

FRI-UW-8609
December 1986

THE FEASIBILITY OF ANADROMOUS FISH PRODUCTION
ABOVE THE ALDER/LA GRANDE HYDROELECTRIC PROJECTS
ON THE NISQUALLY RIVER

by

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Final Report
for

The Nisqually Indian
Tribe

Approved:

Submitted: _____

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ABSTRACT

This study was conducted to determine the feasibility and benefit/cost of utilizing the stream habitat in the upper Nisqually River basin for anadromous fish production above the Alder/La Grande hydroelectric projects. The total elevation gain from the tailrace below La Grande powerhouse to the top of Alder Dam is 699 feet. Neither dam was constructed with fish passage facilities.

Water quality (temperature and turbidity) was evaluated with an estimate of the potential fish production from the upstream habitat. Reservoir trapping efficiencies, handling mortality, turbine passage mortality, marine survival and total adult return were calculated. Escapement requirements for full seeding resulted in a potential harvestable surplus, depending on the option, of 3,268 to 7,668 coho, 1,847 to 4,042 chinook and 28 to 978 steelhead.

A series of ten potential options were evaluated along with twelve actions. Five of the options were dismissed for lacking in technical feasibility, requiring excessive capital expense or providing insufficient benefits. The benefit-cost analysis was applied to the remaining five options. A benefits analysis was based on a project life of 50 years, a discount rate of 3 percent, a commercial value for coho and chinook salmon of \$1.00/lb and a sport value of \$144/fish for steelhead. In general, insufficient fish production and excessive costs are associated with utilization of the upstream habitat. Only one option (Option 10, a trap and haul facility at the Centralia Dam and hatchery culturing, with an Alder reservoir smolt trap and haul operation) had a positive benefit/cost ratio. Thus, only one option can be recommended as feasible for introduction of anadromous fish into the upper drainage.

ACKNOWLEDGMENTS

This report was sponsored by the Nisqually Indian Tribe and administered by Mr. George Walter, Tribal Natural Resources Director. The following individuals are thanked for their aid and assistance in locating or supplying information on which this report is based:

Nisqually Indian Tribe

George Walter
Bill Harrington-Tweit
John Kerwin

Washington Department of Game

Bob Lucas
Tom Cropp
Paul Mongillo

Tacoma City Light

Paul Svoboda
James Dean
Jack Bernhartson

U.S. Fish and Wildlife Service

Bob Wunderlich

U.S. Geological Survey

Rod Williams

U.S. Forest Service

Ray Scharpf

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Introduction

The effort of fishery management agencies to achieve additional means to expand anadromous salmonid production has lead to an attempt to utilize fish habitat above natural falls and some hydroelectric facilities. Expansion of anadromous salmonids into currently unutilized habitat involves a broad range of questions which must be addressed. The feasibility of using habitat presently unavailable to anadromous salmon and steelhead trout runs above the Alder/La Grande hydroelectric projects on the Nisqually River is of interest to the Nisqually Indian Tribe. This two-dam complex, owned and operated by Tacoma City Light, was constructed without fish passage facilities. The objective of this study is to determine the feasibility and benefit/cost of utilizing the available habitat above these projects for anadromous fish production.

Description of Hydro-projects and Study Area

The Nisqually River basin above the La Grande powerhouse, located at river mile 40.8, is the focus of this review. The original diversion dam for this powerhouse was constructed in 1912 at river mile 44.3 and diverted up to 700 cfs to the powerhouse. In 1942-45, a two-dam complex was constructed that replaced much of the original facility. La Grande Dam, located at river mile 42.5, diverts water through a 14.5 ft diameter tunnel 6,400 feet long to a downstream powerhouse (Fig. 1). The tunnel feeds five steel penstocks approximately 120 feet long. Four of them have diameters of four feet while the remaining one is 11.5 feet.

La Grande is a concrete gravity dam with a height of 192 feet above the riverbed and 434 feet above the shut-down no spill river elevation below the powerhouse (Fig. 2). The La Grande reservoir is 1.7 miles long and averages about 1/8 of a mile wide with a reservoir area at maximum surface area of 45 acres (Table 1). The total capacity of La Grande reservoir is 2,700 acre feet with an active storage of 1,053 acre feet. The water level elevation may fluctuate a maximum of 25 feet; however, water level elevations have not exceeded a range of 5.1 ft (928.8 - 933.9 ft) since 1981. Average annual flow is 1400 cfs with a retention time of 0.37 days. The level of the penstock intake is 60 feet below the maximum pool elevation of 935 feet. La Grande reservoir extends to the Alder Dam tailrace.

The La Grande power plant has five turbines, four of which are rated at 8,000 h.p. at 450 r.p.m. at an operating design head of 415 feet, and the fifth turbine rated at 55,000 h.p. at 257 r.p.m. and generating at design head of 407 feet. The four similar turbines are horizontal shaft Francis type manufactured by Allis-Chalmers while the fifth is a vertical shaft Francis type manufactured by Pelton Waterwheel Company. The peak capability of this facility is 64,000 KW.

Alder Dam, a continuous concrete arch with a height of 285 feet above the riverbed, was completed in 1945 at river mile 44.2 (Fig. 1). Alder Reservoir is 7.5 miles in length with a surface area at maximum elevation of 3,065 acres (Table 1). The total reservoir capacity is 232,000 acre feet with an active storage of 179,600 acre feet. Annual water level elevation may fluctuate a maximum of 93 feet from a maximum gross head of 273 feet to a minimum of 180 feet (Fig. 2); however, water level elevations have not exceeded a range of 61 ft (1146 - 1207 ft) since 1969. Average annual flow is 1400 cfs with an average retention time of 62.3 days. The level of the

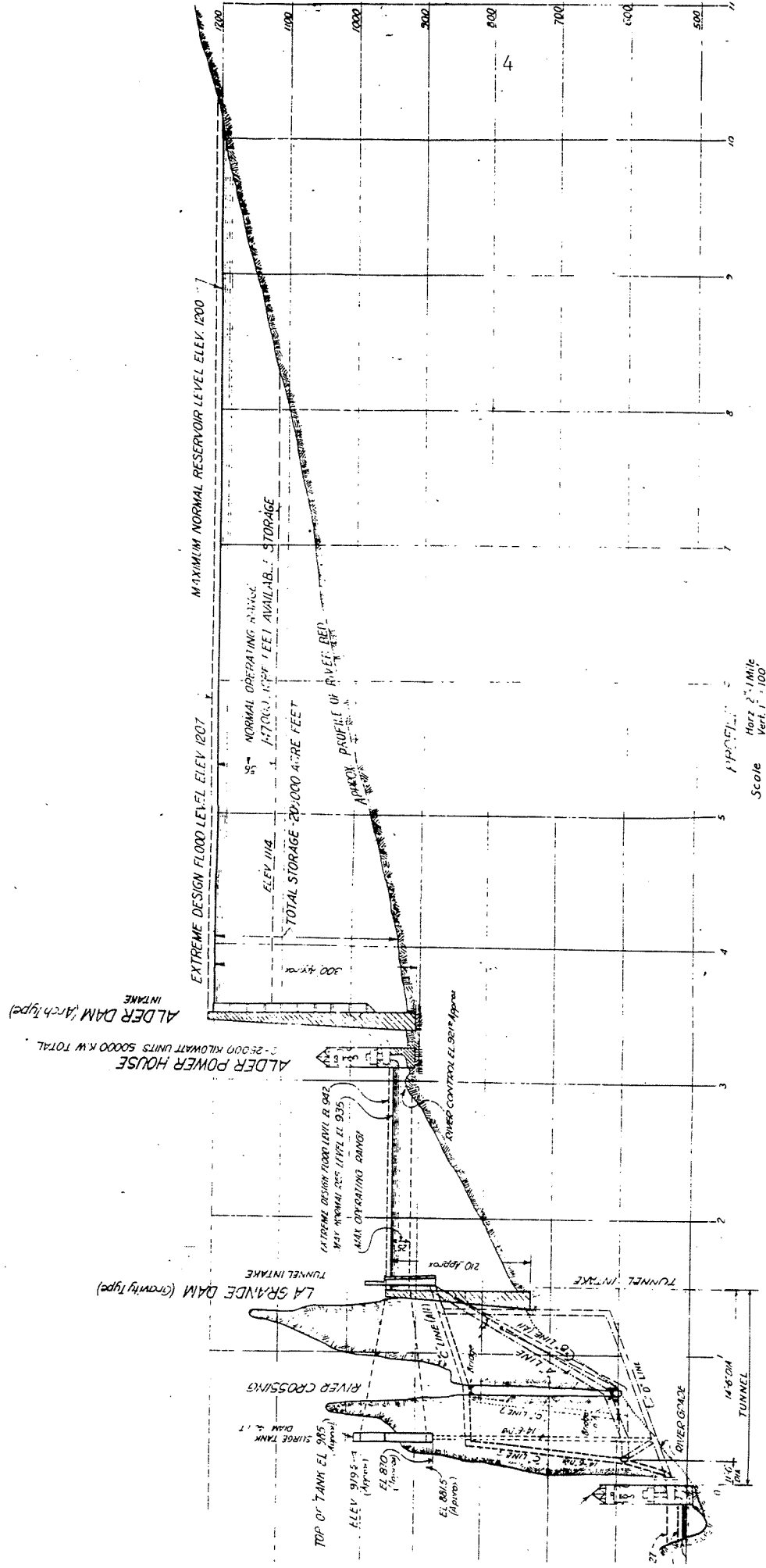


Figure 2. Profile of the Alder/La Grande hydroelectric system indicating elevation changes, penstock and tunnel alignments. (Source: Tacoma City Light planning document circa. 1940 showing the proposed (now current) facilities superimposed on former facilities).

Table 1. Physical data for Alder and La Grande reservoirs (Source: Tacoma City Light unless otherwise indicated).

Parameter	Alder	La Grande
Average annual flow (cfs)*	1,400	1,400
Maximum flow (cfs)*	27,100	27,100
Minimum flow (cfs)*	0	0
Full pool elevation (ft)	1,207	935
Surface area (acres)	3,065	45
Total storage capacity (ac-ft)	232,000	2,700
Active storage capacity (ac-ft)	179,600	1,053
Dead storage (ac-ft)	52,400	1,647
Average retention time, days	62.9	0.37
Flow/volume ratio	0.06	5.33
Penstock depth (ft)	217	60
Maximum depth (ft)	285	192
Reservoir length, miles	7.5	1.7
Reservoir width, miles	2.16	0.13
Miles of shoreline	28	3.5
Maximum drawdown (ft)	93	25
Normal operating range (ft)	61**	5.1***
Mean reservoir temperature of upper 30 ft (March 25, 1965 to June 30, 1970)	10.6°C	--

* USGS water supply data
 ** Period 1969-86 TCL data
 *** Period 1981-86 TCL data

penstock intakes are 217 feet below the maximum pool elevation of 1207 feet. There are two 10 foot diameter penstocks approximately 160 feet long.

Two vertical shaft Francis type turbines manufactured by the Pelton Waterwheel Company are each rated at 34,500 h.p. at 225 r.p.m. at an operating design head of 273 feet. The rated capability of this plant is 50,000 KW. Both dams have an 8.9 foot diameter river outlet controlled with a bungler valve. The river outlet elevation in Alder Dam is 972.5 feet while that in La Grande dam is 790 feet. These river outlets are seldom used.

Reservoir Water Quality

Formal studies of the limnology of either Alder or La Grande reservoirs have not been conducted; however, data have been collected infrequently on both. Vertical temperature profile data on Alder reservoir were taken at monthly intervals at several locations during the period 1965 to 1970 (Tacoma City Light, unpublished). Water quality measurements were expanded to a broad suite of parameters by the U.S. Geological Survey during the period 1974 to 1983 on Alder reservoir. Measurements for La Grande reservoir were not evaluated because of the rapid rate of turnover and limited size of this run-of-river reservoir, the facility is expected to have little influence on water quality modifications. Although a number of other water quality measurements have been made by the USGS, this analysis will be limited to temperature and turbidity which directly influence fish behavior and production.

Vertical temperature data taken on the log boom near Alder Dam in 1965 were plotted (Fig. 3). These data showed that the reservoir was homothermous through March 25. However, by May 4 the water column had become stratified with a well developed thermocline between the depths of 25 and 50 feet. Thermal stratification of the upper 100 feet of the reservoir persisted

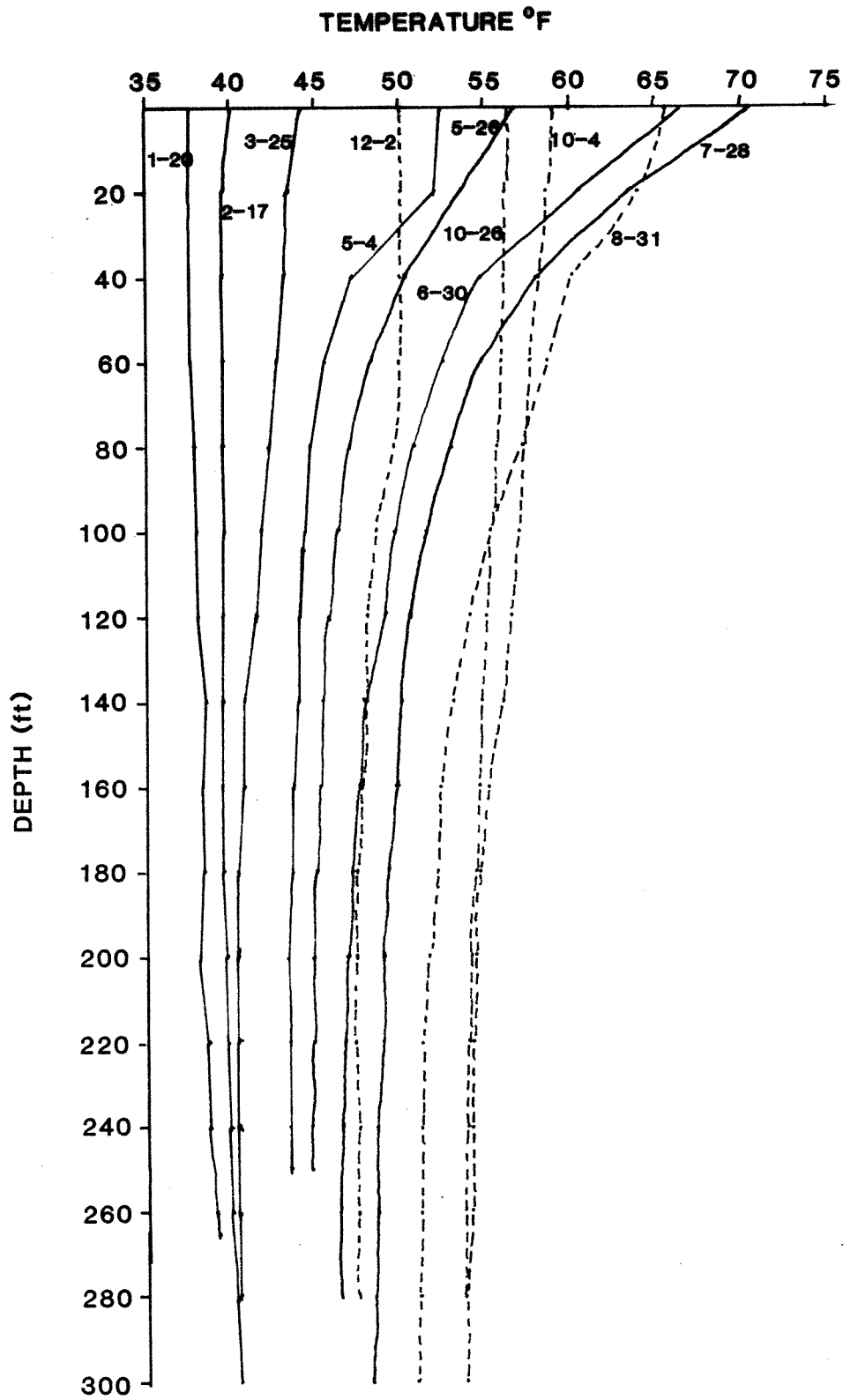


Figure 3. Vertical temperature profiles for Alder Reservoir taken near Alder Dam during 1965. (Tacoma City Light).

through August. Stratification had decreased by early October allowing the mixing of the entire water column and raising the overall temperature of the entire water mass in the reservoir. Minimum temperatures were reached in January.

An analysis of the available temperature data (City of Tacoma, unpublished) from the upper 30 feet of Alder reservoir for the period March 25, 1965 to June 30, 1970 from profiles taken at a log boom at Alder Dam, a log boom near Elbe, and a buoy near the mouth of the Little Nisqually River showed an average of 10.6°C for the spring emigration period. A similar comparison of reservoirs by Goodwin (1967) found that juvenile salmonid fish passage was excellent in reservoirs with a temperature of less than 10.78°C. This suggests that the surface temperatures of Alder reservoir during the April-June salmonid emigration period remain cool enough to allow the successful operation of surface oriented juvenile salmonid passage facilities. Such facilities evaluated by Goodwin (1967) included a skimmer in conjunction with an upstream ladder exit, surface gulper, and surface louver system.

The effects of Alder reservoir on downstream water temperatures are to reduce the extremes found above the reservoir and to increase the maximum average temperature of the river by 2°C. The reservoir also shifts the maximum from July-August to September causing water temperatures in excess of those occurring upstream to persist in the lower river through the month of February (Fig. 4).

Alder reservoir water column turbidity data reported in Nephelometric Turbidity Units (NTU) by the USGS for the period October 1978 to June 1983 were evaluated (Table 2). The turbidity at any single depth was never reported below 1 NTU. The average turbidity was less than 5 NTU during the months of March-July while for the remainder of the year (August-February)

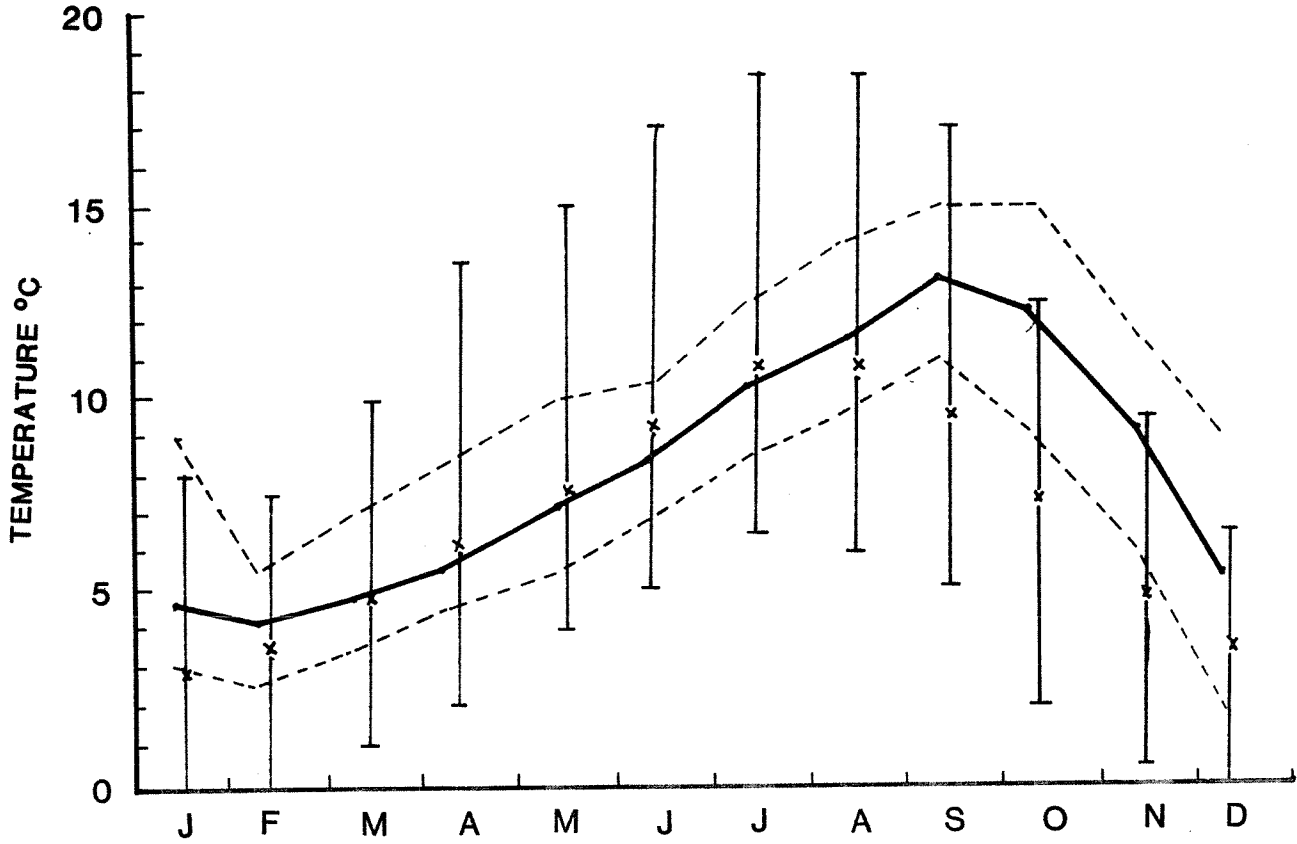


Figure 4. Monthly maximum, minimum and mean water temperatures of the Nisqually River taken at National, WA. (vertical bars) above Alder/La Grande projects and those taken below La Grande powerhouse (solid and dashed curves) (Source U.S. Geological Survey).

Table 2. Alder Reservoir turbidity (NTU) for the period October 1978 to June 1983 (Source USGS).

Depth (ft)	Date											
	18 Oct 78	8 Nov	6 Dec	12 Jan 79	7 Feb	7 Mar	12 Apr	9 May	6 Jun	11 Jul	8 Aug	12 Sep
1	15	15	10	8	5	6	2	1	1	2	5	8
20	10	15	10	9	6	6	2	1	2	2	11	9
50	10	15	10	9	6	8	2	1	1	2	7	30
100	15	15	8	10	10	9	4	2	1	1	2	15
250	20	25	10	10	35	8	4	2	1	2	6	40
	11 Oct 79	15 Nov	12 Dec	16 Jan 80	6 Feb	18 Mar	9 Apr	14 May	12 Jun	9 Jul	13 Aug	17 Sep
1	10	15	15	8	6	3	2	1	1	3	15	20
20	15	10	15	9	6	3	2	1	1	6	25	20
50	20	15	15	7	5	3	2	1	1	5	15	40
100	35	10	20	7	5	3	3	2	1	2	5	25
250	35	15	45	15	6	3	2	2	2	2	25	--
	18 Oct 80			21 Jan 81			15 Apr 81			15 Jul 81		
1	30			15			4			1		
100	4			15			5			1		
225	5			15			--			2		
		18 Nov 81			10 Feb 82			5 May 82			11 Aug 82	
1		8			5			2			2	
100		9			5			3			3	
250		8			6			3			5	
			15 Dec 82		23 Mar 83				22 Jun 83			
1			7		3				1			
100			8		3				2			
225			25		2				3			
Mean	17.2	13.5	15.2	10.5	8.2	4.6	2.8	1.6	1.4	2.4	9.7	23.0

average monthly water column turbidity ranged from 8.2 to 23.0 NTU. A plot of the turbidity values (Table 3) of the Nisqually River at Elbe, WA (USGS) (Fig. 5) show turbidity was highest during June through November. Lowest values occurred from December through May when the high elevations remained frozen. Occasional high turbidity may occur during the winter following a warming trend with precipitation in the form of rain occurring at the upper elevations. Turbidity of the river at La Grande indicated consistently lower values with a lag in the minimum turbidity through the month of July (Fig. 5). The moderating influence of Alder Reservoir is apparent on the downstream turbidity values.

Fish Habitat Above Alder Reservoir

Nisqually tribal biologists surveyed most of the stream habitat above Alder Reservoir (Nisqually Tribe 1980). The habitat was surveyed on the basis of the length of each stream which would be accessible to adult salmon and steelhead if placed above Alder Dam (Williams et al. 1975). Numerous stream width measurements were made by the Tribe at intervals throughout each stream in order to estimate total wetted perimeter at low stream discharge in September.

Seventeen streams were identified as having measurable accessible habitat above Alder reservoir. These streams were segregated into the fourteen remaining clear throughout most of the year and the three glacial streams (Table 4). The total accessible length of clear streams was 39.6 miles with a low flow surface area 495,494 yds². There are 26.1 miles of accessible glacial streams; however, the habitat in these streams is of less value than that existing in the clear tributaries. The glacial streams are characterized by high gradients, large unstable cobble, extensive braiding, high suspended

Table 3. Turbidity of Nisqually River at Elbe and LaGrande, WA. (USGS).

Date	Turbidity (NTU) Elbe	Turbidity (NTU) LaGrande (River)
11 Oct. 1978	45	--
18 "	20	20
8 Nov.	30	25
8 "	75	--
6 Dec.	2	10
12 Jan. 1979	2	10
7 Feb.	40	15
7 Mar.	25	8
12 Apr.	1	4
9 May	2	2
6 Jun.	35	1
11 Jul.	25	1
8 Aug.	35	5
12 Sep.	20	20
11 Oct.	40	30
15 "	2	10
12 Dec.	5	45
16 Jan. 1980	2	9
6 Feb.	3	7
18 Mar.	1	3
9 Apr.	4	3
14 May	4	2
12 Jun.	20	2
9 Jul.	280	2
13 Aug.	350	20
17 Sep.	--	30
16 Oct.	40	7
21 Jan. 1981	3	15
15 Apr.	1	6
15 Jul.	6	2
18 Nov.	3	8
10 Feb. 1982	2	5
5 May	2	3
11 Aug.	30	3
15 Dec.	4	20
23 Mar. 1983	1	3
22 Jun.	4	2
14 Sep.	<u>80</u>	<u>10</u>
	x = 33.6 NTU	x = 10.2 NTU
	Range 1-350 NTU	Range 1-45 NTU

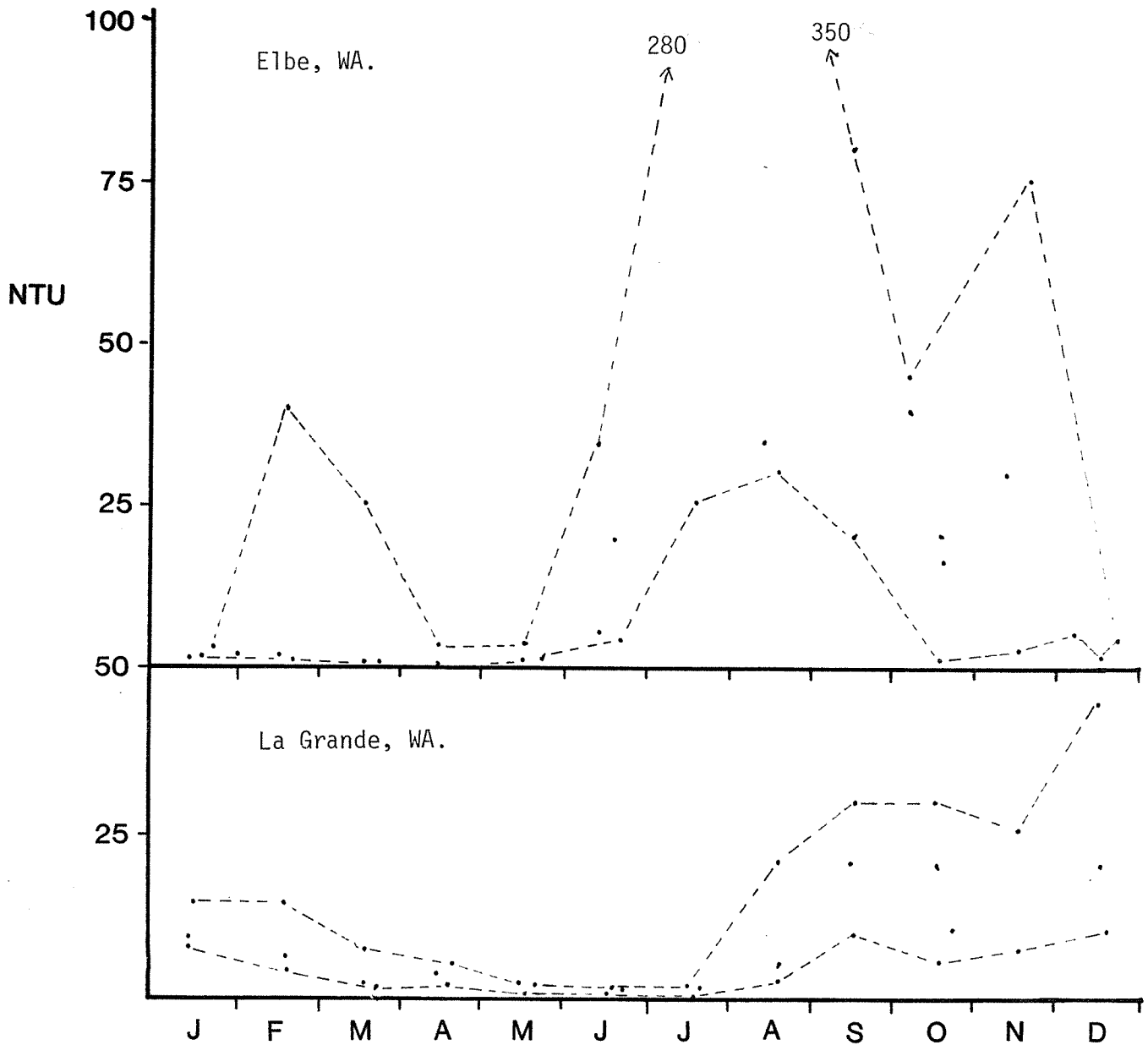


Figure 5. Envelope plots of the available monthly turbidity data in NTU for the Nisqually River at Elbe, WA. and the river below La Grande powerhouse. (Source U.S. Geological Survey).

Table 4. Upper Nisqually River tributary areas for clear and glacial streams above Alder Reservoir.

Stream	Stream number	Turbidity NTU	Accessible length (mi)	Average width (yds)	Area (yd ²)
<u>Clear</u>					
Little Nisqually River	11-0138		2.9	7.3	37,259
East Creek	11-0161		3.1	7.7	42,011
" "	" "		3.1-4.8	4.7	14,062
Mineral Creek	11-0165		3.6	12.0	76,032
" "	" "		3.6-7.3	7.0	45,584
No. Fk. Mineral Creek	11-0172		5.8	7.0	71,456
Round Top Creek	11-0166		5.5	4.0	38,720
Coal Creek	11-0168		0.3	1.7	898
Summit Creek	11-0171		0.4	3.3	2,323
Reese Creek	11-0192		2.1	2.7	9,979
Big Creek	11-0194		0.85	18.0	26,928
" "	" "		0.85-4.33	10.0	61,248
" "	" "		4.33-6.0	7.3	21,456
Catt Creek	11-0195		1.3	11.7	26,770
Lake Creek	11-0196		0.5	4.0	3,520
Berry Creek	11-0266		0.9	5.0	7,920
Horse Creek	11-0294		1.4	3.3	8,131
Copper Creek	11-0225		0.4	1.7	1,197
Total			39.6		495,494
<u>Glacial</u>					
Nisqually River	11-0008	x = 33.6 range (1-350)	22.5	46.0	75,992*
" "					25,088**
" "					223,946***
Tahoma Creek	11-0246		2.3	17.0	68,816
Kautz Creek	11-0246		1.3	14.3	32,718
Total			26.1		
			65.70		
* coho juveniles					
** chinook "					
*** steelhead "					

sediment loads and low water temperatures. In order to achieve a more realistic estimate of the usable habitat available in the mainstem Nisqually River the weighted usable habitat totals for juvenile coho, chinook and steelhead life stages based on HABTAT output for 90% exceedance flows was used (Chapman 1981). These values no doubt overestimate the usable habitat because the effects of high suspended sediment loading on primary and secondary production were not considered. The habitat estimates for the glacial Tahoma and Kautz creeks were based on the length-width method used for the clear tributaries because HABTAT output was not available for these streams. This in turn overestimates the total usable habitat in the glacial tributaries.

Of the clear streams only the Little Nisqually River lies in a drainage basin which is totally within the national forest where limited logging activity has taken place. The Little Nisqually River drains steeper, heavily forested mountain slopes and shows more typical mountain stream characteristics, with numerous cascades and small falls, separated by relatively short pool-riffle stretches, where the bottom is mostly of larger rock material, with some gravel and rubble areas. Moderate numbers of rainbow and cutthroat trout are found in this stream with rainbow more common in the lower reaches. Some fish undoubtedly move out of Alder reservoir to spawn in this stream (B. Lucas, pers. comm.). In 1986, the Little Nisqually river was put on special regulations by the Washington Department of Game prohibiting bait fishing, placing a minimum size limit of 12 inches and a two fish catch limit to allow more fish to reach sexual maturity.

Mineral Creek is an extensive moderate gradient stream course. It is characterized by good quality pool-riffle habitat, a gravel-rubble bottom and good to excellent cover. Agricultural land borders much of its lower reaches, with extensive clear-cut logging on privately owned land over the higher

headwater slopes which has produced logging debris jams in this stream that break loose at high flow and sluice-out the stream. Despite these problems, the stream offers excellent habitat in some areas, particularly in the lower-gradient part of the stream. The stream is easily accessible, especially from the town of Mineral, upstream, and overfishing has been a problem. Special regulations were placed on the mainstem and north fork of Mineral Creek in 1986 by the Washington Department of Game. This system has moderate numbers of both rainbow and cutthroat trout. Some of the rainbow caught in the spring exceed 20 inches and are probably spawners moving up from Alder reservoir. Spawning kokanee have also been observed in Mineral and Roundtop creeks during early November (Bob Lucas, pers. comm.).

East Creek offers habitat conditions similar to Mineral Creek. It is a very low gradient stream throughout its accessible length and the upper watershed has been heavily logged. This is an extremely important stream which supports most of the kokanee spawning run that moves out of Alder reservoir in late October and November. Spawner survey data for Oct. 11 and 26, 1984 showed 900 and 3900 kokanee, respectively, in 1.4 and 2.1 miles surveyed (T. Cropp, pers. comm.). He reported the average size of female kokanee was 35 cm (30-37 cm range) and the average male of 38 cm (34-40 cm range). Kokanee use the lower three miles of East Creek for spawning. Very few resident trout are found in East Creek perhaps due to high summer water temperatures and low flow (B. Lucas, pers. comm.).

Very little is known about fish use in the larger remaining tributaries, Big, Catt, Horse and Berry creeks, which offer moderate gradient habitat with good pool-riffle conditions in the lower extremities. The accessible portions of these streams exhibit mixed rubble and gravel bottom with dense cover by deciduous trees and underbrush and some conifer timber. These streams are

near campgrounds and are heavily fished. The Department of Game used to plant fish in Berry and Big creeks (B. Lucas, pers. comm.). Resident populations are predominantly cutthroat trout in low numbers.

Reservoir Sport Fishery

The Washington Department of Game has managed a sport fishery in Alder reservoir since its completion in 1945. The reservoir has been planted with rainbow trout, silvers (kokanee salmon), cutthroat trout, and winter and summer steelhead from time to time (Table 5). Plants were not made during fourteen of these years up to 1985 with the period from 1957 to 1969 receiving the least attention (Table 5). Big, East and Mineral creeks received very infrequent plants of steelhead, rainbow, cutthroat and eastern brook trout. The record for stream plants is very inconsistent and all plants were stopped in 1977 (Table 5).

Creel census data on Alder reservoir indicate that relatively large numbers of fish were caught during the period 1946 to 1960 after which there was a significant decline in the catch and/or the effort to obtain the information (Table 6). During the late 1940's and 1950's the catch consisted of black crappie, rainbow and cutthroat trout, and kokanee. No creel checks were made between 1974 and 1981, and the limited effort in recent years provides little data to compare with previous years. The actual sport catch may be larger than the data indicate or it may truly have declined in recent years to an insignificant fishery.

Anadromous salmonids introduced into the upper Nisqually River basin will compete with the resident fishes for space and food, and increase predator-prey interactions. The value of the apparently limited sport fishery comes into question and insufficient data are available to answer this question.

Table 5. Alder reservoir, Big, East and Mineral Creek fish plants by Washington Department of Game for the period 1945 to 1985. (Source Washington Department of Game).

Record of Plantings				
Date of Planting	Species	Size	Number	Source of Fish
Alder Lake				
July 31, 1945	Rainbow	1-1/2"	66,500	So. Tacoma Hat.
" 11 "	"	2"	50,964	" " "
" 11 "	"	1-3/4"	56,250	" " "
" 12 "	"	2"	47,025	" " "
" 12 "	"	2"	45,900	" " "
" 13 "	"	2"	48,800	" " "
" 13 "	"	2"	56,400	" " "
Aug. 31 "	"	1-1/2"	78,750	" " "
" 31 "	"	1-1/2"	87,500	" " "
" 31 "	"	1-1/2"	87,500	" " "
June 26, 1946	"	2"	33,750	" " "
" 27 "	"	2"	32,750	" " "
Apr. 18, 1947	"	2"	78,750	" " "
" 18 "	"	2"	78,750	" " "
" 19 "	"	2"	78,750	" " "
" 19 "	"	2"	71,250	" " "
May 5 "	"	2"	33,880	" " "
" 5 "	"	2"	38,500	" " "
July 7 "	"	4-1/2"	6,000	" " "
" 7 "	"	3-1/2"	12,600	" " "
" 8 "	"	3-1/2"	14,332	" " "
" 8 "	"	4"	10,000	" " "
" 8 "	"	4"	9,880	" " "
Oct. 8, 1948	"	2-1/2"	40,300	" " "
Apr. 11, 1949	"	5-1/2"	8,983	Mossyrock Hat.
" 12 "	"	5-1/2"	9,385	" " "
Apr. 4, 1950	"	7 - 9"	6,000	Puyallup Hat.
" 5 "	"	7-8-1/2"	4,010	" " "
" 5, 1951	"	4/#	5,000	" " "
" 23, 1953	Silvers	3000/#	400,000	" " "
Mar. 29, 1954	"	3000/#	793,000	" " "
Apr. 25, 1955	"	3300/#	700,000	" " "
Aug. 25 " *	Cutthroat	800/#	2,400	Mossyrock Hat.
Apr. 30, 1956	Silvers	3000/#	825,000	Green River Hat.
May 5 "	"	3000/#	94,000	" " "
May 26, 1959	Rainbow	909/#	158,000	Puyallup Hat.
June 17 "	"	1840/#	25,750	" " "
" 17 "	"	1200/#	86,400	" " "
Aug. 1966	"	75/#	20,475	" " "
July 1970	"	49/#	35,515	" " "
June 1971	"	140/#	58,100	" " "
June 1, 1972	"	73/#	59,495	" " "
May 1973	"	360/#	29,880	" " "
May 1976	"	95/#	73,815	" " "
May 1976	Rainbow	100/#	54,000	Puyallup Hat.
June 1977	"	150/#	41,550	Tokul Creek

Table 5. (continued)

Date of Planting	Species	Size	Number	Source of Fish
<u>Alder Lake (continued)</u>				
Aug. 1977	L. Cow.	520/#	11,960	So. Tacoma Hat.
" "	W. Sthd.			" " "
" "	W. Sthd.	155/#	11,625	" " "
Apr. 1978	Rainbow	193/#	19,300	Puyallup Hat.
" "	"		49,280	" " "
June 1979	"	166/#	168,129	" " "
Aug. "	S. Sthd.	85/#	26,775	So. Tacoma Hat.
" "	"	105/#	24,750	" " "
Aug. 1979	"	204/#	111,384	Puyallup Hat.
June 1980	Rainbow	253/#	59,695	Tokul Creek Hat.
June 1980	"	82-94/#	101,678	Puyallup Hat.
Jan. 1981	"	1690/#	136,700	" " "
June 1981	"	90-148/#	150,256	" " "
Feb. 1982	"	84/#	31,416	" " "
May 1982	"	108-148/#	127,072	" " "
1983	"	83/#	119,952	
1984	"	216/#	219,538	
1985	"	140/#	108,920	
<u>Big Creek</u>				
June 23, 1934	Steelhead	2-1/8"	35,750	Chambers Cr. H.
" 23 "	"	2-1/8"	39,000	Puyallup Hat.
Apr. 6, 1940	Rainbow	8-1/2"	2,043	So. Tacoma Hat.
Aug. 31, 1942	"	2"	28,550	" " "
July 1968	S. R. Cutt.	170/#	3,230	Mossyrock Hat.
" "	E. Brook	220/#	2,200	" " "
June 1974	S. R. Cutt.	4/#	1,800	" " "
June 1975	" " "	4/#	2,000	" " "
May 1977*	TKCT	1300/#	3,250	Tokul Cr. Hat.
<u>East Creek</u>				
Aug. 31, 1942	Rainbow	2-1/2"	24,445	So. Tacoma Hat.
" 16, 1951	"	1000/#	150,000	" " "
Mar. 21, 1952	Silvers	3000/#	325,000	Puyallup Hat.
Sept. 8, 1961	Rainbow	600/#	3,000	" " "
<u>Mineral Creek</u>				
Aug. 31, 1942	Rainbow	2-1/2"	26,495	So. Tacoma Hat.

* Beaver Ponds.

Table 6. Creel census data for Alder reservoir from 1946 to 1986. (Washington Department of Game).

Year	Number of fishermen	Number of days checked	Number					Total fish caught	Average catch		
			Catfish	Black Crappie	Cutthroat trout	Perch	Rainbow trout			Kokanee	
Alder Lake											
1946	885				185			6,278	6,463	7.3	
1947	629							2,661	2,661	4.2	
1948	315		112					995	1,067	3.4	
1949	276							825	825	3.0	
1950	112							524	524	4.7	
1951	146		315					922	1,237	8.5	
1952	271		3,101					123	3,224	11.9	
1953	16		72					5	77	4.8	
1954	100		801		25			74	913	9.1	
1955	745		7,270		79			1,002	9,416	12.6	
1956	487		2,749		606			405	3,999	8.2	
1957	1,113		2,126		396			327	3,391	3.0	
1958	368		65		859				1,712	4.6	
1959	24	2	2				1	2	34	1.4	
1960	183	6	250		6		45	321	1,422	7.8	
1961	37	2	403		27		8		445	12.0	
1962	85	2	388		64		174	18	644	7.6	
1963	68	4	28		5		131		200	2.9	
1964									36		
1965	No check	2			32		28	11	34	105	2.9
1966	36										
1967											
1968	No check										
1969	9	1					30	3	33	3.7	
1970	No check										
1971	10	1			14		9		24	2.4	
1972	No check										
1973	10	1			13		1	12	26	2.6	
1982	33	51 hrs					2	3	6	0.18	
1983	166	322 hrs					18	79	97	0.58	
1984	47	93 hrs					3	23	26	0.55	
1985	21	44 hrs			126				128	6.1	
1986	58	108 hrs			9			8	19	0.33	

The existence of populations of spawning rainbow trout and kokanee salmon utilizing upstream tributaries suggests that self-sustaining stocks of resident fish have become established in the reservoir. These fish may be providing an important local fishery but it will require a formal study effort for 2-3 years to develop an adequate data base upon which to evaluate this fishery.

Potential Fish Production

Two conceptual groups of methodologies applied by fish management agencies to estimate salmonid production were reviewed by Knutzen et al. (1986). These methods are either density-based or escapement-based. Density-based methods focus on fish production per unit of stream habitat. The density of parr per unit of stream habitat is a density-based method usually employed by agencies which manage habitat. Escapement-based methods focus on the number of adults returning to a stream or to a specific portion of a stream. Spawning ground counts (e.g., carcass or redd counts) and counts of adults at dams are examples of escapement-based methods. These methods are used mainly by the agencies responsible for harvest management.

The only method which could be applied to the estimation of potential fish production above Alder/La Grande on the Nisqually River was density-based because no anadromous salmonid production occurs there now. Data were also available which provided an assessment of the existing habitat.

Following a careful review of Chapman (1981) a density-based approach was utilized to estimate the smolt production potential in the streams above Alder reservoir. However, important considerations were incorporated into this analysis which were not included in the earlier estimate. Smolt densities of 0.26, 0.31 and 0.022/yd² were applied for coho, chinook and steelhead,

respectively, in clear streams (Chapman 1981). In glacial streams smolt densities were reduced to 0.10, 0.16, and 0.011/yd² for coho, chinook and steelhead, respectively. The density for coho was previously applied by WDF (1977) to the tributaries of the Nisqually River citing a poor rearing environment. The densities for chinook and steelhead production were reduced by 50% due to the high turbidity of these streams. An extensive review of the potential effect of turbidity on light penetration and plant production in shallow interior Alaska streams (Lloyd 1985) indicated a 50% reduction from clear-water plant production was likely. Nevertheless the fish production potential in glacial streams is very likely overestimated due to the gross method of habitat assessment. The total estimated smolt production potential for both clear and turbid streams above Alder Reservoir was 146,580, 173,859 and 14,475 for coho, chinook and steelhead, respectively (Table 7). These estimates do not depart substantially from Chapman (1981); however, he only considered 10 streams and made no allowance for the lower productivity in glacial streams. It also should be recognized that it is unrealistic to assume that the production of each of the three species could be maximized simultaneously in the watershed. If all species were to be managed simultaneously in the same habitat the production potential would be reduced for each to the total carrying capacity biomass for each stream.

These production estimates could be disputed if recent advances in methodology had occurred or if the results of recent studies on glacial and clear streams had indicated the use of higher smolt densities. A review of recent work by Gibbons et al. (1985) did not indicate that an increase in the density of steelhead parr was warranted in this study even though higher densities have been observed in some Washington streams. Recent salmon production estimates have been escapement-based and have not developed smolt

Table 7. Nisqually River tributary areas and estimated smolt production potential for clear and glacial streams above Alder Reservoir.

Stream	Stream number	Turbidity NTU	Accessible length (mi)	Average width (yds)	Area (yd ²)	Coho smolts @ 0.26/yd ²	Chinook smolts @ 0.31/yd ²	Steelhead smolts @ 0.022/yd ²
Clear								
Little Nisqually River	11-0138		2.9	7.3	37,259	9,687	11,550	820
East Creek	11-0161		3.1	7.7	42,011	10,923	13,023	924
" "	" "		3.1-4.8	4.7	14,062	3,656	4,359	309
Mineral Creek	11-0165		3.6	12.0	76,032	19,768	23,570	1,673
" "	" "		3.6-7.3	7.0	45,584	11,852	14,131	1,003
No. Fk. Mineral Creek	11-0172		5.8	7.0	71,456	18,579	22,151	1,572
Round Top Creek	11-0166		5.5	4.0	38,720	10,067	12,003	852
Coal Creek	11-0168		0.3	1.7	898	233	278	20
Summit Creek	11-0171		0.4	3.3	2,323	604	720	51
Reese Creek	11-0192		2.1	2.7	9,979	2,595	3,093	215
Big Creek	11-0194		0.85	18.0	26,928	7,001	8,348	592
" "	" "		0.85-4.33	10.0	61,248	15,924	18,987	1,347
" "	" "		4.33-6.0	7.3	21,456	5,579	6,651	472
Catt Creek	11-0195		1.3	11.7	26,770	6,960	8,299	589
Lake Creek	11-0196		0.5	4.0	3,520	915	1,091	77
Berry Creek	11-0266		0.9	5.0	7,920	2,059	2,455	174
Horse Creek	11-0294		1.4	3.3	8,131	2,114	2,520	179
Copper Creek	11-0225		0.4	1.7	1,197	311	371	26
Total			39.6		495,494	128,827	153,600	10,895
Glacial						@0.10/yd ²	@0.16/yd ²	@0.011/yd ²
Nisqually River	11-0008	x = 33.6 range (1-350)	22.5	46.0	75,992*	7,599	4,014	
" "	" "				25,088**			2,463
" "	" "				223,946***			757
Tahoma Creek	11-0246		2.3	17.0	68,816	6,882	11,010	
Kautz Creek	11-0246		1.3	14.3	32,718	3,272	5,235	360
Total			26.1		17,753	17,753	20,259	3,580
			65.70			146,580	173,859	14,475

* coho juveniles
 ** chinook
 *** steelhead

densities per unit of habitat (Seiler et al. 1981 and 1984). Studies of smolt densities comparing clear streams and glacial streams have been very limited. Based on this review little justification could be found to support the use of higher smolt densities in the upper Nisqually River system.

To determine how much of the potential production of each species may be realized in the lower river the following assumptions were made. A smolt trapping efficiency on Alder reservoir of 50, 60 and 10% for coho, chinook and steelhead, respectively, was based on general experience and knowledge of salmonid smolt behavior. Of course, the efficiency of every trap and site is specific to each system and there is no way to determine a precise estimate without actual data. Since coho smolts would average about 135 mm in length, we assumed a 50% efficiency for this species. No allowance was made for residualization in the reservoir, a characteristic of this species. The efficiency for chinook smolts was increased to 60% because this species after rearing for about 3 months upstream, would move through the reservoir at a smaller average size (85 mm). The smaller size would result in a stronger orientation toward the surface and would increase the efficiency. Steelhead smolts, after rearing one or two years upstream, would migrate through the reservoir at the largest average size (about 190 mm) and would be least oriented to the surface, resulting in the lowest trapping efficiency.

Handling mortality for smolts trapped and hauled to the lower river was estimated at 10, 15 and 5 percent for coho, chinook and steelhead, based on the size of the fish. These rates may be less in an actual operation but are rarely zero.

A review of Bell (1981), Collins and Ruggles (1982), Cramer and Oligher (1960, 1961, and 1964), Hamilton and Andrew (1954), Ruggles and Collins (1981), Schoeneman and Junge (1954), Seiler (1985), and Wunderlich (1983)

showed actual turbine passage test mortality rates ranging from 15 to 76%. A comparison of five experiments at projects with heads similar to La Grande and one similar to Alder was made. We calculated from the available data the average mortality through the large wheels at Alder and La Grande dams for fish of the size previously indicated in this report at approximately 37%. The mortality rate through a small unit at La Grande would be approximately 94.5%. The mortality through the two-dam system using the large units only would be approximately 60%. Using the large Alder and the small La Grande units, the mortality would be approximately 97.5%. Using equally mixed flows through large and small units at La Grande would result in approximately a 75% mortality. These mortality rates do not include predation losses. All units were assumed to be running at best efficiency and all fish were assumed to be surface pressure acclimated when entering the units. Any variation in these factors would result in lower survival.

The mortality rates for passage of smolts through Alder and La Grande dams was based on the above evaluation. The smolts not trapped were all assumed to pass through Alder Dam with a 37% mortality. The remainder then passed through La Grande dam with a 75% mortality rate. It is apparent that the passage of fish through either dam should be avoided and that any plan dependent on the passage through La Grande dam would carry a low probability of success.

The total number of smolts reaching the lower river via the trap and haul route and through the turbines were summed for each species and marine survival rates of 0.08, 0.036 and 0.10 (Chapman 1981) were applied to coho, chinook and steelhead, respectively. This yielded a total adult return for coho, chinook and steelhead of 6,200, 3,586 and 343, respectively (Table 8). The harvestable surplus (catch) was estimated by assuming full seeding and

Table 8. Estimated smolt passage survival, adult return, escapement, and catch by species and selected option.

	Smolt Passage Survival			
	Option 3	Options 6 & 10	Options 8 & 9	Upper Mainstem Nisqually River screen-culture
	Trap & haul	Through turbines	Total	With fish culture
<u>Coho</u>				
Potential production			146,580	146,580
Smolts surviving to below La Grande powerhouse	65,961	11,543	77,504	77,504
Adult return			6,200	6,200
Escapement			2,932	160
Catch			3,268	6,040
C/E ratio			1.11:1	37.8:1
<u>Chinook</u>				
Potential production			173,859	173,859
Smolts surviving to below La Grande powerhouse	88,668	10,953	99,621	99,621
Adult return			3,586	3,586
Escapement			1,738	132
Catch			1,847	3,454
C/E ratio			1.06:1	26.2:1
<u>Steelhead</u>				
Potential production			14,475	14,475
Smolts surviving to below La Grande powerhouse	1,375	2,052	3,427	3,427
Adult return			343	343
Escapement			315	16
Catch			28	327
C/E ratio			0.09:1	20.4:1
				122,314
				97,851
				7,828
				160
				7,668
				47.9:1
				144,927
				115,942
				4,174
				132
				4,042
				30.6:1
				12,422
				9,938
				994
				16
				978
				61.1:1

that each adult coho, chinook and steelhead produces 50, 100 and 46 smolts, respectively. After meeting the escapement requirements, 3,268, 1,847 and 28 coho, chinook and steelhead were estimated to be the harvestable surplus.

Increased production efficiency, either through hatchery fish culturing alone (Option 6) or through fish culturing and an upper mainstem Nisqually River screen and trap (Option 8), will increase substantially the above estimates of total adult return and harvestable surplus.

Fish Diseases

The potential for the introduction of fish diseases with the introduction of fish into previously unutilized upstream habitat is much more serious on some river systems than on others. An example of a system where disease implications are very serious is the Cowlitz River, because two large mitigation hatcheries utilize river water downstream from two large reservoirs (Stober 1986). The effects of introduced disease for which no treatment exists can devastate intensive fish culture. The Nisqually River system is different from the Cowlitz in that thus far hatcheries have not been sited to utilize river water. Hatcheries currently operating on the Nisqually River utilize spring or tributary water supplies only. Although no agency or individual would intentionally transport or release diseased fish into the wild, if such an occurrence were to happen inadvertently, it would not impact large downstream hatchery operations on the Nisqually River. However, it might infect the susceptible stocks in the river system for some time. But, since fish are planted in the Nisqually system each year the risk of disease introduction, with the use of standard hatchery disease control procedures, should be no higher than at present.

The pathogens which are of most concern are those for which there is no

known cure, viruses (e.g. IHNV) and specific parasitic pathogens (C. shasta). Steelhead trout, sockeye and chinook salmon are most susceptible to IHNV, with mortalities in sockeye juveniles ranging as high as 100% (Mulcahy et al. 1983). Currently, it is believed that the disease is transmitted primarily horizontally (through the water, fish to fish) and only rarely vertically (parent to progeny). Coho salmon appear to be refractory to the IHNV, with only one isolation of the virus being reported for coho (Round Top Hatchery, Oregon). Recent investigations indicate the presence of ENV in some coho stocks, but this virus is thought by fishery pathologists as being only minimally pathogenic. The risk of introducing new pathogens into the Nisqually River system appears to be minimal as long as disease control measures are taken with all fish introduced into the basin. Of the salmonid species considered, sockeye presented the greatest potential risk of introducing IHNV into the watershed and were therefore eliminated from further consideration in this report.

Stock Source

The most difficult problem of introducing anadromous fish into the upper Nisqually River watershed results from the creation of a mixed stock fishery in the lower river. The spawner/recruit curve will be lower for the upper river stocks than it is for the presently managed lower river stocks. Therefore, in order to ensure adequate escapement to the upper river the catch rate on the lower river stocks will have to be reduced. The impact of reduced catch on the existing fishery (lower river stocks) may cost more than can be realized in production from the upper river tributaries.

To minimize the conflict in management, an effort should be made to select stocks which are known to have slightly different timing than those

already in the lower river. In many cases there are a number of valid biological reasons for prohibiting the transfer of stocks between river basins and any transfers would have to be approved by a number of state and federal fisheries agencies. Nevertheless, the following suggestions are made. An early coho salmon stock exists in the Cowlitz River which could be introduced to the upper Nisqually River watershed. Coho return to the Cowlitz River from late August to mid-March (Hager and Hopley 1981). Early coho in that river system are arbitrarily designated as those returning prior to October 15. This timing will probably conflict with the fall chinook run in the Nisqually River; however, mesh size regulations may allow the selective catch of each species minimizing harvest management conflicts.

Spring chinook salmon from White River stock may be the best selection for chinook introduction into the upper watershed. Although the redevelopment of this seriously depressed stock is just beginning to show signs of a positive response, it will be several years before it will have reached a level for reintroduction into other areas. If this stock could be utilized in the future it would minimize conflicts with lower river fall chinook stocks due to its spring-summer entry into the river. Once the run became established this would allow a separate controlled fishery to allow adequate escapement to the upriver trapping facility. The use of spring chinook could alter the production assumptions due to year around rearing and larger smolts resulting in lower trapping and passage efficiencies; however, these difficulties are manageable with selected strategies.

Potential Options

A series of ten potential options has been identified for consideration in an attempt to introduce anadromous salmon and steelhead to the Nisqually River above Alder reservoir. These options have been prioritized on the basis of overall feasibility with primary consideration focused on sound biological principles in the management of fisheries in the upper Nisqually River basin. Each option entails a number of actions which are consistent with the life cycle requirements of anadromous salmonids, the existing modifications of the habitat, and the future modifications required. The goal of each option is to attempt to introduce anadromous salmon and steelhead trout runs above the La Grande/Alder hydroelectric project which may be managed on a sustained basis in the future.

Option #1. Provide volitional access for all adult anadromous salmonids above La Grande and Alder dams and pass smolts downstream over both dams.

Option #2. Trap and haul adults of all anadromous salmonid species (coho, chinook and steelhead) above La Grande and Alder dams and pass smolts downstream over both dams.

Option #3. Trap and haul adults of all salmonid species above La Grande and Alder dams and collect smolts at Alder Dam and haul to lower river.

Option #4. Trap and haul only adult coho and chinook above La Grande and Alder dams and collect smolts at Alder Dam and haul to lower river.

Option #5. Trap and haul only adult coho above La Grande and Alder dams and

collect smolts in Alder reservoir and haul to lower river.

Option #6. Trap adult coho, chinook and steelhead for artificial propagation with resulting progeny liberated as fingerlings into upstream tributaries and collect smolts in Alder reservoir and haul to lower river.

Option #7. Trap adult coho for artificial propagation with resulting progeny liberated as fingerlings into upstream tributaries and collect smolts in Alder reservoir and haul to the lower river.

Option #8. Trap adult coho, chinook and steelhead for artificial propagation with resulting progeny liberated as fingerlings into upstream tributaries and collect smolts at a screening structure near river mile 54 on the upper mainstem Nisqually River below the mouth of Mineral Creek, and haul to the lower river.

Option #9. Trap adult coho and chinook at Centralia Dam fish ladder and capture steelhead brood stock below La Grande powerhouse by beach seine for artificial propagation with resulting progeny liberated as fingerlings into upstream tributaries and collect smolts at a screening structure near river mile 54 on the upper mainstem Nisqually River below the mouth of Mineral Creek, and haul to lower river.

Option #10. Trap adult coho and chinook at Centralia Dam fish ladder and capture steelhead brood stock below LaGrande powerhouse by beach seine for artificial propagation with resulting progeny liberated as fingerlings into upstream tributaries, collect smolts in Alder reservoir

and haul to lower river.

Actions associated with each option.

All ten options have been presented to indicate a range of possibilities, the interactions of various actions and the degree of difficulty in trying to introduce a sustained run of anadromous fish above the Alder/La Grande projects. Each option has been expanded into a number of actions necessary for its execution. All options may be considered possible prior to the consideration of cost which in many options is strongly associated with technical feasibility of various engineering alternatives. Cost approximations of the major engineering modifications indicated under many of the options were a collaborative effort of both authors. The reader is advised that the approximate costs presented are not estimates. Estimates require a far more detailed evaluation than was possible in this study. The approximate costs presented in this evaluation are for comparative purposes only and none have been weighted. The reader is also strongly cautioned that some approximations are based on a number of assumptions which are all positive. These assumptions could be found to be in error, either through additional information or the discovery that potential engineering modifications are not feasible and, therefore, eliminate an option. Table 9 lists the actions included in each option with the associated approximate cost.

Option 1. Provide volitional access for all adult anadromous salmonids above

La Grande and Alder dams and pass smolts downstream over both dams.

Action 1A. Construct a fishway over La Grande and Alder dams for upstream

adult fish passage: The construction of a complete fish ladder over a dam

Table 9. List of action items included with each option and the approximate associated cost.

	Option										Cost millions
	1 Coho, Chin. & SH	2 Coho, Chin. & SH	3 Coho, Chin. & SH	4 Coho, Chin.	5 Coho only	6 Coho, Chin. & SH	7 Coho only	8 Coho, Chin. & SH	9 Coho, Chin. & SH	10 Coho, Chin. & SH	
1A. La Grande/Alder adult fishway	X										\$165.0
1B. Alder smolt passage facility	X	X									5.0
1C. La Grande smolt passage facility	X	X									6.5
2A. Adult trap & haul facility (below La Grande PH)		X	X	X	X	X	X	X			4.0
2B. Adult hauling		X	X	X	X	X	X	X			.020-.050
3C. Alder Reservoir smolt trap facility		X	X	X	X	X	X	X	X		.5
3D. Smolt hauling			X	X	X	X	X	X	X		.020-.025- .030
6B. Take broodstock & haul to hatchery						X	X	X	X		.025
6C. Hatchery culture to fingerling size						X	X	X	X		.016-.038
6D. Haul & plant fingerlings						X	X	X	X		.025-.050
8E. Construct & operate a screening structure on upper Nisqually River							X	X	X		4.86
9A. Adult trap & haul facility (Centralia Dam)								X	X		.150
Total Cost (millions)	\$176	15.55	4.58	4.58	4.54	4.64	4.60	9.0	5.153	0.793	

consists of building a ladder that ascends the entire dam and continues to the forebay pool. Design of adult fish ladders has been discussed in detail by Clay (1961), Eicher (1973), and Bell (1984). Getting fish to enter a ladder requires the same considerations as for trapping and hauling. Fish passage up the ladder usually can be accomplished when a proper combination of fishway design and operation to ensure adequate flows throughout a run. Getting fish to exit the ladder may require adjustable weirs, gates, or submerged orifices at the upper end of the ladder. Ladders have been installed at many locations, and generally have not created problems if they were designed and operated correctly.

Construction of a fish ladder to allow the passage of adult anadromous salmonids in the winding narrow canyon where La Grande/Alder dams are located would require the development of engineering solutions to problems associated with construction in unstable rock formations. A fishway at this site would rise from elevation 508 ft to 1207 ft, a total vertical rise of 699 feet. It would be very difficult to attach a fish ladder to the canyon walls with reliability.

A tunnel fishway was considered on a direct line from La Grande powerhouse to the top of Alder Dam. The tunnel would be 11,880 feet long on a horizontal to vertical ratio of 17:1. This is necessary to avoid introducing and collecting adult migrants in La Grande reservoir. An additional collection structure in La Grande reservoir would be costly, difficult to design and inefficient. In addition, fish attempting to pass through La Grande reservoir would have a high fall back mortality through the turbines. The approximate cost of a tunnel fishway is about \$165 million with a low assurance that adequate numbers of fish would actually ascend to the top. No dam of this height has been laddered for salmonids.

Action 1B. Construct collection and passage facilities for downstream migrant smolts at Alder Dam: Fish leaving spawning and rearing areas upstream of dams face a number of obstacles in their seaward migration: 1) mortality or residualism in the reservoir; 2) mortality in turbines or connected structures; 3) mortality in spillways; 4) mortality in the tailrace; and 5) stranding downstream of the reservoir due to fluctuating water levels.

The average water temperature of the upper 30 feet of Alder reservoir was found to remain below 10.6°C during the smolt emigration period (April-June). This suggests that a surface smolt collection facility might be effective. However, since this temperature is an average for the period it would be important to know when the surface temperature reaches and exceeds 15°C. The temperature data for Alder reservoir suggest that 15°C may be reached as early as mid-June, after which surface smolt collection would become less effective because the high temperature would force the fish deeper in the water column.

Gulpers, skimmers and lake traps each with net leads and pumped attraction water were considered appropriate smolt collection systems for Alder reservoir. The general plan of a gulper has been described by Eicher (1970) and reviewed by Wampler et al. (1985). It consists of a floating inclined plane trap with pumped attraction flow into the trap. Fish captured by the inclined plane are strained from the attraction water by a horizontal screen and passed to the tailrace or another point downstream by a much smaller amount of diversion water. Installations have been tested at the Baker, Merwin, Mayfield and Lookout Point reservoirs. The Baker gulper has had some difficulty in attracting smolts, apparently because the fish tend to occupy levels of the reservoir so deep that the gulper cannot attract them (Orrell, WDF, pers.

comm.). The installation of net leads increased its effectiveness (Semple and McLeod 1975), but performance was still not entirely satisfactory. The Merwin gulper has been made to perform satisfactorily with the addition of net leads, and was tested at 74% collection efficiency for yearling coho (Allen and Rothfus 1976). In contrast, the Mayfield gulper was not satisfactory, even with net leads, and the Lookout Point trap was also ineffective. Most other cases have not yielded consistently good results (Eicher 1970). The general problem with guplers is that they lose effectiveness when some other source of attraction flow competes with the gulper's attraction or high surface temperatures cause fish to descend below the trap.

Skimmers are like guplers except that they are supported by the dam and do not float. They have been described by Eicher (1970) and Bell (1984). Skimmers can either be in a fixed position or be adjustable, riding on rails to follow the forebay level. They have been installed at the Pelton, Green Peter, Cougar, Fall Creek and Round Butte dams. The Green Peter installation has had 75 to 84% passage efficiency for chinook, 67% for summer steelhead, but only 33 to 57% for winter steelhead (Wagner and Ingram 1973). On the other hand, the Cougar and Fall Creek facilities have not had consistently good collection efficiency (Moon 1969).

Lake traps have been used successfully to trap smolts at Lake Merwin and Wynoochee reservoirs (Hamilton et al. 1970; Dunn 1978), but they were not as useful in the White River drainage (Seiler, WDF, pers. comm.). Lake traps operate on the principle of a fyke trap by guiding fish with net leads to a floating pot and spiller connected by tapered web tunnels. Collection efficiency at Wynoochee ranged from 12 to 56% for hatchery

coho, and 7 to 12% for hatchery steelhead (Dunn 1978). Factors affecting efficiency include siting, length and position of leads and surface water temperature.

The addition of net leads can sometimes be used to increase the effectiveness of gulpers, skimmers, and lake traps (Semple and McLeod 1975), but effectiveness is site-specific (Ruggles and Collins 1981). Addition of net leads to the Baker collectors increased effectiveness but had no such result at Brownlee Dam. There, trash made it impossible to keep the lead in one piece.

The spill of water from Alder Dam is very infrequent and under current operating conditions could not be utilized to establish a flow of attraction water to facilitate smolt collection near the dam. The spillway design on the dam does not appear to be conducive to high smolt passage survival due to roughness of the channel and the turbulent hydraulic conditions in the plunge pool which have a high potential for strike during passage. A gulper or skimmer could be designed to pump attraction water to maximize the efficiency of collection near the dam. This system would have to be designed to function over the normal annual reservoir fluctuation of 61 feet and be constructed to withstand large woody debris, high wind and wave action which are likely to occur. The approximate cost of such a system is about \$5 million. Screening should also be considered to prevent the passage of smolts through the deep turbine intakes if complete downstream passage facilities were to be developed; however, the cost of screening has not been included. The probability of developing a successful cost effective downstream migrant system for this dam remains low.

Action 1C. Construct collection and passage facilities for downstream migrant smolts at La Grande Dam: The run-of-river La Grande reservoir has a limited retention time with a high probability of a turbulent flow throughout the water column. The penstock intakes are located at a depth of 60 feet and do not provide a significant separation from the surface which normally fluctuates 5 feet. Therefore, it would be more difficult to achieve a high smolt collection efficiency in a surface collection system. A system similar to that suggested for Alder reservoir would be needed at a similar cost of \$5 million. Screening to prevent the passage of smolts into the intake tunnel has been included at a cost of \$1.5 million. Under present operating conditions of no-spill at La Grande Dam a smolt collection facility would require a 1.5 mile long pipeline to carry the smolts to the river below the La Grande powerhouse. The total minimum cost of this action is \$6.5 million. The probability of developing a successful cost effective downstream migrant system for this dam is low.

Potential changes in the operation of La Grande to achieve a controlled spill for the passage of smolts were considered and rejected. The small volume of spill could not be expected to attract large numbers of smolts away from the large volume of flow through the intake tunnel. The potential loss of smolts in the channel between the dam and the powerhouse with an intermittent flow regime could be quite high due to stranding, residualization in pools and predation. The benefit/cost would not be improved if the power lost to spill were included in the analysis.

Total approximate cost of Option #1 is about \$176 million.

Option #2. Trap and haul adults of all anadromous salmonid species (coho, chinook and steelhead) above La Grande/Alder dams and pass smolts downstream over both dams.

Action 2A. Construct a trap and haul facility on the Nisqually River below the La Grande powerhouse for adult salmonids: Fish entering a river and bound for the area upstream of a dam must fulfill the criteria listed by Banks (1969); 1) travel upstream to the area of the fish collection facility; 2) enter the fish collection facility; 3) be transported safely over the dam; 4) avoid falling back over the dam; and 5) find their way through the reservoir to the spawning grounds.

Most upstream fish passage facilities are designed to fulfill criteria (2) and (3) above (Wampler et al. 1985). Various methods will be evaluated on their ability to do so. Fulfillment of other criteria is largely a matter of design and operation of the particular site and facility.

The trap and haul method consists of trapping adults at some point downstream of the dam, loading them into a truck, and hauling them upstream of the dam for release. A typical facility consists of: a rack or barrier dam to direct fish into a ladder; an attraction flow to stimulate fish to enter the ladder; a ladder just long enough to accommodate normal high flows and yet encourage fish movement; a trap; a holding area to keep fish until they are periodically removed; a brail to remove fish; and a hopper to load fish into a truck. Most traps also have a specific sorting area where fish can be counted and examined for species composition and for mark recovery.

Trapping and hauling is a proven technique widely applied in the Northwest. It is best suited to high dams (those with more than 100 feet

of head) with runs smaller than 20,000 fish per year (Clay 1961). The Wynoochee, Baker, Green Peter, and Mud Mountain dams are some examples. The Baker facilities have been described in detail by Clay (1961), and the Green Peter facilities were described by Moon (1969). These authors did not note any problems inherent in this mode of fish passage. The method is especially appropriate for spring chinook, because this race has difficulty ascending high ladders (Gunsolus and Eicher 1970). This option presents an alternative to the construction of an upstream fishway. A trap and haul facility similar to that needed on the Nisqually River was previously planned for a similar project on the Similkameen River below Enloe Dam (Fanning et al. 1984). This facility would include a barrier dam, fishway, trap, fish evaluation area and loading facility for tank trucks. The cost of such a facility is approximately \$4 million.

Action 2B. Haul adults of all anadromous salmonid species above Alder Reservoir: Location of the trap and haul facility at the upstream limit of anadromous fish movement should eliminate problems of sorting the catch. All fish moving past the mouth of the Mashel River to the trap and haul facility would be trucked upstream. It is not expected that significant numbers of fish destined for other tributaries might stray upstream and into the trap.

The cost of hauling adults of all species above both dams is about \$50,000 per year.

Action 2C. Construct collection and passage facilities for downstream migrant smolts at Alder Dam: (See Action 1B).

Action 2D. Construct collection and passage facilities for downstream migrant smolts at La Grande Dam: (See Action 1C).

Total approximate cost of Option #2 is about \$15.55 million.

Option #3. Trap and haul adults of all salmonid species above La Grande and Alder dams and collect smolts at Alder Dam and haul to lower river.

Action 3A. Construct a trap and haul facility on the Nisqually River below the La Grande powerhouse for adult salmonids: (See Action 2A).

Action 3B. Haul adults of all anadromous salmonid species above Alder Reservoir: (See Action 2B).

Action 3C. Construct a smolt collection facility on Alder Reservoir.

The most efficient site for this facility is probably near the mouths of the upper Nisqually River and East Creek along both shores of the reservoir. However, it may be necessary to experiment with several trap sites in order to discover the most efficient location. The narrows in the reservoir between river mile 48 and 49 may be a preferred site for a single set of leads across the narrows attached to a floating trap. The closer the trap(s) are placed to the head of the reservoir the lower the loss due to predation, residualism and behavioral avoidance of the trap.

The approximate cost of this facility is about \$500,000.

Action 3D. Haul smolts of all anadromous salmonid species to the river below La Grande powerhouse.

The approximate cost of hauling is about \$30,000 per year.

Total approximate cost for Option #3 is about \$4.58 million.

Option #4. Trap and haul only adult coho and chinook salmon above La Grande and Alder dams and collect smolts at Alder Dam and haul to lower river.

Action 4A. Construct a trap and haul facility on the Nisqually River below the La Grande powerhouse for adult salmonids: (See Action 2A).

Action 4B. Haul adult coho and chinook above Alder Reservoir: (See Action 2B).

Action 4C. Construct a smolt collection facility on Alder Reservoir. (See Action 3C).

Action 4D. Haul smolts of two species to the river below La Grande powerhouse.

The approximate cost of hauling is about \$25,000 per year.

Total approximate cost for Option #4 is about \$4.575 million.

Option #5. Trap and haul only adult coho above La Grande and Alder dams and collect smolts in Alder reservoir and haul to lower river.

Action 5A. Construct a trap and haul facility on the Nisqually River below the La Grande powerhouse for adult salmonids: (See Action 2A).

Action 5B. Haul adult coho above Alder reservoir: (See Action 2B).

The approximate cost of hauling is \$20,000.

Action 5C. Construct a smolt collection facility on Alder reservoir: (See Action 3C).

Action 5D. Haul coho smolts to the river below La Grande powerhouse:

The approximate cost of hauling is about \$20,000 per year.

Total approximate cost for Option #5 is about \$4.54 million.

Option #6. Trap adult coho, chinook and steelhead for artificial propagation with resulting progeny liberated as fingerlings into upstream tributaries and collect smolts in Alder reservoir and haul to the lower river.

Action 6A. Construct a trap and haul facility on the Nisqually River below the La Grande powerhouse for adult salmonids: (See Action 2A).

Action 6B. Take gametes from coho, chinook and steelhead and haul to hatchery:

Approximate cost of \$25,000 per year.

Action 6C. Culture coho, chinook salmon and steelhead trout in the Nisqually Tribal hatchery to a fingerling size of 80/lb:

The number of eggs required for culture and full seeding of the upstream tributaries was estimated by back calculating from the estimated smolt potential. The number of fingerling coho, chinook and steelhead to be planted was increased by 50% to allow for mortality during the rearing stages following planting into the tributaries prior to emigration. The number of coho, chinook and steelhead fingerlings to be planted are 220,000, 260,000 and 22,000, respectively. A 25% hatchery egg mortality was allowed in addition resulting in the number of eggs needed for full seeding of 275,000 coho, 325,000 chinook, and 27,500 steelhead.

Estimating a fecundity of 3500 eggs/female for coho and steelhead and 5000 eggs/female for chinook salmon the following number of females are needed for egg taking: 80 coho, 66 chinook and 8 steelhead. An equal number of males results in 160 coho, 132 chinook and 16 steelhead which would be removed from the run as brood stock for eggs and milt. The principal advantage of taking eggs and hatchery culture is that more adults can be allowed in the harvest (Table 8).

It is anticipated that these planting densities will ensure the

potential production capacity is reached. However, if all species are planted into the same stream system then the potential production of each will be reduced. The cost of production has been estimated by assuming that the fingerlings will be out-planted at 80/lb on the basis of the highest capital and operating expenditures estimated by Senn et al. (1984) of \$6.00 per pound. The approximate cost of culturing coho is \$16,500, chinook \$19,500, and steelhead \$1,650. The total approximate cost is \$37,650 per year.

Action 6D. Hauling and outplanting cultured fingerlings into upstream tributaries:

The fingerlings would be planted in small numbers at numerous access sites throughout the streams of the upper watershed. In order to adequately distribute fish through inaccessible reaches new access sites may need development; however, the costs associated with this cannot presently be calculated.

The approximate cost of hauling and outplanting is \$50,000.

Action 6E. Construct a smolt collection facility on Alder Reservoir: (See Action 3C).

Action 6F. Haul smolts of both species to the river below La Grande powerhouse: (See Action 3D).

Total approximate cost for Option #6 is \$4,642,650.

Option #7. Trap adult coho only for artificial propagation with resulting progeny liberated as fingerlings into upstream tributaries and collect smolts in Alder reservoir and haul to the lower river.

Action 7A. Construct a trap and haul facility on the Nisqually River below

the La Grande powerhouse for adult salmonids: (See Action 2A).

Action 7B. Take gametes from coho and haul to hatchery: (See Action 6B).

Action 7C. Culture coho and salmon in the Nisqually Tribal hatchery to a fingerling size of 80/lb: (See Action 6C).

The approximate cost of coho culture is \$16,500/year.

Action 7D. Haul and outplant cultured coho fingerlings into upstream tributaries: (See Action 6D). The approximate cost is \$25,000 for a single species.

Action 7E. Construct a smolt collection facility on Alder Reservoir: (See Action 3C).

Action 7F. Haul smolts of both species to the river below La Grande powerhouse: (See Action 3D).

Total approximate cost of Option #7 is \$4,596,500.

Option #8. Trap adult coho, chinook, and steelhead for artificial propagation with resulting progeny liberated as fingerlings into upstream tributaries, collect smolts at a screening structure near river mile 54 on the upper mainstem Nisqually River below the mouth of Mineral Creek and haul to the lower river.

Action 8A. Construct a trap and haul facility on the Nisqually River below the La Grande powerhouse for adult salmonids: (See Action 2A).

Action 8B. Take gametes from coho, chinook and steelhead and haul to hatchery: (See Action 6B).

Action 8C. Culture coho, chinook salmon and steelhead trout in the Nisqually Tribal hatchery to a fingerling size of 80/lb: (See Action 6C).

Action 8D. Haul and outplant cultured coho, chinook, and steelhead

fingerlings into upstream tributaries: (See Action 6D).

Action 8E. Construct a smolt collection facility on the upper mainstem Nisqually River near river mile 54 below the mouth of Mineral Creek.

A low diversion dam would be constructed across the river to divert approximately 80% of the maximum flow of the river during the months of April-June and September-October. These are the periods when smolt emigration usually occur. The screening facility will be designed for a flow of 3000 cfs. The water and juvenile fish will be diverted to a self-cleaning screen. The fish will be separated and passed into a holding facility from which they will be loaded into a tank truck for movement downstream. The screen will be designed to retain the smallest size fish which migrate down the river and will therefore be 100% efficient during the time the design flow is not exceeded. The bypass reach would be kept as short as possible with a minimum flow and an upstream ladder would be provided for adult trout migrating out of Alder lake.

The approximate cost of this screening facility is calculated at the rate of \$1200/cfs. The screen structure would cost about \$3.6 million, the fish holding and loading facility about \$225,000 and the diversion dam about \$1.0 million. The total approximate cost of the facility is \$4.86 million. This single structure would screen all of the upper tributaries except East Creek and the Little Nisqually River. Both could be left for the production of resident fishes for Alder reservoir. With the exclusion of these tributaries, total smolt production estimates for this option have been reduced somewhat.

Action 8F. Haul smolts of both species to the river below La Grande powerhouse: (See Action 3D).

Total approximate cost of Option #8 is \$8,967,650.

Option #9. Trap adult coho and chinook salmon at Centralia Dam fish ladder and capture steelhead brood stock below La Grande powerhouse by beach seine for artificial propagation with resulting progeny liberated as fingerlings into upstream tributaries and collect smolts at a screening structure near river mile 54 on the upper mainstem Nisqually River below the mouth of Mineral Creek, and haul to lower river.

Action 9A. Construct an adult trap and haul facility at the Centralia Dam for coho and chinook salmon. A drop box structure would be added to the Centralia fish ladder to intercept and temporarily retain migrants which would then be hauled out for processing. This structure would also satisfy fisheries management needs for upstream migrant counts, species composition and provide a source of brood stock for the Clear Creek hatchery.

A steel framed drop box would be designed with a nylon mesh net lining to minimize the loss of scales from the fish captured. With the exception of the drop box, very few modifications would be made to the existing canal structures. Therefore, most of the cost would result from operation and maintenance of a temporary facility including a crane needed to haul the drop box.

In order to avoid interception of steelhead destined for upstream tributaries, all would be released above the Centralia facility. The small number of brood stock needed for this program would be captured by beach seine below the La Grande powerhouse. If a steelhead stock can be developed to home to the upper watershed, capture of the brood stock at this location will ensure the same stock is replanted upstream each year.

The approximate cost of this section is \$150,000.

Action 9B. Take gametes from coho, chinook and steelhead and haul to hatchery: (See Action 6B).

- Action 9C. Culture coho, chinook salmon and steelhead trout in the Nisqually Tribal hatchery to a fingerling size of 80/lb: (See Action 6C).
- Action 9D. Haul and outplant cultured coho, chinook and steelhead fingerlings into upstream tributaries: (See Action 6D).
- Action 9E. Construct a smolt collection facility on the upper mainstem Nisqually River near river mile 54 below the mouth of Mineral Creek: (See Action 8E).
- Action 9F. Haul smolts of both species to the river below La Grande powerhouse: (See Action 3D).
- Total approximate cost of Option #9 is \$5,153,000.
- Option #10. Trap adult coho and chinook at Centralia Dam fish ladder and capture steelhead brood stock below La Grande powerhouse by beach seine for artificial propagation with resulting progeny liberated as fingerlings into upstream tributaries, collect smolts in Alder reservoir and haul to lower river.
- Action 10A. Construct an adult trap and haul facility at the Centralia Dam for coho and chinook salmon: (See Action 9A).
- Action 10B. Take gametes from coho, chinook and steelhead and haul to hatchery: (See Action 6B).
- Action 10C. Culture coho and chinook salmon and steelhead trout in the Nisqually Tribal hatchery to fingerling size of 80/lb.: (See Action 6C).
- Action 10D. Haul and outplant cultured coho, chinook and steelhead fingerlings into upstream tributaries: (See Action 6D).
- Action 10E. Construct a smolt collection facility on Alder reservoir: (see Action 3C).

Action 10F. Haul smolts of all three species to the river below La Grande powerhouse: (See Action 3D).

Total approximate cost for Option #10 is \$793,000.

Benefit/Cost Analysis

The benefit analysis was developed over a project lifetime of 50 years. Coho and chinook salmon were projected on a 4-year cycle while steelhead trout were projected on a 6-year cycle. It was assumed that the maximum adult return could be achieved from year one of the economic analysis due to hatchery fry plants in all accessible tributaries every year. Of course it would require four years from project initiation before the first adult salmon and six years before the first adult steelhead would return from this project. The catch was maximized throughout the project life and full seeding was assumed.

The net monetary value was placed at \$1.00/lb for commercially caught coho and chinook salmon. The average weight of coho and chinook salmon was estimated at 10 and 22 lbs per fish, respectively. The net monetary value for sport-caught adult steelhead trout was placed at \$144 (Meyer 1984).

The discount rate chosen for this analysis is 3%. This is the risk-free rate of time preference used by BPA for power system analysis and projected evaluation. The present value of projected benefits for coho, chinook and steelhead with smolt trapping on Alder reservoir and partial turbine passage is presented in Table 10. The present value of projected benefits for coho, chinook and steelhead was calculated for options 3, 6, 8, 9 and 10. These values were calculated using the following formulation by Grant, Iveson and Leavenworth (1976):

Table 10. Total value by selected option, present value by species, costs and associated B/C ratios.

	Present Value					
	Option 3	Option 6	Option 8	Option 9	Option 10	
	Adult trap below La Grande, reservoir smolt trapping & turbine passage	Adult trap below La Grande, fish culture, trap & haul smolts	Adult trap below La Grande, culture, smolt screening upper mainstem Nisqually River	Adult trap at Centralia Dam, culture smolt screening upper mainstem Nisqually River	Adult trap at Centralia Dam, fish culture, trap & haul smolts	B/C ratio
	B/C ratio	B/C ratio	B/C ratio	B/C ratio	B/C ratio	B/C ratio
Coho Harvest Benefit	\$ 761,336	\$1,407,120	\$1,786,388	\$1,786,388	\$1,407,120	0.139
Chinook Harvest Benefit	946,637	1,770,267	2,071,634	2,071,634	1,770,267	0.161
Steelhead Harvest Benefit	107,163	1,251,452	3,742,876	3,742,876	1,251,452	0.291
Total Harvest Benefit	\$1,815,136	\$4,428,839	\$7,600,898	\$7,600,898	\$4,428,839	0.590
Total Capital Cost	4,580,000	4,642,650	8,967,650	5,153,000	793,000	
Total O&M Cost (3%)	6,870,000	6,963,975	13,451,475	7,729,500	1,189,500	
Total Cost	\$11,450,000	\$11,606,625	\$22,419,125	\$12,882,500	\$1,982,500	

$$\text{Present worth} = \sum_{i=1,4} (P/A, 3\%, N \text{ yrs}) \times (P/F, 3\%, (N-6) \text{ yrs}) \times (y) \times \# \text{ of fish}$$

$$i = 1, 6$$

$$\text{where: present worth of year groups} = (P/A) = \frac{(1+i)^N - 1}{i(1+i)^N}$$

$$\text{and: present worth of each year group at year zero} = (P/F) = \frac{1}{(1+i)^N}$$

and: $N = \#$ of years (50)

$i =$ discount rate (3%)

$y =$ value of fish or value per pound of fish.

The present value figures by species and selected option are presented in Table 10.

These project scenarios were selected as the potentially most feasible and represented the maximum benefit/cost ratio for each species. As pointed out in an earlier section, it is unlikely that all three species could be maximized in the same habitat; however, a total value has been used for the purpose of discussion.

The benefit/cost analysis consists of identifying and quantifying project benefits and costs and determining the B/C ratios. The analysis was performed on a present worth basis. A federal discount rate of 3 percent and a project life to 50 years was assumed. There are three components to this benefit/cost analysis, including determination of:

- benefits
- costs: capital and operation-maintenance
- B/C ratios.

Project costs were approximated for each of the ten options, but only

five were selected for further analysis. Capital costs are those incurred at the beginning of the project, including construction, engineering services and equipment. Operation and maintenance costs were estimated at 3% of capital costs for a 50-year period. Inflation was not included in this analysis because it was assumed that the value of the fish would increase at the same rate as the increase in operating costs therefore cancelling each other. The B/C ratios are presented in Table 10 by species for the five selected options. These options selected for analysis should have produced the best B/C ratios of the ten potential options. The B/C ratios strongly indicate that only Option 10 presents a cost effective means of introducing anadromous fish into the upper watershed.

Recommendations

Ten potential options were developed in an effort to explore the most reasonable possibilities which could be applied to bring the upstream tributaries above Alder/La Grande dams into anadromous fish production. Options 1 and 2 are eliminated on the basis of questionable technical feasibility of passing fish either up or down over these very high dams and the associated costs in doing so. Option 4 utilizing coho and chinook was included because of the inefficiencies in attempting to trap steelhead smolts in reservoirs. Options 5 and 7 were included using only coho salmon in case diseases were an overriding concern with the upstream introductions. Disease does not appear to present excessive risk, making these options unnecessary. The benefits resulting from any option which utilizes less than all three species are so low as to quickly eliminate any further consideration.

Options 3, 6, 8, 9 and 10 were selected for detailed analysis. Each utilized all three species in order to maximize the potential benefit which

could be realized. The inefficiencies in reservoir smolt trapping and turbine mortality, along with releasing adults above the reservoir, are apparent in Option 3 even though it has a low capital cost. Option 6 relies on inefficient smolt trapping in the reservoir but no longer transfers adults above the reservoir. Instead brood stock is taken for eggs and milt to improve on the reproductive efficiencies allowing an increase in the harvest. Option 6 resulted in a B/C ratio of 0.382. Option 8 was included to evaluate the increased efficiency gained by placing a fish screening facility on the upper mainstem Nisqually River along with the culture of eggs to maximize harvest. This option resulted in a B/C ratio of 0.339 due to the high capital and O&M costs associated with the trap and haul facility and the smolt screening structure.

Option 9 was based on the elimination of an adult trap and haul facility below La Grande powerhouse and substituting a lower cost adult trapping facility at the Centralia Dam fish ladder. This reduced both the capital and operation and maintenance costs and yielded a B/C ratio of 0.59. Option 10, the least costly option identified in this study, combines Option 9, the trap and haul facility at the Centralia Dam and hatchery culturing, with the Alder reservoir smolt trap and haul operation identified in Options 3 and 6. This reduced the capital costs substantially and yielded the highest B/C ratio (2.234) that could be achieved in this analysis.

It is clear that the only option that is cost effective (Option 10) is a combination of least costly actions, regardless of their production efficiencies. Because of the limited upstream productivity, only this combination of low cost actions proves cost effective. It is also clear that the upstream screening facility is not cost effective, despite the fact a facility such as this does increase the harvest benefit substantially. Based on the range of options evaluated, only Option 10 can be recommended.

Summary

This study was conducted to determine the feasibility and benefit/cost of utilizing the stream habitat in the upper Nisqually River basin for anadromous fish production above the Alder/La Grande hydroelectric projects. La Grande Dam is 192 feet high and Alder Dam is 285 feet high. The total elevation gain from the tailrace below La Grande powerhouse to the top of Alder Dam is 699 feet. Neither dam was constructed with fish passage facilities.

Vertical temperature profiles of Alder reservoir and the surface waters to a depth of 30 feet indicate surface oriented juvenile salmonid passage facilities may be effective until surface temperatures exceed 10.8°C in mid-June. Reservoir water column turbidity exceeds 5 NTU August through February reducing productivity. The low flow stream habitat above Alder reservoir was estimated in fourteen clear and three glacial streams. The area available in clear streams was estimated at 495,494 yd² while 177,526 yd² occur in the glacial streams. Potential fish production was based on smolt densities in clear streams. Potential production in glacial streams was reduced by 50%. The total estimated smolt production potential for both clear and turbid streams was 146,580, 173,859 and 14,475 for coho, chinook and steelhead, respectively. Reservoir trapping efficiencies, handling mortality, turbine passage mortality in Alder and La Grande Dams, marine survival and total adult return were calculated. Subtracting escapement requirements for full seeding from the adult return resulted in the following harvestable surplus:

	<u>Option 3</u>	<u>Option 6 and 10</u>	<u>Option 8 and 9</u>
Coho	3,268	6,040	7,668
Chinook	1,847	3,454	4,042
Steelhead	28	327	978

A series of ten potential options were evaluated, along with twelve

actions. Five of the options were dismissed for lacking in technical feasibility, requiring excessive capital outlay, or providing insufficient benefits. Smolt passage survival for the remaining options was estimated. Option 3 analyzed the scenario of adult trap and haul with release in streams above Alder reservoir of all three species, partial trap and haul of smolts from the reservoir and partial passage through the turbines in both dams, and escapement/harvest estimates. The scenario for Option 6 was the same as Option 3 except the escapement was reduced to only enough brood stock to provide eggs and milt for hatchery culture to fully seed the streams with fry of all three species. The scenario for Option 8 modified Option 6 by adding a screening structure on the upper mainstem Nisqually River in conjunction with fish culture and fry plants. The smolt screening structure located near river mile 54 would screen all upper tributaries except East Creek and the Little Nisqually River. The smolts would be hauled and released in the lower river.

Option 9 modified Option 8 by eliminating the adult trap and haul facility below the La Grande powerhouse and substituting a low cost trap and haul facility at the Centralia Dam. Option 10, the least costly option identified in this study, combines Option 9, the trap and haul facility at the Centralia Dam and hatchery culturing, with the lower cost Alder reservoir smolt trap and haul operation identified in Options 3 and 6.

A benefit analysis was developed over a project lifetime of 50 years, a discount rate of 3 percent and the commercial value of coho and chinook set at \$1.00/lb and the sport value of steelhead at \$144/fish. The benefit cost analysis consisted of identifying and quantifying project benefits, costs and determining B/C ratios.

The results of the benefit/cost analysis are:

Option 3	0.159
Option 6	0.382
Option 8	0.339
Option 9	0.590
Option 10	2.234

For all options except Option 10, potential fish production above Alder reservoir is insufficient to offset the high costs of overcoming the problems associated with the Alder/La Grande hydroelectric complex. Option 10 presents a combination of low cost actions and a much more positive benefit cost ratio than the other options. Therefore, it is considered the only feasible means of introducing anadromous fish into the upper watershed.

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