PCWA-L-186

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1. INTRODUCTION

1.1 PURPOSE

This exhibit describes the distribution and abundance of fish resources in the South Fork Rubicon River and develops a basis for determining the minimum flow requirements of fish species using the South Fork Rubicon River. Federal and State fish and wildlife agencies were consulted throughout the development of studies incorporated into this exhibit.

1.2 DESCRIPTION OF STUDY REGION

The section of the South Fork Rubicon River studied (Figure S-1) extends approximately 6.4 miles downstream from the proposed diversion site (6,440 ft) on the South Fork Rubicon River to Robbs Forebay (5,290 ft). At present, flow is not regulated or diverted. Several falls and cascades, occurring in exposed bedrock areas and large enough to prevent upstream migration by fish, have been identified in the upper half of the study section. Vegetation bordering the river is predominantly coniferous forest, although alder growth is heavy in some areas. Stream banks are generally rocky or sandy; however, undercut banks which provide cover for fish are sporadically found throughout the section. The 6.4 miles of stream were divided into three segments, shown as Area 01, Area 02, and Area 03 on Figure S-1.

The South Fork Rubicon River discharge is largely a function of snowmelt runoff. Runoff is characterized by high spring (April to June) discharges (50-275 cfs), low summer and fall (July to November) discharges (0.4-30 cfs) and periodically high winter (December to March) discharges (8-115 cfs). Historical records (1910-1914) for a gauge (#4,290) located within 1 km of the downstream end of the project area recorded a maximum daily discharge of 709 cfs on 31 December 1913 and a minimum daily discharge of 0 cfs during 1-13 September 1910 and 26-31 August 1912 (USGS 1924).

Three areas of the South Fork Rubicon River between the proposed diversion and Robbs Forebay were studied. The upper segment, Area 01, is approximately 1.2 miles long, has a low-to-moderate gradient (104 ft/mile), and is separated from the middle segment, Area 02, by a very steep, rocky cascading fall that prevents fish movement between the segments. The 820-ft reach of Area 01 chosen as the representative study site (Reach 05) is at approximately 6,310 ft elevation and contains many pools and rocky runs; riffles were less frequent and longer than the pools and runs. Larger pools and runs were studded with boulders and large cobble which provided good cover for juvenile and adult trout. The shallower riffles had less instream cover, with gravel and small cobble being dominant. Detritus, silt, and sands accumulated in the deepest pools, and decomposed granite was found in the gravel riffles. Tall conifers provided shade on the stream except during the middle of the day (1100-1700 hours). Less than 15 percent of the stream has significant bankside canopy. Area 01 is immediately downstream of the proposed diversion site.

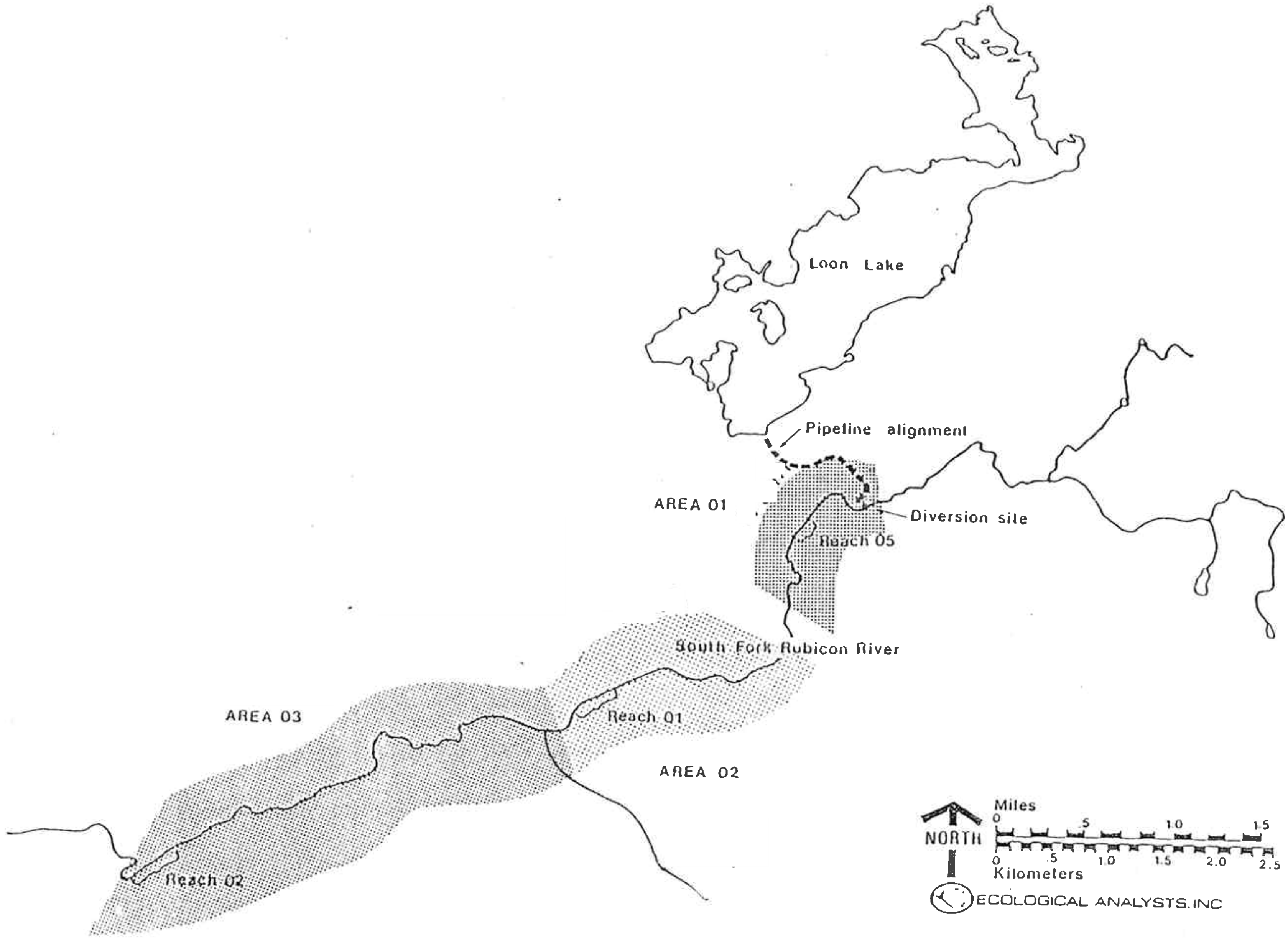

Figure S-1 Study areas and reaches of the South Fork Rubicon River referred to in this report.

The middle segment, Area 02, is approximately 1.6 miles long, beginning just below the cascading falls and ending just upstream of Poison Hole Creek. This segment has a steeper gradient (175 ft/mile), particularly in the upper and lower portions, than the upper reach. The 1,260-ft reach of Area 01 chosen as the representative study site (Reach 01) is at approximately 5,760 ft elevation and contains a relatively flat upper end having bankside canopy (25 percent), whereas the lower end was steeper and had little bankside canopy. The upper end was characterized by fairly shallow (to 2 ft) pools with gravel, sand, and silt substrates and by rocky riffles containing small boulders, cobble, and small amounts of gravel. Bankside canopy over the pools and large rocks in the riffles provided modest cover for trout. The lower end was characterized by small pools and runs that flowed over bedrock, boulders, and large cobble; and by riffles containing large cobble, gravel, and a few boulders. Good instream cover for trout was available in the few deep (2-6 ft) pools, and cover was modest in the riffles and runs. A 70-ft section of shallow run over bedrock was largely uninhabitable by trout.

The lower segment, Area 03. is approximately 3.6 miles long, beginning at Poison Hole Creek and ending at Robbs Forebay. This segment has a moderate gradient (112 ft/mile). The 1,660-ft reach of Area 03 chosen as the representative study site (Reach 01) is at approximately 5,300 ft elevation and contains several long (to 100 ft) riffle-pool combinations in the lower half, and shorter riffle-pool (and run) combinations in the upper half, where the stream gradient was slightly steeper. Bankside canopy covered less than 10 percent of the stream, and most of the shade was created by the conifers bordering it. Instream cover was modest in the lower half and poor in a large, exposed pool that had few large rocks or undercut banks usable by trout. The upper half also lacked bankside canopy, and there was little undercut bank habitat. The pools and runs were generally smaller and shallower than those in the lower half, but large rocks in the stream provided modest instream cover throughout this section.

2. METHODS

2.1 FISH SPECIES ABUNDANCE AND BIOMASS

Fish populations were sampled using Smith-Root Type VII and Type VIIIa backpack electroshockers with a hand-held anode probe and a trailing cathode. To improve shocking efficacy, salt blocks were placed in the river to increase specific conductance of the water. A measured length of the reach was blocked off with small-mesh nets prior to electroshocking. Stunned fish were captured with 3/8-in. mesh and 505-μm mesh dip nets.

Three passes of shocking were done from the downstream net to the upstream net. Occasionally, only two passes were made when the number of fish captured on the second pass was small enough relative to the first pass to ensure less than a 10 percent error in the total population estimate; a table developed by Price et al. (1979) was used to make this determination. The duration of shocking was recorded from the electroshocker timer. Captured fish were held in a water-filled bucket and returned to the river after shocking.

After each pass, fish were identified to species, counted, weighed, and measured. Weights were measured by displacement in a 50- or 500-ml graduated cylinder: a 1-ml displacement was assumed to represent one gram of fish. When weights were not obtained, a weight-length relationship was used to estimate weights.

Population estimates were made for those fish species for which there were sufficient data. Population sizes at the three-pass sites were calculated by a least-squares regression of catch per unit effort, versus cumulative catch using Leslie or De Lury method (Robson and Regier 1971; Ricker 1975). Confidence limits ($\alpha = 0.05$) were calculated following Ricker (1975, p. 150). At the two-pass sites, population sizes and confidence intervals were calculated following Seber and Le Cren (1967) and Robson and Regier (1971) as follows:

$$N = (C_1^2 - C_2)/(C_1 - C_2)$$

$$\mathrm{var}(N) = C_1^2\ C_2^2(C_1 + C_2)/(C_1 - C_2)^4$$

where

N = population estimate
C_1 = number caught on pass one
C_2 = number caught on pass two.

Approximate confidence limits ($\alpha = 0.05$) were calculated as $N \pm 2[SE(N)]$.

The size (age) class structure of the fish populations was determined by analysis of length frequency histograms; obvious separations between size groups were used to distinguish age classes. This provided an adequate method of determining population age structure in most cases.

The number of fish per mile was calculated as the number of fish estimated per shocked length of stream, multiplied by 52.8 for 100-ft sections, or 26.4 for 200-ft sections. The standing stock, in pounds per acre, was calculated from the biomass of fish measured per shocked area of stream. Both the estimated numbers of fish per mile and pounds per acre were calculated for various size (age) classes of fish.

2.2 MACROINVERTEBRATE DIVERSITY AND ABUNDANCE

Macroinvertebrate populations are important in the food web as primary consumers and scavengers, and in Sierran trout streams they provide much of the food for fish. The composition, distribution, and abundance of macroinvertebrate populations can provide indications of the productivity of the stream and of its potential to support trout populations.

Benthic macroinvertebrates were collected using a 1-ft^2 Surber sampler with 1-mm mesh net and a codend attached. Three 1-ft^2 sites along each transect line were sampled. The organisms from these sites were combined to form a single representative sample for each transect. Sample sites were determined by choosing areas representative of each stream transect that met the physical requirements for Surber sampling.

Samples were collected by placing the Surber net opening toward the current at each sample site. Large rocks and boulders within the sampled area were brushed clean, and the remaining substrate was stirred so that loosened organic material floated into the net. Collections from the three sites along each transect were combined, and the sample was preserved in a 9-percent formalin solution.

Samples were processed in the laboratory, and invertebrates were identified and placed in 75-percent ethyl alcohol for storage.

2.3 INSTREAM FLOW AND USABLE AREA

The purpose of the instream flow study is to provide information that will assist in the evaluation of proposed flow regimes in the South Fork Rubicon River from the standpoint of habitat suitability.

Approaches taken for instream flow studies vary considerably, ranging from statistical analyses of historical flow rates to detailed computer simulation models mapping available spawning grounds under a range of flow rates (Stalnaker and Arnette 1976). The approach used on the South Fork Rubicon River is the incremental methodology developed by the Cooperative Instream Flow Service Group of the U.S. Fish and Wildlife Service (Bovee and Cochnauer 1977). This methodology was selected because it represents a comprehensive integration of information regarding biotic and abiotic features of the stream to estimate minimum flow requirements.

The incremental methodology combines data for various physical parameters of a stream with the probability that a given fish species will use the stream for certain activities at various values for the physical parameters. The product is an estimate of the weighted usable area (WUA) of the stream that is potentially available to the fish for the prescribed activities. In the South

Fork Rubicon River studies, data were collected at low stream flows and hydraulic simulation was not used. The instream flow methodology was used to calculate potential usable area for these rates.

The physical parameters selected in this study to determine the usability of the South Fork Rubicon River were stream velocity, depth, and substrate composition. The fish species and activities selected for inclusion in the study were rainbow trout (Salmo gairdneri) spawning, adult, juvenile, and fry utilization. The flow rate studied was the naturally occurring flow rate of approximately 2 to 4 cfs.

The principal goal of the incremental methodology is to extrapolate the total usable area of a stream from data gathered at only a few transects. Selection of representative study areas and transects is therefore critical to the accuracy of the method. The way in which study sites were selected was as follows:

1. The course of the South Fork Rubicon River under consideration between the proposed diversion point and Robbs Peak Forebay was characterized by gradient, soil and bedrock composition, cover type, depth, pool-to-riffle ratio, and human utilization, and segregated into three homogeneous areas, designated Area 01, 02, and 03 (Figure S-1), each of which was studied independently.

2. Each area was partitioned into equally-sized reaches, each considered to be representative of the segment. Of these, four were selected randomly as candidate study areas, and one reach was chosen for study on the basis of its accessibility.

Each study site was surveyed to establish a downstream benchmark elevation and to establish the length and steepness of the reach. A series of transects were then established across the river channel; their location was determined by the representativeness of identifiable habitat types in the reach, such as pools, runs, and riffles. These transects were marked with permanent headstakes established at known distances and elevations relative to the benchmark. All surveying was done with a transit, rod, and steel tape.

The physical parameters measured at 2-ft intervals along these transects were velocity, depth, and substrate type. Velocities were measured with a Price-Gurley Pygmy current meter; depths were measured with a graduated staff; and substrates were visually assessed and assigned to categories on a modified Wentworth scale. Measurements were made at discharges of 2 to 4 cfs. The probabilities of use of the stream by fish under various combinations of velocity, depth, and substrate type were estimated for spawning of rainbow trout and for general inhabitation by rainbow trout fry, juveniles, and adults. The probabilities of use were taken directly from the literature of the USFWS Instream Flow Group (Bovee 1978) but were modified slightly to account for the fact that field studies in the South Fork Rubicon River did not document use of deep water by fry. The resulting data were used as input to the USFWS HABTAT computer model.

From the input data the HABTAT model computes total usable area for each species and activity under a given flow rate using the following steps:

1. The total surface area of the reach is divided into a number of rectangular cells whose boundaries are defined as the interval distance between sampling points along each transect, and the calculated fraction of the distance between a transect and the next transect upstream.

2. A measured value of water depth, velocity, and substrate composition is assigned to each cell.

3. Each physical parameter value is converted to a probability-of-use value using probability-of-use curves.

4. Weighted usable area for a cell is the product of the three probability-of-use values and the area of the cell.

5. Total usable area is the sum of the weighted usable areas.

3. RESULTS AND DISCUSSION

3.1 FISH SPECIES ABUNDANCE AND BIOMASS

Throughout the South Fork Rubicon River study region, only one fish species was captured, rainbow trout (*Salmo gairdneri*). Figures S-2, S-3, and S-4 and Tables S-1 and S-2 summarize rainbow trout population structure, abundance, and biomass.

The length frequency distribution of rainbow trout in Reach 05 of Area 01 shows two distinct size classes, corresponding to 0+ (young-of-the-year) and 1+ (between 1 and 2 years old) age classes, and an overlapping distribution of older fishes, presumably (2+ and 3+) age classes (Figure S-2). In contrast, the length frequency distributions for Reach 01 of Area 02 and Reach 02 of Area 03 shows rather distinct separations of all size (age) classes (Figures S-3 and S-4). The trout in Area 02 were age 0+, 1+, 2+, and 3+ fish. Only two size classes were apparent in Area 03, corresponding to 0+ and 1+ age class fish.

Age distributions differed substantially among the three study sites. Adult-sized trout (>150 mm) comprised 15.3 percent (417 fish/mile) of the population in the upper site, 7.7 percent (111 fish/mile) in the middle site, and none were collected in the lower site (Table S-1). The substantial numbers of young-of-the-year and juvenile trout at the lowest study site indicate that adults are present in this area, even though none were collected there during the sampling. Data collected in Area 03 during the summer of 1978 showed the adults comprised 9.5 percent of the population, or 116 fish/mile (Cressey et al., unpublished data).

Adult trout comprised 52.9 percent of the biomass in the upper site, 30.6 percent in the middle site, and 0 percent in the lowest site (Table S-1). Adult biomass dominated the total trout biomass in the upper site (31.2 lb/acre of a total 58.9 lb/acre), and was greater than the total trout biomass reported in the middle site (29.3 lb/acre) and in the lowest site (22.7 lb/acre). Although no adult-size trout were collected in Area 03 during this study, the total trout biomass (22.7 lb/acre) was similar to that reported for the area in 1978 (21.4 lb/acre) by CDF&G (1978).

The upper study area, approximately 1.2 miles long, is estimated to support 3,177 rainbow trout with a biomass of 122.6 lb (Table S-2). The middle study area, approximately 1.6 miles long, is estimated to support 2,286 rainbow trout, with a biomass of 62.5 lb. The lower area, approximately 3.6 miles long, is estimated to support 12,473 rainbow trout with a biomass of 158.6 lb (Table S-2).

The weighted average biomass of all trout for the three areas of the South Fork Rubicon River was 31.1 lb/acre. The weighted average number of adult trout per mile was 106. When an average of 116 adults/mile is used for Area 03 (not the 0 adults/mile found in 1980), the weighted average is 171 adults/mile. This average biomass is similar to the value of 41 lb/acre reported by Gerstung (1973) for 102 northern Sierra Nevada streams, and the average number of adults

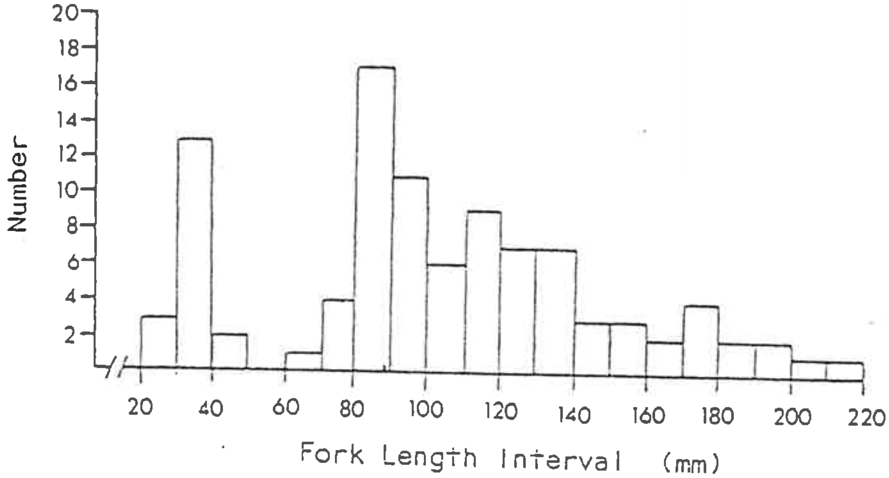

Figure S-2 Frequency versus fork lengths of Rainbow trout captured by electrofishing in Area 01, Reach 05, South Fork Rubicon River.

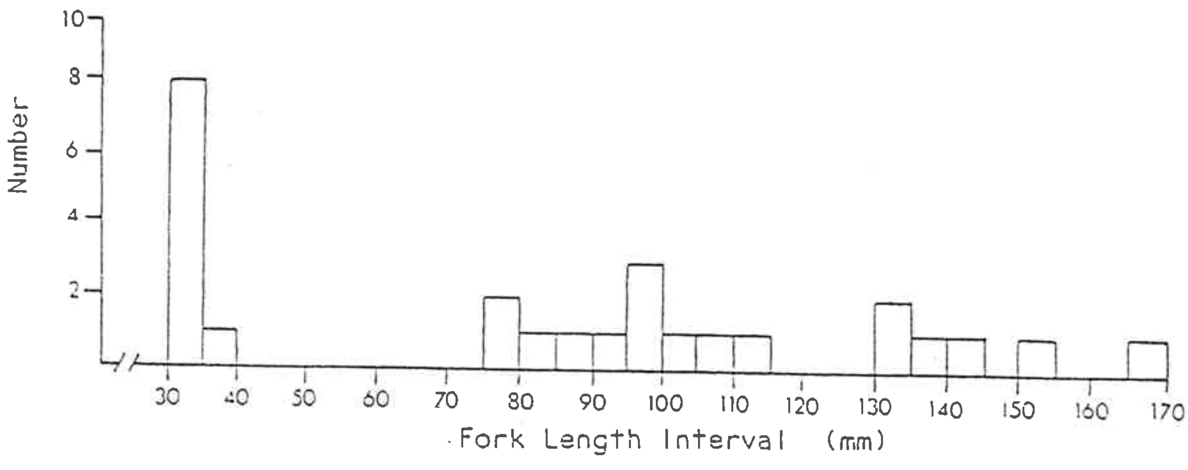

Figure S-3 Frequency versus fork length of Rainbow trout captured by electrofishing in Area 02, Reach 01, of South Fork Rubicon River.

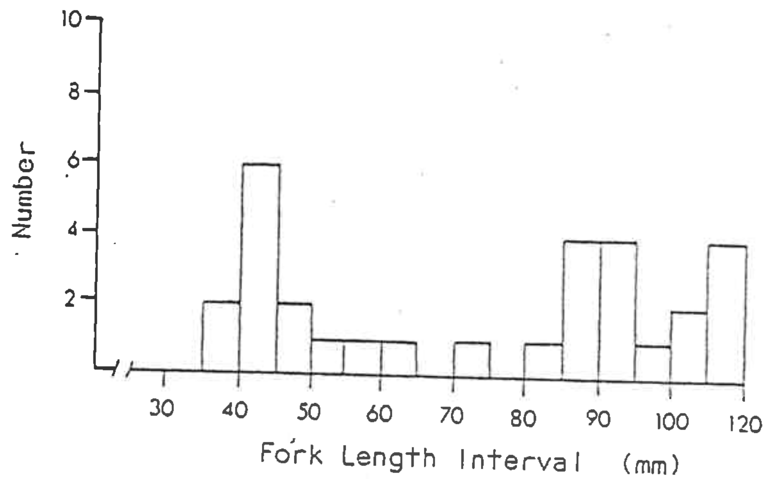

Figure S-4 Frequency versus fork lengths of Rainbow trout captured by electrofishing in Area 03, Reach 02, South Fork Rubicon River.

TABLE S-1 NUMBERS AND BIOMASS PERCENTAGES AND STANDING STOCK ESTIMATES FOR RAINBOW TROUT IN THE SOUTH FORK RUBICON RIVER

Study Site	Size Class	Percentage of Total Number	Percentage of Total Biomass	Standing Stock lb/acre	Standing Stock number/mile
Area 01, Reach 05	>150 mm	15.3	52.9	31.2	417
	110-149.9	26.5	30.6	18.0	721
	60-109.9	39.8	16.0	9.4	1,082
	<60.0	18.4	0.5	0.3	502
TOTAL		100.0	100.0	58.9	2,722
Area 02, Reach 01	>150 mm	7.7	30.6	9.0	111
	115-149.9	15.4	36.3	10.7	222
	70-114.9	42.3	31.0	9.0	602
	<70	34.6	2.1	0.6	491
TOTAL		100.0	100.0	29.3	1,426
Area 03, Reach 02	>150 mm	-	-	-	-
	115-149.9	-	-	-	-
	70-114.9	57.4	92.5	21.0	2,001
	<70	42.6	7.5	1.7	1,489
TOTAL		100.0	100.0	22.7	3,490

TABLE S-2 NUMBERS AND BIOMASS OF RAINBOW TROUT CALCULATED TO OCCUR IN 100-FOOT SECTIONS OF AREAS 01, 02, AND 03 OF THE SOUTH FORK RUBICON RIVER

Study Site	Number (95% CL)	Biomass (lb)	Entire Area Number (95% CL)	Entire Area Biomass (lb)
Area 01, Reach 05[(a)]				
Size Class				
150 mm	8 (6-10)	1.063	488 (366-610)	64.9
Total	52 (42-68)	2.009	3,177 (2,563-4,150)	122.6
Area 02, Reach 01				
Size Class				
150 mm	2 (2-4)	0.226	169 (169-676)	19.1
Total	27 (20-57)	0.738	2,286 (1,693-4,825)	62.5
Area 03, Reach 02[(b)]				
Size Class				
150 mm	None	None	None	None
Total	66 (55-85)	0.839	12,473 (10,394-16,064)	158.6

(a) Calculated from data collected in a 200-foot section.
(b) Weights were calculated from weight-length relationship developed for South Fork Rubicon River rainbow trout and not measured directly.

per mile is substantially lower than the 224 reported by Gerstung. However, when the adult/mile average of 171 is used, the difference between the South Fork Rubicon River and Gerstung's value is much less.

Table S-3 shows the standing stock data from the three areas of the South Fork Rubicon compared to standing stock data from five other northern Sierran streams of similar elevation, gradient, and summer discharge. The South Fork Rubicon River has a lower standing stock (31.1 vs 42.4 lb/acre) and adult trout density (111 or 171 vs 189 adults/mile) than the averages for the 102 Sierra Nevada streams reported by Gerstung (1973).

Other data for the South Fork Rubicon River study areas are limited to a fish population survey made in Area 3 during the summer of 1978 (Cressey et al., unpublished data). Their data, cited earlier, indicated that the rainbow trout population biomass has increased slightly (22.7 vs 21.4 lb/acre), while the total number of trout, except adults, has increased substantially (3,490 vs 1,223 number/mile). The smaller number of trout reported in 1978 may have resulted from poor reproductive success during the 1976-1977 drought. Conversely, better water conditions in the South Fork Rubicon River in 1979-1980 may have allowed a high reproductive success.

It appears from the data collected in this study, and from those of similar streams, that the South Fork Rubicon River supports an average trout biomass and adult trout densities within the ranges expected for a stream of its size. Both biomass and adult trout densities are below the averages for similar streams, but the differences are not substantial.

3.2 MACROINVERTEBRATE DIVERSITY AND ABUNDANCE

The composition, distribution, and abundance of benthic macroinvertebrates collected along each transect at each reach are shown in Tables S-4, S-5, and S-6. Aquatic insects were predominant in the samples, with eight orders represented, consisting of forty different genera and species. The overall abundance of organisms per square foot is highest in the middle study area ($44/ft^2$). The middle study area supports the greatest number of Ephemeroptera (mayflies) and Plecoptera (stoneflies), while the most downstream study area supports the greatest abundance of Trichoptera (caddisflies). Although the relative abundance of Chironomidae (midge) larvae follows the general trend of being greatest in the middle study area. All study areas show a substantial abundance of this food source which is suitable for small trout.

Benthic macroinvertebrate densities in the South Fork Rubicon River were generally lower than average densities reported in other mountain streams. The mean weighted density of invertebrates in the South Fork Rubicon River was 30 organisms per square foot; mean density was highest in the middle area ~~($44.4/ft^2$), and less in the~~ upper ($25.7/ft^2$) and lower ($25.6/ft^2$) areas. Mean densities in other mountain streams ranged from 10 to 105 per ft^2 (Reed and Bear 1966), 108 to 135 per ft^2 (Allan 1978) and 62 to 166 per ft^2 (Elliott 1973). These data indicate that the South Fork Rubicon River does not support benthic invertebrate populations as large as those in other mountain streams.

Benthic invertebrates are the major source of food for trout in streams (Elliott 1973). Benthic invertebrate densities in the South Fork Rubicon River are lower than densities reported in many other mountain streams. However,

TABLE S-3 TROUT POPULATION BIOMASS (LB/ACRE) AND ADULT DENSITIES (ADULT/MILE) IN SIX NORTHERN SIERRA NEVADA STREAMS

Stream	Elevation (ft)	Gradient (ft/mile)	Average Late Summer Flow (cfs)	Density (adult/mile)	Biomass (lb/acre)
Jones Fork[1]	4,800	30	1	53	40
Little Silver[1]	4,800	100	1	70	55
Kirkwood Creek[1]	7,000	50	<1	616	91
Gerle Creek[1]	6,013	60	10	70	10
Pilot Creek[1]	4,000	90	3	137	16
S.F. Rubicon[2]	6,310	104	<4	417	59
S.F. Rubicon[2]	5,760	175	<4	111	30
S.F. Rubicon[2]	5,300	112	<4	0	23

[1] Gerstung, unpublished data
[2] This study

TABLE S-4 MACROINVERTEBRATE TAXA COLLECTED ALONG TRANSECTS IN AREA 01, REACH 05, OF THE SOUTH FORK RUBICON RIVER

	TRANSECT					
	01	02	03	04	05	06
TAXON	#/SQ. FT.					
HYDRA SP.	0	0	0	0	0	0.33
OLIGOCHAETA	0	0	0.67	0	0	0
AMPHIPODA	0	0	0	0	0	0.33
DODDSIA SP.	0	0.67	0	1	0	0
HESPEROPERLA PACIFICA	0	0	0	0.33	0	0
ISOPERLA SP.	0	0	0	0.33	0	0
ALLOPERLA SP.	0	0	0.33	0	0	0
BAETIS SP.	0	2	0.67	1.67	4	0
CINYGMULA SP.	0	0	0.33	0	0	0
RHITHROGENA SP.	0	0	0	0	1	0
EPHEMERELLA SP.	0	0	0	0.67	0.67	0
PARALEPTOPHLEBIA SP.	0.33	0	0.33	0.33	0	0
THYSANOPTERA	0	0	0.33	0	0	0
GERRIS SP.	0.33	0	0	0	0	0
SIALIS SP.	0	0.67	0	0	0	0
ZAITZEVIA SP.	0	0	0	0	0	0.33
EUBRIANAX EDWARDSI	0.33	1.33	7.33	0	0.67	0
DYTISCUS SP.	0	0	0.33	0	0	0
OREODYTES SP.	0	3.33	0	0	0	0
PHILOPTAMIDAE	0	0	0.33	0	0	0
WORMALDIA SP.	0	0	1	1	0	0
POLYCENTROPUS SP.	0	0	0.33	0	0.67	0
PARAPSYCHE SP.	0	0	0	0	0	0.33
AGRAYLEA SP.	0	0	0	0.33	0	0
LIMNEPHILIDAE	0	0.67	0	0	0	0
APATANIA SP.	0	0.67	0	0.33	0.67	0.33
NEOPHYLAX SP.	0	0	2	0	0	0
SIMULIDAE	0	0	0	0	32	0
CHIRONOMIDAE	0.33	76.67	0	0	1.67	0
ARANEAE	0.33	0	0	0	0	0
ACARINA	0.33	0	0.33	0.33	0	0
*EPHEMEROPTERA	0	2	0	0	0	0
*HEPTAGENIIDAE	0.33	0	0	0	0	0
TOTAL #/SQ. FT.	2.33	88	14.33	6.33	41.33	1.67
TOTAL # OF TAXA	6	8	13	10	8	5
DIVERSITY (H LN)	1.79	0.53	1.79	2.1	0.91	1.61
DIVERSITY (H LOG10)	0.78	0.23	0.78	0.91	0.4	0.7

* - MUTILATED (NOT INCLUDED IN DIVERSITY INDEX COMPUTATION)

TABLE S-5 MACROINVERTEBRATE TAXA COLLECTED ALONG TRANSECTS IN AREA 02, REACH 01, OF THE SOUTH FORK RUBICON RIVER

TAXON	TRANSECT 01	02	03	05	06	07
	#/SQ. FT.					
AMPHIPODA	0	0	0	0	0.67	0
DODDSIA SP.	0.67	0	0	0.33	0.67	20
MALENKA SP.	0	0	0	0	0	2
ISOPERLA SP.	0.67	0.33	0.67	0	0	13.33
ALLOPERLA SP.	0.67	0.33	0	0.33	0	0
SIPHLONURUS SP.	0	2	0	0	0	0
BAETIS SP.	2.67	4	4	2.67	0	2
HEPTAGENIA SP.	6	0	0	0	0	1.33
STENONEMA SP.	0	0	0.67	2	0	0
IRONODES SP.	0	0	0	0	0	2.67
RHITHROGENA SP.	0	0	0	0.33	0	2
EPHEMERELLA SP.	0	0	0	0.67	0	2.67
PARALEPTOPHLEBIA SP.	3.33	0.67	0	1	3.33	1.33
SIALIS SP.	0.67	0	0	0	2	0
EUBRIANIX EDWARDSI	0	0.67	0	1.33	1.33	0
OREODYTES SP.	0.67	1	0	1.33	0.67	0
TRICHOPTERA	0	0	0.33	0	0	0
POLYCENTROPUS SP.	0	0	0	0	0	0.67
RHYACOPHILA SP.	0	0.33	0.33	0	0	0
HYDROPTILA SP.	0	0	0	0.33	0	0
LIMNEPHILIDAE	0.67	0	0	0	0	0
ECCLISOMYIA BILERA	0.67	0	0	0	0	0
APATANIA SP.	0	0	1.67	0	0	0
SERICOSTOMATIDAE	0	0.33	0	0	0	0
DIPTERA	0.67	0	0	0	1.33	2
TIPULIDAE	0	0	0	1	0	0
HEXATOMA SP.	0	1.33	0	0	0	0
CHIRONOMIDAE	66.67	3.33	10.33	3.33	5.33	44.67
*PLECOPTERA	0	0	0	0.33	0	0.67
*CHLOROPERLIDAE	0	0	0.33	0	0	0
*EPHEMEROPTERA	10.67	0	2	1.67	3.33	4
*HEPTAGENIIDAE	0	1	0	0.67	0	0.67
TOTAL #/SQ. FT.	94.67	15.33	20.33	17.33	18.67	100
TOTAL # OF TAXA	12	11	7	12	8	12
DIVERSITY (H LN)	0.92	2.01	1.27	2.2	1.8	1.64
DIVERSITY (H LOG10)	0.4	0.87	0.55	0.96	0.78	0.71

* - MUTILATED (NOT INCLUDED IN DIVERSITY INDEX COMPUTATION)

TABLE S-6 MACROINVERTEBRATE TAXA COLLECTED ALONG TRANSECTS IN AREA 03, REACH 02, OF THE SOUTH FORK RUBICON RIVER

TAXON	TRANSECT 01	02	03	04	05	06	07
	#/SQ. FT.						
NEMATODA	0	0	0	0	0	0	0.33
OLIGOCHAETA	0	0	0	0	0	0	0.67
COROPHIUM SPINICORNE	0	0	0	0	0	0.67	0
DODDSIA SP.	1.33	0	0	0	0	1	1.67
MALENKA SP.	0	0	1.67	0	0	0	0
HESPEROPERLA PACIFICA	0	0	1	0.67	0	0	0
PERLINODES SP.	0	0	0	0	0	3	0
ISOPERLA SP.	0	0	0	0	0	0.33	0
ALLOPERLA SP.	0	1.33	1	0	0	1.33	0
SIPHLONURUS SP.	0.67	0	0	0	0	0	0
BAETIS SP.	0.33	0.67	1.67	1.33	0.33	4	1
HEPTAGENIA SP.	3	0	0.67	0	0.67	0	1
CINYGMULA SP.	0	0	0	0	0	2	0
EPHEMERELLA SP.	0.33	0	0	0	0	0	0.67
PARALEPTOPHLEBIA SP.	1.33	3.33	0	0	0.33	0	0
THYSANOPTERA	0	0	0	0	0	1	0
NEOHERMES SP.	0	0.67	0	0	0	0.33	0
ELMIDAE	0	0	0	0	0	0.67	0
EUBRIANIX EDWARDSI	1.33	0.67	0.67	1.33	1	1.67	0
OREODYTES SP.	0.33	0.67	0.33	0.67	0	0	0
CURCULIONIDAE	0	0	0	0	0	0.33	0
POLYCENTROPUS SP.	1.33	0	0.33	0	0.33	0	0
PARAPSYCHE SP.	0	0	0	0	0	0.33	0
RHYACOPHILA SP.	0	0	0	0	0	1.33	0
GLOSSOSOMA SP.	0	0	0	0	0	0	1
AGAPETUS SP.	0	0	0	0	0	2	0
ANAGAPETUS SP.	0	0	0	0	0.33	0	0
HYDROPTILA SP.	0	0	0	0	0	0.33	0
LIMNEPHILIDAE	0	2	0	0	0	0	0
APATANIA SP.	1	1.33	0.33	0.67	0.33	0	2.33
NEOPHYLAX SP.	0	0	0	0	0	4	0
CLOSTOECA DISJUNCTA	0	0	0	0.67	0	0	0
HELICOPSYCHE BOREALIS	0	0	0.33	0	0	0.67	0
DIPTERA	0	0.67	0	0	0	0	0
TIPULIDAE	0	2	0	3.33	0	0.67	0
ANTOCHA SP.	0	0	0	0	0	0	0.33
HEXATOMA SP.	0.67	0	0	0	0.33	0	3
SIMULIDAE	0.33	0	0	0	0	0	0
CERATOPOGONIDAE	0	0.67	0	0	0	0	0
CHIRONOMIDAE	2	26.67	4	29.33	1.33	16	5.67
ACARINA	0	0	1	0	0	0	0.33
*EPHEMEROPTERA	0	2	0	4	0	0	0
*HEPTAGENIIDAE	0	0	0.67	0	0.33	0	0.67
*DIPTERA	0	0	0	0	0.33	0	0
TOTAL #/SQ. FT.	14	42.67	13.67	42	5.67	42.33	18.67
TOTAL # OF TAXA	13	12	12	8	9	21	12
DIVERSITY (H LN)	2.34	1.41	2.16	0.93	2.03	2.33	2.1
DIVERSITY (H LOG10)	1.02	0.61	0.94	0.4	0.88	1.01	0.91

* - MUTILATED (NOT INCLUDED IN DIVERSITY INDEX COMPUTATION)

there is no obvious relationship between total trout biomass or adult trout densities and invertebrate densities. The upper study area supports the lowest invertebrate biomass and the greatest trout biomass, whereas the lower area supports the lowest biomass and a similar invertebrate density. These data suggest that under the conditions found in the summer of 1980, benthic invertebrate biomass did not have a substantial influence on trout biomass.

3.3 INSTREAM FLOW AND USABLE AREA

The predictions of weighted usable area within each of the three representative areas are presented for various stages of rainbow trout in Table S-7. All values are output from the USFWS HABTAT models using field data collected from 30 July to 6 August 1980 at measured discharges of 4 cfs in Areas 01 and 02 and 2 cfs in Area 03.

Prediction of probable trout populations as functions of usable area cannot be made from these data. However, the HABTAT output data can be used to indicate possible areas of concern with regard to a specific activity. From the data in Table S-7 it appears that spawning (and fry incubation area) is severely limited at the measured discharges of 2 and 4 cfs.

However, there were indications that most trout had spawned from May to mid-June, and that most fry (which incubate in the gravel nest for 2-3 weeks after hatching) had emerged from the gravel nests by mid-July (Table S-8), when spawning and incubation area was probably much greater than the area calculated for early August by the HABTAT model. Estimates of discharge made by Ecological Analysts, Inc. in late June indicated that about 10 to 15 cfs were flowing in the upper study area and about 20 cfs in the lower study area. Runoff during 1980 was colder and occurred later in the spring than normal, and may have delayed spawning and fry emergence by several weeks (J. Richards, CDF&G, 1980, personal communication). This suggests that May and June discharges are crucial months for spawning and incubation in most years, and that July is important in regard to incubation only in late runoff years.

The South Fork Rubicon River discharge is generally greater in the middle and lower study areas than in the upper area because of additional flows from small, intermittent tributaries and Poison Hole Creek, as well as from site slope drainage, during the winter and spring. Because discharge is greater in the middle and lower areas, the discussion of discharge effects on spawning and fry incubation discharge focuses on the upper area where the greatest effect of the project would occur.

Recent discharge data for the South Fork Rubicon River do not exist for the study areas. Discharge was measured near the downstream end of the lower study area for the years 1910-1914. Discharge during these years was calculated at the upper study area (Area 01) based upon the relationship between land area drained at each location (Table S-9). For the critical trout spawning and incubation months, discharge in the upper site averaged about 48 cfs in May, 26 cfs in June, 3 cfs in July, and 0.4 cfs in August.

TABLE S-7 USABLE AREA (FT^2 PER 1,000 FT OF STREAM) FOR RAINBOW TROUT STAGES IN STUDY AREAS 01, 02, AND 03 OF THE SOUTH FORK RUBICON RIVER[(a)]

Stage	Usable Area (ft^2)		
	Area 01	Area 02	Area 03
Spawning	-	5.44	1.97
Adults	1,601.73	1,302.94	696.36
Juvenile	992.31	995.62	475.49
Fry	1,580.05	1,616.68	977.44

(a) Calculated using the USFWS HABTAT model with field data collected during July and August 1980

TABLE S-8 ESTIMATED PERIODS OF RAINBOW TROUT SPAWNING AND FRY INCUBATION-EMERGENCE IN THREE STUDY AREAS OF THE SOUTH FORK RUBICON RIVER, 1980(a)

Area	Length Class (mm)	Mean Size (mm)	Number in Sample	Emergence Time(b)	Begin Incubation(c)	Begin Spawning(d)
01	20-30	25	3	10 AUG	20 JUL	20 JUN
	30-40	35	13	10 JUL	20 JUN	20 MAY
	40-50	45	2	10 JUN	20 MAY	20 APR
02	30-35	32.5	8	6 JUL	15 JUN	15 MAY
	35-40	37.5	1	20 JUN	30 MAY	30 APR
03	35-40	37.5	2	20 JUN	30 MAY	30 APR
	40-45	42.5	6	7 JUN	17 MAY	17 APR
	45-50	47.5	2	21 MAY	30 APR	30 MAR

(a) Data collected on 20 August 1980 in Areas 02 and 03, and on 3 September 1980 in Area 01.

(b) Emergence time calculations assumed that rainbow trout fry emerge from the gravel at about 17 mm TL (J. Wang, EA, 1980, personal communication) and have an average growth rate of 10 mm/month (obtained from information in Carlander 1950). The number of days required for fry to grow from emergence size to the mean size of the length class was subtracted from the collection date to yield the emergence time.

(c) Incubation generally lasts 2-3 weeks (Moyle 1976). Because water temperatures were probably cooler this year, the more conservative estimate of 3 weeks was used.

(d) Hatching generally requires 3-4 weeks at 10-15° C (Moyle 1976). Because water temperatures were probably cooler this year, the more conservative estimate of 4 weeks was used for calculating spawning time.

TABLE S-9 AVERAGE DAILY DISCHARGE (CFS) IN THE SOUTH FORK RUBICON RIVER NEAR THE DOWNSTREAM END OF AREA 03 FOR MAY THROUGH AUGUST, 1910-1914[a] AND ESTIMATED DISCHARGE OF THE PROPOSED DIVERSION (AREA 01)[b]

	Average Daily Discharge (cfs)							
	May		June		July		August	
	Area 03	Area 01	Area 03	Area 01	Area 03	Area 01	Area 03	Area 01
1910	99.5	25.9	18.3	4.8	1.6	0.4	0	0
1911	265	68.9	274	71.2	29.6	7.7	3.4	0.9
1912	169	43.9	77.8	20.2	5.6	1.4	1.0	0.3
1913	164	42.6	50.7	13.2	9.2	2.4	2.4	0.6
1914	225	58.5	89.4	23.2	-	-	-	-
Total	922.5	239.8	510.2	132.6	46.0	11.9	6.8	1.8
Mean	184.5	48.0	102.0	26.5	11.5	3.0	1.7	0.4
Maximum	265	68.9	274	71.2	29.6	7.7	3.4	0.9
Minimum	99.5	25.9	18.3	4.8	1.6	1.4	0.0	0.0

(a) Data from U.S. Geological Survey.

(b) Discharge of the diversion site is calculated as 26 percent of the discharge reported at the recording gauge below Area 03. Low discharges during the summer may not be accurate (Tudor Engineering Company, unpublished data).

Simulated discharge for the South Fork Rubicon River at the proposed diversion site, based on discharge measured in the South Fork Silver Creek, are available for the years 1950-1959 (Table S-10). These simulations show mean monthly discharges similar to those measured for the years 1910-1914 for May and June, but higher discharges in July and August.

These data indicate that the natural minimum mean monthly discharges in the upper study area during the primary spawning months (May and June) were 10 cfs or greater. The natural minimum mean monthly discharges during the early incubation-emergence period (May-June) were generally 10 cfs or greater. Discharges during the late incubation-emergence period (July) averaged 8 cfs based on simulated data, and half of the years had discharges greater than 10 cfs. In contrast, the historical data indicate that discharge in July seldom exceeds 5 cfs in the upper area.

The proposed operation of the South Fork Rubicon River Diversion (with a maximum diversion rate of 50 cfs and a minimum fish release of 2 cfs) will provide adequate spawning area and incubation area in all of the study areas during May, based on the comparison of natural minimum monthly discharges and the projected release plus spill discharges under project operation. Exhibit I of this application discusses project operation; Figures I-1 and I-2 present monthly hydrographs for median, low flow, high flow, and average year discharges at the South Fork Rubicon River diversion site. Discharge under project operation will equal or exceed the natural minimum (10 cfs) which occurred about 30 percent of all years. Using the criterion of equalling or exceeding the natural minimum monthly discharge, June discharge (2 cfs release plus spill) would be adequate in Areas 02 and 03, but may be limiting in Area 01 as discharge will range 5-10 cfs. However, these discharges are well above the 4 cfs at which no spawning area was measured (Table S-7). Discharges of 5-10 cfs are regarded as marginal, but probably adequate, for providing the small amount of spawning gravel (150-225 ft^2/1,000 ft of stream) necessary to support the present population (Table S-11).

The combined July release plus spill may possibly be limiting to incubating fry in all areas under the proposed diversion, especially in Areas 01 and 02. In years when the spawning and incubation is delayed (such as in 1980), low July discharge would be a serious problem for incubating fry.

The usable areas for emerged fry, juvenile, and adult rainbow trout habitat measured at 2 and 4 cfs was presented in Table S-7. These data show that usable area for all life stages is similar between Area 01 and Area 02, but that usable area for all life stages is substantially lower in Area 03. This is best explained because the discharge was 2 cfs in Area 03 and 4 cfs in Areas 01 and 02. Adult habitat decreased from Area 01 to Area 03, and so did the density of adults. Usable area, at least in part, appears to explain the differences in adult trout densities. Another factor which may explain the density pattern is fishing pressure. Area 03 was the most accessible of the three areas to fishermen, and evidence of heavy fishing pressure was observed during the course of this study. Area 01, which had the greatest density of adult trout, was the least accessible to fishermen and much less evidence of fishing was found there compared to Areas 02 and 03.

TABLE S-10 APPROXIMATE AVERAGE DAILY DISCHARGE (CFS) IN THE SOUTH FORK RUBICON RIVER AT THE DIVERSION SITE (AREA 01) FOR MAY THROUGH AUGUST, 1950-1959(a)

Year	Average Daily Discharge (cfs)			
	May	June	July	August
1950	50	40	10	1
1951	30	10	3	<1
1952	80	45	18	<4
1953	30	50	15	<2
1954	30	10	<2	<1
1955	35	15	<2	<1
1956	50	30	12	2
1957	40	15	5	<1
1958	55	40	14	<4
1959	20	10	<2	<1
Total	420	265	83	<18
Mean	42	26.5	8.3	<1.8
Maximum	80	50	18	<4
Minimum	20	10	2	<1

(a) Data are simulated from measured discharges of South Fork Silver Creek (Tudor Engineering Company, unpublished data).

TABLE S-11 AMOUNT OF SPAWNING AREA (FT^2/1,000 FT OF STREAM) NECESSARY TO MAINTAIN THE PRESENT LEVEL OF FRY PRODUCTION FOR AREAS 01, 02, AND 03 OF THE SOUTH FORK RUBICON RIVER REPORTED BY THIS STUDY(a)

Spawning Area per Redd (ft^2)(b)	Redds (No./1,000 ft)(c)	Total Area (ft^2/1,000 ft)
Area 01		
12	12.5	150
18	12.5	225
Area 02		
12	12	144
18	12	216
Area 03		
12	37	447
18	37	666

(a) Values are based on spawning area requirements at 12 and 18 ft^2 per spawning female.

(b) Spawning area was reported as 18 ft^2 by the U.S. Forest Service (1969). A smaller estimate was calculated from a redd size of 3 ft^2 reported from the closely related Gila trout (Salmo gilae) by Rinne (1980) which was multiplied by a factor of 4 to account for normal redd territorial needs of salmonids as reported in Burner (1951).

(c) The number of redds needed to maintain trout production was calculated by dividing the known density of young of the year (fry) by the survival rate from egg to fry. An average survival rate of 0.045 was used, which is based upon data for the closely related cutthroat trout (S. clarki) reported by Snyder and Tanner (1960). This yielded the number of eggs needed to produce the measured number of fry. The total egg production was divided by the number of eggs per female spawner (about 800 as determined from information in Carlander (1950) and Moyle (1976) to yield the number of females (or redds) necessary to maintain the current level of fry production.

Fry and juvenile usable area was similar between Areas 01 and 02, and was about twice that calculated for Area 03 (Table S-7). This relationship appears to be directly influenced by discharge, which was measured in Areas 01 and 02 to be twice that of Area 03. However, the density of fry and juvenile trout (numbers/mile) was 2-3 times greater in Area 03 compared to Areas 01 and 02. This suggests that usable area does not directly regulate the density of small rainbow trout. One possible explanation for the observed relationship is that adult trout, which are more abundant in Areas 01 and 02, limit the density of small trout. This could result from competition for food or space, or by direct predation on the smaller fish. These possibilities were not investigated in this study.

Post-project discharges from November to April are considered adequate to allow overwintering of trout. The discharges will be above the summer to fall discharges measured in 1980. Therefore, usable area for rainbow trout will be greater than that measured in the summer of 1980, and probably will be adequate for the trout.

Overall, the usable area available to emerged fry, juveniles, and adults will be adequate at discharges as low as 4 cfs in Areas 01 and 02. A discharge of 2 cfs supported a large non-adult trout population and provided adult habitat in Area 03. Despite the availability of adult usable habitat in Area 03, none were found at the sampling site. Their absence may be explained by heavy fishing pressure or the site selected for sampling may, by chance, not have contained adults that exist in the area.

The analysis of rainbow trout life history requirements and usable area indicates that the proposed project may substantially impact late season incubation of fry. The only means to avoid this problem is curtailment of diversions in July. Because the water available for diversion is negligible from August through October, cessation of diversions from July 1 through October 31 is suggested.

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