1971 Report

PROGRESS REPORT ON FISH-PROTECTIVE FACILITIES AT LITTLE GOOSE DAM AND SUMMARIES OF OTHER STUDIES RELATING TO THE VARIOUS MEASURES TAKEN BY THE CORPS OF ENGINEERS TO REDUCE LOSSES OF SALMON AND STEELHEAD IN THE COLUMBIA AND SNAKE RIVERS

PREPARED BY

WESLEY J. EBEL
HOWARD L. RAYMOND
CLIFFORD W. LONG
WILLMAN M. MARQUETTE
RICHARD KRCMA
DONN PARK

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NOAA
National Marine Fisheries Service
North Pacific Fisheries Research Center
2725 Montlake Boulevard East
Seattle, Washington 98102

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INTRODUCTION

Research by the National Marine Fisheries Service since 1968 (Beiningen and Ebel, 1970; Ebel, 1971; and Raymond, 1971) indicated that substantial losses have occurred among both juvenile and adult salmon as a result of the construction of three new dams--John Day, Lower Monumental, and Little Goose. The primary cause of the losses was identified as supersaturation of nitrogen gas. Large volumes of water discharged through the spillways entrain air and plunge it to depths of over 50 feet (15 m) resulting in supersaturation of nitrogen gas (Ebel, 1969). The most recent estimates (Raymond, 1971) of losses to juvenile populations of chinook and steelhead migrating downstream in the Snake River indicated that these populations may soon be reduced to critically low levels unless immediate action is taken to eliminate these losses. The Army Corps of Engineers initiated several actions in an attempt to reduce these losses. These actions included: (1) the support of the National Marine Fisheries Service research proposal to develop and test a collection and transportation system which involves collecting and transporting juvenile salmon and steelhead from Little Goose Dam to locations downstream from Bonneville Dam; (2) the installation and testing of prototype slotted bulkhead gates for passage of water through skeleton bays without supersaturating with N_2; (3) establishment of a task force for directing load and flow control on the Columbia and Snake Rivers; and (4) continue development of a mathematical model for prediction and possible control of nitrogen gas supersaturation.

This report summarizes progress by the National Marine Fisheries Service relative to the foregoing actions. Specific areas of research covered are: the traveling screen and orifice bypass tests, transportation studies, surveys of dissolved nitrogen concentrations, and related fish survival studies.

TRAVELING SCREEN AND ORIFICE BYPASS STUDIES

Three traveling screens were constructed and tested during the spring outmigration of juvenile salmon and steelhead. In addition, tests were made to determine factors responsible for retarded passage of fish from gatewells into submerged ports. Some descaling of fish was noted, and several tests were made to determine the source of descaling.

Traveling Screen Tests

Evaluation of the traveling screens considered mechanical operation and fish guiding efficiency.

Mechanical operation.--The drive systems of the traveling screens were found to be underdesigned. As a consequence, we experienced considerable lost time while the screens were out of service for repairs. Breakdowns were serviced by replacement of the broken part because extensive redesign to upgrade design strength would have required too much time. Extensive redesign, modification, and testing of the screens were begun immediately after termination of the fish run. These tests, although incomplete at the time, indicate that the drive system problems are solved.

Fish guiding efficiency.--Tests were made to measure fish guiding efficiency of the traveling screens. In these tests, screens were installed in intakes 2-A, 2-B, and 2-C. Twelve fyke nets strained all of the flow passing under the traveling screen in intake 2-B, and a special closure net prevented unguided fish from passing above the fyke nets (Figure 1).

Fish guided into the gatewell were prevented from escaping back into the intake by a vertical barrier screen (Figure 1). Periodic failure of automatic counters in the gatewell orifice necessitated closure of the orifices so that all fish diverted into the respective gatewells could be accounted for.

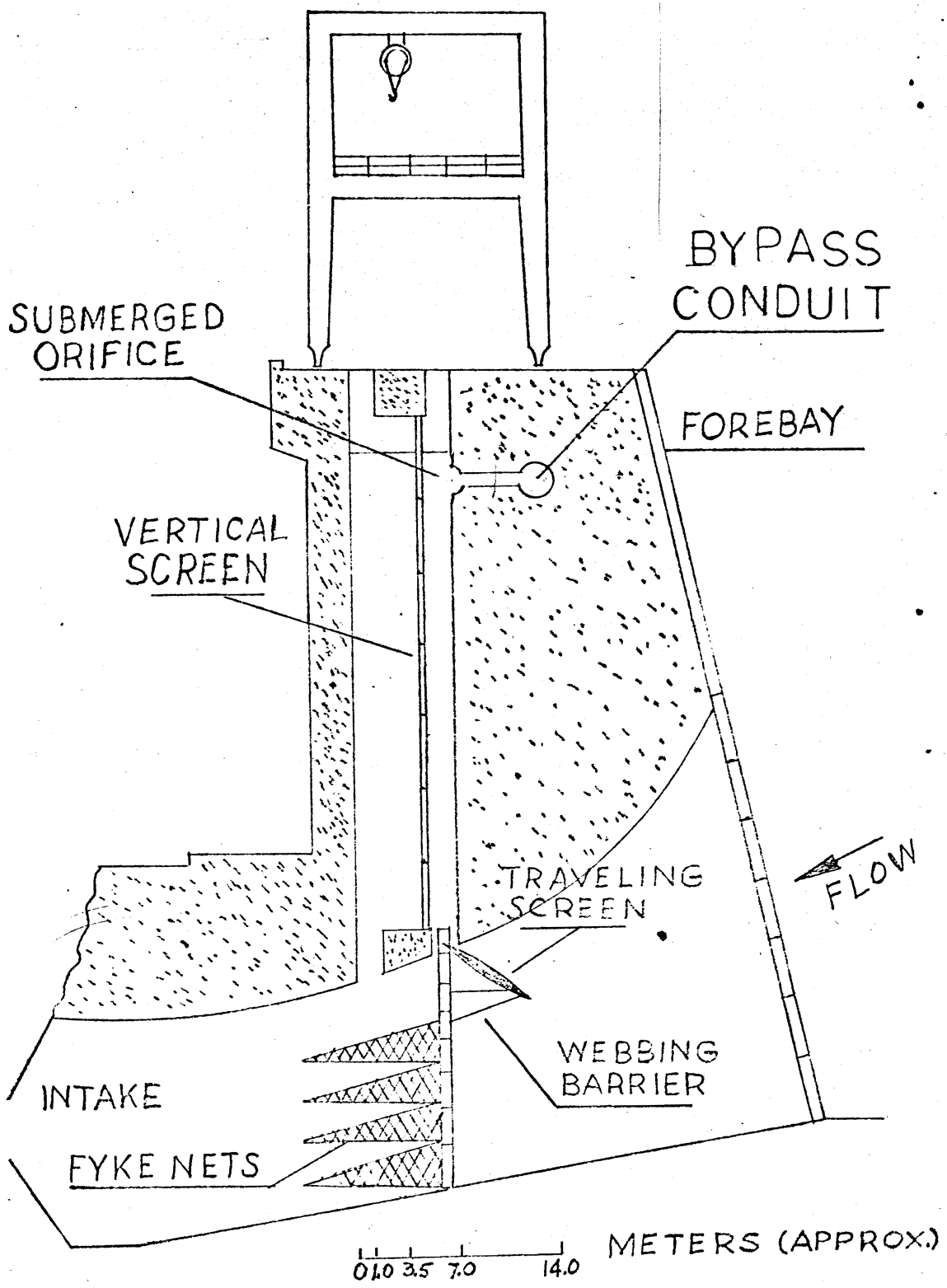

Figure 1.--Cross section of turbine intake at Little Goose Dam showing main water passage and associated fish diversion and sampling equipment.

Guided fish were removed from the gatewell with a dip net, and unguided fish taken by the fyke nets beneath the traveling screen were recovered after the screen and support structure were removed from the intake.

To begin a test, all traveling screens were lowered into fishing position in the intakes immediately after turbine number 2 was shut down. All fish in the three gatewells were then removed by dipnetting and the turbine was turned on and brought to maximum power output (115% overload).

To terminate a test, the turbine was shut down and fish in the gatewells were removed by dipnetting before the traveling screen was raised.

On April 22, two tests were conducted. Test number one began at 0130 and terminated at 0530, and test number two began at 0900 and terminated at 1830. Guiding efficiencies for chinook and steelhead appear in Table 1; a range of 81 to 97% was indicated.

Orifice Fish Passage Tests

Evaluation of fish passage efficiency was largely based on gross estimates of fish retention in the gatewells. Only near the termination of the fish run was it possible to make actual counts of fish that had passed through gatewell orifices for comparison with the number of fish failing to do so, i.e., those fish remaining in the gatewell.

Four of the nine gatewells involved were equipped with vertical barrier screens (Figure 1). These were 1-B, 2-A, 2-B, and 2-C. Most of the tests were conducted in these gatewells because dipnetting of standard gatewells (without vertical barrier screens) was too inefficient.

Table 1.--Fish guiding efficiencies of traveling screen for two tests conducted April 22, 1971, in turbine intake 2-B.

	Chinook			Steelhead		
	Guided	Unguided	Percent guided	Guided	Unguided	Percent guided
	number	number	percent	number	number	percent
Test No. 1 0130 - 0530	378	28	93%	290	68	81%
Test No. 2 0900 - 1830	1297	134	91%	1563	56	97%

At the outset, it was obvious that fish were accumulating in both the standard gatewells and gatewells equipped with vertical barrier screens. Even special crowders (Figure 2) were employed to achieve faster rate of passage from gatewells through the bell-mouthed submerged ports. The crowders improved rate of passage, but retention was still at an unacceptably high level. During these preliminary tests, the gatewells remained uncovered and the orifices were not lighted.

On May 19 we installed in gatewells 1-B, 2-A, and 2-B clear plastic inserts that converted the bell-mouthed orifices to the non-tapered type used at McNary Dam. Each insert was equipped with a mercury vapor lamp such that the illumination, when the lamps were on, exited from the entrance of the orifice. This simulates the condition that worked so successfully at McNary Dam in 1969.[1/] When the initial test on the effect of orifice lighting was made the control gatewell (no orifice lighting) contained nearly 2,200 fish whereas the test gatewell (75-watt mercury vapor lamp in conjunction with non-tapered orifice) held only 500 fish.

Following the initial exploratory trial we attempted to assess fish passage efficiency through orifices by more precise means. Automatic fish counters inserted in several orifices failed to provide reliable data. As an alternative, we operated each gatewell under a test condition for 24 hours followed by a control condition; i.e., the orifice was screened to retain all fish that entered the gatewell. At the end of a 12-day period, the variability of the data was too great for reliable estimates of orifice passage efficiency.

1/ Final Report to Corps of Engineers "Research on Gatewell-Sluice Method of Bypassing Downstream Migrant Fish Around Low-Head Dams," May 8, 1970.

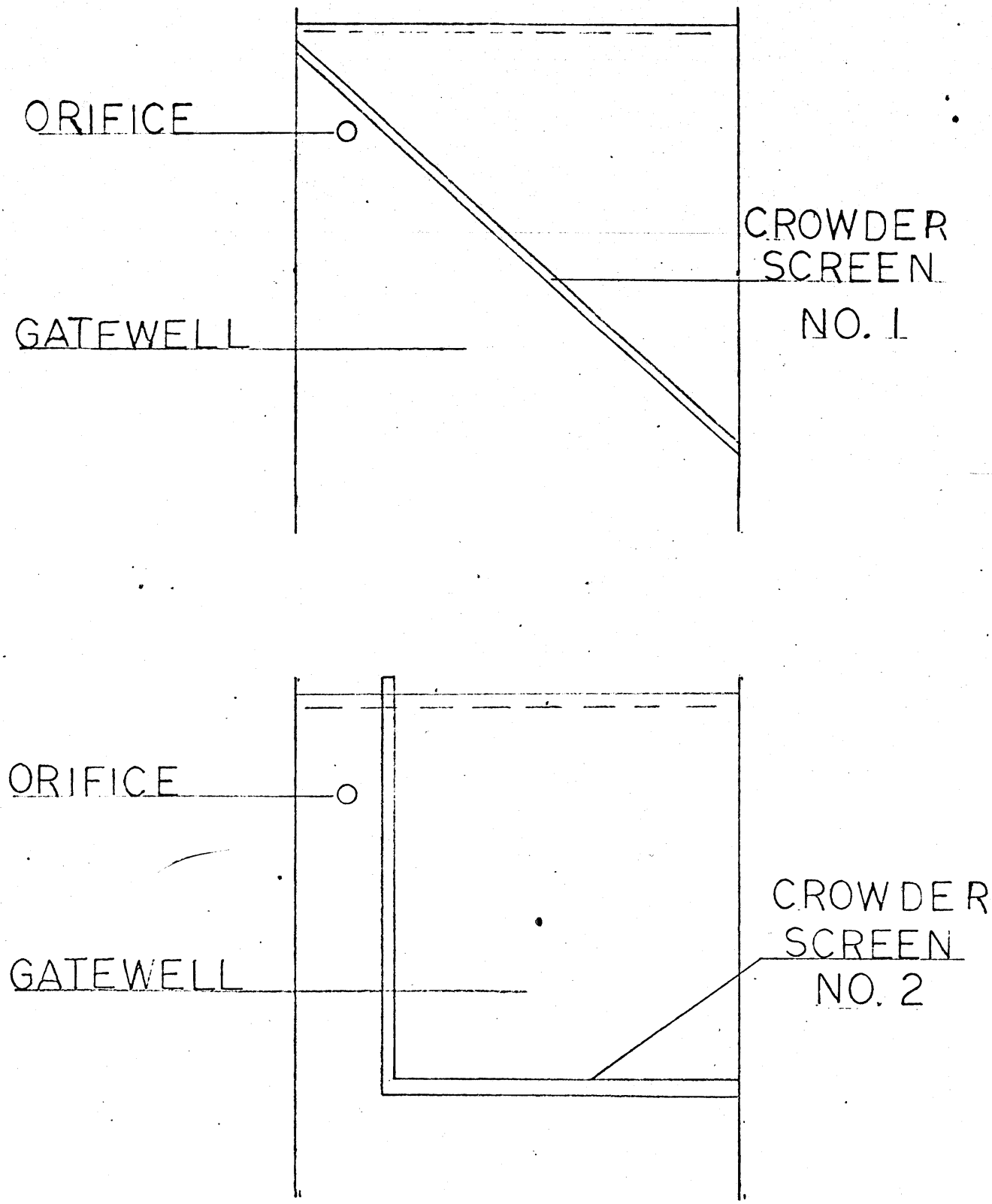

Figure 2.--Cross section of gatewell showing two types of screens used to crowd fish into near vicinity of orifice to enhance fish passage.

Beginning June 8, abeyance of other research activities provided an opportunity to obtain reliable data on orifice passage efficiency. Gatewells 1-B, 2-A, and 2-B were used for the tests. All other orifices in gatewells associated with operating turbines were closed so that only fish from test gatewells would enter the bypass conduit for transport to the collector, thus providing a precise count of fish passing through orifices during a test. Fish remaining in the gatewells were removed by dipnetting. To produce standard hydraulic conditions at the orifices, five orifices in skeleton units were opened; we presumed no fish would use these orifices.

Two conditions were tested; a lighted gatewell in combination with a lighted orifice (LL) and a darkened gatewell in combination with a lighted orifice (DL). All three gatewells had the same combination of light conditions during a test, and each condition was tested for 24 hours, alternately, from June 8 to 15.

A screen was placed over each orifice to terminate a test. While the screens were in place, all fish were removed from the fish collection system and from the gatewells and tallied separately. Fish from the three gatewells were combined and represented the residualism. The screens were removed to begin the next test immediately after the new lighting conditions were established.

Table 2 lists each test result and the average residualism. Conditions tested in this experiment were the two best conditions for fish passage found at McNary in 1969. At Little Goose Dam, however, these conditions resulted in considerably less satisfactory fish passage by comparison.

Table 2.--Fish passage efficiencies for two combinations of light conditions; LL means lighted gatewell and lighted orifice and DL means darkened gatewell and lighted orifice.

Date	CHINOOK						STEELHEAD					
	L L			D L			L L			D L		
	Orifice passage	Residuals	Percent residuals	Orifice passage	Residuals	Percent residuals	Orifice passage	Residuals	Percent Residuals	Orifice passage	Residuals	Percent residuals
	No.	No.	%	No.	No.	%	No.	No.	%	No.	No.	%
June 8 - 9	50	24	32				154	102	40			
June 9 - 10				39	25	39				160	113	41
June 10 - 11	69	35	34				233	241	51			
June 11 - 12				110	38	26				155	86	36
June 12 - 13	130	74	31				185	118	39			
June 13 - 14				64	18	22				182	53	23
June 14 - 15	63	28	31				52	28	35			
Average	312	161	34	213	81	28	624	489	44	497	252	34

Therefore, additional tests under varying conditions and with larger samples of fish are proposed for study next year.

Factors Associated with Descaling

From time to time some fish were found to be descaled and efforts were made to discover the cause. Although other workers on the project reported descaling, only one man (Mr. Willman Marquette) was used to evaluate percentage descaling.

Groups of 50 or more fish were selected in relation to types of exposure to various possible causes of the descaling and were given to Mr. Marquette for inspection and classification.

We considered the following factors as potential causes of descaling.

1. Gatewell dipnet
2. Standard gatewell
3. Gatewells with vertical barrier screens
4. Traveling screens
5. Gatewell orifices and bypass conduit
6. Duration of time spent in gatewells

Although the analysis is incomplete at this time, we have yet to find a correlation between degree of descaling and any of the six factors examined.

There is some indication that the fish may have been descaled before entering the gatewells. One possible cause might be accumulated debris on the trash racks across the entrance to the intakes. There is also the possibility that descaling occurred at some point further upstream before arrival of the fish at the project.

TRANSPORTATION AND HOMING

Progress of the transportation studies during the past year (1971) at Little Goose Dam are summarized in this section of the report.

Objectives of the transportation research by the National Marine Fisheries Service research were: (1) transport all juvenile chinook collected at Little Goose Dam to locations below Bonneville Dam; (2) continue evaluation of the transport by marking 50,000 chinook for release as controls and 50,000 for release as test or transported fish; (3) mark and release 50,000 steelhead as controls and 50,000 for transport below Bonneville to evaluate the effect of transporting steelhead; (4) test and evaluate the holding and handling facility at Little Goose for collecting, handling, and efficiently transferring fish to transport trucks; and (5) determine whether large numbers of naturally migrating wild and hatchery stocks of juvenile salmon and steelhead can be transported without excessive mortality.

General Experimental Design

Juvenile steelhead and chinook used for the transportation experiment were divided into 4 groups--2 control and 2 test or transported groups. One control group was marked and released about 10 km upstream from Little Goose Dam at Central Ferry; the other control group was marked and released directly into the tailrace about 150 meters downstream from the powerhouse. The transported or test groups were hauled in tank trucks to two locations downstream from Bonneville Dam. One release site was at Dalton Pt. 17 km from Bonneville on the Oregon side; the other release site was at the Washington State boat launching site about 2 km downstream from Bonneville Dam on the Washington side.

Separate tag codes and brands were designated for each experimental group; the codes were changed three times during the marking periods; the brands were changed weekly.

Evaluation of the survival and homing ability of these groups will be based on adult returns to the commercial and sport fishery, Little Goose Dam, and the spawning grounds. An adult tag detection and fish separator similar to that installed at Ice Harbor Dam will be used for evaluation of adults returning to Little Goose Dam.

Evaluation of downstream survival of juveniles is dependent on the recovery of sufficient numbers of test and control fish in the estuary.

Collection, Marking and Transport Procedures

Juvenile salmon were collected from the gatewells by use of the orifice bypass system and by use of a specially designed gatewell dip net. Fish entering the gatewell orifices passed by way of a collection pipe (Figure 3) to the holding area downstream from the tailrace deck. Fish dipped with the gatewell net were transferred to the holding area by tank truck. It was necessary on several occasions to dip the fish because of poor passage through the orifices. Fish passing from the gatewells by way of the collector pipe passed through a Morton grader for sorting by size. We adjusted the grades so that most of the juvenile chinook would be separated from the steelhead before entering the holding ponds. Fish dipped from the gatewells were not sorted before release in the ponds. Whenever possible, fish dipped from the gatewells were kept separate and were not marked as experimental fish. These fish were usually transported unmarked.

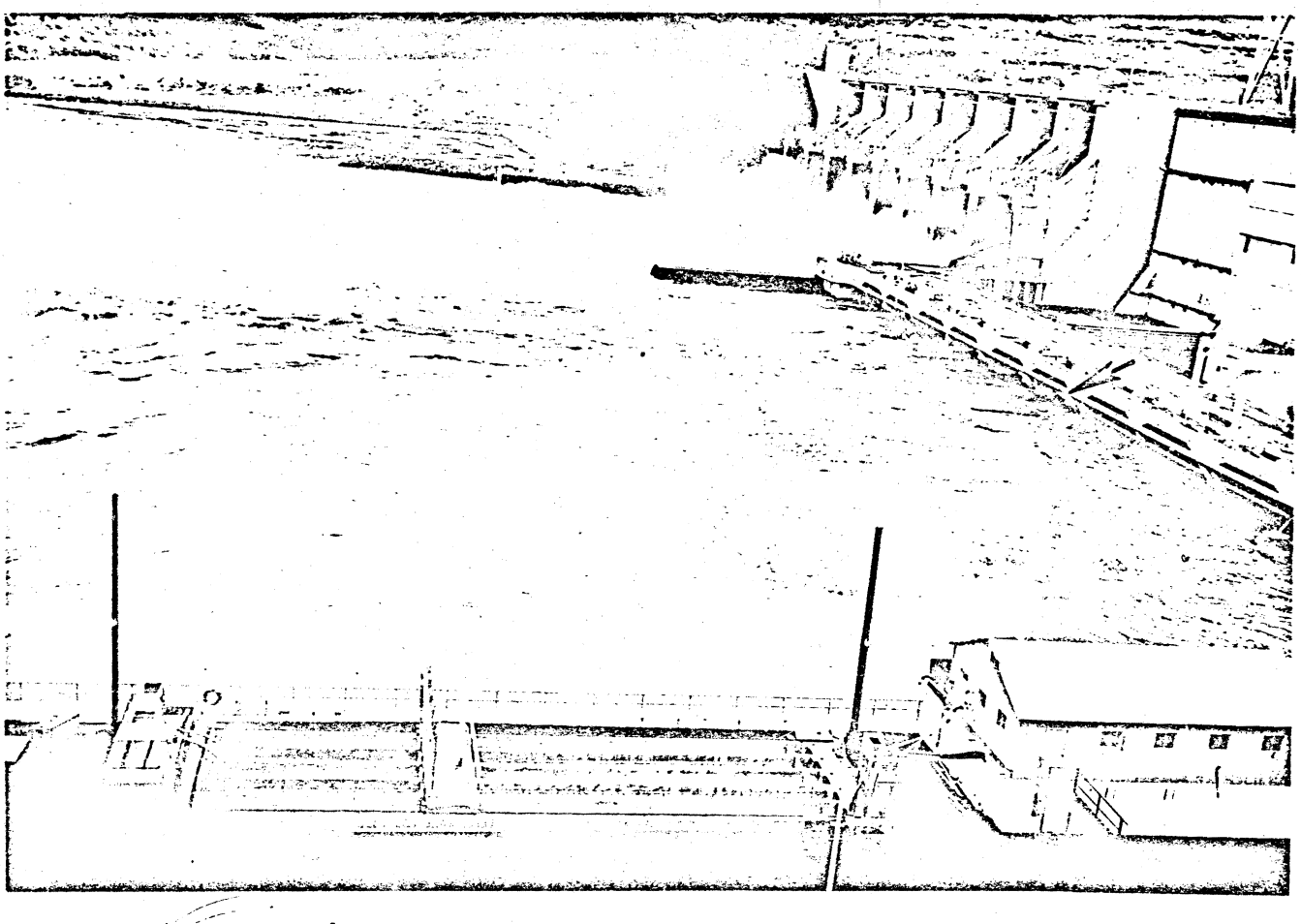

Figure 3.--Orifice bypass transport pipe (arrow) and raceways for holding juvenile salmon and steelhead at Little Goose Dam.

Fingerling chinook and steelhead were pumped into the marking building with a 5-inch Paco model fish pump where they were anesthetized and sorted. Previously marked fish were returned to the river in the tailrace of the turbine discharge. Each of the remaining fish was cold-branded with liquid nitrogen (Mighell, 1969), the adipose fin was excised, and a magnetic wire tag (Jefferts et al., 1963) was inserted in the snout. Before passing into the transport truck, the fish went through a magnetic field and detection coil; an improperly tagged fish was automatically rejected and returned to the marker for retagging. Steelhead and chinook were kept in separate compartments in the tank truck whenever both species were hauled simultaneously. Load densities were governed by the size of the daily catch which did not exceed 16,000 fish. All fish were transported in a 5,000-gal capacity truck with aeriation, refrigeration, and filtration. Load densities were always less than 1 pound per gal.

Water chemistry measurements were taken at the time of release for every load transported. Concentrations of ammonia, nitrogen, dissolved oxygen, carbsn dioxide, ph and total alkalinity were recorded. All releases were made at dusk. Records of mortality were kept during marking and at time of release.

Results

Results of the transportation experiment at Little Goose Dam are limited to enumeration of the marked experimental groups (Table 3) and the unmarked groups (Table 4) that were successfully released at the control and test release sites. Evaluation of the results of these releases will be made upon return of the adults in 1973. Evaluation of downstream survival to the estuary yielded insufficient results due to limited recovery of the various groups.

TABLE 3.--Numbers of juvenile chinook and steelhead marked and released by group from Little Goose Dam; spring 1971.

Marking period	Release site	Brand[1/]	Chinook	Steelhead	Release site	Brand[1/]	Chinook	Steelhead
April 6-17	Central Ferry	LD-1K	2,845	3,133	Bonneville boat launch area	RD-1H	2,033	1,615
" 19-24	"	LA-K	5,286	4,686	"	RA-T	8,993	4,159
" 26-May 1	"	LA-[illegible]	4,679	6,793	"	RA-[illegible]	7,662	12,414
" 3-8 May	"	LA-[illegible]	2,583	9,031	"	RA-[illegible]	7,754	12,778
" 10-15 "	"	LA-[illegible]	3,133	3,653	"	RA-[illegible]	3,300	6,690
" 17-22 "	"	LA-F	922	4,291	"	RA-H	5,202	5,877
" 24-June 4	"	LA-[illegible]	1,975	5,459	"	RA-[illegible]	1,687	4,377
		Sub-total	21,423	37,046		Sub-total	36,631	47,910
April 6-17	Little Goose Tailrace	LD-1F	1,265	801	Dalton Pt.	RD-1Y	1,390	619
" 19-24	"	LA-W	1,553	1,389	"	RA-J	4,742	2,418
" 26-May 1	"	LA-[illegible]	3,186	7,208	"	RA-[illegible]	12,414	4,836
May 3-8	"	LA-M	3,998	6,716	"	RA-[illegible]	6,092	9,008
" 10-15	"	LA-[illegible]	2,910	4,692	"	RA-[illegible]	8,613	8,226
" 17-22	"	LA-S	1,278	1,788	"	RA-P	3,246	3,424
June 24-June 4	"	LA-[illegible]	364	913	"	RA-[illegible]	2,829	6,465
		Sub-total	14,554	23,507		Sub-total	39,326	34,996
		Grand total	35,977	60,553		Grand total	75,957	82,906

1/ LD, LA, RD and RA indicate brand positions; i. e. left dorsal, left anterior, right dorsal, right anterior.

TABLE 4.--Numbers of unmarked juvenile chinook and steelhead collected at Little Goose and Ice Harbor Dams and transported to release locations downstreams from Bonneville Dam, spring 1971.

Date	Release site	Chinook	Steelhead
Collected at Little Goose Dam			
April 19-24	Bonneville boat launch area	428	819
" 26-May 1	"	1,356	2,488
May 10-15	"	4,100	7,770
" 17-22	"	-	1,110
April 26-May 1	Dalton Pt.	3,221	9,500
May 3-8	"	4,000	16,000
" 10-15	"	1,500	3,000
" 17-22	"	2,500	9,580
	Sub-total	17,105	50,267
Collected at Ice Harbor Dam			
April 19-24	Bonneville boat launch area	4,976	-
" 26-May 1	Dalton Pt.	3,308	-
May 3-8	Bonneville boat launch area	10,679	3,900
" 10-15	Dalton Pt.	5,621	10,671
" 17-22	Bonneville boat launch area	300	3,687
May 24-June 4	Dalton Pt.	899	2,518
	Sub-total	25,783	20,776
	Grand total	42,888	71,043

As indicated in the tables, approximately 112,000 chinook and 143,000 steelhead were marked for the Little Goose experimental groups. Approximately 43,000 chinook and 71,000 steelhead were transported unmarked. This includes 20,776 steelhead and 25,783 chinook collected and transported from Ice Harbor Dam. The grand total of fish handled at Little Goose and Ice Harbor Dam was about 383,000; approximately 285,000 of these were transported and released downstream from Bonneville Dam. Our goal of 50,000 marked fish per experimental group was exceeded in all cases except in the chinook control groups which totaled about 36,000 fish.

Records of mortality recorded at the time of release of the transported groups indicated an overall average of 0.87 percent mortality for chinook and 0.16 percent mortality for steelhead. This low mortality rate indicates that the cooling and aeration systems used in the transport tanks are about as efficient as any in use at this time. Samples of fish were held from each load for 48-72 hours at the Bonneville hatchery in an attempt to determine delayed mortality. Delayed mortality of steelhead ranged from 0-3.3 percent with an overall average of 0.97 percent. Chinook ranged from 3.4-51.2 percent with an overall average of 22.8 percent. We question whether this apparent high delayed loss of chinook accurately reflects the post-release mortality. Stress from holding a smolting stock of chinook may have been the dominant factor rather than stress from marking and transporting. The best and most valid information pertaining to downstream survival of the transported groups will come from the returning adults in 1973.

The holding and handling facility at Little Goose Dam operated with notable precision. Fish handled were in generally excellent condition. One improvement will be made before the next season. The fish grader will be modified so that it will be self-cleaning, and the electronic counters enumerating fish entering the ponds will be modified to provide a more accurate count.

DISSOLVED NITROGEN IN THE COLUMBIA AND SNAKE RIVERS WITH OBSERVATIONS OF EFFECTS ON STEELHEAD AND CHINOOK

Monitoring of the dissolved nitrogen levels in the Columbia and Snake Rivers was continued in 1971 to determine (1) effects on nitrogen levels of changes in flow distribution that would result from additional turbines at Little Goose and John Day Dams; (2) relation of flow and load control to nitrogen levels; (3) effect of the prototype slotted gates; and (4) effect of prevailing saturation levels on survival of juvenile and adult steelhead and chinook migrants. The following report summarizes data collected and analyzed to date.

Methods

The methods used for collection and analysis of the nitrogen samples in 1971 were identical to those reported by Ebel in 1970 except that stations at Portland and Washougal were not sampled, and the tailrace station at John Day Dam was moved from the south to the north side of the river.

The effect of the nitrogen saturation on fish was based on techniques similar to those used in 1970. Fish holding tests conducted in previous years with salmon in the forebay of Ice Harbor Dam were repeated with steelhead in 1971. Daily observations of gas bubble disease symptoms in juvenile steelhead and chinook arriving at Ice Harbor Dam were recorded and population estimates based on recapture of marked groups from upstream locations were continued.

Information on the condition of mature adults will be based on data from Rapid River hatchery and spawning ground surveys made by Idaho Fish and Game and the National Marine Fisheries Service. These data are incomplete at this time, but preliminary observations indicate significant prespawning mortalities have occurred.

Nitrogen Concentrations

Forebay (10 m depth) and tailrace (surface) concentrations of dissolved nitrogen for 1970 and 1971 on the Columbia and Snake Rivers are compared in Figure 4. Appendix Table 1 gives the oxygen and nitrogen concentration, location, temperature, depth and flow at the time the individual samples were taken in 1971.

Nitrogen concentrations in both the Snake and Columbia Rivers were considerably higher in April and early May of 1971 than in 1970 even though two additional turbines were in operation at Little Goose Dam in 1971. The higher levels in 1971 were due to abnormally high flows in the Snake River for this time of the year. For example, flows at Little Goose Dam during the April 6 to May 4 surveys in 1971 ranged from 99,700 to 199,000 cfs; in 1970 during the same period, the flows ranged from 41,300 to 66,500 cfs.

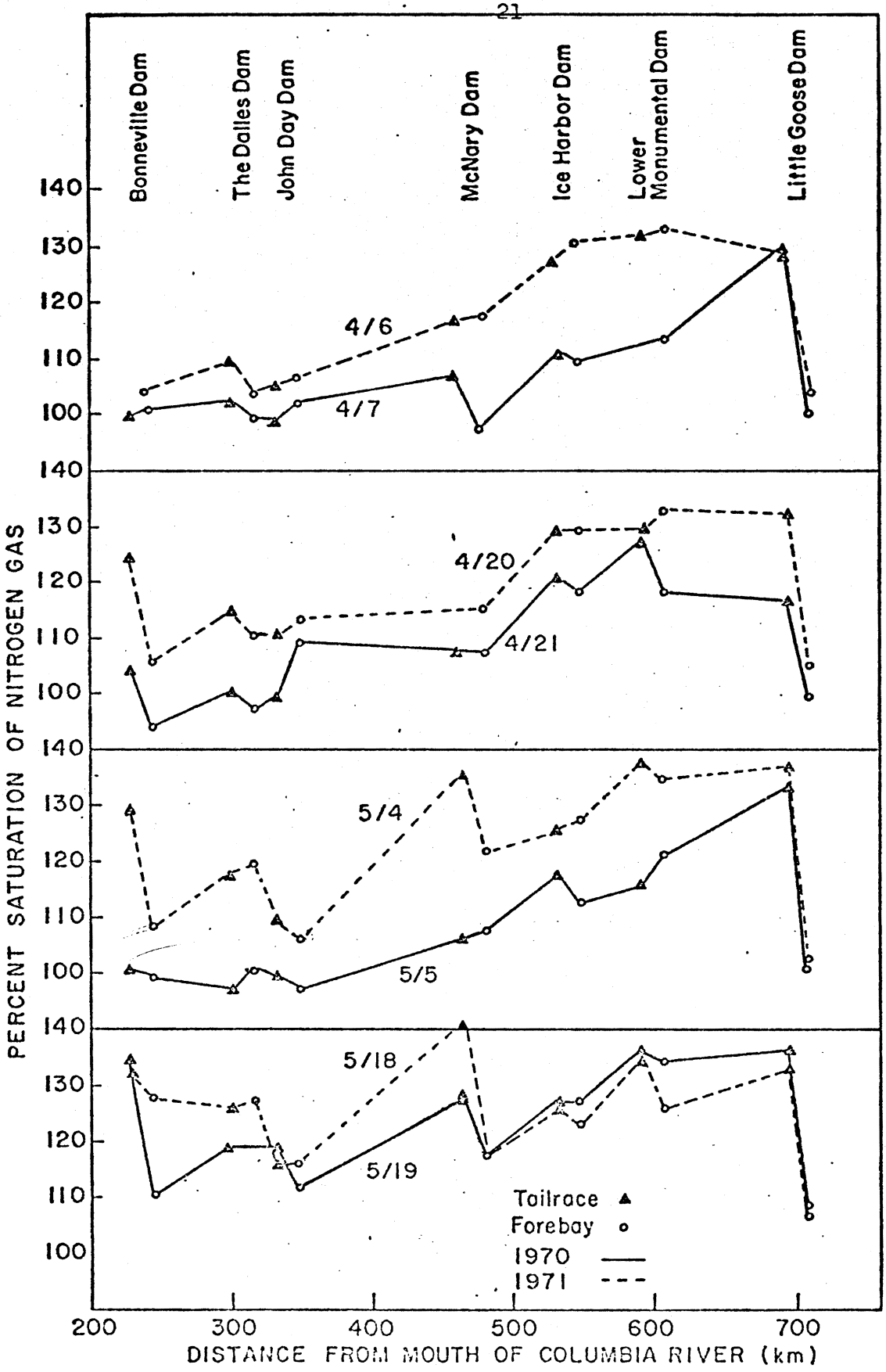

FIGURE 4.--Forebay (10 m) and tailrace concentrations (surface) of dissolved nitrogen gas in samples from Little Goose Dam to Bonneville Dam April-August 1971.

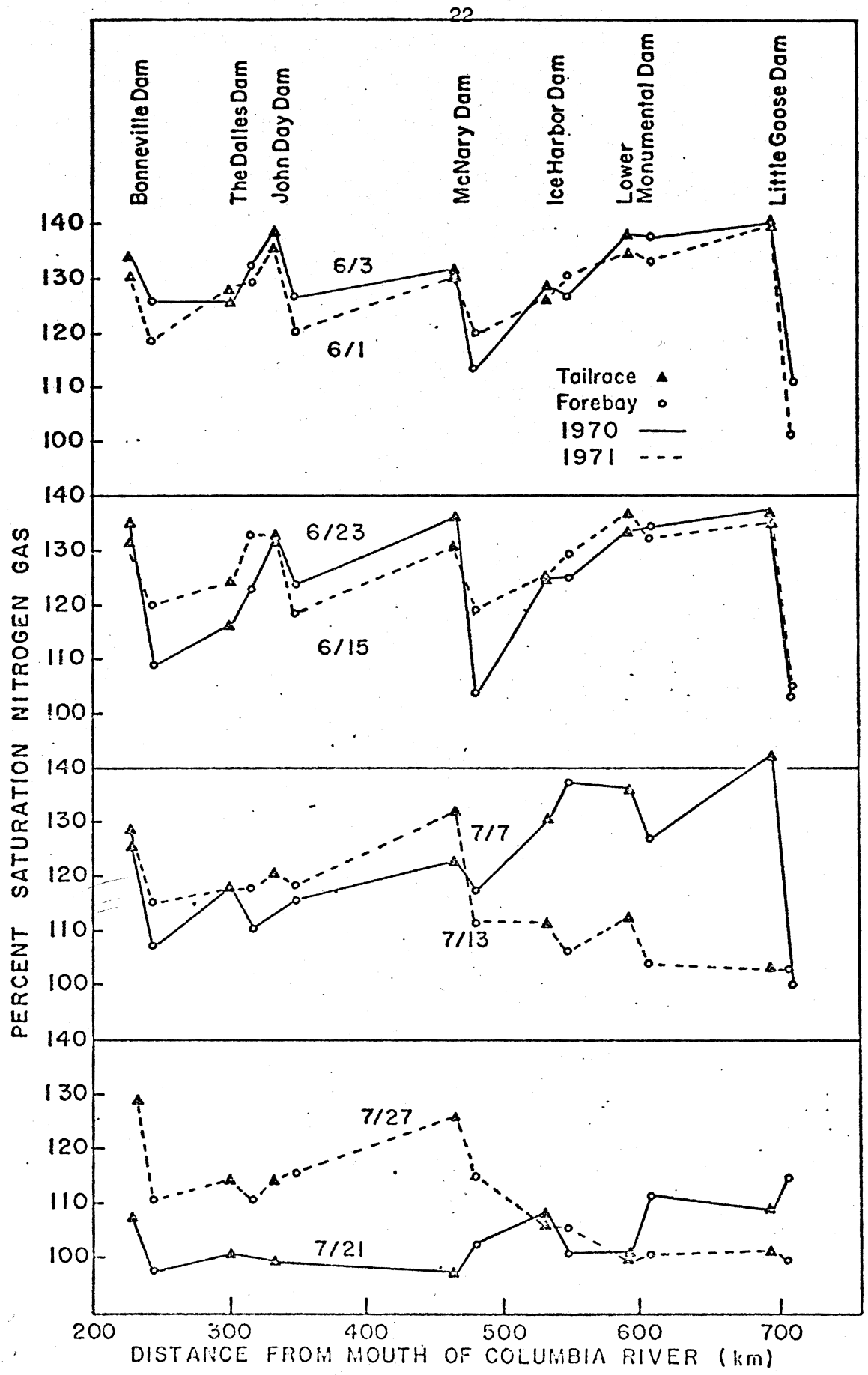

Figure 4.--Continued

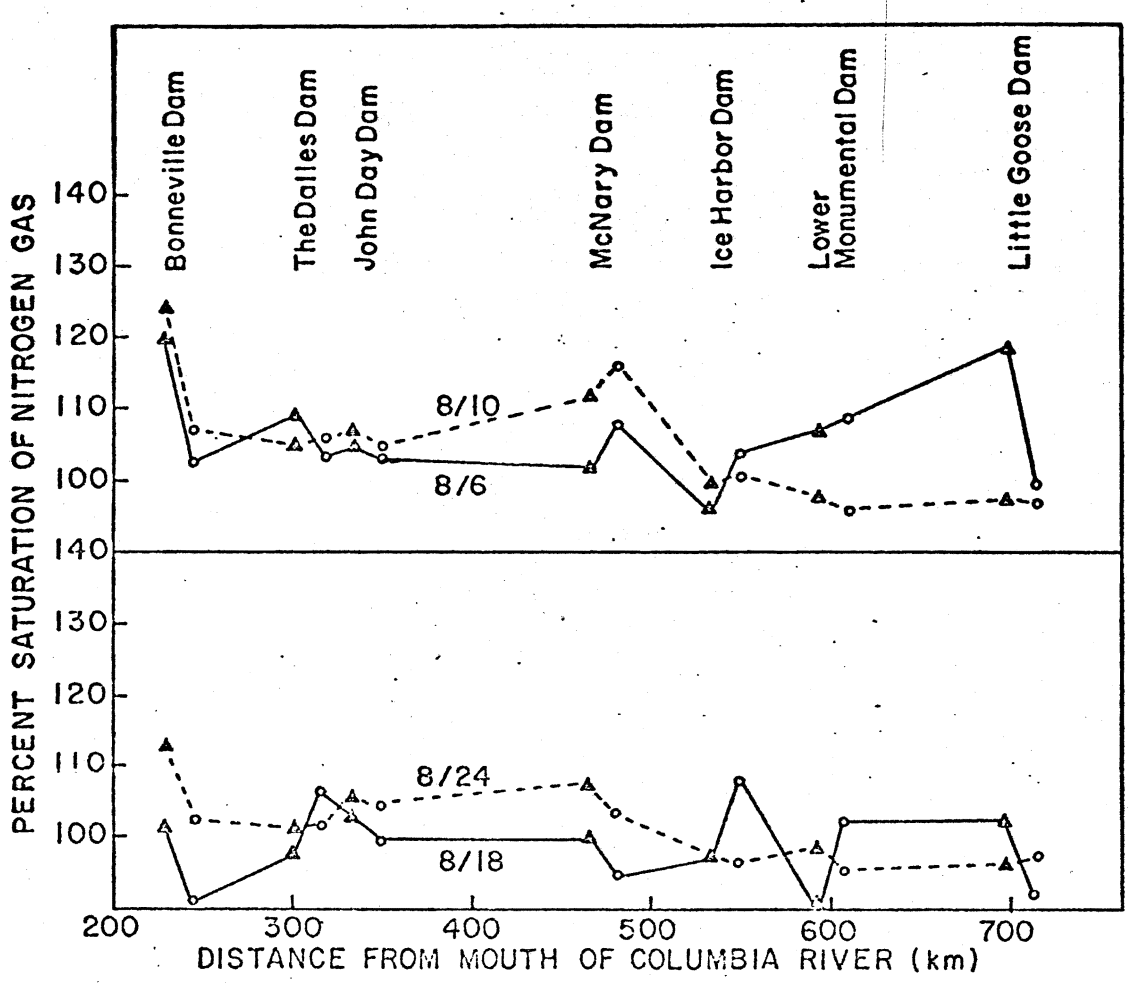

Figure 4.--Continued

However, from mid-May to August 10, the concentrations of nitrogen gas in the Snake River were slightly lower than concentrations recorded in 1970 in spite of the higher flows, reflecting the benefit achieved from the additional turbines and the load control measures instituted at that time. The flow and load control measures did not reduce the nitrogen concentrations in the Snake during early April because of the decision of the task force committee to continue spilling at Brownlee Dam and hold this reservoir down for flow control at a later date when the peak juvenile migrations in the Snake coincided with planned early releases of hatchery fish in the lower river. Storage at Brownlee began on April 26 and lasted about 3 days. Reduction in flow in the Snake and the Columbia Rivers during late April measurably reduced the concentrations of nitrogen in the lower Columbia (Prescott) as indicated in Table 5. Before flow control, average concentration was 112 percent saturation; after flow control, 108 percent. Although we were unable to sample the Snake River at that time, daily records of the percentage of juvenile chinook with gas bubble disease at Ice Harbor Dam indicate a dramatic effect. For example, the average percentage of chinook with symptoms of gas bubble disease 7 days prior to flow control was 17.5 as compared to 7.2 during the flow control period, a reduction of 59 percent.

Effect of Slotted Gates

On May 10, 11, and 13 we sampled upstream and downstream from the slotted gates installed in unit 6 at Little Goose Dam. The results of these analyses (Table 6) indicate that the slotted gates successfully passed appreciable flows through the skeleton bays without supersaturating the water with nitrogen gas.

TABLE 5.--Average concentration of dissolved nitrogen before and during flow control in the Columbia River at Prescott, Oregon.

Date	Nitrogen	Mean daily flow at Bonneville
	Percent Saturation	(KCFS)
	Before Flow Control	
April 21	114	286.6
April 22	110	296.6
April 23	-	276.6
April 25	113	273.4
April 26	112	225.3
April 27	113	181.0
Average	112	
	During Flow Control	
April 28	110	186.3
April 29	107	196.3
April 30	107	203.9
May 1	108	273.3
May 2	108	317.4
Average	108	

TABLE 6.—Percent saturation of dissolved nitrogen in samples taken upstream and downstream from the slotted gates at Little Goose Dam, May 10-13, 1971. Tailrace concentration below turbines and spillway shown for comparison.

Date	Sample location	Depth	Temperature	River flow	Nitrogen
		m.	C.	KCFS	Percent saturation
May 10	Forebay	15.0	11.7	214.7	109.5
	Tailrace Turbine No. 1	0.5	11.9	214.7	105.9
May 11	Forebay	15.0	11.7	214.7	106.9
	Forebay	0.5	11.7	214.7	106.2
	Tailrace below slotted gate	0.5	11.7	214.7	106.2
	Tailrace below slotted gate in backroll	0.5	11.9	214.7	104.2
May 13	Forebay	15.0	11.9	224.8	105.6
	Forebay	0.5	11.9	224.8	105.1
	Tailrace below slotted gate in backroll	0.5	11.9	224.8	106.3
	Tailrace spillway side 500 m downstream	0.5	11.9	224.8	138.7

Estimation values (106.2-106.3) measured in the tailrace downstream from the slotted gates were not significantly different from those (105.6-109.5) measured in the forebay above.

Effect of Nitrogen Supersaturation on Fish

Nitrogen saturation levels in the tailrace of Lower Monumental Dam are plotted (Figure 5) in relation to percentage symptoms of gas bubble disease in chinook and steelhead samples collected at Ice Harbor Dam. Temperature of the forebay of Ice Harbor Dam and sample size, which reflects total population passing Ice Harbor Dam, are also plotted. Tailrace concentrations at Lower Monumental Dam remained high (above 125% saturation) from April 8 to July 1, the last data shown. Percentage symptoms of gas bubble disease in chinook and steelhead fluctuated, but a regression line drawn through the points shows a general increase in percentage symptoms from April 8 on. The increase in gas bubble symptoms appears to be correlated with increases in temperature and nitrogen levels, indicating the synergistic effect of nitrogen supersaturation and temperature increase. Similar relationships were evidenced in previous laboratory studies by the National Marine Fisheries service (Ebel et al., 1971).

The grouped sample size data indicates that the majority of both populations (chinook and steelhead) passed Ice Harbor Dam before the index of gas bubble symptoms exceeded 25 percent which helps verify data shown later which indicates survival of the populations of juvenile chinook migrating in the Snake River was about 20 percent better than last year.

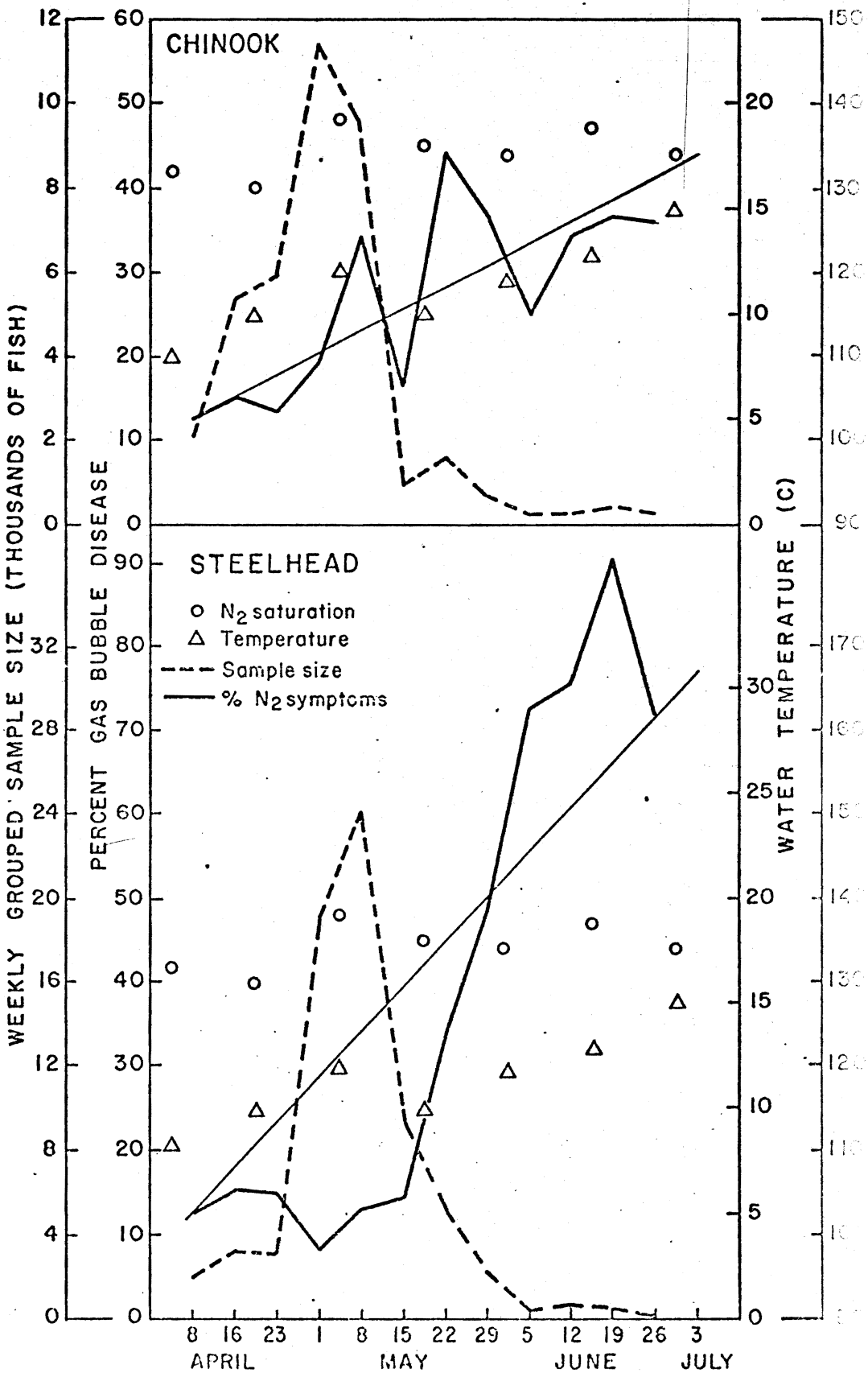

Figure 5.--Percentage gas bubble disease symptoms in juvenile [illegible] and chinook in relation to nitrogen concentrations and temper[illegible] of tailrace samples at Lower Monumental Dam. Sample size re[illegible] magnitude of the migrating populations is also shown.

Live-cage tests at Ice Harbor with steelhead smolts (Table 7) indicated that mortality in the deep cage--which allows the fish to seek depths to 4.5 m--ranged between 36 and 73 percent from May 4 to June 9. This is nearly identical to the results recorded last year when various stocks of chinook were tested. Mortality of chinook in the same cage under similar levels of nitrogen and temperature was 45-68 percent. It is interesting to note that survival of the individuals in the last test (No. 3) was best even though nitrogen levels were slightly higher than the first 2 tests. One explanation might be that the individuals used in the last test were more resistant to nitrogen. Migrants used in the last test were almost entirely from wild stocks, whereas those in the earlier tests were primarily fish originating from the Dworshak hatchery.

These tests, of course, indicate that substantial losses must have occurred among the steelhead populations migrating in the Snake River. Estimates in the following section verify this.

TABLE 7.--Mortality of naturally migrating juvenile steelhead collected at Ice Harbor and held in cages at various depths in the forebay of the Ice Harbor Dam, 4 May - 9 June, 1971.

Holding time	Cage depth (m) and mortality (%)			
	Surface	.75 - 1.0 m	3.0 - 4.0 m	0 - 4.5 m
Test No. 1 1/, May 4 - May 11, 1971				
24 hrs	100	77	-	-
48 hrs	-	100	-	-
7 days	-	-	22	68
Test No. 2 2/, May 19 - May 25, 1971				
24 hrs	100	94	-	-
48 hrs	-	100	-	-
7 days	-	-	0	73
Test No. 3 3/, June 2 - June 9, 1971				
24 hrs	95	89	-	-
48 hrs	100	100	-	-
7 days	-	-	13	36

1/ Water temperature and nitrogen concentration at start: 12.1° C and 127 percent of saturation; at end, 11.5° C and 123 percent of saturation.

2/ Water temperature and nitrogen concentration at start: 10.0° C and 123 percent of saturation; at end 10.0° C and 127 percent of saturation.

3/ Water temperature and nitrogen concentration at start: 11.6° C and 131 percent of saturation; at end 11.6° C and 125 percent of saturation.

SURVIVAL AND TIMING OF JUVENILE CHINOOK AND STEELHEAD POPULATIONS MIGRATING IN THE SNAKE RIVER

Timing and survival measurements, as in 1970, were based primarily on recoveries at Ice Harbor Dam of fish collected, marked, and released at Riggins on the Salmon River. Marks were changed every 3 days to obtain a measure of timing and differences in survival throughout the outmigration. Additional data was available from releases of marked fish from hatcheries and control releases of marked fish at Central Ferry from fish collected at Little Goose Dam.

Estimates of survival of migrants are based on a comparison of the observed recovery percentage of a marked fish release group with the expected recovery percentage based on independent experiments at Ice Harbor Dam. Numbers of fish marked and subsequently recovered at Little Goose and Ice Harbor Dams are given in Table 8.

Survival Estimates of Chinook Salmon

Chinook from the Salmon River migrated faster and survival was slightly better to Ice Harbor Dam in 1971 than in 1970. Travel time averaged 17 days and the peak of migration at Ice Harbor occurred on May 4 compared to 25 days and May 13 in 1970 (Table 9).

TABLE 8.--Number of fish marked and subsequently recovered at Little Goose and Ice Harbor Dams.

Release area	Species	No. marked	No. recovered	
			Little Goose	Ice Harbor
Riggins (wild)	Chinook	53,000	1,934	503
Rapid River (Hatchery)	Chinook	250,000	5,480	944
Pahsimeroi River (Niagara Hatchery)	Steelhead	100,000	773	28
Clearwater River (Dworshak Hatchery)	Steelhead	544,000	13,629	6,158
Hayden Creek	Steelhead	25,000	28	0
Central Ferry (Little Goose control)	Chinook	21,400	744	95
	Steelhead	37,000	2,597	729

TABLE 9.--Average travel time and migration peak for juvenile chinook salmon from the Salmon River to Ice Harbor Dam (1966-1971).

Year	Travel time (days)	Ice Harbor Dam	
		Peak of migration	Water flow
1966	14	4/27	48,000
1967	17	5/3	42,000
1968	16	4/26	37,000
1969			
1970	25	5/13	88,000
1971	17	5/4	188,000

Trap on Salmon River not operated in 1969.

Average water flows in 1971 were much higher than in any of the previous years of this study. Research by Raymond (1968) has shown a relation between river discharge and rate of migration (i.e., the greater the volume of discharge the faster the migration rate of the fish). Therefore, we assume that the faster average travel time recorded in 1971 was attributable to the higher flow.

Survival of chinook from the Salmon River to Ice Harbor Dam was 48% in 1971 compared to 30% in 1970. The lower mortality indicated in 1971 was probably a result of the chinook traveling faster, thus being exposed for less time to high N_2 levels. Holding experiments by Ebel (1971) have indicated increases of mortalities by N_2 with increased exposure time. As shown in Table 10, survival of the early release groups with an average travel time of 26 days was 33-40%, comparable to the travel time and survival in 1970: survival increased to 52% for these fish only requiring 13 days to travel to Ice Harbor Dam. Since most of the fish were in the latter group, overall survival averaged 48%. Based on those data, and the high incidence of gas bubble symptoms on the fish, additional exposure to high nitrogen in the Columbia River may result in a total mortality to the estuary as high as the loss indicated in 1970.

TABLE 10.--Survival, timing, and travel time of juvenile chinook from the Salmon River for varying water flows (1971).

Water flow (1,000 of cfs)	Survival (%)	Travel time	Timing (Median fish)
117	33	23	4/21
100	40	26	4/27
117	37	26	4/30
117	37	20	5/1
211	52	15	5/5
211	52	13	5/6
220	57	13	5/11
220	44	10	5/11
Average 188	48	17	5/5

Survival Estimates of Steelhead Trout

Insufficient native steelhead were collected and marked in the Salmon River to obtain an estimate of their survival. Large releases of steelhead from the Dworshak and Niagara hatcheries did, however, provide a basis for survival estimates of this species.

Survival in 1971 from both hatcheries declined significantly over 1970 (Table 11). The decrease in survival was not entirely caused by high N_2 in the river but probably reflected condition and movement of the fish at the time of release. In 1970 both groups (Dworshak and Niagara) moved out and left their respective streams (Clearwater and Pahsimeroi Rivers) in good numbers. In 1971 information from Idaho Fish and Game indicated that most of the release in the Clearwater River left but only 50% of the release left the Pahsimeroi River. Also, in 1971, 45% of the steelhead from Dworshak were released on March 15 and 55% on April 19, yet both groups arrived at Ice Harbor Dam at about the same time.

Measured survival to Little Goose Dam (upstream from the high concentrations of dissolved nitrogen) was 40% for steelhead from the Dworshak Hatchery and 67%[1/] for fish from Niagara Hatchery. Indicated losses between Little Goose and Ice Harbor Dam, where the N_2 was highest, were 25% for Dworshak steelhead (about the same as 1970) and 85% for steelhead from Niagara Hatchery. Timing of the downstream migration of the two groups may explain their differences in survival. Peak migration at Ice Harbor of the steelhead from Dworshak was May 7 compared to June 7 for steelhead from the Niagara Hatchery. Symptoms of gas bubble disease in steelhead migrants at Ice Harbor were far more prevalent in early June than in early May. Thus it would appear that the stresses on fish migrating in early June were greater than those in the previous month and, as a result, survival declined markedly.

1/ Assuming 50% of the Niagara stock remained upstream.

TABLE 11.-Survival of steelhead from Dworshak and Niagara hatcheries to Ice Harbor Dam 1970 and 1971.

	1970	1971
Dworshak	75	30
Niagara	50	5

SUMMARY AND CONCLUSIONS

The results of the National Marine Fishery Service's research conducted in conjunction with the Corps of Engineers effort to reduce losses of migrating salmon and steelhead are summarized as follows:

1. Tests on the diversion of migrants from the turbine intakes with the traveling screens indicated that from 81 to 97 percent of the chinook and steelhead entering the intake were diverted into the gatewells for bypass. Difficulties with the traveling screens were the direct result of various breakdowns of the drive system of the screens. Extensive redesign and modification was completed after termination of the fish run. These changes are presently being tested; the results to date indicate that the drive system problems are solved.

Tests of lighted orifice inserts indicated that passage was improved when the bell-mouth orifice was restricted and lighted, but further testing during peak time of migration is needed to fully evaluate the orifice insert.

2. The collection, holding, handling and transporting systems at Little Goose Dam operated with notable precision. Approximately 255,000 chinook and steelhead were marked for experimental releases. A grand total of 383,000 chinook and steelhead were handled at Little Goose and Ice Harbor Dams; of these, about 285,000 were transported downstream. Mortality during transport of the various groups was insignificant, but some delayed mortality of chinook was indicated by post release holding tests. Overall downstream survival of the various groups was not determined because of insufficient data from purse seine catches in the estuary. Evaluation of the experimental releases will be based on returning adults in 1972 and 1973.

3. Nitrogen concentrations in the Snake and Columbia Rivers were higher in April and early May in 1971 than in 1970 in spite of the measures taken by the Corps of Engineers to reduce the levels of nitrogen supersaturation. Concentrations in the Snake after mid-May were about the same or slightly lower than those of 1970. Flow control measures begun on April 26 were successful in reducing the concentrations of dissolved nitrogen for about 1 week. The prototype slotted gate tested at Little Goose was 100 percent successful in passing water through the skeleton bays without increasing the nitrogen content. Observations of the effect of supersaturation on fish indicated that significant losses to juvenile populations of steelhead and chinook must have occurred.

4. Survival estimates of juvenile chinook migrating in the Snake River indicated an increase in survival of 20 percent over last year with an overall survival estimate of 48 percent. A precise estimate of juvenile steelhead populations was difficult to make because of the apparent difference in behavior among the various stocks. Survival estimates of two hatchery stocks of steelhead, although not precise, did indicate that substantial losses occurred. The increase in survival of the chinook migrants was most likely due to the faster travel time resulting in a much shorter exposure to the high concentrations of nitrogen.

Although the total collection of fish fell below our expectations because of extremely high flows and mechanical breakdowns of the traveling screens, we consider the results of the past season more than moderately successful.

LITERATURE CITED

BEININGEN, K. T., AND W. J. EBEL.

1970. Effect of John Day Dam on dissolved nitrogen concentrations and salmon in the Columbia River, 1968. Trans. Am. Fish. Soc. 99: 664-671.

EBEL, W. J.

1971. Dissolved Nitrogen Concentrations in the Columbia and Snake Rivers in 1970 and their effect on chinook salmon and steelhead trout. Natl. Mar. Fish. Serv. Spec. Sci. Rep. In press.

1971. Thermal tolerance of juvenile salmon in relation to nitrogen supersaturation. Natl. Mar. Fish. Serv. Fish Bull. In press.

RAYMOND, H. L.

1971. Survival and timing of the 1970 and 1971 migration of juvenile chinook salmon and steelhead trout from the Snake River. Natl. Mar. Fish. Serv., Biol. Lab., Seattle, Wash. (unpublished manuscript).

1968. Migration rates of yearling chinook salmon in relation to flows and impoundments in the Columbia and Snake Rivers. Trans. Am. Fish. Soc. 97: 356-359.

Appendix Table 1.--Concentrations of dissolved nitrogen and oxygen gas and related water temperatures and stream flows in the Columbia and Snake Rivers, 4 April to 10 August 1971.

LOCATION	DATE MO	DY	YR	TIME	DEPTH FEET	TEMP DEG C	MEAN DAILY FLOW SPILL KCFS	GATE OPEN	TOTAL KCFS	OXYGEN PPM	OXYGEN SAT	NITROGEN PPM	NITROGEN SAT
COLUMBIA RIVER													
ABOVE MOUTH SNAKE	04	20	71	01040	000	07.4		00		13.30	110.6	21.40	108.4
LWR MONUMENT FOREBAY													
1/4 MI UP CENTER	04	20	71	00943	000	09.8		08		14.00	123.7	24.60	131.4
LWR MONUMENT FOREBAY													
1/4 MI UP CENTER	04	20	71	00943	033	09.8		08		14.10	124.6	24.90	132.9
LWR MONUMENT FOREBAY													
1/4 MI UP CENTER	04	20	71	00900	000	09.4		07		11.30	098.8	19.40	102.7
LITTLE GOOSE FOREBAY													
1/4 MI UP CENTER	04	20	71	00900	033	09.4		07		11.20	097.9	20.10	106.3
LITTLE GOOSE TAILRACE													
1/4 MI DN SPILL SIDE	04	20	71	00919	000	09.4		07		14.10	123.3	24.90	131.7
LWR MONUMENT TAILRACE													
SPILL SIDE	04	20	71	00957	000	09.9		08		14.10	124.8	24.30	129.9
ICE HARBOR TAILRACE													
1/2 MI DN SPILL SIDE	04	20	71	01030	000	10.2		09		13.80	122.6	00.00	000.0
MCNARY DAM FOREBAY													
1/4 MI UP SPILL SIDE	04	20	71	01148	000	09.3		03		00.00	000.0	00.00	000.0
MCNARY DAM FOREBAY													
1/4 MI UP SPILL SIDE	04	20	71	01148	033	09.2		03		13.10	114.4	00.00	000.0
MCNARY DAM FOREBAY													
1/4 MI UP POWER SIDE	04	20	71	01200	000	08.7		03		00.00	000.0	00.00	000.0
MCNARY DAM FOREBAY													
1/4 MI UP POWER SIDE	04	20	71	01200	033	08.6		03		13.20	113.1	22.20	115.6
MCNARY TAILRACE													
1/4 MI DN POWER SIDE	04	20	71	01220	000	09.8		03		00.00	000.0	00.00	000.0
MCNARY TAILRACE													
1/4 MI DN SPILL SIDE	04	20	71	01245	000	09.1		03		00.00	000.0	00.00	000.0
JOHN DAY FOREBAY													
1/4 MI UP CNTR	04	20	71	01400	000	09.0		00		00.00	000.0	00.00	000.0
JOHN DAY FOREBAY													
1/4 MI UP CNTR	04	20	71	01400	033	09.0		00		13.00	112.6	21.50	113.0
JOHN DAY TAILRACE													
POWER SIDE	04	20	71	01415	000	08.8		00		12.73	109.6	21.20	110.7

ppendix Table 1.--Continued.

LOCATION	DATE MO DY YR	TIME	DEPTH FEET	TEMP DEG C	MEAN DAILY FLOW SPILL KCFS	GATE OPEN	TOTAL KCFS	OXYGEN PPM	OXYGEN SAT	NITROGEN PPM	NITROGEN SAT
HE DALLES FOREBAY 1/4 MI UP CENTER	04 20 71	01427	000	08.7		23		12.50	107.8	21.20	110.7
HE DALLES FOREBAY 1/4 MI UP CENTER	04 20 71	01427	033	08.7		23		12.60	108.2	21.10	110.1
HE DALLES TAILRACE 1/2 MI DN SPILL SIDE	04 20 71	01450	000	08.8		23		12.70	109.5	21.90	114.4
ONNEVILLE FOREBAY POWER SIDE	04 20 71	01521	000	08.8		18		12.30	105.9	20.50	107.2
ONNEVILLE FOREBAY POWER SIDE	04 20 71	01521	033	08.8		18		12.10	104.2	20.20	105.6
ONNEVILLE TAILRACE 1/4 MI DN SPILL SIDE	04 20 71	01528	000	08.8		18		14.30	123.1	24.00	124.6
OLUMBIA RIVER WASHOUGAL CNTR	04 20 71	01500	000	09.2		00		13.40	116.3	23.50	124.0
OLUMBIA RIVER PRESCOTT CENTER	04 20 71	01100	000	09.5		00		12.60	110.1	21.60	114.5
OLUMBIA HARRINGTON PT -ESTUARY	04 20 71	01000	000	09.1		00		12.20	105.5	19.80	104.2
OLUMBIA RIVER VANCOUVER-I5	04 20 71	01600	000	09.3		00		13.30	116.0	23.10	122.0

Appendix Table 1.--Continued.

LOCATION	DATE MO	DY	YR	TIME	DEPTH FT.	TEMP °C	HOURLY FLOW SPILL KCFS	GATE OPEN	TOTAL KCFS	OXYGEN PPM	OXYGEN SAT	NITROGEN PPM	NITROGEN SAT
ITTLE GOOSE FOREBAY	5	4	71	1542	0	11.6	131.6	6	199.0	10.5	96.8	18.7	103.4
ITTLE GOOSE FOREBAY	5	4	71	1542	33	11.6	131.6	6	199.0	10.6	97.1	18.6	102.4
ITTLE GOOSE TAILRACE	5	4	71	1554	0	11.6	131.6	6	199.0	13.6	125.7	24.6	136.2
OWER MONUMENT FOREBAY	5	4	71	1636	0	11.9	125.6	8	196.2	13.0	120.7	23.3	130.1
OWER MONUMENT FOREBAY	5	4	71	1636	33	11.8	125.6	8	196.2	13.3	123.1	24.3	134.9
OWER MONUMENT 1/2 MI DOWN FR TAILRACE	5	4	71	1650	0	11.8	125.6	8	196.2	13.7	127.1	24.8	137.7
CE HARBOR FOREBAY SPILL SIDE	5	4	71	1714	0	12.2	139.3	10	187.1	12.8	119.6	22.6	126.4
CE HARBOR FOREBAY SPILL SIDE	5	4	71	1714	33	12.1	139.3	10	187.1	13.0	121.5	22.8	127.6
CE HARBOR TAILRACE 1/4 MI DOWNSTREAM	5	4	71	1722	0	12.0	139.3	10	187.1	12.7	118.7	22.4	125.3
OLUMBIA ABOVE SNAKE MOUTH	5	4	71	1732	0	11.1	0.0	0	0.0	12.8	117.3	20.5	112.3
CNARY FOREBAY SPILL SIDE	5	4	71	1440	0	11.7	198.0	18	433.3	12.4	114.7	19.8	109.8
CNARY FOREBAY SPILL SIDE	5	4	71	1440	33	11.8	198.0	18	433.3	12.7	117.6	20.1	111.6
CNARY FOREBAY POWERHOUSE SIDE (Oregon)	5	4	71	1452	0	11.2	198.0	18	433.3	12.8	116.9	21.7	119.0
CNARY FOREBAY POWERHOUSE SIDE (Wash)	5	4	71	1452	33	11.0	198.0	18	433.3	12.9	117.4	21.8	119.3
CNARY TAILRACE SPILL SIDE	5	4	71	1330	0	11.3	198.0	18	433.3	13.8	126.7	24.5	134.8
CNARY TAILRACE POWERHOUSE SIDE	5	4	71	1339	0	11.1	198.0	18	433.3	12.9	117.5	21.5	117.9
OHN DAY FOREBAY CENTER	5	4	71	1250	0	11.3	194.2	20	445.6	11.3	103.4	19.1	105.0
OHN DAY FOREBAY CENTER	5	4	71	1250	33	11.2	194.2	20	445.6	11.4	104.1	19.4	106.4

rpendix Table 1.--Continued

LOCATION	DATE MO	DY	YR	TIME	DEPTH FT.	TEMP C	HOURLY FLOW SPILL KCFS	GATE OPEN	TOTAL KCFS	OXYGEN PPM	OXYGEN SAT	NITROGEN PPM	NITROGEN SAT
OHN DAY TAILRACE													
SPILL SIDE	5	4	71	1240	0	11.3	194.2	20	445.6	11.7	107.2	19.8	109.0
ALLES FOREPAY	5	4	71	1220	0	11.3	250.7	23	450.5	12.7	116.2	21.9	120.4
ALLES FOREBAY	5	4	71	1220	33	11.2	250.7	23	450.5	12.7	116.2	21.7	119.2
ALLES TAILRACE													
SPILL SIDE	5	4	71	1210	0	11.4	250.7	23	450.5	12.3	113.0	21.4	117.9
ONNEVILLE RESERVOIR	5	4	71	1140	0	11.0	287.7	18	434.5	11.4	103.6	19.8	108.3
ONNEVILLE RESERVOIR	5	4	71	1140	33	11.0	287.7	18	434.5	11.5	104.5	19.8	108.3
ONNEVILLE DOWNSTREAM	5	4	71	1130	0	11.2	287.7	18	434.5	13.2	121.3	23.6	129.5
OLUMBIA WASHOUGAL	5	4	71	1400	0	11.4	0.0	0	0.0	13.5	124.7	23.6	130.0
OLUMBIA VANCOUVER	5	4	71	1430	0	11.2	0.0	0	0.0	13.4	122.6	23.4	129.0
OLUMBIA PRESCOTT	5	4	71	1034	0	11.3	0.0	0	0.0	12.2	111.8	21.2	116.5
OLUMBIA HARRINGTON PT -ESTUARY	5	4	71	1000	0	11.2	0.0	0	0.0	11.7	107.2	19.8	109.1

pendix.Table 1.--Continued

LOCATION	DATE MO	DY	YR	TIME	DEPTH FEET	TEMP DEG C	HOURLY FLOW SPILL KCFS	GATE OPEN	TOTAL KCFS	OXYGEN PPM	OXYGEN SAT	NITROGEN PPM	NITROGEN SAT
ITTLE GOOSE FOREBAY	5	18	71	925	0	9.5	93.4	7	184.0	11.0	96.8	18.7	99.2
ITTLE GOOSE FOREBAY	5	18	71	925	33	9.5	93.4	7	184.0	11.3	99.3	20.1	106.4
ITTLE GOOSE TAILRACE	5	18	71	945	0	9.6	93.4	7	184.0	14.2	124.9	24.9	132.4
OWER MONUMENT FOREBAY	5	18	71	955	0	10.1	110.7	8	179.3	13.7	122.3	23.2	124.5
OWER MONUMENT FOREBAY	5	18	71	955	33	9.8	110.7	8	179.3	14.3	126.2	23.6	125.9
OWER MONUMENT 1/2 MI DOWN FR TAILRACE	5	18	71	1008	0	9.9	110.7	8	179.3	14.8	131.6	25.1	134.5
CE HARBOR FOREBAY SPILL SIDE	5	18	71	1028	0	10.0	136.0	10	183.4	13.5	120.2	22.9	123.0
CE HARBOR FOREBAY SPILL SIDE	5	18	71	1028	33	10.0	136.0	10	183.4	13.5	119.8	22.8	122.5
CE HARBOR TAILRACE 1/4 MI DOWNSTREAM	5	18	71	1041	0	10.2	136.0	10	183.4	13.8	123.0	23.3	125.2
OLUMBIA ABOVE SNAKE MOUTH	5	18	71	1057	0	10.6	0.0	0	0.0	12.7	114.8	21.1	114.7
CNARY FOREBAY SPILL SIDE	5	18	71	1220	0	11.8	308.8	22	467.9	12.6	117.1	20.7	114.9
CNARY FOREBAY SPILL SIDE	5	18	71	1220	33	10.8	308.8	22	467.9	12.7	115.3	20.9	113.8
CNARY TAILRACE SPILL SIDE	5	18	71	1243	0	11.1	308.8	22	467.9	14.3	130.7	25.6	140.3
CNARY FOREBAY POWERHOUSE SIDE Oregon	5	18	71	1231	0	12.6	308.8	22	467.9	12.6	118.8	20.8	117.1
CNARY FOREBAY POWERHOUSE SIDE	5	18	71	1231	33	10.8	308.8	22	467.9	13.1	118.4	21.9	118.8

pendix Table 1.--Continued

LOCATION	DATE MO	DY	YR	TIME	DEPTH FEET	TEMP DEG C	HOURLY FLOW SPILL KCFS	GATE OPEN	TOTAL KCFS	OXYGEN PPM	OXYGEN SAT	NITROGEN PPM	NITROGEN SAT
MCNARY TAILRACE POWERHOUSE SIDE	5	18	71	1249	0	10.8	308.8	22	467.9	13.1	118.9	23.4	127.5
JOHN DAY FOREBAY CENTER	5	18	71	1332	0	11.6	228.0	20	478.2	11.7	107.8	20.0	110.6
JOHN DAY FOREBAY CENTER	5	18	71	1332	33	11.6	228.0	20	478.2	12.0	110.6	21.0	116.2
JOHN DAY TAILRACE SPILL SIDE	5	18	71	1350	0	11.4	228.0	20	478.2	12.3	113.0	21.1	116.3
DALLES FOREBAY	5	18	71	1405	0	11.5	279.0	23	476.4	13.6	125.1	23.5	129.8
DALLES FOREBAY	5	18	71	1405	33	11.6	279.0	23	476.4	13.3	122.5	23.0	127.1
DALLES TAILRACE SPILL SIDE	5	18	71	1416	0	11.6	279.0	23	476.4	13.5	124.4	22.7	125.6
BONNEVILLE RESERVOIR	5	18	71	1448	0	11.9	350.3	14	495.5	12.9	120.2	21.9	121.9
BONNEVILLE RESERVOIR	5	18	71	1448	33	11.9	350.3	14	495.5	13.1	121.6	22.9	127.4
BONNEVILLE DOWNSTREAM	5	18	71	1455	0	12.0	350.3	14	495.5	13.8	129.2	23.7	132.2
COLUMBIA PRESCOTT	5	18	71	1647	0	12.4	0.0	0	0.0	12.2	114.8	21.5	120.6
COLUMBIA HARRINGTON PT -ESTUARY	5	18	71	1619	0	12.8	0.0	0	0.0	12.1	115.3	21.3	120.6

Appendix Table 1.--Continued

LOCATION	DATE MO	DY	YR	TIME	DEPTH FEET	TEMP DEG C	HOURLY FLOW SPILL KCFS	GATE OPEN	TOTAL KCFS	OXYGEN PPM	OXYGEN SAT	NITROGEN PPM	NITROGEN SAT
LITTLE GOOSE FOREBAY	6	1	71	1443	0	9.8	118.7	8	196.0	11.50	101.5	19.00	101.4
LITTLE GOOSE FOREBAY	6	1	71	1443	33	9.6	118.7	8	196.0	11.44	100.5	19.10	101.5
LITTLE GOOSE TAILRACE	6	1	71	1455	0	9.8	118.7	8	196.0	14.94	131.9	26.14	139.5
LOWER MONUMENT FOREBAY	6	1	71	1513	0	10.8	143.5	8	193.5	14.00	126.6	24.40	132.9
LOWER MONUMENT FOREBAY	6	1	71	1513	33	10.7	143.5	8	193.5	14.00	126.4	24.50	133.2
LOWER MONUMENT 1/2 MI DOWN FR TAILRACE	6	1	71	1522	0	10.8	143.5	8	193.5	14.20	128.4	24.62	134.1
ICE HARBOR FOREBAY SPILL SIDE	6	1	71	1542	0	11.6	157.3	10	191.2	13.90	128.1	23.70	131.1
ICE HARBOR FOREBAY SPILL SIDE	6	1	71	1542	33	11.6	157.3	10	191.2	13.90	128.1	23.70	131.1
ICE HARBOR TAILRACE 1/4 MI DOWNSTREAM	6	1	71	1550	0	11.7	157.3	10	191.2	13.54	125.1	22.80	126.4
COLUMBIA ABOVE SNAKE MOUTH	6	1	71	1601	0	11.6	0.0	0	0.0	12.85	118.4	21.06	116.5
MCNARY FOREBAY SPILL SIDE	6	1	71	1349	0	12.8	274.5	17	479.1	12.00	113.7	20.10	113.8
MCNARY FOREBAY SPILL SIDE	6	1	71	1349	33	12.0	274.5	17	479.1	11.90	110.7	20.40	113.1
MCNARY TAILRACE SPILL SIDE	6	1	71	1255	0	12.2	274.5	17	479.1	13.83	129.3	23.30	130.1
MCNARY FOREBAY POWERHOUSE SIDE Oregon	6	1	71	1356	0	13.0	274.5	17	479.1	12.80	121.9	21.60	122.1

pendix Table 1.--Continued

LOCATION	DATE MO	DY	YR	TIME	DEPTH FEET	TEMP DEG C	HOURLY FLOW SPILL KCFS	GATE OPEN	TOTAL KCFS	OXYGEN PPM	OXYGEN SAT	NITROGEN PPM	NITROGEN SAT
MCNARY FOREBAY POWERHOUSE SIDE	6	1	71	1356	33	11.9	274.5	17	479.1	12.85	118.9	21.60	120.1
MCNARY TAILRACE POWERHOUSE SIDE wash	6	1	71	1301	0	12.0	274.5	17	479.1	12.83	119.3	21.80	121.5
JOHN DAY FOREBAY CENTER	6	1	71	1215	0	13.4	250.0	20	500.0	12.20	117.3	21.10	120.7
JOHN DAY FOREBAY CENTER	6	1	71	1215	33	13.1	250.0	20	500.0	12.30	117.4	21.20	120.6
JOHN DAY TAILRACE SPILL SIDE	6	1	71	1200	0	13.2	250.0	20	500.0	14.06	134.5	23.80	135.7
DALLES FOREBAY	6	1	71	1144	0	13.1	320.4	23	505.5	13.20	126.0	22.90	130.1
DALLES FOREBAY	6	1	71	1144	33	13.1	320.4	23	505.5	12.70	121.2	22.80	129.7
DALLES TAILRACE SPILL SIDE	6	1	71	1135	0	13.1	320.4	23	505.5	13.12	125.2	22.50	128.0
BONNEVILLE RESERVOIR	6	1	71	1107	0	13.1	378.3	18	512.3	12.70	121.2	21.00	119.5
BONNEVILLE RESERVOIR	6	1	71	1107	33	13.1	378.3	18	512.3	12.40	118.3	20.90	118.9
BONNEVILLE DOWNSTREAM	6	1	71	1100	0	13.2	378.3	18	512.3	13.35	127.8	23.03	131.1
COLUMBIA PRESCOTT	6	1	71	1005	0	13.1	0.0	0	0.0	11.75	112.1	20.90	118.9
COLUMBIA HARRINGTON PT -ESTUARY	6	1	71	0935	0	12.7	0.0	0	0.0	11.38	107.7	20.75	117.1

pendix Table 1.--Continued.

LOCATION	DATE MO	DY	YR	TIME	DEPTH FEET	TEMP DEG C	HOURLY FLOW SPILL KCFS	GATE OPEN	TOTAL KCFS	OXYGEN PPM	OXYGEN SAT	NITROGEN PPM	NITROGEN SAT
LITTLE GOOSE FOREBAY 1/4 MI UP CENTER	6	15	71	920	0	13.0	119.9	8	187.1	10.42	99.0	17.80	101.1
LITTLE GOOSE FOREBAY 1/4 MI UP CENTER	6	15	71	920	33	12.9	119.9	8	187.1	11.29	107.3	18.36	104.1
LITTLE GOOSE TAILRACE 1/4 MI DN SPILL SIDE	6	15	71	936	0	13.0	119.9	8	187.1	13.68	130.3	23.79	135.2
LWR MONUMENT FOREBAY 1/4 MI UP CENTER	6	15	71	957	0	13.0	142.9	8	190.2	13.20	125.7	23.00	130.7
LWR MONUMENT FOREBAY 1/4 MI UP CENTER	6	15	71	957	33	12.9	142.9	8	190.2	13.40	127.4	23.40	132.7
LWR MONUMENT TAILRACE 1/2 MI DN SPILL SIDE	6	15	71	1005	0	13.0	142.9	8	190.2	13.43	127.9	24.16	137.3
ICE HARBOR FOREBAY 1/4 MI UP CENTER	6	15	71	1027	0	12.9	142.6	10	189.9	13.10	124.5	22.60	128.1
ICE HARBOR FOREBAY 1/4 MI UP CENTER	6	15	71	1027	33	12.8	142.6	10	189.0	13.20	125.1	22.90	129.7
ICE HARBOR TAILRACE 1/2 MI DN SPILL SIDE	6	15	71	1037	0	12.8	142.6	10	189.0	13.37	126.7	22.30	126.3
COLUMBIA RIVER ABOVE MOUTH SNAKE	6	15	71	1047	0	13.0	0.0	0	0.0	12.56	119.6	20.52	116.6
MCNARY DAM FOREBAY 1/4 MI UP SPILL SIDE	6	15	71	1154	0	14.4	274.5	15	467.1	11.80	116.0	19.10	111.4
MCNARY DAM FOREBAY 1/4 MI UP SPILL SIDE	6	15	71	1154	33	13.4	274.5	15	467.1	11.90	114.4	19.50	111.6
MCNARY TAILRACE 1/4 MI DN SPILL SIDE	6	15	71	1215	0	13.6	274.5	15	467.1	13.69	132.1	22.60	129.9
MCNARY DAM FOREBAY 1/4 MI UP POWER SIDE	6	15	71	1205	0	15.0	274.5	15	467.1	12.00	119.6	20.20	119.1
MCNARY DAM FOREBAY 1/4 MI UP POWER SIDE	6	15	71	1205	33	13.4	274.5	15	467.1	12.40	118.9	21.00	120.1
MCNARY TAILRACE 1/4 MI DN POWER SIDE	6	15	71	1221	0	13.5	274.5	15	467.1	12.32	118.7	20.90	119.3
JOHN DAY FOREBAY 1/4 MI UP CNTR	6	15	71	1345	0	14.6	279.4	20	497.1	11.80	116.6	19.90	115.9

pendix Table 1.--Continued

LOCATION	DATE MO	DY	YR	TIME	DEPTH FEET	TEMP DEG C	HOURLY FLOW SPILL KCFS	GATE OPEN	TOTAL KCFS	OXYGEN PPM	OXYGEN SAT	NITROGEN PPM	NITROGEN SAT
JOHN DAY FOREBAY 1/4 MI UP CNTR	6	15	71	1345	33	14.1	279.4	20	497.1	11.90	116.2	20.40	118.3
JOHN DAY ~~FOREBAY~~ Tailrace 1/2 MI DN. Spill Side	6	15	71	1402	0	14.0	279.4	20	497.1	12.95	126.2	23.00	133.1
THE DALLES FOREBAY 1/4 MI UP CENTER	6	15	71	1420	0	14.0	298.3	23	491.5	13.10	127.7	22.50	130.2
THE DALLES FOREBAY 1/4 MI UP CENTER	6	15	71	1420	33	14.0	298.3	23	491.5	13.30	129.6	22.90	132.5
THE DALLES TAILRACE 1/2 MI DN SPILL SIDE	6	15	71	1432	0	14.1	298.3	23	491.5	12.76	124.6	21.40	124.1
BONNEVILLE FOREBAY 1/2 MI UP SPILL SIDE	6	15	71	1520	0	14.2	357.2	18	506.5	12.10	118.4	20.40	118.5
BONNEVILLE FOREBAY 1/2 MI UP SPILL SIDE	6	15	71	1520	33	14.2	357.2	18	506.5	12.30	120.4	20.80	120.9
BONNEVILLE TAILRACE 1/4 MI DN SPILL SIDE	6	15	71	1530	0	14.2	357.2	18	506.5	13.26	129.8	22.68	131.8
COLUMBIA PRESCOTT	6	15	71	1715	0	14.2	0.0	0	0.0	12.02	117.6	20.50	119.1
COLUMBIA HARRINGTON PT -ESTUARY	6	15	71	1650	0	13.6	0.0	0	0.0	12.36	119.3	20.90	120.1

Appendix Table 1.--Continued

LOCATION	DATE MO	DY	YR	TIME	DEPTH FEET	TEMP DEG C	HOURLY FLOW SPILL KCFS	GATE OPEN	TOTAL KCFS	OXYGEN PPM	OXYGEN SAT	NITROGEN PPM	NITROGEN SAT
ITTLE GOOSE FOREBAY 1/4 MI UP CENTER	6	29	71	935	0	13.7	71.5	8	158.5	10.50	101.7	17.70	101.8
ITTLE GOOSE FOREBAY 1/4 MI UP CENTER	6	29	71	935	33	13.7	71.5	8	158.5	10.50	101.7	17.68	101.7
ITTLE GOOSE TAILRACE 1/4 MI DN SPILL SIDE	6	29	71	945	0	13.7	71.5	8	158.5	12.40	120.0	21.85	125.7
WR MONUMENT FOREBAY 1/4 MI UP CENTER	6	29	71	1011	0	14.4	86.8	8	155.3	12.50	122.9	21.70	126.5
WR MONUMENT FOREBAY 1/4 MI UP CENTER	6	29	71	1011	33	14.3	86.8	8	155.3	12.40	121.7	21.40	124.5
WR MONUMENT TAILRACE 1/2 MI DN SPILL SIDE	6	29	71	1018	0	14.3	86.8	8	155.3	13.58	133.3	23.08	134.3
CE HARBOR FOREBAY 1/4 MI UP CENTER	6	29	71	1038	0	15.3	106.8	10	154.1	12.40	124.4	20.90	121.9
CE HARBOR FOREBAY 1/4 MI UP CENTER	6	29	71	1038	33	15.0	106.8	10	154.1	12.30	122.6	20.90	123.2
CE HARBOR TAILRACE 1/2 MI DN SPILL SIDE	6	29	71	1048	0	15.2	106.8	10	154.1	12.90	129.1	21.40	126.6
OLUMBIA RIVER ABOVE MOUTH SNAKE	6	29	71	1055	0	13.8	0.0	0	0.0	12.30	119.3	19.80	114.2
CNARY DAM FOREBAY 1/4 MI UP SPILL SIDE	6	29	71	1112	0	15.0	245.7	22	446.0	12.00	119.6	19.40	114.4
CNARY DAM FOREBAY 1/4 MI UP SPILL SIDE	6	29	71	1112	33	14.4	245.7	22	446.0	12.10	119.0	19.50	113.7
CNARY TAILRACE 1/4 MI DN SPILL SIDE	6	29	71	1125	0	14.6	245.7	22	446.0	13.53	133.7	22.80	133.4
CNARY DAM FOREBAY 1/4 MI UP POWER SIDE	6	29	71	1116	0	14.6	245.7	22	446.0	12.20	120.6	19.40	113.5
CNARY DAM FOREBAY 1/4 MI UP POWER SIDE	6	29	71	1116	33	14.2	245.7	22	446.0	12.00	117.4	19.80	115.1
CNARY TAILRACE 1/4 MI DN POWER SIDE	6	29	71	1128	0	14.3	245.7	22	446.0	11.94	117.2	19.80	115.2
OHN DAY FOREBAY 1/4 MI UP CNTR	6	29	71	1328	0	15.9	244.4	20	435.4	11.60	117.9	19.40	116.2

ppendix Table 1.--Continued

LOCATION	DATE MO	DY	YR	TIME	DEPTH FEET	TEMP DEG C	HOURLY FLOW SPILL KCFS	GATE OPEN	TOTAL KCFS	OXYGEN PPM	OXYGEN SAT	NITROGEN PPM	NITROGEN SAT
JOHN DAY FOREBAY													
1/4 MI UP CNTR	6	29	71	1328	33	15.4	244.4	20	435.4	11.70	117.8	19.70	116.9
JOHN DAY TAILRACE													
1/2 MI DN SPILL SIDE	6	29	71	1340	0	15.3	244.4	20	435.4	13.50	135.4	22.80	135.1
THE DALLES FOREBAY													
1/4 MI UP CENTER	6	29	71	1350	0	15.1	242.0	23	413.2	12.80	127.9	21.90	129.3
THE DALLES FOREBAY													
1/4 MI UP CENTER	6	29	71	1350	33	14.7	242.0	23	413.2	13.00	128.7	22.30	130.7
THE DALLES TAILRACE													
1/2 MI DN SPILL SIDE	6	29	71	1400	0	15.4	242.0	23	413.2	12.80	128.6	21.00	124.6
BONNEVILLE FOREBAY													
1/2 MI UP SPILL SIDE	6	29	71	1445	0	15.0	295.6	18	446.3	11.90	118.6	19.80	116.8
BONNEVILLE FOREBAY													
1/2 MI UP SPILL SIDE	6	29	71	1445	33	15.9	295.6	18	446.3	12.00	122.0	20.00	119.8
BONNEVILLE TAILRACE													
1/4 MI DN SPILL SIDE	6	29	71	1450	0	15.5	295.6	18	446.3	12.85	129.5	22.22	132.2
COLUMBIA RIVER													
PRESCOTT CENTER	6	29	71	1630	0	15.8	0.0	0	0.0	11.42	115.8	19.80	118.4
COLUMBIA													
HARRINGTON PT -ESTUARY	6	29	71	1606	0	15.4	0.0	0	0.0	11.78	118.4	20.19	119.8

pendix Table 1.--Continued

LOCATION	DATE MO DY YR	TIME	DEPTH FEET	TEMP DEG C	HOURLY FLOW SPILL KCFS	HOURLY FLOW GATE OPEN	HOURLY FLOW TOTAL KCFS	OXYGEN PPM	OXYGEN SAT	NITROGEN PPM	NITROGEN SAT
.ITTLE GOOSE FOREBAY											
1/4 MI UP CENTER	7 13 71	0939	0	18.6	0.0	0	72.3	10.20	109.8	16.40	102.8
.ITTLE GOOSE FOREBAY											
1/4 MI UP CENTER	7 13 71	0939	33	17.2	0.0	0	72.3	9.90	103.6	16.84	103.1
.ITTLE GOOSE TAILRACE											
1/4 MI DN SPILL SIDE	7 13 71	0950	0	17.4	0.0	0	72.3	9.97	104.7	16.80	103.2
.WR MONUMENT FOREBAY											
1/4 MI UP CENTER	7 13 71	1007	0	18.2	8.7	3	72.7	10.70	114.3	16.80	104.6
.WR MONUMENT FOREBAY											
1/4 MI UP CENTER	7 13 71	1007	33	17.2	8.7	3	72.7	10.10	105.7	17.10	104.7
.WR MONUMENT TAILRACE											
1/2 MI DN SPILL SIDE	7 13 71	1018	0	17.3	8.7	3	72.7	11.10	116.4	18.30	112.3
ICE HARBOR FOREBAY											
1/4 MI UP CENTER	7 13 71	1035	0	17.6	28.6	10	72.4	10.80	113.9	17.20	106.0
ICE HARBOR FOREBAY											
1/4 MI UP CENTER	7 13 71	1035	33	17.3	28.6	10	72.4	10.60	111.1	17.30	106.1
ICE HARBOR TAILRACE											
1/2 MI DN SPILL SIDE	7 13 71	1022	0	17.3	28.6	10	72.4	11.14	116.8	1820	111.7
COLUMBIA RIVER											
ABOVE MOUTH SNAKE	7 13 71	1050	0	15.4				12.13	121.9	19.70	116.9
MCNARY DAM FOREBAY											
1/4 MI UP SPILL SIDE	7 13 71	1106	0	16.8	96.4	15	262.9	12.60	130.6	18.80	114.4
MCNARY DAM FOREBAY											
1/4 MI UP SPILL SIDE	7 13 71	1106	33	16.3	96.4	15	262.9	12.20	125.1	18.50	111.5
MCNARY TAILRACE											
1/4 MI DN SPILL SIDE	7 13 71	1122	0	16.5	96.4	15	262.9	13.36	137.6	21.80	131.9
MCNARY DAM FOREBAY											
1/4 MI UP POWER SIDE	7 13 71	1112	0	16.9	96.4	15	262.9	12.30	127.7	18.80	114.6
MCNARY DAM FOREBAY											
1/4 MI UP POWER SIDE	7 13 71	1112	33	16.0	96.4	15	262.9	12.00	122.2	18.60	111.5
MCNARY TAILRACE											
1/4 MI DN POWER SIDE	7 13 71	1127	0	16.1	96.4	15	262.9	11.94	122.0	18.80	113.0
JOHN DAY FOREBAY											
1/4 MI UP CNTR	7 13 71	1307	0	18.7	58.5	20	285.1	11.90	128.4	18.70	117.4

pendix Table 1.--Continued

LOCATION	DATE MO DY YR.	TIME	DEPTH FEET	TEMP DEG C	HOURLY FLOW SPILL KCFS	HOURLY FLOW GATE OPEN	HOURLY FLOW TOTAL KCFS	OXYGEN PPM	OXYGEN SAT	NITROGEN PPM	NITROGEN SAT
OHN DAY FOREBAY											
1/4 MI UP CNTR	7 13 71	1307	33	16.4	58.5	20	285.1	12.10	124.4	19.60	118.4
OHN DAY TAILRACE											
1/2 MI DN SPILL SIDE	7 13 71	1315	0	16.4	58.5	20	285.8	11.94	122.7	20.00	120.9
HE DALLES FOREBAY											
1/4 MI UP CENTER	7 13 71	1330	0	16.4	103.5	23	274.1	11.70	120.2	19.20	116.0
HE DALLES FOREBAY											
1/4 MI UP CENTER	7 13 71	1330	33	16.7	103.5	23	274.1	11.70	121.0	19.20	116.5
HE DALLES TAILRACE											
1/2 MI DN SPILL SIDE	7 13 71	1335	0	16.7	103.5	23	274.1	12.00	124.1	19.40	117.7
ONNEVILLE FOREBAY											
1/2 MI UP SPILL SIDE	7 13 71	1420	0	16.3	151.0	18	274.6	12.00	123.1	18.90	113.9
ONNEVILLE FOREBAY											
1/2 MI UP SPILL SIDE	7 13 71	1420	33	16.4	151.0	18	274.6	12.00	124.6	19.00	115.8
ONNEVILLE TAILRACE											
1/4 MI DN SPILL SIDE	7 13 71	1425	0	16.7	151.0	18	274.6	12.95	133.9	21.24	128.9
OLUMBIA RIVER											
PRESCOTT CENTER	7 13 71	1546	0	17.1				11.45	119.5	19.30	118.0
OLUMBIA											
HARRINGTON PT -ESTUARY	7 13 71	1521	0	17.3				11.40	119.5	19.20	117.6

Appendix Table 1.--Continued

LOCATION	DATE MO	DY	YR	TIME	DEPTH FEET	TEMP DEG C	HOURLY FLOW SPILL KCFS	GATE OPEN	TOTAL KCFS	OXYGEN PPM	OXYGEN SAT	NITROGEN PPM	NITROGEN SAT
ITTLE GOOSE FOREBAY 1/4 MI UP CENTER	7	27	71	930	0	25.8	0.0	0	39.3	8.10	100.6	14.30	99.7
ITTLE GOOSE FOREBAY 1/4 MI UP CENTER	7	27	71	930	33	22.6	0.0	0	39.3	7.90	92.3	14.92	99.5
ITTLE GOOSE TAILRACE 1/4 MI DN SPILL SIDE	7	27	71	948	0	22.1	0.0	0	39.3	7.43	85.9	15.30	101.3
WR MONUMENT FOREBAY 1/4 MI UP CENTER	7	27	71	1015	0	24.2	0.0	0	39.7	8.70	104.8	15.10	103.0
WR MONUMENT FOREBAY 1/4 MI UP CENTER	7	27	71	1015	33	21.9	0.0	0	39.7	8.30	95.6	15.28	100.8
WR MONUMENT TAILRACE 1/2 MI DN SPILL SIDE	7	27	71	1031	0	21.6	0.0	0	39.7	7.88	90.2	15.23	100.0
CE HARBOR FOREBAY 1/4 MI UP CENTER	7	27	71	1050	0	22.9	0.0	0	43.1	9.30	109.2	15.60	104.4
CE HARBOR FOREBAY 1/4 MI UP CENTER	7	27	71	1050	33	21.5	0.0	0	43.1	8.50	97.1	16.10	105.6
CE HARBOR TAILRACE 1/2 MI DN SPILL SIDE	7	27	71	1100	0	21.4	0.0	0	43.1	8.60	98.1	16.20	106.0
OLUMBIA RIVER ABOVE MOUTH SNAKE	7	27	71	1110	0	17.8				11.34	119.1	18.45	114.2
'CNARY DAM FOREBAY 1/4 MI UP SPILL SIDE	7	27	71	1128	0	20.5	28.3	6	261.4	11.50	128.8	18.20	117.5
'CNARY DAM FOREBAY 1/4 MI UP SPILL SIDE	7	27	71	1128	33	19.4	28.3	6	261.4	10.90	119.4	18.30	116.2
'CNARY TAILRACE 1/4 MI DN SPILL SIDE	7	27	71	1150	0	19.6	28.3	6	261.4	11.90	130.8	19.65	125.2
'CNARY DAM FOREBAY 1/4 MI UP POWER SIDE	7	27	71	1140	0	20.6	28.3	6	261.4	11.20	125.7	18.00	116.4
'CNARY DAM FOREBAY 1/4 MI UP POWER SIDE	7	27	71	1140	33	19.1	28.3	6	261.4	10.50	114.3	18.20	115.0
'CNARY TAILRACE 1/4 MI DN POWER SIDE	7	27	71	1156	0	19.2	28.3	6	261.4	10.84	118.2	17.90	113.3
JOHN DAY FOREBAY 1/4 MI UP CNTR	7	27	71	1400	0	22.5	27.2	17	252.8	10.80	125.9	17.55	117.1

Appendix Table 1.--Continued

LOCATION	DATE MO	DY	YR	TIME	DEPTH FEET	TEMP DEG C	HOURLY FLOW SPILL KCFS	GATE OPEN	TOTAL KCFS	OXYGEN PPM	OXYGEN SAT	NITROGEN PPM	NITROGEN SAT
JOHN DAY FOREBAY													
1/4 MI UP CNTR	7	27	71	1400	33	20.2	27.2	17	252.8	10.30	114.7	17.90	115.1
JOHN DAY TAILRACE													
1/2 MI DN SPILL SIDE	7	27	71	1408	0	20.4	27.2	17	252.8	10.28	114.9	17.69	114.1
THE DALLES FOREBAY													
1/4 MI UP CENTER	7	27	71	1427	0	20.3	43.5	23	241.4	10.30	114.8	17.40	112.0
THE DALLES FOREBAY													
1/4 MI UP CENTER	7	27	71	1427	33	20.4	43.5	23	241.4	9.90	110.6	17.30	111.5
THE DALLES TAILRACE													
1/2 MI DN SPILL SIDE	7	27	71	1440	0	20.4	43.5	23	241.4	10.16	113.5	17.70	114.1
BONNEVILLE FOREBAY													
1/2 MI UP SPILL SIDE	7	27	71	1507	0	20.5	89.5	13	238.5	10.20	114.2	17.40	112.3
BONNEVILLE FOREBAY													
1/2 MI UP SPILL SIDE	7	27	71	1507	33	20.6	89.5	13	238.5	10.15	114.5	17.10	110.6
BONNEVILLE TAILRACE													
1/4 MI DN SPILL SIDE	7	27	71	1517	0	20.6	89.5	13	238.5	11.42	128.2	20.00	129.4
COLUMBIA RIVER													
PRESCOTT CENTER	7	27	71	1621	0	21.0				10.00	113.1	17.30	112.6
COLUMBIA													
HARRINGTON PT--ESTUARY	7	27	71	1615	0	20.2				9.76	108.7	17.30	111.3

Appendix Table 1.--Continued.

LOCATION	DATE MO	DY	YR	TIME	DEPTH FEET	TEMP DEG C	HOURLY FLOW SPILL KCFS	GATE OPEN	TOTAL KCFS	OXYGEN PPM	OXYGEN SAT	NITROGEN PPM	NITROGEN SAT
ITTLE GOOSE FOREBAY 1/4 MI UP CENTER	8	10	71	1015	0	24.9	0.0	0	32.3	7.40	90.4	14.70	101.2
ITTLE GOOSE FOREBAY 1/4 MI UP CENTER	8	10	71	1015	33	23.8	0.0	0	32.3	6.69	79.9	14.39	97.6
ITTLE GOOSE FOREBAY 1/4 MI UP CENTER	8	10	71	1015	100	23.4	0.0	0	32.3	5.50	65.2		
ITTLE GOOSE TAILRACE 1/4 MI DN SPILL SIDE	8	10	71	1035	0	23.5	0.0	0	32.3	6.46	76.7	14.50	97.9
WR MONUMENT FOREBAY 1/4 MI UP CENTER	8	10	71	1117	0	24.5	0.0	0	30.3	7.80	94.5	14.20	97.2
WR MONUMENT FOREBAY 1/4 MI UP CENTER	8	10	71	1117	33	23.7	0.0	0	30.3	6.70	80.0	14.20	96.1
WR MONUMENT FOREBAY 1/4 MI UP CENTER	8	10	71	1117	100	23.4	0.0	0	30.3	6.60	81.6	15.19	102.3
WR MONUMENT TAILRACE 1/2 MI DN SPILL SIDE	8	10	71	1130	0	23.7	0.0	0	30.3	6.62	79.0	14.60	98.8
CE HARBOR FOREBAY 1/4 MI UP CENTER	8	10	71	1200	0	26.7	0.0	0	34.5	8.50	107.3	14.20	100.1
CE HARBOR FOREBAY 1/4 MI UP CENTER	8	10	71	1200	33	23.9	0.0	0	34.5	7.10	85.0	14.96	101.6
CE HARBOR FOREBAY 1/4 MI UP CENTER	8	10	71	1200	100	23.3	0.0	0	34.5	6.10	72.2		
CE HARBOR TAILRACE 1/2 MI DN SPILL SIDE	8	10	71	1212	0	23.9	0.0	0	34.5	7.30	87.4	14.80	100.5
OLUMBIA RIVER ABOVE MOUTH SNAKE	8	10	71	1220	0	19.8	0.0			10.60	117.0	18.02	115.1
CNARY DAM FOREBAY 1/4 MI UP SPILL SIDE	8	10	71	1236	0	23.0	0.0	1	209.2	12.10	142.3	17.00	114.0
CNARY DAM FOREBAY 1/4 MI UP SPILL SIDE	8	10	71	1236	33	21.5	0.0	1	209.2	11.10	126.8	17.20	112.8
CNARY TAILRACE 1/4 MI DN SPILL SIDE	8	10	71	1251	0	21.0	0.0	1	209.2	11.20	126.7	17.20	112.0
CNARY DAM FOREBAY 1/4 MI UP POWER SIDE	8	10	71	1242	0		0.0	1	209.2	11.50		17.30	

ppendix Table 1.--Continued

LOCATION	DATE MO	DY	YR	TIME	DEPTH FEET	TEMP DEG C	HOURLY FLOW SPILL KCFS	GATE OPEN	TOTAL KCFS	OXYGEN PPM	OXYGEN SAT	NITROGEN PPM	NITROGEN SAT
'CNARY DAM FOREBAY													
1/4 MI UP POWER SIDE	8	10	71	1242	33	20.6	0.0	1	209.2	10.50	117.8	18.00	116.4
'CNARY TAILRACE													
1/4 MI DN POWER SIDE	8	10	71	1255	0	20.5	0.0	1	209.2	10.80	120.9	17.60	113.6
JOHN DAY FOREBAY													
1/4 MI UP CNTR	8	10	71	1440	0	24.5	0.0	0	198.7	9.20	111.8	15.60	106.8
JOHN DAY FOREBAY													
1/4 MI UP CNTR	8	10	71	1440	33	21.7	0.0	0	198.7	8.80	100.9	16.00	105.3
JOHN DAY TAILRACE													
1/2 MI DN SPILL SIDE	8	10	71	1448	0	21.7	0.0	0	198.7	9.08	104.1	16.30	107.2
THE DALLES FOREBAY													
1/4 MI UP CENTER	8	10	71	1502	0	21.6	0.0	0	201.5	8.90	101.8	16.00	105.1
THE DALLES FOREBAY													
1/4 MI UP CENTER	8	10	71	1502	33	21.9	0.0	0	201.5	8.80	101.4	16.20	106.9
THE DALLES TAILRACE													
1/2 MI DN SPILL SIDE	8	10	71	1510	0	21.7	0.0	0	201.5	8.90	102.1	16.00	105.3
BONNEVILLE FOREBAY													
1/2 MI UP SPILL SIDE	8	10	71	1538	0	21.8	77.6	11	206.8	9.20	105.8	15.60	102.7
BONNEVILLE FOREBAY													
1/2 MI UP SPILL SIDE	8	10	71	1538	33	21.6	77.6	11	206.8	9.50	108.7	16.40	107.9
BONNEVILLE TAILRACE													
1/4 MI DN SPILL SIDE	8	10	71	1546	0	21.7	77.6	11	206.8	10.82	124.1	18.96	124.7
COLUMBIA RIVER													
PRESCOTT CENTER	8	10	71	1710	0	22.7				9.20	107.6	16.10	107.4
COLUMBIA													
HARRINGTON PT -ESTUARY	8	10	71	1642	0	23.3				9.00	106.5	16.20	109.1