Evaluation of the effectiveness of radio-telemetry methods to monitor passage routes of juvenile salmonids at Ice Harbor Dam, 1996

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Coastal Zone and Estuarine Studies Division

Northwest Fisheries Science Center

National Marine Fisheries Service

Seattle, Washington

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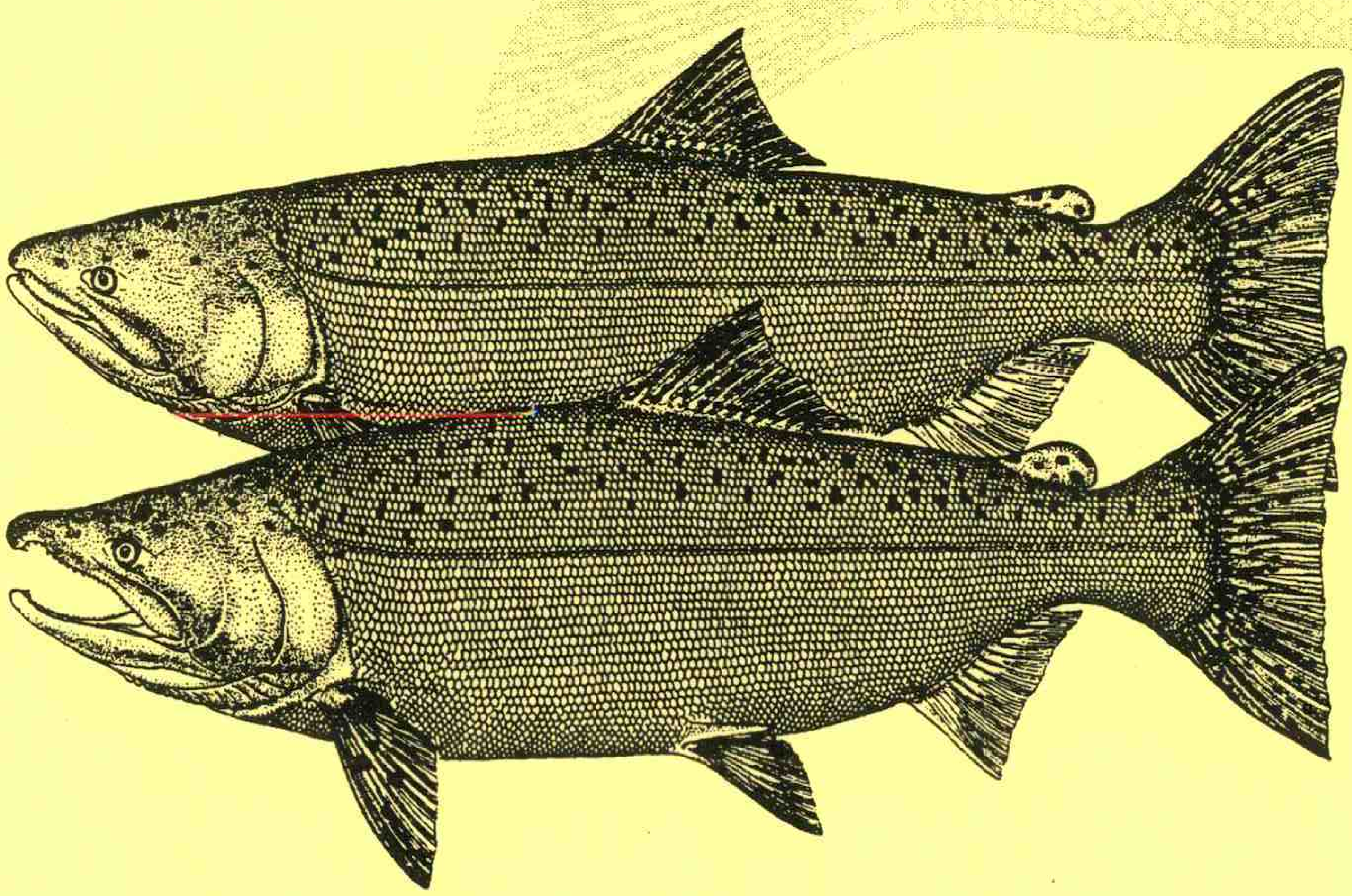

EVALUATION OF THE EFFECTIVENESS OF RADIO-TELEMETRY METHODS TO MONITOR PASSAGE ROUTES OF JUVENILE SALMONIDS AT ICE HARBOR DAM, 1996

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EXECUTIVE SUMMARY

Radio-telemetry research has provided considerable knowledge on adult salmonid behavior. Recently, miniaturization of electronic components has led to construction of transmitters small enough for implantation in juvenile salmonids and has provided the means to monitor smolt behavior during downstream migration. The objective of this study was to determine the feasibility of monitoring all potential passage routes of juvenile salmonids through a hydroelectric dam. Ice Harbor Dam in the Snake River (RKm 15.6) was the study site.

The study was conducted in two phases. In Phase I, radio tags were embedded in a neutrally buoyant object about the size and shape of a juvenile salmonid and released into a turbine intake, spillbay, and the juvenile bypass/collection system at Ice Harbor Dam to test equipment and initial tag-detection probabilities. In Phase II, radio tags were surgically implanted in live fish, which were subsequently released through the different passage routes.

We used a 30-MHZ telemetry system that combined individually coded 1.0 and 0.5 second pulse rate tags (with battery durations of 3, 7, or 15 days) and fast scanning receivers. This allowed us to monitor tagged fish passing through all passage routes even under high water-velocity conditions. Tags were procured from commercial vendors and were built to meet specifications of equipment developed by the National Marine Fisheries Service.

New designs for supporting underwater antennas were tested for detecting passage of radio-tagged juvenile salmonids through a spillbay and a turbine unit (representing unguided

fish passing through the draft tubes). Standard methods were used to install underwater and air antennas at gatewell and juvenile bypass monitoring sites.

One hundred percent of both the simulated and live radio-tagged fish that were released through the turbine/draft tubes and gatewell tests were detected. Detections for radio-tagged live fish passing through the bypass channel and over the spillway were 90 and 70%, respectively. Detection of tagged fish at the juvenile sampling facility was 40%. Modified equipment needs to increase tag detections at spillway and juvenile bypass system monitoring sites were identified, and further improvements are currently underway.

INTRODUCTION

Radio-telemetry is an effective research tool for monitoring the behavior of adult salmonids in rivers, reservoirs, and at hydroelectric dams. More recently, this methodology has been applied to monitor the behavior of juvenile salmonids during downstream migration. Miniaturization of electronic components has led to improvements in transmitter size, making them suitable for implantation in juvenile salmonids. Giorgi et al. (1988) determined that juvenile salmonids with gastric-implanted radio tags could provide acceptable estimates of powerhouse and spillway passage.

A floating hypalon curtain with a depth of 18.3 m and stretching diagonally across the forebay of a hydroelectric dam about 0.8 km upstream from the juncture of the spillway and powerhouse to a shoreline has been proposed for guiding juvenile salmonids away from the powerhouse to the spillway for downstream passage. A proposed evaluation of this device has been considered for Ice Harbor Dam at river kilometer (RKm) 15.6 on the Snake River (Fig. 1) and if found successful, the floating curtain would be installed at Lower Granite Dam (RKm 173).

If a floating curtain test is conducted at Ice Harbor Dam, a minimum acceptable fish passage efficiency (FPE) of 80% must be met or the floating curtain will be removed. The FPE will be determined in part from monitoring radio-tagged smolts. Therefore, accurate monitoring of all passage routes selected by radio-tagged smolts will be essential during testing.

In preparation for the proposed floating curtain experiment at Ice Harbor Dam, the U. S. Army Corps of Engineers, Walla Walla District, (COE) requested that the National Marine Fisheries Service (NMFS) develop baseline radio-telemetry information on juvenile

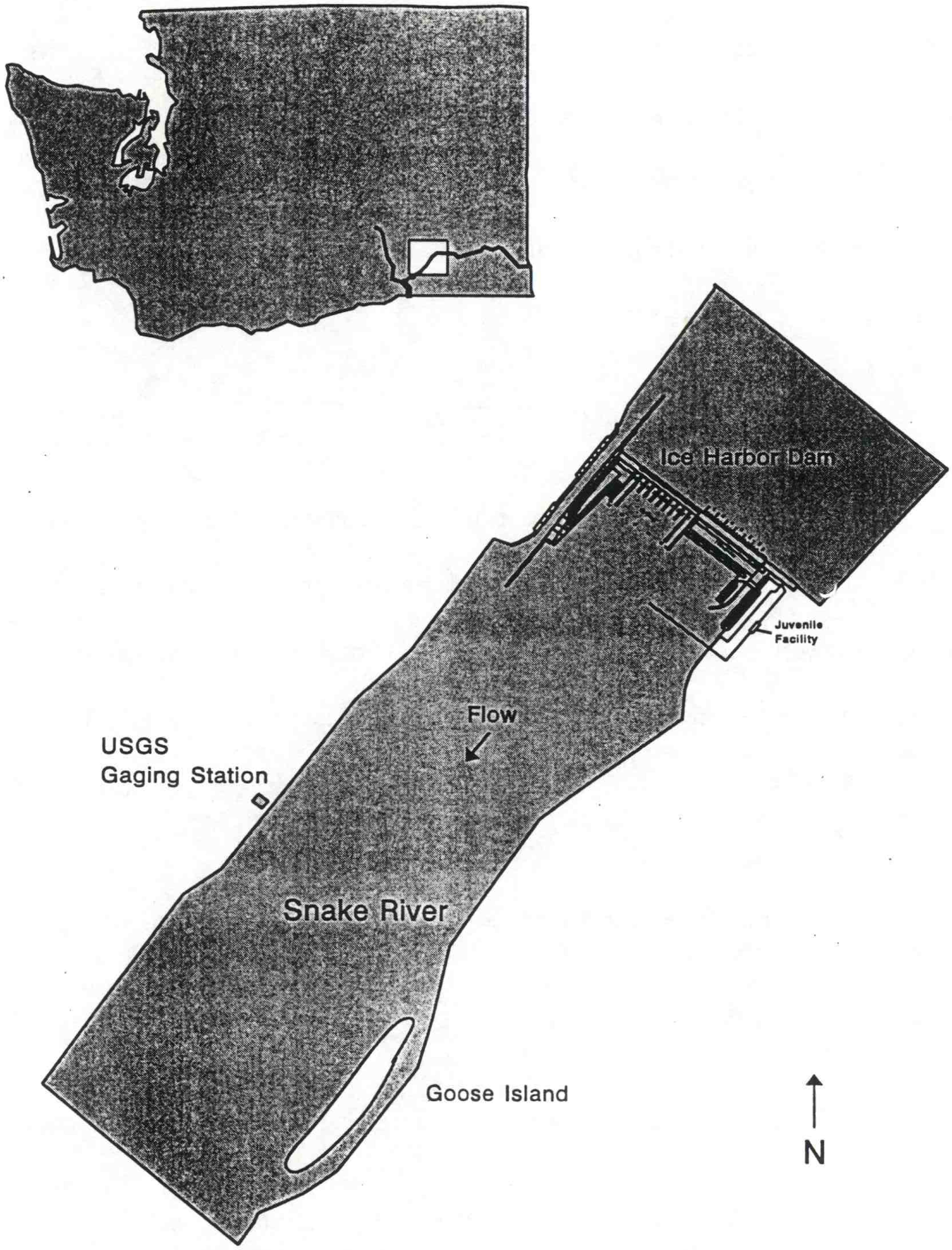

Figure 1. Study area of Ice Harbor Dam radio-telemetry project, 1996.

fish passage routes, applicable not only to Ice Harbor Dam but other dams as well. To meet the request, NMFS refined procedures for installing and operating a radio-telemetry system that accurately monitors all routes of passage available to radio-tagged smolts. In preparation for a future curtain study, the research outlined in this report evaluated the effectiveness of the NMFS radio-telemetry methods and equipment. Ice Harbor Dam, due to its close proximity to the NMFS maintenance and field electronic shop facilities at Pasco, WA, was chosen as the study site.

OBJECTIVES

The primary objective of the 1996 baseline radio-telemetry research was to evaluate the effectiveness of NMFS radio-telemetry methods and equipment used to monitor passage routes through a powerhouse (turbine intake and smolt bypass system) and spillway. The study was conducted in two phases. Specific goals for this study were covered by the following research tasks:

Phase I

Task 1: Determine the efficiency and effectiveness of NMFS radio-telemetry equipment and procedures required to monitor the passage of radio tags, embedded in simulated fish, through specific routes of passage (turbine intake, spillway, gatewell/bypass orifice and collection channel, and tailrace) at a hydroelectric dam.

> **Task 1.1:** Determine tag range and reliability of prototype 30 MHZ radio transmitters designed for tagging and tracking of juvenile chinook salmon and steelhead.
>
> **Task 1.2:** Determine optimum locations and positioning techniques for installation of underwater or air antennas at a turbine intake, a spillbay, the juvenile bypass/collection system, and the tailrace.

Task 1.2.1: Determine source and impact of radio interference affecting reception at proposed test dam (Ice Harbor Dam) and develop methods for eliminating any resultant deleterious effects.

Task 1.3: Determine antenna range and reliability at a turbine intake, a spillbay, the fish bypass/collection system, and the tailrace.

Task 1.4: Monitor passage of radio tags embedded in simulated fish through a turbine intake, a spillbay, the gatewell/bypass orifice and collection channel, and the tailrace.

Phase II

Task 2: Determine the efficiency and effectiveness of NMFS radio-telemetry equipment and procedures to monitor the passage of radio tags implanted in live hatchery juvenile salmonids through specific routes of passage (turbine intake, spillway, juvenile bypass/collection system, and tailrace) at a hydroelectric dam.

Task 2.1: Confirm tag range and reliability of prototype radio transmitters designed for tagging and tracking of juvenile chinook salmon and steelhead with live radio-tagged fish.

Task 2.2: Confirm optimum locations and positioning techniques for installation of air and underwater antennas at a turbine intake, a spillbay, the juvenile bypass/collection system, and the tailrace with live radio-tagged fish.

Task 2.3: Confirm antenna range and reliability at a turbine intake, a spillbay, the fish bypass/collection system, and the tailrace with live radio-tagged fish.

Task 2.4: Determine efficiency and effectiveness of NMFS radio-telemetry methods and equipment required for recording the passage of radio tags implanted in live fish, through the turbine intake (unguided fish), from the turbine intake to the juvenile bypass/collection system (guided fish), through a spillbay, and in the tailrace.

Task 2.5: Determine effectiveness of NMFS radio-telemetry methods and equipment required for monitoring the passage of radio tags, implanted in live fish, under tainter gates with standard deep spill.

Task 2.6: Determine effectiveness of NMFS radio-telemetry methods and equipment required for monitoring the passage of radio tags, implanted in live fish, through a spillbay incorporating stop logs covered with metal "skin" plates (surface skimming spill condition).

MATERIALS AND METHODS

This study utilized the 30-MHZ radio-telemetry system developed by NMFS. Self-contained, nine-channel, radio-telemetry receivers were strategically installed to record the presence of radio-tagged fish within specific areas of test locations. Specifically monitored areas of the dam included Spillbay 1, Turbine Unit 3 draft tubes, Gatewell 3B, juvenile collection channel, fingerling sampling facility, and the tailwater area about 2 km downstream from the dam (Figs. 1 and 2 and Table 1).

Two types of telemetry receivers were used to monitor passage of simulated fish and movement and behavior of radio-tagged juvenile salmonids during the study period. Both receivers consisted of a radio receiver, data processor, internal clock, and data logger and allowed monitoring up to nine channels simultaneously. Each unit was powered by a 120 VAC power converter, or could be operated using 12 VDC battery in conjunction with solar panels.

The first type of receiver was originally developed and assembled by NMFS electronics shop personnel. The NMFS receiver unit was used in situations where the scanning rate (1.25 seconds) was of primary importance. The second type of telemetry receiver, Model SRX-400, was purchased from Lotek Engineering Inc.,[1] Newmarket, Ontario, Canada and due to a slower scanning rate (12.45 seconds), was used in locations where water velocities were lower, and radio tags were present for longer durations.

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

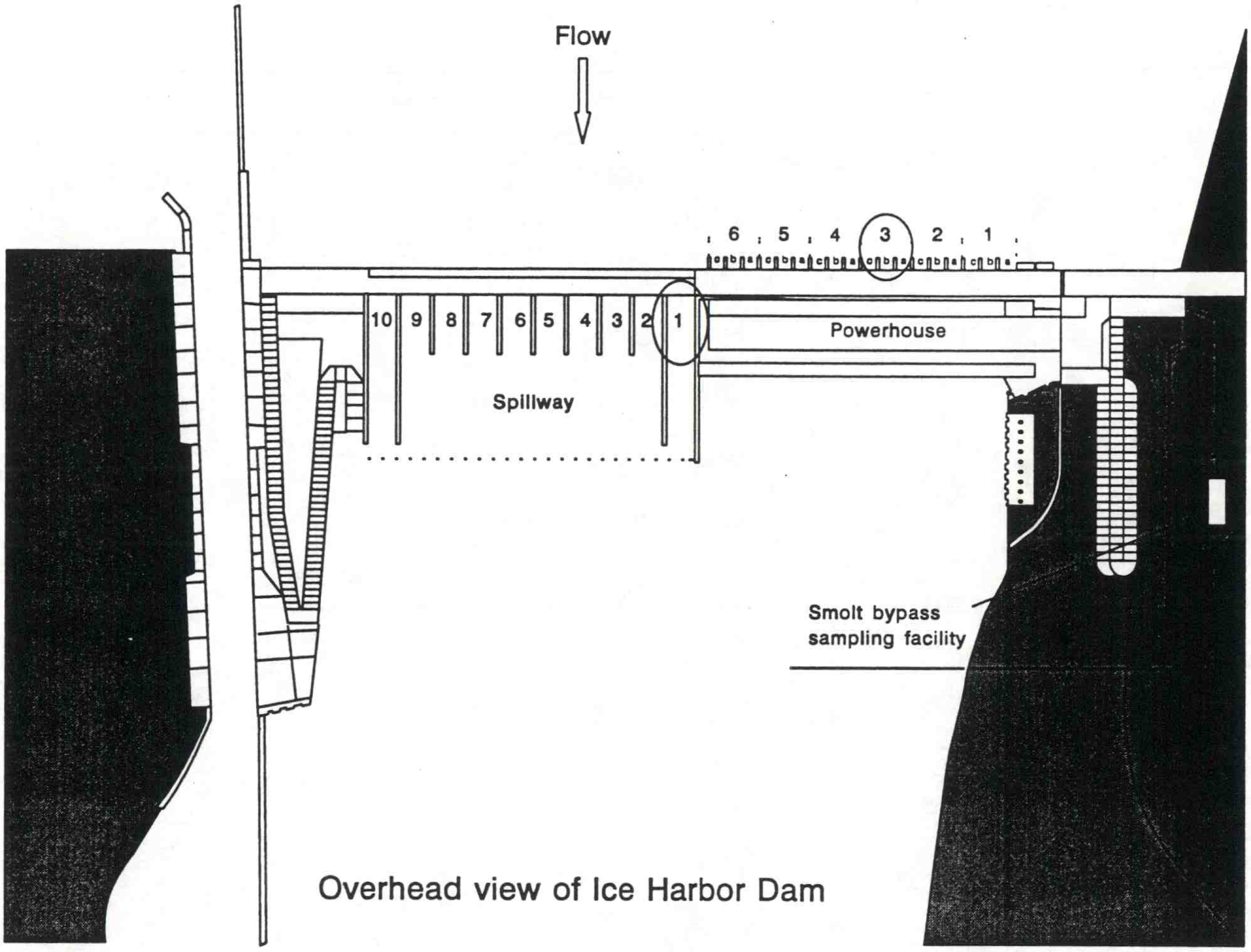

Figure 2. Overhead view of Ice Harbor Dam (circles indicate areas where specific tests were conducted).

Table 1. Location of radio-telemetry monitors at Ice Harbor Dam, 1996.

Monitor number	Monitor Location
1-12	Turbine draft tubes (unit 3)
13	Downstream side of spillbay 1
14	Upstream side of spillbay 1
15	Smolt bypass collection channel
16	Gatewell (Turbine Unit 3, Slot b)
17	Smolt bypass sampling facility
18	Downstream from dam on Goose Island
20	Downstream from dam at USGS gaging station

Radio tags suitable for implantation in juvenile chinook salmon and steelhead smolts were purchased from Advanced Telemetry Systems Inc. (ATS). The radio tags for the study had a tag life of 3, 7, or 15 days. The effective range of these transmitters was unknown at the beginning of this study but was expected to be about 60-100 m by air reception and 2-6 m by underwater reception. The tags transmitted, with either 60 pulses/min or 120 pulses/min (base pulse rates of 1 or 0.5 second, respectively), on one of nine frequencies spaced 10 KHz apart (30.170 MHZ to 30.250 MHZ). However, Channel 6 (30.220 MHZ) was not utilized due to excessive radio interference. Each tag transmitted a unique identification code number, which was obtained through a double pulse transmission by the tag every 0.5 or 1 second (depending on the base pulse rate).

The ATS tags were sealed in an epoxy capsule measuring about 1.8 cm in length, 0.5 cm in diameter, and weighed 1.4 g in the air and were equipped with a flexible external whip antenna measuring 30 cm.

Radio tags were used to tag both simulated and live fish. "Simulated fish" (transmitters embedded in neutrally buoyant objects about the size and shape of a juvenile salmonid) were released to follow the same passage routes that a smolt might follow. Simulated fish allowed testing of equipment and collection of preliminary baseline information without the use of live fish.

Two types of antennas (underwater and air) were utilized for radio-tag signal reception. Underwater antennas identified radio-tagged fish as they approached and passed a specific point. Underwater antennas consisted of coaxial cable with the shielding and protective cover stripped off 10 cm from the distal end and were used to isolate an area of reception. Types of air antennas included, 1) directional tuned-loop antennas used at fixed sites for general area tracking and fish passage where underwater antennas were not effective, and 2) multiple element Yagi antennas installed at sites downstream from the dam to monitor large expanses of the river. A 4-element Yagi antenna was installed at Monitor Site 20 on a hill above the north shoreline. Monitor Site 18, on Goose Island, was equipped with a 2-element Yagi antenna to monitor the narrower channel on the south side of the island, and a 3-element Yagi antenna monitored the wider, main river expanse on the north side of the island.

Test Sites

Turbine Intake

Two draft tubes direct all discharge from each turbine to the tailrace (Figs. 3 and 4). Water velocity through the draft tubes was estimated to be about 3.66 m/s (Pers. comm., Martin L. Ahmann, Walla Walla District, COE). Therefore, a specially constructed frame was required to monitor each draft tube of Turbine Unit 3. Fixed-site receivers with 12 underwater antennas attached to each draft tube frame (Fig. 5) identified tagged fish as they approached and passed a strategic location in the draft tube.

Spillbay

Two tuned-loop antennas were mounted on the forebay side of Spillbay 1 to record the approach of tagged fish but were used only in preliminary testing for depth range of tags. Two tuned-loop antennas were also mounted on the downstream side of the spillbay to record tagged fish that had passed over the spillbay.

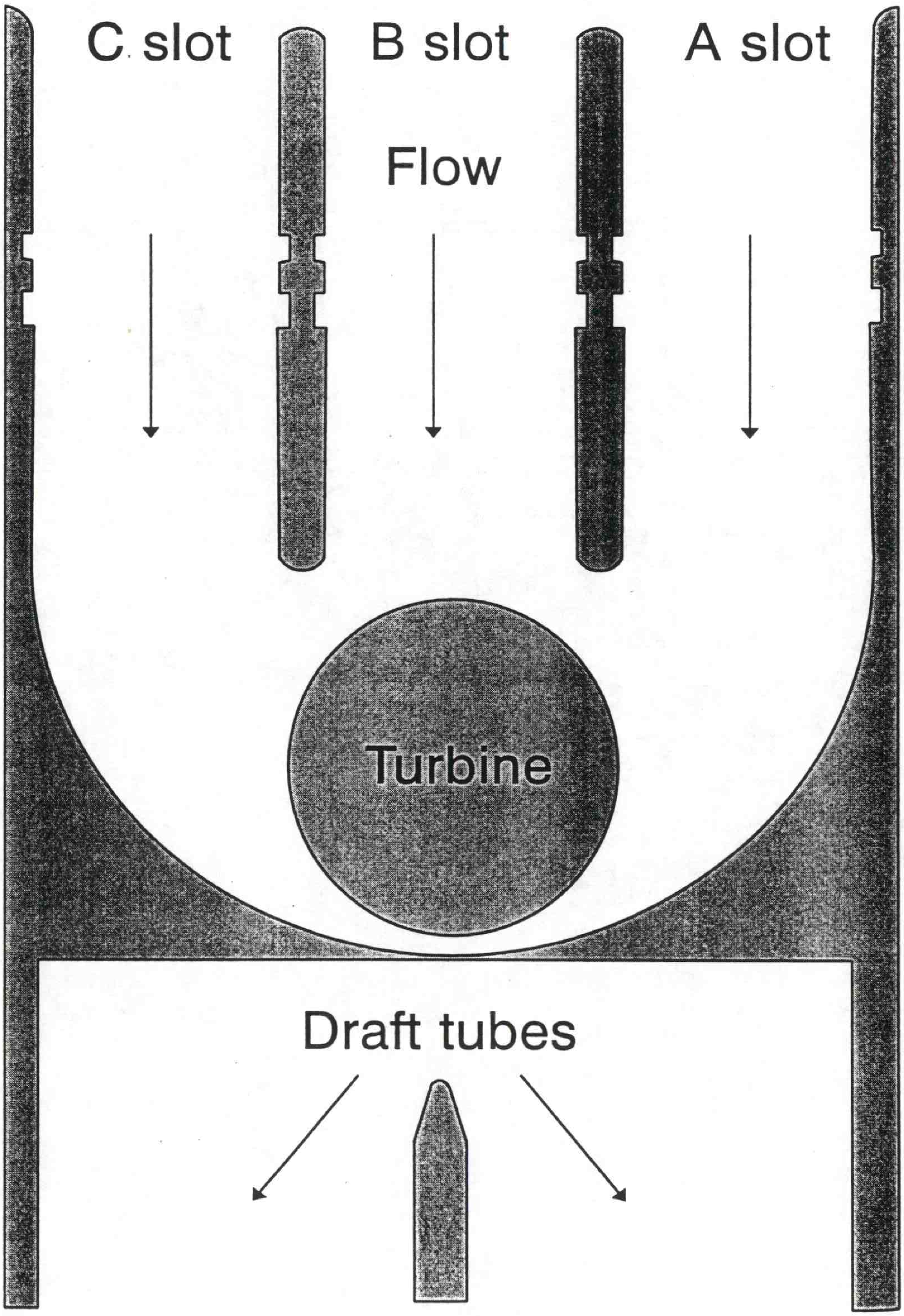

Figure 3. Overhead schematic of an Ice Harbor Dam turbine unit.

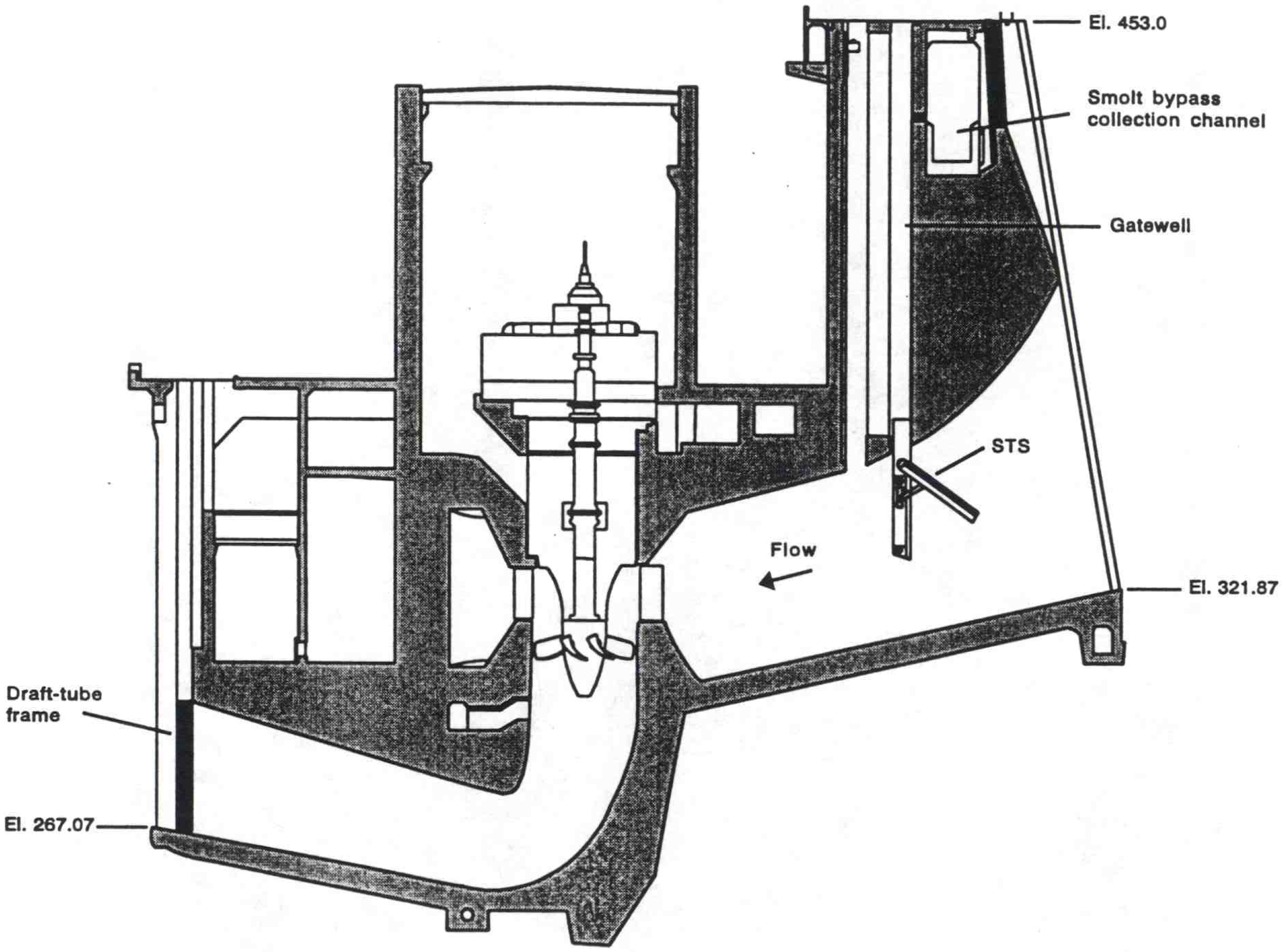

Figure 4. Cross section of the powerhouse at Ice Harbor Dam.

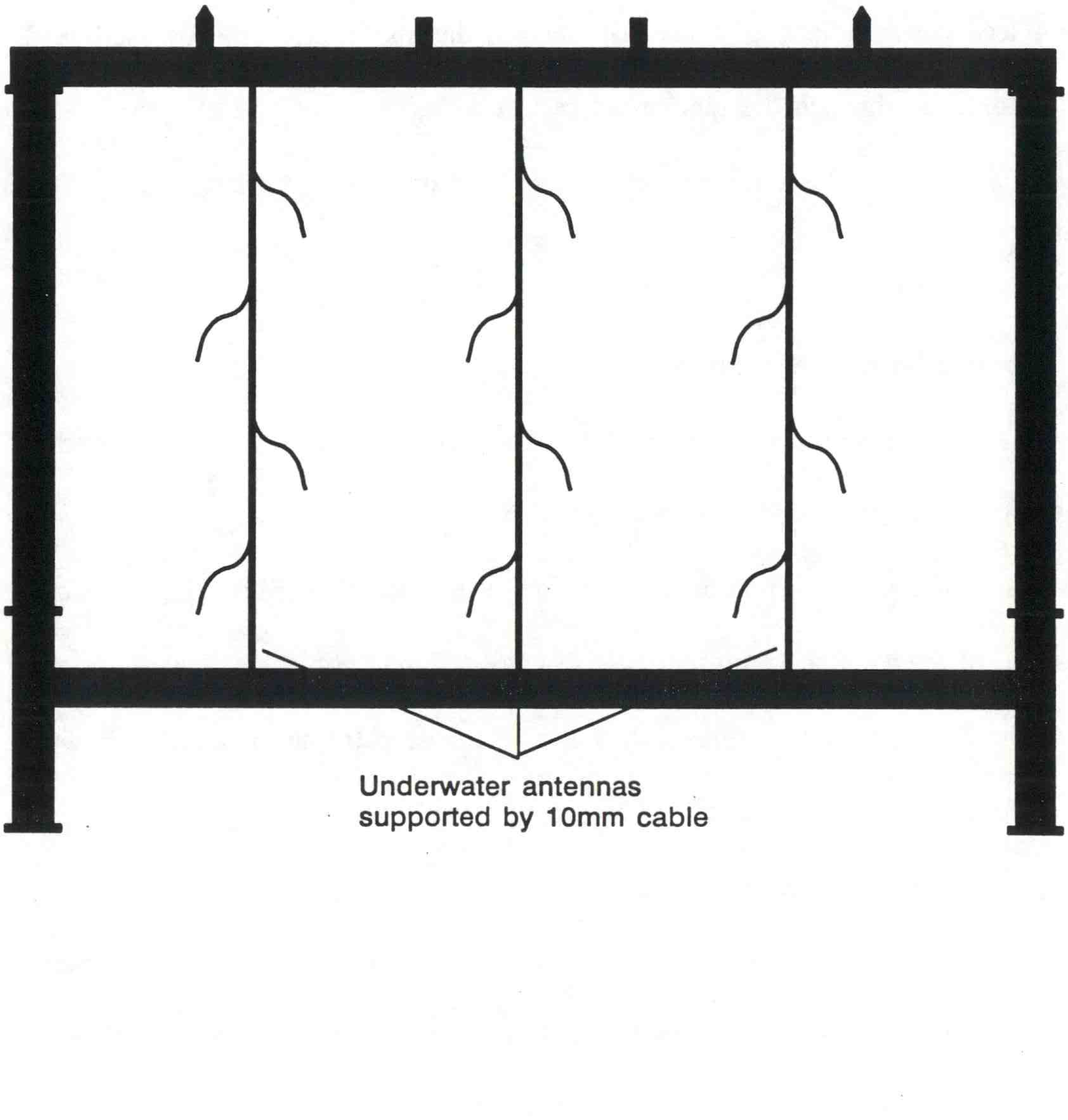

Figure 5. Support frame for underwater antennas placed in each draft tube of Turbine Unit 3.

In order to detect radio tags at precise underwater locations near the spill gate, we developed a tube structure to house and position underwater antennas in the forebay about 2.5 m in front of and above the bottom of the tainter gate. A single underwater antenna was housed in a 6.35 cm diameter pipe on the upstream side of Spillbay 1 to record tagged fish passing under the tainter gate from the forebay to the tailwaters via the spillway (Fig. 6). A lead weight attached to the distal end of the underwater antenna facilitated lowering the antenna through the tube structure to the desired depth. Therefore, the antenna could easily be pulled to the surface to check its condition and returned to the monitoring position.

Juvenile Bypass/collection System

Two underwater antennas, each with the distal end weighted, were suspended in the gatewell to detect the presence of radio-tagged fish.

Two air antennas (loop) were mounted in the juvenile bypass/collection system to verify passage of tagged fish (representing fish guided from the turbine intake) from the gatewell to the bypass channel. One underwater antenna located in Gatewell 3-B verified presence of fish. In addition, tagged fish exiting gatewells through the orifices were interrogated in the bypass channel.

Air antennas were placed in the bypass/collection channel to verify the passage of radio tags from the gatewell into the bypass system. Passage from the bypass channel to the sampling facility was monitored by air antennas mounted on the flume upstream from the juvenile separator.

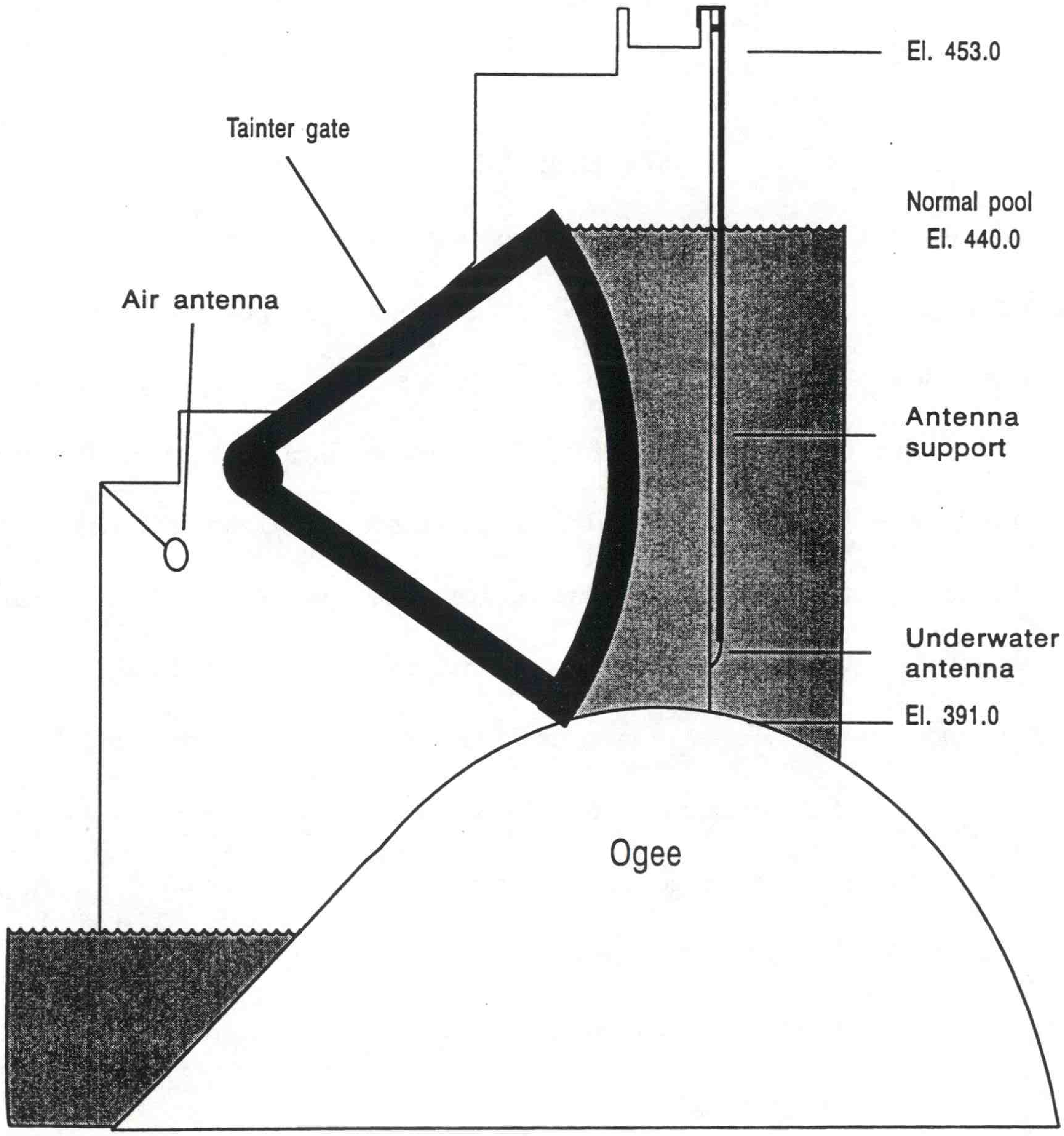

Figure 6. Cross section of Spillbay 1 during testing at Ice Harbor Dam, 1996.

Tailwaters

One 4-element Yagi air antenna was mounted on the north shore and two 3-element Yagi air antennas were mounted on Goose Island to detect radio-tagged fish passing through the tailwaters.

Simulated Fish

We considered a variety of objects for use as simulated fish and chose two for initial trials with test tags. First, we inserted a juvenile radio tag through a hole drilled in a racquet ball and added a sufficient amount of lead shot to achieve the buoyancy required for the ball to float just under the water's surface. Finally, we filled the ball with insulation foam from a pressurized can (as used to fill spaces around house windows) and sealed the hole with silicone caulking compound. The racquet ball version of the simulated fish was found to be unsatisfactory. Apparently, water was forced into the balls when they were compressed by about six atmospheres of pressure in the turbine intake and draft tubes.

In the second effort to develop a simulated fish, we used a foam rubber, key chain float (as used with boats). We removed the key chain and inserted the radio tag into the hole in the float and applied silicone to keep the tag in place. Both, balls and floats, were spray painted a fluorescent orange color to aid in locating and recovering the simulated fish in an effort to reuse the radio tags.

The key chain float functioned very well as a simulated fish. The simulated fish appeared to pass through the release hoses and the passage routes in a manner similar to live fish. A total of 18 radio tags were embedded in simulated fish and utilized throughout Phase I of this study.

Test Fish

Test fish were hatchery juvenile chinook salmon (*Oncorhynchus tshawytscha*) and steelhead (*O. mykiss*) held on site for the evaluation of the juvenile bypass at Ice Harbor Dam (a separate study). Forty-four juvenile hatchery salmonids served as live test fish during Phase II of the radio-telemetry study.

In our studies at Ice Harbor Dam in 1995 (Swan et al., 1995), we radio tagged juvenile salmonids using the gastric implant method. We had experienced some regurgitation of radio tags in holding containers prior to release of tagged fish. In addition, some regurgitation subsequent to the release of radio-tagged fish was also suspected. As a result of that experience, in 1996, we used a surgical implant technique similar to methods described by Hockersmith et al. (1995). The surgical implant method proved highly satisfactory. During this study, we recorded only one mortality prior to the release of tagged fish.

Both simulated and live fish were released one at a time. Releases at the spillway were made through a 7.6 cm hose attached to a 7.6 cm steel pipe that housed the underwater antenna. Releases for the draft tube tests were made through a 7.6 cm hose that extended from the intake deck through Gatewell 3-B to the submerged traveling screen (STS). The distal end of the release hose was attached to the downstream side of the STS.

Test Sequence

Testing focused on separate routes of passage (e.g. a turbine intake and a spillbay) and was conducted in two phases. Initial testing utilized radio tags imbedded in simulated fish and addressed tag detection and signal range and location and efficiency of antennas and receivers.

During Phase I, radio-tagged simulated fish were released into a single turbine intake, a single spillbay, the gatewell and bypass/collection channel. During each trial, data including identification of tags and respective number of detections recorded per tag were collected along with anecdotal observations. To determine tag range, tags were released upstream from Monitor Sites 18 and 20 and allowed to drift with the river current past the monitor sites while suspended at depths of about 1-3 m. Four types of tags (3-day tags with pulse rates of 60 or 120 pulses/min and 7- day tags with 60 or 120 pulses/min) were used during the range testing. Phase II provided data with live radio-tagged fish for comparison with the results of Phase I.

Simulated fish were released into the spillbay and turbine intake through a 7.6 cm hose and were placed into the gatewell and bypass channel by hand. Test fish were released by lowering them in buckets of water.

RESULTS AND DISCUSSION

Installation of test equipment began in March. Phase I of the testing focused on the individual tasks in succession, using simulated fish (test tags), and was conducted during April. Phase II, with radio-tagged live fish, was conducted during May.

Phase I

> **Task 1:** Determine the efficiency and effectiveness of NMFS radio-telemetry equipment and procedures required to monitor the passage of radio tags, embedded in simulated fish, through specific routes of passage (turbine

intake, spillway, gatewell/bypass orifice and collection channel, and tailrace) at a hydro-electric dam.

During the initial testing in Phase I, some difficulty was experienced in detecting simulated fish when they were at the surface of the water. After the project was completed and during consultation with the manufacturer of the radio tags, we concluded that because the tags were tuned for total immersion in water, if any portion of the tag antenna protruded from the water, a substantial decrease in signal strength could occur. Subsequent tests with the simulated fish attached to weighted lines at a depth of at least 1 m resulted in a detection rate of 100% by the Yagi air antennas at the downstream monitor sites.

Although recovery of the simulated fish was desirable for subsequent reuse of the radio tags few were recovered downstream from the dam. The low recovery rate may have been resulted in part from erratic flows, high velocities, and water pressures in the spill basin and tailrace, and excessive radio interference, collectively reducing the chances of locating the tags either visually or by telemetry.

Task 1.1: Determine tag range and reliability of prototype 30-MHZ radio transmitters designed for tagging and tracking of juvenile chinook salmon and steelhead.

All transmitters were recorded with adequate signal strength output up to a distance of about 330 m with Yagi antennas. Underwater antennas were effective for tag detection up to 3-4 m. The ATS juvenile radio tags tested were judged reliable for conducting a behavior study with live juvenile salmonids.

Task 1.2: Determine optimum locations and positioning techniques for installation of underwater or air antennas at a turbine intake, a spillbay, the juvenile bypass/collection system, and the tailrace.

During this task, we had not received our full supply of radio tags; therefore, most of our testing with simulated fish was accomplished with tags having a 7-day battery life combined with a signal output of 60 or 120 pulses/min (Table 2). Mounting underwater antennas on a support frame positioned in a draft tube was the most practical method for both equipment installation and detection of unguided radio-tagged juvenile salmonids. All simulated fish (100%) released into the turbine intake were detected by the draft tube antenna array and monitors, the tube-mounted underwater antenna monitoring the forebay side of the tainter gate detected 100% of the simulated fish, and 100% of the simulated fish introduced into the test gatewell were detected.

At the upstream side of the spillway, tuned-loop air antennas located on the parapet wall overlooking the near forebay were found to be of limited value. These antennas were only effective in recording radio-tagged fish and simulated fish near the surface, to a depth of about 3 m. However, the tuned-loop air antennas installed on the downstream side of Spillbay 1 were 100% efficient at detecting simulated fish as they passed over the spillbay.

None of the 7-day test tags in simulated fish were recorded in the collection channel. Detection of these tags may have been affected by the tag antenna's partial exposure to air at the surface of the water. In addition, a low gain setting was required on the receivers for Sites 15 and 17 due to high interference levels. Lower gain settings can contribute to lower detection rates especially if signal output is weak.

Two of four test tags were detected at the smolt bypass sampling facility. In addition to intense radio interference in this area, a very short exposure time for detection existed due to the flow in the flume at the upstream end of the sampling facility. NMFS

Table 2. Detection efficiency of radio-telemetry monitors at downstream sites for radio-tagged simulated fish released during testing at Ice Harbor Dam, 1996.

Test site	Number of tags tested	Number detected	Number of detections n	Range	Median	Monitor efficiency (%)
Draft tubes	7	7	16,158	31-5,294	89	100
Bypass system[a]	4	2	--	------	--	50
Spillway	3	3	17	1-5	2	100
Total	14	12	--	-----	--	86

[a] All simulated fish were detected in the gatewell, none in the collection channel, and two were detected at the juvenile facility.

monitors were not utilized at Monitor Site 17 due to limited space and apparently the Lotek monitors were unable to scan at an adequate rate to detect tags efficiently in the high velocity. However, partial exposure of the tag antennas to the air may also have reduced detection efficiency at this site.

Task 1.2.1: Determine source and impact of radio interference affecting reception at proposed test dam (Ice Harbor Dam) and develop methods for eliminating any resultant deleterious effects.

Ambient "noise" (interference created by general electrical fields such as by operating turbines and electrical and internal combustion engines or frequencies such as created by flowing water) all contribute various radio frequencies which can be confused with or even block valid signals from radio tags. Simulated fish passing through the bypass channel and the juvenile sampling facility were poorly detected, most likely due to excessive interference (electrical and frequency noise). We found that changing the orientation of antennas, lowering the gain setting on receivers, or moving the monitoring site to a new location were of some value in reducing radio interference. However, more concentrated testing in the vicinity of the tailrace deck of hydroelectric dams is needed.

Task 1.3: Determine antenna range and reliability at a turbine intake, a spillbay, the fish bypass/collection system, and the tailrace.

Antenna range is partially determined by the signal strength from a transmitter. Due to the inherent variability stemming from the electronic components used in the construction of radio tags, signal strength of transmitters will vary. Consequently, the efficiency of detection equipment can be greatly affected, especially when the effects of signal strength variability are compounded with other factors such as interference, depth, range, and antenna orientation. The NMFS monitor/receiver equipment detected radio tag signals with underwater antennas at ranges of 3-4 m. Radio tags positioned at depths of 3-4 meters were detected with 3- and 4-element Yagi air antennas. When used in a noise (electrical or frequency) saturated area, NMFS receiving equipment combined with tuned-loop air antennas, provided a detection range of about 100 m. Detection was limited to 20 m or less with the Lotek receivers.

Task 1.4: Monitor passage of radio tags, embedded in simulated fish, through a turbine intake, a spillbay, the gatewell/bypass orifice and collection channel, and the tailrace.

During the primary series of simulated fish testing, 14 radio-tagged, simulated fish were used. All were 7-day tags (8 at 60 pulse/min and 6 at 120 pulse/min).

Seven radio-tagged simulated fish were released into the turbine intake. All seven tags were detected as they passed through the draft tubes by the complex of Monitors 1-12 with underwater antennas mounted on the draft-tube frames. There were a total of 16,158 records, ranging from 31-5,294 and a median of 89 detections per tag.

Three radio-tagged simulated fish were passed through Spillbay 1. All tags were detected by both the upstream (underwater antennas) and downstream monitors (air antennas). The upstream monitor recorded a total of eight detections, with a median of two detections per tag, ranging from one to five detections. The downstream monitor performed similarly with nine total detections, with a range from two to five and a median of two detections per tag.

Four radio-tagged simulated fish were released into the gatewell and passed from it to the bypass/collection system. All tags were detected from the time of introduction into the gatewell until exiting through the bypass orifice. There were a total of 175 detections, with a range of 24-95 and a median of 28 detections per tag. The tags were not detected while passing through the collection channel, probably due to the antennas partially projecting from the water into the air resulting in a low signal output. However, when the four tags reached the juvenile sampling facility, two were detected with a total of three detections.

Phase II

Task 2: Determine the efficiency and effectiveness of NMFS radio-telemetry equipment and procedures to monitor the passage of juvenile radio tags, implanted in live hatchery juvenile salmonids, through specific routes of passage (turbine intake, spillway, juvenile bypass/collection system, and tailrace) at a hydroelectric dam.

Forty-two radio-tagged hatchery juvenile salmonids were released during Phase II. Twenty-two were released into the turbine intake for the draft-tube tests. Ten fish were released in the spillway and 10 fish were released in the gatewell/bypass channel tests (Table 3). All of the 42 radio-tagged live fish were recorded by at least one monitor after they were released.

Of the 10 fish released in the gatewell/bypass channel tests, 5 were released into Gatewell 3B and allowed to pass into the bypass channel via the orifice. All five fish were recorded on Monitor 16. Four of those fish passed into the bypass collection channel, and the fifth fish remained in the gatewell for at least 96 hrs when the power cord for Monitor 16 was unplugged in order to move the gantry crane. Therefore, a total of nine radio-tagged fish were either released into and passed from the gatewell into the bypass collection channel or were released directly into the bypass channel where all nine were recorded on

Table 3. Detection efficiency of radio-telemetry monitors installed on Ice Harbor Dam for detection of radio-tagged hatchery juvenile salmonids, 1996.

Test site	Number released	Number detected	Number of detections			Monitor efficiency (%)
			n	Range	Median	
			Draft tube			
All receivers	22	22	2,426	21-322	69.5	100
			Bypass system			
Gatewell[a]	5	5	-----	--------	----	100
Collection channel	5	9[b]	1,186	2-850	33.0	100
Sampling facility	10	4	13	1-9	2.0	40
			Spillway			
Upstream	10	9	57	2-13	4.0	90
Downstream	10	7	60	1-23	4.0	70

[a] Radio-tagged fish remained in the gatewell for some time before exiting resulting in exceptionally high numbers of detections.

[b] Includes four of the five fish released into the gatewell.

Monitor 15. However, only four (44%) of those nine fish were recorded at the sampling facility.

A downstream detection efficiency of 71% was determined for fish released into the gatewell/collection channel (Table 4). However, the fates of other radio-tagged fish after departing downstream from the passage routes were undetermined. Range and reliability of the transmitters used in this study were determined to be acceptable for conducting behavior studies with juvenile salmonids.

Task 2.1: Confirm tag range and reliability of prototype radio transmitters designed for tagging and tracking of juvenile chinook salmon and steelhead with live radio-tagged fish.

A total of 70 radio tags were used throughout the study. Two tags (2.9%) failed prior to release of the radio-tagged fish and were removed from the study. It is possible that the tags did not actually fail, but the batteries were drained of power when magnets taped on the tags may have been inadvertently moved out of position on the tags when transported or moved about while in storage resulting in a power drain of the batteries.

Task 2.2: Confirm optimum locations and positioning techniques for installation of air and underwater antennas at a turbine intake, a spillbay, the juvenile bypass/collection system, and the tailrace with live radio-tagged fish.

The monitor/receiver and antenna locations utilized in Phase II of this study (with the exception of the downstream spillway loop air antennas) were in locations that detected radio-tagged juvenile salmonids passing through all routes of passage through Ice Harbor Dam and were based on testing with radio-tagged, simulated fish during Phase I.

Table 4. Detection efficiency of radio-telemetry monitors at downstream sites for radio-tagged hatchery juvenile salmonids released during testing at Ice Harbor Dam, 1996.

Test site	Number of fish released	Number detected	Number of detections			Monitor efficiency (%)
			n	Range	Median	
Draft tubes	22	13	168	1-51	11	59
Bypass system	10	10	226	1-66	14	100
Spillway	10	7	76	2-16	12	70
Total	42	30	470	1-66	12	71

The air antennas for the downstream location might have performed better if they had been positioned closer to the water column passing over the ogee. However, transmitter orientation and exposure to the air may have affected detection.

Task 2.3: Confirm antenna range and reliability at a turbine intake, a spillbay, the fish bypass/collection system, and the tailrace with live radio-tagged fish.

All of the 22 radio-tagged test fish that passed through Turbine Unit 3 were detected by the underwater antenna array mounted on the draft tube frames. A total of 2,426 detections with a range of 21-322 detections per fish (median = 69.5) were recorded.

The air antennas used at the tailwater monitor sites appeared to function satisfactorily. An improvement might result from installing more antennas to span the greater expanse of the river (i.e., antennas mounted on buoys).

Task 2.4: Determine efficiency and effectiveness of NMFS radio-telemetry methods and equipment required for recording the passage of radio tags implanted in live fish, through the turbine intake (unguided fish), from the turbine intake to the juvenile bypass/collection system (guided fish), through a spillbay, and in the tailrace.

Efficiencies of the 30-MHZ radio-telemetry monitors utilized at all test sites at Ice Harbor Dam in 1996 are shown in Figure 7. Monitors 1-12 recorded 100% of the radio-tagged hatchery juvenile salmonids passing through the draft tubes of Turbine Unit 3.

Detection efficiencies for monitor sites at the gatewell, bypass channel, and sampling facility were 100, 100, and 44%, respectively.

Monitor 13 with 2 loop air antennas, located at the downstream side of Spillbay 1, was 70% efficient at recording the passage of radio-tagged fish. Nine of 10 radio-tagged fish (90%) released were recorded on Monitor 14 on the upstream side of Spillbay 1. The fish that was not recorded on monitor 14 was recorded on the downstream side of Spillbay 1.

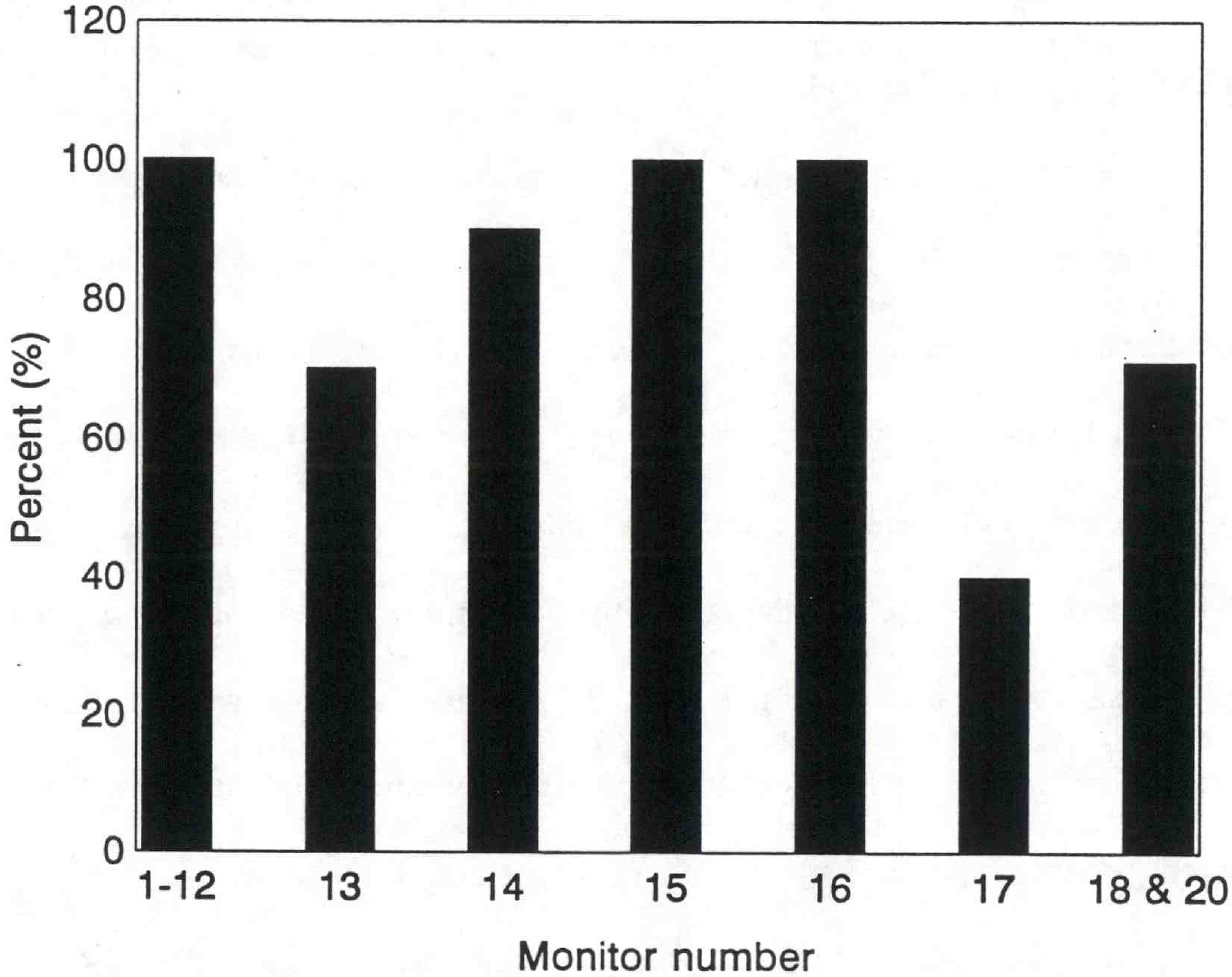

Figure 7. Detection efficiency of 30-MHz radio-telemetry equipment installed at Ice Harbor Dam for detection of radio-tagged hatchery juvenile salmonids, 1996. (See Table 1 for monitor locations)

Detection efficiency of the downstream monitor sites was 71%.

Task 2.5: Determine effectiveness of NMFS radio-telemetry methods and equipment required for monitoring the passage of radio tags, implanted in live fish, under tainter gates with standard deep spill.

The method developed for positioning upstream underwater antennas at the spillway was highly effective for both monitoring (90% detection efficiency) and antenna maintenance. Two or three underwater antennas per spillbay would probably ensure maximum detection efficiency at that location. However, more testing is needed at the downstream spill antenna location (40% detection efficiency) for verifying spill passage of radio-tagged fish.

The lower detection rate of radio tags at the downstream side of the spillway may have been the result of the undetected radio-tagged fish being out of the water column when passing over the spill. The lower detection rate for the downstream side of the spillway was more apparent when the spill gate was set at larger openings.

Task 2.6: Determine effectiveness of NMFS radio-telemetry methods and equipment required for monitoring the passage of radio tags, implanted in live fish, through a spillbay incorporating stop logs covered with metal "skin" plates (surface skimming spill condition).

Due to logistical concerns at Ice Harbor Dam during the 1996 research season, installation of stop logs in the test spillbay was not possible. Therefore, this task was not completed.

SUMMARY

1. We determined that entry, passage behavior, and passage verification, relative to individual surface collection devices, of radio-tagged juvenile salmonids at collection and bypass facilities of hydroelectric dams are highly feasible. NMFS' 30-MHZ radio-telemetry system utilizing a combination of individually coded 1 and 0.5 second pulse rate tags and the fast scanning receivers permitted monitoring radio-tagged fish passing through short dimensional openings under high velocity flows. Further testing of minor modifications should correct detection problems encountered at the spillway (downstream side) and juvenile sampling facility.
2. Range and reliability of radio tags used in this study were determined to be acceptable for detection up to distances of 330 m with Yagi antennas, 3-4 m with underwater antennas. When used in a noise (electrical or frequency) saturated area, tuned-loop air antennas, NMFS receiving equipment combined with tuned-loop air antennas provided a detection range of about 100 m to a depth of 3-4 m. Detection range was 20 m or less with Lotek receivers.
3. Antenna configurations and locations utilized in this study (with some modification to downstream spillway and juvenile sampling facility sites) were determined to be in optimal for the detection of radio-tagged juvenile salmonids passing through all routes of passage through Ice Harbor Dam.
4. Underwater antennas mounted on support frames positioned in the draft tubes were determined to be the most practical method for both equipment installation and detection and protection of radio-tagged juvenile salmonids passing through a turbine intake.

5. The method developed during this study for positioning underwater antennas at the upstream side of the spillway was highly effective for both monitoring radio-tagged fish and antenna installation and maintenance.

RECOMMENDATIONS

1. A radio-telemetry study should be conducted at a hydroelectric dam to completely monitor all routes of passage available to juvenile salmonids.
2. Radio interference (electrical and frequency noise) occurs at extreme levels at downstream, near-dam vicinities of tailrace, collection facilities, and spill basin areas of hydroelectric dams. Further testing of radio-telemetry methods for detection of juvenile radio tags in near-surface situations is needed for fine tuning of technique.

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