STUDIES TO EVALUATE THE EFFECTIVENESS OF OUTLET FLOW-CONTROL AND DEBRIS CONTROL DEVICES AT MCNARY AND LITTLE GOOSE DAMS, 1998

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EXECUTIVE SUMMARY

During the 1998 spring and summer juvenile salmonid migrations, we conducted descaling evaluations and orifice passage efficiency (OPE) tests using a mark and release method at McNary Dam. Descaling and OPE tests were conducted in Turbine Units 4 and 5, which were equipped with extended-length submersible bar screens and inlet flow vanes, to evaluate outlet flow-control (OFC) and orifice shelter devices. In addition, dip-net recapture efficiency tests were conducted.

Mean OPE for yearling chinook salmon during the spring OFC tests was 61.0 and 82.8% for 60 and 80 MW loads, respectively. Respective mean descaling rates for yearling chinook salmon at 60 and 80 MW loads were 4.4 and 10.8% with the OFC off, and 6.2 and 8.3% with the OFC on.

Spring testing of the orifice shelter was not completed because test equipment was not available in time for the juvenile yearling chinook migration. Testing was further delayed due to high numbers of juvenile subyearling chinook salmon in early July. We conducted four tests during the week of 13 July, but had to conclude testing due to warm water in the gatewells. For OPE, no significant differences were detected between slots or orifice shelter deployment conditions; however, a significant difference was found between test units, with OPE in Unit 4 higher than in Unit 5 (means of 84.5 and 65.7%, respectively). No significant differences in descaling were found between units, slots, or orifice shelter deployment conditions.

Recapture efficiency tests on 24 June in Slots 4B and 5B with subyearling chinook salmon resulted in a recapture efficiency of 100%. Marked fish were recovered in nearly the same condition as when they were released. Descaling and mortality due to handling was minimal.

A mark and recapture method was also used to evaluate an enlarged bypass orifice at Little Goose Dam. The enlarged orifice at Little Goose Dam caused no obvious problems for passage of migrating juvenile salmonids, but was still subject to blockage from debris buildup within the gatewell.

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INTRODUCTION

McNary Dam, at River Kilometer 467 (River Mile 292), is operated by the U.S. Army Corps of Engineers (COE), and is the fourth hydroelectric project from the mouth of the Columbia River. It is also the first dam downstream from the confluence of the Columbia and Snake Rivers, influencing anadromous fish migrations from both river systems. Completed in 1954, McNary Dam is equipped with 14 turbine units, 22 spillbays, a navigation lock, and fish bypass systems. McNary Dam contains a modern juvenile fish bypass system to collect downstream-migrating salmonids for transport to release sites below Bonneville Dam or to bypass them to the river below the dam.

Beginning in the early 1980s, submersible traveling screens (STS) were used to diverted juvenile salmonids away from turbines and into the bypass system. Studies from 1991 to 1996 (Brege et al. 1992; McComas et al. 1993, 1994, 1997) found extended-length submersible bar screens (ESBS) to be much more efficient than earlier devices at diverting juvenile salmonids out of turbine intakes (Fig. 1). Inlet flow-control vanes and ceiling beam extensions used in conjunction with the ESBS further increased its effectiveness. In 1996, ESBSs were installed as standard operating equipment in Turbine Units 1 through 6, and by 1997 all 14 units were equipped with ESBSs.

Model studies conducted at the COE Waterways Experiment Station indicated that a device known as an orifice shelter can alter flow patterns in the upper gatewell area to reduce debris accumulation and blockage of the juvenile fish bypass orifice (Fig. 1). However, construction and delivery delays of the new orifice shelter device prohibited us from conducting a detailed study. During the delay, we continued the 1997 evaluation of the effects of outlet flow-control devices on orifice passage efficiency (OPE) and juvenile salmonid descaling at different levels of turbine-unit operation. Outlet flow-control devices are used to regulate flows into the gatewell and help control debris accumulations on the vertical barrier screens.

Little Goose Dam on the Snake River (River Kilometer 113, River Mile 70) is the third dam from the confluence with the Columbia River. Little Goose Dam is equipped similarly to McNary Dam, but with only 6 turbine units and 12 spillbays.

The orifices that pass water/fish from the gatewells to the juvenile fish bypass channel at Little Goose Dam have been 30.5 cm (12 in) in diameter. The annual spring runoff generally brings an increase in aquatic vegetation or woody debris that can accumulate throughout the year. Each type of debris can create unique fish passage problems at the dams. Woody debris is intercepted and deflected into the gatewells by the diversion screens and will often partially or even completely block the gatewell orifices. This not only reduces flow into the bypass channel, but can cause descaling and other injury to smolts.

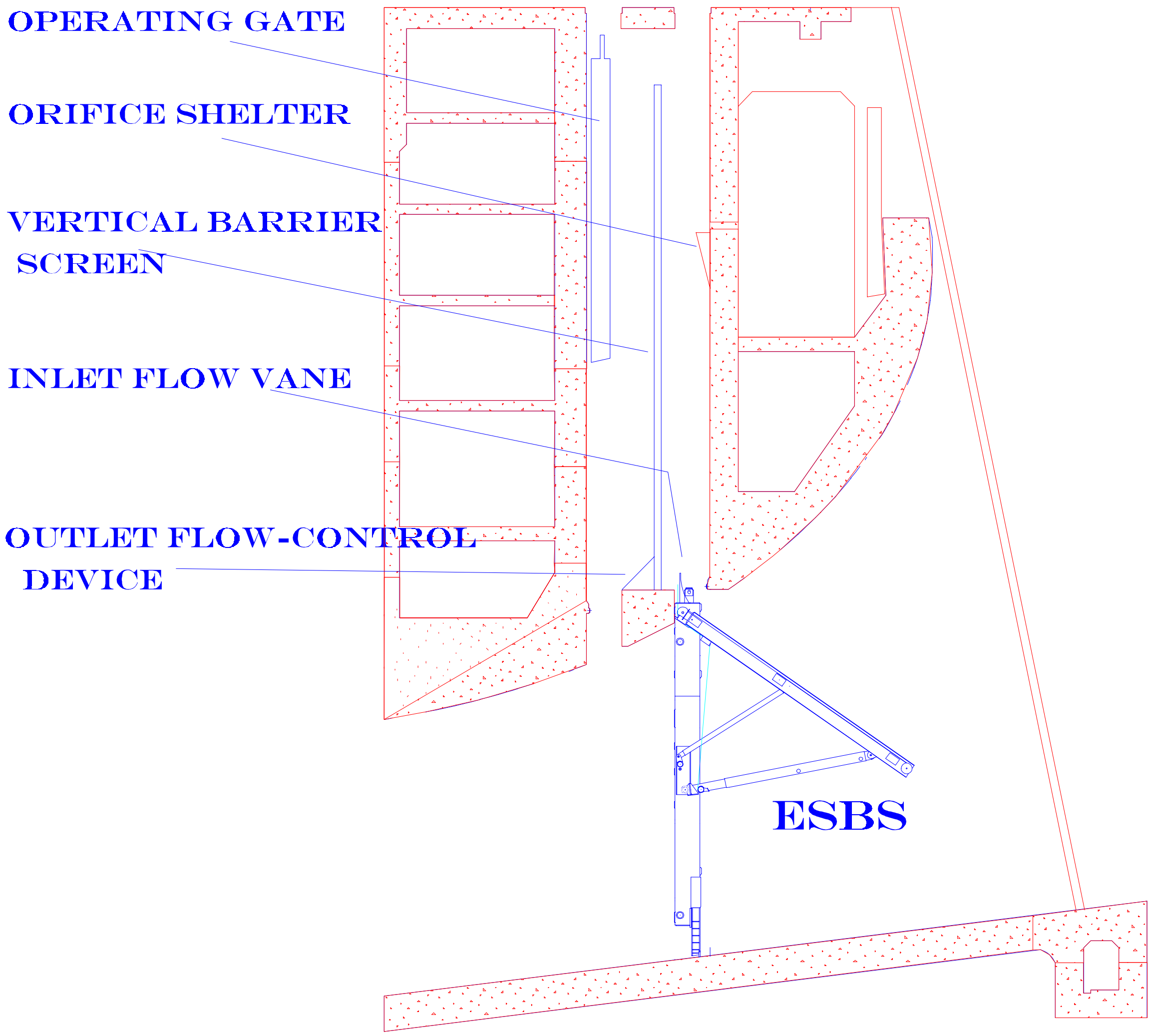

Figure 1. Cross section of turbine unit at McNary Dam with extended-length bar screen, outlet flow-control device, inlet flow vane, orifice shelter, and operating gate in place. Outlet flow-control device is shown in the lowered (off) position

During the 1997 juvenile salmonid migration, exceptionally high river flows swept an unusually large amount of debris downstream. At Little Goose Dam, Turbine Units 1 and 2, near the south shoreline, received the brunt of this excess, and the orifices in these units were often blocked.

Prior to the 1998 spring outmigration, the diameter of the south orifice of Gatewell A in Turbine Unit 1 was enlarged to 35.6 cm (14 in). Also, this orifice was equipped with a knife-gate shear mounted on the gatewell or entrance side of the orifice. This device was designed to clear or remove debris-caused blockages of the orifice.

Research objectives for 1998 were as follows:

1) During the spring juvenile salmonid migration, evaluate the effects of outlet flow-control devices and different turbine-unit loadings on descaling and OPE at McNary Dam.

2) After its construction, begin evaluation of the orifice shelter at McNary Dam.

3) Evaluate the effects of an enlarged orifice on debris control and on descaling and general fish condition at Little Goose Dam.

Outlet flow-control studies (Objective 1) were conducted from 5 to 30 May 1998. Limited testing of the orifice shelter (Objective 2) occurred from 6 to 17 July. The enlarged orifice study (Objective 3) occurred from 29 April to 18 May at Little Goose Dam.

OBJECTIVE 1: EVALUATE THE EFFECTS OF OUTLET FLOW-CONTROL DEVICES AND DIFFERENT TURBINE-UNIT LOADINGS ON DESCALING AND OPE AT MCNARY DAM

Approach

Orifice passage efficiency and descaling measurements were conducted during the spring season to evaluate the effects of outlet flow-control devices on juvenile salmonids in Slots 4B and 5B located near the center of the McNary Dam powerhouse. The effects of outlet flow-control devices were further evaluated after a delay in construction and delivery of the orifice shelter suspended its evaluation schedule (to be discussed under Objective 2).

Guided fish were confined to the upstream bulkhead slot by the vertical barrier screen (VBS) that separated the bulkhead slot from the downstream gate slot (Fig. 1). The outlet flow-control (OFC) devices (Fig. 1) were located on the downstream upper surface of the ceiling beam of Slots 4B and 5B. The position of the flow-occluding louver was alternated every 2 days between the raised and lowered position (Appendix Table 1).

The raised or "OFC-on" position reduced the flow of water through the downstream gate slot while the lowered or "OFC-off" position had no effect on flow through the downstream gate slot. Discharge (flow) through Units 4 and 5 was alternated daily between 12 and 16 thousand cubic feet per second (kcfs). Megawatt (MW) loading at these discharges was approximately 60 and 80 MW depending on unit head. At certain times during the spring season, 16 kcfs flow through the unit produced less than 80 MW due to low hydraulic head at the dam.

Each of the gate slots had two 30.5-cm (12-in) fingerling bypass orifices that emptied into the open juvenile fish bypass channel (Fig. 1). The orifices could be opened or closed from the bypass channel by an air-operated slide gate. The orifices were located on 1.1-m (42-in) centers from the ends of the gate slot at elevation 330 ft mean sea level (msl). Normal operating pool for the reservoir varies between elevations 335 and 340 ft, averaging 337.5 ft (103 m) msl. The normal gatewell drawdown due to turbine loading is 30.5 cm (1 ft) resulting in an average orifice submergence of 2 m (6.5 ft) from the gatewell surface.

The methods for determining OPE were similar to those used in previous OPE studies with guidance screens (Brege et al. 1997a,b). Prior to the start of a test, slots were dipnetted to remove any residual fish (Swan et al. 1979). The turbine units were run continuously during the month-long test period. Test slots were dipnetted daily, and the collected fish anesthetized with tricaine methanesulfonate (MS-222) and examined.

From the collected fish, 100 juvenile salmonids per OPE replicate were caudal fin clipped and held in a specially designed release canister for 1 hour to monitor short-term mortality. Obviously injured fish were not included in the marked group. Marked fish were released in the center of the test gatewells, 9.1 m (30 ft) below the surface, and allowed to exit the gatewells through the juvenile fish bypass orifice.

The north orifice was closed and the south orifice was open during all OPE tests. Turbine loads were alternated between 60 and 80 MW daily with changes made at the conclusion of each OPE test. The orifice discharge into the ice/trash sluiceway was monitored twice a day to make sure the orifices were not plugged or closed inadvertently. At a specified time each test day, all fish were dipnetted from the gatewells. A typical OPE test lasted 22 hours, beginning at 2000 h on one day and ending at 1800 h the next day. Orifice passage efficiency was calculated as the number of clipped fish that exited the gatewell divided by the total number released.

The gatewell dipnetting technique for OPE relies on the assumptions that fish survive the marking process in good condition, fish exiting the gatewell do so via the bypass orifice, and all fish remaining in the gatewell are captured by the dip net. To ensure the reliability of these assumptions, dip-net efficiency tests were conducted periodically throughout the spring and summer outmigration. During these tests, fish were marked, held for 1 hour in the release canister to observe any immediate mortality, and then released in the gatewell with both orifices closed. Several hours later the gatewell was dipnetted and the catch examined and enumerated.

Descaling of fish captured during OPE tests was monitored using standard Fish Transportation Oversight Team descaling criteria (Ceballos et al. 1993). Juvenile salmonids were not classified as descaled if scale regeneration had begun. Fish with bird marks or fungal growth were not considered descaled. Head injuries, such as folded operculums and eye injuries, were recorded. The objective was to determine whether the test conditions were adversely impacting fish condition, so injuries which had obviously occurred at some time prior to the test were not included. The test design provided for 20 OPE measurements in each of the test slots during the spring juvenile salmonid outmigration.

Extended-length bar screens equipped with inlet flow vanes similar to those tested during OPE tests in 1995 at The Dalles Dam were used in all test slots (Brege et al. 1997a).

Results and Discussion

Yearling Fish

Testing for OPE began 5 May and ended 30 May when fish numbers dropped at the end of the spring outmigration (Appendix Table 1). For Objective 1 during the spring season, we handled the following numbers of juvenile salmonids during OPE and descaling tests: 2,297 subyearling chinook salmon, 17,759 yearling chinook salmon, 2,516 steelhead, 2,769 coho salmon, and 11,708 sockeye salmon for a total of 37,049 fish. We marked and released 5,600 yearling chinook salmon (included in the above count) during our spring OPE tests.

Total river flow through McNary Dam was near normal during the 1998 spring outmigration. Average daily river flow was about 300 kcfs at the beginning of May and rose above 400 kcfs for a short time at the end of May. In contrast, average daily river flows in 1997, a high flow year, were about 100 kcfs higher. With normal 60-MW loading at McNary Dam, about 160 kcfs (13 operating turbine units times 12 kcfs/unit) can be discharged through the powerhouse. Average daily river flow over the spillway seldom exceeded the amount going through the powerhouse during the spring outmigration.

Data were analyzed using an analysis of variance (ANOVA) technique due to uneven sample sizes for different groups. Means listed are “Least Square Means” from the ANOVA calculations and may vary slightly from “raw means” obtained through arithmetic manipulations. Actual figures for the ANOVA calculations are in Appendix Table 2.

During the spring tests with yearling chinook salmon, there was a significant difference in OPE between the low (60 MW) and high (80 MW) load conditions (means of 61.0 and 82.8%, respectively). No difference in OPE was found between the OFC-on and OFC-off conditions (mean of 71.9% for each). No difference in OPE was found between slots 4A, 4B, 5A, and 5B, which had means of 74.4, 73.0, 74.1, and 66.1, respectively. Figure 2 shows daily OPE through the test season, and Appendix Table 2 shows the ANOVA calculations. The difference in OPE with load was similar to that observed in 1997 at McNary Dam, where there was a significant difference in OPE between the low (60 MW) and high (80 MW) load conditions (means of 68.5 and 87.9%, respectively)(Brege et al. 1998).

Descaling for yearling chinook salmon during OFC evaluations was found to be significantly different with the OFC off (means of 4.4 and 10.8% at the 60 and 80 MW loads, respectively). No significant difference in descaling was found between the two different loads with the OFC on (6.2 and 8.3% at the 60 and 80 MW loads, respectively). No difference in descaling was found between slots 4A, 4B, 5A, and 5B, which had mean descaling rates of 8.9, 6.1, 7.3, and 7.5%, respectively. Appendix Table 2 shows the ANOVA calculations.

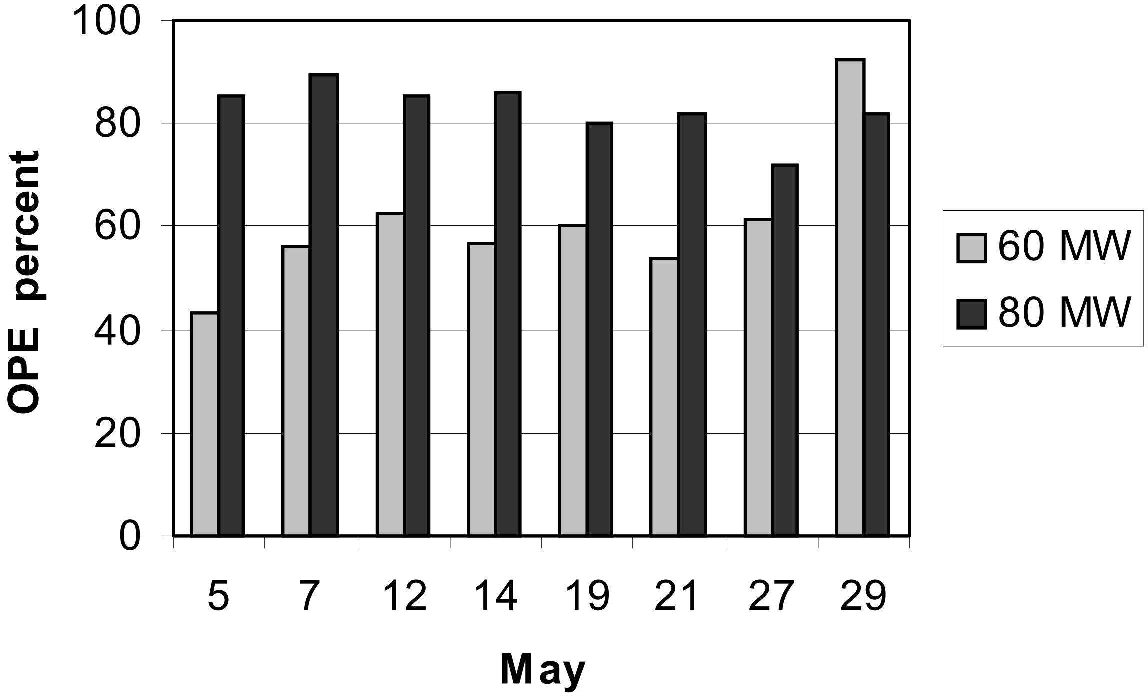

Figure 2. Daily yearling chinook salmon orifice passage efficiency (OPE) at 60 and 80 MW during outlet flow-control tests at McNary Dam, 1998.

Subyearling Fish

No OFC evaluations were conducted during the subyearling chinook salmon outmigration. The orifice shelter device arrived on 29 June, and preparations were made for testing the new device. Dip-net efficiency tests on 24 June in Slots 4B and 5B with subyearling chinook salmon resulted in a recapture efficiency of 100% in both slots. There was no descaling or mortality due to handling.

OBJECTIVE 2: EVALUATE THE EFFECTS OF ORIFICE SHELTERS ON DESCALING AND OPE AT MCNARY DAM

Approach

Descaling and OPE tests were conducted at McNary Dam to evaluate the effects of orifice shelters (OSs) on juvenile salmonids in Slots A and B of Turbine Units 4 and 5. Methods used for OPE and descaling were identical to those described under Objective 1. An OS is a wedge-shaped flow diverter constructed of steel plate. It is about 7.9 m (23 ft) long, 2.4 m (8 ft) high, 0.6 m (2 ft) thick, and weighs 4 tons. The OS devices were suspended by pendant cables from the intake deck and positioned 6 inches below the bypass orifice against the upstream surface of the gate slot by air-operated cylinders (Fig. 1).

Preliminary tests were conducted in Slot 6B to check for gross fish-condition problems prior to the regular test series in Units 4 and 5. Slot 6B, normally used for flume studies through the season, was equipped with an orifice trap that allowed for the capture of all fish exiting the orifice. Two replicates, each about one-half hour in duration, were conducted with the OS deployed and not deployed.

Results and Discussion

During the summer evaluation of the orifice shelter, we handled the following numbers of juvenile salmonids during OPE and descaling tests: 13,099 subyearling chinook salmon, 4 yearling chinook salmon, 1 steelhead, 8 coho salmon, and 6 sockeye salmon for a total of 13,118 fish (Appendix Table 3). We marked and released 1,583 subyearling chinook salmon (included in the above count) during our summer OPE tests. Subyearling chinook salmon made up 99.9% of the summer catch.

Two OSs, pendant cables, dogging beams, air receivers, air lines, and line fittings arrived at McNary Dam on 29 June, and NMFS crews rigged one OS for use in Slot 6B. On 30 June, preliminary fish-condition tests were conducted with two replicates each, alternating between the OS-deployed and OS-removed condition in Slot 6B, and using the orifice trap in the fingerling bypass gallery to recover all fish. Each test consisted of a 15- to 45-minute run and ended when at least 100 juvenile salmonids had been collected in the orifice trap. No gross injuries or descaling were apparent during these preliminary tests.

The second OS was assembled and Slots 4B and 5B were reconfigured for OS deployment. Several logistical and mechanical problems were addressed during the reconfiguration. These included modifications to dogging beams and handrails in the test slots; addition of metal tabs, both to the handrail stanchions and the OS body at catch points to allow for the safe deployment of the device; drilling of relief holes through the top of the OS deck plate to allow entrapped air to escape; and assembly and mechanical testing of air lines and fittings for the air rams and receiver tanks.

High fish numbers prevented us from further testing until 13 July, and OS evaluations resumed from 14 to 17 July. Two OS devices were alternately deployed between the A and B slots of Units 4 and 5. Four days of OPE and descaling tests resulted in eight replicates. However, by the end of the week, water temperatures had risen to 72°F, and testing had to be terminated.

Analysis of variance calculations for the OS tests are shown in Appendix Table 2. For OPE, no significant differences were indicated for slot or OS deployment conditions; however, a significant difference was found between test units, with OPE in Unit 4 higher than in Unit 5 (means of 84.5 and 65.7%, respectively). A similar difference at McNary Dam was noted in 1997 with yearling chinook salmon (Brege et al. 1998). No significant differences in descaling were found between units, slots, or OS deployment conditions.

OBJECTIVE 3: EVALUATE THE EFFECTS OF AN ENLARGED GATEWELL ORIFICE ON DESCALING, GENERAL FISH CONDITION, AND POTENTIAL DEBRIS CONTROL AT LITTLE GOOSE DAM

Approach

Groups of hatchery yearling chinook salmon were marked and released into the "A" gatewells of Turbine Units 1 and 2 to test the effects of an orifice enlargement from 0.3 m (12 in) to 0.4 m (14 in) at Little Goose Dam. To limit handling of test fish, we used fish that were part of the daily samples taken by Washington Department of Fish and Wildlife personnel at Lower Granite Dam. All fish were examined for marks and descaling/injury prior to marking with PIT tags. The PIT tags allowed us to use the detection-by-code recovery system in place at Little Goose Dam. This system contains a database of known PIT-tag codes and enables researchers to divert individual PIT-tagged fish from the general population for examination.

The test fish were collected and marked in groups of 100 at Lower Granite Dam, transported to Little Goose Dam in oxygenated, 946-L (250-gallon) aluminum tanks, and released the following day into the designated gatewells. The fish were held overnight at the Little Goose juvenile collection facility and supplied with fresh river water. Fish were released with a 284-L (75-gallon) aluminum release canister similar to that used at McNary Dam. A small cherry-picker crane positioned the cannister 9.1 m (30 ft) below the surface and in the center of the gatewell.

We planned a minimum of 20 and a maximum of 30 paired releases (paired by day) during the spring outmigration, with analysis by paired t-test. Using expected binomial variation, and assuming a background descaling rate of 5%, we would be able to detect differences within 2% between the two orifices. A secondary part of the study was to monitor debris buildup and passage through the enlarged and standard-size orifices.

Results and Discussion

We encountered several problems during the study. First, low numbers of test fish were collected during some of the daily samples at Lower Granite Dam. This was caused by few hatchery yearling chinook salmon being available and also by high numbers of steelhead juveniles in the daily sample, which further reduced our ability to collect chinook salmon. In addition, the computers that ran the detection-by-code system at Little Goose Dam failed during several of our tests.

We began tagging and releasing replicates on 29 April and ended the tests on 18 May. Table 1 summarizes the release data for the study. During this period, we made a total of nine paired releases with 1,607 total fish released (783 into the control gatewell (12 in) and 824 into the test gatewell (14 in)). We recovered 367 (47%) from the control gatewell, and 343 (42%) from the test gatewell. Only one recovered fish was considered descaled. We did see some minor descaling (< 10%) in each group (5% in the control and 6% in the test gatewells, respectively). The low percentage of recovered fish made it difficult to statistically evaluate our passage data. However, the fact that only a few fish in each group were considered marginally descaled suggests that effects on fish condition were minimal and similar for the two orifices.

On 13 May, during our tag and release study, the enlarged orifice in Gatewell 1A was blocked by debris. This answered the question as to whether an enlarged orifice would beome blocked, but we do not know to what degree, if any, it might be less susceptible to blockage than a standard-size orifice. Also, when blockage in the enlarged orifice was caused by debris lodging within the walls of the orifice, the knife-gate shear could not be used to remove the blockage. At this time it appears that project personnel must rely on observation and man-power to keep gatewell orifices free of debris.

Table 1. Daily totals for hatchery spring chinook salmon that were PIT tagged and released into gatewells with either 12-in diameter (control) or 14-in diameter (test) orifices at Little Goose Dam, 1998.

Date released	Control gatewell 12-in orifice	Test gatewell 14-in orifice
30 April	90	98
4 May	100	99
5 May	100	100
6 May	100	100
7 May	100	100
8 May	100	100
12 May	42	40
14 May	72	73
16 May	79	75
18 May		39
	-------	-------
Totals	783	824

SUMMARY

1) Orifice passage efficiency for yearling chinook salmon during OFC evaluations at McNary Dam was higher at the 80-MW turbine load than at the 60-MW load, with mean OPEs of 82.8 and 61.0%, respectively. The difference, 21.8%, was statistically significant.

2) With the OFC off, mean descaling for yearling chinook salmon was significantly higher at the 80-MW load (10.8%) than at the 60-MW load (4.5%). With the OFC on, there was no significant difference between 80 and 60-MW loads, with mean descaling rates of 8.3 and 6.2%, respectively.

3) The orifice shelter did not have any detectable effect on OPE or descaling with subyearling chinook salmon.

4) The enlarged orifice tested at Little Goose Dam created no noticeable problems for fish passage, but it also did not eliminate the problem of orifice blockage by debris.

5) The knife-gate shear was unable to unblock the orifice when the blockage resulted from debris within the orifice walls.

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APPENDIX

Appendix Table 1. Orifice passage efficiency (OPE) data from tests at McNary Dam, 1998.

Test date	Orifice shelter OFC condition	Number marked	Number recovered	OPE (%)	Unit load in MW
			Unit 4, Slot A		
<u>Spring Tests</u>					
5 May	NA	100	15	85	80
6 May	NA	100	69	31	60
7 May	NA	100	19	81	80
8 May	NA	100	62	38	60
12 May	NA	100	1	99	80
13 May	NA	100	40	60	60
14 May	NA	100	3	97	80
15 May	NA	100	48	52	60
19 May	NA	100	17	83	80
20 May	NA	100	16	84	60
21 May	NA	100	0	100	80
22 May	NA	75	39	48	60
27 May	NA	75	13	83	80
28 May	NA	50	16	68	60
29 May	NA	50	8	84	80
30 May	NA	50	1	98	60
<u>Summer Tests</u>					
14 July	OS OUT	100	30	70	60
15 July	OS IN	100	8	92	60
16 July	OS OUT	100	14	86	60
17 July	OS IN	96	4	96	60
			Unit 4, Slot B		
<u>Spring Tests</u>					
5 May	OFC ON	100	27	73	80
6 May	OFC ON	100	50	50	60
7 May	OFC OFF	100	9	91	80
8 May	OFC OFF	100	61	39	60
12 May	OFC ON	100	15	85	80
13 May	OFC ON	100	45	55	60
14 May	OFC OFF	100	0	100	80
15 May	OFC OFF	100	41	59	60
19 May	OFC ON	100	18	82	80
20 May	OFC ON	100	28	72	60
21 May	OFC OFF	100	3	97	80
22 May	OFC OFF	75	33	56	60
27 May	OFC ON	75	28	63	80
28 May	OFC ON	50	21	58	60
29 May	OFC OFF	50	5	90	80
30 May	OFC OFF	50	1	98	60
<u>Summer Tests</u>					
14 July	OS IN	100	42	58	60
15 July	OS OUT	100	13	87	60
16 July	OS IN	98	9	91	60
17 July	OS OUT	100	4	96	60

Appendix Table 1. Continued.

Test date	Orifice shelter OFC condition	Number marked	Number recovered	OPE (%)	Unit load in MW
		Unit 5, Slot A			
Spring Tests					
5 May	NA	100	9	91	80
6 May	NA	100	54	46	60
7 May	NA	100	13	87	80
8 May	NA	100	28	72	60
12 May	NA	100	36	64	80
13 May	NA	100	35	65	60
14 May	NA	100	24	76	80
15 May	NA	100	53	47	60
19 May	NA	100	8	92	80
20 May	NA	100	44	56	60
21 May	NA	100	21	79	80
22 May	NA	75	33	56	60
27 May	NA	75	2	97	80
28 May	NA	50	5	90	60
29 May	NA	50	12	76	80
30 May	NA	50	4	92	60
Summer Tests					
14 July	OS OUT	100	32	68	60
15 July	OS IN	100	26	74	60
16 July	OS OUT	94	44	53	60
17 July	OS IN	98	38	61	60
		Unit 5, Slot B			
Spring Tests					
5 May	OFC OFF	100	8	92	80
6 May	OFC OFF	100	53	47	60
7 May	OFC ON	100	0	100	80
8 May	OFC ON	100	25	75	60
12 May	OFC OFF	100	6	94	80
13 May	OFC OFF	100	30	70	60
14 May	OFC ON	100	29	71	80
15 May	OFC ON	100	31	69	60
19 May	OFC OFF	100	36	64	80
20 May	OFC OFF	100	71	29	60
21 May	OFC ON	100	49	51	80
22 May	OFC ON	75	33	56	60
27 May	OFC OFF	75	41	45	80
28 May	OFC OFF	50	35	30	60
29 May	OFC ON	50	11	78	80
30 May	OFC ON	50	7	86	60
Summer Tests					
14 July	OS IN	100	21	79	60
15 July	OS OUT	98	25	74	60
16 July	OS IN	100	56	44	60
17 July	OS OUT	99	27	73	60

Appendix Table 2. Analysis of variance calculations for orifice passage efficiency (OPE) and descaling data from tests at McNary Dam, 1998.

OPE - Outlet Flow Control Device - Yearling Chinook

ANOVA source	DF	Sum of squares	Mean square	F	P
Slot	3	746.81	248.937	0.89032	0.4525011
OFC	1	0.06	0.063	0.00022	0.9881297
Load	1	7612.56	7612.562	27.22621	0.0000033
Slot *OFC	3	1373.06	457.687	1.63691	0.1923672
Slot *Load	3	428.56	142.854	0.51092	0.6765549
OFC *Load	1	742.56	742.562	2.65576	0.1093371
Residuals	51	14259.81	279.604		

Slot	4A	4B	5A	5B	(not different)
Mean	74.438	73.000	74.125	66.062	
SE	4.180	4.180	4.180	4.180	
OFC	OFF	ON			(not different)
Mean	71.875	71.938			
SE	2.956	2.956			
Load	60MW	80MW			(60 < 80)
Mean	61.000	82.812			
SE	2.956	2.956			

Appendix Table 2. Continued.

Descaling - Outlet Flow Control Device - Yearling Chinook

ANOVA source	DF	Sum of squares	Mean square	F	P
Slot	3	59.9221	19.9740	1.48841	0.2311478
OFC	1	2.1488	2.1488	0.16012	0.6910245
Load	1	252.0257	252.0257	18.78021	0.0000866
Slot *OFC	3	16.6475	5.5492	0.41351	0.7441408
Slot *Load	3	42.5086	14.1695	1.05587	0.3777527
OFC *Load	1	62.5372	62.5372	4.66009	0.0364967
Residuals	43	577.0493	13.4198		

Slot	4A	4B	5A	5B	(not different)
Mean	8.9063	6.100	7.3062	7.4583	
SE	0.9892	0.9892	0.9892	0.9892	

OFC:Load

Dim 1 : OFC

Dim 2 : Load

Off	60MW	80MW	(60 < 80)
Mean	4.451	10.830	
SE	0.987	0.987	

On	60MW	80 MW	(60 not different from 80)
Mean	6.191	8.299	
SE	0.987	0.987	

Appendix Table 2. Continued.

OPE - Orifice Shelter Device - Subyearling Chinook

ANOVA source	DF	Sum of squares	Mean square	F	P
Unit	1	1406.2	1406.2	7.35	0.027
Slot	1	0.3	0.3	0.00	0.972
OS	1	9.0	9.0	0.05	0.834
Unit *Slot	1	42.2	42.2	0.22	0.651
Unit *OS	1	4.0	4.0	0.02	0.889
Slot *OS	1	676.0	676.0	3.53	0.097
Unit *Slot *OS	1	49.0	49.0	0.26	0.626
Error	8	1531.0	191.4		
Total	15	3717.7			

Means

<u>Unit</u>	<u>N</u>	<u>OPE</u>	<u>SE</u>	(4 > 5)
4	8	84.500	4.891	
5	8	65.750	4.891	
<u>Slot</u>	<u>N</u>	<u>OPE</u>	<u>SE</u>	(not different)
A	8	75.000	4.891	
B	8	75.250	4.891	
<u>OS</u>	<u>N</u>	<u>OPE</u>	<u>SE</u>	(not different)
no	8	75.875	4.891	
yes	8	74.375	4.891	

Appendix Table 2. Continued.

Descaling - Orifice Shelter Device - Subyearling Chinook

ANOVA source	DF	Sum of squares	Mean square	F	P
Unit	1	0.123	0.123	0.07	0.798
Slot	1	0.422	0.422	0.24	0.637
OS	1	0.04	0.040	0.02	0.884
Unit *Slot	1	2.56	2.560	1.46	0.262
Unit *OS	1	0.722	0.722	0.41	0.539
Slot *OS	1	6.503	6.503	3.70	0.091
Unit *Slot *OS	1	1.69	1.690	0.96	0.356
Error	8	14.06	1.758		
Total	15	26.12			

Means

	N	OPE	SE	
Unit				(not different)
4	8	2.6125	0.4688	
5	8	2.7875	0.4688	
Slot	N	OPE	SE	(not different)
A	8	2.5375	0.4688	
B	8	2.8625	0.4688	
OS	N	OPE	SE	(not different)
no	8	2.6500	0.4688	
yes	8	2.7500	0.4688	

Appendix Table 3. Descaling data from orifice passage efficiency and descaling tests at McNary Dam, 1998.

	Subyearling chinook			Yearling chinook			Steelhead			Coho			Sockeye		
Test date[a]	Desc.	Catch	%	Desc.	Catch	%	Desc.	Catch	%	Desc.	Catch	%	Desc.	Catch	%
							Unit 4, Slot A								
4 May (R)[b]				41	430	9.5	0	20	0.0	2	35	5.7	63	315	2.0
5 May	0	8	0.0	82	798	10.3	3	127	2.4	15	348	4.3	240	513	46.8
6 May	0	3	0.0	28	389	7.2	1	75	1.3	3	158	1.9	195	889	22.0
7 May	0	1	0.0	71	587	12.1	9	109	8.3	31	302	10.3	136	372	36.6
8 May	0	2	0.0	6	145	4.1	0	49	0.0	0	13	0.0	43	293	14.7
11 May (R)	0	8	0.0	35	270	13.0	1	50	2.0	1	15	6.7	85	495	17.2
12 May	0	5	0.0	44	489	9.0	2	16	12.5	1	22	4.5	40	194	20.6
13 May	0	6	0.0	15	298	5.0	5	67	7.5	0	6	0.0	35	166	21.1
14 May	0	2	0.0	42	252	16.7	1	7	14.3	0	11	0.0	9	29	31.0
15 May	0	16	0.0	20	336	5.9	2	48	4.2	0	8	0.0	49	220	22.3
18 May (R)	3	17	17.6	45	525	8.6	3	69	4.3	1	79	1.3	120	431	27.8
19 May	0	11	0.0	30	255	11.8	0	15	0.0	2	84	2.4	35	146	24.0
20 May	1	50	2.0	6	98	6.1	0	3	0.0	0	8	0.0	18	100	18.0
21 May	0	4	0.0	4	50	8.0				0	1	0.0	10	51	19.6
22 May	0	29	0.0	1	33	3.0	1	5	20.0	0	2	0.0	3	6	50.0
26 May (R)	1	113	0.9	10	121	8.3	2	11	18.2	0	8	0.0	24	96	25.0
27 May	1	24	4.2	5	28	17.9	0	4	0.0	0	3	0.0	1	5	20.0
28 May	5	100	5.0	3	34	8.8	0	6	0.0	0	11	0.0	2	39	5.1
29 May	16	131	12.2	26	93	28.0	2	36	5.6	17	87	19.5	12	27	44.4
30 May	0	8	0.0												
14 Jul (OUT)	12	537													2.2
15 Jul (IN)	19	614	3.1												
16 Jul (OUT)	6	298													2.0
17 Jul (IN)	1	106	0.9												

Appendix Table 3. Continued.

Test date[c]	Subyearling chinook			Yearling chinook			Steelhead			Coho			Sockeye		
	Desc.	Catch	%	Desc.	Catch	%	Desc.	Catch	%	Desc.	Catch	%	Desc.	Catch	%
Unit 4, Slot B															
5 May (ON)	0	4	0.0	43	1018	4.2	3	161	1.9	5	268	1.9	151	542	27.9
6 May (ON)	0	2	0.0	7	124	5.6	0	35	0.0	0	18	0.0	42	325	12.9
7 May (OFF)				30	532	5.6	1	52	1.9	4	107	3.7	78	427	18.3
8 May (OFF)	0	2	0.0	11	203	5.4	0	112	0.0	0	18	0.0	62	368	16.8
11 May (ON-R)	0	7	0.0	14	311	4.5	1	32	3.1	0	24	0.0	40	248	16.1
12 May (ON)	0	3	0.0	49	898	5.5	1	37	2.7	0	30	0.0	27	124	21.8
13 May (ON)	1	7	14.2	23	298	7.7	3	71	4.2	0	3	0.0	24	114	21.0
14 May (OFF)	0	0	0.0	16	175	9.1	0	5	0.0	0	4	0.0	8	45	17.8
15 May (OFF)	1	13	7.7	30	519	5.8	2	32	6.2	0	10	0.0	32	196	16.3
19 May (ON)	1	15	6.7	40	456	8.8	1	25	4.0	6	146	4.1	70	258	27.1
20 May (ON)	2	30	6.7	13	205	6.3	0	21	0.0	1	21	4.8	21	161	13.0
21 May (OFF)	1	8	12.5	8	109	7.3	0	2	0.0	0	9	0.0	11	77	14.3
22 May (OFF)	3	26	11.5	3	69	4.3	0	15	0.0	0	5	0.0	4	27	14.8
26 May (ON-R)	2	160	1.2	9	239	4.0	0	24	0.0	1	8	12.5	21	103	20.4
27 May (ON)	6	74	8.1	9	91	9.9	0	20	0.0	0	11	0.0	2	12	16.7
28 May (ON)	7	87	8.0	1	51	2.0	0	19	0.0	1	15	6.7	10	51	19.6
29 May (OFF)	22	144	15.3	18	66	27.3	1	31	3.2	4	35	11.4	7	12	58.3
30 May (OFF)	0	18	0.0	0	7	0.0	0	1	0.0	0	1	0.0	0	1	0.0
14 Jul (IN)	16	426	3.8												
15 Jul (OUT)	28	615	4.6												
16 Jul (IN)	4	108	3.7												
17 Jul (OUT)	1	149	0.7										1	2	50.0

Appendix Table 3. Continued.

	Subyearling chinook			Yearling chinook			Steelhead			Coho			Sockeye		
Test date	Desc.	Catch	%	Desc.	Catch	%	Desc.	Catch	%	Desc.	Catch	%	Desc.	Catch	%
Unit 5, Slot A															
4 May (R)	0	2	0.0	46	378	12.2	0	21	0.0	0	8	0.0	43	137	31.4
5 May				19	341	5.6	1	32	3.1	2	60	3.3	129	346	37.3
6 May	0	2	0.0	1	108	0.9	1	62	1.6	0	13	0.0	83	439	18.9
7 May	0	2	0.0	8	181	4.4	0	24	0.0	1	31	3.2	204	581	35.1
8 May	0	4	0.0	7	90	7.8	1	34	2.9	0	19	0.0	38	196	19.4
12 May	0	13	0.0	43	820	5.2	4	59	6.8	0	39	0.0	40	240	16.7
13 May	0	7	0.0	18	209	8.6	2	42	4.8	0	5	0.0	8	67	11.9
14 May	0	11	0.0	44	733	6.0	3	70	4.3	1	52	1.9	19	147	12.9
15 May	2	13	15.4	19	299	6.4	2	37	5.4				23	158	14.6
18 May (R)	0	6	0.0	7	87	8.0	0	3	0.0	1	14	7.1	19	95	20.0
19 May				33	142	23.2	2	11	18.2	2	76	2.6	18	66	27.3
20 May	1	21	4.8	2	85	2.3	0	5	0.0	0	2	0.0	11	101	10.9
21 May	3	44	6.8	10	145	6.9	0	10	0.0	0	17	0.0	13	101	12.9
22 May	0	21	0.0	4	38	10.5	0	1	0.0	2	3	66.7	1	18	5.6
27 May	1	59	1.7	7	68	10.3	0	10	0.0	1	12	8.3	2	21	9.5
28 May	0	50	0.0	1	21	4.8	0	18	0.0	1	9	11.1	3	41	7.3
29 May	9	128	7.0	15	64	23.4	0	6	0.0	3	29	10.3	6	23	26.1
30 May	2	63	3.2	13	55	24.0				1	10	10.0	1	8	12.5
14 Jul (OUT)	107	3,015	3.6												
15 Jul (IN)	25	871	2.9	1	2	50.0				0	1	0.0			
16 Jul (OUT)	77	1,637	4.7							0	1	0.0	1	2	50.0
17 Jul (IN)	6	633	0.9												

Appendix Table 3. Continued.

	Subyearling chinook			Yearling chinook			Steelhead			Coho			Sockeye		
Test date	Desc.	Catch	%	Desc.	Catch	%	Desc.	Catch	%	Desc.	Catch	%	Desc.	Catch	%
							Unit 5, Slot B								
5 May (OFF)				26	410	6.3	6	164	3.7	2	80	2.5	88	270	32.6
6 May (OFF)				2	83	2.4	3	61	4.9	0	31	0.0	48	150	32.0
7 May (ON)	0	1	0.0	10	124	8.1	4	77	5.2	0	21	0.0	33	127	26.0
8 May (ON)	0	18	0.0	5	64	7.8	1	33	3.0	0	8	0.0	15	121	12.4
12 May (OFF)	0	4	0.0	58	751	7.7	1	58	1.7	0	26	0.0	17	117	14.5
13 May (OFF)	0	4	0.0	12	226	5.3	3	95	3.2	2	7	28.6	10	48	20.8
14 May (ON)	0	6	0.0	40	631	6.3	1	37	2.7	1	17	5.9	28	143	19.5
15 May (ON)	0	18	0.0	9	173	5.3	2	25	8.0	0	2	0.0	17	102	16.7
19 May (OFF)	3	29	10.3	63	359	17.5	2	29	6.9	7	163	4.3	48	105	45.7
20 May (OFF)	2	38	5.3	6	120	5.0	0	10	0.0	0	10	0.0	11	76	14.5
21 May (ON)	4	67	6.0	13	152	8.5	1	12	8.3	0	33	0.0	18	94	19.1
22 May (ON)	0	27	0.0	1	31	3.2	1	8	12.5	0	1	0.0	5	18	27.8
27 May (OFF)	6	282	2.1	18	104	17.3	2	37	5.4	3	35	8.6	7	23	30.4
28 May (OFF)	1	93	1.1	2	35	5.7	0	9	0.0	0	2	0.0	6	30	20.0
29 May (ON)	6	49	12.2	3	22	14.0	0	4	0.0				8	16	50.0
30 May (ON)	1	77	1.3	1	8	12.5							2	5	40.0
14 Jul (IN)	24	836	2.9												
15 Jul (OUT)	34	1503	2.3	1	1	100.0				0	2	0.0			
16 Jul (IN)	41	1085	3.8				0	1	0.0	0	3				0.0
17 Jul (OUT)	8	666	1.2	0	1	0.0				0	1	0.0	0	2	0.0

[a] Test configuration: IN = orifice shelter in, OUT = orifice shelter out.

[b] Catch figures while dipnetting for recruitment: R = data collected while recruiting fish for marking.

[c] Outlet flow-control (OFC) device configuration: ON = OFC on, OFF = OFC off.