Biological Evaluation of the Prototype Gatewell Lift-Tank System at Lower Granite Dam, 1994

CZES

Coastal Zone and Estuarine Studies Division

Northwest Fisheries Science Center

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Seattle, Washington

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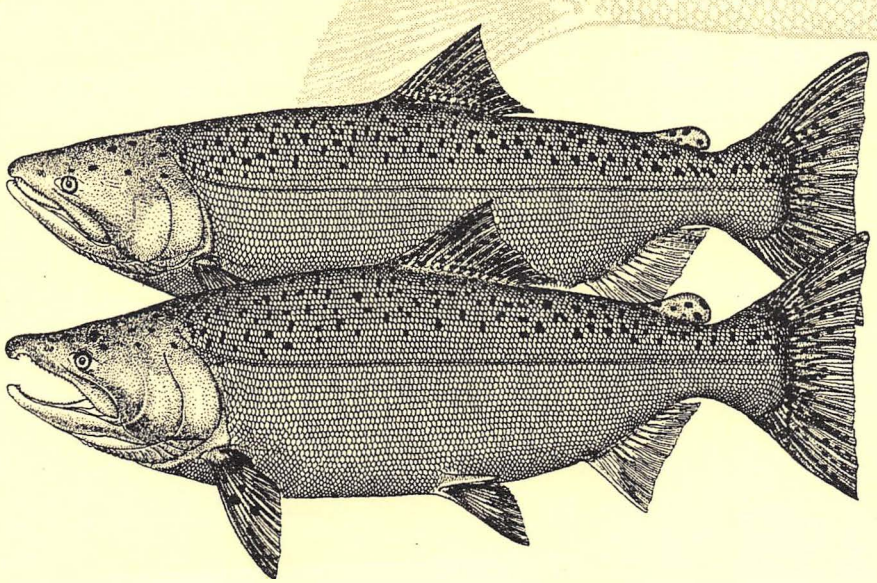

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INTRODUCTION

A proposed drawdown of Lower Granite Reservoir (Fig. 1) would reduce turbine intake gatewell water levels at the dam to an extent that would prevent normal egress of migrant salmonid smolts to the fingerling bypass collection gallery, as described by Matthews et al. (1977) (COE 1994a). This could result in large numbers of fish stranded in the gatewells (COE 1993).

Because of this anticipated stranding, several options for fish removal from gatewells were considered, including dip baskets (Swan et al. 1979), lift tanks, air-lift pumps, and screw pumps. After analysis of these options, lift tanks emerged as the preferred choice (Fig. 2).

Although similar to existing gatewell dip baskets, the lift tanks differ in several significant ways, such as size; frequency and duration of operation; and fish collection, transfer, and delivery (Fig. 3) (COE 1994b). Furthermore, unlike gatewell dip baskets, the proposed lift-tank system had not been evaluated.

At the request of the U.S. Army Corps of Engineers (COE), the National Marine Fisheries Service (NMFS) conducted a study to evaluate a prototype lift tank in 1994. Results of that study are presented in this report.

MATERIALS AND METHODS

The testing schedule was extremely compressed in order to meet COE schedules necessary to develop an operational lift-tank system for proposed reservoir drawdown tests (Table 1).

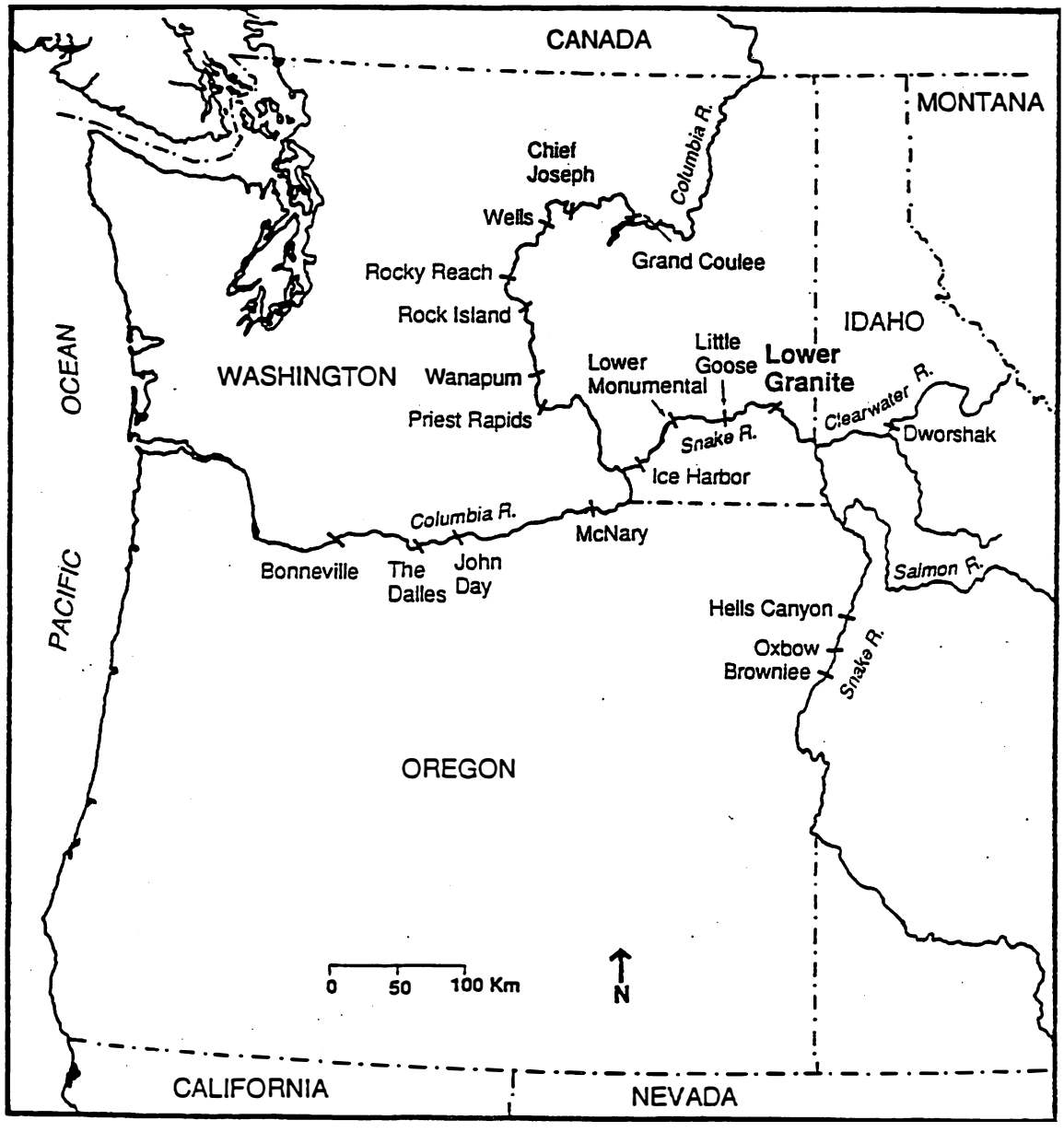

Figure 1.--Location of Lower Granite Dam relative to other hydroelectric projects of the Snake and Columbia Rivers.

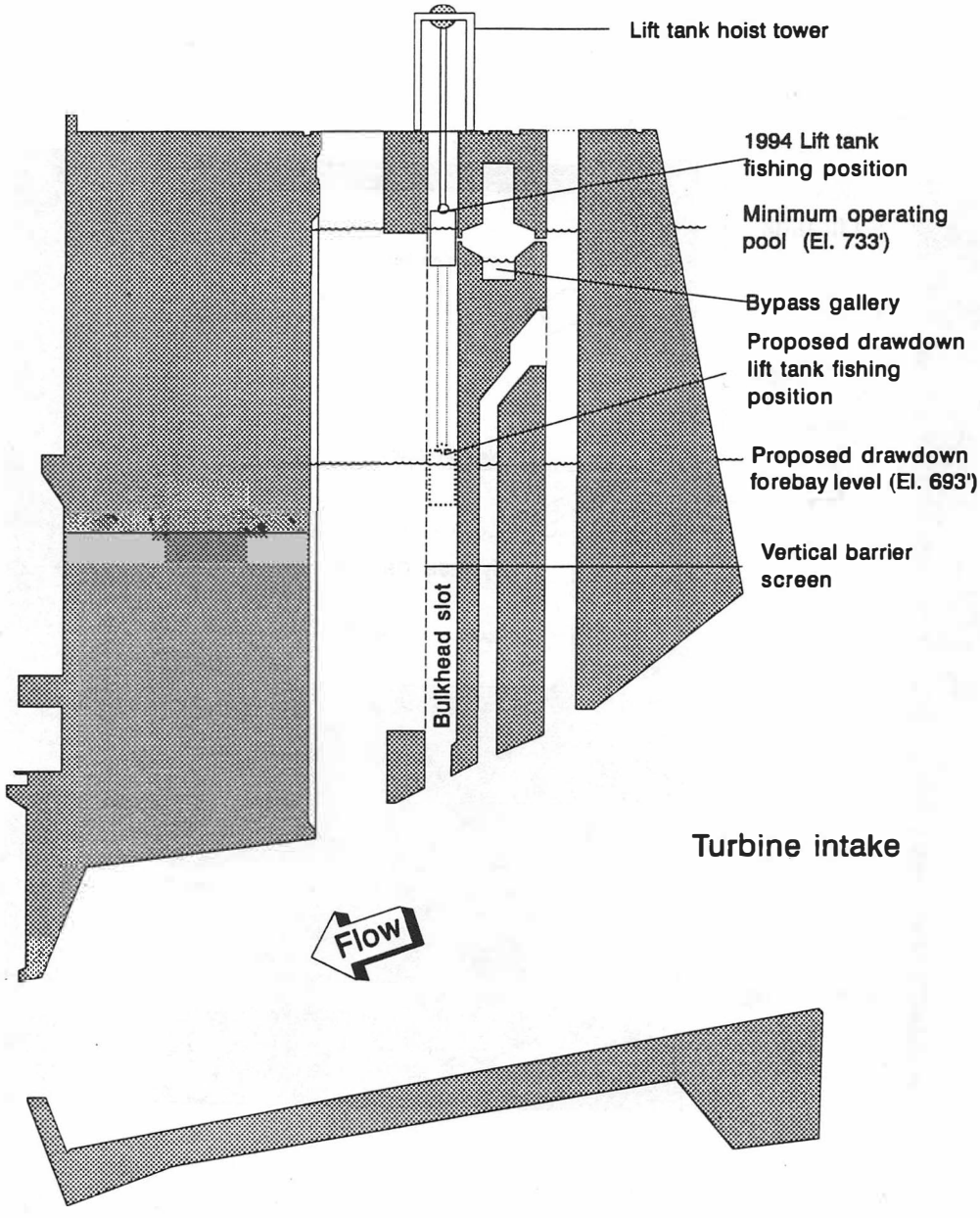

Figure 2.--Cross-section of a turbine intake at Lower Granite Dam showing the lift tank in the bulkhead slot for the 1994 study and at the proposed drawdown level.

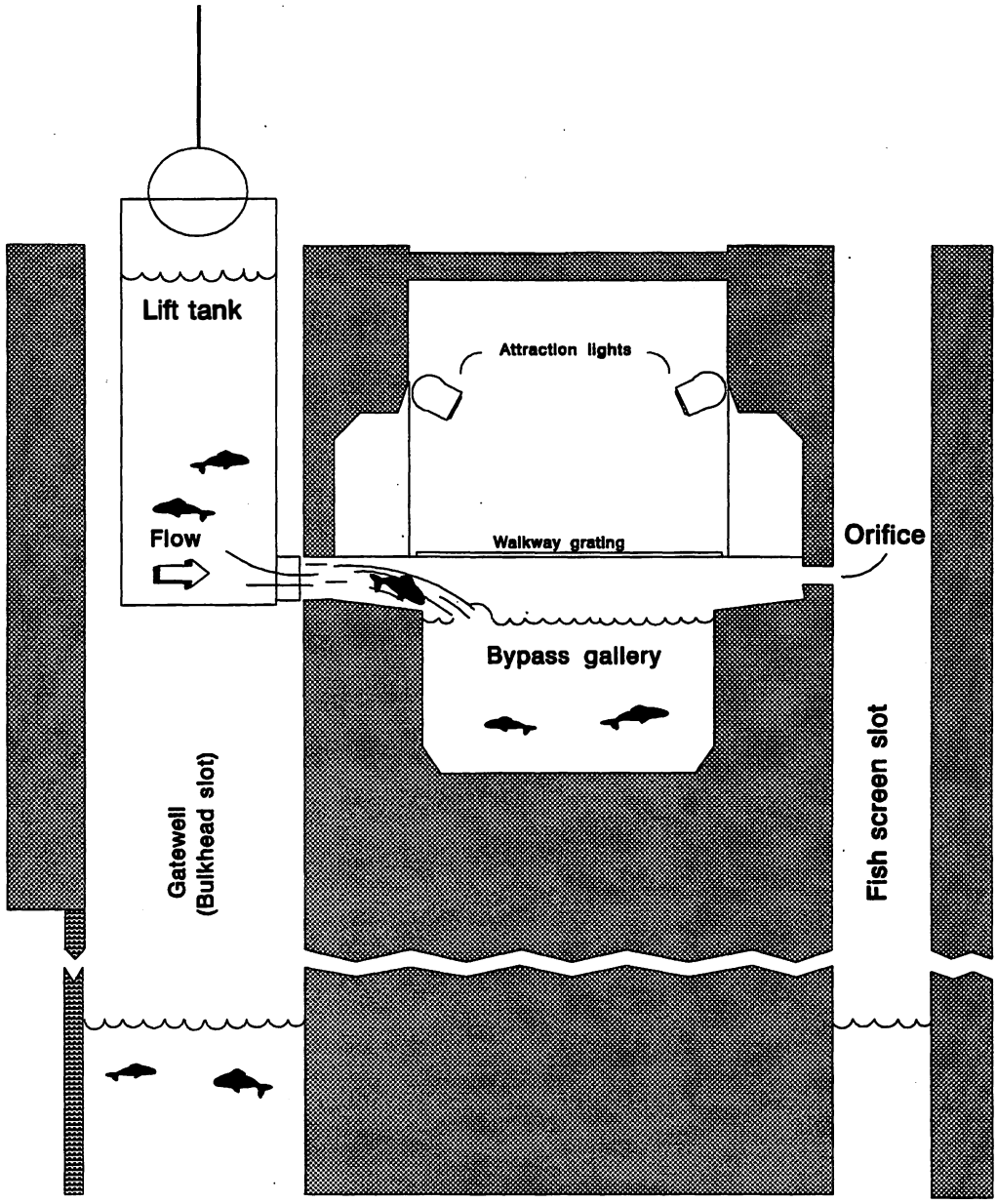

Figure 3.--Cross-section of lift tank releasing fish through the orifice into the fingerling bypass gallery at Lower Granite Dam for a proposed biological drawdown test.

Table 1.--Schedule for the lift-tank biological evaluation at Lower Granite Dam, starting June 18, 1994.

Test Phase	Test Day	Replicate	Testing and Gatewell Activity
I	1		Tagged fish
	2	1 & 2	Tagged fish; lift-tank test in Slot 6A
	3	3	Tagged fish; lift-tank test in Slot 6A
	4	4	Tagged fish; lift-tank test in Slot 6A
	5	5	Tagged fish; lift-tank test in Slot 6A
	6		Tagged fish
II	7	1	Tagged fish; Dip-basket test in Slot 4B Lift-tank test in Slot 6A
	8	2	Tagged fish; Dip-basket test in Slot 4B Lift-tank test in Slot 6A
	9	3	Tagged fish; Dip-basket test in Slot 4B Lift-tank test in Slot 6A
	10	4	Tagged fish; Dip-basket test in Slot 4B Lift-tank test in Slot 6A
III	11	1	Tagged fish; Dip-basket test in Slot 4B Lift-tank test in Slot 6A
	12	2	Tagged fish; Dip-basket test in Slot 4B Lift-tank test in Slot 6A
	13	3	Tagged fish; Dip-basket test in Slot 4B Lift-tank test in Slot 6A
	14	4	Dip-basket test in Slot 4B Lift-tank test in Slot 6A
	15		Gear clean-up, end of project

The 1994 evaluation was conducted with steelhead (*Oncorhynchus mykiss*) only. Complete testing of the lift-tank system and evaluation of its effects on yearling chinook salmon (*O. tshawytscha*) requires additional studies.

The lift tank consisted of a steel box measuring 7-m long, 1.1-m wide, and 1.8-m deep and held about 11.7 kL of water (Fig. 4). The floor (gate) of the tank was hinged. The gate was opened when the tank was lowered into the gatewell so that fish could swim into the tank. To remove fish from the gatewell, the gate was closed, and the tank was then lifted with fish and water to the bypass orifice. The inner surface of the tank floor was designed to drain water from each end of the tank to the orifice connection (Fig. 5). The support structure for the lift tank was bolted and grouted to the intake deck. The lift tank was designed to be fully automated and during a drawdown scenario would operate 24 h/day with each cycle taking about 1 h.

The lift tank was equipped with a debris screen system to remove large debris from the gatewell when the lift tank was raised. It was mounted inside of the tank and consisted of an array of parallel cables spaced at 15.2 cm intervals, each enclosed in a vertical tube on the downstream side of the tank. The cables were attached to a square steel beam positioned length-wise at the top of the tank. Prior to raising the lift

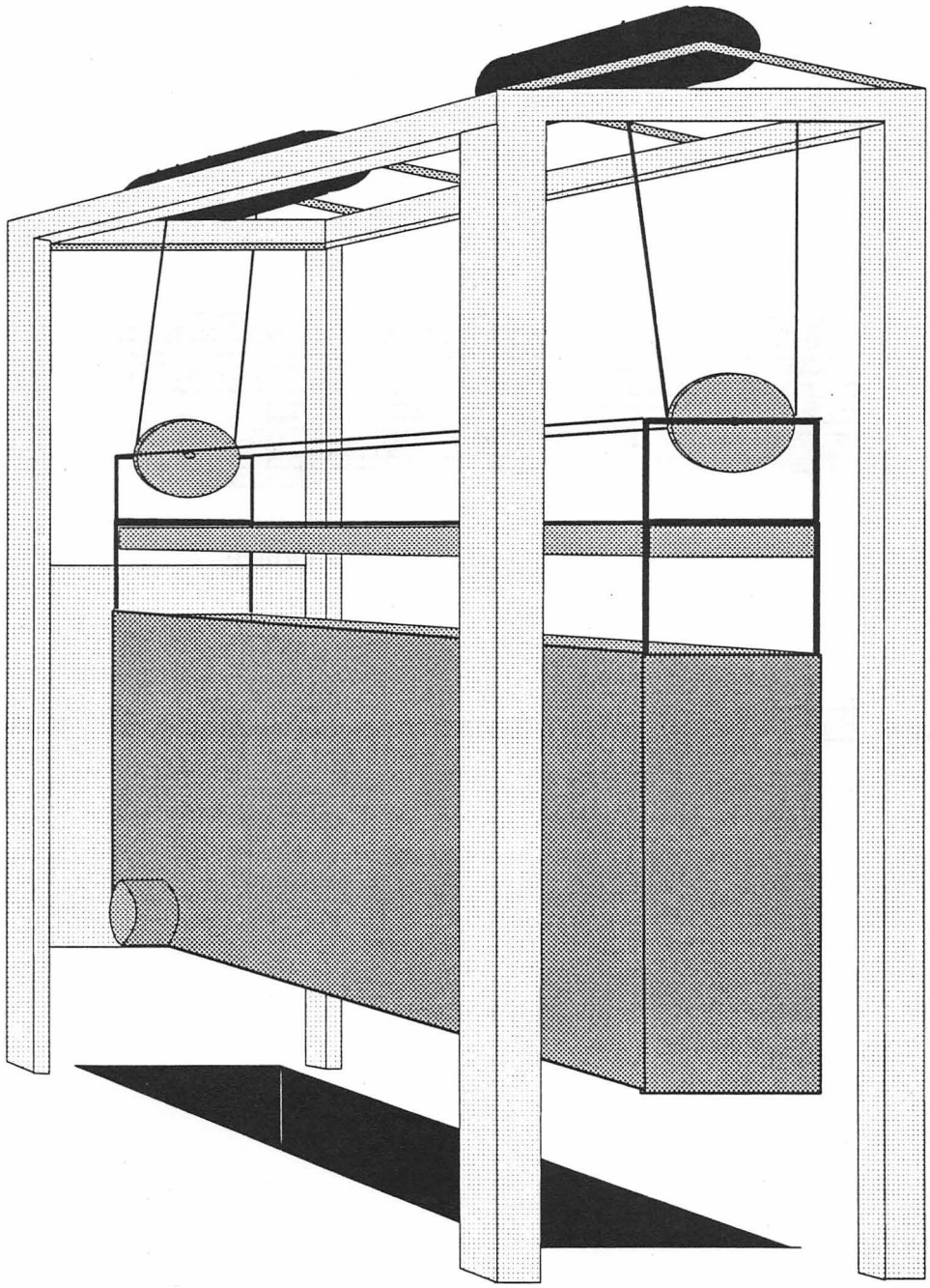

Figure 4.--Lift tank and support structure.

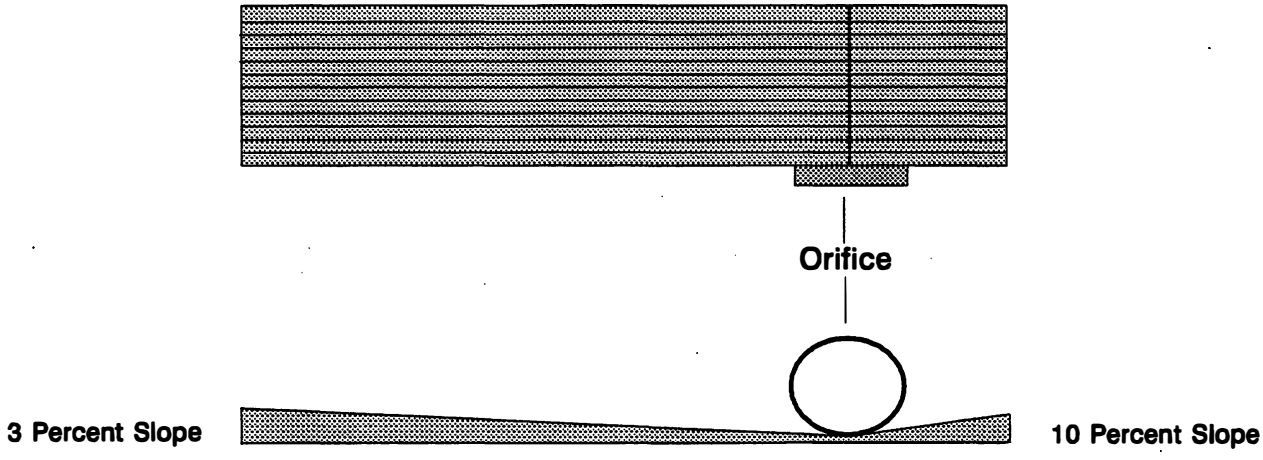

Figure 5.--Plan and side views of lift-tank floor (gate) showing slope to the orifice.

tank from the fishing position, the steel beam was pulled across the top of the tank by a chain and sprocket system powered by a pneumatic motor. The pneumatic motor failed to operate throughout the evaluation. Therefore, the debris screen system was not tested.

A formal consultation, as required by Section 7 of the Endangered Species Act, was requested and approved for the incidental take of wild and listed hatchery yearling chinook salmon, subyearling fall chinook salmon, and sockeye salmon (*O. nerka*). Incidental catches of these species were unavoidable as a result of the lift-tank evaluation.

Location

The lift-tank tests were conducted in bulkhead Slot 6A equipped with a standard submersible traveling screen (STS) and a blocked vertical barrier screen (BVBS) (Fig. 6). The BVBS consisted of the modified balanced-flow vertical barrier screen (MBFVBS) removed from bulkhead slot 4A and further modified to consist of four upper panels of balanced-flow vertical barrier screen and six lower panels that were blocked by covering them with plywood. The BVBS was installed in bulkhead slot 6A to simulate estimated gatewell flows at a forebay elevation of 692 ft during the proposed drawdown. These estimates were based upon hydraulic model studies conducted at the COE's Waterways Experiment Station at Vicksburg, Mississippi.

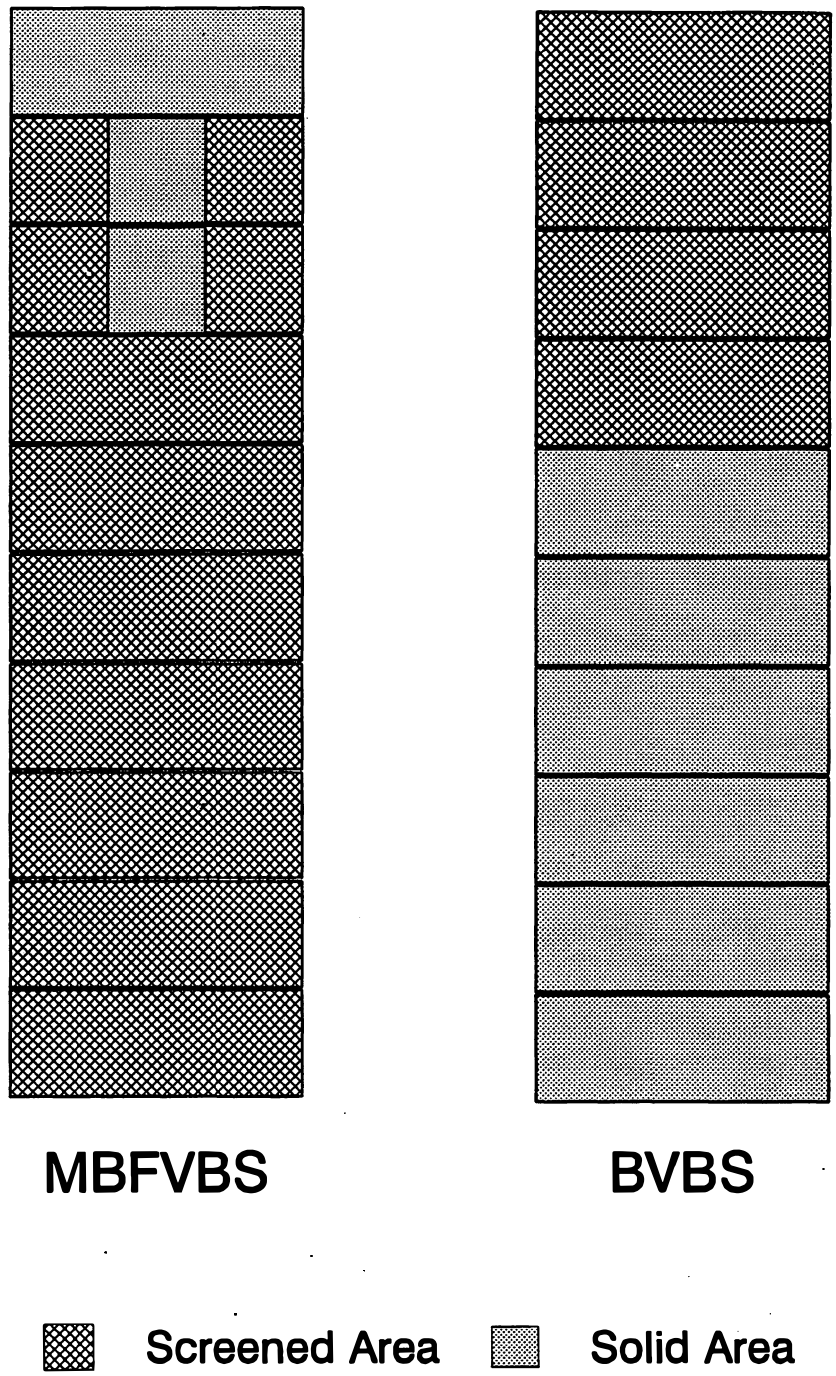

Figure 6.-- View of two vertical barrier screen configurations at Lower Granite Dam. The modified balanced flow vertical barrier screen (MBFVBS) formerly located in bulkhead slot 4A was further modified as a blocked vertical barrier screen (BVBS) and installed in bulkhead slot 6A.

A standard dip basket was used to remove control fish from Slot 4B (with a MBFVBS and a standard STS) to compare descaling incidence and collection efficiency with the test slot. The configuration of test equipment is shown in Figure 7.

Test Fish

River-run hatchery steelhead were collected at the juvenile collection facility at Lower Granite Dam. Fish for different treatment and control groups were marked with small, colored Floy[1] T-bar tags. Descaling was assessed according to Fish Transport Oversight Team guidelines (Ceballos et al. 1992). Fish naturally recruited into the gatewell during test periods were also counted and examined for descaling and fish condition.

Test Sequence

The evaluation of the gatewell lift-tank system was conducted in three phases. Phase I addressed operating procedures for the lift tank, evaluated effects of confinement in and exit from the lift tank, and established descaling and fish condition indices. Phase II assessed collection efficiency and effectiveness of the water-draining process (dewatering) for the lift tank and provided further information on descaling and fish condition. Phase III assessed changes in fish behavior and location in the gatewell as a result of lift-tank position in the gatewell, and

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

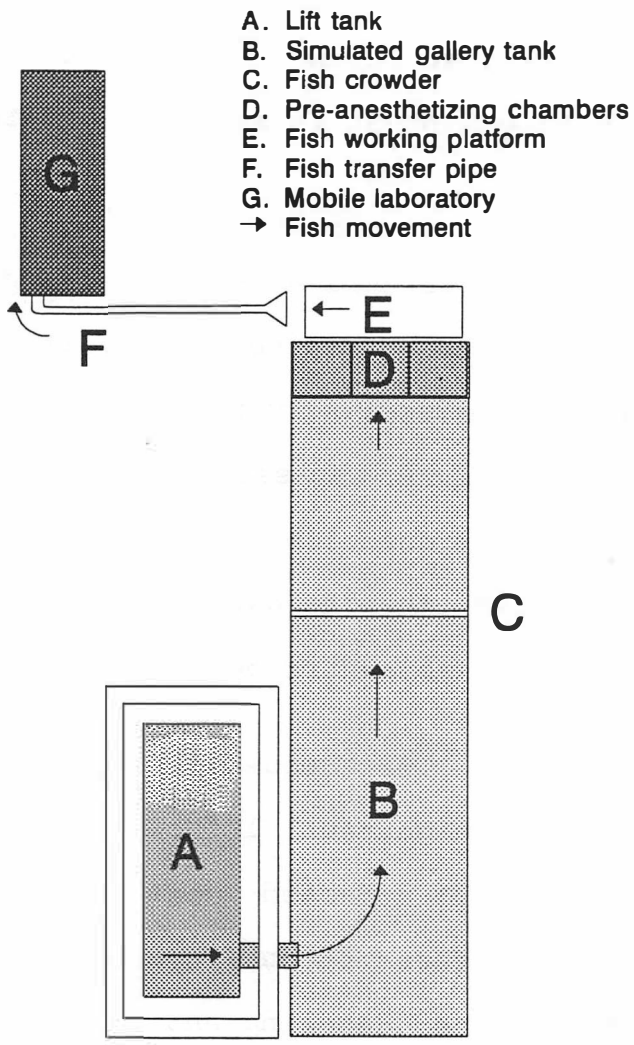

Figure 7.--Plan view of test facilities for the 1994 lift-tank evaluation.

evaluated collection efficiency and descaling after complete operating cycles of the lift tank.

During testing, Turbines 4 and 6 were operated at 135 MW which corresponded to turbine intake flows of approximately 18,450 cfs per unit. Gatewell orifices from Slots 4B and 6A were closed to prevent escape of marked test fish. Above-water procedures and fish behavior and movement were video taped throughout the evaluation.

Phase I. On-Deck Testing

Phase I testing was conducted on the intake deck and examined the combined effects of containment in and exit from the lift tank. Prior to testing, treatment and control fish were examined for descaling and differentially marked. Descaled fish were not used in the experiment. Tagged treatment fish were placed into the lift tank and allowed to pass, via an orifice coupling, into a tank that simulated the bypass gallery (gallery tank). Control fish were released directly into the gallery tank. All fish in the gallery tank were crowded to a pre-anesthetic chamber and anesthetized. Fish were then counted and examined to determine descaling, injury, and mortality rates. To facilitate fish handling, examinations were conducted in a NMFS mobile laboratory parked on the intake deck. Condition of fish released from the lift tank was compared to control fish released directly into the gallery tank.

For calculation of sample sizes, we assumed background and additional treatment descaling incidences of 1% each. We

determined that approximately 2,400 steelhead were required for testing, and planned on using 400 fish (200 test and 200 control) for each of 6 tests. Treatment and control descaling incidence were compared by paired t-tests at the $\alpha = 0.05$ significance level.

We videotaped fish exiting the tank via the orifice opening to determine any unusual fish behavior and problems with tank design. The bottom gate of the lift tank was designed to empty all fish from the tank during the water draining process. However, prior experience with similar designs and fish behavior suggested that additional flush water might be necessary, and in certain cases, still might not be adequate in removing all fish.

Phase II. Gatewell Testing with Lift Tank Fully Submerged

The objectives of Phase II testing were to evaluate 1) collection efficiency (i.e., the percentage of available fish collected with each lift-tank immersion in the gatewell); 2) fish escapement, either by passing between the lift-tank sides and gatewell sides or by remaining below the lift tank; and 3) the effect of lift-tank operation on fish condition.

Testing began with the lift tank lowered to maximum fishing depth where the upper and lower ends of the lift tank were approximately 1.4-m and 4.9-m, respectively, below the water surface in the gatewell. Traditionally, the dip basket has been fished at a depth of about 24.4 m.

Marked fish were transferred into the gatewell via a 7.6-cm diameter hose from the intake deck and released just below the

water surface in the gatewell. After allowing 20 minutes for fish dispersion and acclimation, the bottom gate of the lift tank was closed. The lift tank was then raised to the deck, the orifice fittings coupled, and fish were released through the orifice into the simulated gallery tank (Fig. 4). This process was repeated two more times to recover fish (with the exception that no additional fish were released).

Once in the gallery tank, fish were handled and inventoried as in Phase I. Descaling in Phase II evaluations could have resulted from operation of the lift tank in the gatewell, exit of fish from the lift tank to the gallery tank, or post-treatment fish handling. Causes of descaling were partitioned by releasing marked control fish in the simulated gallery tank using the procedures previously described for Phase I. The net result indicated that descaling was caused by lift-tank operation including exit of fish from the lift tank.

Condition of fish collected with the lift tank was also compared with that of fish collected with a standard dip basket. For every lift-tank test, marked fish were also released into Slot 4B, and after 20 minutes were collected using a standard gatewell dip basket.

We assumed that Phase I descaling would be 2%, that standard dip basket descaling would be 2%, and that the lift-tank collection operation would cause an additional 1% descaling. As a result, we determined that 4 replicates of approximately 1,000 fish each were necessary for the lift-tank and dip-basket groups.

Control replicates were released into the simulated gallery tank as in Phase I. Sample sizes were adjusted once actual tests were conducted and variability of treatment effects was determined. The comparisons of between treatment and control descaling and between lift tank and standard dip basket were made by two-sample t-tests at the $\alpha = 0.05$ significance level.

Phase III. Gatewell Testing with Lift Tank above Water

Phase III evaluated the proposed operational cycle for the lift-tank system. It provided information on 1) the effect of lowering the lift tank on fish in the gatewell, 2) lift-tank collection efficiency, and 3) fish condition after exposure to the entire operational cycle.

Phase III testing began with the opened lift tank suspended above the water surface in the gatewell. Marked fish were released below the water surface as in Phase II. After a period of approximately 20 minutes to allow fish to disperse and acclimate, the lift tank was lowered to the same depth as in Phase II and closed. The lift tank was then raised to the deck, the orifice fittings coupled, and fish released into the simulated gallery tank as in Phase II. This process was repeated 2 more times with the lift tank remaining at maximum fishing depth with the bottom gate open for 20 minutes prior to being closed and raised.

Initially, the standard gatewell dip basket was fished in Slot 4B using similar procedures and at the same depth as the lift tank. This proved ineffective. Consequently, the dip

basket was lowered to 15.2 m after the first two replicates in Phase II, and during Phase III, it was lowered to 24.4 m, closer to the standard depth for dip baskets.

During Phases II and III, the overhead orifice light located on top of the lift tank was turned on during Replicates 1 and 3 and off during Replicates 2 and 4 to determine if the light provided any collection benefit.

Test Schedule

The original testing schedule (Table 1) was constrained by the late delivery and release of the prototype lift tank, delay in issuance of the Section 7 formal consultation, and the relatively narrow time frame that inriver hatchery steelhead were available. The emergency spill program contributed to limited collection of juvenile hatchery steelhead.

RESULTS

The goal of tagging 18,400 juvenile hatchery steelhead was not met due to the low numbers of juvenile salmonids migrating through Lower Granite Dam. A total of 5,214 hatchery steelhead were tagged and released for testing during the three phases of the lift-tank evaluation.

Phase I. On-deck Testing

We reduced the size of test groups to about 200 hatchery steelhead (100 fish each for treatment and control groups) for each of the five replicates in Phase I testing. Average descaling was 1.3% for the treatment fish and 0.6% for the controls (Table 2).

The moderate slope of the floor in the lift tank failed to drain water efficiently. The majority of water did not drain from the lift tank until approximately 3.5 minutes after the orifice slide gate was opened. Review of video tapes indicated that most fish did not begin exiting the lift tank until the water level had decreased to the top of the orifice. At that time, the low water elevation in the lift tank produced a slower flow of water. As a result, fish resisted exiting and remained in the lift tank. About 5 to 10 fish remained in the tank after water had been completely removed, 5 to 5.5 minutes after the orifice slide gate had opened. These last fish either had to be removed by hand or forced to exit with use of additional water from a hose. However, the added water was not effective, and

Table 2.--Percent descaling of hatchery steelhead during Phase I of the lift-tank biological evaluation at Lower Granite Dam, 1994.

	Treatment			Control		
Replicate	Number sampled	Number descaled	Percent descaled	Number sampled	Number descaled	Percent descaled
1	99	3	3.0	99	0	0.0
2	101	0	0.0	67	0	0.0
3	113	3	2.7	114	9	7.9[1]
4	118	3	2.5	97	3	3.1
5	117	0	0.0	119	0	0.0
6	138	0	0.0	157	0	0.0
Total	686	9		539	3	
Average			1.3			0.6

[1] Handling problem, control data not used for this replicate.

instead compounded the removal problem by attracting fish away from the orifice.

Phase II. Gatewell Testing with Lift Tank in Water (submerged 4.9 m)

During Phase II testing, the majority of marked fish were recovered in the first dip of the lift tank (Table 3). Over the 4 replicates, an average of 83.7% of the tagged fish were recovered in the first dip, 9.5% in the second dip, and 1.4% in the third dip for an overall recovery rate of 94.5% for 3 dips.

In comparison, the standard dip basket averaged 96.0% collection efficiency after 4 dips. Efficiency was affected by the depth to which the dip basket was fished. In the first 2 replicates, the dip basket was fished at approximately the same depth as the lift tank (bottom at approximately 4.9 m). Percent recovery after 3 dips was unusually low, and a fourth dip to 15.2 m was required. Beginning with the third replicate, the dip basket was fished at 15.2 m, closer to the usual depth of 24.4 to 27.4 m. This improved fish collection, eliminating the need for the fourth dip. Collection efficiency of the dip basket totaled 97.8% after three dips in Replicates 3 and 4.

About 16.3% of the tagged fish evaded collection by the lift tank during the first dip. We were unable to determine if fish evaded collection by passing between the lift-tank and the gatewell walls or by swimming deeper than the lift-tank fishing depth before the bottom gate was closed.

Table 3.--Collection efficiency and percent descaling of hatchery steelhead during Phase II of the lift-tank biological evaluation at Lower Granite Dam, 1994.

		Lift-tank efficiency in Slot 6A (%)					Control	
Replicate[1]	Number released	First lift	Second lift	Third lift	Total	Percent descaled	Number sampled	Percent descaled
1	168	75.6	15.5	0.6	91.7	1.3	-	-
2	299	88.0	5.0	1.7	94.6	1.1	99	1.0
3	115	86.1	4.3	1.7	92.2	0.0	-	-
4	295	83.1	12.5	1.4	96.9	1.7	97	0.0
Total	877						196	
Average		83.7	9.5	1.4	94.5	0.8		0.5

		Dip-basket efficiency in Slot 4B (%)					
Replicate	Number released	First dip	Second dip	Third dip	Fourth dip[2]	Total	Percent descaling
1	97	33.0	0.0	2.1	61.9	96.9	0.0
2	299	76.9	0.7	1.3	16.7	95.7	0.0
3	115	93.9	1.7	0.0	-	95.7	0.9
4	298	96.6	2.0	0.0	-	98.7	0.7
Total	809						
Average		81.3	0.5	0.7	27.8	96.0	0.4

[1] The overhead orifice light located on top of the lift tank was turned on during Replicates 1 and 3 and off during Replicates 2 and 4.

[2] The dip basket was originally fished at the same depth as the lift tank (about 4.9 m). At that depth, a fourth dip was required to recover fish. After Replicate 2, the dip basket was fished closer to the traditional depth at about 15.2 m.

On the average, descaling during Phase II testing was 0.8% for the treatment fish and was 0.5% for the controls. Nominal descaling (treatment effect only) was 0.3%. Descaling for the dip basket treatment fish was 0.4%.

During Phase II testing, 42 unmarked fish were collected by the lift tank in Slot 6A, and 50 were collected by the dip basket in Slot 4B (Table 4). Only 3 unmarked juvenile chinook salmon were collected with the lift tank compared to 14 collected with the dip basket, possibly due to the difference in fishing depths. Several of the juvenile chinook salmon collected by the lift tank were descaled. However, numbers of these fish collected for each replicate were small, and we were unable to determine the cause(s) of the descaling.

Phase III. Gatewell Testing with Lift Tank above Water

Lowering the lift tank into the gatewell while tagged hatchery steelhead were in the gatewell seemed to have little effect on collection. During the first dip of the lift tank, 84.7% of the tagged fish were recaptured. Total collection by the lift tank averaged 95.0% (Table 5).

Recovery percentages for the dip basket were higher for Replicates 2, 3, and 4 due to the change in fishing depths. With the exception of the first replicate, the standard dip basket recovered an average of 97.3% of the tagged fish in the first dip. Overall collection efficiency for the dip basket throughout Phase III averaged 98.0%.

Table 4.--Incidental fish collected during Phase II of the lift-tank biological evaluation at Lower Granite Dam, 1994.

	Lift tank (Slot 6A)				
Replicate	Hatchery steelhead	Wild steelhead	Hatchery chinook	Wild chinook	Sockeye
1	26	-	-	-	-
2	8	-	1	-	-
3	3	-	1	-	-
4	3	-	-	1	-
Total	40	-	2	1	-

	Dip basket (Slot 4B)				
Replicate	Hatchery steelhead	Wild steelhead	Hatchery chinook	Wild chinook	Sockeye
1	9	-	2	4	1
2	10	1	-	3	-
3	11	2	1	3	-
4	2	-	1	-	-
Total	32	3	4	10	1

Table 5.--Collection efficiency and percent descaling of hatchery steelhead during Phase III of the lift-tank biological evaluation at Lower Granite Dam, 1994.

		Lift-tank efficiency in Slot 6A (%)						Control	
Replicate[1]	Number released	First lift	Second lift	Third lift	Total	Number descaled	Percent descaled	Number sampled	Percent descaled
1	129	80.6	9.3	3.9	93.8	2	1.7	94	0.0
2	161	85.7	5.6	4.3	95.7	3	1.9		
3	287	86.8	6.6	3.1	96.5	1	0.4		
4	245	83.7	8.2	1.6	93.5	1	0.4		
Total	822							94	
Average		84.7	7.3	3.0	95.0	7	0.9		0.0

		Dip-basket efficiency in Slot 4B (%)					
Replicate	Number released	First dip	Second dip	Third dip	Total	Number Descaled	Percent Descaled
1	114	33.3	59.6	2.6	95.6	1	0.9
2	121	98.3	0.8	0.0	99.2	1	0.8
3	255	96.1	1.2	0.8	98.0	4	1.6
4	216	98.1	0.5	0.0	98.6	1	0.5
Total	706						
Average		87.0	10.3	0.7	98.0	7	1.0

[1] The overhead orifice light on top of the lift tank was turned on during Replicates 1 and 3 and off during Replicates 2 and 4.

Descaling in the lift-tank treatment group averaged 0.9%. No descaling was found in the control group. Descaling in the dip basket averaged 1.0%. Nine, 1, and 87 unmarked yearling spring chinook salmon, sockeye salmon, and steelhead, were incidentally collected by the lift tank and dip basket, respectively (Table 6).

The overhead orifice light on top of the lift tank had no effect on fish recovery, suggesting that the light was ineffective in attracting fish to the surface during daylight. Mean recovery for Phases II and III when the light was on (94.1% for Replicates 1 and 3) was 1.1% lower than when the light was off (95.2% in Replicates 2 and 4) (Tables 3 and 5). No tests were conducted during darkness.

Appendix Table 1 lists the handling mortality of hatchery steelhead during the lift-tank biological evaluation. No handling mortality of other species was observed. Numbers of fish used during testing and the analysis of those data are provided in Appendix Tables 2 through 5.

Table 6.--Incidental fish collected during Phase III of the lift-tank biological evaluation at Lower Granite Dam, 1994.

	Lift tank (Slot 6A)				
Replicate	Hatchery steelhead	Wild steelhead	Hatchery chinook	Wild chinook	Sockeye
1	3	-	-	-	-
2	16	-	-	1	-
3	7	-	-	-	-
4	3	-	-	1	-
Total	29	-	-	2	-

	Dip basket (Slot 4B)				
Replicate	Hatchery steelhead	Wild steelhead	Hatchery chinook	Wild chinook	Sockeye
1	14	-	-	-	-
2	9	2	1	-	1
3	24	4	-	1	-
4	5	-	2	3	-
Total	52	6	3	4	1

DISCUSSION

Preliminary evaluation of the lift-tank system indicated that its collection efficiency was satisfactory (compared with standard gatewell dip baskets) and that its use for the collection and transfer of fish did not cause excessive descaling, injuries, or mortalities. However, the lack of detrimental effects may have been a result of the specific test conditions. Test results might have been different had the evaluation occurred during the spring migration period when fish numbers were higher and the species composition was different.

For example, the low descaling incidence may have resulted from a combination of low fish densities and the use of steelhead juveniles, which have less deciduous scales. Maximum number of fish in the lift tank at any time during testing was about 250, and given the lift-tank capacity of 11,925 L of water (COE, 1994a), this number resulted in a density of 1 fish per 48 L. In the future, during the peak of the juvenile salmonid migration, several thousand fish might be collected in one dip of the lift tank, increasing densities considerably.

Increased densities and propensity of fish to resist exiting the tank could lead to higher incidences of descaling, injury, or mortality, particularly if combined with the presence of sharp edges inside the lift tank and adult fish. Occasionally, adult fish are collected in dip baskets, and their activity may also cause descaling of juvenile fish.

SUMMARY

1. The lift-tank system efficiently and safely collected and transferred tagged juvenile steelhead released into the gatewell.

2. Fewer than 1% of the tagged steelhead collected and transferred via the lift-tank system were descaled.

3. The evaluation indicated that the lift-tank system is, at a minimum, as effective as the standard gatewell dip baskets.

4. Few non-target species were captured with the lift tank but a variety of other species were caught with the dip basket, most likely because the dip basket was fished at a much deeper depth.

5. Several potential design weaknesses of the lift-tank system were observed and noted.

RECOMMENDATIONS

1. Before installation of operational lift tanks, further testing should be conducted during a spring migration to evaluate the lift-tank system under normal migratory conditions when fish densities in gatewells are higher and the species composition is different.

2. Testing should involve both chinook salmon and steelhead.

3. The lift-tank orifice connection to the existing orifice of the bypass gallery should be evaluated for fish safety.

4. Testing should be extended to longer durations to examine equipment reliability in terms of fish handling.

5. Several potential problems with lift-tank system design were noted and should be addressed before additional testing, including;

   a. The debris screen was not working at the time of the test. Considering the potential amount and size of debris encountered at Lower Granite Dam, debris separation/removal systems should be tested before implementation of the lift-tank system.

   b. The inner walls of the lift tank were cluttered with debris-screen system hardware. Many sharp edges inside the tank including conduit clips and nuts and bolts may cause descaling when fish are in high numbers. The majority of sharp edges would be eliminated with modifications to the current debris-screen system. The system should be completely covered, mounted on the

outside of the tank, or replaced with a bar grating to handle debris and adult fish.

c. Structures near the orifice opening caused erratic flows precluding smooth release of fish and may cause descaling with high fish densities. These structures should be shielded to provide laminar flow from the lift tank.

d. The floor (inner surface of the bottom gate) of the lift tank did not have an appropriate slope to drain water efficiently from the tank. Therefore, most fish remained in the tank until nearly all water has drained. We recommend increasing the slope on the floor to drain water faster, promote a more efficient fish exit, and eliminate the need for flush water.

e. The eye bolts associated with the cable attachments for opening and closing the bottom gate of the lift tank were surrounded by large gaps which may be harmful to small fish. These eye bolts should be replaced with eye bolts with longer shanks that would allow covering of the gaps without restricting cable attachment.

f. The limit switch that controlled the upward movement of the lift tank de-activated on several occasions. As a result, the lift tank remained stationary until the limit switch was manually activated and the operating system was re-set. Because the lift tank had several leaks, a malfunction of the limit switch while the tank

was suspended could result in complete draining of the lift tank. A more reliable limit switch should be implemented.

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APPENDIX

Observations

1. Lift-tank sides and gatewell walls have minimal clearance. When the lift tank was operated, STS extension cables were moved by upwelling flow and tended to rub or catch on the bottom lip of the tank. In one instance, a cable was caught by the lift tank and pulled the support, badly damaging a hand rail before the lift tank was manually stopped. There is a possibility of greater damage if the lift tank is left unmanned.

2. The spooling mechanism which raised and lowered the lift tank appeared to work. However, we were unsure if the current mechanism can safely lower the tank an additional 12 m without causing damage to the cables and sheaves on top of the tank support beam.

3. The emergency stop switch disrupted power to the entire system rather than just halting the movement of the lift tank. Loss of power could lead to pump failure or, at night, delay problem assessment and repair.

4. While being raised, the lift tank leaked from numerous areas including the orifice gate, corners of the bottom gate, and walls.

5. The lift tank could not be easily viewed from the control panel. Therefore, it was difficult to manually operate the system efficiently.

6. The liquid crystal display (LCD) screen was ineffective at normal summer temperatures. Heat from direct sunlight caused the screen to blank out.

7. The float-limit switch did not have adequate support along the shaft. Also, the limit switch occasionally did not disengage while at simulated gallery orifice level causing a halt to operations until the switch was tripped manually.

8. When full of water, the lift tank shifted downstream against the wall of the gatewell while being lifted.

Suggestions For Improvements To The Lift Tank

1. To avoid the possibility of catching STS extension cables, the tank could be made narrower and/or slots could be made on the tank to accommodate the cables. In addition, if the lift tank is used in a gatewell with an extended STS, a slot for the center lifting cable should be incorporated into the lift tank. Also, brushes mounted around the top of the tank would guide fish into the tank and hold cables out of the way against the wall.

2. Emergency kill switches should be located at multiple points for safety purposes. The switches should only shut off the movement of the tank rather than the whole system.

3. In addition to or in place of the LCD screen, install labeled buttons to perform the desired functions.

4. Eliminate or completely cover all protruding structures inside the tank and make the inside as smooth as possible.

5. Redesign the orifice opening to provide smoother flow of water. In addition, install the slide gate and air cylinder outside the tank or enclose within a smooth cover.

6. The bottom gate of the tank currently has a dual-slope design. Changing to a tri-slope design with the third slope leading to the opening, increasing the slope and/or putting a small reservoir at the exit may provide a safer and more efficient exit for the fish.

The Simulated Gallery Tank

1. The pump to fill the simulated gallery had inadequate pumping capacity.

2. A semi-permanent screen at the orifice end of the tank would permit use of submersible pumps to supply water to fish-holding facilities.

3. A 10.2 cm quick-disconnect hose fitting on the upstream side of the simulated gallery tank would facilitate control fish releases and help to reduce congestion of traffic on the intake deck during testing.

Appendix Table 1.--Incidental mortality of hatchery steelhead during the lift-tank biological evaluation at Lower Granite Dam, 1994.

	Phase I mortality						
	Pre-release			After collection (laboratory)			
	Lift tank			Lift tank			
Replicate	Treatment	Control	Dip basket	Treatment	Control	Dip basket	Incidental
1	1	1	-	0	0	-	-
2	0	0	-	0	0	-	-
3	0	0	-	0	0	-	-
4	1	1	-	1	1	-	-
5	3	1	-	0	0	-	-
6	2	1	-	3	0	-	-
Total	7	4	-	4	1	-	-

	Phase II mortality						
	Pre-release			After collection (laboratory)			
	Lift tank			Lift tank			
Replicate	Treatment	Control	Dip basket	Treatment	Control	Dip basket	Incidental
1	0	-	1	1	-	2	0
2	1	1	0	1	0	13[1]	0
3	1	-	1	0	-	0	0
4	5	0	2	3	2	0	0
Total	7	1	4	5	2	15	0

	Phase III mortality						
	Pre-release			After collection (laboratory)			
	Lift tank			Lift tank			
Replicate	Treatment	Control	Dip basket	Treatment	Control	Dip basket	Incidental
1	2	1	1	0	0	0	0
2	5	-	1	0	0	0	0
3	13	1	7	0	3	7	0
4	2	-	1	0	-	1	0
Total	22	2	10	0	3	8	0

[1] Fish mortality occurred in holding tank and was caused by blockage in water hose.

Appendix Table 2.--Analysis of lift-tank data collected for juvenile hatchery steelhead during Phase I of the lift-tank biological evaluation at Lower Granite Dam, 1994.

	Treatment[1]			Control[2]		
Replicate	N	Number descaled	Percent descaled	N	Number descaled	Percent descaled
1	99	3	3.0	99	0	0.0
2	101	0	0.0	67	0	0.0
3	113	3	2.7	114	9	7.9[3]
4	118	3	2.5	97	3	3.1
5	117	0	0.0	119	0	0.0
6	138	0	0.0	157	0	0.0
7				99	1	1.0
8				97	0	0.0
9				94	0	0.0
Total	686	9	1.3	829	4	0.5
		Binomial 95%C.I.+/-	0.9		Binomial 95%C.I.+/-	0.5
		Mean	1.4		Mean	0.5
		s.e.	0.6		s.e.	0.4
		Empirical 95%C.I.+/-	1.6		Empirical 95%C.I.+/-	0.9

[1] Treatment fish were released from the lift tank through the simulated orifice.
[2] Control fish were released directly into the simulated gallery tank.
[3] Handling problem, data not used.

Appendix Table 3.--Analysis of lift-tank data collected for juvenile hatchery steelhead during Phase II of the lift-tank biological evaluation at Lower Granite Dam, 1994.

Replicate	Number released	Number recovered dip 1	dip 2	dip 3	Percent dip 1	Percent dips 1-3	Number descaled	Percent descaled
1	168	127	26	1	75.6	91.7	2	1.3
2	299	263	15	5	88.0	94.6	3	1.1
3	115	99	5	2	86.1	92.2	0	0.0
4	295	245	37	4	83.1	97.0	2	0.7
Total	877	734	83	12			7	
Average					83.7	94.5		0.8
		Binomial 95%C.I.+/-			2.4	1.5		0.6
				Mean	83.2	93.9		0.7
				s.e.	2.7	1.2		0.3
		Empirical 95%C.I.+/-			8.7	3.9		0.8

Appendix Table 4.--Analysis of lift-tank data collected for juvenile hatchery steelhead during Phase III of the lift-tank biological evaluation at Lower Granite Dam, 1994.

Replicate	Number released	Number recovered dip 1	dip 2	dip 3	Percent dip 1	Percent dips 1-3	Number descaled	Percent descaled
1	129	104	12	5	80.6	93.8	2	1.7
2	161	138	9	7	85.7	95.7	3	1.9
3	287	249	19	9	86.8	96.5	1	0.4
4	245	205	20	4	83.7	93.5	1	0.4
Total	822	696	60	25	84.7	95.0	7	0.9
		Binomial 95%C.I.+/-			2.5	1.5		0.6
				Mean	84.2	94.9		1.0
				s.e.	1.4	0.7		0.4
		Empirical 95%C.I.+/-			4.3	2.3		1.2

Appendix Table 5.--Analysis of dip-basket data collected for juvenile hatchery steelhead during Phases II and III of the lift-tank biological evaluation at Lower Granite Dam, 1994.

Replicate	Number released	Number recovered dip 1	dip 2	dip 3	dip 4	Percent dip 1	Percent dips 1-3	Percent dip 1-4	Number descaled	Percent descaled
1	97	32	0	2	60	33.0	35.1	96.9	0	0.0
2	299	230	2	4	50	76.9	78.9	95.7	0	0.0
3	115	108	2	0		93.9	95.7		1	0.9
4	298	288	6	0		96.6	98.7		2	0.7
5	114	38	68	3		33.3	95.6		1	0.9
6	121	119	1	0		98.4	99.2		1	0.8
7	255	245	3	2		96.1	98.0		4	1.6
8	216	212	1	0		98.2	98.6		1	0.5
Total (3)	1119	1010	81	5		90.3	97.9			
			Binomial 95%C.I.+/-			1.7	0.8			
					Mean	86.1	97.6			
					s.e.	10.6	0.7			
			Empirical 95%C.I.+/-			27.2	1.7			
Total (4)	396	262	2	6	110	66.2	68.2	96.0		
			Binomial 95%C.I.+/-			4.7	4.6	1.9		
Total (all)	1515								10	0.7
							Binomial 95%C.I.+/-			0.4
								Mean		0.7
								s.e.		0.2
							Empirical 95%C.I.+/-			0.4

(3) 3 dips all to about 24.4 m as is traditional
(4) Dips 1-3 made at same depth as lift tank and dip 4 was to 15.24 m.