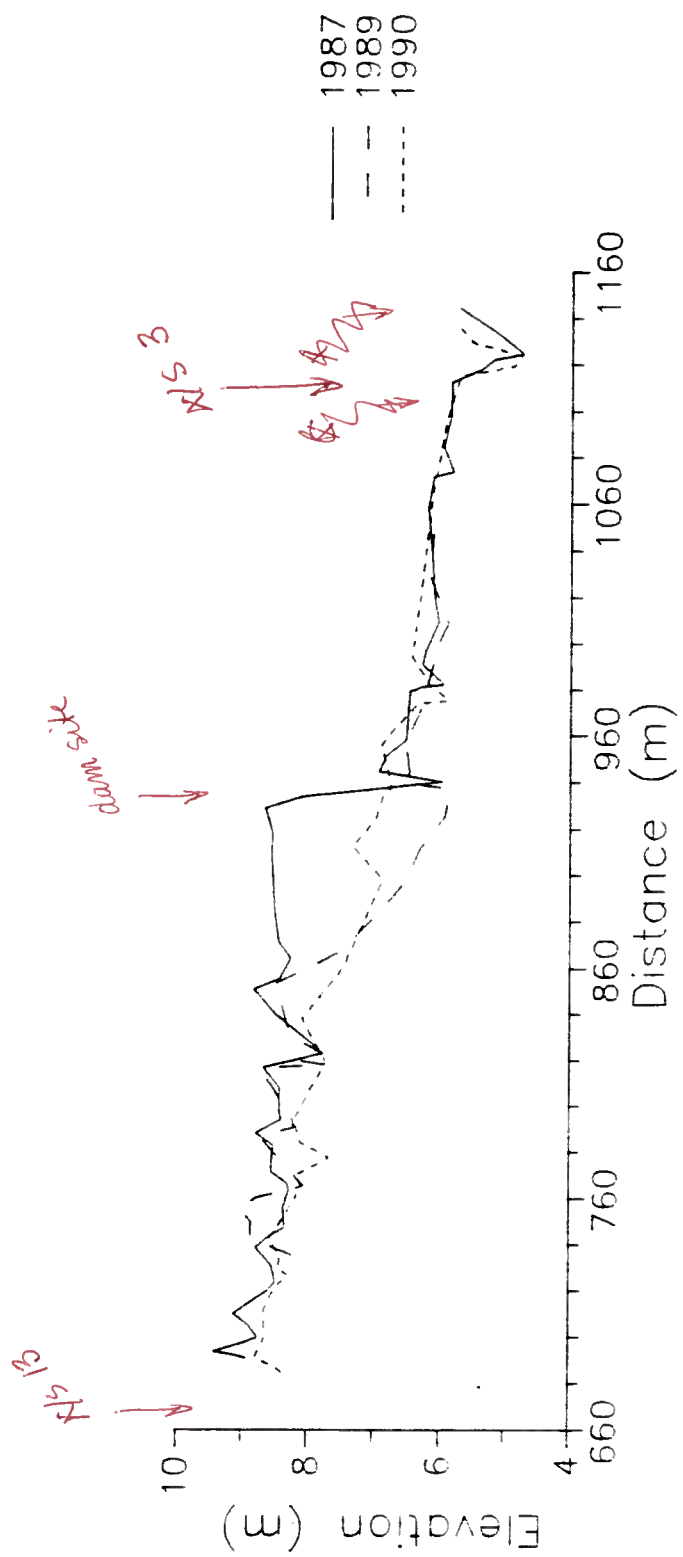


FIG. 6



Lost Man Creek was surveyed from the Prairie Creek Hatchery fish weir (Station 1+72) to the double bridges upstream of the RNP picnic grounds bridge (605 meters upstream of the picnic grounds bridge). The total distance surveyed was 2,484 meters. To determine if dam removal affected spawning distributions on Lost Man Creek, the stream was divided into three reaches. The hatchery reach (100 m) was in the lowest section of Lost Man Creek where spawning distributions are influenced by hatchery structures. It extended from the hatchery weir to the lower dam. The lower reach extended from the lower hatchery dam to the upper dam on Lost Man Creek (892 m), and the upper reach extended from the upper dam upstream to the double bridges (1492 m). The hatchery, lower and upper survey reaches were different in length; 4, 36 and 60 percent of the total distance, respectively.

Live salmonids, carcasses, and redds were recorded for 100 meter sections up to the picnic bridge. Monumented channel distance information was not available from the picnic bridge upstream to the second upstream double bridge. Consequently, all observations in this section of the stream were combined to represent a 605 m section. The frequency and cumulative percentages of the numbers of live salmonids, carcasses and redds observed along Lost Man Creek were plotted for each survey and summarized annually.

V. RESULTS

A. Physical Monitoring and Evaluation

Channel Stability. Cross section plots for pre- and post-dam removal, and for WY 90 and WY 91 are presented in Appendix A. Channel changes at cross sections for WY 90 and WY 91 are quantified in Appendix B.

The Lost Man Creek dam was removed in August 1989. A total volume of 1,695 m³ of sediment was excavated from the channel and placed in a stable location in the middle of the right bank terrace. This excavated amount accounted for about 44 percent of the total volume of sediment impounded behind the dam.

As a result of dam removal and excavation of impounded sediment, the channel cross sections in the immediate vicinity of the dam (X/S 4 - 7) increased in channel cross-sectional area (Fig. 5) and were up to 50 percent wider and up to 2.6 m deeper. Channel excavation created a sediment basin with a high sediment deposition efficiency.

During the first winter following the removal of the dam (WY 90), Cross Sections 8 through 11 scoured and Cross Sections 3 through 7 filled. The total volume of sediment scoured upstream of the dam (610 m³, X/S 8-11) was deposited immediately downstream in the excavated area (719 m³, X/S 3-7). Longitudinal profiles indicate that the extra 100 m³ of aggradation at the dam site was probably derived from upstream erosion of the channel bed. Streambed profiles in the immediate vicinity of the dam also reflected similar channel changes observed at cross sections (Fig. 6). The downstream most cross sections either scoured (X/S 2) or showed no channel change (X/S 1).

In WY 91, minor scouring occurred upstream of the dam site (X/S 4-14) and minor filling occurred downstream of the dam (X/S 1-3). However, the change in mean streambed elevation at cross sections was negligible and within measurement error.

Channel gradient prior to dam removal was 0.23 percent in the reach upstream of the dam and 0.67 percent in the reach immediately downstream of the dam. Excavation of impounded sediment locally increased the gradient to 1.09 percent within this reach and created a local drop in base level. The change in base level and over-steepened channel gradient caused a nick-point to migrate upstream. The nickpoint started in the excavated reach and proceeded to scour about 400 m upstream over the winter (Fig. 7). By the end of WY 90, the channel downcut and the gradient decreased to 0.76 percent in the reach upstream of the former dam site. In contrast, the channel gradient of the lower 1.3 km of Lost Man Creek did not change from the summer of 1987 (0.63%) to the spring of 1990 (0.63%).

Sediment Size Distribution. D_{84} , D_{50} , and D_{16} values for pre-dam removal (WY 89), WY 90 and WY 91 are presented in Appendix C. Table 1 presents D_{50} values at cross sections. The D_{50} is the particle size diameter in millimeters at which 50 percent of the sample is finer. The sediment size distribution of the three cross sections sampled above the dam increased in D_{50} and the cross section located in the riffle immediately downstream of the dam decreased in size. At the downstream end of the study reach, D_{50} increased at Cross Section 2 and decreased at Cross Section 1.

Residual Pool Depths. The difference between the average residual pool depth in 1987 and 1990 were not significant ($\alpha=0.05$). Average residual pool depth for the upper reach was 0.91 ± 0.28 m in 1987 and 1.01 ± 0.30 m in 1990. In the lower reach, the average residual pool depth was 0.78 ± 0.30 m in 1987 and 0.76 ± 0.35 m in 1990. Between 1987 and 1990, there was also no change in the total number of pools in either reach.

B. Biological Monitoring and Evaluation

Habitat Typing.

Summer and winter habitat surveys were conducted pre-dam removal in 1988 and post-dam removal in fall 1990 and winter 1991. Survey dates and discharges on Lost Man Creek for winter and summer habitat surveys are summarized in Table 2. Summer and winter habitat type distribution, surface area, volume, length, width, average and maximum depth are summarized in Appendix D.

Summer Habitat Typing A comparison of the volume distribution of pools, riffles and runs indicates that dramatic changes occurred primarily within the dam reach (Fig. 8). Prior to removal of the dam, pools comprised 80% of the habitat volume with riffles and runs accounting for 9% and 11% respectively in the dam reach. Following removal of the dam, habitat distribution shifted in response to excavation of in-channel sediment and dam removal. Pool volume decrease to only 40% of the total habitat and riffle and run volume increased proportionally to 31% and 29% respectively. In the upper reach, relatively minor changes were

Lost Man Creek Longitudinal Profile

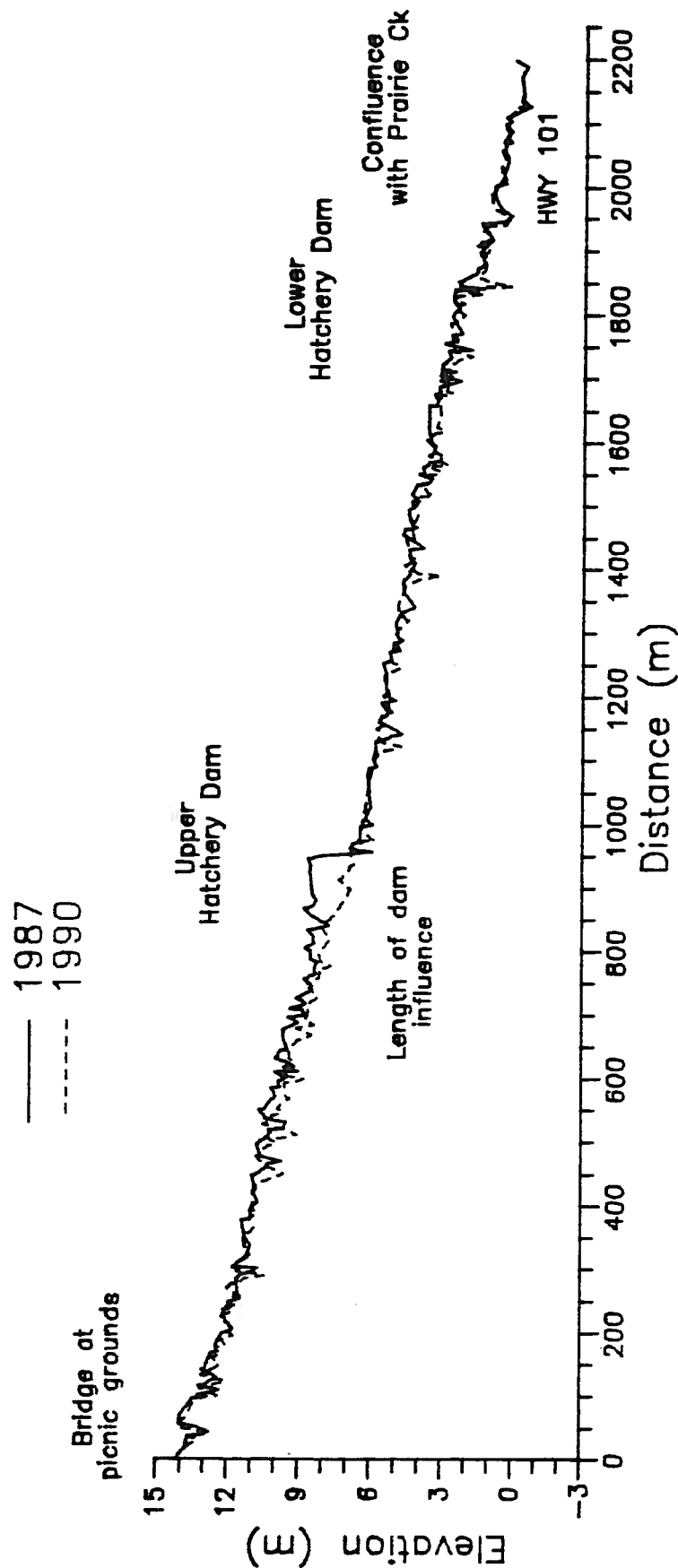
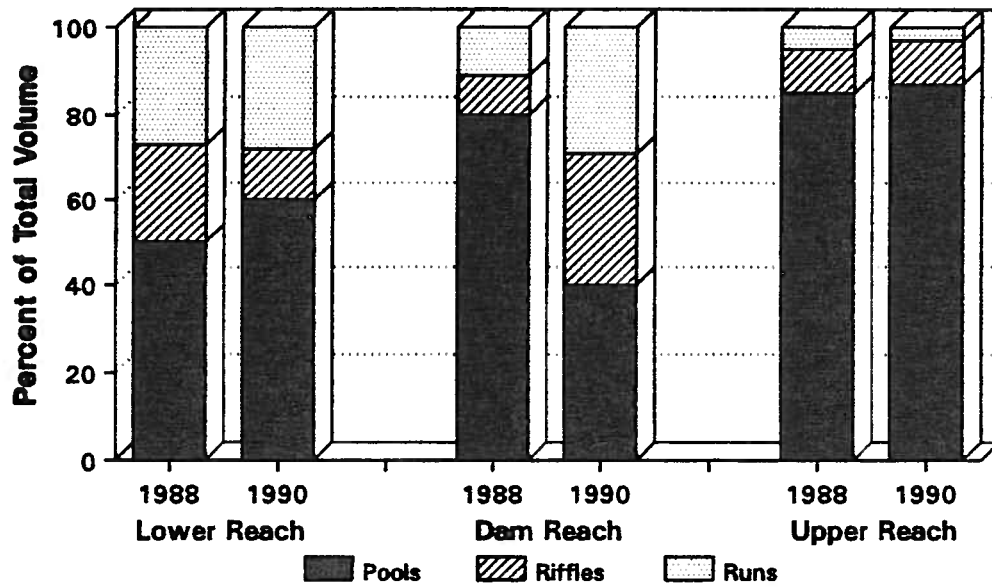


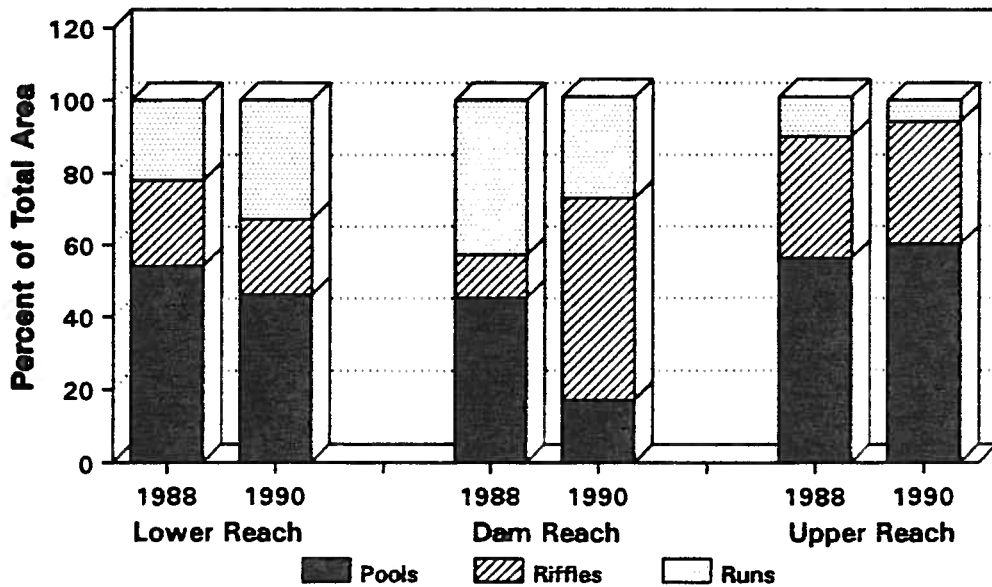
Table 2. Date, season and discharge on Lost Man Creek when habitat typing was conducted on Lost Man Creek.

DATE OF SURVEY	SEASON	DISCHARGE (cfs)
June 15 - 16, 1988*	Winter Baseflow	25.6
August 31 to Sept. 1, 1988	Summer Baseflow	1.95
April 27 - 28, 1991	Winter Baseflow	~20
Sept. 17 - 18, 1990	Summer Baseflow	1.30
* A late storm in WY 1989 enabled fish habitat typing to be conducted on Lost Man Creek which closely approximated average winter flows.		

LOST MAN CREEK SUMMER HABITAT TYPING Volume Distribution



Area Distribution



observed, and pool:riffle:run ratios generally comprise 85, 10 and 5 percent of the volume respectively. In the lower reach, there was a slight shift in habitat distribution following dam removal with an increase in pool volume from 50% to 60% and a concurrent decrease in riffle volume from 23% to 12%. Surface area distribution showed similar trends.

Winter Habitat Typing The changes in the winter volume distribution of pools, riffles and runs following removal of the dam were similar to those observed in the summer habitat but were less dramatic. Most changes were localized within the dam reach (Fig. 9). Prior to dam removal, habitat volume distribution of pools, riffles and runs was 59%, 18% and 23%, respectively in the dam reach. The most obvious change post dam removal in this reach was an increase in riffle volume from 18% to 44% of the total volume and a concurrent decrease in pools and runs volume. Relatively minor changes occurred in the lower reach and upper reach. In the lower reach, pools volumes did not change following dam removal (60% of total volume distribution) and a relatively minor increase in run volume and a subsequent decrease in riffle volume was observed. In the upper reach following dam removal, run volume remained about seven percent of the total habitat volume and a minor increase in pool volume from 70% to 79% and a concurrent decrease in riffle volume from 22% to 15% was observed. Surface area distribution showed similar trends.

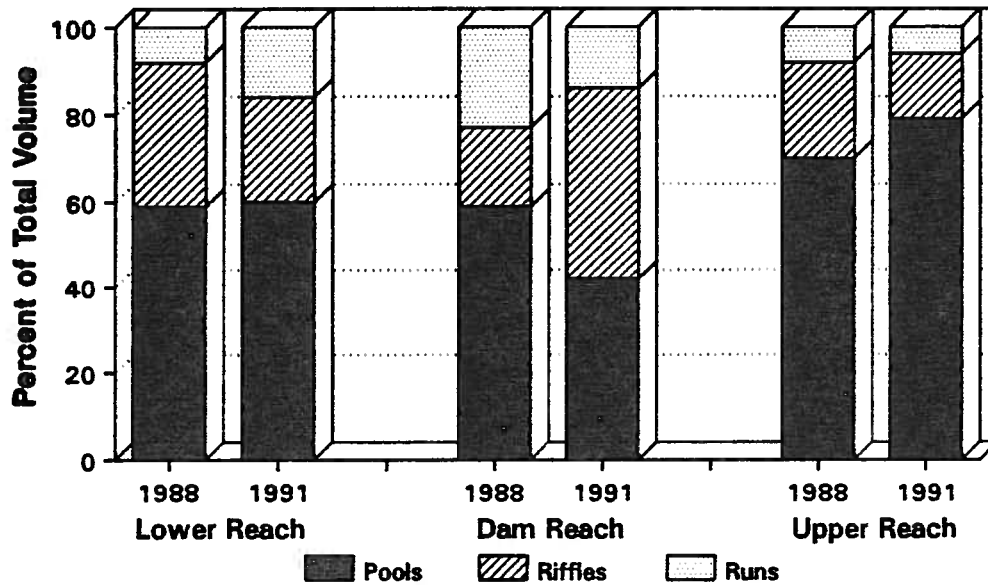
During this study inherent problems with the habitat typing technique became obvious and will be discussed in the next section.

Spawner Surveys. Nineteen surveys were conducted between February 1985 and March 1992. The numbers of live adult salmonids, carcasses and redds observed in three reaches (hatchery, lower and upper survey reaches) are recorded for each spawning survey in Appendix E. Annual spawning data are summarized for each reach in Appendix F and for chinook salmon only in Appendix G. The frequency distribution and the cumulative percent of live salmonids, carcasses and redds in Lost Man Creek are graphed for each year in Appendix H and specific seasonal survey information is presented Appendix I.

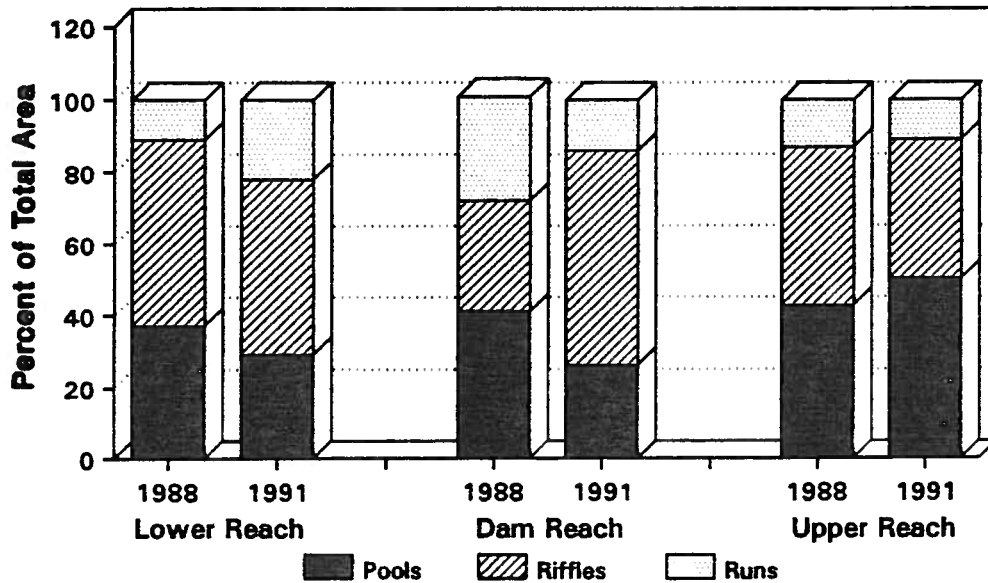
The influence of the Prairie Creek hatchery and lower hatchery dam on spawning distributions is evident by the large numbers of fish that were observed in the 100-meter hatchery reach between the weir and the lower hatchery dam (Fig. 10). Although the hatchery reach represented only four percent of the total distance surveyed, in some years up to 51 percent of the adult salmonids were observed in this reach (Appendix F). Those fish were probably homing in on the hatchery itself or could not migrate past the lower dam at the survey flows. In order to determine the effects of dam removal on fish distribution in Lost Man Creek, observations below the lower hatchery dam were not included in evaluating spawning distribution data. Table 3 presents the total number and relative percentages of live adult salmonids, carcasses and redds observed annually from 1985 to 1992 in the lower and upper reach. Table 4 presents similar information but for Chinook salmon only.

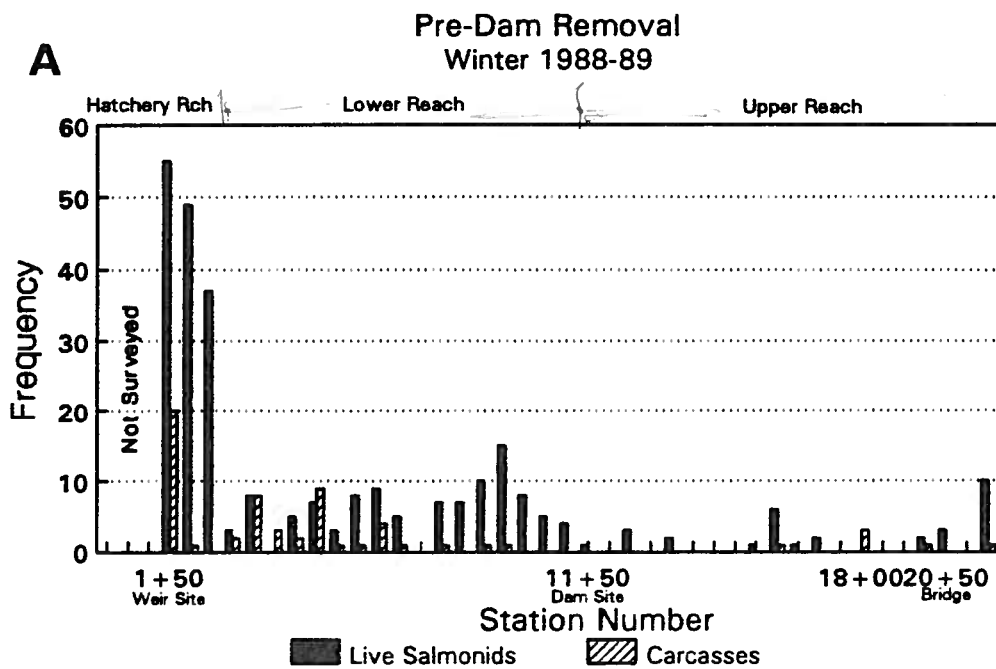
A plot of the cumulative percent of live and dead salmonids observed versus stream distance shows a change in the spawning distribution following dam removal (Fig. 11). Prior to dam removal, the number of salmonids observed above the dam site levels off and indicates few fish using the reach above the dam (Fig. 11A). In contrast, the distribution of salmonids was fairly

LOST MAN CREEK WINTER HABITAT TYPING Volume Distribution

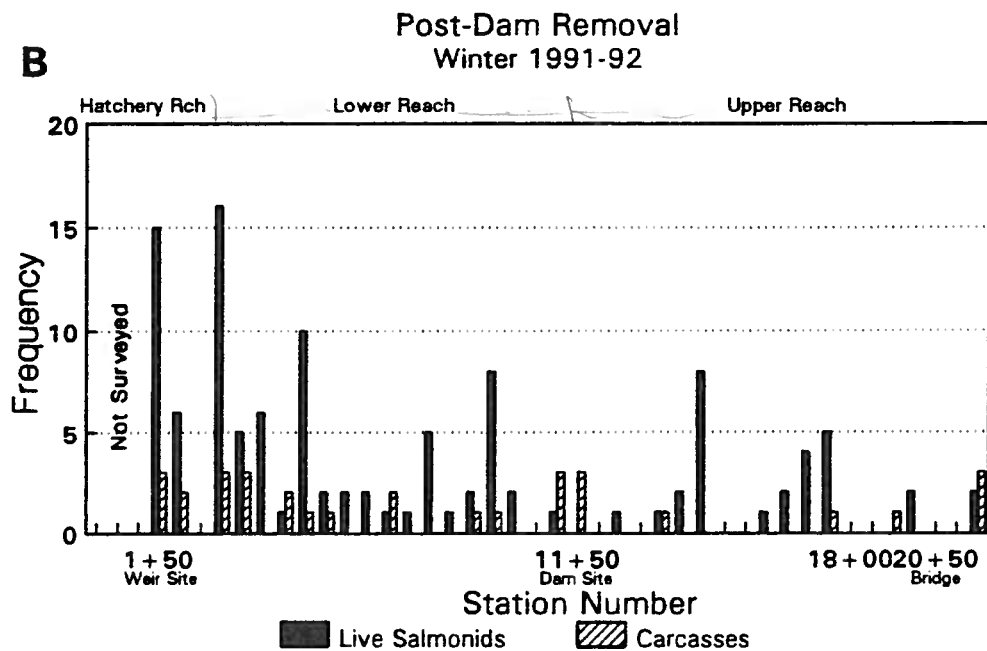


Area Distribution

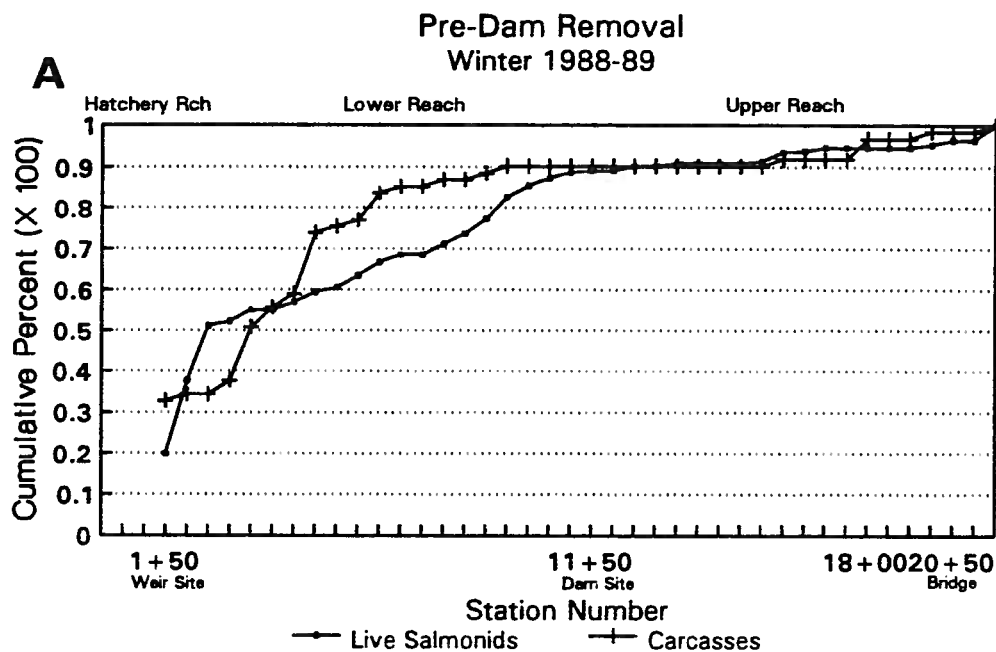




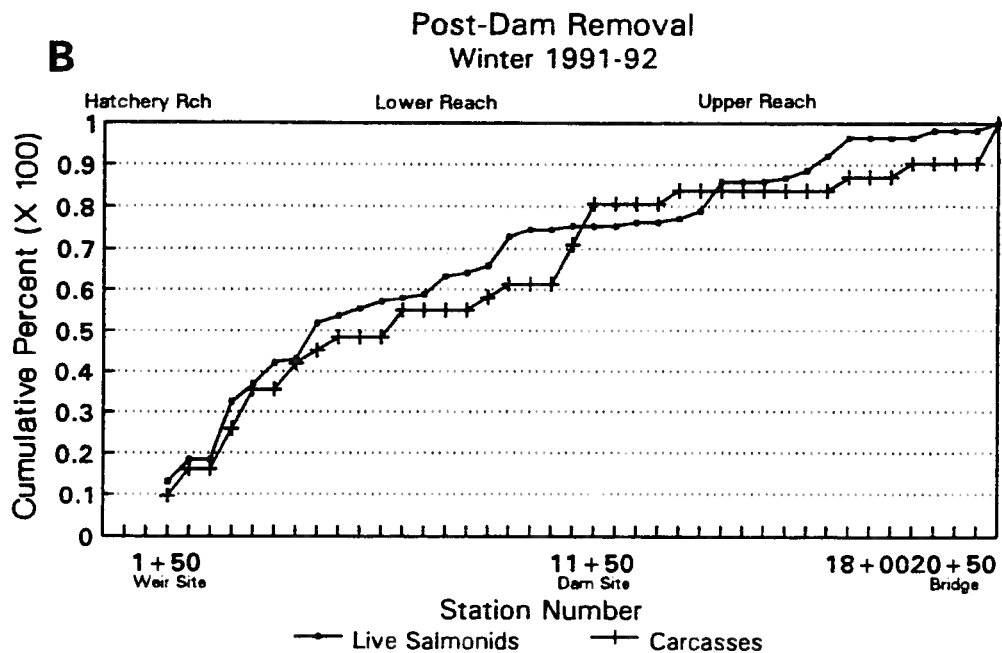
(Dec 6, Jan 25, Feb 15)



(Jan 2 & 29, Feb 13, Mar 3 & 24)



(Dec 6, Jan 25, Feb 15)



(Jan 2 & 29, Feb 13, Mar 3 & 24)

Table 5. Percentage of live adult salmonids, carcasses, and redds observed pre and post dam removal. To remove the influence of the lower hatchery dam on fish distribution and focus on the relative distribution of the fish pre and post dam removal, only observations above the lower hatchery dam were included in this analysis.

PERIOD	NO. OF YEARS (Surveys)	LIVE SALMONIDS			CARCASSES			REDDS		
		Lower Reach (%)	Upper Reach (%)	Total No.	Lower Reach (%)	Upper Reach (%)	Total No.	Lower Reach (%)	Upper Reach (%)	Total No.
PRE-DAM REMOVAL	4 (7)	77	23	270	75	25	119	83	17	145
POST-DAM REMOVAL	3 (11)	61	39	207	48	52	84	64	36	236

Table 6. Percentage of live adult Chinook salmon and carcasses observed pre and post dam removal. To remove the influence of the lower hatchery dam on fish distribution and focus on the relative distribution of the fish pre and post dam removal, only observations made above the hatchery dam were included in this analysis. (Only those live fish positively identified as Chinook are included in the live fish category.)

PERIOD	NO. OF YEARS (surveys)	LIVE CHINOOK			CHINOOK CARCASSES		
		Lower Reach (%)	Upper Reach (%)	Total No.	Lower Reach (%)	Upper Reach (%)	Total No.
PRE-DAM REMOVAL	4 (7)	59	41	37	89	11	27
POST-DAM REMOVAL	3 (11)	44	56	9	44	56	18

spread out and more uniform throughout the stream following removal of the dam (Fig. 11B).

Spawning surveys indicate that in winters following the removal of the dam, the relative percentage of carcasses and redds more than doubled in the reach above the dam site (Table 5). The percentage of live adult salmonids observed upstream of the old dam site also increased from 23 percent to 39 percent.

The annual distribution of live chinook and chinook carcasses observed above and below the dam are variable (Table 4) and may reflect the low number of chinook salmon observed. However, if data are summarized for the pre- and post-dam removal periods, the relative percentages of both live fish and carcasses increase above the dam site (Table 6). Spawning survey data indicates that prior to dam removal 41 percent of the live adult chinook and 11 percent of the carcasses were observed above the dam site. Following dam removal, the percent of live adults and carcasses observed above the dam both increased to 56 percent. After the dam was removed chinook spawning was almost equally distributed between the lower and upper reaches with slightly more chinook utilizing the area upstream of the dam. Although the survey distances below and above the dam are unequal (40% and 60% respectively), distribution trends were different after the dam was removed, regardless of distance differences.

VI. DISCUSSION

A. Physical Monitoring and Evaluation

In August 1989, the upper hatchery dam was removed on Lost Man Creek. The dam structure and about 44 percent of the sediment impounded behind the dam was excavated and removed from the stream.

The two years following removal of the dam (WY 90 and 91) received lower than normal rainfall and peak flows were less than a two-year recurrence interval. As a result, the channel adjustments observed due to dam removal have been under very low flow events.

Following the first winter storms (WY 90) after the dam was removed, the reach immediately upstream of the dam experienced dramatic channel adjustments. However, channel adjustments were highly localized. The channel upstream of the excavated portion began to scour, exposing bedrock and large boulders in the streambed. Channel morphology and pattern changed significantly from a simple pool-riffle morphology to a high gradient riffle as head cut erosion migrated upstream. Channel adjustments caused extensive undercutting and bank erosion in the reach upstream of the dam. Streambank alders fell or slid as a block into the channel. The volume of sediment scoured in the reach above the dam was deposited immediately downstream causing extensive localized channel filling and a slight increase in the elevation of the first riffle downstream of the dam. In addition, excavation of impounded sediment created a local drop in base level which combined with a steeper channel gradient to cause a nickpoint to migrate upstream during winter flows in WY 90. However, cross sections and longitudinal profiles indicate downcutting was localized in the reach upstream of the dam and the amount of sediment scoured from the channel generally balanced the amount of material filled downstream.

In contrast to changes observed in WY 90, no significant changes occurred at channel cross sections in WY 91.

Pebble count data indicate that over the 1990-91 winter, sediment size distribution increased or stayed the same in the area upstream of the dam (Cross Section 7 - 10) and in general, decreased in size downstream of the dam. Since 1989, the D_{50} sediment size at cross sections upstream of the dam increased an average of 25 mm, and resulted in an increase of 1.5 to 3 times the initial D_{50} particle size. An increase was expected because excavation locally increased the channel gradient which increased the stream power and the ability to locally transport larger particle sizes. In addition, scour removed finer sediment and exposed underlying coarser bed material. Since 1989, the D_{50} at Cross Sections 1 and 3 below the dam decreased in size, 6 mm and 15 mm respectively; Cross Section 2 increased 7 mm.

Removal of the dam did not cause a change in the average residual pool depth on Lost Man Creek. Between 1987 and 1990, the average residual pool depths did not change significantly. Although some pools changed locations during this time period, there was no change in the total number of pools in the upper or lower reach.

The Environmental Assessment estimated channel recovery and the development of pool-riffle morphology to take three to eight years under normal flow conditions. Based on the study results, this time period seems reasonable.

B. Biological Monitoring and Evaluation

Habitat Typing. The most significant changes in summer and winter habitat occurred in the managed portion of the stream where the dam was removed and in-channel sediment excavated from behind the dam. Channel response to the dam removal included a loss of pool volume and an increase in riffle and run habitat volume. The upper and lower reaches showed relatively minor change. The distribution of surface area indicated similar trends.

There are inherent limitations and problems with the habitat typing technique. While habitat typing is a good tool for basin wide planning; however, we have found it is not an appropriate technique to monitor smaller changes, for example monitoring changes in the lower reach downstream of the dam. There are limitations to the magnitude of change habitat typing can detect. MacDonald and others (1991) stated that the use of habitat typing for monitoring environmental change has not been extensively tested. Although extensive stream habitat surveys have recently been initiated on other streams in the Pacific Northwest, much of the data has not been analyzed yet. The results from these other studies are expected to document a large amount of variability in undisturbed streams. Subsequent surveys will be needed to determine natural variability within the aquatic habitat and analysis will need to be developed to distinguish changes due to land management activities from changes due to natural causes.

One obvious problem with the habitat typing data is that although flows were targeted for both the winter and summer baseflows habitat typing, the surveys were conducted at different discharges. In particular, the winter surveys in WY 89 and WY 91 were surveyed at a discharge of 25.6 and 20 cfs, respectively. This six cfs difference could account for differences

in water level and areas of the channel mapped. The water surface elevation, water depth and the wetted perimeter of the channel are different at different discharges. Secondary channels may be filled with water at higher flows and not at the lower flows. These differences result in shifts in habitat composition and proportion.

The length of stream channel typed was longer in both the 1988 winter and summer baseflow surveys (6 and 11 percent longer in length, respectively). Due to differences in water elevation, it appears that secondary channels were typed in the 1988 winter baseflow survey that were not typed in the 1991 survey and resulted in differing survey lengths.

No data on the natural background variation and shifts of the stream habitat types in undisturbed streams are available and need to be quantified. This information is necessary to differentiate habitat changes due to natural causes from changes due to management activities. For example, pools formed by woody debris are dynamic in nature. During higher flows, woody debris may shift, move downstream or be deposited outside of the active channel. These changes will, in turn, cause changes in the volume and distribution of these pools and the associated habitat immediately upstream and downstream. It is necessary to quantify this variation in order to analyze habitat typing data to document impacts due specifically to management activities.

Spawner Surveys. Prior to dam removal, the dam was a partial barrier to migrating chinook salmon. Spawning data indicate that removal of the dam increased spawning access and utilization to the upstream portions of Lost Man Creek above the dam.

VII. CONCLUSIONS

Physical monitoring and evaluation indicate that as a result of dam removal, minimal sedimentation occurred downstream of the dam. Most habitat changes were confined to the managed portion of the creek where the dam was removed and streambed altered.

Spawning surveys from 1985 to 1992 indicate that removal of the Lost Man Creek dam has allowed a greater percentage of the adult salmonids to migrate and spawn upstream of the old dam site. The relative percent of live adult salmonids, carcasses and redds nearly doubled upstream of the old dam site following dam removal.

Lost Man Creek is recovering from past logging and road construction activities in the watershed. Removal of the dam assists in the natural recovery of the stream and helps restore 2.9 km of stream for salmonid spawning and rearing habitat. Although low peak winter flows have persisted throughout the study period, the channel is locally adjusting its gradient and morphology following the removal of the dam.

VIII. REFERENCES

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