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PEN REARING AND IMPRINTING OF FALL CHINOOK SALMON

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ABSTRACT

Backwaters and protected sites located along the Columbia River between John Day and Priest Rapids dams, and the lower reaches of the Umatilla, Yakima, and Snake rivers were surveyed to determine their suitability for experimental rearing of age-0 fall (upriver bright) chinook salmon. All but eight potential study sites observed were judged as unusable based on criteria which included depth, area, accessibility, potential water level and temperature fluctuations, entrance-access to the river, public use, and obvious water quality problems. These eight sites were then thoroughly evaluated to determine suitability for rearing studies, using water quality and biological data to supplement physical observations. The criteria used in the final selection of rearing sites included an assessment of water source, depth, temperature, and quality, proximity to natural spawning sites, ease of adult capture, and benthos and zooplankton abundance.

Two sites were selected as satisfying the most criteria for experimental rearing studies: Rock Creek (river km 337) and Social Security Pond (river km 468). All other sites surveyed were ranked as either less desirable, or unusable for these studies.

INTRODUCTION

Historical anadromous fish populations have been severely impacted by the construction and operation of hydroelectric dams on the Columbia River. Previously used spawning and nursery habitat has either been eliminated, inundated, or rendered useless by main stem dams and reservoirs. These losses have been partly compensated for by increased hatchery production, especially in the Columbia River stretch below The Dalles Dam. For example, compensation for lost spawning habitat of fall chinook salmon caused by the John Day Project has been the release of fish reared at Bonneville Hatchery (Oregon Department of Fish and Wildlife) and at Spring Creek National Fish Hatchery (U.S. Fish and Wildlife Service). The adults, however, return to the hatcheries from where they are released and do not enter the fishery above the respective points of origin. Therefore, it has become necessary to develop a methodology for moving the production of the anadromous fishery back into the upper reaches of the Columbia River Basin.

The goal of the present project is to determine the feasibility of rearing and acclimating age-0 fall (upriver bright) chinook salmon in "off-station" facilities (an acclimation pond and a backwater) located above John Day Dam. Should the methodology prove feasible in returning adults into the John Day reach, it could be applied throughout the Columbia River Basin. Returning adults will be available for harvest by the Zone VI Indian fishery, for brood stock in subsequent off-station rearing projects, and for outplanting in nearby rivers and streams.

The primary task in 1983 was to select a suitable backwater and a pond between John Day and Priest Rapids dams where fall chinook salmon could be reared, released, and subsequently recaptured. Future tasks will concentrate on developing methodolgy to pen-rear and acclimate juvenile fall chinook salmon, on comparing off-station rearing with hatchery production, and on capturing and evaluating the returning adults,

Study Location, Criteria, and Methods

Accessible backwaters and ponds from John Day Dam (river km 348) to Priest Rapids Dam (river km 639) and the lower reaches of the Umatilla, Yakima, and Snake rivers were surveyed for possible use as rearing areas for age-0 fall chinook salmon (Figure 1). Aerial photographs, U. S. geological Survey topography maps, a river cruising/navigation atlas, various road maps, and personal communication with other fishery workers in the area were used to identify potential sites and access routes. Locations considered accessible and potentially usable were then visited during a "windshield" survey in June and July. Specific sampling dates, observations, and sampling detail varied among locations as sites were eliminated from further consideration because they did not meet established criteria.

Initial criteria used in evaluating sites were depth, area, accessibility, potential for water temperature or level fluctuations, excessive current or wave action, entrance-access to the river, public use, and obvious potential water quality problems.

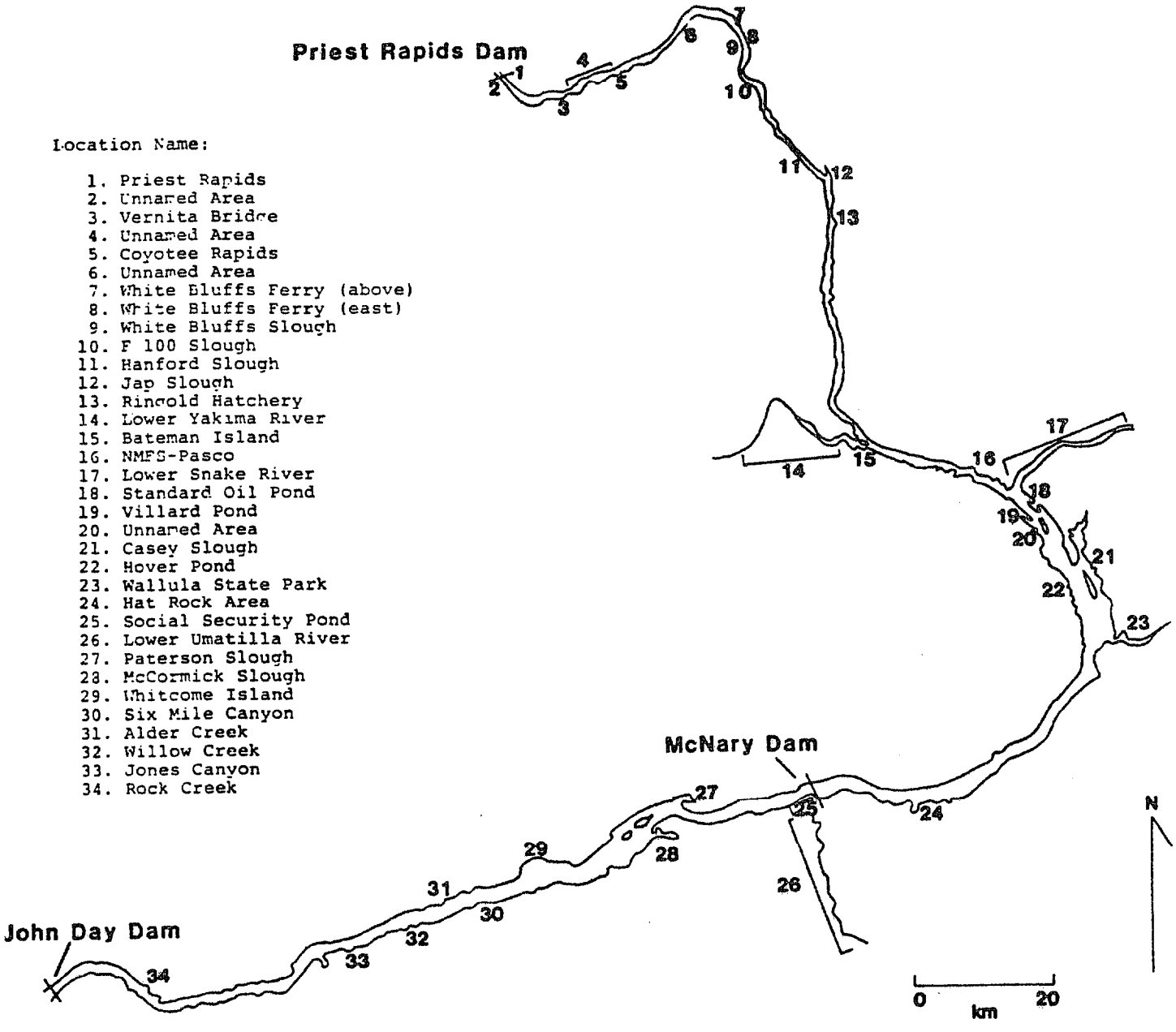


Figure 1. Columbia River basin from John Day Dam to Priest Rapids Dam indicating areas considered for pen rearing studies.

The purpose for choosing these initial criteria were:

Depth - Minimum required depth for maintaining pens was established at 6.1 m to insure proper bottom clearance and effective water movement around and through enclosures. Therefore, all sites not at least 6.1 m deep at minimum water level were considered unacceptable.

Area - Sites observed were limited to those regarded to be of sufficient size to construct a series of net-pen enclosures which will cover about .03 ha.

Access - Once fish are placed into the enclosures, it will be necessary to closely monitor and provide care for them until release. Suitable access for construction and installation of rearing enclosures is also essential.

Water temperature and level fluctuations - Excessive temperature fluctuations are unacceptable because of the inability of fish in enclosures to escape undesirable temperatures. Water level fluctuations would hamper placement and maintenance of enclosures.

Public use - Vandalism and curious observers could disrupt experiments, thus heavily used sites were of low priority.

Water quality problems - Water quality concerns primarily included potential low dissolved oxygen concentrations and watershed drainage into backwaters. Confining fish in enclosures for the intended studies will prohibit them from avoiding unacceptable water quality conditions by emigrating into a more desirable zone.

Sites judged to meet the minimum qualifications were evaluated in more detail. Final criteria for site selection were uniqueness of water

source, feasibility of adult capture, proximity to natural spawning areas, water quality, benthic and zooplankton estimates and more detailed physical profiles. Biological data and water chemistry characteristics were not emphasized because sampling occurred in July-September, rather than during the proposed spring rearing period. Reasons for establishing these final criteria were:

Water source - As juveniles the fish adapt to distinct ambient odors in their surroundings. When they return as adu lts they seek out the odors to which they were exposed during their stay in respective natal streams or other points of origin.

Study results will be partially evaluated on the basis of returning adults; hence, imprinting fish to unique water odors and luring them back to the sites from where they are released was a primary concern addressed in choosing final study sites. Finding a water source with unique characteristics was preferable over the introduction of artificial odors because of uncertainties in the success and implementatin of using an artificial imprinting medium such as morpholine.

Adult capture - In order to fully evaluate the success of the study it will be necessary to capture returning adults. Feasibility and construction of efficient capture facilities was evaluated at each of the study sites.

Proximity to natural spawning areas - Returning adults not captured could spawn in natural areas within relatively close proximity to study sites if suitable habitats were available.

Water quality - A thorough water quality profile of each study site was obtained in order that those areas with obscure water quality problems could be eliminated.

Benthic and zooplankton estimates - The composition of the natural food supply and relative densities were determined in order that the numbers of available prey could be compared among sites.

Physical profiles - Depth and contour maps were prepared from detailed depth and measurement observations at each sample site. Bottom contour and water volume will be important in final placement of study enclosures.

Water quality parameters, including dissolved oxygen, pH, conductivity, and temperature were recorded (at two-week intervals where possible) using a multi-parameter water analyzer; during part of the study an oxygen-temperature meter, a conductivity meter, and a pH meter were used. A thorough water quality analysis obtained once included: alkalinity, hardness, nitrate and nitrite, ammonia, orthophosphate, sulfate, cadmium, chloride, calcium, cobalt, lead, magnesium, molybdenum, sodium, sulfide, and total and dissolved copper, iron, manganese, and zinc. Samples were collected, preserved, and shipped to a commercial testing laboratory for analysis. sechi disk transparencies were recorded on each sample date.

Two replicate zooplankton tows were taken twice during the study at those sites satisfying final criteria (except Rock Creek, which was sampled only once). Tows were made using a metered high speed Miller sampler with a 153 um mesh net. The sampler was towed from near bottom to surface in an oblique fashion. Three replicate benthos samples were taken once at each site using a mini-Ponar dredge (sample area 0.023 m^2) and

were sieved through a 600 um mesh screen. Samples were preserved in 10% formalin and returned to the laboratory where benthic organisms were identified and enumerated to the lowest practicable taxon.

Results

Thirty-four sites along the Columbia River from Priest Rapids Dam to John Day Dam, including the lower Umatilla, Yakima, and Snake rivers, were considered as possible sites for pen rearing (Table 1 and Appendix Tables A, B, and C). Maximum depths at these sites ranged from 0.9 m to over 12.0 m and surface areas from 0.1 to about 260 ha. Depths of less than 6.1 m at low water were found in the majority of the backwaters. Although surface area was not a critical element in the selection process, areas extremely small or large were considered less desirable than others. Access to all sites surveyed was variable but generally adequate for the study. Potential temperature and water level fluctuations in the reach from Priest Rapids to the headwaters of McNary reservoir (about river km 522) made sites located along this stretch less desirable than other areas based on backwater exposure, location and susceptiblility to discharge variations. No suitable sites off the main channel, and protected from the main current, were found in the lower reaches of the Umatilla and Yakima rivers. Lower reaches of both rivers were characterized by shallow depths, unstable bottoms and potential, unacceptable water 1 eve1 and temperature fluctuations.

Table 1. Name, location, and summary of intial selection criteria for all areas considered during reconnaissance survey. (River mile in parentheses)

Name	Location (river km)	Max. Depth[1] (m)	Surface Area (ha)	Access	Stability (temp & water level)
Rock Creek	367 (228)	12.8	22.7	Excellent	Good
Jones Canyon	386 (240)	4.9	2.0	Good	Good
Willow Creek	397 (252)	9.4	78.1	Good	Excellent
Alder Creek	416 (258)	2.4	14.7	Good	Good
Six Mile Canyon	418 (260)	-	1.2	Good	Good
Whitcomb Island	430 (267)	4.6	55.1	Good	Good
McCormick Slough	441 (274)	3.6	261.3	Good	Good
Paterson Slough	447 (287)	2.7	7.8	Good	Good
Lower Umatilla River (lower 48 km)	462 (289)	(backwaters shallow and unstable)			
Social Security Pond	468 (291)	6.7	7.0	Good	Excellent
McNary Ponds	468 (291)	<6.1	5.0	Good	Excellent
Hat Rock area	479 (298)	0.9	10.2	Excellent	Good
Wallula State Park	505 (314)	0.9	45.5	Good	Good
Hover Pond	510 (317)	3.3	8.8	Good	Fair
Casey Slough	512 (318)	4.6	156.5	Good	Good
Unnamed area	515 (320)	<6.1	71.4	Poor	Fair
Villard Pond	520 (323)	5.5[2]	11.0	Good	Good
Standard Oil Pond	520 (323)		-	Excellent	Good
Lower Snake River (Ice Harbor to mouth)	522 (324)	(backwaters all extremely shallow - no ponds)			
NMFS - Pasco	524 (326)	(raceways)			
Bateman Island	538 (335)	-	5.8	Excellent	Fair
Lower Yakima River (Benton City to mouth)	539 (335)	(backwaters all small and unstable - no ponds)			
Ringold Hatchery	571 (355)	(hatchery ponds and raceways)			
Jap Slough	573 (356)	9.1	4.5	Fair	Fair
Hanford Slough	584 (363)	7.0	17.7	Good	Fair
F100 Slough	590 (367)	3.0	1.6-18.2	Poor	Poor
White Bluffs Slough	595 (370)	3.7	4.9	Excellent	Poor
White Bluffs Ferry (east)	595 (370)	3.0	1.5	Good	Poor
White Bluffs ferry (above)	596 (370)	4.0	1.9	Good	Poor
Unnamed area	603 (375)	<6.1	19.6	Good	Poor
Coyote Rapids	616 (383)	2.3	0.2	Good	Poor
Vernita Bridge	626 (389)	<6.1	0.1	Good	Poor
Unnamed area	636 (396)	2.4	5.3	Good	Poor
Priest Rapids	639 (397)	2.1	38.2	Good	Good

[1] Depths at time of sampling unless otherwise noted
[2] Maximum depth at minimum pool

Twenty-six of the original sites surveyed were eliminated after comparison with the intial criteria of depth, surface area, access, public use, and stability. Sites were eliminated primarily because of inadequate depth or potentially high instability. The remaining eight sites selected for additional evaluation included: Rock Creek (river km 367), Jones Canyon (river km 386), Willow Creek (river km 397), Paterson Slough (river km 447), Social Security Pond (river km 468), Villard Pond (river km 520), Jap Slough (river km 573), and Hanford Slough (river km 584). These sites conformed most closely to the final criteria established for pen-rearing studies. Depths ranged from 6.1 to 12.8 m and surface areas from 2.0 to 78.1 ha; access was adequate for all, while potential stability ranged from fair at Hanford and Jap sloughs to good or excellent in other areas.

One of the primary concerns in selecting final study sites was the presence of a unique water source to facilitate imprinting fish for their subsequent return as adults. Rock Creek, Willow Creek, Social Security Pond, and Jap Slough were the only sites receiving flow from "unique" sources--Rock and Willow creeks from respective drainage creeks, Social Security Pond from effluent water flowing out of a series of upstream ponds, and Jap Slough from suspected subterranean irrigation return flows. Water source for Jones Canyon, Paterson Slough, Villard Pond, and Hanford Slough was the Columbia River.

Water quality parameters were generally within normal levels in the eight sites (Table 2). Rock Creek, Jones Canyon, Willow Creek, Social Security Pond, and Hanford Slough had no unusually high or low levels of any of the 23 parameters tested, and no concentrations were above those

Table 2. Water quality information obtained at primary study sites, 1983. (All units in mg/l; sample dates in parentheses)

PARAMETER	Rock Creek (10-17)	Jones Canyon (8-5)	Willow Creek (8-5)	Paterson Slough (9-6)	Social Security Pond (8-4)	Villard Pond (9-7)	Jap Slough (8-4)	Hanford Slough (8-3)
Alkalinity (as $CaCO_3$)	73	58	58	70	52	67	130	58
Hardness (as $CaCO_3$)	74	68	72	82	60	72	180	64
Nitrate & Nitrite (as N)	.08	.11	.07	1.50	.24	.38	.92	.05
Ammonia (total)	.06	.21	.06	.37*	.08	.23*	1.10*	.08
Ortho Phosphate (as P)	.052	.043	.016	.025	<.005	.020	<.005	<.005
Sulfate (as SO_4)	12	3	3	13	8	15	75	2
Cadmium	<.002	<.002	<.002	<.002	<.002	<.002	<.002	<.002
Chloride	3	4	2	2	2	2	11	<1.0
Calcium	19	16	16	20	14	18	40	15
Cobalt	<.01	<.05	<.05	<.02	<.05	<.02	<.05	<.05
Copper (total)	.013	.01	.009	.005	<.005	<.005	<.005	<.005
Copper (dissolved)	<.005	<.005	<.005	.005	<.005	<.005	<.005	<.005
Iron (total	.48	.38	.40	.35	.20	.30	.15	.25
Iron (dissolved)	.31	.05	.12	<.05	<.05	<.05	<.05	<.05
Lead	<.01	<.005	<.005	<.005	<.005	<.005	<.005	<.005
Magnesium	6.0	4.2	4.2	5.1	4.0	5.1	13	3.8
Manganese (total)	.06	.06	.03	.12	.04	.03	1.10	.02
Manganese (dissolved)	<.01	<.01	.01	.02	<.01	.01	<.01	<.01
Molybdenum	<.10	<.10	<.10	<.10	<.10	<.10	<.10	<.10
Sodium	7.0	4.3	4.1	5.0	4.8	6.0	23	2.1
Zinc (total)	.01	.26	.03	.09	.05	.08	.02	.18
Zinc (dissolved)	<.01	.04	.03	<.01	.05	.01	.02	.18
Sulfide	<.02	<.10	<.10	<.02	<.10	<.02	.30	<.10

* Concentrations of un-ionized ammonia were above 0.02 mg/l which is the lowest acceptable level for freshwater aquatic life. These concentrations are variable and are affected by pH and water temperature (U.S. Environmental Protection Agency 1976).

known to be toxic to freshwater organisms (U. S. Environmental Protection Agency 1976). However, in Villard Pond and Paterson and Jap sloughs, relatively high concentrations of un-ionized ammonia were detected. In addition, at Jap Slough alkalinity, hardness, nitrate-nitrite, sulfate, calcium, magnesium, manganese, sodium, and sulfide concentrations were high in comparison to other sites; nitrate-nitrite levels were highest in Paterson Slough.

Near surface concentrations of dissolved oxygen ranged from 8.4 to 12.0 mg/l in the eight study sites (Table 3 and Appendix Table B). Bottom concentrations at several of the sites, however, fell undesirably low (below 5.0 mg/l), and occasionally, in late summer were below 1.0 mg/l - - - lethal to fish during prolonged exposure (Boyd 1979). Those areas where dissolved oxygen concentrations near bottom reached either undesirable or lethal levels (to fish) included Rock Creek, Social Security Pond, and Jap Slough. Temperatures varied seasonally, with higher readings near surface (Table 3 and Appendix Table B). Temperatures rarely exceeded 20°C, except for readings taken in late July and August.

The pH levels ranged from 7.3 to 9.0, within the most desirable range (6.5 - 9.0) for fish (Boyd 1981) (Table 3 and Appendix Table B). Conductivity ranged from 124 to 192 umhos/cm at all sites except Jap Slough where levels were higher, ranging from 220 to 695 umhos/cm. Secchi disk readings were between 66 and 185 cm at sample sites from Villard Pond downstream.

The potential natural fish food supply, which will act as a supplement to commercial food in subsequent rearing studies will include zooplankton,

Table 3. Ranges of parameter values taken at primary study sites.

PARAMETER	Rock Creek	Jones Canyon	Willow Creek	Paterson Slough	Social Security Pond	Villard Pond	Jap Slough	Hanford Slough
Dissolved oxygen-surface (mg/1)	9.5-11.6	9.0-11.9	8.4-10.2	9.2-11.6	8.5-11.8	11.2-12.0	9.0-10.6	10.0-11.7
Dissolved oxygen-bottom (mg/1)	0.5-11.2	3.8-11.0	7.5-10.0	5.6-11.2	3.1-11.1	9.9-10.3	O-2-6.8	10.0-12.4
Temperature-surface (°C)	8.7-23.5	13-21-7	13.2-21.1	15-19.7	10.8-25.0	10.8-19.5	14.8-24.3	14.0-21.0
Temperature-bottom (°C)	4-16	13-O-20.3	13-20.3	13-18	10.8-19,2	10.8-16.8	13-16.6	14.0-19.1
PH	8.0*	7.9-8.7	7.4-8.5	8.4-8.6	7.9-8.4	8.6-9.0	7.8-8.5	7.3-8.6
Conductivity (pmhos/cm)	185"	151-184	151-194	168-182	176-200	175-275	220-695	124-141
Secchi disk (cm)	66-185	155-163	81-137	89-96	107-140	89-137	165-234	196-318

* No other data available

benthos, and terrestrial insects as drift. Zooplankton densities are usually quite variable, depending on fish predation and a host of environmental factors, including nutrients, water quality, and water temperature (Hutchinson 1967).

Microcrustacean zooplankton densities were highest in Paterson and Jap sloughs, Jones Canyon, and Social Security Pond, intermediate at Rock and Willow creeks, and lowest at Villard Pond and Hanford Slough (Table 4). Taxonomic composition and distribution of the zooplankton varied among sample sites, but Rosmina, Daphnia, Cyclopoida, and Calanoida were commonly most abundant with Chydorus, Diaphanosoma, Leptodora, Ceriodaphnia, and Alona, rarely collected.

Benthos populations were mostly composed of smaller bodied organisms. Populations were much higher in Villard Pond than at any of the other sites; relatively high densities were also taken in Hanford Slough, Rock Creek, Jones Canyon, Social Security Pond, and Willow Creek (Table 5). Low densities were encountered at Paterson and Jap sloughs. Oligochaeta was the most abundant taxon collected from all sites; Chironomidae was the only other taxon commonly collected. Nematoda and Amphipoda were found in relatively high numbers in some areas. Other taxa collected included Chaoborus (Social Security Pond), Hexagenia (Villard Pond), Polychaeta (Jones Canyon), and Musculium (Jap Slough).

Table 4. Number per liter of microcrustacean zooplankton collected at primary study sites, 1983. (Sample dates in parentheses)

TAXON	Rock Creek (10-17)	Jones Canyon (8-5)	Jones Canyon (9-22)	Willow Creek (8-5)	Willow Creek (9-22)	Paterson Slough (9-6)	Paterson Slough (9-21)	Social Security Pond (8-4)	Social Security Pond (9-22)	Villard Pond (9-7)	Villard Pond (9-20)	Jap Slough (8-3)	Jap Slough (9-19)	Hanford Slough (8-3)	Hanford Slough (9-19)
Cyclopoida	4.5	25.2	24.1	1.9	13.5	122.1	37.8	26.8	10.0	3.3	1.9	58.4	33.4	1.3	0.2
Calanoida	0.2	0.1	1.0	0.4	0.4	26.6	0.2	12.7	43.5	1.4	1.0	2.2	40.4	0.2	T
Daphnia	4.8	80.3	49.0	56.3	9.2	0.0	13.6	131.4	9.5	12.4	6.6	28.2	41.2	T	T
Bosmina	61.9	4.8	25.1	T	1.9	13.4	339.4	0.0	0.2	0.1	1.5	2.5	3.8	3.0	3.0
Chydorus	0.0	0.0	0.4	0.0	0.0	3.6	11.0	0.0	0.0	0.0	0.1	0.4	0.0	T	0.0
Diaphanosoma	0.0	0.0	0.3	0.2	0.0	0.0	0.0	0.7	8.2	0.0	0.1	21.0	5.8	T	0.1
Leptodora	0.0	0.7	0.0	0.2	T	0.2	0.2	0.0	0.4	T	T	0.1	0.1	0.0	T
Ceriodaphnia	0.0	0.0	0.6	0.0	0.0	0.4	0.8	0.0	0.0	0.2	0.0	0.9	0.9	0.1	0.1
Alona	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	T	0.1	0.0	0.0	T	0.0
Total No.	71.7	111.1	100.5	59.0	25.0	166.3	403.0	171.6	71.8	17.4	11.3	113.7	125.6	4.6	3.4

Table 5. Number per square meter of benthic organisms collected from primary sampling sites, 1983. (Sample dates in parentheses)

TAXON	Rock Creek (10-17)	Jones Canyon (8-5)	Willow Creek (8-5)	Paterson Slough (9-6)	Social Security Pond (8-4)	Villard Pond (9-7)	Jap Slough (8-3)	Hanford Slough (8-3)
Oligochaeta	4,045	3,879	2,672	732	2,888	12,012	1,724	6,983
Chironomidae	**861**	345	345	258	215	1,679	56	129
Nematoda	**0**	56	43	0	216	0	0	0
Chaoborus	**0**	**0**	**0**	**0**	13	0	0	0
Hexagenia	**0**	**0**	**0**	**0**	**0**	43	0	0
Amphipoda	**0**	**0**	**0**	**0**	**0**	**1,765**	**0**	**0**
Polychaeta	**0**	43	0	0	0	0	0	0
Musculium	0	**0**	**0**	**0**	**0**	**0**	**13**	**0**
Total No./m^2	**4,906**	4,323	3,060	990	3,332	15,499	1,793	7,112

DISCUSSION

The number of sites found suitable for experimental rearing of age-0 fall chinook salmon was small compared to the total number surveyed. The eight primary study sites, selected from 34 original sites, were ranked in order of how closely they met the final criteria considered essential for successful backwater and pond rearing studies. Positive and negative aspects of each site were considered based on their suitability as study sites and not strictly on their potential as management production areas. Physical features were emphasized and were the dominant criteria in final ranking of study sites since biological and chemical parameters were not determined during the season of the year when rearing will occur.

1. Rock Creek

Positive Aspects - Rock Creek has adequate depth and surface area for construction of pen and blockseine enclosures. Temperature fluctuations would probably not be extreme, especially during April and May, because the site is relatively protected and flow surges from the Columbia River are minimal. Water level fluctuations would be primarily associated with operations of John Day Dam; fluctuations of 0.3 - 1 m are common, but since the site is quite deep the enclosures should not be affected if properly located.

Water quality, and benthos and zooplankton densities at this site were acceptable with one exception--low dissolved oxygen concentrations were recorded near bottom in July 1979 (U.S. Fish & Wildlife 1980). Brief

periods of low oxygen levels can be expected near bottom in most backwaters during warm months. However, the present study proposes to release fish prior to the summer period when oxygen conditions may become limiting. In addition, extension of pens to within only 3 m of the bottom should minimize any effects of low dissolved oxygen concentrations near bottom.

Rock Creek proper provides a unique water source for imprinting and there is evidence that fall chinook adults have returned to use the stream as a natural spawning area (Personal observation, fall 1983). Traps could be easily installed near the water source for adult capture.

Negative Aspects - The primary disadvantage for using this site may be the potential for vandalism. Other fishery workers have indicated that vandals have been a major problem in Rock Creek, and because of the isolated location, few patrols are made through the area by local law enforcement officials.

Other natural spawning areas are not apparent within several miles of Rock Creek. In dry years natural low flows from Rock Creek may limit its use for natural spawning.

Summary - Rock Creek backwater has a unique water source, satisfies desired depth requirements, and is relatively protected, facilitating construction of blockseine and adult capture facilities. The water source, Rock Creek, could act as a natural spawning area for adult returns. Vandals can be discouraged by requesting routine patrols, proper placement of enclosures, and signs explaining the project.

2. Social Security Pond

Positive Aspects - Social Security Pond is the last in a series of small recreation ponds located below McNary Dam. The water source is from the ponds above, making it unique for imprinting. Flow through the pond is relatively constant and water levels do not fluctuate. Depth, surface area, water quality, and biological samples were all adequate for rearing studies. Vandalism should be minimal because the area is routinely patrolled. Smolt release and adult trapping should be relatively easy and this location was the only site surveyed which resembled a usable acclimation pond.

Negative Aspects - Flow through the pond may not be adequate to exchange water in and near the pens. The combination of low water exchange and build-up of excess food and waste may result in lower dissolved oxygen concentrations than desired.

Summary - Social Security Pond is an appropriate site for rearing studies because of its location adjacent to the river, stability, size, and unique source of water.

3. Willow Creek

Positive Aspects - Willow Creek is a large, open backwater area providing a number of locations for pen and blockseine enclosures. Water quality and biological data were acceptable, and no risk to pen rearing studies was evident. Vandalism may be reduced in this area because the study location could be placed where it would be highly visible from

Interstate 84. Willow Creek, flowing into the upstream end of the backwater, would provide a unique water source for imprinting.

Negative Aspects - Seasonally low flows from Willow Creek in September and October may not be adequate for imprinting or for attracting returning adults. Adult capture would be difficult because of the large size of the backwater. The area may be unprotected from winds because of the size and configuration of the embayment.

Summary - Willow Creek has acceptable physical features and there were no indications of inadequacies in water quality or biological samples. This area could be used if one of the other sites were found unusable due to unforsee problems.

4. Hanford Slough

Positive Aspects - Physical features, water quality, and location of the Hanford Slough were ideal; additionally, this location is in the vicinity of natural spawning sites in the Columbia River. Construction and placement of adult traps and a blockseine enclosure would be relatively simple.

Negative Aspects - The area is subject to severe water level and temperature fluctuations because of its proximity to the main flow of the river. Daily water level elevation changes of 2 m and temperature fluctuations of 9°C have been observed (personal communication, Duane Neitzel, Battelle Northwest Laboratories). During high water elevations, flows from the upstream end result in extreme velocities which could

disrupt rearing enclosures. The water source is not unique since it is an extension of the Columbia River. Zooplankton densities were the lowest observed at any primary site, probably a reflection of densities in the river proper.

Summary Hanford Slough is a desirable location because of its physical features, restricted public access, and proximity to natural spawning areas. However, water level fluctuations and flow through the backwater could make feasibility of holding enclosures in this backwater impossible and may alter water temperatures unacceptably. The water source is not unique, thus an organic chemical for imprinting would be required.

5. Villard Pond

Positive Aspects - Portions of this backwater have suitable depth and surface area; water quality and biological samples were also acceptable; benthos densities were highest in this area.

Negative Aspects - Access may be limited during certain periods. There was no apparent source of unique water; water exchange was dependent on back flow from the Columbia River. Gravel and mud flats less than 0.4 m deep extend from the mouth to 300-400 m into the river making it difficult for adults to return. Un-ionized ammonia concentrations were relatively high.

Summary Certain areas in this backwater may be usable for these studies, however, the lack of a unique water source, existance of an extensive mud flat into the river from the mouth of the backwater, and

presence of somewhat questionable water quality standards in August precluded the use of this area for rearing studies.

6. Paterson Slough

Positive Aspects - This area was large, access good, most water quality parameters acceptable, and biological densities adequate.

Negative Aspects - Most of this backwater was too shallow; the areas where depths were adequate (over 6.1 m) were isolated. This would force returning adults to negotiate very shallow conditions, making their return difficult. There was no apparent source of unique water for imprinting. Relatively high un-ionzed ammonia concentrations were regarded as sublethal, however, normal growth and development could be affected (Boyd 1979).

Summary - Depth of this backwater was too shallow and variable for these studies; no unique water source was found.

7. Jones Canyon

Positive Aspects - Jones Canyon is a relatively small backwater with adequate depth and acceptable water quality and biological profiles. The area is subject to reservoir fluctuations, but with proper placement enclosures should not be affected. Access to the reservoir from the backwater is through a short railroad bridge which would facilitate construction of adult capture nets.

Negative Aspects - There was not a unique water source flowing into Jones Canyon. Inflows come from intermittent precipitation runoff during heavy rains. This area receives heavy public use and vandalism may be high.

Summary - Jones Canyon does not appear to have adequate water exchange, nor does it have a source of unique water.

8. Jap Slough

Positive Aspects - This location was relatively isolated and of proper depth and surface area. There appeared to be good potential for natural spawning along this stretch of the Columbia River.

Negative Aspects - Water quality in Jap Slough appeared to be adversely influenced by subterranean irrigation return flows from the east bank of the river. In addition, consistently low dissolved oxygen concentrations indicated that the area would probably not support rearing pens stocked with fish.

Flow from the Columbia River would enter the backwater from upstream at high discharge but isolation from the river would result during low discharges. Water temperatures may also be influenced by sudden inflows into the backwater which could influence ambient temperatures considerably. The use of Jap Slough for this study was of concern to the Washington Department of Fisheries because of its close proximity to Ringold Springs Hatchery.

Summary - Jap Slough was considered least acceptable of a 11 primary sites primarily because of poor water quality and water level instability.

CONCLUSION

The study will be conducted in Rock Creek and Social Security Pond, the two locations ranked highest based on selected criteria. These sites were considered the best available for adequately harboring net-pen and/or blockseine enclosures, without costly modification. The areas are accessible for routine care and monitoring of the fish, both have acceptable water quality and natural food supplement and unique water sources, and, both are in the vicinity of natural spawning areas. Willow Creek and Hanford Slough were also considered usable, but are less desirable for the intended studies because of certain physical limitations.

REFERENCES

Boyd, C.E. 1979. Water Quality in Warmwater Fish Ponds. Craftmaster Printers, Inc., Opelika, Ala. 359 pp.

Hutchinson, G.E. 1967. A Treatise on Limnology II. Introduction to Lake Biology and the Limnoplankton. John Wiley and Sons, New York. 1115 pp.

U.S. Environmental Protection Agency. 1976. Quality Criteria for Water. Washington, D.C. 256 pp.

U.S. Fish and Wildlife Service. 1980. Columbia River Backwater Study: Phase One. Fisheries Assistance Office, Vancouver, WA.

Appendix A. Backwaters considered for rearing age-0 fall chinook, but regarded as unacceptable based on initial survey criteria.

1.	Location:	Priest Rapids Dam, east bank, upper pond and lower pond, river km 639
	Depth:	Max. 2.1 m, average 1.5 m
	Comments:	Ponds are fairly stable but too shallow. Access, good; water source, spring.
2.	Location:	River km 636, west bank
	Depth:	Max. 2.4 m
	Comments:	This backwater was too shallow for our purposes. Subject to water level and temperature fluctuations. Access, good.
3.	Location:	One mile above Vernita Bridge, river km 626, west bank
	Comments:	This pond may be exposed to currents at high water; may be suitable as a temporary acclimation pond. Too shallow. Access, good; water source, backwater.
4.	Name:	Coyote Rapids
	Location:	River km 616, west bank
	Depth:	Max. 2.3 m, average 1.8 m
	Comments:	Dimensions 30.5 m x 61.0 m, too shallow for our purposes. At high flows water may flow through this backwater at high velocities - unstable. Access, good; water source, backwater.

5.	Location:	River km 603
	Comments:	Too shallow; access, good; water source, backwater.
6.	Location:	Above White Bluffs Ferry, river km 596, east bank
	Depth:	Max. 4.0 m, average 1.8 m
	Comments:	While this backwater may be large enough there was an irrigation return which may cause problems. Conductivity exceeded 650 micromhos/cm. High flows may also connect this backwater to the backwater below to form a slough. Access, good; water source, backwater.
7.	Name:	White Bluffs Ferry
	Location:	River km 595, east bank
	Depth:	Max. 3.3 m at mouth
	Comments:	This backwater was too Shallow and conductivity was too high, (an irrigation canal drains into this area). Access, good.

8. Name: White Bluffs Slough

Location: River km 595, west bank

Depth: Max. 3.7 m

Water Quality: D.O. Surface (mg/l) - 12.6
D.O. Bottom (mg/l) - 14.6
PH - 8.18
Cond. (micromhos/cm) - 122

Temperature surface - 17.0
Temperature bottom - 15.0

Comments: This backwater was too shallow. Additional water quality obtained from Battelle Northwest, Richland: Minimum water temperature, 9°C (5-30-79); maximum water temperature, 30°C (6-27-79); 7°C fluctuation in water temperature in one day; 2m fluctuation in water level in one day. Access, excellent; water source, backwater.

9. Location: FlOO Slough, river km 590 (west bank)

Depth: Max. 3.0 m, average 2.75 m

Comments: This slough has potentially high "flow through" at high river flows. Deeper parts of the slough become isolated (no connection to the river) during low flows. Water was high when soundings were taken - too shallow. Access, poor.

Appendix A. (Continued)

10.	Location:	Ringold Springs Hatchery, river km 571
	Comments:	The Washington Departments of Fish and Game have rearing facilities here. They would be utilizing their ponds for rearing steelhead during the times that we would need space. Their spring chinook pond was normally dry April through June to kill snails which are eye fluke hosts.
11.	Location:	Lower Yakima River, Benton City to the mouth (including mouth area), river km 539.
	Comments:	We found no suitable sites in this area. Backwaters were either too small or too shallow and unstable; water temperature and level fluctuations could be excessive.
12.	Location:	Upriver and downriver sides of Bateman Island, river km 538, west bank
	Comments:	While this area has adequate depth, public use was very high and potential vandalism eliminated this as a study site.
13.	Location:	National Marine Fisheries Service, Pasco (raceways), river km 524
	Comments:	Too controlled; too similar to hatchery conditions.

14.	Location:	Ice Harbor Dam (Snake River) down to the railroad bridge (below the mouth of the Snake River) in the Columbia River, river km 522.
	Comments:	All backwater locations in this area were too shallow.
15.	Name:	Standard Oil Backwater
	Location:	River km 520, west bank
	Comments:	Very high public use. Potential vandalism was the major concern which eliminated this backwater.
16.	Location:	Backwater at river km 515 (west bank)
	Depth:	Max. <6.1 m
	Comments:	This backwater was connected to the river by only a subsurface culvert.
17.	Name:	Casey Slough
	Location:	River km 512, east bank
	Depth:	Max. 5.5 m
	Comments:	While this backwater was big enough, depth would be marginal at minimum pool and areas with adequate depth may be subject to high winds (ie., fetch was 8+ km) coming from south. Depths from the boat ramp to deeper areas are not adequate for normal outboard operation, public access areas are "ok".

18.	Name:	Hover Pond
	Location:	River km 510 (west bank)
	Depth:	Max. 3.4 m
	Comments:	Too shallow
19.	Location:	Mouth of Walla Walla River (large backwater above highway bridge), river km 505.
	Depth:	Max. 0.9 m
	Comments:	Too shallow
20.	Location:	Hat Rock area, river km 479
	Depth:	>6.1 m
	Comments:	Backwaters in this area were too shallow and have heavy public use.
21.	Location:	McNar Ponds, recreation area and rearing ponds, river km 468.
	Comments:	Only one pond above the one we have been sampling regularly has suitable depths. None of the ponds (other than the one described separately) has direct outflow to the Columbia River. Access, good.

22.	Location:	Lower Umatilla River, river km 462.
	Comments:	We looked at the lower river below Stanfield and found nothing suitable. Topographic maps also revealed nothing suitable in the lower 30 miles. Jim Phelps, the Oregon Dept. of Fish and Wildlife district fisheries biologist, knew of no suitable locations in this area.
23.	Name:	McCormick Slough
	Location:	River km 441, Washington side
	Depth:	Max. 4.6 m
	Comments:	Too shallow
24.	Name:	Whitcomb Island
	Location:	River km 430
	Depth:	Max. 3.3 m
	Comments:	Too shallow
25.	Name:	Six Mile Canyon
	Location:	River km 418
	Depth:	<6.1 m
	Comments:	Culvert opening not adequate

Appendix A. (Continued)

26.	Name:	Alder Creek
	Location:	River km 416, Washington side
	Depth:	<6.1 m
	Comments:	Too shallow

Appendix B. Profiles of primary study sites.

1. Name: Rock Creek

   Location: River km 367, Washington side

   Depth: Max. 12.8 m

   Access: Excellent (boat dock)

   Water Source: Rock Creek - estimated flows of 0.57 m^2/s present in October; higher flows would be expected during most other periods of the year. (Underground flow suspected when creek has no visible flow.)

   Surface Area: 22.7 ha

   Comments: Rock Creek appears to provide a reliable year-round unique water source and adult capture should be relatively easy. This area may be best suited for a blockseine. There could be vandalism problems here. Adult fall chinook were observed in the creek proper during September 1983.

	SAMPLE DATE			
	3-7-79	5-l-79	7-18-79	10-17-83
D.O. Surface (mg/l)	11.6	11.2	9.5	10.8
D.O. Bottom (mg/l)	11.2	10.4	0.5	10.0
Temp. Surface (°C)	8.7	13.0	23.5	11.5
Temp. Bottom (°C)	4.0	9.5	16.0	11.0
PH	---	--	--	8.0
Cond. (micromhos/cm)	---	---	---	185
Secchi Disk (cm)	66	96	112	185

2. Name: Jones Canyon

Location: River km 386, Oregon side

Depth: Max. 7.3 m

Access: Good

Water Source: Intermittent runoff

Surface Area: 2.0 ha

Comments: D.O. was relatively low at the bottom on August 5. Historical water quality data indicate no problems. This area gets some public use and may be subject to vandalism.

	SAMPLE DATE				
	8-5	8-25	9-6	9-22	10-6
D.O. Surface (mg/l)	10.9	9.0	9.2	10.4	11.9
D.O. Bottom (mg/l)	3.8	7.6	8.2	10.5	11.0
Temp. Surface (°C)	21.7	18.6	18.0	15.0	13.0
Temp. Bottom (°C)	20.3	17.6	17.2	14.0	13.0
PH	7.9	8.3	8.4	8.4	8.7
Cond. (micromhos/cm)	151	153	158	175	184
Secchi Disk (cm)	---	157	157	155	163

Appendix B. (Continued)

3. Name: Willow Creek

Location: River km 397, Oregon side

Depth: 119 m max., 7.6 m in good pen area

Access: Good (boat ramp)

Water Source: Willow Creek (low flows of <0.06 m^3/s in September and October may not be high enough to accoodate adult recapture)

Surface Area: 78.1 ha

Comments: Additonal data taken in past years was consistant with our survey and indicates no water quality or physical problems. Appears well suited for our needs.

	SAMPLE DATE				
	8-5	8-25	9-6	9-22	10-6
D.O. Surface (mg/l)	9.4	8.8	8.4	10.2	9.5
D.O. Bottom (mg/l)	7.5	8.1	8.3	10.0	8.6
Temp. Surface (°C)	21.1	19.0	17.7	14.8	13.2
Temp. Bottom (°C)	20.3	18.0	17.3	13.8	13.0
PH	7.4	8.0	7.7	8.3	8.5
Cond. (micromhos/cm)	151	153	158	175	194
Secchi Disk (cm)	137	89	86	107	81

4. Name: Paterson Slough

Location: River km 447, Washington side

Depth: Max, 7.9 m

Access: Good road access.

Water Source: None

Surface Area: 7.9 ha in pen-rearing area

Comments: This backwater is large and has adequate depth in some areas. The primary problem with this location is that the most suitable rearing zone is a long distance from the mouth, across deep and shallow areas. Adults may have difficulty returning to the area.

	SAMPLE DATE 8-25	9-6	9-21
D.O. Surface (mg/l)	9.2	10.8	11.6
D.O. Bottom (mg/l)	5.6	5.8	11.2
Temp. Surface (°C)	19.7	19.3	15.0
Temp. Bottom (°C)	18.0	17.0	13.0
PH	8.4	8.6	8.6
Cond. (micromhos/cm)	168	171	182
Secchi Disk (cm)	96	---	89

5. Name: Social Security Pond (McNary Pond)

Location: River km 468, immediately below McNary Dam, Oregon side

Depth: Max. 6.1 m, area average approximately 5.1 m

Access: Good

Water Source: Constant flow through this pond is fed from pipe flowing from series of ponds above and through a controlled outlet. Outflow through two overflow culverts.

Surface Area: 7.0 ha

Comments: Boats are allowed on the pond without motors, but usage is minimal. The pond is stocked with catchable trout throughout the spring and summer and supports a moderate trout and panfish fishery. There may be a potential low D.O. problem. Vandalism should not be a problem. It does not appear that construction of a second powerhouse will interfere with our studies.

	SAMPLE DATE				
	8-5	8-25	9-6	9-22	10-19
D.O. Surface (mg/l)	9.7	8.5	9.0	10.3	11.8
D.O. Bottom (mg/l)	3.1	7.6	8.9	10.5	11.1
Temp. Surface (°C)	25.0	21.8	18.0	14.0	10.8
Temp. Bottom (°C)	17.0	19.2	18.0	14.0	10.8
PH	---	7.9	8.2	8.4	8.4
Cond. (micromhos/cm)	---	180	176	192	200
Secchi Disk (cm)	---	140	107	132	127

6. Name: Villard Pond

Location: River km 520, backwater on Columbia River (just below Snake River mouth) below railroad bridge on east side of the Columbia River

Depth: Max. 7.9 m

Access: Good railroad road, Road access may be controlled and unavailable.

Water Source: Backwater

Surface Area: 11.0 ha

Comments: There are gravel and mud flats less than 0.4 m deep extending from the mouth three to four hundred meters; this may be too shallow for returning adults.

	SAMPLE BATE		
	9-7	9-20	10-19
0.0. Surface (mg/l)	11.7	12.0	11.2
D.O. Bottom (mg/l)	9.9	10.3	10.0
Temp. Surface (°C)	19.5	14.2	10.8
Temp. Bottom (°C)	16.8	12.5	10.8
PH	9.0	8.7	8.6
Cond. (micromhos/cm)	175	188	275
Secchi Disk (cm)	112	a9	137

7. Name: Jap Slough

Location: River km 573, east bank

Depth: Max. 10.1 km, average 5.5 m

Access: Good

Water Source: There is potential for high flow-through or complete isolation. Possibly spring fed (no visible inflow from the upper slough area but outflow noted on September 7, 1983).

Surface Area: 4.5 ha

Comments: July 21 - Oxycline between 3.7 m and 5.5 m
*August 4 - Conductivity ranged from 274 (surface) to 695 (bottom), oxycline at 4.3 meters
August 23 - Oxycline between 3.0 m and 4.9 m
September 7 - Oxycline at 4 to 6 meters depth
Conductivity was similar to that in the river on July 21 but was much higher than the river on successive dates. We suspect some kind of irrigation return or underground seepage. There was constant visible flow out of the backwater with visible inflow only during river flows in excess of 4,248 m^3/s. The proximity to the WDF and WDG Ringold Spring rearing facilities may also pose problems.

	SAMPLE DATE				
	7-21	8-4	8-23	9-7	9-19
0.0. Surface (mg/l)	9.0	9.29	9.9	9.25	10.6
D.O. Bottom (mg/l)	0.5	0.46	0.2	0.4	6.8
Temp. Surface (°C)	21.2	24.3	19.3	18.0	14.8
Temp. Bottom (°C)	13.0	16.6	14.0	13.5	13.5
PH	8.5	8.25	8.4	7.8	8.25
Cond. (micromhos/cm)	220	---	500	530	580
Secchi Disk (cm)	178	234	165	178	180

8. Name: Hanford Slough

Location: River km 584, west bank

Depth: Max. exceeds 6.1 m

Access: Good (4x4 would be necessary to sample this backwater year-round)

Water Source: Water currents through this backwater may be excessive during river flows above 7,080 m^3/s

Surface Area: 17.7 ha

Comments: Duane Neitzel of Battelle Northwest indicated that at high flows water may flow in at high velocities from upstream. Extreme high water level and temperature fluctuations may be expected (2 m depth changes and daily water temperature changes of up to 9°).

	SAMPLE DATE				
	7-19	8-3	8-23	9-7	9-19
D.O. Surface (mg/l)	11.7	11.0	10.0	11.5	11.9
D.O. Bottom (mg/l)	12.4	10.0	10.7	10.9	11.4
Temp. Surface (°C)	15.5	21.0	17.0	15.9	14.0
Temp. Bottom (°C)	14.8	19.1	17.0	15.3	14.0
PH	8.2	7.3	8.4	8.5	8.6
Cond. (micromhos/cm)	124	133	137	141	137
Secchi Disk (cm)	244	259	196	221	318

Appendix C.

Depth and contour maps for primary study sites evaluated during 1983.

ROCK CREEK

Map developed from U.S. Army Corps of Engineers aerial photograph (July 5, 1978) at reservoir elevation 267.3 feet above mean sea level (msl). Soundings were taken in 1979 and corrected to 267.3 msl. Contours are in feet.

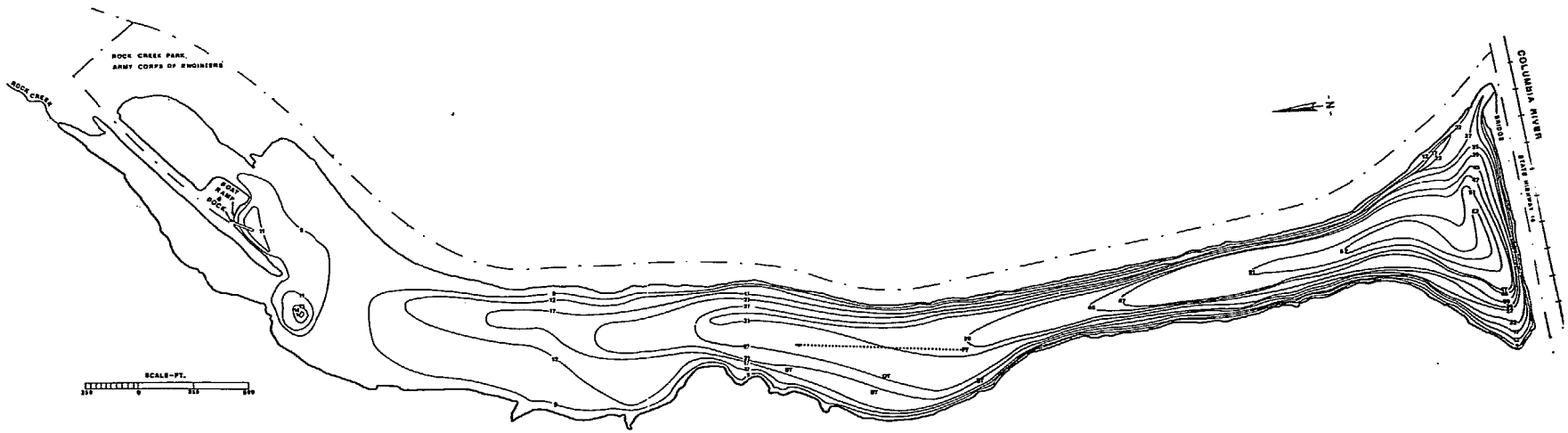
LOCATION: John Day Reservoir
Klickitat County, Washington
T. 3 N., R. 19 E., Sections 29 & 32
River Mile 228.5

Physical characteristics at U.S. Army Corps of Engineers normal minimum operating elevation.

Reservoir Elevation	257 msl
Surface Area	56 acres
Maximum Depth	42 feet
Volume	1015 acre-feet

LEGEND

PT-Plankton Tow
BT-Bottom Sample
OT-Oxygen-Temperature
Road
Railroad



This map was reproduced in part from Columbia River backwater study: Phase one, September 1980, U.S. Fish and Wildlife Service.

JONES CANYON

Map developed from U.S. Army Corps of Engineers aerial photograph (August 10, 1978) at reservoir elevation 265.1 feet above mean sea level (msl). Soundings were taken in 1979 and corrected to 265.1 msl. Contours are in feet.

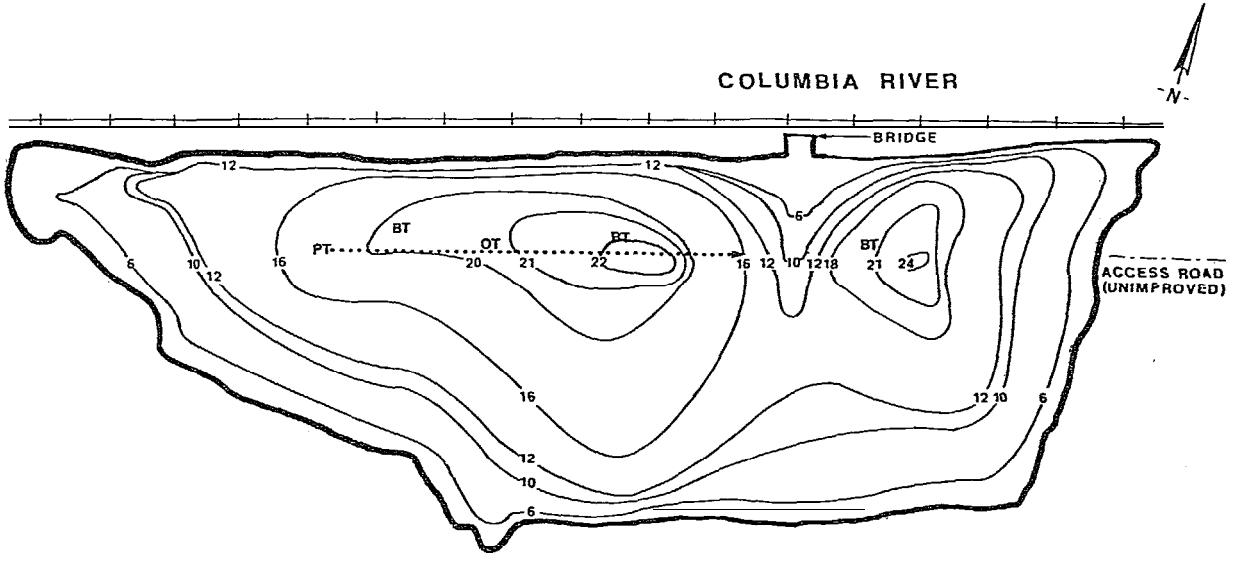
LOCATION: John Day Reservoir
Gilliam County, Oregon
T. 3 N., R. 21 E., Section 30
River Mile 239.5

Physical characteristics at U.S. Army Corps of Engineers normal minimum operating elevation.

Reservoir Elevation	257 msl
Surface Area	5 acres
Maximum Depth	16 feet
Volume	43 acre-feet

LEGEND

PT-Plankton Tow
BT-Bottom Sample
OT-Oxygen-Temperature
Road
Railroad



This map was reproduced in part from Columbia River backwater study: Phase one, September 1980, U.S. Fish and Wildlife Service.

WILLOW CREEK

Map developed from U.S. Army Corps of Engineers aerial photograph (March 14, 1978) at reservoir elevation 264.6 feet above mean sea level (msl). Soundings were taken in 1979 and corrected to 264.6 msl. Contours are in feet.

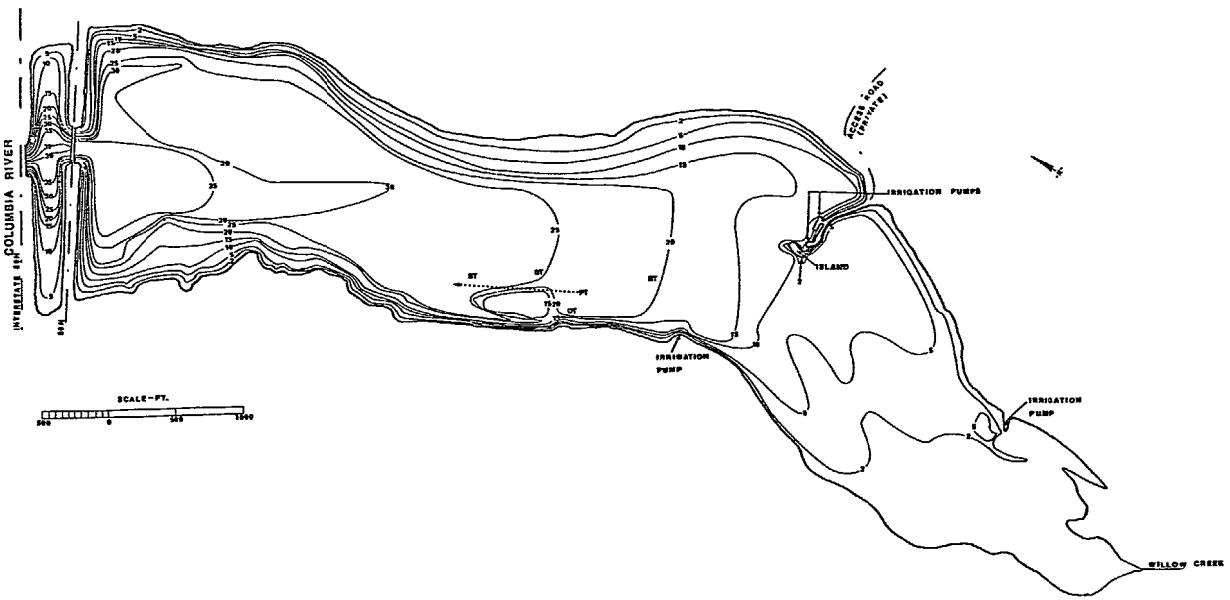
LOCATION: John Day Reservoir
Gilliam County, Oregon
T. 4 N., R. 22 E., Sections 25 & 36
River Mile 252.5

Physical characteristics at U.S. Army Corps of Engineers normal minimum operating elevation.

Reservoir Elevation:	257 msl
Surface Area	: 193 acres
Maximum Depth	: 31 feet
Volume	: 2641 acre-feet

LEGEND

PT-Plankton Tow
BT-Bottom Sample
OT-Oxygen-Temperature
Road
Railroad



This map was reproduced in part from Columbia River backwater study: Phase one, September 1980, U.S. Fish and Wildlife Service.

PATERSON SLOUGH

Map developed from U. S. Army Corps of Engineers photograph (September 19, 1978) at reservoir elevation 267.1 feet above mean sea level (msl) Soundings were taken on September 21, 1983 and corrected to 267.1 msl. Contours are in feet.

LOCATION: John Day Reservoir Benton County, Washington T. 5N., R. 28E., Sections 10 and 15, River Mile 278.

Physical characteristics at U. S. Army Corps of Engineers normal minimum operating elevation.

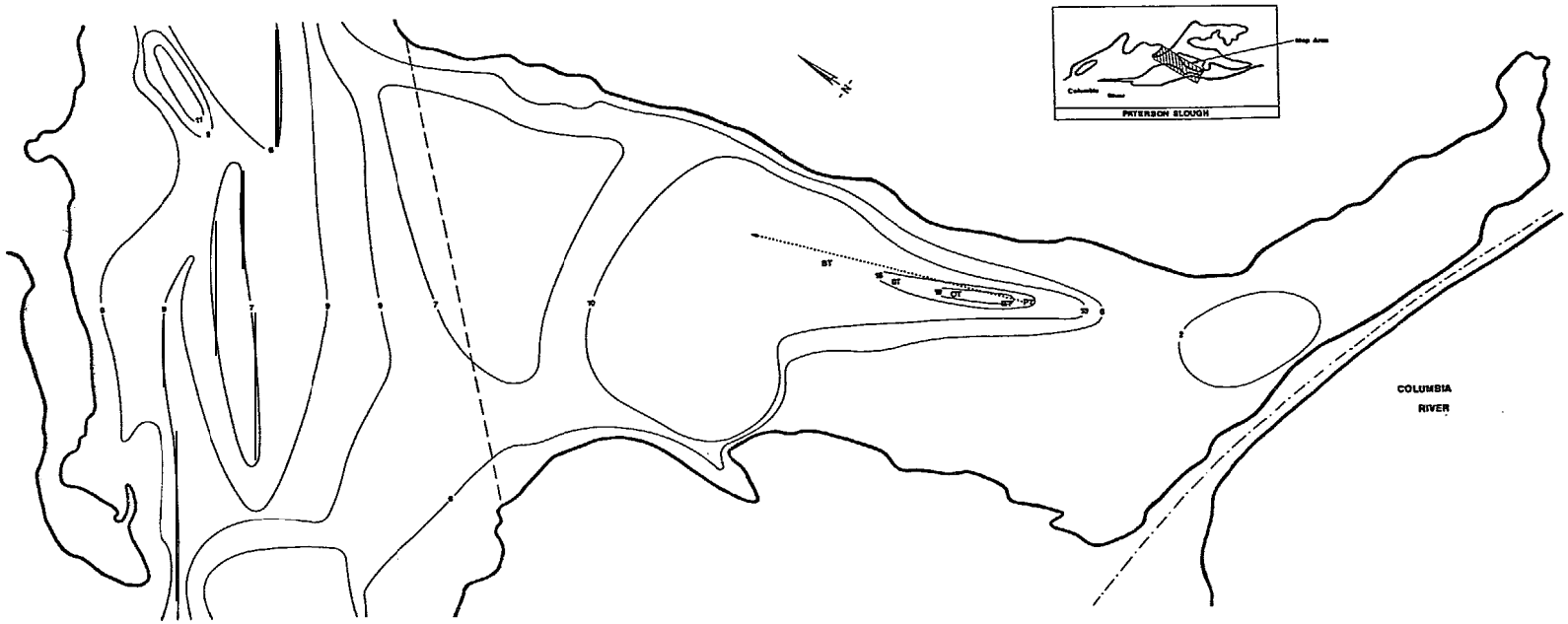
Reservoir Elevation	:	257 msl
Surface Area	:	19.4 acres
Maximum Depth	:	9 feet
Volume	:	49.5 acre-feet

LEGEND

PT-Plankton Tow OT-Oxygen-Temperature
BT-Bottom Sample ---Road
---Physical characteristics describe area to the right of this line.

SCALE - FT.

300 0 300 900



SOCIAL SECURITY LAKE

Map developed from U.S. Army Corps of Engineers photograph (September 19, 1978). Water level is constant year-round. Contours are in feet.

LOCATION: Umatilla County, Oregon T. 5N., R. 28 E., Section 9, River Mile 290.7.

Physical characteristics at the time of mapping, August 24, 1983.

Surface Area	:	17.4 acres
Maximum Depth	:	22 feet
Volume	:	191 acre-feet

LEGEND

PT-Plankton Tow	—— Road
BT-Bottom Sample	◄— Inflow
OT-Oxygen-Temperature	• Outflow

SCALE – FT.

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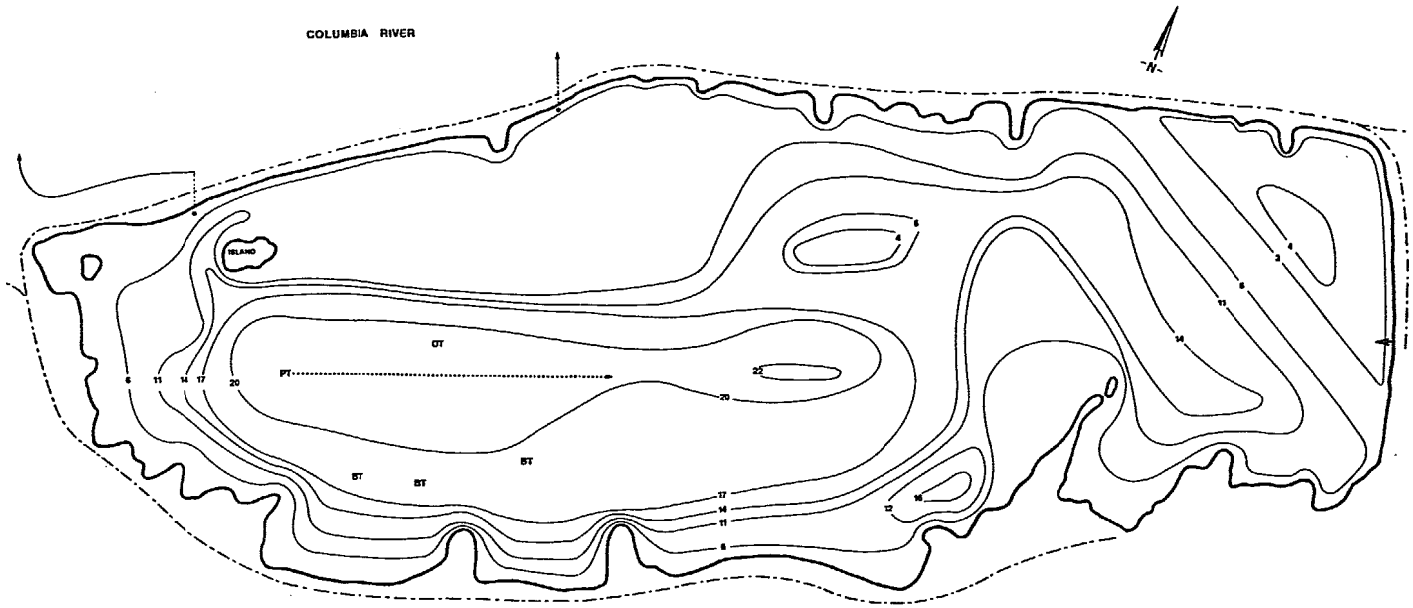


VILLARD POND

Map developed from U.S. Army Corps of Engineers photograph (August 28, 1981) at reservoir elevation 338.5 feet above mean sea level (msl). Soundings were taken on September 20, 1983 and corrected to 338.5 msl. Contours are in feet.

LOCATION: McNary Reservoir Walla Walla County, Washington T. 8N., R. 30 E., Sections 12 and 13, River Mile 323.

Physical characteristics at U.S. Army Corps of Engineers normal minimum operating elevation.

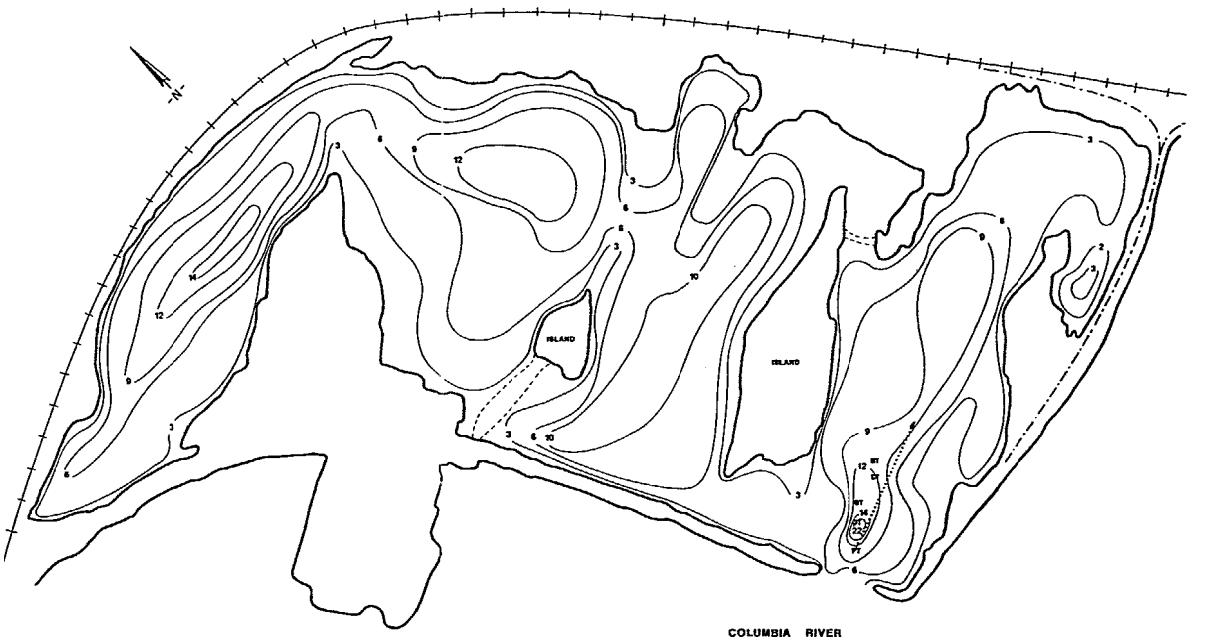
Reservoir Elevation	:	334.5 msl
Surface Area	:	27.1 acres
Maximum Depth	:	18 feet
Volume	:	103 acre-feet

LEGEND

PT-Plankton Tow
BT-Bottom Sample
OT-Oxygen-Temperature
Road
Railroad
Mud Flat

SCALE—FT.

250 0 250 500



JAP SLOUGH

Map developed from aerial photos provided by Battelle Northwest and the U.S. Army Corps of Engineers. Discharge from Priest Rapids Dam at the time of mapping was 159 Kcfs. Contours are in feet.

LOCATION: Columbia River, Franklin County, Washinton T. 12 N., R. 28 E., Section 10, River Mile 356.5.

Physical characteristics at the time of mapping, August 4, 1983.

Priest Rapids Discharge	:	159 Kcfs
Surface Area	:	11.1 acres
Maximum Depth	:	30 feet
Volume	:	116 acre-feet

LEGEND

PT-Plankton Tow
BT-Bottom Sample
OT-Oxygen-Temperature
---Road

SCALE—FT.
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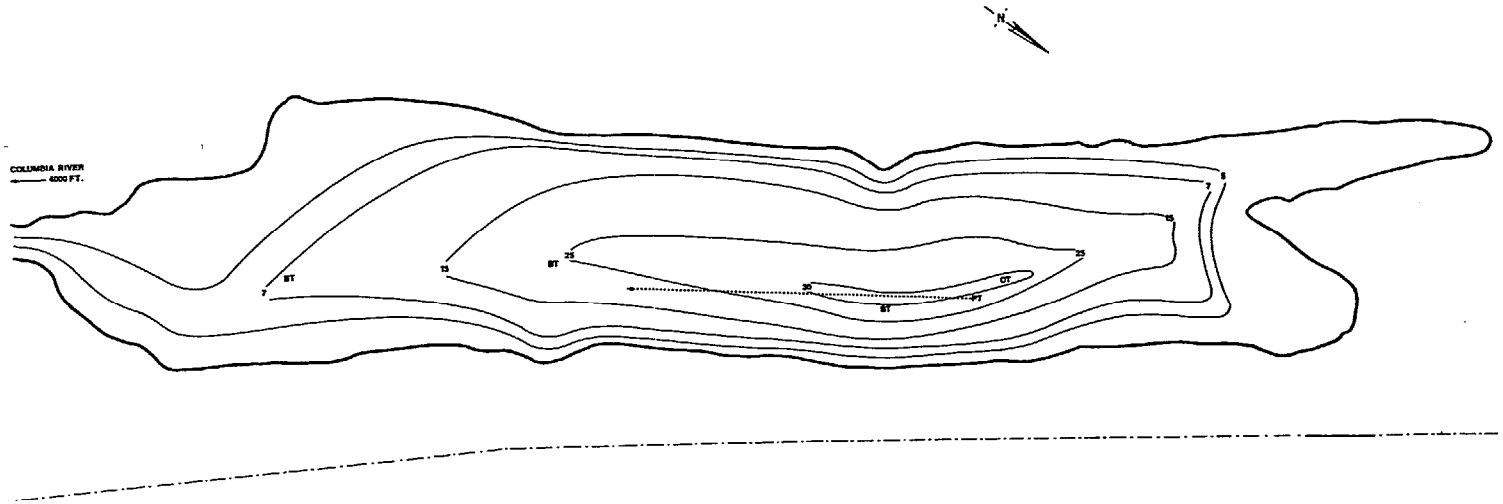

HANFORD SLOUGH

Map developed from aerial photos provided by Battelle Northwest and the U.S. Army Corps of Engineers. Discharge from Priest Rapids Dam at the time of mapping was 148 Kcfs. Countours are in feet.

LOCATION: Columbia River, Benton County, Washinton T. 13N., R. 27 E., Sections 23, 24, and 25, River Mile 362.2.

Physical Characteristics at the time of mapping, August 3, 1983.

Priest Rapids Discharge:	148	Kcfs
Surface Area	: 43.7	acres
Maximum Depth	: 23	feet
Volume	: 480	acre-feet

LEGEND

PT-Plankton Tow
BT-Bottom Sample
OT-Oxygen-Temperature
Boat Ramp
Road
Power Lines

SCALE-FT
0 100 200 400