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Coastal Zone and Estuarine Studies

**Migrational Characteristics
of Juvenile Salmon and Steelhead Trout
in the Columbia River System, 1981**

**Volume II
Radio Tracking of Juvenile Salmonids
in John Day Reservoir**

**by
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INTRODUCTION

Salmon (Onchorynchus spp.) and steelhead (Salmo gairdneri) populations in the Columbia River system have been adversely affected by the growth of agriculture, general population, and hydroelectric production (Raymond 1979). Fishery agencies are concerned with the large losses of juvenile seaward migrating smolts. This loss, sometimes as high as 98% (Sims et al. 1978), is an enormous and complex problem. Even with collection and transportation operations at upriver dams, large numbers of smolts remain in the river for a volitional outmigration. As agriculture and power demands grow, spill is no longer readily available, and smolts are forced to pass through the powerhouse. Protection of these nontransported smolts is a concern, especially at John Day Dam. Special flows, spills, and sequential load dropping (SLD) have been used in conjunction with the bypass system at John Day Dam, but the system is not effective enough, and more information is necessary before design changes are made.

In the past, research studies were dependent on release and recovery of large groups of marked fish. The results were often expressed as relative survival rates between two points with no information on when or where events occurred. To obtain a better understanding of fish behavior, a detailed study of the movement of individual fish is needed. Radio tracking is a proven method for effectively studying behavior of individual free-swimming adult salmonids (Monan and Liscom 1973, 1975, 1976), but until recently radio tracking of juvenile smolting salmonids on the Columbia River was impossible because of the large size of the radio tag.

National Marine Fisheries Service (NMFS) electronics personnel have developed a miniature internal radio fish tag. This tag is suitable for

tagging juvenile salmonids as small as 145 mm long. Others (Young et al. 1972; Knight et al. 1977; Fried et al. 1978; Tyler et al. 1978) have used small tags on salmonids before, but their tags were too large for the average chinook salmon smolt in the Columbia River. The NMFS miniature radio tag was first used in the spring of 1980 at John Day Dam (Sims et al. 1981).

In the spring of 1981, NMFS was contracted by the U.S. Army Corps of Engineers (CofE) to conduct several studies to aid in the development of a better smolt bypass system at John Day Dam. The juvenile radio tracking study was to monitor approach patterns of smolts to John Day Dam under various modes of spill and turbine sequencing; a 20-day test of two spill conditions with and without SLD was devised. The work was to be accomplished in the forebay of John Day Dam using the behavior of individually radio-tagged fish as the basis of the study.

METHODS

Site

Radio-tagged juvenile salmonids were tracked in the immediate vicinity of John Day Dam--River Kilometer (RKm) 347 to 353 (Figure 1). At this point, the river is about 1 km wide, and a major tributary, the John Day River, enters on the Oregon shore at RKm 351. John Day Dam was chosen because of the problems associated with smolt passage at the dam, and because it provided the opportunity to coordinate radio tracking activities with NMFS monitoring and CofE hydroacoustic work. All activities were able to utilize the varied spill and turbine flows.

Flow patterns immediately upstream from the dam (RKm 347-348) were substantially influenced by the operation of the dam. When all of the flow

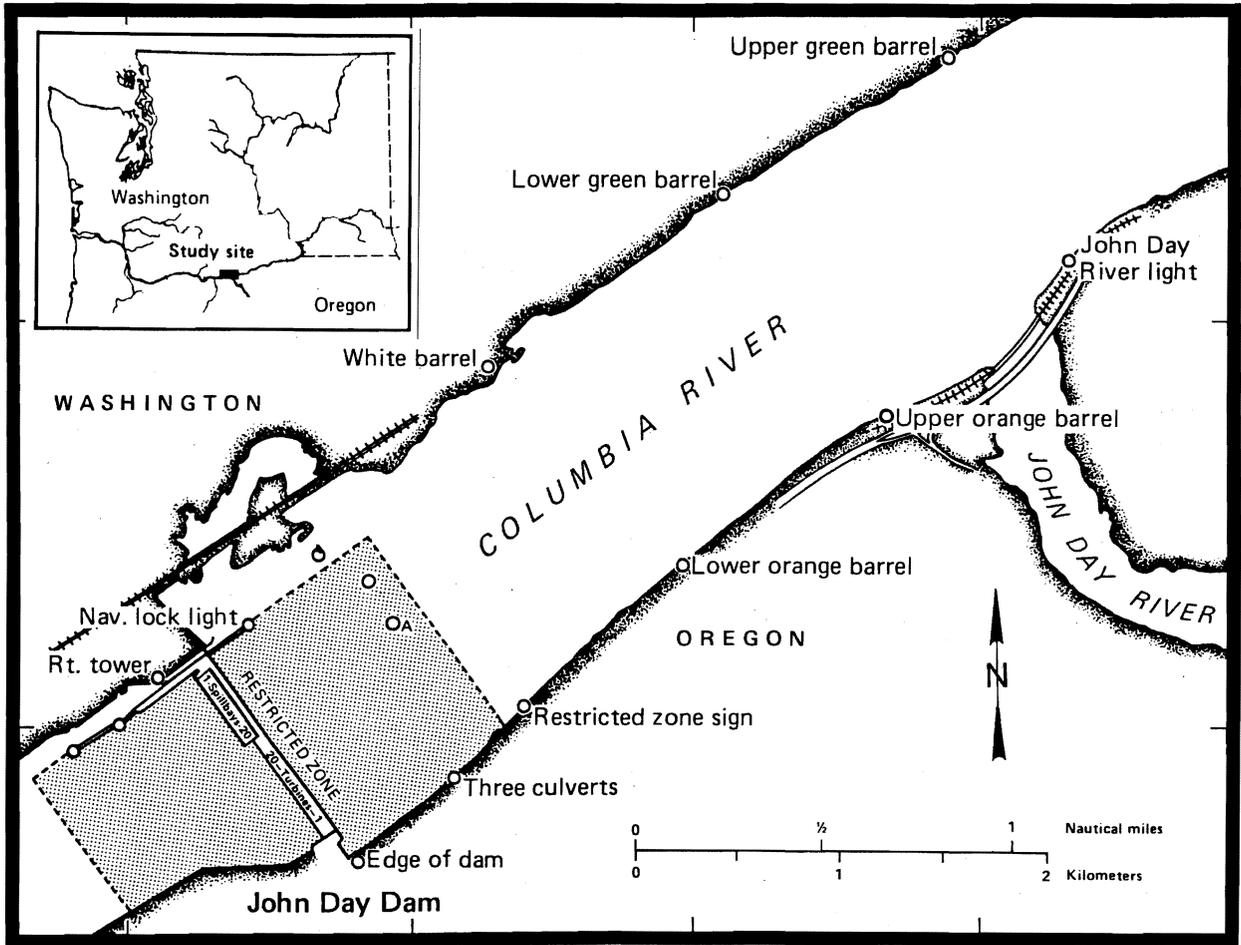


Figure 1.--Study area for radio tracking of juvenile salmonids at John Day Dam, 1981.

passing the dam was through the powerhouse, the flow net was concentrated toward the Oregon side of the river. If water was also being spilled, the flow net spread toward the Washington side. The degree of spread was dependent upon the quantity of water being spilled in relation to the quantity being passed through the powerhouse. The effects of two modes of spilling water were tested during the study, surface spill from Bays 16, 17, and 18 and deep spill from the remainder of the spill bays. Surface spill was restricted to three bays because it was necessary to place stop logs upstream from the spillgates in the bays where water was spilled from the surface.

Equipment

The juvenile radio tag was developed by NMFS electronics personnel to provide a means of monitoring movements of individual smolts. The radio tags are battery powered transmitters that operated on a carrier frequency of approximately 30 megahertz (MHz). The transmitter and batteries are coated with acrylic and a mixture of paraffin and beeswax to form a flattened cylinder 26 x 9 x 6 mm which weighed approximately 2.9 g in air. For identification purposes, each tag transmitted on one of nine specific frequencies spaced 10 kilohertz (KHz) apart (30.17 through 30.25 MHz). Tracking range of the tag varied from 50 to 150 mm depending on the output of the tag (200-640 mV) and the depth of the fish. Pulse rate was two per second and tag life was 7 to 10 days.

Receivers and antennas were the same as those described by Liscom et al. (1978). Hand held directional loop antennas 46 cm in diameter were used with the portable radio receivers. The receiver amplified the tag signal and produced an audible tone. Bearings to the tags were obtained by

rotating the antenna to null out the tag signal. Two boats (7.3 and 6.4 m long) were used as tracking platforms.

Procedures

Tagging

Juvenile fish to be tagged were usually collected during normal morning operation of the airlift pump in the gatewell of Turbine Unit 3 at John Day Dam. Smolts chosen for radio tagging were longer than 152 mm and showed minimum descaling. Fish to be tagged were anesthetized in a solution of MS-222 (175 ppm). Once anesthetized (about 10 s), the fish were removed from the anesthetic solution and measured. The radio tag was then dipped in glycerin and inserted into the fish's mouth. A plastic drinking straw was used to push the tag through the esophagus into the stomach. The flexible antenna extended out of the fish's mouth. Care was taken during tagging to ensure the fish was completely immobilized, as any movement during insertion of the tag could rupture the heart. If the tag was not inserted far enough, it was regurgitated by the fish, usually within an hour. The elapsed time from when a fish was placed in the anesthetic until it was tagged and placed in the recovery tank was usually no more than 30 s.

Tagged fish were hand-held in the recovery tank until they could swim on their own (up to 5 min). Fish longer than 160 mm appeared to be fully recovered in about 1 h; the recovery of smaller fish took up to 3 h. No fish shorter than 152 mm was tracked. After recovery, the tagged fish were placed in a livewell on the tracking boat, transported to the release site, released into the river, and tracking commenced.

Tracking

The tracking range (50-150 m) and large size of the study area (5 km long by 1 km wide) required tracking by boat rather than from shore stations. Two boats, each with a two-man crew, were used for tracking the tagged fish. One person operated the boat while the second operated the antenna and receiver. To stay within range of the tagged fish, one boat was deployed upwind from the fish, and the other boat was deployed to one side of the fish's expected location. As the relative position of the boats and fish changed, the boats would change position, one at a time, in anticipation of the relative movement.

Positional fixes for plotting the fish's location on tracking maps were made by placing a boat directly over the fish's location and then fixing the location of the boat on the map. The boat was judged to be directly over a fish when a strong signal was received throughout the entire 360° rotation of the antenna. Positional fixes to determine the location of the boat were made by measuring, with a sextant, the horizontal angle between fixed navigational aids and/or brightly colored and lighted markers placed at known positions on the river bank. The angles when plotted with a three-arm protractor provided a very accurate and fast method of locating fish positions on a navigational chart (Dunlap and Schufeldt 1969). Short tracking ranges and high winds required that constant cross bearings be taken to stay with the fish. If the signal was lost, a marker buoy was dropped at the point of last contact, and the area was searched until the tagged fish was relocated.

Sequential Load Dropping

Sequential load dropping (SLD) was a process used in conjunction with spill during the 20-night test period. It entailed opening the spill and systematically reducing the load on the operating turbines at 5 min intervals beginning at 2100 h on specified nights of the test. As an example, at 2059 h, turbines 1-16 were operating and there was no spill. At 2100 h, the spill was opened and the flow through Turbines 1 and 2 was reduced to zero. At 5-min intervals, the next two units were dropped until only Units 13-16 were operating. This condition continued until 2400 h, when the spill was closed and the turbines were placed in operation as needed. The four conditions of the test were:

- (1) 80 kcfs spill and 80 kcfs reduced turbine flow (SLD).
- (2) 80 kcfs spill and unreduced turbine flow.
- (3) 40 kcfs spill and 80 kcfs reduced turbine flow (SLD).
- (4) 40 kcfs spill and unreduced turbine flow.

The purpose of SLD was to create a flow-net that would draw fish toward the spill from the Oregon side of the river. Reduction and compression of the turbine flow resulted in a larger percentage of river flow passing over the spillway.

River Flow

River flows were varied in the vicinity of the dam by changing the spill and turbine loading conditions. Various combinations of spill/no spill and turbine loading with or without SLD were used during periods of peak passage (2100 to 0200 h). During tracking, total flows ranged from a low of 112 kcfs with 43 kcfs spill (38%) and SLD, to a river flow of 477

kcfs with involuntary spill of 194 kcfs (41%). The lowest flow without spill was 150 kcfs and the highest 290 kcfs.

Four specific spill/turbine loading conditions were tried during a test on 20 consecutive evenings (7-26 May). The remainder of the season, natural river flows and forebay fish concentration (CofE sonar observations and NMFS monitor catches) determined the spill/turbine conditions used for any particular evening. Radio-tagged fish were tracked under the various conditions to determine if fish passed over the spill in direct proportion to the percent of water being spilled and to determine the effect of SLD and shallow spill on fish movement and passage.

Release Sites

Radio-tagged fish were released at two locations in the John Day forebay. The primary site was approximately one-fourth of the river width directly out from the lower green barrel on the Washington shore (Figure 1). When poor weather conditions prevented tracking in this vicinity, fish were released at Buoy A on the edge of the forebay restricted zone. This area was protected from wind by the dam, and tracking was always possible. Fish releases were generally made within an hour of 1900 h.

RESULTS AND DISCUSSION

Field work on radio-tagged fish was conducted in the forebay of John Day Dam from 20 April to 11 June 1981. Thirty-five juvenile salmonid smolts (18 chinook salmon, 17 steelhead) were radio tracked (Table 1). The mean length of the chinook salmon tracked was 162 mm (152 - 176 mm), and the mean steelhead length was 177 mm (161 - 220 mm). Of the total 35 fish, 18 were tracked until they passed the dam.

Table 1.--Radio tracking summary.

Fish Number	Species	Size (mm)	Release site	Release time	Duration of track (h)	Cause of termination	Passage					
							Location	Time (h)	Discharge (kcfs)		Turbine	
1	Ch	172	Above John Day R.	1045	4.0	Lack of movement						
2	Ch	162	Above John Day R.	0905	13.1	Passage	Turbine 13C	2210	0			224
3	Sthd	180	Lower green barrel	1820	5.1	Lack of movement						
4	Ch	160	Lower green barrel	1739	5.2	Passage	Turbine 10	2249	13	(16-18)		230
5	Sthd	180	Buoy A	1812	0.6	Lost signal						
6	Sthd	170	Lower green barrel	1811	0.0	Lost signal						
7 ^{a/}	Sthd	176	Lower green barrel	1748	6.9	Lack of movement						
8 ^{b/}	Sthd	170	Lower green barrel	1840	0.0	Lost signal						
9 ^{a/}	Ch	170	Lower green barrel	1707	10.0	Lack of movement	Turbine 3B ^{e/}	0245	0 ^{g/}			165
10 ^{b/}	Ch	152	Buoy A	1908	2.1	Passage	Turbine 13C	2115	77	(13-20)		166
11 ^{a/}	Sthd	192	Buoy A	1856	3.8	Passage	Spill 15/16	2245	84	(13-20)		88
12 ^{b/}	Ch	170	Lower green barrel	1825	2.9	Passage	Spill 15	2120	79	(13-20)		260
13 ^{b/}	Sthd	161	Lower green barrel	1829	1.5	Lost signal						
14 ^{a/}	Sthd	187	Buoy A	1812	9.0	Passage	Turbine 1B ^{f/}	0315	0 ^{g/}			135
15 ^{a/}	Ch	160	Lower green barrel	1950	0.7	Lost signal						
16 ^{a/}	Sthd	220	Lower green barrel	1955	6.1	Passage	Spill 16	0200	80	(13-20)		80
17 ^{b/}	Sthd	168	Lower green barrel	1947	3.5	Lack of movement						
18 ^{d/}	Ch	171	Lower green barrel	1806	4.2	Passage	Turbine 16A	2215	39	(13-20,16-20)		188
19 ^{c/}	Ch	162	Buoy A	1825	5.2	Passage	Spill 20	2336	43	(16-20)		70
20 ^{d/}	Sthd	165	Buoy A	1948	3.5	Lack of movement						
21 ^{c/}	Sthd	167	Lower green barrel	1932	0.0	Lost signal						
22 ^{c/}	Ch	169	Lower green barrel	1856	4.3	Passage	Spill 20	2311	68	(13-20)		83
23 ^{d/}	Ch	154	Lower green barrel	1825	3.1	Lost signal						
24 ^{c/}	Sthd	188	Lower green barrel	1822	2.3	Lost signal						
25 ^{c/}	Sthd	161	Lower green barrel	1840	0.0	Lost signal						
26	Ch	176	Lower green barrel	1850	2.5	Passage	Spill 17	2130	132	(1-20)		317
27	Ch	154	Lower green barrel	1250	3.9	Passage	Spill 16	1645	81	(1-20)		309
28	Ch	155	Lower green barrel	1730	4.5	Passage	Spill 16	2200	200	(1-20)		261
29	Sthd	188	Buoy A	1819	0.0	Lost signal						
30	Sthd	173	Buoy A	2000	4.3	Passage (?)	Turbine 8C	0020	200	(1-20)		167
31	Ch	160	Lower green barrel	1259	5.6	Passage	Turbine 16A	1835	81	(1-20)		316
32	Ch	152	Lower green barrel	1838	3.5	Passage	Turbine 1A	2206	201	(1-20)		237
33	Ch	152	Lower green barrel	1925	2.7	Passage	Turbine 9B	2208	176	(1-20)		217
34	Ch	170	Lower green barrel	1810	4.0	Passage	Spill 10	2210	163	(1-20)		235
35	Sthd	164	Lower green barrel	1325	0.0	Lost signal						

^{a/} Test condition 1.--80 kcfs spill and 80 kcfs turbine flow (SLD).

^{b/} Test condition 2.--80 kcfs spill and unreduced turbine flow.

^{c/} Test condition 3.--40 kcfs spill and 80 kcfs turbine flow (SLD).

^{d/} Test condition 4.--40 kcfs spill and unreduced turbine flow.

^{e/} Test fish was recovered from gatewell 3B by monitoring crew at approx. 0245 h.

^{f/} Signal from test fish was found in gatewell 1B after completion of track.

^{g/} Test spill had been secured for the night.

The increase in the number of fish tracked over 1980 was due to several factors; the major one was the increased power output of the tag which resulted in a greater effective tracking range. With increased tracking range and a larger second tracking boat, it became possible to track in all but the most inclement weather.

Of the 18 fish tracked to the dam, nine passed through the turbines and nine went over the spill. Eleven tracks were terminated when the signal was lost and could not be relocated (nine steelhead, two chinook salmon), whereas six were terminated at our discretion due to a lack of downstream movement (four steelhead, two chinook salmon). Plots of the individual fish tracks are in the Appendix (Fish 1-35). Due to the small number of fish tracked, no tests for statistical significance were applied. Results should be viewed as trends that are open to discussion and change with future work.

General Movement and Behavior

The primary release site in 1981 (one-fourth of the river's width out from the Washington lower green barrel) was approximately 2 to 3 km downstream from the 1980 release sites. The first two tracks of the season were used to confirm that movement was similar to 1980. The majority of 1980 fish and the first successful track of 1981 (a longer track) passed through the release site selected for 1981. Fish released at this site generally stayed on the Washington side of the river for about 1 km--approximately half way to the forebay restricted zone--before making any movement to the center or across the river. This cross-over movement was generally downstream from that found in 1980. There were three fish that

initially moved across to the Oregon shore, and one fish traveled in the middle of the river. The shorter tracks, released at Buoy A (Figure 2), followed no general pattern.

By the time the fish reached the upstream limit of the restricted zone at John Day Dam, they were spread across the entire width of the river (Figure 3). Two areas showed a concentration of fish; the area at the northern corner of the restricted zone and the area approximately 400 m from the Oregon shore. In general, movement was steadily downstream to the vicinity of the restricted zone. Some fish continued moving downstream to the dam, and others slowed down until dusk before moving on. Some cross-river movement took place just inside the restricted zone, and some extreme lateral movements occurred at the face of the dam. Passage locations were spread from Turbine Unit 1 to Spill Bay 10 (Figure 3). Two radio-tagged fish were later recovered from the turbine intake gatewells. Of the fish passing through the powerhouse in 1980 and 1981, 25% were located in the gatewells.

Tracking indicated that in general, the location of a fish as it entered the restricted zone determined whether it would pass through the turbines or spill. A line drawn straight upstream from the junction of the spillway and powerhouse roughly divided the river in half. Eight fish (half) entered on the Washington side of the line and eight (Fish 9 entered twice) on the Oregon side. In each case, only two of the eight fish passed the dam on the opposite side of the river from where they entered the restricted zone (Figure 3). Of the successful short tracks from Buoy A (a point close to the the half-way dividing line), two fish passed through the powerhouse, and two fish passed through the spill.

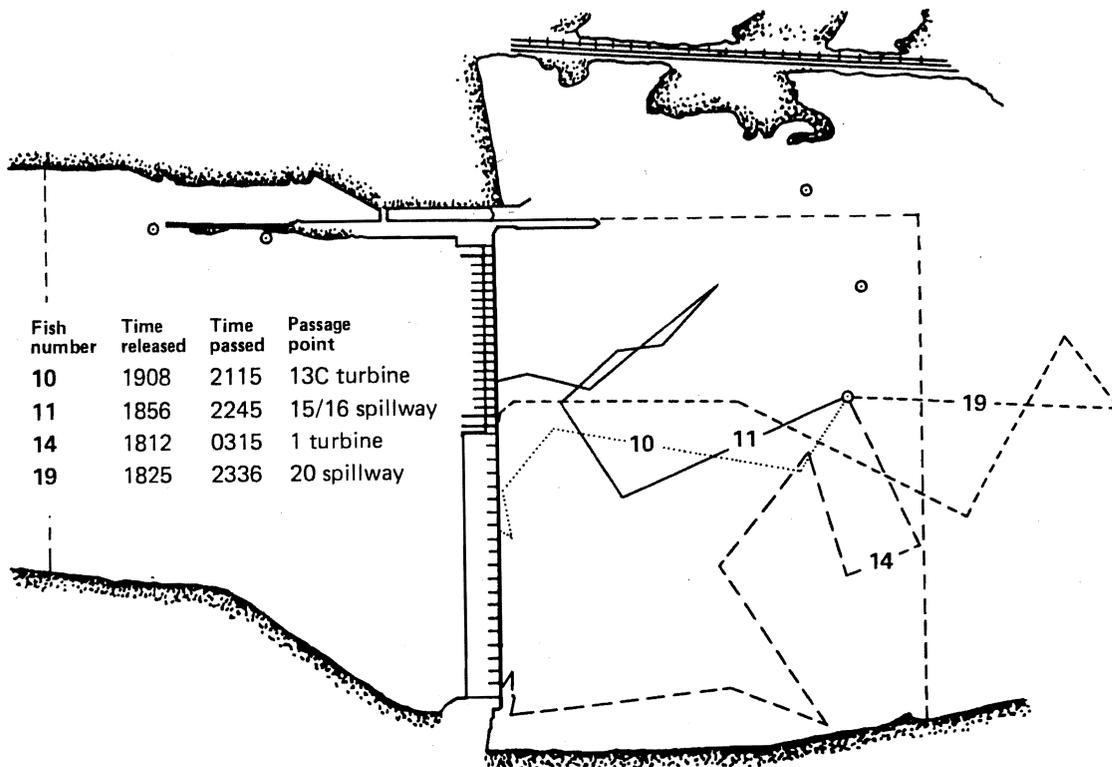


Figure 2.--Short radio tracks of juvenile salmonids released at Buoy A in the forebay of John Day Dam, 1981.

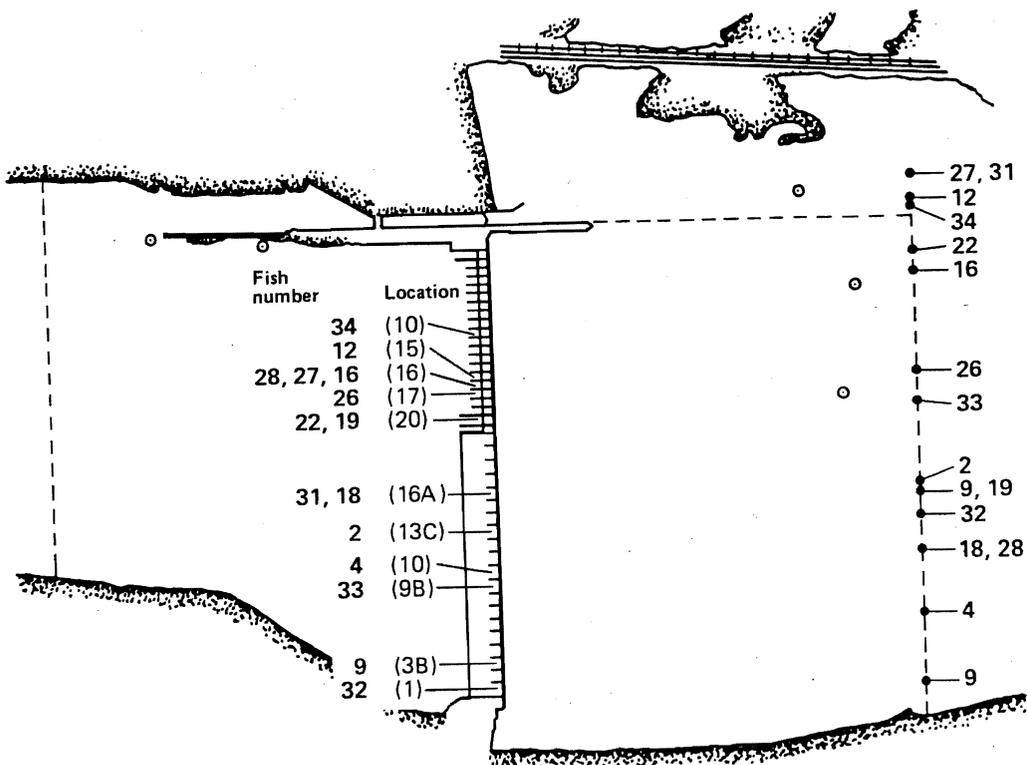


Figure 3.--Forebay restricted zone at John Day Dam showing points of entry and points of passage of radio-tracked juvenile salmonids, 1981.

There were fish that entered the restricted zone at almost identical locations yet passed the dam at completely different locations. Movements from similar entry points (Figure 3) were:

(1) Fish 18 and 28. Fish 18 entered during no spill, took 3 h to transit (spill started after 1 h 45 min) and passed at Turbine Unit 16A (17% spill). Fish 28 entered with a constant 43% spill and passed via Spill 16.

(2) Fish 9 and 19. Fish 19 was actually released at Buoy A but initially moved upstream out of the restricted zone. It reentered the restricted zone later in the day; there was spill, and SLD was occurring. It moved quickly to the spill and passed Spill Bay 20. Fish 9 entered the restricted area during a period of no spill. It then moved upstream and to the Oregon shore. During SLD, it moved down along the Oregon shore to the powerhouse where it backed off from the dam until normal turbine operations resumed and passed through Unit 3.

(3) Fish 26 and 33. Fish 26 and 33 entered the restricted zone during spill (20 and 32%). Fish 33 moved directly to Turbine 9 and passed, even though 45% of the river flow was spill at the time. Fish 26 moved directly to Turbine Unit 3 and then, following the face of the dam, moved to Spill 17 for passage during 25% spill.

(4) Fish 12, 16, 22, and 34. These fish entered during or just before spill and passed over the spillway.

(5) Fish 27 and 31. These two fish stayed the closest to the Washington shore and were expected to pass over the spill. Fish 27 did, but 31 crossed over to Turbine 1 and back to Turbine 16 for passage. (This lateral movement will be discussed more later.)

(6) Fish 11 and 14. Both were released in the restricted zone prior to spill (Figure 2). Fish 11 meandered on the spill side of the restricted zone and when spill started passed over the spillway, whereas 14 meandered to the Oregon side and passed through the powerhouse when the turbines came back on line.

Flow net appeared to be an important factor influencing smolt approach behavior at the dam. Without knowledge of the exact flow patterns, correlations with a fish's movement could not be made. Neither could it be determined how far from the dam the fish were influenced, nor how a change in the conditions could affect the fish.

A study in 1982, under contract with the Bonneville Power Administration, will measure the exact current patterns (flow net) under varying discharge conditions at John Day Dam. This should identify where the flows are and how long they take to stabilize.

Steelhead accounted for 9 of the 11 tracks that were terminated due to a lost signal and 4 of the 6 tracks terminated due to a lack of movement. Most of the signal losses took place immediately upon release. It almost certainly had to be a result of the steelhead diving to depths beyond the range of the receivers (approximately 15 m). On occasion, the signal loss was only temporary, but at other times, the signal was not regained even after 1 to 2 h of searching. Overall, more information was obtained from the chinook salmon smolts tracked.

Lateral Movement at the Dam

There were several instances of delay at the face of the dam involving lateral movement of fish that did not readily pass the dam. Many fish

showed this tendency to a small degree (see individual tracks). Fish 16, 26, 31, and 34 showed the tendency to a greater degree, and Fish 26 and 31 were the prime examples.

River flows were high (approximately 400 kcfs), with between 20 and 30% spill during the entire tracks of both fish. Fish 26 showed steady downstream progress until it arrived at the face of the dam at Turbine Unit 3. In the next hour the fish remained at the face of the dam while it worked its way past the operating turbines (3-16), empty turbine bays, and two deep spillways before passing through the second surface spill. While this lateral movement was taking place, the fish was also moving up and down in the water column as well as reversing its direction several times. Fish 31 arrived at the other side of the dam in the vicinity of Spill Bay 14, followed the same back and forth and up and down motion, and worked its way past deep and surface spills and empty and active turbine bays to Turbine Unit 1. It then worked its way back to the empty turbine bays before it turned around once more, and passed through Turbine Unit 16A. These two tracks indicated that where a fish entered the restricted zone or where it approached the face of the dam did not always indicate where it may ultimately pass the dam.

Turbine and deep spill intakes were located at 18 and 15 m depths, respectively. Comparison of signal strengths showed that the fish generally traveled at depths shallower than this while in the reservoir. By diving in the vicinity of the dam, they apparently were seeking a way past the obstruction. The fact that the fish kept returning to shallower depths may have indicated the entrances were beyond their preferred depths.

Effects of Spill

Tracking indicated there was a relationship between spill and smolt passage. Without spill, every fish tracked to the dam would have had to go through the turbines to pass. With spill provided, half of the tracked fish passed over the spillway. In 1980, however, none of the fish tracked to the dam passed over the spillway even though there were varying amounts of spill (Sims et al. 1981).

The benefits of SLD were not as obvious. It appeared the flows resulting from SLD affected some areas and not others. A detailed flow study would be required to fully develop this information. It was evident, however, that Fish 9 and 14 did not move with the flow established by SLD as they came down the Oregon shore or while they stayed in front of Turbine Units 1-3. Fish 11, 16, and 22 were in a position that they would have been expected to pass over the spill with or without SLD and they did. Track 19 was the only one that may have been affected by SLD. This fish entered the restricted zone on the Oregon half of the river and passed over the spill during SLD. This was an indication that SLD may have been beneficial, but one fish was certainly not conclusive.

Three spill bays (16, 17, and 18) were set up for shallow spill this year to determine if it would attract more fish than the deep spill (all other spill bays). At least four of the nine fish (and maybe five--Fish 11 was questionable) that passed over the spillway utilized the shallow spill. This percentage of use of the shallow spill by radio-tagged fish (44 or 56%) was higher than the percentage of water passing through the shallow spill. Any definitive numbers on shallow versus deep spill usage should come from the CofE hydroacoustic study.

Several radio-tagged fish moved past deep spillbays before passing at a shallow spill location. Fish 16 arrived at the dam in front of Bay 13. In the next 75 min it worked its way from Bay 13 to 15, back to Bay 13, and once more over to Bay 15. The signal changes from periods of weak to strong indicated possible changes in depth (deep to shallow). The fish finally moved in front of Bay 16, the first shallow spillbay encountered, and passed shortly thereafter. Fish 26 arrived at the dam at Turbine Unit 3. In the next hour, it passed all the operating turbines, empty turbine bays, and two deep (20, 19) and two shallow spillbays (18, 17) before passing through Spill Bay 16. Again, this fish appeared to be up and down in depth as it progressed across the dam. Fish 28, moving quickly, arrived at Spill Bay 11; moved across the spillway until it got to Spill 16, the first shallow spill; and passed immediately.

Movement Rates

The average rate of downstream movement (net speed from point A to point B downstream and does not take into account meanders that the fish might take) in John Day Reservoir was 0.46 km/h (0.09-1.24 km/h) (Table 2). This movement rate was slightly faster than in 1980 (0.39 km/h). Releases in 1981 were later in the day and timed for normal evening passage, which eliminated some of the meanderings of 1980. Two tracks (2 and 19) were of much longer duration and slower than the average, which lowered the overall rate of movement. During the actual tracking in 1981, movement was felt to be faster with less delays than in 1980. River flows during the last one-third of the tracks were higher than any of those encountered in 1980.

Table 2.--Net downstream movement rates of radio-tagged salmonid smolts in John Day Dam forebay, spring 1981.

Fish number	Species	Duration of track (h)	Net downstream movement		
			Distance (km)	Rate of travel (km/h)	Travel per day (km/day)
1	Ch ^{a/}	4.0	-(0.8) ^{b/}	-(0.20)	-(4.8)
2	Ch	13.1	4.7-	0.36	8.64
3	Sthd	5.1	0.5	0.10	2.40
4	Ch	5.2	3.1	0.60	14.40
5	Sthd	0.6	0.4	0.67	16.08
6	Sthd ^{a/}	-	-	-	-
7	Sthd	6.9	1.2	0.17	4.08
8	Sthd ^{a/}	-	-	-	-
9	Ch	10.0	3.1	0.31	7.44
10	Ch	2.1	0.8	0.38	9.12
11	Sthd	3.8	0.8	0.21	5.04
12	Ch	2.9	3.1	1.07	25.68
13	Sthd	1.5	0.6	0.40	9.60
14	Sthd	9.0	0.8	0.09	2.16
15	Ch	0.7	0.4	0.57	13.68
16	Sthd	6.1	3.1	0.51	12.24
17	Sthd	3.5	0.7	0.20	4.80
18	Ch	4.2	3.1	0.74	17.76
19	Ch	5.2	0.8	0.15	3.60
20	Sthd ^{a/}	3.5	-(0.4) ^{b/}	-(0.11)	-(2.64)
21	Sthd ^{a/}	-	-	-	-
22	Ch	4.3	3.1	0.72	17.28
23	Ch	3.1	2.0	0.65	15.60
24	Sthd	2.3	0.5	0.22	5.28
25	Sthd ^{a/}	-	-	-	-
26	Ch	2.5	3.1	1.24	29.76
27	Ch	3.9	3.1	0.79	18.96
28	Ch	4.5	3.1	0.69	16.56
29	Sthd ^{a/}	-	-	-	-
30	Sthd	4.3	0.8	0.19	4.56
31	Ch	5.6	3.1	0.55	13.20
32	Ch	3.5	3.1	0.89	21.36
33	Ch	2.7	3.1	1.15	27.60
34	Ch	4.0	3.1	0.78	18.72
35	Sthd ^{a/}	-	-	-	-
Total		120.6	55.3		

$$\text{Average rate} = \frac{\text{distance (total)}}{\text{duration (total)}} = 0.46$$

^{a/} Not included in calculations

^{b/} Fish movement was upstream

By species (Table 3), movement rates were 0.59 km/h for chinook salmon and 0.22 km/h for steelhead compared to 0.52 and 0.40 km/h, respectively, in 1980.

SUMMARY AND CONCLUSIONS

In the spring of 1981, radio-tracking studies were conducted to monitor approach and passage of salmonid smolts under various modes of spill and turbine sequencing at John Day Dam. Thirty-five smolts (18 chinook salmon, 17 steelhead) were tracked as they approached the dam.

1. Smolts tracked ranged in length from 152 to 176 mm for chinook salmon and 161 to 220 mm for steelhead.
2. Chinook salmon smolts were more easily tracked than steelhead smolts.
3. Of the 18 fish tracked to the dam, 9 passed through the turbines and 9 went over the spill.
4. In 75% of the cases, the side of the river a fish was on when it entered the forebay restricted zone determined whether a fish would pass over the spill or through the turbines--Washington, spillway; Oregon, powerhouse.
5. There were several instances of delays and extensive lateral movement at the face of the dam.
6. Spill was beneficial to the smolt outmigration.
7. The percentage of radio-tagged fish using the shallow spill was higher than the percentage of water passing through the shallow spill.
8. Insufficient numbers of tagged fish passed during the potential

Table 3.--Movement rates by species of radio-tagged chinook salmon and steelhead smolts in John Day Dam forebay, Spring 1981.

Fish number	Net downstream movement (km/h)					
	Chinook salmon			Steelhead		
	Duration (h)	Distance (km)	Rate of travel (km/h)	Duration (h)	Distance (km)	Rate of travel (km/h)
1 ^{a/} b/	4.0	-(0.8)	-(0.20)			
2	13.1	4.7	0.36			
3				5.1	0.5	0.10
4	5.2	3.1	0.60			
5 ^{a/}				0.6	0.4	0.67
6 ^{a/}				-	-	-
7 ^{a/}				6.9	1.2	0.17
8 ^{a/}						
9	10.0	3.1	0.31			
10	2.1	0.8	0.38			
11				3.8	0.8	0.21
12	2.9	3.1	1.07			
13				1.5	0.6	0.40
14				9.0	0.8	0.09
15	0.7	0.4	0.57			
16				6.1	3.1	0.51
17				3.5	0.7	0.20
18	4.2	3.1	0.74			
19	5.2	0.8	0.15			
20 ^{a/} b/				3.5	-(0.4)	-(0.11)
21 ^{a/}				-	-	-
22	4.3	3.1	0.72			
23	3.1	2.0	0.65			
24				2.3	0.5	0.22
25 ^{a/}				-	-	-
26	2.5	3.1	1.24			
27	3.9	3.1	0.79			
28	4.5	3.1	0.69			
29 ^{a/}				-	-	-
30				4.3	0.8	0.19
31	5.6	3.1	0.55			
32	3.5	3.1	0.89			
33	2.7	3.1	1.15			
34	4.0	3.1	0.78			
35 ^{a/}				-	-	-
Total	77.5	45.9		43.1	9.4	
Average Rate = $\frac{\text{Distance (Total)}}{\text{Duration (Total)}}$			0.59	0.22		

a/ Not included in calculations

b/ Fish movement was upstream

influence of sequential load dropping to evaluate its effectiveness on tagged salmonids.

9. The rates of downstream movement were slightly faster in 1981, than in 1980.

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APPENDIX

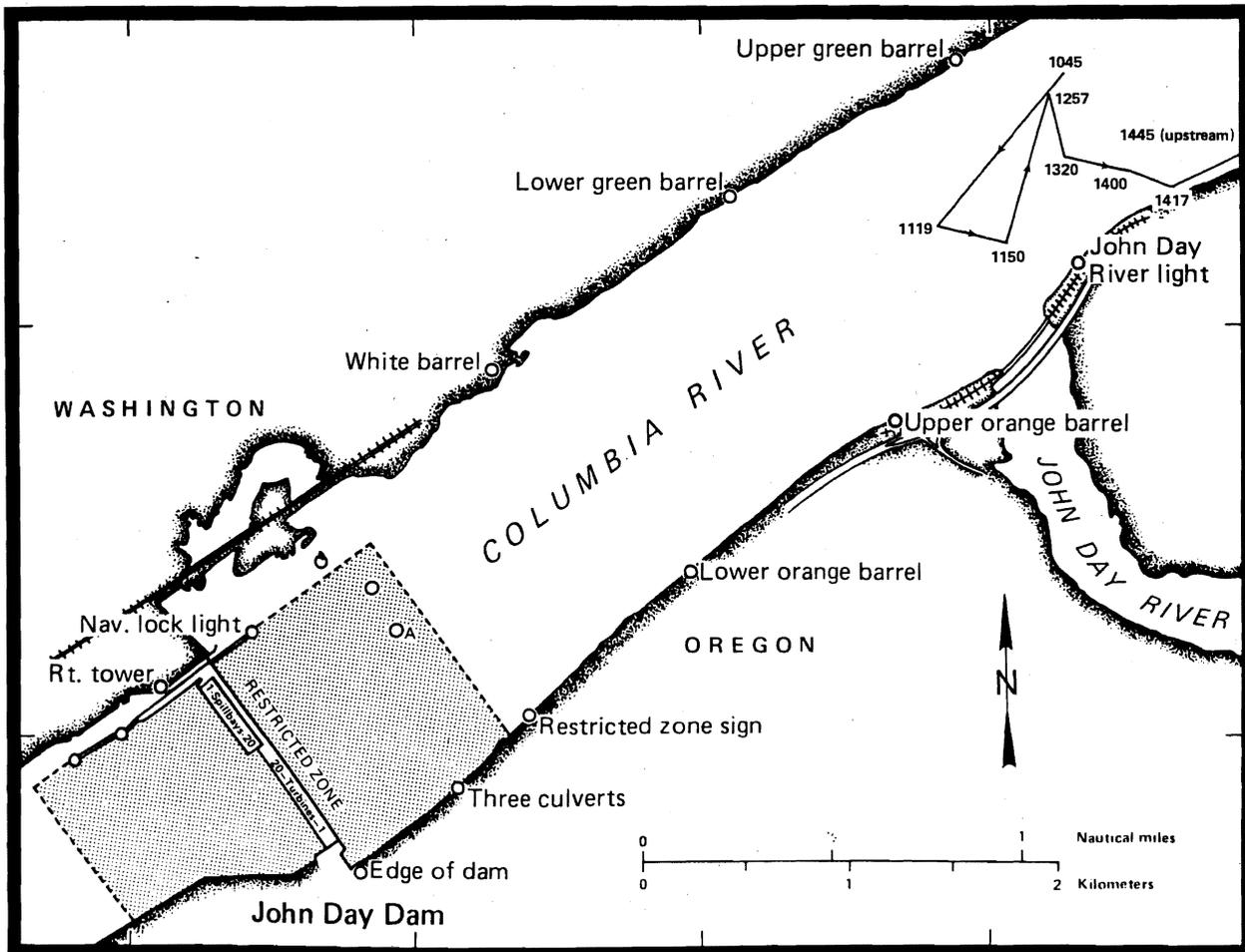
INDIVIDUAL RADIO TRACKS OF JUVENILE
SALMONIDS IN THE FOREBAY OF JOHN DAY DAM, 1981

Fish number 1
 Chinook salmon 172 mm
 23 April 1981

Fish number 1 was the first track of the season. The crew became familiar with all phases of the tracking operation. Signal strength was good with an effective tracking range of 60-90 m. The track was terminated due to a lack of downstream movement.

Flow Kcfs

Time	0800	0900	1000	1100	1200	1300	1400			
Total	206.4	212.8	209.5	175.9	159.3	163.5	174.2			
Turbine	206.4	212.8	209.5	175.9	159.3	163.5	174.2			
Spill										
% spill										

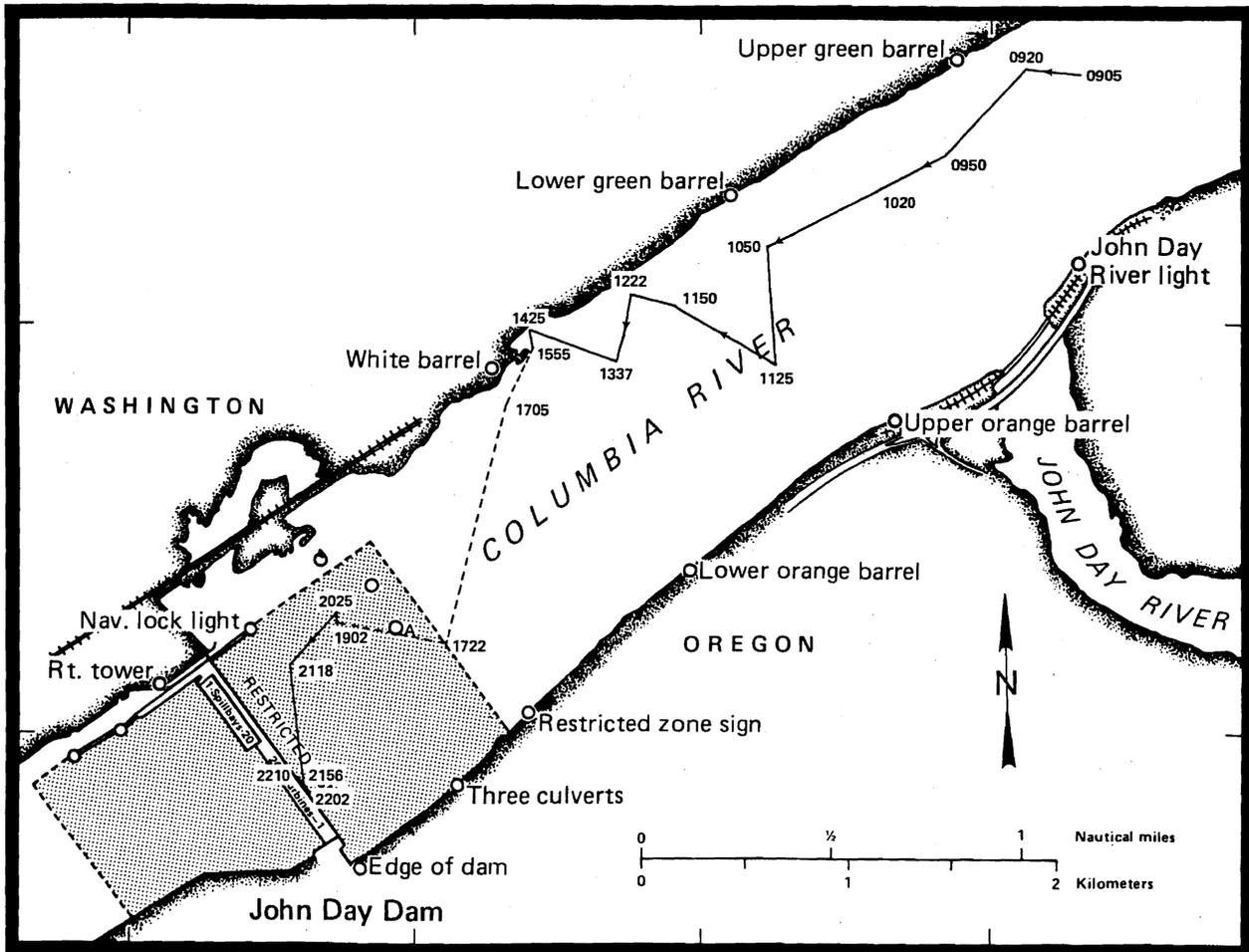


Fish number 2
 Chinook salmon 162 mm
 28 April 1981

Fish number 2 was released upstream of the proposed release site in the vicinity of the 1980 releases. It passed through the proposed release site, held in a small cove on the Washington shore for 1.5 h and again for approximately 2 h near the northern corner of the restricted zone. The fish arrived at the dam near Turbine Unit 16, moved to 10, and back to 13B for a 2210 h passage (diving several times along the way). Effective tracking range was 80-90 m and there was no spill.

Flow Kcfs

Time	1300	1400	1500	1600	1700	1800	1900	2000	2100	2200
Total	236.5	242.2	241.9	235.8	232.7	233.1	244.2	246.2	246.2	223.6
Turbine	236.5	242.2	241.9	235.8	232.7	233.1	244.2	246.2	246.2	223.6
Spill										
% spill										

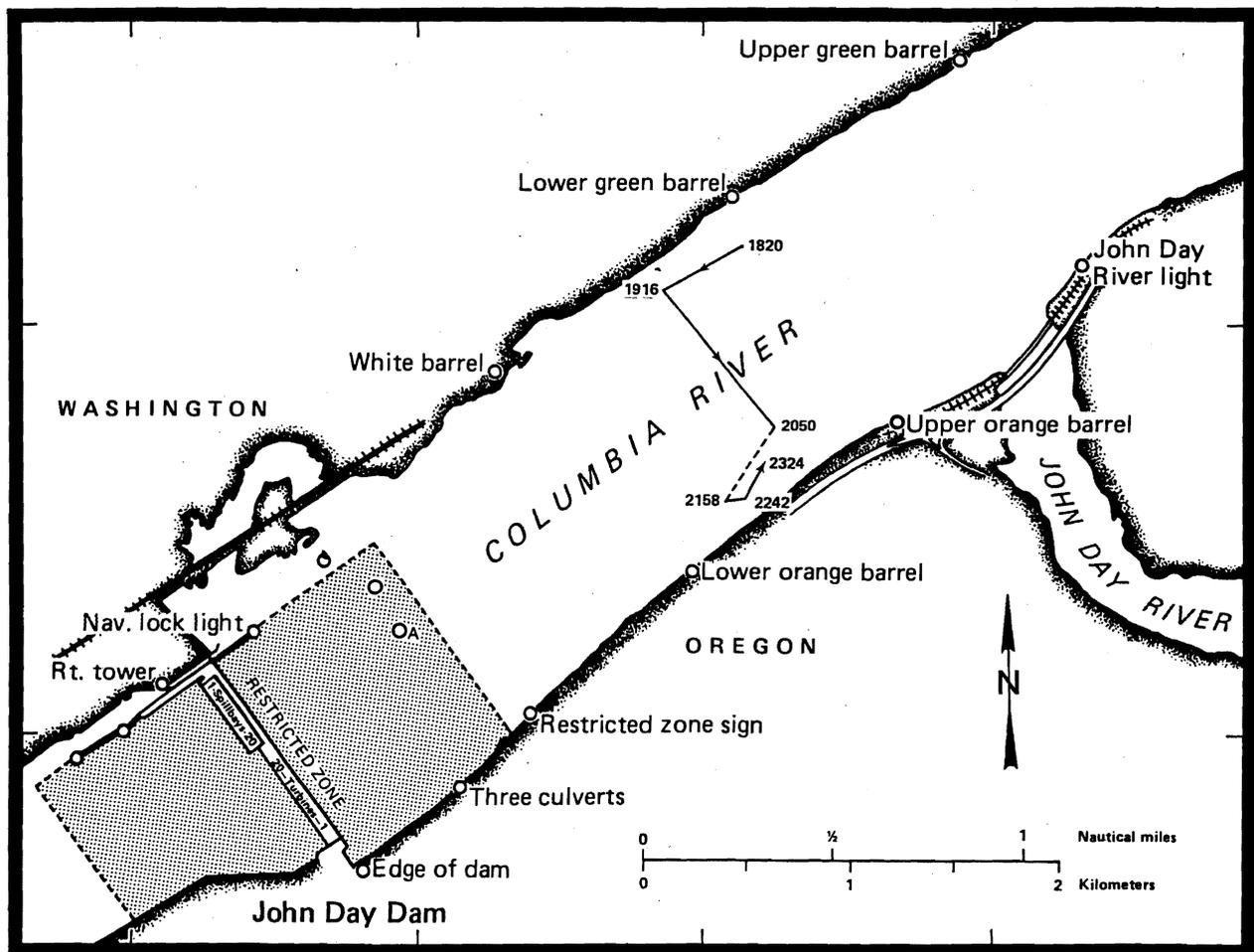


Fish number 3
 Steelhead trout 180 mm
 29 April 1981

Fish number 3 was the first fish released from the predesignated release site (approximately one-fourth of the river width off the lower green barrel on the Washington shore). The fish started down the Washington side, but then crossed straight over to the Oregon side and didn't show much movement the remainder of the evening. The track was terminated for lack of movement when it became apparent the fish would not have been in a location that it could have been affected by any normal spill pattern. Tracking range was 60-90 m.

Flow Kcfs

Time	1600	1700	1800	1900	2000	2100	2200	2300	2400
Total	247.7	235.2	241.8	243.2	244.2	229.7	232.2	233.8	202.5
Turbine	247.7	235.2	231.9	232.6	233.6	217.3	220.8	220.6	198.9
Spill			9.4	10.1	10.1	10.1	10.9	10.9	3.1
% spill			4	4	4	4	4	4	1

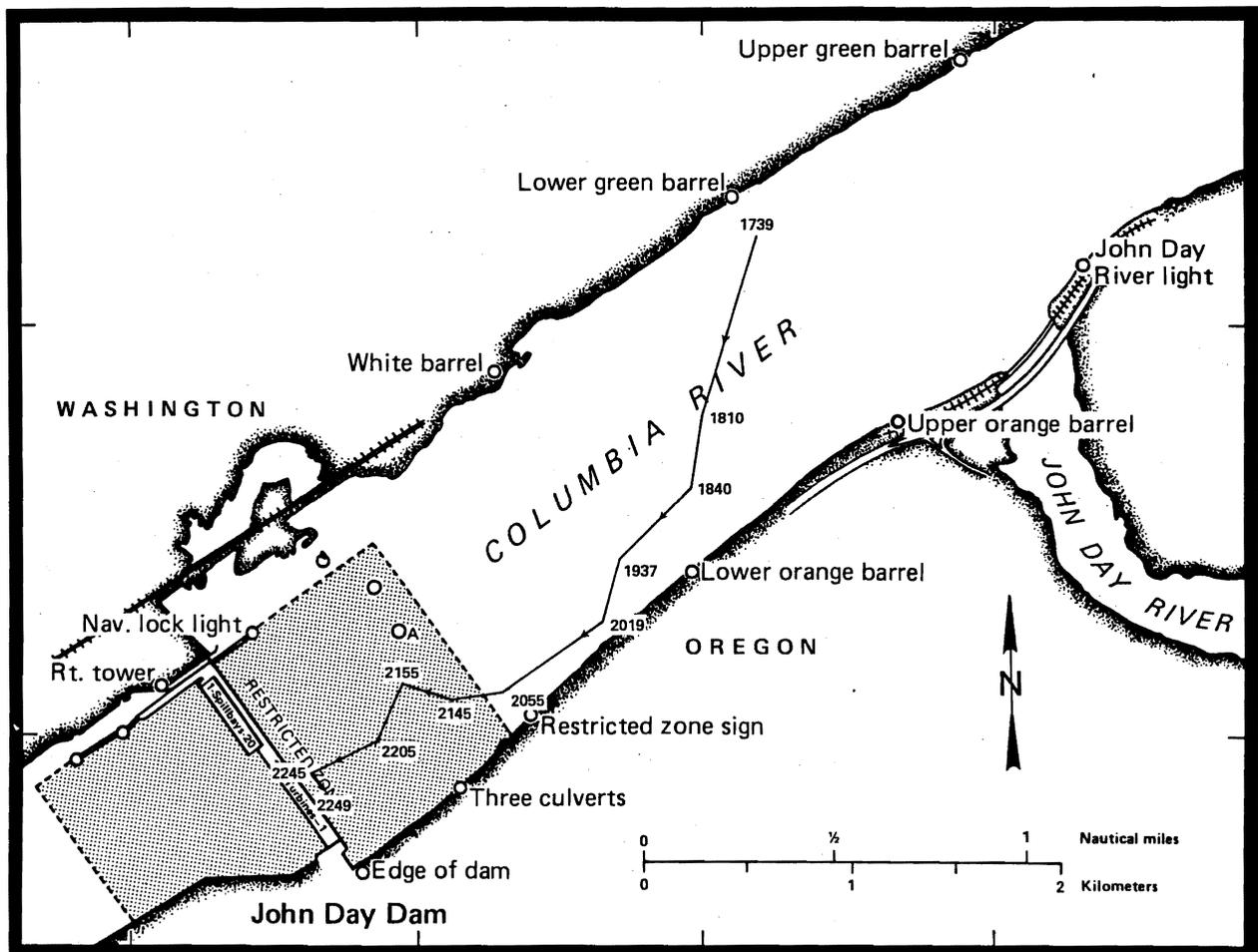


Fish number 4
 Chinook salmon 160 mm
 30 April 1981

Track number 4 went well with a strong signal most of the evening even though the weather affected the boats. The fish moved from the release site to the Oregon side and moved steadily to the dam and passed through Turbine Unit 10 at 2249 h. The effective tracking range was 50-100m and there was a spill of 14 kcfs at the time of passage.

Flow Kcfs

Time	1700	1800	1900	2000	2100	2200	2300			
Total	245.0	243.9	255.8	256.9	258.9	259.3	242.1			
Turbine	242.7	243.4	244.1	243.5	246.6	244.1	228.7			
Spill			9.4	12.9	11.8	12.9	12.9			
% spill			5	5	5	5	5			

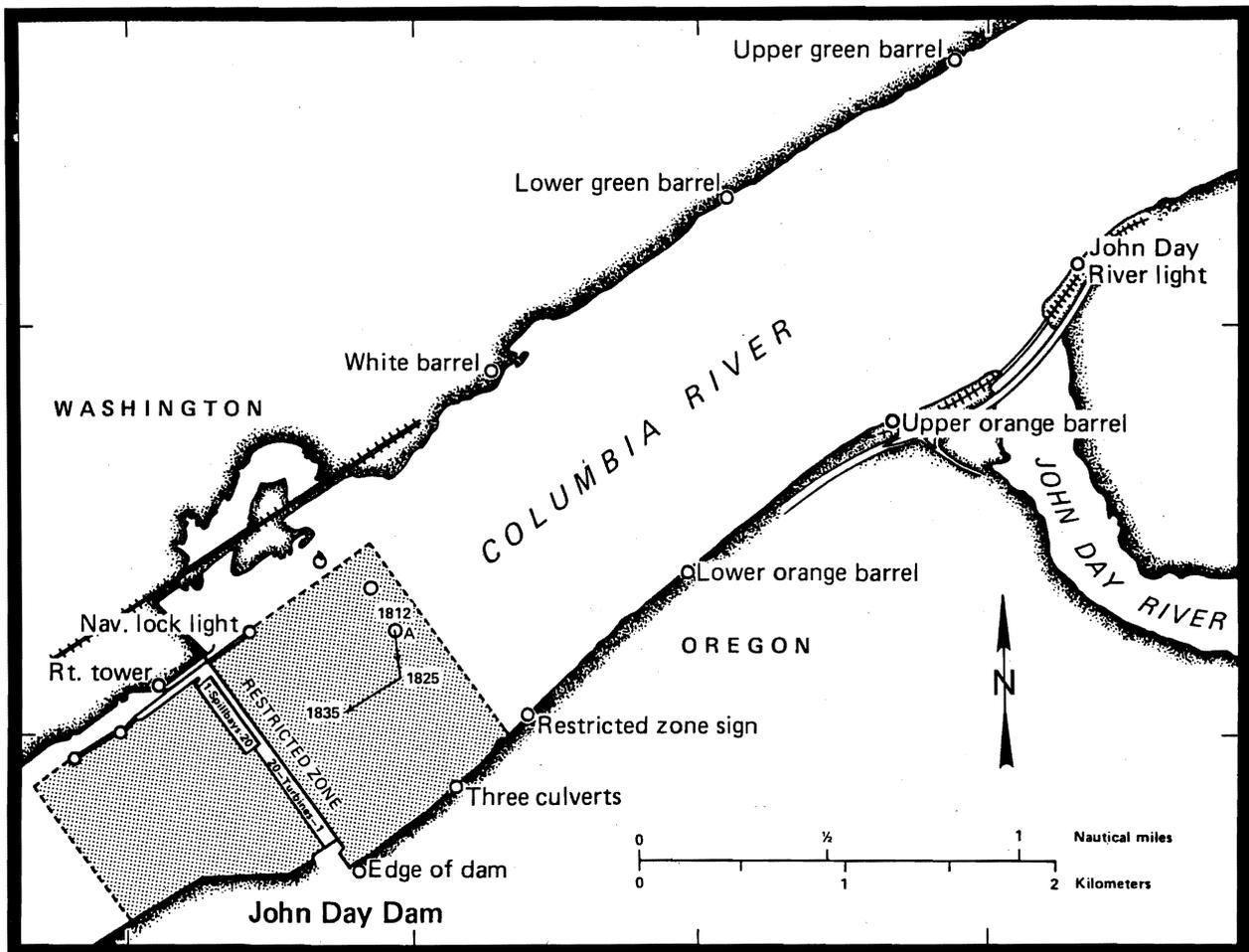


Fish number 5
 Steelhead trout 180 mm
 1 May 1981

Buoy A in the forebay restricted zone was the release site for fish number 5. The tag had a low output and the signal was lost shortly after release. Tracking range was 30-50 m.

Flow Kcfs

Time	1600	1700	1800						
Total	219.0	201.5	214.8						
Turbine	219.0	201.5	214.8						
Spill									
% spill									

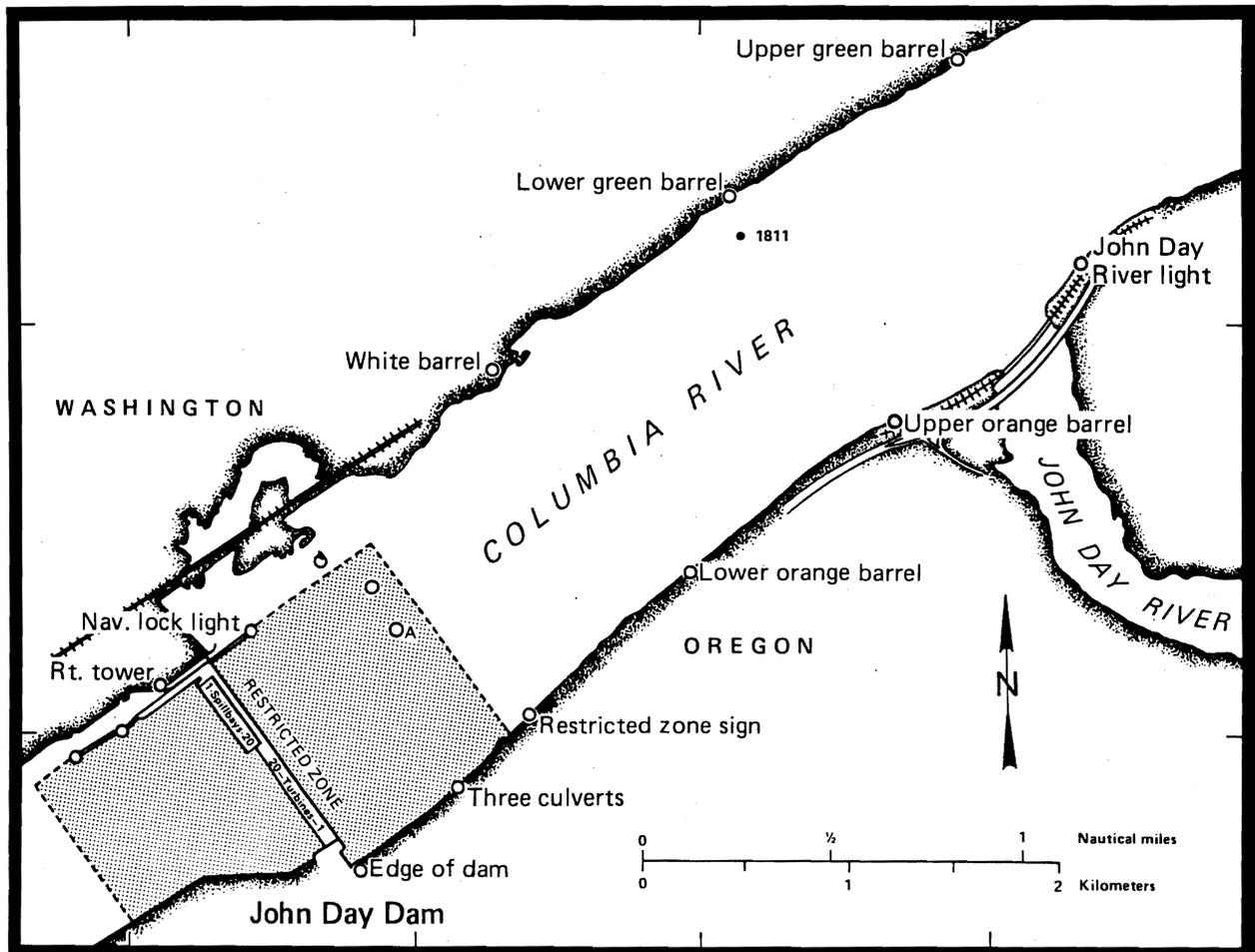


Fish number 6
 Steelhead trout 170 mm
 5 May 1981

The signal from fish number 6 decreased steadily from the time of release and was lost within a couple of minutes. It was believed the fish dove to depths beyond our tracking capability.

Flow Kcfs

Time	1800								
Total	290.3								
Turbine	280.4								
Spill	90.4								
% spill	31								

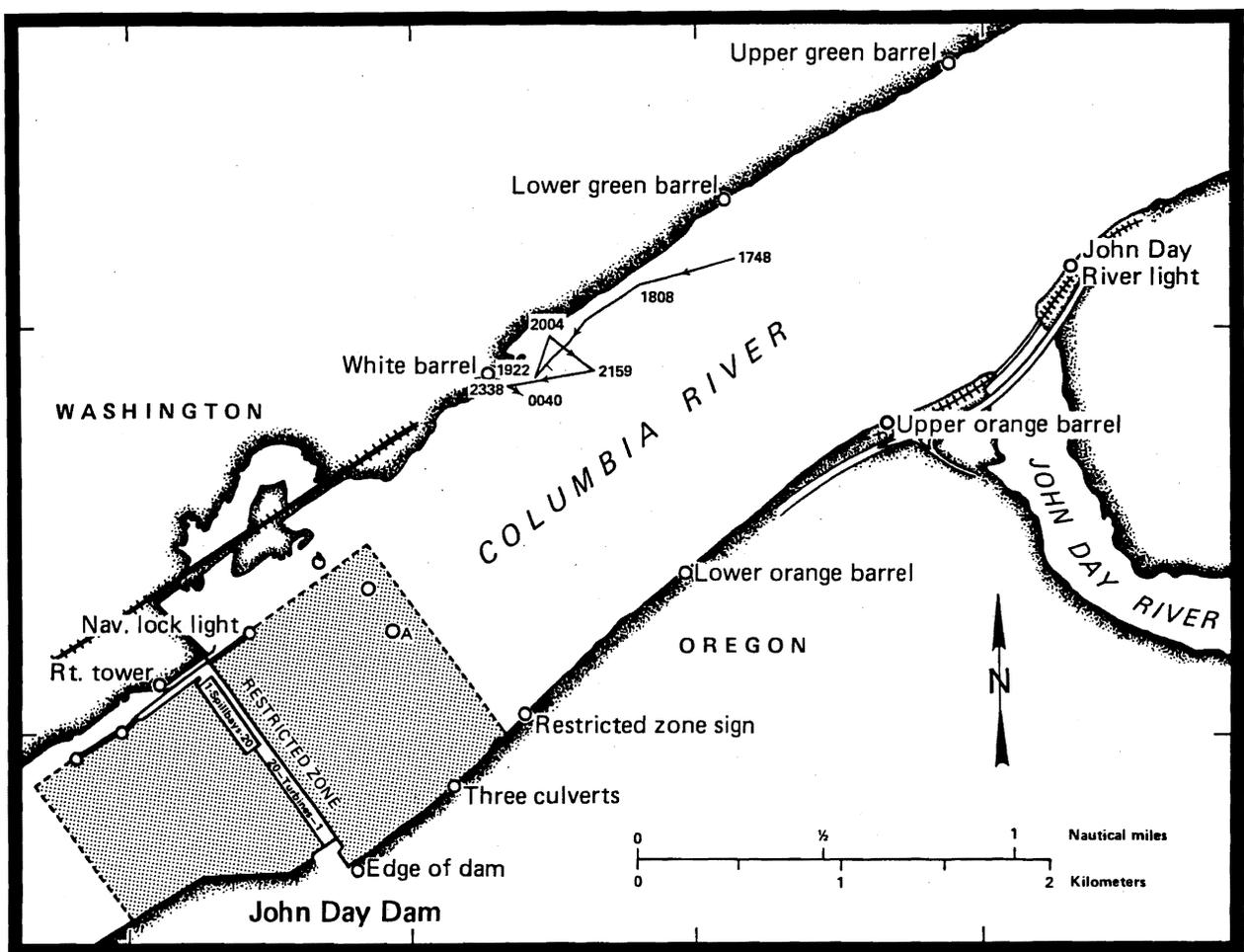


Fish Number 7
 Steelhead trout 176 mm
 6 May 1981

Track number 7 was terminated after 7 h of tracking because of lack of movement. Five hours were spent in the vicinity of the small cove near the white barrel on the Washington shore. Tracking range was excellent (100-200 m).

Flow Kcfs

Time	1700	1800	1900	2000	2100	2200	2300	2400	0100
Total	281.2	281.8	281.1	283.2	281.9	295.6	305.9	262.8	262.8
Turbine	280.7	281.3	280.6	280.9	281.4	281.8	279.9	260.7	260.7
Spill						11.5	23.7	1.6	1.6
% spill						4	8	1	1

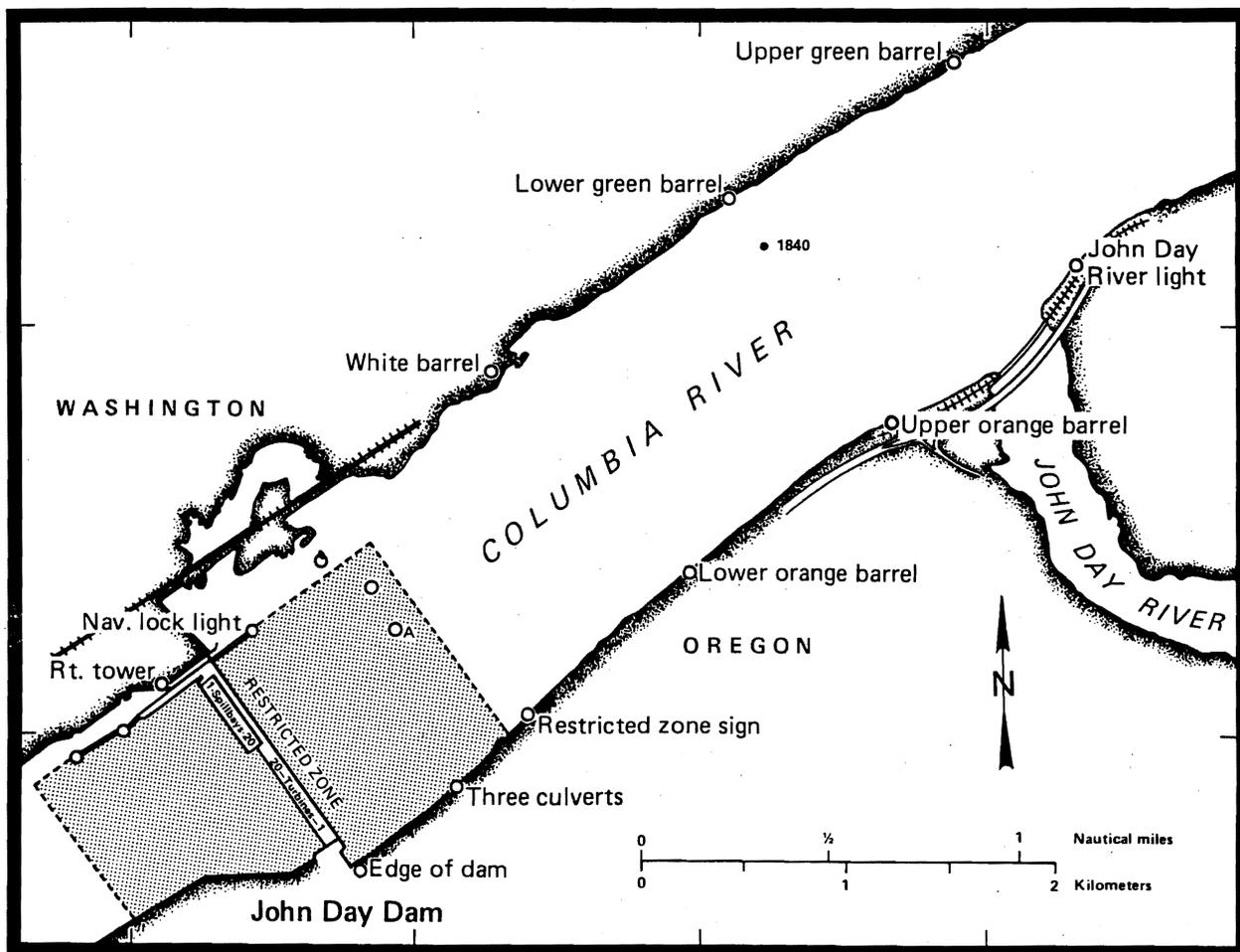


Fish number 8
 Steelhead trout 170 mm
 6 May 1981

Fish number 8 sounded upon release and the signal was lost within a minute.

Flow Kcfs

Time	1800																		
Total	289.5																		
Turbine	289.5																		
Spill																			
% spill																			

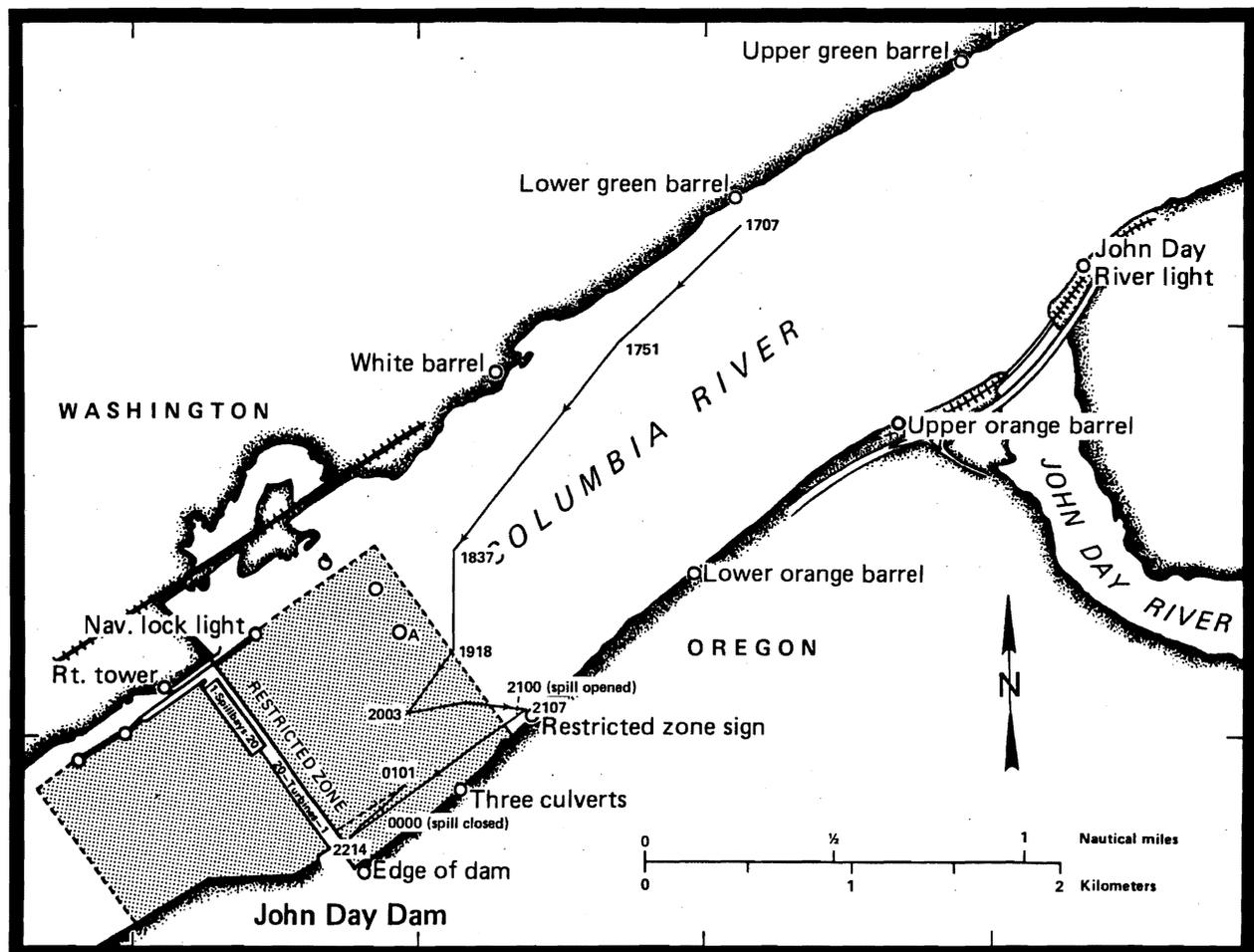


Fish number 9
 Chinook salmon 170 mm
 8 May 1981

Fish number 9 moved steadily from the release site toward the dam arriving at the face of the dam in the vicinity of Turbine Unit 3, arriving after SLD and commencement of spill. The fish then backed away from the face of the dam several hundred meters. Tracking was terminated at 0101 h (an hour after the turbines were put back in operation) and no forward progress had been made in 3 h. The fish was recovered from gatewell 3B by the monitoring crew on their 0300 h sample. Tracking range was 100-120 m, and spill had made up as much as 50% of the river flow.

Flow Kcfs

Time	1700	1800	1900	2000	2100	2200	2300	2400	0100	0200
Total	229.4	231.7	227.8	227.3	225.6	174.6	166.7	164.0	127.6	165.1
Turbine	228.9	231.2	227.3	226.8	221.7	91.8	80.5	80.6	126.1	164.6
Spill					1.6	82.3	83.9	82.9	1.1	
% spill					1	47	50	51	1	

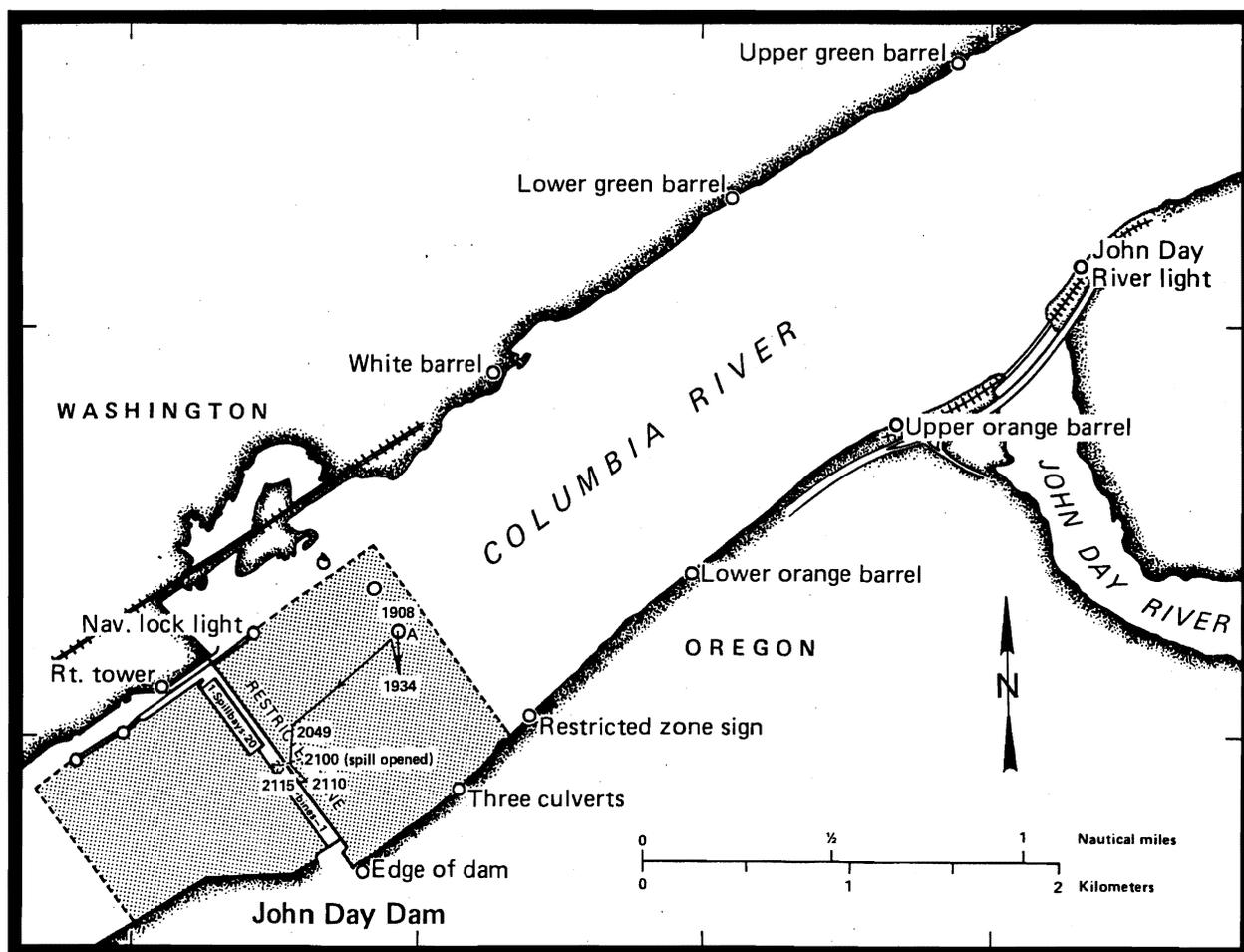


Fish Number 10
 Chinook salmon 152 mm
 9 May 1981

Track number 10 was started at Buoy A. The track went well and the fish passed through Turbine Unit 13C at 2115 hours. Spill was started at 2100 hours and it did not seem to influence the fish while it was at the face of the powerhouse. Tracking range was 100 m.

Flow Kcfs

Time	1900	2000	2100	2200						
Total	196.9	207.6	166.8	222.6						
Turbine	196.4	205.3	166.3	143.5						
Spill				76.8						
% spill				35						

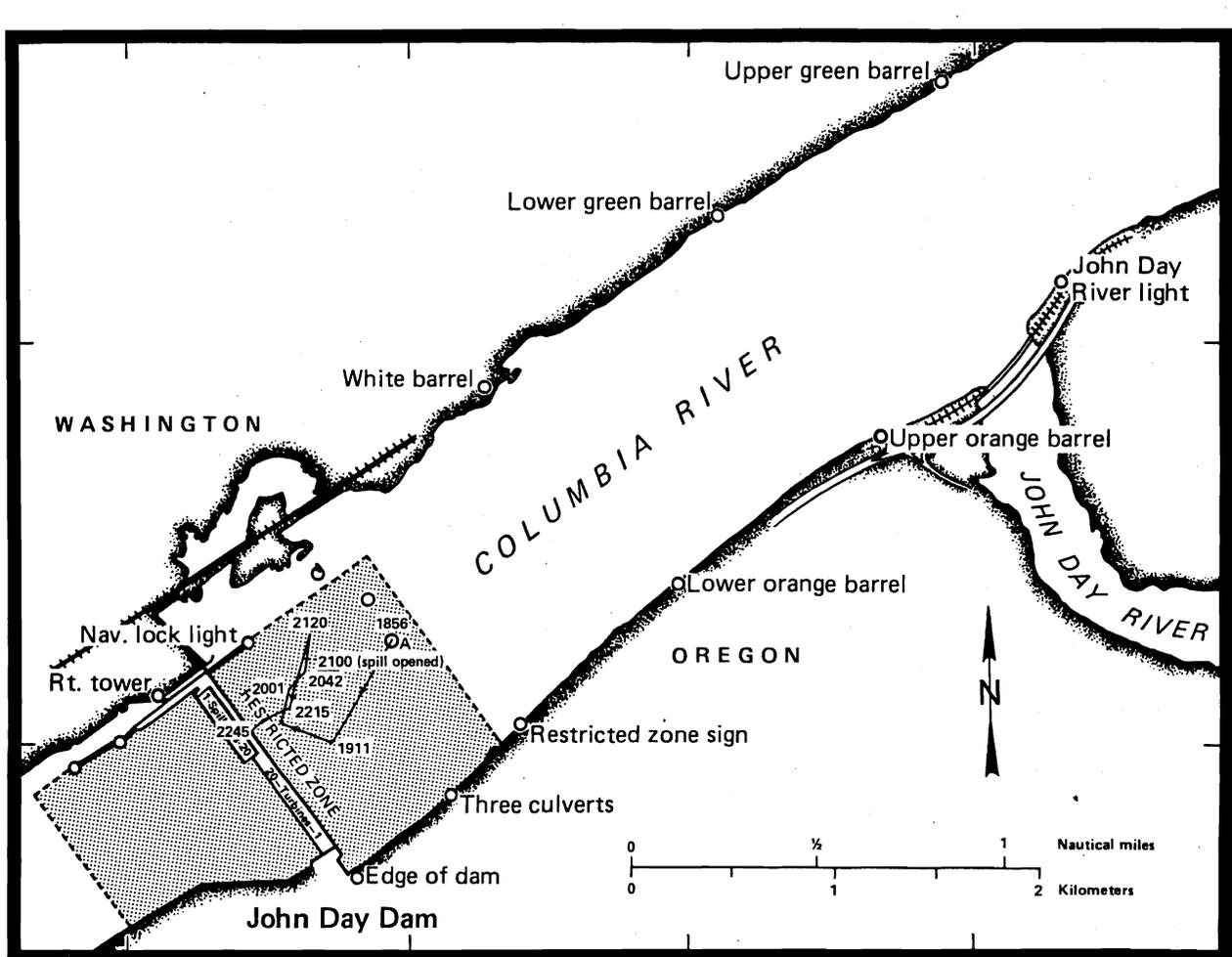


Fish number 11
 Steelhead trout 192 mm
 10 May 1981

Fish number 11 was released at Buoy A prior to the SLD and spill. The fish initially started for the dam but changed direction and meandered for 2 h. Approximately half an hour after the spill was opened the fish headed for the dam. The fish made several dives in the vicinity of spill bays 15 and 16 and according to signals received, passed over 15. Two receivers were being used on the spillway and one on the boat at the time of passage. At the time Unit 15 was deep spill open 10 stops (15.1 kcfs) and 16 was surface spill open 4 stops (6.1 kcfs). Effective tracking range was 80-100 m.

Flow Kcfs

Time	1800	1900	2000	2100	2200	2300				
Total	206.8	196.7	186.4	186.4	166.5	165.0				
Turbine	204.5	196.2	185.9	185.9	88.0	78.8				
Spill					78.0	83.9				
% spill					47	51				

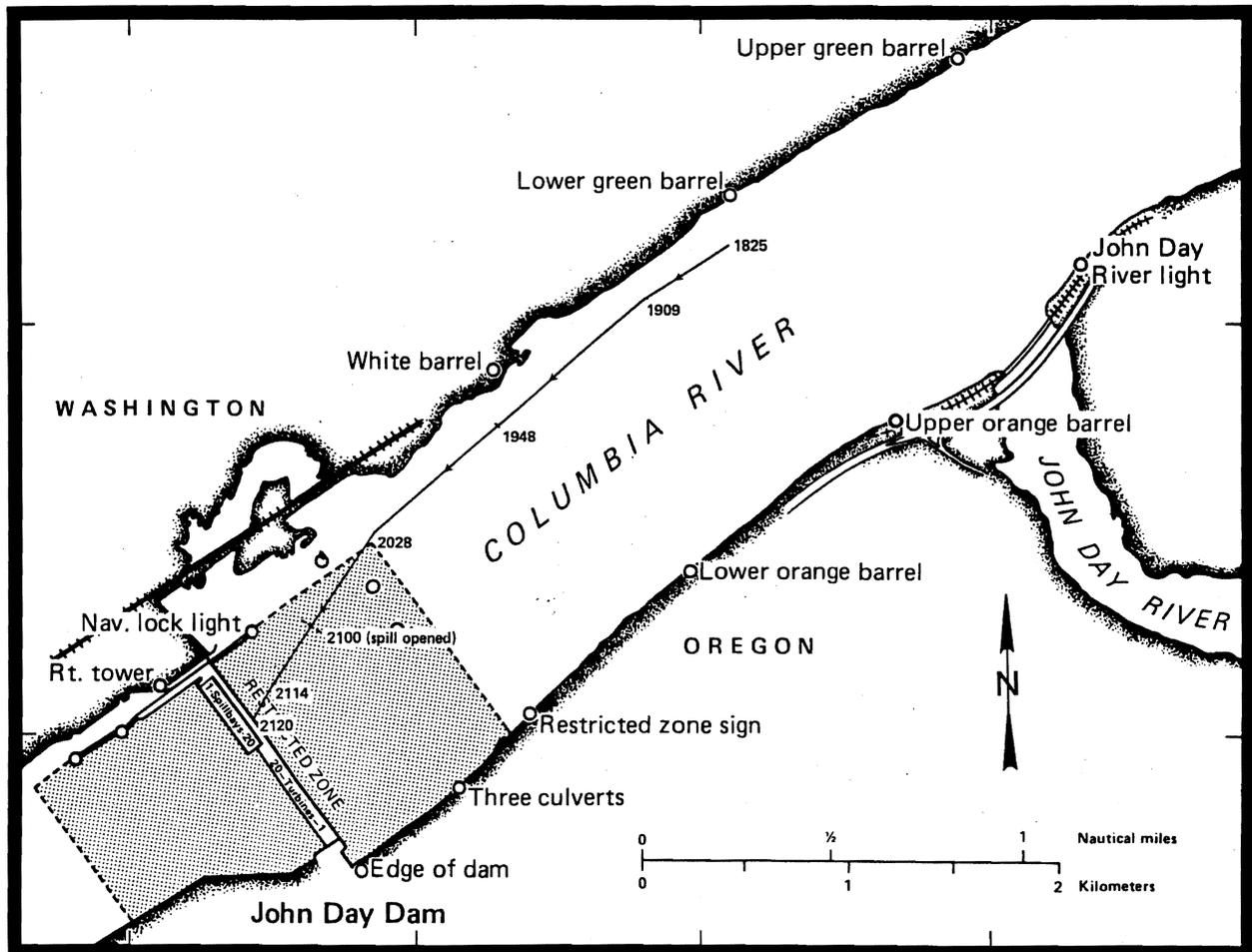


Fish Number 12
 Chinook salmon 170 mm
 12 May 1981

We released fish number 12 from the primary release site. Movement to the dam was steady all the way and passage was at Spill Bay 15 with no delay. Effective tracking range was 150 m.

Flow Kcfs

Time	1800	1900	2000	2100	2200					
Total	240.9	248.2	253.5	259.9	277.5					
Turbine	240.9	248.2	253.5	259.9	197.7					
Spill					79.3					
% spill					29					

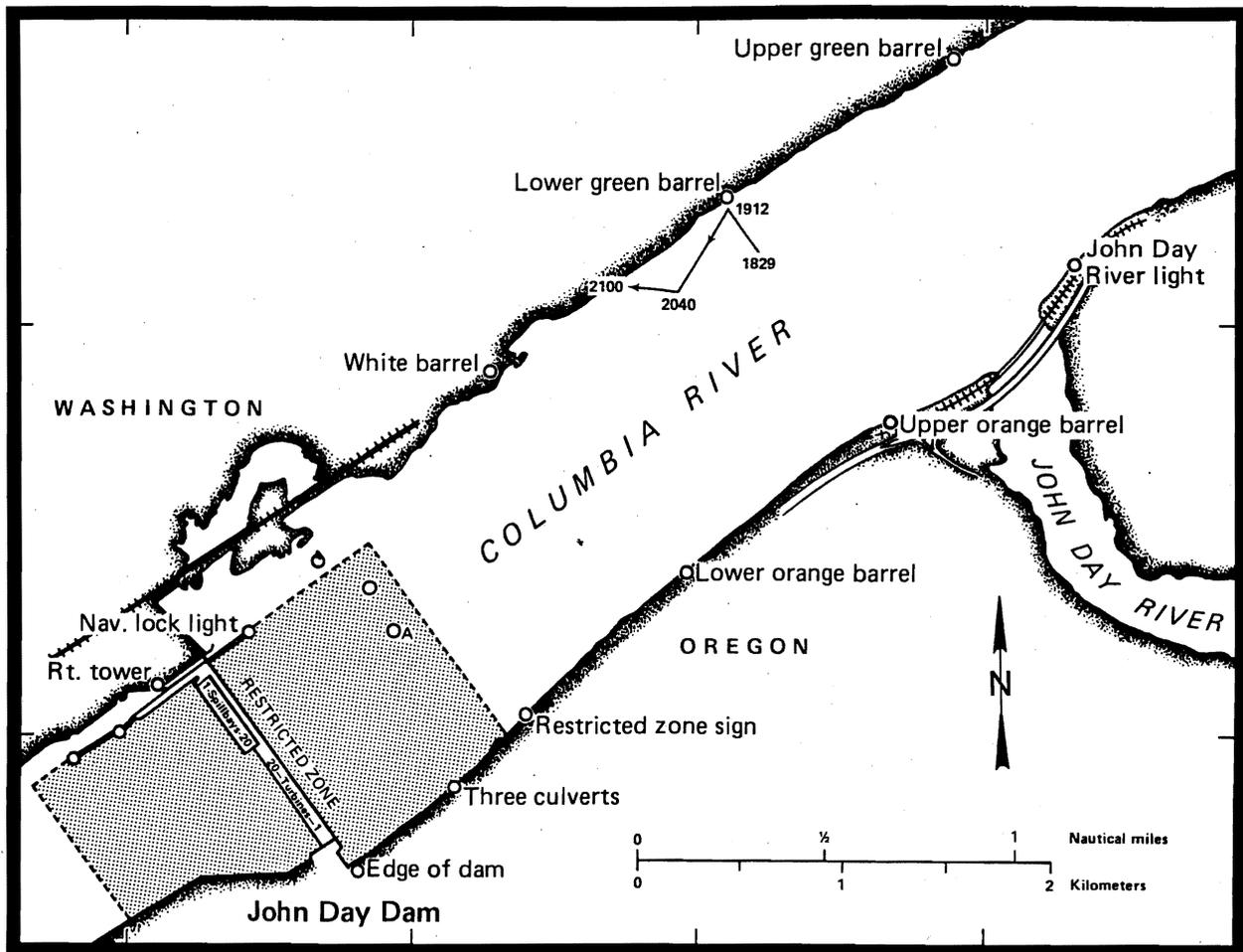


Fish Number 13
 Steelhead trout 161 mm
 13 May 1981

Fish number 13 moved very slow until the signal was lost. The signal loss was immediate and could have been 1) a quick dive, 2) predation, or 3) regurgitation of the tag. Effective tracking range was 130 m.

Flow Kcfs

Time	1800	1900	2000	2100	2200					
Total	254.5	256.8	261.0	232.1	268.1					
Turbine	254.0	256.3	260.5	229.8	190.2					
Spill					77.5					
% spill					29					

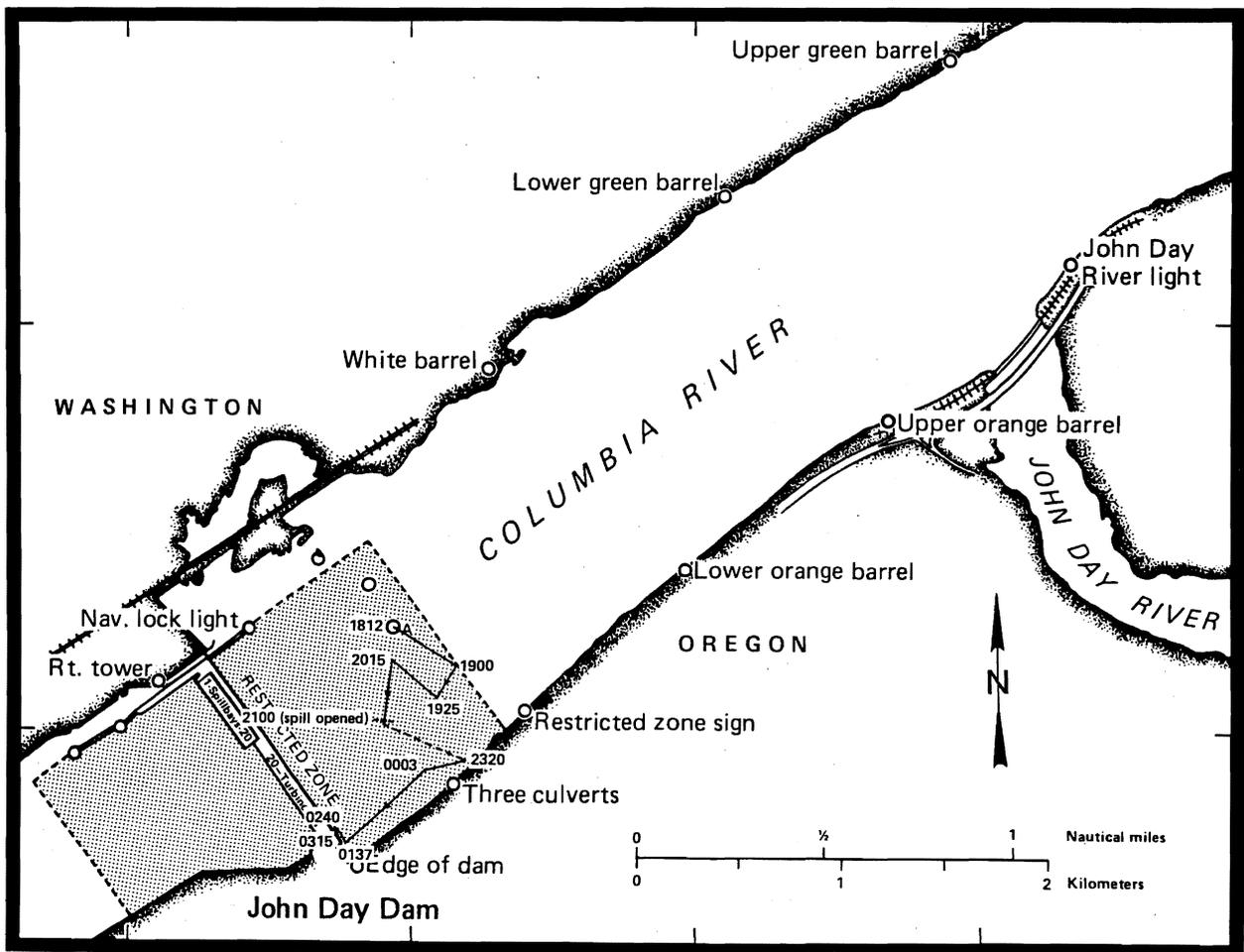


Fish number 14
 Steelhead trout 187 mm
 14 May 1981

Fish number 14 was released at Buoy A and moved slowly over to the Oregon shore. It was not attracted by the SLD and spill. Instead the fish remained out in the restricted zone until the turbines resumed normal operations and then moved to the powerhouse. The signal was lost at Unit 3B, but the fish was later located in Gatewell 1B, from the deck of the dam. The movement of this fish appeared to be similar to that of fish number 9.

Flow Kcfs

Time	1900	2000	2100	2200	2300	2400	0100	0200	0300	0400
Total	242.7	229.1	182.4	161.2	163.6	160.8	148.1	160.4	137.4	183.3
Turbine	242.2	226.8	181.9	83.4	80.8	80.7	102.0	116.9	132.4	182.8
Spill				77.3	82.3	79.6	45.6	41.2	3.0	
% spill				48	50	50	30	25	2	

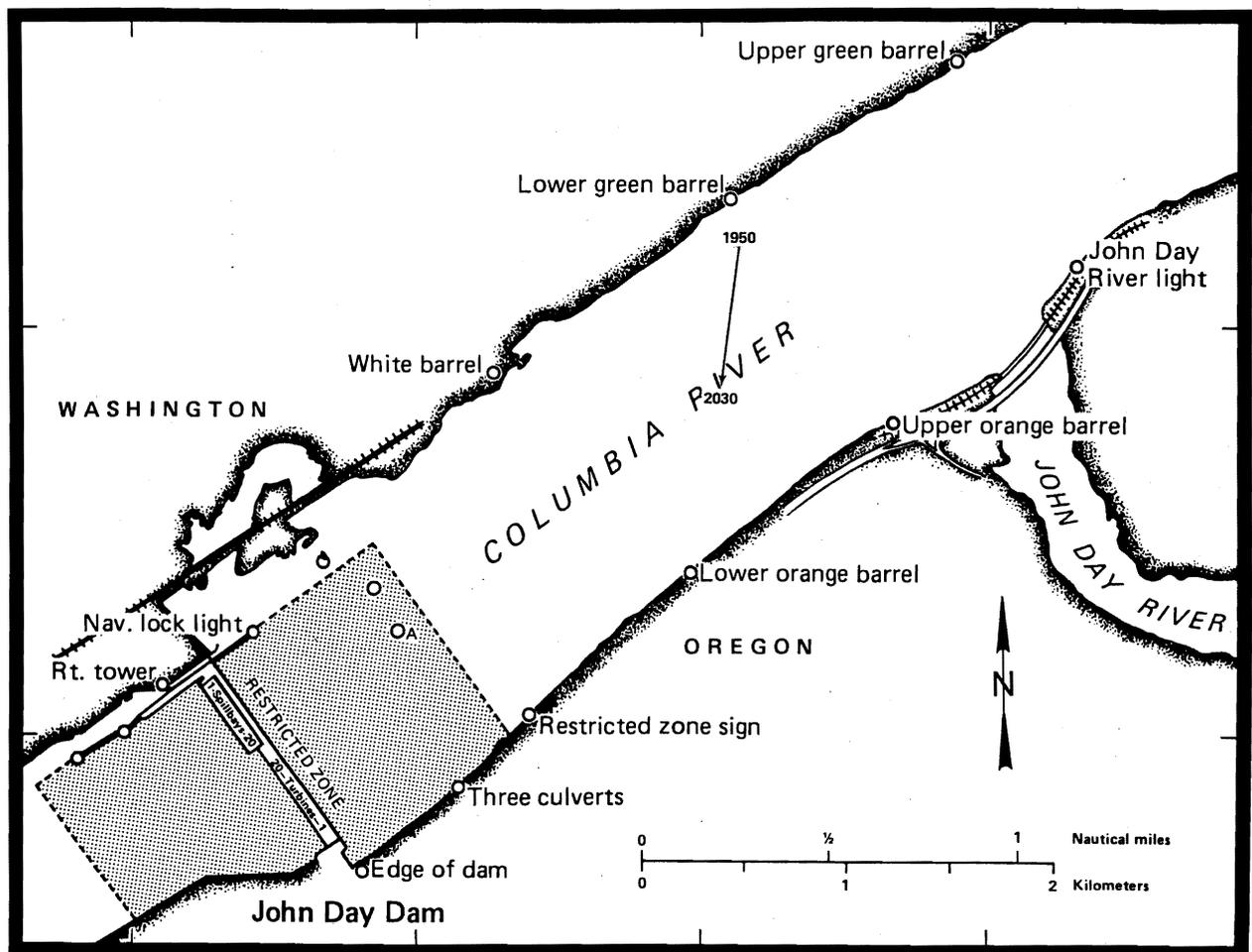


Fish number 15
 Chinook salmon 160 mm
 16 May 1981

Fish number 15 was tracked for only a short time. The signal was heard only when directly above the fish, indicating the fish was deeper than normal. Tracking range was 20-60 m.

Flow Kcfs

Time	1700	1800	1900	2000	2100					
Total	225.4	220.8	217.8	229.3	179.1					
Turbine	225.4	220.8	217.8	229.3	179.1					
Spill										
% spill										

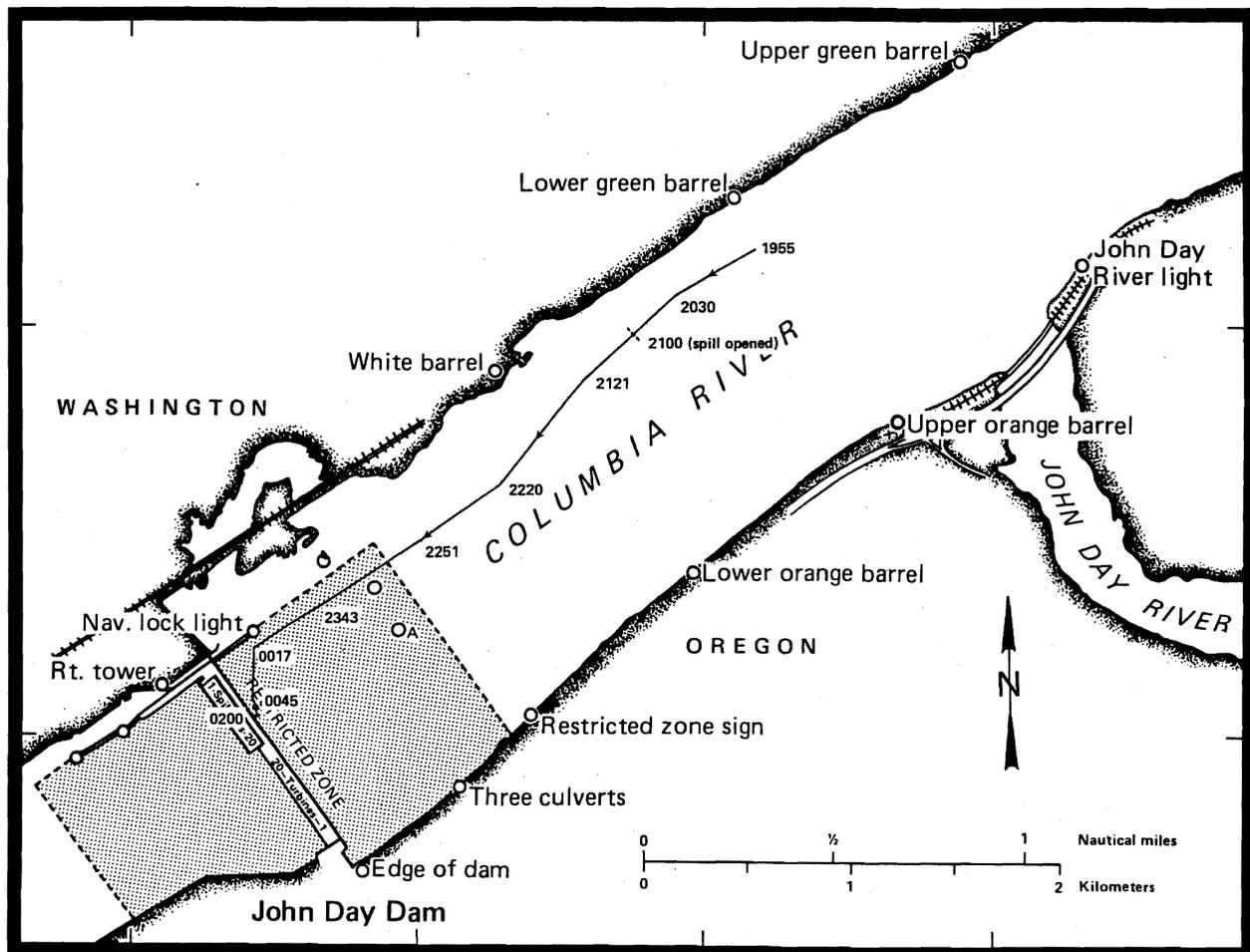


Fish number 16
 Steelhead trout 220 mm
 17 May 1981

Fish number 16 moved steadily along the Washington shore and entered the restricted zone near the nav. lock pier. From there the fish moved across the spill area to Spill Bay 13. It spent 1-1/2 hours moving back and forth directly in front of 13, 14, and 15, three times. It then moved in front of Spill Bay 16 (the first surface spill) and passed after 15 minutes. The scheduled spill was to end at 0000 h but was extended to 0300 h because of high fish activity in the area. Effective tracking range was 60-80 m.

Flow Kcfs

Time	1700	1800	1900	2000	2100	2200	2300	2400	0100	0200
Total	193.4	149.5	172.2	167.6	167.6	171.4	159.6	165.8	159.2	161.2
Turbine	191.1	149.0	169.9	167.1	167.1	91.9	79.6	84.0	79.2	79.4
Spill						79.5	79.5	79.5	79.5	79.5
% spill						47	50	48	50	50

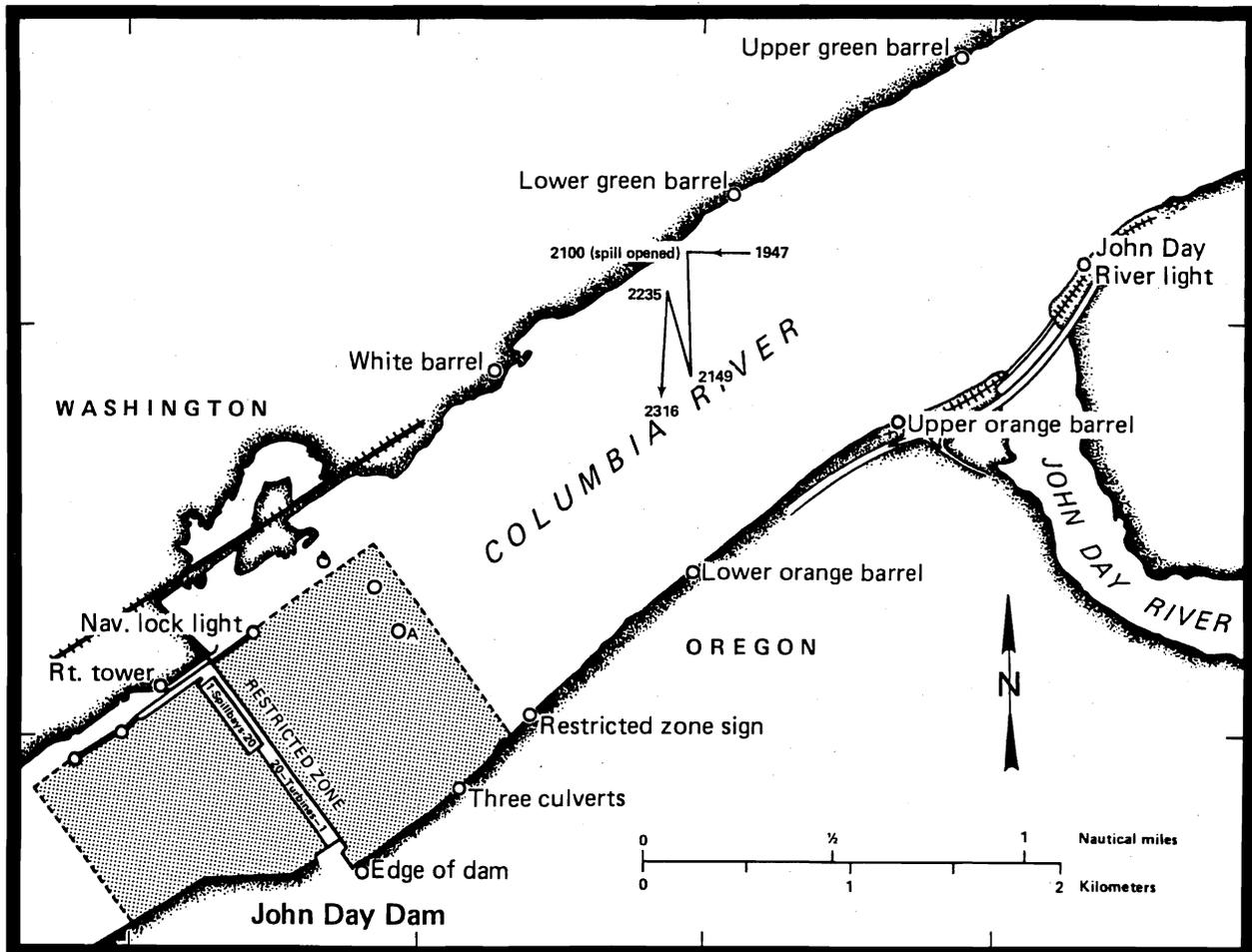


Fish number 17
 Steelhead trout 168 mm
 18 May 1981

Track number 17 was terminated due to lack of movement while still within 1/2 km of the release site. The amount of spill was the same as for fish number 16, although without SLD, only 35% of the river flow was spill as compared to 50% for fish 16. Effective tracking range was 100 m.

Flow Kcfs

Time	1700	1800	1900	2000	2100	2200	2300	2400		
Total	245.2	243.9	247.3	270.6	240.7	228.0	221.7	217.7		
Turbine	244.7	243.4	246.8	268.3	240.2	148.0	141.7	135.9		
Spill						79.5	79.5	79.5		
% spill						35	36	37		

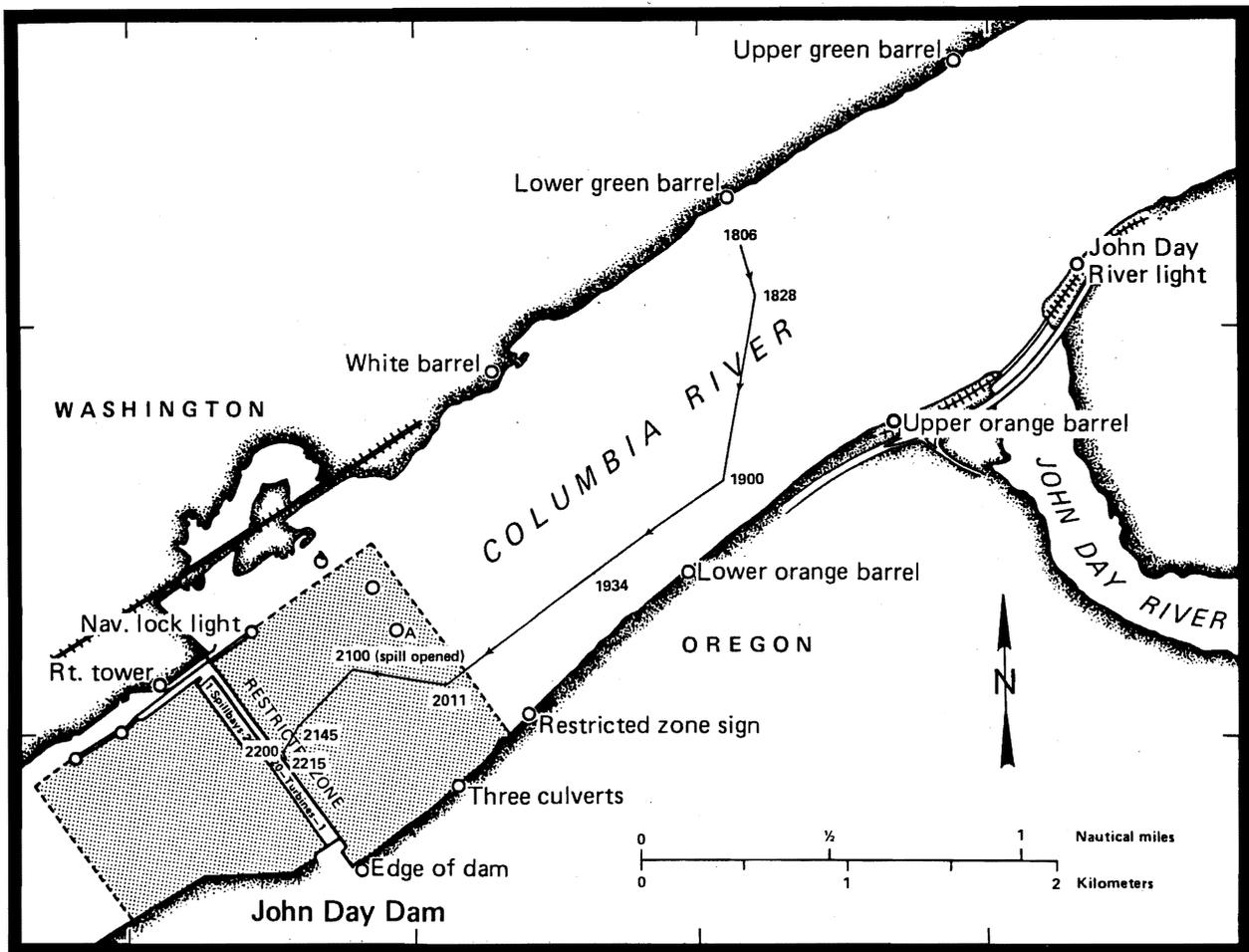


Fish Number 18
 Chinook salmon 171 mm
 19 May 1981

Fish number 18 moved from the release site to the Oregon shore, progressed steadily to the dam, and passed through Turbine Unit 16A with little hesitation. At the time the spill opened, the fish was almost directly out from Spill 20/Turbine 20, but as it moved closer to the dam it stayed on the powerhouse side of what appears to be an area of little or no current in front of the empty turbine bays (17-20). The spill at passage was 40 kcfs (17% of river flow) spread out over 8 spill bays and there was no SLD. Tracking range was 100 m.

Flow Kcfs

Time	1600	1700	1800	1900	2000	2100	2200	2300		
Total	225.1	244.8	253.6	256.3	256.9	234.6	229.9	227.0		
Turbine	224.6	244.3	252.1	255.8	256.4	232.3	189.6	187.2		
Spill							39.8	39.3		
% spill							17	17		

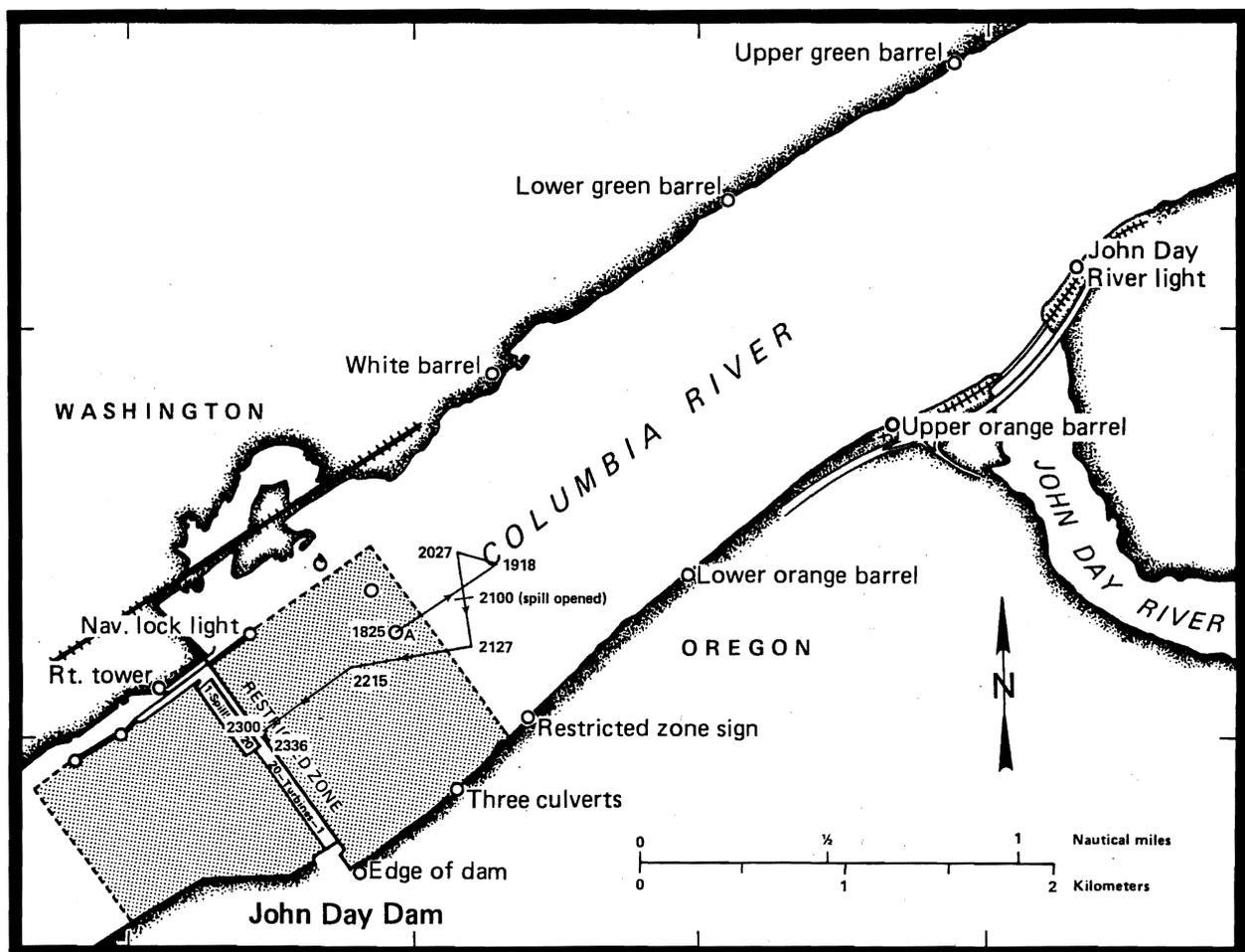


Fish Number 19
 Chinook salmon 162 mm
 20 May 1981

Fish number 19 headed upstream for about an hour before reversing and then moved steadily for the dam. It moved at varying depths in front of spill bays 18-20 for about 1/2 hour before passing through Spill 20. Spill made up 35% of the river flow and there was SLD. Tracking range was 125 m.

Flow Kcfs

Time	1600	1700	1800	1900	2000	2100	2200	2300	2400
Total	183.3	216.2	232.6	217.6	220.1	174.1	123.5	126.5	112.4
Turbine	182.8	213.9	232.1	215.3	219.6	173.6	84.5	81.5	69.2
Spill							36.7	42.7	42.7
% spill							30	34	38

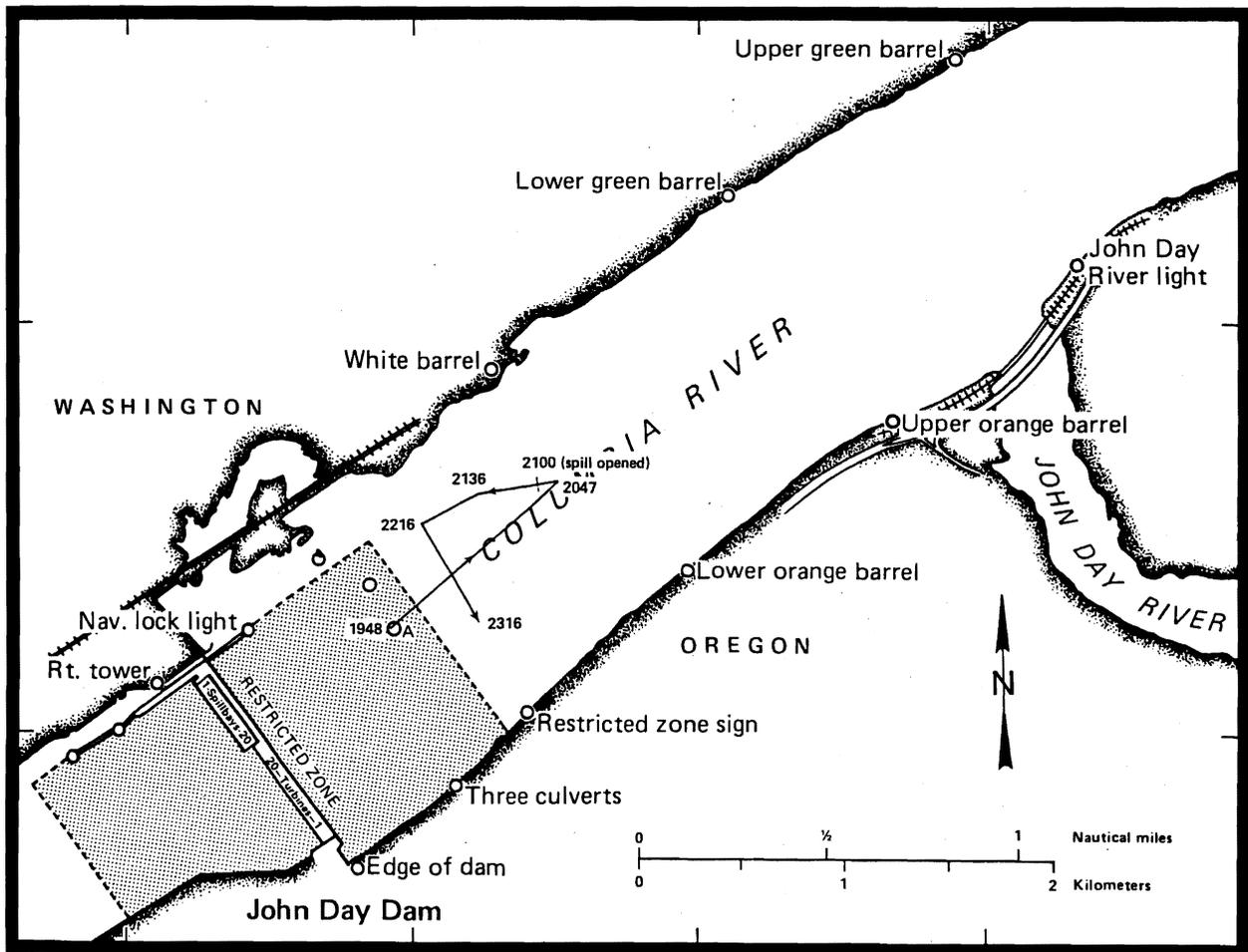


Fish number 20
 Steelhead trout 165 mm
 21 May 1981

Fish number 20 moved upstream upon release as number 19 had. However number 20 did not make significant headway towards the dam during the scheduled spill period, even though there was almost twice the river flow as the night before (213 vs 126 kcfs). Tracking range was 125-150 m.

Flow Kcfs

Time	1700	1800	1900	2000	2100	2200	2300	2400		
Total	279.5	275.7	273.0	232.8	226.3	215.0	212.9	212.6		
Turbine	277.2	273.4	270.4	232.3	225.8	173.8	169.7	169.3		
Spill						40.7	42.7	42.4		
% spill						19	20	20		

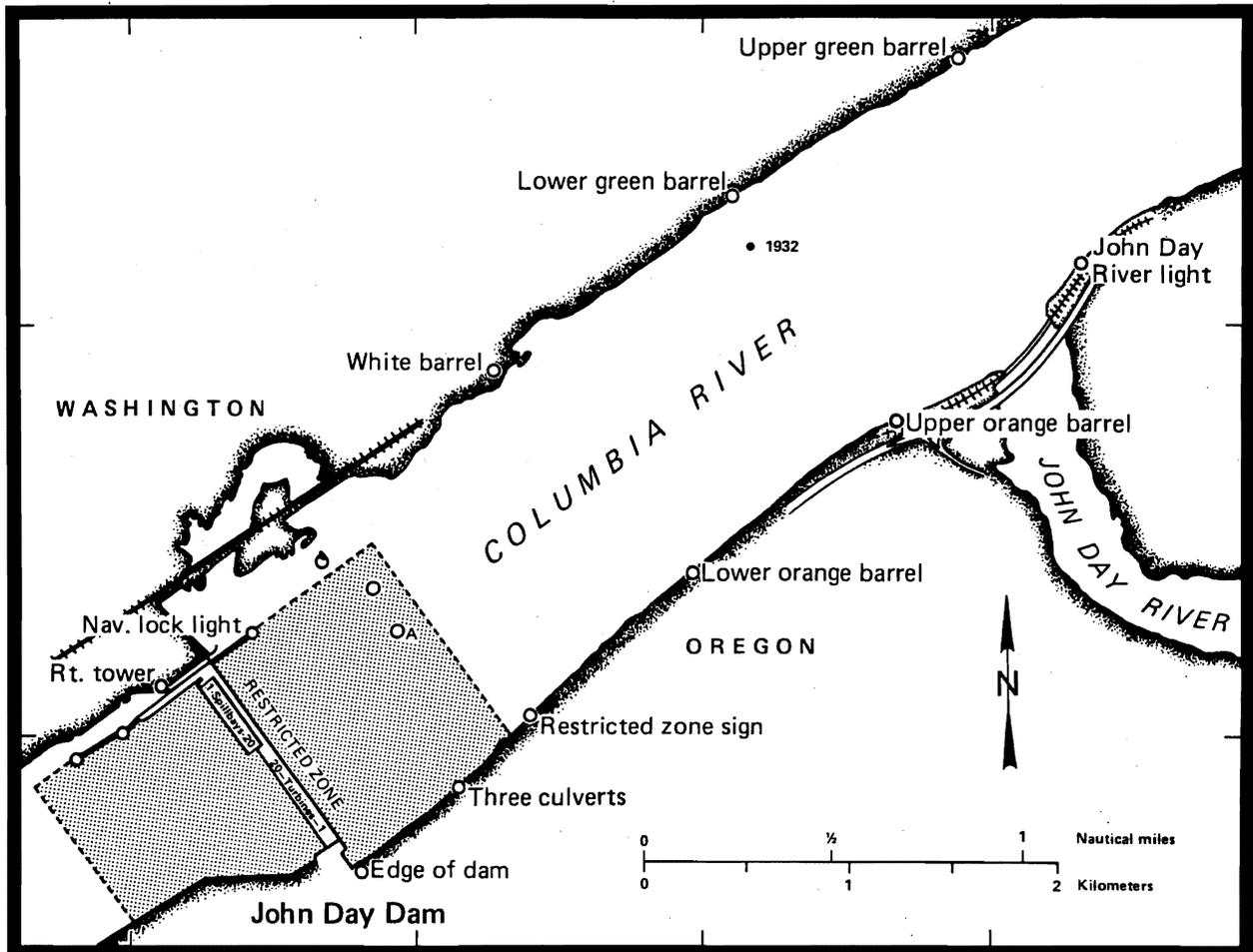


Fish Number 21
 Steelhead trout 167 mm
 22 May 1981

Fish number 21 was lost immediately upon release.

Flow Kcfs

Time	1900								
Total	258.8								
Turbine	258.8								
Spill									
% spill									

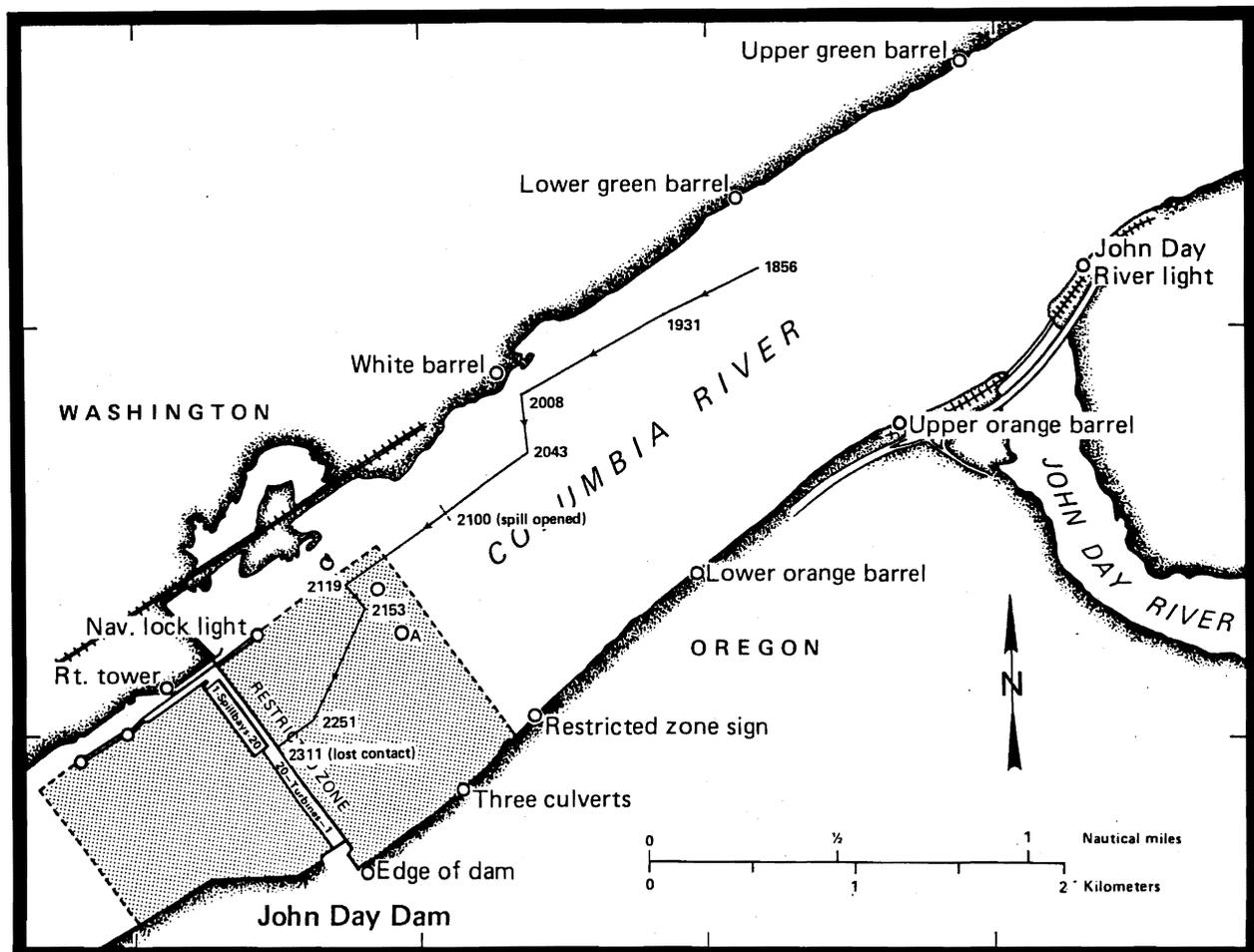


Fish number 22
 Chinook salmon 169 mm
 23 May 1981

Upon release, fish number 22 stayed on the Washington side into the restricted zone, making steady progress all the way. Halfway through the restricted zone, the signal became poor (depth, predation?) and remained so the rest of the track. This fish was the first one to venture into the area in front of the empty turbine bays. It did not cross the area to active turbines, but disappeared in front of empty Turbine Bay 20. After discussion, considering the sonar activity in the area, it was determined the fish most likely passed through Spill Bay 20. At the time of signal loss, 50% of the river flow was over the spillway. Tracking range was 175 m.

Flow Kcfs

Time	1600	1700	1800	1900	2000	2100	2200	2300	2400
Total	274.0	275.5	271.5	273.6	273.2	268.4	129.0	159.3	153.2
Turbine	271.1	273.2	271.0	271.3	272.7	267.9	88.3	77.6	83.0
Spill							40.5	81.2	67.9
% spill							32	51	44

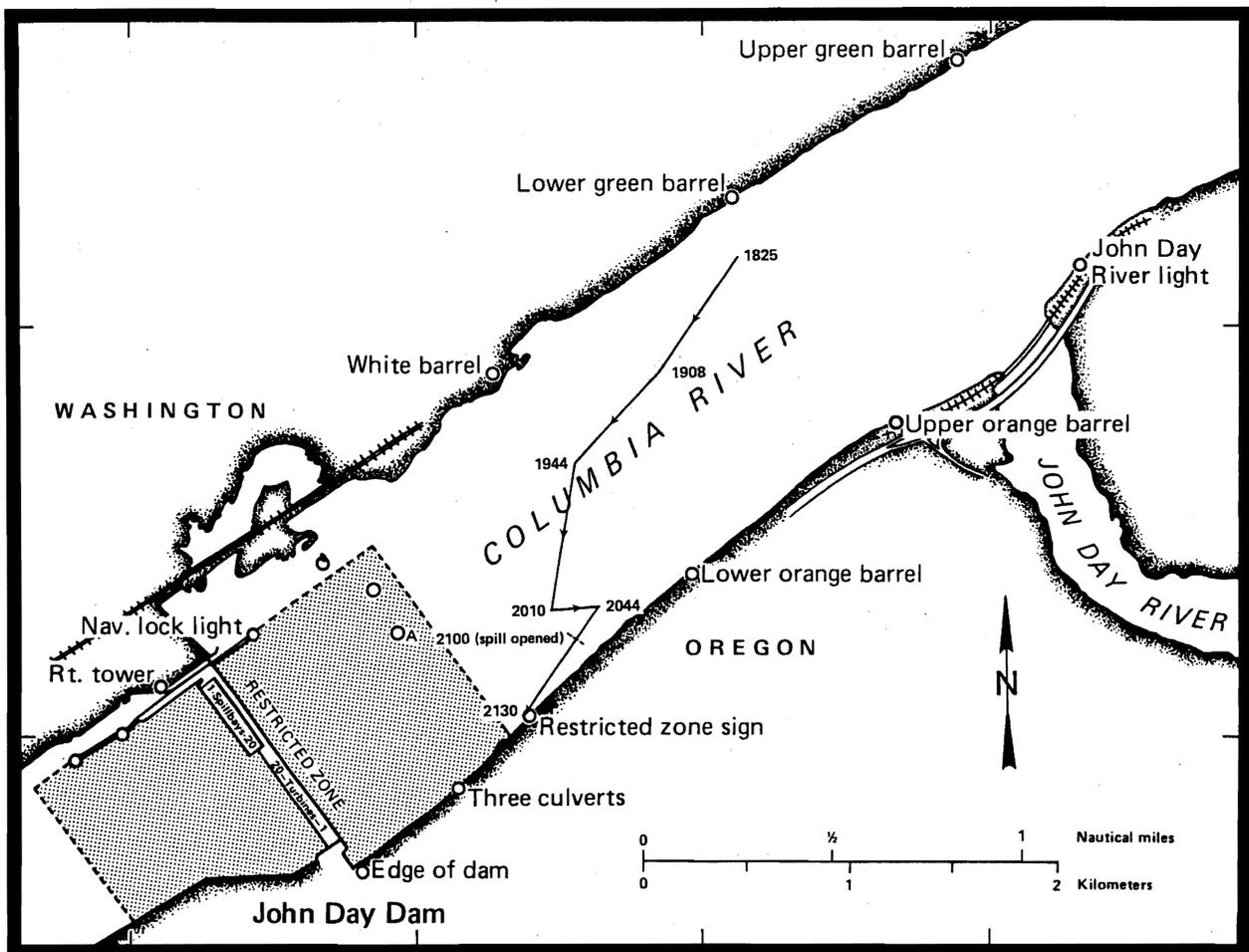


Fish number 23
 Chinook salmon 154 mm
 24 May 1981

Fish number 23 moved diagonally across the river to the Oregon shore with steady progress. The track was terminated due to a lack of movement and signal deterioration (predation?). The signal got weaker as well as slower, but stayed on the same location (approximately 20' of water). Until that time, tracking range was 100-130 m.

Flow Kcfs

Time	1600	1700	1800	1900	2000	2100	2200			
Total	276.8	275.3	274.1	273.9	254.0	249.1	289.7			
Turbine	276.8	275.3	274.1	273.9	254.0	249.1	249.2			
Spill							40.5			
% spill							14			

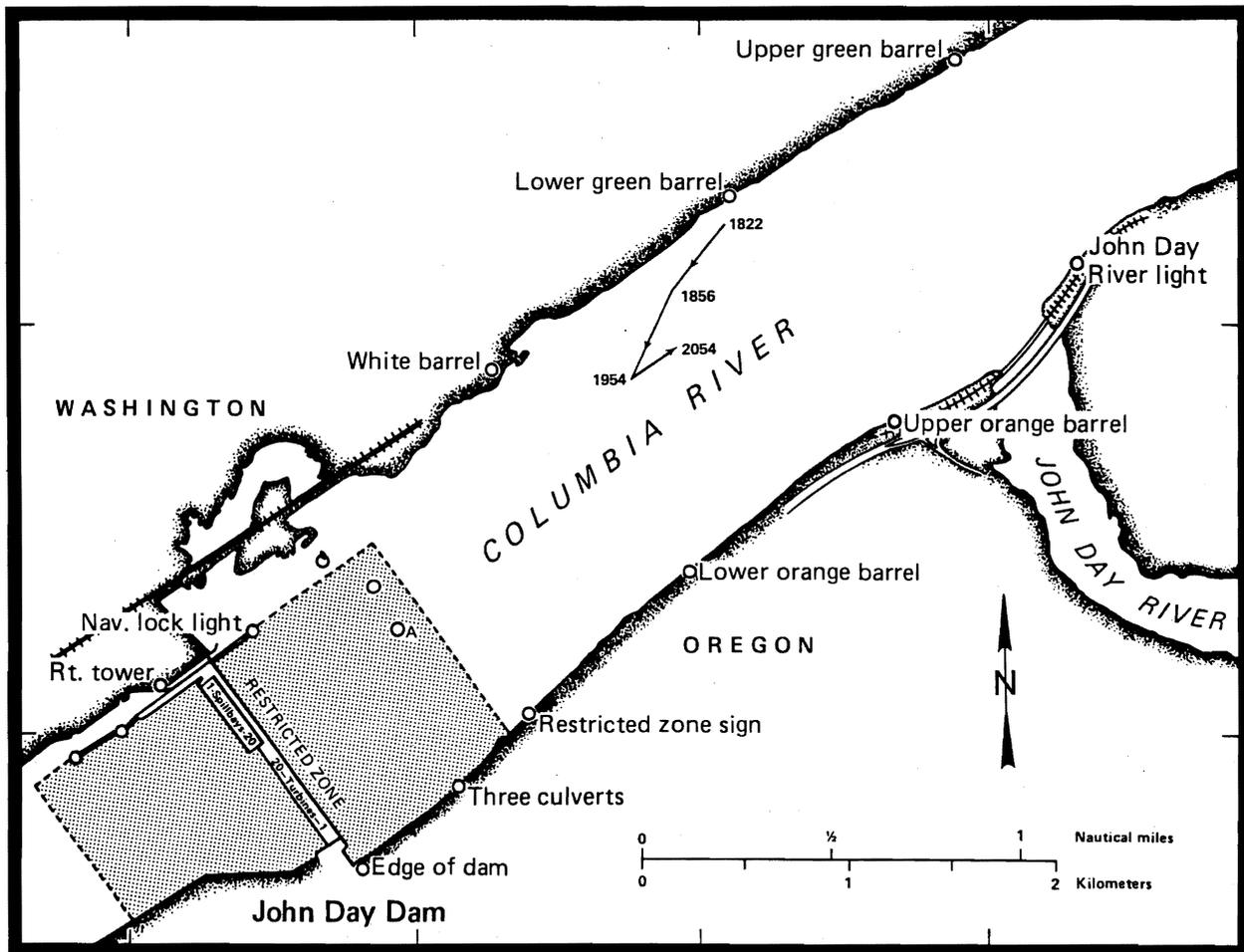


Fish number 24
 Steelhead trout 188 mm
 25 May 1981

Fish number 24 was tracked in bad weather with a poor signal and eventually lost.

Flow Kcfs

Time	1600	1700	1800	1900	2000	2100			
Total	178.2	191.0	231.6	223.5	230.1	232.3			
Turbine	178.2	191.0	231.6	223.5	230.1	190.5			
Spill						41.8			
% spill						18			

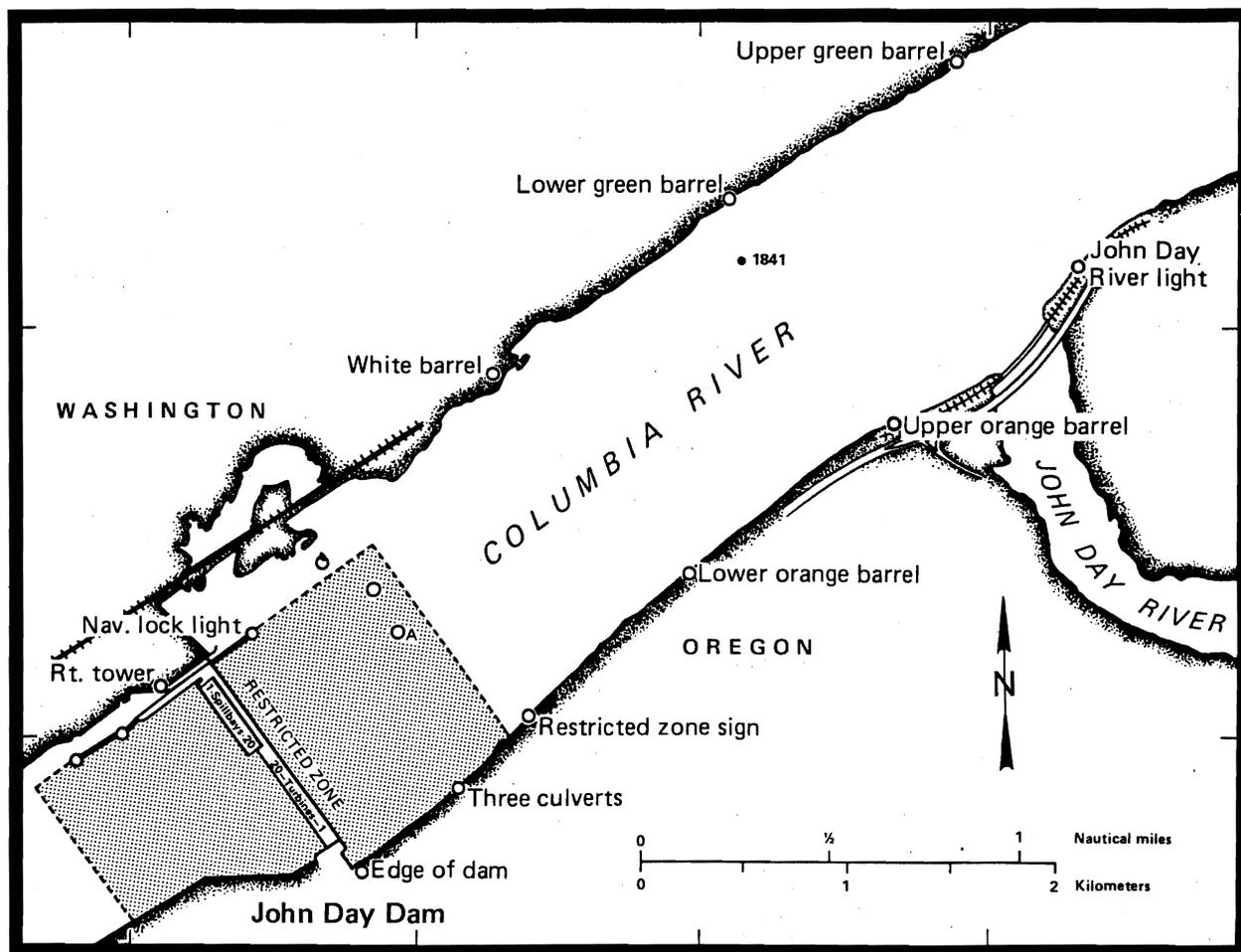


Fish Number 25
 Steelhead trout 161 mm
 29 May 1981

Fish number 25 was lost immediately upon release.

Flow Kcfs

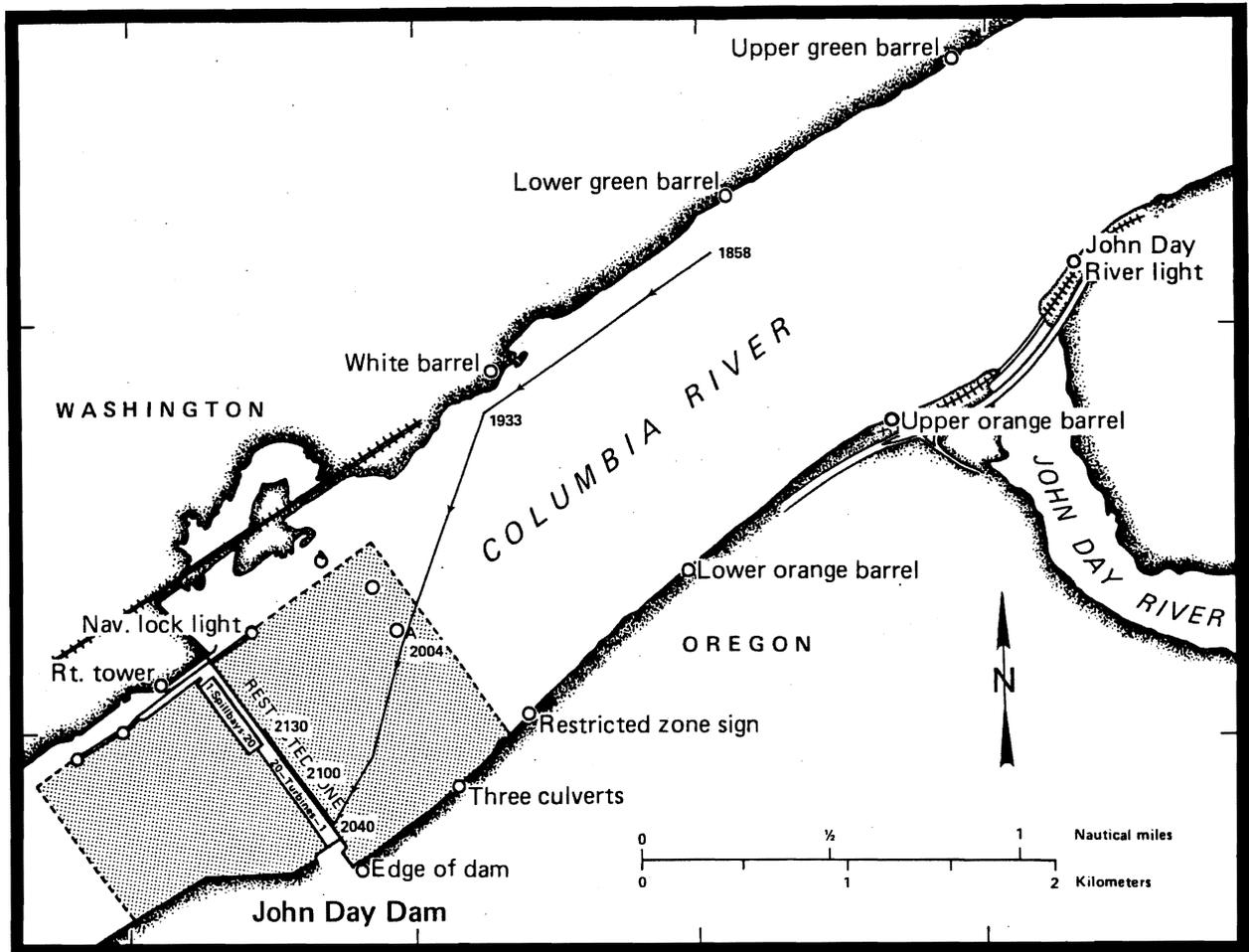
Time	1800									
Total	329.4									
Turbine	248.2									
Spill	80.7									
% spill	25									



Fish Number 26
 Chinook salmon 176 mm
 31 May 1981

River flow was very high during the track of fish number 26. The fish moved very fast until it got to the face of the dam at Turbine Unit 3. While constantly moving up and down in depth, this fish moved all the way across the active turbines, the empty turbine bay area, and the deep spills, until it passed through Spill Bay 17, the middle of the surface spills (16, 17, 18). While the fish was at the face of the dam, river flow averaged about 400 kcfs of which 25% was spill.

Time	1800	1900	2000	2100	2200				
Total	329.4	389.3	393.0	392.5	405.5				
Turbine	307.8	311.5	312.8	312.1	317.4				
Spill	79.2	79.2	79.2	92.9	132.7				
% spill	20	20	20	23	29				

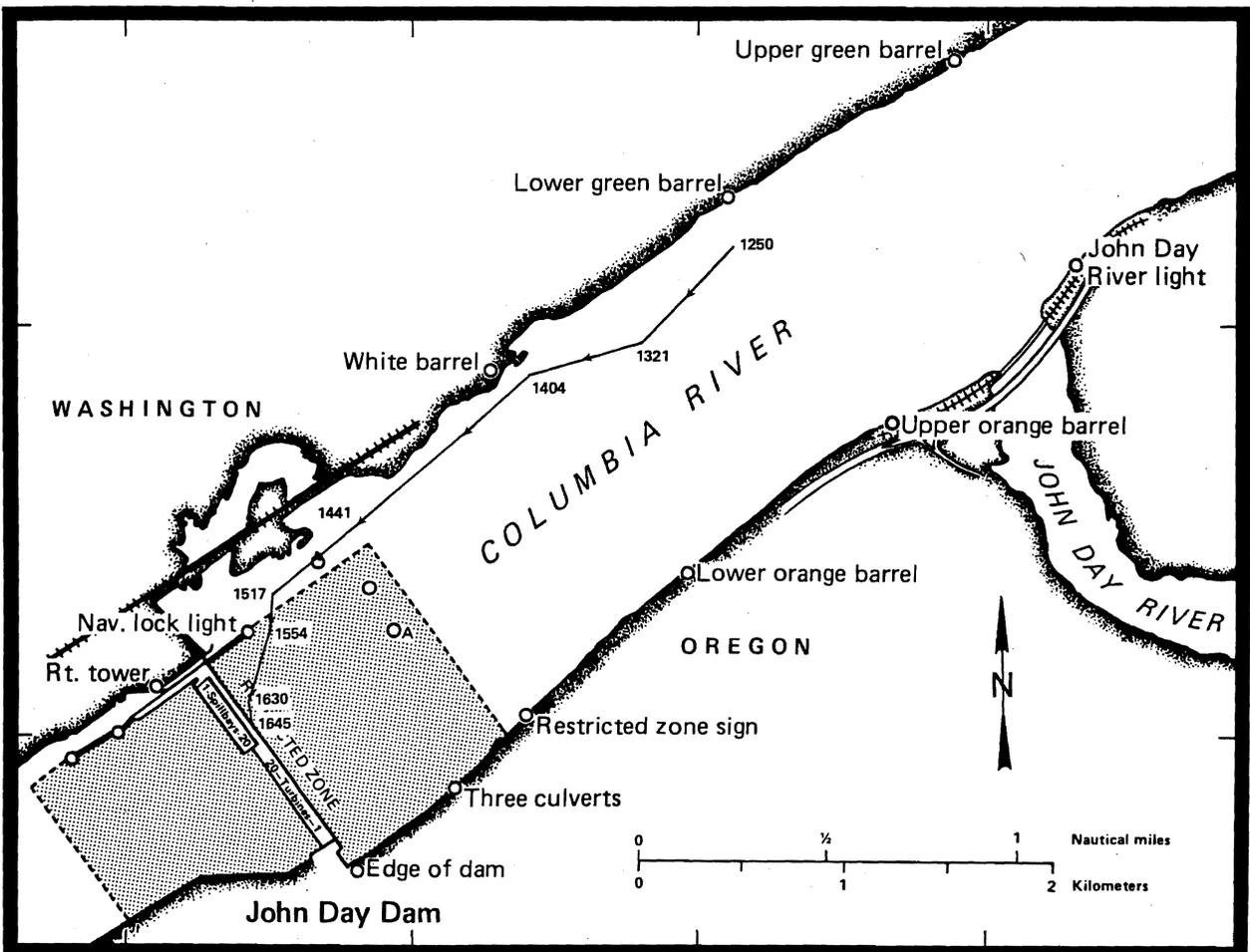


Fish number 27
 Chinook salmon 154 mm
 1 June 1981

Because the river flows were so high and fish were moving so well, track number 27 was started at 1250 h. The fish moved quickly downstream staying close to the Washington shore, entering the restricted zone near the nav. lock. It moved diagonally to the face of the spillway and then over to the surface spill where it went through Spill Bay 16, the first surface spill it came to. Twenty-one percent of the total 391 kcfs river flow was spill at the time of passage. Effective tracking range was 90 m.

Flow Kcfs

Time	1200	1300	1400	1500	1600					
Total	380.2	398.5	387.7	391.8	390.7					
Turbine	299.0	307.3	306.5	308.8	309.5					
Spill	80.7	80.7	80.7	80.7	80.7					
% spill	21	20	21	21	21					

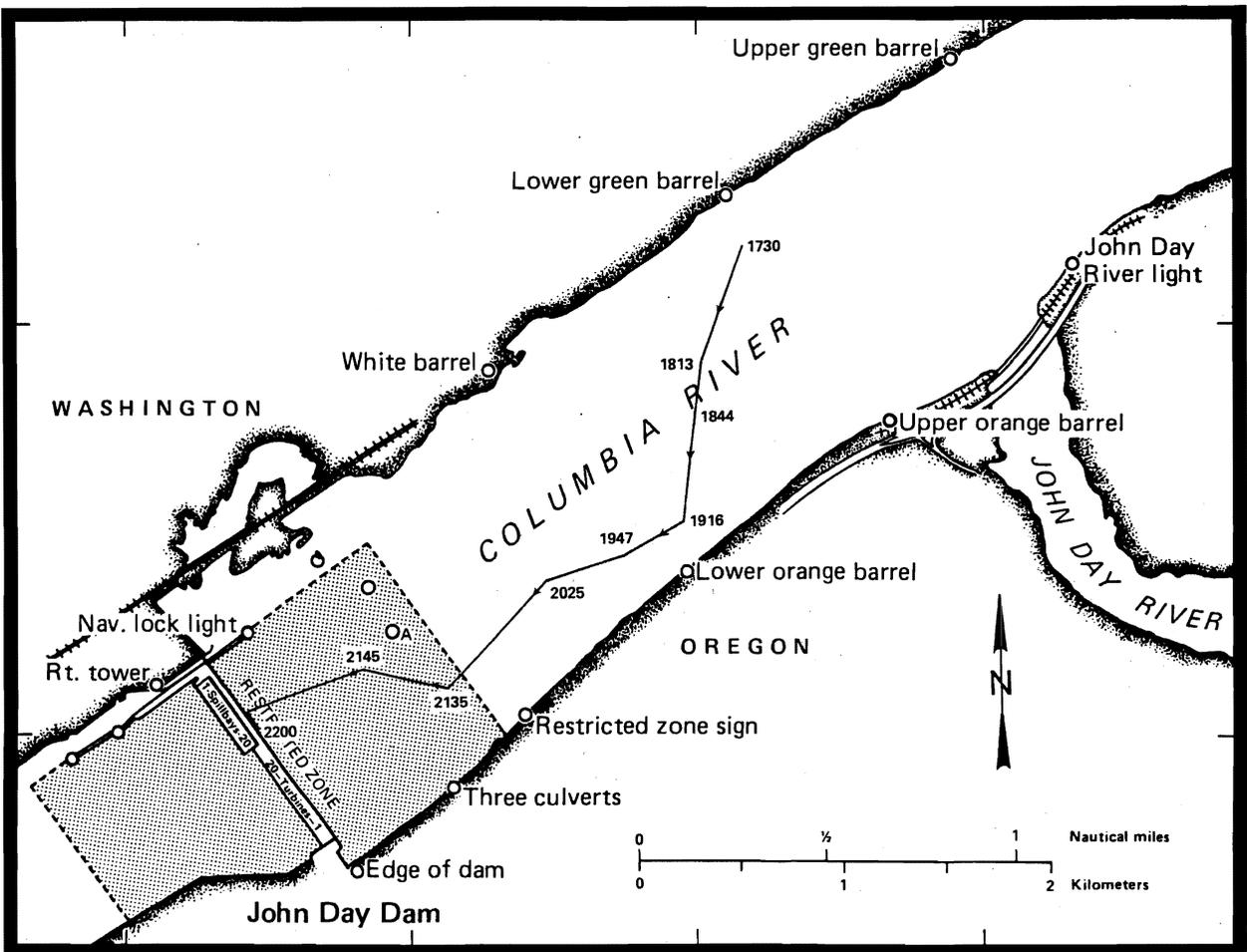


Fish Number 28
 Chinook salmon 155 mm
 1 June 1981

Fish number 28 was the second fish of the day. This fish passed through surface spill 16. At the time of passage, river flow was 461 kcfs and 43% was spill. The fish arrived at the spillway at Bay 11, moved very quickly to 16, and did not delay before going through 16.

Flow Kcfs

Time	1700	1800	1900	2000	2100	2200				
Total	390.0	430.4	443.1	442.3	476.6	461.4				
Turbine	308.8	313.6	314.4	310.5	281.8	261.4				
Spill	80.7	116.3	128.2	131.3	194.3	199.5				
% spill	21	27	29	30	41	43				

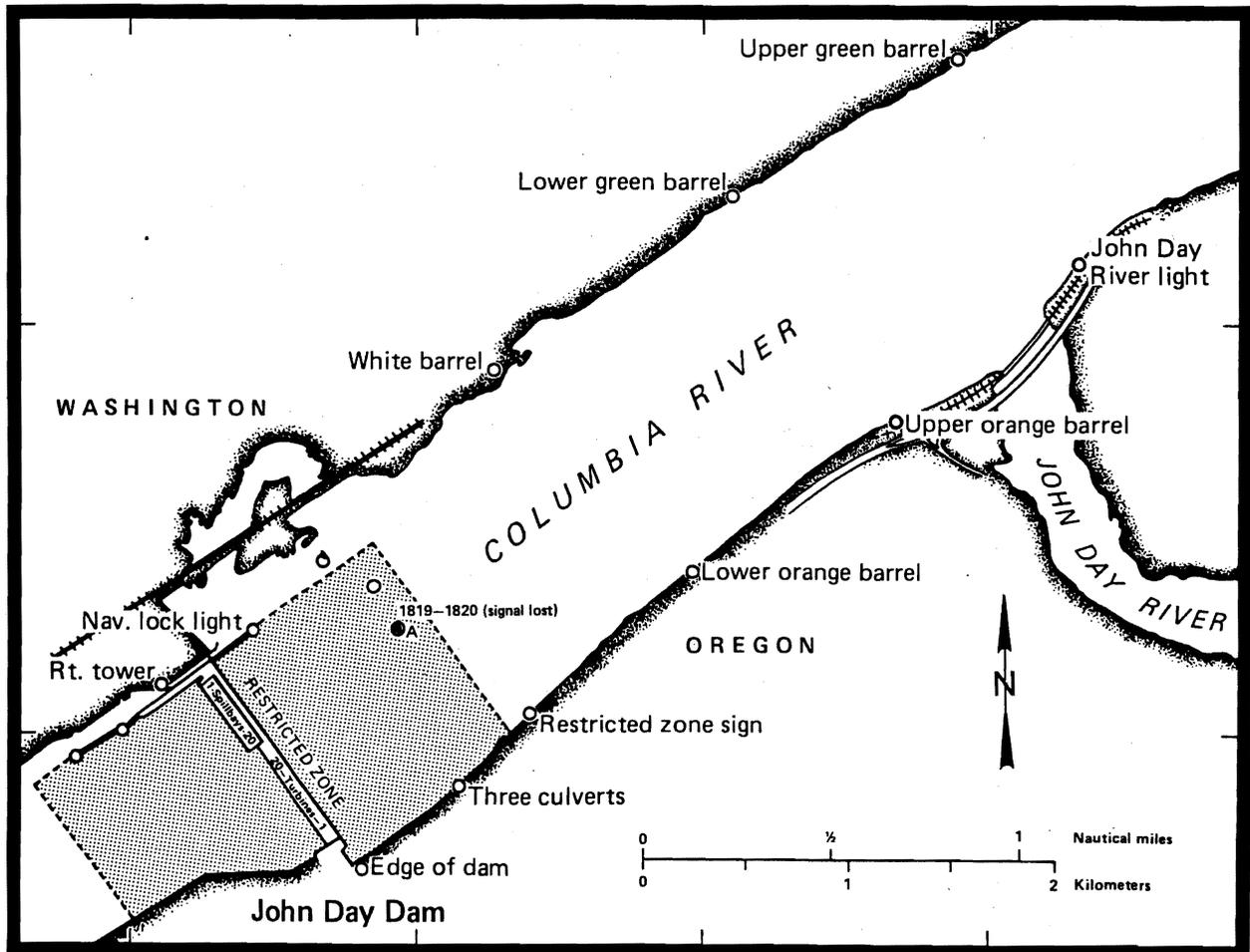


Fish Number 29
 Steelhead trout 173 mm
 2 June 1981

Fish number 29 was released at Buoy A and was lost within a minute.

Flow Kcfs

Time	1800								
Total	390.7								
Turbine	309.5								
Spill	80.7								
% spill	21								

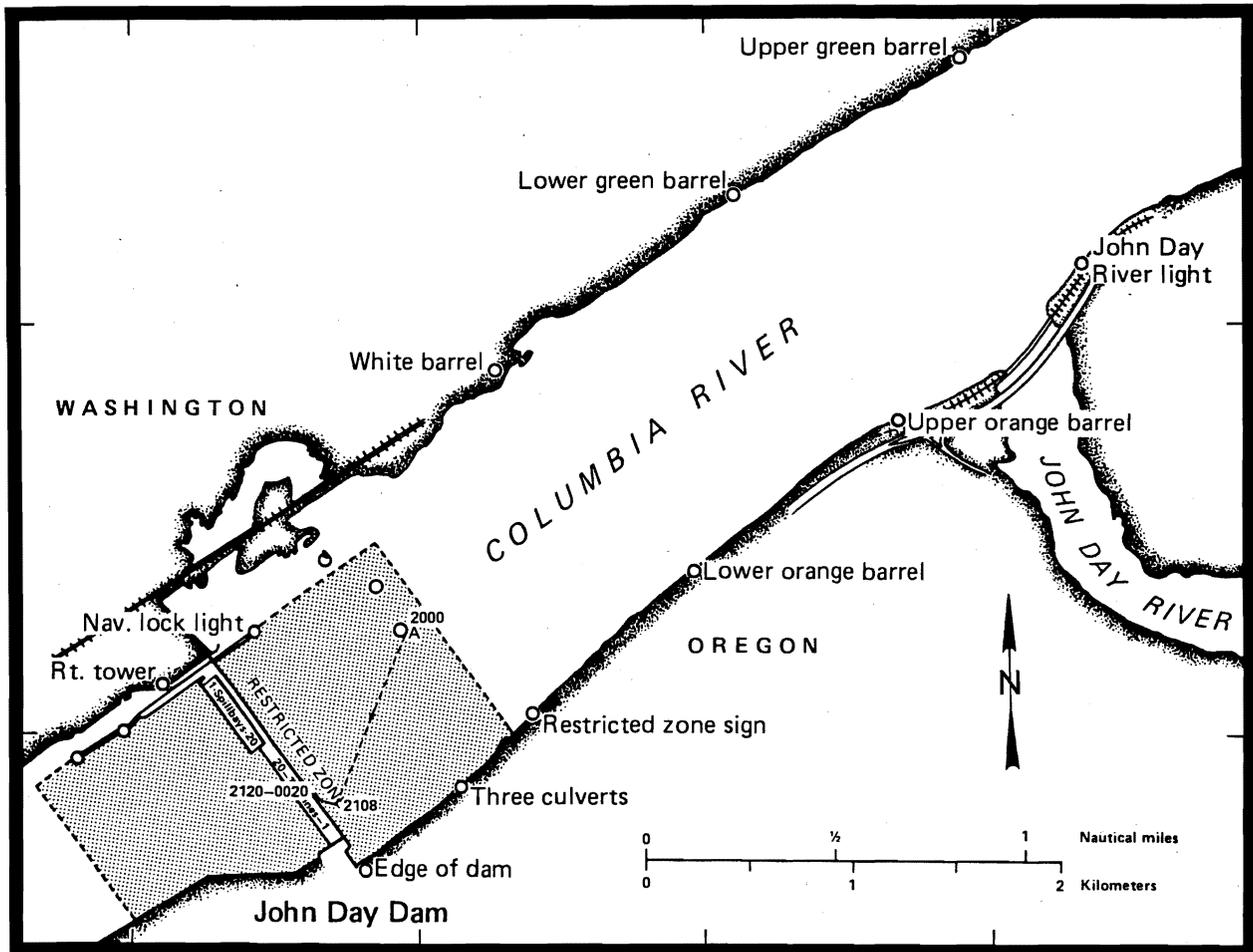


Fish Number 30
 Steelhead trout 186 mm]
 2 June 1981

Track number 30 was lost within a couple of minutes of release, but was found in front of Turbine 5 an hour later. The fish slowly made its way to Units 7 and 8. At 2150 hours, the signal slowed and became distinctly weaker (predation?). The rest of the evening (2-1/2 hours) the fish meandered in front of Turbine Units 7A and 8C, and the track was finally terminated at 0020 hours without having completely lost the signal.

Flow Kcfs

Time	2000	2100	2200	2300	2400	0100				
Total	388.5	359.8	406.0	380.8	386.8	405.1				
Turbine	307.3	269.5	247.2	222.0	186.8	205.8				
Spill	80.7	89.8	158.3	158.3	199.5	198.5				
% spill	21	25	39	41	52	49				

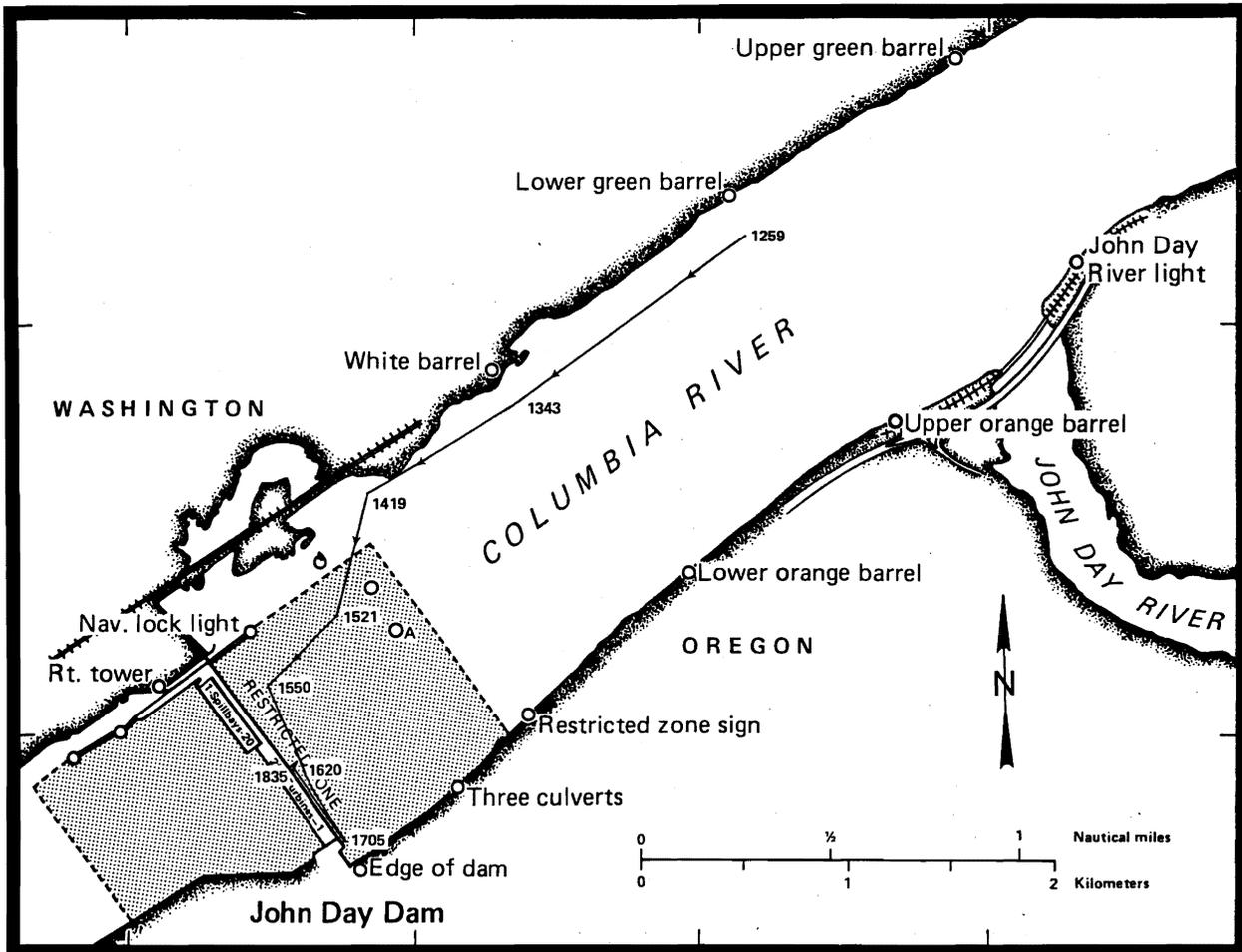


Fish Number 31
 Chinook salmon 160 mm
 4 June 1981

This fish moved across the spill, rejecting all spill bays (surface and deep). It then moved across the empty turbine bays and all the way to Turbine Unit 1, reversed course, and again rejected all the turbines as it moved to the empty Turbine Unit 17. There, instead of continuing past the empty turbine bays, it turned around again, went back to Unit 16, and made its passage at Turbine Unit 16A.

Flow Kcfs

Time	1200	1300	1400	1500	1600	1700	1800	1900		
Total	399.3	397.5	390.2	386.7	395.8	400.2	399.1	397.4		
Turbine	318.1	316.3	309.0	304.9	314.6	317.2	316.1	316.2		
Spill	80.7	80.7	80.7	81.3	80.7	80.7	80.7	80.7		
% spill	20	20	21	21	20	20	20	20		

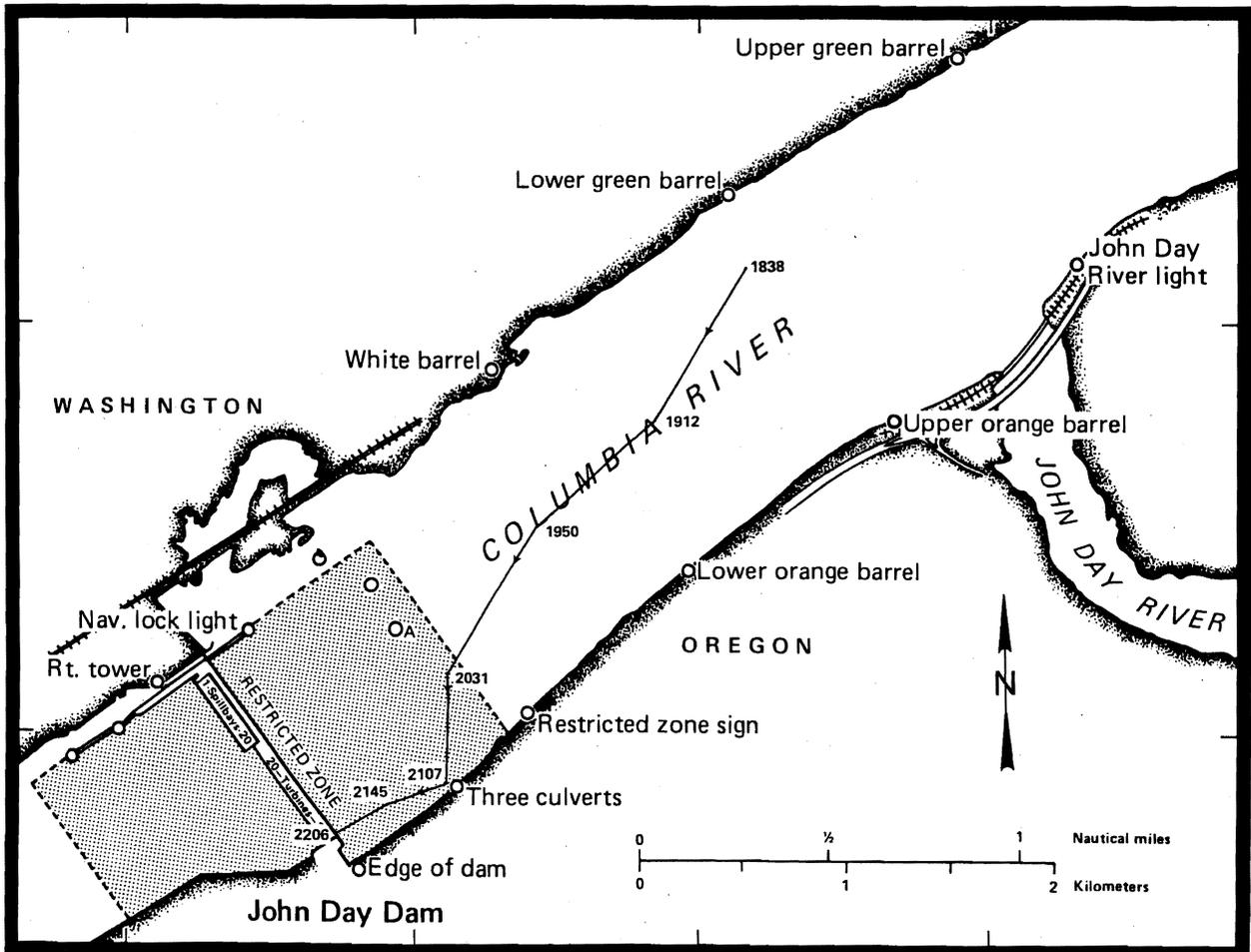


Fish Number 32
 Chinook salmon 152 mm
 5 June 1981

Fish number 32 passed through Turbine Unit 1A. Tracking range was 50 m.

Flow Kcfs

Time	1800	1900	2000	2100	2200	2300				
Total	404.4	403.2	401.8	419.7	421.5	438.3				
Turbine	323.2	322.0	318.5	264.0	260.9	236.7				
Spill	80.7	80.7	82.8	155.2	160.1	201.1				
% spill	20	20	21	37	38	46				

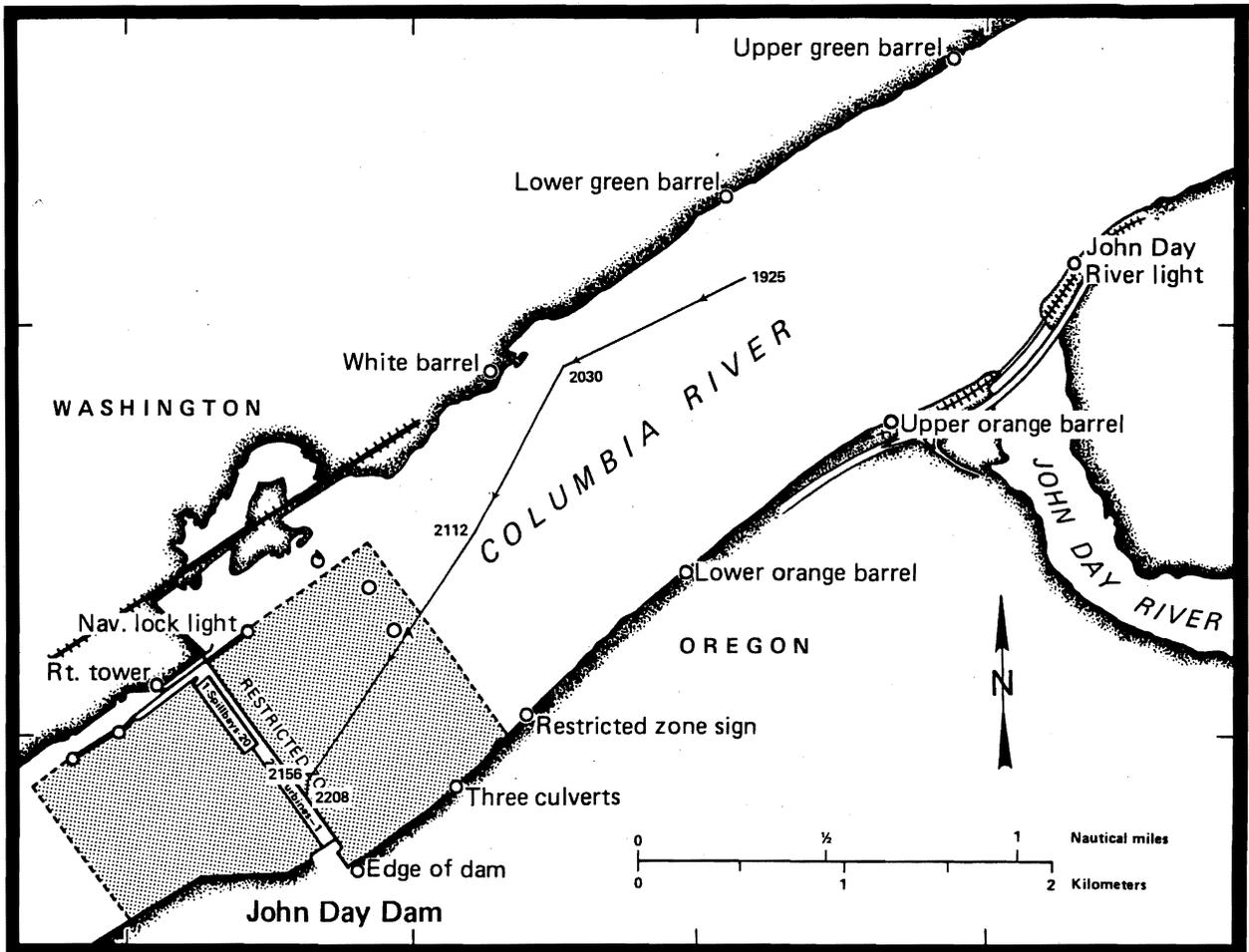


Fish number 33
 Chinook salmon 152 mm
 6 June 1981

Fish number 33 moved quickly downriver and even though one-third of the river was spill as it approached, the fish crossed to the powerhouse and went through Turbine Unit 9B.

Flow Kcfs

Time	1900	2000	2100	2200	2300					
Total	408.3	405.4	412.5	416.9	393.5					
Turbine	325.3	323.3	279.4	276.8	217.2					
Spill	80.7	81.6	130.6	134.6	175.8					
% spill	20	20	32	32	45					

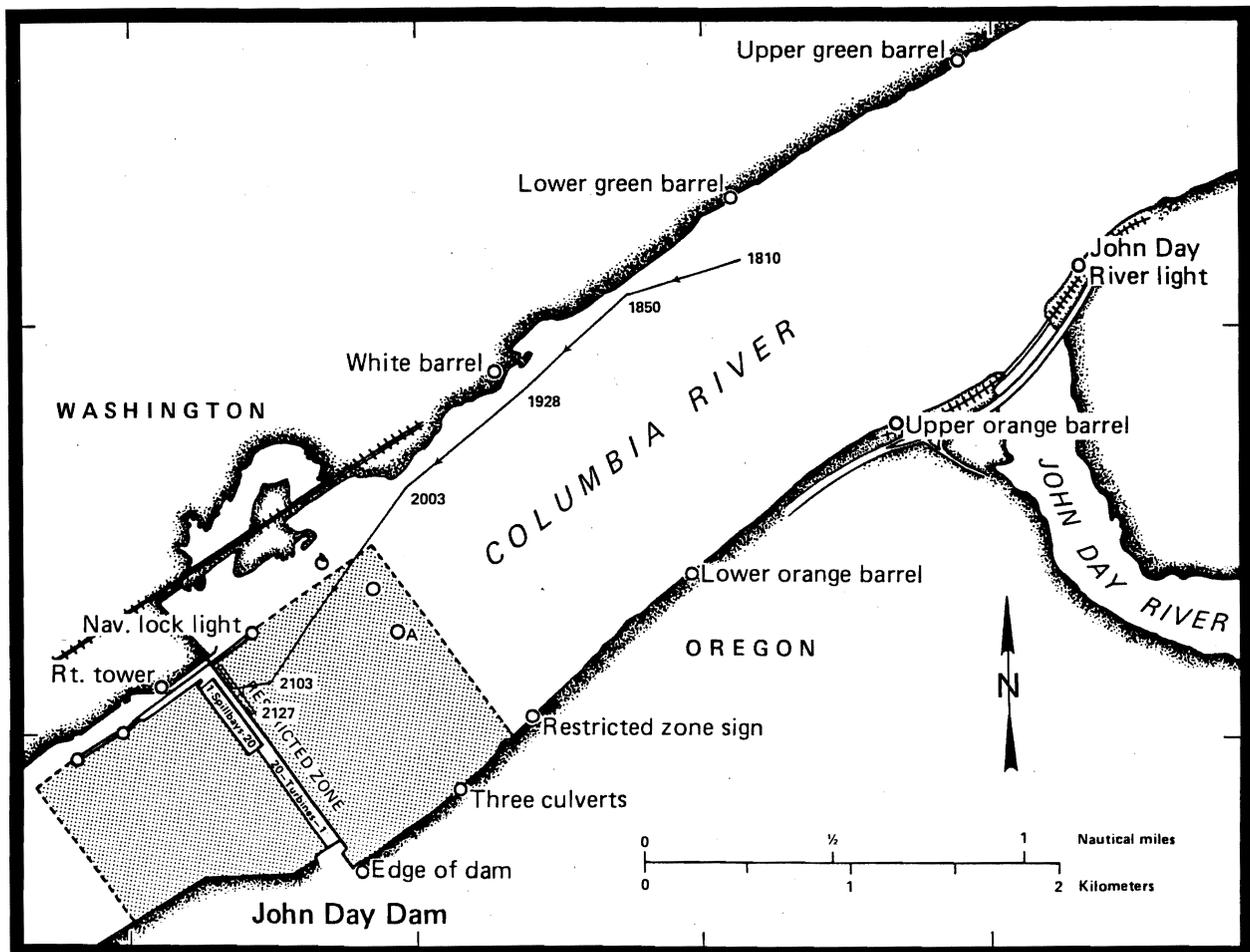


Fish number 34
 Chinook salmon 170 mm
 7 June 1981

Fish number 34 followed the path of 27 and 31, and arrived at the dam in the vicinity of Spill Bay 8. It moved all the way to the fish ladder exit on the Washington side, turned around, went back to Unit 10. The fish held there for approximately 0.5 h until the spill was increased from 130 to 200 kcfs. Within 5 min the fish passed through Spill Bay 10.

Flow Kcfs

Time	1800	1900	2000	2100	2200	2300			
Total	402.2	403.5	401.7	402.0	399.9	398.6			
Turbine	322.5	322.0	322.0	322.3	319.7	235.1			
Spill	79.2	79.2	79.2	79.2	79.7	163.0			
% spill	20	20	20	20	20	41			



Fish number 35
 Steelhead trout 164 mm
 10 June 1981

Fish number 35 was lost within 5 min of release.

Flow Kcfs

Time	1300								
Total	419.2								
Turbine	219.2								
Spill	97.7								
% spill	23								

