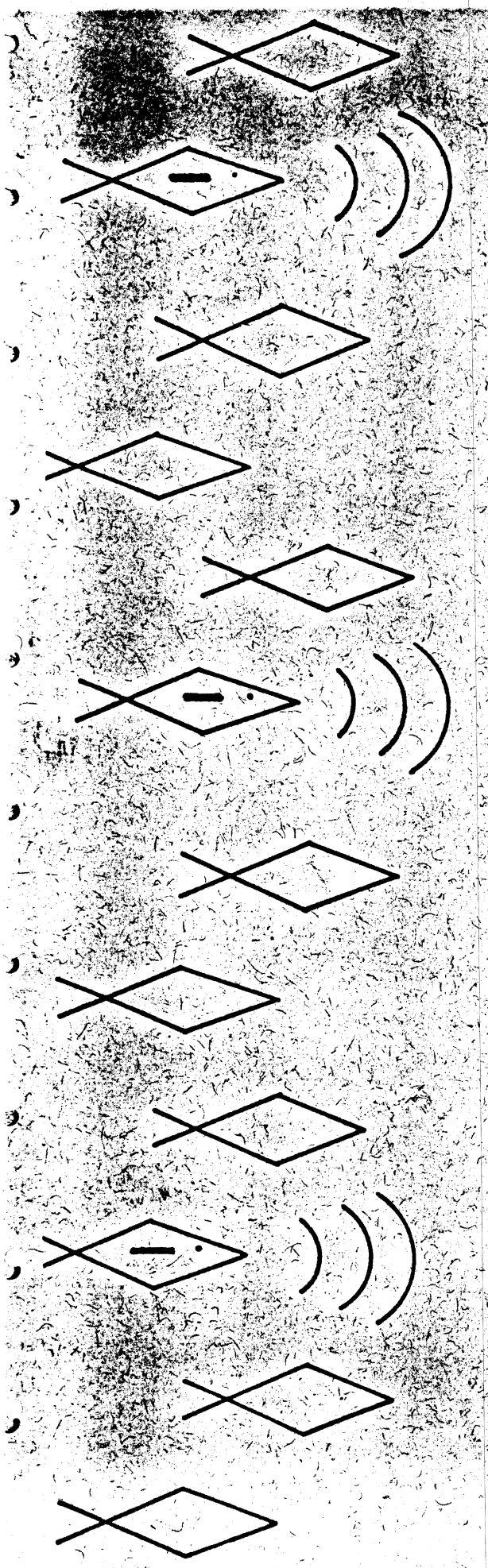

FINAL REPORT

RADIO TRACKING STUDIES TO EVALUATE THE EFFECT OF THE SPILLWAY DEFLECTORS AT LOWER GRANITE DAM ON ADULT FISH PASSAGE, 1975

by

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Financed by
U.S. Army Corps of Engineers
Portland District
(Delivery Order No. DACW68-75-C-0112)

and

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2725 Montlake Boulevard East
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January 1976

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INTRODUCTION

The need to control the introduction of dissolved gases into the Columbia and Snake Rivers has initiated major modifications to the spillways of dams in the system. Levels of supersaturation have been reached that cause substantial losses of migrating salmon (Ebel, 1971). To alleviate the problem, spillway deflectors are being installed to prevent spillway discharge from plunging to depths; thereby, reducing the amount of dissolved gases in the water. These modifications change hydraulic conditions immediately below the spillways to the extent that the fishery agencies and the U.S. Army Corps of Engineers believed it necessary to investigate the effects on fish to make certain that no conditions adversely effecting the survival and passage of fish resulted.

Radio-tracking studies were initiated at Lower Monumental Dam (Monan and Liscom, 1974) and Bonneville Dam (Monan and Liscom, 1975) to determine the effects the new hydraulic conditions might have on adult salmon survival and passage. Both studies were done with only a partial installation of deflectors--Lower Monumental Dam with two deflectors out of eight spillbays, and Bonneville Dam with four deflectors out of 18 spillbays. Further modifications were held in abeyance until results could be reviewed. No evidence was developed that indicated any injury to fish entering the potentially dangerous area below the deflectors nor was it shown that the hydraulic conditions inhibited fish passage. With this information available, additional deflectors are to be installed at other dams and modifications completed at dams with partial installations. However, before all dams were modified, a study was needed at a dam where a total complement of deflectors was installed.

Lower Granite Dam on the Snake River was selected for the radio-tracking study as the dam provided an installation with a full complement of deflectors. The primary objectives of the study were to determine in a prototype situation: (1) to what degree adult salmon frequent the potentially dangerous area below the spillway deflectors, (2) if salmon are severely injured or killed by conditions created by the spillway deflectors, and (3) effects of hydraulic patterns from spillway deflectors on entry of adult salmon to fish collection facilities.

EXPERIMENTAL SITE AND EQUIPMENT

Lower Granite Dam is on the Snake River, 107.5 miles upstream from the confluence of the Snake and Columbia Rivers at Pasco, Washington. Overall length of the dam is 3,230 feet. The powerhouse is 656 feet long and extends from the south shore. Adjacent to the powerhouse is the eight-bay spill, 512 feet in length. All eight bays have spillway deflectors. The remaining part of the dam includes the navigation locks and an earth filled section extending to the north shore.

Construction of Lower Granite Dam is unique among lower Snake River Dams in that the locks are about mid-stream rather than near the shore (Figure 1). The actual lock structure extends about 720 feet downstream from the spillway with an attached, solid wingwall extending an additional 480 feet downstream. A large area of "quiet" water north of the locks and wingwall results from this arrangement.

Fish pass over the dam through a single fishway on the south shore. There are three entrances to the fishway: (1) south entrance--located at the south end of the powerhouse, (2) powerhouse collection system--located along

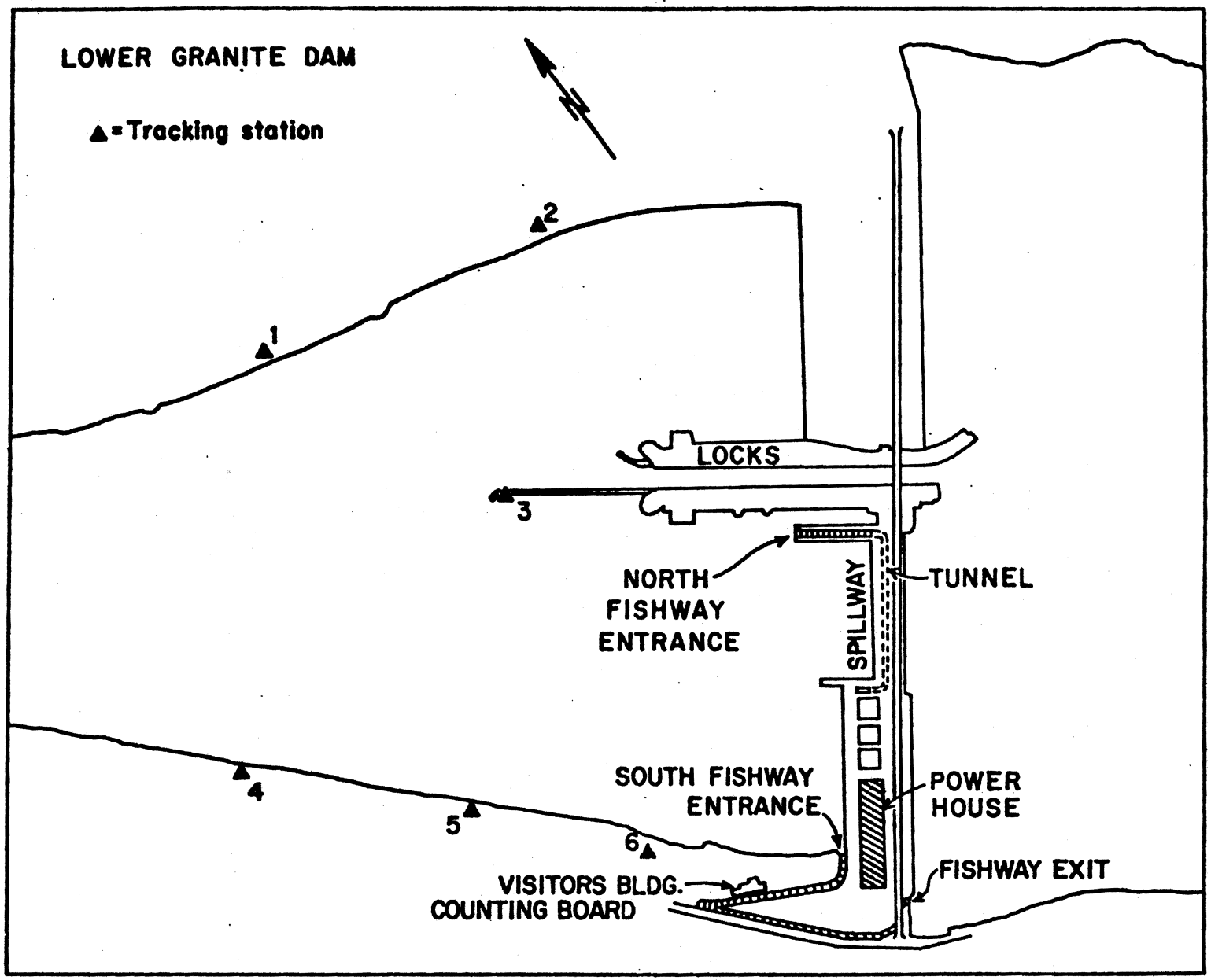

Figure 1.--View of Lower Granite Dam showing the fish tracking stations.

the face of the powerhouse, and (3) north entrance--located at the north end of the spill section. The north entrance is located at the end of a concrete channel extending about 240 feet downstream from the north end of the spill. Fish swim up the channel to the base of the dam and enter an illuminated tunnel passing under the spillway to the powerhouse where they exit into the powerhouse collection system. They may remain in the collection system to reach the south fishway entrance or exit into the tailrace. After ascending the fishway, the fish exit directly into the forebay between the turbine intakes and the south shore.

Radio Tag

The radio tag is a small radio transmitter operating on a carrier frequency of approximately 30 megahertz (MHz). Batteries power the transmitter for about 17 days. Transmitter and batteries are sealed in a plastic capsule about 3.5 inches long and 0.75 inch in diameter. Tags weigh about 1 ounce in water and are carried in the stomach of the fish except for a small wire antenna extending from the tag, through the fish's esophagus, to the roof of the mouth where it is attached by means of a plastic anchor. Nine frequencies are used: 30.17, 30.18, 30.19, 30.20, 30.21, 30.22, 30.23, 30.24 and 30.25 MHz. This provides nine separately identifiable tag codes.

Direction Finder - Receiver and Antenna

The direction finder-receiver used by the trackers is a self-contained, battery-operated unit that receives the radio signal from the antenna, amplifies it, and converts it to an audible tone. The operator can monitor any one of the nine tag frequencies at any one time. To eliminate as much extraneous noise as possible, each operator used ear phones to listen to the signal.

A directional loop antenna 18 inches in diameter was used for tracking, except when fish were very close to the tracker. Then, a similarly constructed antenna having only an 8-inch diameter loop and a correspondingly sharper null pattern was used.

Certain vehicles were equipped with a direction-finder receiver and antenna. They were used as mobile units and moved throughout the study area. In addition to the conventional tracking receiver, a search receiver placed in each mobile unit enabled the operator to search for fish much more easily and rapidly. The unit automatically searched for tag signals as the mobile moved about. When a signal was received by the omni-directional antenna the receiver identified the code frequency, the sonalert gave an audible signal, and the code registered on a panel. The operator could then stop and switch to the directional loop antenna and finder-receiver to locate the source of the signal. The search receiver unit was powered from the vehicles battery.

Fishway Monitoring Units

Movement of fish in the fishways was monitored by two different systems. One was a simple unit used to alert fish counters to the presence of a tagged fish in a specific area. The other was a sophisticated telemetry unit that transmitted data on the movements of tagged fish in the fishways to the data collection center.

The simple alert system was a battery-powered receiver and antenna unit placed in the fishway counting station to alert the counters to the presence of a tagged fish. This system did not distinguish between specific tag codes. The antenna, a standard 18-inch loop, mounted slightly in front of and above the counting area, was positioned to pick up tag signals from the area

adjacent to the counting station. A sonalert audio alarm device provided a beeping sound that could be heard by the fish counter when a radio-tagged fish approached the counting station. The gain on the receiver was set to activate the sonalert only when a tagged fish was in the immediate vicinity of the counting station.

Telemetry units monitored the fishway entrances and determined when specific tagged fish entered. The exit was also monitored to determine the time of a specific fish's exit from the fishway. Each telemetry unit received signals from two antennas in the fishway, one located just inside the entrance, or exit, and the other about 100 feet away, either upstream or downstream. As the tag signals came into the receiver unit (located adjacent to the fishway) it determined the tag frequencies, converted the information to a tone code, and transmitted the appropriate code via radio transmitter to the receiver in the data collection center. The tone code was automatically decoded and a flashing light on a panel array indicated the tag frequency and location. By viewing the light panel and clock, observers determined the time each tagged fish moved into or exited a specific fishway. The display panel also indicated whether the fish was near the upstream or downstream antenna. By noting the sequence of events, the observer could determine if the fish was moving up, holding, or moving down the fishway.

EXPERIMENTAL PLAN

Plans were to tag and track as many spring chinook salmon as possible from May 12 through June 12. Fish were to be captured and tagged at Little Goose Dam, 37 miles downstream from Lower Granite Dam, and released at a public boat launch 1 mile above Little Goose Dam. Tagged fish were to be tracked as

they approached Lower Granite Dam and their movements below the dam, in the fishways, and immediately above the dam were to be plotted and recorded.

Spill conditions were to be what the U.S. Army Corps of Engineers and the fishery agencies agreed upon as desirable for existing river flow conditions. Spill conditions and fish movements would be observed and if a problem relating to fish movement or passage was detected, suggestions would be made to alleviate or remedy the situation. This was especially important as certain phases of Lower Granite Dam construction were still in progress.

EXPERIMENTAL PROCEDURES

Trapping and Tagging

Trapping fish for tagging was done with the adult separator at Little Goose Dam (Ebel 1974). Fish to be radio-tagged were diverted into the trap by setting the separator so all fish went into the trap until a sufficient number of fish were collected. Only chinook salmon relatively free of injuries and over 640 mm in fork length were used. No fish previously tagged by other agencies were used for radio tagging.

Chinook salmon to be radio tagged were anesthetized and a radio tag was inserted into the stomach of the fish through the mouth. A short antenna extending from the tag was attached to the roof of the mouth by a plastic anchor. For visual identification, a color coded spaghetti tag was attached to the back of the fish below the dorsal fin.

Tagged fish were placed in a fish hauling tank and trucked to the release site. The initial release on May 16 consisted of 9 separately coded fish. Subsequent releases were made only when a particular coded fish

crossed Lower Granite Dam and continued upstream or in some other way left the study area. When this occurred, another fish with the same radio-tag code was tagged and released. We attempted to keep nine separately identifiable tagged fish in the study area at all times. A total of 30 chinook salmon were tagged. Table 1 summarizes the tagging and release data.

Tracking and Plotting

Little monitoring of radio-tagged salmon was done between Little Goose and Lower Monumental Dams because of inaccessibility to the river by vehicle. First contact with tagged fish was usually by mobile tracking units about 5 miles downstream from Lower Granite Dam. When contact was made the crew at the dam was given the information to alert them of the coming fish.

Tracking at the dam was done on a 24-hour basis with three crews made up of trackers and plotters. Fish were intensively tracked in the areas immediately above and below the dam. Fixed tracking stations were set up on both sides of the river (Fig. 1). In addition, one site was established on the downstream end of the wingwall extending downriver from the navigation lock. Mobile tracking units were deployed throughout the area as needed.

All tracking was under the direction of the plotter located in the control center. When a tagged fish entered the study area, the plotter determined which trackers could best monitor the fish's location and called, via two-way radio, for bearings on specific fish from specific trackers. Trackers determined bearings from their tracking stations to the tagged fish and reported to the plotter.

Each tracking station consisted of a wooden shelter equipped with a fixed antenna mount, compass rose, and loop antenna. The antenna was mounted

Table 1.--Summary of tagging data, for chinook salmon used in the study at Lower Granite Dam, May 16-June 12, 1975.

Date Released at Little Goose Dam	Species	Flag Color	Radio Tag Code	Fish Length mm
May 16	Chinook	Red/Green	14K	1000
" "	"	"	2H	850
" "	"	"	29G	940
" "	"	"	33J	900
" "	"	"	33L	880
" "	"	"	9F	810
" "	"	"	13I	950
" "	"	"	12D	880
" "	"	"	42E	870
" 27	"	Orange/White	23D	1000
" "	"	"	26G	930
" "	"	"	2K	870
" "	"	"	14I	910
" 29	"	"	14F	810
" "	"	"	6H	880
" 30	"	"	5J	890
" "	"	Blue/Yellow	1K	710
June 1	"	"	1D	700
" "	"	Orange/White	10E	710
" "	"	Blue/Yellow	4F	970
" "	"	"	6G	840
" "	"	"	29I	770
" 4	"	Red/White	1G	740
" "	"	"	8I	870
" "	"	Blue/Yellow	13H	910
" "	"	Red/White	20D	820
" 7	"	Orange/White	4L	870
" "	"	Blue/Yellow	29E	780
" 9	"	Blue/Orange	5I	980
" "	"	"	21D	930

above the shelter and coupled into the mount so the geometric axis or null point of the antenna corresponded to a pointer that rotated with the antenna over the compass rose. The tracker established a bearing to the tagged fish by tuning his receiver to the frequency of the tag, rotating the antenna until the null point was determined, and then noting the location of the pointer on the compass rose. Simultaneously, a second and perhaps a third tracker did likewise; the bearings were radioed to the plotter.

Locations of fish were established by triangulation and plotted in real-time on charts made from an aerial photograph showing the position of tracking stations and corresponding compass roses. A time-sequence series of plots provided details on the path taken by the fish. The number of plots and the interval between plots depended upon how fast a fish was moving and the number of tagged fish being tracked in the area.

Anomalies of radio-wave transmission were immediately apparent with this plotting system. Because bearings were so closely coordinated, false bearings were readily apparent. When this occurred, the plotter immediately called for additional bearings from other tracking stations or from mobile units.

EFFECT OF SPILLWAY DEFLECTORS ON FISH

Radio tracking of chinook salmon took place between May 16 and June 12. Total river flows ranged from 47,000 to 204,000 cfs and averaged 143,000 cfs. Spill ranged from 5000 to 159,000 cfs with an average of 105,000 cfs.

Of the 30 chinook salmon radio-tagged, 27 reached the dam and their movements were recorded. Nineteen fish (70%) were tracked into the potentially hazardous flow area directly below the deflectors. Subsequent observations

of the movements of these fish did not indicate any physical disability or alteration of their previous behavior. In addition, these fish were carefully scrutenized at the counting station viewing window as they ascended the fishway and no visible injuries were observed.

FALLBACK OF FISH OVER THE DAM

Fallback or fish being swept back over the dam after they have exited the fishways into the forebay can be a significant problem at a dam, e.g. Bonneville Dam (Monan and Liscom, 1975). Consequently, the behavior of tagged fish exiting the fishway at Lower Granite Dam was monitored to determine if there was any indication of a potential fallback problem. Because the dam was still under construction and not being operated in a normal manner, the data on fallback have limited value. However, some fallback did occur and is reported for general information.

Out of the 17 radio-tagged fish that were tracked over the dam, three (15%) fell back over the spillway. The first two radio-tagged fish to cross the dam fell back; one on May 18 and the other on May 19--spill at the time was 142,000 and 137,000 cfs respectively. The third fallback occurred on June 6 when the spill was 130,000 cfs.

While all the fish that fell back recrossed the dam, tracking indicated and observations at the fishway counting station confirmed that one of the fish was severely injured. Both of the other fallbacks reascended with no indication of any injuries. All of the fish were delayed in successfully passing by the dam. The amount of delay was 2, 8, and 20 (injured fish) days. During their reascent, all three fish used a different fishway entrance than they used on their initial ascent.

GENERAL OBSERVATIONS

When examining the behavior of the fish in the immediate vicinity of the dam, consideration must be given to the fact that the dam was essentially still under construction. For the most part, only one turbine was on the line with a second operating intermittently. Consequently, the flow patterns in the vicinity of the dam were not representative of what will take place when the dam is complete and operating as designed. In addition, construction work generated excessive activities in, above, and around the fishways.

Below the Dam

During the study period, 27 of the 30 radio-tagged chinook salmon were tracked in the study area at Lower Granite Dam. The remaining three were found below Little Goose Dam. One was recovered dead, and the other two were still swimming below Little Goose Dam when the study ended. Of the 27 tagged fish reaching the study area, 17 eventually passed over the dam during the 4 weeks of tracking. Two fish were tracked in the study area below the dam for several days and then the signals abruptly stopped. Thorough searches were made throughout the area, but the signal were never heard again. The remaining 8 fish were near the dam or in the vicinity at the time the study was terminated (Table 2).

Behavior below the dam was variable. The time from release to the first plot near the dam varied from 20 to 76 hours, averaging 35 hours. The average rate of travel was approximately 1 mile per hour for the 36 miles. The time tagged fish spent at the dam from first plot until leaving the fishway exit was from 9 to 218 hours and averaged 78 hours.

When approaching the dam, the north shore was favored by 56% of the fish, 33% entered along the south shore and 11% approached from mid-channel.

Table 2.--Activities of radio tagged chinook entering study area but not ascending dam during the tracking period.

Tag Code	Date Tagged	Date entered Area	Days in Area	Summary of Activities
5J	5/30	5/31	13	Entered south shore. Moved throughout study area during entire period. Entered north fishway six times, south fishway once. Passed through tunnel three times. Left area seven times.
1K	5/30	6/2	11	Made one pass in front of powerhouse. All other time spent in "quiet" area. Left area three times.
4F	6/1	6/2	11	Entered south shore Swam throughout study area. Entered both fishways Left area four times
13H	6/4	6/7	6	Spent entire time in or near "quiet" area.
29E	6/7	6/9	4	Spent most of time in "quiet" area Went half way to north fishway once. Moved to south shore directly across from "quiet" area once.
4L	6/7	6/8	5	Entered south shore. Spent much time on this shore. Never went to north shore. Much movement in front of powerhouse and spill. Never entered any fishways.
21D	6/9	6/11	2	Three hours after entering area, entered north fishway to tunnel. Dropped out of fishway and within three hours left immediate study area.
5I	6/9	6/10	3	Spent entire time in "quiet" area. Left study area once.

Milling about below the dam was extensive, but certain preferred routes were apparent (Fig. 2). All routes experienced back and forth movement with none used exclusively for any one direction. Holding areas were well defined with the "quiet" water area north of the locks and its extending wingwall the most frequently used. Of the total hours spent by tagged fish in the immediate area below Lower Granite Dam, 44% were spent in this area. All but two tagged fish reaching the dam spent some time in the "quiet" water. The mid-channel area just below the spill and powerhouse was used 12% of the time. At this point, the current from a large eddy in front of the powerhouse turned downstream and merged with the spill flows. The eddy was partially due to lack of turbine flow and a strong back current from the spill.

Tagged fish determined as having been within the potentially dangerous spill area made 49% of their entries into this area when spill was between 50,000 and 65,000 cfs. These conditions existed 24% of the total tracking time. Spill of 126,000 to 159,000 cfs was present 35% of the time and 16% of the entries were made then. The fact that some radio-tagged chinook were plotted close to the spill and maintained themselves in that location for some time, indicates that subsurface hydraulic conditions are present that fish can negotiate unharmed.

Relatively little time was spent adjacent to, but downstream from the fishway entrances. Only 1.5% of the total time tagged fish spent in the area was spent in front of either fishway entrance.

Fishway Data

There were 88 entries made into the fishway entrances, 42 into the north entrance and 46 into the south entrance. Of the total entries, 19% resulted

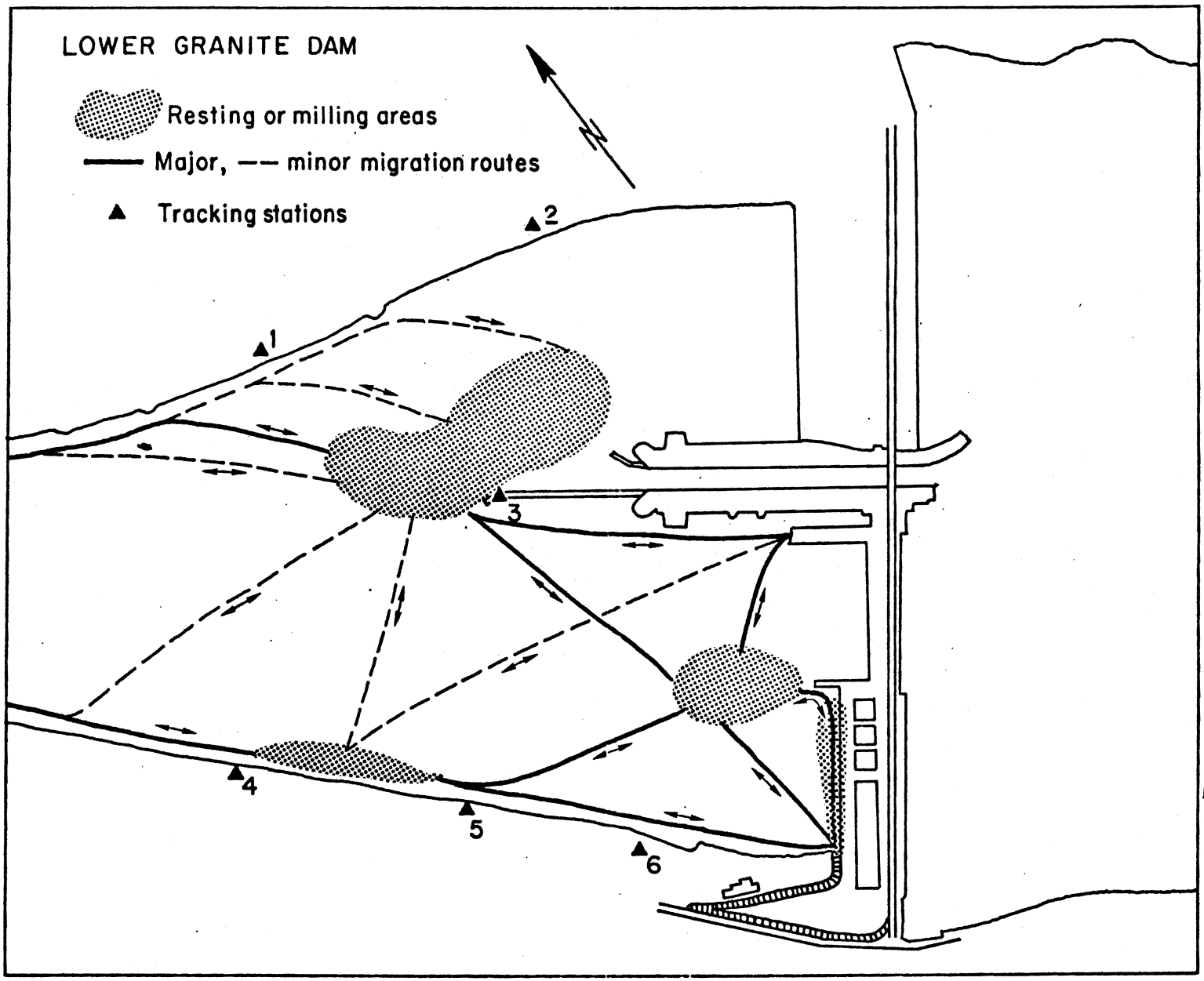

Figure 2.--Routes used by radio-tagged chinook and locations of main resting areas.

in fish passage over the dam. Most fish made more than one entry to the fishway before passage; 35% made one entry only. Both entrances were entered by 53% of the tagged fish. Only 12% of the fish entered a single entrance more than once before crossing the dam. On their final entrance before crossing the dam, 4 fish used the north entrance and 13 used the south. Once they made their final entrance, the fish spent an average of 4 hours negotiating the fishway and crossing the dam.

Tagged fish did not show any interest in the north entrance until May 20. Up to that time, fish had made six entries into the south entrance resulting in two passages. On May 20, between 1500 and 1700 hours, the spill gates were regulated to change the spill pattern. To reduce flow by the north entrance, flow from bays 6-8 was reduced by 30% with like increases in the center area. Soon after, a tagged fish approached the north entrance and entered at 1745 hours. Tagged fish made use of the entrance from then on, resulting in 47% of the fish making their initial entry into the north entrance. However, while fish entered the fishway and moved up the channel initially, they were reluctant to continue through the tunnel under the spill section. During the early part of the study the lights in the tunnel were off. When the lights were turned on, the fish moved through more readily. During the remainder of the study, 30 trips were made from the north entrance through the tunnel into the powerhouse collection system. However, 87% ended with the fish exiting into the tailrace.

The tunnel was also entered by four fish via the powerhouse collection system.

Tagged fish recoveries

Recoveries of radio-tagged chinook salmon passing over Lower Granite Dam were all from the Salmon River or its tributaries. A total of five tags were recovered; one from the Rapid River Hatchery and four from spawning grounds. One of the five recovered near Stanley, Idaho, had been a fallback at Lower Granite Dam.

One of the three tagged fish that had fallen back over Little Goose Dam was later recovered in poor condition at the adult separator at Little Goose Dam.

CONCLUSIONS

1. Spring chinook salmon swim near or into the discharge from a spillway with a total complement of deflectors.
2. Spring chinook salmon do not experience debilitating injuries when swimming of their own volition into the area immediately below a spillway discharging all water over deflectors at discharges up to 159,000 cfs.
3. Hydraulic patterns from spillway deflectors have an effect on entry of adult salmon to collection facilities. The patterns may be manipulated to enhance passage.
4. Fallback of salmon occurs at Lower Granite Dam during periods of spill.
5. The fishway at Lower Granite Dam effectively passes adult spring chinook salmon.
6. Most fish reaching the powerhouse collection system, by way of the north entrance, return to the tailrace.

ACKNOWLEDGMENTS

The following staff members of the National Marine Fisheries Service (NMFS), Northwest Fisheries Center, Seattle, Washington, participated directly in the study: Charles J. Bartlett, Gordon F. Esterberg, Donald L. Thorne, and Charles D. Volz.

The helpful and cooperative attitudes of all personnel of the U.S. Army Corps of Engineers at Lower Granite Dam was greatly appreciated.

We are grateful to the staff of the NMFS at Little Goose Dam for trapping fish to be tagged for the study.

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