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4.14A MIGRATORY BEHAVIOR OF RADIO-TAGGED JUVENILE COHO SALMON THROUGH SWIFT RESERVOIR, 2001 (AQU 14A)

In conjunction with several other aquatic studies, this report is key to assessing the feasibility of reintroducing anadromous salmonids (*Oncorhynchus* sp.) to portions of the North Fork Lewis River. An over-riding issue for the potential reintroduction of anadromous fish upstream of Swift No. 1 is whether juvenile salmonids will migrate through Swift Reservoir and arrive at the face of the dam in numbers adequate to warrant the design and construction of a smolt-collection device. A fundamental consideration involves describing the migratory behavior of juveniles through the reservoir. It is not clear whether the current velocities and patterns in the reservoir will effectively direct smolts through the reservoir to the dam. Smolts lost to predation or residualism in the reservoir may limit opportunities to collect the number of smolts necessary to yield a self-sustaining population. Descriptions of migratory patterns in the reservoir, migration rate through the reservoir, arrival distributions at the dam, and an index of the number of smolts successfully traversing the reservoir will provide fundamental information to make decisions regarding the merits of providing smolt-passage facilities at the dam. The purpose of this study is to provide that information for a hatchery population of coho salmon (*O. kisutch*).

4.14A.1 Study Objectives

The study will address 2 primary objectives:

- Assess minimum survival rates of radio-tagged coho smolts to Swift Dam, and determine if radio-tagged fish pass the project.
- Describe migratory behavior of the radio-tagged smolts within Swift Reservoir including travel time, migration rate, and arrival distribution. Describe general movement patterns in Swift Reservoir and near the intake structure of Swift Dam.

A secondary objective of the study is to evaluate the detection efficiencies of the aerial and underwater forebay telemetry systems at Swift Dam.

Minimum reservoir survival can be estimated by calculating the proportion of fish released at the head of the reservoir that survive to and are detected at the dam. It should be noted that these estimates represent the absolute minimum survival, because they include mortality associated with handling, actual reservoir mortality, tag life limits (approximately 26 days) that may be exceeded if fish are very slow migrants, and detection efficiencies of fixed telemetry sites and mobile surveys less than 100 percent.

4.14A.2 Study Area

Swift No. 1, the most upstream project on the North Fork Lewis River, is approximately 72.4 kilometers from the confluence with the Columbia River (Figure 4.14A-1). Construction of Swift No. 1 Project began in 1956 and was completed by 1958. It includes an earthfill embankment dam with a single intake and tunnel that extends down past a surge tank. Downstream of the tank, the tunnel branches into 3 penstocks that supply water to three 70 MW Francis generator units in a powerhouse at the base of the dam. The intake is 44.3 meters deep (centerline) at a normal full pool elevation of 304.8 meters msl. Swift No. 1 utilizes two 15.2 by 15.5 meter taintor gates for spillway overflow. Swift Reservoir, formed by the dam, is approximately 18.5 kilometers long and has a surface area of about 4,680 acres at full pool. Gross storage capacity of the reservoir is 755,500 acre-feet.

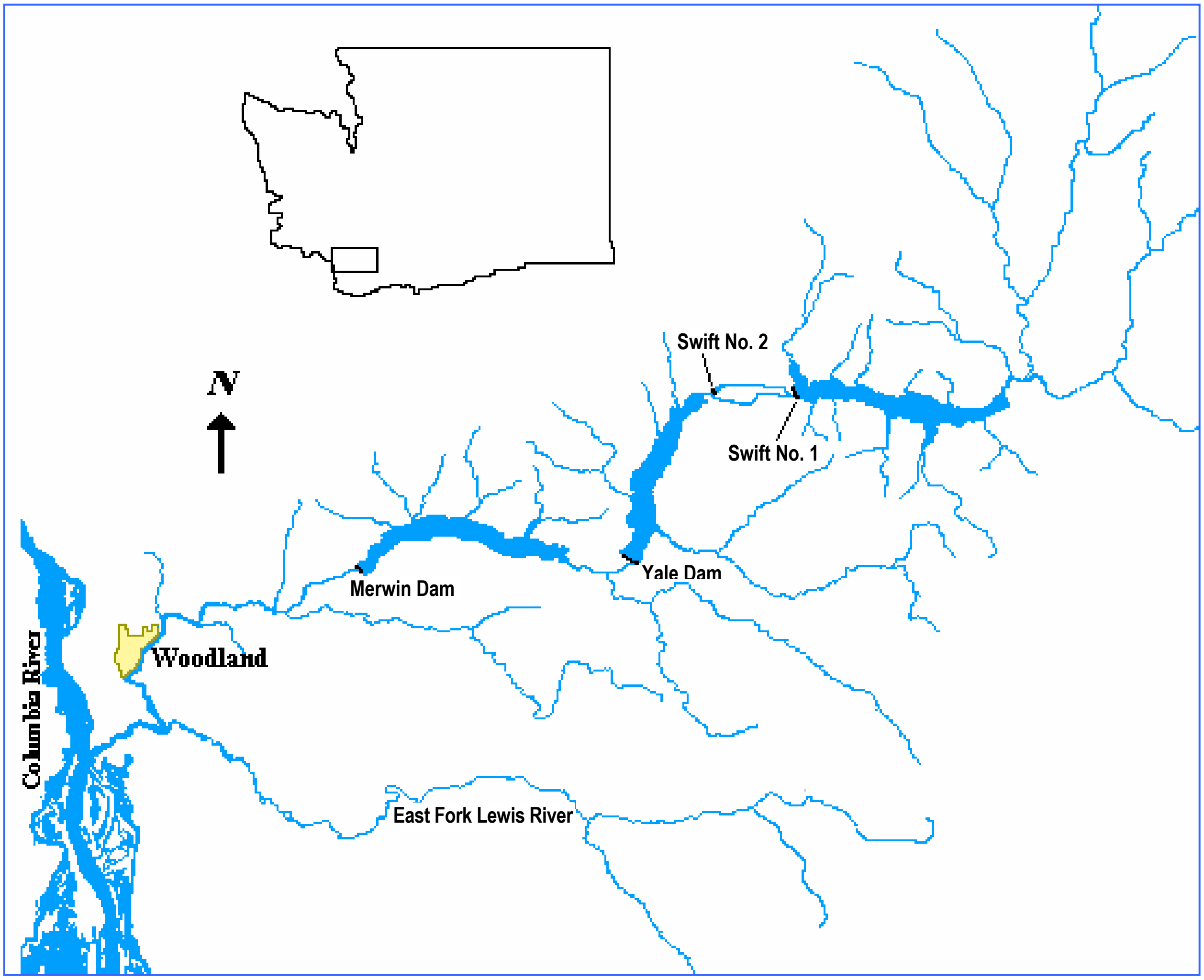


Figure 4.14A-1. Location of dams on the North Fork Lewis River in southwest Washington.

4.14A.3 Methods

4.14A.3.1 Radio Telemetry

Radio Transmitters

Pulse-coded radio transmitters developed by Lotek Engineering of Newmarket, Ontario, Canada were used for this study. The model MCFT-3GM transmitters are available on 25 unique frequencies (channels), with a total of 212 unique codes on each of the 25 frequencies within a given frequency range (i.e., 148 MHz). The transmitters were

8.2 mm in diameter and 18.9 mm in length, and weigh 1.75 grams in air and 1.40 grams in water. The transmitters were equipped with two 1.5-volt batteries that provided a total output of 3.0 volts. This configuration results in a typical operational life of 26.0 days at a 5.0 second transmission rate (1 pulse every 5.0 seconds). The transmitters were equipped with a 24-cm stainless steel external antenna, sheathed in a clear plastic material for protection.

Channel/Code Selection

Prior to the study, on March 23, 2001, noise evaluations of the Swift No. 1 project were conducted to assess ambient background noise at the primary study site. This was done in order to select channel/code combinations for use in the study that would not coincide with ambient background noise at the project which would complicate data analysis and reduce the detection efficiency. Assessments were conducted in the forebay and tailrace of the project and were designed to determine what, if any, channel/code combinations were particularly noisy.

Evaluations included monitoring 10 of the possible 25 frequencies[1] within the 148 MHz range (148.320-148.500, with 20 KHz increments), with either 3- or 4-element Yagi antennas in the areas of interest for approximately 4.0 hours. In addition, noise evaluations of the tailrace area were performed, particularly around the substation, with a hand-held antenna. None of the available channels or codes was excessively noisy. The 4 frequencies that logged the fewest ambient background events during the assessment were selected to minimize the potential for conflict. These were channel 1 (148.320 MHz), channel 3 (148.360 MHz), channel 6 (148.420 MHz), and channel 8 (148.460 MHz), with codes 1-15 used for each channel. A total of 60 unique channel/code combinations were used in this study.

Biotelemetry System

Radio-tagged fish were monitored using 2 radio telemetry techniques. First, fixed-telemetry sites were used at the forebay and tailrace of the dam to monitor movements near the project. Second, radio-tagged fish were monitored with mobile-telemetry surveys in Swift Reservoir and the Swift No. 2 canal.

Signal input at fixed telemetry sites was balanced at each antenna so that a tagged fish at a given depth and distance from any antenna within a specified or adjacent zone would provide similar signal strengths (power) relative to one another. Signal input was amplified as close to the receiving antenna as possible to offset signal loss through coaxial cable and other electronic connections. Because individual amplifiers can vary in performance, it is necessary to attenuate the signal strength at the receiver so that it equals the signal received at the amplifier. This is accomplished by transmitting a signal of known strength through the system and attenuating each antenna so that the signal received at the receiver is equal to the transmitted signal. This procedure was implemented for each fixed tele-

[1] Ten of the available 25 frequencies were evaluated since these were the only frequencies available from the manufacturer.

metry site. The following discussion provides details on each of the telemetry systems and mobile survey methods.

Forebay Aerial System

The forebay aerial system was located on the upstream side of the intake structure of the dam and consisted of two 3-element Yagi antennas (Figure 4.14A-2). The antennas were aimed horizontally to provide continuous coverage of the forebay from the south shore to the earthen dam. The antennas were also aimed vertically to provide maximum coverage from the face of the intake structure out to a distance of approximately 300 meters. The antennas were combined together and monitored by a single Lotek SRX receiver, which logs and stores the radio transmissions. The 4 frequencies or channels (1, 3, 6 and 8) were monitored for a period of 6.0 seconds for each receiver cycle, which resulted in a receiver cycle time of 24.0 seconds. Therefore, each channel was monitored for 6.0 seconds out of every 24.0-second cycle. The receiver was powered by a 12-volt deep cycle battery that was connected to a 10-amp battery charger. The battery charger was in turn powered by a 110-volt AC power supply.

Detection by this system was a function of depth and distance of the radio-tagged fish from the receiving antennas. That is, the signal strength of a fish close to the antenna at depth could be the same as a fish 300 meters from the antenna, but near the surface. Therefore, the depth and distance of a tagged fish from the receiving antenna could not be ascertained. Instead, only presence or absence could be determined.

Forebay Underwater System

The forebay underwater system was deployed to detect fish that approached the intake structure at a depth too great to be detected by the aerial system (depth > 8 meters). Because of the depth of the actual intake (the centerline of the intake at full pool was 44.3 meters), it was not possible to deploy underwater antennas at this location. Instead, bared-coax antennas were deployed at 3 separate transects (designated as North, Middle and South), with a shallow and deep antenna within each transect at depths of approximately 9.1 and 18.5 meters, respectively (Figure 4.14A-3). Collectively, these antennas provided detection capabilities beyond what could be obtained by the forebay aerial system. The system as a whole was designed to provide detection across the full width of the trashrack structure from where the aerial system coverage ended to a depth approximately 10 meters below the top of the trashracks.

Six underwater antennas were deployed for this system and were designated as North Top, North Bottom, Middle Top, Middle Bottom, South Top, and South Bottom. The underwater system was monitored with an SRX receiver and a DSP (Digital Spectrum Processor) unit and was powered by the same battery/charger system used to power the forebay aerial system. The DSP unit allowed all channels and antennas to be monitored simultaneously, which eliminates receiver cycling and the likelihood of missing radio

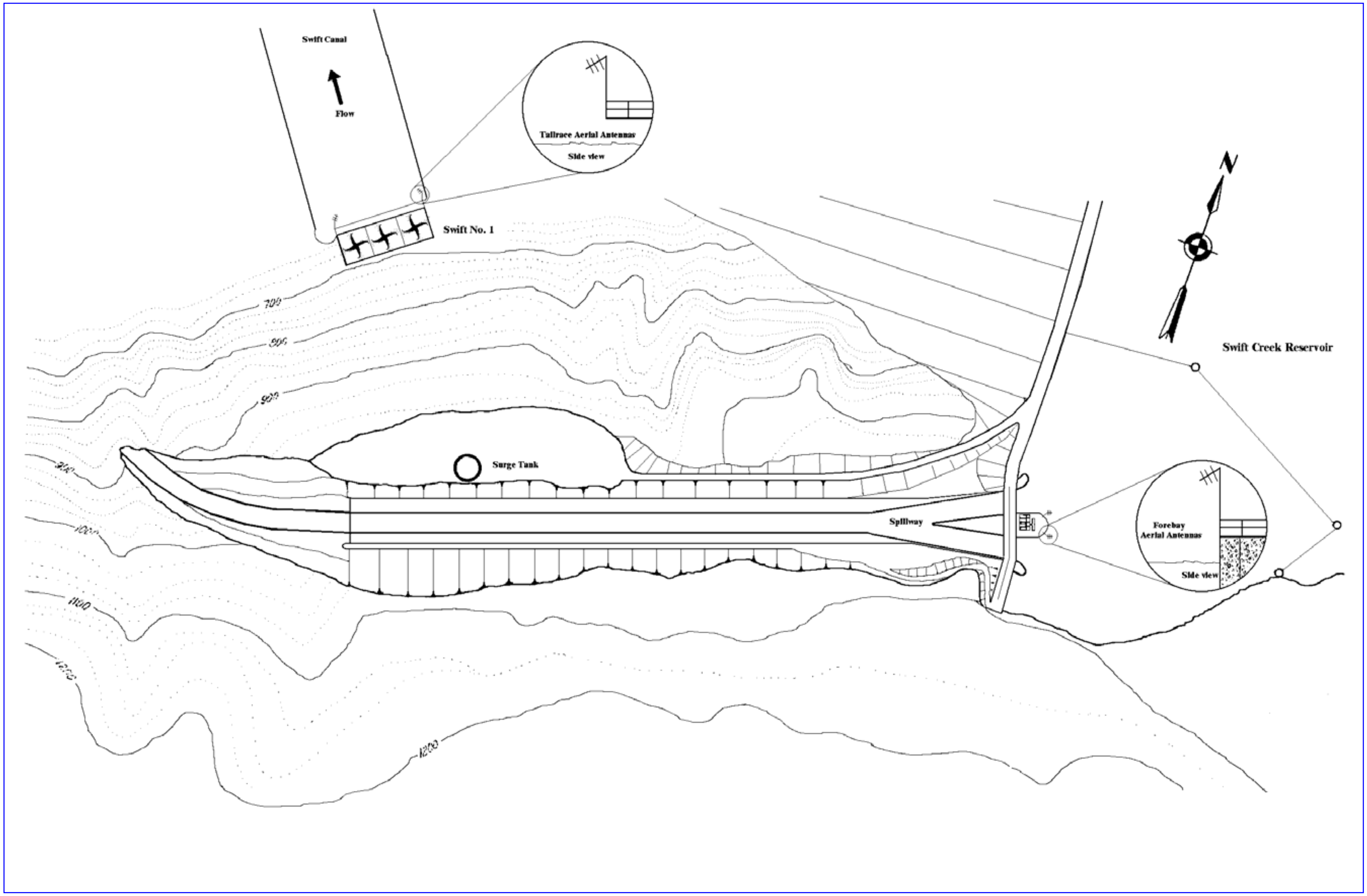


Figure 4.14A-2. Location of aerial antennas in the forebay and tailrace of Swift No. 1.

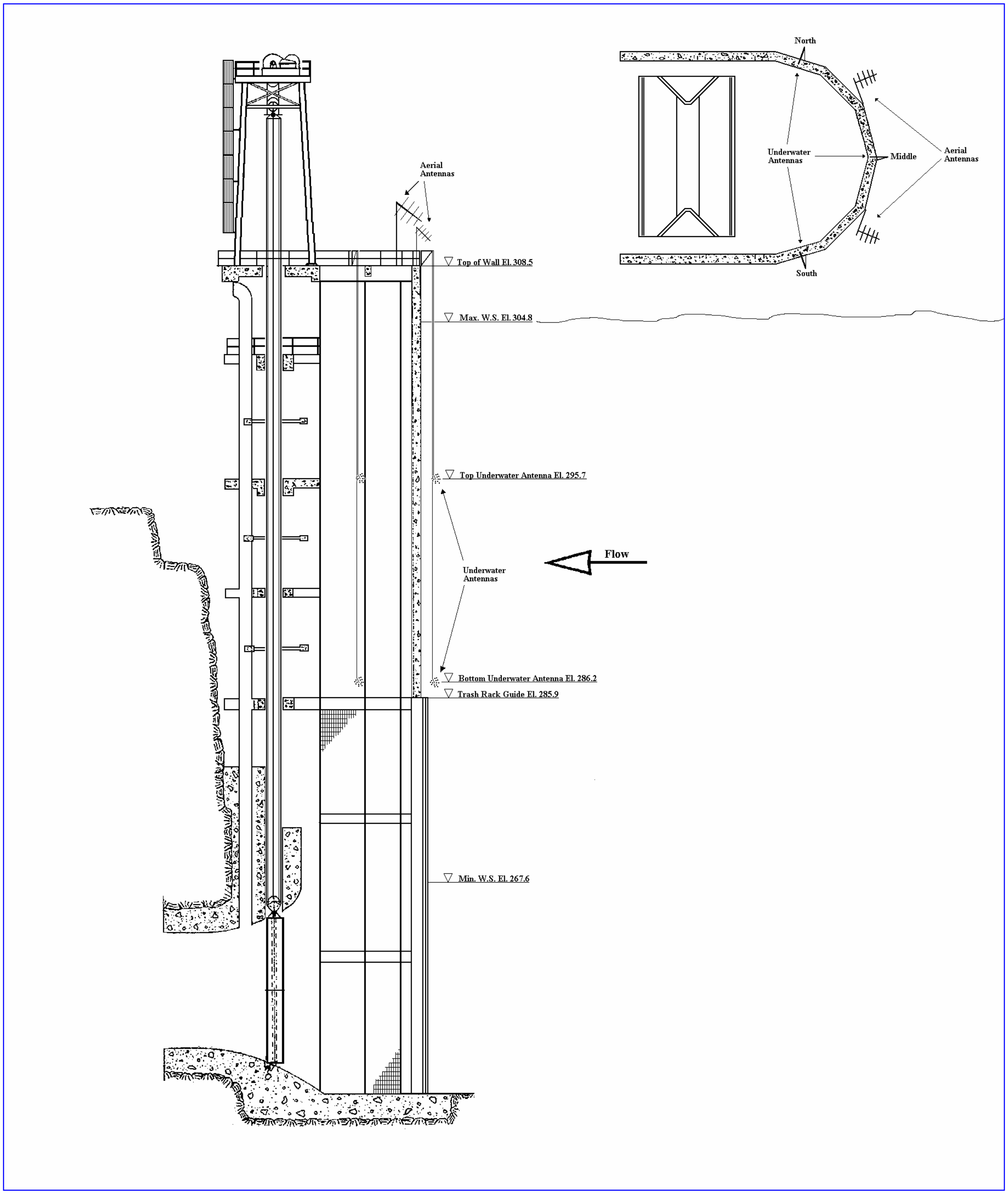


Figure 4.14A-3. Side and plan view of aerial and underwater antennas used in the forebay of Swift No. 1. All depth measurements are in meters above mean sea level.

transmissions during the receiver cycling process[2]. Because all 6 antennas were monitored individually, fish location could be used to determine if patterns at the intake structure existed as radio-tagged fish approach.

Tailrace Aerial System

The purpose of the tailrace aerial system was to detect radio-tagged fish that had passed Swift No. 1 via the turbine intake, and subsequently through the turbine units. The system consisted of two 3-element Yagi antennas located on the walkway on the downstream side of the powerhouse, with one antenna on either side of the canal (Figure 4.14A-2). Both antennas were aimed towards the middle of the canal at an angle 40 degrees off from the face of the powerhouse structure. Since the antennas used at this site have a horizontal detection field of 80 degrees, the tailrace area was effectively monitored from the face of the powerhouse to each shore. Detection distance from the powerhouse was a function of the depth of the radio-tagged fish, but in most circumstances likely extended beyond the point where the canal changed course in a westerly direction.

This system was monitored by a single SRX unit, which was configured with a 5.5 second scan time and a 22.0 second receiver cycle time. A 12-volt RV battery connected to a 10-amp charger and 110-volt power supply powered the system.

Mobile Telemetry Surveys

From May 18 to June 29, 2001, 12 boat surveys were conducted on Swift Reservoir and one vehicle survey along Swift canal was used to track radio-tagged coho salmon. The boat was outfitted with two 3-element Yagi antennas combined together and mounted in the bow of the boat. Each antenna was aimed 30 degrees off the mid-line of the boat to provide a combined detection field of approximately 140 degrees. Surveys were conducted by cruising the perimeter of the reservoir at a distance of approximately 30 to 100 meters from the shore. On 3 successive surveys, biologists cruised the middle of the reservoir to track fish that might have been in deep open-water habitat. This survey method subsequently was dropped because almost all fish that could be detected were along the shoreline or in tributary bays of the reservoir.

When fish were detected, antennas at the bow of the boat were used to locate fish by signal strength (power) or by the volume (sound) of the radio tag. Swift Reservoir was separated into 6 zones easily recognized by visual landmarks (Zone 1 is at the head of the reservoir and Zone 6 near the dam). These zones were used to describe the general location of fish within the reservoir (see AQU 14A Appendix 1). When signal strength was greater than 125 power points, the location of a tagged fish was marked on a 7.5-minute map (AQU 14A Appendix 1). At the time the data were analyzed, each channel/code combination (representing a unique fish) was assigned an identification number to represent the location of each fish on a given survey (AQU 14A Appendix 1). In zones where fish had a tendency to congregate (i.e., Zone 1), the boat was stopped and

[2] DSP units are best used in underwater applications because they are sensitive to ambient background noise.

channels were monitored individually until all of the fish in the detection area were logged. Fish were then tracked until a position could be recorded.

The single survey of the Swift canal was conducted to confirm that no fish were passing the project via the turbines and going undetected by the tailrace aerial system. The survey was conducted by traveling the access road along the canal from the dam to the roadway bridge with a SRX receiver outfitted with a whip antenna. During that survey, no fish were detected downstream of the Swift 1 Dam.

4.14A.3.2 Fish Collection

Hatchery coho salmon were collected from the Lewis River Hatchery and transported by truck to the Pine Creek Forest Service Station one day prior to tagging. At the hatchery, fish were placed in a 1200-liter transport tank supplied with recirculated water and oxygen. For each replicate, 30-40 fish were collected to account for rejection due to injuries, descaling and inadequate size. At the Forest Service Station, transported fish were acclimated to well water used at the site, and were held for 48 hours in a 208 liter container prior to tagging to reduce stress associated with the collection and transport process.

4.14A.3.3 Fish Tagging

Biologists surgically implanted transmitters in 60 hatchery coho salmon following procedures outlined in Summerfelt and Smith (1990). Three replicates, with 20 fish per replicate, were tagged. Surgery was conducted in 3 steps: (1) pre-operative MS-222 bath, (2) surgical implantation of the radio-transmitter, and (3) freshwater recovery. Test animals were anesthetized in a pre-operative solution of MS-222 at 100 mg/L until fish lost equilibrium. During surgery, the MS-222 concentration was reduced to 50 mg/L to maintain anesthesia. Fish were rejected for tagging if they had external injuries, scale loss greater than 20 percent, or measured less than 145 mm fork length.

During surgery, the fish was placed on a V-shaped Plexiglas cradle that was integrated into a rectangular catchment tray. A hose fed through one end of the surgical cradle supplied anesthetic water to the fish during surgery. Fish were placed into the cradle and swabbed with iodine at the incision site, then sprayed with a diluted solution of Pro-polyaqua (synthetic fish mucous). Radio-tags were implanted through a 1.0-cm incision between the pectoral and pelvic fins slightly off the mid-ventral line. To reduce the potential of post-operative infection, several drops of Oxtet© oxytetracycline were placed into the body cavity. A beveled cannula was inserted through the incision into the body cavity. The beveled side was slid against the body wall and pierced the skin near the vent. The radio-transmitter antenna was inserted into the cannula, and both the cannula and the antenna were pulled through the exit site. The radio-transmitter was then inserted into the body cavity and the incision closed with 2-3 sutures.

The procedure concluded with a second application of iodine over the sutures and a spray of Pro-polyaqua. Scalpel, cannula, and tweezers were immersed in isopropyl alcohol for 2–4 minutes after each fish. Radio-tagged fish were held in 18.9-liter buckets for 48 hours prior to release to facilitate recovery. Each bucket contained 2 radio-tagged fish separated by a clear Plexiglas partition to eliminate the possibility of the antennas becoming entangled. Numerous holes were drilled into the Plexiglas to allow water circulation, rough edges were sanded, and the partition was siliconed into place. A large moving van was used to tag, hold, and transport the tagged fish.

4.14A.3.4 Fish Release

Radio-tagged fish were transported to Eagle Cliff Park on the Lewis River approximately 200 meters upstream from Swift Reservoir. Replicates 1, 2 and 3 were released in the afternoon on May 17, 21 and 25, 2001, respectively, between the hours of 1330-1500. Prior to transport and release, all radio-tagged fish were scanned with an SRX receiver to verify that the radio-transmitter was functioning and coding properly. In addition, all fish were observed in the buckets prior to release to verify that none exhibited any signs of post-operative stress such as loss of equilibrium. At the release site, individual buckets were hauled down to the river and fish were released away from the shoreline into the main current to encourage downstream movement into the reservoir.

4.14A.3.5 Data Management

Three separate types of data files were compiled in a single database to assess migration behavior within the reservoir. The first file contained tagging and release information for each of the tagged fish released at Eagle Cliff on the Lewis River (Table 4.14A-1). It presents the date of release, tagging information, date of transport, and fork length for each fish by channel, code and replicate. The second file contained all boat tracking information, which included zone and time of detection. All fish detected during boat tracking surveys were recorded on 7.5-minute maps of Swift Reservoir at least twice a week.

Table 4.14A-1. Summary information for hatchery coho salmon smolts implanted with radio tags. Transport date is 24 hrs before tagging and release is 48 hrs after tagging.

	Date							
Replicate	Transported	Tagged	Released	Time	Channel	Code	Fish ID	FKL (mm)
1	5/14/01	5/15/01	5/17/01	14:14	1	1	1	155
1	5/14/01	5/15/01	5/17/01	14:14	1	2	2	164
1	5/14/01	5/15/01	5/17/01	14:14	1	3	3	172
1	5/14/01	5/15/01	5/17/01	14:14	1	4	4	168
1	5/14/01	5/15/01	5/17/01	14:37	1	5	5	184
1	5/14/01	5/15/01	5/17/01	14:37	3	6	21	153
1	5/14/01	5/15/01	5/17/01	14:37	3	7	22	149
1	5/14/01	5/15/01	5/17/01	14:37	3	8	23	173
1	5/14/01	5/15/01	5/17/01	14:37	3	9	24	150
1	5/14/01	5/15/01	5/17/01	14:37	3	10	25	162
1	5/14/01	5/15/01	5/17/01	14:55	6	1	31	167
1	5/14/01	5/15/01	5/17/01	14:55	6	5	35	184
1	5/14/01	5/15/01	5/17/01	14:55	6	6	36	162
1	5/14/01	5/15/01	5/17/01	14:55	6	10	40	150
1	5/14/01	5/15/01	5/17/01	14:55	6	11	41	150
1	5/14/01	5/15/01	5/17/01	14:37	8	11	56	184
1	5/14/01	5/15/01	5/17/01	14:37	8	12	57	169
1	5/14/01	5/15/01	5/17/01	14:55	8	13	58	160

Table 4.14A-1. Summary information for hatchery coho salmon smolts implanted with radio tags. Transport date is 24 hrs before tagging and release is 48 hrs after tagging (cont.)

Replicate	Date			Time	Channel	Code	Fish ID	FKL (mm)
	Transported	Tagged	Released					
1	5/14/01	5/15/01	5/17/01	14:55	8	14	59	171
1	5/14/01	5/15/01	5/17/01	14:55	8	15	60	155
2	5/18/01	5/19/01	5/21/01	14:48	1	6	6	164
2	5/18/01	5/19/01	5/21/01	14:48	1	7	7	159
2	5/18/01	5/19/01	5/21/01	14:48	1	8	8	159
2	5/18/01	5/19/01	5/21/01	14:48	1	9	9	154
2	5/18/01	5/19/01	5/21/01	14:48	1	10	10	167
2	5/18/01	5/19/01	5/21/01	14:48	3	11	26	175
2	5/18/01	5/19/01	5/21/01	14:48	3	13	28	170
2	5/18/01	5/19/01	5/21/01	14:48	3	14	29	153
2	5/18/01	5/19/01	5/21/01	14:48	3	15	30	152
2	5/18/01	5/19/01	5/21/01	14:48	6	2	32	159
2	5/18/01	5/19/01	5/21/01	14:48	6	7	37	169
2	5/18/01	5/19/01	5/21/01	14:48	6	8	38	160
2	5/18/01	5/19/01	5/21/01	14:48	6	12	42	154
2	5/18/01	5/19/01	5/21/01	14:48	6	13	43	155
2	5/18/01	5/19/01	5/21/01	14:48	8	1	46	161
2	5/18/01	5/19/01	5/21/01	14:48	8	2	47	173
2	5/18/01	5/19/01	5/21/01	14:48	8	3	48	158
2	5/18/01	5/19/01	5/21/01	14:48	8	4	49	173
2	5/18/01	5/19/01	5/21/01	14:48	8	5	50	155
3	5/22/01	5/23/01	5/25/01	13:13	1	11	11	162
3	5/22/01	5/23/01	5/25/01	13:13	1	12	12	160
3	5/22/01	5/23/01	5/25/01	13:13	1	13	13	158
3	5/22/01	5/23/01	5/25/01	13:13	1	14	14	152
3	5/22/01	5/23/01	5/25/01	13:13	1	15	15	154
3	5/22/01	5/23/01	5/25/01	13:13	3	1	16	164
3	5/22/01	5/23/01	5/25/01	13:13	3	2	17	157
3	5/22/01	5/23/01	5/25/01	13:13	3	3	18	172
3	5/22/01	5/23/01	5/25/01	13:13	3	4	19	173
3	5/22/01	5/23/01	5/25/01	13:13	3	5	20	160
3	5/22/01	5/23/01	5/25/01	13:13	3	12	27	162
3	5/22/01	5/23/01	5/25/01	13:13	6	3	33	164
3	5/22/01	5/23/01	5/25/01	13:13	6	4	34	157
3	5/22/01	5/23/01	5/25/01	13:13	6	9	39	163
3	5/22/01	5/23/01	5/25/01	13:13	6	14	44	173
3	5/22/01	5/23/01	5/25/01	13:13	6	15	45	160
3	5/22/01	5/23/01	5/25/01	13:13	8	6	51	153
3	5/22/01	5/23/01	5/25/01	13:13	8	7	52	154
3	5/22/01	5/23/01	5/25/01	13:13	8	8	53	156
3	5/22/01	5/23/01	5/25/01	13:13	8	9	54	168
3	5/22/01	5/23/01	5/25/01	13:13	8	10	55	165
							Mean:	162

The third file contained information from fixed station receivers that were checked approximately every other day to ensure proper operation (i.e., battery voltage, receiver time, memory status, etc.), and downloaded at least once a week. All downloaded files were converted to ASCII format and appended to a master receiver file. At the end of the study, all fixed station receiver files and boat tracking data were coded with a receiver number and combined into a relational database for final data analysis.

4.14A.3.6 Data Analysis

Data were analyzed to assess travel time, arrival distribution, detection efficiency, intake approach behavior, and minimum survival to Swift No. 1. Before data analysis began, criteria were developed to distinguish valid detections from ambient background noise. The criteria helped to eliminate invalid detections (noise) that were recorded on fixed station receivers. The following criteria were used to eliminate invalid detections at all fixed station receivers:

- No fish can be detected before the date and time of release.
- A valid detection must have at least 2 hits (records) within 0.5 hrs.
- Valid detections cannot occur out of sequence (i.e., detection in the tailrace cannot be valid if the fish is detected in the reservoir at a later date).

To ensure the integrity of the results, a second independent data analysis was conducted.

4.14A.4 Key Questions

This study contributes to a partial understanding of the following "key" watershed questions, identified during the Lewis River Collaborative Watershed Studies meetings:

- What types of reintroduction methods might be successful in the Lewis River Watershed and what is the potential cost and engineering feasibility of each of these methods (e.g., trapping and hauling, construction of fish ways, screening, stocking of fry and planting of eggs)?

  A key issue to understanding if potential reintroductions will be successful is to describe the survival and migration behavior of juvenile coho in Swift Reservoir. That is, will the progeny of reintroduced coho salmon or hatchery outplants migrate to Swift Dam and survive at rates that indicate provisions for smolt-collection or passage facilities at the dam. In this first year, hatchery coho salmon were implanted with radio tags to describe survival and migration behavior. Subsequent research may focus on different salmonid species and comparisons with natural migrants in conjunction with operation of a smolt-collection device. Other aquatic studies address issues related to reintroduction, management and performance of anadromous fish in the Lewis River Basin.

- What physical, chemical, and biological conditions currently exist in project reservoirs or stream habitats that may affect anadromous fish movements and migrations and how might potential impact resulting from these conditions be reduced?

Section 4.14A.5 of this study contributes information useful in answering this question.

- What types of interspecific interactions may occur with various options for reintroducing anadromous fish?

  A new study, AQU 16, will address this question.

- What types of reservoir management alternatives might increase the potential success of anadromous fish reintroductions efforts (e.g., reservoir drawdown to facilitate downstream migration of smolts)?

  Information derived from coho smolt radio tracking in Swift Reservoir will contribute to this analysis. Other investigations, including AQU 5, AQU 10, AQU 11, and AQU 13, provide additional information.

4.14A.5 Results

4.14A.5.1 Fish Handling

Hatchery coho salmon implanted with radio-transmitters varied in length from 149 to 184 mm with an average fork length of 162 mm (Table 4.14A-1). All fish tagged in the first replicate were released on May 17, 2001. One fish in Replicate 2 died shortly after surgery and was replaced on the day of tagging. A second fish in Replicate 2 could not maintain equilibrium the day of release and was removed. The tag was recovered and used to tag an additional fish in Replicate 3. One fish in Replicate 3 could not maintain equilibrium the day of release; therefore, an additional fish was tagged and released that day. The fish in Replicate 3 that was tagged and released the same day was detected on both the aerial and underwater system at Swift No. 1.

Well water supplied at Pine Creek Forest Service Station was tested for total dissolved gases (TDG). The total dissolved gas level was less than 110 percent and temperature was near a constant 10°C. All fish transported from Lewis River Hatchery were acclimated to the Pine Creek well water if the temperature differed more than 2°C. For the last replicate, the temperature differed by 5°C. Therefore, the fish were acclimated to the well water at a rate of 1°C every 15 to 20 minutes. The temperature at the release site varied from 8.2 to 11.5°C at time of release.

4.14A.5.2 Migration Behavior

To assess the migration behavior of radio-tagged fish through the reservoir, travel time and migration rates were calculated for each fish from the point of release to the intake structure, using the first detection by the underwater system as the metric to assess arrival. The underwater system provided the most accurate measure of migration time to the project; since the range of the underwater antennas is approximately 9 meters, it clearly establishes arrival at the project. Conversely, depending on the depth of the tagged fish, its distance to the project at the time of first detection by the aerial system could vary from a few meters to as much as 300 meters.

The median travel time[3] for the 48 fish detected by the underwater system at the project intake was 3.6 days and varied from 1.0 day to 22.6 days. The median migration rate to the project intake was 5.2 km/day and varied from 0.8 km/day to 19.1 km/day (Table 4.14A-2; Figure 4.14A-4).

4.14A.5.3 Arrival Distribution

Arrival distribution at Swift Dam was compiled within 1.0-day intervals for fish detected at the underwater antenna system. Most fish detected (43/48) were observed at the project within 7.0 days of release (Figure 4.14A-5). More than half (27/48) of all the fish that were detected at the project were observed within 4 days of release. The greatest number of fish detected by time interval was for the periods of 1.0-2.0 days and 3.0-4.0 days after release (10 and 9 fish, respectively).

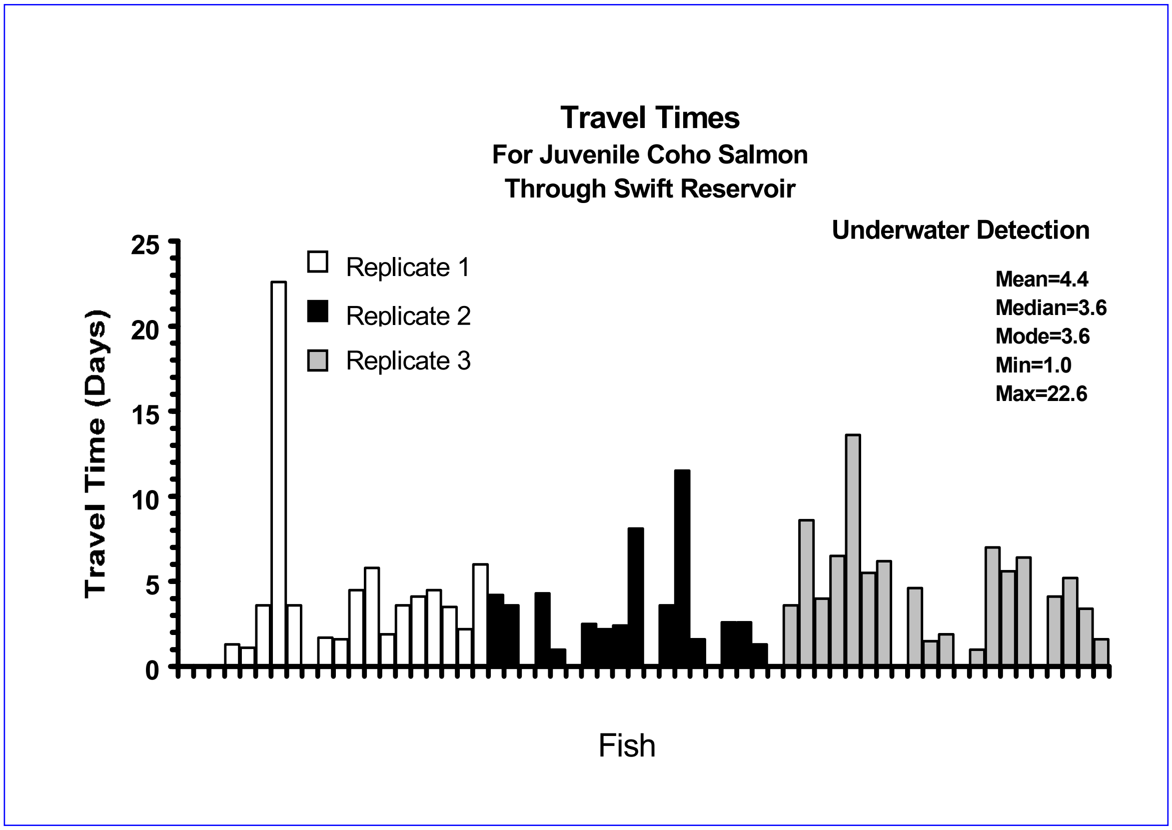
Table 4.14A-2. Migration rate and travel time for radio-tagged coho salmon smolts released at Eagle Cliff on the Lewis River to Swift No. 1 underwater detection array.

Replicate	Channel	Code	Migration Rate (km/d)	Travel Time (days)
1	1	1	-	-
1	1	2	-	-
1	1	3	-	-
1	1	4	13.8	1.3
1	1	5	17.6	1.1
1	3	6	5.2	3.6
1	3	7	0.8	22.6
1	3	8	5.2	3.6
1	3	9	-	-
1	3	10	11.0	1.7
1	6	1	11.6	1.6
1	6	5	4.1	4.5
1	6	6	3.2	5.8
1	6	10	9.7	1.9
1	6	11	5.2	3.6
1	8	11	4.5	4.1
1	8	12	4.1	4.5
1	8	13	5.4	3.5
1	8	14	8.3	2.2
1	8	15	3.1	6.0
2	1	6	4.4	4.2
2	1	7	5.2	3.6
2	1	8	-	-
2	1	9	4.3	4.3
2	1	10	17.9	1.0
2	3	11	-	-
2	3	13	7.3	2.5

[3] Researchers used the median, which is the mean of the 2 middle values, when sample size (n = 48) was even. The median is less sensitive than the mean when the data set includes extremely large or small values.

Table 4.14A-2. Migration rate and travel time for radio-tagged coho salmon smolts released at Eagle Cliff on the Lewis River to Swift No. 1 underwater detection array (cont.)

Replicate	Channel	Code	Migration Rate (km/d)	Travel Time (days)
2	3	14	8.3	2.2
2	3	15	7.8	2.4
2	6	2	2.3	8.1
2	6	7	-	-
2	6	8	5.2	3.6
2	6	12	1.6	11.5
2	6	13	2.2	8.6
2	8	1		-
2	8	2	7.0	2.6
2	8	3	7.1	2.6
2	8	4	13.9	1.3
2	8	5	-	-
3	1	11	5.1	3.6
3	1	12	2.2	8.6
3	1	13	4.7	4.0
3	1	14	2.8	6.5
3	1	15	1.4	13.6
3	3	1	3.4	5.5
3	3	2	3.0	6.2
3	3	3	-	-
3	3	4	4.1	4.6
3	3	5	12.6	1.5
3	3	12	9.8	1.9
3	6	3	-	-
3	6	4	19.1	1.0
3	6	9	2.6	7.0
3	6	14	3.3	5.6
3	6	15	2.9	6.4
3	8	6	-	-
3	8	7	4.5	4.1
3	8	8	3.6	5.2
3	8	9	5.5	3.4
3	8	10	11.5	1.6
		Mean:	6.4	4.4
		Median:	5.2	3.6
		Mode:	5.2	3.6
		Range:	18.3	21.6
		Minimum:	0.8	1.0
		Maximum:	19.1	22.6



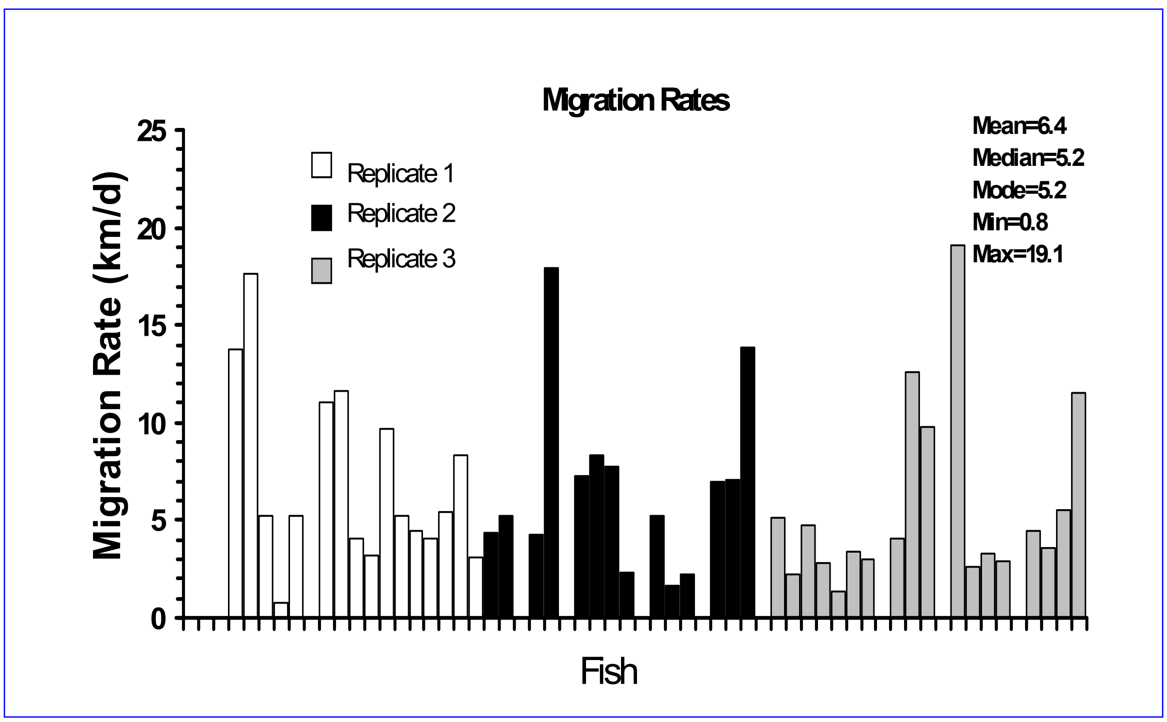


Figure 4.14A-4. Travel times and migration rates for juvenile coho salmon released at Eagle Cliff on the Lewis River to detection on the underwater antenna array at Swift No. 1.

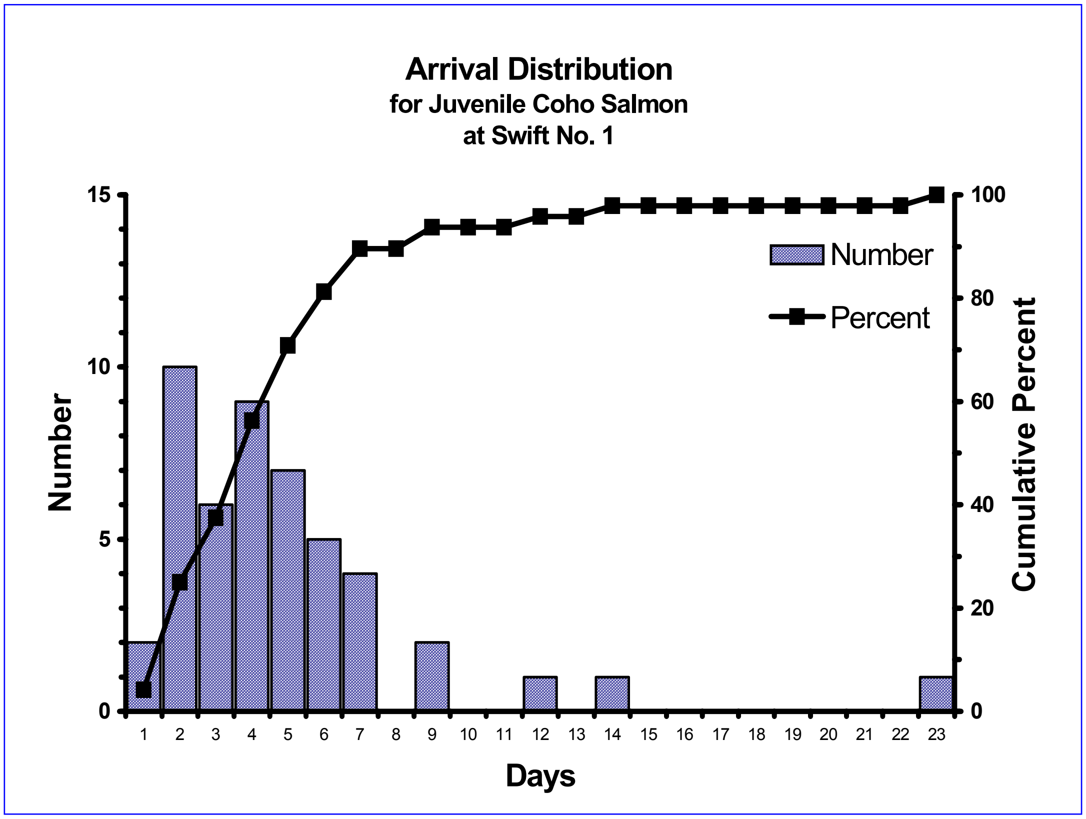


Figure 4.14A-5. Arrival distribution in numbers and cumulative percent for juvenile coho salmon detected on the underwater antenna system at Swift No. 1.

The total number of days radio-tagged fish spent near the project area varied based on detections by the aerial and underwater systems (Figure 4.14A-6). The mean length of time radio-tagged fish were detected within the forebay of Swift No. 1 was 9.9 days and 5.8 days for the aerial and underwater systems, respectively (Table 4.14A-3). The maximum number of days radio-tagged fish were detected by each system was 24 days for the aerial system, and 16 days for the underwater system. For the aerial system, only 1 of 54 fish were detected on one day, and for the underwater system, only 6 of 48 fish were detected on a single day. The greater number of fish and length of time fish were detected at the aerial system is probably due to the much larger detection area created by the aerial system.

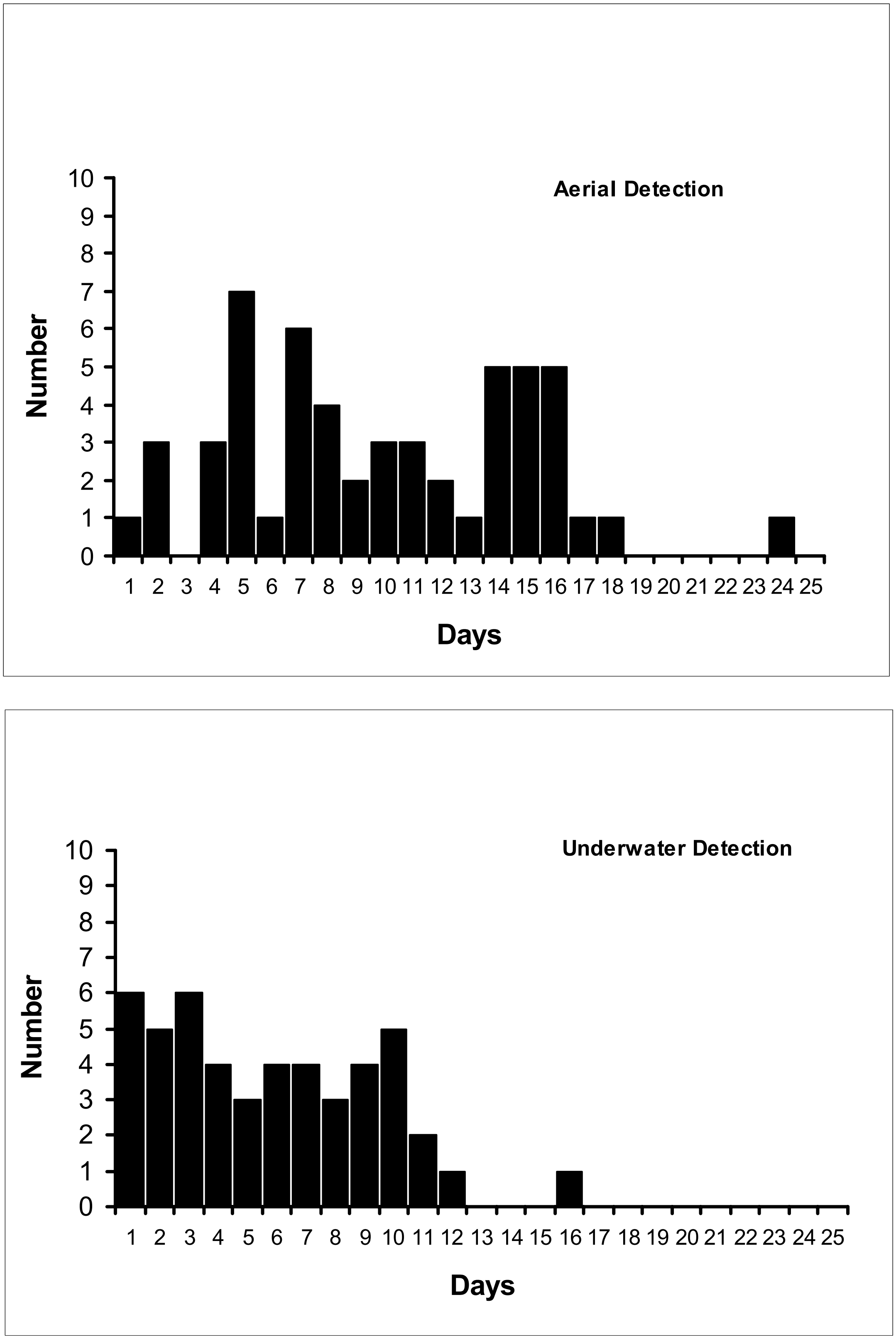


Figure 4.14A-6. Number of days radio-tagged coho salmon were detected by aerial and underwater systems at the forebay of Swift No. 1.

Table 4.14A-3. Number of days radio-tagged coho salmon smolts were detected at the aerial or underwater system at Swift No. 1.

Replicate	Channel	Code	Aerial	Underwater
1	1	1	-	-
1	1	2	-	-
1	1	3	-	-
1	1	4	13	16
1	1	5	7	8
1	3	6	6	3
1	3	7	7	1
1	3	8	14	9
1	3	9	-	-
1	3	10	8	7
1	6	1	14	9
1	6	5	15	9
1	6	6	16	9
1	6	10	10	10
1	6	11	15	11
1	8	11	11	5
1	8	12	4	4
1	8	13	5	3
1	8	14	8	7
1	8	15	16	7
2	1	6	24	6
2	1	7	2	1
2	1	8	-	-
2	1	9	11	3
2	1	10	16	12
2	3	11	7	-
2	3	13	7	2
2	3	14	2	1
2	3	15	5	5
2	6	2	9	2
2	6	7	-	-
2	6	8	15	3
2	6	12	5	1
2	6	13	15	7
2	8	1	12	-
2	8	2	15	6
2	8	3	14	2
2	8	4	17	10
2	8	5	2	-
3	1	11	14	8
3	1	12	10	2
3	1	13	12	10
3	1	14	5	2
3	1	15	14	5
3	3	1	11	8
3	3	2	5	1
3	3	3	1	-
3	3	4	10	6
3	3	5	8	6

Table 4.14A-3. Number of days radio-tagged coho salmon smolts were detected at the aerial or underwater system at Swift No. 1 (cont.).

Replicate	Channel	Code	Aerial	Underwater
3	3	12	9	3
3	6	3	4	-
3	6	4	7	4
3	6	9	5	1
3	6	14	18	10
3	6	15	7	4
3	8	6	4	-
3	8	7	5	3
3	8	8	16	11
3	8	9	16	10
3	8	10	8	4
		Mean	**9.9**	**5.8**
		Median	**9.5**	**5.5**
		Mode	**5.0**	**3.0**
		Range	**23.0**	**15.0**
		Minimum	**1.0**	**1.0**
		Maximum	**24.0**	**16.0**

4.14A.5.4 Fish Movement within Swift Reservoir

Mobile boat surveys were conducted to complement telemetry from fixed station receivers and to provide information on fish location and movement upstream from the forebay of Swift No. 1. The overall detection efficiency of mobile boat surveys was 97 percent. Specifically, of the 60 radio-tagged fish released at the head of the reservoir, 58 were detected during the 12 boat surveys (Table 4.14A-4). The two fish that were not found by boat tracking were not detected at any telemetry sites during the course of the study.

During the 12 mobile surveys, more than half of the detections for juvenile coho salmon were in either Zone 1 (30.7 percent) or Zone 6 (21.5 percent) (Table 4.14A-5 and AQU 14A Appendix 1). This observation comports well with the number of fish that traversed the reservoir at least once. That is, fish that were observed in Zone 6 after release were detected on a later survey in Zone 1. Nearly half (48 percent) of the fish exhibited this behavior. At the extreme, one fish “#4” made the journey from Zone 1 to Zone 6 three times (Table 4.14A-4). Table 4.14A-4 indicates that many of the fish moved back upstream from Zone 6 to Zone 1 by the end of the study period.

Most fish detections were along the north (44 percent) and south (33 percent) shores of Swift Reservoir (Table 4.14A-6). Fish detections also occurred in areas not along the shoreline. Some fish detections (7 percent) were in the Lewis River near the release site. In fact, several fish were captured in a screw trap operated by the WDFW just upstream of the release site (see AQU 13). Other fish detections (8 percent) occurred in open water areas of Swift Reservoir. During mobile surveys, detections of fish in the forebay accounted for only 8 percent of fish detections made in Swift Reservoir. In general, most fish were either detected in the larger river inlets or in one of the many small cove areas in the reservoir (AQU 14A Appendix 1). Fish were often detected near accumulations of driftwood, particularly along the north shore and in Zone 1, where logs aggregated due to wind and wave action.

Table 4.14A-4. Capture history matrix for radio-tagged coho salmon smolts observed during mobile surveys by zone of detection in Swift Reservoir.

Replicate	Channel	Code	Fish ID	May						June						Total
				18	19	22	26	28	31	4	8	11	16	18	29	Unique
1	1	1	1	1	3	1	1	3	1	1	1	1	1	1		1
1	1	2	2				2	2	2	2	2	2		2		1
1	1	3	3	1		3										1
1	1	4	4		6		6	1	6	1	6		1	1		1
1	1	5	5		5		3	1						1		1
1	3	6	21		3			5	2		2		1	1		1
1	3	7	22			6						1		1		1
1	3	8	23	2	3	2	6	2	4	5	1	1	1	1		1
1	3	9	24		2		2	2	2	2	2	2	2	2		1
1	3	10	25		6		3	1	6			1	1			1
1	6	1	31					2		2						1
1	6	5	35		3	5	1	6	6	2		1	5	1		1
1	6	6	36		3								6	3		1
1	6	10	40		6	5	6	1		2	1	1	1	5		1
1	6	11	41	1	2	3	4	3	6	4	6	5	6	3		1
1	8	11	56	2	1	5	3		5	3			1			1
1	8	12	57		3	6	6	1	1	1	1	1	1	1		1
1	8	13	58		3	5	4	1	2	2	3	1	1	1		1
1	8	14	59		6	6	1	3	5	1	6	1	1	1		1
1	8	15	60	1	3	5	6	6	3	6						1
2	1	6	6			2				4	6			6		1
2	1	7	7			2	2	3								1
2	1	8	8			3	5	5								1
2	1	9	9				5	1	4		5	5	5	2	3	1
2	1	10	10				3	3	6	6	2	6	1	1		1
2	3	11	26			3	2			6		6	6	6		1
2	3	13	28			6		1								1
2	3	14	29													0
2	3	15	30				6	2		1	1	1	1	1		1
2	6	2	32				3	5	3	5	3	2	1	1		1
2	6	7	37													0
2	6	8	38			6	6		6		4	6	6	6		1
2	6	12	42			1	4		4	6	1	4	1	1	1	1
2	6	13	43			2	6	1	6	5	6	3	6	1		1
2	8	1	46				3	1	2							1
2	8	2	47			6	6	5	3	6	1	1	2	1		1
2	8	3	48				3	5	6	6	2	1	1	1		1
2	8	4	49			6	1	1	4	2	1	1	1	1		1
2	8	5	50			1	1	1	1	1	1	1	1	1		1
3	1	11	11				3	3	6	3	6	5	6	4		1
3	1	12	12				1	3	3	3	3	6	3	5	1	1
3	1	13	13				6	6	5	5	1	1	3	5		1

Table 4.14A-4. Capture history matrix for radio-tagged coho salmon smolts observed during mobile surveys by zone of detection in Swift Reservoir (cont.).

Replicate	Channel	Code	Fish ID	May						June						Total
				18	19	22	26	28	31	4	8	11	16	18	29	Unique
3	1	14	14				3	3	4		2		1	1	1	1
3	1	15	15					5		6	6	1	3		1	1
3	3	1	16				3	1		4	5	1		3	3	1
3	3	2	17				6	3	6	2	1	1	1	1	1	1
3	3	3	18				2		2	2	2	2	2			1
3	3	4	19				5	3		5	2	3		5	2	1
3	3	5	20				3	1	6	5	1	3	1	1		1
3	3	12	27				2	5	6	6	6	1	5			1
3	6	3	33				6	2	2	2	2	2	2	2	2	1
3	6	4	34				6	3	6	6	1	1				1
3	6	9	39					6		6	6	6			6	1
3	6	14	44				6	4	6	6			6	5	6	1
3	6	15	45				3	5	6	6		1		5		1
3	8	6	51					1	2	2	2	2	2	2	1	1
3	8	7	52				4	1	2	1	6	1	4	1		1
3	8	8	53				2		5	6	3	6	4	6	4	1
3	8	9	54				3	5	5		5	2	6	5	1	1
3	8	10	55				3	1	2	1	6	5	5	5	5	1
			Detections:	**6**	**17**	**23**	**48**	**48**	**42**	**44**	**42**	**43**	**42**	**44**	**15**	**58**
			Fish Released:	**20**	**20**	**39**	**60**	**60**	**60**	**60**	**60**	**60**	**60**	**60**	**60**	**60**
			Percent Detected:	**30**	**85**	**59**	**80**	**80**	**70**	**73**	**70**	**72**	**70**	**73**	**25**	**97**

Table 4.14A-5. Number of radio-tagged coho salmon smolts detected by zone for each mobile survey and percent of fish detected in each zone.

Zone	May						June						Total	Percent
	18	19	22	26	28	31	4	8	11	16	18	29		
1	4	1	3	6	17	3	8	13	22	20	23	7	127	30.7
2	2	2	4	7	6	10	11	10	7	5	5	2	71	17.1
3	0	8	4	14	11	4	3	4	3	3	3	2	59	14.3
4	0	0	0	4	1	5	3	1	1	2	1	1	19	4.6
5	0	1	5	3	9	5	6	3	4	4	8	1	49	11.8
6	0	5	7	14	4	15	13	11	6	8	4	2	89	21.5
Total	**6**	**17**	**23**	**48**	**48**	**42**	**44**	**42**	**43**	**42**	**44**	**15**	**414**	

Table 4.14A-6. Detection summary by location and zone for radio-tagged coho smolts observed during boat tracking surveys on Swift Reservoir.

Survey	Location					Zone						Total
	North Shore	South Shore	Swift Forebay	Open Water	Lewis River	1	2	3	4	5	6	
1	4	2	0	0	0	4	2	0	0	0	0	6
2	3	9	4	1	0	1	2	8	0	1	5	17
3	8	8	6	0	1	3	4	4	0	5	7	23
4	16	22	6	3	1	6	7	14	4	3	14	48
5	20	21	0	6	1	17	6	11	1	9	4	48
6	21	13	7	0	1	3	10	4	5	5	15	42
7	20	16	5	0	3	8	11	3	3	6	13	44
8	24	7	4	2	5	13	10	4	1	3	11	42
9	20	11	1	6	5	22	7	3	1	4	6	43
10	19	12	0	8	3	20	5	3	2	4	8	42
11	18	13	0	6	7	23	5	3	1	8	4	44
12	9	4	0	0	2	7	2	2	1	1	2	15
Total	**182**	**138**	**33**	**32**	**29**	**127**	**71**	**59**	**19**	**49**	**89**	**414**
Percent	**44.0**	**33.3**	**8.0**	**7.7**	**7.0**	**30.7**	**17.1**	**14.3**	**4.6**	**11.8**	**21.5**	

Researchers suspect that some of the fish that never made it to Swift No. 1 residualized or were preyed upon. Some notable observations include:

- Fish "#8" was detected in the small inlet at Diamond Creek on 5/28/01 (AQU 14A Appendix 1, page 5). The signal was located, 2 mergansers were observed resting on the shoreline where the signal appeared to originate. When approached, the signal strength increased until the mergansers flew away. The signal was lost when the mergansers left the area and the fish was never detected on subsequent survey (Table 4.14A-4).

- Fish "#24" was detected on 10 surveys in the exact same location (Table 4.14A-4; AQU 14A Appendix 1, pages 2-11). On one of the last surveys, the area was visually inspected to see if the tag had been shed or extruded by an unknown predator. No tag was found, but the behavior of this fish was unlike any other radio-tagged fish released. Other fish detected in the same zone on numerous surveys were detected at different locations within the same zone. Three scenarios could explain the behavior of this fish: (1) predation, (2) tag loss, or (3) mortality associated with handling.

- Fish "#1" and "#2" were never detected at Swift No. 1 but were detected on several surveys at different locations within the same zone (Table 4.14A-4; AQU 14A Appendix 1). It is believed that these 2 fish residualized in the upper reservoir. Fish "#3" was only detected twice in the upper reservoir.

The boat tracking information suggests that most fish were actively moving throughout the reservoir, possibly along the shoreline. Because most coho salmon smolts tend to migrate at night (Sandercock 1991), it is hard to make this conclusion with only daytime surveys. It is possible that fish moved to open water at night to migrate. There was a clear tendency for radio-tagged coho salmon to return upriver after making an initial downstream movement towards the dam. Moreover, the number of detections near stream outlets and along the dam suggest that many of the fish may have been "searching" for downstream passage.

4.14A.5.5 Reservoir Survival

Minimum survival rates for radio-tagged coho salmon smolts that migrated through Swift Reservoir were based on unique channel code detections by the aerial system at the dam. Researchers relied on the aerial system detections to calculate the minimum survival estimate since it had the highest detection efficiency near the project. Furthermore, since all of the fish that were detected by the underwater system were also detected by the aerial array, there was no need to include the underwater system to establish successful passage through the reservoir.

The minimum survival rate is simply the proportion of released fish that were detected with the aerial system at the dam. This is a minimum estimate of survival, and does not take into account mortality associated with the collection, tagging and release procedures, nor does it account for live fish that successfully traverse the reservoir but were not detected due to tag loss, tag failure and detection efficiencies of the telemetry systems that are likely less than 100 percent. Finally, this estimate also does not account for fish that were alive, but did not migrate completely through the reservoir. Minimum survival through the reservoir was 90.0 percent (54 of 60 fish) (Table 4.14A-7).

4.14A.5.6 Behavior Near Intake

To assess behavior of the 48 radio-tagged fish detected at the intake structure of the dam, the data were analyzed to provide 3 separate indices. Researchers combined different sets of antennas to form antenna arrays to discern patterns in vertical or horizontal distribution of fish as they first approached and moved around the intake structure. The south, middle and north antennas for both the top and bottom arrays were combined to evaluate vertical distribution. To evaluate horizontal distribution, researchers combined the top and bottom antennas for each of the south, middle and north arrays. First, the antenna array where fish were initially detected as they approached the intake structure was examined. This index defined the location where fish encountered the intake structure during their downstream migration through the reservoir. Second, repeat detections at each antenna were documented when radio-tagged fish approached the intake structure on subsequent visits. Repeat detections were separated by a minimum of 2 hours from other previous detections. This index helped explain behavior as fish make repeat attempts to migrate downstream. Finally, researchers used the total number of detections recorded at individual antennas to evaluate where fish spend most of their time near the intake structure.

Table 4.14A-7. Detections by channel and code at fixed telemetry sites in the forebay and tailrace and within Zone 6 by mobile surveys ("1" denotes presence).

Replicate	Channel	Code	Forebay Aerial[1]	Forebay Underwater[1]	Both[2]	Either[3]	Zone 6[4]	Tailrace Aerial
1	1	1	-	-	-	-	-	-
1	1	2	-	-	-	-	-	-
1	1	3	-	-	-	-	-	-
1	1	4	1	1	1	1	1	-
1	1	5	1	1	1	1	-	-
1	3	6	1	1	1	1	-	-
1	3	7	1	1	1	1	1	-
1	3	8	1	1	1	1	1	-
1	3	9	-	-	-	-	-	-
1	3	10	1	1	1	1	1	-
1	6	1	1	1	1	1	-	-
1	6	5	1	1	1	1	1	-
1	6	6	1	1	1	1	1	-
1	6	10	1	1	1	1	1	-
1	6	11	1	1	1	1	1	-
1	8	11	1	1	1	1	-	-
1	8	12	1	1	1	1	1	-
1	8	13	1	1	1	1	-	-
1	8	14	1	1	1	1	1	-
1	8	15	1	1	1	1	1	-
2	1	6	1	1	1	1	1	-
2	1	7	1	1	1	1	-	-
2	1	8	-	-	-	-	-	-
2	1	9	1	1	1	1	-	-
2	1	10	1	1	1	1	1	-
2	3	11	1	-	-	1	1	-
2	3	13	1	1	1	1	1	-
2	3	14	1	1	1	1	-	-
2	3	15	1	1	1	1	-	-
2	6	2	1	1	1	1	-	-
2	6	7	-	-	-	-	-	-
2	6	8	1	1	1	1	1	-
2	6	12	1	1	1	1	1	-
2	6	13	1	1	1	1	1	-
2	8	1	1	-	-	1	-	-
2	8	2	1	1	1	1	1	-
2	8	3	1	1	1	1	1	-
2	8	4	1	1	1	1	1	-
2	8	5	1	-	-	1	-	-
3	1	11	1	1	1	1	1	-
3	1	12	1	1	1	1	1	-
3	1	13	1	1	1	1	1	-
3	1	14	1	1	1	1	-	-
3	1	15	1	1	1	1	1	-

Table 4.14A-7. Detections by channel and code at fixed telemetry sites in the forebay and tailrace and within Zone 6 by mobile surveys ("1" denotes presence) (cont.).

Replicate	Channel	Code	Forebay Aerial[1]	Forebay Underwater[1]	Both[2]	Either[3]	Zone 6[4]	Tailrace Aerial
3	3	1	1	1	1	1	-	-
3	3	2	1	1	1	1	1	-
3	3	3	1	-	-	1	-	-
3	3	4	1	1	1	1	-	-
3	3	5	1	1	1	1	1	-
3	3	12	1	1	1	1	1	-
3	6	3	1	-	-	1	1	-
3	6	4	1	1	1	1	1	-
3	6	9	1	1	1	1	1	-
3	6	14	1	1	1	1	1	-
3	6	15	1	1	1	1	1	-
3	8	6	1	-	-	1	-	-
3	8	7	1	1	1	1	1	-
3	8	8	1	1	1	1	1	-
3	8	9	1	1	1	1	1	-
3	8	10	1	1	1	1	1	-
		Total	**54**	**48**	**48**	**54**	**37**	**0**

Minimum Survival Estimate: 90 percent

1. Represents a unique detection for a given fish at this site.
2. Represents a detection for a given fish at both the forebay aerial and underwater sites.
3. Represents a detection for a given fish at either the forebay aerial or underwater sites.
4. Represents a unique detection for a given radio-tagged fish in Zone 6 with biweekly boat surveys.

For vertical distribution, it was found that 95.8 percent of radio-tagged coho were first detected in the top antenna array (Table 4.14A-8; Figure 4.14A-7). Likewise, when repeat visits were examined, 92.7 percent of radio-tagged fish were detected in the top array near the intake structure (Table 4.14A-8; Figure 4.14A-7). The average number of visits to the intake structure was 8.1 visits (sum of first detections plus total for repeat detections divided by 48). Finally, residence time, indicated by total number of detections, was 88.2 percent for the top array (Table 4.14A-8; Figure 4.14A-7).

Table 4.14A-8. Number and percent of detections for first, repeat and total detections of radio-tagged juvenile coho salmon by antenna array on the underwater antenna system at Swift No. 1.

	First Detection				Repeat Detections				Total Detections			
	North	Middle	South	Total	North	Middle	South	Total	North	Middle	South	Total
Top	25	11	10	46	158	43	115	316	13,298	8,416	18,031	39,745
Bottom	0	0	2	2	4	3	18	25	1,386	571	3,363	5,320
Total	**25**	**11**	**12**	**48**	**162**	**46**	**133**	**341**	**14,684**	**8,987**	**21,394**	**45,065**
Top	52.1%	22.9%	20.8%	95.8%	46.3%	12.6%	33.7%	92.7%	29.5%	18.7%	40.0%	88.2%
Bottom	0.0%	0.0%	4.2%	4.2%	1.2%	0.9%	5.3%	7.3%	3.1%	1.3%	7.5%	11.8%
Total	**52.1%**	**22.9%**	**25.0%**	**100%**	**47.5%**	**13.5%**	**39.0%**	**100%**	**32.6%**	**19.9%**	**47.5%**	**100%**

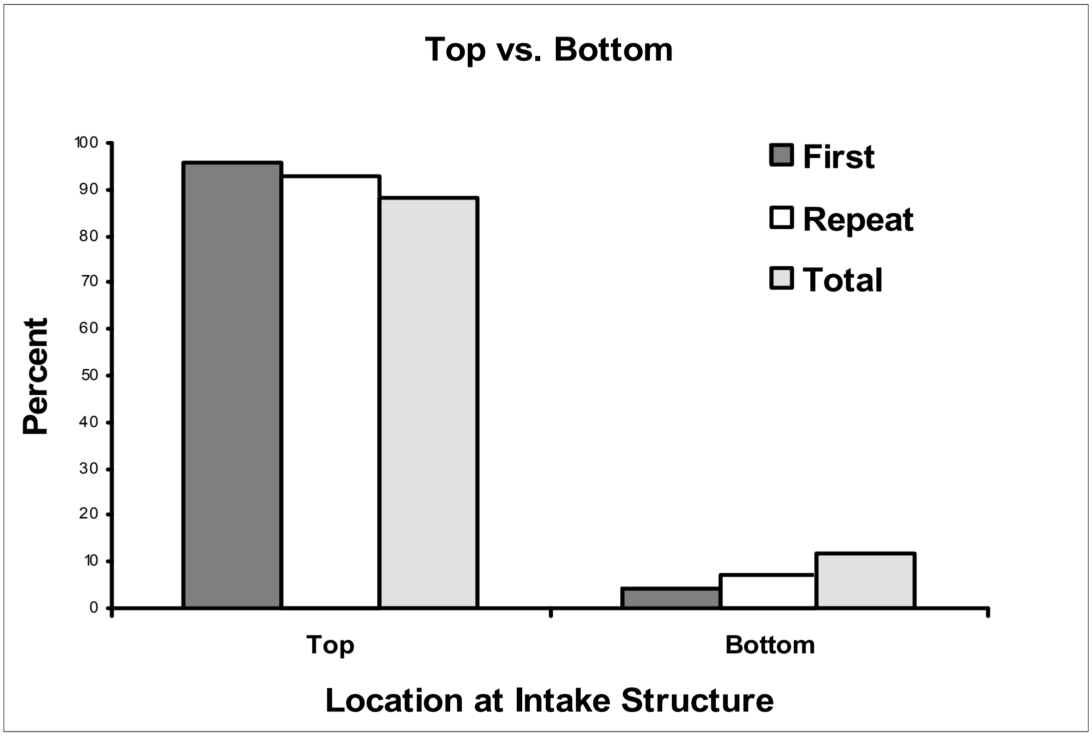


Figure 4.14A-7. The location of first, repeat and total detections at the intake structure of Swift No. 1 Dam.

Definite horizontal patterns were also exhibited at the time of first and repeat detections at the intake structure. A total of 52.1 percent of the fish were first detected in the north array. For repeat visits, 47.5 percent were detected in the north array on subsequent approaches (Table 4-14-8; Figure 4-14-8). However, the total number of detections was greatest for the south array at 47.5 percent (Table 4.14A-8; Figure 4.14A-8). This indicates that radio-tagged fish, while near the intake structure, spent the greatest time on the south side.

Collectively, these results demonstrate that radio-tagged coho salmon smolts approached the intake structure on their first and repeat encounters in the upper 13.8 meters of the water column, typically on the north side. However, most radio-tagged coho resided on the south side of the intake, indicating in a southerly movement after initial contact with the intake structure.

4.14A.5.7 Detection Efficiency

Researchers compared detections by fixed station receivers at the forebay of Swift No. 1 and boat tracking surveys in Zone 6 of Swift Reservoir. The aerial system accounted for 100 percent of the fish that were detected by either the underwater system or mobile surveys in Zone 6 (Table 4.14A-7). The underwater system recorded 88 percent (48 of 54) of the fish detected by the aerial system. Mobile surveys in Zone 6 detected 68 percent (37 of 54) of the fish detected by the aerial system. However, boat surveys identified 2 fish that were not detected on the underwater antenna system. The difference in detection efficiency for fixed station sites was not unexpected considering that the aerial antennas had a much larger detection zone than the underwater antenna array in the forebay. Furthermore, boat surveys only capture a small time interval in Zone 6, while the fixed-aerial system operated continuously.

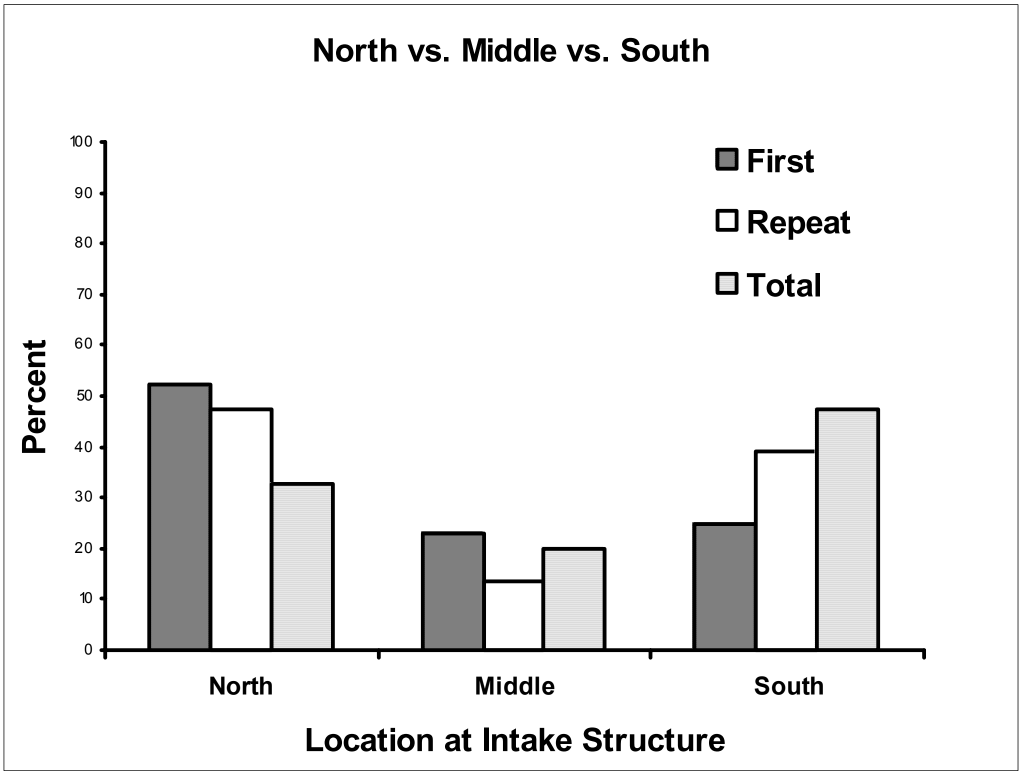


Figure 4.14A-8. The location of first, repeat and total detections at the intake structure of Swift No. 1 Dam.

The comparison of efficiency for different telemetry techniques helped confirm the application of these data for analysis of behavior and survival. The comparison of underwater and aerial detection efficiency showed that underwater antennas have too limited a detection area to assess survival. Clearly, some of the fish that were not detected on the underwater system survived migration through the reservoir. Likewise, the aerial system would not be the best indicator for travel time or arrival distribution if some of the fish never approached the intake structure and would not be available for a collection device. Mobile surveys were never intended to assess survival, travel time or arrival distribution; instead, the purpose of the mobile surveys was to assess reservoir behavior. However, if some portion of the fish detected by mobile surveys in zone 6 had not been detected by the aerial system, then an adjustment could be made to reservoir survival.

4.14A.5.8 Fish Passage at Swift No. 1 Dam

During the course of the study, the tailrace telemetry system detected no radio-tagged fish downstream from Swift No. 1 Dam, indicating that none of the fish passed the dam. Review of detections for all 60 radio-tagged fish by the aerial and underwater forebay systems, mobile boat surveys, and the tailrace mobile survey indicate similar results.

However, normal destruction tests conducted on the model MCFT-3GM are only to 6-atmosphere of pressure or about 50.3 meters (165 ft.) of depth. The pressure encountered in the penstock at Swift No. 1 could be as much as 11-atmospheres of pressure or about 103.6 meters (340 ft.) of depth. Clearly, without destruction tests to 11-atmospheres, no positive result on passage can be assured.

4.14A.6 Discussion

4.14A.6.1 Reservoir Survival and Migration

The minimum survival rate for the population of radio-tagged hatchery coho salmon juveniles through the Swift Reservoir was 90.0 percent. This estimate represents the absolute survival minimum since it does not account for mortality associated with effects of collection, handling or tagging, nor does it account for tag failure and detection efficiencies of telemetry systems that are less than 100 percent. In addition to the relatively short travel time through the reservoir, the minimum survival estimate suggests that the radio-tagged fish successfully traversed the reservoir, and were detected at a common location within 300 meters of the intake structure at the dam.

The lack of detections in the canal downstream from the dam, the minimal number of detections on the lower array at the intake structure, and the observed upstream movement through the reservoir after detection near the dam, all indicate that fish do not readily pass Swift No. 1. In effect, the dam serves as a barrier to downstream migration. Although no formal studies of entrainment had been conducted at Swift No. 1 at the time of this study (PacifiCorp and Cowlitz PUD 2000), the lack of fish passage documented by this radio telemetry study may indicate that the deep-water penstock at Swift No. 1 does not effectively entrain migrant coho salmon smolts.

Despite the lack of observed passage at the dam, the large proportion of radio-tagged fish detected near the intake structure holds promise for the successful deployment of a smolt-collection device. Results suggest that if a collection device sampled the upper 13.8 meters of the water column, as many as 95.8 percent (46/48) of the downstream migrants that were detected by the underwater antenna system, 80 percent (48/60) would be susceptible to collection. Therefore, 77 percent of the fish released (46/60) would be susceptible to collection. Furthermore, the observed repeat visits by radio-tagged fish, and the length of time spent near the intake structure suggests that multiple capture opportunities would be present.

Capture histories of radio-tagged fish at the intake structure also demonstrate that the majority of fish were detected in the northern array, either during the first or subsequent visits. The fact that the majority of overall detections were in the southern array, an indicator of the length of time radio-tagged fish spent in any given array, indicates that the fish move south after initial contact with the intake structure. This suggests that a collection device would best be orientated with a north-facing entrance.

4.14A.6.2 Detection Efficiencies

One of the objectives of this study was to assess the detection efficiencies of the various telemetry systems and methods used in this study. In part, this evaluation confirms proper operation of the system and validates the results due to detections by multiple systems and methods. However, the primary purpose of this objective was to assess the utility of these systems in the event of subsequent research.

Generally, all of the systems and methods performed as well as anticipated. The mobile boat surveys detected 96.7 percent of the tagged fish during one or more surveys, and were instrumental in the observation of upstream reservoir movement after detection at the dam. The aerial system at the dam detected 90.0 percent of the radio-tagged fish released at the head of the reservoir, and 100 percent of the fish detected by the underwater system and those detected in Zone 6 during mobile surveys. Assuming that some reservoir-related mortality occurred, it indicates that the efficiency of this system approached 100 percent. Since not all of the fish detected by this system were in turn detected in Zone 6 by the mobile surveys, nor by the underwater system, the aerial system appears ideally suited to assess the survival rate of radio-tagged fish through the reservoir.

Although the underwater array at the intake structure did not detect all of the fish that were recorded by the aerial system, it should not be assumed that this system operated less efficiently. The discrepancy in detections is likely due to the large detection area of the aerial system relative to the underwater array. The underwater array allowed detailed assessments of fish movement at the intake structure that cannot be made with data from the aerial system.

Because no radio-tagged fish passed through the dam, the tailrace aerial system efficiency cannot be ascertained. However, the fact that no radio-tagged fish were detected by this system is extremely valuable in confirming reservoir and forebay observations that indicated a lack of passage.

The main conclusions of this study are:

- The minimum survival estimate for the radio-tagged hatchery population of coho salmon smolts through the Swift Reservoir was 90 percent.
- The median travel time through the reservoir was relatively short at 3.6 days, with a range of 1.0 to 22.6 days. The median migration rate to the project intake was 5.2 km/day and varied from 0.8 km/day to 19.1 km/day.
- After detection at the dam, many of the radio-tagged fish were detected during boat surveys upstream of the project, indicating up-reservoir movement.
- No radio-tagged fish were detected downstream from Swift Dam, indicating that the dam may serve as a barrier to downstream migration.

- Of the fish detected at the intake structure of the dam, 95.8 percent were initially detected in the upper 13.8 meters of the water column, and 92.7 percent were detected at depths less than 13.8 meters during subsequent visits.
- Of the fish detected at the intake structure of the dam, most were first detected in the northern array during the first and subsequent visits 52.1 percent and 47.5 percent, respectively.
- On average, radio-tagged fish visited the intake structure 8.1 times.
- Finally the behavior and survival of coho salmon smolts to Swift Dam suggest that a surface-oriented collection trap may be used to bypass downstream coho migrants.

4.14A.7 Schedule

Study objectives for assessment of migratory behavior of coho salmon in Swift Reservoir are complete. In part, this study has established a framework for continued assessment of migratory behavior for other juvenile salmonids. In spring of 2002, the initial plan is to use radiotelemetry to study migratory behavior of radio-tagged juvenile hatchery chinook salmon in conjunction with deployment of a Merwin trap. Complimentary to the 2002 study, plans are currently being developed to use an external tag to mark downstream migrants that originate from the North Fork Lewis River upstream from Swift Reservoir. That work will provide additional information on behavior of juvenile chinook salmon in Swift Reservoir.

4.14A.8 References

PacifiCorp and Cowlitz PUD. 2000. Initial Information Package (IIP) for the Lewis River Projects. Prepared for PacifiCorp, Portland, Oregon, and Cowlitz County PUD No. 1, Longview, Washington.

Sandercock, F. K. 1991. Life history of coho salmon. Pages 395-446, in: C. Croot and L. Margolis, editors. Pacific Salmon Life Histories. UBC Press, University of British Columbia, Vancouver, BC.

Stevenson, J.R., A.E. Giorgi, W.R. Koski, K.K. English, and C.A. Grant. 1997. Evaluation of juvenile spring chinook and steelhead migratory patterns at Rocky Reach and Rock Island dams using radio telemetry techniques, 1996. Report prepared for Public Utility District No. 1 of Chelan County. 18 pp. plus appendices.

Summerfelt, R.C., L.S. Smith. 1990. Anesthesia, Surgery and Related Techniques. Pages 213-263 in: C. B. Schreck and P. B. Moyle, editors. Methods for Fish Biology. American Fisheries Society, Bethesda, Maryland.

4.14A.9 Comments and Responses on Draft Report

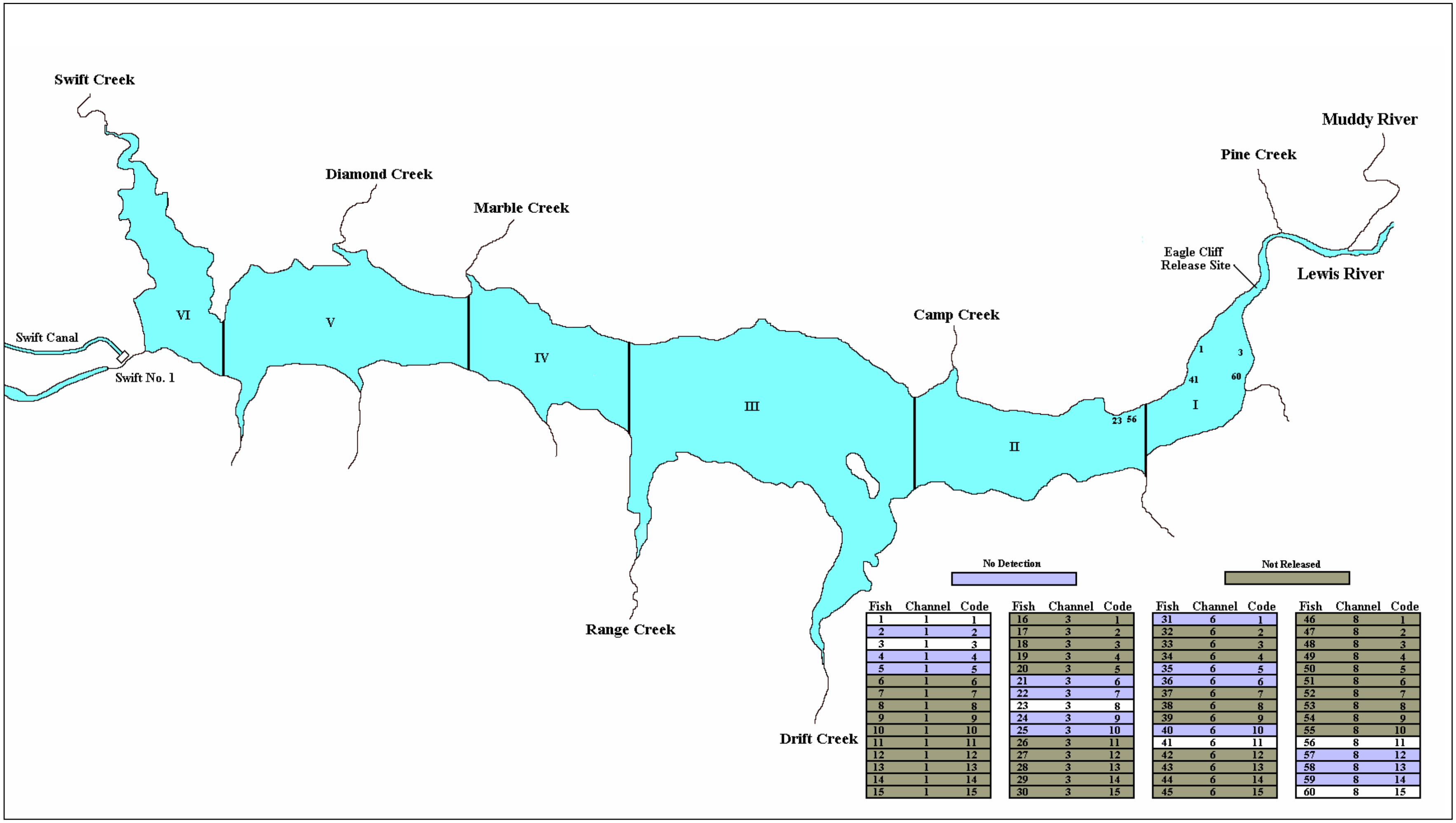
This section presents stakeholder comments provided on the draft report, followed by the Licensees' responses. The final column presents any follow-up comment offered by the stakeholder and in some cases, in italics, a response from the Licensees.

Commenter	Volume	Page/ Paragraph	Statement	Comment	Response	Response to Responses
WDFW – JIM BYRNE	1	AQU 14A	Coho Smolts in Swift.	Need a trap at dam to complete this study about reservoir survivals and trapping potential.	The objectives of this study are to 1) assess minimum survival rates of radio-tagged coho to Swift Dam and 2) describe migratory behavior within Swift Reservoir. Trap development, installation and evaluation depend on the results of AQU-17 (which will be available by October 2002).	It would have been nice to compare the survivals of study fish to all coho smolts transiting the reservoir. Smolts were available but a collection facility was not.
WDFW – KAREN KLOEMPKEN	1	AQU 14A-1 para 1, first sentence	Sentence structure.	May want to change "upstream-most project" to "most-upstream project" thus making the sentence more readable.	This editorial change will be made.	
WDFW – KAREN KLOEMPKEN	1	AQU 14A-17 Fig. 4.14A-6	Both figures in Figure 4.14A-6.	Both figures are labeled as "Underwater Detection." There isn't any figure for aerial detection. They also look like the same measurements, just different patterns in the bars.	Figures will be corrected.	
WDFW – KAREN KLOEMPKEN	1	AQU 14A-19 para 3, sixth sentence	Missing word(s) in sentence.	The beginning of the sentence doesn't sound right. Is there something missing from the outside of the parenthesis? "Only (8 percent) of fish"? If the info within the parenthesis is removed the sentence doesn't make sense.	The following sentence will be inserted: "During mobile surveys, detection of fish in the forebay accounted for only eight-percent of fish detections made in Swift Reservoir."	

Commenter	Volume	Page/ Paragraph	Statement	Comment	Response	Response to Responses
WDFW – KAREN KLOEMPKEN	1	AQU 14A-26 Figure 4.14A-7	Figure 4.14A-7.	The bar pattern for "Repeat" detections in the top array doesn't match the legend and bottom array patterns.	Figure will be corrected.	
WDFW – KAREN KLOEMPKEN	1	AQU 14A-27 Figure 4.14A-8	Figure 4.14A-8.	Figure is missing the legend for the bar patterns.	Figure will be corrected.	
WDFW – KAREN KLOEMPKEN	1	AQU 14A-28 para 2	Fish entrainment.	This study cannot, without an entrainment study, "indicate that the deep-water penstock at Swift No. 1 does not effectively entrain migrant coho salmon smolts." The lack of fish passage documented by the radio telemetry study would indicate the limits of the study results. Not expand them beyond their limitations.	This is not an entrainment study. However, Table 4.14A-8 clearly shows that the radio-tagged coho were more surface-oriented during the time of the study (normal full pool). That is why we said, "…lack of fish passage documented by this radio telemetry study **may indicate** that the deep-water penstocks at Swift No. 1 do not effectively entrain migrant coho salmon smolts. We used the word **"may"** only to express the possibility. Results of the entrainment study will need to be evaluated for timing of coho entrainment and or migration.	

AQU 14A Appendix 1

Location of Radio-tagged Juvenile Coho Salmon in Swift Reservoir



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Fish	Channel	Code
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Fish	Channel	Code
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43	6	13
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Fish	Channel	Code
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55	8	10
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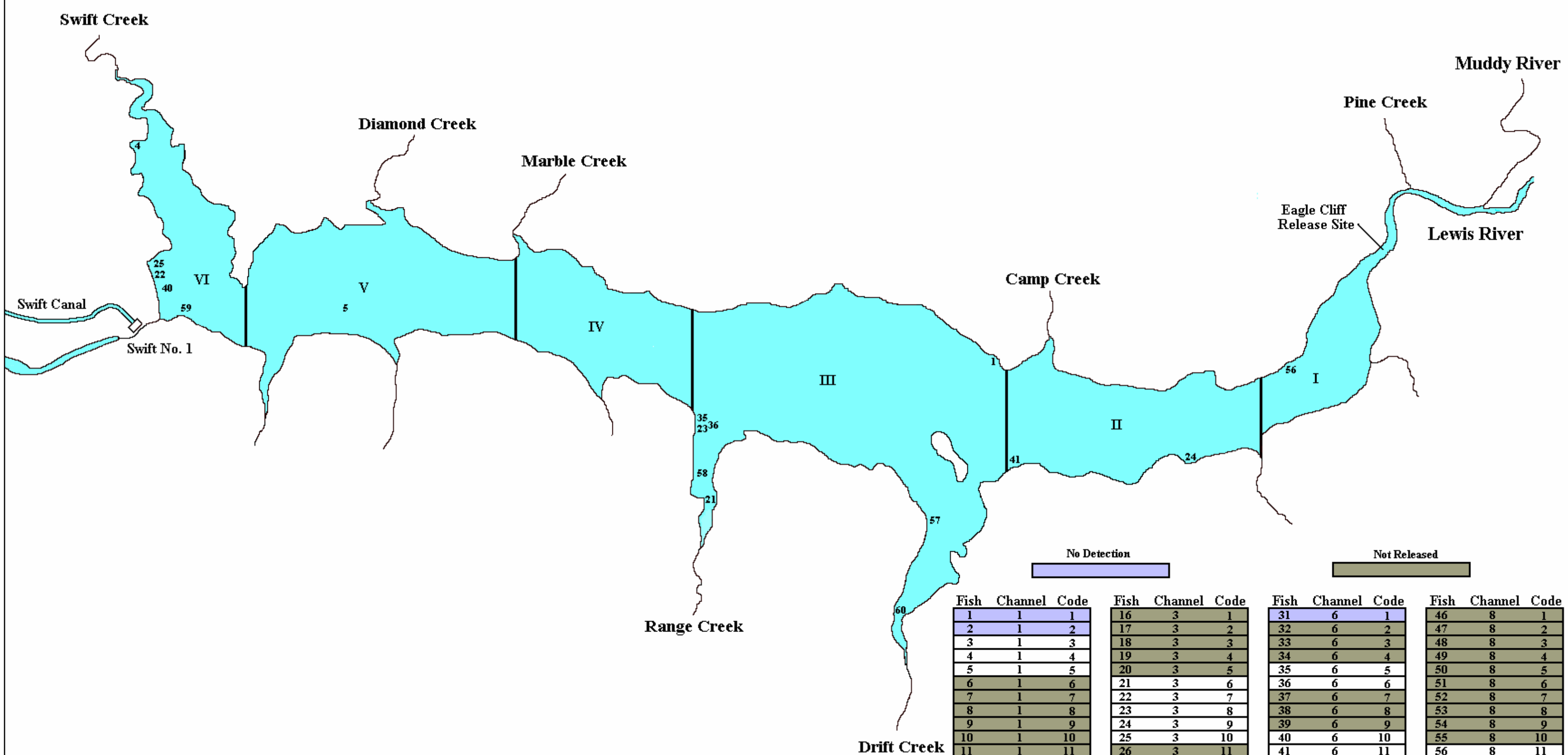
Location of radio-tagged juvenile coho salmon in Swift Reservoir during boat tracking survey on 5/18/01.



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Fish	Channel	Code
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Fish	Channel	Code
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42	6	12
43	6	13
44	6	14
45	6	15

Fish	Channel	Code
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47	8	2
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53	8	8
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55	8	10
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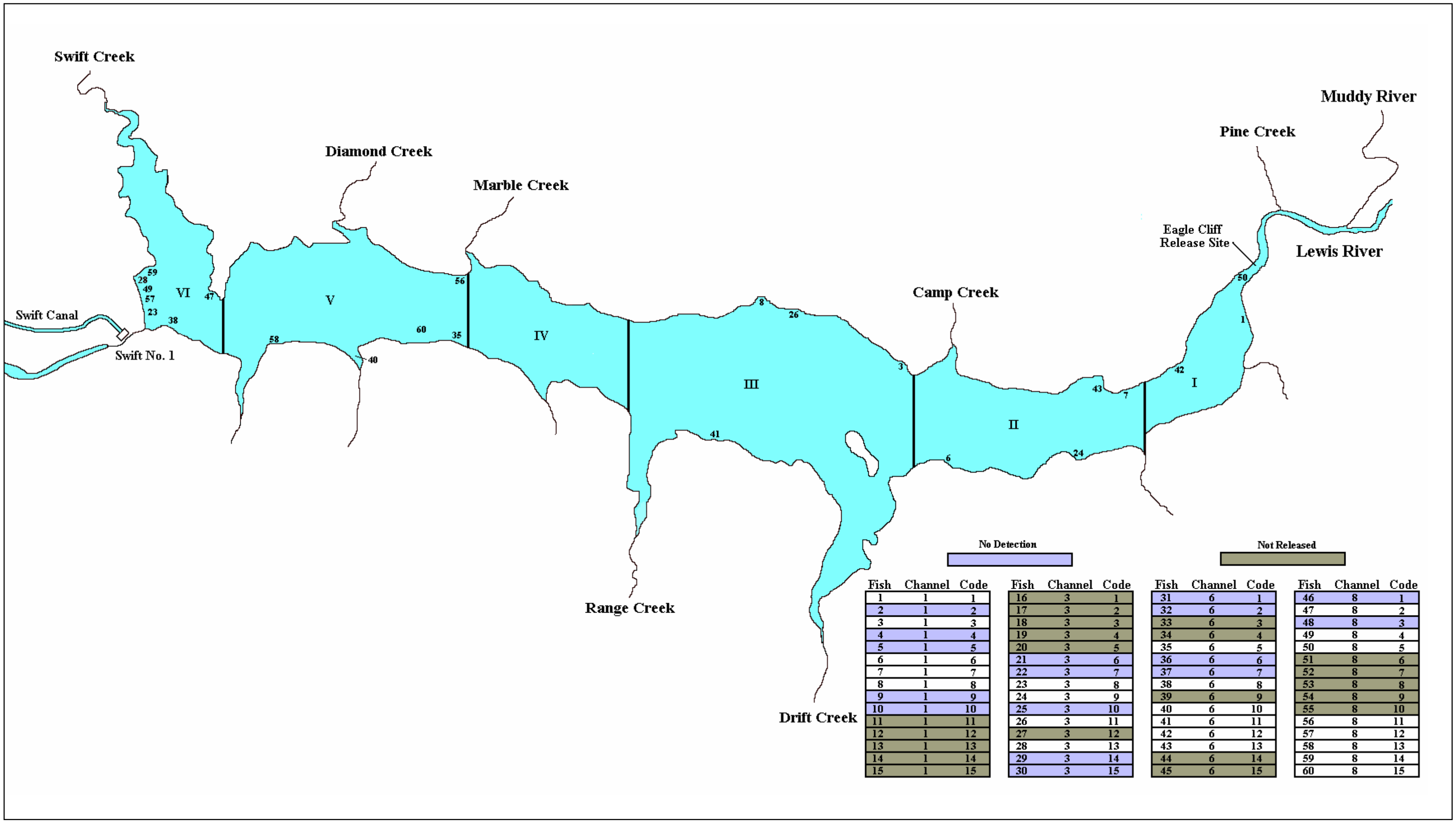
60	8	15

Location of radio-tagged juvenile coho salmon in Swift Reservoir during boat tracking survey on 5/19/01.



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14	1	14	29	3	14	44	6	14	59	8	14
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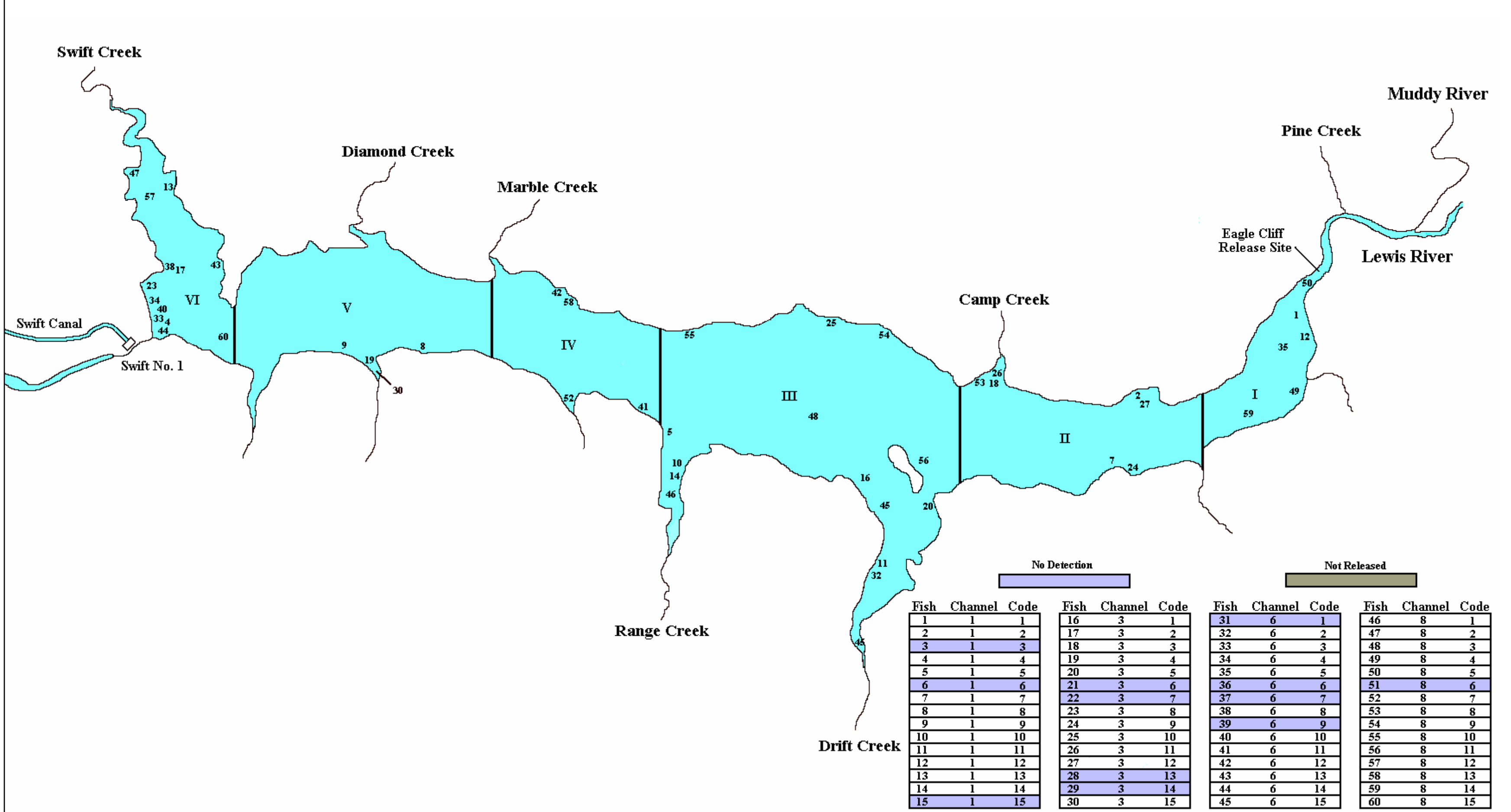
Location of radio-tagged juvenile coho salmon in Swift Reservoir during boat tracking survey on 5/22/01.



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12	1	12	27	3	12	42	6	12	57	8	12
13	1	13	28	3	13	43	6	13	58	8	13
14	1	14	29	3	14	44	6	14	59	8	14
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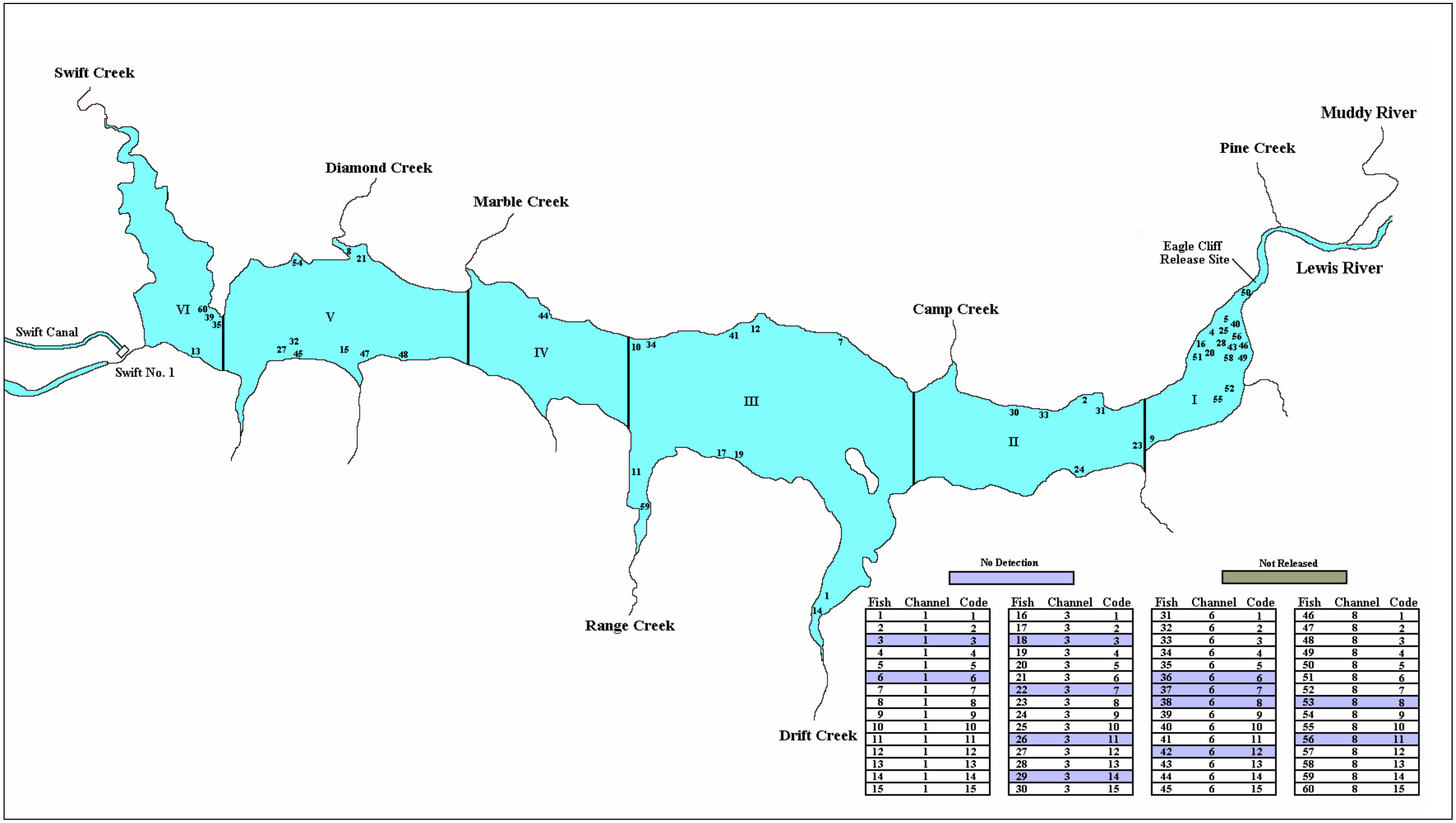
Location of radio-tagged juvenile coho salmon in Swift Reservoir during boat tracking survey on 5/26/01.



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14	1	14	29	3	14	44	6	14	59	8	14
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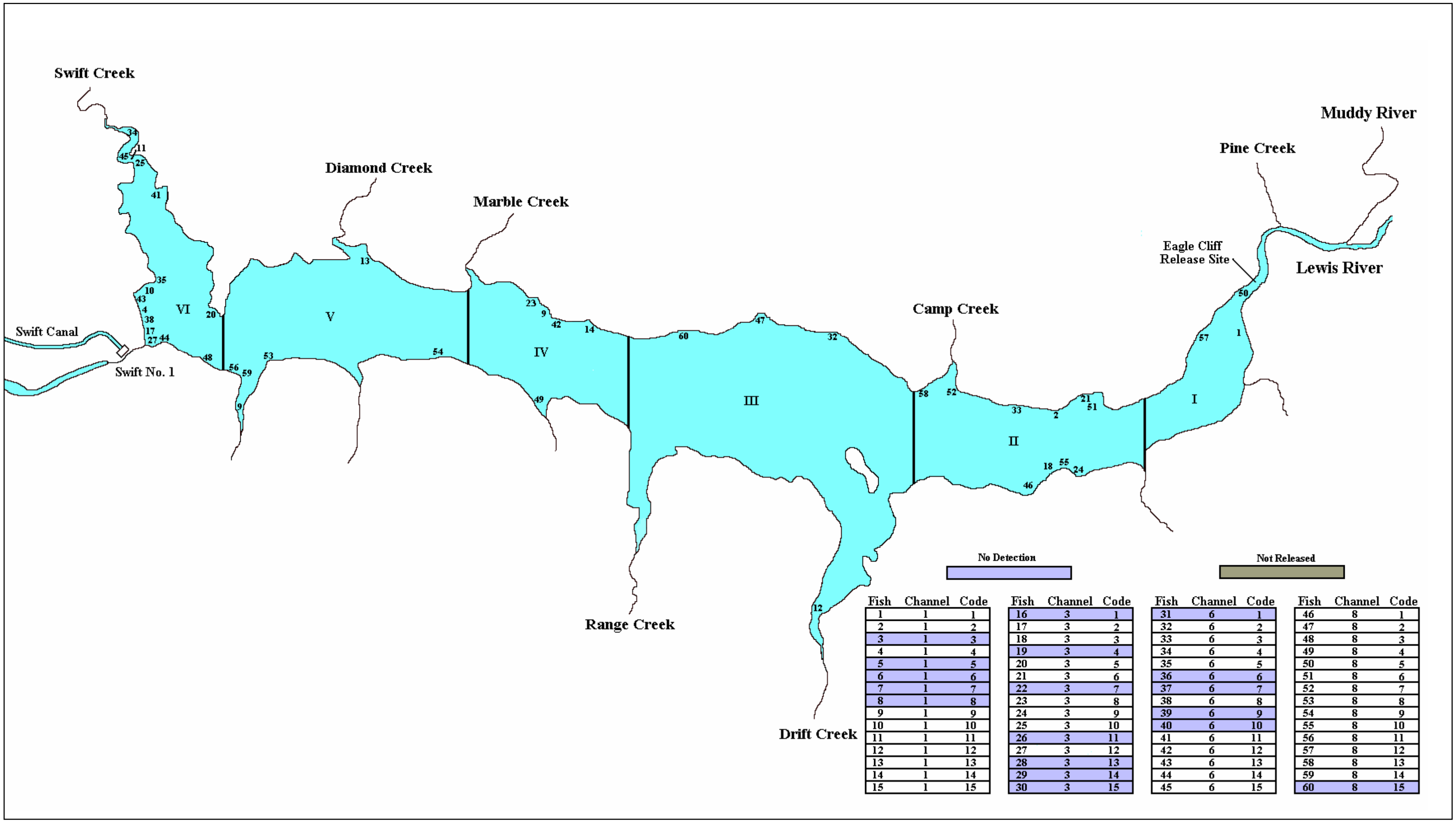
Location of radio-tagged juvenile coho salmon in Swift Reservoir during boat tracking survey on 5/28/01.



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12	1	12	27	3	12	42	6	12	57	8	12
13	1	13	28	3	13	43	6	13	58	8	13
14	1	14	29	3	14	44	6	14	59	8	14
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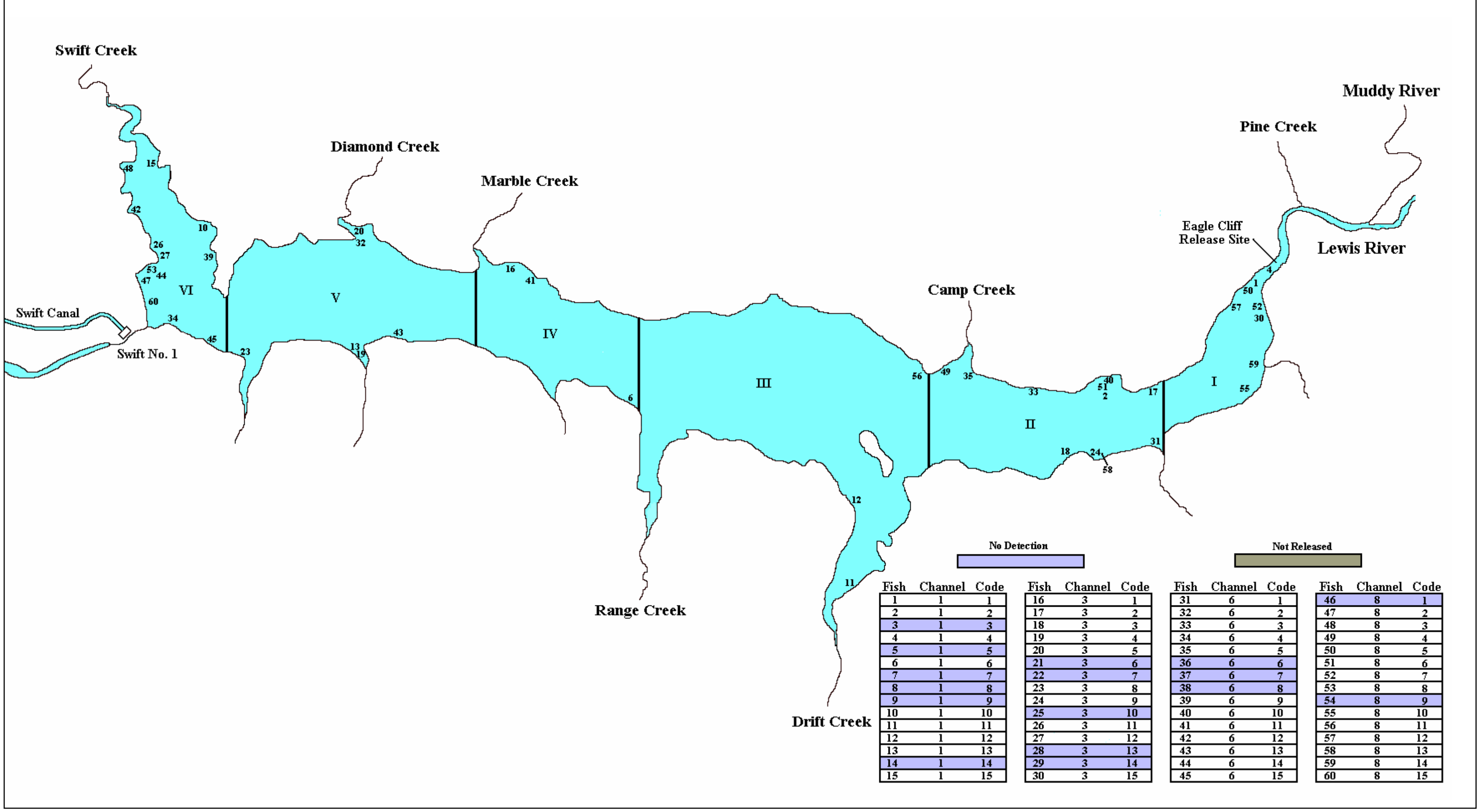
Location of radio-tagged juvenile coho salmon in Swift Reservoir during boat tracking survey on 5/31/01.



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9	1	9
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11	1	11
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15	1	15

Fish	Channel	Code
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30	3	15

Fish	Channel	Code
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Fish	Channel	Code
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54	8	9
55	8	10
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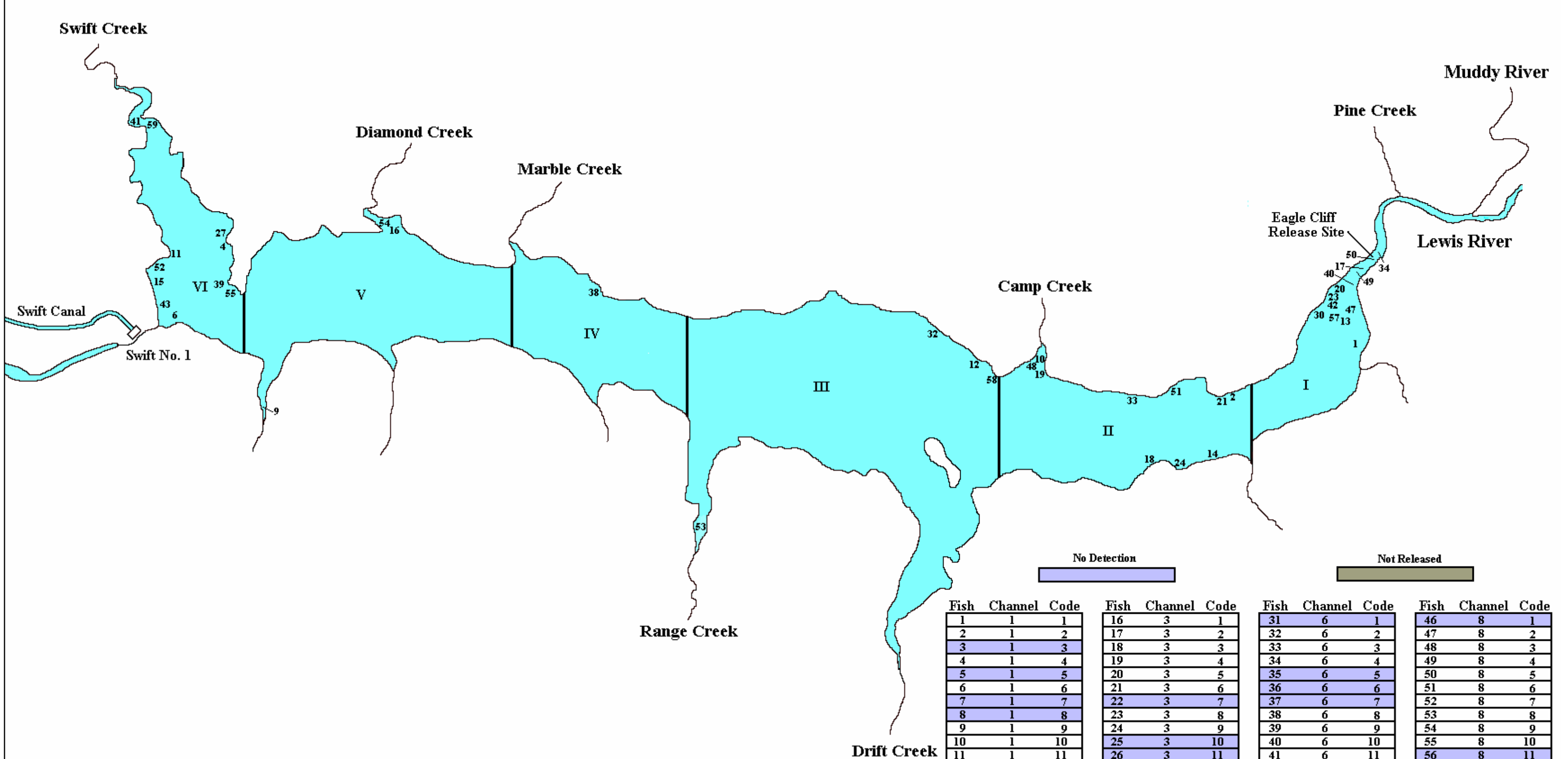
59	8	14
60	8	15

Location of radio-tagged juvenile coho salmon in Swift Reservoir during boat tracking survey on 6/4/01.



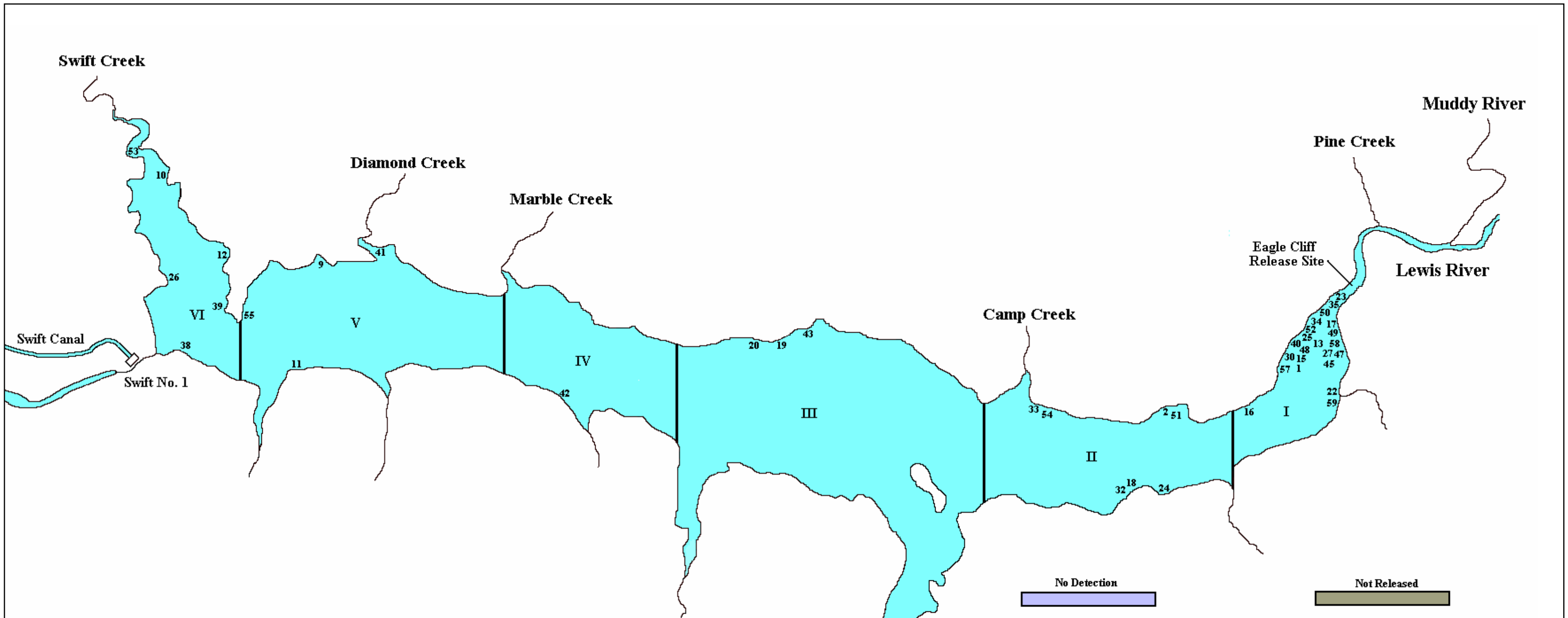
Fish	Channel	Code
1	1	1
2	1	2
3	1	3
4	1	4
5	1	5
6	1	6
7	1	7
8	1	8
9	1	9
10	1	10
11	1	11
12	1	12
13	1	13
14	1	14
15	1	15

Fish	Channel	Code
16	3	1
17	3	2
18	3	3
19	3	4
20	3	5
21	3	6
22	3	7
23	3	8
24	3	9
25	3	10
26	3	11
27	3	12
28	3	13
29	3	14
30	3	15

Fish	Channel	Code
31	6	1
32	6	2
33	6	3
34	6	4
35	6	5
36	6	6
37	6	7
38	6	8
39	6	9
40	6	10
41	6	11
42	6	12
43	6	13
44	6	14
45	6	15

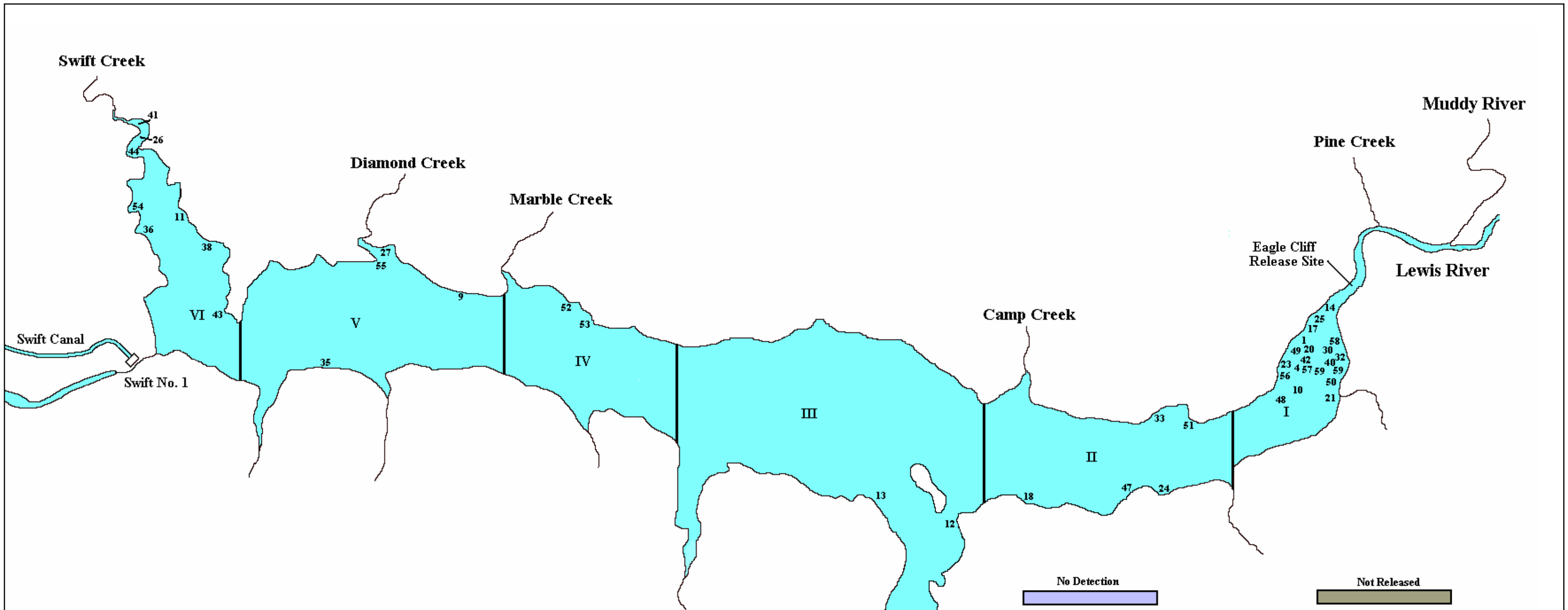
Fish	Channel	Code
46	8	1
47	8	2
48	8	3
49	8	4
50	8	5
51	8	6
52	8	7
53	8	8
54	8	9
55	8	10
56	8	11
57	8	12
58	8	13
59	8	14
60	8	15

Location of radio-tagged juvenile coho salmon in Swift Reservoir during boat tracking survey on 6/8/01.



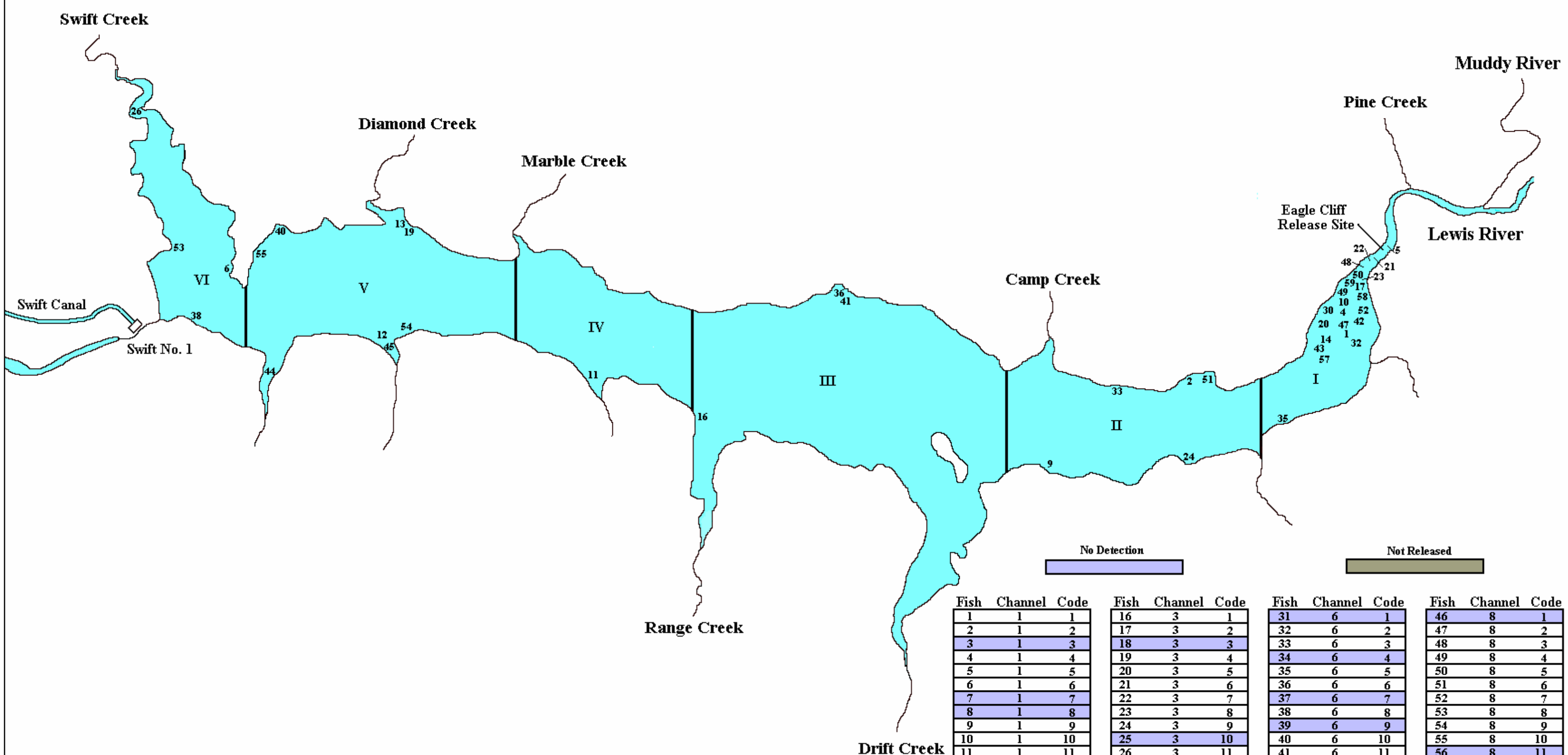
Fish	Channel	Code	Fish	Channel	Code	Fish	Channel	Code	Fish	Channel	Code
1	1	1	16	3	1	31	6	1	46	8	1
2	1	2	17	3	2	32	6	2	47	8	2
3	1	3	18	3	3	33	6	3	48	8	3
4	1	4	19	3	4	34	6	4	49	8	4
5	1	5	20	3	5	35	6	5	50	8	5
6	1	6	21	3	6	36	6	6	51	8	6
7	1	7	22	3	7	37	6	7	52	8	7
8	1	8	23	3	8	38	6	8	53	8	8
9	1	9	24	3	9	39	6	9	54	8	9
10	1	10	25	3	10	40	6	10	55	8	10
11	1	11	26	3	11	41	6	11	56	8	11
12	1	12	27	3	12	42	6	12	57	8	12
13	1	13	28	3	13	43	6	13	58	8	13
14	1	14	29	3	14	44	6	14	59	8	14
15	1	15	30	3	15	45	6	15	60	8	15

Location of radio-tagged juvenile coho salmon in Swift Reservoir during boat tracking survey on 6/11/01.



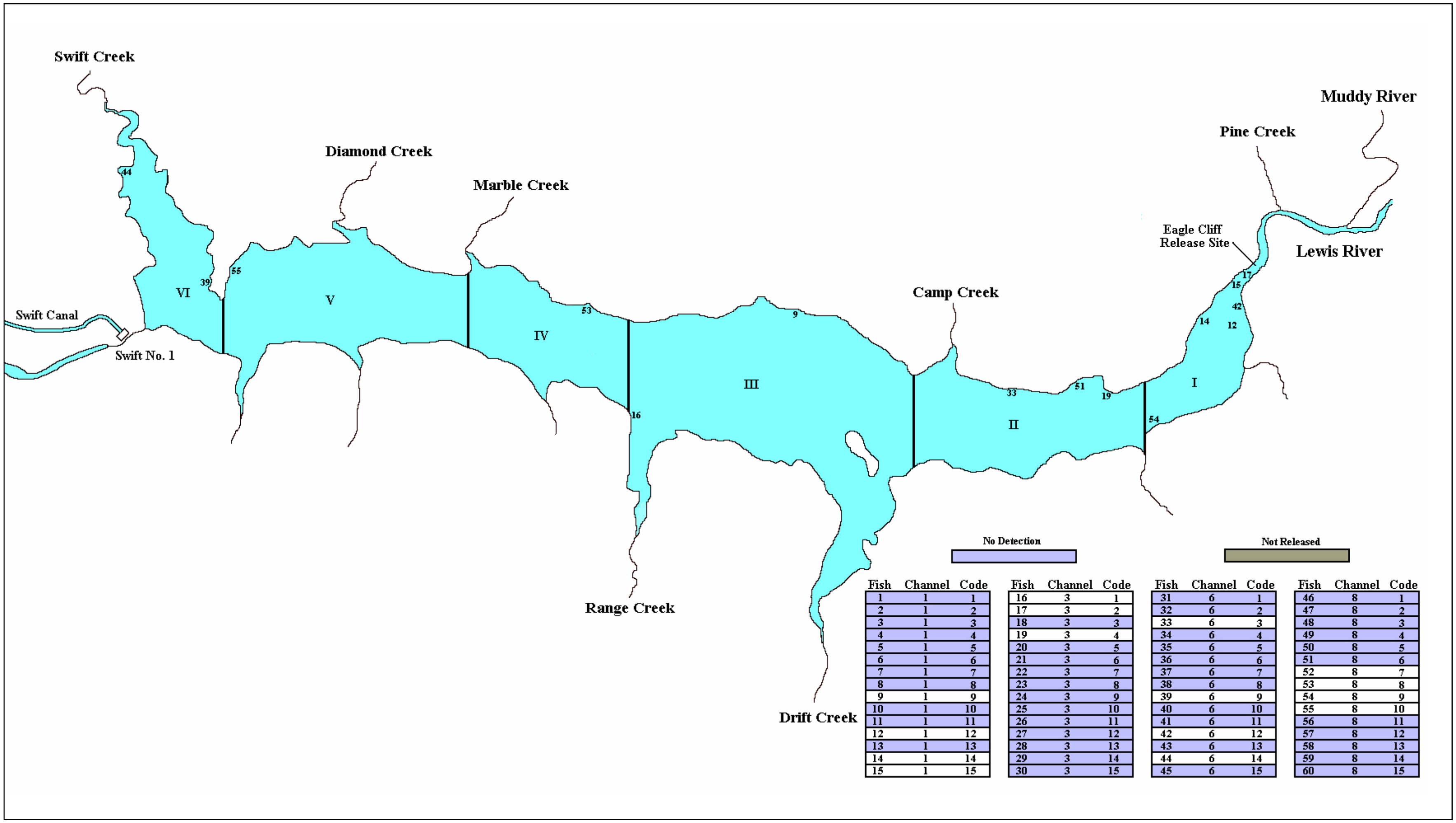
Fish	Channel	Code	Fish	Channel	Code	Fish	Channel	Code	Fish	Channel	Code
1	1	1	16	3	1	31	6	1	46	8	1
2	1	2	17	3	2	32	6	2	47	8	2
3	1	3	18	3	3	33	6	3	48	8	3
4	1	4	19	3	4	34	6	4	49	8	4
5	1	5	20	3	5	35	6	5	50	8	5
6	1	6	21	3	6	36	6	6	51	8	6
7	1	7	22	3	7	37	6	7	52	8	7
8	1	8	23	3	8	38	6	8	53	8	8
9	1	9	24	3	9	39	6	9	54	8	9
10	1	10	25	3	10	40	6	10	55	8	10
11	1	11	26	3	11	41	6	11	56	8	11
12	1	12	27	3	12	42	6	12	57	8	12
13	1	13	28	3	13	43	6	13	58	8	13
14	1	14	29	3	14	44	6	14	59	8	14
15	1	15	30	3	15	45	6	15	60	8	15

Location of radio-tagged juvenile coho salmon in Swift Reservoir during boat tracking survey on 6/16/01.



Fish	Channel	Code	Fish	Channel	Code	Fish	Channel	Code	Fish	Channel	Code
1	1	1	16	3	1	31	6	1	46	8	1
2	1	2	17	3	2	32	6	2	47	8	2
3	1	3	18	3	3	33	6	3	48	8	3
4	1	4	19	3	4	34	6	4	49	8	4
5	1	5	20	3	5	35	6	5	50	8	5
6	1	6	21	3	6	36	6	6	51	8	6
7	1	7	22	3	7	37	6	7	52	8	7
8	1	8	23	3	8	38	6	8	53	8	8
9	1	9	24	3	9	39	6	9	54	8	9
10	1	10	25	3	10	40	6	10	55	8	10
11	1	11	26	3	11	41	6	11	56	8	11
12	1	12	27	3	12	42	6	12	57	8	12
13	1	13	28	3	13	43	6	13	58	8	13
14	1	14	29	3	14	44	6	14	59	8	14
15	1	15	30	3	15	45	6	15	60	8	15

Location of radio-tagged juvenile coho salmon in Swift Reservoir during boat tracking survey on 6/18/01.



Fish	Channel	Code	Fish	Channel	Code	Fish	Channel	Code	Fish	Channel	Code
1	1	1	16	3	1	31	6	1	46	8	1
2	1	2	17	3	2	32	6	2	47	8	2
3	1	3	18	3	3	33	6	3	48	8	3
4	1	4	19	3	4	34	6	4	49	8	4
5	1	5	20	3	5	35	6	5	50	8	5
6	1	6	21	3	6	36	6	6	51	8	6
7	1	7	22	3	7	37	6	7	52	8	7
8	1	8	23	3	8	38	6	8	53	8	8
9	1	9	24	3	9	39	6	9	54	8	9
10	1	10	25	3	10	40	6	10	55	8	10
11	1	11	26	3	11	41	6	11	56	8	11
12	1	12	27	3	12	42	6	12	57	8	12
13	1	13	28	3	13	43	6	13	58	8	13
14	1	14	29	3	14	44	6	14	59	8	14
15	1	15	30	3	15	45	6	15	60	8	15

Location of radio-tagged juvenile coho salmon in Swift Reservoir during boat tracking survey on 6/29/01.