April 2000

CLE ELUM LAKE ANADROMOUS SALMON RESTORATION

FEASIBILITY STUDY: SUMMARY OF RESEARCH

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CLE ELUM LAKE ANADROMOUS SALMON RESTORATION FEASIBILITY STUDY: SUMMARY OF RESEARCH

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EXECUTIVE SUMMARY

Between 1987-1993, the National Marine Fisheries Service (NMFS), Northwest Fisheries Science Center, conducted a Bonneville Power Administration (BPA)-funded study of the feasibility of restoring sockeye salmon to Cle Elum Lake in the Yakima River Basin. Recently, renewed interest has emerged concerning the possibilities of providing anadromous fish passage above Cle Elum Dam as part of water storage improvements under Section 1206 of the 1994 Yakima River Basin Water Enhancement Project Act, Title XII of Public Law 103-434. NMFS provides the following summary overviews of research projects conducted at Cle Elum Lake under BPA Contract DE-AI79-86-BP64840, Project 86-45 with the hope of providing a foundation to expedite development of these fish passage alternatives.

Construction of irrigation dams without fish passage facilities resulted in the extirpation of sockeye salmon from the Yakima River Basin in the early 1900s. At the onset of the program in 1987, sockeye salmon were considered by many investigators to be difficult to culture. High prespawning mortality, inability of fish to mature in captivity, low egg viability, and low fry-to-smolt survival due to a viral pathogen (infectious hematopoietic necrosis) were viewed as potential barriers to success.

Prior to our study, sockeye salmon culture had been terminated in Washington State in the 1960s due to these problems. Initial phases of the study demonstrated that combinations of net-pen holding of prespawning adults in a lacustrine environment and isolated incubation and rearing of progeny could produce healthy juveniles for research and enhancement of extirpated runs. The study provided information that helped reestablish sockeye salmon culture in the state of Washington. During 1989-1993, NMFS annually outplanted about 100-350,000 sockeye salmon juveniles at Cle Elum Lake.

Merwin trapping efforts in Lake Cle Elum during spring 1990-1993 indicated that in most years juvenile sockeye salmon outplanted to the lake survived and grew well. Investigation of fish passage from the tailrace of Cle Elum Dam through the Yakima River system during 1989-1993 suggested there were no severe blockages to migration of sockeye salmon in the Yakima River system downstream of Cle Elum Dam during the normal late-March to early-May period of smolt outmigration for sockeye salmon in the Columbia River Basin. However, fish passage studies at Cle Elum Dam during spring 1989-1993 suggested a fish passage problem at the dam during much of the outmigration period. The results of the studies suggest that, if mechanical traps and fishways are constructed at Cle Elum Dam, sockeye salmon can be restored to Cle Elum Lake. However, these traps will need to be constructed to pass fish at forebay elevations up to 10 m lower than the current spillway elevation.

Although the focus of research was on defining lake and river conditions under which sockeye salmon can survive and outmigrate, the potential for success was heightened with the return of adult fish. In 1991 and 1992, four and seven adults, respectively, returned from pilot-scale smolt releases. In 1993, over 20 adults returned. These first returns of sockeye salmon to the Yakima River Basin in over 60 years were extremely encouraging regarding the potential for supplementation to aid in recolonization of lost habitat above Cle Elum Dam.

PREFACE

Support for this research came from electrical rate payers of the Pacific Northwest through the Bonneville Power Administration.

DISCLAIMER

Reference to trade names does not imply endorsement by the National Marine Fisheries Service, NOAA.

CONTENTS

INTRODUCTION

During the late 1980s-mid 1990s, the National Marine Fisheries Service (NMFS) conducted a series of Bonneville Power Administration (BPA) funded research projects (BPA Contract DE-AI79-86-BP64840, Project 86-45) aimed at studying the feasibility of restoring anadromous salmon above irrigation reservoirs in the Yakima River Basin of Washington state (Fig. 1). The Yakima River system historically supported large runs of anadromous salmonids which contributed significantly to the Columbia River harvest. Habitat destruction and overfishing drastically reduced run abundance by the early 1900s. Subsequently, salmon runs were extirpated from upper reaches of the Yakima River Basin by the construction of irrigation storage reservoirs without fishways at Cle Elum, Kachess, Keechelus, and Bumping Lakes (Davidson 1965, Robison 1957, Mullan 1986). A focus of the NMFS research was to study the feasibility for anadromous salmonids to recolonize the habitat above reservoirs in the Yakima River Basin without disruption to irrigation withdrawals. A primary concern was whether anadromous fish could successfully exit reservoirs and survive downstream passage through the Yakima and Columbia Rivers to the ocean.

Cle Elum Lake was selected as the test site for the restoration study because it was the largest of the four irrigation storage reservoirs in the Yakima River system, and because it was considered to have the greatest volume of fish spawning and rearing habitat in and above the reservoir. Sockeye salmon (*Oncorhynchus nerka*) were selected as the anadromous salmon test species because they could best utilize the primarily mid-water, plankton-oriented rearing habitat available in Cle Elum Lake at the time (Mongillo and Faulconer 1982). Because anadromous sockeye salmon were extirpated from the Yakima River Basin, it was necessary to develop a donor stock derived from sockeye salmon returning to the adjacent Wenatchee River Valley.

During the course of the study, innovative fish culture techniques were employed that helped lead to the resurrection of sockeye salmon culture in Washington State. Importantly, these techniques formed a foundation of husbandry approaches that were subsequently used to help prevent extinction of U.S. Endangered Species Act (ESA)-listed Redfish Lake sockeye salmon in Idaho (Flagg et al. 1995, 1998). Recovery of donor stock juveniles released in the Yakima River Basin provided information indicating that it was feasible to restore anadromous salmon above Cle Elum Reservoir. No severe impediments to outmigration were noted though the Cle Elum and Yakima Rivers. However, the irrigation dam on Cle Elum Lake was noted as an obstacle to both downstream and upstream migration. In addition, the springtime fill/spill cycle of the reservoir was noted to be often out of synchrony with the springtime outmigration needs of the fish; this led to a recommendation to develop a juvenile bypass capable of operating at levels 10+ m below current spilldeck elevation. Spawning ground evaluations indicated sufficient habitat to accommodate returning adult fish. However, limnological evaluations of the zooplankton-based food resources in Cle Elum Lake suggested that inlake fertilization may be necessary to increase carrying capacity for juvenile anadromous salmonids. Releases of fish from the study resulted in the first returns of anadromous sockeye salmon to the Yakima River Basin since the early 1900s.

Information from the results of these studies have been presented in a number of ways including: 1) over two dozen articles, reports, and fisheries meeting proceedings (Slatick 1987a-c; Slatick and Mighell 1987; Flagg and Mighell 1988; Harrell and Flagg 1988; Flagg and Harrell 1989; Flagg 1989; Flagg et al. 1988; 1989a-b, 1990a-e, 1991a-e, 1992a-b, 1993a-b) and 2) during the years of the study, at monthly meeting of the BPA/Yakama Indian Nation sponsored Yakima Basin Fisheries Project Technical Work Group. Nevertheless, information from the research projects was never formally consolidated. Recently, renewed interest has emerged concerning the possibilities of providing anadromous fish passage above Cle Elum Dam. Section 1206 of the 1994 Yakima River Basin Water Enhancement Project Act, Title XII of Public Law 103-434 provides for increased storage capacity in Cle Elum reservoir. The Act also contains provisions for developing fish passage alternatives. NMFS provides the following summary overviews of research projects conducted at Cle Elum Lake under BPA Contract DE-AI79-86-BP64840, Project 86-45 with the hope of providing a foundation to expedite development of these fish passage alternatives.

Description of Study Area

1) Study site:

The Yakima River Basin (Fig. 1) is the second largest sub-basin of the Columbia River Basin in Washington State. The river originates high in the Cascade Mountains, then runs 320 km through the Yakima Valley to join the Columbia River near Richland, Washington. Its headwaters drain approximately 15,540 km^2 of the eastern slopes of the Cascades and carry off more than 3.7 billion m^3 of water each year, most of which is dedicated to irrigation (Mongillo and Faulconer 1982, Mullan 1986).

Cle Elum Lake is the largest of the four irrigation storage reservoirs in the Yakima River Basin (Fig. 2). Cle Elum Dam is the only apparent physical barrier to the restoration of salmonid populations to Cle Elum Lake. The dam was built without any provision for migrating juveniles or adults, and blocks the access of fish to considerable spawning and rearing habitat. It was constructed in the early 1930s by the U.S. Bureau of Reclamation (USBR), and the high (40 m) earth and concrete dam increased the maximum surface area of the lake from about 1,210 ha to about 2,020 ha at full pool. It provides about 0.56 billion m^3 of water for irrigation in the Yakima River Valley.

2) Study species:

Mature Columbia River Basin sockeye salmon are comparatively small fish (average weight 1.4 - 3.6 kg) which spawn during early fall along the shores of lakes or in tributaries to lakes. The young emerge from the gravel in the spring and usually spend between 1 - 2 years in a nursery lake before migrating to sea as smolts. Outmigration of smolts from the Columbia River Basin usually occurs between late March and early May. These fish remain 2 - 3 years in the ocean before returning as adults to spawn. The adults enter their home river system from late June through early August, spend the summer months in their nursery lake, and spawn in natal areas in September through October (Foerster 1968, Mullan 1986, Burgner 1991).

3) Study objectives:

An ecosystem-based approach is required to successfully restore fish in habitats; all aspects of the species/habitat interface must be properly functioning for supplementation to succeed. The studies described in this report were designed to answer key questions relating to whether restoration of self-supporting populations of anadromous salmon to Cle Elum Lake would indeed be possible. They were:

1) Could a suitable sockeye salmon donor stock be identified and successfully cultured to provide juveniles for conducting survival and outmigration studies at Cle Elum Lake?
2) Would existing habitat and forage permit juvenile fish stocked into the lake to survive through smoltification?
3) Does adequate spawning habitat for returning adults exist above Cle Elum Lake?
4) Would smolted juveniles orient to the lake outlet and attempt to leave the lake at appropriate times of the year? If not, could biological or engineering solutions be developed?

5) Could smolts leaving the lake successfully migrate downstream through the Cle Elum and Yakima Rivers?
6) Could adults return through the Yakima River to the proximity of Cle Elum Lake?

Positive answers to all the above questions were considered a requirement for a determination of feasibility of restoring sockeye and other anadromous salmonids to underutilized habitats in and about Cle Elum Lake.

SECTION I: SUMMARY OF FISH HUSBANDRY RESEARCH

From research by: Thomas A. Flagg, James L. Mighell, Lee W. Harrell,
Thomas E. Ruehle, Emil Slatick, Tony J. Novotny, Carl W. Sims,
and Conrad V. W. Mahnken

Introduction

A first priority to determine the feasibility for anadromous salmonids to recolonize the habitat in and above Cle Elum Lake in the Yakima River Basin was selection of a target species for conducting juvenile outmigration research. Sockeye salmon (*Oncorhynchus nerka*) were selected as the anadromous salmon test species because it was felt they could best utilize the primarily mid-water, plankton-oriented rearing habitat available in Cle Elum Lake at the time (Mongillo and Faulconer 1982). The Yakima River watershed historically supported large runs of sockeye salmon (Robison 1957). Until 1855, sockeye salmon (then called blueback salmon) were listed as the second most abundant salmon in the Yakima River. The early developmental period in the Yakima Valley, from 1850 to 1900, contributed to the rapid decline in fish populations in the Yakima River. The construction of crib dams without fishways in Lakes Keechelus and Kachess in 1904, in Lake Cle Elum in 1905, and Bumping Lake in 1910 eliminated viable sockeye salmon runs from the upper Yakima River Basin (Davidson 1965).

Because anadromous sockeye salmon were extirpated from the Yakima River Basin 50 years ago, it was necessary to develop a suitable donor stock. Fortunately, the adjoining (Wenatchee River) basin to the north had a viable anadromous run of sockeye salmon with presumed (genetic and run-timing) similarities to the historic Yakima River Basin stock (Fig. 1). Lake Wenatchee also was considered geographically and limnologically similar to Cle Elum Lake (Mongillo and Faulconer 1982, Mullan 1986).

Therefore, adult sockeye salmon returning to the Wenatchee River Basin were selected as a suitable donor stock to provide juveniles for transplanting to Cle Elum Lake.

At the onset of the program, sockeye salmon were considered by many to be difficult to culture. Previous attempts to rear sockeye salmon in captivity were hindered by high prespawning mortality, low rates of maturity, low egg viability, and low fry-to-smolt survival due to infectious hematopoietic necrosis (IHN) viral disease (Mullan 1986, Amos et al. 1989, Meyers et al. 1990). The culture of sockeye salmon in Washington State was in fact terminated in the 1960s because of such problems (Mullan 1986). Yearly incidence of IHN virus in naturally spawning Lake Wenatchee sockeye salmon was seen as a possible barrier to transplanting juveniles to the Yakima River Basin. Although the Yakima River Basin was considered an IHN positive watershed, policy and reason dictated that only IHN-negative fish be transferred to the Yakima Basin. These problems were resolved during the course of this study through strict disease prevention techniques and modern culture methodologies which were specifically adapted for use with sockeye salmon.

For the study, returning adult sockeye salmon were captured during their upstream migration in the Wenatchee River, transported to Lake Wenatchee, and held to maturity in floating net-pens (Figs. 1 and 3). They were then spawned, and the gametes transferred to the NMFS Northwest Fisheries Science Center (NWFSC) in Seattle for incubation and early rearing (Fig. 4). All spawners were surveyed for the presence of IHN, and eggs were incubated in a quarantine system. Certified IHN-free progeny of these groups were then transported to Cle Elum Lake (Fig. 4) each year for use in the various research activities described in subsequent sections of this report. An overview of fish husbandry activities are presented below.

Adult Fish Collection and Holding

From 1988-1992, between 263-520 returning adult sockeye salmon were captured yearly from the Wenatchee River (Table 1) at either Dryden Dam (1987 and 1988) or Tumwater Dam (1988, 1989, 1990, 1991, and 1992). Fish were generally captured near the peak timing of run return in mid-late July. Captures at Dryden Dam utilized the Chelan County Public Utility District's fish collection system at the dam. For captures at Tumwater Dam, NMFS installed a temporary Denil trap system in the fishway at the dam (for a description of a Denil steep pass system, see Rajaratnam and Katopodis 1984). Each year, NMFS was issued appropriate Washington State Department of Fisheries (WDF) scientific collection and fish transfer permits for the collection and transportation of fish and subsequent gametes.

Adult sockeye salmon captured from the Wenatchee River were transported to Lake Wenatchee in a 6,000-liter fish transportation truck. At the lake, fish were transferred to a 9-m long fish-hauling barge containing a set of 25 m^3 holding tanks supplied with pumped flow-through water. The fish were then barged out to a set of floating modular net-pens located near the upper end of the lake in 12- to 15-m of depth within 500 m of the mouth of the White River (Fig. 4). Each 4.8-m square module consisted of wood and steel walkways supported by styrofoam floats and contained one 7.5-m deep net with 3.8-cm stretch mesh. All fish were held at densities of about 1.5 kg/m^3 in net-pens in Lake Wenatchee for up to 91 days to maturity. Between 1987-1992, survival from capture to spawning ranged from 71-95% (Table 1).

Spawning

Maturing adult fish were sorted by appearance according to stages of maturity during mid-to-late September. Between 250-504 fish were spawned each year (Table 1). To inspect potential spawners, each net-pen was raised gradually (approximately 2.5 m/5 minutes) to a final depth of about 1.5 m. All fish were crowded to one side and the pen was divided into halves. Fish were then lifted by the caudal peduncle and checked for ripeness. For female fish, gentle pressure was applied anterior to the vent to determine looseness of the egg mass and, if ripe, a few eggs were expressed to visually examine egg quality. Males were checked for milt in a similar manner.

Mature females with free-flowing eggs were loaded onto the transport barge into one holding tank and mature males were placed in the other tank. Fish not yet mature were immediately returned to the unoccupied section of the net-pen. The transport barge was then moved to the beach and the fish were spawned in a portable spawning trailer. All discharge water from the trailer was routed through a central drain to a settling basin and periodically disinfected with a solution of 100 ppm iodophor.

At the trailer, fish were killed by a blow to the head, placed in a V board, and bled by cutting the gill arches. After bleeding, carcasses were disinfected in 100 ppm iodophor. Female carcasses were opened by surgical incision of the abdomen and eggs collected into individually numbered plastic bags. Milt from males was expressed into individually numbered vials by gentle pressure anterior to the vent. Eggs and milt were transported to the NWFSC in Seattle (Fig. 3) in insulated coolers containing ice (about a 2.5-hour trip).

Between 1987-1992, male spawner size (fork length) ranged from about 500-545 mm average and female spawners ranged from 490-520 mm. Female fecundity ranged from about 2,225 to 2,725 eggs/fish. Average eyed egg survival (viability) ranged from 40 to 80% (Table 1). Fertilization of eggs began immediately upon arrival at the laboratory. Ovarian fluid was rinsed from each (individual female) egg lot. In 1988, eggs were fertilized and water hardened in iodophor in an effort to limit potential vertical disease (IHN) transfer. However, this appeared to result in unacceptably low egg viability (Table 1). Therefore, in subsequent years, egg lots were placed in a 1-liter plastic container and fertilized (dry method) with the sperm from one male. Fertilized eggs were then water hardened for an initial 3 to 5 minutes and then disinfected in 100 ppm iodophor solution for an additional 10 minutes.

Viral Certification

A potential drawback in using the Wenatchee River stock sockeye salmon as a donor stock for studies in the Yakima River Basin was that they were known to be heavily infected with IHN on the spawning grounds (Mullan 1986). The Yakima River System, on the other hand, was considered to be relatively free of IHN. Therefore, a primary concern was ensuring that any broodstock, and subsequent juveniles, used for the studies were free of IHN virus. During the program, each adult male and female spawner (Table 1) was examined for the presence of IHN and other replicating viruses by an American Fisheries Society Board certified Fish Pathologist. In addition, representative samples of offspring (Table 2) were also analyzed.

For 1988-89, the health certification was conducted by the Battelle Marine Laboratory in Sequim, Washington. For 1990-92, the analyses were conducted by the WDF virology laboratory in Olympia, Washington. IHN viral incidence of fish held in the net-pens appeared to have little resemblance to prevalence on the spawning grounds. Natural spawners in the Lake Wenatchee headwater streams (Fig. 3) remained (usually highly) positive in all years, while net-pen held spawners were 100% negative in 1987-88 and 1991-92 and only 30 and 21% positive in 1989 and 1990, respectively.

Investigators now believe that IHN may be primarily contracted and spread through horizontal transmission from a low number of heavily infected carriers (Wolf 1988, Amos et al. 1989, Meyers et al. 1990). Our results support this hypothesis. It is probable that no IHN-carrier fish were captured in 1987-1988 or 1991-1992. In 1989 and 1990, one to several of the captured fish may have been carriers that served as a focus for limited spread of IHN virus in net-pen-held fish. Net-pen isolation of prespawning salmon appears to be a promising management technique to help produce healthy donors for aiding rebuilding of depleted stocks.

Eggs from positive spawners were donated to WDF for use in enhancement of the Lake Wenatchee run. Only eggs from viral-free groups were retained for use in the Yakima. Importantly, juveniles from these groups (Table 2) remained 100% IHN virus negative during rearing.

Fish Rearing

Eggs were incubated and juveniles reared at a hatchery at the NWFSC in Seattle. The laboratory conformed to state and federal isolation and quarantine standards. Over 280 isolation incubators (Novotny et al. 1985) were used to hold eggs from individual paired matings. In addition, rearing spaces were segmented into several isolation areas containing 1.2-1.8-m circular tanks (over 50 total) to maintain quarantine standards. The facility was supplied with pathogen-free water processed through a series of dechlorinators and chillers to ensure quality. Fish were reared using standard fish culture methods (Piper et al. 1982). Between 1988-1993, juvenile survival ranged from about 80 to 90%. In general, the size of fish released in late summer to early fall ranged from 5-10 g and 70-100 mm, and that of yearling smolts was 10-20 g and 100-130 mm.

Juvenile sockeye salmon were outplanted from the NWFSC to the Yakima River Basin every year between 1988-1993. The specific details of each outplanting are given in Table 2. The majority of juveniles from each brood-year were released into Cle Elum Lake to provide a population for recovery evaluation. Most releases into Cle Elum Lake were made in late summer to early fall, anticipating that they would first overwinter in the lake and then outmigrate naturally the next spring. However, in some years fish were also released to the lake in early spring. The remainder of the juveniles were released into the tailrace of Cle Elum Dam to aid in delineating springtime changes in fish passage conditions through the Yakima River system. In most cases, all the released fish were given coded-wire-tags (Jefferts et al. 1963) and freeze-branded (Park and Ebel 1974). Sub-samples were also PIT tagged (Prentice et al. 1990a, 1990b).

Discussion

Husbandry techniques of spawner isolation and quarantine rearing of juveniles were successful in providing a donor stock of sockeye salmon for use in determining the feasibility of restoring anadromous salmon runs above irrigation reservoirs in the Yakima River Basin. The husbandry portion of the study provided almost 940,000 juveniles that were released in, or just below, Cle Elum Lake (Table 2). In fact, the techniques utilized in the program were judged successful enough that they ultimately formed a foundation of husbandry approaches that went on to be used to help prevent extinction of ESA-listed Redfish Lake sockeye salmon in Idaho (Flagg et al. 1995, 1998). Details of lake and river releases can be found in following sections (Section IV) of this report.

SECTION II: SUMMARY OF CLE ELUM LAKE WATERSHED SURVEYOF POTENTIAL ANADROMOUS SALMONID SPAWING HABITAT

From habitat surveys by: Emil Slatick and Vic Park

Introduction

Cle Elum Lake is the largest of the four reservoirs in the Yakima River Basin (the others are Kachess, Keechelus, and Bumping Lakes) that originally supported sockeye and other anadromous salmonid runs. Reestablishment of self-sustaining anadromous sockeye salmon runs in these now unproductive areas could significantly enhance the salmonid resource of the Yakima River Basin. A basic requirement for reintroduction of anadromous salmonids is availability of suitable spawning habitat. Cle Elum Lake has a large and diverse watershed consisting of the main Cle Elum River above the lake and five major tributary streams (Fig. 2). Three of these watercourses (the Cle Elum, Cooper, and Waptus Rivers) contain substantial potential spawning habitat for anadromous salmonids (Spotts 1981). Representative areas within the watershed were surveyed in an effort to determine potential quality and carrying capacity of spawning habitats. Information from these surveys is presented below. In addition, several upstream blockages to migration are identified and passage improvements suggested.

Fish Passage Barriers

Cle Elum River

The upstream barrier on the Cle Elum River is Cle Elum Falls (Fig. 2). Cle Elum Falls can be seen and reached from the USFS Road 4330 between Camp and Fortune Creeks. This barrier consists of three principal waterfalls and extends over a distance of about 100 m. The first falls is the largest and is estimated to be about 3 m high and the other two falls are each about 2 m high. These falls would probably require considerable engineering modifications to provide adequate fish passage.

Cooper River

The major barrier on the Cooper River is located approximately 1 km up the Cooper River trail from Salmon La Sac (Fig. 2). This barrier consists of about six small waterfalls flowing over steep rocks and extending for about 100 m. The largest of the falls is estimated to be about 1.5 to 2 m high. This barrier could probably be made passable for fish and still retain its scenic value by selectively blasting some of the falls and constructing additional pools.

Waptus River

The barrier on the Waptus River is Waptus Falls located in the Alpine Lakes Wilderness area (Fig. 2). The falls are located about 100 m upstream from the Hour Creek campsite, and are a 2 hour walk up the Waptus Lake trail from Salmon La Sac. This barrier consists of a series of three waterfalls extending for about 10 to 15 m. The first falls is the largest and is estimated to be over 6 m high. These falls are an absolute block to upstream fish passage and would probably require laddering for anadromous fish passage.

Results of Spawning Habitat Surveys

Cle Elum River

The section of the Cle Elum River above Cle Elum Lake extends about 22 km from Tucquala Lake to the upper (full pool) end of Cle Elum Lake (Fig. 2). The Cle Elum River was surveyed for potential spawning habitat in two representative areas consisting of a small (about 0.5 km) section directly above full pool elevation and a 4.5 km section directly below Tucquala Lake.

Spawning habitat within the 4.5 km surveyed section from Tucquala Lake to Fortune Creek was judged to be composed mostly of good spawning substrate (Fig. 2). The area appeared to have a minimal usable width of 2-4 m. If 30% of the area were actually prime habitat, this would represent a minimum of about 3,000 m^2 of spawnable habitat (Fig. 2). Sockeye salmon spawning redds in good gravel spawning habitats in the Lake Wenatchee watershed averaged 1.5-2.0 m^2 at high density spawning, with optimal habitat needs per pair of adults estimated to be up to four times these observed ranges (Foerster 1968). Based on these estimates, the section of habitat between Tucquala Lake and Fortune Creek might be able to accommodate 500-2,000 spawning pairs. However, it should be noted that considerably more in-depth spawning habitat evaluations are needed for accurate determination of area-specific carrying capacities. It should also be noted that this upper river area is above a series of falls (see Fig. 2, and above) that may block adult passage under many water flow conditions.

Spawning habitat within the surveyed section (about 0.5 km) just above full pool elevation was judged to be made up of intermediate quality substrate with a minimal usable width of 10 m, for a minimum total of about 5,000 m^2 of spawnable habitat in this section (Fig. 2). A combination of intermediate-to-large cobble spawning gravel substrates appears representative of most of the main Cle Elum River for the next 15 km from the survey section to the Fortune Creek area (Fig. 2). However, Cle Elum River volume and width (and subsequent usable spawning habitat) is reduced significantly after the confluence with the Cooper and Waptus Rivers. While good information is available concerning spawner capacities of prime habitats (see above), carrying capacity information for marginal habitats is harder to estimate. A spawning area comparable to the survey area (5,000 m^2) might support 1-3,000 pairs of fish if it were prime habitat.

However, the more marginal quality of the surveyed habitat would probably support only a fraction of that number. Nonetheless, in aggregate, the 15 km of habitat from the surveyed section to the Fortune Creek area would probably support many thousands of spawning pairs. Again, it should be cautioned that considerably more in-depth spawning habitat evaluations are need to for accurate determination of area specific carrying capacities.

Cle Elum Lake, Upper Lake Bed

In the fall of the year, large sections of the upper end of Cle Elum Lake are exposed due to the effects of summer irrigation discharge lowering the reservoir level. During the survey (October 1986), approximately 5.5 km of lake bed was exposed (Fig. 2). The upper 1.5 km section had intermediate spawning habitat as characterized above. The next (approximately 1.5 km) section of river bed downstream was mostly large cobble and had poor spawning potential. After this section, the river split into two main channels about half way through the dry lake bed; each section had about 2.5 km of potentially good spawning habitat. Estimated usable spawning habitat width varied from about 5-10 m throughout the section. The lower sections below the channel split alone probably contained over 25,000 m^2 of good spawning habitat.

Based on minimal and optimal redd densities suggested in Foerster (1968; see above), the "dry lake bed" section (Fig. 2) could probably theoretically support at least 6-15,000 spawning pairs. However, this area may not be functional spawning habitat in many years. In years that the "dry lake bed" section remained exposed from spawning until fry emergence, the habitat would probably function correctly for a stream spawning stock. However, in years when the irrigation storage flooded the upper lake bed section prior to fry emergence, severe alterations in incubation temperature would probably occur, causing sub-optimum emergence timing and lowered fry performance and survival.

Cooper River

The Cooper River had good spawning conditions from just above Cooper Lake upstream into the wilderness area (Fig. 2). The spawning potential was estimated to be over 10,000 m^2 spawnable gravel. However, a series of waterfalls exists below the survey area; these could be a block to adult upstream passage (see above). Below Cooper Lake, the river areas surveyed had much less spawnable gravel than the upper reach. However, numerous dry channels containing good gravel were located in the area and may become available with changing river conditions. If all habitats in the Cooper River were available, a range of 2-5,000 spawning pairs could probably be accommodated. However, most of this potential would rely on passage being available to upper areas, and, as noted above, considerable more in-depth spawning habitat evaluations are need to for accurate determination of area-specific carrying capacities.

Waptus River

The Waptus River from Waptus Falls to the confluence with the Cle Elum River had poor spawning potential (Fig. 2). The river bed had large cobble and rocks with few pockets of spawnable gravel. Although Spotts (1981) indicated that the river above the falls has a very high spawning potential, the falls are a block to migrating salmonids.

Discussion

Spotts (1981) estimated that the main Cle Elum River had over 18,000 m^2 of spawnable gravel. At spawning capacities estimated by Forester (1968; see above), Spotts' (1981) estimate for the main Cle Elum River would equate to a minimum of 3-

12,000 spawning pairs. Our surveys suggest that considerable additional spawning potential is available throughout the Cle Elum River watershed. Because of the destabilized nature of the shoreline of Cle Elum Lake from the fill-spill cycle of the reservoir, little littoral spawning habitat is probably available in the lake itself.

SECTION III: CLE ELUM LAKE PRODUCTIVITY AND FERTILIZATION POTENTIAL

From literature reviews by: Douglas B. Dey

Introduction

Cle Elum Lake is the largest but least productive of the major irrigation reservoirs in the Yakima River Basin (Goodwin and Westley 1967, Mongillo and Faulconer 1982). There is evidence that production levels were much higher in Cle Elum Lake prior to the damming of the lake and the elimination of its anadromous sockeye salmon runs. To re-establish the Cle Elum Lake sockeye salmon runs, one of the basic requirements is that productivity levels in the lake be sufficient to support the pre-migratory juvenile population. This report discusses the recent productivity status of Cle Elum Lake, reviews the results of relevant lake fertilization studies, and assesses the suitability of Cle Elum Lake for artificial fertilization.

Cle Elum Lake Productivity

Cle Elum Lake is one of six Yakima Project storage reservoirs located on the east slope of the Cascade Mountains. Before the construction of its dam, the lake contained a variety of sport fish including mountain whitefish (*Prosopium williamsoni*), rainbow and cutthroat trout (*Oncorhynchus mykiss* and *clarki*), Dolly Varden (*Salvelinus malma*) and burbot (*Lota lota*). Sockeye salmon used the lake for rearing and, along with coho (*0. kisutch*) and chinook (*0. tshawytscha*) salmon, the streams above the lake for spawning (Robison 1957, Mongillo and Faulconer 1982). The carcasses of spawning salmon in streams running into Cle Elum Lake provided a substantial and reliable source of nutrients which was greatly reduced once the dam obstructed the salmon runs. What remains is a much larger body of water (when full) which receives considerably less nutrients.

The productivity of temperate lakes or reservoirs is often determined by the amount of phosphorus present and how efficiently it is used by algae. Mongillo and Faulconer (1982) evaluated the production potential of Cle Elum Lake using different methods which considered direct phosphorus measurements, phosphorus to chlorophyll ratios, measurements of total dissolved solids or conductivity, and mean depth. The results not only indicated that Cle Elum Lake is clearly oligotrophic but that its production potential may be among the lowest of the relatively unproductive Yakima Basin reservoirs. In addition, all trophic levels of the reservoirs were examined individually with basic water chemistry, chlorophyll a, zooplankton, benthic invertebrate, and fish data. Cle Elum Lake ranked lowest for invertebrate and fish production and lowest overall when production of all trophic levels was averaged.

Bioassays conducted by Mongillo and Faulconer (1982) determined the growth stimulation of the alga *Selenastrum capricornutum* in Cle Elum Lake water using different nutrient additions. The results strongly indicated that algal biomass (dry weight) was phosphorus limited (Fig. 5). There were no significant differences between individual additions of nitrogen or trace elements and the controls. Phosphorus addition alone, nitrogen plus phosphorus addition, and nitrogen, phosphorus and trace element addition all resulted in significantly greater growth response than controls. However, nitrogen plus phosphorus addition did not result in significantly increased growth over phosphorus addition alone. Trace element deficiency was indicated by the significantly greater growth in those replicates containing phosphorus, nitrogen and trace elements over either the phosphorus addition or the nitrogen plus phosphorus groups. Table 3 lists the specific trace elements and concentrations added to Cle Elum Lake water in the bioassays.

In lakes with well-oxygenated bottoms such as Cle Elum Lake, phosphorus is eventually tied up in the sediments. Mongillo and Faulconer (1982) reported the analysis of frozen core samples extracted from the original Cle Elum Lake bed in 1980 and 1981.

They found a large phosphorus peak in each of the cores which was attributed to phosphorus released from the land inundated immediately after dam construction in 1933. Because of the alleged pre-dam salmon runs, a high, sustained level of phosphorus was expected to be found in the pre-1933 sediment. These high levels were not detected. However, examination of drawings of the original crib dam fish ladder (constructed in 1906) indicated that fish probably could not pass the crib dam except when the reservoir was full. As it is unlikely the reservoir would have been full in late summer when many of the sockeye salmon were ready to enter the lake, a high level of phosphorus would more likely be observed in sediments deposited prior to the crib dam's construction. Statistical analysis by Mongillo and Faulconer (1982) indicated no significant difference between post-1933 and pre-1933 or post-1906 data. However, post-1906 and pre-1906 phosphorus data were significantly different. Before1906, there was an average of 19% more phosphorus deposited in the sediment each year. These results suggest that salmon runs were probably eliminated by the crib dam in 1906 rather than by the 1933 dam, and that salmon carcasses once contributed appreciably to the phosphorus load of Cle Elum Lake.

Lake Fertilization Studies

The artificial fertilization of lakes and ponds to increase production has a long history in Asian and European fish culture. The first North American study of lake fertilization (Juday and Schloemer 1938) concerned an oligotrophic Wisconsin lake and was followed by studies of lakes and reservoirs in the eastern and southeastern United States (Swingle and Smith 1938, Surber 1943, Swingle 1947, Ball 1949). In Canada, there were a number of early reports on attempts to increase salmonid production by fertilizing small lakes and streams (Huntsman 1948; Smith 1945, 1948, 1955; Langford 1950). Nelson and Edmondson (1955) and Nelson (1957) reported on the fertilization of Bare Lake, Alaska. More recently, considerable work has been done on nutrient enriched lakes (Edmondson 1969, 1972; Lund 1969; Schindler 1975; Fee 1979; Edmondson and Lehman 1981; Findlay and Kasian 1987; Shearer et al. 1987; Mills and Chalanchuk 1987).

The information most relevant to the Cle Elum Lake sockeye restoration project, however, has come from a series of studies supported by the Lake Enrichment Program of the Canada Department of Fisheries and Oceans, Fisheries Research Branch (Costella et al. 1979, 1982, 1983a,b; Hyatt and Stockner 1985; LaBrassseur et al. 1978, 1979; MacIsaac et al. 1981; Nidle et al. 1984; Perrin et al. 1984; Rankin and Ashton 1980; Rankin et al. 1979; Robinson and Barraclough 1978; Simpson et al. 1981; Shortreed and Stockner 1978, 1981; Stephens and Stockner 1983; Stockner 1977, 1979, 1981; Stockner and Shortreed 1978, 1979, 1983, 1985; Stockner and Manzer 1979; Stockner et al. 1980). The preponderance of data (from 10 years of fertilizing up to 15 sockeye salmon nursery lakes in British Columbia) strongly supports the view that lake fertilization is efficacious and is one of the most cost-effective techniques for sockeye salmon enhancement. Increased production of primary and secondary trophic (food) levels was seen in all fertilized lakes. Smolts leaving most fertilized lakes were larger than in the pretreatment condition, and observed marine survival of returning adults surpassed anticipated levels, with commensurate benefits both to the fishery and the escapement.

While many questions remain regarding how enrichment works and how fertilization techniques can be made even more efficient, there are several conclusions common to most of the reviewed studies: 1) nutrient enrichment leads to increased primary production which leads to increased zooplankton biomass, 2) increased biomass and changes in species diversity of zooplankton enhance the nursery capacity of the lake for resident and anadromous salmonids, as indicated by faster growth and higher survival rates, 3) should it be desired, lake recovery or return to pre-fertilized conditions is relatively rapid following cessation of enrichment.

Suitability of Cle Elum Lake for Fertilization

The low productivity of Cle Elum Lake is most likely related to the phosphorus present and how efficiently it is used by primary producers (Mongillo and Faulconer 1982). It is evident from much of the data collected on Cle Elum Lake, including nitrogen to phosphorus ratios and the bioassay results reported above, that phosphorus is limiting at various times of the year. However, estimates by Mongillo and Faulconer (1982) of total phosphorus load per year (TPO_4-P/m^2/yr) are above maximum load standards for oligotrophic waters (Vollenweider 1976). This suggests that for some reason the algae in Cle Elum Lake are not able to efficiently use the available phosphorus. Using data from 757 lakes, Hem et al. (1981) reported that a mean of 29% of the available phosphorus was converted into chlorophyll. For Cle Elum Lake in May and June 1981, this conversion efficiency was estimated to be approximately 5% (Mongillo and Faulconer 1982).

One of the factors which may affect the utilization of phosphorus by algae in Cle Elum Lake is hydraulic retention time or flushing rate. Dillon (1975) described two Ontario lakes with very different phosphorus loading from inflows and very different water retention times. Because the productivity of the lakes did not differ significantly, he concluded that the different flushing rates led to different phosphorus retention times in the lakes and therefore varied the availability of phosphorus to algae. Mongillo and Faulconer (1982) concluded that a relatively high flushing rate was the most significant cause of poor phosphorus conversion in Cle Elum Lake.

The hypolimnetic discharge of water from Cle Elum Lake during drawdown may also be responsible for a further reduction in phosphorus retention. In natural lakes that lose phosphorus to the hypolimnion, much of it can be remixed during turnover and become available again before reaching the sediments. With hypolimnetic discharge, much of the phosphorus below the thermocline may exit the reservoir. A U.S. Department of the Interior report (1975) estimated that 64% of the inflow loading of phosphorus to Cle Elum Lake was lost to the outflow.

Another factor affecting phosphorus utilization and productivity in Cle Elum Lake is the fluctuating water level. In lakes with no major water level changes, nutrients tied up in the littoral zone are recycled by plants, invertebrates, and fish and eventually end up in the pelagic zone. With dramatically changing water levels, the littoral zone cannot use nutrients for plant growth and therefore many species of benthic invertebrates cannot exist. Among the Yakima Basin reservoirs, the farther a reservoir is drawn down, the fewer and smaller the invertebrates present (Mongillo and Faulconer 1982). An extremely limited biological community in the littoral zone reduces mechanisms for storing and recycling nutrients which periodically arrive in large quantities from runoff or other sources. In Cle Elum Lake, fish probably must feed in the pelagic zone on zooplankton because water level fluctuations have all but removed benthic invertebrates in the littoral area.

Discussion

The negative effects of flushing rate, hypolimnetic discharge, and water level fluctuation on phosphorus availability and productivity in Cle Elum Lake could be offset by the addition of nutrients during the growing season. Mongillo and Faulconer (1982) concluded that phosphorus addition alone could greatly increase productivity in all trophic levels, and that phosphorus with a trace-element addition would almost double that increase. The Lake Enrichment Program of British Columbia was contacted and based on information supplied to them regarding Cle Elum Lake and their experience fertilizing sockeye salmon lakes, they suggested the following: 3 to 5 mg/m^2 of liquid phosphorus per week from April to October; the fertilizer should also include nitrogen with a N:P ratio of 15:1, as well as trace elements (Table 3); the cost for fertilizer and application (by air) was estimated to be $30,000 per year (in 1982).

Because the fertilized Canadian lakes have retained their original trophic state, no algal blooms have occurred, and the streams below have remained unchanged. Mongillo and Faulconer (1982) stated that the only change resulting from adding this fertilizer to Cle Elum Lake each year would be a better fishery. Of course, once the sockeye salmon run has been restored, the need for additional nutrients may be reduced and the fertilization process can be phased out.

The conclusions of this report regarding the suitability of Cle Elum Lake for fertilization are based on data collected more than two decades ago. In order to provide a proper background for meaningful comparisons between pre- and post-fertilization conditions, additional limnological studies of current conditions in the lake should be conducted. This assessment should include the collection of physical, chemical, biological, and fisheries data as well as an evaluation of the possible effects of the recent increased human activity (cabins) near Cle Elum Lake.

SECTION IV: SUMMARY OF OUTMIGRATION STUDIES

From research by: Thomas A. Flagg,, Thomas E. Ruehle,
Emil Slatick, and James L. Mighell

Introduction

A primary concern for the potential of restoring anadromous salmonids above irrigation reservoirs in the Yakima River Basin was whether juvenile fish could successfully exit the reservoir and survive downstream passage through the river. From 1989-1992, NMFS evaluated passage potential at Cle Elum Dam and juvenile survival for about 240 km downstream to Prosser Dam.

Fundamental Practices of Outmigration Studies

Fish Release Practices

Juvenile sockeye salmon were outplanted from the NWFSC every year (Table 2). The majority of juveniles from each brood-year were released into Cle Elum Lake to provide a population for recovery evaluation (Table 2). Most releases into Cle Elum Lake were made in late summer to early fall, anticipating that juveniles would first overwinter in the lake and then outmigrate naturally the next spring. However, in some years fish were also released to the lake in early spring. The remainder of the juveniles were released into the tailrace of Cle Elum Dam to aid in delineating springtime changes in fish passage conditions through the Yakima River. In most cases, all the released fish were coded-wire-tagged (Jefferts et al. 1963) and freeze-branded (Park and Ebel 1974). Sub-samples were also PIT tagged (Prentice et al. 1990a, 1990b). In general, the size of fish released in late summer to early fall ranged from 5 - 10 g and 70 - 100 mm, and that of yearling smolts was 10 - 20 g and 100 - 130 mm (see Section I of this report for husbandry histories).

Facilities for the Acclimation of Juvenile Fish

A temporary fish holding facility and field laboratory were constructed for the program at Cle Elum Dam (Fig. 6) through an interagency agreement between NMFS and USBR. The purpose of the facility was to ensure the necessary acclimation, imprinting, and homing fidelity of groups of smolts transferred from the NWFSC for subsequent release in the Cle Elum River.

The fish holding facility consisted of two Conex containers (2.4 x 12.2 m) fitted with circular tanks (five1.2 m and six 0.9 m diameter tanks). Outside the containers were three 2.4 m diameter circular and two rectangular tanks (2.4 m x 6.1 m x 1.2m). The rearing tank system was supplied with water (up to 400 L/min) pumped from the stilling basin below the dam. NMFS was issued a temporary Washington State Department of Ecology (DOE) Water Withdrawal Permit (# S4-29894) for the non-consumptive use of this water. There was also an office trailer on site.

The facility was used every year to acclimate all groups of juvenile sockeye before release into the tailrace of Cle Elum Dam. The minimum period of acclimation was 2 weeks.

Passage Structures at Cle Elum Dam and Fish Collection Practices

Most of the water withdrawals from Cle Elum Lake are made through a deep discharge tube located at the base of the dam. This effectively prevents surface outmigration. However, the dam has five radial water control gates and a spillway structure which extends 5.2 m below full pool (Fig. 7). The USBR agreed to release water over the spillway to enable an evaluation of the hydraulic system at Cle Elum Dam to allow the passage of fish at the surface. As water released from Radial Gate 1 gave the best depth of water flow along the wall of the east (left-hand downstream) wing and appeared to have the least problem with debris, this gate was selected for the experimental water releases.

At the start of the program all water releases for fish passage were made under Gate 1 and fish recovery was estimated at Prosser Dam downstream. Subsequently it was decided to sample directly at the Cle Elum Dam first. Therefore, two sluice gates (0.6 m and 0.9 m) were installed in Radial Gate 1 together with an incline-plane trap connected to the sluice gate discharge (Figs. 8 and 9). This provided safer exit routes for fish and for sampling. The two sluice gates were designed to discharge the water which otherwise would be passed under the radial gate or through the deep water discharge tube at the dam. Later, a floating intake was connected by transition tubes to one of the sluice gates to provide a surface water outflow at all elevations above the spilldeck (Figs. 10, 11, and 12).

The design of the tubes proved to be inadequate and the system did not operate until heavy-duty tubes were installed. This, together with operational requirements at the dam by USBR to use the spillway to meet extensive spring flood control requirements in 1991 and 1992, interfered with sampling activities at the dam for much of the program. Difficulties with sampling fish attempting to migrate from the lake continued into the following year (1993) when the lake did not fill to the height of the spillway due to drought conditions.

Fish Trapping in Cle Elum Lake

From 1990-1993, Merwin traps were installed in Cle Elum Lake each spring to capture juveniles released in the previous late summer to early fall. The traps were sited in random locations in the vicinity of the spillway and outfall to Cle Elum Dam. The wings of the Merwin trap were directed toward the shoreline (Fig. 13), and caught fish moving in a near-shore pattern close to the surface. The traps were not calibrated for recapture efficiency and, therefore, could not be used to estimate survival or outmigration percentages. However, the traps did provide presumptive assessment of whether fish were congregating in the vicinity of the dam and attempting to outmigrate.

Fish Collection at Prosser Dam

Recovery data for the groups of juveniles released were documented at the Chandler Fish Collection Facility, located at the Chandler irrigation diversion canal at the Prosser Dam (Fig. 6). The facility is about 240 km downstream from Cle Elum Lake. The Yakama Indian Nation (YIN) and the USBR jointly operated the Chandler facility during the years of the study. YIN staff monitored fish collection and provided information on recapture numbers and brand type. NMFS installed a PIT-tag monitor station on the flume below the wet separator of the fish collection system. The monitor passively interrogated PIT-tagged fish released by the program. The monitoring station followed the general criteria prescribed by Prentice et al. (1990a and 1990b). A Memorandum of Understanding between YIN, USBR, and NMFS was prepared for the installation and use of the PIT-tag monitor station, and BPA obtained an exemption of experimental radio frequency assignment from the Federal Communication Commission (FCC).

Data Analysis

Actual recoveries of juvenile sockeye salmon at the Chandler Fish Collection Facility from test groups released below Cle Elum Dam were expanded using standard collection parameters for the facility (supplied by the YIN) to estimate total numbers of released fish passing Prosser Dam. Typical parameters were sub-sample rate, entrainment rate, etc. Recovery information (%) was arcsine transformed for analysis. Median travel times to Prosser Dam for the released test groups were calculated first from freeze-brand recovery information (1989), and later from PIT-tag recovery (1990-1993). Recovery information was analyzed by regression analysis.

Cle Elum Lake outmigrant recovery information for each release-recovery cycle at the Chandler facility was expanded by the formula: [(1/B)*L]; where B is the expanded fractional recovery estimate obtained from tailrace releases which occurred during the same period of time when groups of fish which migrated from the lake were recovered at Prosser Dam, and L is the estimated number of Cle Elum Lake outmigrants passing Prosser Dam during the period. The sum of these estimates represent the total number of juvenile sockeye salmon estimated to have migrated pass Cle Elum Dam each year.

Results

Beginning in spring 1989, experiments were carried out to investigate the outmigration of sockeye salmon from Cle Elum Lake and downstream through the Yakima River Basin. Each year (1989 - 1993) the evaluations centered on recovery of fish collected at the Chandler Fish Collection Facility at Prosser Dam and determination of fish travel times through the system.

Results of Activities in 1989

The 1989 study period extended from mid April to mid June. The activities included:

- release of sockeye salmon in the Cle Elum Lake watershed above Cle Elum Dam,
- evaluation of efficiency of water releases under a radial gate in the surface spillway at Cle Elum Dam to attract and pass juvenile sockeye salmon outmigrants, and
- serial release of groups of juvenile sockeye salmon to evaluate spillway bypass at Cle Elum Dam and downstream passage and recovery rates at Prosser Dam.

In 1989, Cle Elum Lake reached spillway discharge elevation (678 m) in early May. It remained at or above this level until early July (Fig. 14). Water releases from Cle Elum Dam ranged from about 2.5 m^3/s (minimum instream flows) to irrigation discharges of over 100 m^3/s (Fig. 14).

A total of about 88,000 1987-brood juvenile sockeye salmon were released into Cle Elum Lake and Cle Elum River (Table 2). All of the fish released were freeze-branded and coded-wire-tagged. In addition, a subsample of 3,000 fish released into Cle Elum Lake were PIT tagged. WDFW Fish Transfer Permits 532-10-88 and 561-1-89 were issued for the transport and release of these fish. The results for 1989 were as follows:

(a) Juvenile fish passage from Cle Elum Dam to Prosser Dam-- In spring about 12,500 sockeye salmon juveniles from the 1987-brood were released into the Cle Elum River in 9 discrete release groups at, or just below, Cle Elum Dam (Table 4). Each release group was transported from the NWFSC to our holding facility at Cle Elum Dam and held about 2 weeks for acclimation prior to release.

Prosser Dam recovery data showed survival was higher (up to 20%) for groups of fish released below Cle Elum Dam during April and early May 1989 and lower (0-2%) for fish released between late May and June 1989 (Table 4). Median travel time to

Prosser Dam was relatively short, between 4 and 12 days, for each of the groups of fish released below Cle Elum Dam (Table 4). There were significant ($P < 0.05$) negative relationships between recovery proportion and both release date and travel time. Increased travel time was also correlated ($P < 0.05$) with increasing release date.

(b) Juvenile outmigration from Cle Elum Lake-- About 76,000 juvenile sockeye salmon from the 1987-brood donor stock reared at the NWFSC were released into Cle Elum Lake during the study period to assess outmigration and downstream passage (Tables 2 and 5). The outmigration success was evaluated through recapture of fish at Prosser Dam.

In mid November 1988, 2 groups of approximately 12,500 fish each were transported from the NWFSC to Cle Elum Lake, and released at a site between the dam and the U.S. Forest Service (USFS) Wish-Poosh Campground (Fig. 2). In spring 1989, additional groups of fish were outplanted to Cle Elum Lake; a total of 4 groups of about 10,000 to 12,000 fish each were released in late March and early May, and 2 other groups of approximately 3,000 fish each were released in late May. The first 4 spring release groups each included 750 PIT-tagged fish, while the last 2 groups did not include any. All of the spring releases into Cle Elum Lake were made from the boat ramp at the USFS Wish-Poosh Campground. Immediately after transfer to the lake all groups of fish appeared vigorous and active with no apparent transfer-related mortalities.

The first fish apparently migrated from Cle Elum Lake when the water rose above spillway elevation in early May. During the 10-day period following initial fill, spillway discharge ranged from about 3-85 m^3/s (Fig. 14). Flow was not severely restricted by the radial gate, and the river running from the lake apparently attracted fish and permitted the observed downstream migration to occur.

An estimated 837 lake-released fish (about 1.1% of the number released in the lake) migrated past the dam when spilling from the dam first occurred in early May (Table 5 and Fig. 15). Median recovery date for this initial group of fish was May 16.

Rain and melting snow in spring 1989 quickly filled Cle Elum Lake to about 3 m above spillway elevation, and USBR restricted the opening beneath Radial Gate 1 to under 12 cm from mid May to early June to maintain required instream flows. Coincidentally, from about the third week of May through the second week of June, only two fish from lake-release groups were recaptured at Prosser Dam (Fig. 15).

Beginning in early June, irrigation water discharges of up to 120+ m^3/s were made from Cle Elum Dam (Fig. 14). An estimated 22,000 lake-release fish (about 28.5% of the number released in the lake) migrated past Cle Elum Dam concurrent with the high volume irrigation discharges made from the dam after early June (Table 5 and Fig. 15). Median recovery date for this group of fish was June 18.

Evaluation of the total recovery data showed that about 22,500 1987-brood age-1 smolts (about 29.6% of the number released in the lake) migrated past Cle Elum Dam in 1989 (Table 5 and Fig. 16). However, only a few of these fish (ca. 3%) subsequently reached Prosser Dam (Table 5). In 1989, most outmigration appeared to occur late in the spring, during periods of declining survival conditions in the Yakima River system (cf. Table 4 and Fig. 15).

From these results it appeared that the ideal period for outmigration was late April to early May, which coincides with minimum in-stream flows below Cle Elum Dam and apparent periods of enhanced survival through the Yakima River. Although the outmigration was expected to coincide with the initial fill of Cle Elum Lake to spilldeck elevation in early May, few fish appeared to have left the lake during this period. During the 1989 study it was not possible to determine if the young fish simply avoided the restricted gate openings in early May, or whether they were injured by shear-plane forces during passage through the dam and subsequently died. Changes were made to the configuration of the system at the dam, and two sluice gates were installed to improve conditions for the 1990 activities (Figs. 8 and 9).

Results of Activities in 1990

The 1990 study period extended from mid March until mid June. Activities included the following elements:

- release of sockeye salmon in the Cle Elum Lake watershed above Cle Elum Dam,
- evaluation of efficiency of water releases through new sluice gates at the surface spillway at Cle Elum Dam to attract and pass juvenile sockeye salmon outmigrants,
- serial release of groups of juvenile sockeye salmon to the Cle Elum River below Cle Elum Dam to evaluate downstream passage and recovery rates at Prosser Dam, and
- direct capture of fish in Cle Elum Lake and at the outfall from Cle Elum Dam.

In 1990, Cle Elum Lake reached spillway discharge elevation (678 m) in mid April and remained at or above this level until mid July (Fig. 17). USBR irrigation releases from Cle Elum Dam during the study period ranged from about 2.5 m^3/s (minimum instream flow) to irrigation discharges of over 110 m^3/s (Fig. 17).

About 86,000 1988-brood juvenile sockeye salmon were released into the Yakima River watershed in 1989-1990 (Table 2). This included approximately 9,000 juveniles released to the Cle Elum River and 77,000 released in Cle Elum Lake. All the fish released were either freeze-branded or coded-wire-tagged. Of the total, 3,000 fish released into the river and 4,500 into the lake were PIT tagged. WDF Fish Transfer

Permits 561-1-89 and 1010-10-90 were issued for the transport and release of these fish. The results for 1990 were as follows:

(a) Juvenile fish passage from Cle Elum Dam to Prosser Dam-- In spring about 9,000 sockeye salmon juveniles from the 1988-brood donor stock were released into the Cle Elum River in 7 discrete release groups at the tailrace of Cle Elum Dam (Table 6). Each release group was transported from the NWFSC to the fish acclimation facility at Cle Elum Dam and held for about 2 weeks prior to release.

Prosser Dam recovery data showed survival was higher (up to 50+%) for groups of fish released at Cle Elum Dam during March and April and lower (2-5%) for fish released in May (Table 6). By June however, recovery proportions appeared to be increasing again (Table 6). Even though there appeared to be a (negative) trend between release date and recovery proportion, the relationship was not significant ($P > 0.05$). Median travel time to Prosser Dam for each group released below Cle Elum Dam was 4 to 10 days (Table 6). There were no significant ($P > 0.05$) relationships between travel time and either release date or recovery proportion.

As with the results in 1989, the 1990 data suggested that early spring river conditions were more conducive to higher outmigration survival of sockeye salmon through the Yakima River system than were late spring conditions. The travel timing results further indicated there were no severe obstacles to fish migration in the free-flowing sections of the Yakima River system.

b) Juvenile outmigration from Cle Elum Lake-- In early spring the outlet structure at Cle Elum Dam was modified. Two sluice gates were installed, and an incline-plane trap was fitted to one of them to facilitate counting of fish migrating past the dam (Figs 8 and 9).

Approximately 77,000 age-1 1988-brood juveniles were released in Cle Elum Lake between December 1989 and late March-April 1990 (Tables 2 and 5). The outmigration success was evaluated at two locations, namely at the incline-plane trap on the gate at Cle Elum Dam, and the Chandler Fish Collection Facility at Prosser Dam (Fig. 6).

The incline plane trap was operated from May 1 when the lake first filled to sluice gate discharge elevation to May 17. During this period all water discharges of up to 3 m^3/s from Cle Elum Lake were made through the two new sluice gates at Cle Elum Dam. The remaining water discharge volumes, of up to 50 m^3/s, were made through the deep water discharge tube at the dam. This initially created a river-like flow from the lake similar to the initial spillway discharge in 1989. However, rains and melting snow in spring 1990 quickly filled the lake to about 5 m above the sluice gate elevation (Fig. 17). In mid May, the incline-plane trap at Cle Elum Dam was removed and USBR was requested to make surface discharges of up to 115 m^3/s through the radial gates (Fig. 17). This alteration in the design of this research element was made to determine if high flow discharges would encourage sockeye to leave the lake.

Very few (< 30) marked fish were recaptured in the incline-plane trap during its operation, even though data from the Merwin trap (see below) indicated relatively large numbers of juveniles were aggregating in the vicinity of the dam. Apparently, few juveniles from either brood year were attracted to the sluice gate water discharge. One reason for this may be that fish were not attracted to the spill from these gates after they were submerged when the reservoir was full. Nevertheless, some fish from each brood year did outmigrate.

An estimated 39 1987-brood age-2 fish (about 0.05% of the number released in the lake) migrated past Cle Elum Dam during early May when the initial spill from the sluice gates occurred (Table 5 and Fig. 15). Median recovery date for these fish was May 15. Additionally, an estimated 1,667 1988-brood age-1 fish (about 2.17% of the number released in the lake) migrated past Cle Elum Dam in early May (Table 5 and Fig. 15). The median recovery date for this group of age-1 fish was May 6.

High volumes of irrigation water were discharged from Radial Gate 1 during the fourth week of May (Fig. 17). These releases were successful in attracting and passing fish. An estimated 19,751 age-2, 1987-brood smolts (about 26.0% of the number released in the lake) migrated past Cle Elum Dam coincident with high volume irrigation water discharges in late May (Table 5 and Fig. 15). Median recovery date for this group of age-2 fish was June 2. Additionally, an estimated 5,970 age-1, 1988-brood smolts (about 7.8% of the number released in the lake) migrated past Cle Elum Dam during late May to mid June (Table 5 and Fig. 15). Median recovery date for this group of age-1 fish was June 15.

Evaluation of the total recovery data showed that 7,637 1988-brood age-1 smolts (about 9.9% of the number released in the lake) and 19,790 1987-brood age-2 smolts (about 26.1% of the number released in the lake) migrated past Cle Elum Dam in 1990 (Table 5 and Fig. 16). However, as in 1989, only a small portion of the fish (about 4% of the 1987-brood, and 23% of the 1988-brood) thought to have migrated from the lake survived to Prosser Dam (Table 5). The Cle Elum Lake fill and spill profile and Yakima River outmigration survival conditions in 1990 were similar to those of 1989 (see above). In 1990, the majority of outmigration opportunity again occurred late in the season when conditions in the Yakima River system were not apparently conducive to good survival (cf. Table 6 and Fig. 15).

The results of the 1990 activities suggested that fish avoided passage through the new sluice gates in Radial Gate 1 once the gates were submerged by the springtime fill. Therefore, for the activities in the following year, it was proposed to construct and test a floating outfall weir attached to one of the sluices.

(c) Trapping results in Cle Elum Lake-- A single Merwin smolt trap (Fig. 13) was located in Cle Elum Lake in the vicinity of the dam to provide data on smolt migration patterns. It was operated from April 12 to the June 12. Nearly 2,200 marked sockeye salmon juveniles were captured in the Merwin trap (Table 7). Both yearling 1998-brood and age-2 1987-brood fish were taken, suggesting that (perhaps large) numbers of sockeye salmon were aggregating in the vicinity of the dam and attempting to outmigrate in spring 1990.

Results of Activities in 1991

The 1991 study period extended from late February until late June. Unusually heavy rain and rapid snow melt produced flooding conditions in the Yakima River during much of this time. The proposed activities for the year included:

- release of sockeye salmon in the Cle Elum Lake watershed above Cle Elum Dam,
- evaluation of efficiency of a floating surface outfall weir attached to one of the discharge sluice gates to attract and pass juvenile sockeye salmon outmigrants,
- serial release of groups of juvenile sockeye salmon to the Cle Elum River below Cle Elum Dam to evaluate downstream passage and recovery rates at Prosser Dam, and
- direct capture of fish in Cle Elum Lake and at the outfall from Cle Elum Dam.

In 1991, the Cle Elum Lake reached spillway discharge elevation (678 m) in early February and remained at or above this level until early August (Fig. 18). The irrigation releases from the dam during the study period ranged from 50 m^3/s minimum flood control flows to irrigation discharges of over 105 m^3 /s (Fig. 18).

About 94,000 1989-brood juvenile sockeye salmon reared at the NWFSC were released into the Yakima River watershed for the 1991 study (Table 2). Included were approximately 18,000 juveniles released to the Cle Elum River and 76,000 released in Cle Elum Lake. All of the fish released were freeze-branded and coded-wire-tagged. Of these, over 4,500 fish released into the lake and 4,500 released into the river were PIT tagged. WDF Fish Transfer Permits 1010-10-90 and 1189-8-91 were issued for the transport and release of these fish. The results for 1991 were as follows:

(a) Juvenile fish passage from Cle Elum Dam to Prosser Dam-- In spring over 18,000 juveniles from the 1989-brood donor stock were released (in 9 discrete release groups) into the Cle Elum River at the tailrace of Cle Elum Dam (Table 8). Each release group was transported from the NWFSC to the acclimation facility at Cle Elum Dam and held for 2 weeks prior to release.

Analysis of fish collection information at Prosser Dam indicated expanded recovery rates were slightly higher (29-93% recovery) for most groups of fish released at Cle Elum Dam between late February-early May then for groups released later in the year (8-22%; Table 8). However, the relationship between release date and recovery proportions was not significant ($P > 0.05$). Median travel time to Prosser Dam was 3 to 12 days for all release groups (Table 8). There were no significant ($P > 0.05$) relationships between travel time and either release date or recovery proportion. This data supported results obtained in 1989-1990 and again confirmed there were no severe obstacles to outmigration in the free-flowing sections of the river system.

(b) Juvenile outmigration from Cle Elum Lake-- As described above, in early spring 1990, NMFS modified Radial Gate 1 at Cle Elum Dam with installation of two sluice gates. The 1990 study suggested that outmigrating fish might not be attracted to flow discharge from these sluice gates after they became submerged during springtime reservoir fill. Therefore, in 1991, NMFS constructed a floating surface outfall weir attached to one of the sluice gates at Cle Elum Dam (Figs 10, 11 ,and 12) to evaluate if this type of exit conduit was more efficient in attracting and passing fish than existing structures. NMFS coordinated the development and construction of the floating surface outfall with the USBR and the Yakima Basin Fisheries Project Technical Work Group.

The floating surface outfall system (Figs. 10, 11, and 12) was designed to act as a surface running-river exit from the lake during springtime periods when reservoir storage requirements dictated flow releases of 2.8 m^3/s or less, and pool elevations were above the surface of the flood control spillway. Incline plane traps (Figs. 8 and 9) were installed on each of the two sluice gates to directly measure fish migration passed the dam. The floating weir and incline-plane traps were staged and tended with a 25-ton NMFS-provided portable crane.

Approximately 76,000 1989-brood sockeye salmon were released in Cle Elum Lake in 1990-1991 (Table 2). Locations for the collection of outmigration evaluation data were planned for (a) the incline-plane trap on Radial Gate 1, and (b) the Chandler Fish Collection Facility at Prosser Dam. However, mechanical problems with the outfall weir discharge tubes and unusually high flood-control water discharges through the radial gates at the dam prevented proper functioning of the incline-plane trap for most of the evaluation period. Therefore, accurate evaluation of the surface outfall weir was not possible.

The unusually high springtime water run-off in 1991 resulted in continuous flood control water releases by the USBR at Cle Elum Dam (Fig. 18). These releases provided excellent passage for juveniles from Cle Elum Lake via the radial gates and discharge spillway at Cle Elum Dam. In 1991, smolts migrated from the lake in two small and three large groups, based on observations made at Prosser Dam (Fig. 15). The majority of outmigrants were recovered at Prosser Dam between mid April and mid May.

Initially an estimated 208 1989-brood age-1 smolts (about 0.27% of the number released in the lake) migrated past Cle Elum Dam in early April (Table 5). The median recovery date for this group of age-1 fish was April 05. The next outmigration period was segmented into three phases to coincide with the in-stream survival calibration groups (designated T-4 to T-6, see Table 6) released below Cle Elum Dam during this period, viz:

> Phase 1: About 5,320 fish were estimated to have passed Prosser Dam between April 15-26. The estimated in-stream survival was about 48%. Therefore, an estimated 11,012 1989-brood age-1 fish smolts (about 14.5% of the number released in the lake) migrated from Cle Elum Lake during this phase.
>
> Phase 2: About 2,932 fish were estimated to have passed Prosser Dam between April 27- May10. The estimated in-stream survival was about 84%. Therefore, an estimated 3,460 1989-brood age-1 fish smolts (about 4.6% of the number released in the lake) migrated from Cle Elum Lake during this phase.
>
> Phase 3: About 1,144 fish were estimated to have passed Prosser Dam between May 11-20, with an estimated in-stream survival of about 93%. Therefore, about 1,224 1989-brood age-1 fish smolts (about 1.6% of the number released in the lake) migrated pass Cle Elum Dam during this period of migratory activity.

Another small group of fish (an estimated 253 fish) arrived at Prosser Dam between early to mid June (Table 5 and Fig. 15). Estimated instream survival was about 23% during that period. Therefore, we estimate that about 1,121 1989-brood age-1 fish smolts (about 1.5% of the number released in the lake) migrated pass Cle Elum Dam during this period.

Overall recovery data for fish in collected in 1991 indicated that about 17,023 1989-brood age-1 smolts (about 22.4% of the number released in the lake) migrated past Cle Elum Dam (Fig. 16). The high volumes of water (flood and flood control discharge) flowing through the Yakima River system in the spring clearly provided excellent conditions for fish passage. An estimated 57% of juveniles that outmigrated from Cle Elum Lake in spring 1991 survived the 240 km to Prosser Dam (Table 5).

(c) Trapping results in Cle Elum Lake-- In 1991, the Merwin trap was operated from April 12 to June 12. Almost 2,500 marked age-1 1989-brood juveniles (about 3.3% of the number released in the lake) were taken in the trap (Table 7). The results were similar to those of 1990 when about 2,200 juveniles were recaptured. In contrast to 1990, no age-2 fish were captured. The large number of recaptured fish indicated active near-shore movement of juveniles during the study period suggesting, as in previous years, that these yearling fish were smolting and searching for an outlet from the lake.

Results of Activities in 1992

The 1992 study period extended from mid March until mid June. The activities for the year included:

- release of juveniles in the Cle Elum Lake watershed above Cle Elum Dam,
- evaluation of the efficiency of the new floating surface outfall weir at the Cle Elum Dam to attract and pass juvenile outmigrants,
- serial release of groups of juveniles to evaluate downstream passage and recovery rates at Prosser Dam, and
- direct capture of fish in Cle Elum Lake and at the outfall from Cle Elum Dam.

In 1992, the Cle Elum Lake reached spillway discharge elevation (678 m) in early April, and remained at or above this level until early June (Fig. 19). USBR irrigation releases from Cle Elum Dam during the study period ranged from about 2.5 m^3/s (minimum in-stream flows) to irrigation discharges of about 100 m^3/s (Fig. 19).

About 95,000 1990-brood juveniles reared at the NWFSC were released into the Yakima River watershed during the study period (Table 2). This included approximately 4,800 sockeye salmon juveniles released to the Cle Elum River and 90,000 fish released in Cle Elum Lake. All the fish released were coded-wire-tagged and a portion of the fish were freeze-branded. In addition, 5,100 of the fish released into the lake and 4,800 of the fish released into the river were also PIT tagged. WDF Fish Transfer Permits 1189-8-91 and 1318-1-92 were issued for the transport and release of these fish. The results for 1992 were as follows.

(**a) Juvenile fish passage from Cle Elum Dam to Prosser Dam--** In spring over 4,800 sockeye salmon juveniles from the 1990-brood donor stock were released into the Cle Elum River in 11 discrete release groups at the tailrace of Cle Elum Dam (Table 9). Each release group was transported from the NWFSC to the acclimation facility at Cle Elum Dam and held for about 2 weeks prior to release.

Collection data at Prosser Dam indicated that recovery rates were much lower (0-30% recovery) for most groups of fish than in previous years (Table 9). No fish were recovered from groups of fish released after early May. There was a significant ($P < 0.05$) negative relationship between release date and recovery proportion. Median travel time to Prosser Dam for the groups (about 12 d average) indicated a protracted outmigration compared with previous years (usually 5-6 d average; see Tables 4, 6, and 8). There was a significant ($P < 0.05$) negative relationship between time and recovery portion. There was no significant ($P > 0.05$) relationship between travel time and release date.

There was no obvious explanation for the low fish recovery at Prosser Dam in 1992. Results in 1989 to 1991 suggested that, under most conditions, there were no severe impediments to migration of sockeye salmon in the free-flowing sections of the Yakima River system. Drought conditions during spring 1992 probably played a role in the lower recovery figures, but other adverse but transitory conditions in the migratory corridor were probably also involved. Another possibility is that the low recoveries may have indicated a general performance failure for the 1990-brood.

(b) Juvenile outmigration from Cle Elum Lake-- In 1991, evaluation of the floating surface weir fish bypass system was compromised by mechanical problems with the outfall weir discharge tubes (see above). Heavy-duty transition tubes were installed and the floating surface intake was successfully deployed in 1992. The system was operated from April 23 to June 2 and appeared to function properly during the entire test period. Visual assessment of water flow into the surface outfall weir indicated that the necessary effect of a 'running river' exit with a discharge range of 1.7-2.8 m^3/s was provided.

The floating surface weir system did not appear to attract and bypass fish. During the entire test period no marked fish were taken in the incline-plane trap below the bypass exit. However, tests probably were compromised by irrigation water discharges at Cle Elum Dam due to drought conditions in the valley that year. USBR maintenance of the deep draft discharge tube in the dam required surface release of these large volumes of water from the reservoir in 1992. These releases were made through Radial Gates 2-5, adjacent to the floating surface weir, and ranged from 20 to 80 m^3/s during the test period (Fig. 19). Surface water releases of about 2.5 m^3/s through the floating surface weir may not have been sufficient to attract fish from competing discharges through the radial gates.

Very few 1990-brood sockeye salmon that were released in Cle Elum Lake in fall-winter 1991 were recovered at Prosser Dam in 1992 (Table 5). As described above, passage survival through the Yakima River system was severely compromised in 1992 compared to previous years. Because of low survival of the river calibration release groups in 1992 (Table 9), expansion values for some lake release groups recaptured at Prosser Dam were extremely high in 1992 (Table 5).

We estimate that about 3,100 (3.5%) of 1990-brood juvenile sockeye salmon released to Cle Elum Lake the previous fall-winter outmigrated past Cle Elum Dam in spring 1992 (Table 5 and Fig. 16). Merwin trap recovery data suggested low numbers of anadromous sockeye salmon searching for an outlet from the lake in 1992 (see below). Similar to 1991, the large volume water releases over the spillway at Cle Elum Dam may have provided excellent attraction and passage for those (few) fish that were seeking to oumigrate in 1992. Nevertheless, potentially large confidence intervals for recovery expansion rates in 1992 invalidated attempts to further define this relationship.

(c) Trapping results in Cle Elum Lake-- Two Merwin traps (Fig. 13) were placed into the lake in 1992, one on either side of the forebay to Cle Elum Dam. The west-shore trap was operated from March 25 to June 17, and the south-shore trap from April 22 to June 17. All marked fish taken in the traps were transferred to the fish acclimation facility below the dam and later released directly into the Cle Elum River.

The number of fish released into the lake for the 1992 study was similar to previous years (Table 2). Nonetheless, Merwin trap data suggested that the near-shore movement of juveniles in the lake during the spring was less than observed in the previous 2 years. For example, about 2,200 marked juveniles were recaptured in a single trap on the west shore of the lake in spring 1990, and 2,500 at that site in 1991 (Table 7). In spring 1992, only 365 marked fish were taken in two traps. The low number of marked sockeye salmon captured in the Merwin traps in 1992 may indicate a general failure of the 1990-brood in the lake (similar to that postulated for the downstream releases, see above). However, new nets were installed in the Merwin traps in 1992 and these may not have fished as efficiently as the nets used in 1990 and 1991. In addition, the drought condition in the upper Yakima River Basin in 1992 may have influenced spatial and temporal distribution of fish in the lake. In any event, in 1992 there is little empirical evidence of near-surface and near-shore oriented populations of anadromous sockeye salmon searching for an outlet from the lake, as observed in 1990 and 1991.

Results of Activities in 1993

The 1993 study period extended from early March until late June. Activities proposed for the year again included:

- release of sockeye salmon in the Cle Elum Lake watershed above Cle Elum Dam,
- evaluation of the efficiency of a floating surface outfall weir to attract and pass juvenile outmigrants,
- serial release of groups of juveniles to the Cle Elum River below Cle Elum Dam to evaluate downstream passage and recovery rates at Prosser Dam, and
- direct capture of fish in Cle Elum Lake and at the outfall from Cle Elum Dam.

Cle Elum Lake never filled to spillway discharge elevation in 1993 because of drought conditions in the Yakima River Basin (Fig. 20). The USBR program made all irrigation releases from Cle Elum Dam through the deep water discharge tube at the base of the dam (Fig. 20).

About 187,000 1991-brood juveniles reared at the NWFSC were released into the Yakima River watershed during the study period (Table 2). Included were approximately 15,000 sockeye salmon juveniles released to the Cle Elum River and 172,000 fish released into Cle Elum Lake. All of the fish released were freeze-branded and coded-wire-tagged. Over 20,000 fish released into the lake and 7,500 fish released into the river were also PIT tagged. WDF Fish Transfer Permits 1400-6-92 and 1506-12-93 were issued for the transport and release of these fish. The results for 1993 are as follows.

(a) Juvenile fish passage from Cle Elum Dam to Prosser Dam-- In spring 1993, almost 15,000 sockeye salmon juveniles from the 1991-brood donor stock were released into the Cle Elum River in 15 discrete release groups at the tailrace of Cle Elum Dam (Table 10). Each release group was transported from the NWFSC to the acclimation facility at Cle Elum Dam and held for about 2 weeks prior to release.

As in previous years, expanded recovery rates were higher (9-37%) for most groups of fish released below Cle Elum Dam during early spring and lower (0.05-18%) for most groups released later in the year. There was a significant ($P < 0.05$) negative relationship between release date and recovery proportion. The study data provided further evidence that early spring river conditions were more conducive to high outmigration survival than late spring conditions. However, the recovery proportion reduction occurred sooner (mid-late April in 1993 vs. early-mid May in other years; see Tables 4, 6, 8, and 9).

Median travel time from Cle Elum to Prosser Dam for all groups was 3 to 16 days (Table 10). This was comparable with (most) previous years and confirmed previous observations of lack of severe fish passage blockages in the river. There was a significant ($P < 0.05$) negative relationship between travel time and recovery portion. There was no significant ($P > 0.05$) relationship between travel time and release date.

(b) Juvenile outmigration from Cle Elum Lake-- Installation and evaluation of the outfall weir was not possible in 1993 due to the drought and subsequent low snow pack. The water level in Cle Elum Lake did not reach spill-deck elevations (Fig. 20) and therefore no release groups of fish had the opportunity to outmigrate past Cle Elum Dam.

(c) Trapping results in Cle Elum Lake-- In 1993 two Merwin traps were used again, sited on either side of the forebay to Cle Elum Dam. The west-shore trap was operated from April 30 to June 16, and the south trap from April 29 to June 16. Active near-shore movement of juveniles in the lake occurred during the spring. A total of 2,387 marked fish were recaptured (Table 7) suggesting, as in previous years, that these yearling fish were smolting and searching for an outlet from the lake. However, as noted above, effective exit routes were not available in 1993 and no fish were recovered at Prosser Dam.

Results of Activities in 1994

About 390,000 1992-brood Lake Wenatchee sockeye salmon were released in Cle Elum Lake in April 1993 (Table 2). WDF Fish Transfer Permit 1505-12-93 was issued for the transfer of these fish from the NWFSC to the Yakima River Basin.

BPA requested discontinuation of further rearing of sockeye salmon at the NWFSC for the Cle Elum project at the end of May 1993. Therefore the subsequent success of the outmigration of 1992-brood fish from Cle Elum Lake was not evaluated in 1994. Consequently, the principal activity in 1994 was focused on data analysis and quantification of the returns of adult sockeye salmon from previous releases into the Yakima River Basin as part of the restoration program.

Discussion

The outmigration studies described in this section of the report focused on primary questions of 1) whether juvenile sockeye salmon would orient to the lake outlet and attempt to leave the lake at appropriate times of the year and 2) whether smolts leaving the lake could successfully migrate downstream through the Cle Elum and Yakima Rivers. Merwin trapping conducted in Cle Elum Lake each spring from 1990-

1993 (Table 7) confirmed that donor populations of sockeye salmon released in the lake survived overwinter and, at smolting in the spring, oriented in the vicinity of the outlet to Cle Elum Dam in an apparent attempt to outmigrate. Cle Elum Dam appears to be the single largest obstacle to outmigration success. Studies from 1989-1993 (Tables 4, 6, 8, 9, and 10) suggest that there are no severe blockages to outmigration from immediately downstream from Cle Elum Dam through the Cle Elum and Yakima Rivers. However, proper sequencing of outmigration timing will be critical to the success (survival) of outmigration.

From 1989-1993, groups of marked sockeye salmon smolts were released in the tailrace at Cle Elum Dam at intervals during the spring of the year (Tables 4, 6, 8, 9, and 10). Fish were recaptured at the Chandler Fish Collection Facility at Prosser Dam (about 240 km downstream) and recovery proportions estimated for the groups. In all studies, a trend was evident indicating a negative correlation between release date and recovery proportion. Analysis of combined (1989-1993) recovery proportion data indicates that recovery proportions for sockeye salmon in the Yakima River system normally decrease substantially throughout the spring (Fig. 21). Life history information for the donor stock (Lake Wenatchee sockeye salmon) indicates that peak outmigration through the mid Columbia River normally occurs by late April (Mullan 1986). In the Yakima River system, recover proportions appear to severely decrease after early May and to be often reduced to only a few percent by June (Fig. 21). It can be presumed that the early spring outmigration timing window for the Lake Wenatchee stock is an adaptive trait favoring higher survival. The data from the Cle Elum study underscores the need to accommodate for mid April peak outmigrations of sockeye salmon passing Cle Elum Dam to maximize downstream survival.

Unfortunately, under the current spilldeck configuration at Cle Elum Dam, the fill/spill cycle of Cle Elum reservoir appears to be out of synchrony with early spring periods of increased downstream smolt survival through the Yakima River system. Figure 22 shows the average biweekly recovery proportions for sockeye salmon smolts released in the tailrace of Cle Elum Dam and recovered at Prosser Dam versus the annual probability (from 1935-1993) of Cle Elum reservoir filling to spilldeck elevation during any biweekly period. Over that 59 year period, Cle Elum reservoir reached spilldeck elevation during the mid-April outmigration period about 30% of the time and had only reached spilldeck elevation about 40% of the time by the end of April. About 3% of the time the reservoir never reached spilldeck elevation throughout the year.

The challenge for enhancement of anadromous salmonids to the Cle Elum Lake watershed will be to provide safe exit routes for smolts seeking to migrate pass the dam during desired early spring outmigration windows. Attempts during this study to provide safe exit routes from the reservoir through reconfiguration of the radial gates at Cle Elum Dam and through installation of floating surface weirs were unsuccessful. Most outmigration from the lake documented during the study (Fig. 16) occurred during late spring when large volume irrigation spills were released through the spillgates and occurred during periods of reduced downstream survival.

Possible engineered smolt bypass configurations at Cle Elum Dam could include a lowered elevation modification of a NMFS tower design (Fig. 23) which could be sited in the lake off shore of the current spillway. The tower design would require netted leads to guide fish. Another design, developed by Summit Technology (Appendix A), would incorporate sets of vertical slide gates positioned on the face of the dam (Fig. 24). Floating gulper traps that attract smolts by creating pumped attraction flows have been used successfully at Baker Lake (WA) to capture sockeye smolts for bypass (Puget Sound Energy, PO Box 90868, Bellevue, WA).

We estimate that an adequate smolt bypass system will probably need to be configured at elevations of at least 10+ m below the current spilldeck elevation to maximize smolt outmigration survival potential. Figure 25 shows springtime (April 1-May 15) Cle Elum Reservoir elevation levels for an 18 year period from 1975-1992. During this period, the reservoir filled to an elevation 10 m below the current spilldeck 72% of the time by April 1, 78% of the time by April 15, and 83% of the time by May 1. Exact elevations for siting smolt bypass structures will depend on design specific engineering evaluation.

SECTION V: ADULT RETURNS, 1991-1995

Summary of Yakama Indian Nation adult fish counts

Return Observations

The YIN conducts surveys of returning anadromous adult salmonids at several locations in the Yakima River Basin, including Prosser and Roza Dams. Beginning in 1991, the first adult sockeye salmon from Cle Elum Lake research releases of Lake Wenatchee stock juvenile sockeye salmon in the Yakima River Basin were documented to return to the Yakima River. Four returning adult sockeye salmon were observed at Roza Dam; two males were recovered on 31 July and 12 October 1991, and two females on 9 September and 8 October 1991.

Adult sockeye salmon from the program's releases continued to return to the Yakima River Basin. Information from YIN fish ladder counts indicates 11 returning adults were recorded at Roza Dam in 1992. In 1993, 20 adults were documented at the Prosser Dam on the lower Yakima River, and 16 of these fish were later observed passing Roza Dam, approximately two-thirds of the way up the Yakima River. In 1994, no fish were observed at either dam. However, again in 1995 an adult was observed passing both facilities.

These were the first returns of sockeye salmon to the Yakima River Basin in over 60 years. These returns were extremely encouraging regarding the potential for supplementation to aid in recolonization of lost habitat above Cle Elum Dam. Obviously, upstream fish passage facilities will be required at Cle Elum Dam to accommodate recolonization of anadromous salmonids to the Cle Elum Lake watershed. A complicating variable will be the low reservoir elevations (up to about 35 m below spilldeck) typical at Cle Elum Lake during the fall after summer irrigation withdrawals.

Adult passage considerations were beyond the scope of the Cle Elum study. However, during the study, NMFS engineers suggested a Denil steep-pass and staged resting pool design to aid fish in negotiating the 40 m dam height. The steep-pass could be supplied with pumped water from the stilling basin below the dam and a watered flume positioned on the upstream dam face to return fish to the lake. A Denil steep-pass or other upstream passage facilities will require design specific engineering evaluations to maximize fish attraction, passage, and survival. In addition, possible thermal blockages to upstream migration of adult sockeye salmon through the Yakima River system should be evaluated.

SECTION VI: CONCLUSIONS AND RECOMMENDATIONS

The NMFS studies described in this report were aimed at helping determine the feasibility for anadromous sockeye salmon to recolonize lost habitat at and above Cle Elum Lake in the Yakima River Basin. An ecosystem-based approach will be required to successfully restore fish into the habitat; all aspects of the species/habitat interface must be properly functioning for supplementation to succeed. As described in the introduction, the studies were designed to answer key questions relating to whether restoration of self-supporting populations of anadromous salmon to Cle Elum Lake would indeed be possible. Positive answers to the questions were considered a requirement for a determination of feasibility of restoring sockeye salmon to underutilized habitats in and about Cle Elum Lake. The questions, and conclusions and recommendations provided by the study were:

1) Could a suitable sockeye salmon donor stock be identified and successfully cultured to provide juveniles for conducting survival and outmigration studies at Cle Elum Lake?

   The study identified the stock of sockeye salmon in the adjoining Wenatchee River Basin to the north of the Yakima River Basin as a viable donor stock. Lake Wenatchee has considerable geographical and limnological similarities to Cle Elum Lake, and the Lake Wenatchee sockeye salmon stock has (presumed) genetic and run-timing similarities to the historic Yakima River Basin stock. Husbandry research conducted during the study (Section I) helped solve health and survival problems that had been hampering sockeye salmon enhancement in Washington State for a number of years. The study demonstrated that combinations of net-pen holding of prespawning adults in a lacustrine environment and isolated incubation and rearing of progeny could produce healthy juveniles for outplanting to Cle Elum Lake.

2) Would existing habitat and forage permit juvenile fish stocked into the lake to survive through smoltification?

The creation of Cle Elum Dam and reservoir increased the maximum surface size of Cle Elum Lake from about 1,210 ha to about 2,020 ha at full pool; providing about 0.56 billion m^3 of water for irrigation in the Yakima River valley. Unfortunately, the fill/spill cycle of the lake and approximately 40 m maximum annual reservoir drawdown has destabilized the lake's littoral zone, resulting in an extremely limited littoral biological community and reduced mechanisms for storing and recycling nutrients. In Cle Elum Lake, fish probably must feed primarily in pelagic zones on zooplankton because water level fluctuations have all but removed benthic invertebrates in the littoral area.

Sockeye salmon are the Pacific salmon species that can probably best utilize the mid-water plankton oriented rearing habitat that presently exists in Cle Elum Lake. However, the forage base could undoubtedly support (limited) numbers of other species. Merwin trapping in the lake during the study (Section IV) suggested that sockeye salmon released in the lake survived overwinter and grew well. However, a review of lake productivity and fertilization potential (Section III) recommended fertilization of the lake with N, P, and trace elements to increase carrying capacity. The review suggested that restoration of salmon runs would offset needs for fertilization (through nutrient input from carcasses) and allow the process to be phased out.

3) Does adequate spawning habitat for returning adults exist above Cle Elum Lake?

Spawning habitat survey information (Section II) suggests that three of the watercourses in the Cle Elum Lake watershed (the Cle Elum, Cooper, and Waptus Rivers) contain substantial potential spawning habitat for anadromous salmonids. Spawning habitat in these rivers could probably support tens of thousands of returning anadromous salmonids. Because of the destabilized nature of the shoreline of Cle Elum Lake from the fill/spill cycle of the reservoir, little littoral spawning habitat is probably available in the lake itself.

4) Would smolted juveniles orient to the lake outlet and attempt to leave the lake at appropriate times of the year? If not, could biological or engineering solutions be developed?

Merwin trapping conducted in Cle Elum Lake each spring from 1990-1993 (Section IV) indicated that donor populations of sockeye salmon released in the lake could survive overwinter and, at smolting in the spring, orient in the vicinity of the outlet to Cle Elum Dam in an apparent attempt to outmigrate. However, Cle Elum Dam appeared to be an obstacle to outmigration success. Attempts during the study to provide safe exit routes from the reservoir through reconfiguration of the radial gates at Cle Elum Dam and through installation of floating surface weirs were unsuccessful.

Most outmigration from the lake documented during the study (Section IV) occurred during late spring when large volume irrigation spills were released through the spillgates. Unfortunately, these occurred during periods of reduced downstream survival (see 5, below). Under the current spilldeck configuration of Cle Elum Dam, the fill/spill cycle of Cle Elum Reservoir appears to be out of synchrony with the need for safe surface passage from the reservoir. Over a 59 year period (1935-1993), Cle Elum Reservoir only reached spilldeck elevation about 40% of the time by the end of April (the period when most fish should have already outmigrated). About 3% of the time the reservoir never reached spilldeck elevation throughout the year.

The challenge for enhancement of anadromous salmonids to the Cle Elum Lake watershed will be to provide safe exit routes for smolts seeking to migrate pass the dam during early spring (late March-early May) outmigration windows normal for Columbia River sockeye salmon stocks. A smolt bypass system configured for maximal smolt passage would probably need to operate at elevations of 10+ m below the current spilldeck. Exact smolt bypass design and siting elevations will depend on design specific engineering evaluation. However, smolt bypass systems using combinations of towers with netted-leads, vertical overfall gates, and pumped attraction flow floating traps have been used successfully elsewhere.

5) Could smolts leaving the lake successfully migrate downstream through the Cle Elum River and Yakima River?

No severe blockages to outmigration were noted downstream of Cle Elum Dam through the Cle Elum and Yakima Rivers. During the study, about 50 groups of marked sockeye salmon smolts were released in the tailrace at Cle Elum Dam and recaptured 240 km downstream at Prosser Dam. Fish from almost all release groups were documented outmigrating pass Prosser Dam (Section IV). However, there was a negative correlation between release date throughout the spring and recovery proportion. Proper sequencing of outmigration timing through installation of adequate smolt bypass at Cle Elum Dam (see 4, above) will be critical to the overall success of outmigration of any stocks of anadromous salmonids introduced above Cle Elum Dam.

6) Could adults return through the Yakima River to the proximity of Cle Elum Lake?
Over the course of the study, over 35 adult sockeye salmon were observed returning upstream through the Yakima River system. These returns were extremely encouraging regarding the potential for supplementation to aid in recolonization of lost habitat above Cle Elum Dam.

Although the study concentrated specifically on sockeye salmon, the answers to the questions listed above should apply to all extirpated anadromous salmonid runs at Cle Elum Lake and may be generally applicable to other nearby impounded irrigation reservoirs. There is considerable lake and stream habitat above irrigation dams in the Yakima River Basin. Historically this habitat supported anadromous salmonids. In our opinion, reopening this habitat to anadromous fish is vital to fully restoring self-sustaining runs in Yakima River Basin.

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Table 1-- Capture and spawning inventory records for sockeye salmon collected from the Wenatchee River for use in the Cle Elum research projects.

		Survival to spawning			
Year	Number Captured	Females	Males	Percent survival (%)	Eyed egg viability (%)
1987	263	137	113	95	40[a]
1988	520	175	210	86[b]	79
1989	520	165	206	71	77
1990	520	215	239	87	61
1991	520	128	376[c]	97	80
1992	520	270	224	95	77

[a] Low viability was probably due to iodophore disinfection during fertilization. After 1987, disinfection was conducted during water hardening of eggs after fertilization.
[b] Sixty-two fish escaped through a hole in a net-pen during holding.
[c] For an unknown reason, female:male ratio of fish trapped in 1991 was about 1:3; resulting in about 250 males being released to spawn naturally.

Table 2-- Annual releases of juvenile sockeye salmon to Cle Elum Lake and the Cle Elum River.

		Release number[a]		
Brood year	Migration year[b]	Cle Elum Lake[c]	Cle Elum River[d]	Total
1987	1989[e]	75,278	12,555	87,833
1988	1990	76,909	9,048	85,957
1989	1991	75,914	18,073	93,987
1990	1992	90,110	4,852	94,962
1991	1993[f]	172,193	14,979	187,072
1992	1994	390,000[g]	0	390,000

[a] All released groups certified negative for IHN virus.
[b] Year of outmigration as 1-year-old smolts.
[c] Majority of fish released to lake as presmolts in September preceding migration year.
[d] Fish released to river below Cle Elum Dam as yearling smolts in March-June of migration year.
[e] About 50% of the 1987-brood outmigrated as age-2 fish in 1990.
[f] Final year of outmigration evaluations.
[g] Fish released as fry in June preceding migration year. Outmigration was not evaluated.

Table 3-- Trace elements and concentrations used in Cle Elum Lake water bioassays (from Mongillo and Faulconer 1982).

	Concentration (mg/l)
Element:	
B	32.460
Mn	115.374
Zn	1.570
Co	0.354
Cu	0.004
Mo	2.878
Fe	33.051
Compound:	
H_3BO_3	185.520
$MnCl_24H_2O$	415.610
$ZnCl_2$	3.271
$CoCl_26H_2O$	1.428
$CuCl_22H_2O$	1.012
$NaMoO_42H_2O$	7.260
$FeCl_36H_2O$	160.000
$Na_2EDTA2H_2O$	300.000

Table 4.-- Number of fish, mark information, release date, and actual and expanded recapture information at Prosser Dam for juveniles of the 1987-brood outplanted to the Cle Elum River, 1989.

				Recovery data[a]				
				Actual[b]		Expanded[c]		Median
Release group[d]	Number of fish[e]	Brand[f]	Release date	number	%	number	%	travel time (d)
T-1 (A)	702	LD 9 (1)	04/27/89	94	13.40	137	19.52	4
T-1 (B)	705	LD 9 (2)	04/27/89	64	9.10	91	12.91	4
T-1 (C)	705	LD 9 (3)	04/27/89	84	11.91	131	18.58	4
T-1 (D)	205	LD 3 (3)	04/27/89	21	10.24	32	15.60	4
T-2	1,823	LA K (1)	05/03/89	159	8.72	239	13.11	5
T-3	1,828	LA 3 (1)	05/04/89	104	5.68	158	8.64	6
T-4 (A)	1,806	LA W (3)	05/23/89	26	1.44	39	2.16	12
T-4 (B)	1,806	LA W (4)	05/23/89	0	0.00	0	0.00	--
T-5	2,975	RD E (4)	06/14/89	40	1.35	67	2.25	6
TOTAL	2,555							

[a] Calculated from freeze brand recoveries in 1989.

[b] Actual number and percent of release group recaptured at fish collection facility.

[c] Number and percent of release group recaptured at fish collection facility expanded for YIN supplied facility sampling rate.

[d] T indicates river survival calibration groups released into the tailrace of Cle Elum Dam; number indicates release sequence; letter in parenthesis indicates replicate release sequence.

[e] All fish were freeze branded and coded wire tagged.

[f] LD = left dorsal; LA = right anterior; RD = right dorsal; letter/number before parenthesis indicates brand; number in parenthesis indicates brand rotation.

Table 5.-- Fish release and recovery information and estimated outmigration pass Cle Elum Dam for 1987- to 1992-brood juvenile sockeye salmon outplanted to Cle Elum Lake, 1989-1993.

Cle Elum Lake release information				**Prosser Dam recapture data**					
Brood Year	Release years[a]	Number of fish released	Recapture year	Median recovery date	Estimated number that passed dam[b]	Expansion factors calibration group[c]	Expansion factors calibration rate[d]	Estimated outmigration past Cle Elum Dam number[e]	Estimated outmigration past Cle Elum Dam %
1987	1988-89	75,278	1989[f]	05/16/89	91	T-2&3[g]	9.20	837	1.11
				06/18/89	487	T-5	44.40	21,622	28.54
					578			22,495	29.65
			1990[f,h]	05/15/90	2	T-4	19.61	39	0.05
				06/02/90	861	T-5	22.94	19,751	26.08
					863			19,790	26.13
1988	1989-90	76,909	1990[f]	05/06/90	85	T-4	19.61	1,667	2.17
				06/15/90	1,663	T-6	3.59	5,970	7.76
					1,748			7,637	9.93

Table 5.-- Continued.

Cle Elum Lake release information				Prosser Dam recapture data					
Brood Year	Release years[a]	Number of fish released	Recapture year	Median recovery date	Estimated number that passed dam[b]	Expansion factors calibration group[c]	Expansion factors calibration rate[d]	Estimated outmigration past Cle Elum Dam number[e]	Estimated outmigration past Cle Elum Dam %
1989	1990-91	75,914	1991[i]	04/05/91[j]	51	T-3	4.07	208	0.27
				04/20/91	5,320	T-4	2.07	11,012	14.51
				05/03/91	2,932	T-5	1.18	3,460	4.56
				05/16/91	1,144	T-6	1.07	1,224	1.61
				06/12/91	253	T-8	4.43	1,121	1.48
					9,700			17,023	22.43
1990	1991-92	90,110	1992[f]	04/22/92	148	T-4&5[g]	5.75	857	0.95
					71	T-6&7[g]	16.93	1,202	1.33
				07/08/92	25	T-12[k]	43.00	1,075	1.19
					244			3,134	3.47
1991	1992-93	172,193	1993[l]	-- -- -- --	0	--	-- --	0	0.00
1992	1993[m]	390,000	[n]	-- -- -- --	--	--	-- --	--	-- --

Table 5.-- Continued.

[a] Most lake release fish released in serial groups from the fall preceding to spring of age-1 outmigration.

[b] Estimated survival of lake release groups to Prosser Dam. From Yakama Indian Nation supplied recapture information.

[c] Calibration group released to Cle Elum River below Cle Elum Dam whose recovery timing coincided with median recapture of lake release component at Prosser Dam (see Tables 5-9).

[d] Release number/expanded recovery number for calibration group released below Cle Elum Dam.

[e] Prosser Dam expanded recapture number for lake releases expanded for estimated instream loss of lake release component.

[f] Groups displayed bimodal recovery at Prosser Dam in 1989, 1990, and 1992.

[g] Average of two calibration groups.

[h] 1987-brood displayed substantial age-2 smolt outmigration.

[i] Groups displayed trimodal recovery at Prosser Dam in 1991.

[j] Outmigration period segmented into phases to coincide with instream survival calibration groups.

[k] T-12 instream calibration group was experimental release of 301 PIT tagged 1991-brood with an estimated seven fish passing Prosser Dam.

[l] Drought conditions resulted in Cle Elum Lake never filling to spillway elevation in 1993. Therefore, no lake released anadromous sockeye salmon were able to outmigrate past Cle Elum Dam in 1993.

[m] Fish released as fry in June preceding age-1 outmigration year.

[n] Outmigration study phase was terminated prior to age-1 outmigration.

Table 6.-- Number of fish, number PIT tagged, release date, and actual and expanded recapture information at Prosser Dam for juveniles of the 1988-brood outplanted to Cle Elum River, 1990.

Release group[d]	Number of fish	Number PIT tagged	Release date	Recovery data[a]: Actual[b] number	Actual[b] %	Expanded[c] number	Expanded[c] %	Median travel time (d)
T-1	1,503	511	03/16/90	81	15.85	267	52.17	7
T-2	1,529	500	03/30/90	58	11.60	250	50.01	4
T-3	1,500	501	04/12/90	30	5.99	140	27.93	4
T-4	1,500	498	05/01/90	27	5.42	751	5.10	8
T-5	1,513	502	05/17/90	8	1.59	22	4.36	10
T-6	1,503	500	06/01/90	38	7.60	139	27.73	4
TOTAL	9,048	3,012						

[a] Calculated from PIT-tag recoveries in 1990.

[b] Actual number and percent of release group recaptured at fish collection facility.

[c] Number and percent of release group recaptured at fish collection facility expanded for YIN-supplied facility sampling rate.

[d] T indicates river survival calibration groups released into the tailrace of Cle Elum Dam; number indicates release sequence.

Table 7.-- Summary of sockeye salmon releases into Cle Elum Lake and numbers and percentages of tagged fish recovered in Merwin traps placed near dam.

Brood Year	Release Years	Release Number	Merwin Trap Recaptures 1990[a]	1991[a]	1992[b]	1993[b]
1987	1988-89	75,278	767[c]	---	---	---
1988	1989-90	76,909	1,420	---	---	---
1989	1990-91	75,914	---	2,520	---	---
1990	1991-92	90,110	---	---	365	---
1991	1992-93	172,193	---	---	---	2,387

[a] Single Merwin trap used for fish collection. The trap was sited on the west shore of Cle Elum Lake about 1 km from Cle Elum Dam.
[b] Two Merwin traps were used for fish collection. One trap was sited on the west shore of Cle Elum Lake about 1 km from Cle Elum Dam. The second trap was sited along the south lake shore off the face of the dam within 0.3 km of the spillway. Data are combined west and south shore trap data.
[c] Fish captured as age-2 smolts.

Table 8.-- Number of fish, number PIT tagged, release date, and actual and expanded recapture information at Prosser Dam for juveniles of the 1989-brood outplanted to Cle Elum River, 1991.

				Recovery data[a]				
		Number		Actual[b]		Expanded[c]		Median
Release	Number	PIT	Release					travel
group[d]	of fish	tagged	date	number	%	number	%	time (d)
T-1	2,503	501	02/26/91	36	7.19	148	29.54	3
T-2	2,021	500	03/11/91	106	21.20	303	60.60	5
T-3	2,020	501	03/25/91	37	7.39	123	24.55	12
T-4	2,027	509	04/09/91	85	16.70	246	48.33	5
T-5	1,991	501	04/23/91	148	29.54	423	84.43	3
T-6	1,994	515	05/07/91	192	37.28	481	93.40	4
T-7	1,996	501	05/21/91	39	7.78	89	17.76	4
T-8	2,024	501	06/04/91	40	7.98	113	22.55	6
T-9	1,992	507	06/18/91	11	2.14	41	8.09	4
TOTAL	18,073	4,536						

[a] Calculated from PIT-tag recoveries in 1991.

[b] Actual number and percent of release group recaptured at fish collection facility.

[c] Number and percent of release group recaptured at fish collection facility expanded for YIN-supplied facility sampling rate.

[d] T indicates river survival calibration groups released into the tailrace of Cle Elum Dam; number indicates release sequence.

Table 9.-- Number of fish, number PIT tagged, release date, and actual and expanded recapture information at Prosser Dam for juveniles of the 1990-brood outplanted to Cle Elum River, 1992.

Release group[d]	Number of fish	Number PIT tagged	Release date	Recovery data[a] Actual[b] number	%	Expanded[c] number	%	Median travel time (d)
T-1	503	503	03/17/92	11	2.18	24	4.77	10
T-2	501	501	03/24/92	11	2.20	20	3.99	16
T-3	489	489	03/31/92	14	2.86	32	6.54	19
T-4	502	502	04/07/92	10	1.99	24	4.78	13
T-5	484	484	04/14/92	58	11.98	145	29.96	6
T-6	480	480	04/21/92	5	1.04	9	1.88	13
T-7	453	453	04/28/92	27	5.96	45	9.93	8
T-8	476	476	05/05/92	0	0.00	0	0.00	--
T-9	511	511	05/12/92	0	0.00	0	0.00	--
T-10	375	375	05/19/92	0	0.00	0	0.00	--
T-11	87	87	05/26/92	0	0.00	0	0.00	--
TOTAL	4,852	4,852						

[a] Calculated from PIT-tag recoveries in 1992.
[b] Actual number and percent of release group recaptured at fish collection facility.
[c] Number and percent of release group recaptured at fish collection facility expanded for YIN-supplied facility sampling rate.

Table 10.-- Number of fish, number PIT tagged, release date, and actual and expanded recapture information at Prosser Dam for juveniles of the 1991-brood outplanted to the Cle Elum River, 1993.

				Recovery data[a]				
				Actual[b]		Expanded[c]		
Release group[d]	Number of fish	Number PIT tagged	Release date	number	%	number	%	Median travel time (d)
T-1	1,005	505	03/09/93	40	7.92	110	21.78	8
T-2	1,000	500	03/16/93	20	4.00	68	13.60	6
T-3	1,005	501	03/23/93	46	9.18	188	37.52	4
T-4	1,049	508	03/30/93	13	2.56	44	8.66	6
T-5	1,014	506	04/06/93	26	5.14	81	16.00	6
T-6	1,007	504	04/13/93	21	4.17	52	10.32	7
T-7	1,015	510	04/20/93	9	1.76	25	4.90	9
T-8	1,008	505	04/27/93	3	0.59	8	1.58	15
T-9	1,012	507	05/04/93	10	1.97	41	8.09	11
T-10	1,009	508	05/11/93	21	4.13	93	18.31	3
T-11	1,005	503	05/18/93	5	0.99	10	1.99	6
T-12	1,007	503	05/21/93	6	1.19	9	1.79	16
T-13	1,007	504	06/01/93	16	3.17	26	5.16	8
T-14	1,001	505	06/08/93	2	0.39	3	0.59	9
T-15	735	508	06/15/93	1	0.20	2	0.40	nd
TOTAL	14,879	7,577						

[a] Calculated from PIT-tag recoveries in 1993.

[b] Actual number and percent of release group recaptured at fish collection facility.

[c] Number and percent of release group recaptured at fish collection facility expanded for YIN-supplied facility sampling rate.

[d] T indicates river survival calibration groups released into the tailrace of Cle Elum Dam; number indicates release sequence.

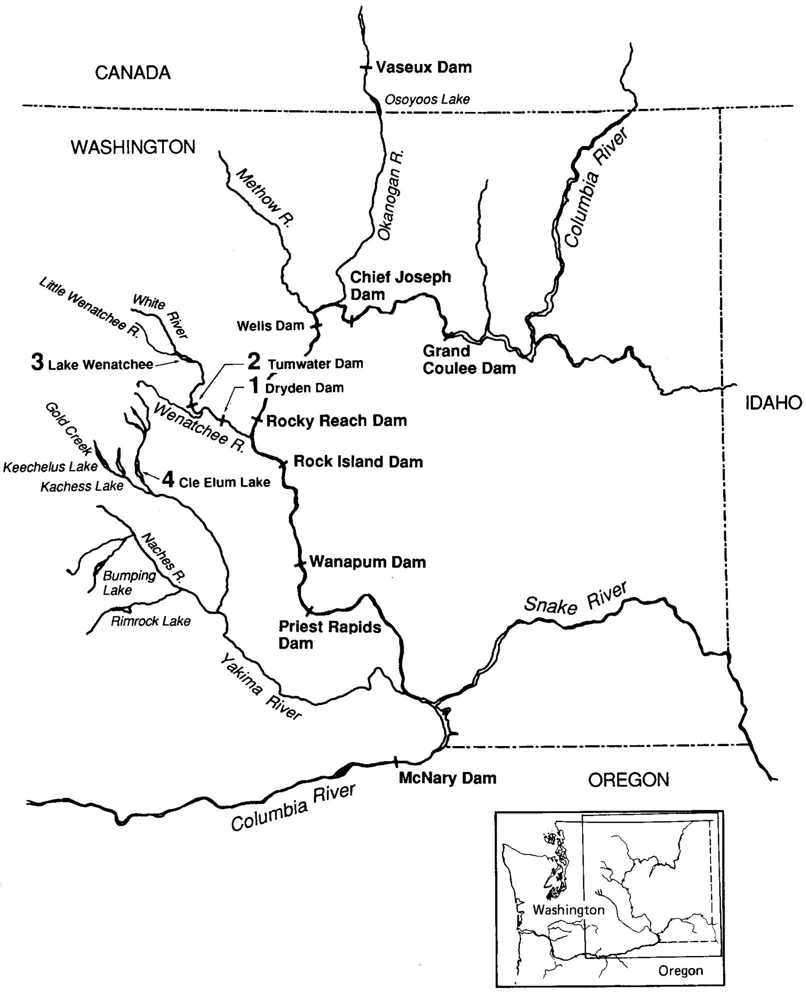


Figure 1. Mid-Columbia Basin map showing study areas in the Wenatchee and Yakima River Basins.

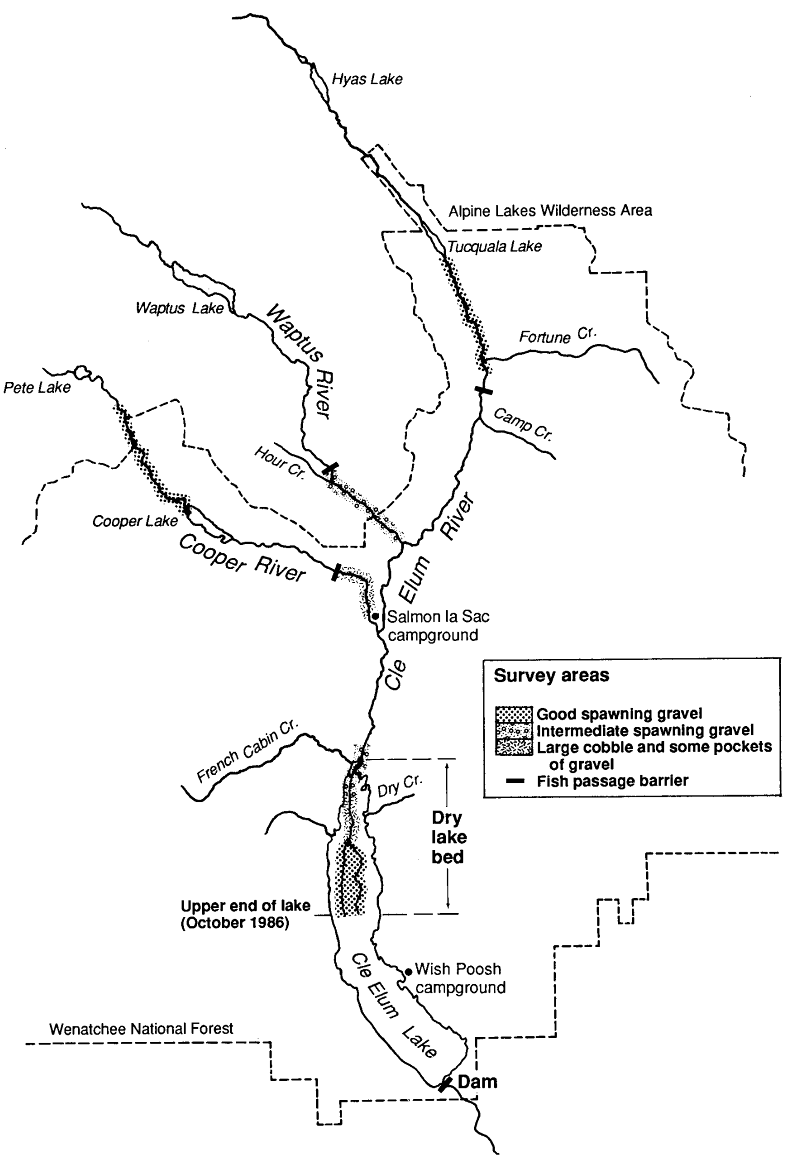


Figure 2. Cle Elum Lake watershed area map.

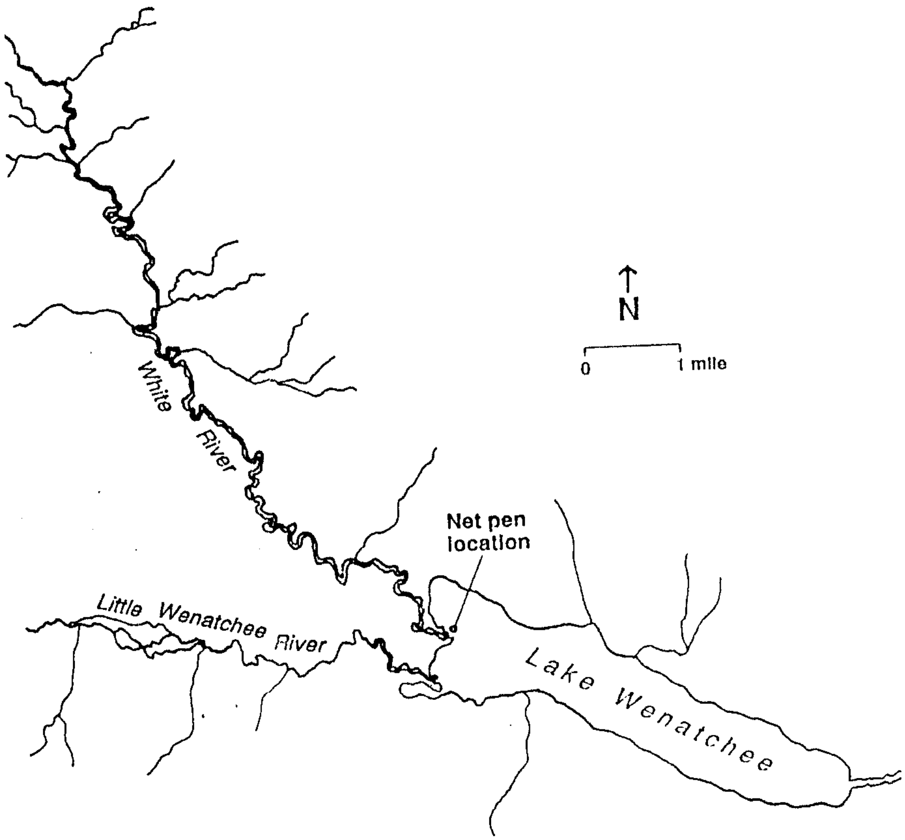


Figure 3. Lake Wenatchee watershed area map.

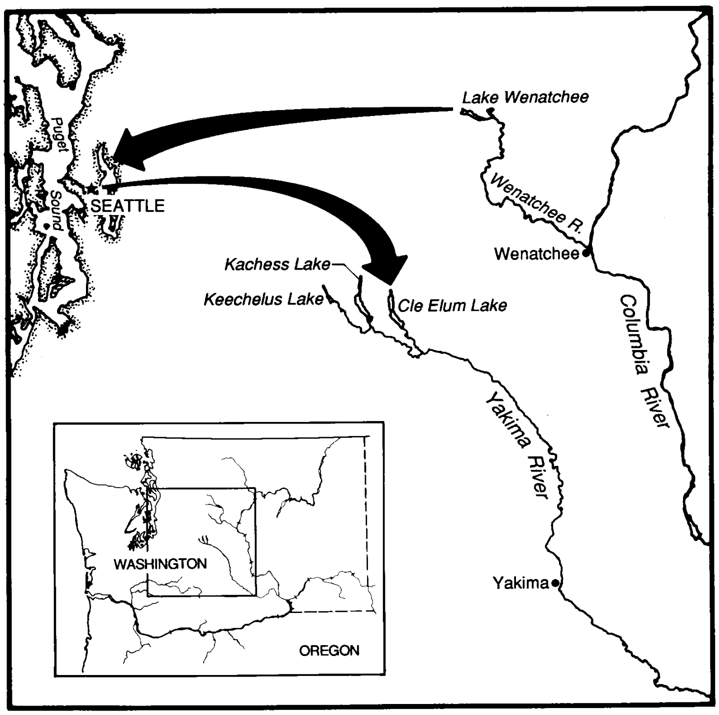


Figure 4. Transfer route of salmon gametes from net-pens in Lake Wenatchee to NMFS Seattle Laboratory and movement of juveniles to Cle Elum Lake.

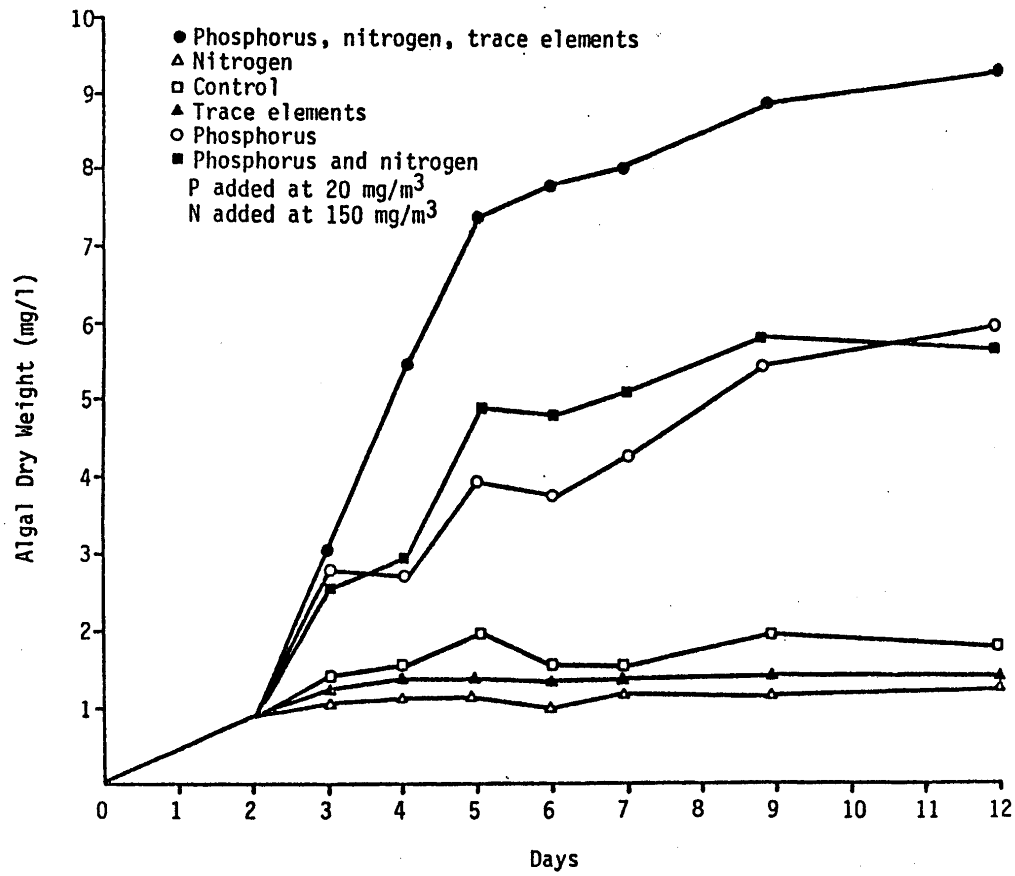


Figure 1.--Bioassay results using Cle Elum Lake water, nutrient additions, and the alga Selenastrum capricornutum (from Mongillo and Faulconer 1982).

Figure 5. Bioassay results using Cle Elum Lake water, nutrient additions, and the alga *Selenastrum capricorutum* (from Mongillo and Faulconer 1982).

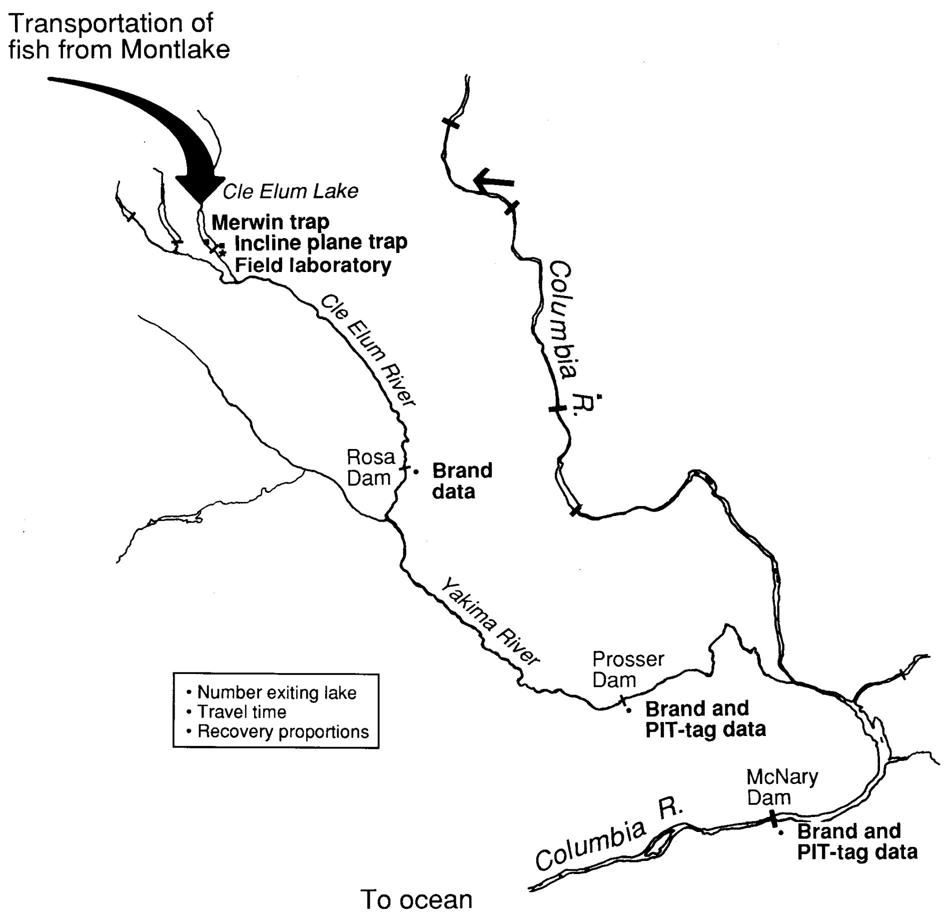


Figure 6. Yakima River Basin area map showing transfer route of juvenile salmon from NMFS Seattle Laboratory and post-release sampling sites.

Figure 7. Radial discharge gates at Cle Elum dam.

Figure 8. Inclined plane fish sampling trap at radial gates at spillway of Cle Elum dam.

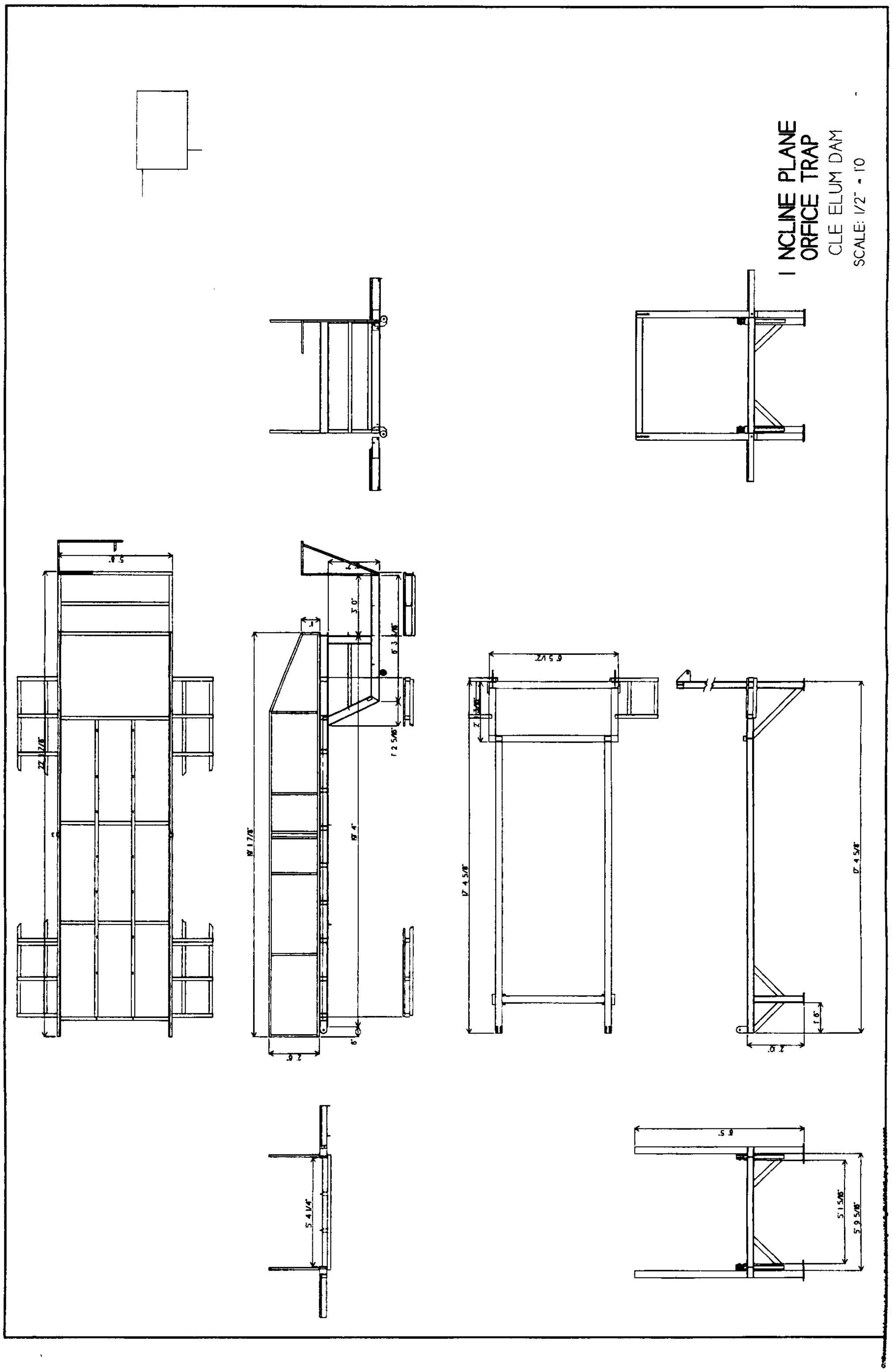


Figure 9. Schematic diagram of inclined plane fish sampling trap installed at the radial gates of the spillway of Cle Elum dam.

Figure 10. Floating smolt bypass trap above radial gates at spillway of Cle Elum dam.

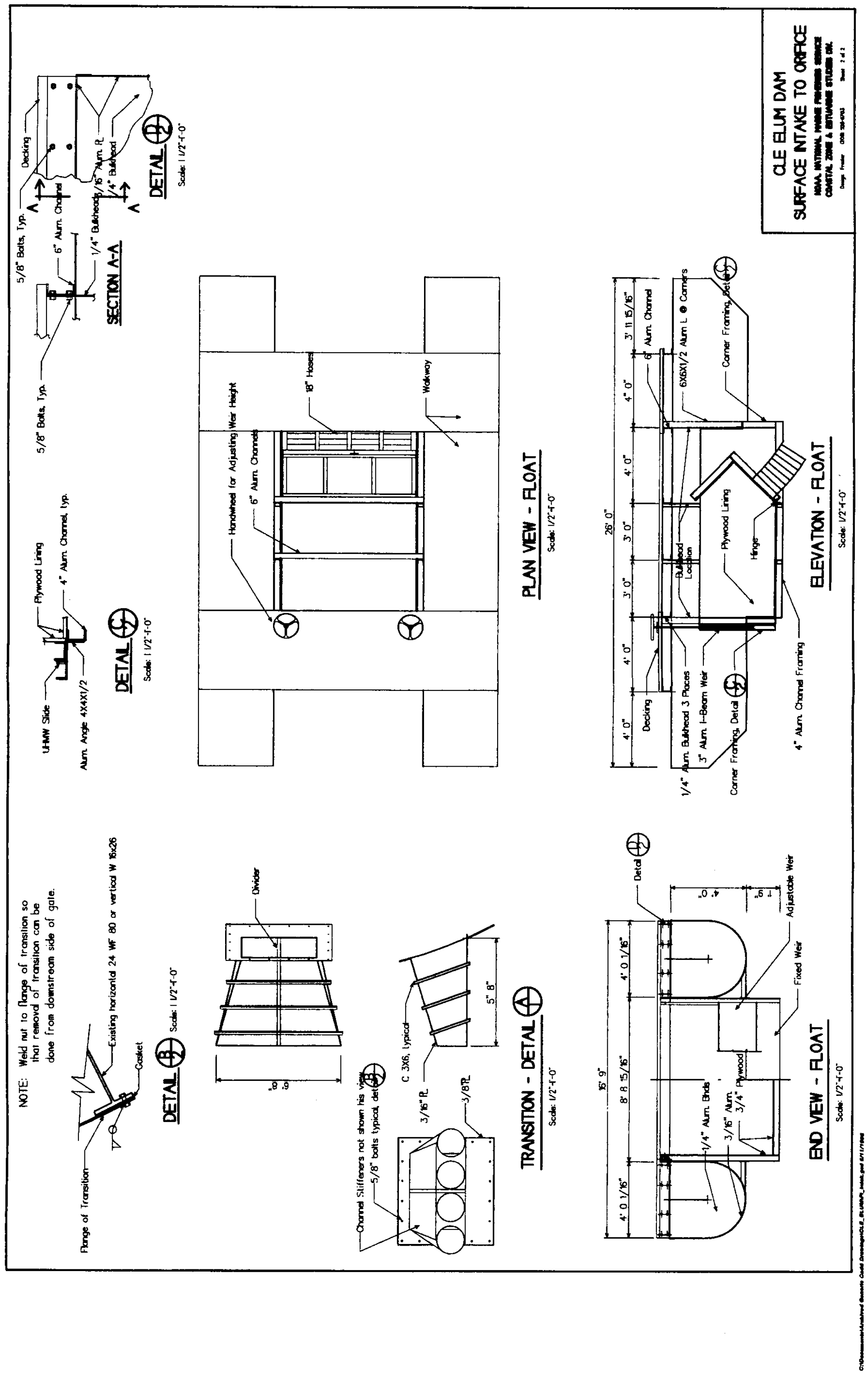


Figure 11. Schematic diagram of floating smolt bypass trap above radial gates at spillway of Cle Elum dam.

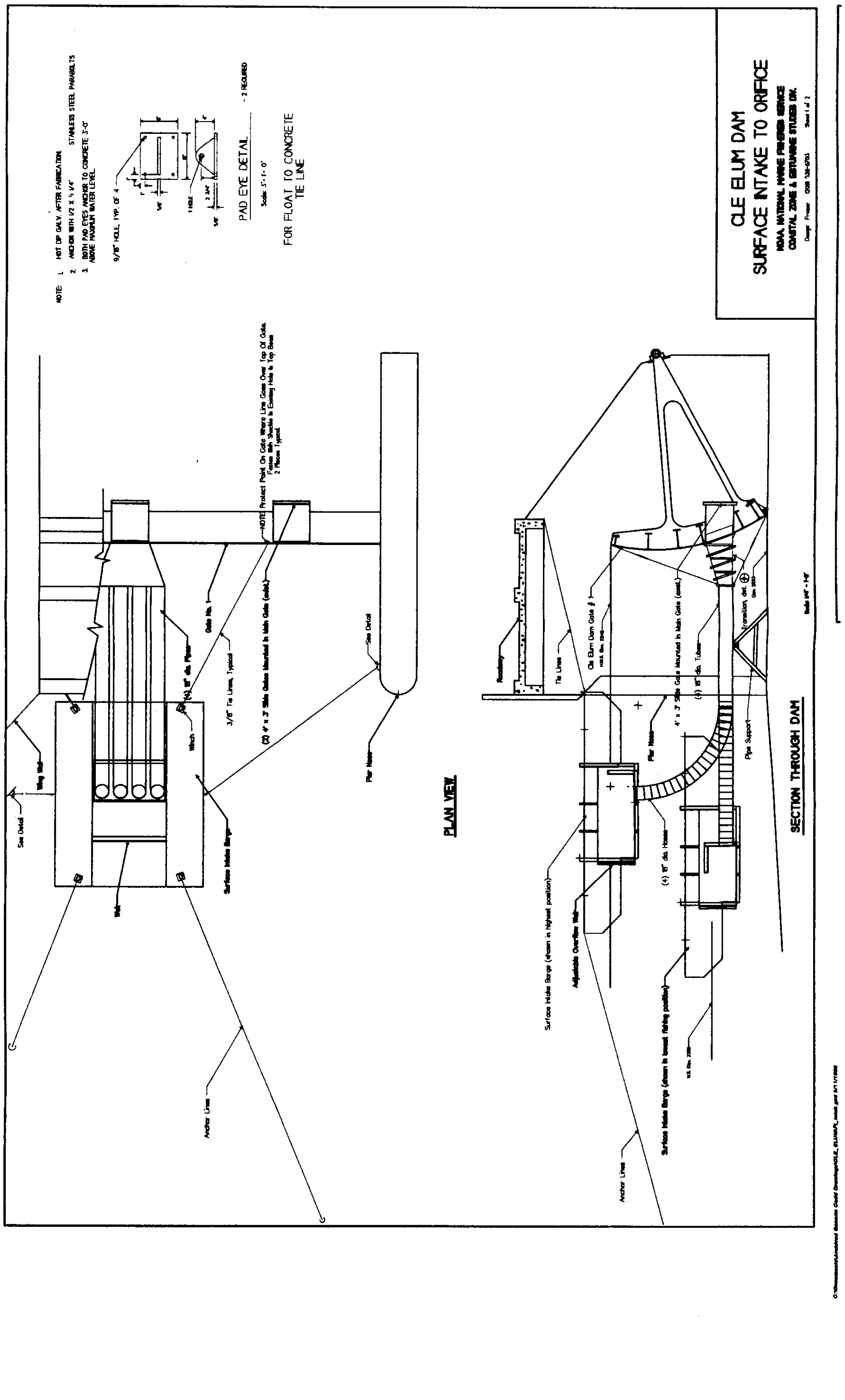
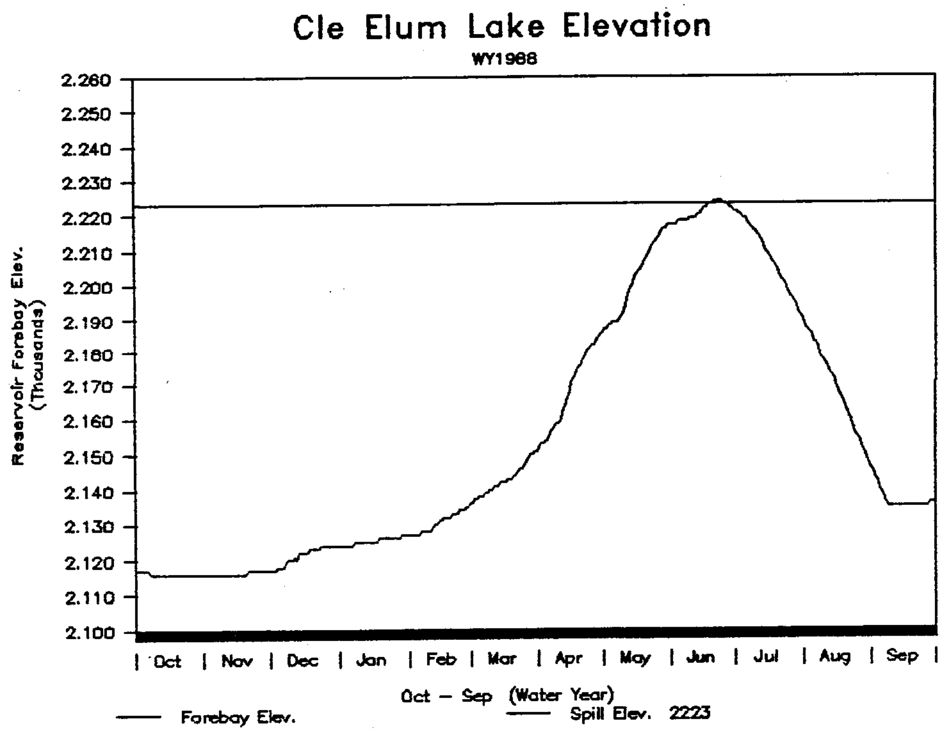


Figure 12. Schematic diagram of attachment of floating smolt bypass trap to radial gates at spillway of Cle Elum dam.

Figure 13. Merwin trap deployed in Cle Elum Lake.



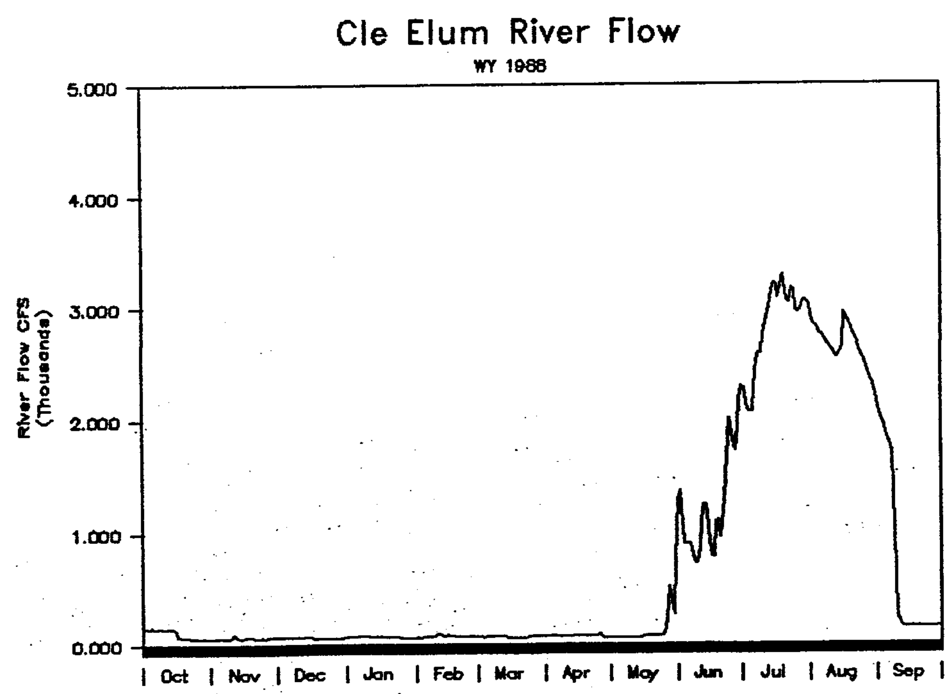


Figure 14. Cle Elum Lake hydrograph and river flow profile, 1989. Vertical line indicates spilldeck elevation.

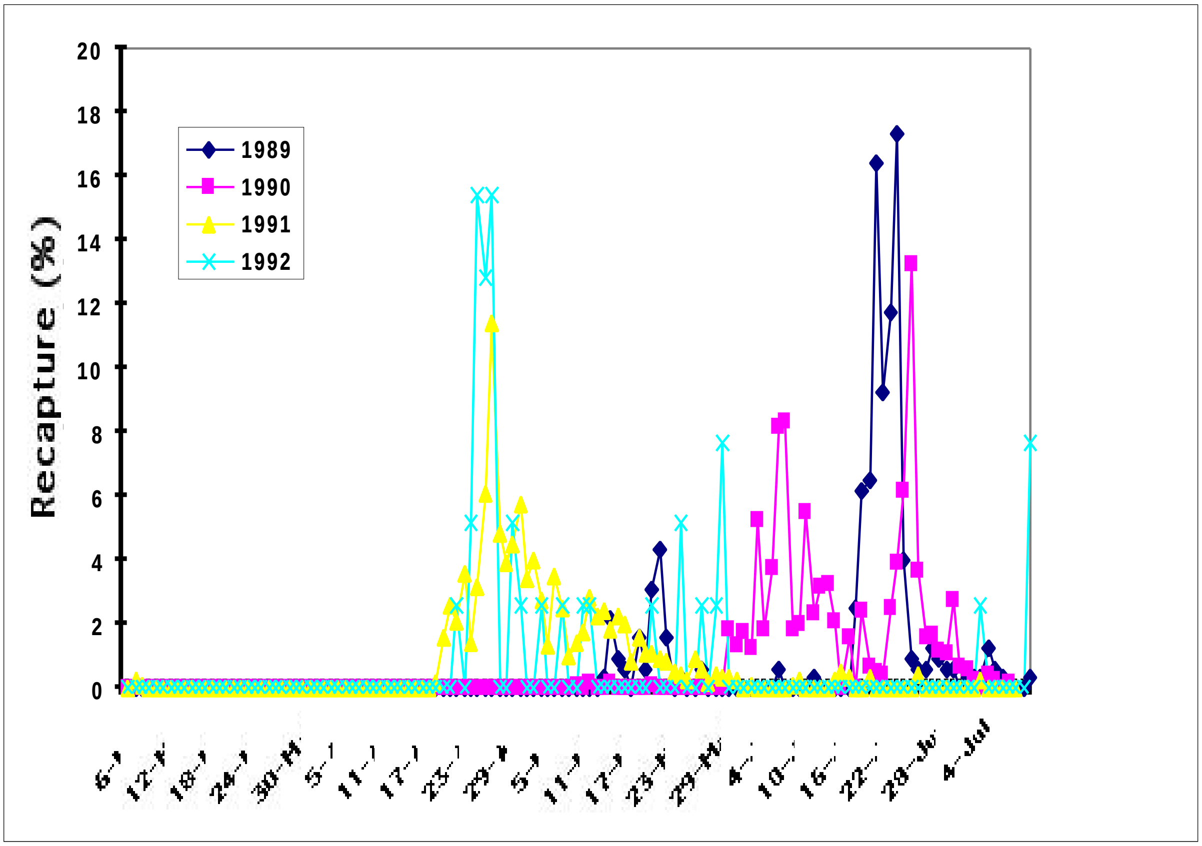


Figure 15. Recovery timing and percentages of total recovery for lake release fish recovered at Prosser Dam during the years of the study. Because of drought related conditions in 1993, Cle Elum Dam did not fill to spilldeck elevation and no fish were able to outmigrate

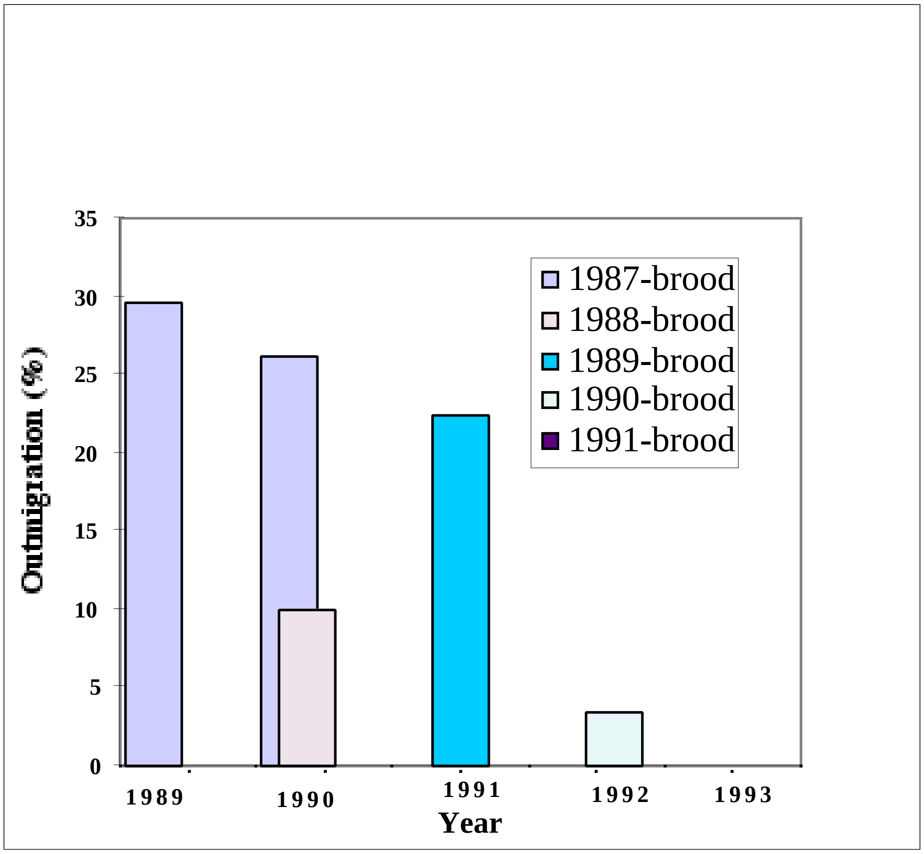
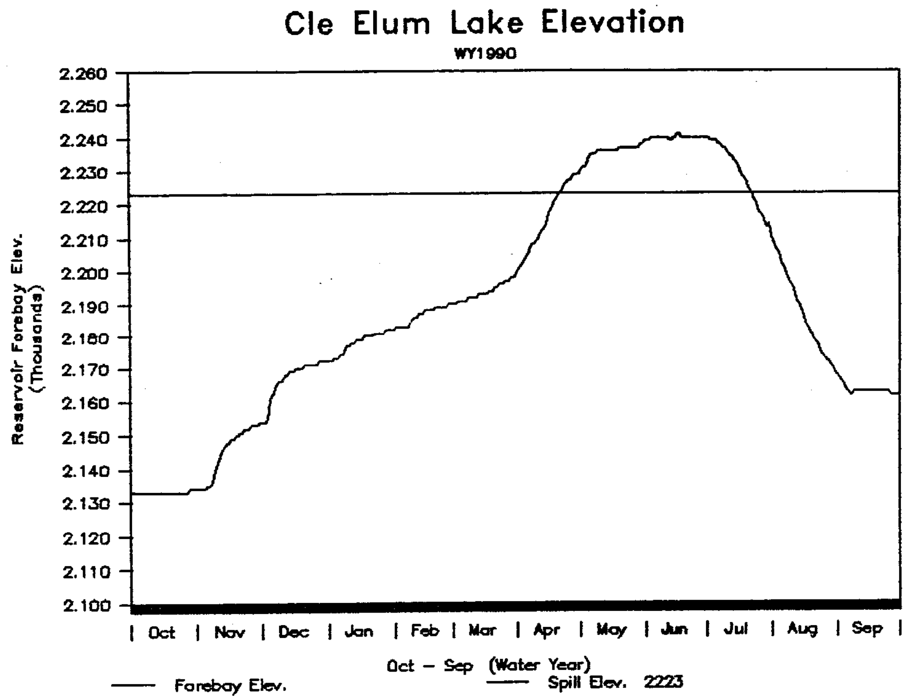


Figure 16. Percent estimated outmigration of 1987-1991 year classes of sockeye salmon from Cle Elum Lake, 1989-1993. Note that the reservoir did not fill to spilldeck elevation in 1993. Therefore, no outmigration was noted for the 1991-brood.



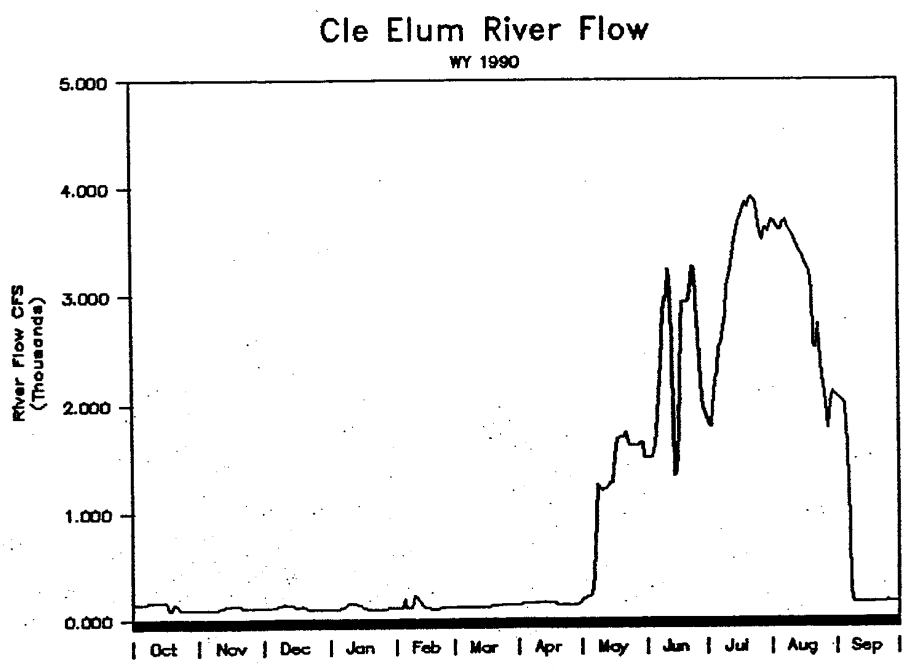
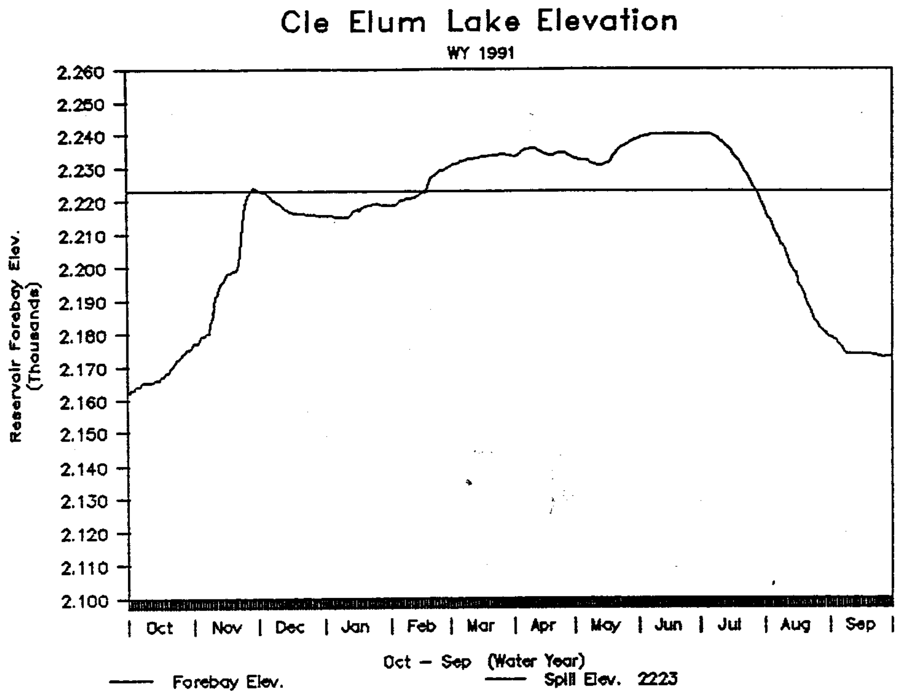


Figure 17. Cle Elum Lake hydrograph and river flow data, 1990. Vertical line indicates spilldeck elevation..



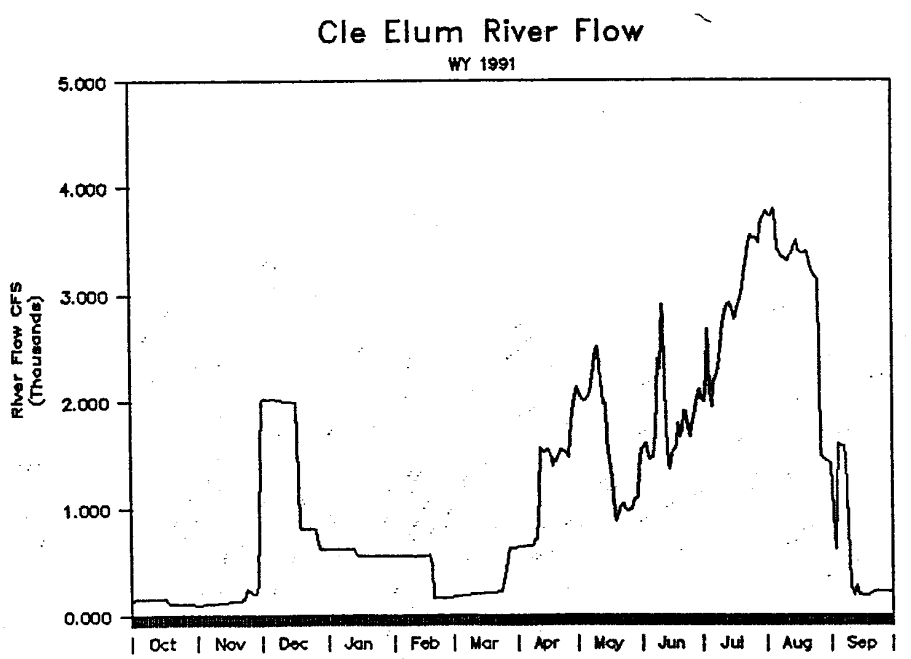
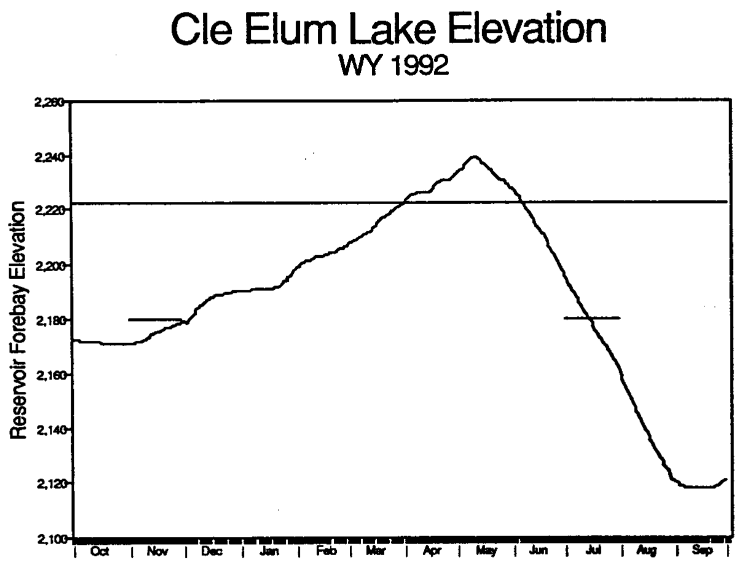


Figure 18. Cle Elum Lake hydrograph and river flow data, 1991. Vertical line indicates spilldeck elevation.



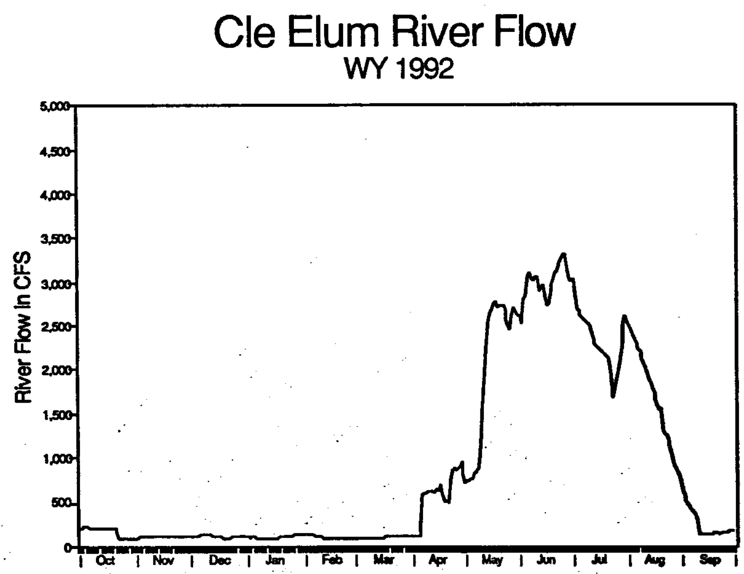
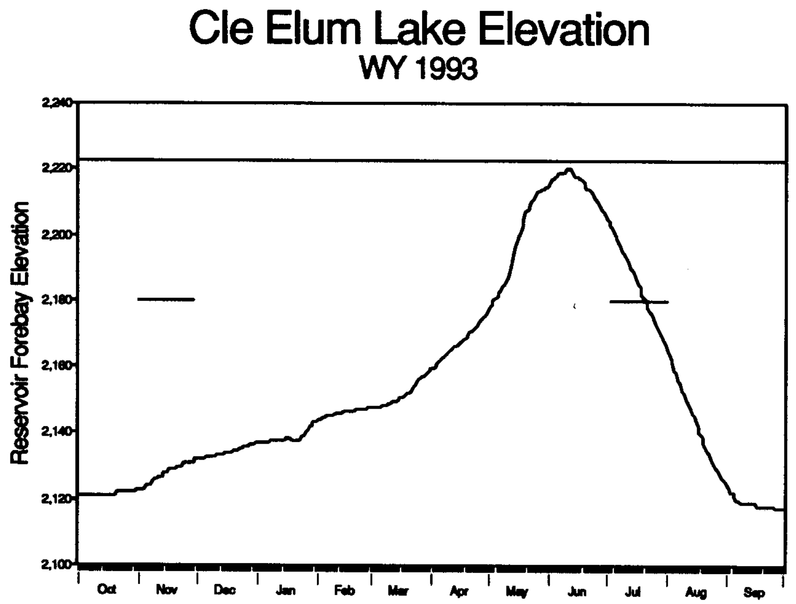


Figure 19. Cle Elum Lake hydrographic and river flow data, 1992. Vertical line indicates spilldeck elevation.



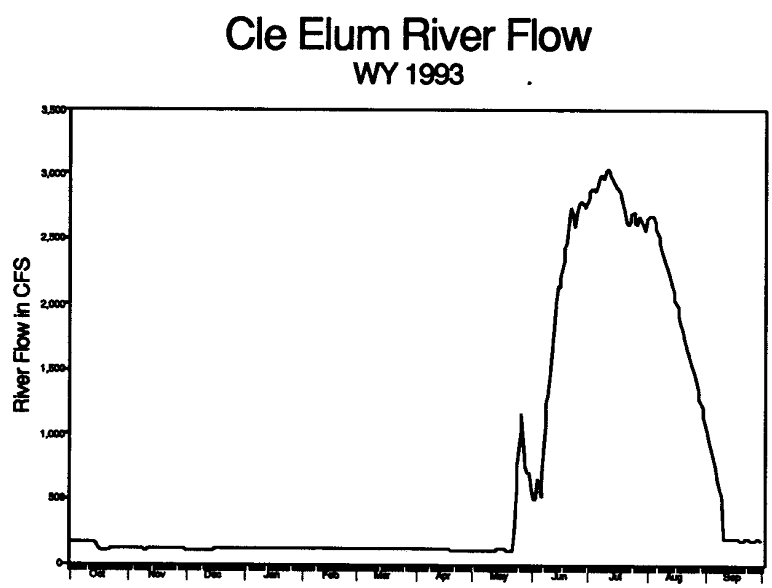


Figure 20. Cle Elum Lake hydrographic and river flow data, 1993. Vertical line indicates spilldeck elevation.

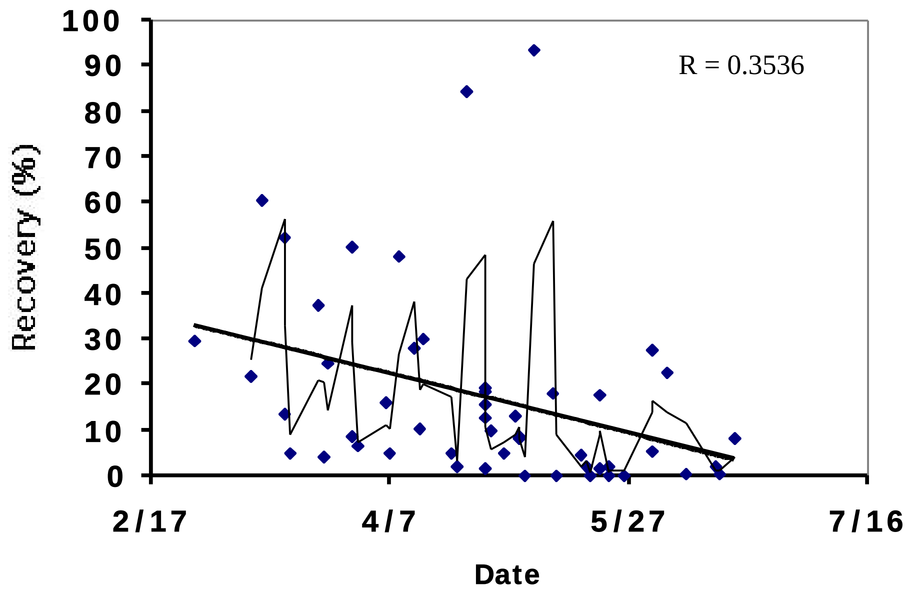


Fig. 21. Recovery proportion for groups of sockeye salmon released to the tailrace of Cle Elum Dam, 1989-1993. Actual data (symbols), least squares regression line and two group moving average are shown.

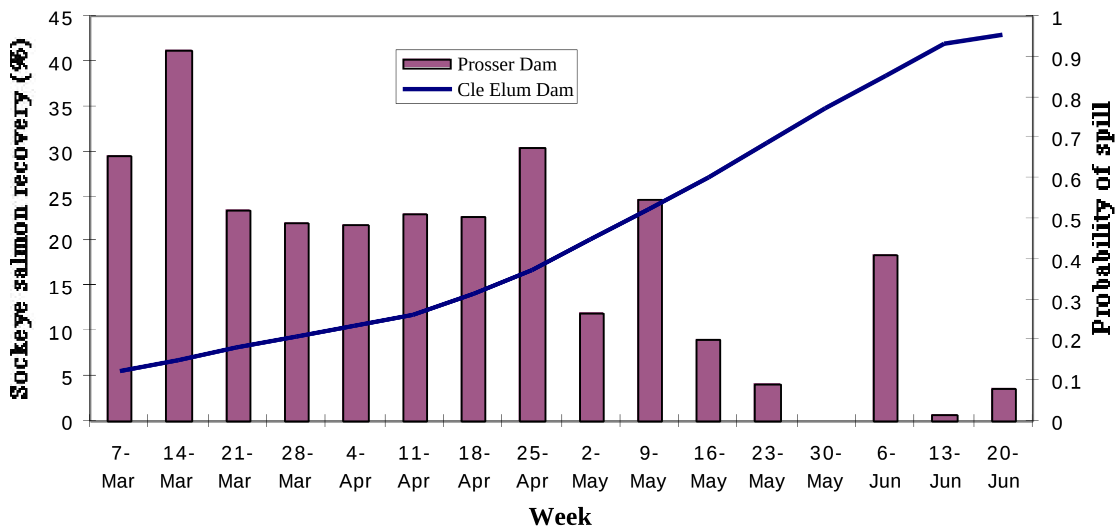


Fig. 22. Average weekly estimated survival to Prosser Dam for groups of sockeye salmon released to the Cle Elum River at the tailrace of Cle Elum Dam (1989-1993) vs. average percent of time Cle Elum Reservoir reached spilldeck elevation by sequential weekly period (1935-1993).

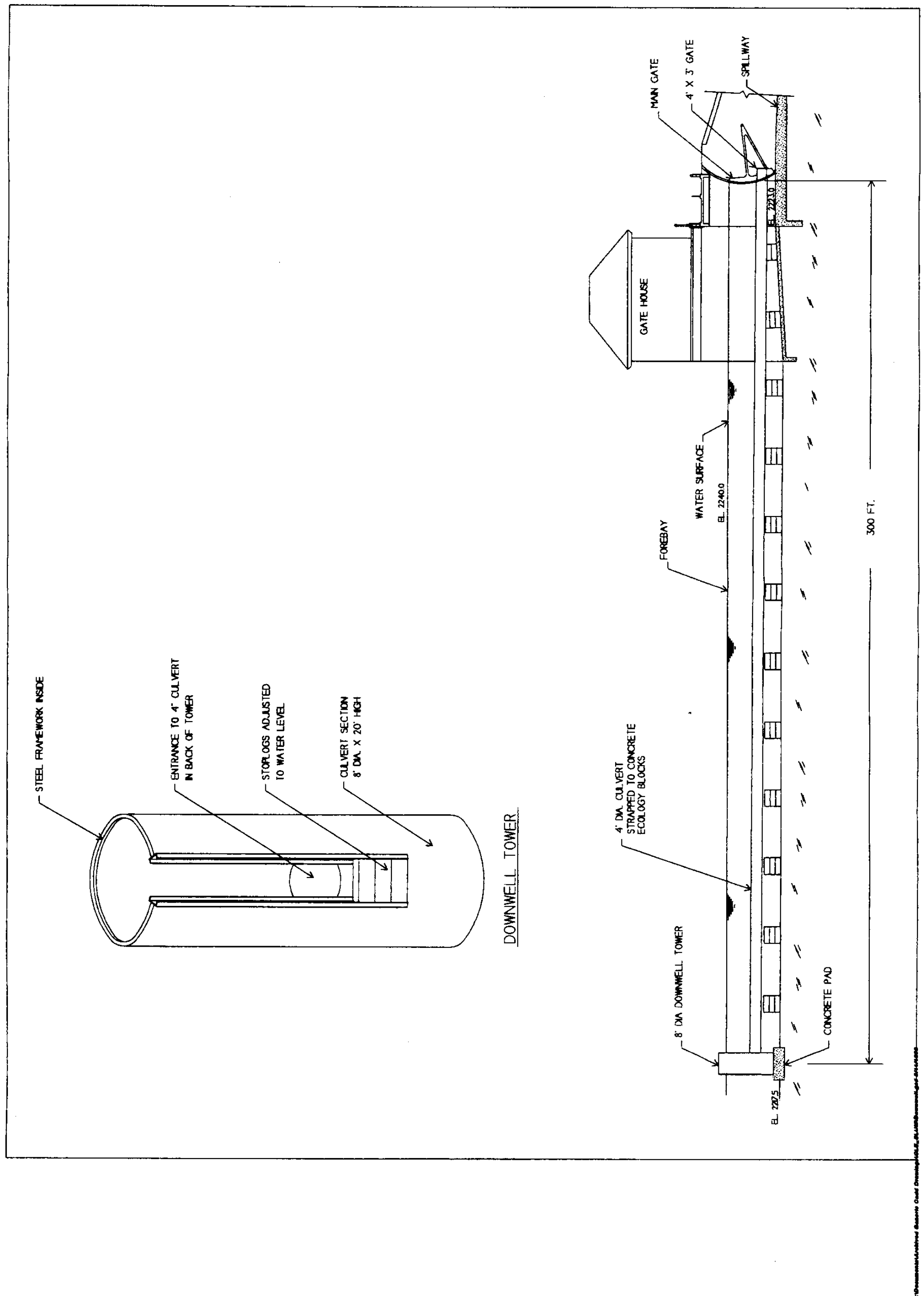


Figure 23. Schematic diagram of tower for bypassing smolts.

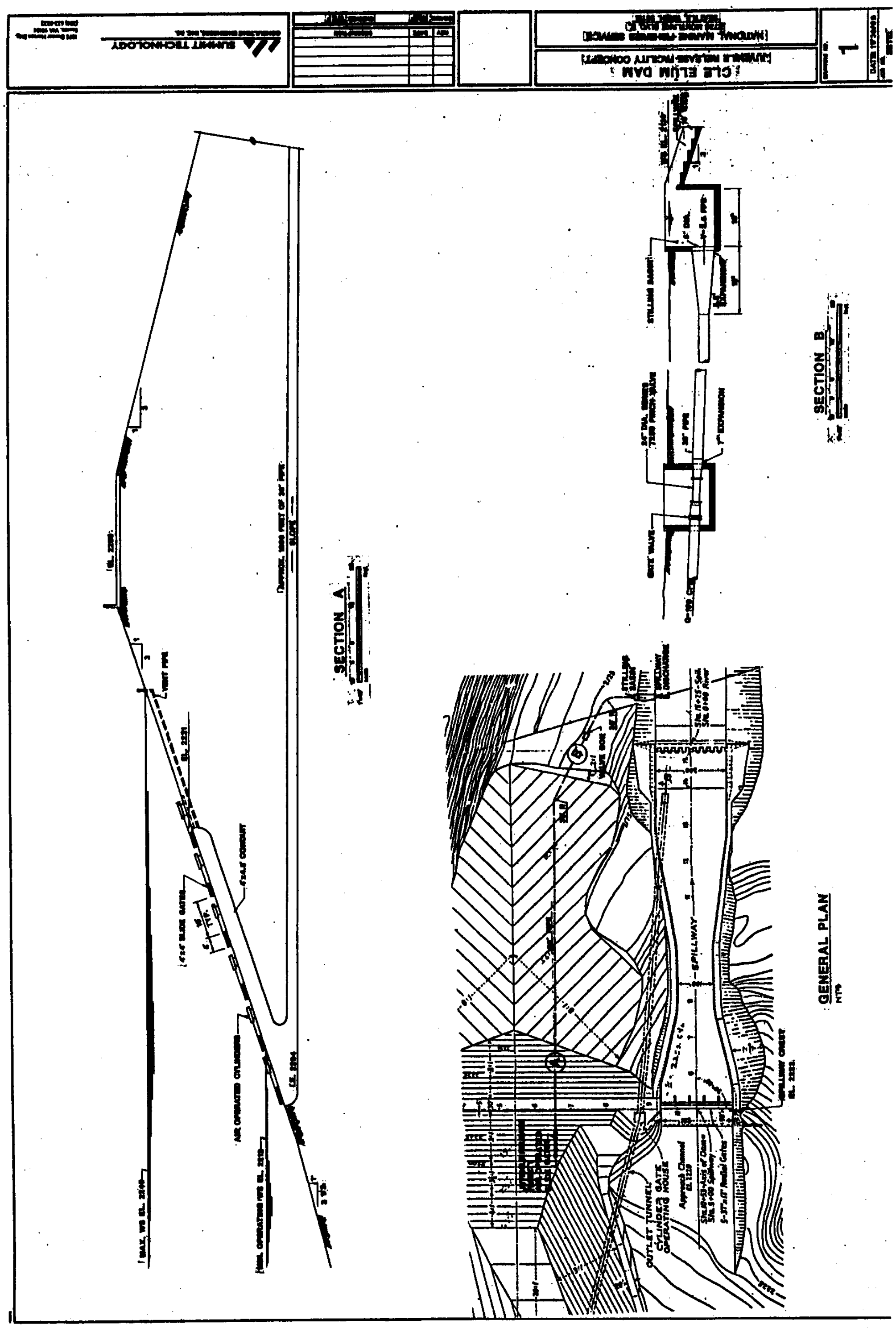


Figure 24. Schematic diagram of vertical slide gate smolt bypass system.

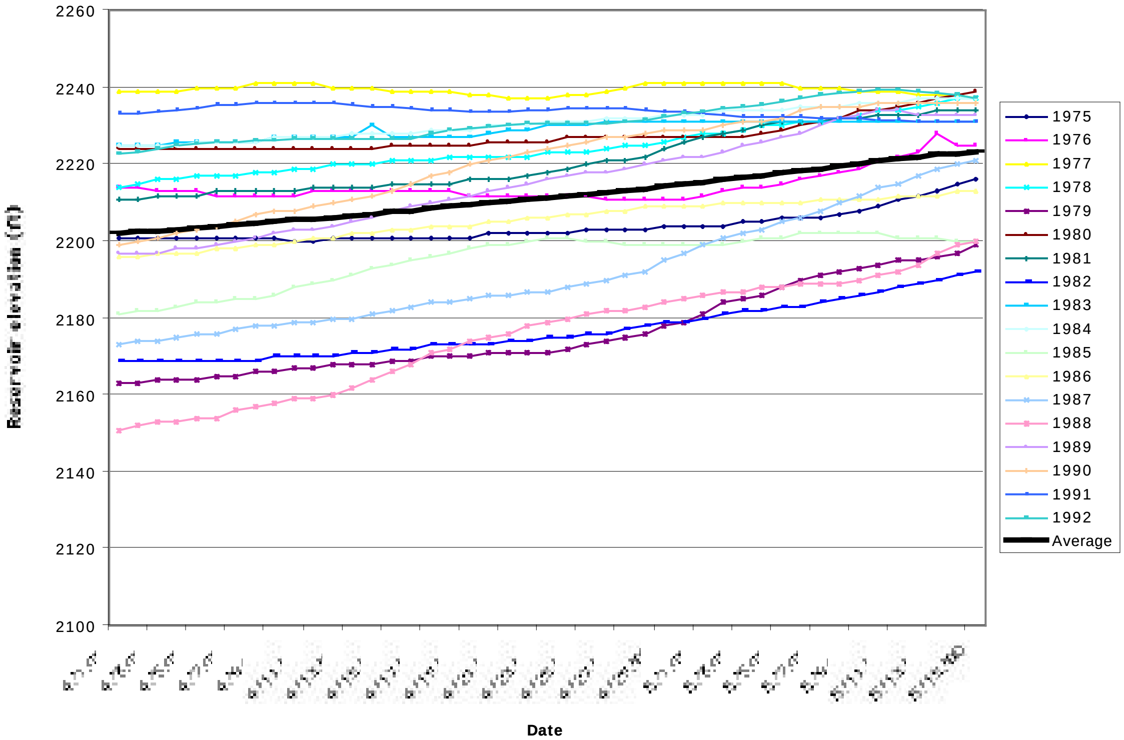


Figure. 25. Cle Elum Reservoir springtime fill profile, 1975-1992. Note: the floor of the spilldeck at Cle Elum Dam is located at elevation 2223.

APPENDIX A:

Summit Technology, Consulting Engineers,

design concept report for a smolt bypass system at Cle Elum Dam

SUMMIT TECHNOLOGY
CONSULTING ENGINEERS, IN~, P.S.

November 30, 1989

U.S. Department of Commerce
National Oceanic and Atmospheric Administration
National Marine Fisheries Service
7600 Sand Point Way N.E.
Seattle, WA 98115-0070

Attention: Mr. Richard Frazier
Subject: Conceptual Design; Cle Elum Dam Juvenile Release Facility Reference Order No. 40-JANF-0-008

Dear Mr. Frazier:

Summit Technology is pleased to submit the enclosed Conceptual Design Report for the Cle Elum Dam - Juvenile Fish Facility.

If you have any questions, or require additional information, please give me or Winn Farr a call.

Sincerely,

John R. Hutchins Principal

JRH:lp

Enclosure

615 Second Avenue Suite 580 Seattle, WA 98104 (206) 622~222

FAX (206) 622A764

SUMMIT TECHNOLOGY
CONSULTING ENGINEERS, INCORPORATED RS.

CLE ELUM DAM JUVENILE FISH FACILITY

CONCEPTUAL DESIGN NARRATIVE

The National Marine Fisheries Service (NMFS) has been investigating the feasibility of re-establishing sockeye salmon in the waters above Cle Elum Dam. Sockeye fingerlings have been placed in rearing pens in the forebay of the dam and will be released in the Spring of 1990.

A minimum water flow of 100 cfs must be released downstream of the dam for fish survival. A 14-foot diameter tunnel, 140-feet below the top of the dam, is normally used to release minimal and non-flood flows. The dam stores water primarily for irrigation and water releases are planned to accommodate the farming community.

In the Spring of 1990, NMFS will conduct a test to determine smolting sockeyes' ability to find and move through a bypass with a water flow of 100 cfs. To facilitate the smolting sockeyes' movement, a 4-foot wide by 3-foot high slide gate will be installed in one of the spillway tainted gates. This gated orifice bypass will regulate flows up to 100 CFAs of water -- depending on the forbear level.

The maximum forbear water level is El. 2240 and the minimum forbear level is approximately 100 feet below the crest. The tainter gates are seated (at El. 2223) on the existing spillway crest. During periods of high water discharge, while the forbear level is above the crest, the tainter gates can be used to bypass migrants. However, this method of passing fish should not be used if the gate is unable to be raised more than six inches.

If the 1990 sockeye smolt studies demonstrate favorable results, the conceptual design (as shown in attached drawing; see Fig. 24) will provide a permanent method of discharging the required minimal downstream river flow and downstream passage for sockeye smolts during out-migration.

A rectangular conduit placed on the upstream face of the dam will be fitted with 4-foot by 4 foot slide gates and air operators. The desired water withdrawal depth can be controlled with the gates. The minimum operating depth should not be less than 3-feet over the highest point on the gate.

The concept shown will provide a way of discharging approximately 100 cfs to 120 cfs between forebay levels of El. 2212 and 2240. A 24" diameter pinch valve will regulate water flow to 100 cfs. The 30 inch diameter pipe water velocity will average approximately 20 fps.

Downstream of the pinch valve, a gradual pipe expansion section will reduce the water velocity to approximately 3.5 fps before it enters a stilling basin. A 10-foot wide spillway crest will maintain a head of approximately 2-feet on the crest. A cascade type spillway should be investigated for returning the migrants to the river. To accomplish the construction of this bypass facility, it is essential to install a 30 inch diameter pipe through the dam.

SUMMIT TECHNOLOGY
CONSULTING ENGINEERS, INC., P.S.

January 10, 1990

National Marine Fisheries Service
Building 4, Room 1167
7600 Sand Point Way N.E.
Seattle, WA 98115-0070

Attention: Richard Frazier
Subject: Cle Elum Dam Juvenile Release Facility

Dear Mr. Frazier:

The opinion of construction cost for the facility shown on the drawing [see Fig. 24] previously provided to you is $620,000.00.

The critical component of the design is the pinch valve. From information received from the distributor and from calculations we have made, the piping system should be designed to allow the pinch valve to be fully opened at the minimum operating head. This will maintain the maximum water velocity through the pinch valve as low as possible. Therefore, the pipe should be sized for minimum required water release from the Cle Elum Dam forebay. If a 100 cfs water flow is not approved, the pipe size shown on the drawing will require changing.

It may be feasible to use more than one pinch valve to increase the head loss. This will allow the system to accommodate flows greater than the existing minimum required downstream water release. If the juvenile release facility concept is accepted, this action should be investigated.

If you have any questions or require additional information, please give Winn Farr or myself a call at 206/622-0222.

John R. Hutchins, Principal

enclosure: Conceptual Design Narrative

615 Second Avenue Suite 590 Seattle, WA 98104 (206) 622-0222
FAX (206) 622A764