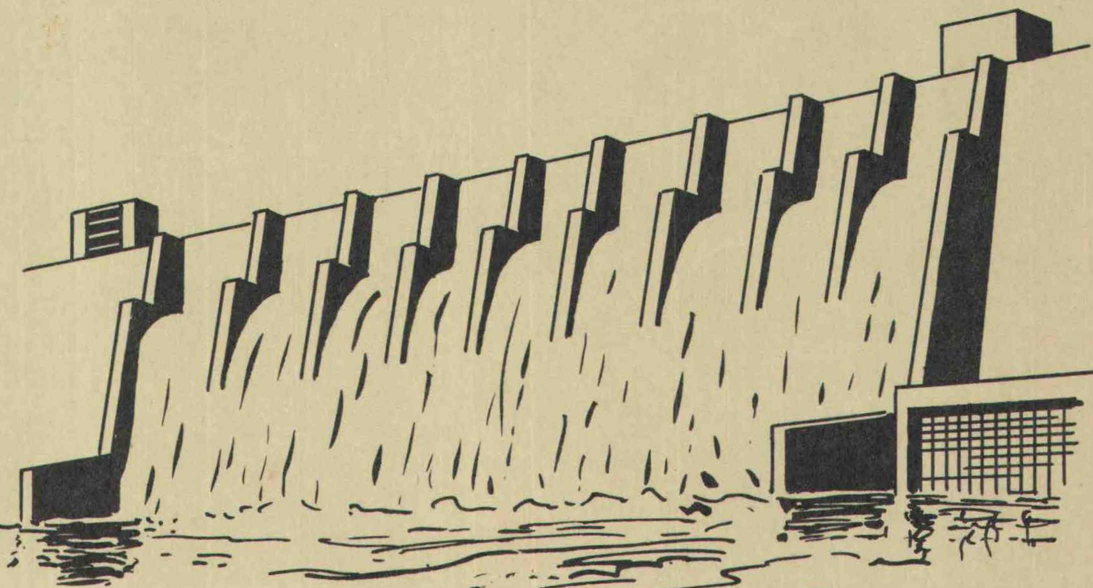
Basin Investigations

SPECIAL REPORT No. 1 1969

EFFECT OF UNUSUALLY LOW DISCHARGE FROM PELTON
REGULATING RESERVOIR, DESCHUTES RIVER, ON
FISH AND OTHER AQUATIC ORGANISMS



OREGON STATE
GAME COMMISSION

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EFFECT OF UNUSUALLY LOW DISCHARGE FROM PELTON REGULATING RESERVOIR, DESCHUTES RIVER, ON FISH AND OTHER AQUATIC ORGANISMS

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Basin Investigations Section
Special Report No. 1

Oregon State Game Commission
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Portland, Oregon
May 1969

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INTRODUCTION

Portland General Electric Company was instructed by the Federal Power Commission to inspect the stilling basin at Pelton regulating dam to determine if it was in safe operating condition. It has not been inspected in the 10 years since the facility was built. The regulating reservoir is part of the Company's Pelton Project. It levels out the varying turbine discharge from Pelton Dam, located about 3 miles upstream, so that discharge into the river below is relatively uniform.

To inspect the stilling basin, it was necessary to close the spillway gates, thus limiting discharge into the river below to water that could be passed through the fishway attraction-water gates on either side and the 54-inch pipe from the junction box near the fish trap. This quantity was predicted to be about one-third of 3,500 cfs (cubic feet per second), the minimum flow presently set by FPC to protect fish life in the Lower Deschutes River. We anticipated the reduction in flow would result in a loss of fish. Since additional inspections may be required in the future, we attempted to get a measure of fish mortality and to understand its causes to enable us to recommend procedures that would reduce mortality to the lowest possible level.

The Company closely coordinated its planning of the inspection with our department, especially as to timing. The date (April 2) was selected to fall as near as possible following emergence of chinook salmon fry and prior to spawning of steelhead and rainbow trout.

An evaluation was made of the effect of the flow reduction on aquatic resources. This is a report of that evaluation. It was done primarily by the Game Commission with assistance from Fish Commission of Oregon, Warm Springs

Tribal Council, and the Company. The Company, the State Engineer, and the Game Commission all had representatives at the regulating dam during the period of reduced flow. A U. S. Geological Survey representative alternated between the gage near the fish trap and the cable crossing 0.3 mile downstream to measure discharge and extend the rating curve for the gage.

METHODS AND MATERIALS

The method of evaluation was to characterize the flow reduction as to extent of drop in water level at various study areas in the 100-mile reach from the dam to the Columbia River (Figure 1), and to examine the exposed areas for stranded and dying fish and other aquatic forms. Emphasis was placed on written accounts with accompanying photographs of the events taking placed. Cameras, staff gages, and other equipment were provided to personnel. In addition, a number of people had two-way radios, which were borrowed from the State Department of Forestry, in an effort to maintain communication and thereby provide maximum flexibility of manpower. A coordinator was stationed at Pelton regulating dam with a two-way radio to announce the progress of the inspection, and to relay messages between the helicopter, which returned to the regulating dam periodically for refueling, and the study groups stationed downstream. Radio relay units were also stationed along the canyon rim to facilitate communication.

Segments of the evaluation were performed by teams assigned to specific areas below the project. These were some of the same study areas used in the Lower Deschutes Study (Aney, Montgomery, and Lichens, 1968) conducted by the Game Commission. Generally, they were areas of gravel bars used by spawning salmon and trout. There were also two mobile teams, one with automobiles and

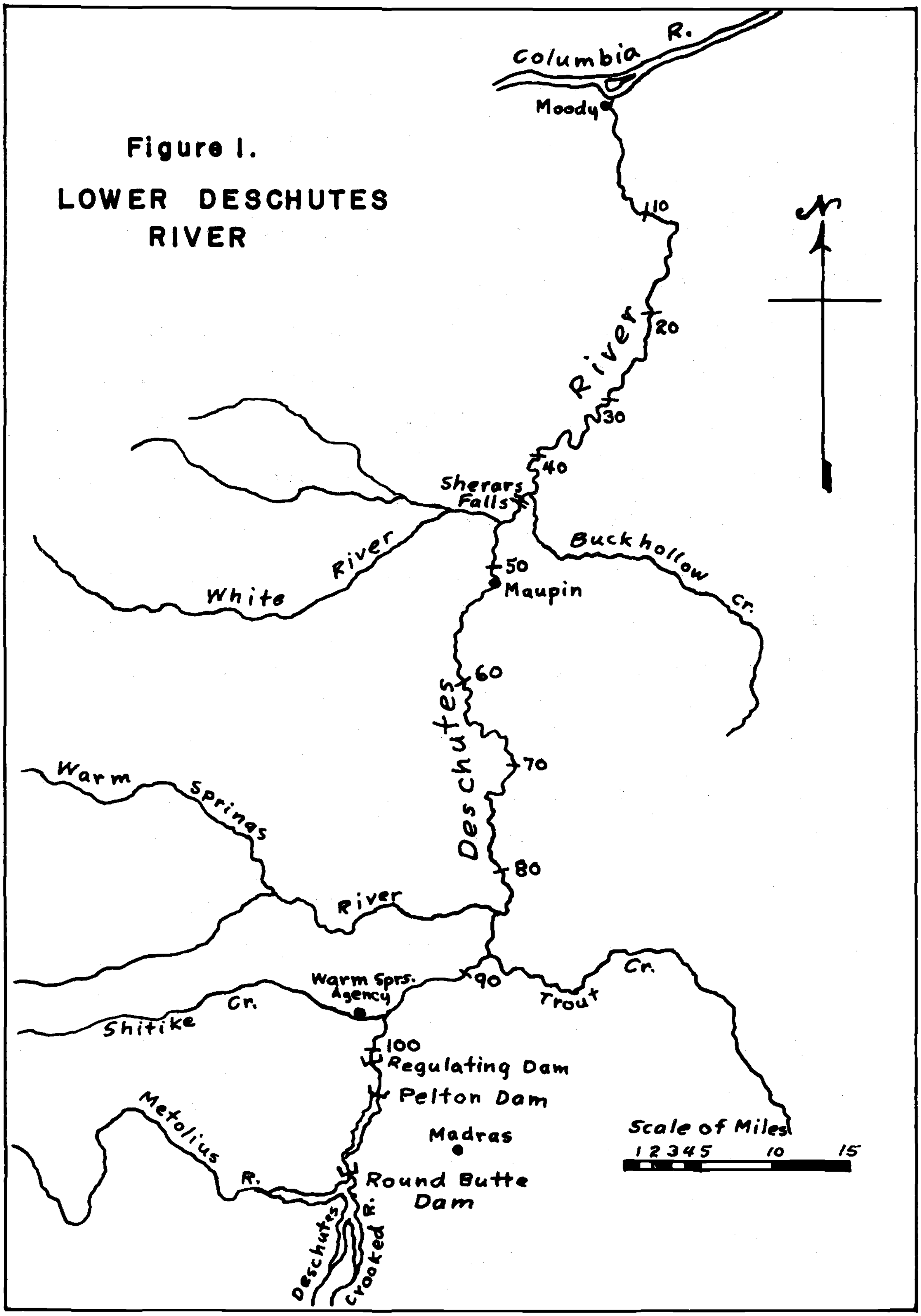
Figure I.
LOWER DESCHUTES RIVER
Columbia R.
Moody
10
20
30
40
River
Sherars Falls
Buckhollow Cr.
50
Maupin
White River
60
70
80
Deschutes
Warm Springs River
90
Trout Cr.
Warm Sprs. Agency
Shitike Cr.
100
Regulating Dam
Pelton Dam
Madras
Metolius R.
Round Butte Dam
Deschutes
Crooked R.
Scale of Miles
1 2 3 4 5 10 15

the other with a Company-provided helicopter, which attempted to follow the trough of the flow reduction downstream, thus providing an overall view of the effect on aquatic resources.

Tributary inflow below the regulating dam was measured the day before to determine its influence on the degree of reduction in river flow.

Prior to the actual flow reduction, the manner in which the study should be conducted was discussed. The question was: would it be better to reduce the flow quickly, get in, make the inspection, and increase the flow as quickly as possible, or, should the reduction be made over a period of several hours with a gradual return to the pre-reduction level after the inspection was completed? Knowing of no precedent that had demonstrated the advantage of one alternative over the other, we chose the first course, i.e., the fast drawdown, inspection, and fast increase in stream flow to its former level.

RESULTS

Portland General Electric Company reduced the flow at the regulating dam from 3,500 cfs to 1,380 cfs at 0800 hours on April 2, and put divers immediately into the water to make the inspection of the stilling basin. The inspection was completed by 0845, with only a minor amount of damage being found. The gates were cracked open to increase the flow gradually over a 1-hour period because the Company feared that spectators might have gathered on the exposed gravel bars downstream, and a rapid increase in flow could endanger them. By about 0940 the flow reached the pre-reduction level of 3,500 cfs. At the request of our department, the Company increased the flow to about 4,000 cfs for a short period in an effort to overrun the trough downstream because reports of the observers in the helicopter indicated that mortality was occurring to fish stranded on some of the bars.

The leading edge of the trough traveled downstream at about 6 miles per hour, reaching the gage at Moody, river mile 1.4, just after midnight (0030 hours) on April 3 (Fig. 2). The rate of travel was quite uniform throughout the 100-mile reach, reflecting the nearly uniform river gradient. Water level at various stations on the river dropped from 0.35 to 1.55 feet. The amount of reduction generally decreased with distance below the regulating dam, although the drop in water level was greatest in the well-defined, relatively narrow channel such as at the USGS cable crossing (Fig. 2a) and at Sherars Falls (Fig. 2h). At Moody (Fig. 2i), the drop was only 0.35 foot.

The low flow just below the regulating dam (1,380 cfs) was 39 percent of the pre-reduction level. Tributary inflow (Table 1) together with channel and bank storage dampened the impact progressively at the study areas downstream (Table 2).

Table 1. Stream flow in major tributaries of Deschutes River below Pelton regulating dam, April 1, 1968.

Tributary	Location of confluence (River miles)	Flow (Cubic feet per second)
Shitike Creek	96.8	83 1/
Dry Creek	94.3	0 1/
Trout Creek	87.0	12 1/
Warm Springs River	83.8	450 1/
White River	46.5	350 2/

1/ Measured by John Fortune and Ken Thompson on April 1, 1968.

2/ From USGS records for April 2, 1968.

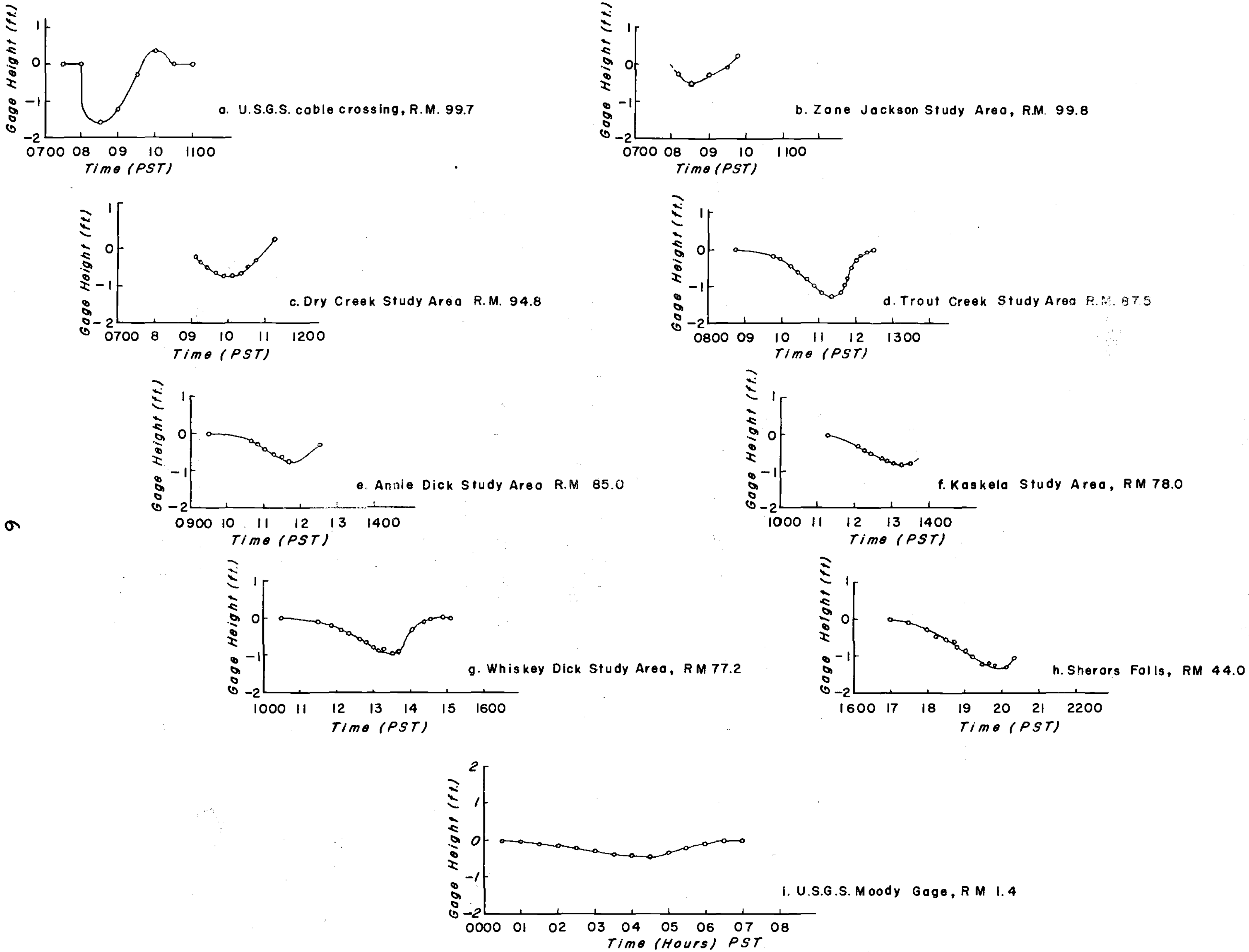

Figure 2. Characteristics of the flow reduction in the Deschutes River, April 2-3,1968
Locations are designated by River Mile (RM)

Table 2. Effect of reduction in discharge from Pelton regulating dam on Deschutes River flow at several points downstream

Location	Pre-reduction flow (cfs)	Minimum flow (cfs)	Percentage of pre-reduction flow
USGS cable crossing, RM 99.7	3,500 1/	1,380 1/	39
Immediately below Shitike Creek, RM 96.8	3,583 2/	1,463 2/	41
Immediately below Warm Springs River, RM 83.8	4,045 2/	1,925 2/	48
USGS gage at Moody, RM 1.4	4,540 1/	3,320 1/	73

1/ Flows from USGS gage readings and rating table.

2/ Theoretical flow based on USGS figures at cable crossing at river mile 99.7 and tributary inflows in Table 1. Channel and bank storage would cause actual minimum flows to be slightly higher than given here.

Attempts at coordinating activities from Pelton regulating dam were forestalled because the two-way radio there would transmit but not receive. There was some communication directly between units on the river, and indirectly through units established as relays on the canyon rim.

The above comments apply generally to the stream below Pelton regulating dam. Detailed observations of what occurred at each of the study areas can be found in the following sections.

Pelton regulating dam, river mile 100.1 (Chuck Campbell and Bob Phillips)

The spillway gates at Pelton regulating dam were closed at 0800, reducing the flow downstream to the quantity of water discharged through the auxillary gates near the fishway entrances and the 54" pipe near the adult fish trap, about 400 feet downstream from the dam. Flow prior to the reduction was 3,500 cfs. A representative of the U. S. Geological Survey measured the reduced discharge at 1,380 cfs.

Divers went into the water to inspect the stilling basin immediately after the flow was reduced (Fig. 3 and 4). A Company report concludes, "A large portion of the basin could not be inspected because of the presence of well-graded boulders and gravel; however, the damage which could be observed was of the extent that no immediate repairs are warranted." (Portland General Electric Company, 1968). The inspection was completed at 0845 and the gates cracked open to begin a gradual increase in flow.

After closure of the gates, water level below the dam dropped 1.55 feet almost immediately, as measured at the USGS cable crossing some 0.3 mile below the dam. (Fig. 2a) Brief examination of a few feet of exposed shoreline revealed that several sculpins and stonefly nymphs were stranded among the rubble (Fig. 5). No salmonids were seen. Loss of salmon and trout from stranding in the area was probably negligible because the exposed stream banks were relatively steep and there were no gravel bars.

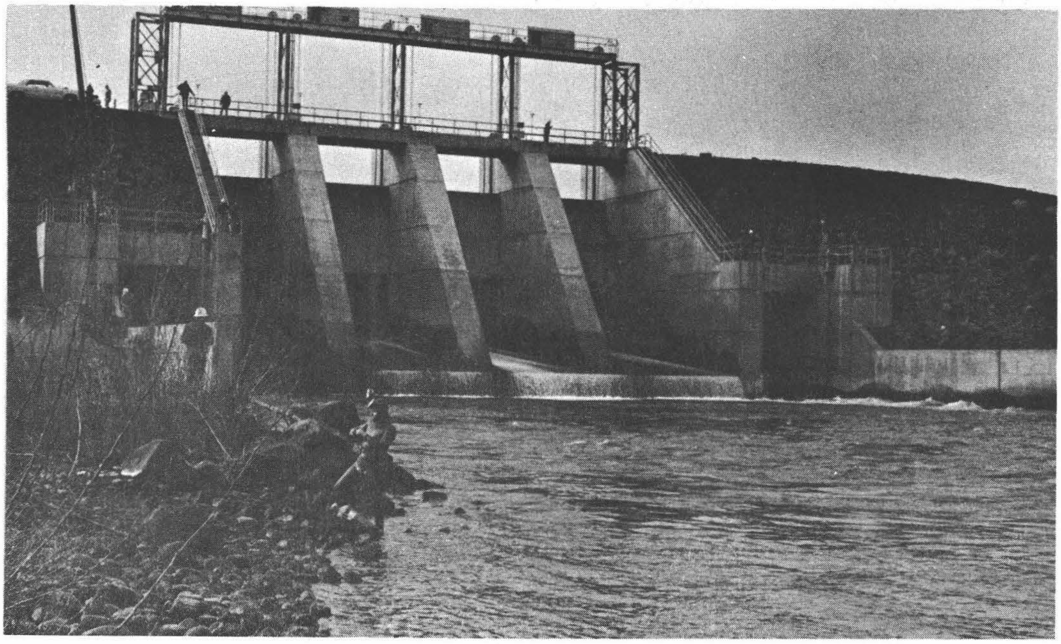

Fig. 3. SCUBA diver prepares to enter water to inspect stilling basin at Pelton regulating dam. (Photo by Phillips)

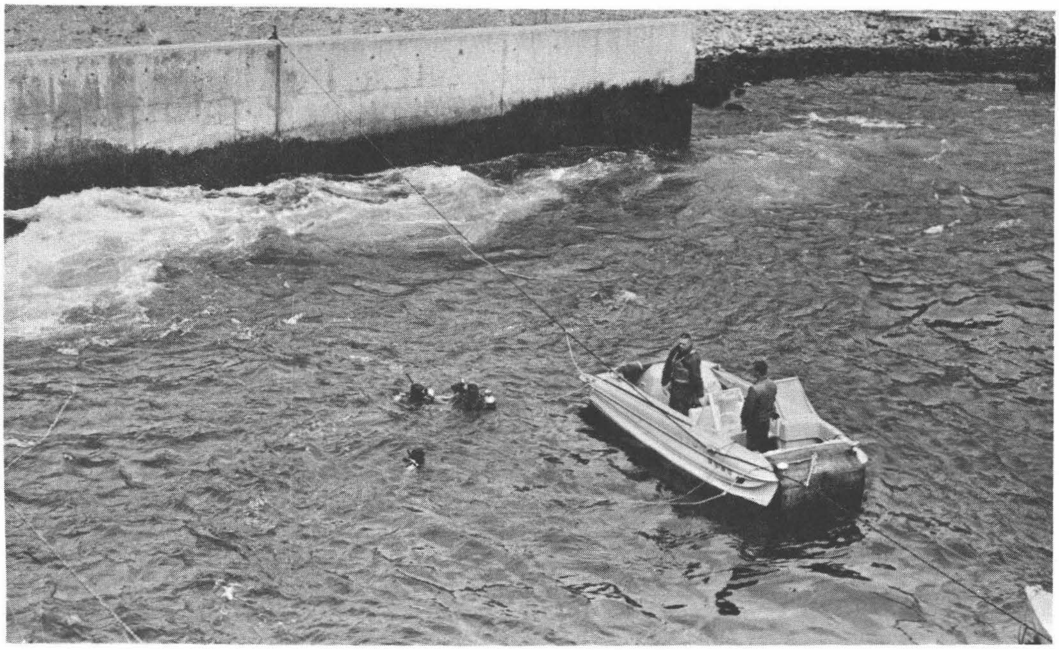

Fig. 4. Divers surface briefly during inspection of stilling basin. (Photo by Phillips)

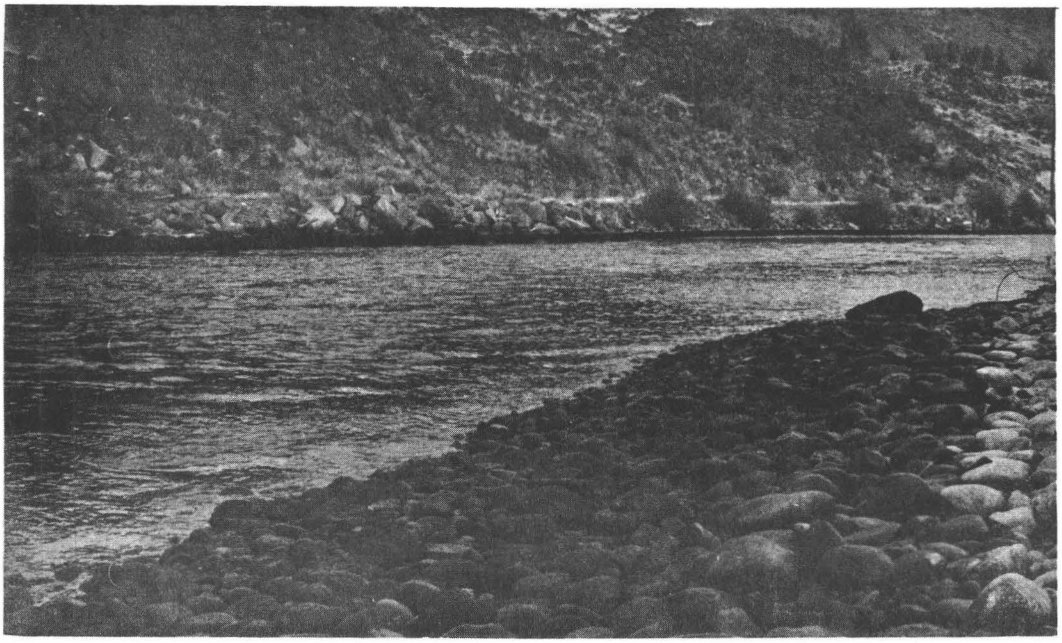

Fig. 5. East shoreline just below Pelton regulating dam that was exposed during flow reduction. (Photo by Rohweder)

Zane Jackson study area, river mile 99.8 (Locke and Herrig)

Things happened more quickly than anticipated at the Zane Jackson study area. Gages had just been installed, but before readings could be taken, the water level had started to fall. Consequently, the first reading at 0807 hours was not representative of the level before the flow reduction (Fig. 2b). The points in Fig. 2b, however, describe the changes in water level from just before the low until flows reached pre-reduction levels. A series of photographs (Fig. 6) also illustrates the change in flow. It is interesting to note that water level declined about 0.5 foot below the pre-reduction level as compared to 1.55 feet at the USGS cable crossing located just downstream.

The decrease in flow below the regulating dam was insufficient to dewater the channel on the west side of the island, where the study area at Zane Jackson is located (Fig. 6). Loss of fish by stranding was therefore small.

One area along the island drained (Fig. 7), stranding two rainbow trout 6 to 8 inches long, and about 30 chinook fry 2 inches long. The fish would have died had they not been removed and placed in deeper water. Numerous sculpins and aquatic insects were also stranded (Fig. 8). Loss of these organisms was minimal because of the short duration of the flow reduction and the cool weather.

East and West Disney study area, river mile 99.0 (Lichens, E. Miller, and Ebert)

The water had already started dropping when we arrived at East Disney. Two gages were placed to record the changes in water level, one 32 feet from shore (Fig. 9) and the second 195 feet into the stream bed (Fig. 10). Photos were taken of the exposed area (Fig. 11) as well as some of stranded fish (Fig. 12).

Most of the time was spent making observations of stranded fish. There were large numbers of 1-3 inch chinook and some trout to 7 inches. The West Disney area was also surveyed for stranded fish; many 1-3 inch chinook and a few small trout were observed, as well as three exposed steelhead redds. We estimated the loss of fish in the East Disney and West Disney areas to number several thousand.

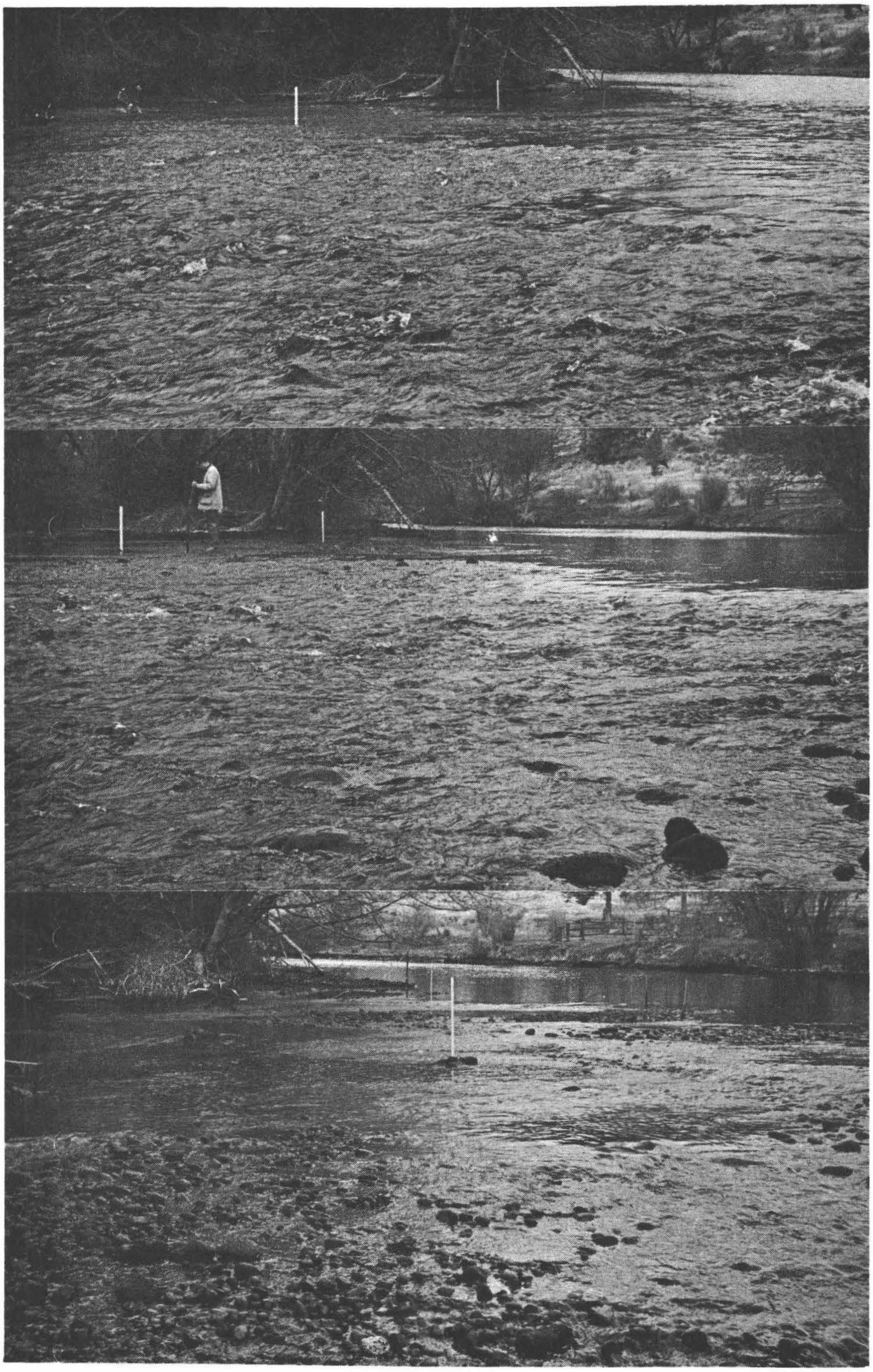

Fig. 6. Zane Jackson study area showing water at normal, intermediate, and low levels. (Photos by Herrig)

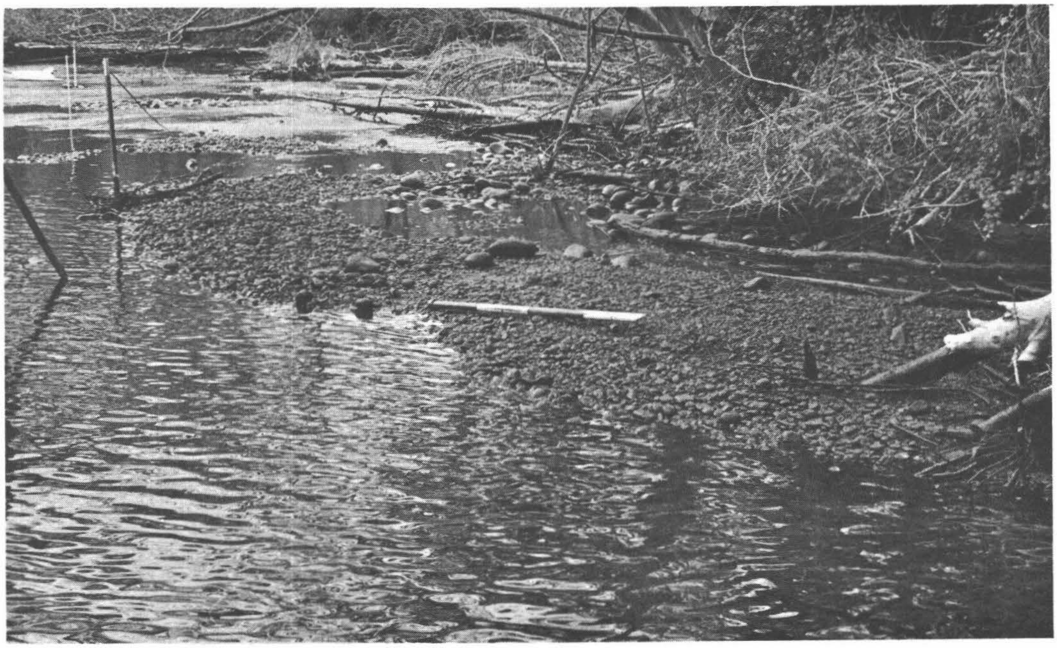

Fig. 7. Zane Jackson study area: exposed bar near island where fish were stranded. (Photo by Herrig)

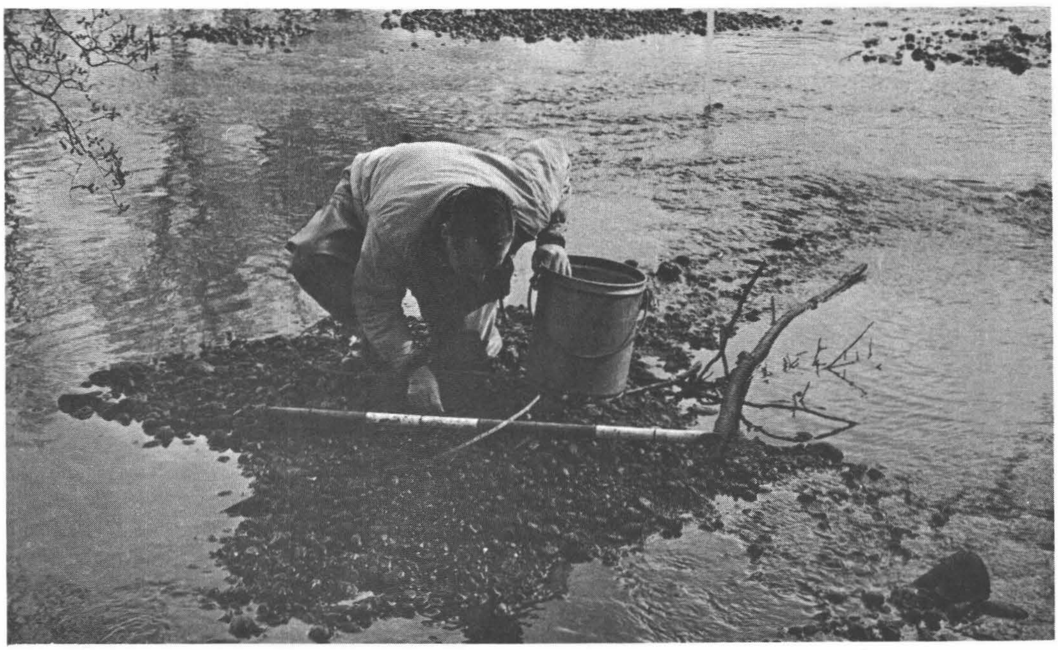

Fig. 8. Zane Jackson study area: collecting stranded aquatic insects. (Photo by Herrig)

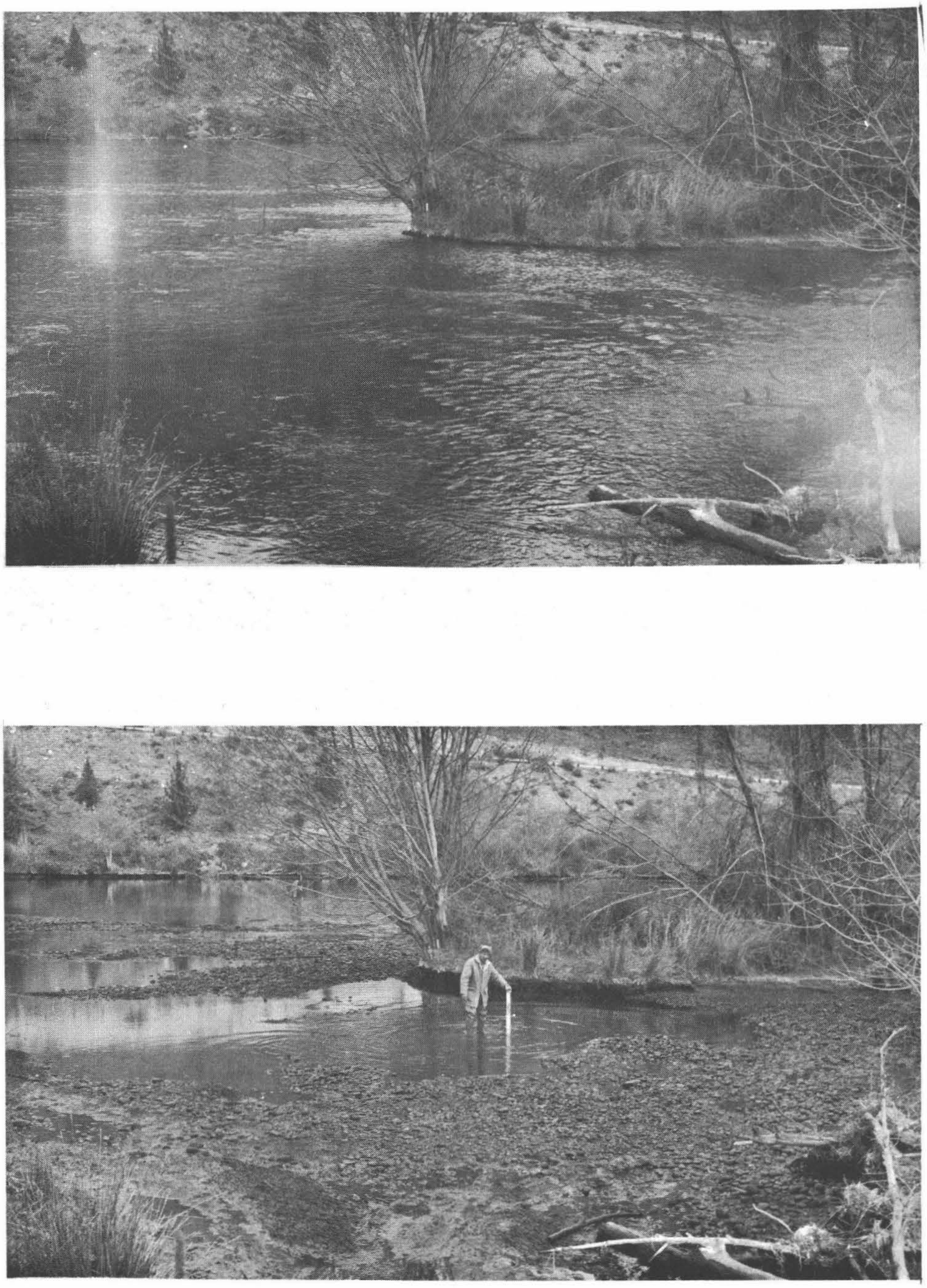

Fig. 9. East Disney study area showing water level beginning to fall (top) and at low point (bottom). (Photos by Ebert)

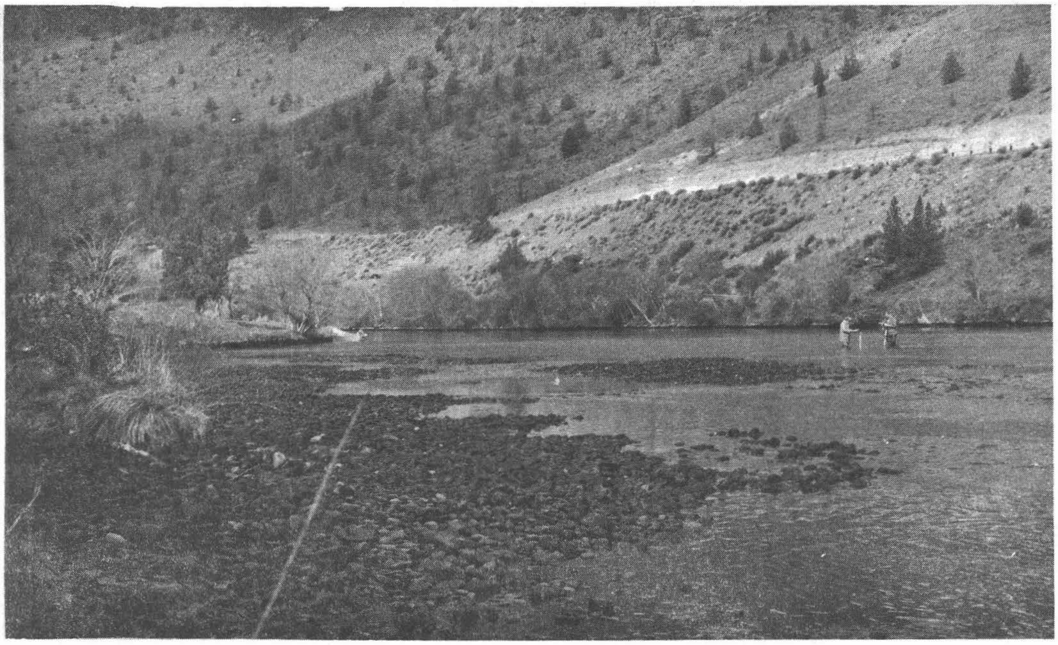

Fig. 10. East Disney study area at low flow, looking upstream. (Photo by Ebert)

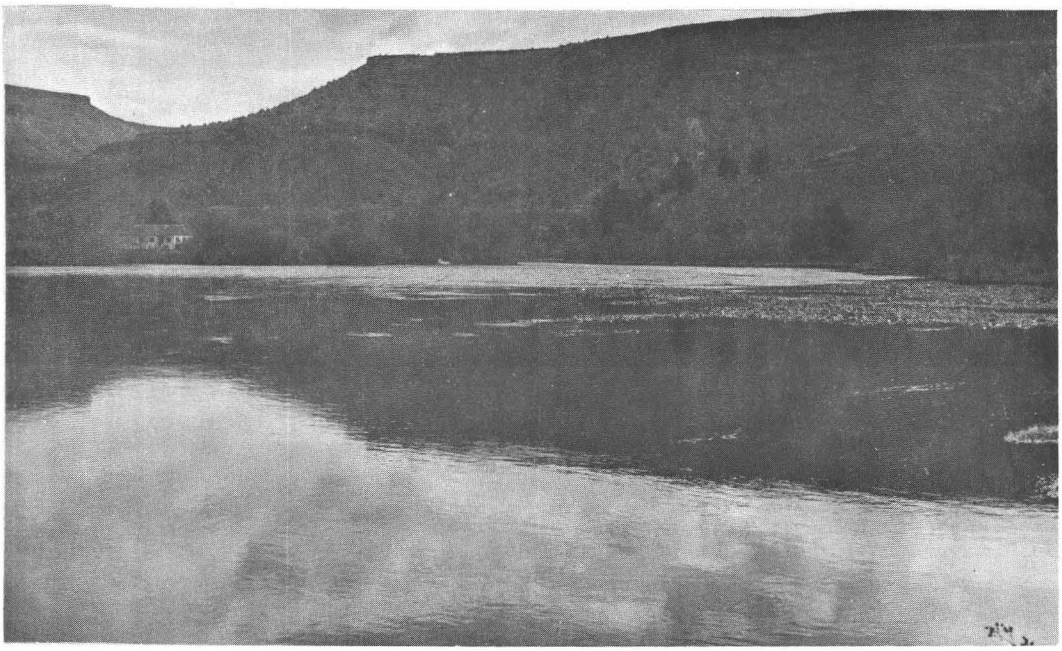

Fig. 11. East Disney study area at low flow, looking downstream. (Photo by Ebert)

Fig. 12. East Disney study area: dead and dying fish stranded by flow reduction. (Photo by Ebert)

Dry Creek study area, river mile 94.8 (Aney, Scherzinger, and Hasselman)

We started to set up the equipment at 0800, and it was anticipated that we had until almost 1000 to complete our initial work. At 0900 it was visually noted that the water level was starting to recede so the gage was immediately set and readings taken periodically during the fall and rise in level (Fig. 2c). Most of the work was accomplished on schedule and the project was completed by 1200. Black and white photographs were taken with a 35mm camera at intervals through the change in water levels (Fig. 13).

Heavy mortality was noted on salmon about 2 inches long (Fig. 14 and 15). On one bar on the east side of the river 40 dead fish were observed. On the west side of the river in the channel on the west side of the island another 47 dead fish were seen. In several instances mortality was noted on trout in the 4 to 5-inch class. Six fish were counted in dried up pools on the south end of the island. Most of the smaller fish were stranded on bars where they were caught in the aquatic weeds or among the rocks where the water seeped out of the pools.

We did not make a total count of the number of dead sculpins but they were numerous, and could be observed on almost every gravel bar and rocky area. Again, no count was kept on whitefish but some small ones about 2 inches long were stranded. There was a high mortality on lamprey ammocoetes in the size range between 3 and 6 inches. On one mud bank 4 feet by 15 feet, 27 ammocoetes were counted.

There was a great quantity of aquatic insects noted in the exposed areas, the greatest concentration being on the gravel substrate. No dead insects were noted during the low water level, but there was apparently some insect mortality from a few killdeer that were foraging along the rocky bars.

No predation of live, stranded fish was noted in this location. After the water had returned to full flow, however, it was observed that eight crayfish were feeding along the shallows on dead salmon fry.

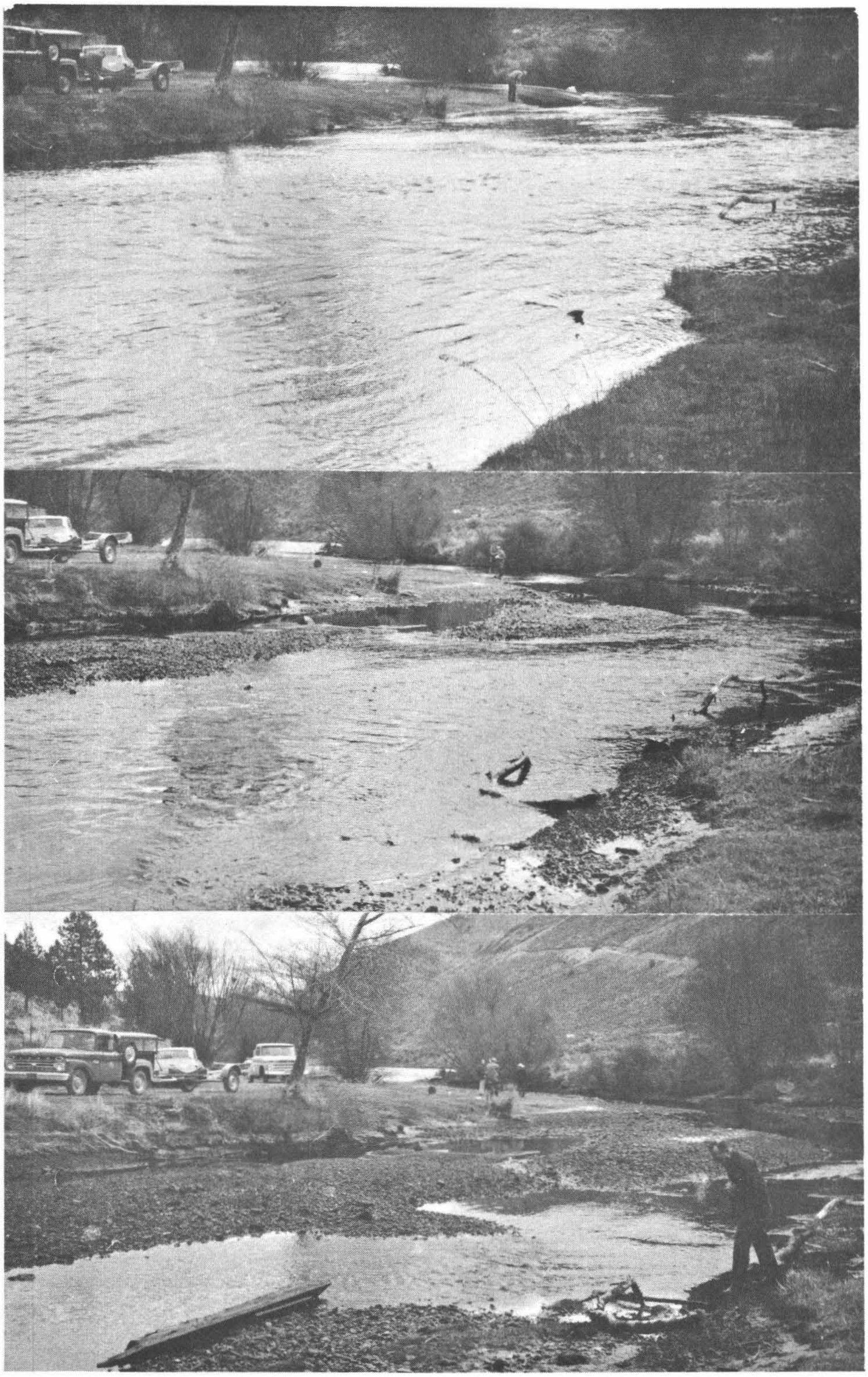

Fig. 13. Dry Creek study area showing water at normal (top), intermediate (middle), and low (bottom) levels. (Photos by Scherzinger)

Fig. 14. Rainbow fingerlings stranded on gravel bar in Dry Creek area. (Photo by Scherzinger)

Fig. 15. Rainbow fingerling stranded in aquatic vegetation at Dry Creek area as river flow was reduced. (Photo by Scherzinger)

Trout Creek study area, river mile 87.5 (Cummings and King)

A staff gage was attached to the steel stake near the east bank at the Trout Creek area. It was the same stake used as a reference for depth and velocity measurements in the Lower Deschutes Study (Aney, et al., 1968). The first reading on the staff gage was made at 0845 (Fig. 2d). A series of depth and velocity measurements was made along the established cross-sections. First decline in water level was noted at 0950. It continued to fall for the next 1 hour and 25 minutes, reaching a low on the gage at 1115. Water had returned to its original level by 1214. Fall and rise of the water level is depicted in Fig. 16.

Much of the stream bottom was exposed at the study area and adjacent stream sections by the reduction in flow (Fig. 16 and 17). Several small chinook and rainbow, and one summer steelhead (marked LV-An) (Fig. 18), were entangled in the weed beds. Four sections of exposed bank 100 feet long and 3 feet wide were surveyed. The number of fish found stranded totaled 3 salmon fry and 6 rainbow fingerlings. However, the count of dead fish is believed to be only a fraction of the total mortality in the sections as fish slipped into crevices between rocks and were difficult to observe.

Numerous sculpins were stranded as were several dace. Many insects were exposed, includding caddisflies, mayflies, and stoneflies.

Fig. 16. Trout Creek study area depicting area exposed by flow reduction. (Photos by Cummings)

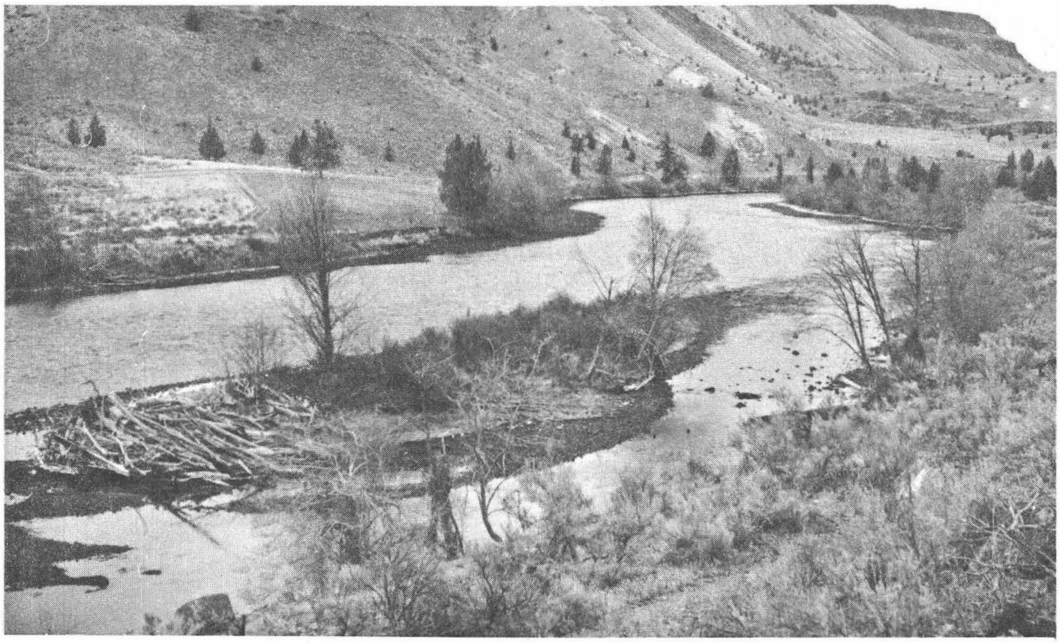

Fig. 17. Trout Creek study area at low water looking downstream from island in Figure 16. (Photo by Cummings)

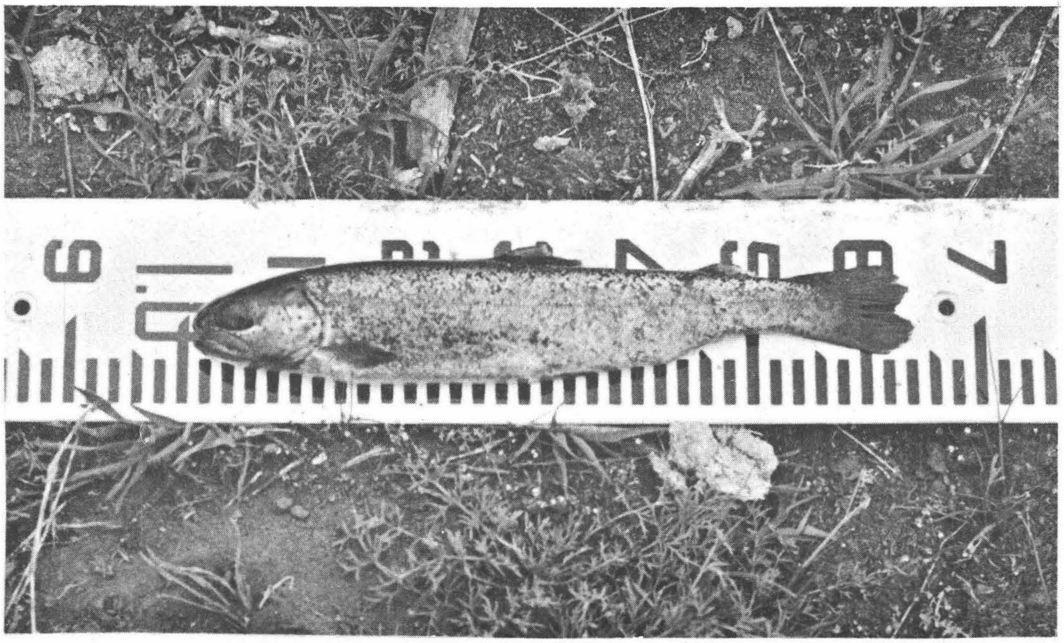

Fig. 18. Hatchery-reared summer steelhead, which had been marked prior to release by excising the left ventral and anal fins, that became entangled in weed beds at Trout Creek study area when water level receded. (Photo by Cummings)

Annie Dick study area, river mile 85.0 (Griggs and Rohweder)

The staff gage was set up and a reading taken at 0945 (Fig. 2e). The drop in water level was first noted at 1045. Thereafter, gage readings were taken periodically through the fall and partial rise of water.

Few salmonids were found stranded in this area because of the absence of bars. The stream bank slopes at such an angle as to allow fish to retreat with the water. Sculpins, being more closely associated with the stream bottom, were stranded in significant numbers. No estimate of their mortality was made, however. Many aquatic insects were stranded but again no estimate of mortality was made.

Kaskela study area, river mile 78.0 (Lichens, E. Miller, and Ebert)

The water level dropped almost 0.9 foot (Fig. 2f), leaving a large area dewatered (Fig. 19). Losses of young chinook were observed but in much smaller numbers than at East and West Disney, due in part to the type of bottom and shoreline. Most of the loss at this station was in the vegetation where the small fish were trying to use it for cover as the water receded.

Whiskey Dick study area, river mile 77.2 (Fortune and Haxton)

The leading edge of trough reached this station at 1120 (Fig. 2g). The low was recorded at 1332 and normal flow was reached again at 1445. Total drop in water level was 0.98 foot. Depth and velocity measurements were taken at the established cross-section perpendicular to the gravel bar and downstream from the island (Aney, et al., 1968).

A staff gage was established in nearly 2 feet of water on the main channel edge of the gravel bar to record the change in water level. Cross-sectional depth measurements were made with approximately every 0.1 foot of fall. Velocity measurements were made in an attempt to define the width suitable for spawning.

A series of photos were taken from the downstream tip of the island at a location used by Aney, et al. (1968), in their work on the river (Fig. 20). A number of other photos were taken before and after the flow reduction for other comparative illustrations.

By the time the water level had fallen half way, or about 0.5 foot, the majority of the most desirable spawning area was exposed or too shallow for use (Fig. 20). For practical purposes all the stations on the west side of the base post could be ignored because water velocity and gravel were inadequate to support spawning on that side. Gravel composition was good as far to the east as we could reach. However, the configuration of the bar did not present an ideal spawning situation as it fell off toward mid-channel at a fair slope and velocities were about 2.5 feet per second.

Only three chinook fry were located in weeds at the lower end of the bar; however, an intensive search was not made. One sucker, 5 inches long, and one crayfish were seen in the exposed area as well as many sculpins and aquatic insects. A close watch was made on the side channel west of the island but it was not completely cut off; a small flow persisted throughout the reduction.

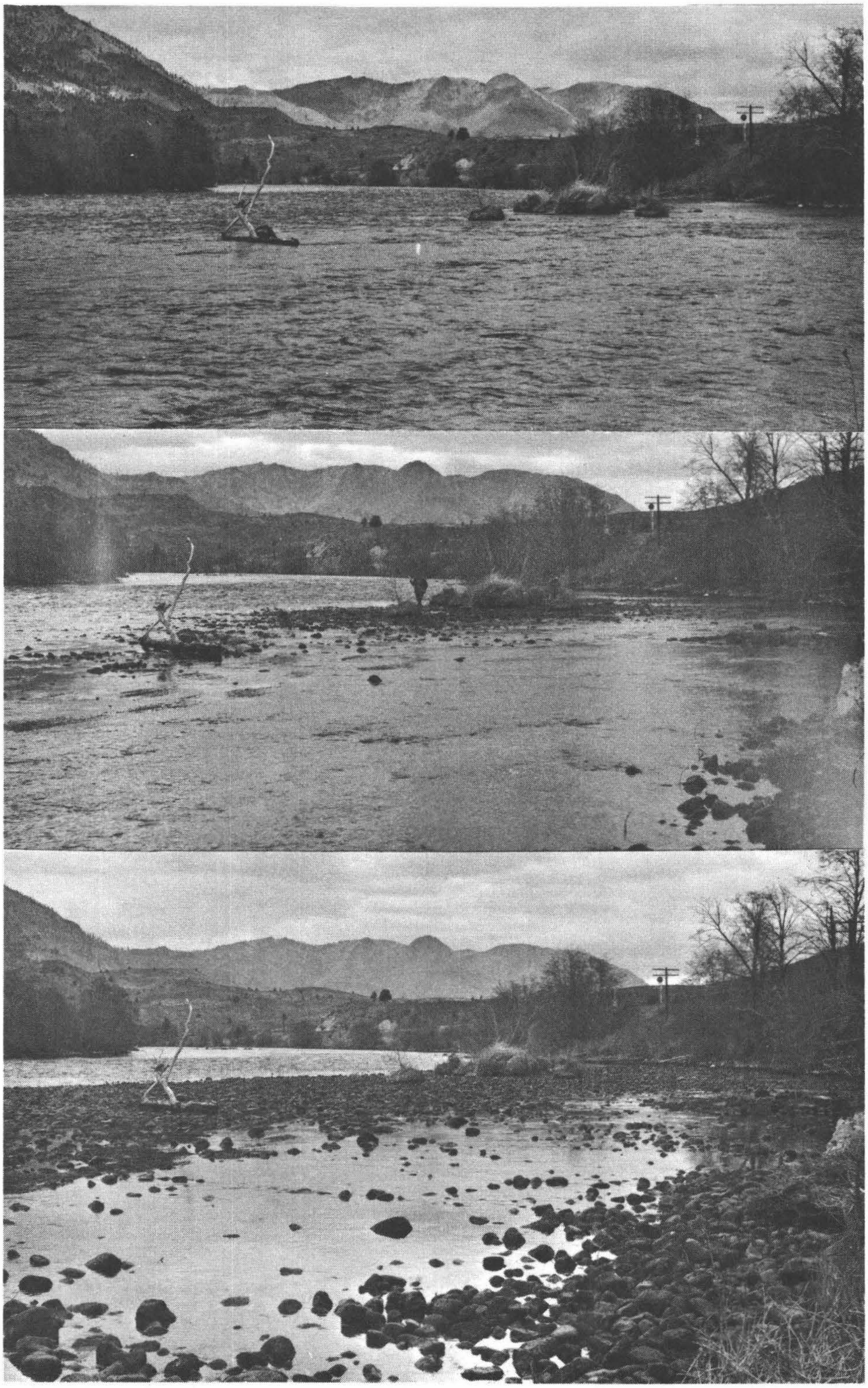

Fig. 19. Kaskela area showing gravel bar exposed at low (bottom), intermediate (middle), and pre-reduction (top) flows.

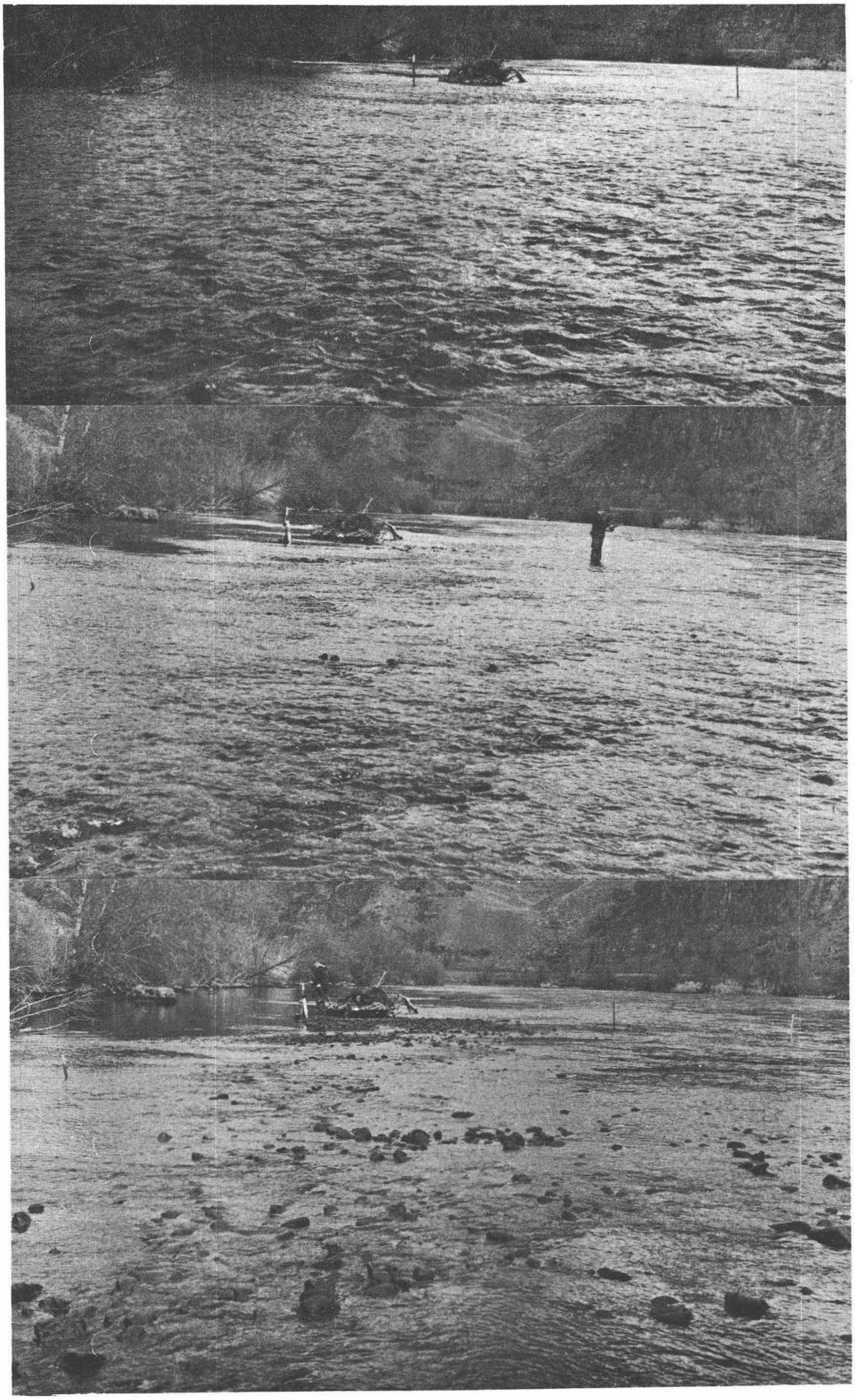

Fig. 20. Whiskey Dick study area showing water receding from normal level (top) to intermediate level (bottom). (Photos by Fortune)

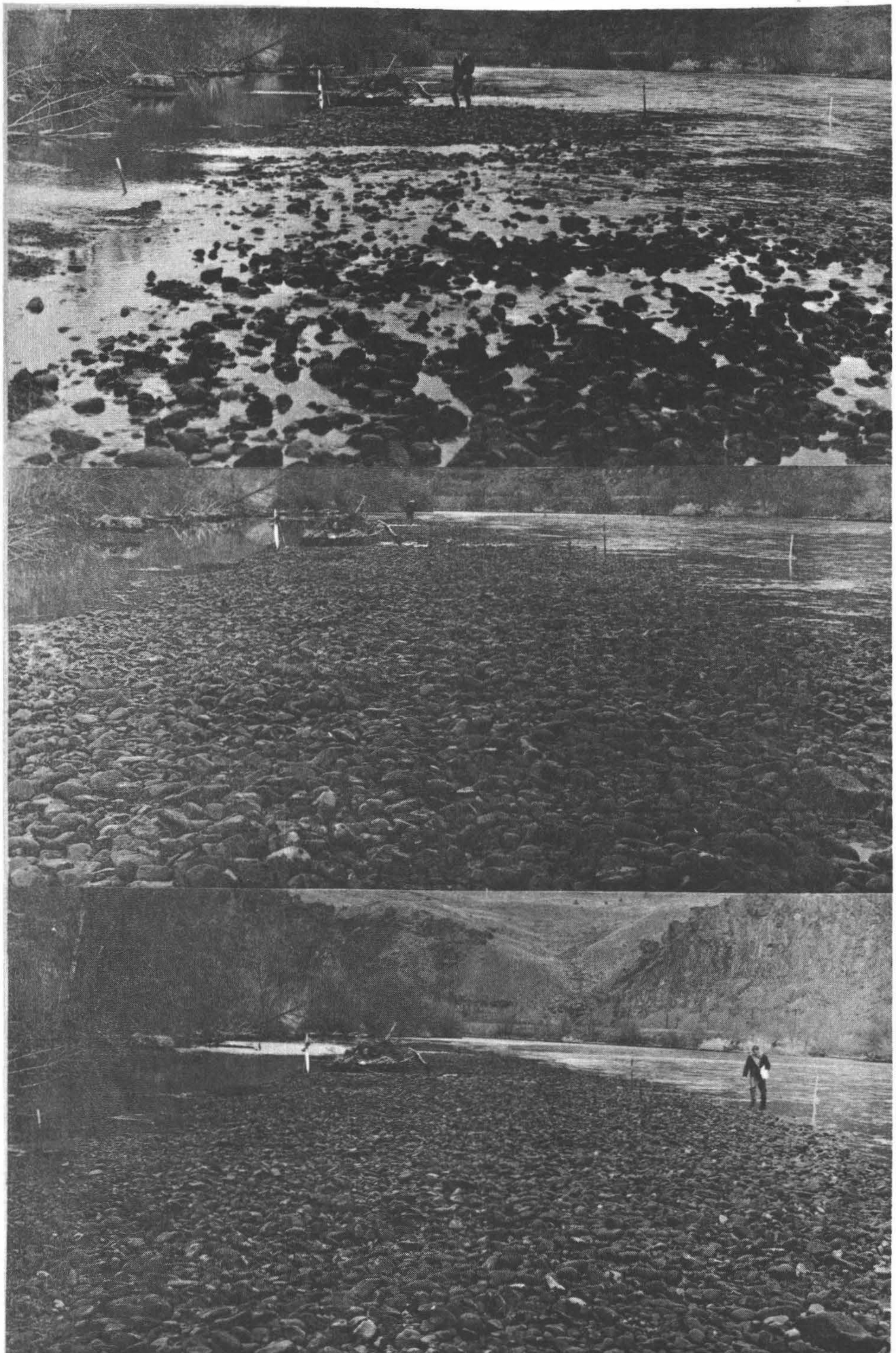

Fig. 20. (continued) Whiskey Dick study area showing water receding from intermediate level (top) to low level (bottom). (Photos by Fortune)

Maupin study area, river mile 47 to 66 (approximately)(Aney, Scherzinger, Pitney, and others)

Sample sections were surveyed along the east bank of the Deschutes River from Maupin to a point 15 miles south of Maupin (Table 3). All salmon and trout mortality was recorded in a given length of river bank (Fig. 21).

Table 3. Mortality of salmon and trout juveniles in sections of exposed stream bank in the Maupin area.

Length of sample	Number of dead trout and salmon
300 feet	7
200 "	1
300 "	14
200 "	1
200 "	0
300 "	5
200 "	0
300 "	8
2,000 feet total	36 total

For the section of river that was covered this would be a loss of 18 fish per 1,000 feet of river bank. No attempt was made to record other species such as sculpins (Fig. 22). It was noted, however, that the lamprey ammocoetes were heavily affected by the flow reduction. On one small mud bank it was estimated that 300 ammocoetes were stranded. Many aquatic insects were also stranded (Fig. 23).

Observations were made on dewatered areas for stranded fish. A large rocky area across from and above Oak Springs was checked closely, and large numbers of 2-inch chinook were trapped in pockets of the rocky bottom. At first little loss was expected as the pockets were holding water, however, the fish were observed darting about and ending up out of water or suffocating in the muck in the small rock pockets. A heavy loss was sustained.

Fig. 21. Dead chinook salmon fry stranded by reduction in flow, Maupin area. (Photo by Aney)

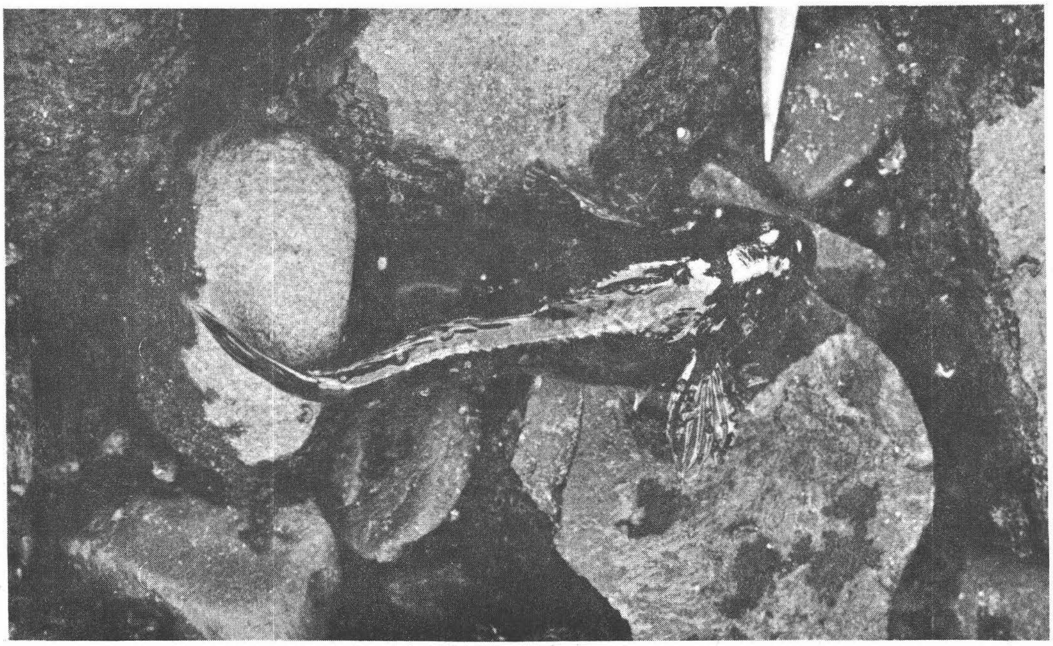

Fig. 22. Live sculpin stranded on gravel bar in area above Maupin. (Photo by Aney)

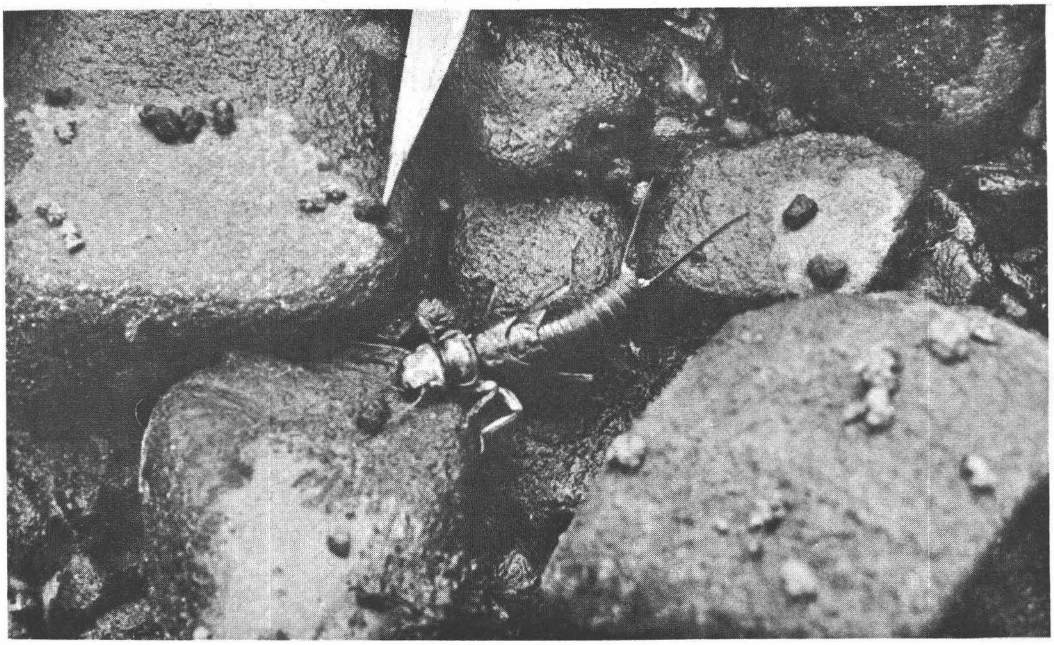

Fig. 23. Live stonefly nymph stranded by reduced flow in area above Maupin. (Photo by Aney)

Sherars Falls study area, river mile 44.0 (Rohweder, A. Miller, and others)

The staff gage was installed and the first reading taken at 1700 before the water began to recede (Fig. 2h). At 1730, the first drop in water level was noted. Periodic gage readings were obtained thereafter through the fall of water. The low was reached at 2006, 2½ hours after the fall was first detected. Total drop was 1.23 feet. Because of the late hour, we did not wait until the water level had resumed its former level, but left after it had begun to rise.

Hundreds of chinook salmon fry and rainbow or steelhead trout up to 4 inches long were stranded as water fell from bedrock areas in the vicinity of the falls. Many small dace were also caught. Primary area of stranding was adjacent to the west fishway (Fig. 24). Water was retained in the pools; thus mortality was low although 10 dead chinook were found on a rocky bar. If the reduction had occurred in daylight in the absence of humans, predators such as birds probably would have taken nearly all of those stranded. Large numbers of aquatic insects were exposed, but no estimate of mortality was made.

Flows in the east fishway were reduced but not to the point where fish passage would have been stopped. The notches on the weirs were nearly full although no water spilled across the weir itself. The west fishway ceased to function at the lower flows; however, water remained in the pools.

Fig. 24. Area on west side of Sherars Falls fishway where fish were stranded.

Moody Gage study area, river mile 1.4 to 5.0 (approximately) (Montgomery, Mathisen, Phillips, and others)

Because of a miscalculation in the rate of travel of the trough in the upstream section, we did not arrive at the area until 0600 on April 3, after the flow had reached its pre-reduction level (Fig. 2i). The shoreline was surveyed on foot in a number of locations as well as being scanned from the roadbed that runs adjacent to the stream in much of the area. We did not see any evidence of mortality; however, this does not mean there was none because predators and scavengers such as birds and crayfish would quickly erase any evidence.

We postulate that mortality was relatively low as compared to upstream areas because the amount of flow reduction was small, the low flow being 73% of the pre-reduction discharge (Table 2). The fall in water level was also low, dropping only 0.35 foot as measured at Moody Gage (Fig. 2i). Also, the changes occurred slowly over a period of 6 hours.

DISCUSSION

The flow below the regulating dam was reduced quickly as requested by the Game Commission. We asked that this be done knowing that some fish would be stranded but also realizing that the shorter the interval the less the damage to the aquatic resources. The primary problem that has to be considered in such an operation, of course, is the extent of water level reduction. Almost as important, is the amount of time that such a reduction takes if we are thinking in terms of a few hours. In the first case, a quick reduction in level would tend to strand more fish than a slow reduction. On the other hand, the more quickly the inspection could be done and the water level restored to its original height the less time predators would have to gather and prey on stranded fish and aquatic insects. Stranding of fish in the areas within a few miles of the dam might have been somewhat less if the flow had been reduced over, say, a 30-minute period instead of the abrupt drop. It would not have eliminated stranding, however, as evidenced from observations in the Maupin area and at Sherars Falls. In these areas, which are 34 to 53, and 56 miles, respectively, below the dam the water level fell over about a 3-hour period (Fig. 2h) yet there were still many fish stranded.

The characteristics of the trough varied markedly with distance below the project. When the curve at USGS cable crossing (Fig. 2a) is compared with the one for Sherars Falls (Fig. 2h), the difference in time of recession is readily apparent. At USGS cable crossing, the water level dropped to the low point in something less than the 30 minutes between the time readings were taken. From visual observations immediately below the regulating dam it appeared the low was reached in a matter of 5 or 10 minutes. At Sherars Falls, first reduction in level was noted at 1730 hours, but it was not until 2½ hours later that the bottom of the trough was reached.

The difference is even more striking when the situation at USGS cable crossing (Fig. 2a) is compared to that at Moody (Fig. 2i). Although the characteristics of the channel differ at the two points, thereby influencing the amount of drop in water level, it is believed to have no influence on duration of the recession. The important thing is that 4 hours were required from the time the leading edge of the trough was evident until the bottom was reached. The increased recession time is caused primarily by two factors. The first of these is channel storage, which is the water stored in the wider parts of a reach that acts as a series of small reservoirs. It usually has the greatest dampening effect. Second is bank storage, which is water actually retained in the bank that flows into the channel when the water level drops.

Continuing the examination of the curve at Moody (Fig. 2i), we can see that much less time, i.e., 2 hours was required for the water to rise from the bottom of the trough to its original level. This is the reverse of the situation that occurred at USGS cable crossing (Fig. 2a) where the period of rise was longer than the period of recession. The reason the situation is reversed at Moody is attributed to the gradual release of water from channel and bank storage during the recession compared to the shorter time of rise that is largely determined by the duration of increasing flow. There was virtually no channel or bank storage between the regulating dam and the USGS cable crossing (Fig. 1) as contrasted to that between the regulating dam and Moody.

The results section sets forth observations on stranding and mortality of fish and other aquatic organisms that give some indication of the damage that occurred. Unfortunately, the data are insufficient from which to project an estimate of the total loss. Even if we were capable of calculating the number stranded and lost along the bank and on the gravel bars, we would still fall short of the total mortality because of predation loss that probably occurred to those small fish that were forced to leave their home territories as the water level fell.

Many fish were killed as a result of stranding when the water level fell. This is especially true on flat gravel bars where water seeped through the interstices trapping the fish. Where the banks were steeper, fewer fish were stranded because they were able to retreat readily with the falling water. Rooted aquatic vegetation intensified the problem of trapping the fish.

Losses were highest among the small fish which have a tendency to seek the shallow areas to escape predation from large fish. The heaviest mortality occurred to newly-emerged chinook salmon fry. Mortality occurred throughout the river but was highest in the East and West Disney areas about 1 mile below the regulating dam. In these areas alone, several thousand were estimated to have died. There were also many rainbow and steelhead fingerlings lost in the same areas, and rainbow up to 8 inches in length were found dead on the exposed bars. Other fish killed by the flow reduction included large numbers of lamprey ammocoetes and sculpins, as well as smaller numbers of whitefish, dace, and suckers. Numerous aquatic insects including caddisflies, mayflies, and stoneflies were exposed when the water receded. Mortality on these forms was relatively low because of the short duration of the reduction and the cool atmospheric conditions. Some crayfish were stranded, but again mortality was low because of their ability to withstand periods of desiccation in the cool atmosphere, and because they were able to crawl across the bars to water.

CONCLUSIONS

1. The flow reduction to inspect the regulating dam stilling basin was destructive of fish life in the river below. This was evident from dead fish, including numerous salmon and trout juveniles, found on exposed gravel bars.
2. The fish were killed by desiccation from stranding on the gravel substrate and on rooted aquatic vegetation when the water level fell. There was probably a predation loss because of increased vulnerability of the small fish as they were forced from their individual territories; however, no attempt was made to measure this loss and consequently we have no data to show this actually occurred.
3. Species of fish found dead included (in approximate order of abundance): chinook salmon, steelhead and rainbow trout, sculpin, lamprey, dace, whitefish and suckers. Other aquatic organisms stranded included mayflies, stoneflies, caddisflies, and crayfish.
4. Mortality was greatest to chinook salmon and steelhead and rainbow trout of less than one year of age.
5. An estimate of total mortality was impossible from the data. In all probability, however, it must have amounted to many thousands for both chinook salmon fry, and steelhead and rainbow trout fingerlings.
6. If it is essential to have future flow reductions of this nature on the Deschutes River, I recommend:
   a. Higher flows be maintained below the regulating dam by discharging 600 cfs through both the right and left bank attraction-water gates. The right gate was only half open because it was feared the full 600

cfs might cause turbulence, thus interferring with the inspection. As it turned out, little turbulence occurred in the stilling basin adjacent to the left gate, and since hydraulic conditions are similar, there would probably be little on the right bank.

b. To insure better communications, all radio units should be checked out in a ½-day dress rehearsal immediately preceding the operation. Also, the helicopter should be equipped with a radio so biologists in it could communicate with the ground units.

c. Consideration should be given to making an estimate of total mortality. This would probably require statistical design of a sampling program from which to infer a total. It would also mean that a measure must be made of increased mortality from predation by larger fish when small fish are forced to leave their home territories by falling water.

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