ANNUAL PROGRESS REPORT

Evaluation of Lower Umatilla River Channel Modifications Below Three Mile Dam, 1984

Preapared by

Anthony A. Nigro
David L. Ward

Columbia River Section
of the
Oregon Department of Fish and Wildlife

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ABSTRACT

This report summarizes results of the first year of a study initiated in September 1984 to evaluate the adequacy of channel modifications made in the lower Umatilla River to improve adult anadromous salmonid passage to Three Mile Dam (RKm 5.6), determine if fish passage or delay problems exist at Three Mile Dam and recommend site specific corrective measures if needed. Movements of steelhead (*Salmo crdneri*) were monitored using mark and recapture and radio telemetry techniques. Thirty four steelhead were marked with T-anchor tags and released in the lower river. Fifteen of those marked were also fitted with radio transmitters.

Three radiotagged steelhead migrated through channel modifications to Three Mile Dam. Two of these fish migrated to the dam in less than 26 hours, but held just below the dam for 7 and 10 days before entering the ladders. The third steelhead delayed for 30 days and entered the west ladder within 24 hours of arrival at the dam. Two other radiotagged steelhead moved upstream through some of the channel modifications but did not migrate to the dam. Only one of 19 marked steelhead not fitted with transmitters was recovered at Three Mile Dam.

Study objectives for 1985 are to determine flows at which fall chinook salmon (*Oncorhynchus tshawytscha*) and steelhead negotiate channel modifications and enter ladders at Three Mile Dam and determine effects of passage through channel modifications on fall chinook salmon and steelhead migration above Three Mile Dam.

INTRODUCTION

Background

The Umatilla River historically supported large runs of spring and fall chinook salmon (Oncorhynchus tshawytscha), coho salmon (Oncorhynchus kisutch), and summer steelhead (Salmo gairdneri) (Thompson and Haas 1960, Oregon State Game Commission (OSGC) 1963). Mortality of juveniles and adults at main stem Columbia River dams, overexploitation by ocean and river fisheries, degradation of spawning and rearing habitat, and delays and blockage of returning adults because of inadequate flows after irrigation diversions have all contributed to the decline of anadromous salmonid stocks in the Umatilla Basin (OSGC 1963, James 1984). Some spring chinook were sighted as recently as 1963 (OSGC 1963), and fall chinook as recently as 1957 (Thompson and Haas 1960), but all that remains of native anadromous salmonid stocks is a small run (about 1,000) of summer steelhead (James 1984, Howell et al. 1985).

Steelhead enter the Umatilla River from October through May. Peak runs usually occur in February and March and peak spawning in April and May (James 1984). Steelhead spawning occurs in the river below and in the north and south forks, and in tributaries including Meacham Creek and Birch Creek (OSGC 1963, James 1984, Howell et al. 1985). Many of the historic and present spawning and rearing areas of anadromous salmonids occur on the reservation of the Confederated Tribes of the Umatilla Indians (CTUIR) (Figure 1).

Efforts are being made by the Oregon Department of Fish and Wildlife, the CTUIR, and federal agencies to restore anadromous salmonid runs in the Umatilla Basin. Releases of 19,000-60,000 hatchery reared, native stock summer steelhead have been made each year since 1981 (Howell et al. 1985). Over 4 million tule fall chinook yearlings were released below Three Mile Dam in 1982. Upriver bright fall chinook were released into the headwaters of the Umatilla drainage in 1983 (100,000 yearlings) and 1984 (225,000 yearlings and 600,000 90-day fry). Continued annual releases of 225,000 fall chinook yearlings are expected through at least 1987 (James 1984).

There are numerous dams on the Umatilla River which divert water for irrigation. The largest of these is Three Mile Dam, constructed in 1914 by the U.S. Bureau of Reclamation (Figure 1). Initial plans to restore anadromous salmonid stocks in the Umatilla Basin include the capture of brood stock at Three Mile Dam (James 1984, Howell et al. 1985). However, success of these efforts depends upon adequate upstream passage to capture facilities at the dam. Flows in the river below the dam are severely reduced (<100 cfs) from July through October by irrigation diversions. Adult fish have had difficulty reaching the dam during these low flows because of barriers present in the lower river (OSGC 1963, James 1984).

In 1983, the Bonneville Power Administration (BPA) funded modifications of the lower Umatilla River channel below Three Mile Dam to improve passage for anadromous salmonids (BPA #83-834). Most of these modifications were made in the summer and fall of 1984 by the Peters and Wood Company of Pasco, Washington supervised by the U.S. Army Corps of Engineers.

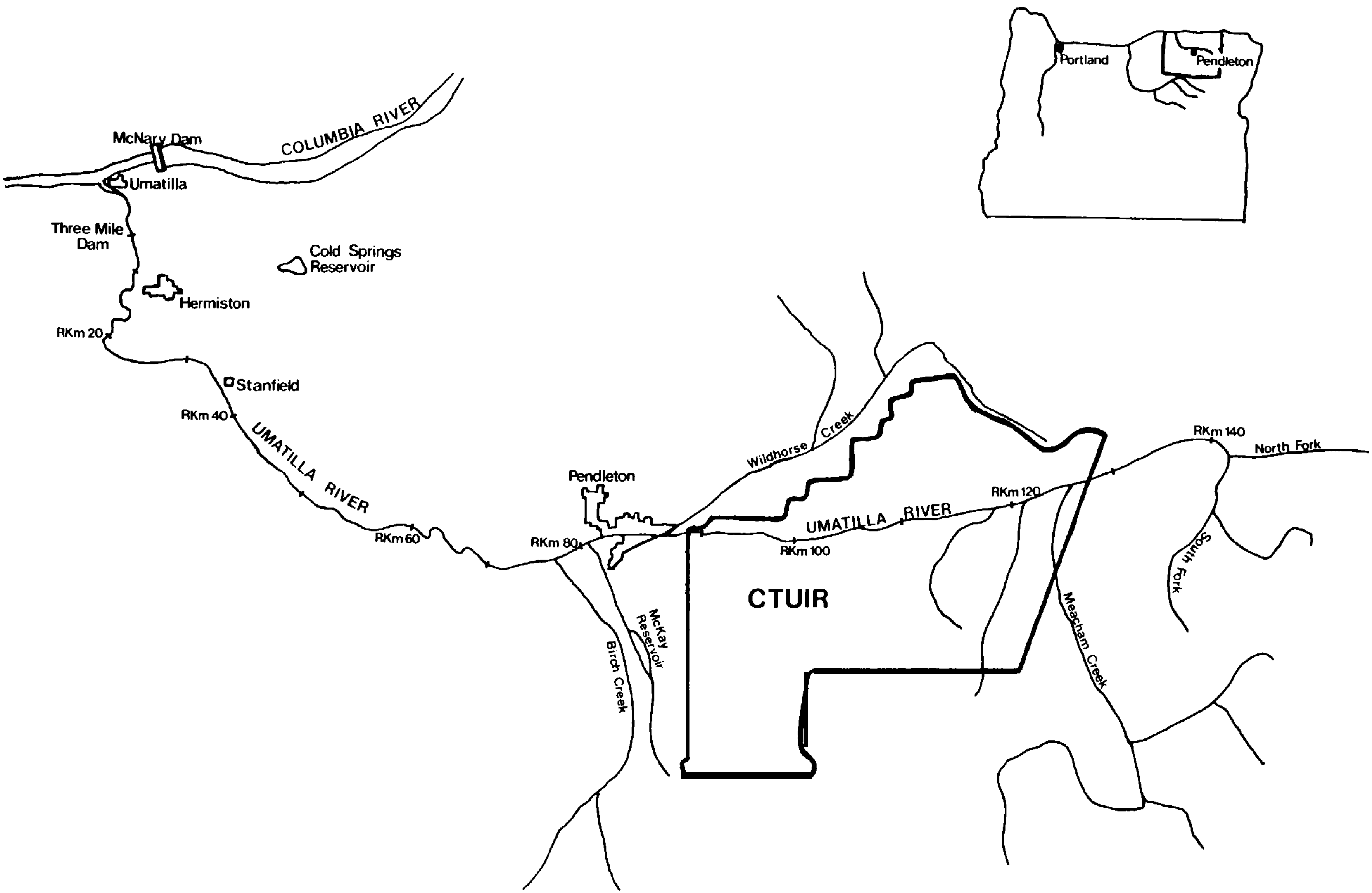

Figure 1. The Umatilla River Basin, including major tributaries and the CTUIR.

This study was conducted from September 1984 through January 1985 to evaluate the upstream movements of steelhead through these channel modifications and at Three Mile Dam. First year objectives were:

1) To examine the adequacy of channel modifications made to improve adult anadromous salmonid passage below Three Mile Dam.

2) To determine if fish passage or delay problems exist at Three Mile Dam.

3) To recommend site-specific corrective measures if needed.

Study Area

The Umatilla River below Three Mile Dam (Figure 2) has a bedrock substrate consisting mostly of basalt. There is less than a one percent stream gradient from the dam to the river mouth. Average flows below the dam range from less than 40 cfs from July through September to about 1,000 cfs in March and April. Flows often approach or equal zero cfs in July and August. During irrigation season (April-October) two cfs are diverted by a small dam at the Brownell Diversion, which is the lowermost irrigation facility on the river located 1.5 miles (2.4 km) below Three Mile Dam (Figure 2).

Prior to modification, the lower Umatilla River contained numerous blind channels and a series of bedrock drops which impeded or blocked upstream passage at low flows (<200 cfs). In some areas, the absence of a defined channel resulted in stream wide riffles which were too shallow at low flows to allow fish passage. The modifications were originally designed to provide a 10 ft (3.1 m) wide and 5 ft (1.6 m) deep channel from 1,000 ft (310 m) below Three Mile Dam to Chinaman's Hole (Figure 2). This design was altered to include depth variations, weirs, and jump pools where necessary to aid passage. The river below Chinaman's Hole is influenced by water levels in Lake Umatilla. No modifications were considered necessary in this section.

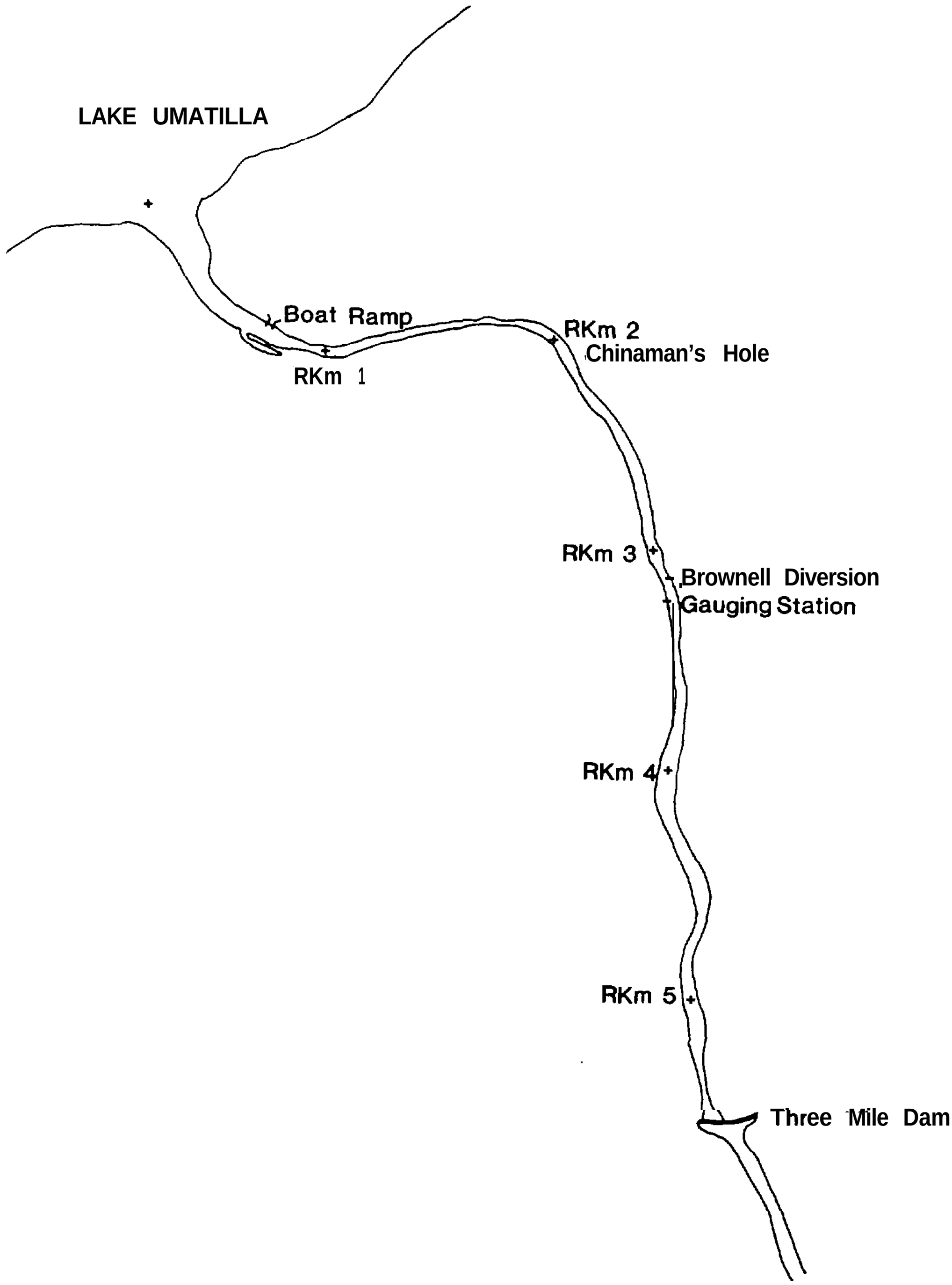

Figure 2. The Umatilla River below Three Nile Dam.

METHODS AND MATERIALS

Field Sampling

Turbidity, water temperature and stream flow were monitored during the study to determine their relationship to fish passage. Morning and afternoon Secchi disk readings (cm) and stream temperatures (0.5°C) were recorded near the Brownell ditch diversion. Daily stream flow data was provided by the USGS from the gauging station located near river kilometer (RKm) 3.3 (Figure 2).

Capture and Handling

Passage of steelhead through lower Umatilla River channel modifications was examined by marking and recapturing fish and by monitoring movements of radiotagged fish. Steelhead were collected from the fish trap in the west ladder at Three Mile Dam and were transported to release sites below channel modifications. Steelhead were collected from the ladder by diverting water from the trap and dip-netting fish from the remaining shallow pools. Steelhead were then anaesthetized in a holding tank containing a solution of 40 mg/l MS 222. Fish were held in the MS 222 solution for less than four minutes (Wedemeyer 1970). Anaesthetized steelhead were removed from the holding tank, were examined to determine sex, fork length (cm), and weight (kg) and were marked with a serial numbered T-anchor tag (Table 1). Marked steelhead were placed in a recovery tank and transported to release sites (Figure 2). Initially fish were released at the boat ramp near the river mouth, but were later released at Chinaman's Hole to reduce fallback into the Columbia River. Steelhead released at the boat ramp were transported in a tank equipped with a water recirculation pump. The maximum holding time in this tank was one hour. Steelhead released at Chinaman's Hole were transported without water recirculation. The maximum holding time was 20 minutes. Marked steelhead were recaptured in the fish trap in the west ladder at Three Mile Dam which was checked at least once daily.

Radio Telemetry

Fifteen marked steelhead were fitted with radio transmitters and their movements were monitored to identify locations where migration was impeded or blocked (Table 2). Transmitters weighed 23 grams, were equipped with a 25-cm long antenna and had a 60-day minimum life. Transmitter frequencies ranged from 49.0 to 49.59 MHz. Pulse rates of transmission signals varied from 62-75 ppm. Transmitters were inserted down the gullet and into the gut of ten steelhead and were externally attached to five others. Transmitters placed into the gut were coated with glycerin to ease passage through the gullet (Winter 1983). The antenna was either passed out the gill cavity (McCleave et al. 1978) or passed out the mouth (Gray and Haynes 1979). Externally attached transmitters were placed just below the anterior portion of the dorsal fin, with the antenna directed posteriorly (Winter 1983) (Figures 3 and 4). A programmable receiver with a hand-held loop antenna was used to locate radiotagged steelhead.

Table 1. Date captured, sex, size and release site of marked steelhead.

Tag Number	Date	Sex	FL (cm)	W (kg)	Release[a]
02412	11-19	F	61	2.1	BR
02413	11-19	F	59	2.0	BR
02414	11-19	F	73	3.8	BR
02417	11-26	F	71	3.5	CH
02418	11-26	F	71	3.8	CH
02419	11-26	F	75	4.0	CH
02422	11-28	F	65	2.8	CH
02452	11-29	M	60	2.0	CH
02456	12-10	M	61	2.3	CH
02459	12-10	F	72	3.5	CH
02462	12-11	M	67	2.8	CH
02463	12-11	F	60	2.3	CH
02466	12-11	M	74	3.5	CH
02467	12-11	F	64	3.4	CH
02468	12-11	F	66	3.0	CH
02470	12-11	M	64	2.4	CH
02426	12-27	M	59	2.0	CH
02427	12-27	F	55	1.7	CH
02428	12-27	M	63	2.4	CH

a BR = Boat Ramp, CH = Chinaman's Hole.

Table 2. Date captured, sex, size, tagging method, and release site of radiotagged steelhead.

Transmitter Frequency (MH_Z)	Date	Sex	FL (cm)	W (kg)	Method[a]	Release[b]
49.54	11-13	M	73	3.5	I	BR
49.28	11-13	F	76	4.4	I	BR
49.50	11-14	F	73	4.1	I	BR
49.58	11-14	M	76	4.7	I	BR
49.48	11-19	M	76	4.0	I	BR
49.22	11-28	F	71	3.2	I	CH
49.36	11-29	F	73	4.0	I	CH
49.00	12-10	F	68	3.1	I	CH
49.43	12-10	F	70	3.4	I	CH
49.57	12-10	F	67	3.0	I	CH
49.24	12-18	F	67	2.9	E	CH
49.29	12-18	M	71	3.5	E	CH
49.59	12-27	M	74	4.0	E	CH
49.02	1-10	M	62	2.4	E	CH
49.26	1-15	F	72	3.9	E	CH

[a] I = Transmitter inserted into stomach, E = Transmitter externally attached.
[b] BR = Boat Ramp, CH = Chinaman's Hole.

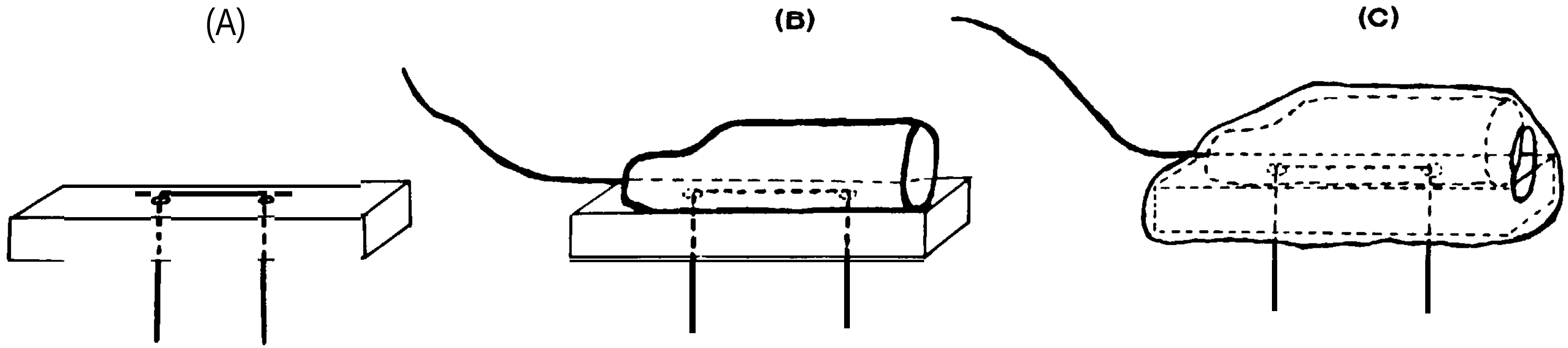

Figure 3. Preparation of radio transmitter for external attachment. A) Soft rubber template with steel wire passed through, B) Transmitter placed on template side opposite the wire ends, C) Template and transmitter encased in heat shrink tubing, leaving antenna and wire ends free.

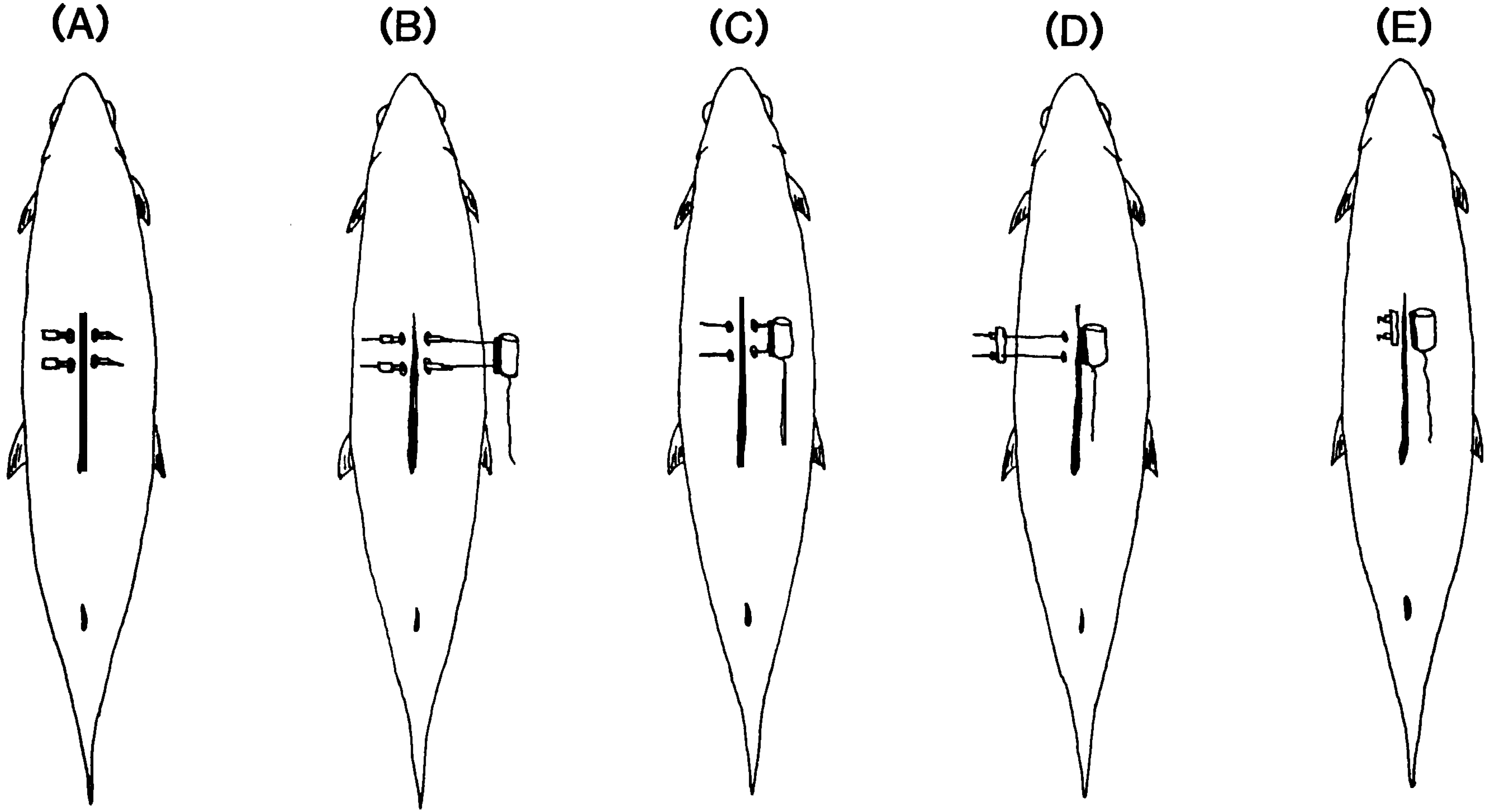

Figure 4. External attachment of radio transmitter. A) The steelhead was first pierced through the back with two hollow needles, B) One steel wire from the transmitter was threaded through each needle, C) The needles were then removed, D) The transmitter was pulled snug against the fish and the wires were threaded through clamps attached to a soft rubber template, E) The template was pulled snug against the fish and the transmitter was secured by crushing the clamps around the wires. Excess wire was removed.

General locations of radiotagged steelhead below Three Mile Dam were determined by triangulation along axes of peak signal strengths. Specific locations were determined by decreasing sensitivity and triangulating along axes of null signals (Winter 1983). Locations were determined from shore (usually within 25 m of the transmitter) and from a helicopter (used every two weeks to locate radiotagged steelhead above Three Mile Dam).

Upon release radiotagged steelhead were located hourly until a pattern of movement was established. Radiotagged steelhead that fell back into the Columbia River were then located twice daily if possible. If a radiotagged steelhead did not move from a specific location it was then located three times daily until movement was detected. When a radiotagged steelhead moved upriver it was located hourly when possible until it ceased movement or entered one of the ladders at the Dam.

A Cartesian grid system overlaid upon a geological survey map of the Umatilla River was used to assign x,y coordinates to the locations of radiotagged steelhead below Three Mile Dam. The origin of the grid system was the USGS gauging station near RKm 3.3. The x axis was directed east-west, and the y axis was directed north-south. Each grid-square represented 25 m.

Data Analysis

Travel times through channel modifications were estimated as the differences between times of release and recapture of marked steelhead and times when radiotagged steelhead were last located below modifications and first located at Three Mile Dam. Locations (RKm) of radiotagged steelhead below and at Three Mile Dam were plotted against time (date) to identify locations where migration was impeded or blocked. Corresponding stream flows, water temperatures, and Secchi disk readings were included in the graphs to examine their relationships to fish passage.

RESULTS

None of the three marked steelhead released at the boat ramp were recovered. Of 16 marked steelhead released at Chinaman's Hole, one was recovered in the west ladder of Three Mile Dam 53 hours after release. Flows during this period ranged from 571-697 cfs, water temperature was 6°C, and Secchi disk readings ranged from 40-67 cm.

Two of five steelhead (280 and 480) released at the boat ramp with gut inserted radio transmitters moved immediately downstream into the Columbia River and did not return to the Umatilla River (Figures 5 and 6). A third steelhead (540) was lost after it held in the Umatilla River for over eight days (Figure 7). The remaining two steelhead (500 and 580) migrated through channel modifications to Three Mile Dam. For steelhead 500, travel time through channel modifications to the area just below Three Mile Dam (RKm 5.5) was less than 17 hours (Figure 8). It held at the dam in the main river channel for 10 days before entering the west ladder (Figure 9). For steelhead 580, travel time from its holding place near RKm 1.8 to the area directly below Three Mile Dam was 10-26 hours (Figure 10). During migration, it was observed to hold at RKm 3.8 for at least two hours, but passed from there to below the dam in less than six hours. It held at the dam in the main river channel for seven days before passing through the east ladder (Figure 9). Flows during the seven day holding period ranged from 401-750 cfs, water temperatures ranged from 6"-7.5°C, and Secchi disk readings from 42-95 cm. At the time the fish entered the east ladder flows were 571 cfs, water temperature was 6°C, and the Secchi disk reading was 67 cm.

Three of five steelhead (000, 220 and 430) released at Chinaman's Hole with gut inserted radio transmitters held at Chinaman's Hole for the remainder of the study period (Figures 11 and 12). A fourth steelhead (570) was lost after it held at Chinaman's Hole for one day. The remaining steelhead (360) took almost 34 days to migrate through the channel modifications to Three Mile Dam (Figure 13). During migration it held at RKm 2.2 for at least 3 days and RKm 3.8 for 30 days before moving upstream to Three Mile Dam. Passage from RKm 3.8 to the dam took less than 16 hours. It entered the west ladder within 24 hours after arrival at Three Mile Dam. While at the dam it was always located near or in the west ladder (Figure 9).

Two of five steelhead (240 and 020) released at Chinaman's Hole with externally attached radio transmitters held at Chinaman's Hole for the remainder of the study period (Figures 14 and 15). A third steelhead (260) held at Chinaman's Hole four days before it was harvested by a sport angler (Figure 16). The remaining two steelhead (290 and 590) negotiated a portion of the channel modifications. Steelhead 290 held at Chinaman's Hole for nine days before it was located approximately 125 m upstream (RKm 2.2). It remained at this location for the remainder of the study period (Figure 17). Steelhead 590 held at Chinaman's Hole for over 12 days before it was located approximately 500 m downstream (RKm 1.6) on the morning of January 9. This fish had apparently begun moving upstream after it was located at Chinaman's Hole on the afternoon of January 8. It was caught and released by a sport angler that afternoon approximately 600 m above Chinaman's Hole (RKm 2.7). After release it apparently moved downstream to where it was located on January 9 (Figure 18). It held there for the remainder of the study period.

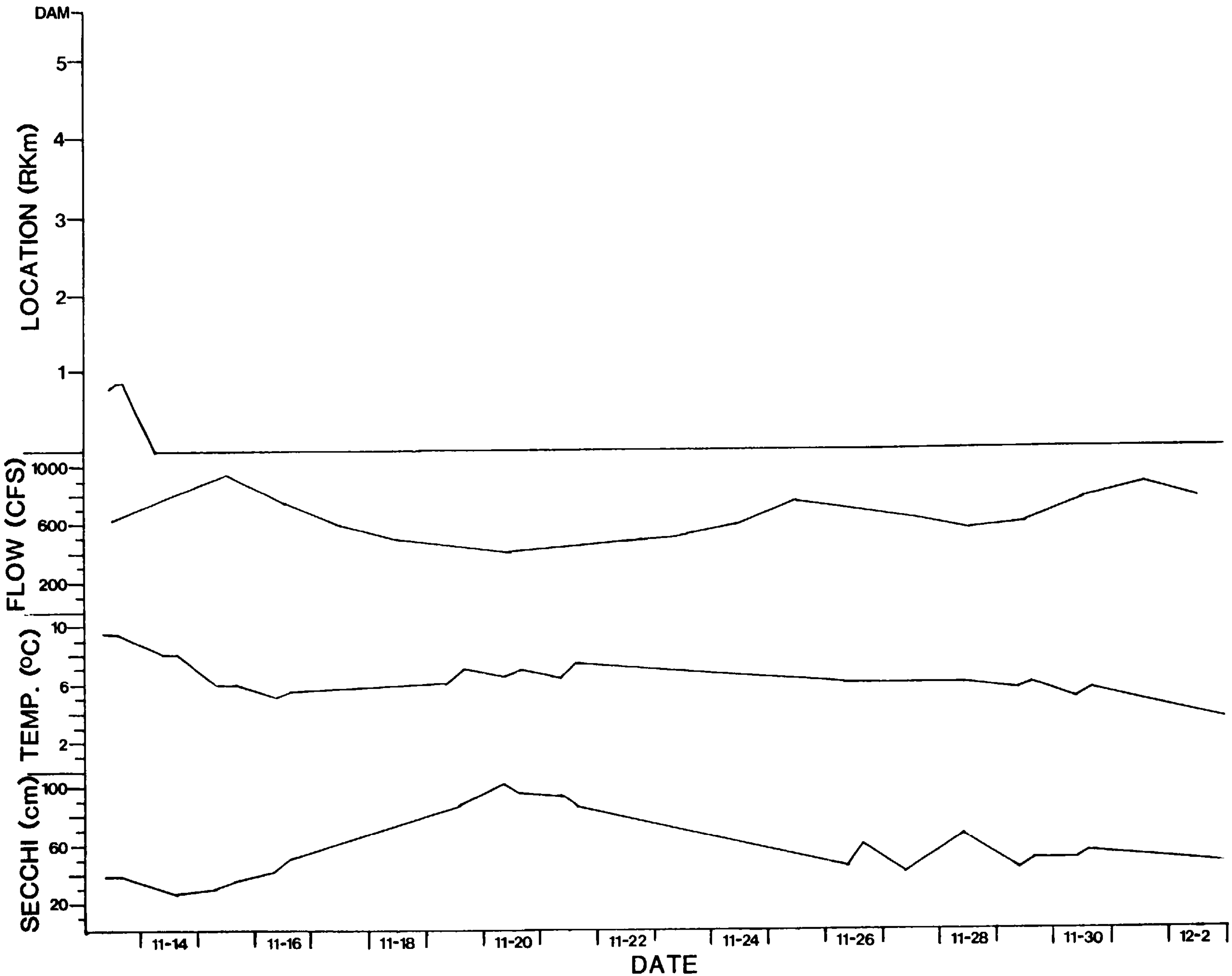

Figure 5. Movements of steelhead 280 between November 13 and December 2, and corresponding streamflows, water temperatures and Secchi disk readings.

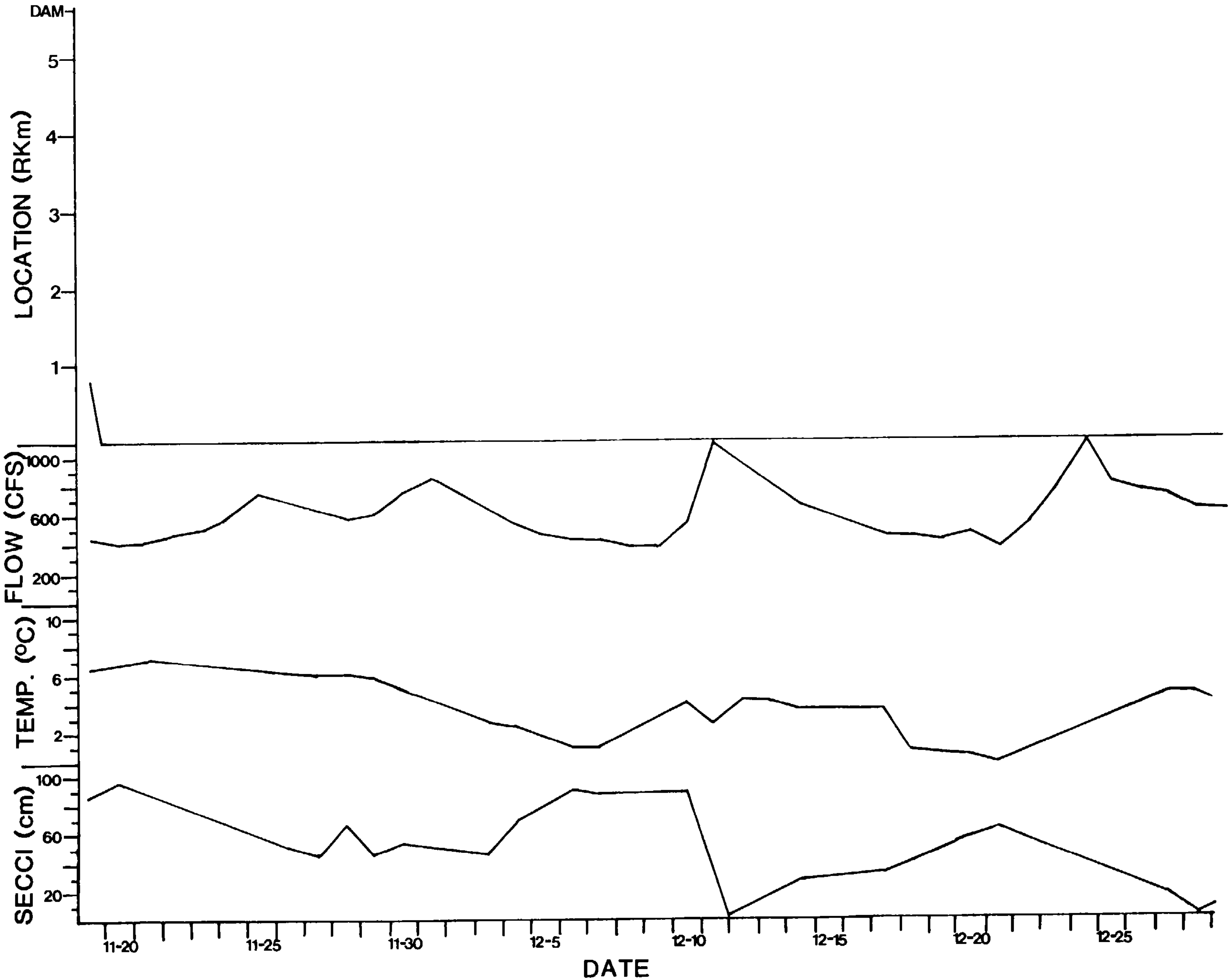

Figure 6. Movements of steelhead 480 between November 19 and December 28, and corresponding streamflows, water temperatures and Secchi disk readings.

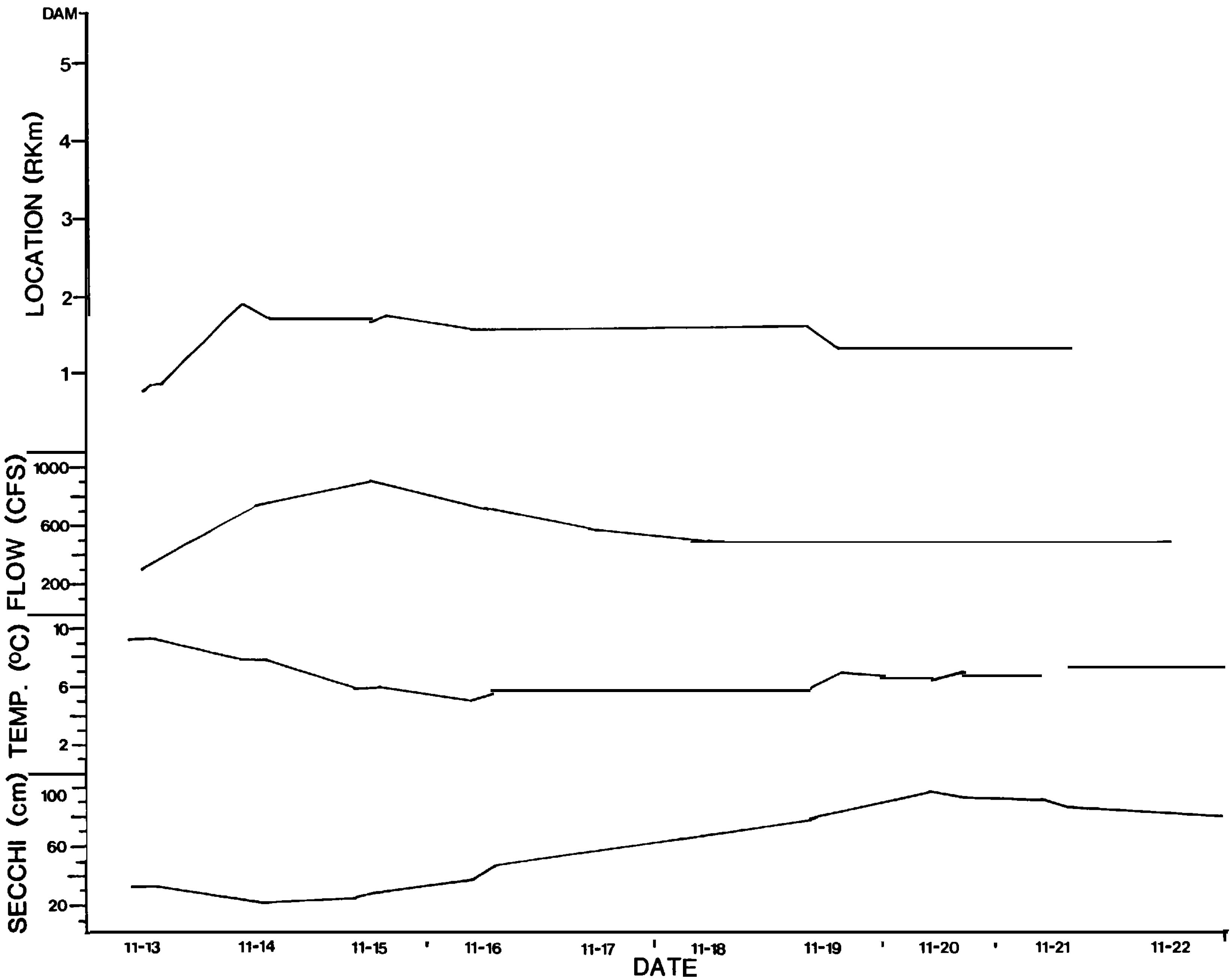

Figure 7. Movements of steelhead 540 between November 13 and November 22, and corresponding streamf ◦ws, water temperatures and Secchi disk readings.

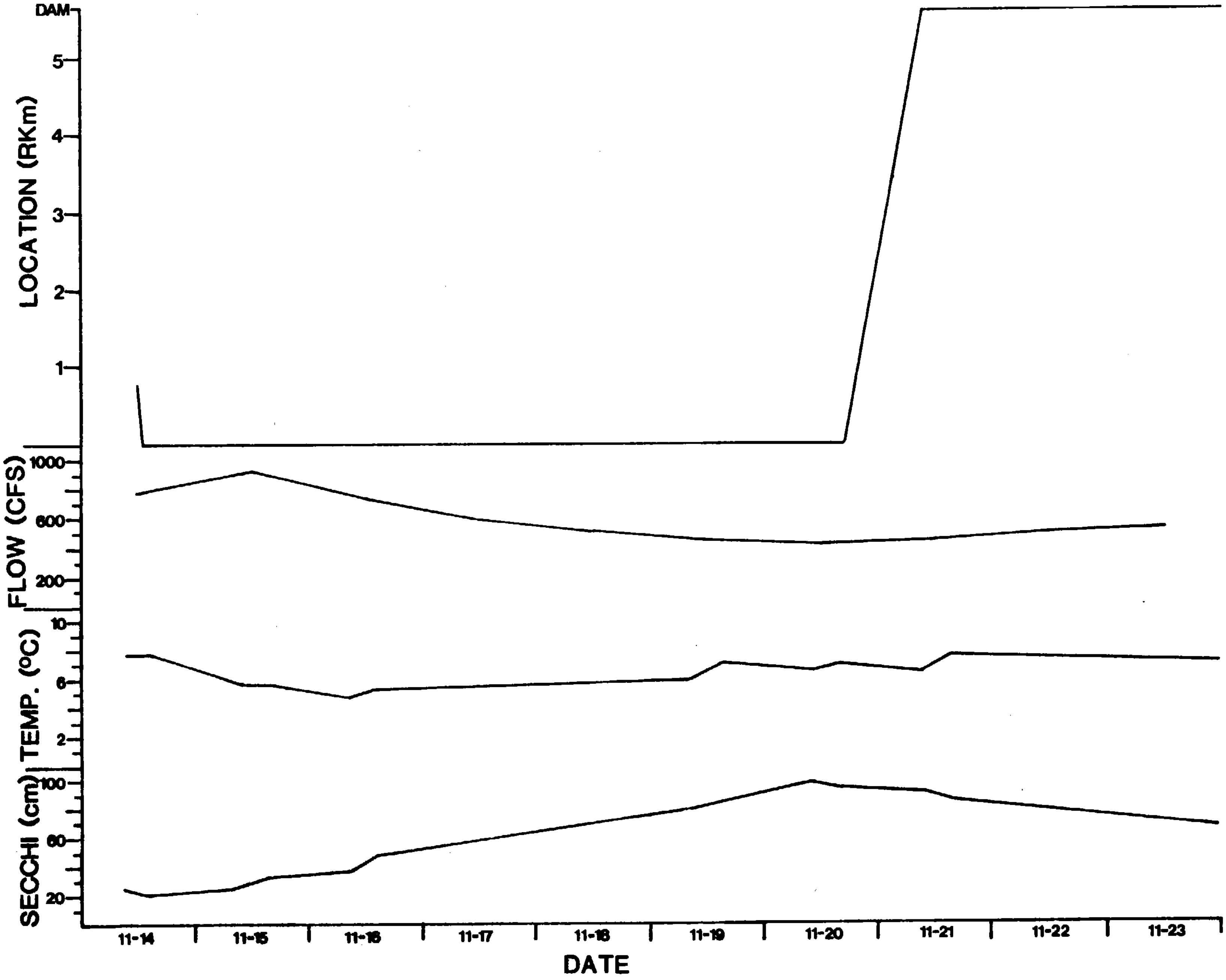

Figure 8. Movements of steelhead 500 between November 14 and November 23, and corresponding streamflows, water temperatures and Secchi disk readings.

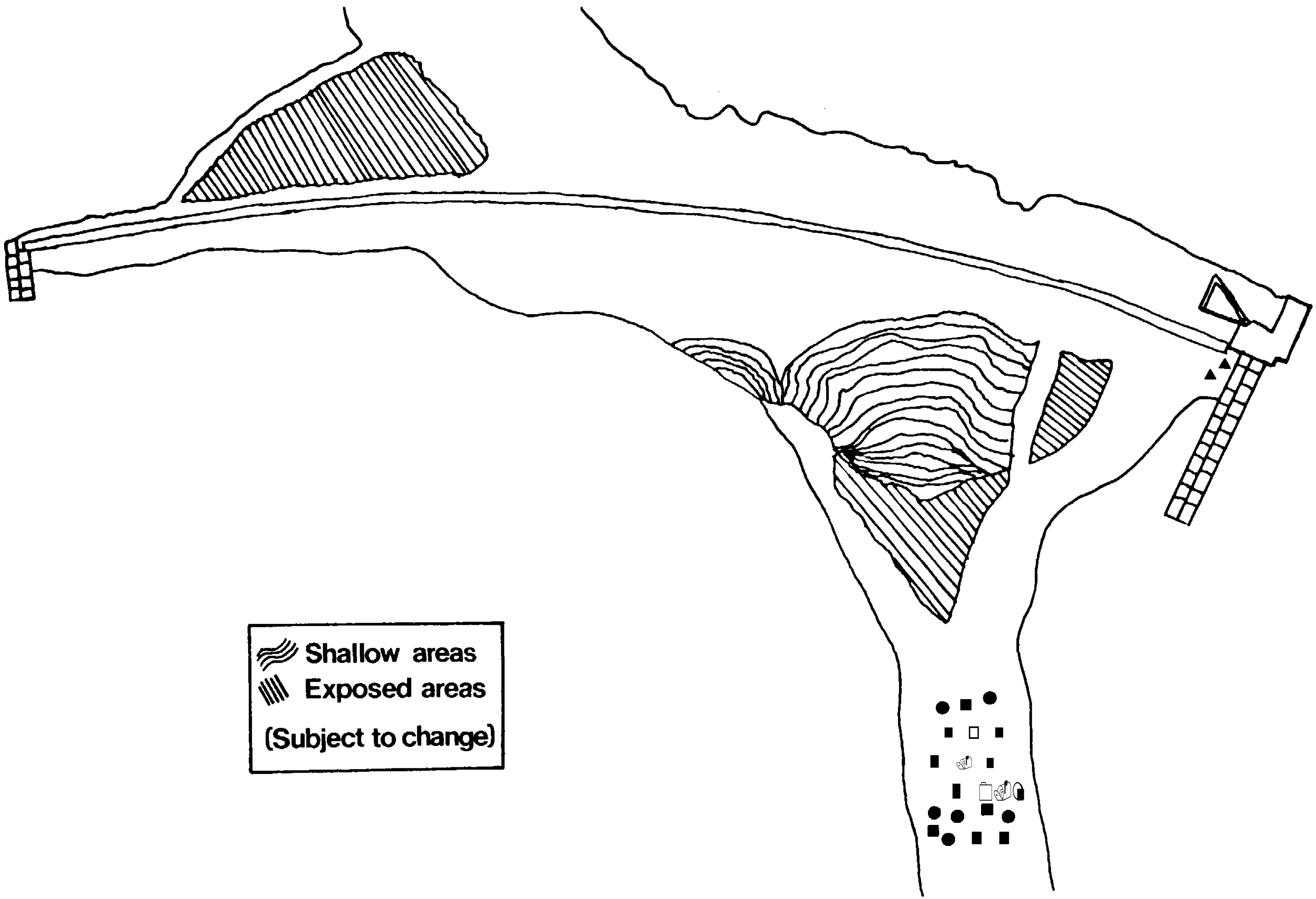

Figure 9. Locations of radiotagged steelhead 580 (●), 500 (■) and 360 (▲) at Three Mile Dam between November 20-27, November 21-30 and January 17-18, respectively.

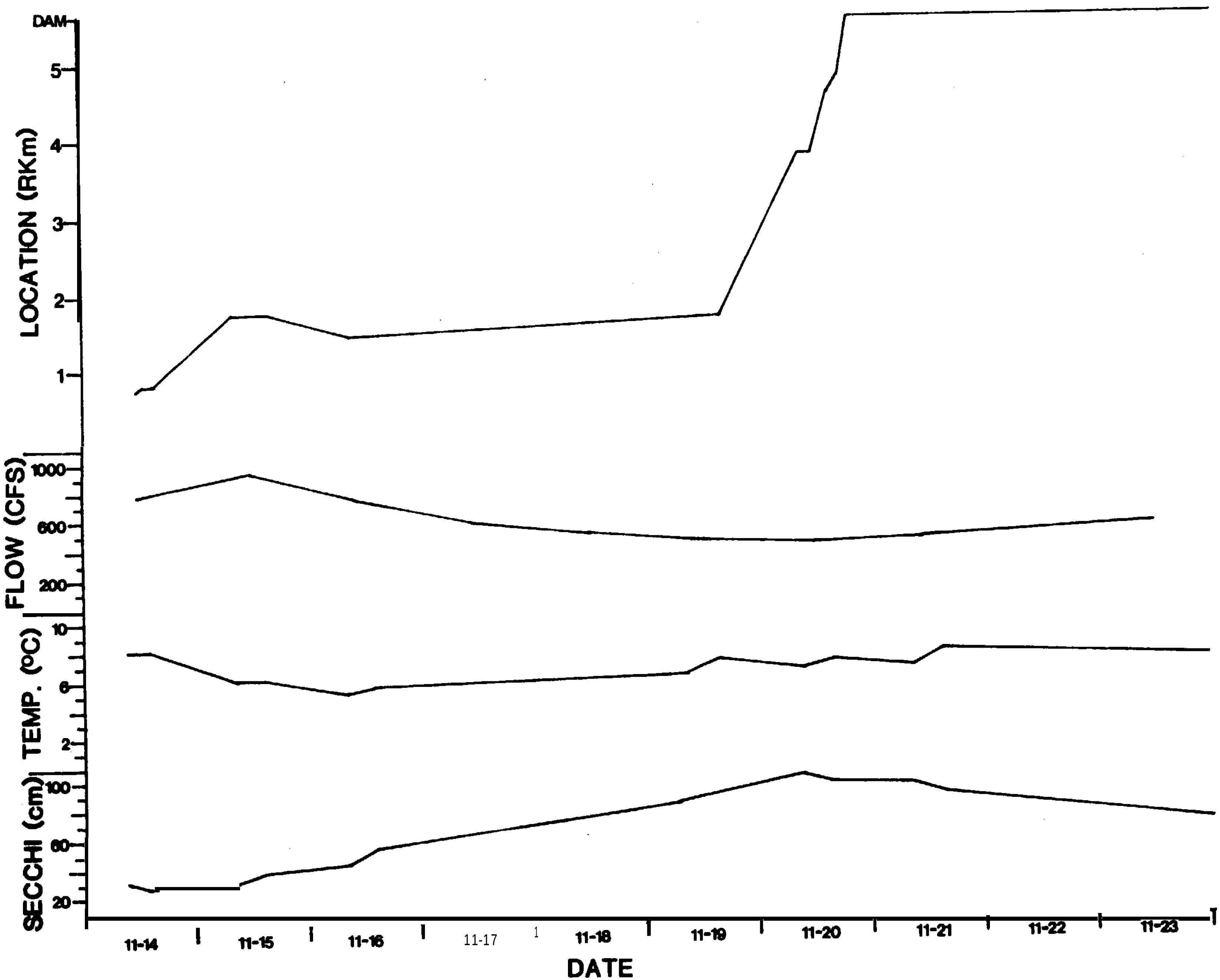

Figure 10. Movements of steelhead 580 between November 14 and November 23, and corresponding streamflows, water temperatures and Secchi disk readings.

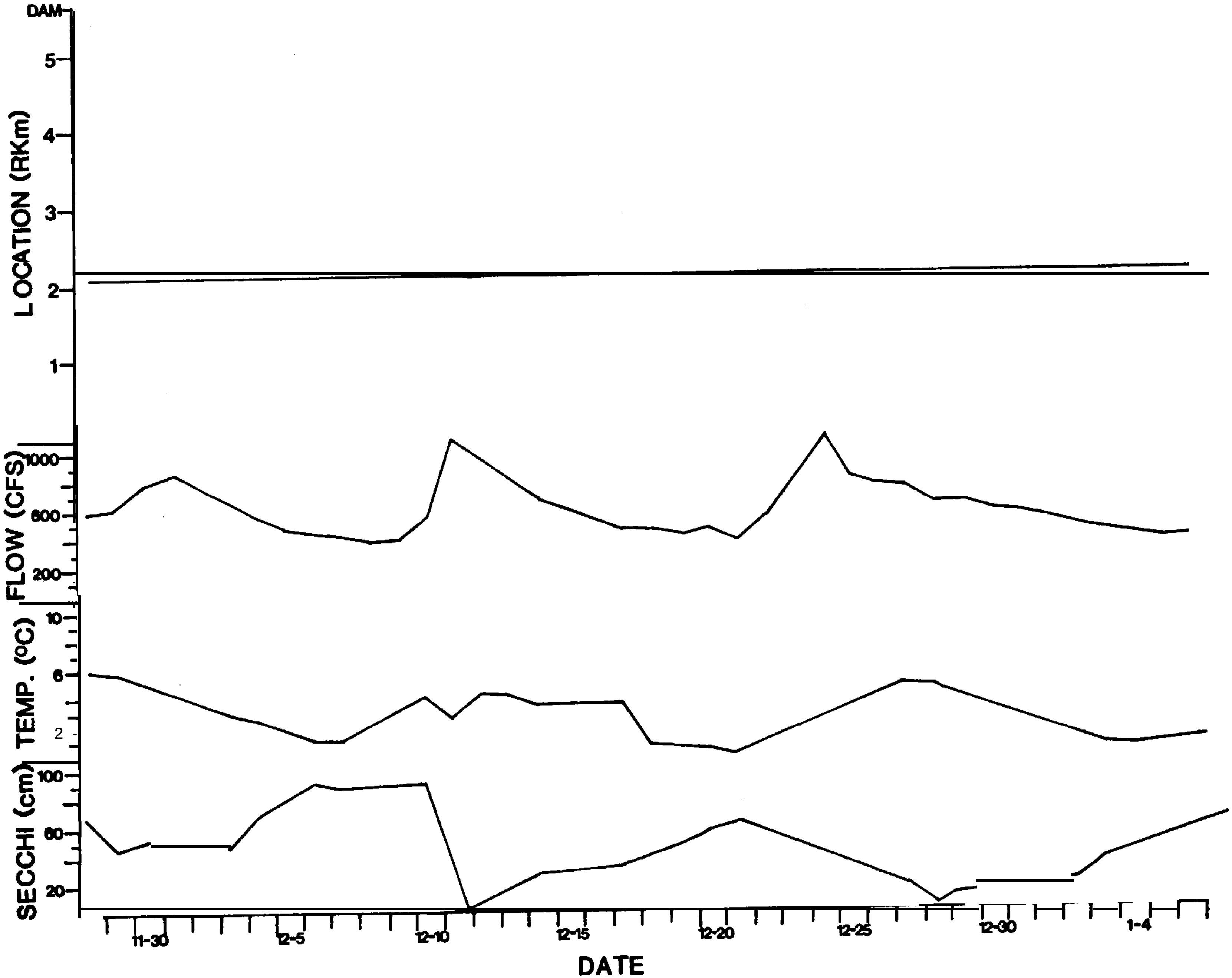

Figure 11. Movements of steelhead 220 between November 28 and January 6, and corresponding streamflows, water temperatures and Secchi disk readings.

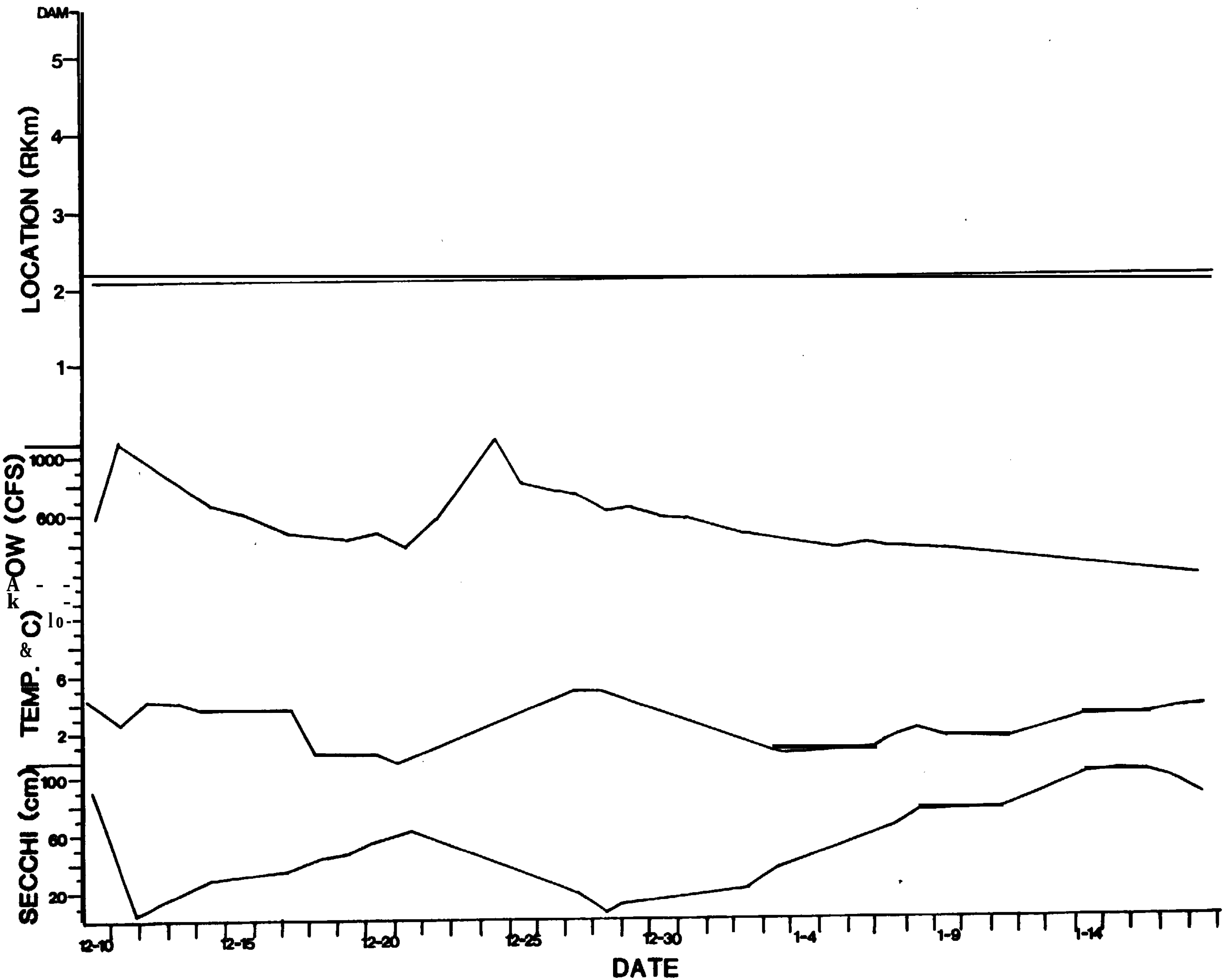

Figure 12. Movements of steelhead 000 and 430 between December 10 and January 18, and corresponding streamflows, water temperatures and Secchi disk readings.

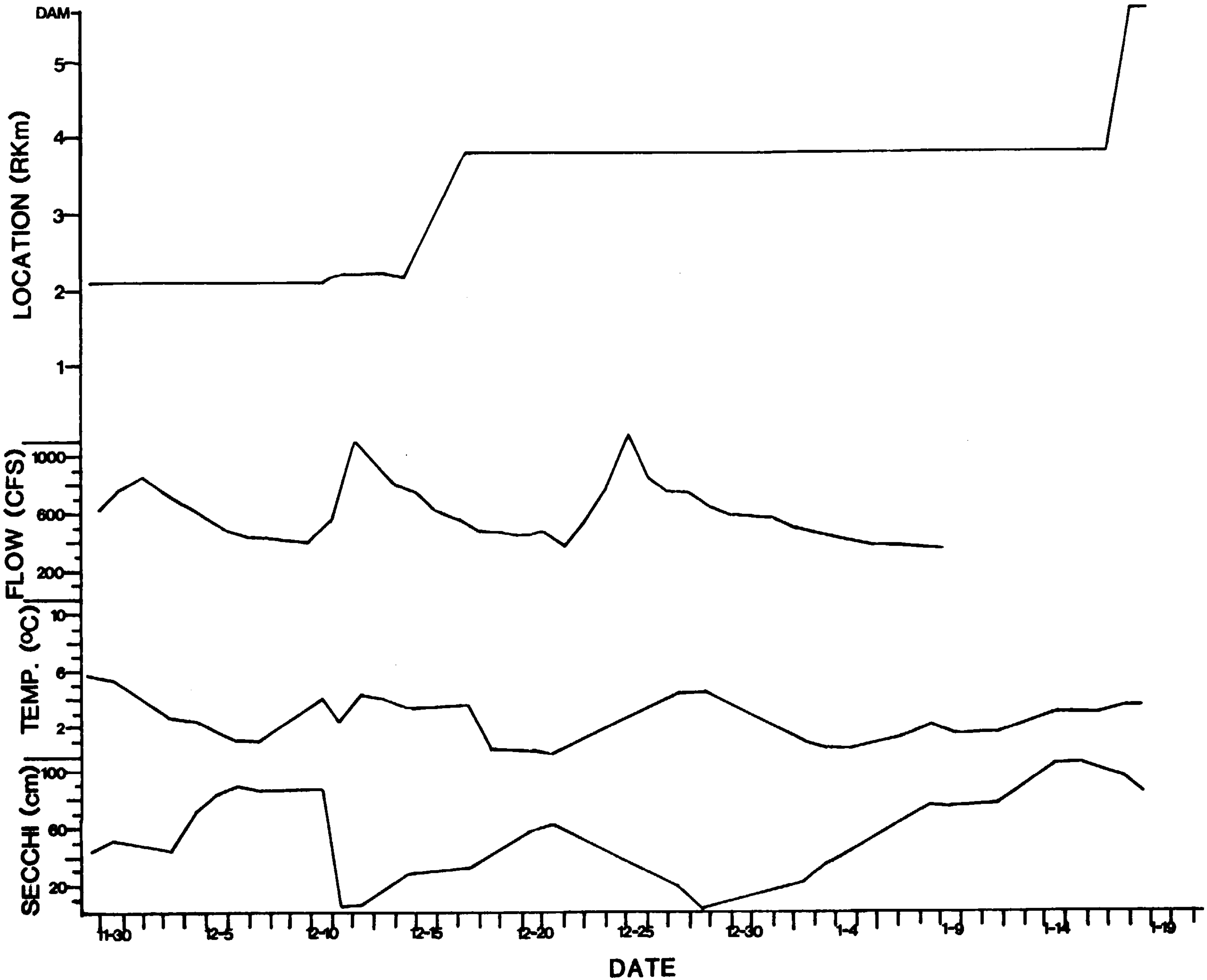

Figure 13. Movements of steelhead 360 between November 29 and January 18, and corresponding streamflows, water temperatures and Secchi disk readings.

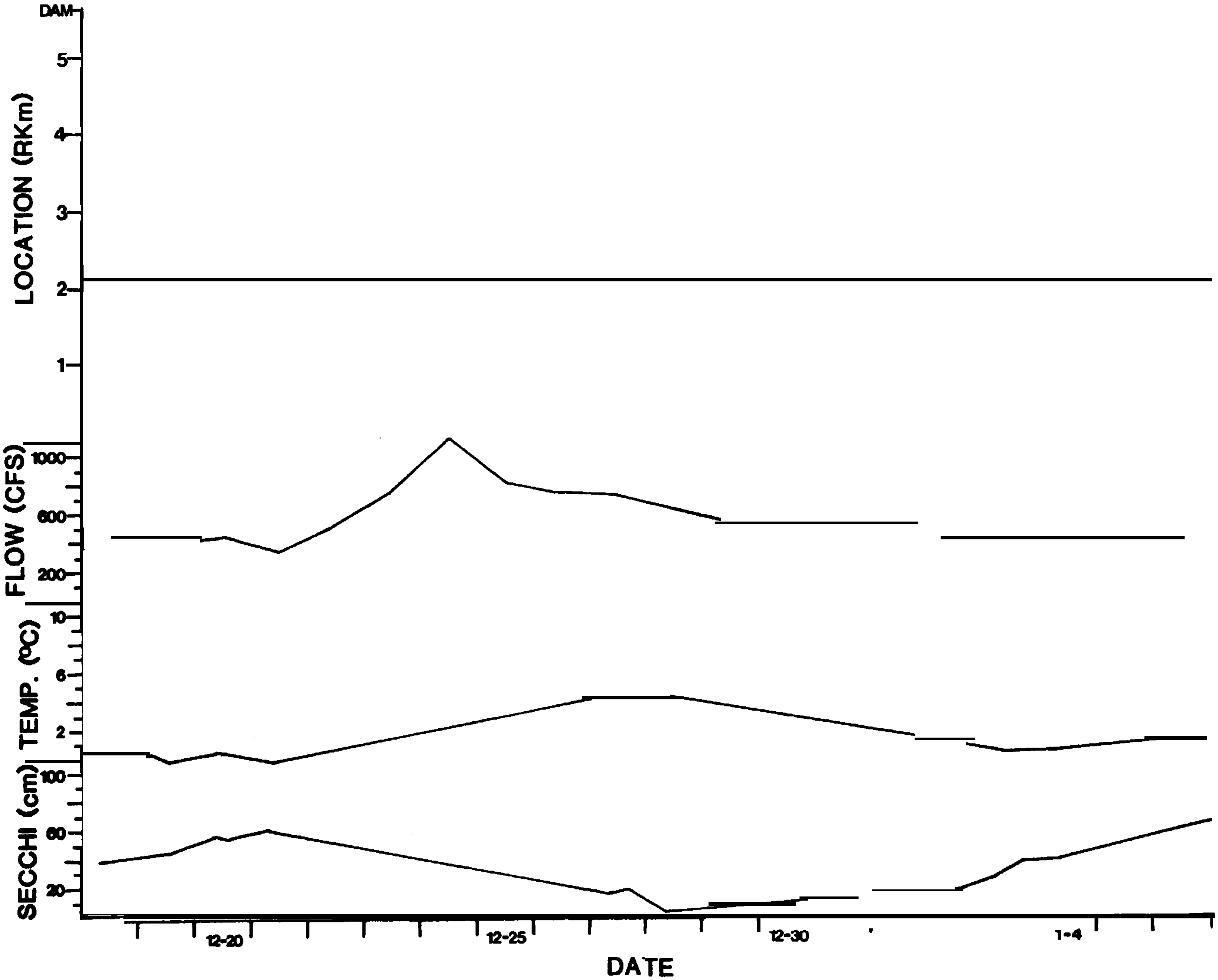

Figure 14. Movements of steelhead 240 between December 18 and January 6, and corresponding streamflows, water temperatures and Secchi disk readings.

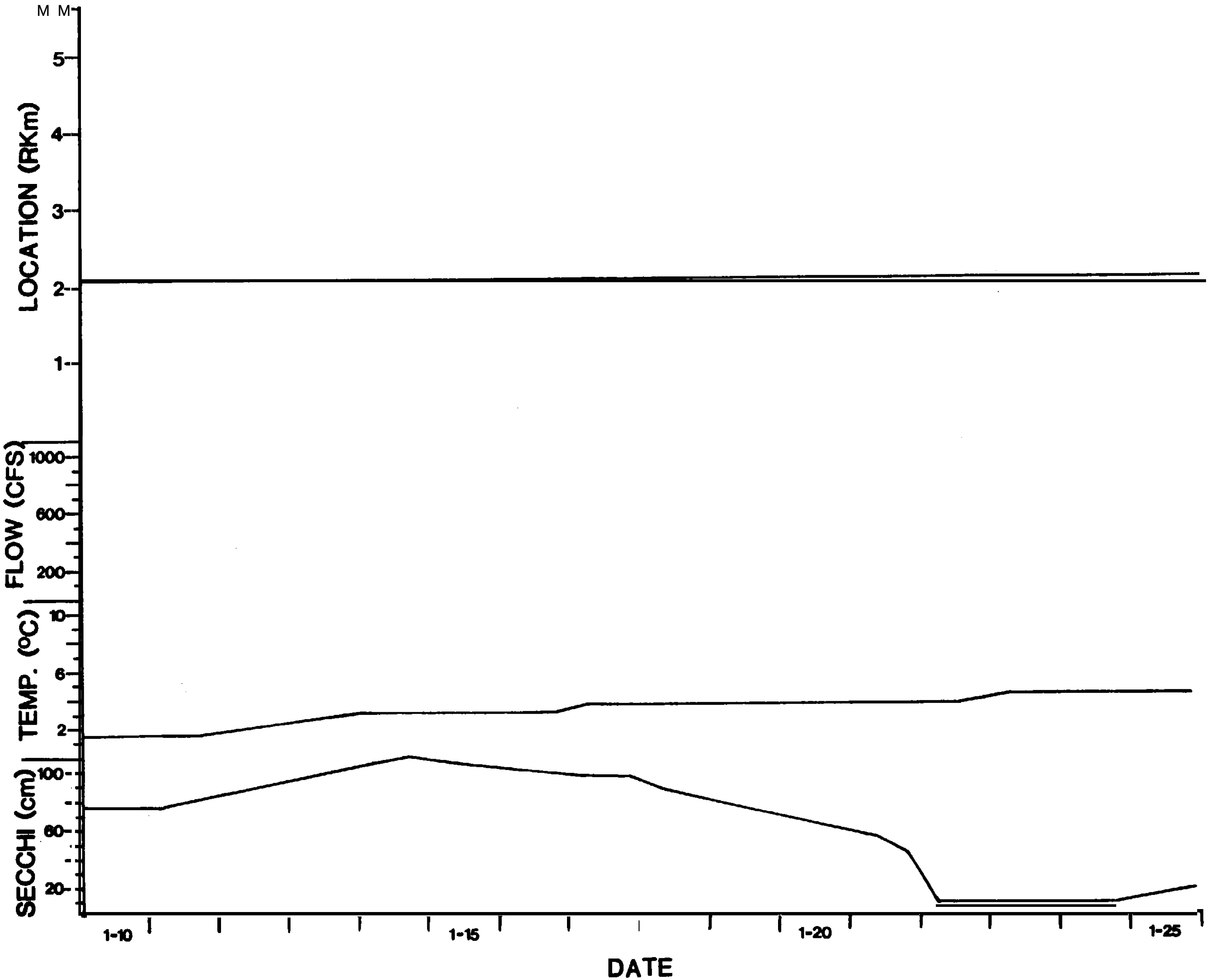

Figure 15. Movements of steelhead 020 between January 10 and January 25, and corresponding streamflows, water temperatures and Secchi disk readings.

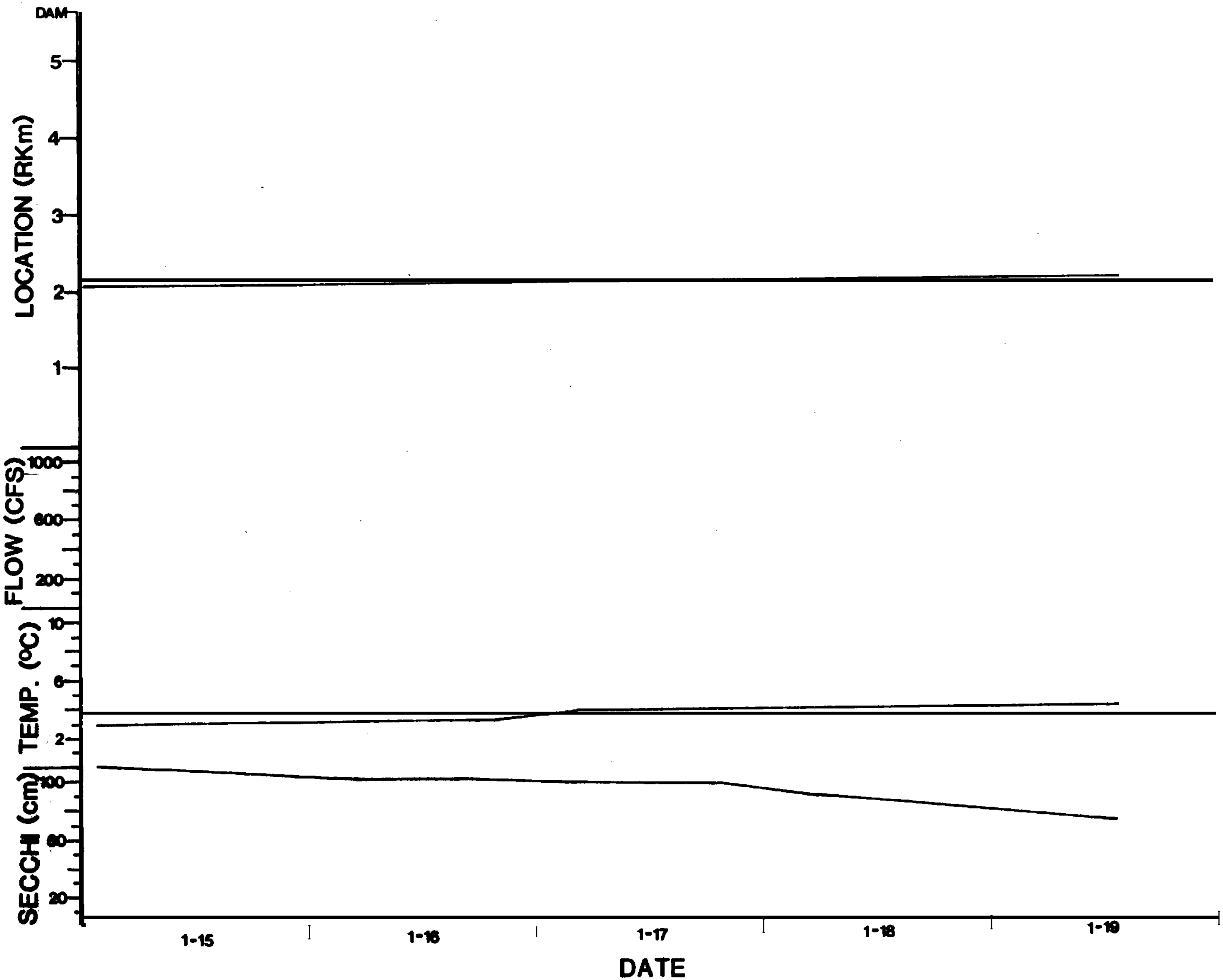

Figure 16. Movements of steelhead 260 between January 15 and January 19, and corresponding streamflows, water temperatures and Secchi disk readings.

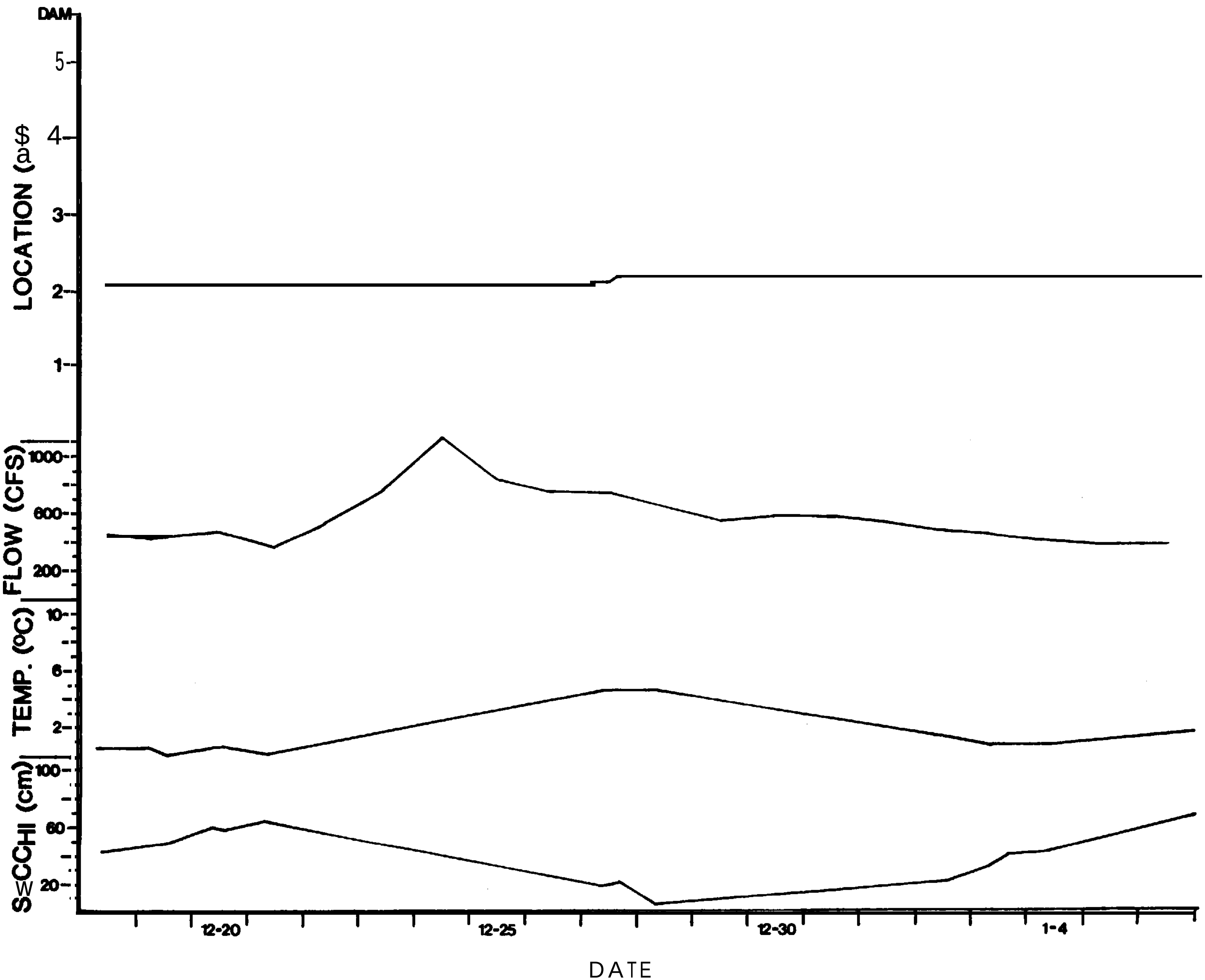

Figure 17. Movements of steelhead 290 between December 18 and January 6, and corresponding streamflows, water temperatures and Secchi disk readings.

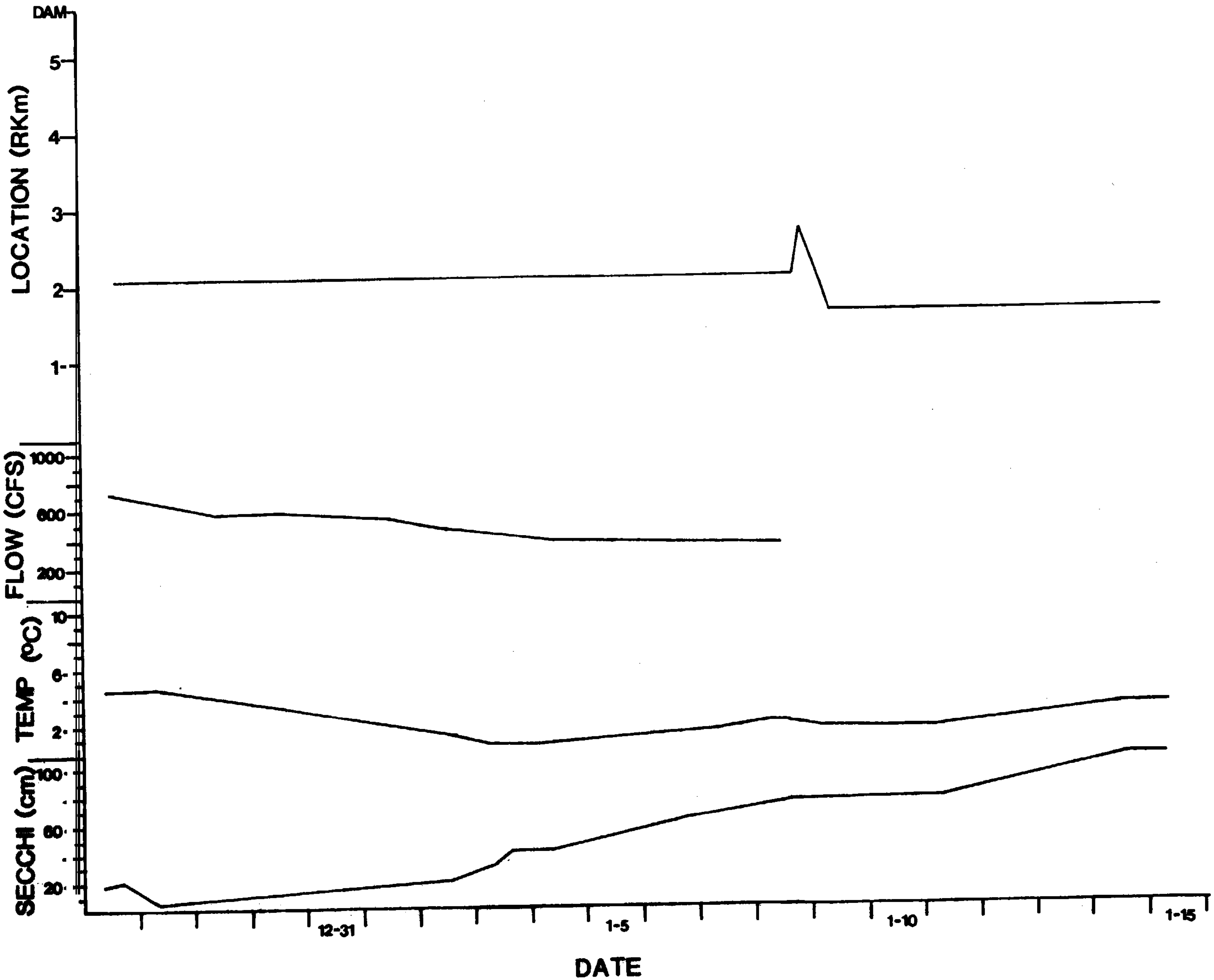

Figure 18. Movements of steelhead 590 between December 27 and January 15, and corresponding streamflows, water temperatures and Secchi disk readings.

DISCUSSION

Recapture of only one of 19 marked steelhead from the west ladder at Three Mile Dam suggests that migration through channel modifications occurred over a protracted period that extended beyond the end of our study and that many steelhead may have passed by Three Mile Dam through the uncontrolled east ladder. Lack of movement by most radiotagged steelhead during our study suggests that river conditions may not have been satisfactory for migration. At least one radiotagged fish passed by Three Mile Dam through the east ladder.

Physical conditions observed during the study (high flows, cold water and high turbidities) made it difficult to conclude that observed delays of radiotagged steelhead at given sites were a result of passage problems. Since steelhead that entered the river during our study did not spawn until the following April or May, short-term delays may have been characteristic of their upstream migration. Steelhead were observed to hold within the modified channel near RKm's 2.2 and 3.8 and at Three Mile Dam. The site near RKm 2.2 had been modified to create a 3.4 m deep x 18 m long pool behind a large boulder. The site near RKm 3.8 is unmodified and most of the flow passes through a narrow chute next to the west bank before emptying into a wide pool. Delays at RKm 2.2 were probably by choice since a radiotagged steelhead passed by this site while another was holding. Delays at RKm 3.8 may have been related to stream conditions since at the time of delays flows ranged up to 1,100 cfs, temperatures were below 4°C and Secchi readings averaged less than 60 cm. Three radiotagged steelhead passed by this site at lower flows (401-419 cfs) and turbidity (88-100 cm) and higher temperatures (6-8°C). Delays at Three Mile Dam may have been by choice since movements from holding sites below the dam to the ladders took less than 24 hours. Radiotelemetric monitoring of fall chinook salmon migration in 1985 should more clearly identify passage problems. Fall chinook salmon enter the river immediately prior to spawning and migration occurs over a period of less than two months.

The immediate downstream movement of steelhead 590 after being caught and released may indicate that catch and release of migrating steelhead by sport anglers may disrupt migration patterns. This observation may be significant because catch and release is a widely-used management tool.

External attachment of radio transmitters appears preferable to gut insertion because smaller sized fish can be radiotagged and risk of damage to the esophagus and stomach of the fish or regurgitation of the radio transmitter is eliminated. Studies of adult salmonid migrations in the Columbia River Basin that used internally placed transmitters (Liscom and Monan 1976, Monan and Liscom 1976, Liscom et al. 1977, Stuehrenburg et al. 1978, Liscom and Stuehrenberg 1983) were limited to radiotagging fish with fork lengths greater than 65 cm. Also, studies on the the upper Sacramento River (J. Smith personal communication) noted regurgitation of internally placed transmitters. Most steelhead examined during our study had fork lengths less than 66 cm and one fish regurgitated its transmitter.

Confidence in the results of radio telemetry studies are increased when migration of radiotagged fish are comparable to control fish, or when radiotagged fish feed normally and strike at angler's bait (Stasko and Pincock 1977). Gray and Haynes (1979) reported that travel times and percent returns of chinook salmon with externally attached radio transmitters did not differ significantly from those of control (T-anchor tagged) fish. However, they found that most salmon with internally placed transmitters eventually swam downstream. Studies in the upper Sacramento River indicated that chinook salmon with externally attached radio transmitters traveled more quickly and exhibited less fallback than those with internally placed radio transmitters (J. Smith, personal communication). During our study, two steelhead with internally placed transmitters were known to have fallen back into the Columbia River. Also, two of five steelhead with externally attached transmitters were caught by sport anglers, whereas none of 10 steelhead with internally placed tags were known to have been caught.

RECOMMENDATIONS

The following objectives are recommended for 1985:

1) Determine flows at which fall chinook salmon and steelhead negotiate lower Umatilla River channel modifications and enter ladders at Three Mile Dam.

2) Determine effects of passage through lower Umatilla River channel modifications on fall chinook salmon and steelhead migration above Three Mile Dam.

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APPENDIX

Table A.1 Water temperatures, Secchi disk readings, streamflows and daily count of steelhead in the west ladder at Three Mile Dam during the study period. Flow data was not available after January 8.

Date		Temp (°C)	Secchi (cm)	Flow (cfs)	Count
11-6	M[a]	7	75	299	
	A				
11-7	M	7	120	250	1
	A				
11-8	M	7	125	270	
	A				
11-9	M	7	120	268	
	A				
11-10	M	-	-	299	
	A				
11-11	M	-	-	340	
	A				
11-12	M	-	-	432	
	A				
11-13	M	9.5	40	604	8
	A	9.5	40		
11-14	M	8	30	786	8
	A	8	28		
11-15	M	6	30	924	0
	A	6	35		
11-16	M	5	41	733	0
	A	5.5	51		
11-17	M	-	-	586	
	A				
11-18	M	-	-	495	
	A				
11-19	M	6	82	432	7
	A	7	88		
11-20	M	6.5	100	401	17
	A	7	95		
11-21	M	6.5	82	419	25
	A	7.5	86		

Table A.1 Continued

Date		Temp ('C)	Secchi (cm)	Flow (cfs)	Count
11-22	M	-	-	484	-
	A				
11-23	M	-	-	502	-
	A				
11-24	M	-	-	598	-
	A				
11-25	M	-	-	750	
	A				
11-26	M	6	43	697	15
	A	6	56		
11-27	M	6	40	618	10
	A	6	48		
11-28	M	6	67	571	5
	A				
11-29	M	5.5	42	604	6
	A	6	50		
11-30	M	5	50	769	5
	A	5.5	55		
12-1	M	-	-	856	2
	A				
12-2	M	-	-	764	-
	A				
12-3	M	3	45	653	0
	A	2.5	43		
12-4	M	2.5	70	552	0
	A	2.5	71		
12-5	M	2	82	473	0
	A	1.5	84		
12-6	M	1	86	423	0
	A	1	94		
12-7	M	1	88	420	0
	A	1	86		

Table A.1 Continued

Date		Temp ('C)	Secchi (cm)	Flow (cfs)	Count
12-8	M	-	-	398	
	A				
12-9	M	-	-	397	
	A				
12-10	M	4.0	89	539	5
	A				
12-11	M	2.0	0	1,100	6
	A	3	0		
12-12	M	4	6	930	0
	A	4.5	10		
12-13	M	4	16	779	0
	A	4	20		
12-14	M	3.5	27	670	0
	A	4	29		
12-15	M			600	-
	A				
12-16	M			542	-
	A				
12-17	M	3.5	29	485	0
	A	3.5	35		
12-18	M	0.5	41	472	2
	A	0.5	42		
12-19	M	0.5	48	422	0
	A	0	49		
12-20	M	0.5	60	474	0
	A	0.5	57		
12-21	M	0	62	371	0
	A				
12-22	M	-	-	538	
	A				
12-23	M	-	-	769	
	A				

Table A.1 Continued

Date		Temp ('C)	Secchi (cm)	Flow (cfs)	Count
	M	-	-	1,130	-
12-24	A				
	M	-	-	834	-
12-25	A				
	M	-	-	743	-
12-26	A				
	M	4.5	19	724	4
12-27	A	4.5	21		
	M	4.5	2	635	0
12-28	A				
	M	-	-	580	-
12-29	A				
	M			594	-
12-30	A				
	M	-	-	577	-
12-31	A				
	M			515	-
1-1	A				
	M			464	0
1-2	A	1	21		
	M	0.5	32	411	0
1-3	A	0.5	40		
	M	0.5	42	394	0
1-4	A				
	M	-	-	379	-
1-5	A				
	M	-	-	382	-
1-6	A				
	M	1.5	65	353	0
1-7	A	1.5	68		
	M	2	73	356	0
1-8	A	2	74		

Table A.1 Continued

Date		Temp (°C)	Secchi (cm)	Flow (cfs)	Count
	M	1.5	74		0
1-9	A	1.5	74		
	M	1.5	74		1
1-10	A	1.5	74		
	M	1.5	76		0
1-11	A				
	M	-	-		-
1-12	A				
	M	-	-		-
1-13	A				
	M				0
1-14	A	3	100		
	M	3	100		1
1-15	A				
	M	3	100		0
1-16	A				
	M	3.5	95		0
1-17	A	3.5	94		
	M	3.5	84		8
1-18	A				
	M	-	-		-
1-19	A				
	M	-	-		-
1-20	A				
	M	3.5	52		0
1-21	A	3.5	40		
	M	3.5	8		0
1-22	A	3.5	5		
	M	4	3		0
1-23	A	4	3		
	M	4	3		0
1-24	A	4	5		

Table A.1 Continued

Date		Temp ('C)	Secchi (cm)	Flow (cfs)	Count
	M	4	20		0
1-25	A				

a M = Morning, A = Afternoon