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4.17 BEHAVIOR OF SALMONID SMOLTS AT SWIFT DAM USING 3-DIMENSIONAL TRACKING WITH ACOUSTIC TAGS (AQU 17)

PacifiCorp and Cowlitz County PUD initiated a study in spring of 2002 to assess the movements and behavior of salmonid smolts in the forebay of Swift No. 1 Dam. The importance of this study among others is to contribute to the evaluation and decision making process pertaining to the reintroduction of anadromous species upstream of Swift Dam. As a part of that evaluation process the main purpose of this study was to investigate the response of Chinook salmon (*Oncorhynchus tshawytscha*) and coho salmon (*O. kisutch*) smolts to different hydro-operations at Swift No. 1 Dam. A prior study using radiotelemetry showed that individual fish tend to congregate near the powerhouse intake tower (Miller et. al 2001). Hydro-operation during the study provided an opportunity to assess how salmonid smolts would respond to flow near the project and contribute to understanding the feasibility of providing fish collection and passage at Swift No. 1.

The operational characteristics present during the study were divided into two categories that included discharge at the dam during spill or non-spill events. During spill events, discharge at the project was provided to approximate how fish might respond to a concentrated surface flow similar to a screened bypass or surface collector. During spill periods, both spill and turbine generation occurred. Non-spill events included only those periods when discharge at the project was provided by turbine generation or when no discharge was present at all.

To document movement and behavior of smolts in the forebay of Swift No. 1, hatchery Chinook and coho salmon were tracked using acoustic tag technology. The acoustic tag system allows researchers to track fish movements 3-dimensionally in areas of interest. Thus, acoustic tags provide a means to evaluate movement under different operational conditions or treatments present in the forebay of Swift No. 1 Dam. Monitoring acoustically-tagged fish combined with a Doppler system that measured flow conditions during both a spill and non-spill events provided the template to evaluate fish behavior.

4.17.1 Study Objectives

The objective of the study was to document the behavior and movements of juvenile Chinook and coho salmon smolts in the forebay of Swift No.1 Dam under different hydro-operations. The specific objectives were:

1) Describe and assess smolt behavior during normal operating conditions. Evaluate the movement and behavior of salmon smolts in the forebay of Swift No. 1 when turbine generation is the only discharge present at the dam.
2) Describe and assess smolt behavior when spill is provided. Evaluate the movement and behavior of salmonid smolts in the forebay of Swift No. 1 when spill discharge is held at 2000 cfs for a 24 hour period, capturing both day and night treatment periods.

3) Characterize forebay current patterns near the dam during periods of spill and non-spill, and provide a three-dimensional image of flow vectors in the forebay.

4.17.2 Study Area

The North Fork of the Lewis River originates on the west slope of Mt. Adams and flows southwest for about 145 kilometers (90 miles) before emptying into the Columbia River, approximately 32 kilometers north of Vancouver. There are four projects upstream from the confluence of the Lewis and Columbia rivers. The sequence of the four Lewis River projects is: Merwin, Yale, Swift No. 2 and Swift No. 1 (Figure 4.17-1).

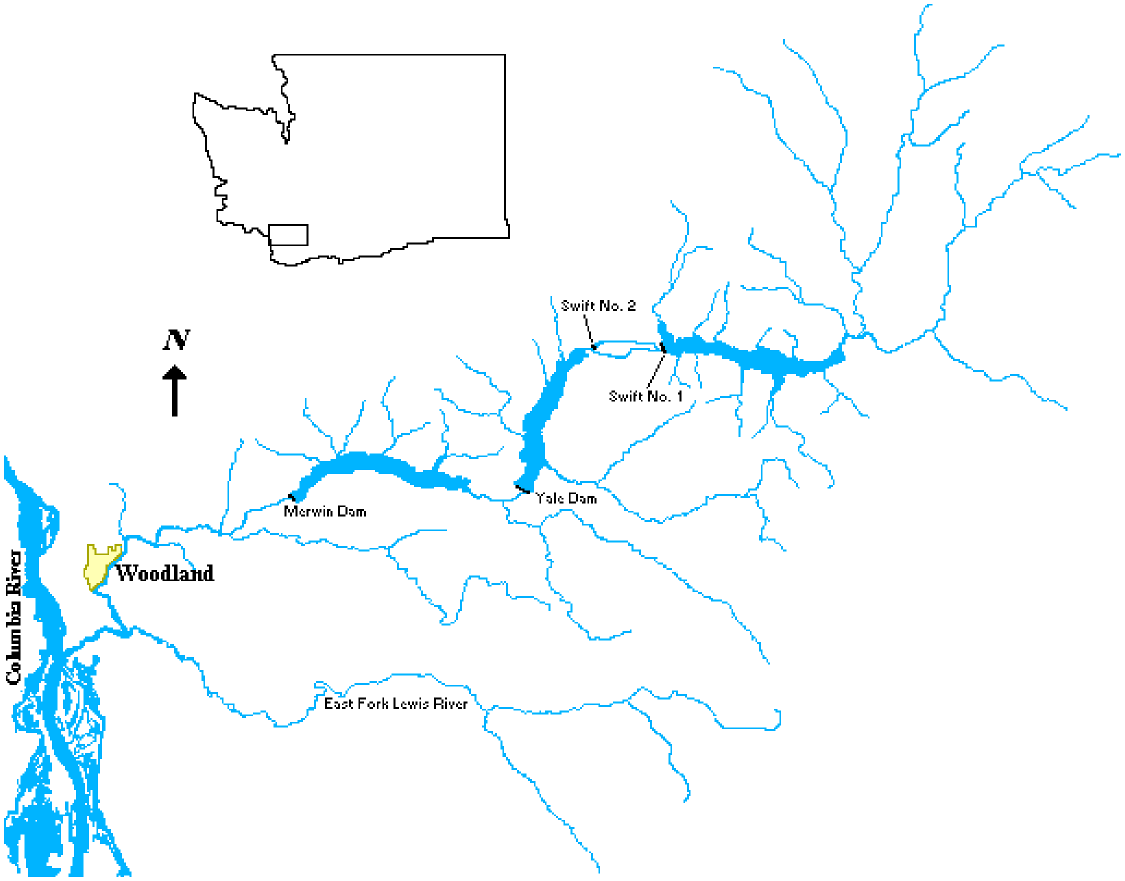


Figure 4.17-1. Location of hydroelectric projects on the North Fork Lewis River.

Swift No. 1 is the most upstream project on the Lewis River and is approximately 72.4 kilometers (45 miles) upstream from the confluence with the Columbia River. Construction of Swift No. 1 Project began in 1956 and was completed by 1958. Swift Dam is 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 three penstocks that supply water to three 70 mw Francis generator units at the powerhouse located at the base of the dam. The intake is 44.3 meters (145 feet) deep (centerline) at a normal full pool elevation of 304.8 meters (1,000 feet) above mean sea level (msl). Swift No. 1 utilizes two 15.2- by-15.5-meter (50- by 51- ft.) taintor gates for spillway overflow (Figure 4.17-2). The taintor gates open from the bottom at a depth 289.6 m. - msl (950 ft.-msl) and have a total overflow capacity of 120,000 cfs at full pool. Swift Reservoir is approximately 18.5 kilometers (11.5 miles) long and has a surface area of about 4,000 acres at full pool. Gross storage capacity of the reservoir is 755,500 acre-feet.

Figure 4.17-2. View of Swift No. 1 Dam displays the two taintor gates and central intake tower.

Pool elevation during the study period (22 March to 16 April 2002) increased from 955.8 to 986.3 ft.-msl (Figure 4.17-3). Pool elevation remained fairly constant (955-957 ft.-msl) for the first 14 days of the study (22 March to 6 April). Thereafter, pool elevation increased about 2.5 feet per day until 16 April.

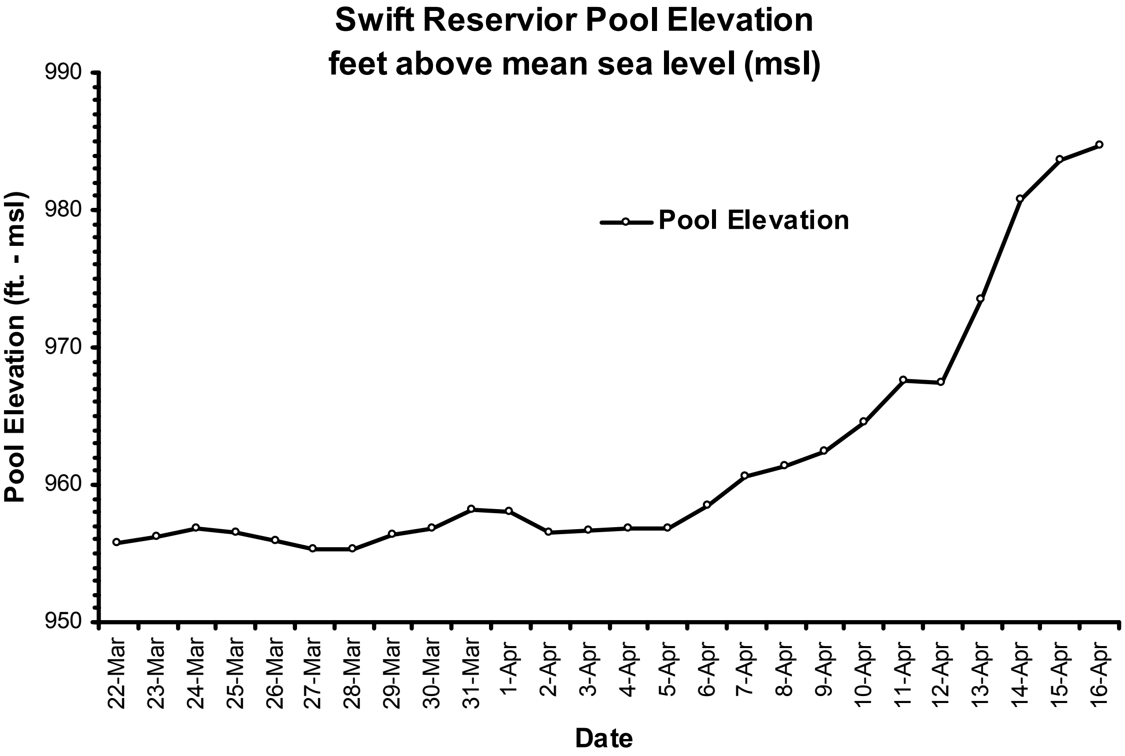


Figure 4.17-3. Swift Reservoir pool elevation (ft.-msl) during the study period from 22 March to 16 April, 2002.

Swift No. 1 Dam is a part of Lewis River complex of hydroelectric units that generally release water for generation based on energy demand, peaking, real-time load following and river and reservoir management. Total hourly discharge at Swift No. 1 during the study varied from 0 to 8,014 (cfs) and was a function of powerhouse operation and periods when spill occurred. Mean daily powerhouse discharge ranged from 0 to 6,950 cfs (Figure 4.17-4). Total discharge at the project was supplemented on two occasions (27 March and 4 April) when a 24 hour spill period (2,000 cfs) was initiated as a test condition to monitor fish movement.

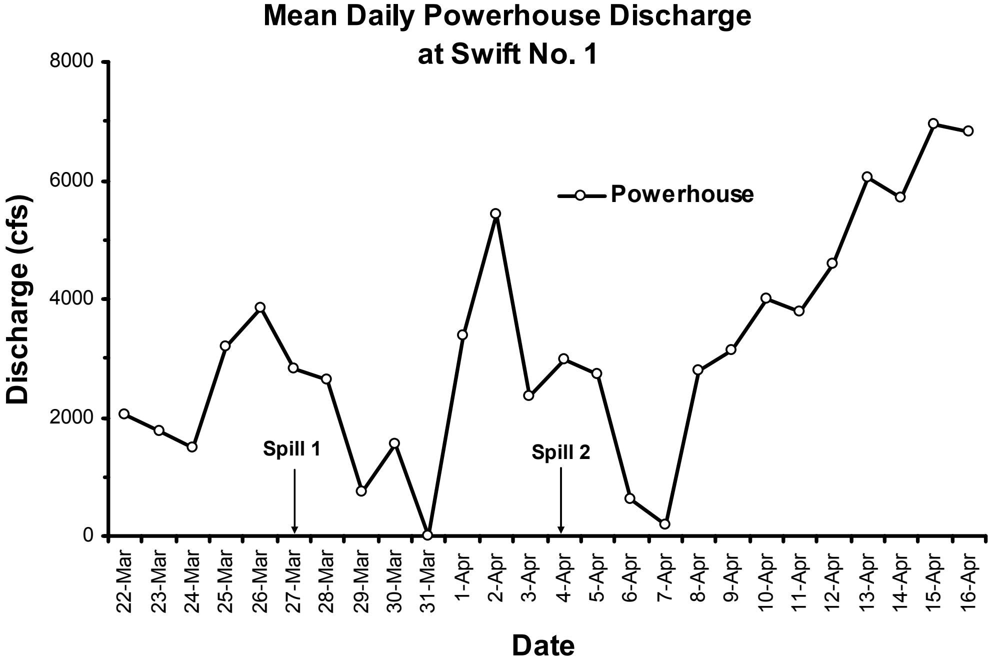


Figure 4.17-4. Mean daily powerhouse discharge at Swift No. 1 during the study period from 22 March to 16 April, 2002.

4.17.3 Methods

4.17.3.1 Experimental Design

We monitored the forebay of Swift No. 1 to document the behavior of acoustically-tagged juvenile Chinook and coho salmon from 22 March to 16 April. We partitioned the study period into spill and non-spill events (five periods) with stable and increasing pool elevation to assess the behavior of juvenile salmonids under different hydro-operation conditions (Table 4.17-1). There was no corresponding period for a spill event with an increasing pool elevation condition. We divided each period into day and night treatments. We used sunrise and sunset reported for Vancouver, WA on 1 April 2002 to partition day and night treatments. Day treatments included those hours of observation from sunrise to sunset (5:50 AM - 6:35 PM PST) and night include hours from sunset to sunrise the following day (6:35 PM- 5:50 AM PST). Each spill period began at 12:00 PM and lasted 24 hours until the next day at 12:00 PM, thus capturing an approximate equal time for day and night treatments.

Table 4.17-1. Experimental groups used to assess the behavior of salmonid smolts under different hydro-operation conditions for spill and non-spill events.

Event	Pool Elevation	Period	Begin	End	Treatments
Non-Spill	Stable	1	3/22/02	3/27/02	Day
					Night
		2	3/28/02	4/4/02	Day
					Night
	Increasing	3	4/5/02	4/16/02	Day
					Night
Spill	Stable	1	3/27/02	3/28/02	Day
					Night
		2	4/4/02	4//5/02	Day
					Night

We compared the behavior between non-spill and spill events and then compared day and night within an event when the pool elevation was stable. The period of non-spill with increasing pool elevation was only compared for day and night treatments within that period.

We released three groups of fish into Swift Reservoir outside the forebay channel. The first group was released into a non-spill condition and was used to evaluate the amount of time needed for fish to travel to the forebay channel. The second and third groups were released into Swift Reservoir at the beginning of a 24 hour-spill period to capture both day and night behavior.

4.17.3.2 Acoustic System

Background

Acoustic tags have been used to monitor fish movement for over 25 years. The majority of tracking studies to date have used manually aimed directional hydrophones. In general, a single hydrophone is mounted in a boat, and the boat follows a tagged fish while it migrates. The detection location is recorded; however, the depth and range from the hydrophone to the fish is not known. In the 1970s attempts were made to use multiple hydrophones to better fix the location of tagged fish. By measuring the difference in arrival time of pings from acoustic tags implanted in fish, the location of each fish can be determined.

The HTI Model 290 system used in this study has the capability to automate the tracking process and thereby fix fish in three dimensions with a high degree of precision. Eight omni-directional hydrophones were used to monitor the forebay of Swift Dam. The hydrophones were placed in known locations and were mapped within a three-dimensional grid. As an acoustic tag passed through the hydrophone array, the difference in the arrival time of each pulse was used to triangulate the exact location of the tag.

Acoustic Tags

The tags selected for use at Swift Dam were HTI 795 series tags. The tags were small, capsule-shaped tags designed to be orally or surgically implanted. The tags were 17.7 mm long and 7 mm in diameter (0.8 x 0.3 inches). The weight in air for each tag was 1.5 g (0.05 oz) and weight in water was 0.8 g (0.03 oz). Transmit power level was approximately 157 dB uPa @ 1 m. Pulse rate and pulse width were programmable. Nominal pulse rate was 1 pulse/sec with a transmit pulse width of 1-3 msec. The useful life of the tag, once activated, was on average 10 to 12 days.

Signal-to-noise performance has been enhanced in the 795-series tags over the previous series through the use of phase-code modulation. This technology allows for higher time resolution for a given signal-to-noise ratio. The tags are programmable to accommodate five different phase-code modulations, with pulse widths ranging from 1 ms to 5 ms. The tags can also be programmed with standard CW pulse widths ranging from 0.1 ms to 10 ms. Through the use of filters in HTI's Acoustic Tag program, the performance can be maximized.

Frequency Selection

Most commercial acoustic tags use frequencies between 50 and 100 kHz; historically 74 kHz has been the most common frequency (Mitson 1978). Two major factors that affect the selection of a transmitting frequency for acoustic tags are the range of detection and size of the tag. In general, as the frequency decreases, both the size of the tag and range of detection increase.

Hydroelectric projects are acoustically noisy over a broad spectrum of frequencies. In general, the ambient noise level decreases with increasing frequencies, since the sounds generated at hydroelectric projects are due primarily to mechanical noise. Results from a 1997 study (HTI 1997) concluded that the best choice for tag frequency at hydroelectric projects was 300-500 kHz (the background noise levels were lower at these frequencies). The tag frequency chosen for this study was 300 kHz.

Hydrophone Deployment

Eight omni-directional hydrophones were installed around the perimeter of the Swift Dam powerhouse forebay (Figure 4.17-5), with a particular focus on the south spill bay. The calculation of the three-dimensional location of the acoustic tags requires that the transmitted signal be detected by four hydrophones that are not located on the same plane. Therefore for this study, six of the hydrophones were mounted near the water surface, while two hydrophones were mounted near the bottom of the forebay at different elevations. Table 4.17-2 presents the X, Y, and Z coordinates of the 8 hydrophones. Moving upstream into the forebay corresponds to an increasing northing and easting value. An increasing Z value corresponds to an increase in elevation in mean sea level.

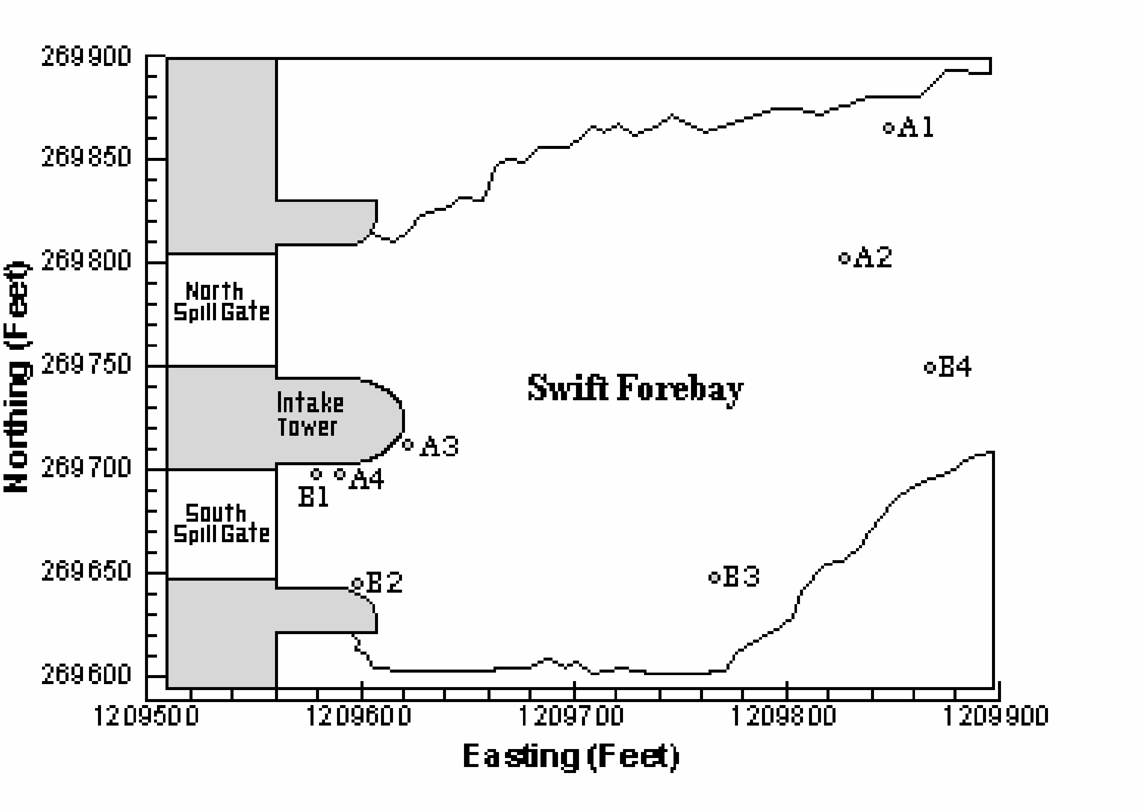


Figure 4.17-5. Location of eight hydrophones used to monitor movement of acoustic-tagged juvenile Chinook and coho.

Table 4.17-2. Location of eight hydrophones placed in the forebay of Swift Dam. Coordinates displayed for X, Y and Z are easting, northing and feet above mean sea level.

	Coordinates			
Hydrophone	**X**	**Y**	**Z**	**Location**
A1	1209848	269870	938	Surface
A2	1209832	269802	879	Bottom
A3	1209622	269716	938	Surface
A4	1209592	269700	910	Bottom
B1	1209583	269697	940	Surface
B2	1209597	269644	930	Surface
B3	1209767	269649	941	Surface
B4	1209868	269749	938	Surface

Four hydrophones (A3, A4, B1, and B2) were mounted to steel plates that were suspended from the front of the penstock walls. Three hydrophones (A1, B3, and B4) were mounted to steel plates that were lowered onto the slopes of the forebay and attached by nylon line to trees to prevent tipping. One hydrophone (A2) was affixed to a platform mount and lowered to the bottom of the forebay. The positions of the hydrophones attached to the dam were initially measured to within a foot in the X, Y, and Z dimensions with GPS. The positions of the near bottom hydrophones were determined by transmitting a signal from the fixed hydrophones to the near bottom hydrophones and measuring the signal delays, in a manner similar to the method used to calculate the three-dimensional position of the tagged fish. The system was fully tested and calibrated prior to release of tagged fish.

Acoustic Tag Tracking System

The HTI Model 290 Acoustic Tag Tracking System was used for this study. The acoustic tag receiver was designed to receive on up to 16 separate hydrophones, though only 8 hydrophones were used in this study. Received signals were synchronized in order to determine time of arrival for each detected pulse. Arrival time of the pulse at each hydrophone was used to determine the location of the tag moving through the forebay. These data were saved in digital format and a tracking program was used to track the received signal from the 8 separate hydrophones. The systems were operated for 24 hours/day, 7 days/week from March 22, 2002 through April 16, 2002.

The fish tracks were plotted in three dimensions using the HTI software program Acoustic Tag. The Acoustic Tag program is an animated, interactive display that allows the user to view individual pulses, large groups of pulses, or the entire trace for each fish. The display provides a three-dimensional background showing a representation of the coverage area including important structures such as the turbine entrances and spill gates (Figure 4.17-6). While actively viewing fish traces within the program, the user can adjust the field of view to move spatially within the program (forward, backward, up, or down). This allows several different perspectives for any given fish trace.

4.17.3.3 Fish Handling

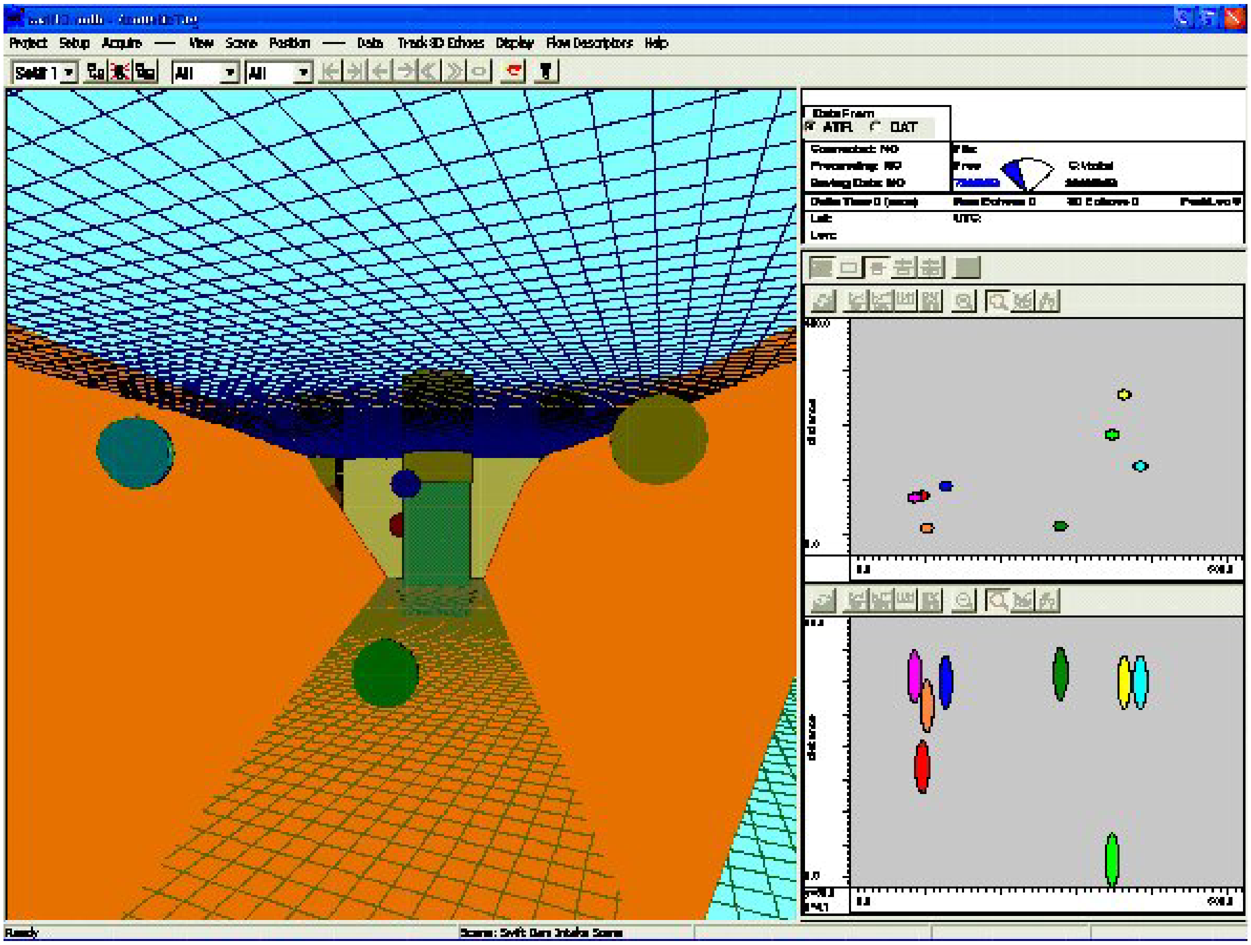
Collection and Transport

We tagged hatchery fish raised at the Merwin and Lewis River hatcheries. Juvenile Chinook salmon smolts were collected from Merwin Hatchery and juvenile coho salmon were collected from the Lewis River Hatchery. Fish were transported in a 500-gallon circular tank supplied with oxygen and recirculated water. Fish were transported to the tagging station at the tailrace of Swift No. 1. There, fish were sorted by species and placed into one of two 55-gallon containers supplied with water. Fish were held in the 55-gallon containers for one day prior to tagging to reduce stress associated with handling and transportation.

Fish Tagging

We gastrically implanted 50 Chinook and 50 coho with acoustic tags. The first release group was 10 Chinook and 10 coho and the second and third release groups each had 20 fish of both species. Fish were tagged in the tailrace of Swift No. 1 and held in 5-gallon buckets for at least 24 hours before they were released to reduce the likelihood of tag regurgitation. We anesthetize fish with MS222 (60 mg/l) before tags were implanted.

We measured fork length for each fish and rejected fish less 140 mm or that had obvious signs of injuries or excessive descaling.



Connected: NO
Processing: NO
Saving Data: NO
Lat:
Lon:
UTC:
Scene: Swift Dam Intake Scene

Figure 4.17-6. View of Swift forebay that displays intake tower, hydrophone location and spill gates from within the Acoustic Tag program.

<u>Fish Releases</u>

Three groups of acoustic-tagged Chinook and coho each were released outside the entrance to the forebay channel. The first group of 10 coho and 10 Chinook (20 fish total) were released at two different locations under a non-spill condition (Figure 4.17-7). Five Chinook and five coho from the first group were released near the shoreline (50 meters) approximately 300 meters upstream from the forebay channel. The other five Chinook and five coho were released mid-channel in the reservoir off Devils Backbone (Figure 4.17-7). This first group of fish that was released was used to determine an appropriate release location for the second and third release groups. That is, depending on the number of fish detected within a given time, we could move the release location to facilitate meeting our study objectives. The second group was released about 200 meters outside the forebay channel along the shoreline. The third group was released 100 meters outside the forebay channel. The last two groups were released at about 12:00 PM on 27 March and 4 April.

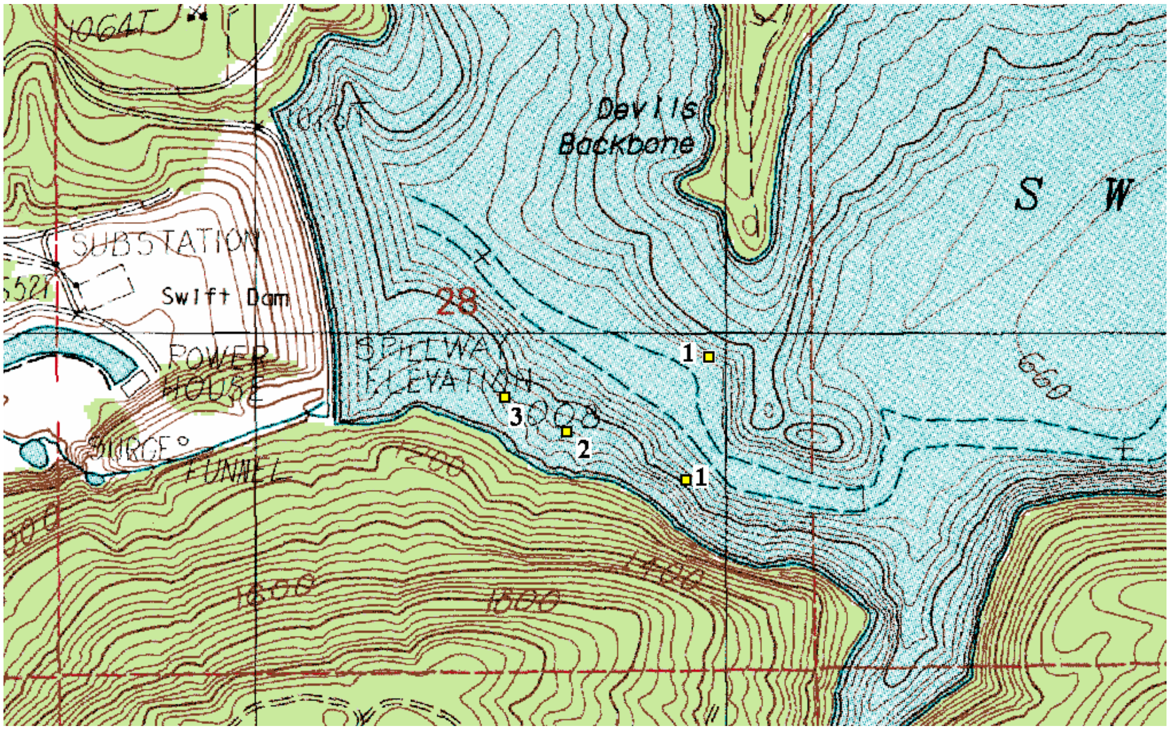


Figure 4.17-7. Release sites for three groups of acoustic-tagged Chinook and coho salmon released into Swift Reservoir.

4.17.3.4 Data Analysis

Just less than one-half million fish positions (in X, Y, and Z coordinates) were recorded over the entire study. These data were analyzed in multiple ways. To estimate different indices of elapsed time we used the echo location times reported for each fish and position. For spill passage, three-dimensional tracks of fish were viewed in the Acoustic Tag program to determine the exit location where the fish was last observed. Fish concentration areas were determined from fish positions that were sorted into distinct bins that described a specific location in the Swift Forebay.

Elapsed Time

We calculated elapsed time indices for the different release groups to evaluate travel time, first detection to last detection, and residence time in the forebay. We used echo location time reported for each fish and position. From the first echo location time reported for each fish, we calculated the time from release to first detection. Likewise, the first echo location time to the last gave us first detection to last detection in the forebay. To estimate forebay residence time, we used a 1-minute criterion to eliminate all echo location times between successive hits that were greater than one minute. The sum of the echo location times less than one minute for each fish was total residence time for that individual fish. We used the median to describe the central tendency for each index because it is less sensitive than the mean to extremely large or small values.

Spill Passage

We reviewed the last hours of detection for each fish that encountered a spill period in the Acoustic Tag program. We included only those fish that were tracked to the south spill gate and crossed the spill gate plane as spill passed fish. To verify passage, the last series of hits for a given fish determined the time of passage during a spill event.

Fish Concentration Areas

We partitioned the data into different experimental groups to cover spill and non-spill periods with day and night treatments to assess fish concentration areas. The data from the different experimental groups and treatments were imported into Tecplot graphic modeling software package. There, we subdivided the Swift Dam study area into 134,400 individual “zones” that delineated the volume of the forebay. Each zone was a 5 foot cube or bin. In order to assess fish residency/density, all fish positions (X, Y, and Z) were assigned to a particular “zone” of residence corresponding to that area in the forebay. That is, the volume of the forebay was populated with a series of three-dimensional cubes that summed the frequency of fish positions for a given cube. The data were then interpolated by the Kriging method (Davis 1973, 1986) between zones to assess general areas of residence in the Swift forebay. The frequency of fish positions within a particular cube of the forebay determined the concentration of fish positions. Many of the zones had a value of zero which indicated that fish were never positioned there. Conversely, large values within a zone indicated numerous positions.

In each plot, we displayed the low, medium and high concentration areas of the forebay. We used the same scale or frequency of hits to describe areas of low, medium and high concentrations. Low concentration areas describe the general distribution of the positions recorded throughout the forebay. Areas of medium concentration generally showed where the detections begin to concentrate and the high concentration areas are where fish have concentrated the most.

Forebay Flow Characterization

Swift Reservoir velocity data were collected by the U.S. Geological Survey, Oregon District on April 3 and 4, 2002. A boat-mounted RD Instruments 600 kHz Broadband ADCP was used to collect velocity and depth data relative to the position of the boat. A Lowrance LCX 15-MT dual frequency echo sounder was used to compute the depths on Day 1(during nonspill conditions), while the ADCP was used on Day 2 (spill conditions) to produce a weighted mean depth based on the values received from each of the four beams of the transducer. A Satloc GPS mobile receiver collected earth-referenced position data using OmniSTAR DGPS real-time differential correction. A laptop computer was used to run the ADCP software, which allowed the operator to view, configure and save all data in real time that was collected by ADCP.

On Day 1, all data were collected in transects that were essentially perpendicular to the "flow" near the face of the spillway structure Swift Dam (Figure 4.17-8). On Day 2 all data were collected in transects that were essentially parallel to the "flow", running from the dam to the log boom. The area outlined in black represents the common area of data collection during spill and non-spill conditions (Figure 4.17-8). In some instances for Day 2 data, the GPS locations were adjusted based on bottom track data due to less than optimum satellite signal reception.

Two files were generated for each day. The ADCP software was used to output ASCII data files. The data was then further manipulated into the required format using the Microsoft Excel spreadsheet program. The first file contained information on boat location (UTM coordinates) during transect survey and the associated depth of the reservoir. The second file contained data in the following order: Location in UTM coordinates, bin depth in feet, velocity magnitude in ft/sec, velocity direction as a bearing, and vertical velocity in ft./sec.

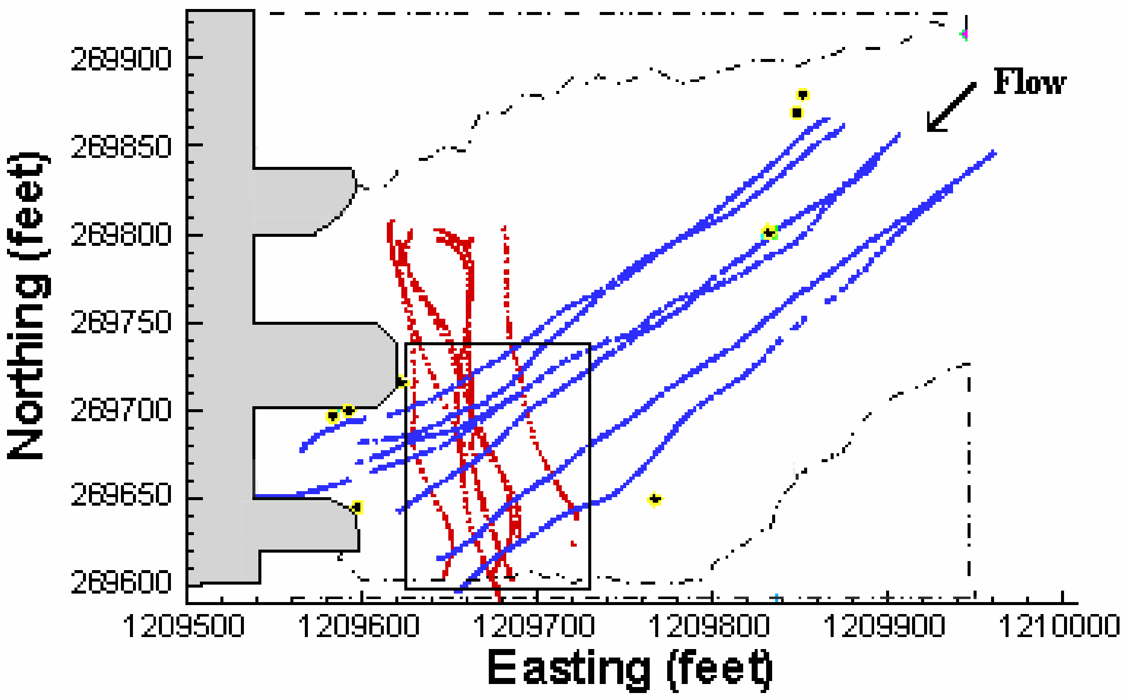


Figure 4.17-8. Transects used to characterize flow in the forebay of Swift No. 1 during spill (blue line) and non-spill conditions (red line).

Note: These lines depict the path of the USGS vessel as it moved to record ADCP data. Rectangle outlines the common area of data collection during spill and non-spill conditions.

The ADCP data were imported from the different operational conditions into Tecplot graphic modeling software package. There, we subdivided the Swift Dam study area into 13,244 individual "zones" that delineated the volume of the forebay. Each zone was a 10 foot cube or bin. In order to characterize flow in the forebay all positions (X, Y, and Z) were assigned to a particular "zone" of residence corresponding to that area in the forebay. That is, the volume of the forebay was populated with a series of three-dimensional cubes that described the velocity and flow vectors for a given cube. The data were then interpolated by the Kriging method (Davis 1973, 1986) between zones to assess general flow patterns in the Swift forebay. The data were interpolated only within the minimum and maximum X and Y values (UTM coordinates) that describe the locations of each of the measurements. That is, a rectangle defines the potential area that the data were interpolated within. These outlined areas helped minimize the error of interpolating the data outside the actual data set (extrapolating). However, within the area interpolated there were areas that had little or no associated data points. Those areas were trimmed in all graphical displays presented in this report.

4.17.4 Key Questions

Several "key" questions identified during the Lewis River Cooperative Watershed Studies process may be partially addressed through this study. Specifically, these questions are:

- How would reservoir management affect movements and migration of anadromous fish if they were reintroduced to the upper watershed?
- What are the characteristics of the velocity profiles currently existing in reservoirs and how would these characteristics potentially affect movement and migration of anadromous salmonids through project reservoir (e.g., travel time, spatial and temporal patterns of downstream migration)?
- 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 fishways, screening, stocking of fry, planting of eggs)?
- What types of fish screens would be needed or desirable if fish passage were constructed?

4.17.5 Results

4.17.5.1 Data Collection

We recorded 202,143 and 242,165 individual fish detections which translate to an equivalent number of positions (X, Y, and Z) for juvenile Chinook and coho salmon, respectively. These fish positions were blocked into spill and non-spill events, and were further blocked into day and night treatments to characterize the variation in behavior of salmonid smolts near the project. The following table indicates the number of fish that encountered each condition and the number of fish positions recorded for each event and treatment (Table 4.17-3).

Table 4.17-3. Number of fish and positions recorded for juvenile Chinook and coho salmon during different periods and treatments for spill and non-spill events.

				Number	
Species	**Event**	**Period**	**Treatment**	**Fish Detected**	**Fish Positions**
Chinook	Spill	Stable Pool Elevation	Day	17	54,665
			Night	6	17,521
	Non-Spill	Stable Pool Elevation	Day	11	7,077
			Night	11	39,459
		Increasing Pool Elevation	Day	7	16,262
			Night	8	67,159
				Total	**202,143**
Coho	Spill	Stable Pool Elevation	Day	10	11,322
			Night	13	10,558
	Non-Spill	Stable Pool Elevation	Day	11	32,381
			Night	12	55,820
		Increasing Pool Elevation	Day	6	29,768
			Night	5	102,313
				Total	**242,165**

4.17.5.2 Detection of Fish

We defined two classes of fish detections. Fish that were detected simultaneously on a minimum of four hydrophones produced three-dimensional tracks. Any fish yielding such tracks were classified as being within the detection system and were designated as entering the forebay near the dam. Forebay detections are defined as the proportion of all fish released that entered the forebay. This type of detection enabled three-dimensional positioning in the forebay of Swift No. 1 and is the focus of our analysis. In some cases tagged fish approached the forebay but did not enter. Such fish can be detected by one to three hydrophones so they are detected, but are not tracked. They were at the perimeter of the detection field of the system. The detection rate for the hydrophone system is defined as the proportion of all fish released that were detected by at least a single hydrophone in the system. This represents the fraction of all fish released that approached the forebay, but did not necessarily enter the forebay near dam.

Detection Rates

The detection rate for three release groups of juvenile Chinook and coho salmon that were detected by at least one hydrophone varied according to species and release group. The percent of juvenile Chinook and coho detected near the forebay varied from 90-95% and 70-85%, respectively (Figure 4.17-9). The highest detection rate for Chinook was for the third release group which was released nearest the project (Table 4.17-4). The highest detection rate for coho salmon (group 2) was achieved for those fish released at an intermediate distance from the forebay.

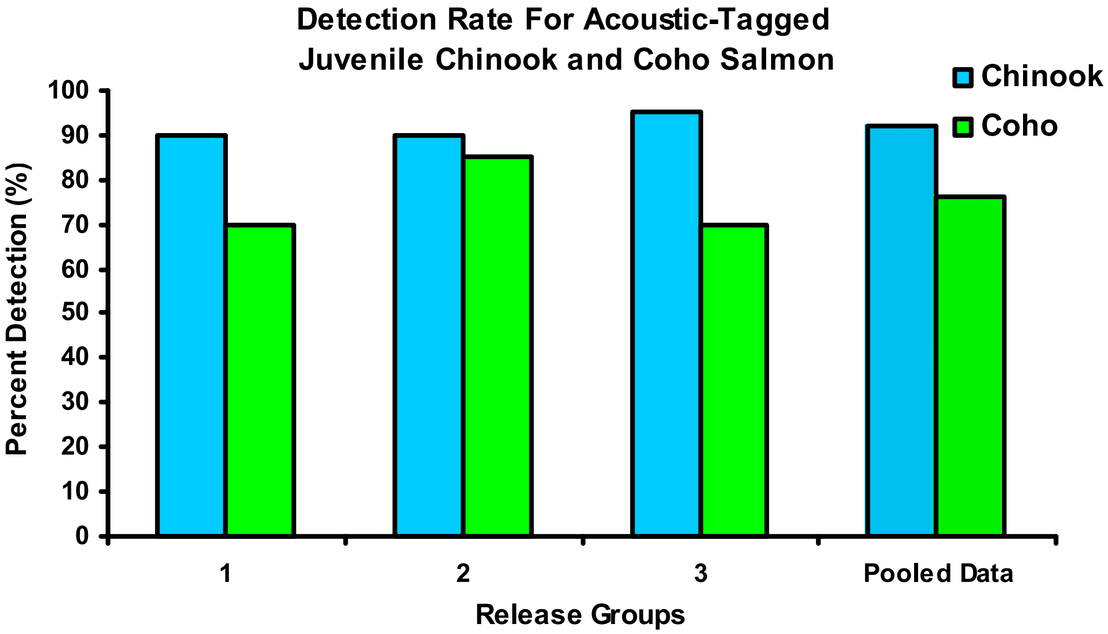


Figure 4.17-9. Percent of acoustic-tagged juvenile Chinook and coho salmon detected by at least one hydrophone near the forebay of Swift No. 1.

Table 4.17-4. Percent detection by at least one hydrophone for three groups of juvenile Chinook and coho salmon released into Swift Reservoir, 2002.

		Number		Percent
Species	**Release Group**	**Released**	**Detected**	**Detected**
Chinook	1	10	9	90
	2	20	18	90
	3	20	19	95
	Pooled Data	**50**	**46**	**92**
Coho	1	10	7	70
	2	20	17	85
	3	20	14	70
	Pooled Data	**50**	**38**	**76**

Forebay Detections

The number of fish detected in the forebay of Swift No. 1 that were detected by at least four hydrophones varied according to species and release group. The number of juvenile Chinook and coho detected in the forebay varied from 70-95% and 50-70%, respectively (Figure 4.17-10). The highest detection rate in the forebay for Chinook salmon was for the third release group which was released nearest the project (Table 4.17-5). Coho release groups one and two had the highest detection rate in the forebay even though they were released furthest away from the project.

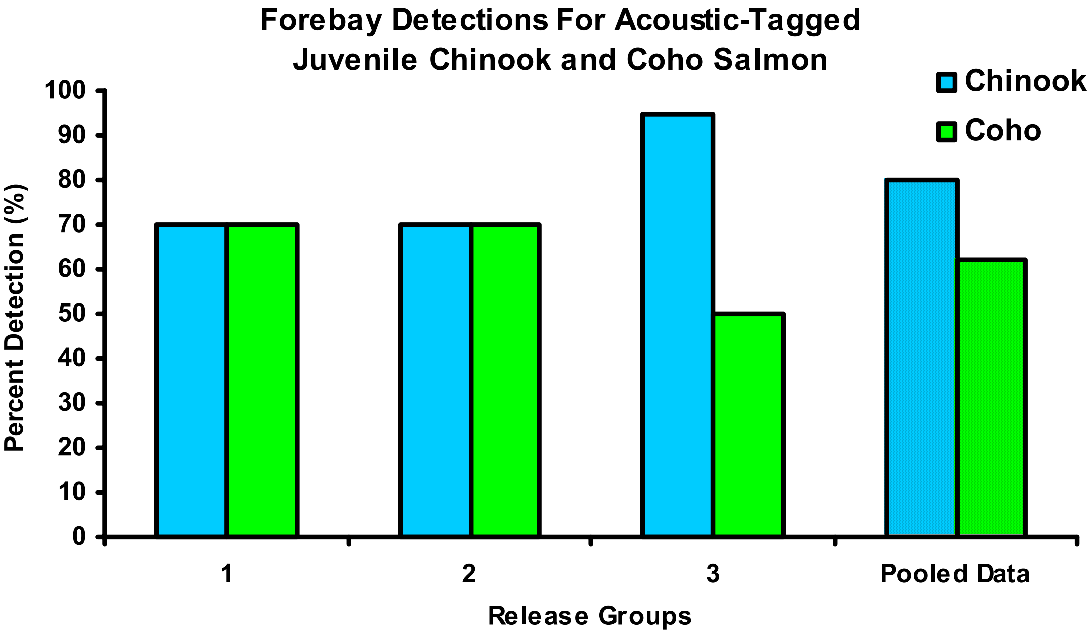


Figure 4.17-10. Percent of acoustic-tagged juvenile Chinook and coho salmon detected by at least four hydrophones in the forebay of Swift No. 1.

Table 4.17-5. Percent of fish detected by at least four hydrophones.

		Number		Percent
Species	**Release Group**	**Released**	**Detected**	**Detected**
Chinook	1	10	7	70
	2	20	14	70
	3	20	19	95
	Pooled Data	**50**	**40**	**80**
Coho	1	10	7	70
	2	20	14	70
	3	20	10	50
	Pooled Data	**50**	**31**	**62**

Exposure to Operating Conditions

The number of juvenile Chinook and coho salmon exposed to different operating conditions showed a similar pattern (Figure 4.17-11). More Chinook were observed in the forebay during a given operating condition than coho and the number of fish present in the forebay decreased as time passed after the spill event stopped (Table 4.17-6).

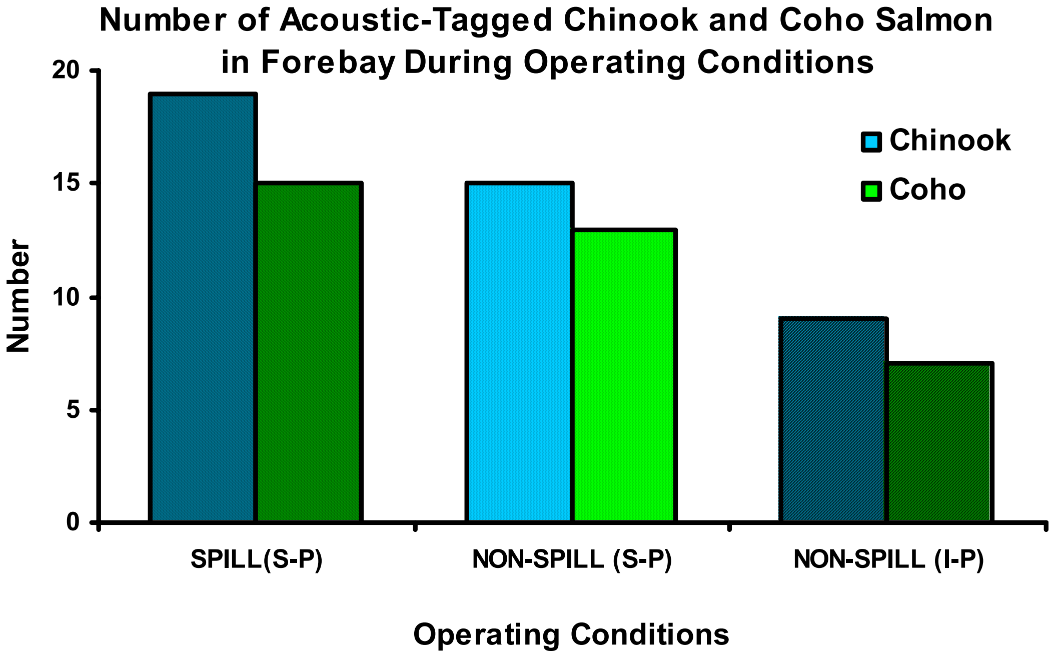


Figure 4.17-11. Number of juvenile Chinook and coho salmon exposed to spill with a stable pool elevation (S-P) and non-spill operating conditions with stable pool and increasing pool elevation (I-P).

Table 4.17-6. Number of juvenile Chinook and coho salmon exposed to different periods of spill and non-spill events.

Species	Event	Period	Detected
Chinook	Spill	Stable Pool Elevation	19
	Non-Spill	Stable Pool Elevation	15
		Increasing Pool Elevation	9
Coho	Spill	Stable Pool Elevation	17
	Non-Spill	Stable Pool Elevation	13
		Increasing Pool Elevation	7

4.17.5.3 Elapsed Time

Release to First Detection

Travel time from release to first detection in the forebay of Swift No. 1 Dam varied widely for both Chinook and coho (Table 4.17-7). The median travel times for coho salmon were more consistent and varied from about 14-21 hours across the release groups. In contrast, Chinook travel time to first detection varied broadly, from about 0.5-41 hours (Figure 4.17-12). Release groups liberated nearest the project exhibited the shortest travel time for both species.

Table 4.17-7. Summary of elapsed time for release to first detection, first detection to last detection and residence time in the forebay of Swift No. 1 Dam for three release groups of juvenile Chinook and coho salmon.

			Time (hrs)		
Species	**Elapsed Time**	**Released Group**	**Median**	**Min**	**Max**
Chinook	Release to First Detection	1	11.10	0.25	51.41
		2	41.20	0.76	219.80
		3	0.64	0.03	280.78
		Pooled Data	**6.71**	**0.03**	**280.78**
	First Detection to Last Detection	1	7.17	0.54	72.86
		2	4.60	0.18	152.05
		3	5.54	0.003	163.66
		Pooled Data	**6.06**	**0.003**	**163.66**
	Forebay Residence	1	1.28	0.07	6.63
		2	1.25	0.12	11.02
		3	3.27	0.04	7.61
		Pooled Data	**1.97**	**0.04**	**11.02**
	Spill Condition	**Pooled Data**	**1.72**	**0.003**	**7.62**
	Non-spill Condition	**Pooled Data**	**0.60**	**0.004**	**6.63**
Coho	Release to First Detection	1	18.26	5.28	99.26
		2	21.03	0.05	283.35
		3	14.45	3.14	151.85
		Pooled Data	**17.40**	**0.05**	**283.35**
	First Detection to Last Detection	1	18.95	0.58	102.72
		2	2.68	0.007	131.70
		3	7.49	0.06	175.29
		Pooled Data	**8.49**	**0.007**	**175.29**
	Forebay Residence	1	1.32	0.03	14.28
		2	0.42	0.04	4.88
		3	1.93	0.03	29.26
		Pooled Data	**1.19**	**0.03**	**29.26**
	Spill Condition	**Pooled Data**	**0.46**	**0.003**	**12.86**
	Non-spill Condition	**Pooled Data**	**1.40**	**0.007**	**14.28**

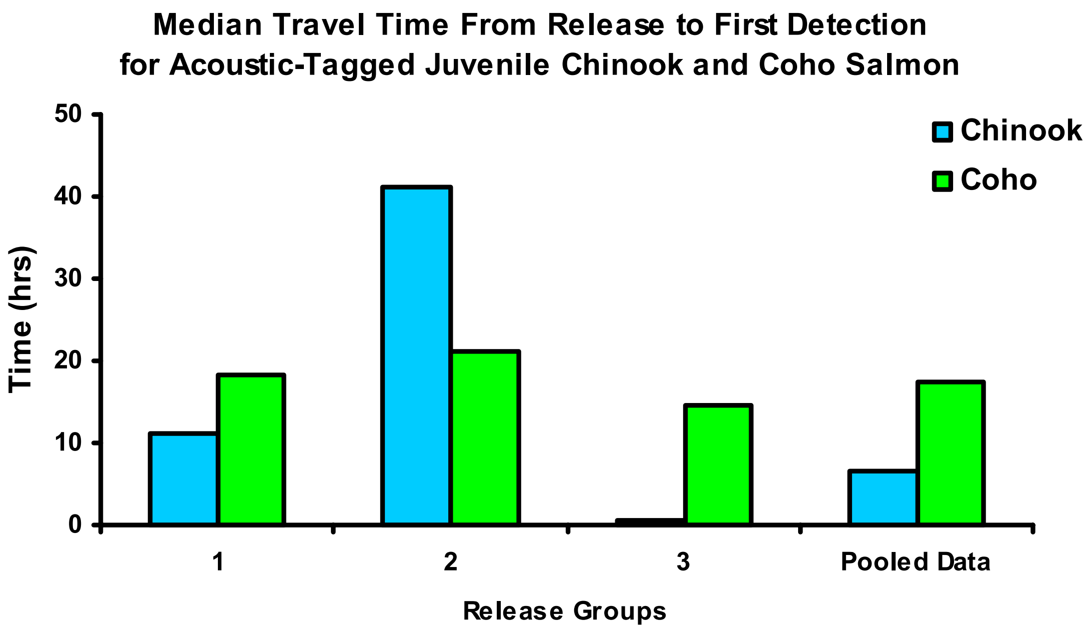


Figure 4.17-12. Median travel times from release to first detection for acoustic-tagged juvenile Chinook and coho salmon.

First to Last Detection

The elapsed time from first detection to last detection by the hydrophone system showed considerable range in time for both Chinook and coho. For Chinook salmon the range was 10 seconds to 163 hours (≈ 6.5 days) (Table 4.17-7). Similarly for coho the range was 25 seconds to 175 hours (≈ 7 days). The median elapsed time varied less for Chinook (4.5-7 hours) than for coho (2.7-19 hours). In general, the pooled data suggests that elapsed time from first to last detection was less than 9 hours for both Chinook and coho (Figure 4.17-13). The considerable range in elapsed time for both Chinook and coho salmon in each release group suggests that some fish left the forebay detection area and returned at a later time. That is, for some fish elapsed time from first detection to last detection is probably not a good measure of resident time in the forebay of Swift No. 1.

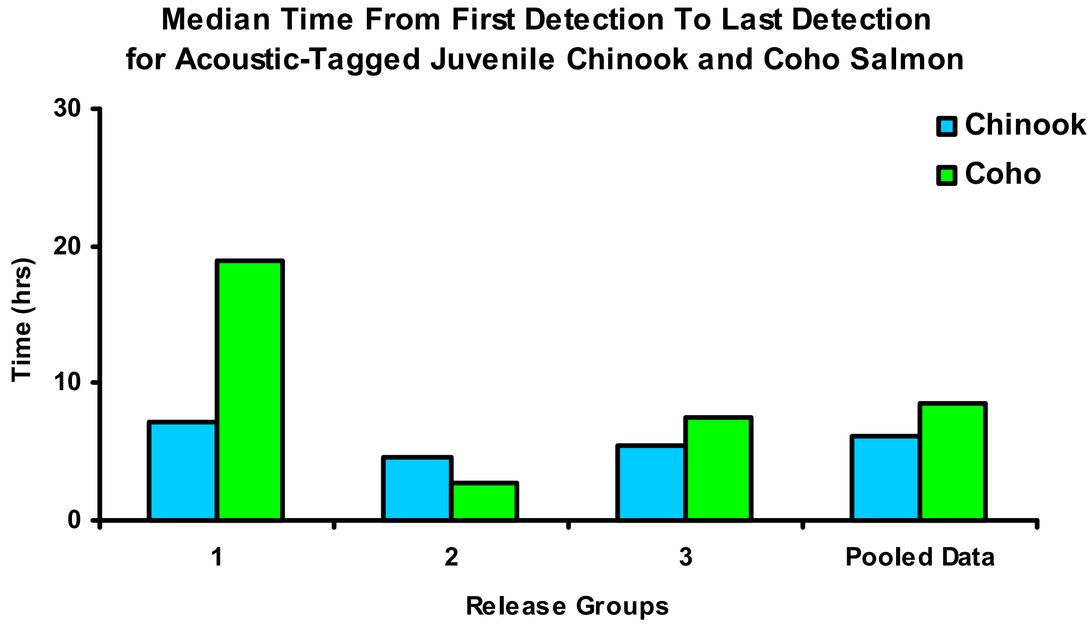


Figure 4.17-13. Median time from first detection to last detection for acoustic-tagged juvenile Chinook and coho salmon.

Forebay Residence

To provide a better measure of residence time in the forebay, we excluded time periods when fish were outside the forebay and not detected on the hydrophone array. In general, the median residence time for Chinook and coho was less than four hours and fish in the third release group spent more time in the forebay for both Chinook and coho (Table 4.17-7, Figure 4.17-14). For two of the three release groups, Chinook salmon spent more time in the forebay than did coho. During spill conditions the median forebay residence time was greater for Chinook than for coho (Table 4.17-7, Figure 4.17-15). When non-spill conditions were present coho spent more time in the forebay than did Chinook (Table 4.17-7, Figure 4.17-15).

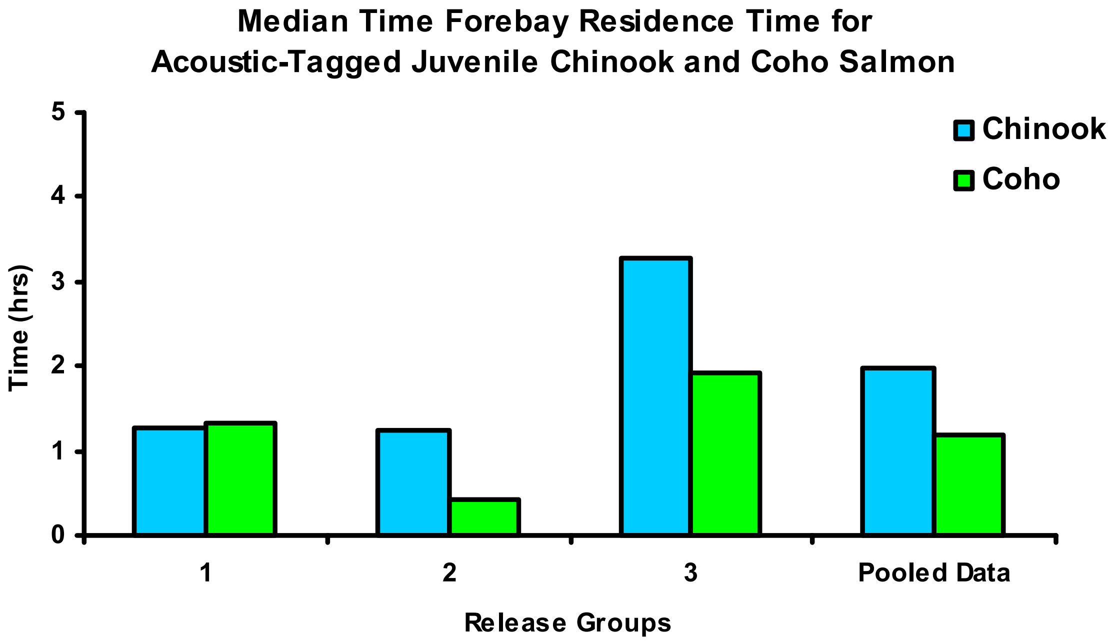


Figure 4.17-14. Median forebay residence time for release groups of acoustic-tagged juvenile Chinook and coho salmon.

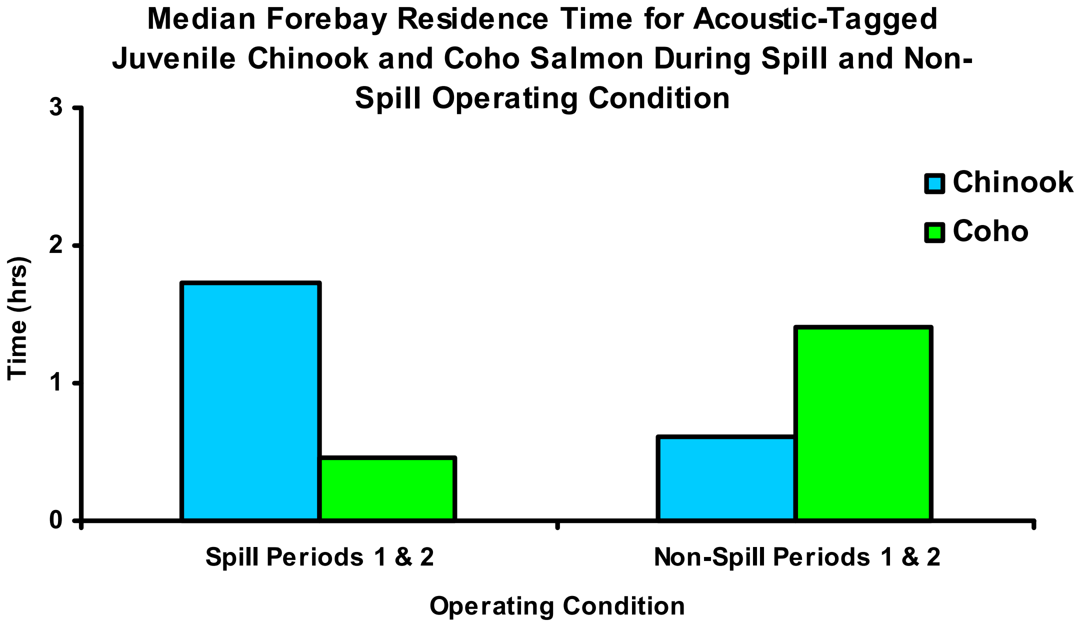


Figure 4.17-15. Median forebay residence time for acoustic-tagged juvenile Chinook and coho salmon during spill and non-spill events.

Spill Passage

We considered the number of fish that passed the project through the spill gate during a spill event as an indicator response to flow near the project. We reviewed the last hour of detection for each fish that encountered a spill period and was never detected again. The criteria for designating a fish as passing the spillway was those fish that were tracked to the south spill gate, then disappeared and were never detected again by the system.

Of all fish released (50 of each species), 38% of the Chinook and 34% of the coho were detected in the forebay during spill. Of the 19 Chinook exposed to spill, 7 (37%) passed through the spillway (Table 4.17-8). This equates to 14% of all Chinook released in the reservoir. Of the 17 coho exposed to spill, only 2 (12%) passed that route, equivalent to 4 % of the total number released (Table 4.17-8).

Table 4.17-8. The number and percent of fish at liberty that were detected in the forebay during spill periods, and the percent that passed through the spillway.

	Spill	Number			Percent	
Species	**Period**	**Available**	**Detected**	**Passed**	**Detection**	**Passage**
Chinook	1	30	6	4	20	67
	2	46	13	3	28	23
	Total	**50**	**19**	**7**	**38**	**14**
Coho	1	30	8	0	26	0
	2	50	9	2	18	22
	Total	**50**	**17**	**2**	**34**	**4**

The number of fish available (at liberty in Swift Reservoir) in the second spill period was adjusted for the number of fish that had passed the spill gate.

4.17.5.4 Fish Concentrations and Distribution

During the study when pool elevation was relatively stable, we compared fish concentrations during spill and non-spill events, and day versus night treatments. We plotted fish concentrations during the non-spill period when pool surface elevation was steadily increasing separate from other periods. The plots were contoured to indicate areas where fish detections were concentrated and show areas of low, medium and high fish concentration in the forebay of Swift No. 1 Dam. We observed shifts in horizontal and vertical distribution of detections during different conditions.

Chinook

Spill vs. Non-spill – In plan view, the distribution of juvenile Chinook was similar during spill and non-spill events (Figure 4.17-16). Fish detections were concentrated in the vicinity of the south spillbay, even when spill was absent, as evidenced by the medium and high density plots (Figure 4.17-14). The fish displayed a proclivity to concentrate in this area, regardless of operating condition. However, there was a slight but noticeable shift closer to the spill gate during the spill event that was indicated in the high detection density plots (Figure 4.17-16). The fish concentration was closer and more central to the south spill gate during a spill event.

All three density plots suggest that Chinook appear somewhat shallower during non-spill conditions (Figure 4.17-17). This is most apparent in the plot depicting the highest concentrations of detections.

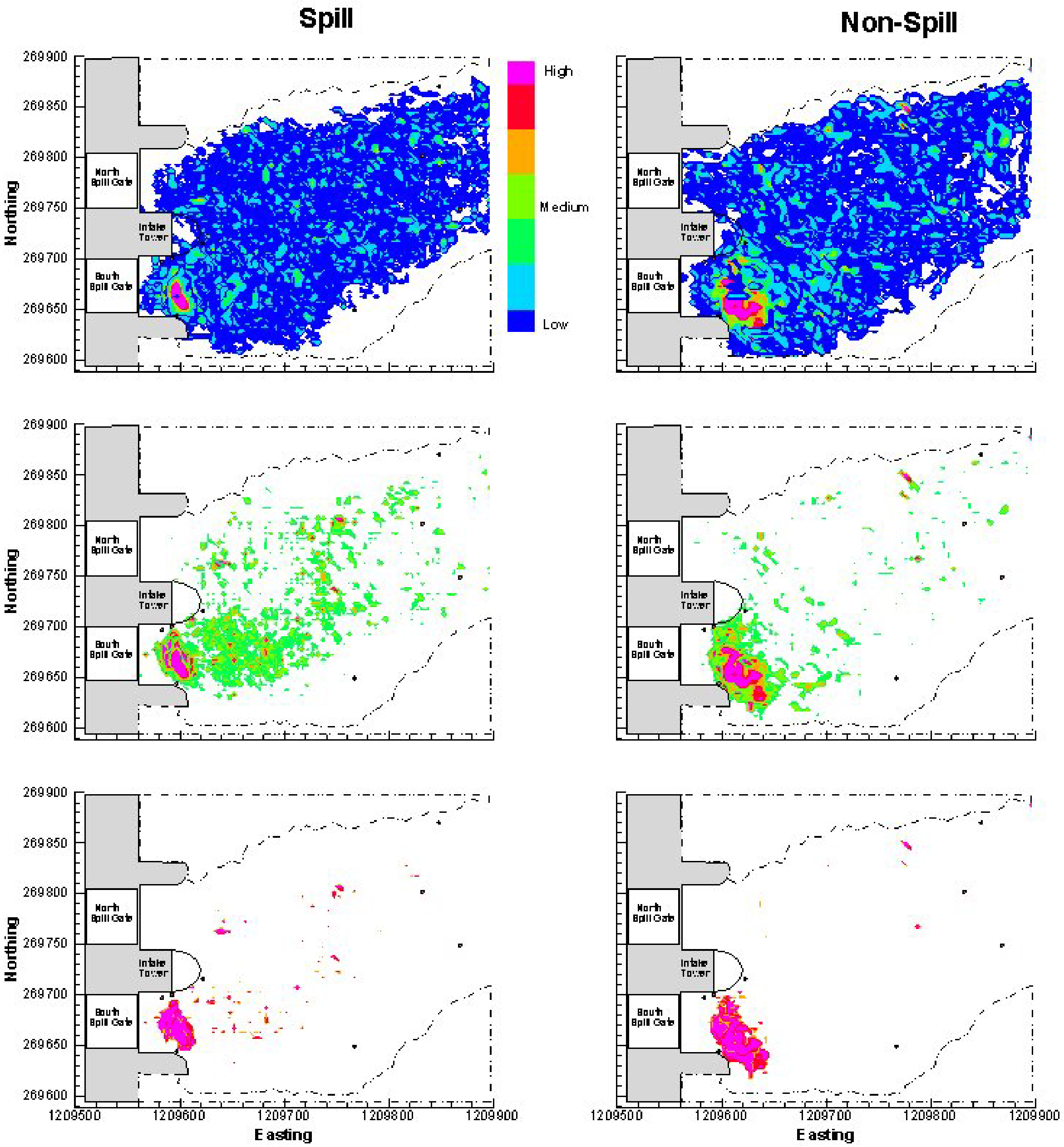


Figure 4.17-16. Plots show areas of low (top), medium (middle), and high (bottom) concentrations of detections for juvenile Chinook salmon during spill (1&2) and non-spill (1&2) periods in the forebay of Swift No. 1, 2002.

Note: During spill events the south spill gate was opened to provide 2000 cfs flow. Black dots depict the locations of the eight hydrophones deployed in the forebay.

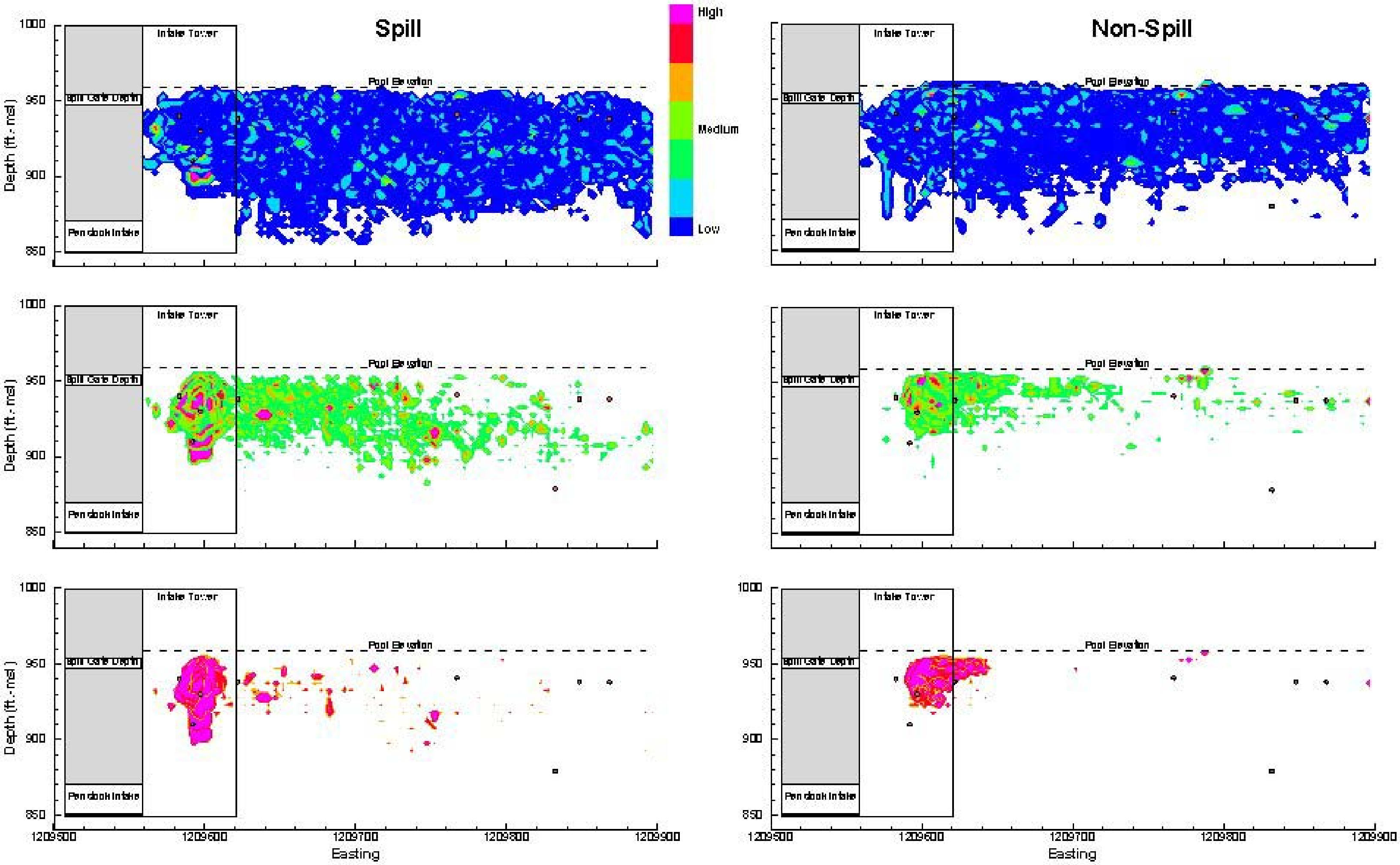


Figure 4.17-17. Plots (side view) show areas of low (top), medium (middle), and high (bottom) fish concentrations for juvenile Chinook salmon detected during spill (1&2) and non-spill (1&2) periods in the forebay of Swift No. 1, 2002.

Note: During spill events the south spill gate was opened to allow 2000 cfs flow. Black dots depict the locations of eight hydrophones placed in the forebay.

Spill (Day vs. Night) – At night when spill occurred, Chinook spent more time closer to the dam and concentrated near the south spill bay than was observed during daylight hours (Figure 4.17-18). This pattern is most evident in viewing the medium and high density plots (Figure 4.17-18). However, even during the day detections were skewed toward the dam and spillway, but not as dramatically as occurred at night.

During the day, Chinook appeared to be distributed over a broader depth range than was observed at night (Figure 4.17-19). Furthermore, fish were generally more concentrated into narrower, more distinct strata during the night. Since there were both more fish and fish positions recorded during the day compared to night, this reinforces the inference that Chinook may be congregating more at night (Table 4.17-3).

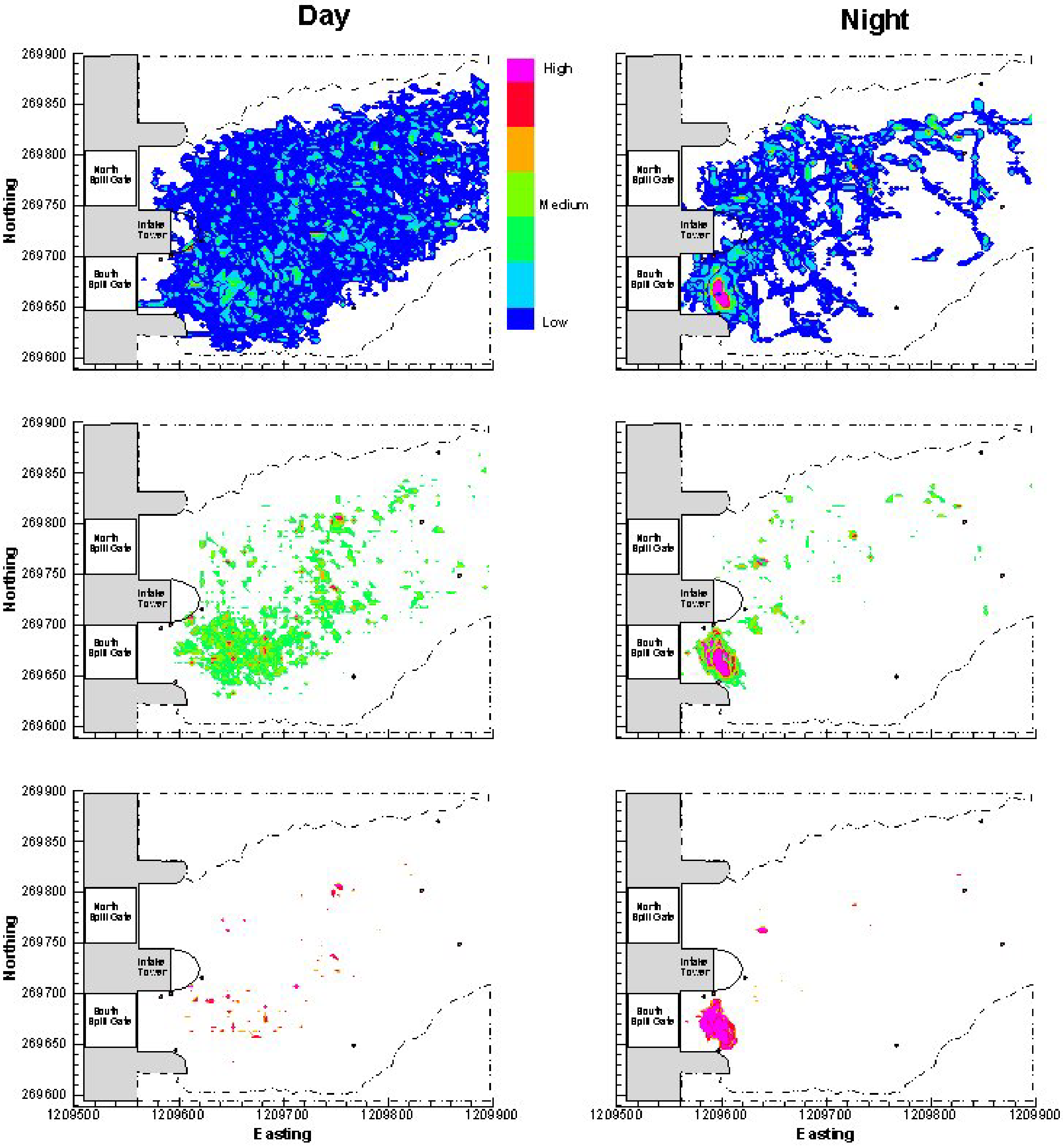


Figure 4.17-18. Plots (plan view) show areas of low (top), medium (middle), and high (bottom) fish concentrations for juvenile Chinook salmon detected during spill events for day and night treatments in the forebay of Swift No. 1, 2002.

Note: During spill events the south spill gate was opened to allow 2000 cfs flow. Black dots depict the locations of eight hydrophones placed in the forebay.

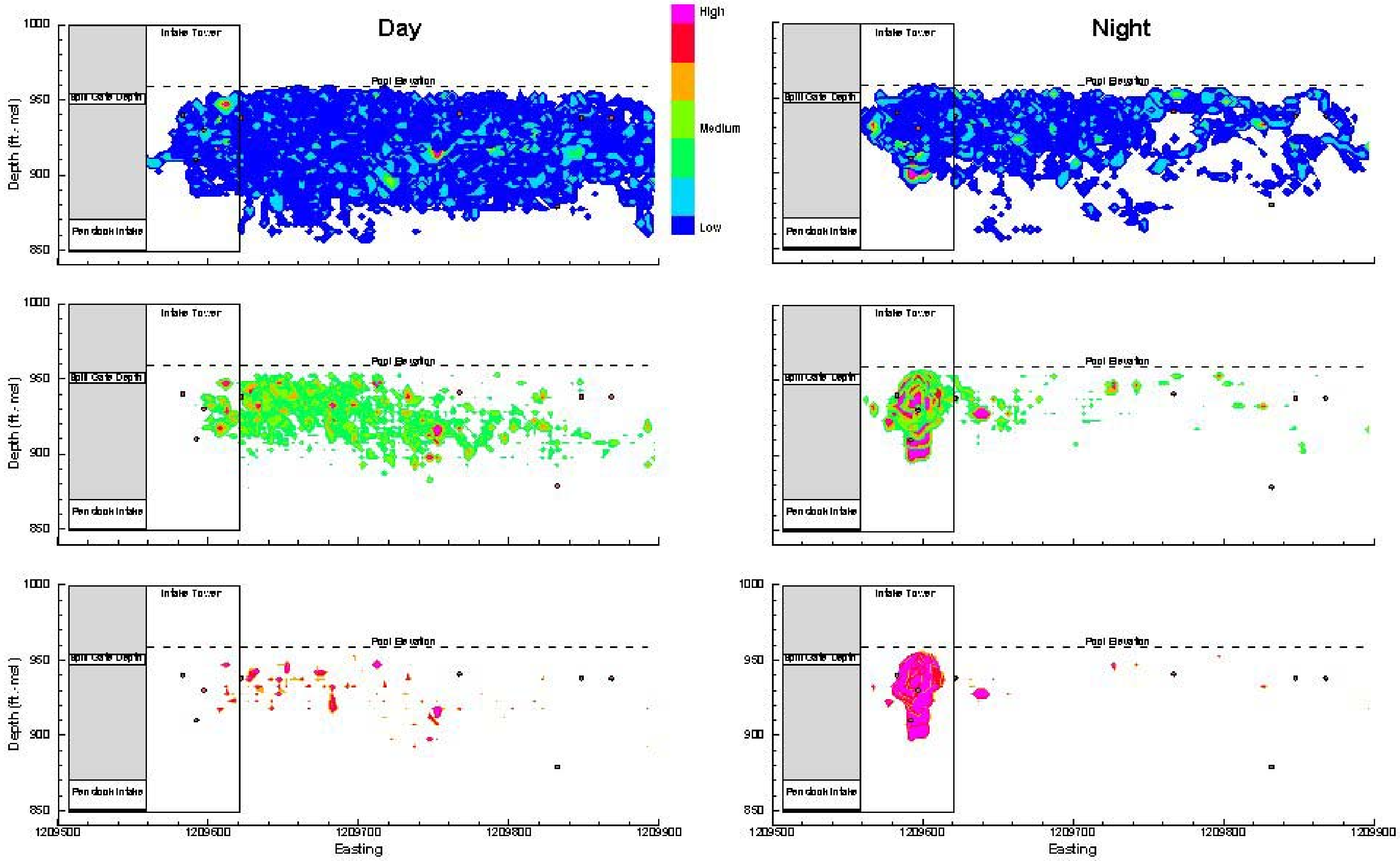


Figure 4.17-19. Plots (side view) show areas of low (top), medium (middle), and high (bottom) fish concentrations for juvenile Chinook salmon detected during spill events for day and night treatments in the forebay of Swift No. 1, 2002.

Note: During spill events the south spill gate was opened to allow 2000 cfs flow. Black dots depict the locations of eight hydrophones placed in the forebay.

<u>Non-Spill (Day vs. Night)</u> – Similar to observations made during spill periods, at night during non-spill, fish were more concentrated near the south spill gate as compared to the daylight period (Figure 4.17-20). The number of fish observed during the day and night periods were equal, but the number of fish positions was much greater at night (Table 4.17-3). This seems to suggest that fish spent less time in the forebay during the day than they did at night and did not tend to have a focal area.

Fish detections were concentrated and surface-oriented during the night (Figure 4.17-21). During the day fish detections were dispersed throughout the depth of the forebay.

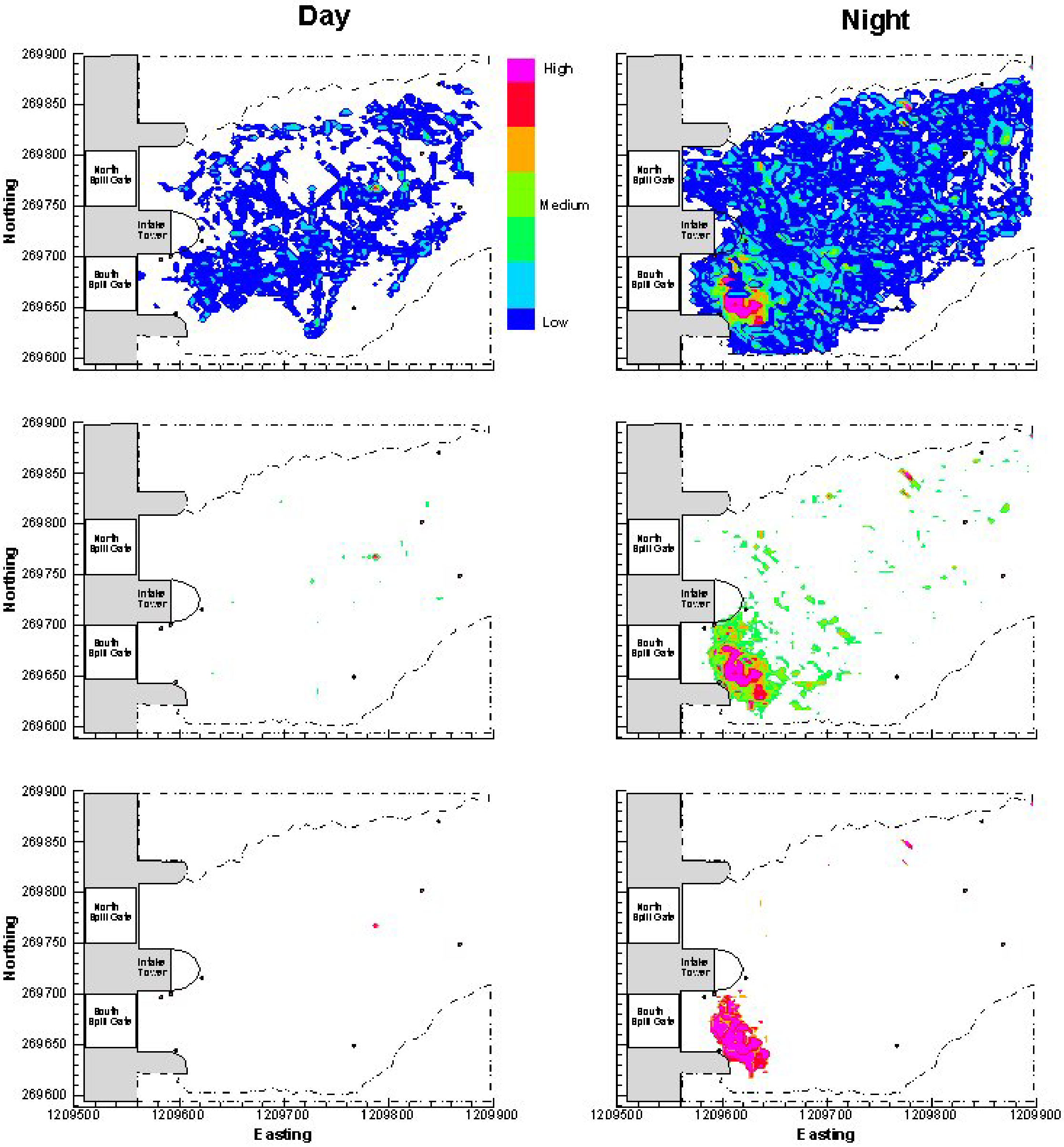


Figure 4.17-20. Plots (plan view) show areas of low (top), medium (middle), and high (bottom) fish concentrations for juvenile Chinook salmon detected during non-spill (1&2) events for day and night treatments in the forebay of Swift No. 1, 2002.

Note: Black dots depict the locations of eight hydrophones placed in the forebay.

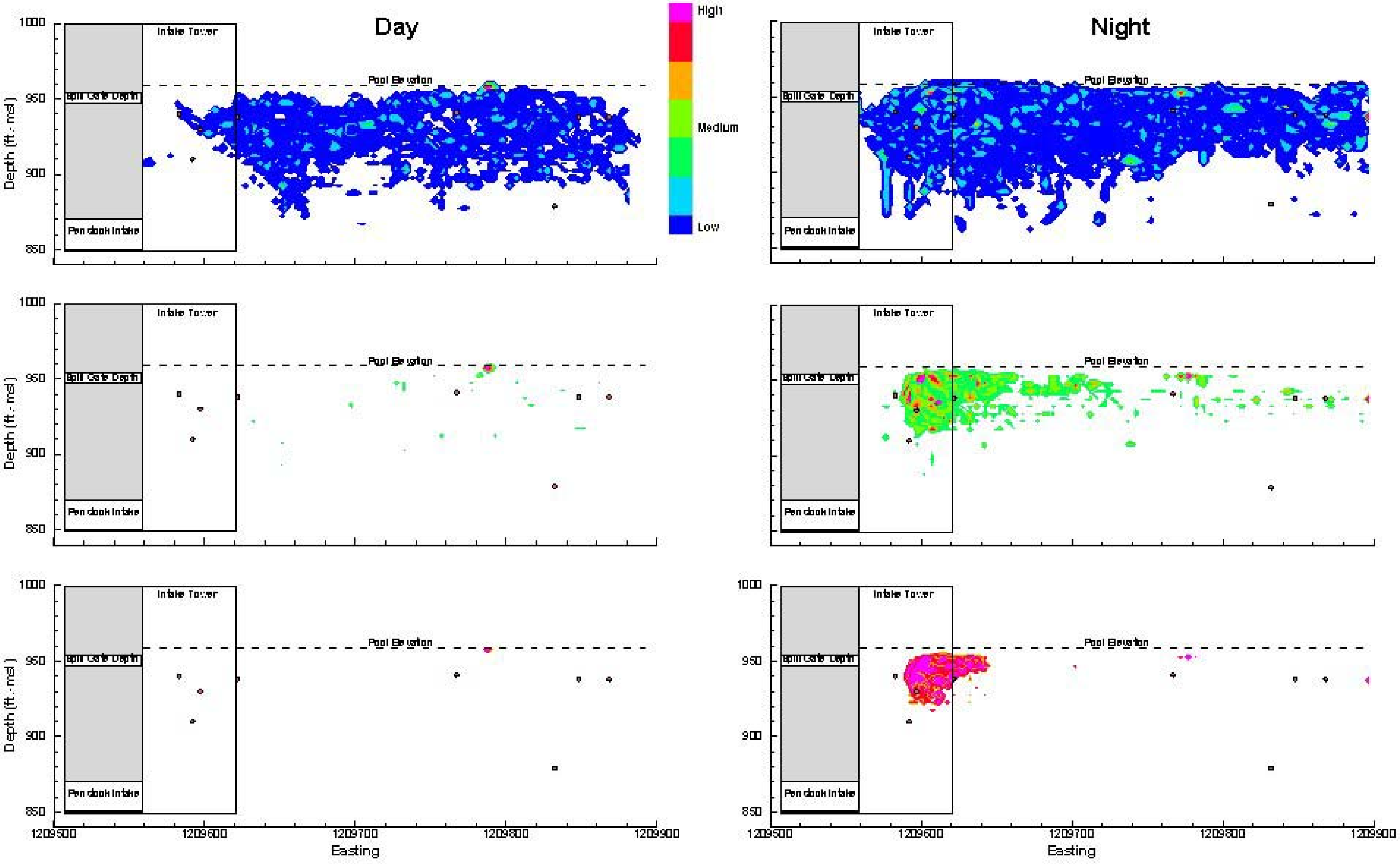


Figure 4.17-21. Plots (side view) show areas of low (top), medium (middle), and high (bottom) fish concentrations for juvenile Chinook salmon detected during non-spill (1&2) events for day and night treatments in the forebay of Swift No. 1, 2002.

Note: Black dots depict the locations of eight hydrophones placed in the forebay.

Non-Spill Period (Increasing pool elevation: Day vs. Night) – Fish in the third non-spill period were more widely distributed throughout the forebay at night than during the day (Figure 4.17-22). Similar to the other non-spill event, few areas of higher concentration were apparent during the day. At night the fish had a larger area of concentration but did not tend to have a focal area. In general they were dispersed unevenly throughout the middle of the forebay. During the day the areas of highest concentration were along the shoreline at the entrance of the forebay channel and the pier nose structure of the north spill gate.

The vertical distribution of fish in the forebay suggests that fish were closer to the surface at night than during the day (Figure 4.17-23). However, it is likely that most of the observations for the day occurred when the pool elevation was lower than those during the night. The areas of higher concentration at night show that fish were distributed throughout the forebay.

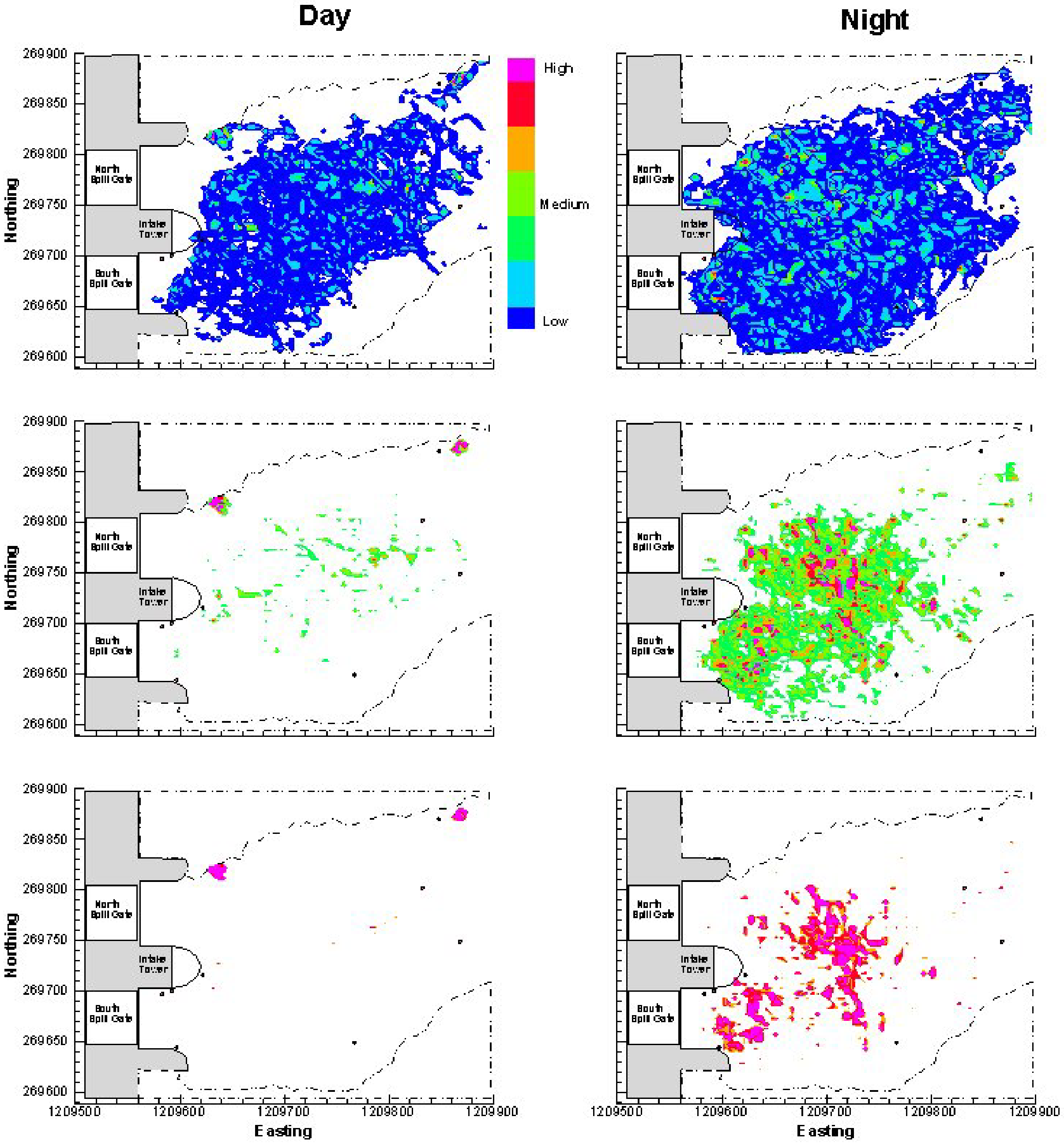


Figure 4.17-22. Plots (plan view) show areas of low (top), medium (middle), and high (bottom) fish concentrations for juvenile Chinook salmon detected during the third non-spill period for day and night treatments in the forebay of Swift No. 1, 2002.

Note: Black dots depict the locations of eight hydrophones placed in the forebay.

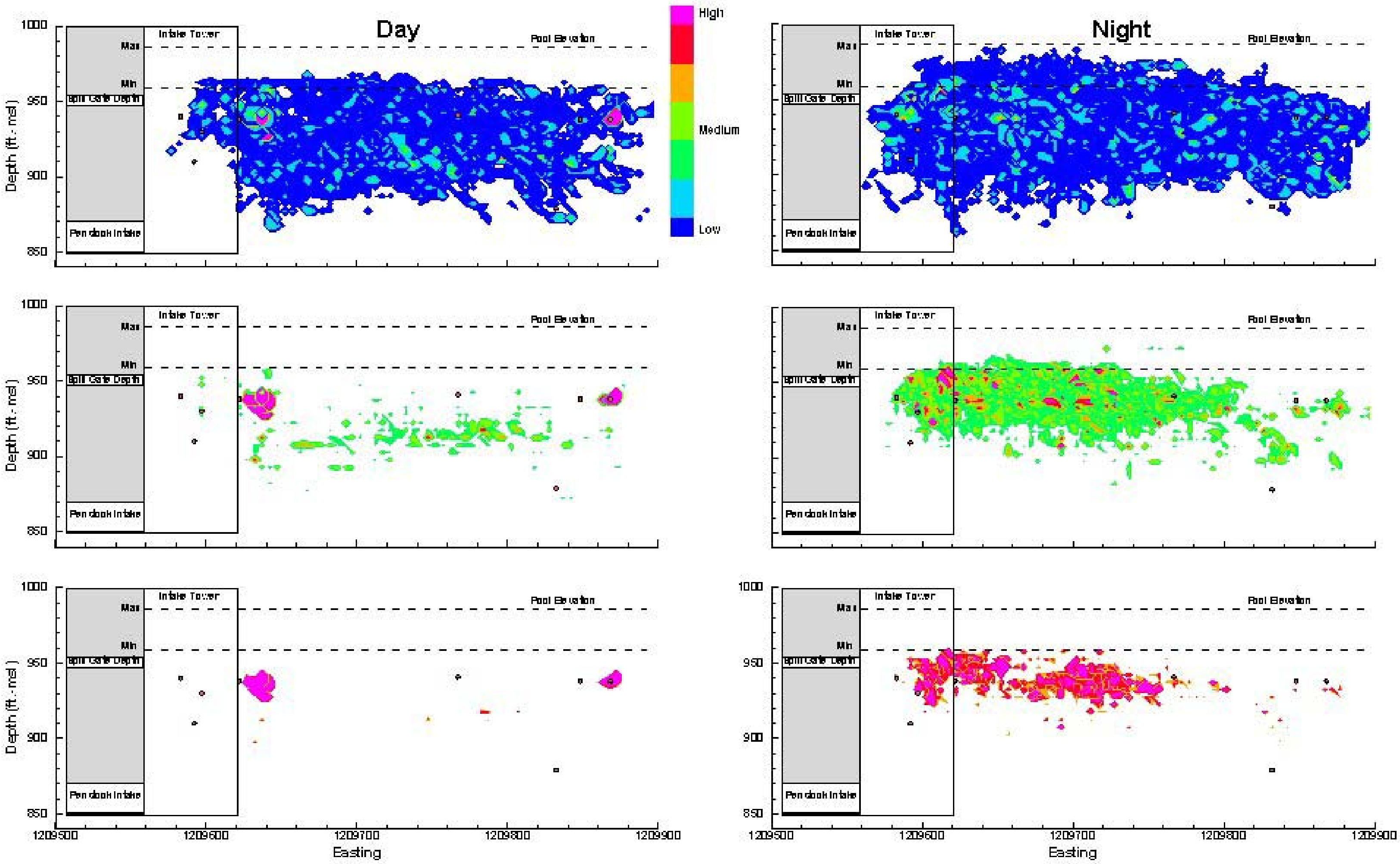


Figure 4.17-23. Plots (side view) show areas of low (top), medium (middle), and high (bottom) fish concentrations for juvenile Chinook salmon detected during the third non-spill period for day and night treatments in the forebay of Swift No. 1, 2002.

Note: Black dots depict the locations of eight hydrophones placed in the forebay.

Coho

Spill vs. Non-Spill – The lowest density plots represent the full coverage evident during the spill period is due to fewer fish being exposed to a relatively brief spill condition (Figure 4.17-24). In contrast, the non-spill condition prior to 4 April spanned a much greater time, allowing a much longer exposure period for the fish at liberty.

The medium density plots provide a better representation of where fish were generally concentrated. The distribution patterns suggest a shift from a more dispersed distribution during the non-spill event to a more localized concentration near the face of the dam during a spill event (Figure 4.17-24). The highest concentrations of fish during the spill condition were generally situated near the front of the spillway, although a few high concentration patches were scattered throughout the forebay. During the non-spill event the highest concentration of fish detections were along the perimeter of the forebay near the shoreline boundary of the forebay and also along the face of the dam.

There was no shift in vertical distribution evident between spill and non-spill periods (Figure 4.17.25). This is most apparent when viewing the medium and high concentration of fish detection. In general the coho occupied the upper one-third of the water column throughout the forebay.

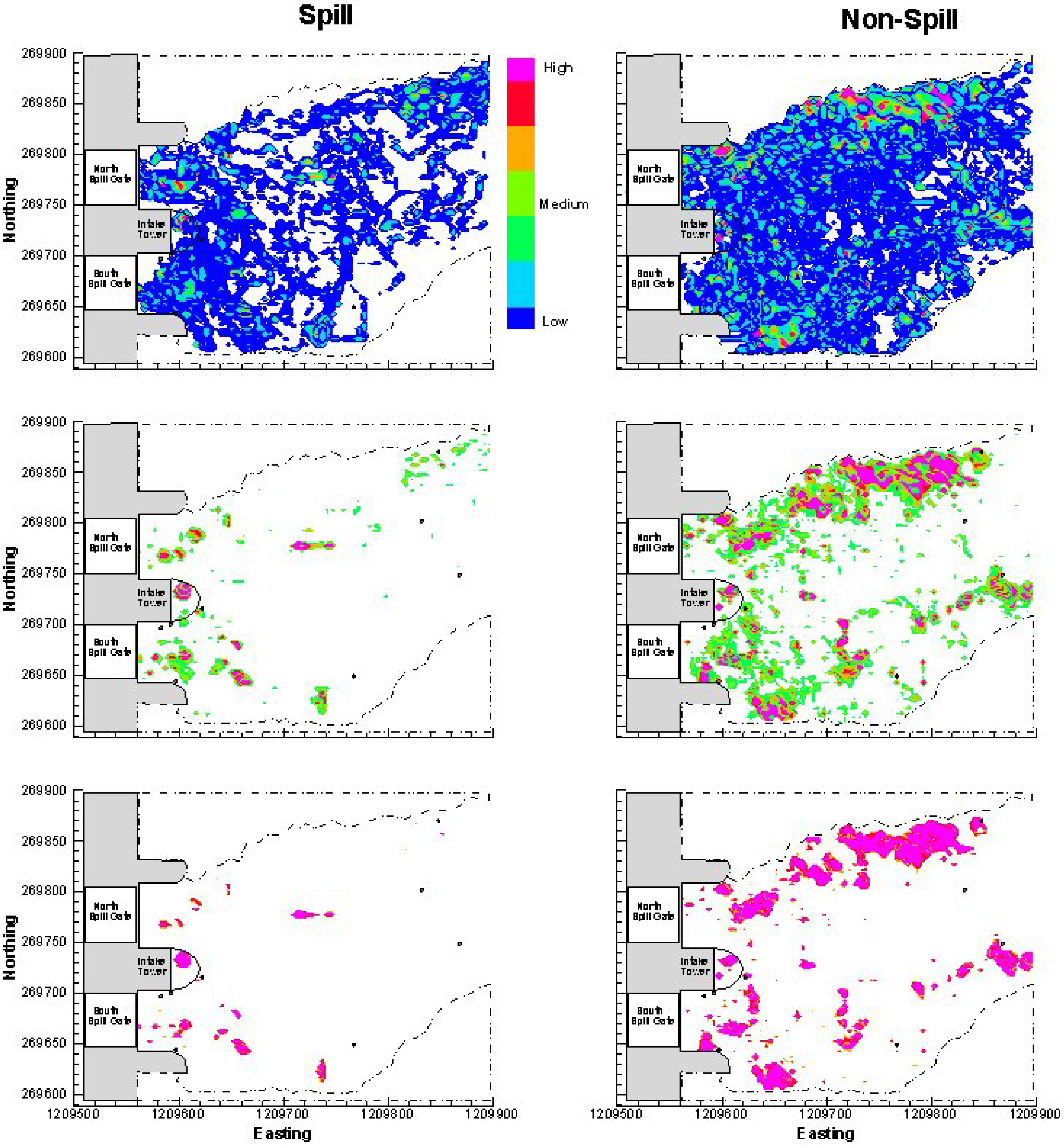


Figure 4.17-24. Plots (plan view) show areas of low (top), medium (middle), and high (bottom) fish concentrations for juvenile coho salmon detected during spill (1&2) and non-spill (1&2) periods in the forebay of Swift No. 1, 2002.

Note: During spill events the south spill gate was opened to allow 2000 cfs flow. Black dots depict the locations of eight hydrophones placed in the forebay.

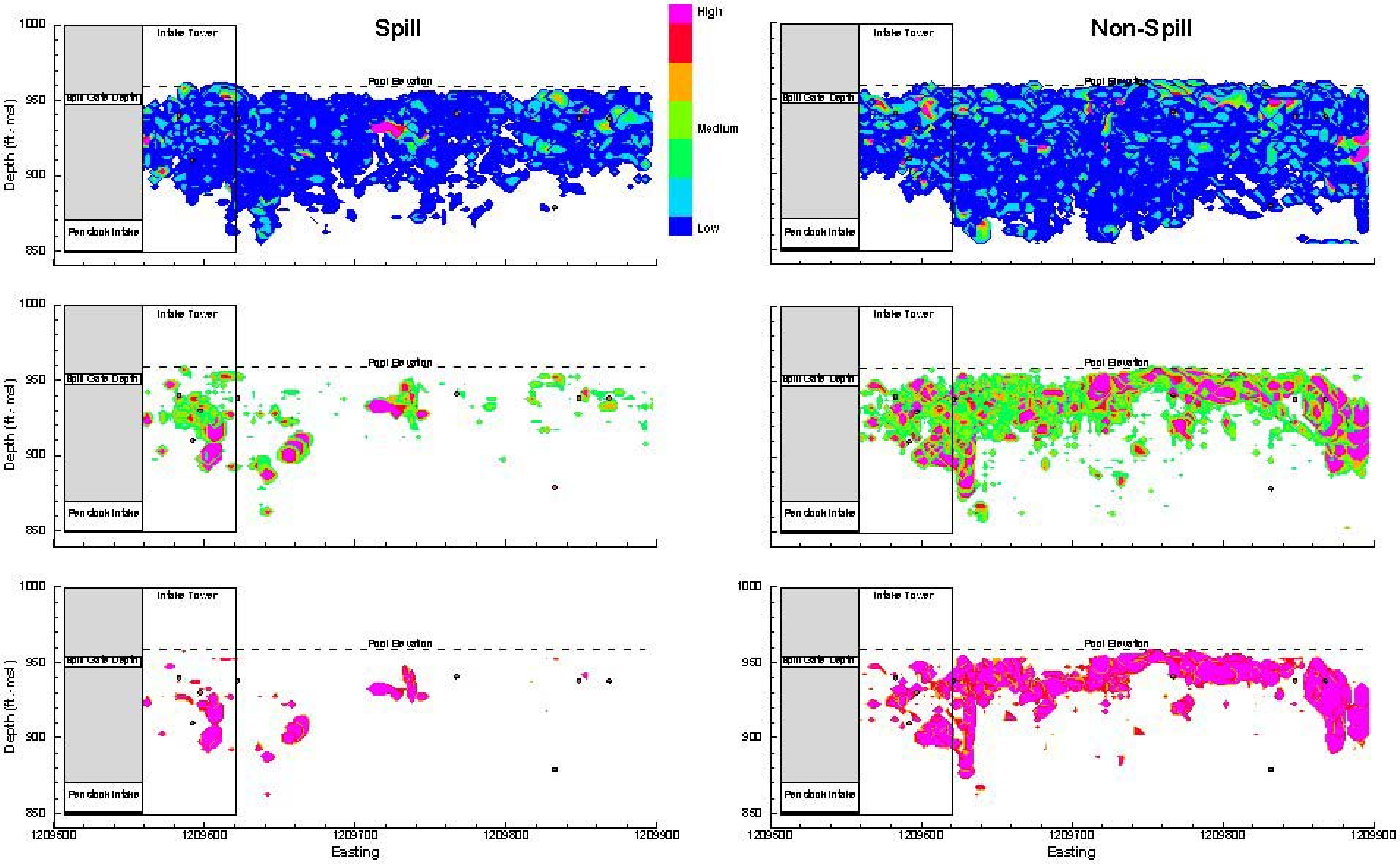


Figure 4.17-25. Plots (side view) show areas of low (top), medium (middle), and high (bottom) fish concentrations for juvenile coho salmon detected during spill (1&2) and non-spill (1&2) periods in the forebay of Swift No. 1, 2002.

Note: During spill events the south spill gate was opened to allow 2000 cfs flow. Black dots depict the locations of eight hydrophones placed in the forebay.

<u>Spill (Day vs. Night)</u> – The medium and highest concentration of fish detections reveal a shift in horizontal distribution from day to night (Figure 4.17-26). During daylight, fish were concentrated near the spillway opening and near the intake tower; however, at night, few detections were recorded in those areas.

During the night, fish detections were near the surface and were higher in the water column than those detected during the day (Figure 4.17-27). Fish were distributed over a greater depth during the day, particularly near the face of the dam.

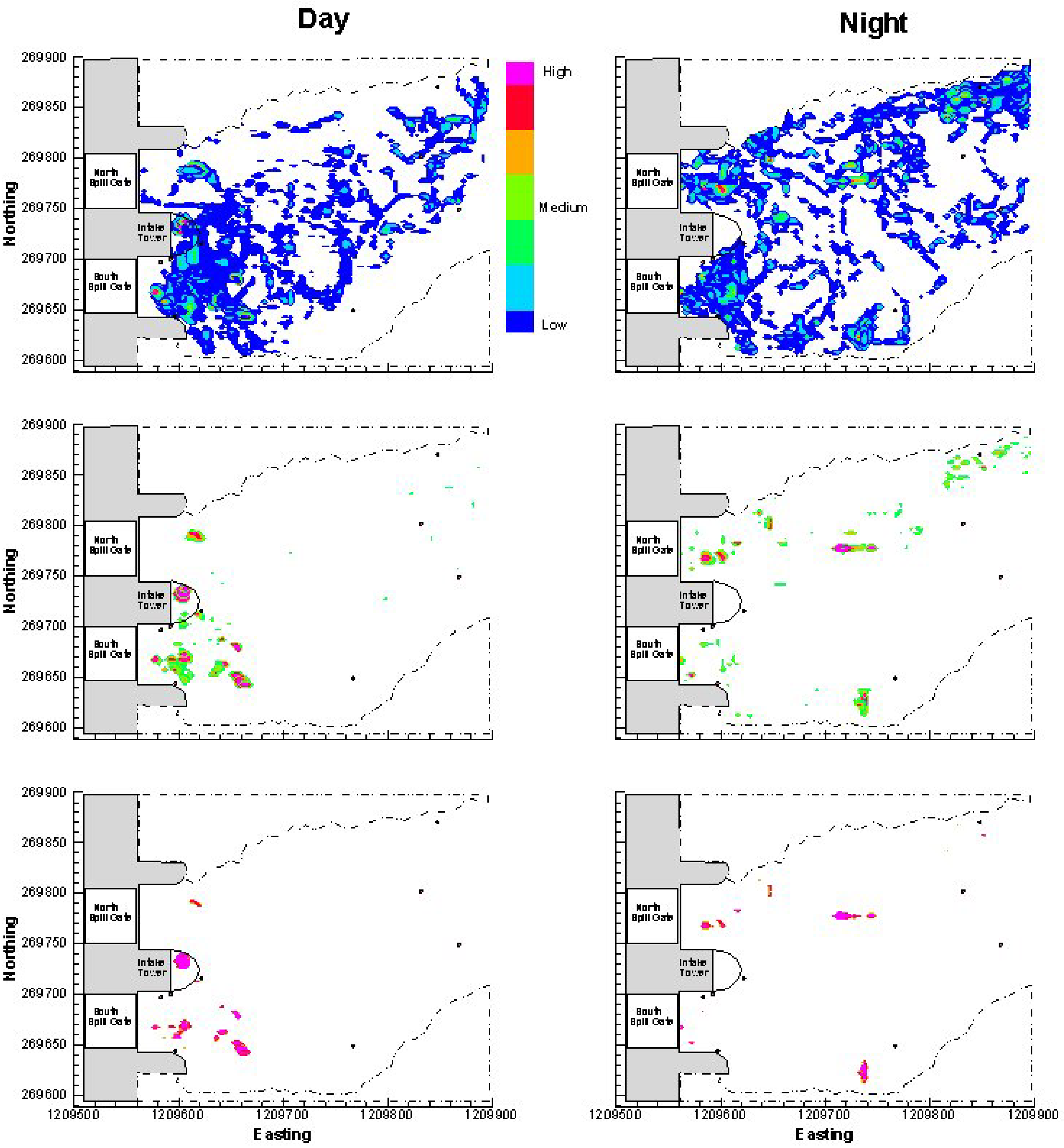


Figure 4.17-26. Plots (plan view) show areas of low (top), medium (middle), and high (bottom) fish concentrations for juvenile coho salmon detected during spill events for day and night treatments in the forebay of Swift No. 1, 2002.

Note: During spill events the south spill gate was opened to allow 2000 cfs flow. Black dots depict the locations of eight hydrophones placed in the forebay.

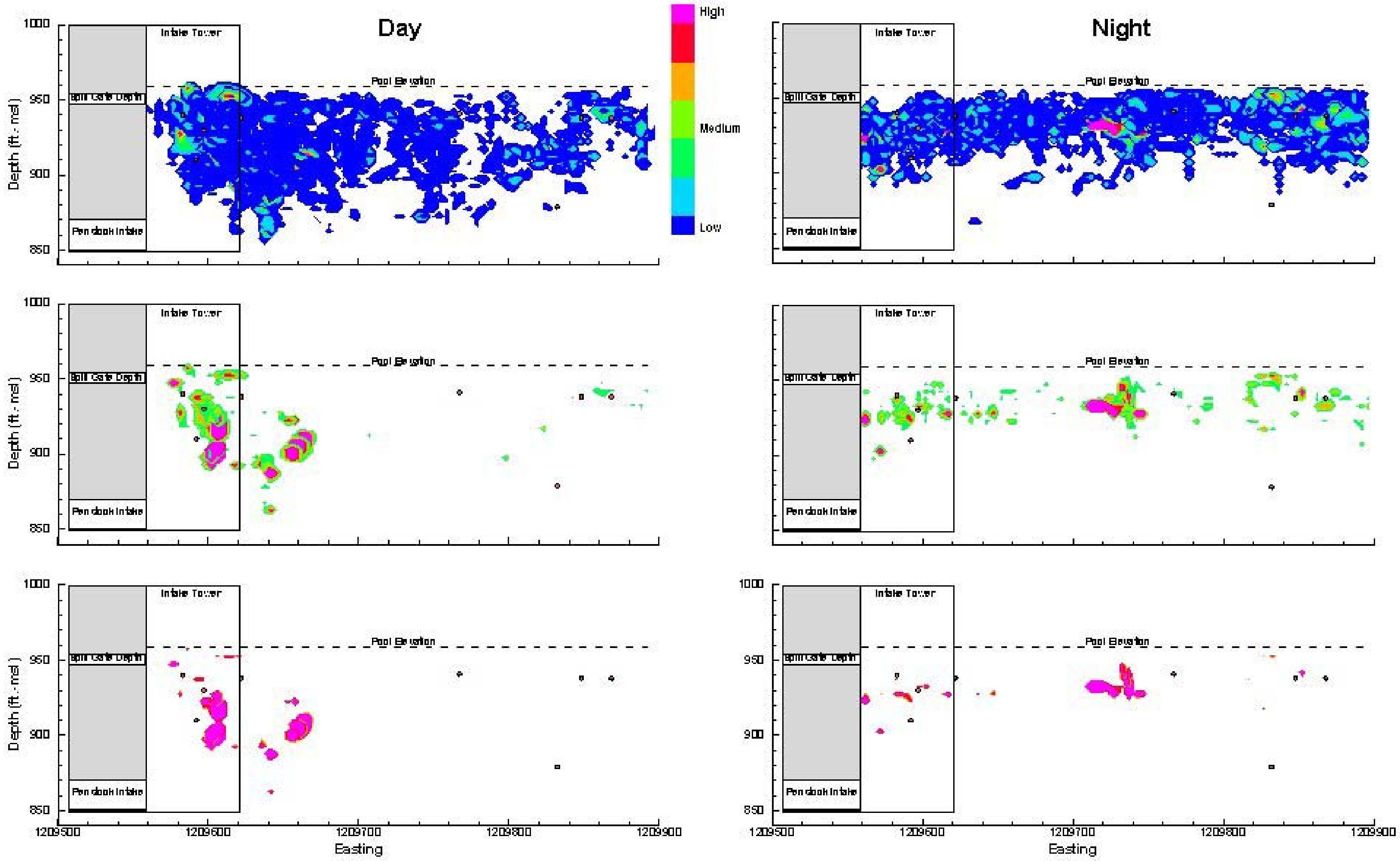


Figure 4.17-27. Plots (side view) show areas of low (top), medium (middle), and high (bottom) fish concentrations for juvenile coho salmon detected during spill events for day and night treatments in the forebay of Swift No. 1, 2002.

Note: During spill events the south spill gate was opened to allow 2000 cfs flow. Black dots depict the locations of eight hydrophones placed in the forebay.

<u>Non-spill (Day vs. Night)</u> – A shift in fish concentration is evident from day to night when viewing the medium and high concentration plots (Figure 4.17-28). Their patterns are consistent with those observed during the spill events. During the day, fish detections were concentrated near the dam, whereas at night, fish detections were most frequent near the perimeter bounded by the shoreline.

The pattern varied from day to night and parallel those observed during spill periods. At night, fish were higher in the water column, forming a relatively uniform band (Figure 4.17-29). In contrast, during the day, fish were distributed over a greater depth extending to the water surface.

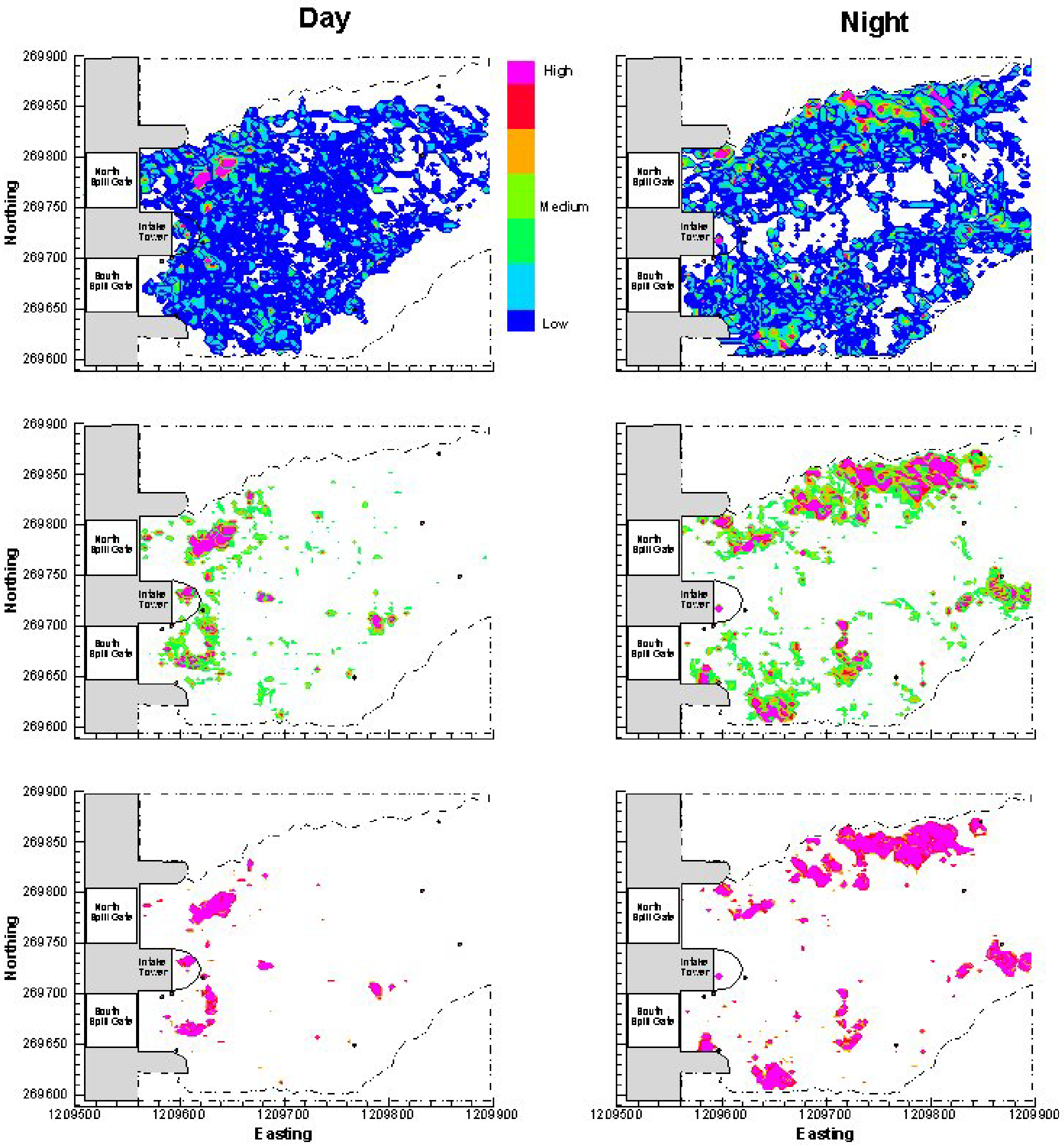


Figure 4.17-28. Plots (plan view) show areas of low (top), medium (middle), and high (bottom) fish concentrations for juvenile coho salmon detected during non-spill events for day and night treatments in the forebay of Swift No. 1, 2002.

Note: Black dots depict the locations of eight hydrophones placed in the forebay.

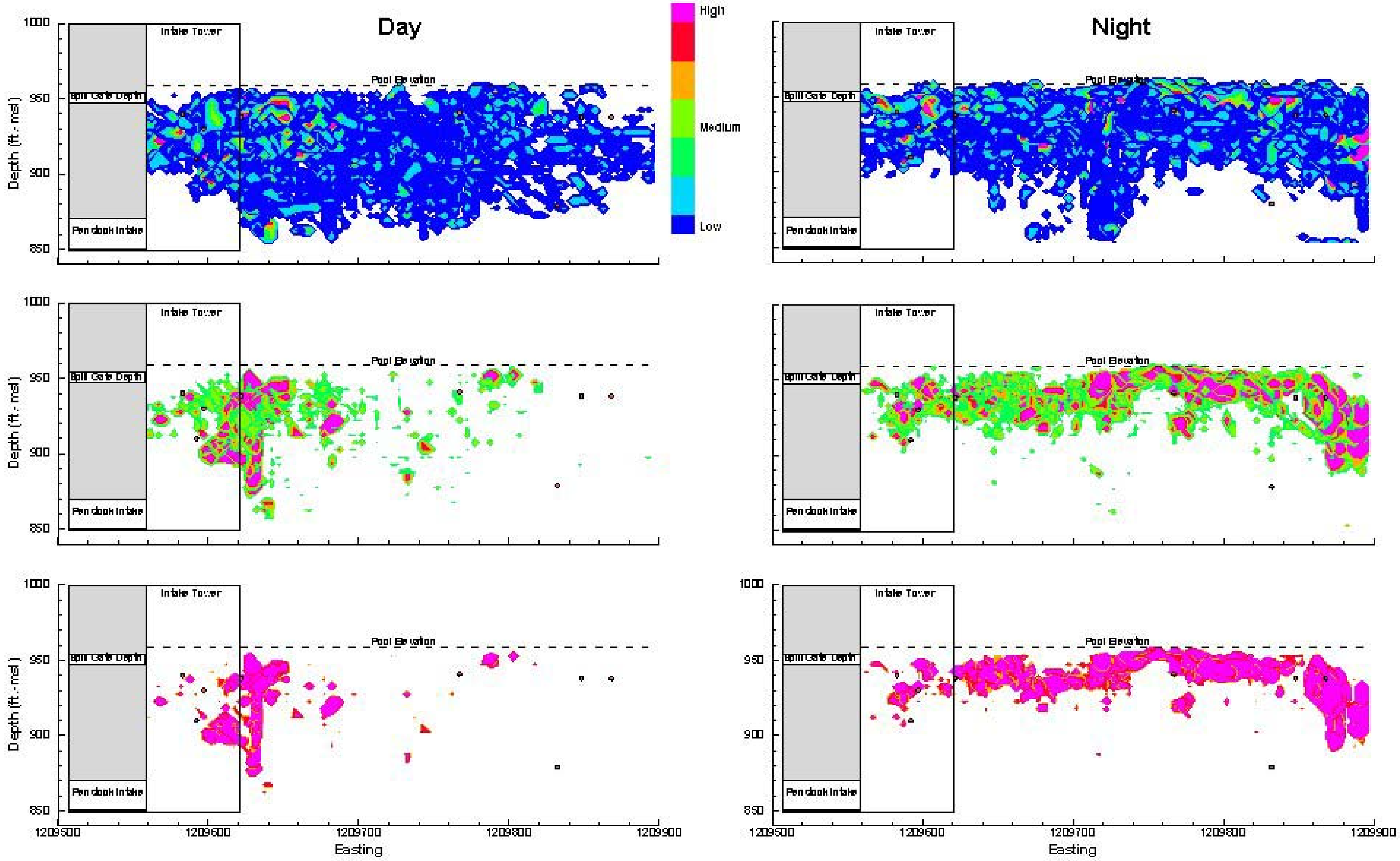


Figure 4.17-29. Plots (side view) show areas of low (top), medium (middle), and high (bottom) fish concentrations for juvenile coho salmon detected during non-spill events for day and night treatments in the forebay of Swift No. 1, 2002.

Note: Black dots depict the locations of eight hydrophones placed in the forebay.

Non-Spill Period (Increasing pool elevation: Day vs. Night) – There does not appear to be a shift in fish position evident for the third non-spill period (Figure 4.17-30). At low fish concentrations, coho tended to have a wider distribution at night. The medium concentration plots show that coho tend to concentrate in the same general areas of the forebay for both day and night (Figure 4.17-30). The highest fish concentration areas at night appear to be larger than the day, but both show similar areas of concentration.

The vertical distribution of coho in the forebay was also similar for day and night treatments (Figure 4.17-31). A slight movement of fish concentration appears closer to the project at night than for fish during the day. The greatest variation in depth for both day and night treatments is exhibited near the project. The number of fish that were observed during the day and night were similar but the number of fish positions was much greater for the night (Table 4.17-3).

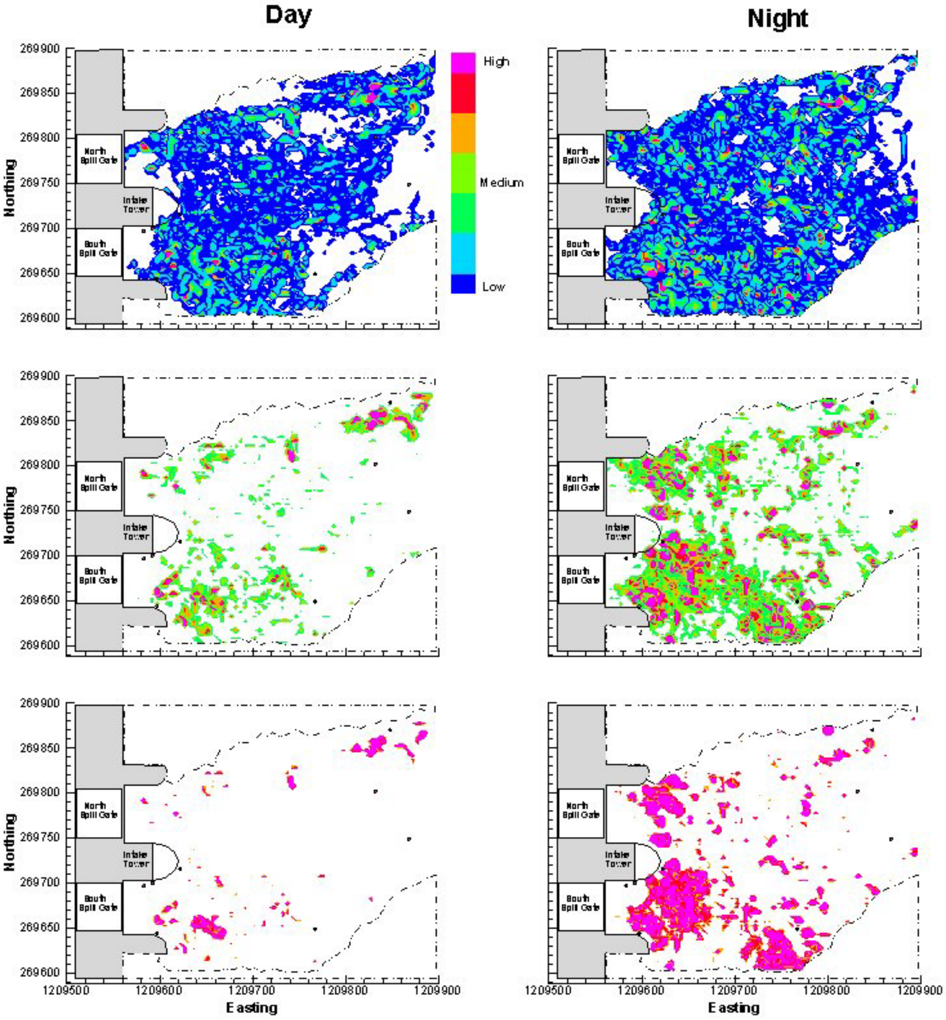


Figure 4.17-30. Plots (plan view) show areas of low (top), medium (middle), and high (bottom) fish concentrations for juvenile Chinook salmon detected during the third non-spill period for day and night treatments in the forebay of Swift No. 1, 2002.

Note: Black dots depict the locations of eight hydrophones placed in the forebay.

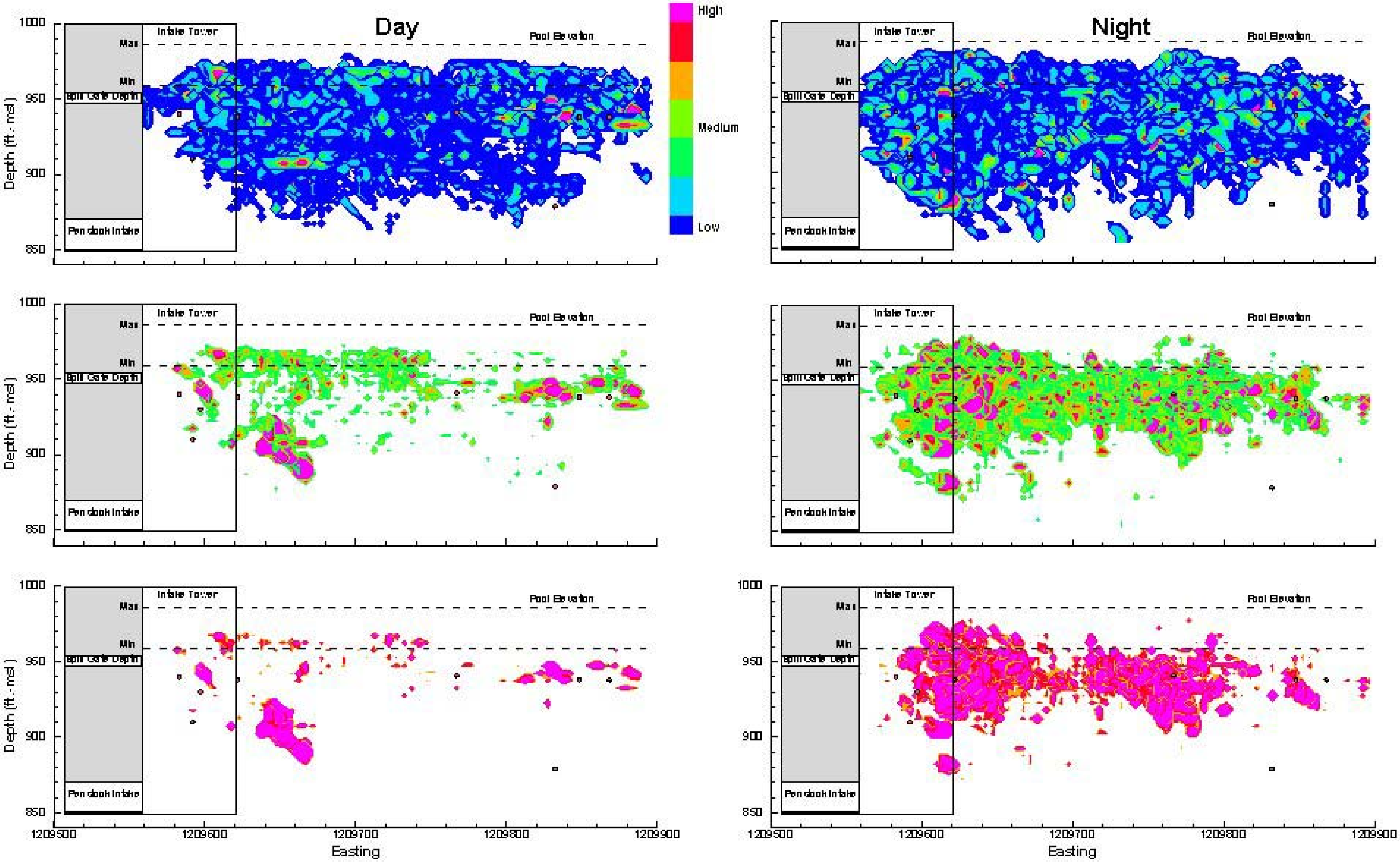


Figure 4.17-31. Plots (side view) show areas of low (top), medium (middle), and high (bottom) fish concentrations for juvenile Chinook salmon detected during the third non-spill period for day and night treatments in the forebay of Swift No. 1, 2002.

Note: Black dots depict the locations of eight hydrophones placed in the forebay.

4.17.5.5 Forebay Flow Characterization

On 3 and 4 April ADCP data were collected to characterize flow conditions in the forebay of Swift No. 1 during spill and non-spill conditions, respectively. Turbine generation varied from 1,850-2,785 cfs when the non-spill condition data were collected. During the spill condition, spill remained constant at 2,000 cfs when data were collected but turbine generation varied from 2,304-2,655 cfs.

Velocity Profiles

We profiled velocities across the forebay at three different 10-foot depth strata. The depth strata were: (1) 946-956 ft.-msl- this is essentially the surface waters that encompasses the spill gate opening at 950 feet, (2) 926- 936 ft.-msl- surface waters that include the top of the trashrack structure, and (3) 896-906 ft.-msl- mid-water column depth. We plotted the data for each depth strata to show the common area of data collection and to depict the difference in velocities during spill and non-spill conditions (Figure 4.17-32).

The common area suggests that the velocities were about 0.5-1.0 fps greater at all depths for the spill condition test (Figure 4.17-32). The general increase in velocities during the spill condition is not unexpected because there was about twice as much discharge passing the project. As depth increased, the common area decreased. Outside the common area in the spill condition test the velocities increased in several spots to about 3.0 fps. These measurements seem to be a little high at such a distance from either the spill gate or the penstock intake. During the spill condition only one transect recorded velocities near the spill gate opening (Figure 4.17-8). Unfortunately, there was very little data collected near the spill gate to interpolate. However, within the first ten feet of that transect the maximum velocity was about 2.9 fps (Figure 4.17-32; 946-956-foot strata).

During the non-spill condition the highest velocities were central to the intake tower at all depths (Figure 4.17-32). The maximum velocity in front of the intake tower during the non-spill condition was 2.0 fps at a depth of 921 ft.-msl. This seems unexpected since the intake to the powerhouse is at a depth of 855 ft.-msl (centerline).

We plotted vertical profiles in front of the south spill gate and the intake tower during both spill and non-spill conditions (Figure 4.17-33). The vertical profiles show a “slice” of the velocities in front of the south spill gate and intake tower. A slice was also taken in the common area as means to compare the velocities during the spill and non-spill conditions.

The vertical profile during the spill condition show a definite pattern (centered at 950 ft.-msl) in front of the south spill gate that nearly extends out to the trashrack (Figure 4.17-33). Here, the velocity in front of the spill gate ranged from 0.73-2.9 fps. In the common area velocities were about twice as high during the spill condition and extended to a greater depth than the non-spill condition. The area between the spill gate and common area displays lower velocities during the spill condition (Figure 4.17-33). This area may represent the horizontal extent or transition of velocities created from opening the spill gate and velocities created from the powerhouse.

Velocities in front of the intake tower during the non-spill condition ranged from 0.36-0.73 fps. The highest velocities were at the top of the trashrack extending outward from the project to greater depths. During spill the velocities in front of the intake tower ranged from 0.36-1.8 fps. Under both conditions the ADCP profile does not appear to detect water velocities at depths below 880 ft-msl.

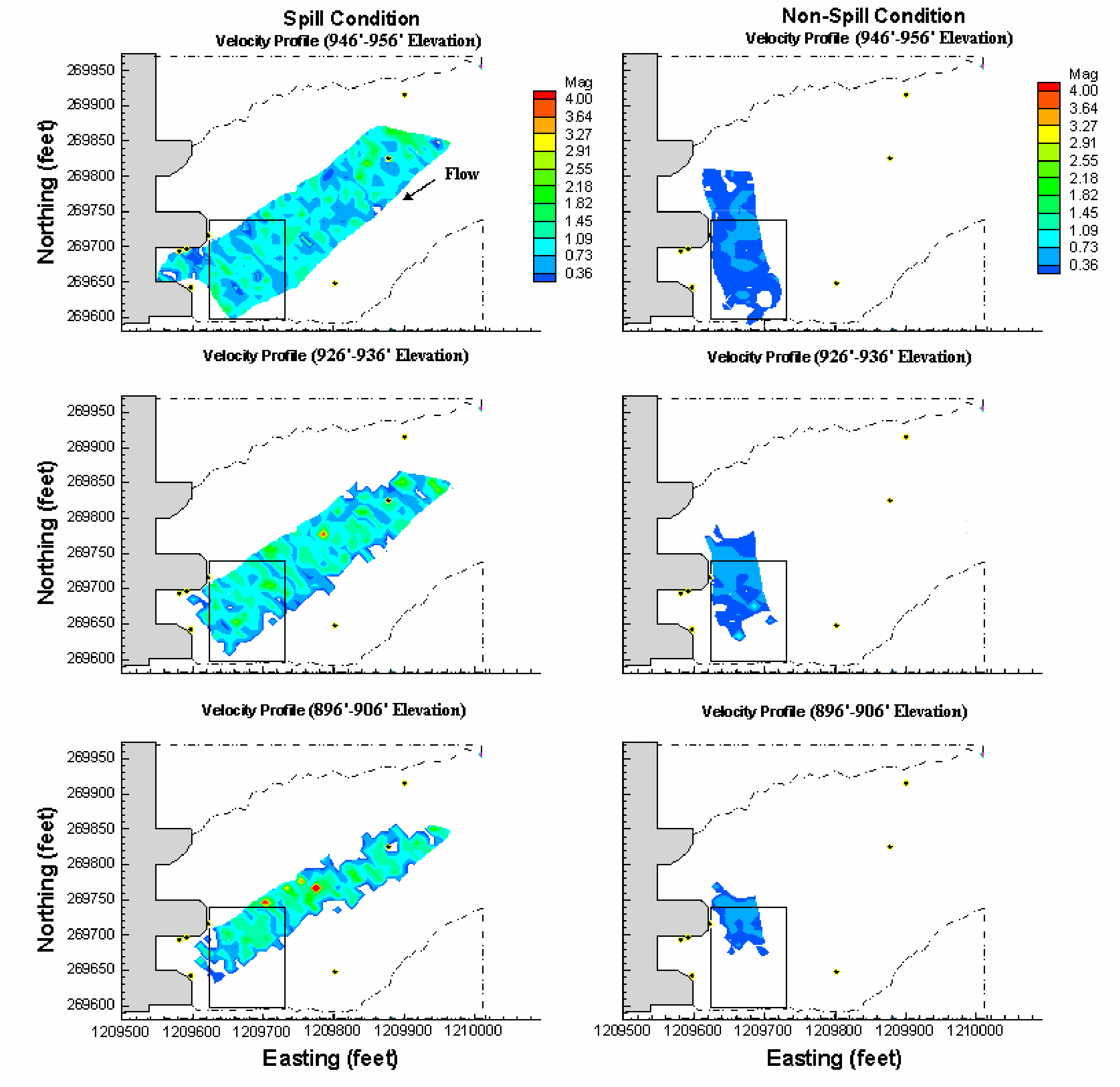


Figure 4.17-32. Plan view of water velocities (ft/sec) at 10 ft vertical strata through the water column from 946-956, 926-936, and 896-906 feet for ADCP data collected in Swift No. 1 forebay during a spill and non-spill conditions.

Note: The black rectangle outlines the common area of data collection under both conditions.

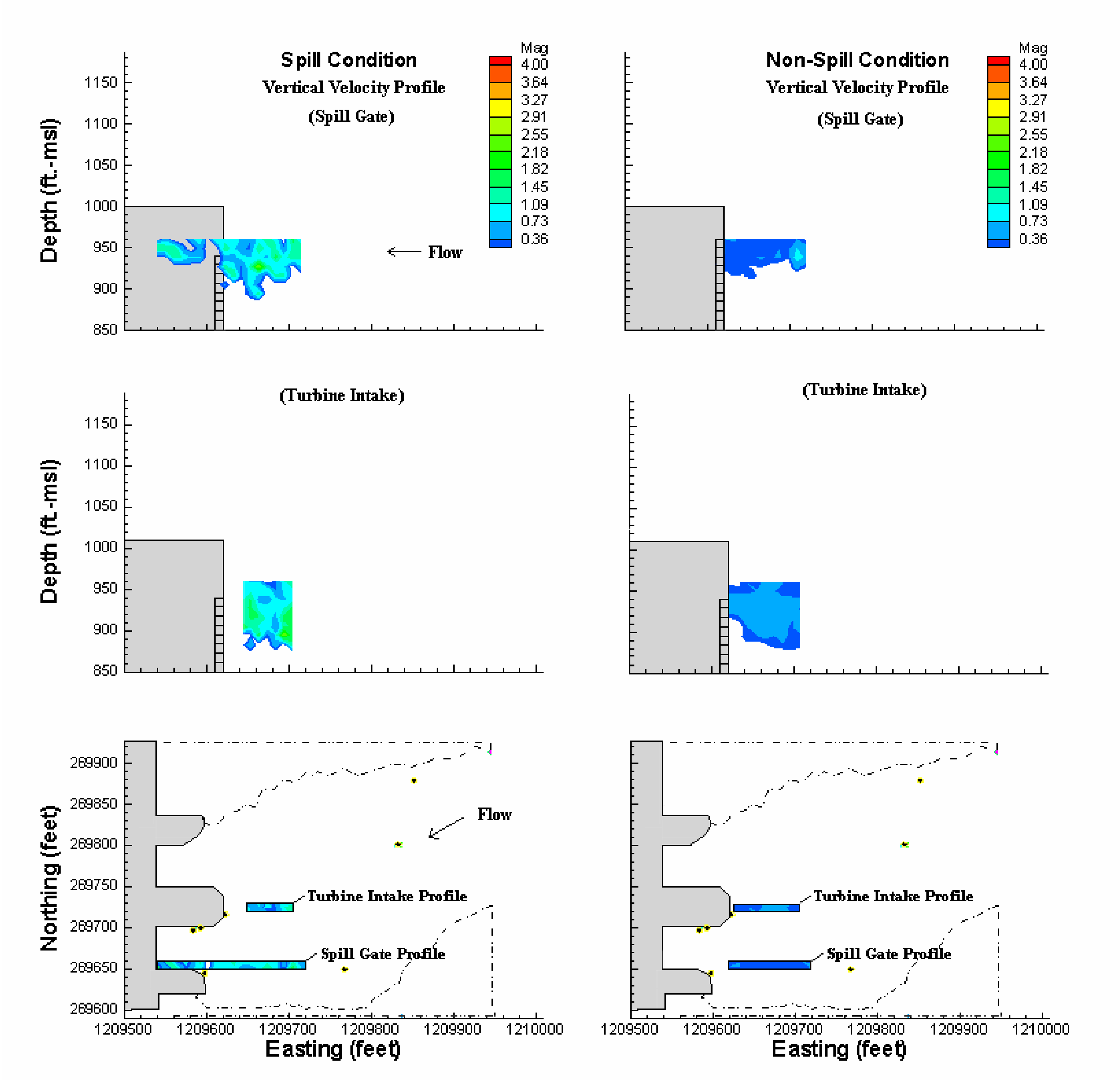


Figure 4.17-33. Vertical velocity profiles in front of the spill gate (top) and in front of the turbine intake (middle) during the spill and non-spill conditions.

Note: The spill gate opening is at 950 ft-msl and the trashrack is represented in the top two graphs by a small vertical stack of squares. At the bottom of the figure there is a horizontal view that displays the slices extracted to produce the vertical profiles.

4.17.5.6 Individual Fish Tracks

We plotted examples of individual fish “tracks” during spill and non-spill conditions. The tracks represent the entire forebay movement that occurred for each fish selected. We selected four coho and four Chinook under different operational conditions to display a variety of movement patterns.

Chinook

For the spill condition we selected two Chinook that passed the project (Figure 4.17-34). The first example displays a Chinook (tag-1490) that remained in the forebay for 6.5 hours. That Chinook moved throughout the forebay but tended to concentrate near the south spill gate, until it passed the project at 9:45 PM (night). Another Chinook (tag-1560) spent only 0.4 hours in the forebay with no local area of concentration before it passed the project at 1:23 PM (day).

During the non-spill condition we selected two Chinook that had different activity patterns (Figure 4.17-34). The first example shows a Chinook (tag-1535) that spent 1.5 hours in the forebay. That Chinook moved mostly in the center of the forebay in front of the intake tower. However, another Chinook (tag-1260) concentrated most of its movement in front of the south spill gate area. The movement pattern for both fish occurred during the non-spill condition when there was turbine generation.

Coho

For the spill condition we selected one coho that passed the project and one that did not (Figure 4.17-35). The coho (tag-1520) that passed the project remained in the forebay for 5.2 hours before it passed the project at 9:14 PM (night). The movement of that coho in the forebay was concentrated near the south spill gate. During a spill condition, another coho (tag-1355) did not approach the south spill gate during the 3.7 hours that it was detected in the forebay. Instead, the fish moved along the north shoreline of the intake channel (Figure 4.14-2) with some movement also observed at the center and south shoreline of the forebay.

During the non-spill condition, we selected two coho that had different movement patterns in the forebay (Figure 4.17-35). The first example displays a coho (tag-1580) that remained in the forebay for 3.5 hours and moved extensively throughout the forebay with some concentration on the north shoreline of the intake channel. Another coho (tag-1405) remained in the forebay for 0.5 hrs and most of the movement was concentrated on the south shoreline of the intake channel. The movement pattern for both fish occurred during the non-spill condition when there was turbine generation.

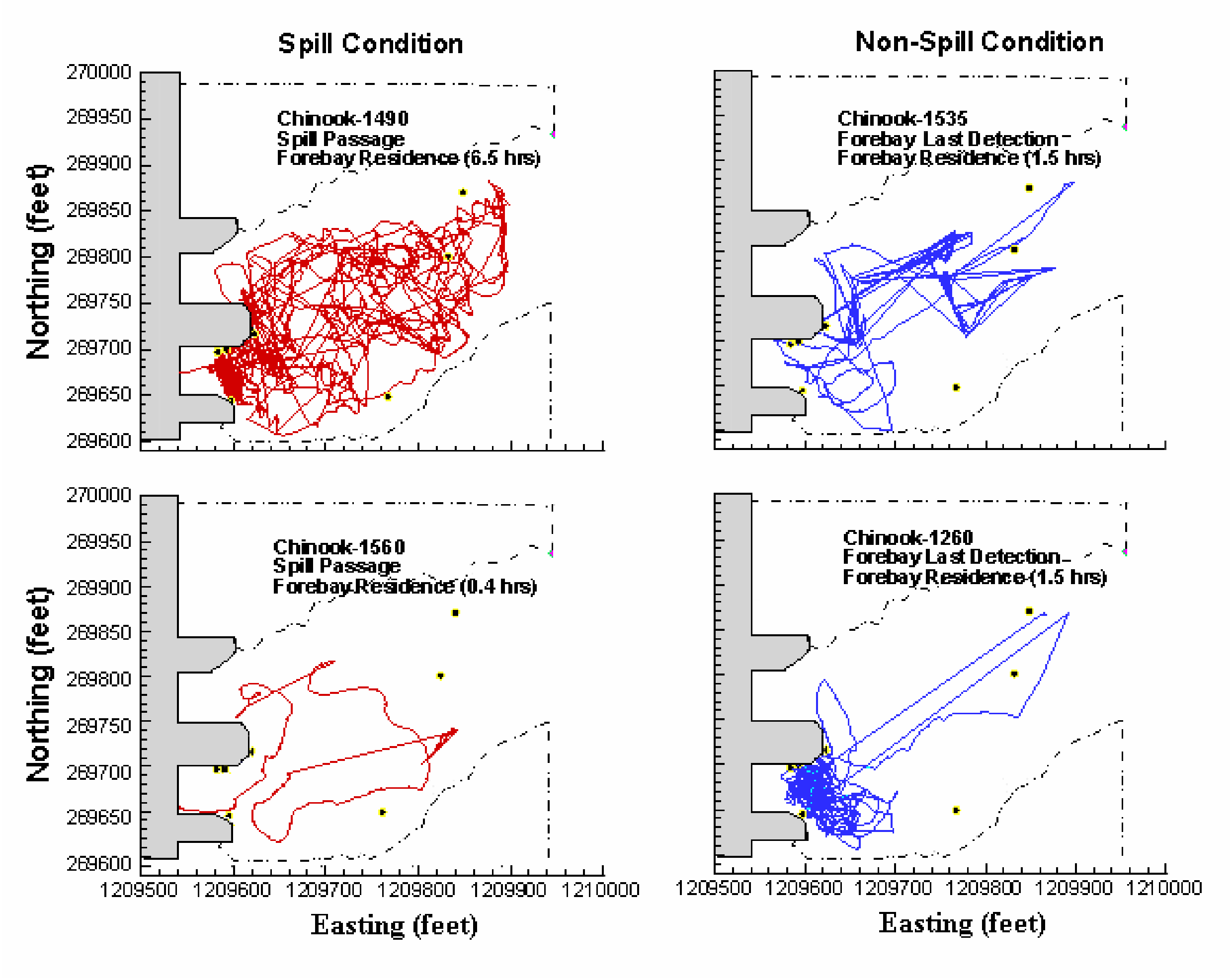


Figure 4.17-34. Individual fish tracks of juvenile Chinook recorded during spill and non-spill conditions in the forebay of Swift No. 1.

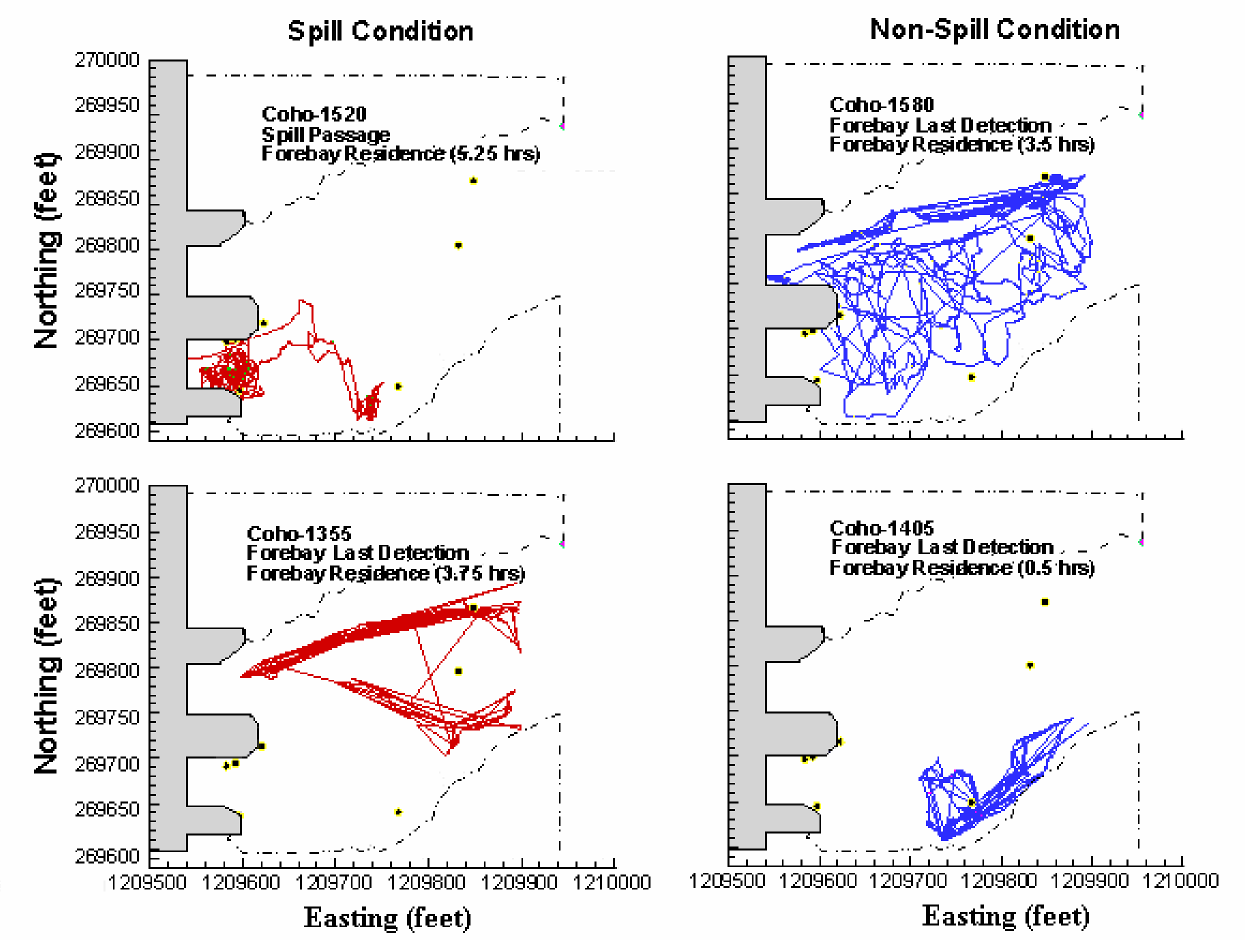


Figure 4.17-35. Individual fish tracks of juvenile coho recorded during spill and non-spill conditions in the forebay of Swift No. 1.

4.17.6 Discussion

Fish liberated at different sites in the forebay readily located the dam where water was being discharged, with 92% of the Chinook and 76% of the coho arriving near the dam. Nearly all of those entered the forebay, with 80% of the Chinook and 62% of the coho tracked three-dimensionally.

Even though only 48 hours of spill occurred over the entire study period, 37% (7 of 19) of the Chinook detected in the forebay passed through the spill gate while spill occurred. In contrast, only 12% (2 of 17) of the coho passed via the spill gate. The density plots suggest that both species concentrated in the vicinity of the spill gate when it was open, so this does not explain the different spill passage rates. Also, the vertical distribution of both species was similar and is not likely a contributing factor. Since the fish used in this study were taken directly from the hatchery early in the spring, it is doubtful that they were fully smolted during the study period. If the two species were at different levels of smolt development, that may have influenced their migratory response and proclivity to locate an outlet. In the future it would be advantageous to document the level of smolt development and use those that are fully smolted. This may result in an increased passage rate and associated behaviors such as forebay residence time and congregation near discharge outlets.

Clearly, both species concentrated near the dam while resident in the forebay. Chinook were localized near the south spill gate when spill was both provided and shut-off, whereas, coho shifted toward that spill gate only when water was discharged. These patterns suggest that both species would take advantage of a surface flow bypass intake if one was located in the vicinity of the dam. Thus, testing a prototype bypass/collector system, like a small scale gulper, would appear to have merit.

The flow characteristics in the forebay revealed that velocities were nearly twice as much during the spill condition than during the non-spill condition, which is not unexpected because there was about twice as much discharge at the project. In general the high fish concentration areas in front of the south spill gate during spill events appeared to approximate the horizontal transition of velocities extending from the spill gate to the common area. Fish may avoid abrupt changes in velocity particularly from a lower to a higher gradient (Bell 1991). A smooth transition and acceleration are desirable to guide or direct fish which helps prevent fish from stopping or hesitating near an entrance. This may, in part, explain the low passage rates observed during spill conditions and the tendency to concentrate in the transition area.

The spill gate opening was narrow in height (about 9 inches) and extended over a broad width (51 feet). This outlet configuration is not typical of the surface collector systems in place throughout the region, and may not have provided the type of water current cue that is most attractive to smolts. For example, systems designed specifically as collector or bypass provide openings that are usually either vertically-oriented (e.g., the surface flow system at Rocky Reach Dam and Wells Dam), or they resemble a compact ice/trash sluice opening situated at the waters surface (e.g., the surface bypass at Bonneville Dam Second Powerhouse). Granted the intent at Swift Dam was to test the concept; however, we think it should be noted that the configuration of the port may not have been optimal in terms of eliciting migratory response in the test fish. Even so, the concept of pursuing surface collection at Swift appears to have merit as evidenced by the collective behaviors observed in 2002.

4.17.7 Schedule

This study is complete.

4.17.8 References

Bell, M. C. 1991. Fisheries handbook of engineering and requirements and biological criteria. Fish passage development and evaluation program 1991. Corps of Engineers, North Pacific Division, Portland, OR.

Davis, J. C. 1973 and 1986. Statistics and Data Analysis in Geology, Second Edition, John Wiley & Sons, New York.

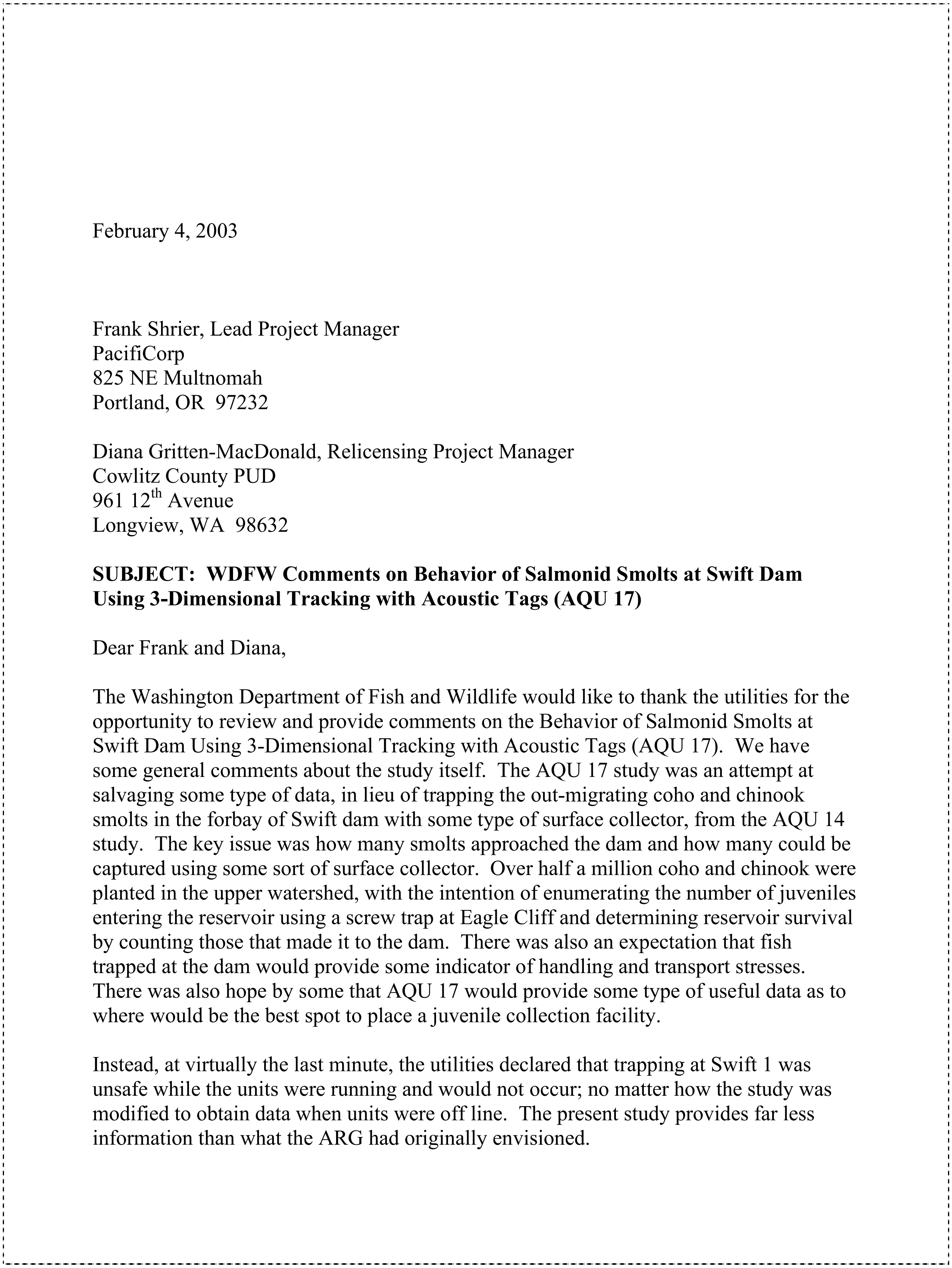
HTI. 1997. Phase 1 Report: Acoustic tag feasibility testing at Rocky Reach Dam. Progress report by HTI to Chelan County PUD, Wenatchee, WA.

Miller, M. D., Stevenson, J. S., Giorgi, A. E., and B. Torrell, 2001. Migratory behavior of radio-tagged juvenile coho salmon through Swift Reservoir. Prepared for PacifiCorp, Portland, OR and Cowlitz County PUD, Longview, WA.

Mitson, R. B. 1978. A review of biotelemetry techniques using acoustic tags. In J. E. Thorpe, editor. Rhythmic activities of fishes. Academic Press, New York.

4.17.9 Comments and Responses on Draft Report

This section presents stakeholder comments provided on the draft report. The Licensees' responses are also provided.



February 4, 2003

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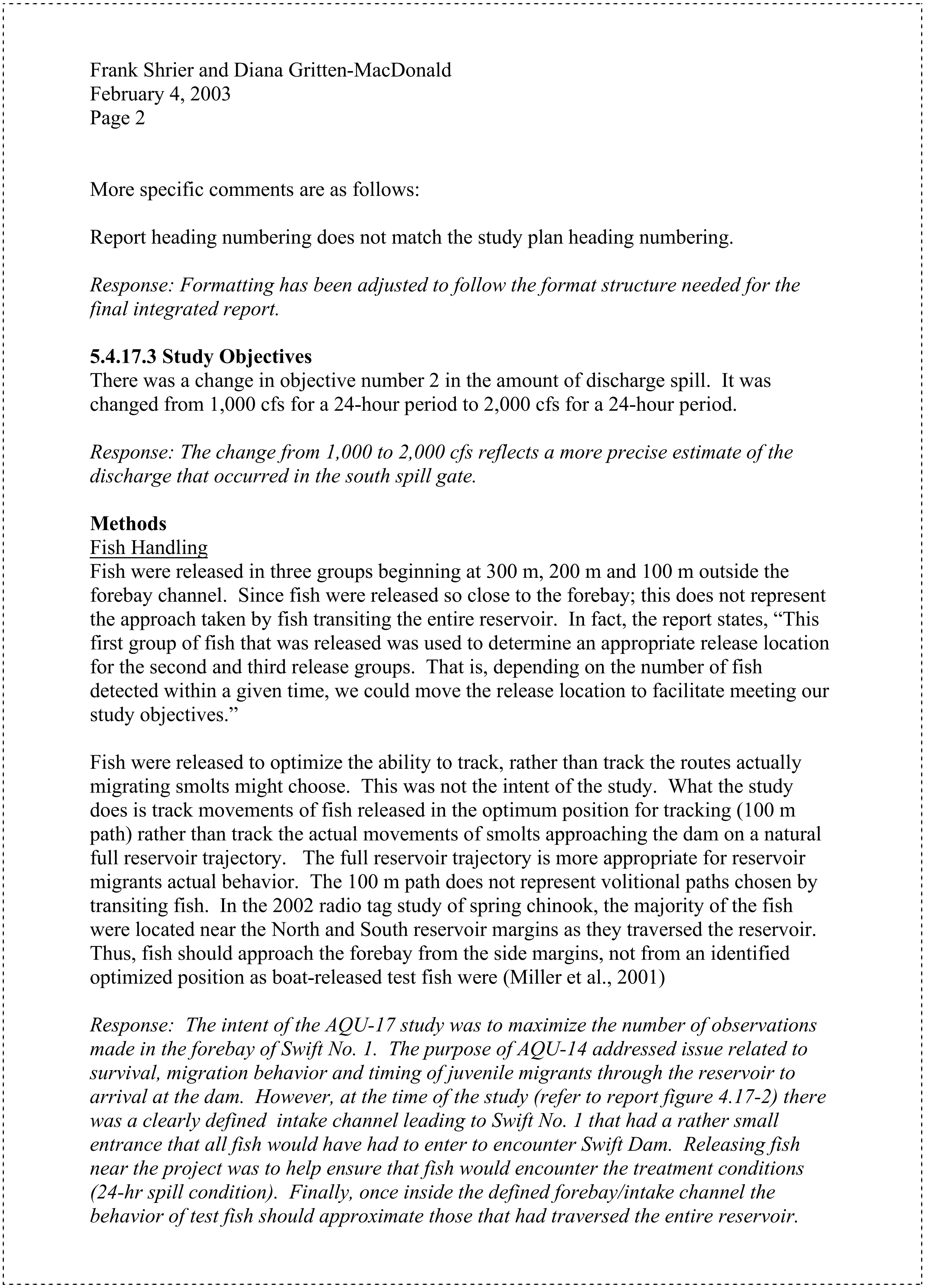
SUBJECT: WDFW Comments on Behavior of Salmonid Smolts at Swift Dam Using 3-Dimensional Tracking with Acoustic Tags (AQU 17)

Dear Frank and Diana,

The Washington Department of Fish and Wildlife would like to thank the utilities for the opportunity to review and provide comments on the Behavior of Salmonid Smolts at Swift Dam Using 3-Dimensional Tracking with Acoustic Tags (AQU 17). We have some general comments about the study itself. The AQU 17 study was an attempt at salvaging some type of data, in lieu of trapping the out-migrating coho and chinook smolts in the forbay of Swift dam with some type of surface collector, from the AQU 14 study. The key issue was how many smolts approached the dam and how many could be captured using some sort of surface collector. Over half a million coho and chinook were planted in the upper watershed, with the intention of enumerating the number of juveniles entering the reservoir using a screw trap at Eagle Cliff and determining reservoir survival by counting those that made it to the dam. There was also an expectation that fish trapped at the dam would provide some indicator of handling and transport stresses. There was also hope by some that AQU 17 would provide some type of useful data as to where would be the best spot to place a juvenile collection facility.

Instead, at virtually the last minute, the utilities declared that trapping at Swift 1 was unsafe while the units were running and would not occur; no matter how the study was modified to obtain data when units were off line. The present study provides far less information than what the ARG had originally envisioned.

Figure 4.17-36. WDFW comments on draft report and Licensees' response.



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More specific comments are as follows:

Report heading numbering does not match the study plan heading numbering.

Response: Formatting has been adjusted to follow the format structure needed for the final integrated report.

5.4.17.3 Study Objectives
There was a change in objective number 2 in the amount of discharge spill. It was changed from 1,000 cfs for a 24-hour period to 2,000 cfs for a 24-hour period.

Response: The change from 1,000 to 2,000 cfs reflects a more precise estimate of the discharge that occurred in the south spill gate.

Methods
Fish Handling
Fish were released in three groups beginning at 300 m, 200 m and 100 m outside the forebay channel. Since fish were released so close to the forebay; this does not represent the approach taken by fish transiting the entire reservoir. In fact, the report states, "This first group of fish that was released was used to determine an appropriate release location for the second and third release groups. That is, depending on the number of fish detected within a given time, we could move the release location to facilitate meeting our study objectives."

Fish were released to optimize the ability to track, rather than track the routes actually migrating smolts might choose. This was not the intent of the study. What the study does is track movements of fish released in the optimum position for tracking (100 m path) rather than track the actual movements of smolts approaching the dam on a natural full reservoir trajectory. The full reservoir trajectory is more appropriate for reservoir migrants actual behavior. The 100 m path does not represent volitional paths chosen by transiting fish. In the 2002 radio tag study of spring chinook, the majority of the fish were located near the North and South reservoir margins as they traversed the reservoir. Thus, fish should approach the forebay from the side margins, not from an identified optimized position as boat-released test fish were (Miller et al., 2001)

Response: The intent of the AQU-17 study was to maximize the number of observations made in the forebay of Swift No. 1. The purpose of AQU-14 addressed issue related to survival, migration behavior and timing of juvenile migrants through the reservoir to arrival at the dam. However, at the time of the study (refer to report figure 4.17-2) there was a clearly defined intake channel leading to Swift No. 1 that had a rather small entrance that all fish would have had to enter to encounter Swift Dam. Releasing fish near the project was to help ensure that fish would encounter the treatment conditions (24-hr spill condition). Finally, once inside the defined forebay/intake channel the behavior of test fish should approximate those that had traversed the entire reservoir.

Figure 4.17-36. WDFW comments on draft report and Licensees' response (cont.).

Detection of Fish

The report states, “The highest detection rate for chinook was for the third release group which was released nearest the project (100 m). The highest detection rate for coho salmon . . . was achieved for those fish released at an intermediate distance (200 m) from the forebay.”

Most fish were detected when spill was occurring. The extra flow due to spill may spur fish into closer proximity to spillways and increase the probability of detection. Spill is good for attracting fish. Up to 37% of experimental chinook passed through the spillway and 12% of coho.

Elapsed Time

Release to First Detection

The report states, “The median travel times for coho salmon were more consistent and varied from about 14 - 21 -hours across the release groups. In contrast, chinook travel time to first detection varied broadly, from about 0.5 - 41 hours.” This is surprising since fish had only to travel 100-300 meters. Swim speed for coho to swim 300 m were 14.2 - 21.4 m/hr. and chinook were 7.3 - 600 m/hr. In the 2002 radio tagging (Miller et al., 2002), showed mean travel times of 5.5 days (140 m/hr) for chinook and 3.6 days for coho (214m/hr) to travel the whole 18.5 km; a distance 62 - 180 times greater than the study release distances. This suggests that the acoustic tags affected fish swimming ability and fish performance.

Response: Acoustic tags like radio tags were selected so that the weight of the tag would not exceed 5% of the body weight of the test fish. USGS Battelle has reported that they have found no deleterious effects for tagged fish following this general guideline. Moreover, the acoustic tag and radio tag are relatively the same size and both have been used to assess survival and behavior of fish. Radio-tagged coho and chinook (2001 and 2002, respectively) were released into the upper Lewis River affording them some initial orientation to flow to begin their migration. The radio-tagged fish were also released later in the year (smolt development) which may have contributed to increased migration speed.

Individual Fish Tracks

Not sure what four individual tracks from 100-tagged fish indicate. Do these represent the most and least direct fish under spill and non-spill situations? This is unclear.

Response: Individual fish tracks were added to the report to give the reader some examples of fish passage and movement in the forebay. Including each individual fish track would have added considerable volume to the report.

Figure 4.17-36. WDFW comments on draft report and Licensees’ response (cont.).

Discussion
The study states, "Fish liberated at different sites in the forebay readily located the dam where water was being discharged, with 92% of the chinook and 76% of the coho arriving near the dam. Nearly all of those entered the forebay with 80% of the chinook and 62 % of the coho released were tracked three-dimensionally." It is very surprising that 8 % of chinook and 24 % of coho did not approach the dam although it was only 100-300 meters in distance.

The study states, "Even though only 48 hours of spill occurred over the entire study period, 37 % (7 of 19) of the chinook detected in the forebay passed through the spill gate while spill occurred. In contrast, only 12 % (2 of 17) of the coho passed via the spill gate. The density plots suggest that both species concentrated in the vicinity of the spill gate when it was open, so this does not explain the different spill passage rates." Since the study ran for 25 days a large percentage of fish moved during the two days of spill.

The study states, "Since the fish used in this study were taken directly from the hatchery early in the spring, it is doubtful that they were fully smolted during the study period". Yet the percentage of hatchery smolts used in reservoir transit studies (18.5 km) arriving at the dam, was 85 % for chinook and 90 % for coho. One has to assume that the probability of selecting full function smolts was similar for both studies, yet there appears to be a discrepancy. The study states, "In the future it would be advantageous to document the level of smolt development and use those that are fully smolted. This may result in an increased passage rate and associated behaviors such as forebay residence time and congregation near discharge outlets." Surveyed fish are supposed to represent a random sample of released fish, not the optimum category of smolt available.

Based on the above paragraph, one has to question the design and objectives of the study. Many ARG participants, desire a study to indicate how many smolts transiting the reservoir will arrive at the dam and be available for fish collection to transit below the dam. The intent is not to maximize fish detections by tracking only "fully smolted" fish and releasing them 100 meters from the forebay. Optimum tag detection has no bearing on real world fish passage and timing.

Response: The percentage of chinook and coho smolts that arrive at the dam and may be available for collection was considered under AQU-14. The release date for chinook and coho in the acoustic study was 22 March-4 April. Radio-tagged coho released in 2001 were liberated about a month later (17-25 May). The desire to document the level of smolt development was an indication that migratory behavior may be influence by time of release. This may be an important factor in future efforts to develop an effective smolt collection system.

Figure 4.17-36. WDFW comments on draft report and Licensees' response (cont.).

The study recognizes the advantage of using a "Gulper" surface flow collection system. Although hydrophones were placed at various depths and one at the bottom of the forebay, there was no discussion of fish approaching turbine intakes and their fate. Since the 2002 entrainment trap (In press) documented spring chinook, coho, steelhead and bull trout entrained by turbines at Swift No. 1 there should be a major discussion of fish approaching turbine entrances.

During the day fish were observed deeper in the water column that at night. Does this make them more susceptible to entrainment during the day? The project is in continuous operation during the day as opposed to evening when demand is less and generation may cease. Fish are deeper, more subject to entrainment; when the project is operational than at night. It would be beneficial to quantify this level of entrainment.

Response: Entrainment was not one of the objectives identified in the study plan.

In general, for the monies spent there was very little practical information generated. This study does not provide a vision of what happens when fish approach the project from a distance, how many might be captured by a surface collector, what handling and transport stresses may be, nor how many fish become entrained through the turbines.

The study validated that spill enhanced fish attraction in the forebay. The speed of fish travel was quite different than for full reservoir transiting fish and acoustic tagged fish approaching the forebay. Recoveries were surprisingly similar for chinook (90-95%) and coho (70-85%) transiting 100-300 meters compared to radio tagged chinook (85%) and coho (90%) transiting 18.5 km of open reservoir. Perhaps radio tags have a superior range. It would seem recoveries should be higher, (especially coho) in fish that only had to travel 300 meters.

The data does not indicate the type, size, structure or location of a future Swift No. 1 fish collector, nor a regime for reservoir flow management. There are no recommendations whether screens are necessary to prevent turbine entrainment. Such a collector will have to be eventually constructed. It would have been useful to use fish available for this study in a manner to resolve some of the basic design for that collector.

Response: The study clearly demonstrated that fish responded to the surface water attraction flow generated from the south spill gate. The location, entrance configuration and attraction flow of a fish collector as well as screens or guide walls will have to be evaluated collectively to enhance trap efficiency. We believe that the type, size and structure of any future fish collector should be evaluated by an engineering/biological design team before a prototype is deployed in the forebay.

5.4.17.8 Products

The main product of this study was a report that would summarize the behavior of juvenile coho and chinook smolts. This goal was achieved. The consultant had a couple of recommendations that bare repeating. One was "…testing a prototype bypass/collector

Figure 4.17-36. WDFW comments on draft report and Licensees' response (cont.).

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system, like a small scale gulper, would appear to have merit". We cannot emphasize this enough. There is a great need to determine if it is possible to capture fish in the forbay of the dam. The other is "…the concept of pursuing surface collection at Swift appears to have merit as evidenced by the collective behaviors observed in 2002".

The report met the objectives of the study plan other than using a water flow of 2,000 cfs instead of 1,000 cfs that was originally agreed to by the ARG.

We would like to again thank the utilities for the opportunity to review and provide comments on the report Behavior of Salmonid Smolts at Swift Dam Using 3-Dimensional Tracking with Acoustic Tags (AQU 17). If you have any questions regarding these comments please call Jim Bryne at 360 906-6751, Karen Kloempken at 360 902-2615 or Curt Leigh at 360 902-2422.

Sincerely,

Curt Leigh
Major Projects Section Manager

CL:kk

cc: David Mudd, HQ
Craig Burley, Vancouver
Karen Kloempken, HQ
Jim Byrne, Vancouver

References

Miller, M. D., Stevenson, J. S., Giorgi, A. E., and B. Torrell, 2001. Migratory behavior of radio-tagged juvenile coho salmon through Swift Reservoir. Prepared for PacifiCorp, Portland, OR and Cowlitz County PUD, Longview, WA.

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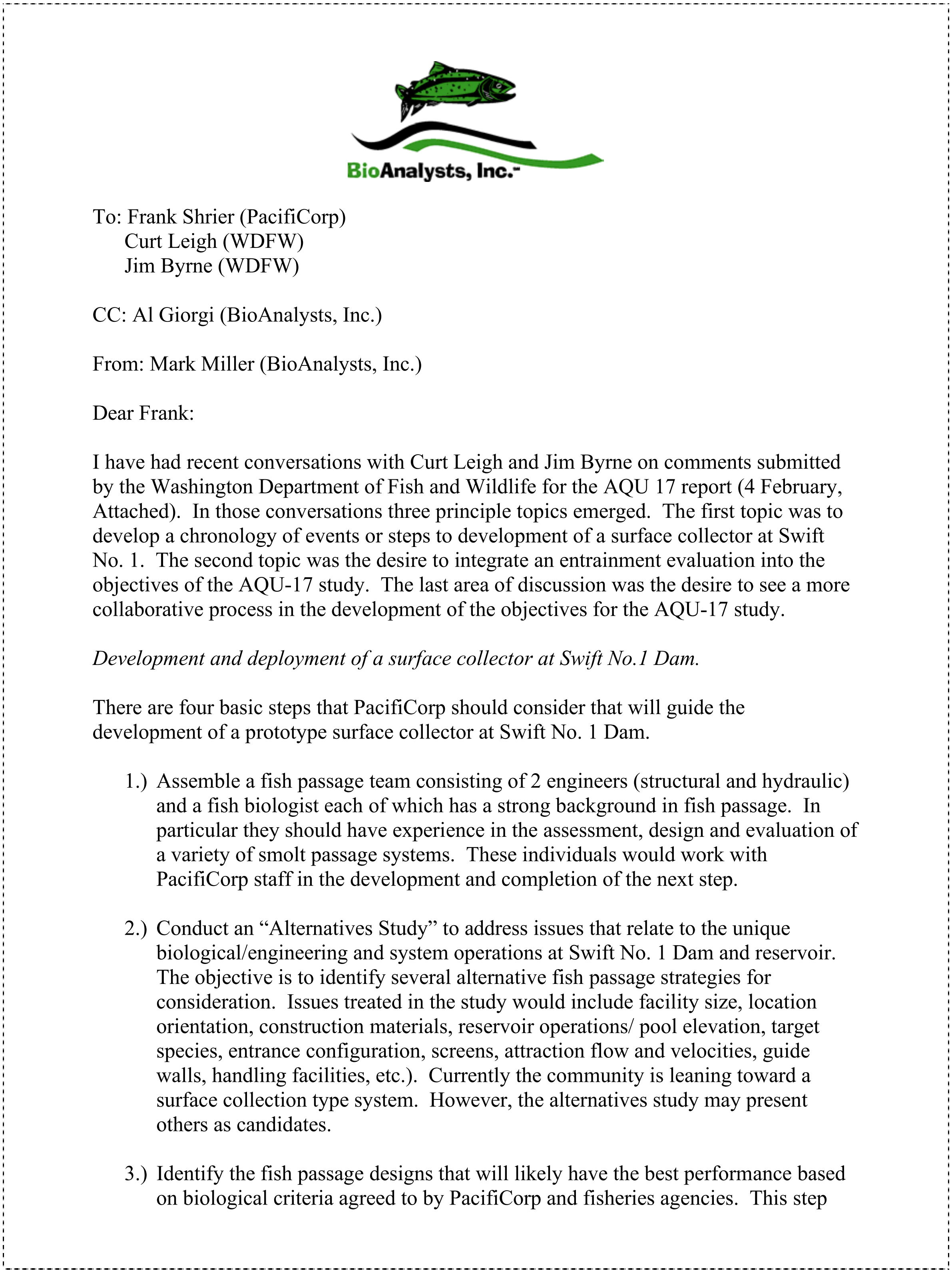
PacifiCorp and Cowlitz PUD. 2003. 2002 Technical Report (In Press)

Figure 4.17-36. WDFW comments on draft report and Licensees' response (cont.).



BioAnalysts, Inc.

To: Frank Shrier (PacifiCorp)
Curt Leigh (WDFW)
Jim Byrne (WDFW)

CC: Al Giorgi (BioAnalysts, Inc.)

From: Mark Miller (BioAnalysts, Inc.)

Dear Frank:

I have had recent conversations with Curt Leigh and Jim Byrne on comments submitted by the Washington Department of Fish and Wildlife for the AQU 17 report (4 February, Attached). In those conversations three principle topics emerged. The first topic was to develop a chronology of events or steps to development of a surface collector at Swift No. 1. The second topic was the desire to integrate an entrainment evaluation into the objectives of the AQU-17 study. The last area of discussion was the desire to see a more collaborative process in the development of the objectives for the AQU-17 study.

Development and deployment of a surface collector at Swift No.1 Dam.

There are four basic steps that PacifiCorp should consider that will guide the development of a prototype surface collector at Swift No. 1 Dam.

1.) Assemble a fish passage team consisting of 2 engineers (structural and hydraulic) and a fish biologist each of which has a strong background in fish passage. In particular they should have experience in the assessment, design and evaluation of a variety of smolt passage systems. These individuals would work with PacifiCorp staff in the development and completion of the next step.

2.) Conduct an "Alternatives Study" to address issues that relate to the unique biological/engineering and system operations at Swift No. 1 Dam and reservoir. The objective is to identify several alternative fish passage strategies for consideration. Issues treated in the study would include facility size, location orientation, construction materials, reservoir operations/ pool elevation, target species, entrance configuration, screens, attraction flow and velocities, guide walls, handling facilities, etc.). Currently the community is leaning toward a surface collection type system. However, the alternatives study may present others as candidates.

3.) Identify the fish passage designs that will likely have the best performance based on biological criteria agreed to by PacifiCorp and fisheries agencies. This step

Figure 4.17-37. Consultant response to additional WDFW comments.

essentially evaluates and ranks those designs that are best suited for Swift No. 1 Dam.

4.) Design and construct a prototype passage system for deployment in 2004. This may be a scaled down version of the envisioned production unit. It would be used during the field evaluation phase. Based on experiences at other dams this phase may require a minimum of 2 and likely more years of field evaluation and reconfiguration. Additionally, laboratory hydraulic modeling may play a role in the design phase.

Integrate entrainment potential into the objectives of the AQU-17 Report

We recognize the value of conducting studies that quantify the level of entrainment for migratory salmonids in Swift Reservoir. However, the design of the acoustic system was not setup to evaluate entrainment in the forebay of Swift No. 1, nor was it one of the objectives of the study. Moreover, the geometry of the hydrophones for route specific passage (spill gate vs. penstock) behavior was only designed for monitoring the south spill gate. In order to quantify the level of entrainment in the AQU-17 study, we would have had to set up a tailrace hydrophone system to confirm the passage of tagged fish, or we would have placed more hydrophones at depth near the penstock opening.

Collaborative process in the development of the objectives for the AQU-17 study

We thought that a collaborative process in the development of study objectives had occurred during the planning phase with the members of the Aquatic Resource Group (ARG). We were not engaged in that forum. Our role was to implement the study and address objectives that were presented to us. In the future, BioAnalysts staff would welcome the opportunity to more formally interact with the ARG in the development of objectives and designs, if requested by PacifiCorp and the ARG.

Best Regards,

Mark Miller

Figure 4.17-37. Consultant response to additional WDFW comments (cont.).