EVALUATION OF THE EFFECTS OF DIFFERENT STREAMFLOW RELEASES ON TROUT HABITAT BELOW HYDROELECTRIC DIVERSION DAMS: TWO CASE STUDIES

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ABSTRACT:

Studies designed to evaluate the effects of different streamflow releases on trout habitat were conducted in the North Fork Feather River between Rock Creek Diversion Dam and Powerhouse and in Hat Creek between Hat Creek No. 2 Diversion Dam and Powerhouse. Physical habitat characteristics (depth, velocity, and substrate) were measured under select streamflow releases along transects at representative stations in each stream. Relative values of three important trout habitat parameters (resting microhabitat, food producing habitat, and spawning habitat) were calculated for each measuring point under each streamflow release through the use of weighting factors assigned to the measured habitat characteristics. The relationships between streamflow release and available resting microhabitat, food producing habitat, and spawning habitat for trout were derived and expressed quantitatively for each transect, station, and stream section. The resulting relationships, which showed considerable variation between stations and between habitat parameters, are discussed in relation to the Federal Energy Regulatory Commission licensing process for hydroelectric power projects.

INTRODUCTION

Most hydroelectric power projects in California involve the diversion of water from natural stream courses, resulting in reduced aquatic habitat downstream of such diversions. A typical hydroelectric project in the Pacific Gas and Electric Company (PG and E) system consists of the diversion of water from an on-stream reservoir formed behind a diversion dam, the conveyance of water by means of canal or tunnel and penstock to a powerhouse located downstream, and the return of water to the natural stream channel several miles below the point of diversion. As a consequence, streamflow in the section of stream between the diversion dam and powerhouse is generally less than the unimpaired natural flow; this condition can be particularly evident during the low-flow summer period. Such a reduction in flow not only reduces the amount of habitat historically available to fish and other aquatic organisms but also may change the habitat type to one that favors a different assemblage of species.

Hydroelectric projects are licensed by the Federal Energy Regulatory Commission (FERC), formerly the Federal Power Commission (FPC), for a period of up to 50 years and must be relicensed when the license term expires. As part of the licensing process, the impact of project operations on aquatic resources must be assessed, and appropriate mitigation measures must be developed. One of the most important aspects of this process is the determination of a streamflow release regime below the point of diversion that provides adequate habitat for a productive fishery, but at the same time is compatible with economical power production. To provide the basis for determining adequate streamflow releases for fish life, PG and E, in cooperation with various conservation agencies, evaluates the effects of different streamflow releases on trout habitat. Following analysis of study results, PG and E and conservation agencies meet in a series of discussion and negotiation sessions to form a fisheries agreement, which includes mutally agreeable streamflow release regimes below project diversions.

The purpose of this paper is to present the results of two different trout habitat-streamflow evaluation studies and to discuss the results of each in relation to the licensing process. The studies were conducted in the North Fork Feather River between Rock Creek Diversion Dam and Powerhouse (Rock Creek-Cresta Project; FERC (1962) and in Hat Creek between Hat Creek No. 2 Diversion Dam and Powerhouse (Hat Creek 1 and 2 Project; FERC 2661).

METHODS

The methodology used in the trout habitat-streamflow evaluation studies was developed and described by Waters (1976). This method employs weighted depth, velocity, and substrate criteria to evaluate trout resting microhabitat, food producing habitat, and spawning habitat under selected streamflow releases. The following paragraphs provide a general description of this methodology as applied in each case study.

Cooperating study participants made an initial survey of the study area to form the details of the study plan. Participants agreed on the locations of sampling stations, the number of transects per station and their locations, the distance between measuring points along each transect, and the release flows to be studied. Station locations were selected to be representative of the riffle-run areas in the stream sections under study. Pool areas were avoided because significant ecological changes are not likely to occur in pools with changes in flow except at exceptionally high flows.

Field data collection involved the measurement of physical habitat characteristics (depth, velocity, and substrate) at preselected points along each transect. Depth and velocity (0.2 foot above the substrate) were measured at each point under each streamflow release; substrate type was determined at each point only under the lowest flow release.

Through computer analysis, the measured physical habitat characteristics were related to three important trout habitat parameters (resting microhabitat, food producing habitat, and spawning habitat). A weighting factor between 0 and 1.0 was assigned to each individual velocity, depth, and substrate value for each habitat parameter. The determination of weighting factors was based on a review of the literature relating the physical habitat characteristics to the trout habitat parameters. The weighting factors assigned to each physical habitat characteristic at each measuring point under each streamflow release were multiplied together, yielding a single composite relative value between 0 and 1.0. Relative units for each habitat parameter under each streamflow were totaled for each transect, station, and series of stations within a single stream section. Mean relative units and 90 percent confidence limits were calculated for each of the totals.

The final product of the computer analysis was a series of tables and a graphical representation of mean relative units of each habitat parameter versus streamflow release for each station and stream section. Included with mean relative units on the Y-axis of each plot were scales showing the equivalent number of optimum quality square feet and square meters of a particular habitat parameter in the entire stream section under study. These values were calculated by multiplying mean relative units by actual streambed area at the highest streamflow release studied. These calculations allow the comparison of habitat values between streams and between sections in the same stream.

CASE STUDY 1:
ROCK CREEK-CRESTA PROJECT (FERC 1962)

The Rock Creek-Cresta Project, completed in 1950, consists of two hydroelectric power units on the North Fork Feather River in Plumas and Butte Counties (Figure 1). The project was licensed by the FPC in 1947 for a period of 35 years; minimum flow releases below project dams were established in 1950 by amendment to the project license. In an effort to meet the 1982 license expiration date, PG and E has already initiated the relicensing process.

Prior to power development, a productive trout fishery reportedly existed in the Rock Creek and Cresta sections of the North Fork Feather River. However, under project

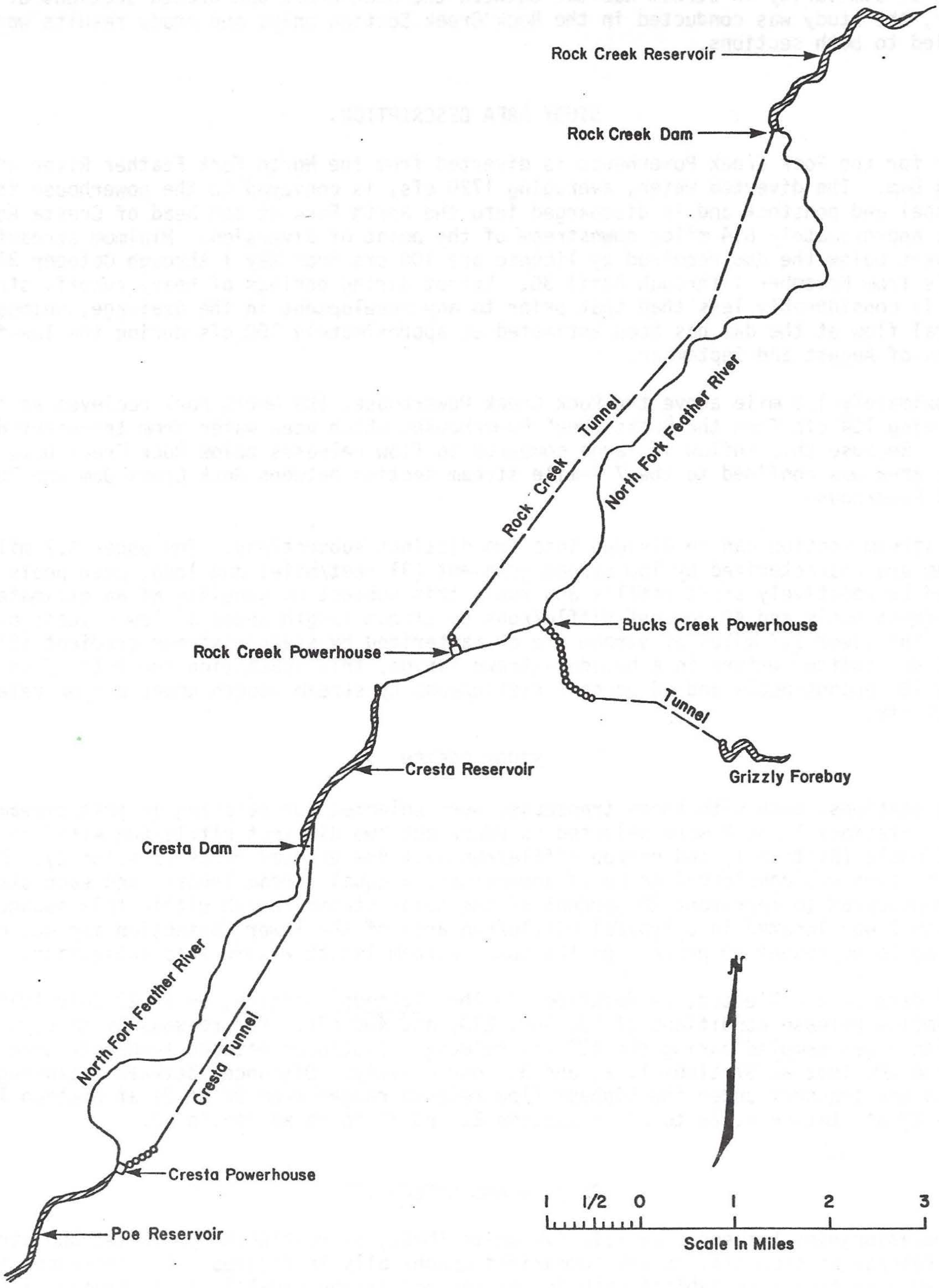

Figure 1 - Rock Creek-Cresta Hydroelectric Project.

operation, nongame fish populations have predominated despite chemical treatment and trout planting operations by the California Department of Fish and Game (CDF&G). Thus, as part of the relicensing process, a trout habitat-streamflow evaluation study was deemed necessary to determine if increased streamflow releases could improve the trout fishery. Because of similarity in stream habitat between the Rock Creek and Cresta sections of the river, the study was conducted in the Rock Creek Section only, and study results were applied to both sections.

STUDY AREA DESCRIPTION

Water for the Rock Creek Powerhouse is diverted from the North Fork Feather River at Rock Creek Dam. The diverted water, averaging 1720 cfs, is conveyed to the powerhouse through a tunnel and penstock and is discharged into the North Fork at the head of Cresta Reservoir, approximately 8.4 miles downstream of the point of diversion. Minimum streamflow releases below the dam required by license are 100 cfs from May 1 through October 31 and 50 cfs from November 1 through April 30. Except during periods of heavy runoff, streamflow is considerably less than that prior to any development in the drainage; unimpaired natural flow at the dam has been estimated at approximately 700 cfs during the low-flow months of August and September.

Approximately 1.0 mile above the Rock Creek Powerhouse, the North Fork recieves an inflow averaging 154 cfs from the Bucks Creek Powerhouse, which uses water from tributary drainages. Because this inflow is large compared to flow releases below Rock Creek Dam, the study area was confined to the 7.4-mile stream section between Rock Creek Dam and Bucks Creek Powerhouse.

This stream section can be divided into two distinct subsections. The upper 4.7 miles of stream are characterized by low stream gradient (31 feet/mile) and long, deep pools connected by relatively short riffles and runs; this subsection sonsists of an estimated 60 percent pools and 40 percent riffle/runs by stream length under a flow release of 100 cfs. The lower 2.7 miles of stream are characterized by steeper stream gradient (81 feet/mile) and swifter waters in a boulder-strewn canyon; this subsection consists of an estimated 10 percent pools and 90 percent riffle/runs by stream length under a flow release of 100 cfs.

STUDY DESIGN

Three stations, each with three transects, were selected for sampling in this stream section. Stations 1 and 2 were selected to represent two distinct riffle/run with many exposed rocks (Station 1) and narrow riffle/run with few exposed rocks (Station 2). Each habitat type was considered to be of approximately equal stream length, and each station was considered to represent 20 percent of the total stream length within this subsection. Station 3 was located in a typical riffle/run area of the lower subsection and was considered to represent 90 percent of the total stream length within this subsection.

Field data were collected, as described in the "Methods" section, on 24-27 July 1978 under streamflow release conditions of 50, 100, 213, and 400 cfs. For reasons of safety, only Station 1 was sampled during the 400 cfs release. Distances between transects were 50, 75, and 200 feet at Stations 1, 2, and 3, respectively. Distances between measuring points per transect under the highest flow release ranged from 26 to 27 at Station 1, 26 to 27 at Station 1, 26 to 30 at Station 2, and 31 to 34 at Station 3.

RESULTS AND DISCUSSION

The relationships between mean relative units (MRUs) of resting microhabitat and streamflow release at each station are summarized graphically in Figures 2-4. Increases in available resting microhabitat with increasing streamflow (50-213 cfs at Station 1, 50-100 cfs at Station 2, and 50-100 cfs at Station 3) can be attributed to higher velocities at the higher flows.

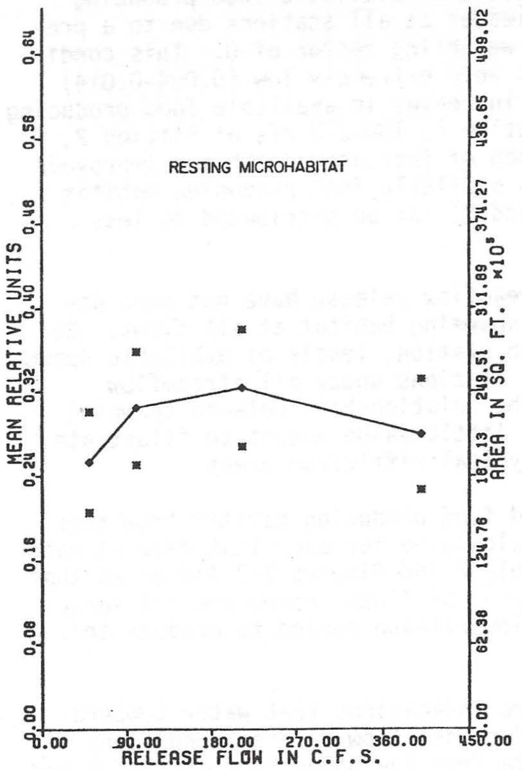

Figure 2. Relationship between mean relative units of resting microhabitat and streamflow release for Station I in the North Fork Feather River.

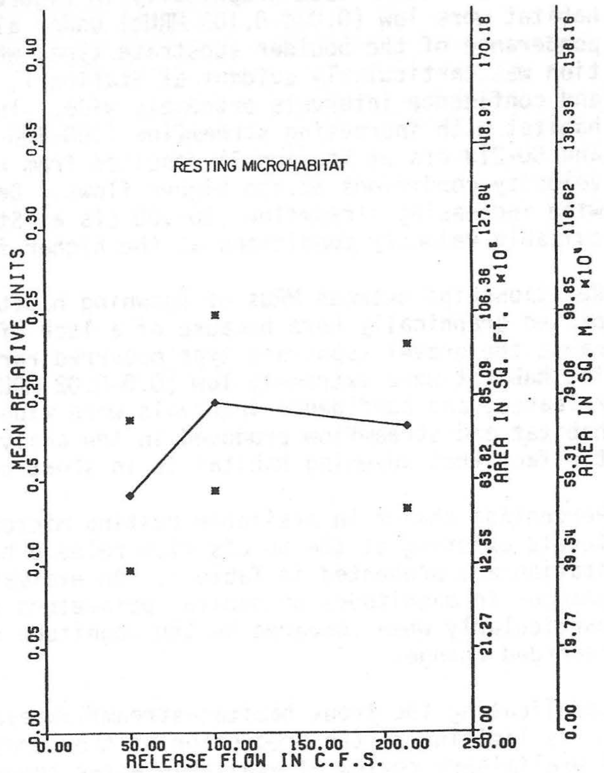

Figure 3. Relationship between mean relative units of resting microhabitat and streamflow release for Station 2 in the North Fork Feather River.

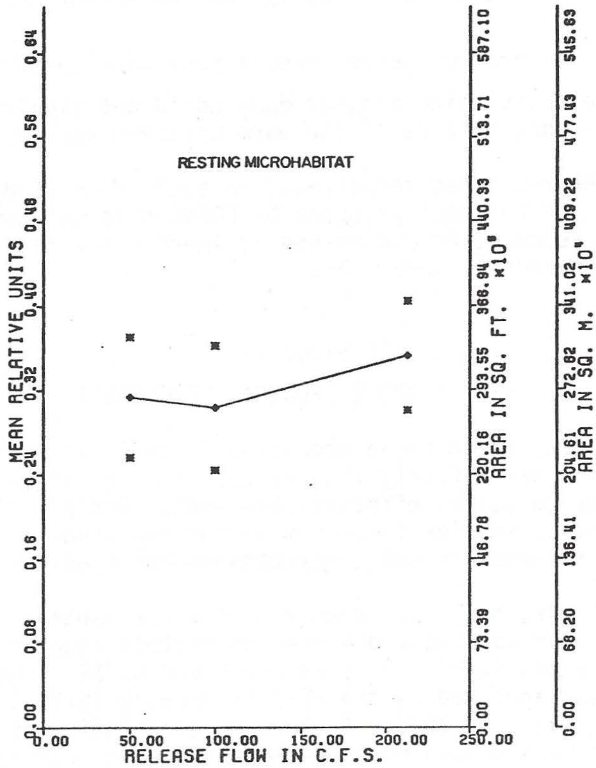

Figure 4. Relationship between mean relative units of resting microhabitat and streamflow release for Station 3 in the North Fork Feather River.

The relationships between MRUs of food producing habitat and streamflow release at each station are summarized graphically in Figures 5-7. Levels of available food producing habitat were low (0.004-0.103 MRUs) under all flow releases at all stations due to a preponderance of the boulder substrate type, which has a weighting factor of 0. This condition was particularly evident at Station 1, where MRUs were extremely low (0.004-0.014) and confidence intervals extremely wide. In general, increases in available food producing habitat with increasing streamflow (100-400 cfs at Station 1, 100-213 cfs at Station 2, and 50-213 cfs at Station 3) resulted from a combination of increased depth and improved velocity conditions at the higher flows. Decreases in available food producing habitat with increasing streamflow (50-100 cfs at Stations 1 and 2) can be attributed to less suitable velocity conditions at the higher flows.

Relationships between MRUs of spawning habitat and streamflow release have not been depicted graphically here because of a lack of suitable spawning habitat at all flows. Because the gravel substrate type occurred rarely at each station, levels of available spawning habitat were extremely low (0.0-0.02 MRUs) for all stations under all streamflow releases, and confidence intervals were wide. Thus, the relationships between spawning habitat and streamflow produced in the analysis are of little value except to illustrate the fact that spawning habitat is in short supply in typical riffle/run areas.

Percentage change in available resting microhabitat and food producing habitat from those levels existing at the 50 cfs flow release have been calculated for each test flow at each station and presented in Table 1. An evaluation of Table 1 and Figures 2-7 indicates that changes in magnitudes of habitat parameters over the range of flows tested are not large, particularly when compared to the magnitude of streamflow release needed to produce the recorded changes.

Complicating the trout habitat-streamflow evaluation are indications that water temperatures limiting to the production of trout may exist under most flow release conditions. A preliminary review of available water temperature data from the upper North Fork Feather River (Unpublished data, PG&E Co.) indicates that:

1. Under current project releases, daily minimum temperatures exceed 20.0°C during much of the midsummer period and may occasionally exceed 22.5°C in the Rock Creek and Cresta sections of the river. Daily maximum temperatures reach as high as 23.5°C.
2. Warm temperatures in project waters result from warm upstream sources.
3. Increased flow releases below project dams would not significantly alter current temperature conditions because of the warm upstream sources.

Based on the results of the trout habitat-streamflow evaluation study and a review of the water temperature problem, it has been proposed by CDF&G that management techniques other than increased streamflow releases be considered to improve the fishery. Discussions concerning this proposal are currently under way.

CASE STUDY 2:
HAT CREEK 1 AND 2 PROJECT (FERC 2661)

The Hat Creek 1 and 2 Project, which began operation in 1921, consists of two hydroelectric power units on Hat Creek in Shasta County (Figure 8). The FPC issued a license for the project in October 1975 for 35 years, effective May 1965. Article 32 of that license required that PG and E conduct studies to determine the magnitude of fishery resources and the need for minimum flow releases in Hat Creek between Hat Creek No. 2 Dam and Powerhouse.

In fulfillment of this article, fishery inventory and trout habitat-streamflow evaluation studies were conducted, and an agreement designed to protect aquatic habitat and resources in the general project area was developed by PG and E and CDF&G. The agreement was completed in April 1978 and was approved by the FERC in Janaury 1979; all items of the agreement will be implemented by January 1980. A thorough description of these studies and a copy of the agreement have been presented by Kubicek and Adams (1978). The final sections of this paper will present the most important aspects of the trout habitat-streamflow evaluation study, leading to the agreement.

TABLE 1. Percentage change in available resting microhabitat and food producing habitat from those levels existing at a 50 cfs flow release, calculated for each test flow at each station in the Rock Creek section of the North Fork Feather River.

	Percentage Change in Resting Microhabitat from Level Existing at 50 cfs			Percentage Change in Food Producing Habitat from Level Existing at 50 cfs		
Station	100 cfs	213 cfs	400 cfs	100 cfs	213 cfs	400 cfs
1	20	28	10	-62	-13	51
2	39	28	-	-12	19	-
3	-3	13	-	32	59	-

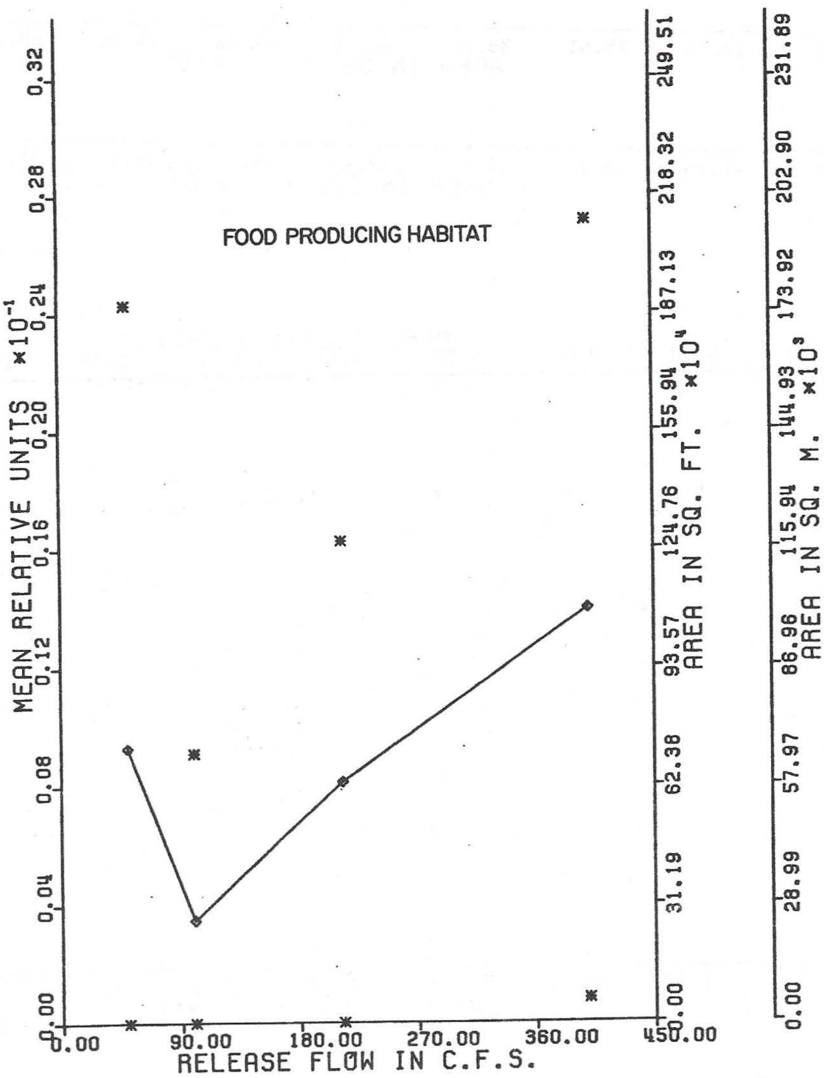

Figure 5. Relationship between mean relative units of food producing habitat and streamflow release for Station I in the North Fork Feather River.

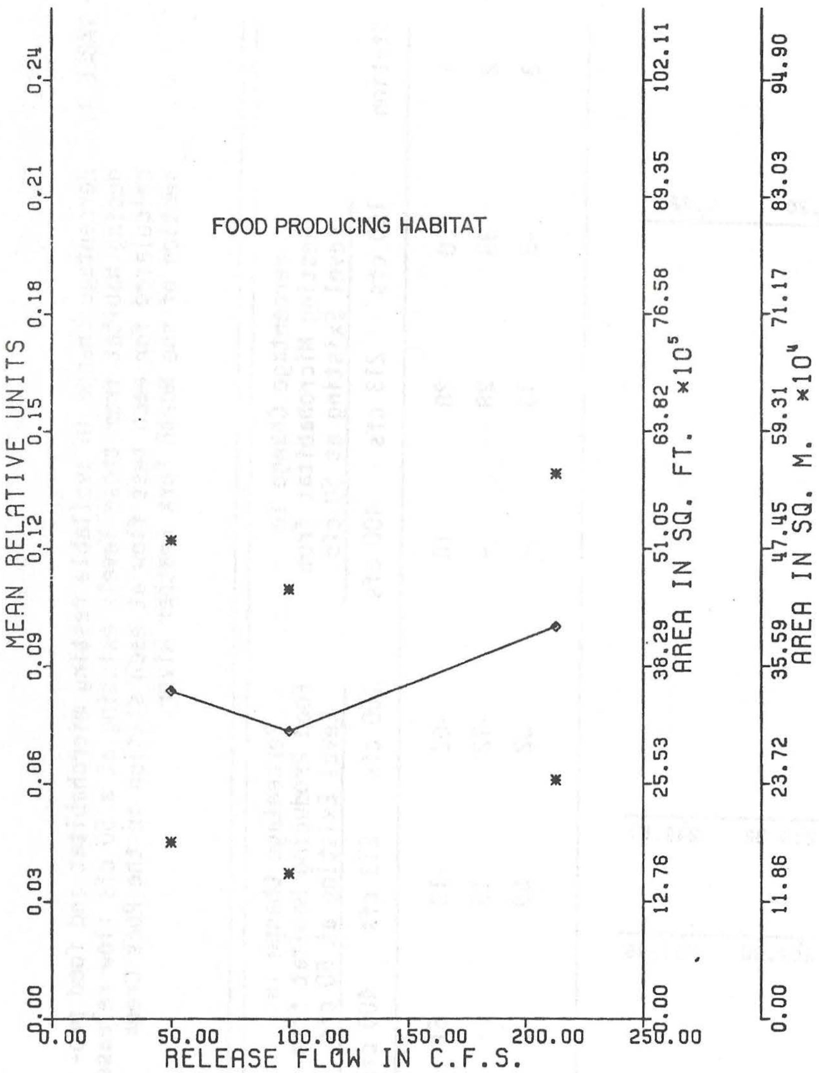

Figure 6. Relationship between mean relative units of food producing habitat and streamflow release for Station 2 in the North Fork Feather River.

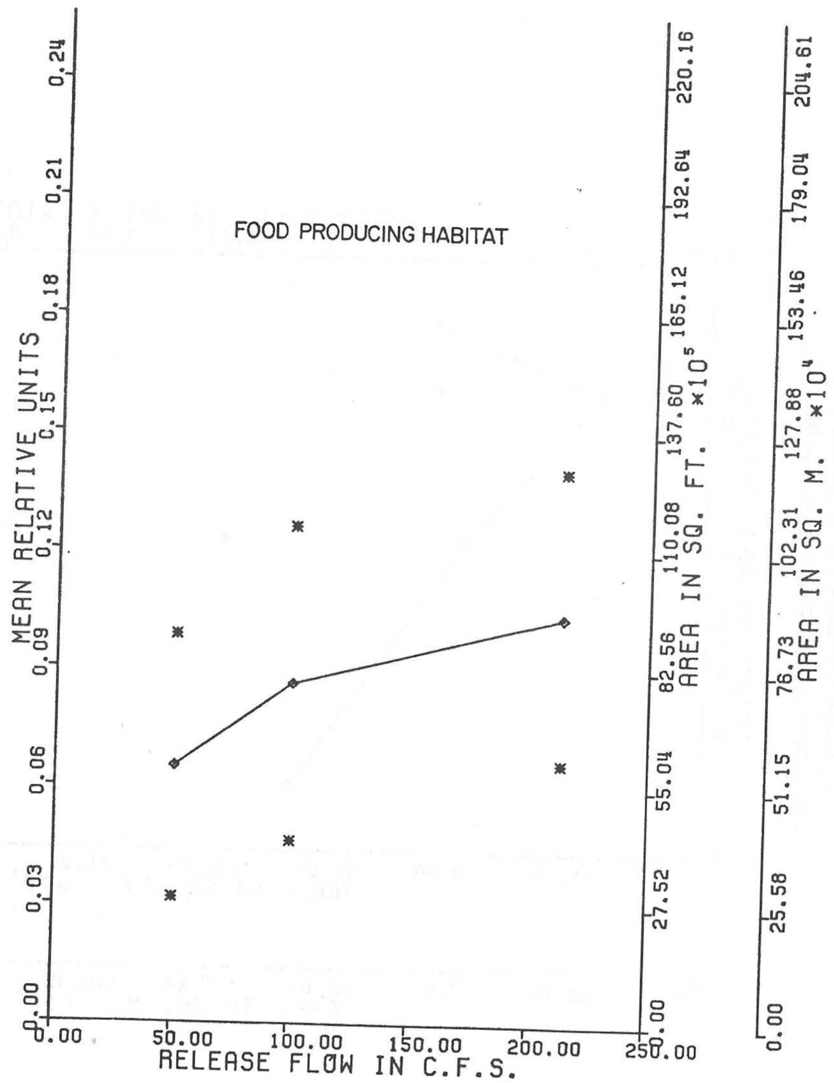

Figure 7. Relationship between mean relative units of food producing habitat and streamflow release for Station 3 in the North Fork Feather River.

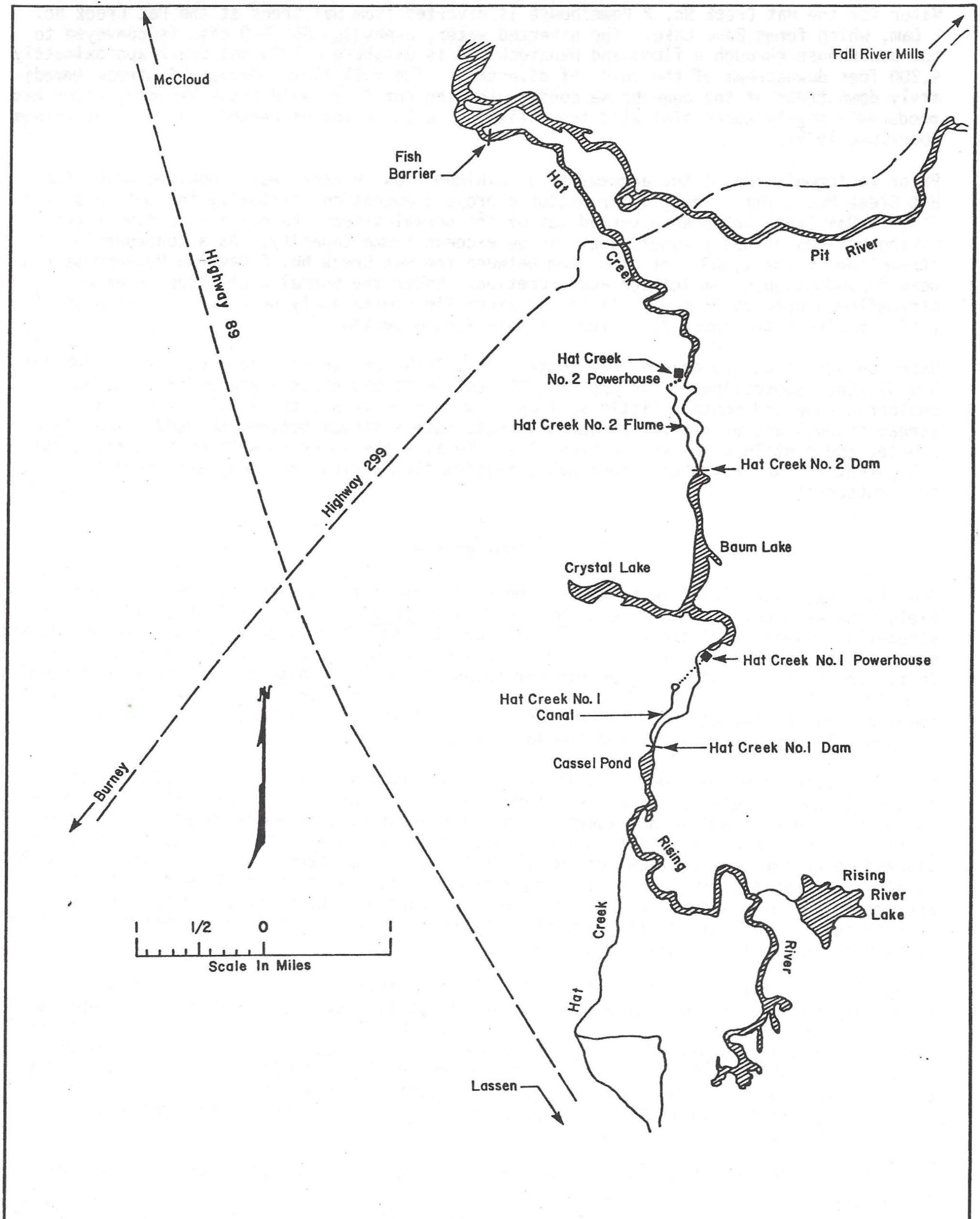

Figure 8– Hat Creek 1 and 2 Hydroelectric Project.

STUDY AREA DESCRIPTION

Water for the Hat Creek No. 2 Powerhouse is diverted from Hat Creek at the Hat Creek No. 2 Dam, which forms Baum Lake. The diverted water, averaging 500-600 cfs, is conveyed to the powerhouse through a flume and penstock and is discharged into Hat Creek approximately 4,200 feet downstream of the point of diversion. The full-flown section of stream immediately downstream of the powerhouse constitutes the Hat Creek Wild Trout Project, which has produced a highly successful wild trout fishery in 3.3 miles of rehabilitated tro-t stream (Gerstung 1975).

Prior to formulation of the agreement, no minimum flow releases were required below the Hat Creek No. 2 Dam. Thus, under historic project operation, virtually the entire streamflow of Hat Creek has been diverted out of the normal stream channel a this dam, except during periods of heavy runoff when inflow exceeds flume capacity. As a consequence, streamflow in the 4,200 feet of stream between the Hat Creek No. 2 Dam and Powerhouse has been dependent upon dam leakage and accretion. Under the normal 0 cfs flow release, streamflow increases from a small intermittent flow immediately below the dam to approximately 6 cfs in the lower 2,700 feet of this stream section.

Based on steamflow and channel characteristics, this section of stream can be divided into two distinct subsections. The upper 1,500 feet of stream channel are precipitous and boulder-strewn and contain little surface flow. In contrast, the lower 2,700 feet of stream channel are of flatter stream gradient, have a stream bottom composed primarily of rubble, and contain a greater surface flow. Because the lower subsection held the greatest potential for trout, the trout habitat-streamflow evaluation study was confined to this subsection.

STUDY DESIGN

Two stations, each with five transects, were selected for study in the lower subsection. Field data were collected, as described in the "Methods" section, on 8-10 June 1976 under streamflow release conditions of 5, 15, 30, and 52 cfs. The distance between transects at each station was 25 feet; the distance between measuring points on each transect was 2 feet. The number of measuring points per transect under the highest flow release ranged from 20 to 24 at Station 1 and 15 to 17 at Station 2. Results from the two stations were combined and considered to represent 100 percent of the lower subsection because of the uniform nature of the habitat and the lack of major pool areas.

Data resulting from the trout habitat-streamflow evaluation study were combined with fishery inventory data collected in October 1976 under the normal 0 cfs release to estimate the population of trout to be expected under different streamflow releases. Through subjective evaluation of the existing stream habitat, resting microhabitat was generally considered to be the most critical of the three habitat parameters under study. Assuming that resting microhabitat is the key limiting factor, it follows that as streamflow releases are increased there should be a one-to-one relationship between the percentage increase in resting microhabitat and the percentage increase in trout population numbers above that level existing at the normal 0 cfs release.

Using the MRUs of resting microhabitat for the two stations combined, the percentage increase in resting microhabitat above that level existing at the normal 0 cfs release was calculated for several selected flow releases (5, 12, 15, 30, 50 and 52 cfs). For those flows not actually evaluated during the streamflow study (0, 15, and 50 cfs), MRUs of resting microhabitat were calculated by linear regression methods. Based on the results of the study and for the purposes of these calculations, it was assumed that a linear relationship existed for MRUs of resting microhabitat versus streamflow between 0 and 12 cfs, 12 and 30 cfs, and 30 and 52 cfs.

Population estimates of each trout species in the lower subsection of stream were then calculated for selected flow releases by the following formula:

$$N_a = (N_o)(I_a) + N_o,$$

where N_a is the population estimate of a species in the lower subsection (i.e., 2,700 feet of stream) for the increased flow release (a), N_o is the population estimate of the same species in the lower subsection for the 0 cfs release (as calculated by Kubicek and Adams 1978), and I_a is the appropriate percentage increase in resting microhabitat for the increased flow.

At flow releases greater than 0 cfs, the upper subsection (i.e., 1,500 feet of stream) becomse viable trout habitat as well. Thus, the population estimates calculated above were expanded to make population estimates for the total length of viable habitat (i.e., 4,200 feet) by the following formula:

$$N_t = \frac{4200}{2700} N_a,$$

where N_t is the total population estimate of a species in the entire stream section and N_a is the population estimate of the same species in the lower subsection.

RESULTS AND DISCUSSICN

Relationships between trout habitat parameters (resting microhabitat, food producing habitat, and spawning habitat) and streamflow release for both stations combined are summarized graphically in figures 9-11. Levels of all parameters increased with streamflow throughout the range of flows tested in response to increased wetted area, increased depth, and improved velocity conditions at the higher flow releases. Because the gravel substrate type occurred rarely, levels of available spawning habitat were low (0.006-0.040 MRUs) under all streamflow releases, and confidence intervals were wide.

Percentage increases in available resting microhabitat above that level existing at the normal 0 cfs release, calculated for several selected streamflow releases, are presented in Table 2. Based on these data, population estimates of trout under the selected flow conditions are presented in Table 3.

The largest increase in population size per cfs increase is expected to occur between 0 and 5 cfs, as a result of the initial increase in the length of viable trout habitat occurring at streamflow releases greater than 0 cfs. At the normal 0 cfs flow release, the upper subsection has an intermittent flow, and trout habitat is virtually nonexistent. However, at a 5 cfs flow release, the upper subsection flows continuously, providing an additional 1,500 feet of viable habitat. A subjective visual comparison of the subsections indicated that the upper subsection probably does not provide as good a habitat for trout as the lower subsection at each flow release. Thus, population estimates for flows greater than 0 cfs, which were based on general equivalence of habitat between the subsections, are probably slight overestimates. Nevertheless, these estimates provide for reasonable comparisons of population sizes to be expected at selected releases.

Through a series of discussion and negotiation sessions, PG and E and CDF&G agreed that fishery benefits resulting from increased streamflows in Hat Creek between Hat Creek No. 2 Dam and Powerhouse were small, particularly when compared to costs resulting from lost power production. Fishery benefits resulting from increased streamflows were minimized because of the short length of stream involved (4,200 feet), the precipitous nature of the upper subsection, and the close proximity of this stream section to the highly productive Wild Trout Section of Hat Creek. Therefore, PG and E and CDF&G also explored other measures that would improve aquatic habitat in the general area of the Hat Creek 1 and 2 Project. Those measures recommended by Gerstung (1975) as aprt of a Hat Creek management plan were used as a basis in developing a fisheries agreement.

The agreement consisted of the following items:

1. Minimum stream flow releases of 8 cfs below Hat Creek No. 2 Dam and 2 cfs below Hat Creek No. 1 Dam will be maintained to provide additional aquatic habitat and to prevent the standing of trout, which occurs following spills from these dams.
2. The rate of change in spill release from Hat Creek No. 2 Dam will be reduced to prevent damage to aquatic organisms and to reduce the potential for stranding of trout.

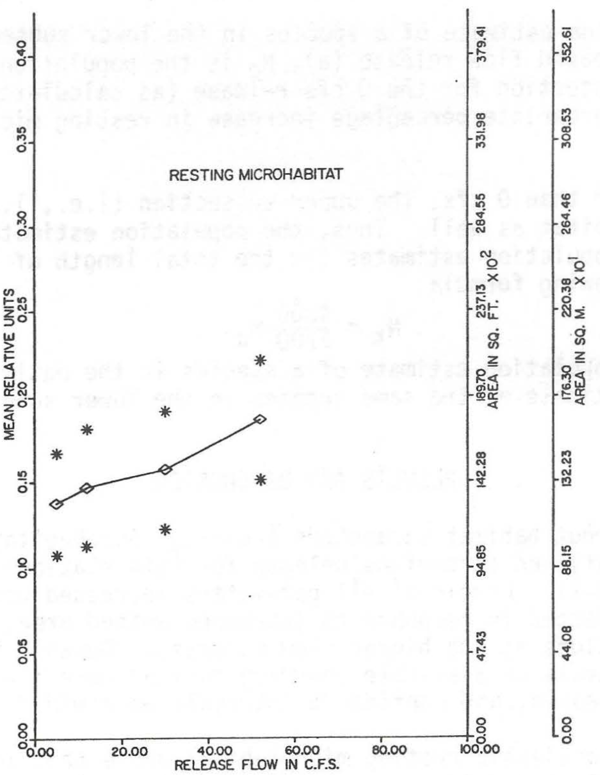

Figure 9. Relationship between mean relative units of resting microhabitat and streamflow release for the combined Hat Creek Stations.

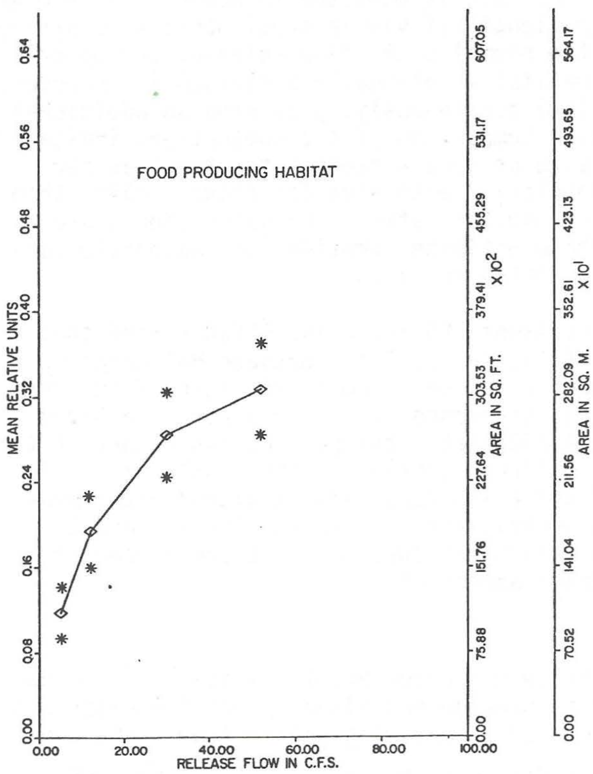

Figure 10. Relationship between mean relative units of food producing habitat and streamflow release for the combined Hat Creek Stations.

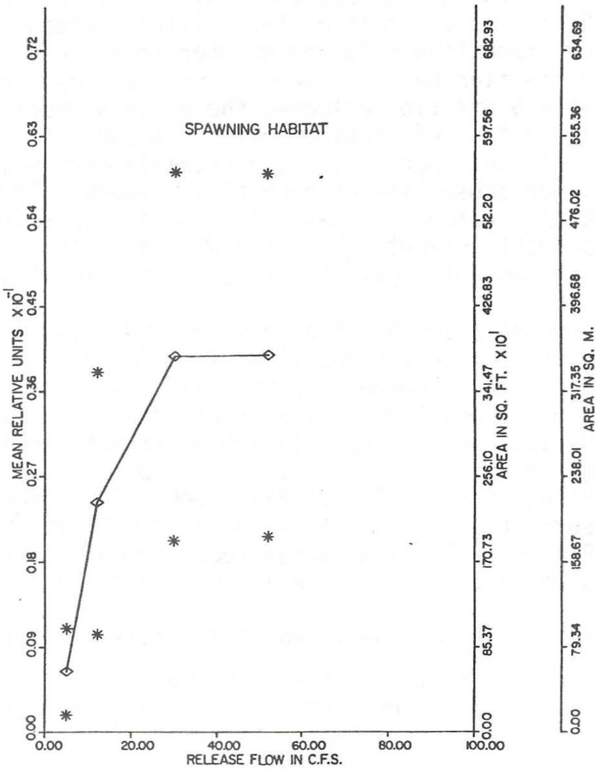

Figure 11. Relationship between mean relative units of spawning habitat and streamflow release for the combined Hat Creek Stations.

3. Cattle will be excluded from the Wild Trout Section of Hat Creek between Hat Creek No. 2 Powerhouse and the Highway 299 bridge to prevent damage to stream banks and riparian habitat.

4. Vehicular traffic along the Wild Trout Section of Hat Creek between Hat Creek No. 2 Powerhouse and Highway 299 will be restricted to reduce erosion potential, prevent soil compaction, reduce noise levels, and improve the esthetic quality of the area.

5. Fluctuations in the surface elevation of Baum Lake will be minimized to upgrade the littoral habitat and to improve fisherman access.

The full text of the agreement has been presented by Kubicek and Adams (1978).

TABLE 2. Percentage increase in mean relative units of resting microhabitat above that level existing at the normal 0 cfs flow release, calculated for selected streamflow release conditions in Hat Creek.

Release (cfs)	Mean Relative Units of Resting Microhabitat	Increase in Units Above that Level Existing at 0 cfs	Percentage Increase
0	0.1311	-	-
5	0.1378	0.0067	5
12	0.1472	0.0161	12
15	0.1489	0.0178	14
30	0.1573	0.0262	20
50	0.1838	0.0527	40
52	0.1865	0.0554	42

TABLE 3. Numbers of trout expected to inhabit Hat Creek between Hat Creek No. 2 Dam and Powerhouse under selected streamflow releases.

	Streamflow Release Below Hat Creek No. 2 Dam						
	0	5	12	15	30	50	52
Rainbow Trout (*Salmo gairdneri*)	284	464	495	504	530	618	627
Brown trout (*Salmo trutta*)	22	36	38	39	41	48	49
Total Trout	306	500	533	543	571	666	676

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