NATURAL PROPAGATION AND HABITAT IMPROVEMENT IDAHO: LOLO CREEK AND UPPER LOCHSA

CLEARWATER NATIONAL FOREST

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EXECUTIVE SUMMARY

In 1983, the Clearwater National Forest and the Bonneville Power Administration (BPA) entered into a contractual agreement to improve anadromous fish habitat in selected tributaries of the Cleat-water River Basin. This agreement was drawn under the auspices of the Northwest Power Act of 1980 and the Columbia River Basin Fish and Wildlife Program (section 700). The Program was completed in 1990 and this document constitutes the 'Final Report' that details all project activities, costs, accomplishments, and responses.

The Program was funded by BPA with a budget of $425,679 and consisted of 13 projects with 93% of the funding applied "to the ground'.

During this period, the Forest Service contributed a total of $255,000 additional dollars to the Program on a cost-share basis. The overall goal of the Program was to enhance spawning, rearing, and riparian habitats of Lolo Creek and major tributaries of the Lochsa River so that their production systems could reach full capability and help speed the recovery of salmon and steelhead within the basin.

In Lolo Creek, we modified six major barriers to upstream passage and accessed a total of 70.0 km of mainstem and tributary habitats for salmon and steelhead. In the Lochsa, we treated 22 major barriers, and provided 118.2 km of mainstem and tributary habitats for anadromous fish. In terms of enhancement, 250,000m² of rearing habitat and 34.4 ha of riparian habitat were improved in the Lolo Creek system.

For the tributaries of the Lochsa, we improved 277,000m² of rearing and 6,500m² of spawning habitats for salmon and steelhead. Overall, our objective attainment level for the Program averaged 205%. We were able to exceed our objective levels because of the relatively low unit costs.

The state of Idaho evaluated some of the projects of this Program. They concluded that barrier removals or modifications have had the greatest (potential) benefit in terms of parr produced. The Clearwater Forest evaluated other instream improvement projects within the Lochsa River system and statistically detected significantly higher parr densities of steelhead in enhanced over control sites in Pete King, Squaw, Papoose, and East Fork Papoose Creeks over a period of 3-5 years. A similar response for chinook parr was observed in Squaw Creek. Differences in salmonid parr densities were observed in summer and winter rearing habitats in Squaw and Papoose Creeks.

We believe that habitat enhancement is one of many management tools that is important to the rearing of wild and natural stocks of salmon and steelhead in Idaho. It could make the difference between extinction and marginal existence in some local populations.

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I. INTRODUCTION

In 1983 and under the auspices of the Northwest Power Act of 1980 and the Columbia River Basin Fish and Wildlife Program (section 700), the Clearwater National Forest and the Bonneville Power Administration entered into contractual agreements to improve anadromous fish habitat in three major tributaries of the Clearwater River in Idaho. In 1987, the contracts were combined into one and modified to include additional work and tributaries within the Clearwater River Basin. The Project was entitled "Lolo Creek and Lochsa River Habiiat Improvement (#84-6)" and it covered a period from 1963 to 1990 with a budget of $425,679. This report is a final description of all activities associated with the Project including objectives, methodologies, assessments, implementation, evaluations, results, summaries, and conclusions. The essence of which is a full documentation of the Project.

Purpose and Need

The primary purpose of the Project was to mitigate (albeit partial) the juvenile and adult anadromous fish losses accrued through hydroelectric development of the Columbia and Snake River systems by enhancing existing habitats and accessing "new" spawning and rearing habitats of selected Clear-water River tributaries for spring chinook salmon (*Oncorhynchus tshawytscha*) and summer steelhead trout (*Oncorhynchus mykiss*). Most of the opportunities for habitat enhancement and this type of mitigation are located within the boundaries of the Clearwater and Nez Perce National Forests (Clearwater Subbasin Plan, 1990).

According to the Clearwater Subbasin Plan (CSBP), nearly 60% of the available anadromous fish habitat is within the National Forest system. In 1969, the construction of Dworshak Dam on the North Fork of the Clearwater River eliminated 60% of the highest quality habitat in the Clearwater National Forest (Espinosa, 1983). Prior to the enhancement program, the Clearwater NF contained some 1,005 hectares of habitat for anadromous fish. Some of this habitat had been degraded by past development activities and offered a good opportunity for rehabilitation. Other habitats tributary to anadromous fish streams were blocked by natural and man-made migration barriers. Two large watersheds - Lolo Creek and the Lochsa River - offered an abundance of these opportunities. The general project area, streams, and sites are displayed in Figures 1, 2, and 3. Once the ecological factors limiting fish production were determined, an enhancement scenario was designed and implemented to ameliorate the 'limiting factors.'

In Idaho, the need to mitigate for past fish losses is very critical and probably warrants priority consideration within the Columbia River Basin. Salmon and steelhead destined for Idaho tributaries must traverse a gauntlet of eight dams and reservoirs. Mortalities associated with this hydroelectric system have been and continue to be substantial. Natural production plays a primary and quintessential role in the long term viability and genetic integrity of wild and natural stocks of salmon and steelhead in the Clearwater Subbasin. In Idaho, every square meter of habitat for natural production is needed to deal with the gauntlet and insure long term survival.

FIG. 1. MAP OF CLEARWATER NATIONAL FOREST AND PROJECT VICINITY

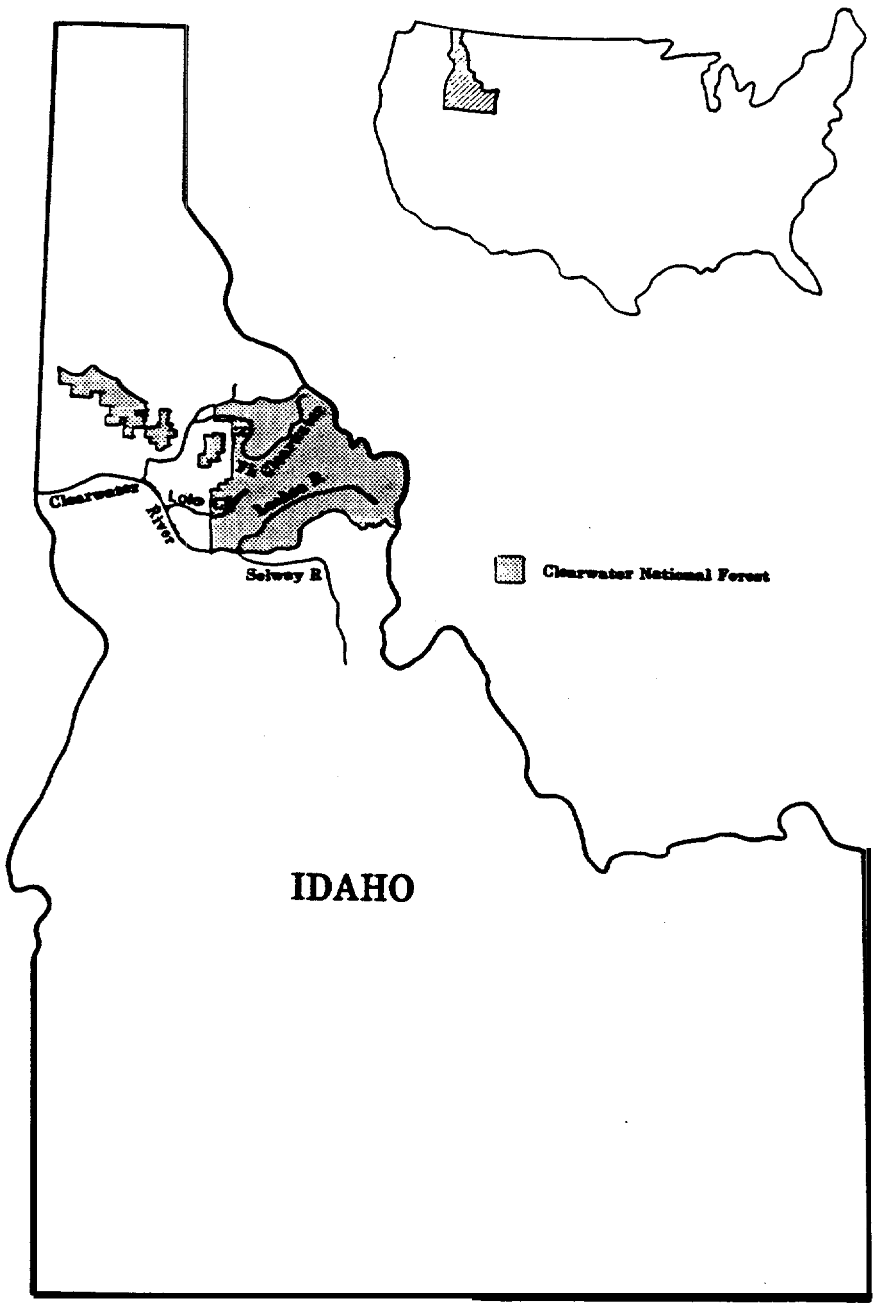
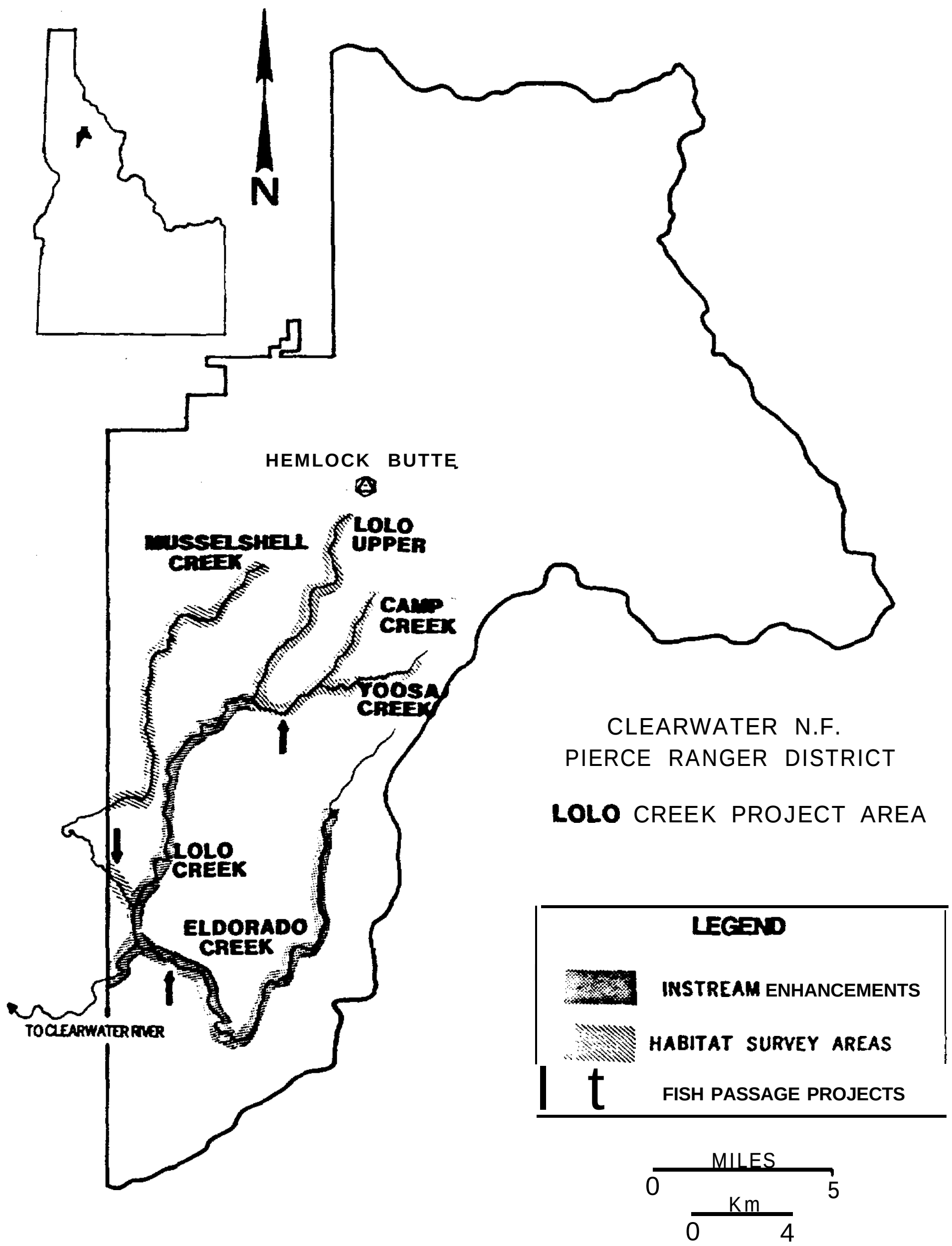


FIG. 2. **LOLO** CREEK PROJECT AREA



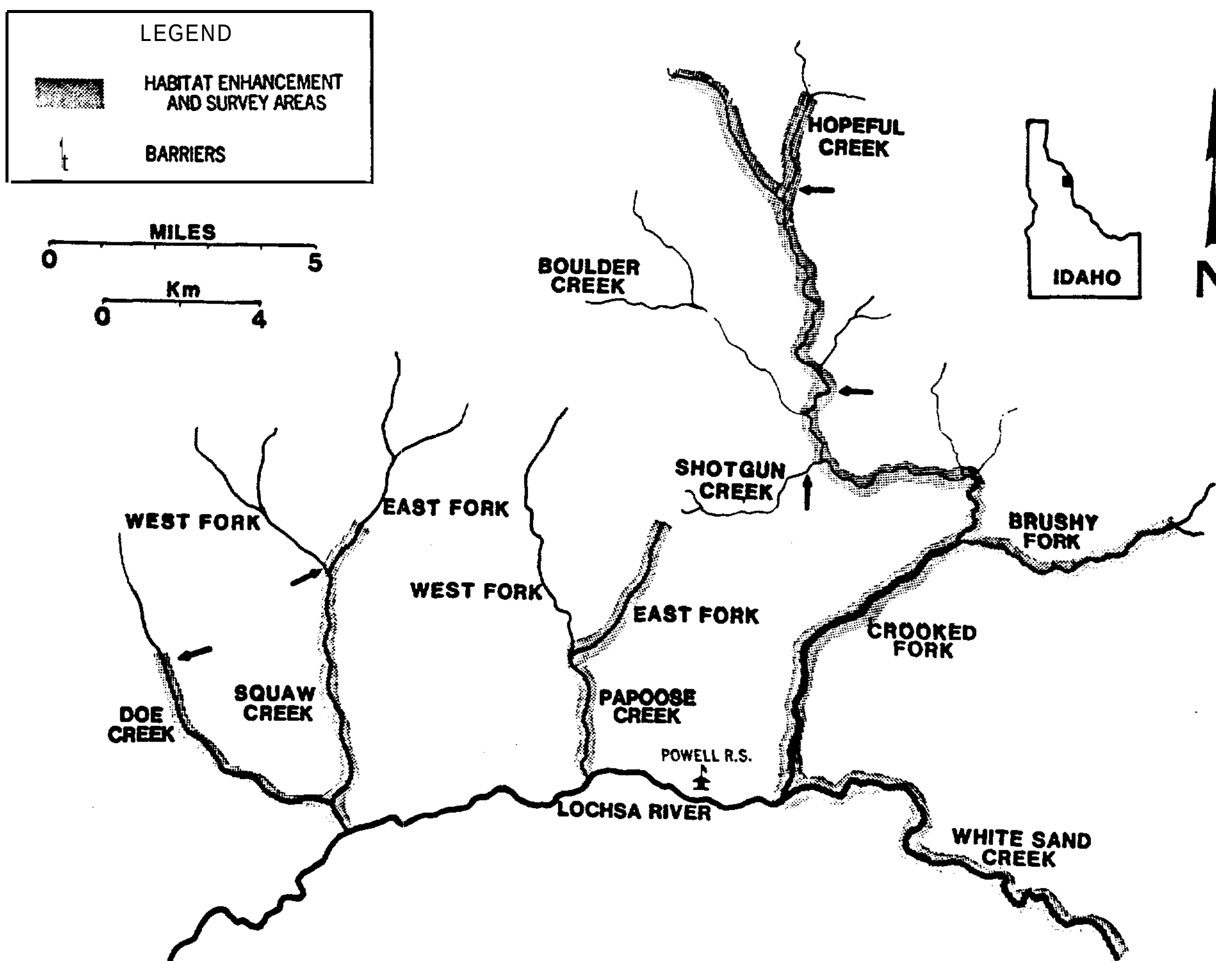


FIG. 3a. PROJECT AREA MAP FOR UPPER **LOCHSA** WATERSHED

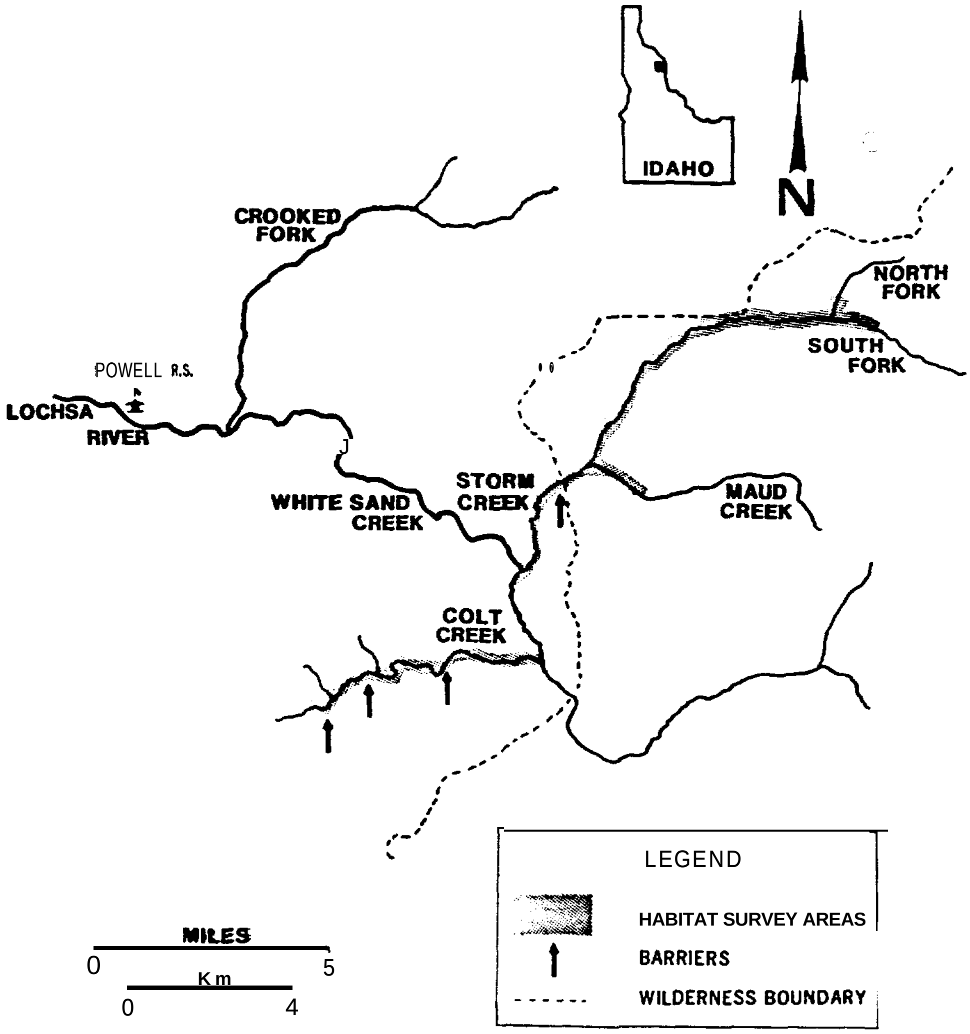


FIG. 3b. PROJECT AREA MAP FOR UPPER **LOCHSA** WATERSHED

II. POPULATIONS AND STOCKING HISTORY

Lolo Creek and the Lochsa River system are significant producers of spring chinook salmon and summer steelhead trout in the Clearwater River Subbasin (Fulton, 1968; Espinosa, 1987; Chapman, 1981; and CSBP, 1990). Chapman (1981) estimated that Lolo Creek and the Lochsa River system were capable of producing 84,000 and 459,000 spring chinook smolts respectively in their pristine condition. Chapman (1981) further estimated that the total return of all Clearwater-produced chinook adults to the mouth of the Columbia River in pristine times equalled 56,881 from Clear-water tributaries and 30,552 from the mainstem channels -- for a total return of 87,433 adults. Espinosa (1983) has estimated that the Lolo system within National Forest boundaries is capable of producing some 52,000 chinook and 28,000 steelhead smolts at full seeding and habitat capability. The Lochsa system (within the Forest) is capable of producing 250,000 steelhead and 378,000 chinook smolts respectively at full seeding and habitat capability (Espinosa, 1983).

Raymond (1988) has documented the recent history of salmon and steelhead runs in the Columbia and Snake River systems. Raymond (1988) concluded that smolt mortalities from new dams built on the Snake River after 1968, plus the already completed dams on the lower Columbia River, reduced the rate of return of Idaho salmon and steelhead to about 4% through the 1968 emigration to less than 1.5% between 1970 and 1974 emigrations. During the low flow periods of 1973 and 1977, smolt mortalities were estimated at 95% or greater (Raymond, 1988). Comprehensive enhancement measures designed to offset dam-related smolt mortalities began in 1975 (Raymond, 1988). Data presented in Figures 4 and 5 reflect this history for wild and natural steelhead stocks in the Clearwater Subbasin. Wild and natural stocks of Cleat-water salmon and steelhead are currently in a long term recovery mode (Raymond, 1988 and CSBP, 1990).

Run estimates for spring chinook have ranged from 1,600 in 1979 to over 7,700 in 1977 with most of the large return years associated with hatchery fish (CSBP, 1990). Escapement in recent years has failed to produce a harvestable surplus. Run estimates for wild and natural steelhead have ranged from a low of near 1,000 in 1975-77 to a high of 8-9,000 in 1982-83 (CSBP, 1990; Figs. 4 and 5). Recent escapement has ranged from 3,100 in 1983 to 6,500 in 1985.

In concert with other integrated efforts to recover upriver stocks, massive hatchery supplementation has been conducted in the Lolo and Lochsa systems. Hatchery stocking of chinook salmon in the Clear-water began in the 1960's and has accelerated in recent years. According to the CSBP (1990), 4.1 million chinook fry have been stocked in the Lochsa from 1972 to 1987. During this same prior, 1.7 million smolts were planted in the Lochsa. Lolo Creek has received similartreatments with 200,000+ pre-smolt releases in 1986, 1987 and 1988. Continuation of heavy supplementation is anticipated within the 1990's as satellite hatchery facilities associated with the State and Nez Perce Tribe have been and will be constructed in the headwaters of the Lochsa and Lolo systems. The satellite rearing system near the confluence of White Sand and Crooked Fork Creeks (Powell, Idaho) is currently in production. Despite the heavy stocking, densities of pre-smolt salmon and steelhead remain at critically low levels in Lolo Creek and tributaries of the Lochsa River (Espinosa et al., 1987) and Parker et al., 1989). Raymond (1988) has presented evidence that return rates for wild chinook salmon to the Snake River system have been much higher than those of hatchery fish. A management strategy for recovery that over-emphasizes hatchery supplementation may be vulnerable to failure.

FIGURE 4. REPRODUCTION CURVE
CLEARWATER RIVER BASIN
STEELHEAD TROUT — 1982 UPDATE

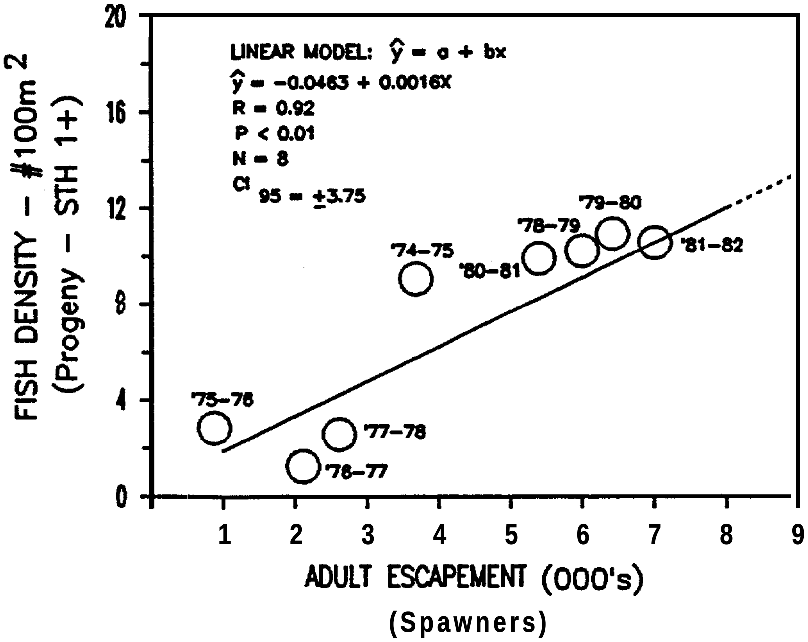


FIGURE 5. WILD STEELHEAD ESCAPEMENT
CLEARWATER RIVER BASIN

III. HISTORY OF FISH HABITAT ENHANCEMENT

Prior to 1983, the history of habitat enhancement for anadromous fish on the Clearwater Forest had been sporadic and limited in scope. Funding limitations prevented comprehensive treatment of stream habitats that were in need of improvement. Over the past 13 years, a rather modest level of projects was funded, implemented, and completed in the Lolo and Lochsa systems. In 1974 and 1977, a partial migration barrier at Lolo Falls was corrected to facilitate upstream migration of salmon and steelhead. Subsequent projects in Lolo Creek have been directed towards sediment abatement and riparian habitat restoration. In the Lochsa drainage, several migration barriers in tributary streams were modified to provide fish passage. A minimal amount of instream structural work was completed in two small tributaries during the late 1970's.

With the advent of the Power Council's and BPA's Columbia Basin Fish and Wildlife Program, it became possible to design and implement projects that dealt with limiting factors on an extensive and intensive basis. In essence, the magnitude of the enhancement would be comprehensive enough to make a measurable difference in productive capability. Lolo Creek and several tributaries of the Lochsa River system offered ample opportunities for this type of treatment. Both areas had been subjected to long histories of impacts associated with timber harvesting and road construction. Baseline habitat surveys indicated that this degradation might be limiting the systems' inherent capability to produce fish.

IV. DESCRIPTION OF PROJECT AREAS

A. Lolo Creek

A detailed description of the Lolo Creek watershed has been presented in Espinosa (1984). Only a summary description will be presented for this report. Lolo Creek, a seventh order stream, enters the mainstem of the Clearwater River from the north at river kilometer 87 and is 67.6 km in length (Fig. 1). The stream flows primarily in a south/south-westerly direction draining approximately 125.5 km of existing and potential anadromous fish streams. Of mainstem Lolo, 29 km are within the National Forest boundary. The remaining 38.6 km traverse a mixed ownership pattern of private, state, Nez Perce Tribe, and the Bureau of Land Management interests. Major tributaries of Lolo are Yakus, Eldorado, Musselshell, Brown, and Yoosa Creeks (Fig. 1). Lolo Creek drains a watershed of approximately 29,542 hectares (ha) within the boundaries of the Forest. The stream has a range in elevation of 1597 meters (m) at its headwater sources near Hemlock Butte to 396 m at its confluence with the mainstem Clearwater River. The range in elevation of the Project Area is 1067 m to 1219 m.

Lolo Creek displays a rather wide amplitude in its seasonal flow regime ranging from an average of 14 m^3/sec during spring run-off to an average of 0.7 m^3/sec during late summer, base flow. During the low flow years of 1986, 1987, and 1988, base flows dropped below 0.6 m^3/sec. At the present time, instream flows are not appropriated by outside interests and are adequate for good salmonid production.

The Lolo Creek watershed has - over time - sustained manifold impacts from timber harvesting, road construction, mining, and grazing operations. In comparison to timber management, deleterious effects on fish habitat from placer mining (gold) and grazing remain at minor levels. The Lolo drainage has a long history (30 years) of timber management on the Forest. During this period, the allowable harvest has ranged from 15 to 30 million board feet. Road construction and riparian harvesting associated with this program have generated some adverse impacts on the Lolo ecosystem. Excessive sedimentation, channel impingement, and elimination of large organic debris are the major impacts documented by Espinosa (1975) during his baseline habitat survey,

Pictorial overviews are presented in Figures 6 and 7.

B. Upper Lochsa

A detailed description of the Upper Lochsa River watershed has been presented in Espinosa (1984) and Kramer et al. (1985). Only a summary of the salient features will be presented in this report.

Crooked Fork and White Sand Creeks reach confluence near Powell, Idaho (1067 m in elevation) to form the Lochsa River (Fig. 1). Both streams are in fact small rivers with each draining approximately 61,000 ha of the Bitterroot Mountains and coursing some 39 km to their merger. These streams are characterized by flow regimes of wide amplitude. Crooked Fork displays a mean discharge of 85 m^3/sec during the peak run-off period and 4.5 m^3/sec during the late summer, base flow; whereas, White Sand exhibits an average flow of 85 m^3/sec during peak run-off and 4.8 m^3/sec at base flows.

The north-side tributaries-Squaw, Doe, and Papoose Creeks--are all third and fourth order streams that flow through dense, mixed coniferous stands of western red cedar, Douglas-fir, Englemann spruce, white pine, ponderosa pine, and larch. These streams are classified primarily as "B" channel types (Rosgen, 1985) with B-2 and B-3 types predominant. These streams drain a variety of landforms that include glacial, valley trains, steep breaklands, colluvial drift slopes, and alluvial flood plains. Breaklands and alluvial plains dominate these watersheds. Granite soils of the Idaho Batholith typify the geology of the area.

All of the drainages except White Sand Creek have been subjected to extensive and intensive activities of timber management for the past 25 years. Riparian harvesting and road construction have substantially degraded the fish habitats of these systems. The upper watershed of Crooked Fork and most of White Sand Creek, however, remain in pristine condition.

All the project streams except Doe Creek support a salmonid community consisting of steelhead trout, chinook salmon, and westslope cutthroat trout (*Oncorhynchus clarki*). Bull trout (*Salvelinus confluentus*) are found in all Upper Lochsa streams. A small population of brook trout (*Salvelinus fontinalis*) inhabit Lolo Creek. Chinook salmon are not found in Doe Creek.

Pictorial overviews are presented in Figures 8-9.

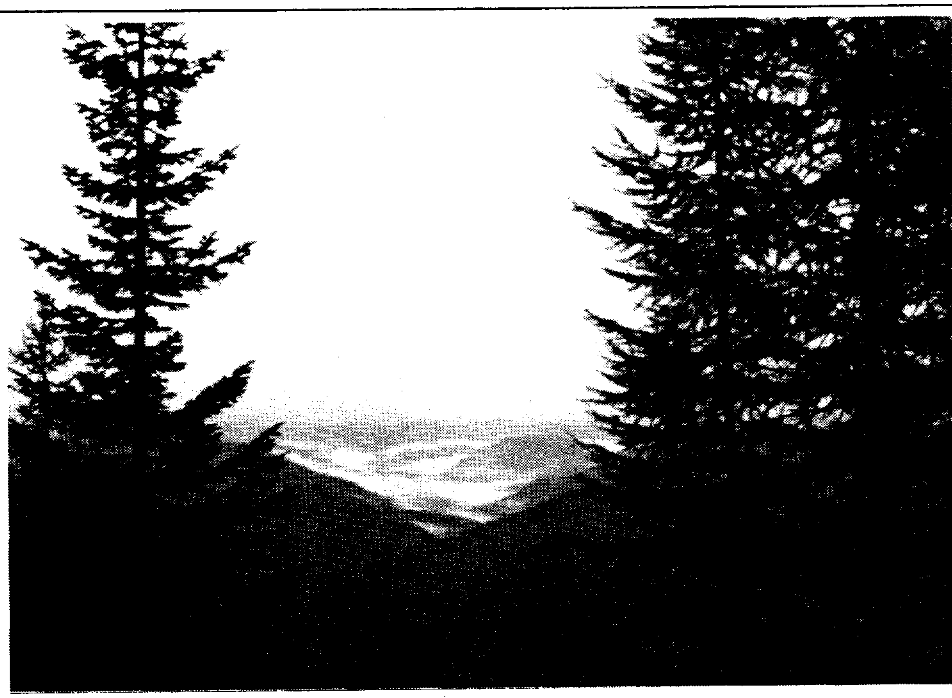


Figure 6. The Lolo Creek Watershed

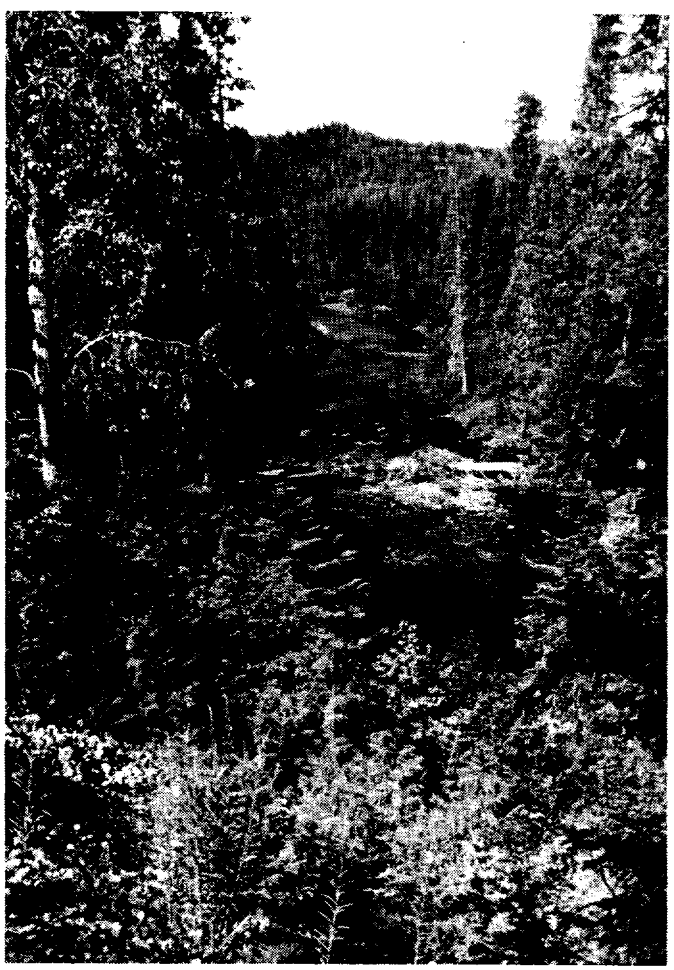


Figure 7. Overview of Lolo Creek

Figure 8. Overview of Crooked Fork Creek

Figure 9. White Sand Creek (Upper Lochsa)

V. METHODS

A. Instream Enhancement

Detailed descriptions of methods are presented in previous BPA reports (Espinosa, 1984; Kramer et al., 1985; Murphy and Espinosa, 1985; and Kramer et al., 1986). Only summaries will be presented here.

All of the streams subjected to structural instream enhancement had experienced a spectrum of impacts from development activities. In many cases, road construction in the riparian zone had impinged upon the natural channel and eliminated a constant source of large woody debris to the channel. The 'bottom line' to this degradation was that habiiat diversity in these systems had been substantially removed for a long period of time. Rearing habitats in these streams were characterized by long stretches of monotypic, shallow riffle-run types (Figs.lO-11). In some situations, surface and mass erosion from logging roads delivered excess sediment to the channels and eliminated diversity. The primary thrust of the treatments was to replace this diversity and enhance the streams' productive capabilities.

Prior to any instream work, baseline habitat surveys were conducted in all project streams (Kramer et al., 1985 and others). The surveys were necessary to document the existing quantity and quality of the habitats so that an assessment of project viability could be made. The amount of spawning, summer rearing, and winter rearing habitats was quantified in each system to facilitate analyses of limiting factors. Key habitat parameters such as pool quality, habitat type stratification, instream and bank cover, substrate diversity, cobble embed-dedness, bank stability, acting and potential woody debris were measured to provide a factual basis for an ecological diagnosis, prognosis, and treatment. In addition, population surveys were conducted in representative reaches to document the composition of the salmonid community and identify target species.

Given this information and analyses, a project plan was then developed which identified the design, scope, and specifics of the project. Stream reaches requiring treatment, access routes for heavy equipment, and supplies of raw materials (trees, root wads, boulders) were identified and located. Biologists, operating from a set of hydraulic and biological criteria, located and marked sites for enhancement. Each treatment reach was traversed and mapped for the entire distance by Project Biologists. At each site, the type and number of structures were identified--e.g. log weir site with root wad (2) and boulder cover (2). The final pre-implementation phase consisted of orientating work crews and contract personnel to the specifics of the project.

Figure 10. A reach of Lolo Creek prior to enhancement.

Figure 11. Monotypic habitat in Squaw Creek prior to enhancement.

Construction and placement of structures for the most part were accomplished with contract equipment rental and Forest Service crews consisting of 2 to 4 Fish or Wildlife Biologists. The contract operating representative (COR) was usually the District Biologist. All project activities were overseen by the Forest Fisheries Biologist, the Project Leader. Heavy equipment such as front-end loaders, rubber tire skidders, and tracked backhoes (excavators) with opposable "thumbs" (e.g. Link Beit-4500, Case-886, and Caterpillars-225 and-236) were used to construct log weirs, k-dams, excavate pools and to place large pieces of woody debris and boulders (Figs. 12-13). The equipment was also utilized to rehabilitate and smooth-over disturbed sites. Crews were used to secure the structures with cable and epoxy-resin attachment systems (Hilti; Figs. 14-l 5). For side channel enhancement, a fisheries engineer was consulted on site selection and design. The consultant provided a construction plan which was implemented according to his specifications. Upon completion of construction activities, all disturbed sites were rehabilitated to abate potential sediment sources by seeding, fertilizing, and planting of grass, deciduous and coniferous trees. All the structures except individual boulders were numbered, catalogued (tagged), photographed (ground and aerial), and mapped for a permanent record. This record has greatly facilitated the process of annual maintenance,

B. Riparian

As part of our baseline habitat inventory, riparian habitat conditions were evaluated. Parameters such as bank cover and stability, potential woody debris, habiiat type, successional stage, community composition, and areas of degradation were assessed and documented. This information was then used to formulate a project design and plan. In this manner, the Section 6 riparian area (meadow complex) of Lolo Creek was identified as requiring rehabilitation and management coordination. Cattle grazing from several allotments in the area was degrading riparian and stream habitats. Moreover, these impacts over time would pose a significant risk to the longevity of instream enhancement structures. Management options were evaluated, and the alternative of fencing off the critical riparian area was selected as the most feasible and effective. The area requiring fencing was mapped and identified on the ground. A fence design that would withstand heavy snow drifts and minimize impacts to wildlife was selected. A contract was prepared incorporating project specifications and bids were solicited.

Riparian areas requiring rehabilitation (usually impacted by timber harvest and road construction) were mapped and identified on the ground. A project plan was then formulated. Most of the riparian work involved the planting of shrubs, deciduous and coniferous trees to stabilize disturbed areas and provide long term sources of woody debris and bank cover. The work was accomplished with Forest Service crews. Details of the riparian projects are presented in Talbert et al. (1988) and Babler et al. (1989).

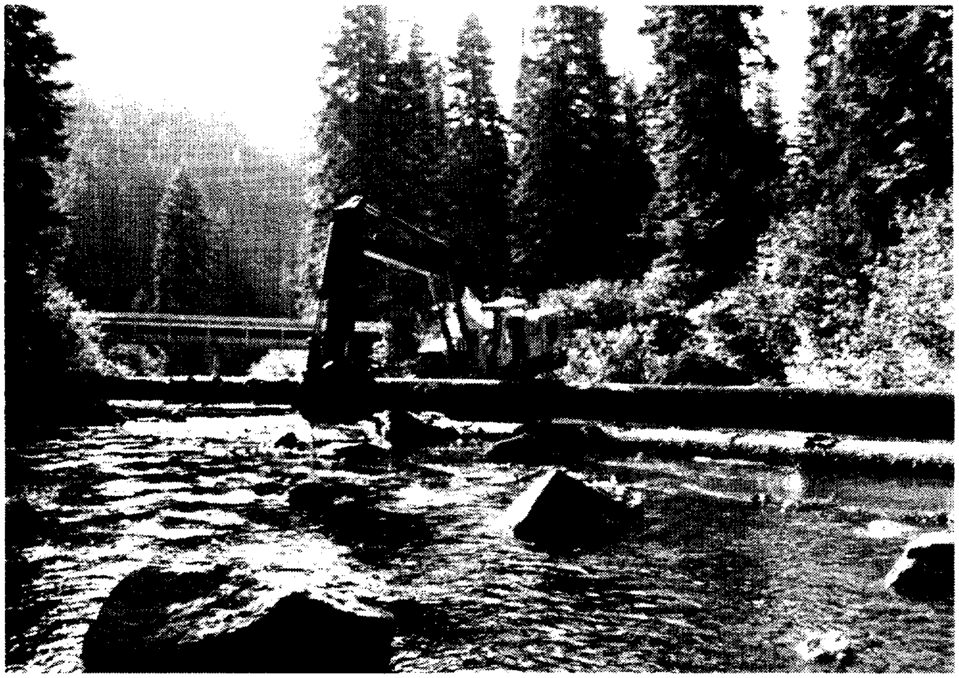


Figure 12. An excavator moving a large log into a weir site in Lolo Creek.

Flgure 13. Weir construction and site preparation In Doe Creek (Upper Lochsa).

Figure 14. Using the Hilti system to attach a large log to bedrock keys in Eldorado Creek (barrier site # 1).

Figure 15. Weir modification of Eldorado Barrier #1. Cables are glued to bedrock.(Hiltisystem).

C. Barriers

Barriers were removed on Eldorado Creek and from several streams in the lower and upper reaches of the Lochsa (Table 1). Each project area was analyzed for specific modifications needed to eliminate the barrier. John Orsborn P.E., and Thomas W. Bumstead of the Albrook Hydraulics Lab of Washington State University surveyed many of the sites and recommended the design of jump pools and weirs.

After initial reconnaissance, barriers were mapped. A transit was used to gather data on depth of pools, height of jumps and the distance covered. The most logical migration route was determined and a series of measurements were made for a profile. Permanent benchmarks were created so that the barriers could be evaluated from pre- and post-project work.

The methodology described will pertain primarily to the boulder and bedrock barriers that required a combination of blasting and weir construction to modify. Debris barriers were removed by blasting apart the debris with explosives. Site specific details of projects can be found in prior publications submitted to Bonneville Power Administration.

At each project site, an initial survey and site analysis was completed to determine the needs for passage. Designs were drawn for a series of jump pools and/or weir construction to back water up to form a negotiable passage for the target species (steelhead trout or chinook salmon).

A Pionjar 120 rock drill and drill biis ranging from one and one half feet to four feet in length, were used for drilling blasting holes. Drilling, done by a two to three person crew, was the most time-consuming part of the project. Depth and number of holes drilled depended upon the degree of reaction desired. Depending on the barrier size, the barrier was either drilled and shot once or drilled several times with the blasting performed sequentially. On larger barriers with several obstructions, one obstruction was worked on and evaluated before starting the next.

Blasting was achieved by using water gel, primacord and blasting caps. All blasting was performed by certified blasters. After blasting, crew members hand picked boulders and rock fragments out of pools. The material was moved on to the bank or pushed downstream.

In addition to blasting jump pools, some sites required the placement of weirs to achieve negotiable pool depth:jump height ratios. Trees were cut on site and moved into place with the use of a chainsaw winch, cables, peavies, prybars and a 'come-along' winch. Drilling and/or blasting was required on some of the banks to establish a straight edge for the end of logs to sit against.

Logs were cabled into place using 9/16" galvanized steel cable and C-l 0 HIT dowelling cement (product by Hilti). Holes were drilled into the bedrock on both sides of the log weir with a Hilti gas operated hammer drill: Holes were filled with the cement and the cables set into place. On the upstream side of the weir, geotextile fabric and hardware mesh were attached to the log and then backfilled with rock and gravel. In sites where high pressure on the weir is expected, a perpendicular brace log was also built. (Site specific methods and materials can be found in individual project reports.)

After the completion of blasting and weir construction, data were collected on depth of pools, height of jumps and the distance covered. During the project, before and after photographs were taken of each barrier. Representative photographs are presented in Appendix A.

Table 1. Summary of barrier removal projects In the Upper Lochsa River drainage, 1984-l 989.

				Rearing Habitat Accessed		
Stream	Year	Barrier Type	Km of Stream	Summer	Winter	Anadromous Spawning Habitat Accessed
Colt Creek	1986	waterfalls & debris jam	17.0 km	103,861 m^2	1,804 m^2	520 m^2
Crooked Fork	1984-88	waterfalls & rock chutes	13.2 km	33,965 m^2	6,849 m^2	1,432 m^2
Hopeful	1984-85	debris jam	9.6 km	9,826 m^2	9,370 m^2	406 m^2
Shotgun Creek	1988	waterfall	4.5 km	22,110 m^2	669 m^2	221 m^2
Spruce Creek	1988-89	waterfall	16.2 km	35,509 m^2	22,785 m^2	1,031 m^2
Storm Creek	1989	debris jam	15.8 km	46,560 m^2	12,560 m^2	3,330 m^2
West Fork Squaw Creek	1987	culvert	6.0 km	*	*	*

* Stream survey data unavailable.

D. Evaluation

Evaluation was an integral part of our program. Two types of projects-instream structural enhancement and passage-were evaluated. Ostensibly, the Idaho Department of Fish and Game was funded to evaluate all of our projects. However, it became apparent that they were unable to accomplish this, Therefore, the Clearwater National Forest covered those additional cost share projects in the Upper Lochsa and Lolo Creek areas. We also reinforced the work conducted by the State by employing some additional evaluation primarily in Lolo Creek. Instream projects were evaluated in Lolo, Eldorado, Squaw, Papoose, and Pete King Creeks. Passage projects were evaluated in Eldorado, Crooked Fork, Spruce, Storm, Colt, Shotgun, West Fork Squaw, and Yoosa Creeks.

We attempted to evaluate instream projects for as long as possible. In Squaw, Papoose, and Pete King Creeks, our period of evaluation was four to five years which constituted one life cycle for steelhead and salmon. In Lolo Creek, our evaluation period was two years. Evaluation time for passage projects was restricted to two years by stocking schedules, adult return cycles, and escapement. However, the Clearwater intends to monitor these projects until definitive information is acquired.

For all projects, our basic evaluation was to employ a 'before-and-after' approach. Where we had good baseline information on habitat and populations, we made comparisons of habitat conditions and population abundance during pre-treatment and post-treatment phases. Most of the projects were evaluated in this manner. For the Eldorado instream projects, we lacked comparable data on populations--so only habitat conditions were assessed. Before-and-after comparisons were made difficult because survey procedures differed somewhat between the two periods. For instream projects, pre-treatment habitat surveys were conducted with a modified ocular technique (Espinosa, 1975). Because the survey techniques differ, the data collected prior to-and-after treatment may not be directly comparable. This may contribute to the variation of the data and validity of the comparisons.

Documentation of post-treatment conditions in habitat quantity and quality was accomplished by employing the Clearwater National Forest's methodology of stream habitat surveys (Espinosa, 1988). The evaluation of habitat in Lolo Creek was conducted by utilizing the transect survey technique. The transect line intercept is a line determined by two points on opposite streambanks and is useful as the location reference for the measurement of habiiat conditions. This procedure allows for the precise measurement of many parameters such as channel width, depth, habitat type and function, instream cover, and substrate diversity. The parameters can be generally classified into four major groups: 1) channel characteristics; 2) habitat function: 3) habiiat quality characteristics; and 4) riparian-debris attributes. The transect spacing was set at 30 m. The first transect was set from a fixed reference point such as the confluence of Yoosa and Upper Lolo Creeks. According to Platts et al. (1983), the transect interval of 30 m is adequate for general data interpretations. Every 5th transect (305 m) was established as a permanent station for future evaluations. The distance between each transect was measured.

In the upper Lochsa area, a slightly different survey procedure was used for the Papoose and Squaw Creek projects. A combination of ocular and total measure techniques was applied. The baseline 'before' survey was completed with a modified ocular survey with some direct measurements and calibration. For the 'after' phase, a set of enhancement structures and their associated habitat was randomly selected from the treated reaches. Control areas were also selected randomly. Control areas were defined as shallow riffle-run habitats that could have been enhanced if so desired. This habitat was very similar to the pre-treatment habitat. At each structure, boundaries of the site were determined by the uppermost and lowest points of influence attributable to the enhancement structure. The entire area was then habitat typed and measured. Our standard survey of key habitat parameters was then applied. Each site was delineated by permanent markers at the top and bottom for future evaluation. Control units were treated in similar fashion. Papoose and Squaw Creeks were later surveyed to determine the overall habitat type profile and to document the changes in habitat quantity. Linear distances were recorded for each habitat type by reach and the number of acting instream debris was recorded. This aspect of the evaluation was a repeat of the baseline work completed in 1986.

The response (or non-response) of fish populations to enhancement was assessed similarly in the Lolo and upper Lochsa streams. Treated and control sites were selected randomly. Enhancement sites were stratified by structure type. Boundaries were marked, and fish populations within the entire wetted area were identified and enumerated by standard snorkel diving techniques. Assessments were conducted during summer baseline flows (August). Each site was sampled by a trained diver, snorkeling upstream from the bottom of the site. Fish were enumerated and classified by age group and species. After snorkeling, the surface area of the habitat was measured, a site description written, and photographs taken. In Lolo Creek, an attempt was made to calibrate the snorkel observations with standard electrofishing sampling. However, we were unable to establish calibration factors because the electrofishing technique was far less accurate than snorkel observations in this stream (Cleat-water BioStudies, 1988). We did use standard electrofishing techniques (depletion sampling) effectively to evaluate winter habitat in the smaller tributaries of the Lochsa River.

One of the major differences in evaluation between the Lolo and upper Lochsa study areas was that the evaluation in Lolo Creek was contracted with Clearwater BioStudies, inc. in 1988. This consulting firm prepared a report for the Clearwater National Forest entitled 'Fish Habitat Characteristics and Salmonid Abundance in the Lolo Creek Study Area During Summer 1988'. Forest Service personnel conducted the evaluations in the Lochsa streams, and in 1989, monitored fish population responses in Lolo Creek. Further details on evaluation procedures are presented in Kramer and Espinosa (1984), Kramer et al. (1987), and Clearwater BioStudies (1988).

During the evaluation period, all of the instream structures and passage projects were annually evaluated for purposes of documenting functional status, maintenance, and replacement needs. Those structures not functioning properly were maintained or replaced (Kramer and Espinosa, 1984).

Evaluation of passage projects was far less involved. Accessible project sites were visited during periods of peak spawning migration to observe functional status, passage conditions, and the attempts of adult fish to negotiate the modified barriers. In some cases, redd and fish count transects were established above the barriers and sampled during the spawning period. For other streams, habitat above the barriers was sampled by snorkel diving and electrofishing procedures to document the presence or absence of juvenile and adult fish.

VI. CHRONOLOGY AND SUMMARY OF SUB-PROJECTS

A. Management Objectives and Targets

In 1984, an original agreement was signed by BPA and the Clearwater Forest to improve habitat in Lolo Creek and the Lochsa River for $74,115 (Project #84-6). Several months later, this contract was modified to include the Eldorado Creek Fish Passage Project which increased the budget to $91,783. Also in 1984, the Cleat-water and Nez Perce Forests signed a cost-share agreement (Project # 8431) with BPA to improve habitat in tributaries of the Clearwater River. This project was funded on a total cost share basis of $185,696 with $76,700 contributed from BPA and $108,996 funded by the Forest Service. The Clearwater National Forest's share of the BPA budget was $32,050. This project was intended to provide funding for habitat inventories so that additional projects could be identified, designed, and implemented by the Forest Service. Watersheds impacted by Forest Service activities(and subsequently mitigated) were selected for survey. Final completion reports on project #84-31 were submitted to BPA in 1986. Some recapitulation of this project's results will be presented here to provide a more comprehensive perspective.

Later in 1987, project #84-6 was expanded to $425,679 to complete all project activities in Lola Creek and the Lochsa River by 1990. This increase in scope and funding allowed for additional enhancement projects, provided for habitat inventories, monitoring, evaluation, and maintenance of completed sub-projects. Essentially, Projects #84-6 and #84-31 grew into a seven year program. The total Program - a combination of Projects #84-6 and #84-31 - is summarized by sub-project, sequence, target objective, funding, and completion date in Table 2. The Program of thirteen sub-projects was totally funded at $457,729 with $395,646 going 'to the ground'. Other project expenses such as overhead and report preparation accounted for the remainder of $62,083. During this period, the Forest Service contributed a total of $255,000 on a cost-share basis - with $123,000 for instream enhancement, $82,000 for watershed restoration, and $50,000 for habitat inventories and project evaluation.

The overall goal of the Program was to enhance spawning, rearing, and riparian habitats of Lolo Creek and the major tributaries of the Lochsa River so that their production systems could reach full capability and help speed the recovery of salmon and steelhead stocks within the Basin.

The objectives are stratified by major watershed, type of project, and sub-project.

B. Lolo Creek

Instream Enhancement: Enhance 30 hectares (75 acres) of summer and winter rearing habitats for steelhead trout and chinook salmon. Increase the yield of steelhead smolts by 12,000 and chinook smolts by 22,000.

Fish Passage: Access 56 kilometers (35 miles) of 'new' habitat for anadromous fish; make available 34 hectares (83 acres) of rearing and 1.4 hectares (3.5 acres) of spawning habitats for steelhead trout and chinook salmon.

Riparian Enhancement: Protect 2 hectares (5 acres) of anadromous fish habitat and 22 hectares (55 acres) of riparian habitat by fencing 1.8 kilometers (1.1 miles) of stream channel; enhance 10 hectares (25 acres) of riparian habitat.

Habitat Inventory: Survey 80.5 kilometers (50 miles) of anadromous fish streams to identify the need for additional habitat improvement.

C. Upper Lochsa

Instream Enhancement: Enhance 34 hectares (85 acres) of summer and winter rearing habitats for steelhead trout and chinook salmon. Increase the yield of steelhead smolts by 34,000 and chinook smolts by 52,000.

Fish Passage: Access 80.5 kilometers (50 miles) of "new" habitat for anadromous fish. Access enough habitat to produce 56,000 steelhead and 54,000 chinook smolts.

Habltat Inventory: Survey 80.5 kilometers (50 miles) of anadromous fish streams to identify the need for addiiional habitat improvement.

Table 2. A Chronology and summary of projects #84-6 and #84-31 In the Clearwater River SubbasIn.

Sub Project (Name & Number)	Drainage(s)	Type	Date Initiated	Date Completed	Target Objective	Budget (Source)
Lolo Instream (#84-6)	Lolo Creek	Instream structural enhancement	1983	1986	Enhance 40-60 acres of rearing habitat: 4,000 steelhead & 10,000 chinook smolts	$91,309 (BPA)
Upper Lochsa Debris (#84-6)	Crooked Fork White Sand Creeks	Instream structural enhancement	1983	1984	Enhance 60-75 acres of rearing habitat: 21,000 steelhead & 36,000 chinook smolt	$27,500 (BPA)
Eldorado Passage (#84-6)	Eldorado Creek (Lolo)	Migration Barrier Removal	1984	1986	Access 47.3 acres of rearing and 3.5 acres of spawning habitats for steelhead & chinook: 12,500 steelhead & 24,000 chinook smolts	$30,668 (BPA)
Lolo Inventory (#84-31)	Lolo, Eldorado, Yoosa, Musselshell, Camp Creeks	Stream habitat inventory	1984	1986	Survey 50 miles of anadromous fish habitat	$5,000 (BPA) $5,000 (USFS)
Upper Lochsa Inventory (#84-31)	Pete King, Fish, Deadman, Squaw, Doe, Papoose, Storm Creeks	Stream habitat inventory	1984	1987	Survey 50 miles of anadromous fish habitat	$18,050 (BPA)
Upper Lochsa Passage (#84-6)	Crooked Fork, Shotgun, Hopeful, Spruce, Colt, W.F. Squaw Creeks	Migration barrier removal	1984	1989	Access 50 miles of anadromous fish habitat: 53,000 steelhead & 54,000 chinook smolts	$65,319 (BPA) $21,000 (USFS)
Upper Lochsa Instream (#84-31)	Squaw, Doe, Papoose, Pete King, E.F. Papoose Creeks	Instream structural enhancement	1985	1985	Enhance 16 miles (25 acres) of anadromous fish habitat: 13,000 steelhead and 16,000 chinook smolts	$71,000 (USFS)

Table 2. A Chronology and summary of projects #84-6 and #84-31 in the Clearwater River Subbasin. (continued)

Sub Project (Name & Number)	Drainage(s)	Type	Date Initiat-ed	Date Com-pleted	Target Objective	Budget (Source)
Eldorado In-stream (#84-31)	Eldorado Creek	Instream structural enhance-ment	1985	1985	Enhance 8 miles (15 acres) of anadromous fish habitat: 8,000 steel-head and 12,000 chinook smolts	$26,000 (USFS)
Project Evalua-tion (#84-6)	Lolo, Pete King, Squaw, Papoose, El-dorado, Whiie Sand, Crooked Fork Creeks	Evaluation of in-stream projects	1985	1989	Document changes in habitat/population re-sponses	$78,200 (BPA)
Project Mainte-nance (#84-6)	Lolo, Squaw, Doe, Pa-poose, White Sand, Crooked Fork Creeks	Annual mainte-nance of structures & addi-tional re-finement of pas-sage projects	1985	1989	Maintain project effective-ness	$34,800 (BPA)
Lolo Fencing (#84-6)	Lolo Creek	Structural Riparian Fencing	1986	1986	Protect 5 acres of anadro-mous fish habitat and 55 acres of riparian habitat fence 1 .1 miles of stream channel	$27,400 (BPA)
Lolo Passage (#84-6)	Musselshell Creek, Yoosa Creek, Eldo-rado Creeks	Migration barrier re-moval	1987	1987	Access 20 miles of anadromous fish habitat (36 acres)	$15,000 (BPA)
Lolo Riparian (#84-6)	Lolo Creek	Riparian Planting	1988	1988	Enhance 25 acres of ri-parian habitat	$6,000 (BPA)

VII. RESULTS

A. Accomplishments: Lolo Creek and Tributaries of the Lower Lochsa

1. Surveys

Lolo Creek - a total stream distance of 71.7 km (44.5 miles) was surveyed in the Lolo (68.5 km) and Orofino Creek (3.2 km) watersheds. A total of 40.7 km (25.3 miles) of mainstem channels in Lolo and Eldorado Creeks was surveyed covering sixty reaches, 1,076 habitat transects, and 430,100 m^2 of stream habitat. A total of 27.8 km (17.3 miles) was surveyed in key tributaries (4) of Lolo Creek covering nine reaches and 158,248 m^2 of habitat. In Orofino Creek, a drainage with potential habitat for anadromous fish, a distance of 3.2 km and surface area of 17,752 m^2 were surveyed. In Lolo Creek proper, 20.5 km of stream were surveyed encompassing some 31 reaches, 683 habitat transects, and 260,000 m^2 of habitat. Intensive surveys in Eldorado Creek covered 20.3 km, 29 reaches, 393 transects, and 170,100 m^2 of habitat.

Lower ***Lochsa*** - a total stream distance of 42.6 km (26.5 miles) was surveyed in 5 tributaries of the lower Lochsa River (Fig. 16). Habitat surveys to determine limiting factors and identify potential projects were conducted in Pete King, Walde, Deadman, Fish, and Boulder Creeks. These streams were covered under Project #84-31, the cost-share agreement.

2. Project Identification

Lolo Creek - a total of twelve major projects was identified in the Lolo Creek watershed. Eight of these projects involve intensive enhancement of instream structure. To date, only one of these projects in mainstem Eldorado Creek has been completed (Vogelsang et al., 1985). On the other hand, three of the four passage projects have been completed. Descriptions and details of the projects are presented in Vogelsang et al. (1985) and Talbert et al. (1988). Representative photographs of project activities are presented in Appendix A. Only one major project (instream enhancement) was identified in the Orofino Creek watershed. It has not been implemented.

Lower ***Lochsa*** - a total of six major projects was identified in these tributaries -three in Walde and one each in Deadman, Fish, and Boulder Creeks. The three projects in Walde have been completed and included fish passage improvement at a natural barrier and installation of log weir sediment traps. The instream improvement needs of Pete King Creek were identified prior to the agreement. The project was completed in 1985. Descriptions and details of the projects are presented in Talbert and Espinosa (1986).

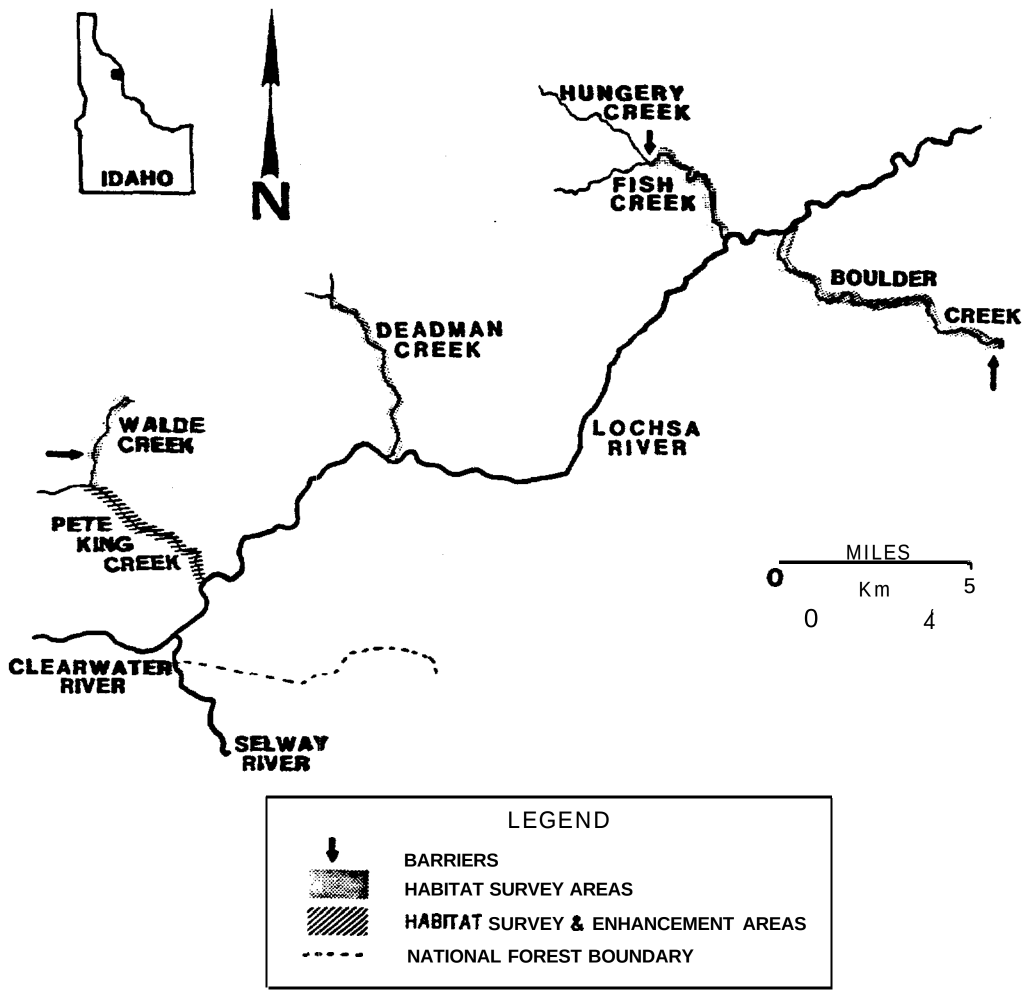


FIG. 16 PROJECT AREA MAP FOR LOWER **LOCHSA** WATERSHED

3. Enhancement

Three types of enhancement will be discussed: instream structural, riparian, and fish passage. With reference to instream work, primary emphasis will be placed upon Lolo Creek, the site of our largest project, and secondarily upon Eldorado and Pete King Creeks.

a. Enhancement Structures - Lolo Creek

A total reach distance of 14.01 km (extensive perspective, "area of influence") was 'enhanced' with the construction and placement of 695 habitat structures. This enhancement treated 68% of the total study area in Lolo Creek and extended over a three year period. The actual stream length treated with structures ('intensive perspective') equalled 6.28 km. The mean number of structures per unit distance was 49.6/km (1 structure every 20 m) of overall reach distance or 110.7/km (1 structure every 9 m) of actual stream length treated. Maps displaying the types, distribution, and concentration of structures are presented in Figs. 17-l 8.

The total expenditure for the project equalled $91,309 with a mean cost per structure of $131, Data presented in Table 3 accounts for the unit cost per structure type. The range in unit costs varied from $10 for pool construction to $6400 for side channel construction. The types of habitat structures, number per type, and probable effects are summarized in Table 4. The cost per 'enhanced' kilometer (extensive) equalled $6,517, whereas, the cost per "treated" kilometer (intensive) was $14,540.

The structure type most frequently used was large individual boulders (36%), followed by root wads (20%), boulder clusters (14%), deflector logs (1 0%), large woody debris (10%). and log weirs (7%) (Fig. 19). Perusal of Table 4 indicates that structures which 'created' pocket water and mainstem pools plus enhanced cover were featured to the extent of 97% of all structures. The ratio of rock to wood type structures was 1.1 to 1.

Table 3. Total project costs (1983-87 combined) per unit structure type for habitat enhancement in Lolo Creek, Idaho.

Structure Type	Unit Cost
K-dam (complete)	$1250
K-dam (modified) reduced wing structure	$800
Log Weir (simple)	$370
Log Weir (complex)*	$500
Boulder Clusters (x 2.5 boulders/cluster)	$38 ($17/rock)
Large Individual Boulders	$16
Large Organic Debris	$52
Anchored Deflector Logs	$30
Boulder Weirs	$220

Table 3. Total project costs (1963-67 combined) per unit structure type for habitat enhancement in Lolo Creek, Idaho. (continued)

Structure Type	Unit Cost
Boulder Deflectors	$130
Lateral Log Deflectors	$90
Bank Cover Devices (labor intensive)	$880
Debris Jam Removal (equipment intensive)	$826
Pool Construction	$10
Winter Habitat Units (boulders/large rubble)	$150
Root Wads	$44
Side Channels	$6400

Average Unit Cost for All Structures - Total Project

Total Budget ÷ Total Structures = $91,309 ÷ 695 = **$131/** Structure

* Log weir complex includes additional boulder and/or woody debris cover in the downstream weir pool.

Table 4. Total types of habltat structures, number per type, and probable enhancement effects of structures placed in Lolo Creek, Idaho.

Type	No.	Probable Effect
K-dam & Log Weirs	46	Pool formation, sediment reduction, and habitat type diversity.
Boulder Weirs	7	Pool formation, sediment reduction, and habitat type diversity.
Boulder Clusters & Reaches	100	'Pocket water', pool formation, cover enhancement, sediment reduction, and habitat type diversity.
Boulder Deflector	1	Pool formation, sediment reduction, gravel bar maintenance, and cover enhancement

Table 4. Total types of habitat structures, number per type, and probable enhancement effects of structures placed in Lolo Creek, Idaho. (continued)

Type	No.	Probable Effect
Root Wads	136	**Cover** enhancement, pool formation, and **habitat** type diversity.
Lateral Deflector Logs	69	Cover enhancement, pool formation, and diversity.
Pool Construction	1	Pool Formation
Bank Cover Devices	12	Cover enhancement and bank stabilization.
Debris Jam Removal	3	Sediment reduction and bank stabilization.
Large Anchored Woody Debris	68	Pool formation, cover enhancement, sediment reduction, and diversity.
Large Individual Boulders	247	-'Pocket water", pool formation, sediment reduction, cover enhancement, and diversity.
Side Channels	3	Habitat type diversity and rearing habitat for 0+ salmonids.
Winter Substrate	2	Winter rearing habitat.
Total =	**695**	

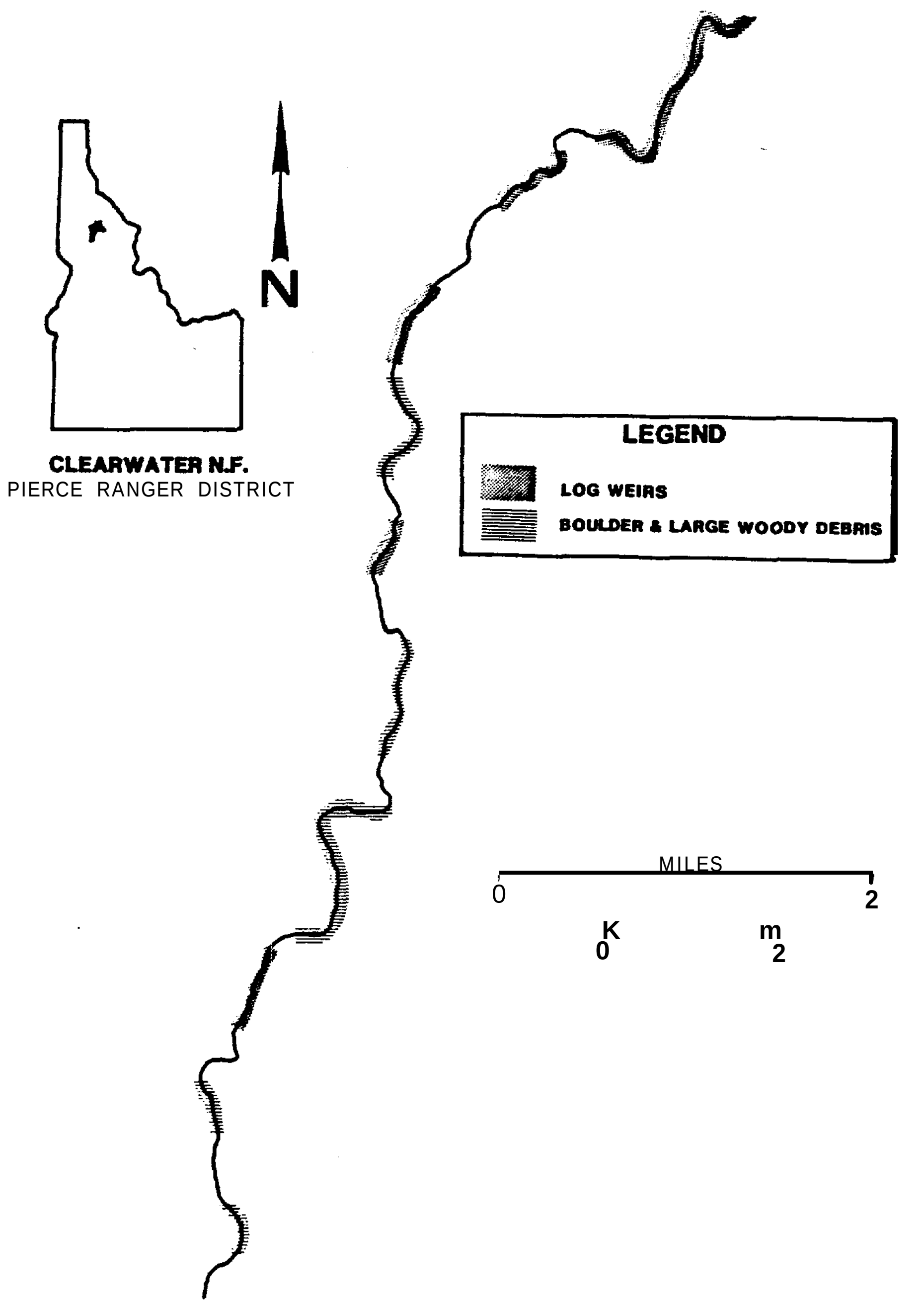


FIG 17. BPA PROJECT MAP - LOLO CREEK

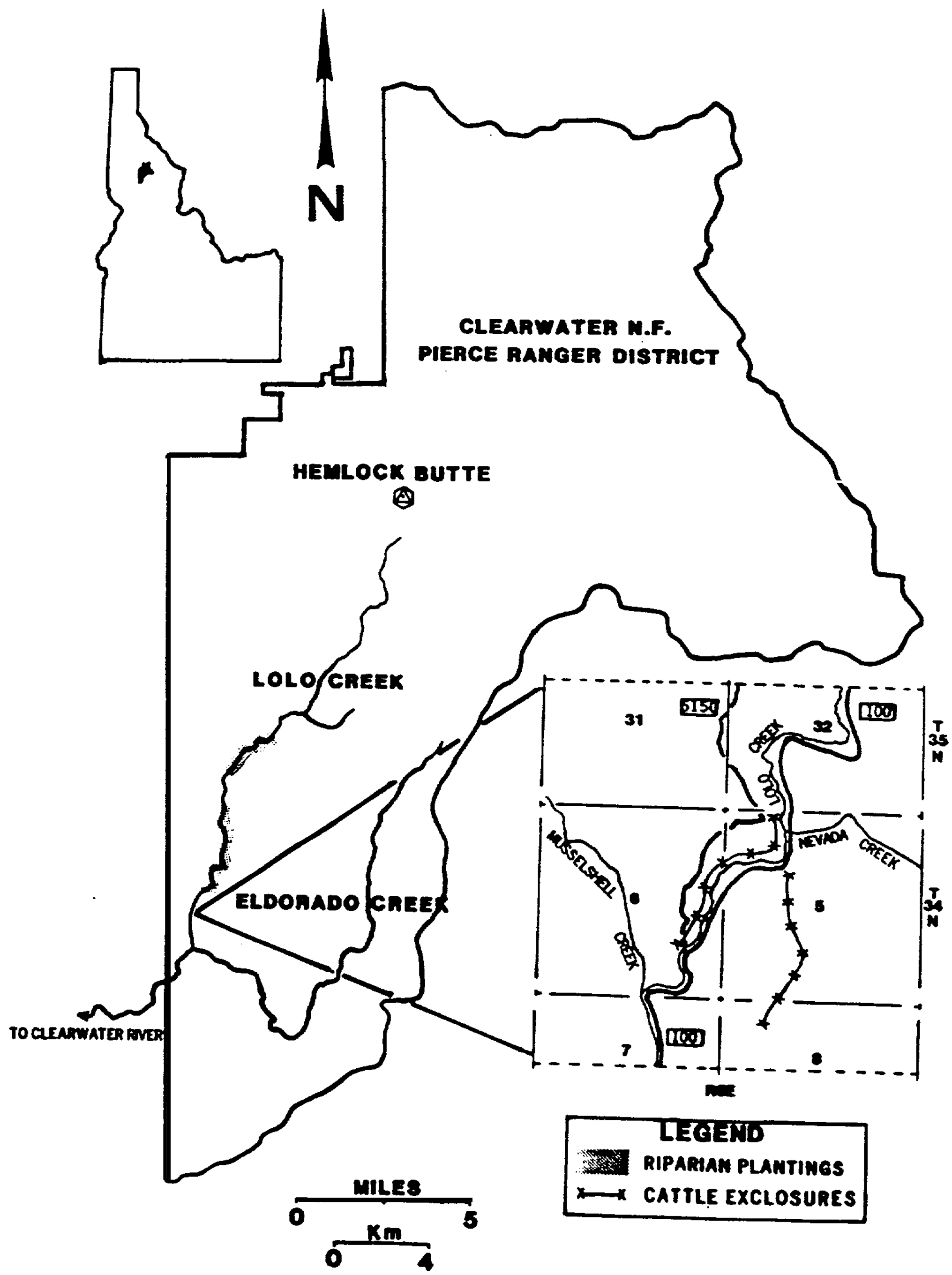
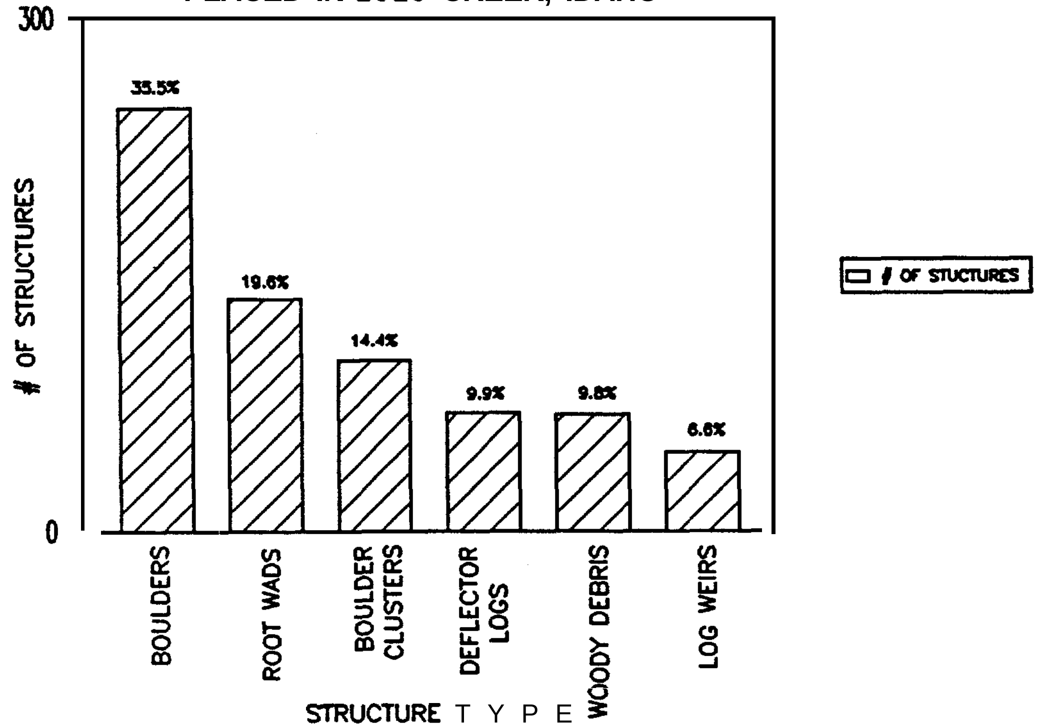


FIG. 18. A MAP OF THE **LOLO** CREEK **RIPARIAN** PROJECT

FIGURE 19. DIVERSITY OF HABITAT STRUCTURE TYPES PLACED IN LOLO CREEK, IDAHO



Log weirs were concentrated in five reaches primarily in the low gradient sections (C-channel types) above White Creek - the critical area for chinook spawning and rearing (Fig. 17). Only one reach in Section 6 was enhanced with log weirs (Fig. 17). Boulders and large woody debris were concentrated in five additional reaches extending from above White Creek to the Forest boundary (Fig. 17). Boulders were placed in higher gradient habitats (B-Channel types) preferred primarily by steelhead trout. All three of the side channels were constructed above White Creek in areas where chinook are most abundant.

Representative photographs of construction, structure types, and activities are displayed in Appendix A.

Eldorado Creek - a total reach distance of 10.62 km was extensively 'enhanced' with the construction and placement of 179 habitat structures. The project treated 55% of the total study area in mainstem Eldorado Creek and was completed in one year. The actual stream length treated with structures ("intensive perspective') equalled 7.08 km and encompassed fourteen reaches with eight consisting of mixed structures (log weirs, boulders) and six of large woody debris (Fig. 20). The average number of structures per unit distance was 16.9/km (1 structure every 59 m) or 25.3/km (1 structure every 40 m) of actual stream length treated. Figure 21 displays the structure types most frequently used in Eldorado Creek. Large woody debris (31%), boulders (34%), and root wads (21%) dominated the distribution. Log and boulder weirs comprised only 13% of the total. Structures that created habitat type diversity and increased instream cover were emphasized in this project. The ratio of rock to wood type structures was 0.7 to 1.

The total expenditure for the project equalled $26,000 with a mean cost per structure of $145. This unit cost per structure is only slightly ($14/structure) higher than the figure for Lolo Creek. The cost per 'enhanced kilometer (extensive) equalled $2,448, whereas, the cost per 'treated' kilometer (intensive) was $3,672. Although the unit cost was only slightly higher for the Eldorado Project ($14/structure), the cost per treated kilometer was considerably lower-almost 4 times-than the Lolo Project. In Lolo Creek, we treated the reaches more intensively with one structure placed every 9 m instead of every 25 m as in Eldorado. Also because of its size, construction in Lolo Creek was more complex and thus, more expensive.

Pete King Creek - a total reach distance of 9.23 km was extensively 'enhanced' with the construction and placement of 191 habitat structures. The actual stream length treated with structures ('intensive perspective') equalled 5.4 km (58.6% of the study area) and encompassed 7 reaches (Fig. 16). The project was completed in two years following the 1986 field season. The average number of structures per unit distance was 35.3/km (1 structure every 28 m) of actual stream length treated. Log and boulder weirs (102) dominated the placement of structures in Pete King. Weirs constituted 53% of the total with boulders (83, 44%) in various arrangements a close second. Structures that created pool habitats and increased the scouring of substrate sediments were emphasized in this project. The ratio of rock to wood type structures was 1.3 to 1.

The total expenditure for the project equalled $40,000 with a mean cost per structure of $209. This unit cost per structure is higher than either Eldorado's ($145) or Lolo's ($131). The higher cost is associated with the fact that percentage-wise the more expensive weir structures were featured over the placement of boulders or woody debris. The cost per 'enhanced' kilometer (extensive) equalled $4,334, whereas, the cost per 'treated' kilometer (intensive) was $7,394. The Pete King project was intermediate in cost per 'treated' kilometer when compared to the Lolo and Eldorado projects. Table 5 displays the comparisons.

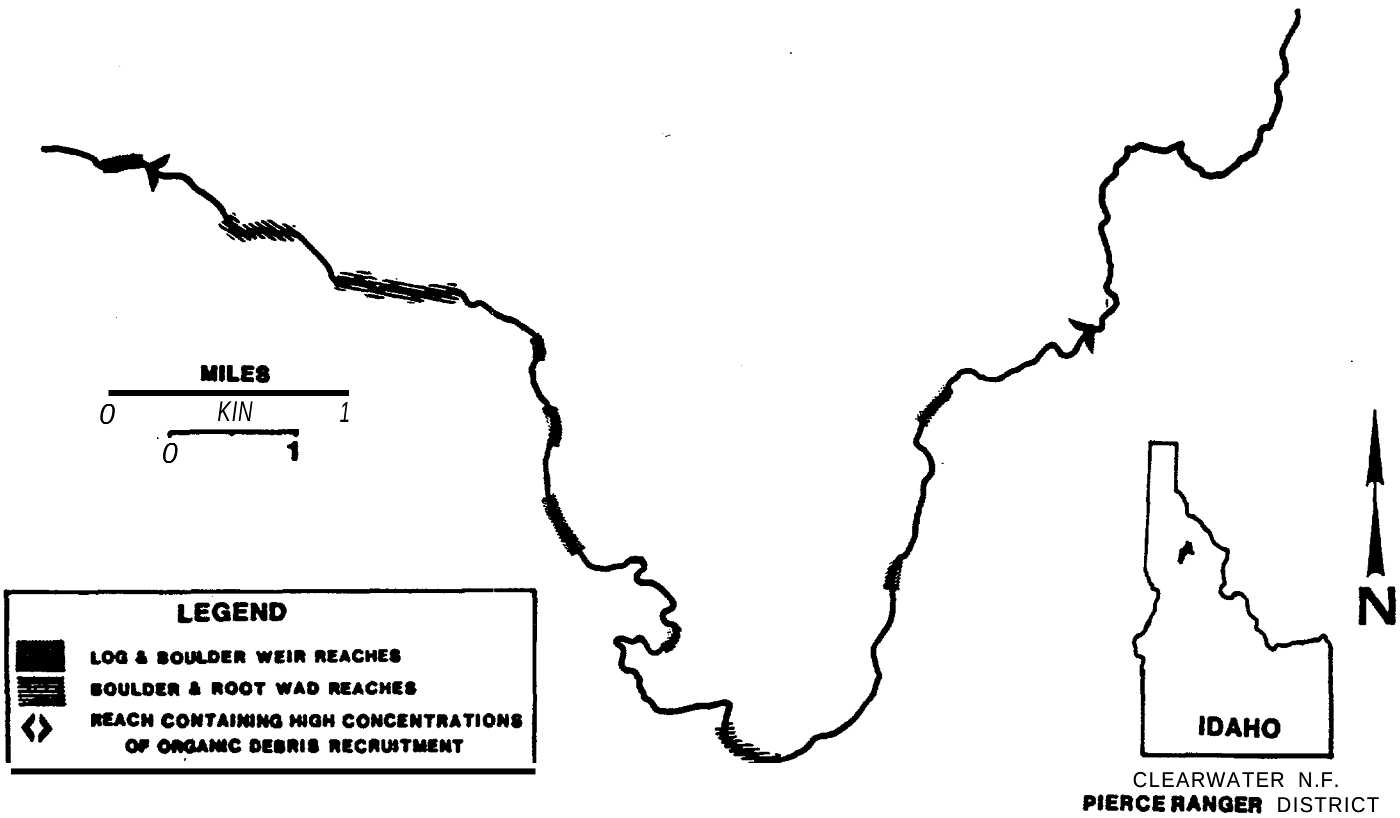


FIG. **20. BPA** PROJECT MAP - ELDORADO CREEK

FIGURE 21. DIVERSITY OF HABITAT STRUCTURE TYPES PLACED IN ELDORADO CREEK, IDAHO

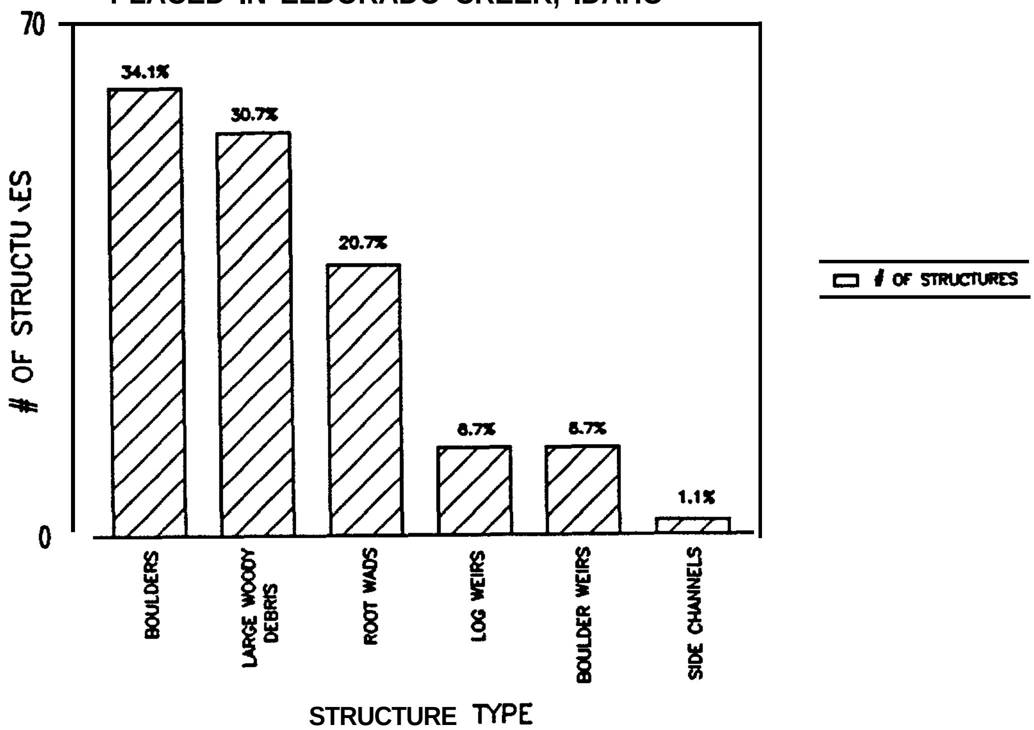


Table 5. A comparison of total project costs for instream structural enhancement in Lolo, Eldorado, and Pete King Creeks, Idaho

Project	Unit Cost Per Structure	Cost Per Kilometer (extensive)	Cost Per 'Treated' Kilometer (intensive)	Total Project costs
Lolo	$131	$6,517	$14,540	$91,309
Eldorado	$145	$2,448	$3,672	$26,000
Pete King	$209	$4,334	$7,394	$40,000

b. Riparian

Two riparian projects were completed in the Lolo Creek watershed (Fig. 18). The first involved the fencing of some **critical** riparian habitat adjacent to several reaches of Lolo Creek that had been structurally improved. Impacts from a grazing allotment were threatening the integrity of the project. A total of 3,200 m (3.2 km) of fence was constructed that protected 20,235 m^2 (2 ha) of spawning and rearing habitats for anadromous fish and 22.3 ha of riparian habitat. The fence consisted of treated wood posts and 3 strands of barbed wire, The construction involved 11 wire gates, 28 comer braces, and 1 cattle guard. Details of the project are presented in Talbert et al. (1988). The total cost of the project was $27,400 ($8,563/km or $1,128/ha). Representative project photographs are presented in Appendix A.

The second project involved the planting of conifers in non-stocked and disturbed sites of Lolo Creek's riparian zone. The primary objective of this project was to provide a long term source of large woody debris (recruitment trees) to the Lolo Creek ecosystem. Parallel road construction within the riparian zone and timber harvesting had essentially removed 50%+ of the potential woody debris along 19 km of Lolo Creek.

Conifers consisted of bareroot 2-year old western white pine and Englemann spruce seedlings were selected as the preferred stock and planted in suitable habitat on an average spacing of 3.7 m X 3.7 m. Planting was conducted in the Spring and covered 34 acres along both sides of Lolo Creek (Fig. 18). The areas ranged in size from 40 m^2 to 10,117 m^2. The average size of the planted area was 3,035 m^2. A total of 6,160 trees was planted within 10.7 ha of riparian habitat at a total project cost of $5,644. The cost per unit of treatment equalled $528/ha. Project details and photographs are presented in Babler et al. (1989).

c. Barriers

Major bedrock and debris barriers to upstream migration of adult anadromous fish in three major tributaries of Lolo Creek were modified and removed (Fig. 3). The most complex project was located in Eldorado Creek where a series of basalt bedrock falls (4) near its confluence with Lolo Creek blocked salmon and steelhead from upstream habitats. This project required multiple modifications with explosives in order to achieve the proper profile. Four major sites were treated with the lowermost and uppermost barriers requiring the most work. A total of eleven pools was initially created by blasting; site 1 required five pools to achieve passage. Further evaluation documented the need for additional blasting at site 4 and structural refinement at site 1. These modifications were completed in 1988 and 1989. At site 1, a large log weir was anchored to the basalt bedrock at the 'lip' of pool 3 (Appendix A.). At site 4, several large rocks were removed with explosives to better re-align the approach flows above the main holding pool. These "final' refinements should allow salmon and steelhead to negotiate successfully the Eldorado 'gauntlet'.

Provision of passage at Eldorado will make available the following mainstem habitats for anadromous fish: 18.67 km of total stream length with 154,600 m^2 of summer rearing, 1,790 m^2 of winter rearing, 1,978 m^2 of spawning habitat for steelhead and 1,745 m^2 of spawning habitat for chinook. Access to the principal tributaries of Eldorado will provide 23.2 km of total stream length with 57,871 m^2 of summer rearing, and 213 m^2 of steelhead spawning habitat.

Excessive accumulations of large woody debris in confined, steep gradient sites of Eldorado, Yoosa, and Musselshell Creeks created partial migration barriers for steelhead and complete barriers for chinook salmon. Removal of the barriers involved blasting, sawing, and hand labor to clear debris from the channels. Debris jams in Eldorado and Yoosa Creeks were completely removed, whereas the barrier at Musselshell was partially removed. We believe unimpeded passage has been provided to these tributaries. Representative project photographs are presented in Appendix A.

Provision of passage in Yoosa and Musselshell Creeks has opened up 8.5 km and 19.6 km of total stream length respectively. A total of 81,815 m^2 of summer rearing, 1 ,155 m^2 of spawning habitat for steelhead and 810 m^2 of spawning habitat for chinook has been made available in Yoosa Creek. Musselshell Creek will provide 109,760 m^2 of summer rearing habitat, 122 m^2 of steelhead and 41 m^2 of chinook spawning habitats. Because of excessive instream sediment, limited amounts of spawning habitat and no winter rearing habitat were identified in Musselshell Creek.

A summary of project accomplishments, costs, and amounts of **'new'** habitat accessed is displayed in Table **6.**

Table 6. A summary of accomplishments and costs associated with fish passage projects in the **Lolo Creek Watershed**

Stream	Barrier Type	Project costs ($)	Total Stream Length Accessed (km)	Cost per km ($)	New SR[1] Habitat Accessed (m²)[3]	New WR[2] Habitat Accessed (m²)	STH (SH[6] M²)	CHS (SH m²)
Eldorado	Bedrock Falls	30,668	18.67 main.[4]	733	154,600	1,790	1,978	1,745
			23.20 tribs.[5]		57,900	213	-----	-----
Yoosa	Debris	5,000	8.5 main.	**588**	**81,800**	**4,040**	**1,155**	**810**
Mus-selshell	Debris	10,000	19.60 main.	510	109,800	---	122	41
Totals		**45,668**	**46.77** main.		**404,100**	**5,830**	**3,468**	2,596

[1] SR = Summer rearing
[2] WR = Winter rearing
[3] m² = square meters
[4] main. = mainstem channels
[5] tribs. = tributaries
[6] SH = Spawning habitat

C. Accomplishments: Tributaries of the Upper Lochsa River

1. Surveys and Project Identification

Crooked Fork and ***White** Sand* Creeks - Crooked Fork Creek was identified as a watershed and stream that had experienced the results of heavy timber harvesting and road building and had potential for enhancement opportunities. In 1979, an intensive habitat survey was completed on the creek by Powell District personnel (Espinosa 1984). White Sand Creek, in a relatively unmanaged watershed, was surveyed in 1971. A review of the data suggested that habitat factors potentially limiting to fish production were: suboptimum levels of pool quality, bank cover, pool/riffle structure and diversity. The amount of suitable spawning habitat was also a potential limiting factor.

RESULTS

During the project identification stage, enhancement work was proposed that would focus on the limiting factors. The stream size dictated that structures installed had to be limited to large (>24 inch diameter breast height) woody debris. A set of specific habitat and channel criteria was established to guide the field identification of reaches and sites suitable for structures. Criteria were based upon limiting factors, hydrology and channel morphology. An overall objective of adding 400 pieces of large organic debris was formulated.

Stream surveys were performed in **Crooked Fork Creek in 1983** which identified several natural waterfalls and rock chutes that precluded passage of spring chinook salmon during late summer flows. In 1984, U.S. Forest Service personnel and Jack Orsborn, consulting engineer, surveyed the project area to determine the best methods for modification to provide optimum fish passage. Additional potential barriers were also located and discussed.

Surveys conducted in Colt **Creek,** a tributary to White Sand Creek, in 1962 and 1974 revealed the presence of several bedrock and debris barriers which limited fish passage into this drainage. Some barrier modification was attempted in 1980 and steelhead trout were stocked in the drainage by Idaho Fish and Game after that time. Fish were sampled in 1986 to detenine the absence or presence and abundance of anadromous fish. Results indicated very little steelhead trout escapement and no chinook salmon escapement. Further survey work in 1986 indicated that extensive modification work would not improve passage for chinook but would alleviate steelhead passage problems. Additional information on this project is detailed in Kramer et al. (1987).

Stream survey data from 1973 and 1979 reported a rock falls barrier in **Shotgun Creek,** tributary to Crooked Fork. In 1981, some preliminary blasting was done in an effort to create deeper pools. This effort was unsuccessful and plans were drawn up for barrier modification. In the summer of 1987 Thomas Bumstead, consultant, and U.S. Forest Service personnel reviewed the barrier to finalize plans prior to modification and construction.

Spruce Creek, tributary to Brushy Fork Creek, was surveyed in 1986. Two migration barriers were located on the lowest mile of stream, a segment owned by Plum Creek Timber Company. Plum Creek agreed to provide access and raw materials (i.e., boulders and trees) for construction of weirs. Details of the Shotgun and Spruce Creek projects are in Fallau et al. (1989).

Storm Creek, a tributary of White Sand Creek, was surveyed in 1986. A primary objective of the survey was to investigate fish migration barriers described by Murphy and Metsker (1962). Barriers previously described were located and mapped. A transit was used to gather data on depth of pools and height of jumps, and it was determined whether barriers existed and if removal was feasible.

Squaw, Doe **and Papoose** *Creeks* **-** during the 1984 field season, 6.4 km of Squaw Creek were surveyed starting from the mouth at the Lochsa River and working upstream. The survey ended where the stream splits and forms the East and West Fork. Doe Creek was surveyed during the 1984 and 1985 field seasons starting from the mouth of Doe Creek at Squaw Creek and ending at the large culvert where the road switches back and begins to climb, diverging from the stream's edge. A total of 7.2 km was surveyed. Papoose Creek was surveyed from the mouth upstream for 7.1 km during the 1984 field season. The stream survey data were summarized and described in homogeneous groups of reaches. Opportunities for enhancement were identified during the survey process.

2. Enhancement

a. Enhancement Structures

Crooked Fork and White Sand Creeks **-** a total of 194 sites were enhanced in these streams in 1983 (Espinosa 1984). Crooked Fork had a total of 118 sites enhanced in 9.1 km of stream (Table 7.). White Sand had 78 sites in 5.6 km of stream (Table 8.). Riparian conifer trees were felled into the streams at these sites to increase pools and structural diversity. In addition, 'opportunity debris', natural debris occurring in the streams, was cabled to nearby anchor points to insure their longevity in the system.

Table 7. A compilation of project statistics for Crooked Fork Creek, 1983.

Reach	Trees Felled	Dominant Species Felled	% Dominant Species	En-hanced Sites	Opportunity Debris	Total Structures
1	7	Cedar	57	5	0	7
2	17	Cedar	59	17	8	25
3	3	Fir	67	6	7	10
4	14	Fir	64	14	3	17
5	25	Spruce	92	18	0	25
6	33	Spruce	73	36	24	57
7	23	Spruce	70	22	6	29
Summary	122	Spruce	52	118	48	170

Table 8. A compilation of project statistics for White Sand Creek, 1983.

Reach	Trees Felled	Dominant Species Felled	% Dominant Species	En-hanced Sites	Opportunity Debrls	Total Structures
1	12	Cedar	58	14	6	18
2	5	Larch and Fir	40	5	0	5
3	21	Cedar	76	17	2	23
4	11	Cedar	45	9	0	11
5	29	Larch	55	31	7	36
Summary	78	Cedar	36	76	15	93

Due to mixed ownership in both drainages, only 20.9 km of stream were actually available for enhancement. Some of the areas on U.S. Forest Service land were unsuitable for treatment due to steep banks, stream gradient, high energy sites and unsuitable riparian trees. Therefore, it was not possible to obtain the goal of 400 trees. A level of 66 percent was achieved. The unit cost per felled riparian conifer **equalled $120/tree** and **$91/structure** for the natural organic debris anchored in place (Table 9).

Squaw, Doe ***and Papoose Creeks -*** a total of 330 structures were constructed in Doe, Squaw and Papoose Creeks in 1985 and 1986 (Table 10). Structures consisted of log weirs, boulder clusters, root wads, deflector logs and boulder weirs. Details of the enhancement work on Doe and Squaw Creeks are located in Kramer et al. (1987). Lee et al. (1988) contains detailed results of the work performed on Papoose and East Fork Papoose Creeks. Structure costs for log weirs and deflector logs ranged from $150 to $500 (Table 9). Individual boulders and root wads cost $5 to $50 per structure.

Squaw Creek **-** prior to treatment, Squaw Creek was often characterized by large amounts of shallow riffle and long stretches of monotypic cascading water. Pool quality rated fair with an average value of less than six (range from one to nine with nine being excellent). Severe road encroachment along this stream had dramatic effects on the riparian area. Stream cleanup projects and lack of debris recruitment left very little debris. After the installation of **instream** structures, surveys indicated a substantial increase in the pool and run habitats and a corresponding decrease in riffle **habitat** (Table 11). Acting **instream** debris increased from an overall average of **32/mile** to **133/mile,** an increase of over 400%.

Log weirs were used to affect 38% of the treated habitat. Log weirs created predominately pool and run habitat, with pool qualii ranging from 6.1 to 8.8 (Tables 12 and 13). Pools created by log weirs had the highest quality of pools (Table 14). Boulders and root wads created primarily pool habitat. The overall pool quality for these structures was generally low but these ratings are expected to increase as future high flows cause additional scouring. Acting **instream** debris increased from an overall average of 32 pieces per mile to 133 pieces per mile, an increase of over **400%,** at the end of the first year.

Doe ***Creek -*** the pre-treatment survey for Doe Creek, exhibited a poor **pool:run:riffle** ratio (3564) (Table 15). Instream structures were constructed to increase the number of pools, the number of **instream** acting debris and improve the quality of pools.

Table 9. Instream habitat enhancement costs.

Location	Structure	Number of Structures	Cost per Structure
Crooked Fork Creek	riparian tree organic debris*	118 48	$120 $91
White Sand Creek	riparian tree organic debris*	76 15	$120 $91
Squaw Creek	log weir/deflector log root wad/boulder reach	52 213	$150-500 $5-50
Doe Creek	log weir/deflector log root wad/boulder reach	35 87	$150-500 $5-50
Papoose Creek	log weir/deflector log root wad/boulder reach	63 240	$150-500 $5-50
East Fork Papoose Creek	log weir/deflector log root wad/boulder reach	49 23	$150-500 $5-50

* Powell costs are 54% more than Lolo costs due to complex access and logistics.

Table 10. Number and types of completed instream habitat enhancement structures for Doe Creek, 1985; Squaw Creek, 1985; and Papoose Creek, 1986.

Structure Type	Doe Creek	Squaw Creek	Papoose Creek	Total
Upstream V	1	0	0	1
Root Wad	18	34	73	125
Log Weir	22	27	44	93
Deflector Log	13	25	19	57
Boulder Reach	8	26	13	47
(Total Boulders)	(69)	(179)	(167)	(415)
Boulder Weir	4	1	2	7
Total No. of Structures	66	113	151	330

Table 11. Comparison of pool/run/riffle habitat (%) and acting debris (no./kilometer) before and after treatment In Squaw Creek, 1987.

	Pre-Treatment				Post Treatment			
Reach	**Pool**	**Run**	**Riffle**	**Debris/Km**	**Pool**	**Run**	**Riffle**	**Debris/Km**
A	31	1	67	36	29	23	48	86
B	31	2	67	35	34	28	38	136
C	40	1	**59**	26	51	23	26	76
D	26	14	60	7	31	20	49	49
E	14	1	85	24	24	18	58	46
A-E	28	4	68	25	34	22	44	74
F	9	1	90	11	29	15	56	67
G	20	2	78	9	41	13	46	73
H	34	1	65	7	21	14	65	27
I	32	1	67	14	35	13	52	54
J	28	1	70	16	35	10	55	59
K	14	1	85	27	24	21	55	52
L	19	2	79	62	24	18	58	100
M	24	2	74	5	36	17	47	49
N	27	2	71	14	45	19	36	50
0	25	3	72	5	49	21	30	39
F-O	23	2	75	17	34	16	50	55

Table 12. Summary of habitat parameters In Squaw Creek, Reaches A-E, by structure type, 1986.

					Habiiat Function by % of Occurrence					Pool Quality			
Structure Type	To-tal Sites	Total Area M^2	Total Struc-tures	Average Area per Structure M^2		P.W.[1]	Alcove	Rif-fle	Run	Poo	P.W.[1]	Alcove	Avg.
Random Boulders	12	1,173.61	54	21.73	1	6	3	46	44	5.2	4.0	4.0	4.1
Deflector Log	9	1,526.13	10	152.61	2	3	10	34	51	9.0	4.6	5.2	5.6
Root Wad plus Boulder	3	634.23	32	19.82	6	6	7	54	27	5.2	4.4	4.3	4.6
Log Weir with no Pool Cover	2	266.24	2	133.12	35	0	18	11	36	8.3	0.0	4.6	7.0
Log Weir with Pool Cover	1	87.04	2	43.52	31	0	9	20	40	9.0	0.0	3.0	7.7
Log Weir with Overhead Cover	1	202.86	2	101.43	57	0	10	5	28	9.0	0.0	5.0	8.4

[1] Pocket Water

Table 13. Summary of habitat parameters in Squaw Creek, Reaches F-O, by structure type, 1986.

					Habitat Function by % of Occurrence					Pool Quality			
Structure Type	To-tal Sites	Total Area M^2	Total Struc-tures	Average Area per Structure M^2	Pool	P.W.[1]	Alcove	Rif-fle		Poo	P.W.[1]	Alcove	Avg.
Random Boulders	11	937.11	60	15.61	0	4	2	28	66	0.0	3.9	4.4	4.1
Boulder Weir	2	456.69	2	228.34	8	1	2	67	22	7.3	3.0	3.5	6.2
Deflector Log	14	1,636.86	19	86.15	1	2	4	18	75	4.0	4.3	4.7	4.5
Root Wad	4	393.70	5	78.74	5	5	9	12	69	6.0	5.2	5.1	5.4
Root Wad plus Boulder	4	868.99	45	19.31	0	5	7	18	70	0.0	4.7	5.5	5.2
Log Weir with no Pool Cover	4	453.98	4	113.49	19	2	11	9	59	8.4	3.8	5.1	6.9
Log Weir with Pool Cover	4	548.35	9	60.92	20	2	5	16	57	6.9	4.1	5.8	6.5
Log Weir with Overhead Cover	15	2297.92	34	67.56	15	1	13	8	63	7.5	3.7	5.4	6.4

[1] Pocket Water

Table 14. Comparison of pre-treatment pool qualities (weighted averages) of ail habitat to post-treatment pool qualities of installed structures for Squaw Creek and Doe Creek, 1986.

Pool Qualities	Squaw Creek Reaches A-E	Squaw Creek Reaches F-O	Doe Creek Reaches A-N
Pre-treatment	5.8	5.2	4.9
Post-treatment			
All Installed Structures	8.2	6.6	5.4
Log Weirs	8.8	7.3	6.1
Boulders and Root Wads	4.6	5.0	5.4
Deflector Logs	6.3	4.2	4.0
Boulder Weirs		6.8	4.2

Table 15. Comparison of pool/run/riffle habitat (%) and acting debris (no./mile) before and after treatment in Doe Creek, 1986.

	Pre-Treatment			Post Treatment		
Reach	Pool/Run	Riffle	Debris/Mile	Pool/Run	Riffle	Debris/Mile
A	34	66	71	75	25	119
B	16	84	76	79	21	184
C	24	76	66	83	17	187
D	27	73	170	57	44	268
E	17	83	38	82	37	152
F	34	66	0	52	48	75
G	28	72	33	64	35	242
H	35	65	58	96	4	76
I	41	59	46	64	3	148
J	42	58	93	53	46	196
K	37	63	102	71	29	288
L	44	56	189	94	6	278
M	51	49	244	66	34	285
N	55	45	190	69	31	260
A-N	35	65	104	73	27	202

The total number of sites enhanced in Doe Creek was 49 (Table 16). Log weirs were the dominant structure type used to affect almost 50% of the total treated habitat. This resulted in an increase in the number of pools and deep run habitat. Pool quality ratings in Doe Creek were not as high as Squaw Creek, which can be attributed to Doe's smaller size and inability to create or maintain the larger and higher quality pool habitat. As a result of the enhancement effort, instream acting debris was increased by almost 95%.

Papoose Creek - Papoose Creek pre-treatment survey data, recorded a low percentage of pool and run habitats throughout much of the stream (Table 17). Monotypic riffle type water comprised between 56% to 83% of the stream depending on the reach. Papoose Creek had **a** total of 40 enhancement sites (Table 18). After treatment, the three structure types affecting most of the enhanced area were root wads **(38%),** boulders (35%) and log weirs (15%). Deflector logs affected 11% of the area and one boulder weir affected 1%. Log weirs produced the highest quality of pools. After the construction of structures, surveys recorded a marked increase in pool/run habitat, thus increasing the amount of available rearing areas. The enhanced sites increased the winter rearing capabilities throughout the stream.

***East Fork* Papoose *Creek* -** a total of 57 sites were enhanced with structures in the East Fork of Papoose Creek (Table 19). Log weirs accounted for 79% of the treated habitat. Deflector logs, root wads, boulders and boulder weirs affected less than 10% each. Log weirs formed the highest percentage of pool habitat and formed pools with the highest quality. Root wads created the next highest quality of pools (average 6.2) while the remainder of the structure types had average pool qualities less than 6.0.

Table 16. Summary of habitat parameters in Doe Creek, by structure type, 1986.

					Habitat Function by%of Occurrence					Pool Quality			
Structure Type	Total Sites	Total Area M²	Total Structures	Average Area per Structure M²	Pool	P.W.[1]	Alcove	Riffle	Run	Poo	P.W.[1]	Alcove	Avg.
Random Boulders	3	281 so	22	12.80	11	2	0	a3	4	4.0	3.1	0.0	3.86
Boulder Weir	1	25.20	1	25.20	88	0	0	0	12	4.2	0.0	0.0	4.21
Deflector Log	12	942.92	23	40.99	5	1	4	46	44	4.3	2.6	1.6	3.2
Root Wad	5	224.75	10	22.47	12	7	2	31	48	7.4	3.8	3.3	5.77
Root Wad plus Boulder	6	396.75	36	11.02	0	14	2	53	31	0.0	5.9	3.1	5.5
Log Weir with no Pool Cover	4	411.35	5	82.27	50	0	0	6	44	5.8	0.0	0.0	5.84
Log Weir with Pool Cover	1	102.0	2	51 .o	53	0	10	0	37	6.8	0.0	4.0	6.37
Log Weir with Overhead Cover	17	1.161.99	37	31.41	54	0	1	15	30	5.7	3.5	3.8	5.67

Pocket Water

RESULTS

Table 17. Comparison of pool/run/riffle habitat (%) and acting debris (no./kilometer) before and after treatment **in Papoose Creek, 1987.**

	Pre-Treatment				Post Treatment			
Reach	Pool	Run	Riffle	Debris/Km	Pool	Run	Riffle	Debris/Km
A	18	15	67	12	41	30	29	43
B	32	20	48	77	57	22	21	102
C	35	14	51	80	46	26	28	106
D	28	14	58	80	43	22	35	132
A-D	29	15	56	65	47	25	28	100
E	24	6	70	81	50	19	31	216
F	25	3	72	116	39	22	39	159
G	15	6	79	45	42	34	24	102
H	23	5	72	75	58	21	21	124
E-H	21	5	74	76	47	24	29	145
I	10	7	83	77	34	25	41	109
J	15	3	82	114	48	24	28	125
I-J	12	5	83	89	41	24	35	114
K	15	2	83	96	43	26	31	96
L	16	2	82	103	45	21	34	120
M	15	3	82	118	48	28	24	176
N	20	1	79	64	45	23	32	115
K-N	17	2	81	93	45	25	30	127

Table 18. Summary of habitat parameters in Papoose Creek, post-treatment

					Habitat Function by % of Occurrence					Pool Quality			
Structure Type	Total Sites	Total Area M²	Total Structures	Average Area per Structure M²	Pool	P.W.[1]	Alcove	Riffle	Run	Pool	P.W.[1]	Alcove	Avg.
Log Weir	5	1,500.5	5	300.1	100	0.0	0.0	0.0	0.0	7.5	0.0	0.0	7.5
Deflector Log	9	1,091.6	14	78.0	52.5	0.0	2.5	32.5	12.5	4.5	0.0	3.0	4.5
Root Wad	17	3,715.7	58	64.1	59.4	3.1	1.0	22.9	13.6	6.2	3.0	4.0	4.5
Boulder Reach	a	3,403.9	106	32.1	14.8	66.1	0.0	10.4	8.7	6.2	3.2	0.0	5.5
Boulder Weir	1	66.0	1	66.0	100	0.0	0.0	0.0	0.0	6.6	0.0	0.0	6.6
Control	5	402.6	5	80.6	38.1	14.3	0.0	33.3	14.3	3.0	3.0	0.0	3.0

[1] Pocket Water

Table 19. Summary of habitat parameters in East Fork Papoose Creek, post-treatment.

					Habitat Function by % of Occurrence					Pool Quality			
Structure Type	To-tai sites	Total Area M²	Total Struc-tures	Average Area per Structure M²	Pool	P.W.[1]	Alcove	Rif-fle	Run	Pool	P.W.[1]	Alcove	Avg.
Log Weir	38	2,371.5	39	60.8	79.2	0.0	0.0	9.4	11.4	7.1	0.0	0.0	7.1
Deflector Log	9	232.5	10	23.3	55.6	11.1	0.0	18.5	14.8	5.4	3.6	0.0	5.4
Root Wad	7	230.9	13	17.8	48.4	9.7	0.0	29.0	12.9	6.3	3.9	0.0	6.2
Boulder Reach	1	96.0	10	9.6	la.2	63.6	0.0	la.2	0.0	6.1	3.9	0.0	5.4
Boulder Weir	2	66.1	2	32.6	66.6	0.0	0.0	31.8	1.6	5.8	0.0	0.0	5.8
Control	5	150.2	5	30.0	16.7	62.5	0.0	20.8	0.0	3.7	3.4	0.0	3.6

[1] Pocket Water

Maintenance - the most common maintenance required during the survey of structures on Squaw, Doe, Papoose and East Fork Papoose Creeks was the reseeding of stream banks where structures had been secured into place. This was caused by a frost with resultant poor seedling survival and by trampling of fishermen using the enhanced sites. These sites were seeded with grass and fertilized; good ground cover was present by August. A debris barrier was located on the mainstem of Papoose Creek that appeared to be a barrier to fish migration. This was opened up by chain saw and hand removal of debris.

During the 1987 season, there was extensive road maintenance performed to move and slope the road away from Squaw Creek where road encroachment was a problem. In areas where the road had widened, the road was graded allowing for a wider buffer strip next to the stream. Buffer strips were seeded and hydromulched with grasses. Those areas with a sufficient riparian strip already existing had gravel placed on the road and the road graded with a slope away from the stream. A total of 7.3 kilometers of road rehabilitation work was completed on Squaw, Doe and Papoose Creeks. The cost of the road work was $82,000 or $11,230.00 per km (Forest Service funds).

b. Barriers

A culvert on the West Fork of Squaw Creek was determined to be a barrier to fish migration during the 1986 survey. It was determined that during the majority of the spawning season the culvert was a total block to both species due to the high velocity. A series of baffles were welded into the culvert to reduce the velocity and provide resting pools for the migrating fish. The culvert baffle on the West Fork of Squaw Creek was completed in October, 1987. The cost of the construction was $11,000. All road rehabilitation work and culvert baffle were funded 100% with USFS funds.

The baffle was evaluated during the next spring run-off and was found in need of modifications. Water flowed over the sides of the baffle into the side channels. Because of the higher velocities, fish were attracted to the side channels instead of to the baffle. In addition, the initial resting pool in the baffle lacked sufficient depth. Stop-gap measures were taken during high flows using sand bags to build up the resting pool. Later in the season, permanent maintenance was completed on the baffle. The sides were built up in order to prevent water from spilling into the side channels. A lip was installed across the front of the baffle to create a deeper initial resting pool.

During the summer of 1984, twelve natural waterfalls and rock chutes in Crooked Fork Creek, previously identified as migration barriers, were drilled, loaded with explosives and detonated (Kramer et al. 1984). The following summer, 1985, further drilling and blasting occurred on ten of the barriers. Hopeful Creek was the site of a large debris jam creating a migration barrier. Work began on this site in 1984 and was completed in 1985. Part of the barrier was removed through cutting and hand removal of debris. The remainder was removed through blasting. **A** bedrock boulder was also removed to prevent further debris accumulation. Details of the Hopeful Creek work and the work completed in 1985 on Crooked Fork can be found in Kramer et **al.** (1986). A debris jam in the lowest reach of Storm Creek was removed through blasting and hand removal during the 1989 field season. Details of this project are found in Fallau et al. (1989).

In 1987, only one site on Crooked Fork exhibited any perceptible change in habitat since completion of modification in 1986. High flows scoured loose material increasing the depth of the jump pool by approximately one-half meter. All other sites did not change significantly .

Two sites on Crooked Fork needed additional work to ensure passage of early fall spawning chinook salmon. Two log weirs were constructed at each site in August, 1987, to create and deepen jump pools (Fallau et al., 1988).

C. Evaluation - Upper Lochsa

1. Enhancement Structures

Squaw Creek **-** surveys were conducted in Squaw Creek prior to treatment and after completion of the enhancement work. The results of the post-treatment analysis show a shift away from the riffle dominated, monotypic habitat (Table 11). Increases in number and quality of pools, amount of spawning and winter rearing habitat and an overall increase in the habitat variability are all evident. Log weirs proved to be the most effective structures in accomplishing increases in winter rearing and spawning habitat.

The post-treatment survey documented an increase in acting debris which contributed to the increase in pool numbers and pool qualities resulting in more variability in habitat function. Habitat function shifted from primarily summer rearing, some of which was marginal in quality, to a more balanced habitat providing summer and winter rearing habitat and spawning habitat. Log weirs were especially effective at creating spawning habitat upstream of the log. Many of these areas have been used for spawning by steelhead and chinook since construction.

Boulder and root wad structures produced small pools in predominantly run and riffle habitat. Pocket water and alcove habitat types, typically formed by boulders and root wads, will inherently have low pool quality ratings due to size and depth limitations and were not looked at as separate habitat types. It was determined that these structure types are somewhat more difficult to place effectively as compared to log weirs.

Doe *Creek* - similar results were seen from enhancement work on Doe Creek. The evaluation of the enhancement work showed a dramatic shift in the pool:run:riffle ratio (Table 15). The shift in the pool:run:riffle ratio is primarily due to the increase in deep run habitat. Evaluation of the enhancement work in Doe Creek showed an increase in winter rearing habitat and an increase in the quality of the summer rearing habitat.

Papoose Creek **-** prior to treatment Papoose Creek was characterized by a large amount of monotypic riffle type habitat. It also was characterized by low percentages of pool and run habitats except in the lower portions of the stream. Post-treatment surveys recorded a marked increase in pool/run habitat, thus increasing the amount of available rearing areas. There was an overall increase of 52% in the number of acting debris after enhancement.

Log weirs produced primarily pool habitat with an average pool **quality** rating of 7.5, creating the highest percentage of pool habitat per structure and the highest quality of pools. Boulders created predominantly pocket water habitat. The overall average of pool quality for boulder reaches was 5.5, generally rating low because of the small size and depth of pocket water pools. Root wads created diverse pool habitats with an overall pool quality of slightly above average (6.2). Although only one boulder weir was installed, it had pool quality ratings similar to log weirs. Riffle and run habitats were more prevalent and pools were of a lower quality in control sites than in enhanced sites.

Untreated control sites were evaluated in addition to treated sites. Rearing habitat in the control sites of Papoose Creek were limited to summer rearing. The enhanced sites increased winter rearing areas from zero to 13.2%. Ten percent of the control sites and 45% of the enhanced sites had spawning habitat (Table 20). Log structures, root wads and boulders were effective in influencing spawning habitat. The high incidence of spawning gravel in the mainstem may be a result of its great capacity to move spawning sized material.

East Fork *of Papoose Creek* - evaluation of enhancement and control sites in East Fork Papoose Creek showed pool qualities in the control sites had a low percentage of pool habitat when compared to enhanced sites. Pool qualities in the control sites were very low with an average of 3.6, less than all of the structure types evaluated. The largest percentage of habitat occurring in control sites was pocket water habitat.

Log weirs formed the highest percentage of pool habitat and had the highest pool quality ratings with an average of 7.1 (Table 19). Two boulder weirs were installed with resulting pool qualities being comparable to those of log weirs. Root wads created high pool quality ratings with an average of 6.2. The remainder of the structure types had average pool qualities of less than 6.0.

East Fork of Papoose Creek control sites lacked winter rearing habitat. The sites that were enhanced with instream structures showed a large increase of winter rearing habitat, with 46% of the rearing area being suitable as winter habitat. Ten percent of the control sites and 11% of the enhanced sites had the presence of spawning habiiat (Table 20). Spawning habitat was created by log structures.

Table 20. **Number and percentage of sites with spawning habitat present, Papoose and East Fork Papoose Creeks, post-treatment.**

Structure Type	Papoose Creek # Sites w/Spawning Habitat	%	E. Fork Papoose Creek # Sites w/Spawning Habitat	%
Log Weir	2	40	5	13
Deflector Log	2	22	1	11
Root Wad	7	50	0	0
Boulder Reach	4	50	0	0
Boulder Weir	0	0	0	0
Combination’	4	80	0	0
Total	19	45	6	11
Control	1	20	0	0

[1] A combination has two or more structure types on one site.

2 Salmonid Response

Fish populations were **censused** in control and enhanced sites in Squaw Creek, Papoose Creek and East Fork Papoose Creek.

Squaw Creek **-** control and enhanced sites in Squaw Creek were snorkeled in 1986 through 1989. In most cases, densities of all fish were higher in treated habitat when compared to untreated habitat (Table 21). In 1986, log weirs had the highest densities of fish with an over three-fold increase in Of chinook salmon and a nine-fold increase in steelhead **≥1+** when compared to control areas, representing a significant difference **($P<0.05$).** This was probably due to the larger pool sizes and greater depths plus good cover. Age 0+ salmonids (steelhead and cutthroat trout) preferred boulder reaches and control sites which were primarily riffle and pocket water.

The 1987 data revealed similar preferences in the yearling+ salmonids and the chinook salmon, all of which were found at their highest densities in log weir sites. Overall, the log weir created habitat contained the highest densities of fish with an average of 57.7 **fish/100m²** while the control sites had the lowest average density of 14.3 fish/l **00m².** The age 0+ salmonids preferred log weir sites and, as in 1986, boulder reaches.

In 1988, all age classes and species were again observed in greater numbers in enhanced sites than in controls. Log weir sites, with habitat dominated by deep pools and good cover, supported the highest densities of all fish groups. Age Of salmonids (steelhead and cutthroat trout) were found in similar densities in root wad and boulder reach sites, 25.1 and 26.8 **fish/100m²,** respectively. Yearling+ steelhead densities were nearly three times higher in log weir sites than boulder reaches, which supported the next highest densities. Cutthroat were observed in log weir and boulder reach sites, while bull trout were found in low densities in all sites.

Data collected in 1989, not previously summarized or published, shows similar results to previous years (Table 21). Log weirs showed the highest overall densities of fish. Densities of age 0 salmonids were similar in log weirs, boulder reaches and control sites. Habitat created by log weirs was favored by the larger size classes of fish. No chinook salmon were observed in Squaw Creek in 1989.

The analysis of variance (l-way **ANOVA)** showed no significant differences in the densities of age 0+ salmonids. Age yearling+ steelhead trout had significantly higher densities in log weir sites and boulder reach sites when compared to controls in 1987 and 1988. Chinook salmon were also found to be in significantly higher densities in log weir habitat when compared to controls. In 1989, the **ANOVA** showed results consistent with previous years' data (Table 22).

Table 21. Mean area and densities (number/l 00m²) of fish by species, age class and structure in Squaw Creek, 1986 - 1989.

	1988		1987		1988		1989	
Species, Age, Structure	Area (m²)	Fish per 1 00m²	Area (m²)	Fish per 100m²	Area (m²)	Fish per 100m²	Area (m²)	Fish per 100m²
Chinook 0+								
Control	84.5	10.4	78.8	1.5	77.3	0.9	100.1	0.0
Log Weir	49.5	31.4	46.3	15.4	51.8	5.1	55.3	0.0
Root Wad	93.9	12.2	78.3	5.7	75.6	3.6	106.8	0.0
Boulder Reach	65.9	15.4	79.5	4.4	66.7	1.9	108.5	0.0
Salmonid 0+								
Control	84.5	17.1	78.8	10.1	77.3	18.1	100.1	20.4
Log Weir	49.5	16.1	46.3	20.8	51.8	35.5	55.3	20.0
Root Wad	93.9	22.1	78.3	12.8	75.6	25.1	108.8	6.9
Boulder Reach	85.9	20.6	79.5	18.9	66.7	26.8	108.5	21.8
Steelhead 1 + & 2+								
Control	84.5	1.6	78.8	2.5	77.3	2.7	100.1	1.5
Log Weir	49.5	14.9	46.3	16.2	51.8	17.0	55.3	10.9
Root Wad	93.9	6.6	78.3	6.7	75.6	4.9	108.8	1.6
Boulder Reach	85.9	4.1	79.5	7.1	66.7	6.3	108.5	1.8

Table 22. ANOVA (l-way) table for comparisons of fish densities in treated habitats versus control sections, Squaw Creek, 1989.

	Steelhead, Age 0+		Steelhead, Age 1 & 2	
Method of Treatment versus Control	DF	F (Observed)	DF	F (Observed)
All-treated Habitat	3, 26	0.62	3, 26	4.25'
Log Weir	1, 17	0.00	1, 17	6.49'
Root Wad	1, 13	1.43	1, 13	0.01
Boulder Reach	1, 14	0.02	1, 14	0.08

[1] P<.05

Note: No age 0+ Chinook were observed in any snorkeling sections during the 1989 survey of Squaw Creek.

Since we were interested in studying the effects of two factors (years and treatments) simultaneously, the data was subjected to further statistical analysis for the entire evaluation period of 1986 to 1989. For chinook salmon and steelhead yearling+ parr, a two-way ANOVA model (unequal but proportional subclass numbers) was used to test for significant differences. The model II is described in detail by Sokal and Rohlf (1981). The null hypotheses (Ho) were: ***Ho1,*** 'there is no significant difference in fish densities by treatment (enhanced vs. control);' and ***Ho2,*** 'there is no significant difference in fish densities for the sub-groups (enhanced vs. control) between years over the evaluation period'.

For steelhead, the **ANOVA** has shown a highly significant effect of enhancement on fish densities **("F"** = 23.10 with **1,1** I6 df, **$P<0.01$).** Densities of yearling+ steelhead were much higher in enhanced habitat over **non-**enhanced **habitat** (controls). However, there was no significant **difference** in fish densities when years were evaluated as the main effect **("F"** = I **.88** with 3,1 I6 df, **$P>0.05$).** The interactive effect of treatment x years was insignificant **($P>0.05$).**

For chinook, the results were more consistent. The **ANOVA** revealed that both treatment and years were significant factors. Chinook densities were significantly higher in enhanced habitats **("F"** = 6.20 with I ,I I6 df, **$P<0.05$);** whereas, chinook densities in enhanced habitats were highly significant over those in control areas during the four year period **("F"** = 15.64 with 3,1 I6 df, **$P<0.01$).** The interactive effect of treatment x years was insignificant at the 0.05 level.

Basically, the results of the **2-way ANOVA** are consistent with the annual analysis (I-way **ANOVA)** with one exception **-** steelhead (years). In 1988, densities of yearling+ steelhead were quite variable within the treatment effect, and this situation may have led to the insignificant effect. With the exception of Ho2 for steelhead, the null hypotheses are rejected.

Chinook densities have dropped considerably from 1986 through 1989 in all sites, enhanced and untreated. The decrease between 1986 and 1987 was especially dramatic. This decline is likely due to a decrease in the number of chinook salmon returning to Squaw Creek rather than a change associated with habitat availability or quality. The drastic decrease in the number of chinook seen in Squaw from 1986 to 1987 did not reflect the increase in the number of adult chinook which passed over the Lower Granite Dam in 1985 and 1986 (US Army Corps of Engineers, 1988). Despite this variation, our treatment effect of enhancement was significantly different than non-enhancement (controls).

Chinook salmon preferred log weir habitat, representing almost one half of the species captured with 0+ salmonids representing the next most frequently captured fish. Age 0+ salmonids highly preferred boulder and control habitats which were primarily riffle habitat. Larger salmonids (greater than or equal to I +) preferred log weir **habitat** over the other habitats. This is probably due to the presence of deeper habitat with substantially greater cover.

Papoose Creek **-** in Papoose Creek, years **1987** and 1988, age 0+ **salmonid** and yearling+ (steelhead and cutthroat trout) densities were higher in all enhanced sites in comparison to control sites (Table 23). This group showed a preference for log weir sites, habitat dominated by large, deep pools with good cover. Age 0+ salmonids were the only fish found in relatively high densities in boulder reaches, which were characterized by pocket water pools that were small in size and shallow in depth. The boulders provide good velocity barriers for the small fish. The small pools do not generally attract larger fish, therefore, predation on young-of-the-year fish may be reduced in these areas.

In 1987, the densities of yearling+ steelhead in control sites and boulder reaches were very close, with 3.6 **fish/100m^2** and 3.4 fish/I **00m^2,** respectively. Steelhead trout and chinook salmon showed a shift of use from root wads in 1987 to boulders in 1988. Both of these types of sites contain predominately riffle and pocket water or small pool habitat.

The yearling+ steelhead and cutthroat trout were found in highest densities in log weir sites. In 1988, densities of yearling+ steelhead and **salmonid** 0+ were roughly twice as high in log weir sites as in root wad sites. Chinook densities were very low in log weir sites. Overall, chinook densities in Papoose Creek increased between 1987 and 1988. Historical data show that chinook salmon numbers in Papoose Creek **tend** to be up when numbers in Squaw Creek are low and low when numbers in Squaw Creek are high.

Data collected in 1989 in Papoose Creek, showed a dramatic increase in the overall fish densities in root wad sites from previous years' data (Table 23). Steelhead trout and chinook salmon utilized root wads more than other structure types or controls. Water levels in 1989 were higher than the previous two years, possibly making that structure type more effective in producing good pool habitat than it has been in lower water. Habitat produced by boulder reaches **was** utilized most by age 0 steelhead and cutthroat trout. Overall fish densities in enhanced sites were higher than in control sites. Fish densities in Papoose Creek in 1989 were considerably higher than densities in Squaw Creek.

In 1990, we conducted an additional year of evaluation on Papoose Creek. Densities of yearling+ steelhead and chinook were higher in enhanced over control habitats. Compared to previous years, densities of both species and differences between enhanced and control habitats were much lower (Table 23). For the 1987 and 1988 data, annual analyses (I-way ANOVA) indicated significant differences in steelhead and chinook densities when comparing the combined enhanced sites with the control areas. In 1989, densities of steelhead parr were significantly higher for combined enhanced sites than control habitat (Table 24). However, for chinook only the root wad structures showed significantly higher densities than those for the controls.

Table 23. Mean area and densities (number/100m²) of fish by species, age class and structure in Papoose Creek, 1987 - 1990.

	1997		1999		1989		1990	
Species, Age, Structure	Area (m^2)	Fish per 100m²	Area (m^2)	Fish per 100m²	Area (m^2)	Fish per 100m²	Area (m^2)	Fish per 100m²
Chinook 0+								
Control	62.4	5.7	66.4	6.2	84.1	5.1	92.9	3.0
Log Weir	61.0	0.9	55.1	0.3	65.5	22.0	55.7	0
Root Wad	64.5	26.9	94.9	29.6	96.3	56.8	148.5	15.9
Boulder Reach	95.0	2.6	88.4	6.7	88.0	27.1	248.2	10.0
Salmonid 0+								
Control	62.4	16.3	66.4	15.6	64.1	39.4	92.9	40.7
Log Weir	61.0	42.9	55.1	59.2	65.5	33.4	55.7	54.9
Root Wad	64.5	28.3	94.9	27.1	96.3	73.6	148.5	45.0
Boulder Reach	95.0	32.5	88.4	25.6	88.0	51.2	248.2	33.4
Steelhead 1+ & 2+								
Control	62.4	3.6	66.4	2.4	84.1	7.6	92.9	12.9
Log Weir	61.0	14.9	55.1	15.8	65.5	18.4	55.7	54.9
Root Wad	64.5	10.5	94.9	7.3	96.3	24.4	148.5	17.4
Boulder Reach	95.0	3.4	88.4	5.9	88.0	16.2	248.2	10.2

Table 24. ANOVA (l-way) table for comparisons of fish densltles In treated versus control sections, **Papoose Creek, 1989.**

Method of ***Treatment*** **versus Control**	**Steelhead, Age 0+** DF	**Steelhead, Age 0+** F (Observed)	**Steelhead, Age 1 & 2** DF	**Steelhead, Age 1 & 2** F (Observed)	Chlnook, Age 0+ DF	Chlnook, Age 0+ F (Observed)
All-treated **Habitat**	3, I6	2.62	3, 16	4.05’	3, I6	1.81
Log Weir	**1,** 7	0.30	**1, 7**	5.64’	**1, 7**	2.02
Root Wad	**1, 6**	4.67	**1, 6**	13.36’	**1, 6**	6.28’
Boulder Reach	**1, 9**	0.81	**1, 9**	4.95	**1, 9**	I.17

[1] P<.05

Evaluation of fish response to enhancement in Papoose Creek was also subjected to a P-way **ANOVA.** Density data on yearling+ steelhead and chinook was tested for the evaluation period **1987-90.** The model and null hypotheses used in the Squaw Creek analysis were utilized in the Papoose assessment.

For steelhead, enhancement (treatment) and years showed highly significant differences in fish densities ("F = 8.64 with I ,81 df, P<0.01 and "F" = 7.90 with **3,81** df, **P<0.01** respectively). The interaction effect between the factors was **insignificant (P>0.05).** Both null hypotheses were rejected.

The chinook analysis revealed insignificant differences in fish densities when only treatment was considered **(P>0.05);** therefore, **Ho1** was accepted. However, the differences in fish densities between the years among the sub-groups was significant **("F"** = 5.25 with **3,81** df, **P<0.01);** Ho2 was rejected. Chinook densities in Papoose Creek over the period were highly variable (Table 23) especially within the various structure types. Distribution of chinook within the various habitat types was extremely patchy. Papoose Creek has been characterized by highly variable adult escapement in recent years. Within sub-group variation was sufficient to mask probable treatment effects.

The statistical analysis is summarized in Table 25. In both streams, densities of steelhead parr were significantly higher in enhanced habiiat over control areas. In Papoose Creek, this difference was consistent between the years of the evaluation period.

Table 26. A summary of P-way ANOVA for Squaw and Papoose Creeks

Stream	Species	Age Class	Ho[1] rejected	Ho accepted	F-Ratio	Significance[2]
Squaw	**Steelhead**	≥1+	Ho1 -treatment	Ho2-years	23.10 I.88	• ⊠ NS
	Chinook	o+	Ho1 -treatment Ho2-years		6.20 15.64	* **
Papoose	Steelhead	≥1+	Ho1 -treatment Ho2-years		8.64 7.90	• ⊠ **
	Chinook	o+	Ho2-years	Ho1 -treatment	2.82 *5.85*	NS **

[1] Null hypotheses: Ho1 = effects due to enhancement; Ho2 = effects due to years.
[2] Probability level of significance: ** = 0.01
• *= 0.05*
NS = non-significant

In Squaw Creek, densities of juvenile chinook were significantly higher in enhanced habitat and consistently different between the years. However, in Papoose the treatment effect of enhancement did not produce any significant differences between densities. There was a significant difference between years in chinook densities among the sub-groups.

East fork *Papoose* Creek - the East Fork of Papoose Creek had higher densities of fish in all the enhanced sites than in the control sites for all years sampled (Table 26). Salmonid 0+ were present in greatest densities in boulder reach sites in 1987. They were present in root wad sites, followed closely by log weir sites in 1988. The yearling+ steelhead and cutthroat trout were found in highest densities in log weir sites with larger and deeper pools. Yearling+ steelhead population densities between 1987 and 1988 were similar, while salmonid 0+ densities showed a substantial increase (from 114.1 to 214.2). No chinook salmon or bull trout were found in this stream.

In 1989, log weir sites showed the highest fish densities for all fish species and size classes sampled (Table 26). Age 0 salmonids also used root wads to a large extent. Cutthroat trout in the 75300 mm size range were found in higher densities in East Fork Papoose Creek than in Papoose and Squaw Creeks in 1989.

The I-way ANOVA showed a significant difference between controls and both log weir and boulder reach sites for yearling+ steelhead in 1987 and 1988. Significant differences were also found when all enhanced sites were compared to controls for yearling+ steelhead. Significant differences were determined between all treated habitat and controls and between log weirs and controls for the age I + steelhead in 1989 (Table 27).

Table 26. Mean area and densltles (number/100m²) of fish by species, age class and structure in East Fork Papoose Creek, 1987 - 1989.

Species, Age, Structure	1987 Area (m²)	1987 Fish per 100m²	1988 Area (m²)	1988 Fish per 100m²	1989 Area (m²)	1989 Fish per 100m²
Salmonld 0+						
Control	31.5	12.3	29.1	22.4	33.7	43.0
Log Weir	31.4	30.4	24.4	75.0	28.8	59.1
Root Wad	20.4	34.4	19.3	83.4	20.0	52.7
Boulder Reach	30.5	37.0	26.9	33.4	30.3	39.7
Steelhead 1 + & 2+						
Control	31.5	I.4	29.1	I.4	33.7	3.6
Log Weir	31.4	25.2	24.4	28.4	28.8	25.4
Root Wad	20.4	12.4	19.3	14.5	20.0	8.2
Boulder Reach	30.5	11.2	26.9	8.4	30.3	10.0

Table 27. ANOVA (l-way) table for comparisons of fish densities in treated habitats versus control sections, **East Fork Papoose Creek, 1989.**

Method of Treatment **versus Control**	Steelhead, Age 0+ DF	Steelhead, Age 0+ F (Observed)	Steelhead, Age 1 & 2 DF	Steelhead, Age 1 & 2 F (Observed)
All-treated Habitat	3, 13	0.37	3, 13	4.60'
Log Weir	1, 8	1.01	1, 8	10.54'
Root Wad	1, 8	0.24	1, 8	1.11
Boulder Reach	1, 5	0.03	1, 5	2.07

[1] P<.05

Although we did not run the East Fork data through the 2-way ANOVA, the one way analysis indicates similar effects of enhancement on densities of steelhead parr.

Despite some variation that is probably due to differential escapement and subsequent seeding of the rearing habitats, we have concluded that enhancement of habitat has had a positive effect on the density of juvenile steelhead and chinook in Squaw, Papoose, and East Fork Papoose Creeks.

3. Barriers

Three of the streams that were sites for major barrier removal projects were snorkeled in 1990 to evaluate the effectiveness of the modifications. All sites were evaluated for maintenance or modification needs. Maintenance was required on several of the structures with the replacement of filter fabric and back-filling weirs being the most common.

The Crooked Fork complex required maintenance for all weirs to be functioning correctly and passable. This was accomplished prior to the adult chinook migration. During the migration period, snorkeling took place below all the barrier sites, among the sites and in three sections above the sites. Below the most downstream weir, several 1 + and 2+ steelhead and cutthroat trout and 0+ chinook salmon were observed. In the barrier pools and throughout the barrler complex, 0+ to 2+ steelhead and cutthroat trout were present. One 0+ chinook salmon was seen in one of the barrier pools. One adult male chinook was seen in one of the middle barrler pools. In the three sites snorkeled above the barriers, fish numbers and species varied. Cutthroat, steelhead and 0+ chinook were observed in the lowest 100 yard section. Sections above and below the confluence of Hopeful and Crooked Fork Creeks both contained steelhead and cutthroat. One adult chinook salmon was observed approximately 1/4 mile below the confluence of Hopeful and Crooked Fork. Apparently chinook salmon and steelhead trout are able to pass successfully over all the downstream barriers.

The barrier site on Shotgun Creek required minor maintenance on the filter fabric of one weir. Maintenance occurred prior to the snorkeling. The stream below the barrier contained a good population of I + and 2+ steelhead along with adult cutthroat and one bull trout. Several 1+ and 2+ steelhead and a few cutthroat were observed in the jump pools of the barriers. Above the barrier, a 500 yard section was snorkeled with only cutthroat present. This stream is not considered a chinook stream. Further evaluation of this project will be required to document effectiveness and the need for additional work.

The barrier **site** on **Spruce Creek** required no maintenance or modifications. The section of stream snorkeled below the barrier had several cutthroat of various age classes, I + and 2+ steelhead and three 0+ chinook salmon. The barrier pools contained several cutthroat and a few I + and 2+ steelhead. A 200 yard reach above the barrier contained four 0+ chinook salmon, two 0+ steelhead or cutthroat, several larger cutthroat and two 2+ steelhead. It appears that steelhead and chinook are successfully negotiating this site.

D. Evaluation - Lolo Creek

1. Enhancement Structures

In 1988, the Cleanvater National Forest contracted Clearwater Biostudies, Inc. to assess fish habitat and abundance of anadromous salmonids in a 20.49 km section of Lolo Creek. The focus of this assessment was the 14.01 km 'enhanced' reach that was treated with a diversity of instream structures, and where 90% of the enhancement was concentrated. The intent of the assessment was to document the 'new' baseline habitat conditions and the changes (ii any) in habitat quantity and quality after enhancement. In addition, populations of anadromous salmonids were sampled in 'enhanced' and control habitats to establish the response or non-response to enhancement. Details of the assessment are presented in a report prepared by Cleatwater Biostudies (1988). Data collected for this assessment have been further summarized and subjected to additional analyses.

Baseline Condltlons -- Post-Enhancement
For the *entire* study *area,* a total of 260,268 m² (26.03 ha) of habitat was estimated with the primary rearing habitat functions stratified as follows: 96.5% summer, 2.8% winter, and 0.7% unusable (Fig. 22). Spawning habitat for chinook totaled 13,505 m², 18,146 m² for steelhead and 1,271 m² for resident fish. In terms of quality, 52% of the chinook and 53% of the steelhead spawning habitats were considered in good condition

(Fig. 23). The diversity of habitat types is displayed in Figure 24 and shows the following profile: 34.9% riffle, 28.5% run, 20.4% pool, 9.5% glide, 4.5% pocketwater, and 2.1% alcove. Nearly 24% of all the pools in the study area have been created by enhancement structures versus 17% for natural woody debris and 43% for boulders/bedrock. The enhancement structures created the highest quality pools with an index rating of 3.6 (72% optimum) versus 3.1 (62% optimum) for natural woody debris. The overall rating of pool quality equalled 2.3 (46% optimum).

For the 'enhanced reach', a total of 161,421 m^2 (16.14 ha) of habitat was estimated: this reach constituted 62% of the entire study area The rearing habiiat was composed of 96.8% summer and 3.2% winter (Fig. 25). This profile was very similar to that of the entire study area. The majority of the spawning habitat is located in this reach with 12,980 m^2 for chinook, 17,378 m^2 for steelhead, and 1,227 m^2 for resident fish. The quality assessment showed that 54% of the chinook spawning habitat and 55% of the steelhead habitat were in good condition (Figs. 26-27). The diversity of habitat types is displayed for the *enhanced reach' plus "B" and "C" channel types within this reach in Figures 2830. A comparison of the major habitat types between the study area and the 'enhanced reach' shows some moderate differences and a more balanced profile in the 'enhanced reach' with increases in mainstem pools and runs to respective levels of 22% and 30% associated with a decrease in riffles (29%). The differences are more pronounced when "B" and "C" channel types are compared (Figs. 28-29). In "C" types, the ratio of pools to riffles and runs is nearly I :I :I with the percentages ranging from 26 to 27%. In "B" types, riffles and runs predominate at 36 to 38% of the total surface area, whereas mainstem pools are less than 13% of the total. This difference in pool habitats between the channel types is due to the fact that 36% of the pool area was created with enhancement structures in "C" channels versus 8% in "B" channels. The pool quality profile was nearly identical to that of the entire study area with an overall rating of 2.3 (46% optimum) and enhancement structures showing the highest quality at 3.5 (70% optimum).

FIGURE 22. LOLO CREEK – ENTIRE STUDY AREA

POST-TREATMENT – PROFILE OF REARING HABITAT FUNCTION

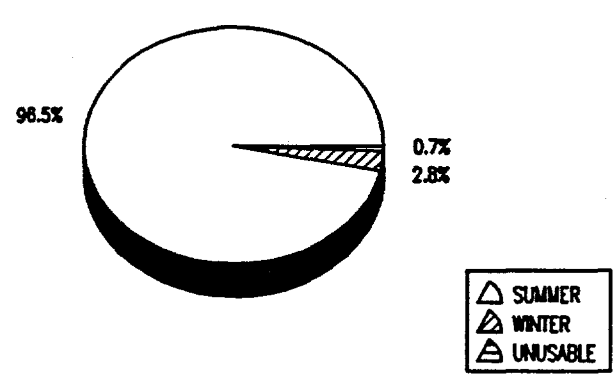


FIGURE 23. LOLO CREEK - ENTIRE STUDY AREA
POST TREATMENT - STRATIFICATION OF SPAWNING HABITAT QUALITY

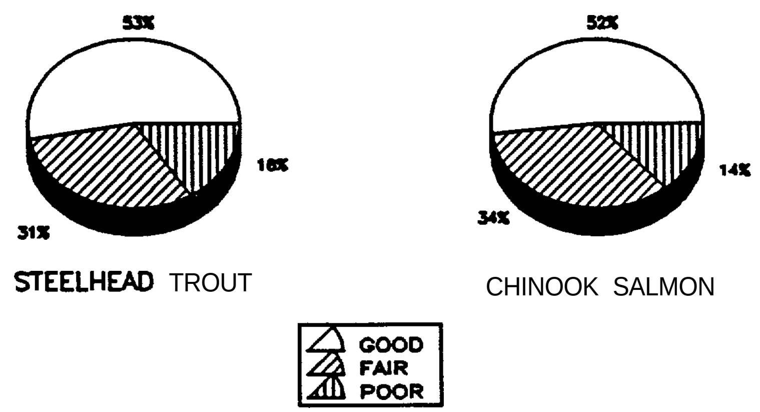


FIGURE 24, LOLO CREEK - ENTIRE STUDY AREA
POST TREATMENT - STRATIFICATION OF HABITAT TYPES

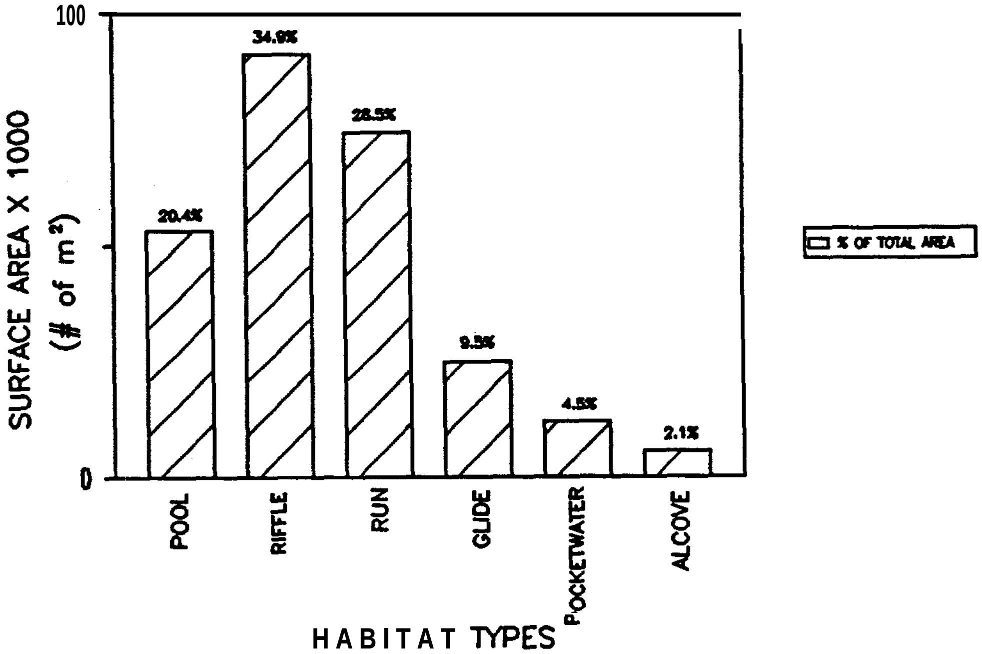


FIGURE 25. STRATIFICATION OF PRIMARY HABITAT FUNCTION IN REARING HABITAT OF LOLO CREEK - ENHANCED REACHES

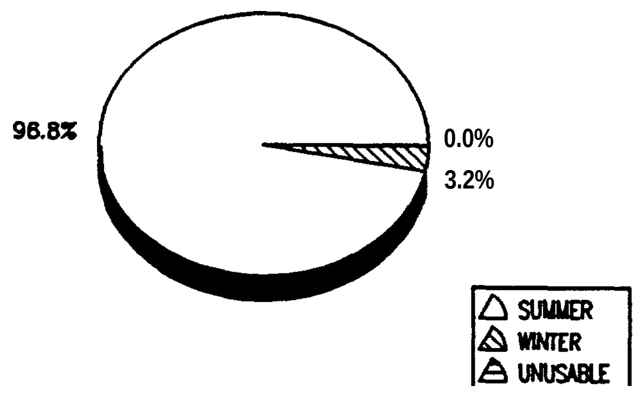


FIGURE 26. STRATIFICATION OF SPAWNING HABITAT FOR CHINOOK SALMON IN THE ENHANCED REACHES OF LOLO CREEK

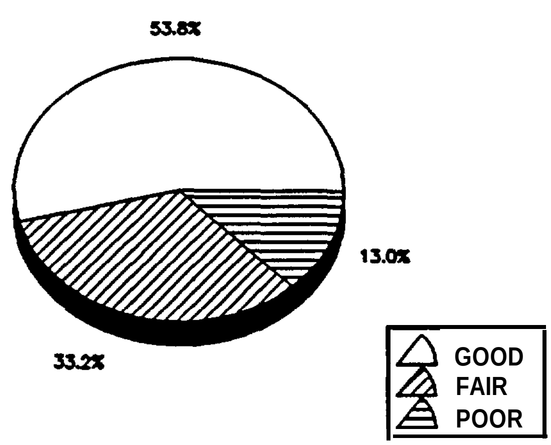


FIGURE 27. STRATIFICATION OF SPAWNING HABITAT FOR STEELHEAD TROUT IN THE ENHANCED REACHES OF LOLO CREEK

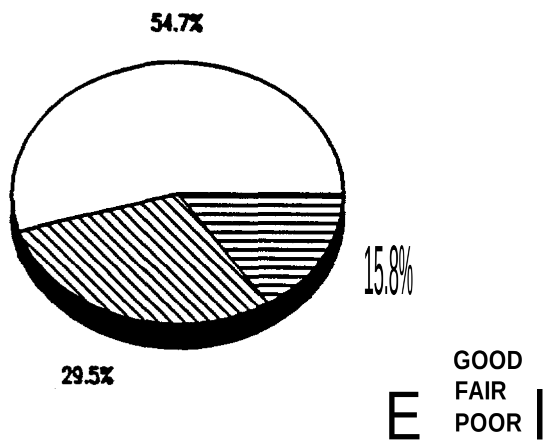


FIGURE 28. LOLO CREEK – POST TREATMENT
ENHANCED REACHES

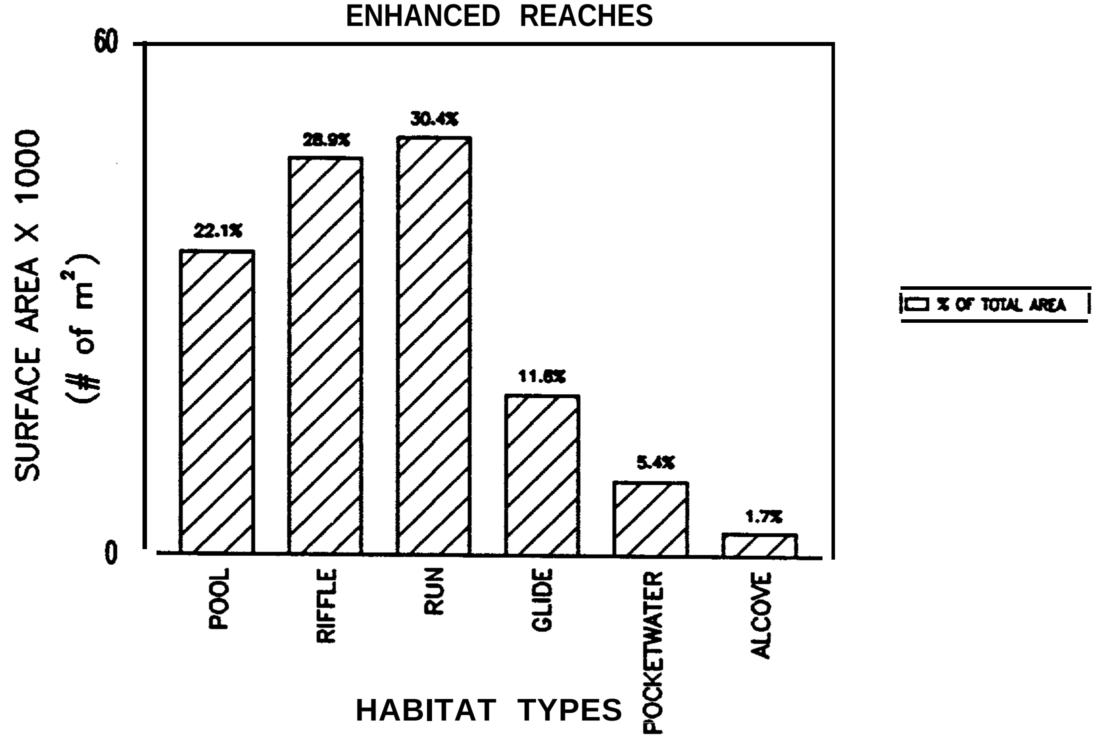


FIGURE 29. LOLO CREEK – POST TREATMENT ENHANCED REACHES – B-CHANNEL TYPES

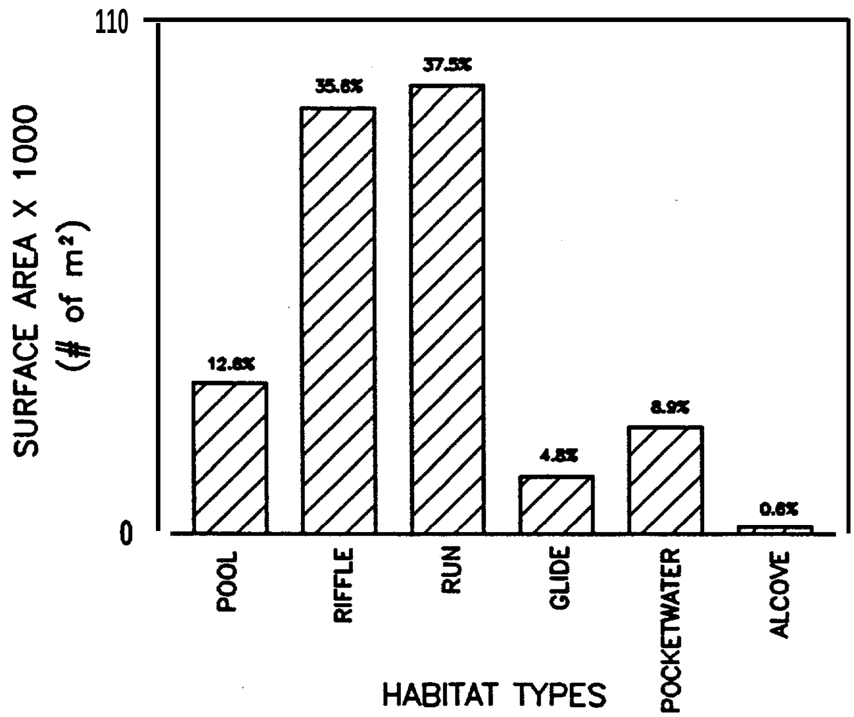
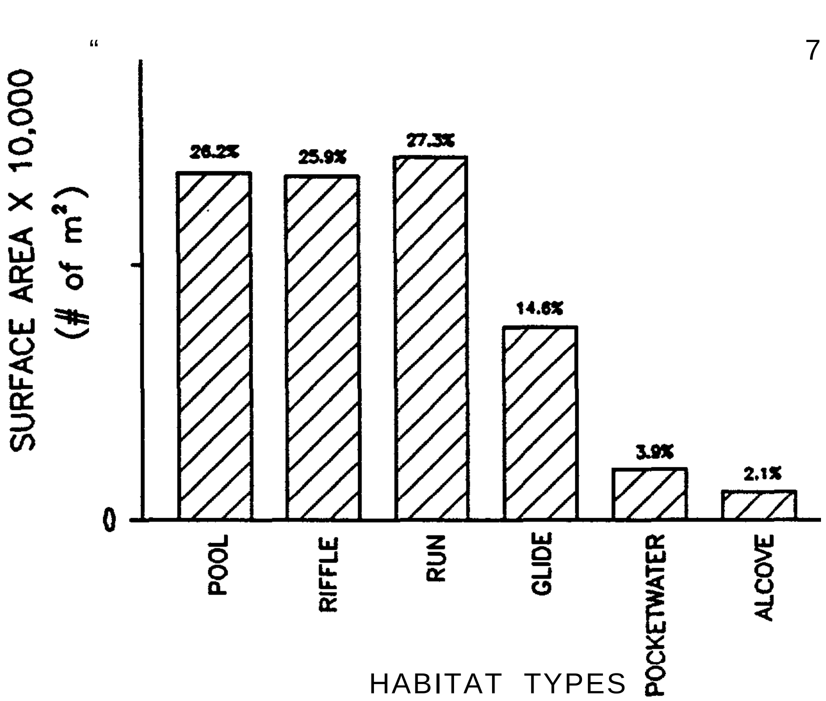


FIGURE 30. LOLO CREEK – POST TREATMENT
ENHANCED REACHES – C-CHANNEL TYPES



2. Salmonid Response

The responses of juvenile salmon and steelhead to habitat modifications were evaluated with standard snorkeling techniques in a random treatment and control study design. An attempt was made to calibrate the snorkel counts with electrofishing (depletion) techniques according to a methodology developed by Hankin and Reeves (1987). However, the procedure requires that electrofish sampling be more accurate than snorkel observation. In this stream, we found the reverse to be true. Because of Lolo's size, low conductivity, and structural diversity, we felt that electrofishing was the less reliable technique. Because of the structural diversity, we were unable to capture all the fish that were stunned or found effective cover. A comparison of numbers showed no consistent pattern. Others sampling Clearwater streams have reported similar results and recommended snorkeling (Petrosky and Holubetz, 1987).

Treatment (enhancement) units were stratified by four major structure types: log weirs, deflector logs, root wads, and boulder clusters. Ten treatment units per type were randomly selected throughout the 'enhanced reach' and only habitat created or directly influenced by enhancement structures was sampled. Five control stations were sampled in unenhanced habitat similar to that which was enhanced. Depending on station size and complexity, one or two divers snorkeled slowly upstream counting numbers of chinook and steelhead by age class. Age 0 and age I chinook did not overlap in length and could be easily distinguished by divers. Steelhead were separated into three age classes based on length: Age 0 (<75 mm), age I (75-I 25mm), and age 2+ (>125mm). After enumeration, divers quantified the fish habitat according to techniques used during the basic survey. Three to five fish habitat transects were measured at each station.

Mean salmonid densities and 95% confidence intervals were calculated for the major structure types and control units. These data were used to evaluate the fish response to enhancement and are summarized in Figures 31-32. Treatment and control data were further analyzed for statistical significance with a one-way analysis of variance (ANOVA). Data combined for all the enhancement types versus the controls display considerable differences for steelhead parr (age classes 1 and 1/2+) and age 0 chinook (Fig. 31). For steelhead parr (1/2+), enhanced habitat is supporting six times the density than the control habitat: and for age 0 chinook, the magnitude is 1.5 times the density in the control units. Response data segregated by structure type is shown in Figure 32. Downstream weir pools and root wads supported the highest densities of steelhead (1/2+) and chinook (0) when compared to those of the deflector logs and boulder clusters. Deflector logs displayed the lowest densities for steelhead and salmon among the structure types. There was little difference in the densities of age 0 steelhead between the enhanced and control habitats.

Statistical analyses (one way ANOVA, model II) was performed on both steelhead and chinook data (Sokal and Rohlf, 1981). In the case of steelhead parr (1/2+), there was a significant difference in fish densities between the enhanced and control units ("F"=6.02 with 1, 43 df; $P<0.05$). The null hypothesis was rejected at the 5% level of probability. With age 0 chinook, the converse was true. There was no significant difference in chinook densities between enhanced and control habitats ("F" = 1.29 with 1, 43 df; $P>0.05$). The null hypothesis was accepted at the 5% level of probability. The 'apparent' significant difference in the chinook data was more than offset by the within unit variation. Additional testing was conducted by stratifying the various enhancement structures against the control units. In each case, the null hypothesis was accepted at the 5% level. The stratum of log weirs and root wads displayed the highest "F" ratio at 2.93 ("F".05 = 4.28 with 1, 23 df). There was considerable variation in the chinook densities from unit to unit. Higher levels of escapement and sampling intensity may effectively deal with the variation in the future.

FIGURE 31. LOLO CREEK, IDAHO — 1989
SALMONID DENSITIES FOR ENHANCED
AND CONTROLLED HABITATS

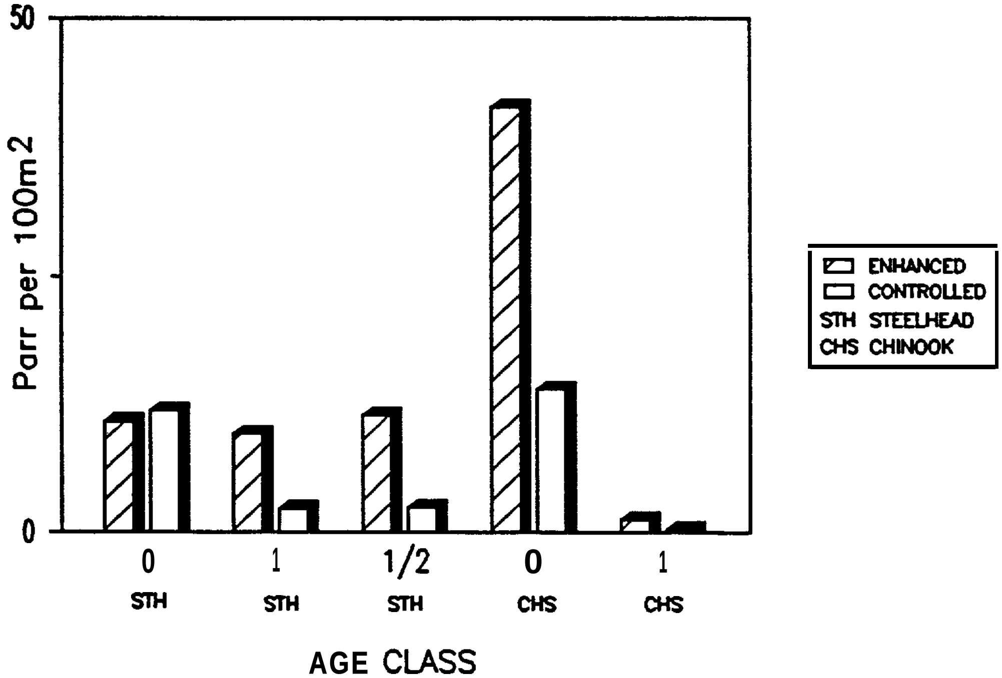
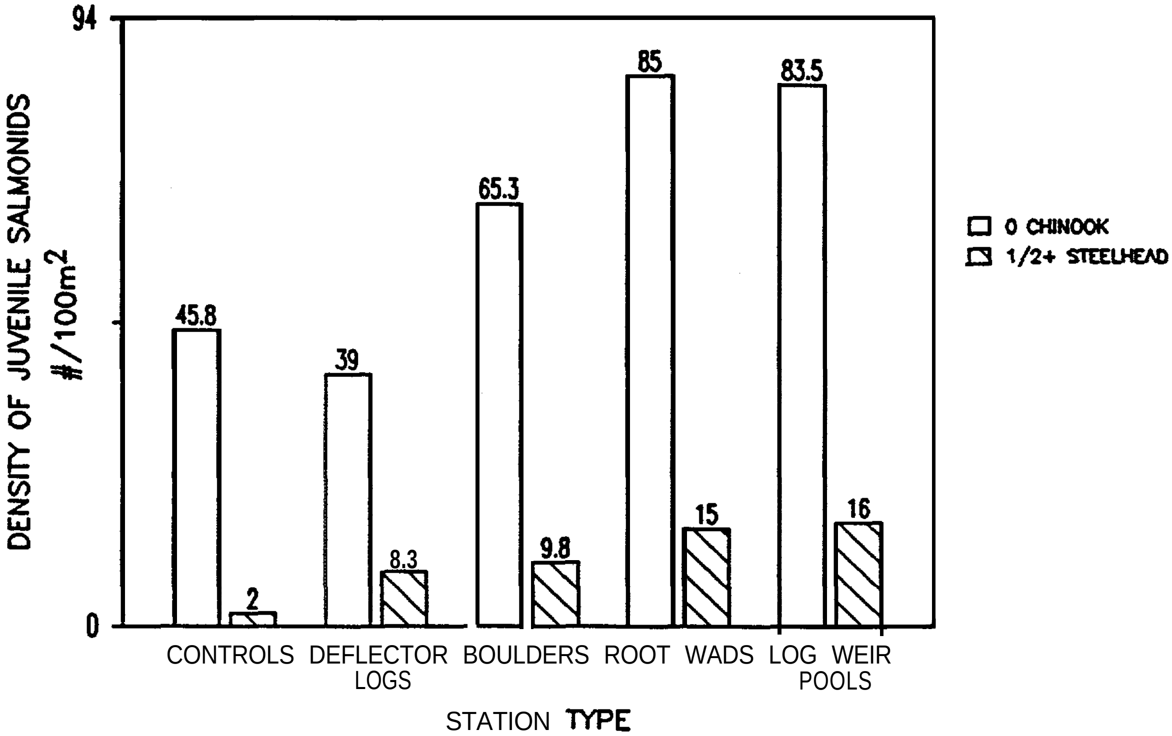


FIGURE 32. DENSITIES OF JUVENILE SALMONIDS
(0 CHINOOK and 1 AND 2+ STEELHEAD)
PER STATION TYPE, LOLO CREEK, 23-27 AUGUST 1988



3. Habitat Comparisons - Before (1974) and After (1988)

In 1974, a baseline survey was conducted in Lolo Creek covering the entire study area and the 'enhanced reach. After initial enhancement, another evaluation survey was conducted by Espinosa et al. (1987). In 1987, the 'enhanced' reach was further modified by additional treatment. In 1988, Clearwater Biostudies evaluated all the work completed to date. Because the methodologies employed in the 1974 and 1988 surveys were different ('modified' ocular vs. transect), the data may not be directly comparable. This may contribute to the variation of the data and comparisons. Other significant sources of variation could be attributed to observer differences and flow differentials. Some comparisons, however, are valid-e.g. pool quality, habitat type diversity, and cobble embeddedness were assessed in a similar manner. Some adjustments in the compilation and analysis of the data were made to enhance the validity of the comparisons--e.g. the ratio of habitat types was simplified from a profile of 5 habitat types (1988) to one of 3 types (1974) so that a comparison could be made. Reach 1 (untreated) was added to the 'enhanced' reach to facilitate before and after comparisons. Reach 1 constitutes only 6.5% of the total habitat between Lolo Forks and the Musselshell confluence.

a. Channel Characteristics

Differences in channel gradient, mean width, mean depth, and width : depth ratio were slight:

YEAR	MEAN GRADIENT (%)	MEAN WIDTH (m)	MEAN DEPTH (cm)	W:D RATIO	TOTAL SURFACE AREA (m^2)	ESTIMATED BASE FLOW (m^3/S)
1974	1.5	10.4	30.0	35:1	163,675	0.65
1988	1.1	11.3	27.6	41:1	173,554	0.35

This variation is probably attributable to differences in observers and survey technique. Despite these differences, the total surface area (total habitat) in 1974 was 94.3% of the total measured in 1988. Although base flows were considerably higher in 1974 (0.65 m^3/S vs 0.35 m^3/S), channel surface area was estimated at nearly 10,000 m^2 greater in 1988. Considering the manifold sources of error, this difference in surface area is probably not significant.

b. Habitat Characteristics

Because of some salient differences in survey techniques, few habitat attributes lend themselves to a valid 'before and after' comparison. However, pool quality, habitat type diversity, cobble embeddedness, and steelhead spawning habitat can be compared. In 1974, Lolo Creek displayed an overall ratio of pools : riffles : runs of 23:37:40; whereas, in 1988 the diversity of habitat types was measured as 29:30:41 (Fig. 33). In terms of total surface area, this 6% change constitutes a net conversion of 10,353 m^2 of riffle to pool habitat types. A more significant reflection of change in pool habitat is possible with a look at the large mainstem pools. In 1974, Lolo Creek lacked large mainstem pools. An index of this 'before' condition in 1988 is the percentage of the total habitat consisting of large pools in unenhanced habitat. Only 12% of the pool area consists of large mainstem pools and likely characterized the situation in 1974. In 1988, this habitat type has been increased to 22% of the total surface area Within the pool habitat type, this change is more dramatic: 52% large pools-'before' to 76% large pools in 1988, an increase of 24%. In terms of square meters, this change equates to 12,132 m^2.

In addition to changes in pool type and quantity, quality levels can be compared. In 1974, the overall pool quality was 59% of optimum; whereas, in 1988 it has been increased to 66% of optimum (Fig. 33). A more significant comparison of 'before and after' pool qualities is displayed in Figure 34; where, quality levels of natural meander pools are contrasted against those created by enhancement structures. The difference is substantial-an increase of 2426% in percent optimum for pools created by enhancement.

FIGURE 33. COMPARISONS OF HABITAT TYPE STRATIFICATION BEFORE AND AFTER ENHANCEMENT IN LOLO CREEK

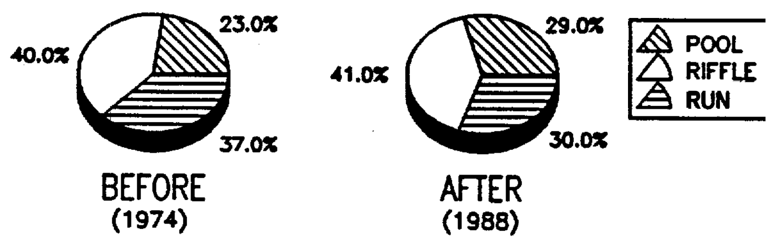


FIGURE 34. COMPARISONS OF HABITAT QUALITY BEFORE AND AFTER ENHANCEMENT IN LOLO CREEK

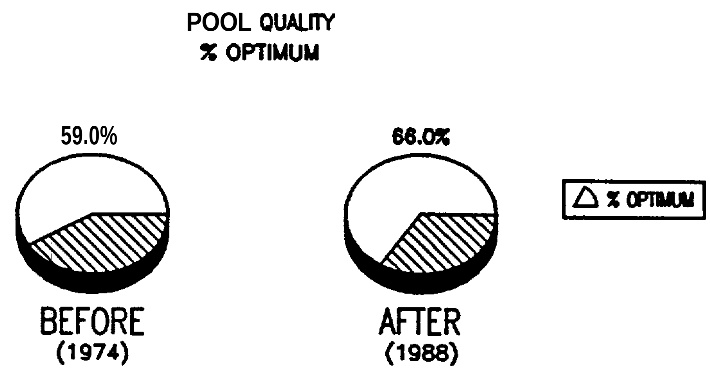
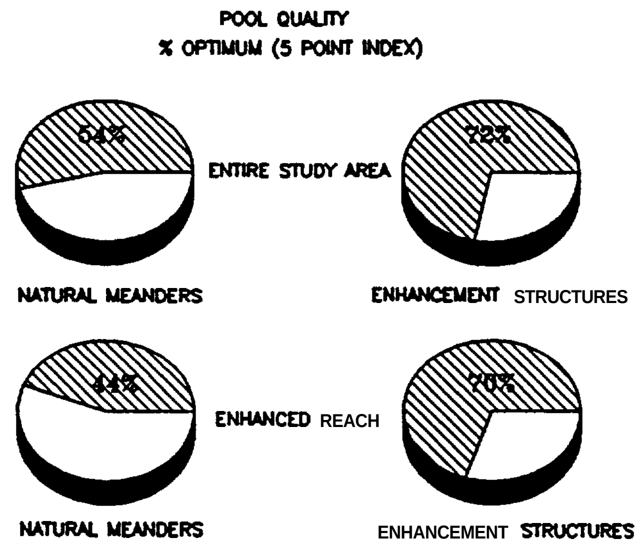


FIGURE 35. POOL QUALITY PROFILES IN LOLO CREEK, ENTIRE STUDY AREA AND ENHANCED REACH - POST TREATMENT



In 1988, late summer streamflows in Lolo Creek were extremely low and constituted only 43% of the decadal average for the month of August. In 1974, August flows were nearly double those observed in 1988. The stratification of habitat types can change appreciably with various flow regimes. It is likely that the low 1988 flows reduced the amount and quality of pool habitat with a concomitant increase in run and glide habitats. Despite the low flows, modest changes in pool habitat attributable to enhancement were observed.

The sediment conditions of the rearing habitat-as indicated by the level of cobble embeddedness-was measured at 54% in 1974. In 1988, it was assessed at 51%. This difference is likely not significant. The survey techniques used to assess cobble embeddedness were different and probably contributed to the variation. It is our assessment that the sediment condition of the rearing habitat in 1988 is essentially the same as observed in 1974 over the entire ‘enhanced reach.

In 1974, 12,029 m^2 of steelhead spawning habitat were enumerated in the ‘enhanced’ reach. In 1988, a total of 17,378 m^2 of spawning area for steelhead was measured-a difference of 5,349 m^2. This difference is probably significant and attributable to the enhancement. Instream structures such as log weirs, woody debris, and deflector logs would tend to collect and create spawning habitat. Because of migration barriers in the early 1970's, chinook spawning habitat was not estimated in 1974. The barriers have been removed, and 12,980 m^2 of spawning area are now available for chinook salmon. The quality of the spawning habitat for anadromous fish is predominately fair to good--86% chinook and 84% for steelhead. At base summer flows, 8% of the total surface area consists of chinook spawning habitat.

4. Barriers

During the seven years of the program, all of the projects were evaluated in one way or the other. Evaluation ranged from periodic, cursory checks to long term, intensive sampling of habiiat and populations. All of the instream structural projects were reviewed annually for maintenance requirements.

Evaluation on some of the larger instream projects such as Lolo and Squaw-Papoose Creeks will continue indefinitely and become part of the Clearwater Forest's annual monitoring program. This report will discuss only the evaluation of the major passage and instream structural projects.

Fish passage projects in **Eldorado, Musselshell, and Yoosa Creeks** were evaluated. Because of the complexity of the Eldorado project, multiple visits were conducted during critical flow and fish migration periods to determine if the modifications had created the desired effect. Spawner escapement and redd surveys above the barrier sites were also conducted to determine the 'bottom line' success of the work in Eldorado and Yoosa Creeks.

The **Musselshell** debris barrier was evaluated immediately after blasting. After several attempts, a migration channel was created that will pass fish (Appendix A.). This site should be reviewed periodically for maintenance as additional debris will undoubtedly collect at this location.

The debris barrier in **Yoosa Creek** was obliterated with explosives (Appendix A). After blasting, loose debris was removed from the flood plain. Passage for chinook salmon was confirmed in 1989 when both adult and juvenile salmon were observed above the barrier site. One chinook redd was observed upstream of Chamook Creek. The presence of juvenile chinook in the rearing habitat was established by electrofishing. Prior to the project, electrofishing documented the presence of only steelhead. It is our determination that passage has been improved for steelhead and has been provided for chinook in Yoosa Creek. Spawner and redd count surveys will be conducted in this drainage annually.

The **Eldorado Falls** complex proved to be a formidable barrier. Repeated blasting at all four sites was required to achieve the desired configurations. After each blast, we evaluated the sites at high flows (steelhead passage conditions) and low-flows (chinook passage conditions). Hydraulic engineers assisted project personnel with this evaluation. Further modification of the site usually followed this analysis. During the field season of 1989, the "final" adjustment to site 1, a ladder-like complex of jump pools, was completed with the anchoring of a large log at the head of the third falls. The efficacy of this refinement will be evaluated during the 1990 migration periods.

Spawner escapement and redd count surveys were conducted in trend index areas to document successful passage to upstream habitats. Periodic visits to the project sites in 1988 and 1989 were made during peak migration periods to observe the fish attempting to negotiate the falls. Rearing habitats above the sites were sampled by snorkel diving and electrofishing to document the presence of naturally-produced salmon and steelhead. Thousands of hatchery fish were stocked in Eldorado starting in 1984 and 1985. The first, significant returns of steelhead and salmon were expected in 1988 and 1989. During the early spring of 1988, a few adult steelhead were observed jumping at the first falls on several occasions. No fish were observed above site 1 or seen jumping at other upstream sites of the complex. Spawner surveys failed to locate any fish or redds in upstream index areas. Apparently the steelhead run to Eldorado was extremely low that year as only a few fish were observed. Sampling of juveniles failed to document adult escapement above the barrier. In 1989, both steelhead and salmon were expected to return to Eldorado. No adult steelhead were seen at the falls or in upstream spawning areas. No redds were counted in a 4.7 km index area. The same result was obtained with chinook salmon-no fish observed jumping, redd-building or spawning. Densities of juvenile steelhead and salmon were extremely low; these fish were probably of hatchery origin. No adult fish were observed below the falls.

Because of low escapements to the Clearwater Basin, the Eldorado project has not had a fair test. The few fish that were observed at the barriers in 1988 could have made it; however, locating those fish in all that habitat above the complex would prove to be extremely difficult.

It is our contention that passage has been made available for both steelhead and chinook. At some high flows, steelhead may have some difficulty negotiating the uppermost barrier (site 4). Chinook salmon should be able to pass the entire complex because they migrate at much lower flows. In any case, evaluation of the Eldorado project needs to continue in order to determine if further modifications are required to facilitate passage.

E. Evaluation - Pete King Creek

Enhancement Structures

Our approach to the evaluation of habitat improvement in Pete King Creek was different. A model was developed **to** evaluate the quality of summer rearing habiiat for steelhead trout. This model is similar in approach to other analogues designed to evaluate the habitat suitability of other species (Binns, 1979 and Hickman and Raleigh, 1982). The model was applied to 'control' and 'enhanced' habitats: and then, correlated against standing crop densities in those habitats. Enhanced habitat was stratified into downstream pools created by log weirs and boulder units (essentially pocket water). Habitat attributes associated with the model were measured at each station with a close interval (3m) transect method. In order to assess the quality of the habitat, the following variables were measured: pool quality, habitat type profile, instream cover, bank cover, substrate diversity, and cobble embeddedness. Details of the model and modeling effort are presented in Appendix B. The data was collected in 1986 and analyzed with standard regression analyses. Upon completion of the validation, the model was applied to the enhanced and non-enhanced reaches of the Pete King system to document changes. More traditional approaches to evaluation of habitat enhancement were also applied to the Pete King project. Densities of salmonid parr were evaluated in enhanced and control habitats for five years (1985 to 1989). The results of the modeling effort are presented in Figure 36. The best (as measured by the coefficient of determination--"R^2") univariate model regressed the rearing quality index (RQI, independent variable) against the number of steelhead parr ($\geq 1+$) per 1 00m² of summer rearing habitat (dependent variable). The relationship is defined by the equation: $\hat{y} = 34.18 + 3.03X$ with $R^2 = 0.64$ and $P < 0.01$. The relationship is significant at the 1% level of probability. In 1986, the combined enhanced habitat which included log weir and boulder structures was evaluated at a mean RQI of 19.0 (range = 16-25). The standard error equalled ± 0.4. The mean RQI for the control habitat (areas of shallow riffle-run habitat types) was assessed at 13.0 (range = 10-15) with a standard error of ± 0.6. Substantial differences in quality between enhanced and control habitats were noted for: pool quality, habitat type profile, and instream cover. Therefore, the enhancement in Pete King was able to increase the RQI of marginal (control) habitat by 6 units. According to the model, a unit increase in quality will result in an increase of 3 parr per 1 00m² of summer rearing habitat. For the post-enhancement condition in Pete King, the model estimates that the habitat capability -- on the average -- has been increased by 18.2 parr/100m².

Wiih the model, it is possible to back-calculate from observed parr densities to RQI indices and determine habitat capabilities. With an estimated full carrying capacity of 30 steelhead parr/100m² at normal flows, the RQI is equal to 21.2. Consequently, the habitat capability of enhanced summer rearing habitat in Pete King is estimated at 89.6% (19.0/21.2) of full potential. This is an increase of 28.3% over the pre-enhancement condition of control habitats in 1986.

We have estimated the overall habiiat capability of Pete King Creek based on a cumulative, reach by reach assessment of quality and quantity utilizing 1987 survey data and the RQI model. This assessment of summer rearing habitat covered a total reach distance of 8.3 km extending from the forks (West Fork and Walde Creek) to the Lochsa River confluence. The habitat capability was calculated at 84.4%. The key parameters for this assessment were:

1. The composite, weighted mean RQI for 8.3 km of Pete King Creek equalled 17.9 or 84.4% of full potential (17.9/21.2).

2. The mean RQI for 5.0 km of enhanced reaches equalled 19.0 or 89.6% of full potential.

3. The weighted mean RQI for 3.3 km of un-enhanced reaches equalled 16.3 or 76.9% of full potential. This includes both 'good' and marginal habitats.

4. Of the total reach distance, 60% was treated with instream structural enhancement.

If we assume that the mean RQI for the un-enhanced reaches of Pete King adequately approximated the pre-enhancement conditions of the system, then the enhancement has increased the habitat capability of the 8.3 km reach by 7.5%.

Over the 5-year period, standing crop densities of steelhead pan (1+/2+) were evaluated in control and enhanced habitats. All of the density data collected during this period was subjected to statistical analysis. A nonparametric analysis of variance-the Kruskal-Wallis test-was used to test the null hypothesis that "there was no significant difference in parr densities observed in enhanced and control habitats during the evaluation period.' The null hypothesis was rejected at the 0.01 level of probability (H = 77.85, P<0.01, N = 96). Therefore, the observed differences are highly significant; and it can be concluded that the treatment of habitat enhancement affects yearling+ steelhead differentially.

A comparison of steelhead densities in control and enhanced habitats is presented in Tables 28-29 and Figures 3638. The following observations were made during the course of the evaluation study:

1. For the 5-year period, the overall mean densities of all age classes of steelhead parr in 'enhanced' habitat were much higher than those of the control habitat.

2. The seeding levels of steelhead 0+ were relatively consistent throughout the period. Therefore, major differences in densities of yearling+ pan between 1985-86 and 1987-89 are probably not attributable to annual variation in escapement and seeding:

3. The density of yearling+ parr in downstream pools of log weirs was twice as high as those observed in boulder habitat and log weir pools with boulder berms placed at their rail-outs'.

4. Pool quality associated with boulder structures and log weir pools with boulder berms is much lower than the quality associated with log weir pools without berms. Boulder berms at pool 'tail-outs' function as sediment traps and reduce pool quality.

5. As a whole, fish densities of all age classes in log weir pools have remained consistently high. This response has been observed elsewhere on the Clearwater Forest in Squaw, Papoose, and Lolo Creeks.

Winter Habitat

Part of our evaluation work looked at the winter habitat aspect of enhancement. We asked and sought answers to several key questions. 'Are we creating both summer and winter rearing habitats with our instream structures?' 'Do we have to specifically design for winter habitat?' 'Are fish differentially utilizing the enhanced versus control habitat?

The objectives of the evaluation were: (1). to identify key variables and components of winter habitat; (2). to document the winter use or non-use of enhanced habitat as contrasted against control areas: (3). to document the utilization of specifically designed and constructed winter habitat versus control habitat: and (4). to document the use of winter habitat in small tributaries by species and size-age class.

Sampling was conducted at Squaw and Papoose Creeks in late November and early December: at Pete King Creek in mid-December and early February; and Lolo Creek in late October. True winter conditions existed at **each** site as water temperatures ranged from 0°C to 2°C. Enhanced and control habitats were sampled in each stream. Only sampling units in Squaw Creek were selected randomly. Downstream pools created by log weirs were sampled in Squaw Creek. All of the upstream pools created by log weirs within which **'winter habitat"** was constructed were sampled in Papoose Creek. Downstream log weir pools were sampled in Pete King Creek. Habitat in control areas of Squaw and Pete King Creeks consisted primarily of shallow runs and riffles. These were areas that could have been enhanced with log weir structures. In Papoose Creek, upstream log weir pools within which no winter habitat had been created were sampled as control units.

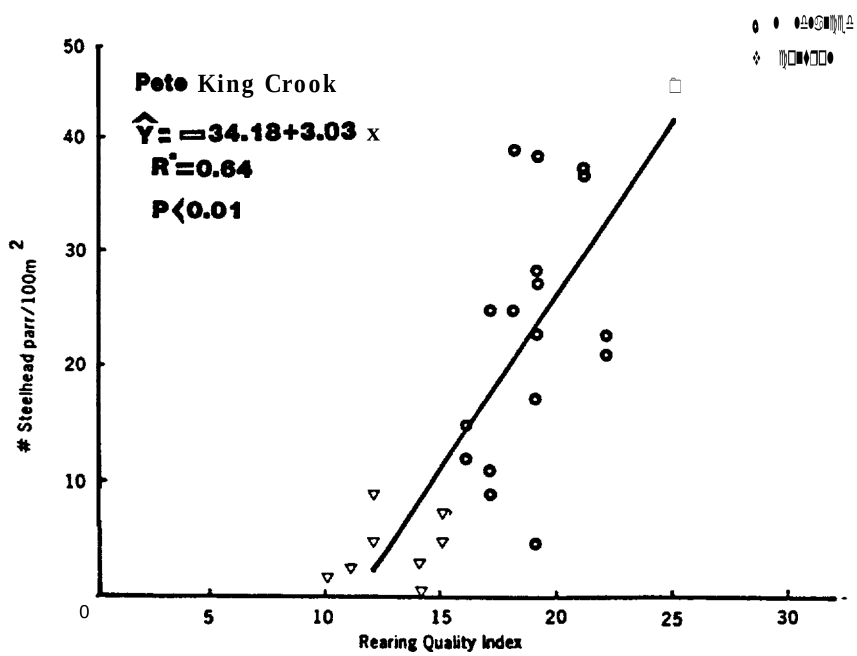


Figure 36. A steelhead vs. summer rearing habltat response model (B-Channel type).

Table 28. A comparison of densities of yearling+ steelhead parr between enhanced and control habitats In Pete King Creek from 1985 to 1989.

Year	Steelhead Parr Habitat Type	≥1+/100m²	% Difference (factorial)[1]
1985	Enhanced Control	28.5 4.1	695
1986	Enhanced Control	24.2 5.7	425
1987	Enhanced Control	12.2 0.3	4067
1988	Enhanced Control	12.1 2.6	465
1989	Enhanced Control	13.4 3.2	419

[1] Factorial difference: i.e., 4.1 X 6.95 = 28.5

Table 29. A comparison of juvenile steelhead and chinook salmon densities in Pete King Creek between "enhanced" and control habitats from 1985 to 1989.

Fish/l 00m²						
Year	Reach	Steelhead Trout				Chinook Salmon
	Structure Type	0+	1+	2+	1+/2+	o+
1985	Log Weir Pools	38.0	22.4	6.1	28.5	0.0
1986		40.3	21.6	4.2	25.8	2.8
1987		49.5	13.7	2.6	16.3	3.7
1988		45.3	15.7	0.9	16.3	1.9
1989		50.8	17.0	1.4	18.4	0.0
5-year	Grand Mean	46.2	17.7	2.7	20.4	2.1
1986	Boulder Units	42.2	14.4	2.3	16.7	0.0
1987		37.3	8.7	0.4	9.1	2.5
1988		36.2	6.4	1.5	7.9	0.0
1989		36.9	10.0	0.5	10.5	0.0
4-year	Grand Mean	37.9	9.6	1.0	10.6	0.6

Table 29. A comparison of juvenile steelhead and chinook salmon denslties In **Pete King Creek between 'enhanced' and control habitats from 1985 to 1989 (continued).**

Fish/l 00m²						
Year	**Reach**	**Steelhead Trout**				**Chinook Salmon**
	Structure Type	**0+**	**1+**	**2+**	**1+/2+**	o+
1985	Controls	**39.5**	3.0	1.1	4.1	1.9
1986		22.7	4.9	0.8	5.7	6.9
1987		9.6	0.3	0.0	0.3	0.0
1988		29.2	2.6	0.0	2.6	0.9
1989		11.1	3.2	0.0	3.2	0.0
5-year	Grand Mean	20.1	3.2	0.4	3.6	3.1

FIGURE 37. A HISTOGRAM OF STEELHEAD PARR DENSITY FOLLOWING ENHANCEMENT IN PETE KING CREEK

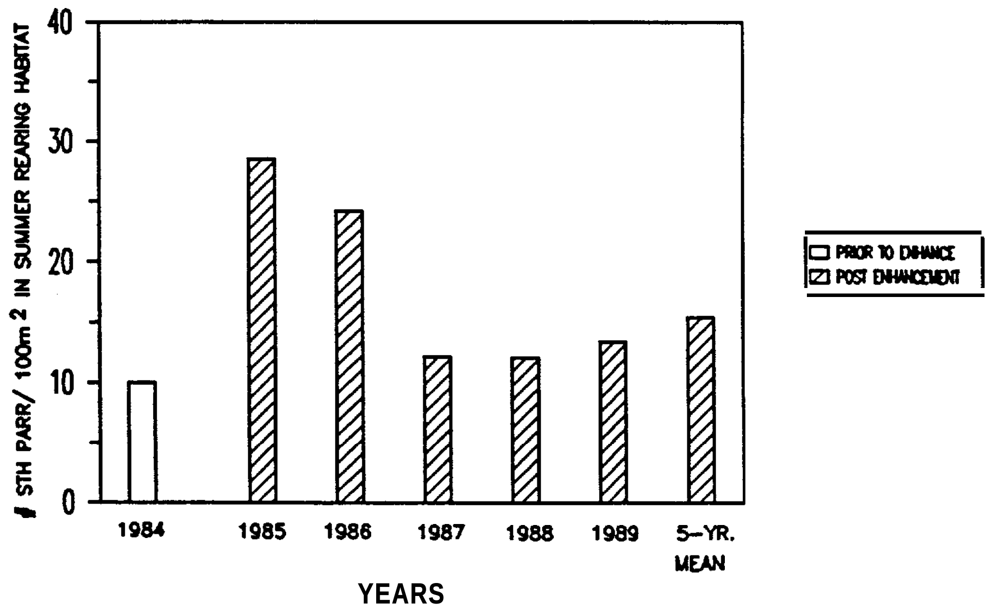
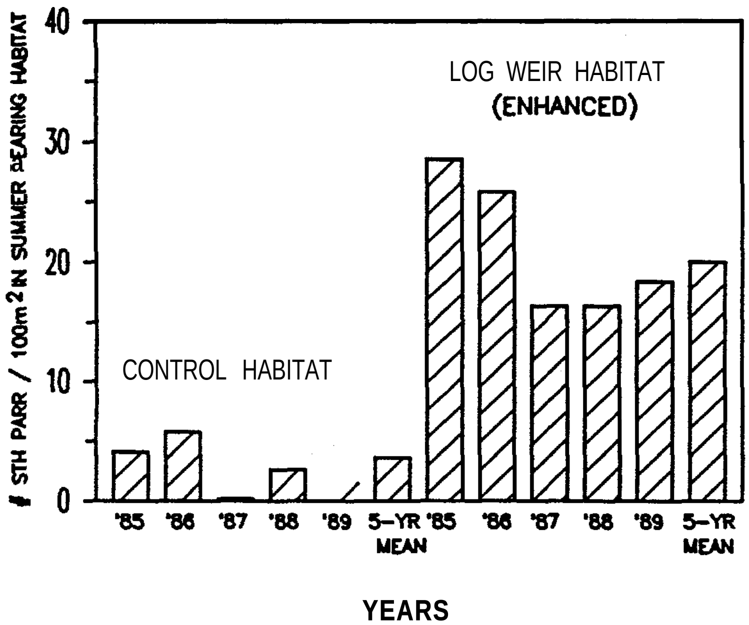


FIGURE 38. PETE KING STEELHEAD PARR RESPONSE TO HABITAT ENHANCEMENT



Fish were captured with Smith-Root backpack fish shockers and blocking nets. The two pass depletion method of electro-fishing was used to estimate population densities. Fish were identified by species and enumerated into size-age classes. Key habitat types (i.e. log weir pools, riffles, runs, et al.) were measured to the nearest 0.1m. A non-parametric analysis of variance-the Kruskal-Wallis test (KW ANOVA) was used to statistically determine the significance of differences in fish densities between the habitats. The null hypotheses were tested at the 5% level of probability.

Data for Squaw Creek is summarized in Figures 3940 plus Tables 30-33. Data collected from Papoose Creek is compared against that of Squaw Creek in Figure 39. The densities of juvenile salmonids in enhanced habitats were much higher than those of the controls. For the chinook and total salmonid categories, it was especially pronounced and statistically significant (K-W test, $P<0.05$). In log weir habitat with wood and rock instream cover, chinook 0+ densities averaged $37.9/100m^2$ versus $0.4/100m^2$ for the controls. For total salmonids, the mean densities were $91.3/100m^2$ for enhanced versus $14.8/100m^2$ for controls (K-W test, $P<0.05$). Although not as dramatic, the response for steelhead was similar.

In Papoose Creek, the design was to specifically construct winter habitat ('rubble ridge") in the upstream pools of log weir structures. The data is summarized in Figure 40 and Tables 34-35. The response in Papoose was very similar to that of Squaw, in that the densities of juvenile salmonids were much higher than those of the controls. As opposed to Squaw Creek, Papoose did not contain any chinook; however, steelhead and cutthroat trout densities were higher. For steelhead, the mean densities in the 'rubble ridge' habitat were 3-4 times higher than the controls. For cutthroat 1/2 parr, the mean density in the enhanced habitat was 10 times higher than the controls. In the combined category (total salmonids), the factorial difference was 3.68.

Densities of juvenile steelhead (all and 1/2 parr) were significantly different at the 5% level of probability, but the total salmonids were not ($P>0.05$). Although the numerical difference was substantial between enhanced versus controls for this category, the inclusion of one control unit of high density in the K-W test with a small sample size was enough to render the difference insignificant.

The total salmonid data for Squaw and Papoose Creeks was pooled to test for significance between enhanced and control densities. There was a significant difference in the pooled density data ($H = 9.20$, 1 d.f., $P<0.05$). In summary, densities of steelhead, chinook, cutthroat, and bull trout (age classes 0+ to 2+) were significantly higher in habitat enhanced with log weirs and rubble collections than those observed in habitat without structures (controls).

In Pete King Creek, the densities of juvenile steelhead (age classes 0+ to 2+) were higher in habitat enhanced with log weirs than controls (Fig. 41 and Table 32). However, the differences were not statistically significant at the 5% level. There was considerable variation in the Pete King data especially for the pooled age classes. This plus the small sample sizes may have masked real differences in densities between the enhanced and control habitats.

Table 30. Mean densitles of juvenile steelhead, cutthroat and chinook salmon in 'enhanced' habitat of Squaw Creek under winter conditions.

Species	Age Class	Mean Density #/100m² ±S.E.[1]
Steelhead	all	24.7 ± 7.4
Chinook	o+	37.9 ± 12.4
Steelhead	1/2 parr	12.0 ± 4.2
Total Salmonids	all	91.3 ± 24.0

Standard error

Table 31. Mean densities of juvenile salmonids in 'control" habitat of Squaw Creek under winter conditions.

Species	Age Class	Mean Density #/100m² ±S.E.[1]
Steelhead	all	13.0 ± 3.2
Chinook	o+	0.4 ± 0.4
Steelhead	1/2 parr	3.5 ± 1.3
Total Salmonids	all	14.8 ± 4.7

[1] Standard error

Table 32. A comparison of mean densities **of juvenile steelhead in 'enhanced.** and control habitats of **Pete King Creek under winter conditions.**

Species	Age Class	Habitat Type	Mean Density #/100m² ± S. E.[1]
Steelhead Steelhead	all[2] all	Enhanced3 Control	27.7 ± 7.7 17.6 ± 9.5
Steelhead Steelhead	1/2 parr 1/2 parr	Enhanced Control	8.2 ± 1.7 1.6 ± 0.8

[1] Standard error
[2] Age classes 0+,1+, and 2+
[3] Enhanced habitat = downstream log weir pools

Table 33. A comparison of summer vs. winter densities of juvenile salmonids in enhanced habitat of Squaw Creek.

Structure #	Structure Type	Species/Age Class	Density: #/100m² Summer	Winter
26	LW Pool w/large woody debris & rubble cover	Chinook 0+ Steelhead 112 parr T. Salmonids	20.0 9.0 61.0	5.5 9.9 41.2
31	LW Pool w/large woody debris cover	Chinook 0+ Steelhead 1/2 parr T. Salmonids	70.0 17.0 121.0	106.3 29.4 201.4
49	LW Pool w/large woody debris cover	Chinook 0+ Steelhead 1/2 parr T. Salmonids	43.0 13.0 73.0	27.0 13.5 56.3
51	LW Pool w/large woody debris cover	Chinook 0+ Steelhead 1/2 parr T. Salmonids	50.0 14.0 81.0	46.3 2.2 66.1
14'	LW Pool w/boulder cover	Chinook 0+ Steelhead 1/2 parr T. Salmonids	92.4 3.8 126.4	43.5 9.2 87.0

[1] Electrofished summer as well as winter; multiple pass depletion.

Table 34. Mean juvenile steelhead and cutthroat trout densities in 'enhanced' winter habitat of Papoose Creek.

Species	Age Class	Habitat Type	Mean Density #/100m² ± S. E.[3]
Steelhead	all[1]	Total Habitat	63.3 ± 14.6
Steelhead	all	Rubble Ridge	53.7 ± 5.2
Steelhead	1/2 parr	Rubble Ridge	22.1 ± 1.7
Cutthroat	1/2 parr	Rubble Ridge	7.7 ± 1.0
Cutthroat	all	Rubble Ridge	38.8 ± 9.4
Total Salmonids [2]	all	Rubble Ridge	72.9 ± 9.5
Total Salmonids	all	Total Habitat	112.0 ± 24.2
Cutthroat	all	Total Habitat	49.5 ± 9.7
Steelhead	1/2 parr	Total Habitat	23.5 ± 3.1

Age classes 0+, 1+, and 2+.
[2] Total salmonids includes all cutthroat and steelhead trout.
[3] Standard error.

Table 35. Densities of juvenile steelhead and cutthroat trout in "control" winter habitat of Papoose Creek.

Stream	Species	Age Class	Density #/100m²
Papoose	Steelhead	all	14.1
	Steelhead	1/2 parr	1.1
	Cutthroat	all	1.1
	Cutthroat	1/2 parr	0.0
	Total Salmonids	all	14.1
Papoose	Steelhead	all	7.2
	Steelhead	1/2 parr	4.3
	Cutthroat	all	0.0
	Cutthroat	1/2 parr	0.0
	Total Salmonids	all	7.2
Papoose	Steelhead	all	25.7
	Steelhead	1/2 parr	11.0
	Cutthroat	all	27.9
	Cutthroat	1/2 parr	2.3
	Total Salmonids	all	53.6
Mean	Total Salmonids	all	25.0

FIGURE 39. MEAN DENSITIES OF JUVENILE SALMONIDS IN "ENHANCED" AND CONTROL HABITATS OF SQUAW CREEK UNDER WINTER CONDITIONS

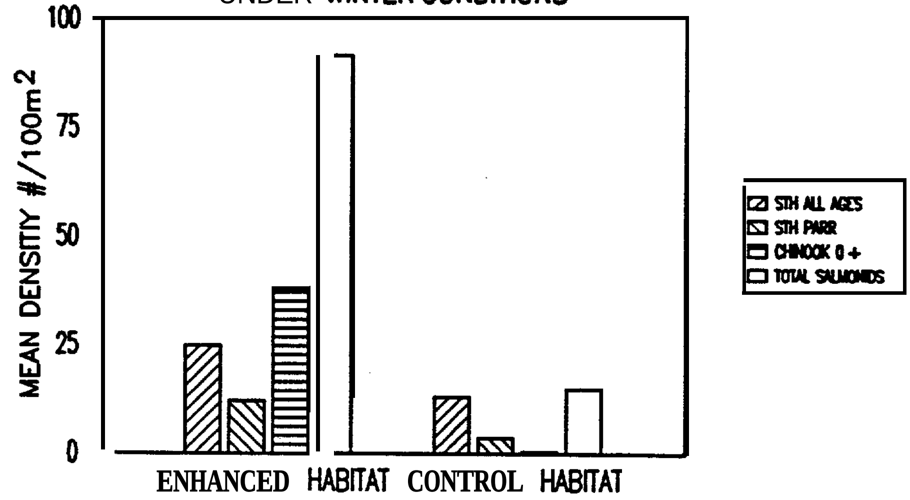


FIGURE 40. MEAN DENSITIES OF JUVENILE SALMONIDS IN "ENHANCED" AND CONTROL HABITATS OF SQUAW AND PAPOOSE CREEKS UNDER WINTER CONDITIONS

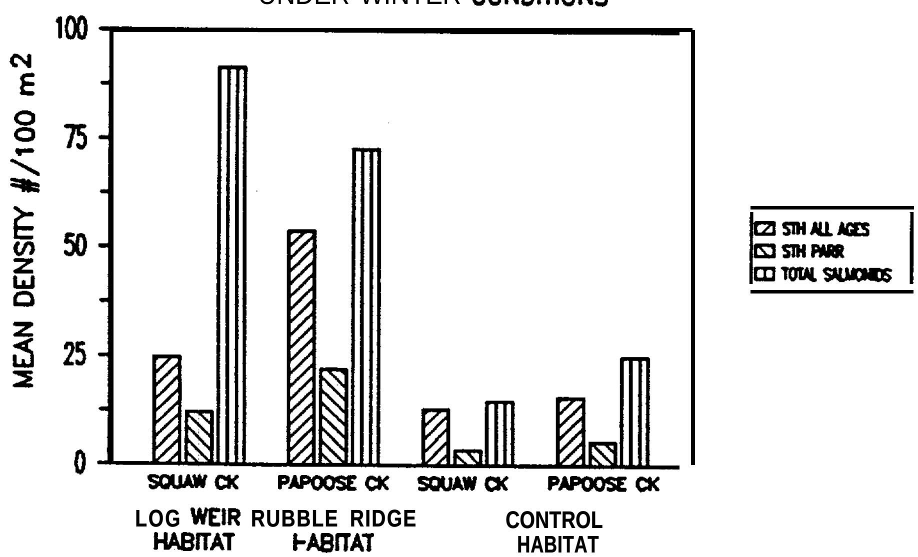


FIGURE 41. MEAN JUVENILE STEELHEAD DENSITIES IN "ENHANCED" AND CONTROL HABITATS OF PETE KING CREEK UNDER WINTER CONDITIONS

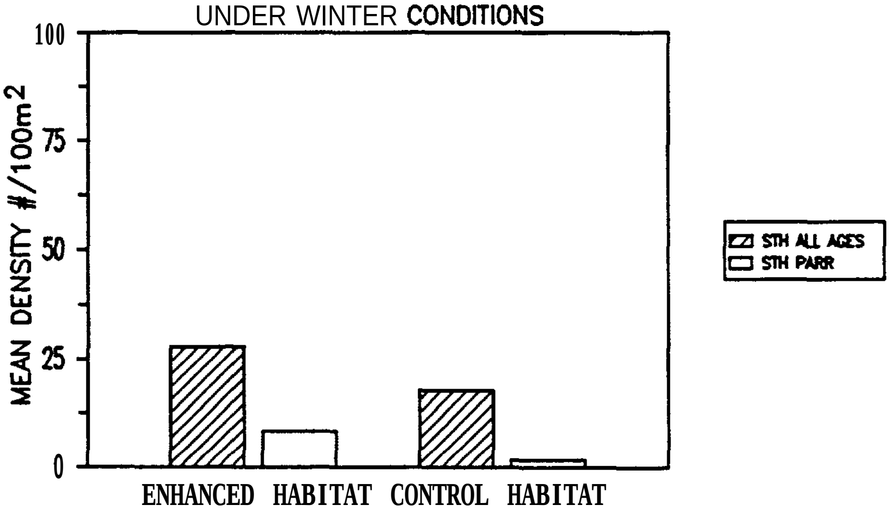


FIGURE 42. A COMPARISON OF SUMMER & WINTER DENSITIES OF CHINOOK 0+ IN ENHANCED HABITAT OF SQUAW CREEK

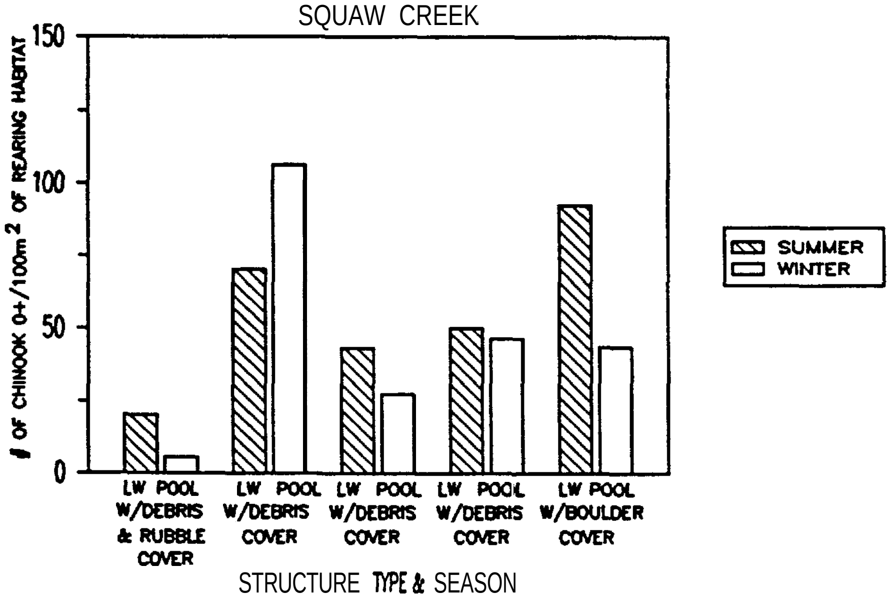
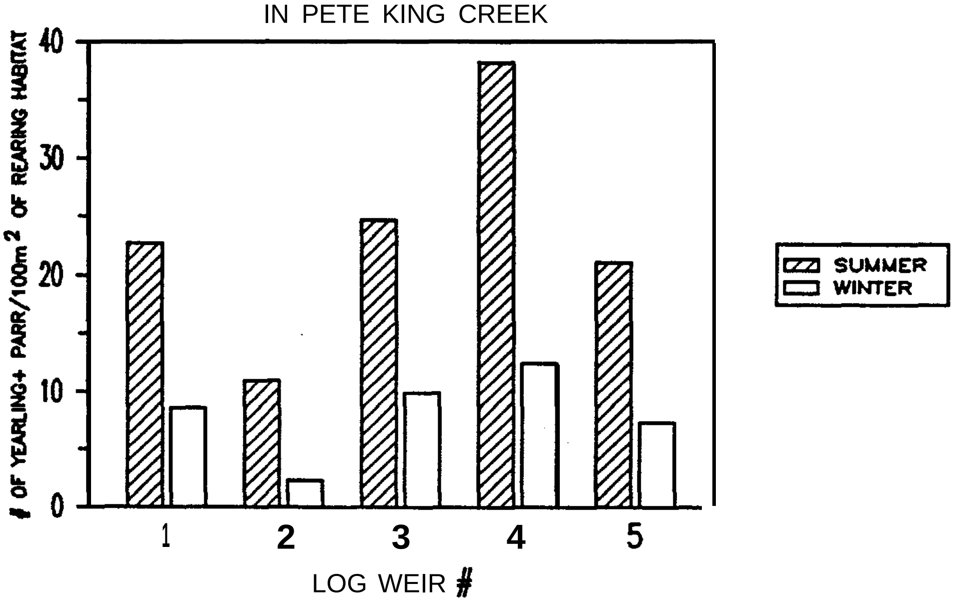


FIGURE 43. A COMPARISON OF SUMMER & WINTER DENSITIES OF YEARLING+ STEELHEAD PARR IN LOG WEIR HABITAT IN PETE KING CREEK



In Squaw and Pete King Creeks, the same pools created by log weirs were sampled to obtain information on seasonal utilization and the transition of summer to winter habitat carrying capacities. The data are summarized in Table 33 and Figures 4243. Because of several variables, a direct comparison between the systems is difficult. In Pete King, the fish community is dominated by steelhead and the habitat is still heavily impacted by sediment (>50% cobble embeddedness). Whereas in Squaw Creek, steelhead and chinook share the habitat, and instream sediment is relatively low (<33% cobble embeddedness). Another difference was that the pools in Squaw Creek were constructed with large woody debris and rubble-boulder instream cover. In Pete King, the diversity in the pools was much lower. Despite these differences, there are some valid comparisons, in Pete King, the densities of steelhead parr (1/2) declined substantially from summer to winter (Fig. 43). The response was relatively consistent from pool to pool, and the average decline for the five pools was 66.3% (range = 59.9 to 79.1%). This response of declining densities from summer to winter was treated statistically and proved to be significant at the 5% level. In Squaw Creek, steelhead parr densities were of similar magnitude or increased in four of five weir pools. As expected, the differences from summer to winter densities of steelhead parr were not significant (P>0.05). For chinook salmon, four of five pools displayed a decline in density from summer to winter. This declination averaged 425% with a substantial range of 7.4 to 72.5%. The differences in chinook densities from summer to winter were not significant at the 5% level. Therefore for both steelhead and chinook in Squaw Creek, there was no statistically significant decline in density from summer to winter conditions.

After sampling a number of streams and a diversity of habitats under winter conditions, two components stand out as critical elements in preferred winter habitat-cover and current velocity--for all salmonid species and size classes that we sampled. Instream cover in the form of large rock (rubble and boulder) placed or found in pool habitats was highly preferred by the larger juveniles of chinook, steelhead, and cutthroat. When adequate cover was linked to very low current velocities (<0.15 mps), it provided critical habitat for wintering salmonids. Cover such as large woody debris, root wads, overhanging vegetation (usually grass), shrub branches, undercut banks, rubble and boulder (small and large) in slack water zones of alcove, pocket water, channel edge, and mainstem pool habitat types was all utilized as winter habitat. The younger and smaller juveniles of all species (age class 0+) used a greater diversity of cover and habitat types. They were frequently found near the channel margin or edge utilizing the available cover. If rock such as small and large rubble had been placed or was available in this zone, it was heavily used by 0+ steelhead and chinook (Lolo Creek). If large rubble (15-30 cm in diameter) and small boulders (10.5 m in diameter) were placed in deeper pool habitats near the channel margins (Lolo Creek), it was very heavily used by the larger juveniles, especially the yearling+ steelhead parr.

VIII. DISCUSSION

Like most of the significant sub-programs within the overall Fish and Wildlife Program of the Columbia River Basin, habitat enhancement in Idaho has experienced its share of controversy, politics, scrutiny, criticism, and bureaucracy. Many question the wisdom of doing any habitat work in upriver areas vis-a-vis downstream mortality problems, low escapement levels, and perceived higher priorities. Criiicism has emanated from both 'outside' agencies and from within. This criticism has, for the most part, not been constructive. Support for habitat work in Idaho from other fisheries entities has at best been inconsistent and at times - absent.

Some critics have campaigned against any habitat work contending that management biologists lacked the knowledge, insight, and technical background to adequately evaluate the need for such work. Others believed that impacts associated with construction activities (instream structural) outweighed the estimated benefits of the project. Criiicism that program funding was being used by agencies as 'in lieu of' funding to correct or mitigate past watershed transgressions was often heard. In summary, there has been no shortage of such commentary and attitudes during the life of our project. Its effect has been to create a more difficult and negative working atmosphere to what should have been a more positive experience. Perhaps it fostered a higher standard of performance. Certainly it created an enhanced level of sensitivity.

Like most large planning and rehabilitation programs with manifold elements and limited budgets, competition for funding and priority considerations is intense. The elements of the Natural Production section such as habitat and passage improvements did receive early consideration and funding. This in itself created controversy and self-serving criticism. Since then, other facets of the program have been initiated and gained dominance. Some of this controversy has, in our opinion, tainted objective evaluation of some habitat projects.

A. SUMMARY ANALYSIS

1. Objectlves and Evaluation

One measure of project effectiveness is the attainment of goals and objectives. The primary goal of the project was to enhance critical habiiats so that production systems could reach full capability and help speed the recovery of salmon and steelhead stocks within the Basin. Our project objectives were stratified into two general categories: habitat and populations. We attempted to modify the habitat to exact a favorable population response. The 'bottom line' evaluation of any anadromous habitat enhancement is whether or not it increases fish production - i.e. smolt yield. Our project is no exception. However, there are major problems associated with using population response as the sole criterion of effectiveness, Escapement levels of salmon and steelhead in Idaho streams remain at low levels, Spawning and rearing habitats are seeded at a mere fraction of their full capabilities (Scully et al., 1990). Within this context, it becomes extremely difficult to measure and document the population responses. Annual variation in escapement and seeding could exceed or mask positive responses attributable to habitat enhancement. Another problem associated with the evaluation of project effects in Idaho is the lack of smolt yield monitoring. Only a few research streams are being monitored by smolt trapping facilities (Scully et al., 1990). Most of the BPA habitat work is being evaluated on the basis of monitoring summer parr densities. Trend enumeration of redds in spawning index areas is also being conducted. An attempt is being made to correlate the parr densities with the redd count data. Nevertheless, the critical link of smolt yield is still missing in most streams and becomes the subject of arcane modeling efforts, assumptions, speculation,and criticism. Until more intense and comprehensive evaluation is conducted, the response of populations to habitat modifications will remain an uncertainty. Therefore, the primary focus of this summary analysis will be upon the habitat.

2. Lolo Creek Watershed

We surveyed a total of 74.9 km of stream habitat and identified 12 major projects. Our survey objective was 80.5 km and to identify any habitat projects that needed implementation. We attained 93% of our stream distance objective and fully met our objective for project identification.

We treated 6 major barriers to upstream passage and accessed a total of 70.0 km of mainstem and tributary habitats. This in turn provided 409,900 m^2 of rearing habitat and 6,100 m^2 of spawning habitat for anadromous salmonids. Our objective was to access 32.2 km of stream length, 337,100 m^2 of rearing and 14,200 m^2 of spawning habitats. We achieved 217% of our stream distance objective, 122% of the rearing habitat objective, and 43% of our spawning habiiat objective.

In terms of instream enhancement, we treated 250,000 m^2 of rearing habitats. We achieved 112% of our enhancement objective. We evaluated habitat enhancement on the basis of whether or not the habitat was more diverse and in better condition following treatment than its pre-project condition. We determined that 250,000 m^2 of habitat was indeed enhanced.

Our objective for riparian enhancement was to treat 34.4 ha of habitat. We accomplished 102% (35.0 ha) of the objective by fencing and planting.

Wiih respect to our pre-project habitat objectives, the overall attainment average equalled 115% for the Lolo Creek phase of the project. We were able to accomplish more because the unit costs per structure and m^2 of habitat accessed were relatively low. For example, our mean unit cost for instream enhancement ranged from $131 to $145 per structure in Lolo and Eldorado Creeks respectively. The unit costs were kept low because many of the structural materials were available on-site and access to the streams was excellent. Overall, our habitat (m^2 of rearing) enhanced-to-cost ratio was 2.1:1 for instream enhancement, 9.1:1 for habitat accessed (m^2)-to-cost for passage (barrier) work and 10.6:1 for riparian habitat (m^2) enhanced-to-cost. Whether or not this work was ultimately cost effective or not depends upon the expression of other variables such as adult escapement, seeding of the habitat, and smolt yield.

3. Lochsa River Watershed

We surveyed a total of 151.9 km of stream habitat and identified 17 major projects. Our survey objective was 80.5 km and to identify any habitat projects that needed implementation. We attained 189% of our stream distance objective and fully met our objective for project identification.

We treated 22 major barriers to upstream passage and accessed a total of 118.2 km of mainstem and tributary habitats. This effort provided 423,264m^2 ((42.3 ha) of rearing habitat and 44,098m^2 (4.4 ha) of spawning habitat for anadromous fish. Our objective was to access 80.5 km of stream length, 291,386m^2 of rearing and 4,374m^2 of spawning habitat. We achieved 147% of our stream distance objective, 145% of our rearing habitat objective, and ten times (1008%) our spawning habitat objective.

For instream enhancement, we treated 277,000m^2 of rearing habitat. We achieved 80.5% of our original objective. In addition, we enhanced 6,500m^2 of spawning habitat of which there was no original objective.

With respect to our pre-project habitat objectives, the overall attainment average equalled 345% for the Lochsa River phase of the project Similar to the Lolo phase, we were able to accomplish more because of the relatively low unit costs. Overall, our habitat (m^2 of rearing) enhanced-to-cost ratio was 2.4:1 for instream enhancement and 4.6:1 for habitat accessed (m^2)-to-cost for passage (barrier) work.

Overall, our objective attainment level for both phases averaged 205%. We enhanced a total of 673,264m² (67.3 ha) of rearing habitat, 55,598m² of spawning habitat,and 344,000m² (34.4 ha) of riparian habitat. In addition, we accessed a total of 833,164m² (83.3 ha) of 'new' rearing and 58,298m² (5.8 ha) of "new' spawning habitats by correcting 28 major barriers to fish passage. We also surveyed a total of 226.8 km of stream length and identified 29 major enhancement projects.

B. STATE'S EVALUATION

Since 1984, the State of Idaho (Idaho Department of Fish and Game - IDFG) has conducted a partial evaluation of habitat enhancement projects on the Clearwater Forest funded by the BPA-NWPPC Program. IDFG has the responsibility of establishing an off-site mitigation record for such projects. They have evaluated both instream enhancement and barrier removal projects in Lolo Creek and a number of tributaries of the upper Lochsa River. Additionally, they have also evaluated projects on the Nez Perce Forest in tributaries of the South Fork, Clearwater River.

Scully et al. (1990) have estimated steelhead and chinook parr abundance attributed to the different types of enhancement projects. Of the four types of projects evaluated - barriers, instream, off-channel, and sediment reduction - they concluded that barrier removals or modifications have had the greatest benefit in terms of parr produced. According to Scully et al. (1990), 52% of steelhead and 72% of chinook parr produced as project benefits from 1986 to 1988 were the result of barrier removals. IDFG also estimated potential parr benefiis attributed to barrier projects (Table 36). They were unable to do a similar estimation for instream enhancement because 'before-and-after' carrying capacity data was not available. For Clearwater Forest projects involving partial and complete removal of barriers, IDFG estimated a potential total of 77,487 steelhead parr (3 projects) and 167,726 chinook parr (2 projects). The IDFG estimation for steelhead parr was in error as they mistakenly used the chinook density multiplier for the Crooked Fork project. The correct figure for Crooked Fork is 13,419 (not 54,521) potential parr. The potential total is 36,385 (not 77,487) steelhead parr (Table 36).

Utilizing Scully's et al. (1990) methodology for estimating potential parr benefits, we have assessed the other barrier projects completed under this program. The results are summarized in Tables 37-38. The total levels of potential parr production estimated for all barrier projects completed on the Clearwater Forest are: 85,694 steelhead and 304,693 chinook.

Table 36. A summary of potential parr benefits attributed to barrier removal projects by Scully et al. (1990).

Barrier Removal	Species	Potential Parr Benefits
Complete Eldorado	Steelhead	14,384
colt	Steelhead	8,582
Partial Crooked Fork	Steelhead	13,419
TOTAL		36,385

Table 36, continued.

Barrier Removal	Species	Potential Parr Benefits
Complete Eldorado	Chinook	110,478
Crooked Fork	Chinook	57,248
TOTAL		167,726

Table 37. A summary of potential steelhead parr benefits attributed to the remainder of the barrier removal projects by Espinosa and Lee (1991).

Barrier Removal	Potential Parr Benefits
Complete Shotgun	3,095
W.Fk.Squaw	623
Doe	5,626
Partial Yoosa	7,362
Musselshell	9,882
Spruce	4,474
Storm	5,867
Walde	717
Fish	11,663
TOTAL	**49,309**

Table 38. A summary of potential chinook parr benefits attributed to the remainder of the barrier removal projects by Esplnosa and Lee (1991).

Barrier Removal	Potential Parr Benefits
Complete W.Fk.Squaw	1,958

Table 38, continued.

Barrier Removal	Potential Parr Benefits
Yoosa	35,992
Musselshell	48,312
Spruce	15,624
Partial Storm	35,081
TOTAL	136,967

Scully et al. (1990) evaluated and statistically analyzed three major instream enhancement projects in the Clearwater Basin. These projects were of similar design and were implemented in Crooked River, Red River, and Lolo Creek. With but one exception, there were no significant differences (2-way ANOVA) in either chinook or steelhead parr densities between treatment and control sections for the three streams. The exception was for chinook parr in Lolo Creek! According to IDFG data, Lolo Creek was one of the best producers of spring chinook during the period 1985-l 988 in the natural production areas monitored by the State (Scully et al., 1990). For this period, Lolo Creek supported the highest mean density of chinook parr of all the natural production areas monitored by the State in the Salmon and Clearwater River Basins (Scully et al., 1990).

It is not clear what role supplementation, habitat enhancement, or both factors interacting together have had on abundance of chinook parr in Lolo Creek. Lolo Creek has had a long history of heavy supplementation with hatchery salmon and steelhead with no apparent positive benefits. It has only been recently that we have observed a pulse in Lolo's abundance of chinook.

In 1988, the Clearwater Forest contracted Clearwater BioStudies (CBS) to evaluate salmonid response to habitat enhancement in Lolo Creek. Their evaluation revealed that both salmon and steelhead were generally more abundant in enhanced over unenhanced habitat. However, the observed densities varied considerably both among and within station types (CBS, 1988). We statistically analyzed the data and discovered that there were significant differences in steelhead parr abundance ($P<0.05$) attributable to enhancement but not in chinook parr densities. A comparison of this analysis with the State's is not valid since Scully's et al. (1990) test covered a four year period.

We have evaluated other instream enhancement projects within the Lochsa River system. We have detected significantly higher parr densities (statistically) of steelhead in enhanced over control sites in Pete King, Squaw, Papoose, and East Fork Papoose Creeks over a period of years. For chinook parr, we have measured a similar response in Squaw Creek. These differences in parr densities were observed both in summer and winter rearing habitats in Squaw and Papoose Creeks.

It is our observation that the steelhead parr response has been more consistent than chinook for the streams we have evaluated. We believe that the escapement of chinook salmon has been more variable than steelhead in Cleat-water streams and has probably contributed to the inconsistency of response.

C. EPILOGUE

The ‘bottom line’ successful response for the BPA-NWPPC enhancement program is increased smolt yield and adult return. In Idaho, it is the recovery of the stocks. Because of low escapement and seeding levels, any fish response evaluation is premature. All of the evaluations conducted in Idaho have suffered from exceedingly low escapement and seeding levels. Conclusions based on such evaluation could lead to false acceptance of null hypotheses.

Some results are promising, however. Adult and juvenile salmon and steelhead have been observed above ‘impassable’ barriers that have been modified. Additional habitats have been provided and await increased escapement to reach full production potential. "Improvement" of instream habitat in a number of streams has shown higher salmon and steelhead parr densities in enhanced habiiat. These streams and projects need to be further evaluated under conditions of full seeding escapement. in addition, smolt yield and adult return should be sampled and evaluated to provide definitive assessment. To some critics, higher parr densities in enhanced habitat merely reflect the movement of fish from one habitat to another, and this response does not reflect increased production. In rebuttal to this contention, movement to higher quality habitat may impart higher probability of survival and could make available less optimal habitat for other fish. In both cases, increased production could be the result.

We believe that habitat enhancement is a management tool that is important to the recovery of wild and natural stocks of salmon and steelhead in Idaho. We also believe that this program on the Clearwater Forest has had a beneficial effect on salmon and steelhead stocks in our treatment streams. Its full effect will be realized in the future when ‘newly’ accessed and ‘enhanced’ habitats are seeded.

Conversely, habitat enhancement is not an exclusive management option. We agree with Scully et al. (1990) that habitat improvement by itself cannot recover severely depressed stocks to levels of abundant surpluses. Consistent improvements in flow and passage conditions during smolt and adult migration periods need to occur for significant recovery of the stocks in Idaho. Idaho stocks of anadromous fish remain in a perilous state. Habitat enhancement could make the difference between extinction and marginal existence in some local populations by improving the survival rate of egg-to-smolt in degraded habitats (Scully et al., 1990). In a general context, its proper role at the present time in Idaho is corollary to other more salient efforts of recovery.

IX. SUMMARY AND CONCLUSIONS

1. In 1983, the Clearwater National Forest and the Bonneville Power Administration entered into a contractural agreement to improve anadromous fish habitat in the Clearwater River Basin.

2. The Program covered a period from 1983 to 1990 with a budget of $425,679; the program consisted of 13 projects with $395,646 going "to the ground.'

3. During this period, the Forest Service contributed a total of $255,000 dollars additional on a cost-share basis - with $123,000 for instream enhancement, $82,000 for watershed restoration, and $50,000 for habitat inventories and project evaluation.

4. The overall goal of the Program was to enhance spawning, rearing and riparian habitats of Lolo Creek and major tributaries of the Lochsa River so that their production systems could reach full capability and help speed the recovery of salmon and steelhead within the basin.

5. In the Lolo Creek watershed, habitat surveys covered 71.7 km of stream length and identified 12 major projects: 8 involving instream enhancement and 4 involving passage improvement.

6. To date, only one of the instream projects has been completed in mainstem Eldorado Creek: whereas, 3 of 4 passage projects have been completed.

7. In the Lochsa River watershed, we surveyed a total of 151.9 km of stream habitat and identified 17 major projects. To date, 11 of these projects have been completed.

8. In Lolo Creek, we modified 6 major barriers to upstream passage and accessed a total of 70.0 km of mainstem and tributary habitats for salmon and steelhead.

9. In the Lochsa, we treated 22 major barriers and provided 118.2 km of mainstem and tributary habitats for anadromous fish.

10. In terms of enhancement, 250,000m² of rearing habitat and 34.4 ha of riparian habitat were improved in the Lolo Creek system.

11. For the tributaries of the Lochsa, we improved 277,000 m² of rearing and 6,500 m² of spawning habitats for salmon and steelhead.

12. Overall, our objective attainment level for the Program averaged 205%. We were able to exceed our objective levels because of the relatively low unit costs.

13. For the Lolo phase, the ratio of habitat accessed (m² of rearing) enhanced-to-cost was 2.1 :1 and for the Lochsa phase, it was 2.4:1 for instream enhancement.

14. Considering barrier projects, the ratios of habitat accessed (m²)-to-cost ranged from 4.6:1 (Lochsa) to 9.1:1 (Lolo).

15. The 'bottom line' evaluation for this Program is increased fish production -- i.e. smolt yield and adults -- and the recovery of the stocks.

16. Whether or not this work was ultimately cost effective or not depends upon the expression of many other variables such as smolt survival, mixed stock harvests, supplementation effects, adult escapement, and seeding of the habitat.

17. The State of Idaho evaluated some of the projects of this Program. They concluded that barrier removals or modifications have had the greatest (potential) benefii in terms of pan produced.

18. The State's evaluation of instream enhancement projects within the Clearwater Basin established that Lolo Creek was the only one that displayed a statistically significant difference between chinook pan densities in enhanced over control habitats. Their data showed that Lolo Creek was one of the best producers of spring chinook during the period 1985-1988 in the natural production areas monitored by the State.

19. The Clearwater Forest evaluated other instream enhancement projects within the Lochsa River system. We have detected significantly higher parr densities (statistically) of steelhead in enhanced over control sites in Pete King, Squaw, Papoose, and East Fork Papoose Creeks over a period of years (3-5). For chinook parr, we have measured a similar response in Squaw Creek. These differences in parr densities were observed both in summer and winter rearing habitats in Squaw and Papoose Creeks.

20. It is our observation that the steelhead pan response has been more consistent than chinook for the streams we have evaluated.

21. Because of low adult escapement and seeding levels in Idaho, any evaluation of fish response to enhancement is premature. Proper evaluation must await adequate escapement and seeding levels. Otherwise, false conclusions may be drawn.

22. Evaluation of BPA-NWPPC projects should continue. We recommend that the instream enhancement projects in Lolo and Squaw Creeks be continued and expanded to include sampling of smolt yield and adult returns.

23. We believe that habitat enhancement is one of many management tools that is important to the recovery of wild and natural stocks of salmon and steelhead in Idaho. It could make the difference between extinction and marginal existence in some local populations.

24. We believe that the BPA-Forest Service program of habitat enhancement has had a beneficial effect on salmon and steelhead in our treatment streams. Hopefully it will help accelerate the recovery of the stocks.

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XI. ACKNOWLEDGMENTS

Many people worked on different facets of this Program. We would like to gratefully acknowledge their hard work and contributions. A special ‘thank you’ to Mr. Larry Everson of BPA for his encouragement, support, expertise, and guidance of ‘Project 84-6’.

The following District Biologists of the Clearwater N.F. executed the Program ‘on-the-ground’: Rich Gritz, Dick Kramer, Wally Murphy, Pat Murphy, and Dennis Talbert. They and their crews did a commendable job of modifying and building habitat under difficult conditions.

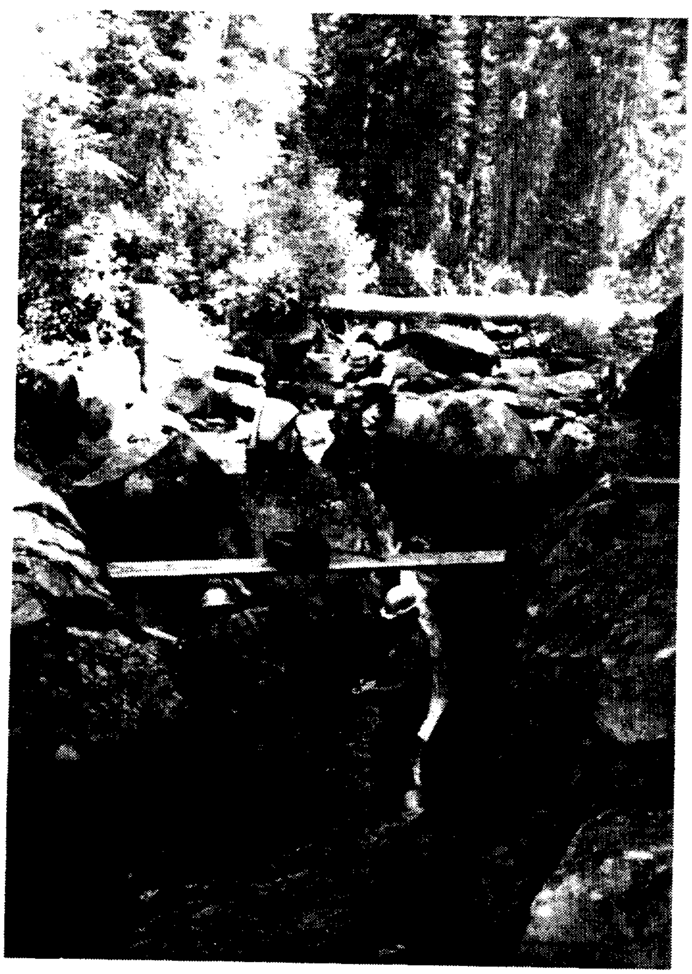
We thank Dr. Jack Orsborn, Tom Bumstead, and Chuck Huntington for their sage advice and counsel.

Other Clearwater N.F. Biologists and Technicians that worked hard on our projects are commended for their dedication and diligent efforts. We thank the following individuals: Wayne Paradis, Hudson Mann, Chris Landstrom, Bob Vogelsang, Gany Seloske, Dave Schoen, Jim Soupir, Shanda Fallau, Steve Babler, Blaine Parker, Ellen Oman, Emilie Fogel, Jeff Butler, Mike Haberman, Brent Clark, Barbara Brisson, Lois Hill, Dale Norton, and Cathy Franks.

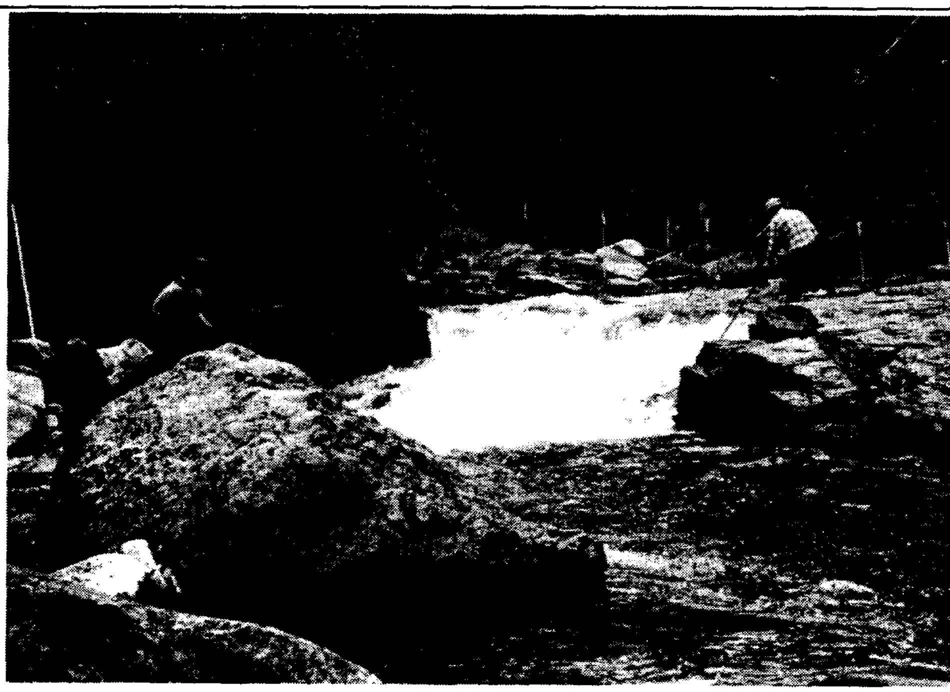
We especially thank John O’Neill and Sarah Walker for their skillful work and diligence in creating graphics and processing the final report. We thank Diana Jones for our cover.

If we have failed to properly recognize some hard working individuals, we thank them for their work and also apologize for our lapse in memory.

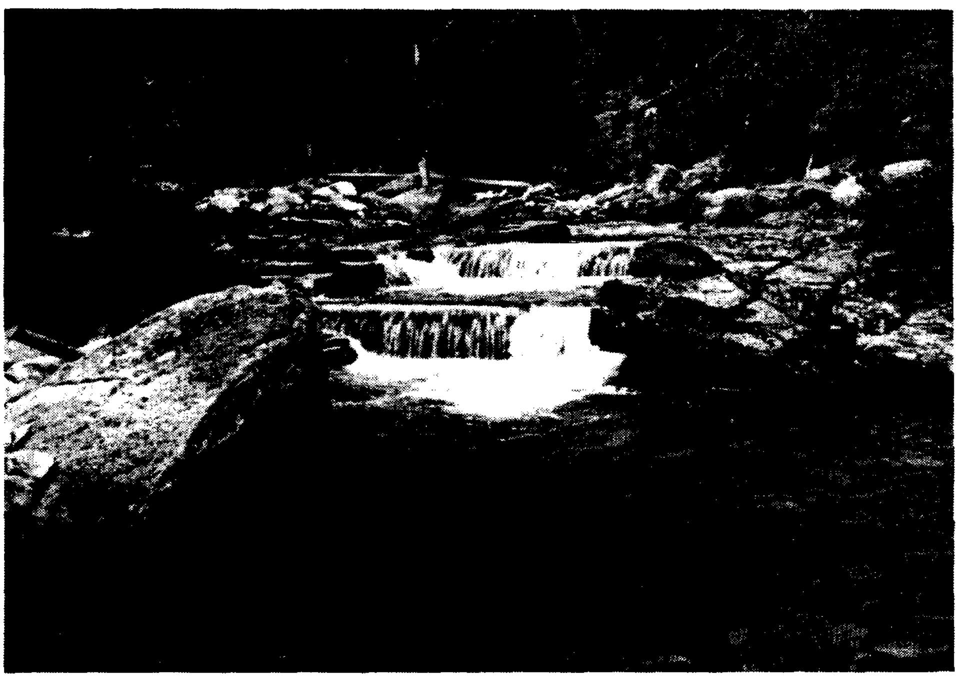
A-l. Migration barrier in Spruce Creek prior to modification.



A-2. Drilling and setting charges in Spruce Creek barrier.

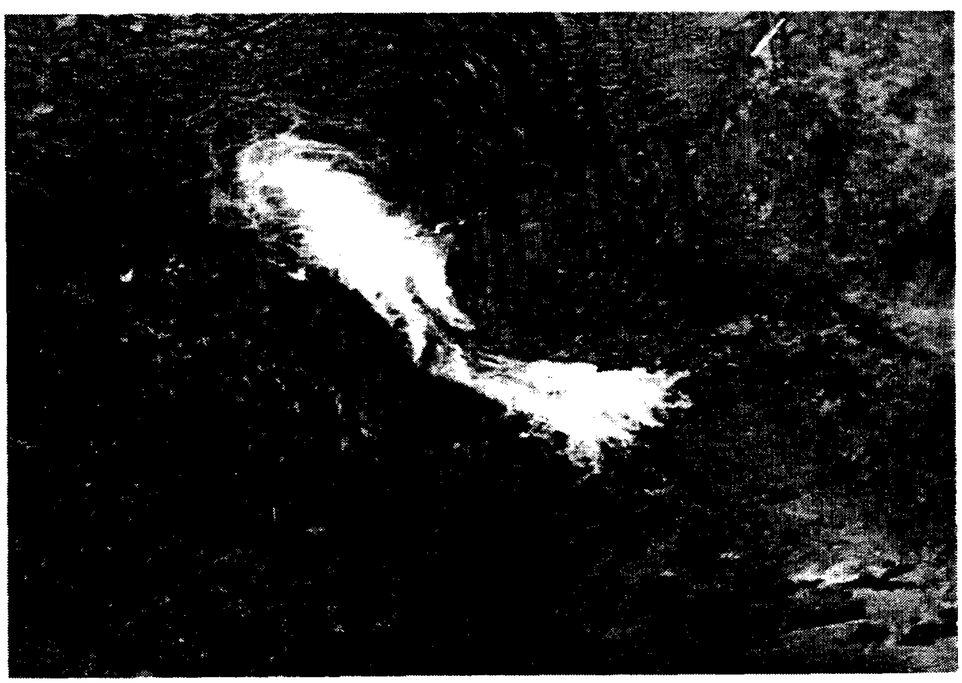


A-3. Major migration barrier to spring chinook in Crooked Fork Creek prior to modification (site #6).



A-4. Completed log weir modification of barrier #6 in Crooked Fork Creek.

A-5. Natural bedrock barrier to upstream migration of salmon and steelhead in Eldorado Creek (site #3).



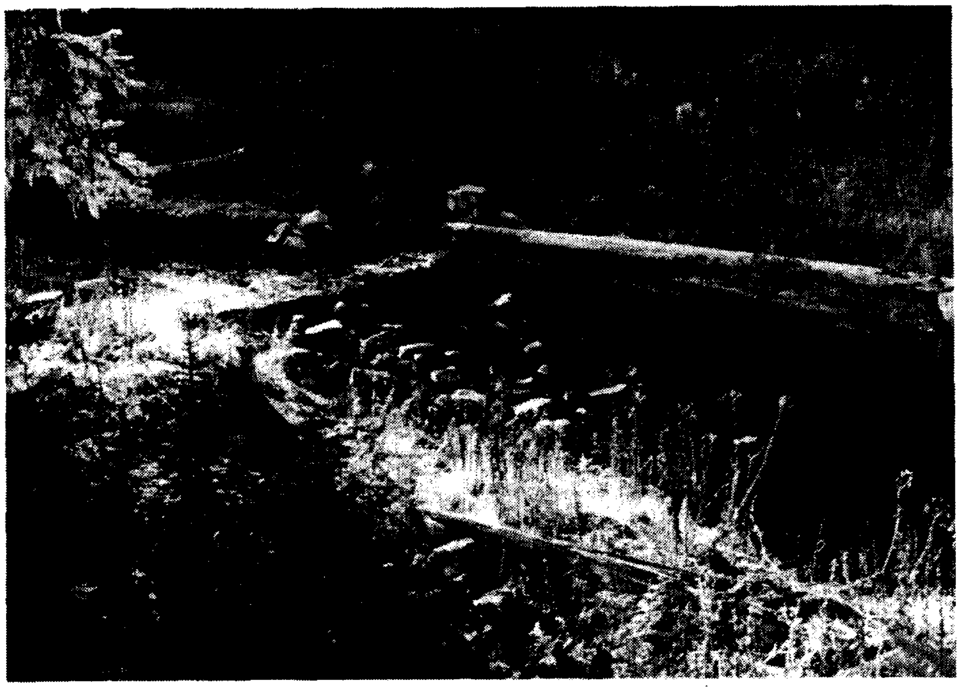
A-6. Barrier #3 in Eldorado Creek following final alteration.

A-7. Post-enhancement survey of Eldorado Creek.

A-8. Summer rearing and spawning habitats in Eldorado Creek, post-enhancement survey.

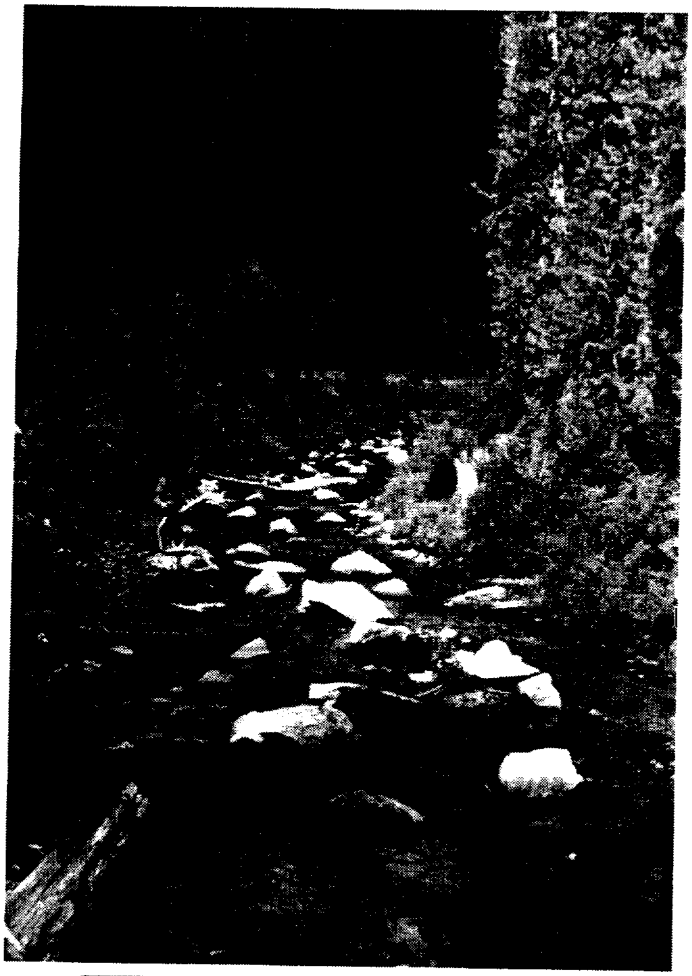
A-9. Excavator constructing instream habitat in Eldorado Creek.

A-10. Stocking of adult steelhead (Dworshak) in Eldorado Creek,

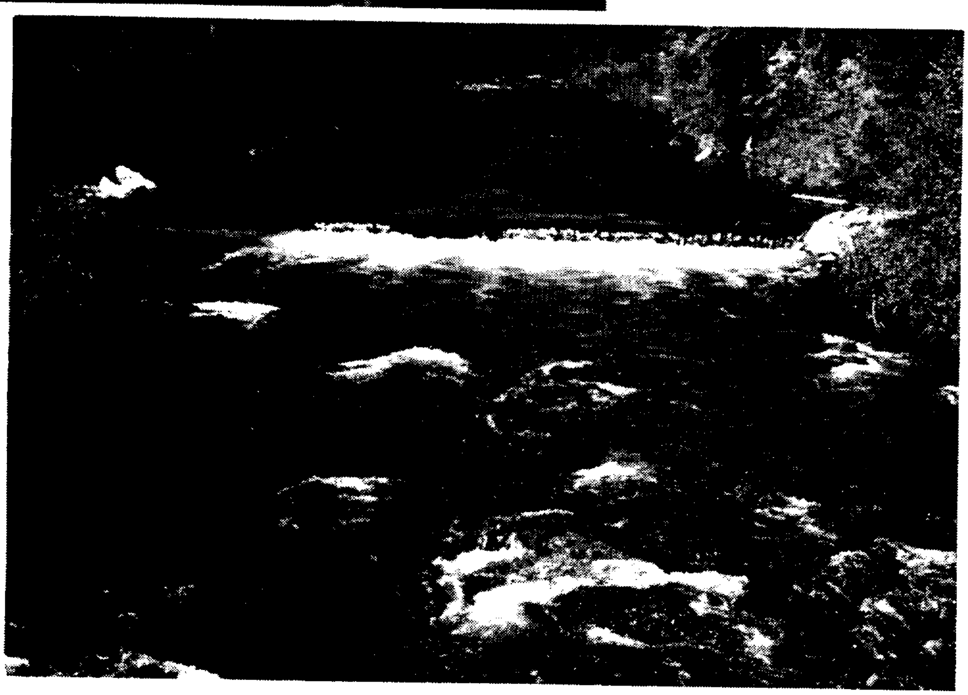


A-11. Constructed summer and winter rearing habitats in Lolo Creek.

A-12. Side channel habitat constructed in Lolo Creek.



A-l 3. A "B-channel" reach in Lolo Creek enhanced with boulders.



A-14. A large log weir with boulder cover in Lolo Creek.

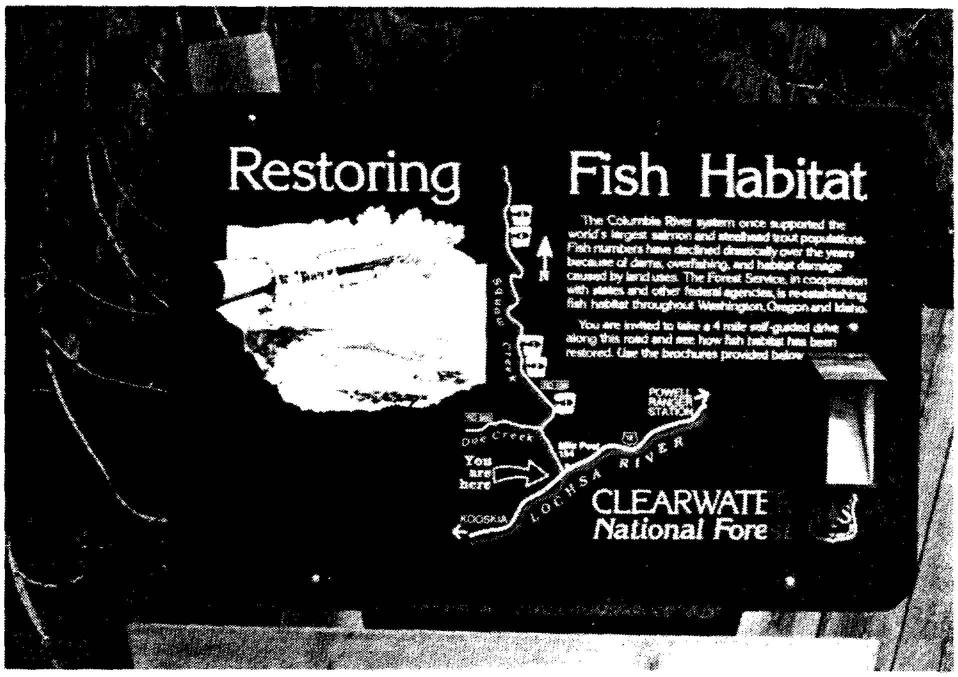
A-15. Riparian habitat and meadow reach of Lolo Creek (section #6) that was fenced to exclude cattle.

A-l 6. Riparian planting along Lolo Creek.

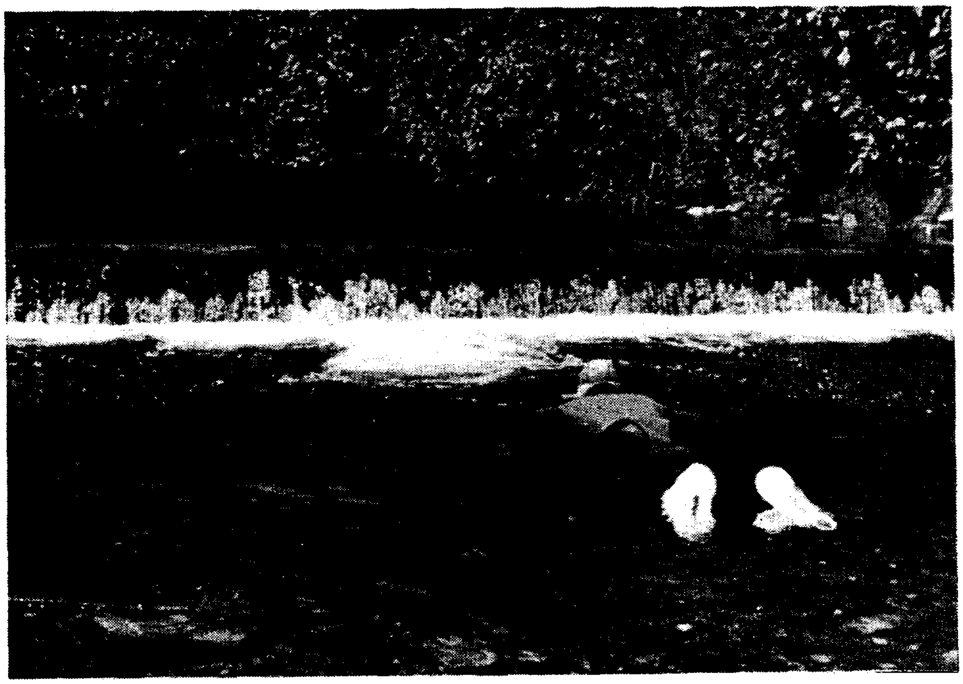
A-17. Debris barrier in Yoosa Creek (Lolo system) prior to removal with explosives.

A-18. Boulder and debris barrier in Musselshell Creek (Lolo system) removed with explosives.

A-l 9. Diagonal log weir with woody debris cover In downstream pool. Spawning habitat in upstream pool - Doe Creek (tributary of Squaw Creek).



A-20. Public information sign and tour route on Squaw Creek detailing project activities and examples of fish habitat restoration.



A-21. Evaluation of salmonid response to habitat enhancement in Pete King Creek (Lower Lochsa system).

A-22. Electrofishing in Squaw Creek to evaluate response to habitat enhancement.

PETE KING MODEL

Summer Rearing Habitat
Enhancement Index Model
Summer Steelhead Trout

BASIN: Lower Lochsa River

DATA SOURCE STREAM: Pete King Creek

CHANNEL TYPE: B-2 (Rosgen, 1986)

STOCK: Clearwater "B" Summer Steelhead Trout

REARING QUALITY INDEX (RQI) VARIABLES AND RATING SCALE

RQI Variables	Rating Scale
X_1 = Pool Quality	I-5
X_2 = Substrate Heterogeneity	I-5
X_3 = Bank Cover	1-5
X_4 = Instream Cover	I-5
X_5 = Habitat Type Stratification	I-5
X_6 = Cobble Embeddedness	I-5

$$RQI = \Sigma X_{1-6} (X_1 + X_2 \ldots\ldots X_6)$$

RQI Variables, Criteria, Quality Standards, and Rating Schemes

Variable: (X_1)	Pool Quality	Quality Standards	Rating
		$7 < X \leq 9$	5
		$6 < X \leq 7$	4
		$5 < X \leq 6$	3
		4 c x ≤5	2
		$3 < X \leq 4$	1

Criteria:

Size	Rating
Pool much longer or wider than the average width of the stream within 30.5 m (100 ft) above and below the point of observation.	3
Pool is about as wide or long as the average width of the stream within 30.5 m (100 ft) above and below the point of observation.	2
Pool much shorter or narrower than the average width of the stream within 30.5 m (100 ft) above or below point of observation.	1

Depth

Deepest part of pool > 0.9 m (3 ft)	3
Deepest pan of pool 0.6-0.9 m (2-3 ft)	2
Deepest part of pool c 0.6 m (2 ft)	1

Cover (see section on instream cover for further explanation).

> 30% of pool bottom obscured by depth, surface turbulence or the presence of structures (logs, boulders, debris)	3
2030% of pool bottom obscured by depth, surface turbulence or structures.	2
c 20% of pool bottom obscured by depth, surface turbulence, or structure.	1

Variable: (X_2)	Substrate Heterogeneity	Quality Standards	Rating
		80% < X	5[2]
		70% < X ≤ 80%	4
		50% c x ≤ 70%	3
		40% < X ≤ 50%	2
		x ≤ 40%	1

[1] Total % substrate surface area in boulder, small and large rubble components or % of transect width.
[2] Downgrade 1 level if any single component exceeds 35%.

Variable: (X_3)	Bank Cover	Quality Standards	Rating
		20% < x	5
		15% < x ≤ 20%	4
		10% < x ≤ 15%	3
		5% < x ≤ 10%	2
		x ≤ 5%	1

Criteria:

% of wetted perimeter with overhanging cover and/or undercut banks.

Variable: (X_4)	Instream Cover	Quality Standards	Rating
		40% ix	5
		25% ≤ X c 40%	4
		15% ≤ X < 25%	3
		10% ≤ X < 15%	2
		X < 10%	1

Criteria:

% of total habitat surface area or transect width consisting of instream cover such as: large woody debris, turbulence. large (>8cm diameter) boulders, instream vegetation, and bedrock overhang.

Variable: **Habitat Type Stratification**
(X_5)

Quality Standards	Rating
Pool-Riff le-Run-PW	
25:25:25:25 (**±5%**	5
15-25: **15-25: 1** 5-25: 15-25 (**±5%)** (Skewed Towards **Pools/PW)**	4'
1 o-1 **5:30-40:30-40:** 1 o-1 5 (**±5%)** (Skewed Towards Rile/Runs)	3
0-10:45-50:45-50:0-10 (**±5%)**	2
≥80% Shallow Riffle or Run	1

Criteria:

% or ratio index of pool, riffle, run, and pocket-water habitat types.

[1] Stratification of **≥60%** pools rate as 4; usually enhanced **habitat** (i.e. log weirs, etc.).

Variable: **Cobble Embeddedness**
(X_6)

Quality Standards	Rating
0% < x 125%	5
25% < X **≤33%**	4
33% c x 150%	3
50% < x 175%	2
75% < x	1

Criteria:

Relative % index that measures the extent that a cobble (7.6 - 30.5 cm diameter) is surrounded by coarse and fine sediments (panicles less than 0.6 cm sieve size).

MODEL EQUATION

$Y = -34.18 + 3.03X$
($R^2 = 0.64$, $P < 0.01$)
(Standard Error = 28.42)
Where, **y** = # of steelhead **parr/100m²**
X = Rearing **Qualilty** Index (RQI)

Criteria:

Habitat units similar in size. Habitat parameters were measured (transect technique). Graphic presentation of the model is presented in Fig. 36, p. 79.

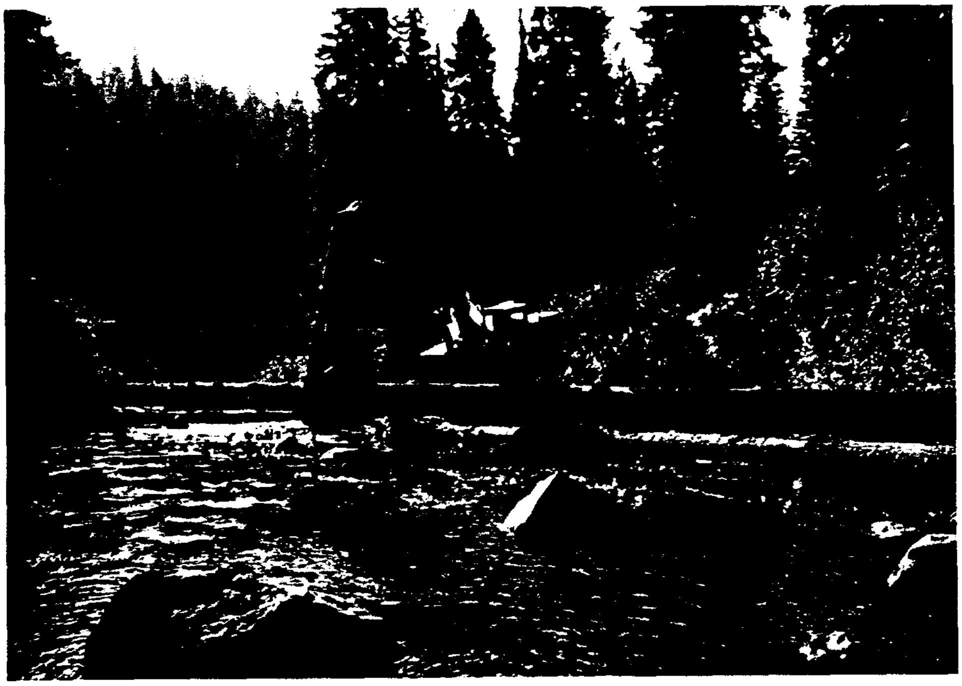


Figure 12. An excavator moving a large log into a weir site in Loio Creek.

Flgure 13. Weir construction and site preparation In Doe Creek (Upper Lochsa).

Construction and placement of structures for the most part were accomplished with contract equipment rental and Forest Service crews consisting of 2 to 4 Fish or Wildlife Biologists. The contract operating representative (COR) was usually the District Biologist. All project activities were overseen by the Forest Fisheries Biologist, the Project Leader. Heavy equipment such as front-end loaders, rubber tire skidders, and tracked backhoes (excavators) with opposable "thumbs" (e.g. Link Belt-4500, Case-886, and Caterpillars-225 and-236) were used to construct log weirs, k-dams, excavate pools and to place large pieces of woody debris and boulders (Figs. 12-13). The equipment was also utilized to rehabilitate and smooth-over disturbed sites. Crews were used to secure the structures with cable and epoxy-resin attachment systems (Hilti; Figs. 14-l 5). For side channel enhancement, a fisheries engineer was consulted on site selection and design. The consultant provided a construction plan which was implemented according to his specifications. Upon completion of construction activities, all disturbed sites were rehabilitated to abate potential sediment sources by seeding, fertilizing, and planting of grass, deciduous and coniferous trees. All the structures except individual boulders were numbered, catalogued (tagged), photographed (ground and aerial), and mapped for a permanent record. This record has greatly facilitated the process of annual maintenance.

B. Riparian

As part of our baseline habitat inventory, riparian habitat conditions were evaluated. Parameters such as bank cover and stability, potential woody debris, habitat type, successional stage, community composition, and areas of degradation were assessed and documented. This information was then used to formulate a project design and plan. in this manner, the Section 6 riparian area (meadow complex) of Lolo Creek was identified as requiring rehabilitation and management coordination. Cattle grazing from several allotments in the area was degrading riparian and stream habitats. Moreover, these impacts over time would pose a significant risk to the longevity of instream enhancement structures. Management options were evaluated, and the alternative of fencing off the critical riparian area was selected as the most feasible and effective. The area requiring fencing was mapped and identified on the ground. A fence design that would withstand heavy snow drifts and minimize impacts to wildlife was selected. A contract was prepared incorporating project specifications and bids were solicited.

Riparian areas requiring rehabilitation (usually impacted by timber harvest and road construction) were mapped and identified on the ground. A project plan was then formulated. Most of the riparian work involved the planting of shrubs, deciduous and coniferous trees to stabilize disturbed areas and provide long term sources of woody debris and bank cover. The work was accomplished with Forest Service crews. Details of the riparian projects are presented in Talbert et al. (1988) and Babler et al. (1989).

Figure 10. A reach of Lolo Creek prior to enhancement.

Figure 11. Monotypic habitat in Squaw Creek prior to enhancement.

V. METHODS

A. Instream Enhancement

Detailed descriptions of methods are presented in previous BPA reports (Espinosa, 1984; Kramer et al., 1985; Murphy and Espinosa, 1985; and Kramer et al., 1986). Only summaries will be presented here.

All of the streams subjected to structural instream enhancement had experienced a spectrum of impacts from development activities. in many cases, road construction in the riparian zone had impinged upon the natural channel and eliminated a constant source of large woody debris to the channel. The 'bottom line' to this degradation was that habitat diversity in these systems had been substantially removed for a long period of time. Rearing habitats in these streams were characterized by long stretches of monotypic, shallow riffle-run types (Figs.lO-11). In some situations, surface and mass erosion from logging roads delivered excess sediment to the channels and eliminated diversity. The primary thrust of the treatments was to replace this diversity and enhance the streams' productive capabilities.

Prior to any instream work, baseline habitat surveys were conducted in all project streams (Kramer et al., 1985 and others). The surveys were necessary to document the existing quantity and quality of the habitats so that an assessment of project viability could be made. The amount of spawning, summer rearing, and winter rearing habitats was quantified in each system to facilitate analyses of limiting factors. Key habitat parameters such as pool quality, habitat type stratification, instream and bank cover, substrate diversity, cobble embeddedness, bank stability, acting and potential woody debris were measured to provide a factual basis for an ecological diagnosis, prognosis, and treatment. In addition, population surveys were conducted in representative reaches to document the composition of the salmonid community and identify target species.

Given this information and analyses, a project plan was then developed which identified the design, scope, and specifics of the project. Stream reaches requiring treatment, access routes for heavy equipment, and supplies of raw materials (trees, root wads, boulders) were identified and located. Biologists, operating from a set of hydraulic and biological criteria, located and marked sites for enhancement. Each treatment reach was traversed and mapped for the entire distance by Project Biologists. At each site, the type and number of structures were identified---e.g. log weir site with root wad (2) and boulder cover (2). The final pre-implementation phase consisted of orientating work crews and contract personnel to the specifics of the project.

Figure 14. Using the Hiiti system to attach a large log to bedrock keys in Eidorado Creek (barrier site # 1).

Figure 15. W'eir modification of Eldo-rado Barrier # I. Cables are glued to bedrock.(Hiltii system).

C. Barriers

Barriers were removed on Eldorado Creek and from several streams in the lower and upper reaches of the Lochsa (Table 1). Each project area was analyzed for specific modifications needed to eliminate the barrier. John Orsborn P.E., and Thomas W. Bumstead of the Albrook Hydraulics Lab of Washington State University surveyed many of the sites and recommended the design of jump pools and weirs.

After initial reconnaissance, barriers were mapped. A transit was used to gather data on depth of pools, height of jumps and the distance covered. The most logical migration route was determined and a series of measurements were made for a profile. Permanent benchmarks were created so that the barriers could be evaluated from pre- and post-project work.

The methodology described will pertain primarily to the boulder and bedrock barriers that required a combination of blasting and weir construction to modify. Debris barriers were removed by blasting apart the debris with explosives. Site specific details of projects can be found in prior publications submitted to Bonneville Power Administration,

At each project site, an initial survey and site analysis was completed to determine the needs for passage. Designs were drawn for a series of jump pools and/or weir construction to back water up to form a negotiable passage for the target species (steelhead trout or chinook salmon).

A Pionjar 120 rock drill and drill bits ranging from one and one half feet to four feet in length, were used for drilling blasting holes. Drilling, done by a two to three person crew, was the most time-consuming part of the project. Depth and number of holes drilled depended upon the degree of reaction desired. Depending on the barrier size, the barrier was either drilled and shot once or drilled several times with the blasting performed sequentially. On larger barriers with several obstructions, one obstruction was worked on and evaluated before starting the next.

Blasting was achieved by using water gel, primacord and blasting caps. All blasting was performed by certified blasters. After blasting, crew members hand picked boulders and rock fragments out of pools. The material was moved on to the bank or pushed downstream.

In addition to blasting jump pools, some sites required the placement of weirs to achieve negotiable pool depth:jump height ratios. Trees were cut on site and moved into place with the use of a chainsaw winch, cables, peavies, prybars and a ‘come-along” winch. Drilling and/or blasting was required on some of the banks to establish a straight edge for the end of logs to sit against.

Logs were cabled into place using 9/16” galvanized steel cable and C-10 HIT dowelling cement (product by Hilti). Holes were drilled into the bedrock on both sides of the log weir with a Hilti gas operated hammer drill. Holes were filled with the cement and the cables set into place. On the upstream side of the weir, geotextile fabric and hardware mesh were attached to the log and then backfilled with rock and gravel. In sites where high pressure on the weir is expected, a perpendicular brace log was also built. (Site specific methods and materials can be found in individual project reports.)

After the completion of blasting and weir construction, data were collected on depth of pools, height of jumps and the distance covered. During the project, before and after photographs were taken of each barrier. Representative photographs are presented in Appendix A.

Figure 6. The Lolo Creek Watershed

Figure 7. Overview of Lolo Creek

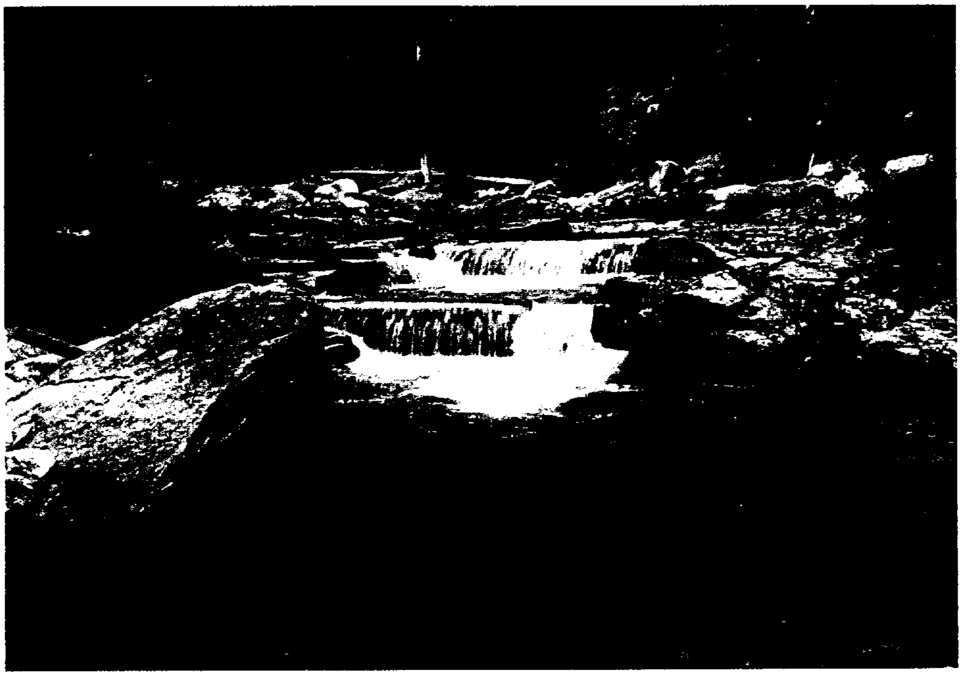
Figure 8. Overview of Crooked Fork Creek

Figure 9. White Sand Creek (Upper Lochsa)

A-l. Migration barrier in Spruce Creek prior to modification.

A-2. Drilling and setting charges in Spruce Creek barrier.

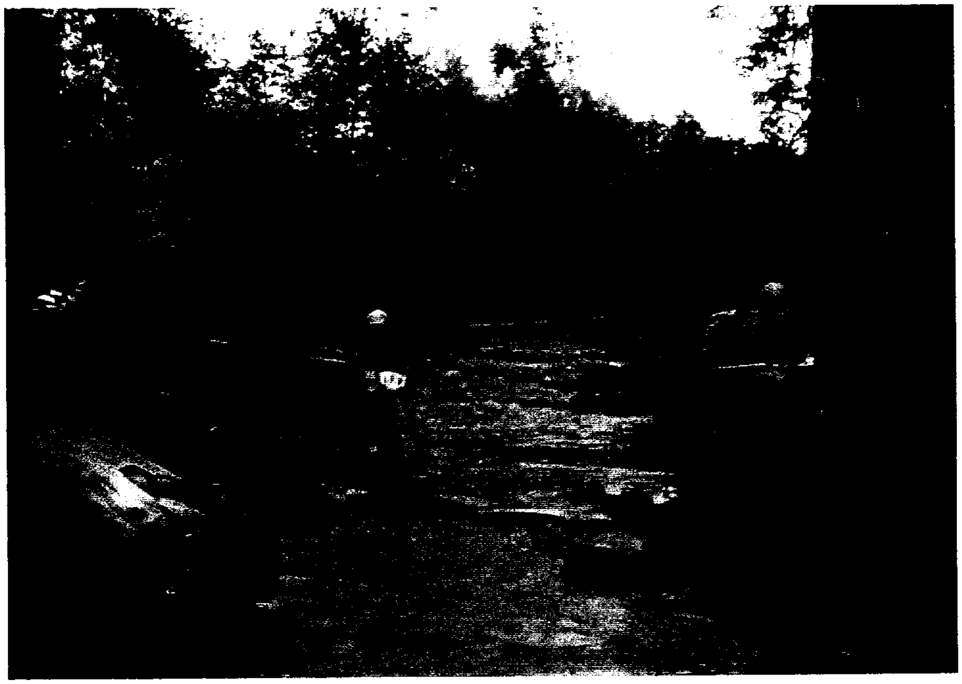
A-3. Major migratlon barrier to spring chinook in Crooked Fork Creek prior to modification (site #6).



A-4. Completed log weir modification of barrier #6 in Crooked Fork Creek.

A-5. Natural bedrock barrier to upstream migration of salmon and steelhead in Eldorado Creek (site #3).

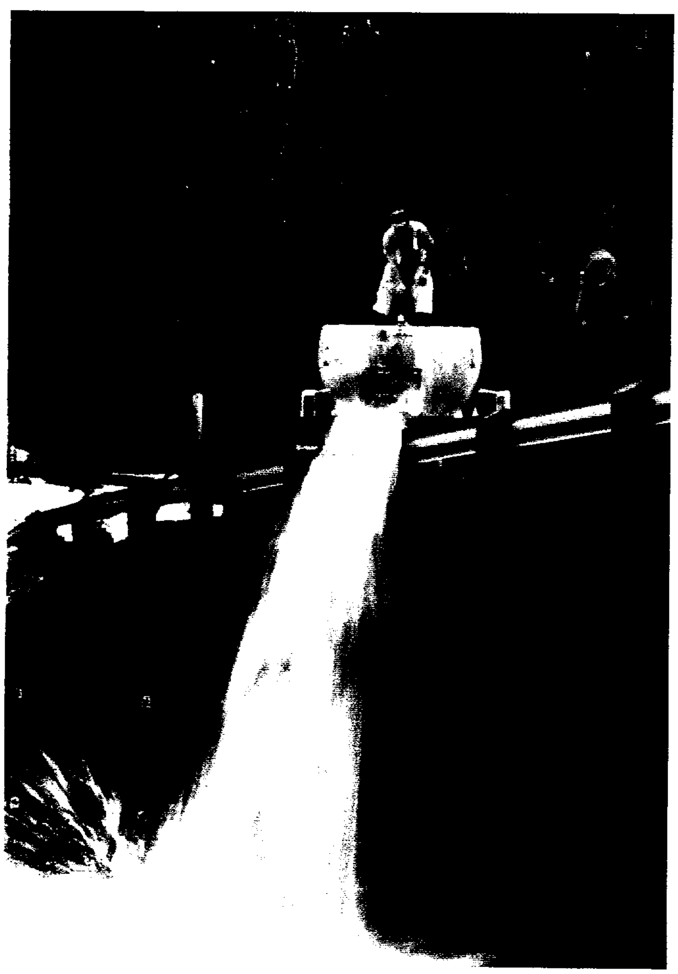
A-6. Barrier #3 in Eldorado Creek following final alteration.



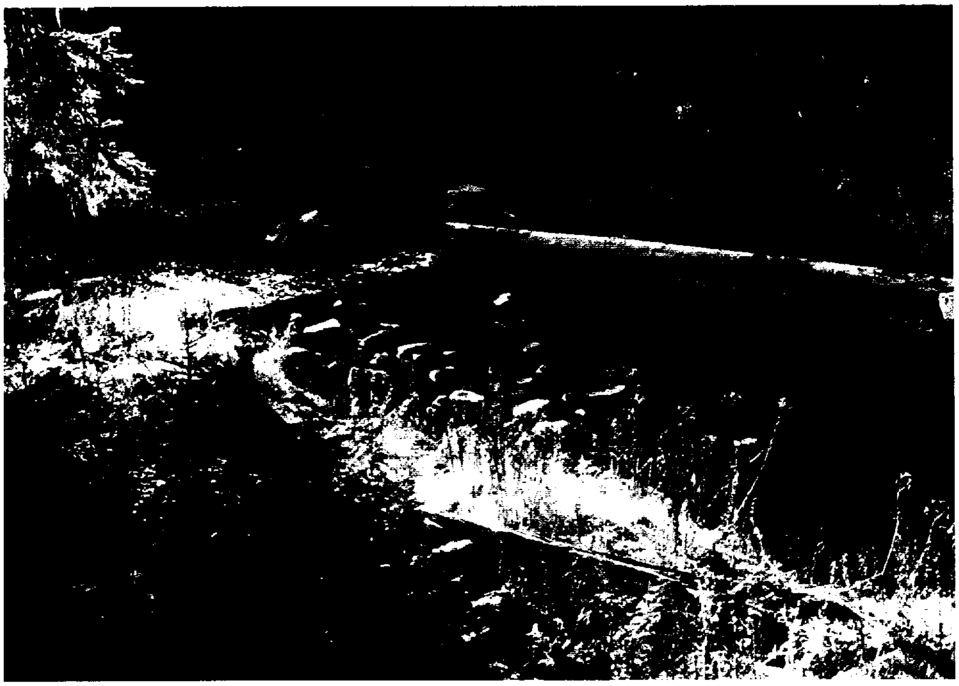
A-7. Post-enhancement survey of Eldorado Creek.

A-8. Summer rearing and spawning habitats In Eldorado Creek, post-enhancement survey.

A-9. Excavator constructing instream habitat in Eldorado Creek.



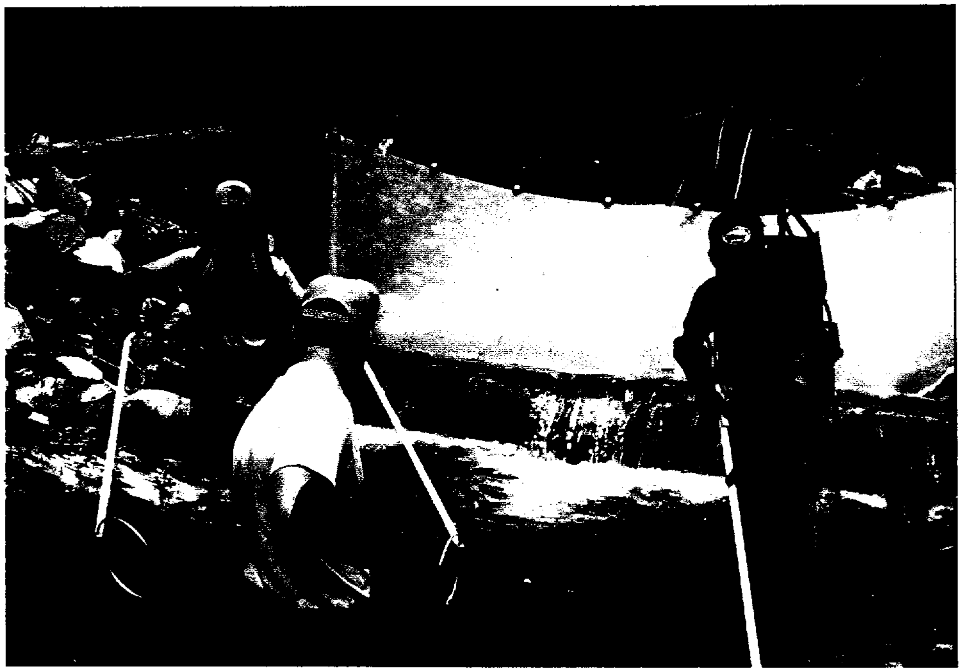
A-l 0. Stocking of adult steelhead (Dworshak) in Eldorado Creek.



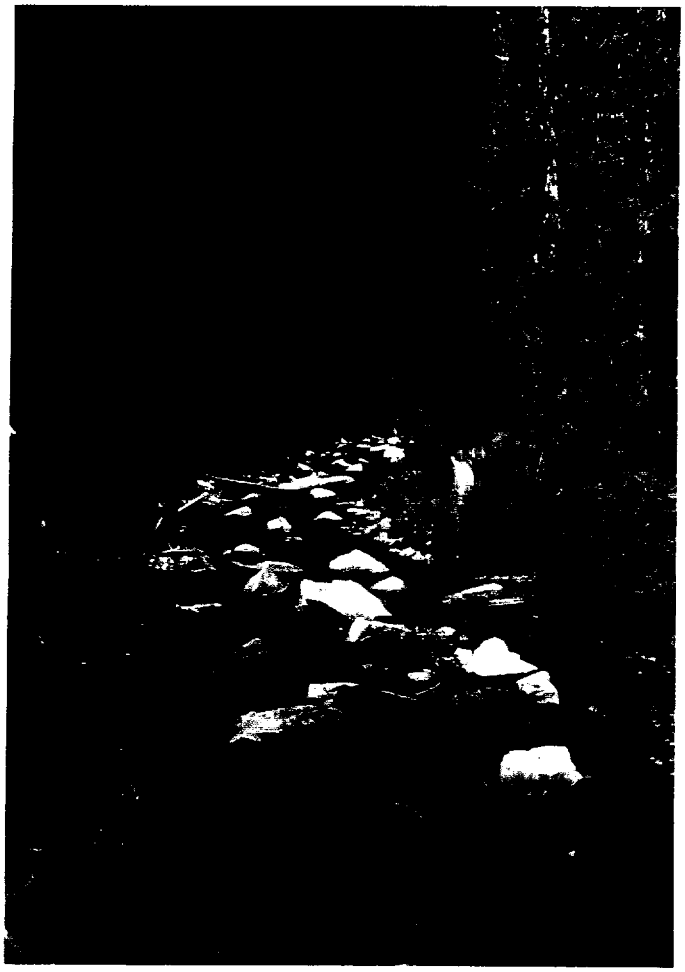
A-l 1. Constructed summer and winter rearing habitats in Lolo Creek.

A-12. Side channel habitat constructed in Lolo Creek.

A-21. Evaluation of salmonid response to habitat enhancement in Pete King Creek (Lower Lochsa system).

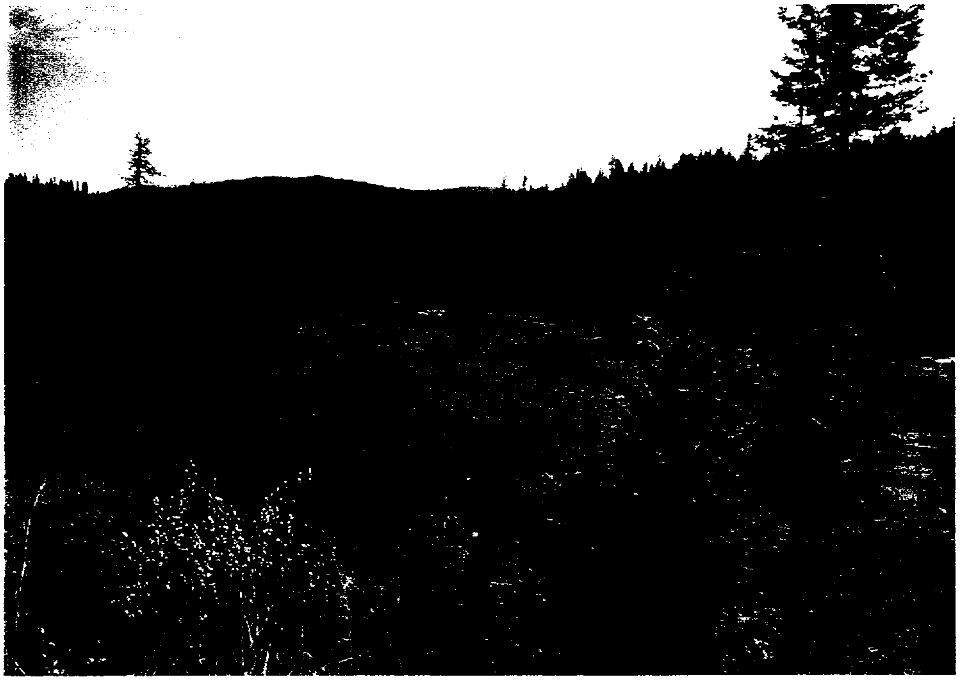


A-22. Electrofishing in Squaw Creek to evaluate response to habitat enhancement.

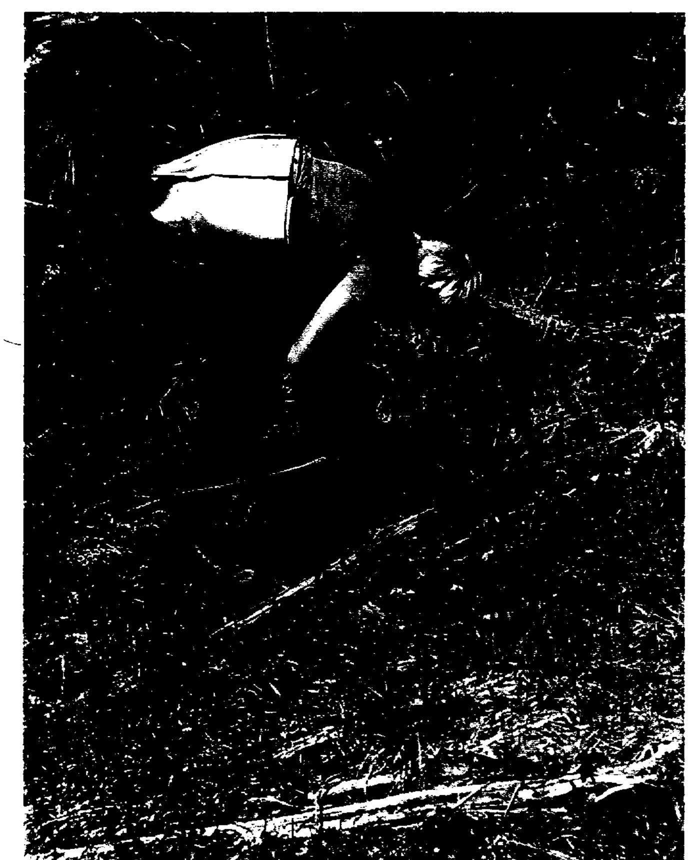


A-13. A "B-channel" reach in Lolo Creek enhanced with boulders.

A-14. A large log weir with boulder cover in Lolo Creek.



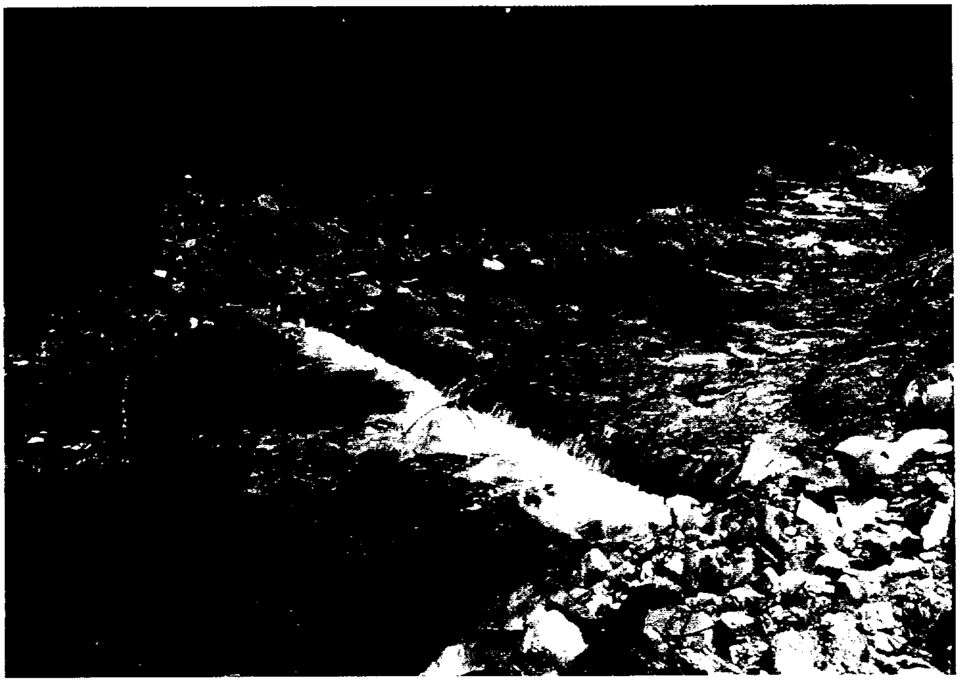
A-15. Riparian habitat and meadow reach of Lolo Creek (section #6) that was fenced to exclude cattle.



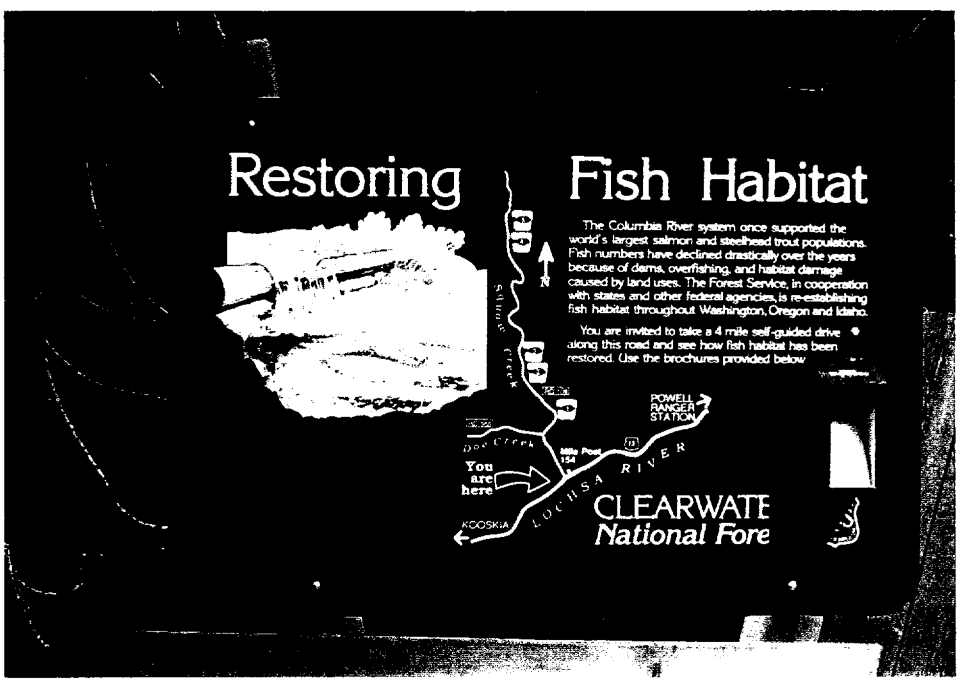
A-l 6. Riparian **planting along Lolo** Creek.

A-17. Debris barrier in Yoosa Creek (Lola system) prior to removal with explosives.

A-18. Boulder and debris barrier in Musselshell Creek (Lolo system) removed with explosives.



A-l 9. Diagonal log weir with woody debris cover in downstream pool. Spawning habitat in upstream pool - Doe Creek (tributary of Squaw Creek).



A-20. Public Information sign and tour route on Squaw Creek detailing project activities and examples of fish habitat restoration.