INSTREAM FLOW AND FISHERIES REPORT
FOR THE
BISHOP CREEK HYDROELECTRIC PROJECT

DRAFT

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INTRODUCTION

This report includes results from studies on the Bishop Creek portions of Southern California Edison Company's Bishop Creek Hydroelectric Project. The results of studies conducted on Birch and McGee creeks are presented in a separate document. The Instream Flow Studies on Bishop Creek consisted of collecting data for, and running, the U.S. Fish and Wildlife Service IFG4 hydraulic simulation model in its one-flow configuration, in conjunction with the U.S. Fish and Wildlife Service HABTAT model, modified so that each cell on each transect was analyzed using the appropriate one of four cover-specific Suitability Index curves provided by the U.S. Fish and Wildlife Service (Aceituno et al. unpublished). These studies differed from many previous Instream Flow Incremental Methodology (IFIM) studies in several particulars:

- Extrapolation of data from individual transects to entire study reaches was based on detailed habitat mapping of the entire stream (Morhardt et al., 1983) so that the transects were weighted in relation to their importance within the study reaches and ultimately their importance in the entire stream. This approach resolved the question of whether a particular set of transects was truly representative of the stream.

- At the request of the California Department of Fish and Game, hydraulic simulation within the IFG4 model was based on data taken at single flows, eliminating the regression equations inherent in the traditional use of the model. This implementation eliminates the production of Velocity Prediction Errors (VPE's) which are based on the residuals from the regressions and are used as a test of goodness of fit of the model. It also changes the meaning of the Velocity Adjustment Factors (VAF's) so that they cannot be used to evaluate the quality of the hydraulic modeling.

- The Suitability Index (SI) curves provided by the U.S. Fish and Wildlife Service specifically for this study (Aceituno et al. unpublished) were not based entirely on the frequency distributions of depth and velocity occurring at the locations at which fish were observed as has usually been the case. They were modified by the agencies in some way to reflect the frequency distributions of random observations of depth and velocity in the streams at places where fish were not observed.

- Different SI curves were provided for locations having no cover, object cover, overhead cover, and both object and overhead cover. Each measurement point on each transect was coded for one of these conditions and the appropriate SI curve was used in the analysis.

To put the results of the instream flow studies into perspective, intensive electrofishing was done on all 11 reaches of Bishop Creek in October and November in 1984, and on Reaches 01-08 in October and November of 1985. These data, along with earlier fish population data collected by the California Department of Fish and Game, provide substantial information about the population sizes and condition of the fish in both the diverted and regulated reaches of Bishop Creek.

With both the population data and habitat data available, it was possible to test whether or not there was any relationship between fish population size and Weighted Useable Area. The minimum monthly values and mean monthly values of Weighted Usable Area (WUA) and Percent Usable Area (PUA) for adults, juveniles, and fry of brown trout (and the means of WUA and PUA for all three life stages) for the 12 months preceding the population sampling were found not to be significantly correlated with any of the 3 measures of population size used (numbers of brown trout per mile, pounds of brown trout per mile, pounds of brown trout per acre). Thus, there is no evidence that altering WUA or PUA by adjusting flows in Bishop Creek would have any effect on the size of Bishop Creek fish populations. The condition of brown trout in Bishop Creek is very good in all reaches, but there are significant differences between reaches which may be related to flow.

Because of the lack of correlation between fish population sizes and WUA, uncertainty about whether the presence of Suitability Index curves accurately reflect preference, and the relatively high numbers of fish in good condition in Bishop Creek under its present operational situation, it seems premature to conclude that output from the PHABSIM/HABTAT model should be used to establish appropriate instream flows. We suggest, therefore, that an 18-20 year experimental program be established on Bishop Creek for the purpose of rigorously determining the biological effects of hydroelectric diversions in eastern Sierran streams. The proposed program consists of a few more years of intensified study under the present diversion conditions, followed by 5 years each of releases of 5, 10, and 15 cfs from all diversion structures. At the end of the 20-year period, future actions would be determined on the basis of the data collected during the studies.

METHODS

Mapping:

The entire section of Bishop Creek illustrated in Figure 1 was mapped by EA staff prior to selection of study locations, and the linear distances were measured for 6 habitat types: riffle, run, pool, low-gradient cascade, medium-gradient cascade, and high-gradient cascade. These are all characterized in Figures 2a and b. The purpose of the mapping was to allow transects to be distributed in habitats with approximately the same frequency as the habitats occurred in the stream (Morhardt et al., 1983). Table 1 lists the distances in each reach consisting of the various habitat types in Bishop Creek.

Selection of Study Reaches Eleven study reaches and transect areas were selected in conjunction with personnel from the U.S. Forest Service and the California Department of Fish and Game on Bishop Creek on the basis of the habitat mappint. These are shown in Figure 3 and are described below.

Bishop Creek Reach 01 - Reach 01 is the 1.7 miles of mainstem Bishop Creek between Southern California Edison Company (SCE) Plants No. 5 and No. 6. This reach has a lower gradient (160 ft/mile) than most other areas of Bishop Creek influenced by SCE's facilities. The cobble substrates in the reach are heavily embedded in sand and silt, unlike the other portions of Bishop Creek, which are mostly free of this embeddedness. The streambed in this reach has a relatively uniform morphology consisting of a series of small shallow pools (less than 2 ft deep), rocky runs, and short riffle sections. The transect area is in a characteristic section of this reach near the midpoint between Plant No. 5 and No. 6.

Bishop Creek Reach 02 - This is the reach between Plant No. 4 and Plant No. 5. Releases from Plant No. 4 control stream flows in this reach, which has a somewhat higher gradient than Stream Reach 1. The transect area is midway between Plant No. 4 and Plant No. 5.

Bishop Creek Reach 03 - This reach is between the confluence of Coyote Creek with Bishop Creek and Plant No. 4. It has a higher gradient (260 ft/mile) than the lower reaches and receives water from releases from Plant No. 3, underflow between Plant No. 3 and the confluence with Coyote Creek, and from Coyote Creek. The transect area is midway between the Coyote Creek confluence and Plant No. 4.

Bishop Creek Reach 04 - Reach 04 is the 1.6 miles of mainstem Bishop Creek between Plant No. 3 and the confluence with Coyote Creek. This reach is located in a very steep canyon, and the gradient is high (approximately 525 ft/mile) in comparison to other reaches of Bishop Creek. The morphology of this reach differs from the others in that the reach is dominated by large

BISHOP CREEK FISHERIES STUDIES

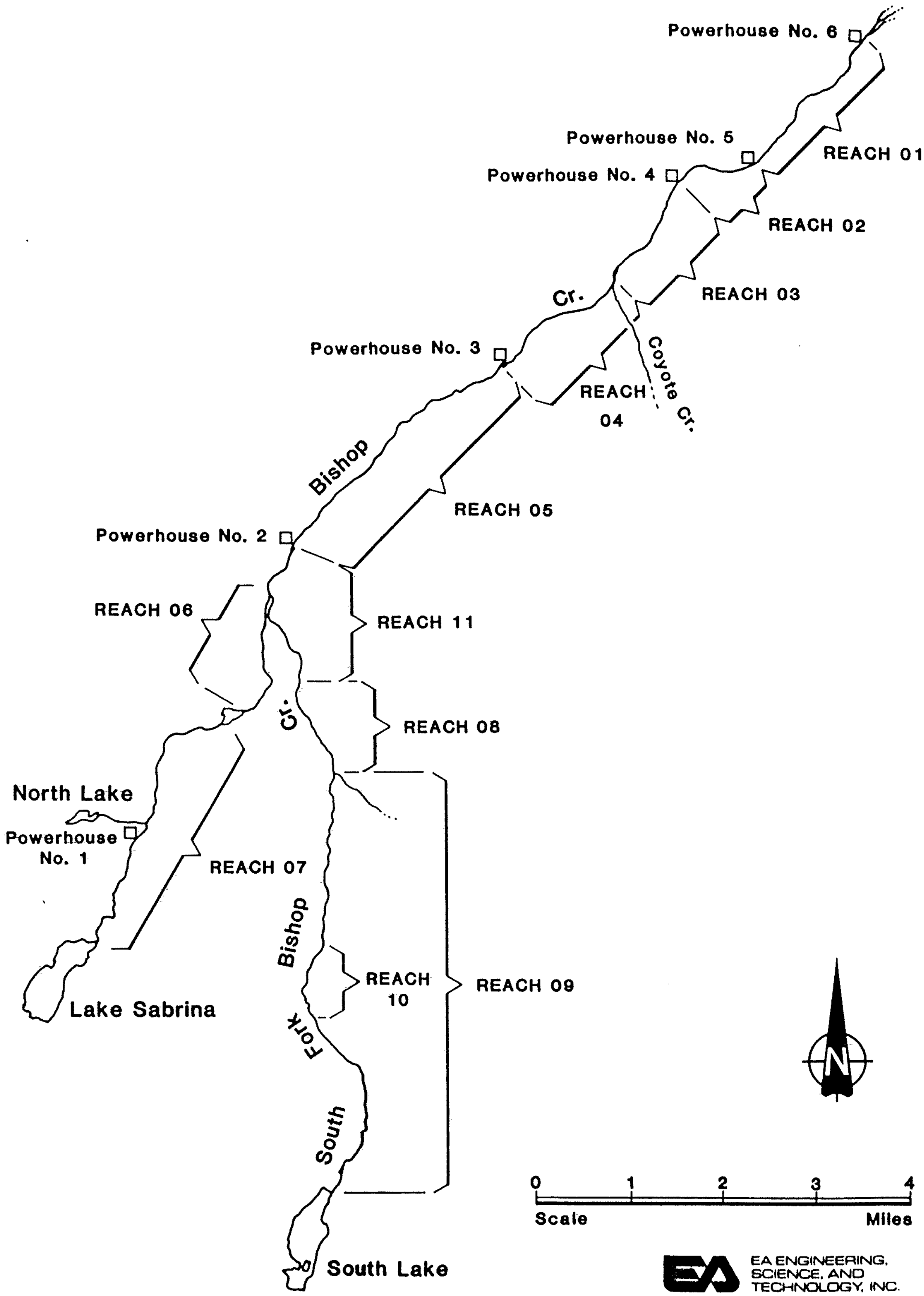
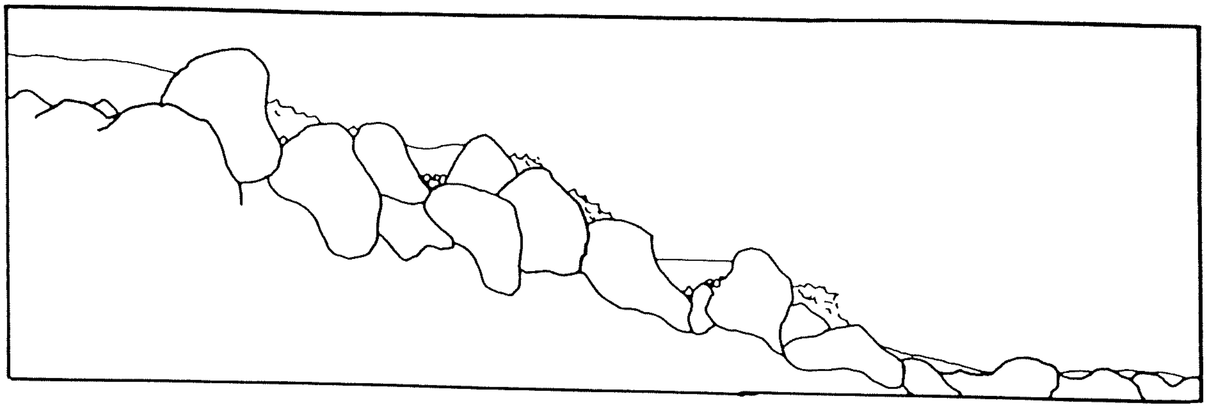
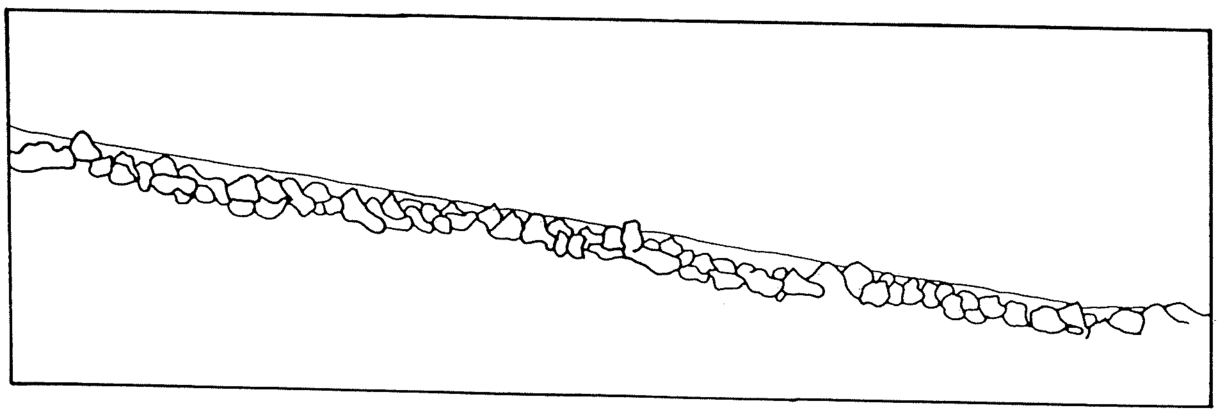


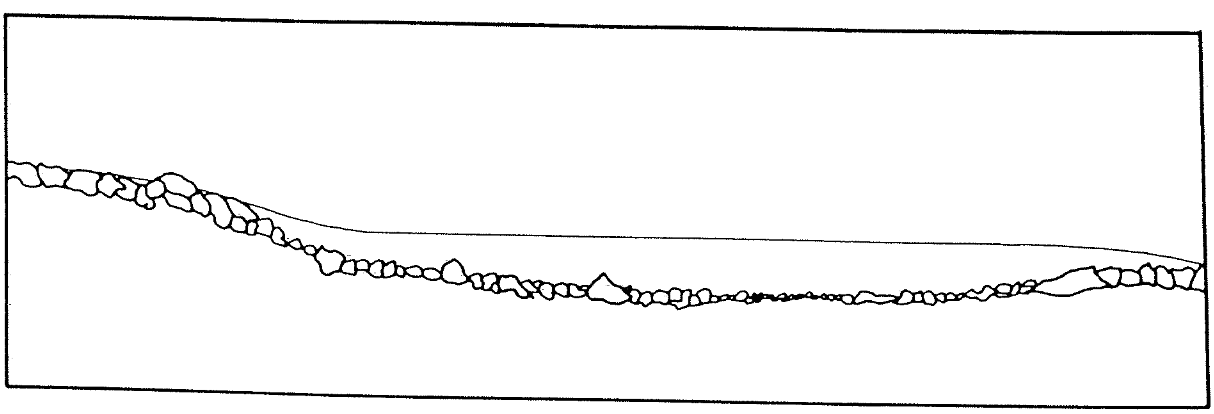
Figure 1. Study Reaches on Bishop Creek.



HIGH-GRADIENT CASCADE: Water velocity extremely high, with considerable turbulence; hydraulic controls very closely spaced. Average water surface gradient very high, but may consist of closely spaced pools separated by falls.

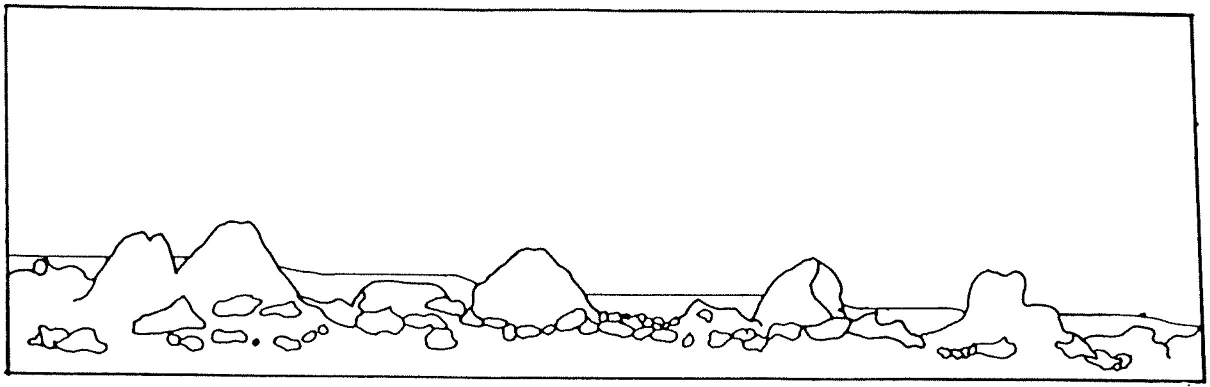


RIFFLE: Water velocity relatively high. Relatively shallow; water surface gradient high, but water level not determined by distinct hydraulic controls. Considerable surface turbulence; zero depth at zero discharge.

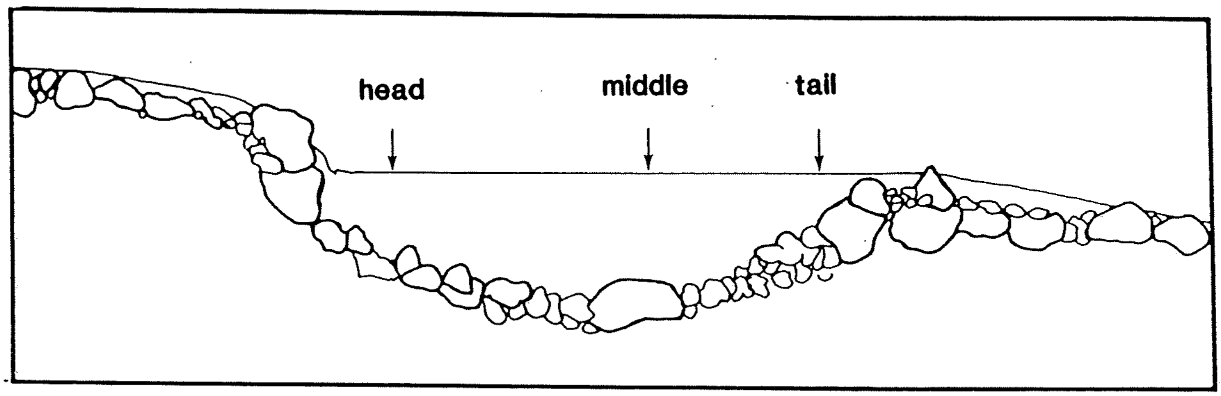


RUN: Relatively fast but nonturbulent flow; deeper than riffle but shallower than pool. Relatively deep, but fairly uniform in depth, without the distinct depression characterizing a pool.

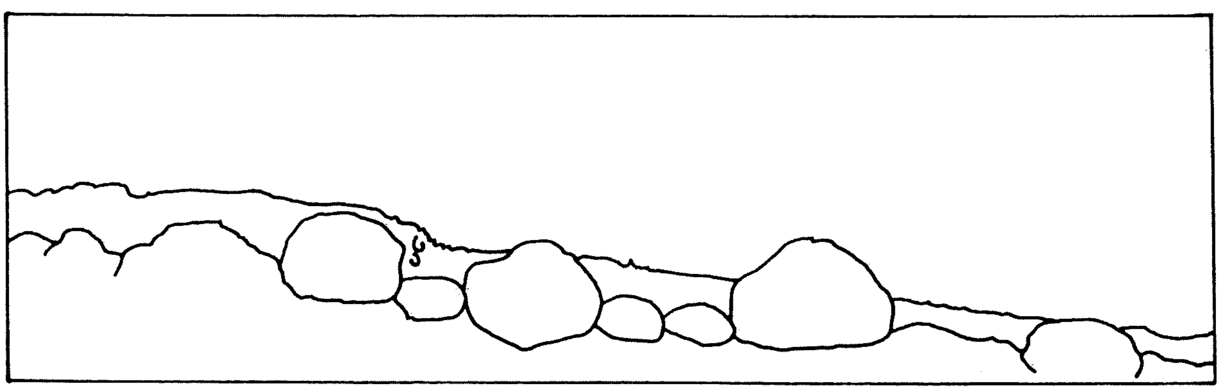
Figure 2a. Major habitat categories of Bishop Creek.



LOW-GRADIENT CASCADE: Run or riffle with frequent obstructions (e.g., boulders, logs) which result in diverse flow patterns.



POOL: Water velocity relatively low, nonturbulent. Relatively deep, with distinct longitudinal depression in stream bed. Water surface gradient very low; water level determined by a distinct hydraulic control.



MEDIUM-GRADIENT CASCADE: Water velocity moderately high; moderate turbulence. Hydraulic controls closely spaced. Average water surface gradient medium, but may consist of closely spaced pools interspersed with high-gradient stretches.

Figure 2b. (continued)

TABLE 1 TOTAL FEET OF EACH REACH OF BISHOP CREEK, PARTITIONED BY HABITAT. REACH 11 WAS PARTITIONED OUT OF REACH 08 AFTER MAPPING AS WAS REACH 10 OUT OF REACH 09.

Habitat Type	01	02	03	04	05	06	07	08/11	09/10	Total
H.G. Cascade			367	713	236	4065	1254	1391	5163	13,189
M.G. Cascade			133	778	837	2087	2380	3084	4091	9,299
L.G. Cascade	1037	1520	812	992	3970	1982	1002	1630	2102	15,047
Run	1976	2323	1495	1951	3598	1187	1623	1897	8101	26,102
Riffle	1087	516	291	654	3022	909	884	2028	4718	14,109
Pool	1924	1444	978	1495	991	1454	362	357	1266	10,271
Total	6024	5803	4076	6583	12,654	11,684	7505	10,387	25,441	86,066

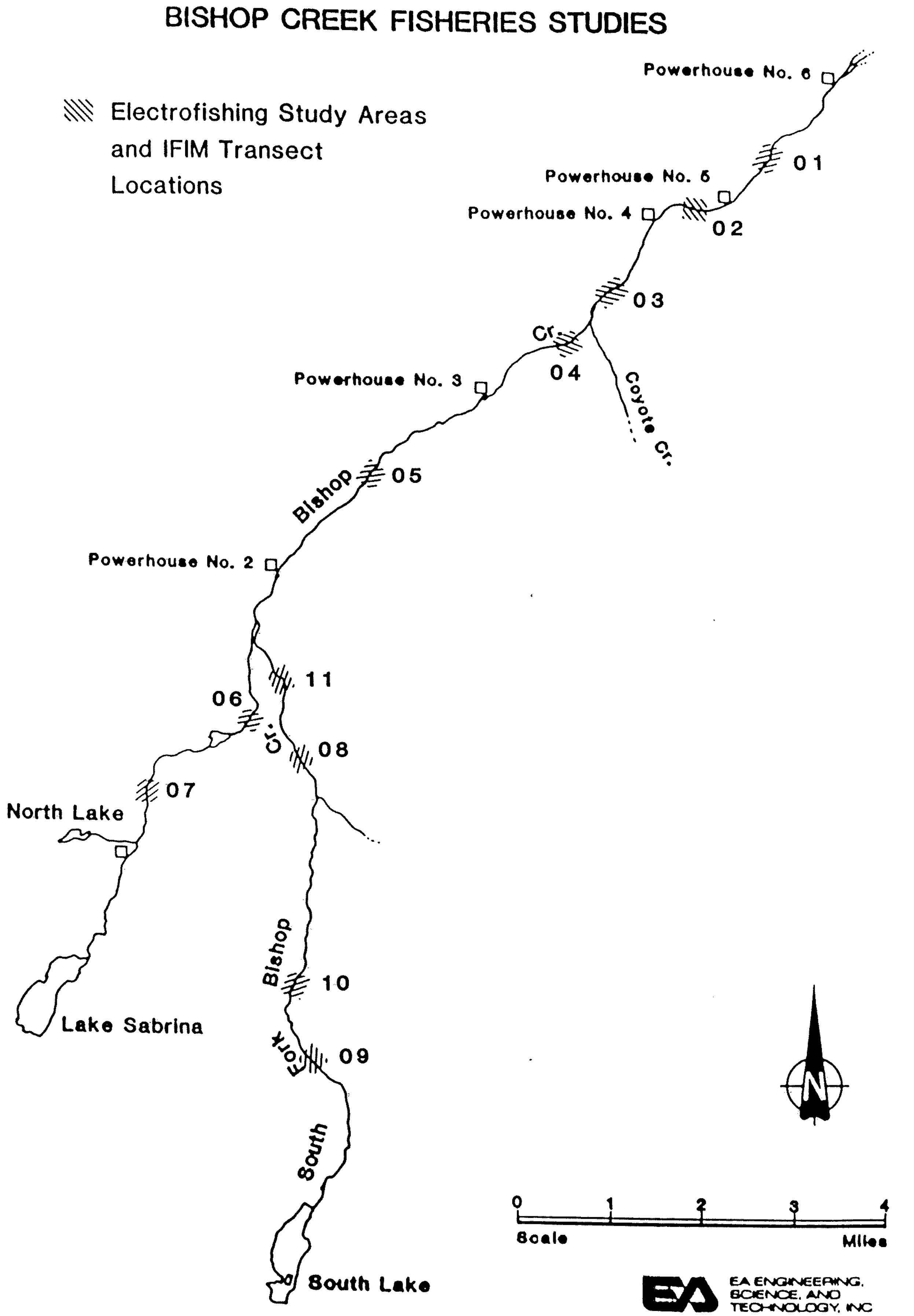


Figure 3. Locations of Electrofishing and PHABSIM transects on Bishop Creek.

pools and deep runs separated by cascades and falls, and the substrates are primarily boulders. The large pools in this reach require more than one transect for proper characterization. The transect area is upstream from the private property boundary above the Coyote Creek confluence.

Bishop Creek Reach 05 - This reach is the 3.2-mile portion of mainstem Bishop Creek between its confluence with the South Fork and Plant No. 3. It has a gradient and general morphology similar to Stream Reach 03, except that it is narrower and shallower, and the substrate rocks are smaller. Flows in most of this reach are controlled by releases from Plant No. 2, but flows in the upper half-mile are functions of releases from Intake No. 2 (the Plant No. 2 forebay) plus flows bypassed at the South Fork Bishop Creek diversion.

Bishop Creek Reach 06 - Reach 06 is the 1.5-mile section of Bishop Creek between Intake No. 2 and the confluence with South Fork Bishop Creek. Most of this reach is of high gradient (>400 ft/mile) and consists of a continuous series of cascades and small pools. Flows in this section are controlled by releases from Intake No. 2. The bed size is markedly smaller than that of Reach 07 upstream from Intake 2, owing to the long duration of the existing diversions. The transect location, is just upstream from the South Lake road crossing.

Bishop Creek Reach 07 - This moderate-gradient (approximately 200 ft/mile) 1.7-mile stretch of the mainstem Bishop Creek between the confluence with the North Fork and Intake No. 2 has a greater diversity of habitats than Reach 06. The streambed is a mixture of high-gradient cascade-pool habitat intermixed with substantial areas of low-gradient riffles and rocky run habitat. The transect area is in the middle of Aspendell.

Bishop Creek Reach 08 and 11 - Reach 08 is the section of South Fork Bishop Creek between the diversion into Intake No. 2 and the Four Jeffreys Campground. Like Reach 06, the bed appears to have decreased in size through aggradation and is now quite different from the upstream reaches. The transect section is adjacent to and below Four Jeffreys Campground. Reach 11 is the high gradient area between the Four Jeffreys Campground and the confluence with the middle fork of Bishop Creek. The transect area is in the steepest part of the canyon.

Bishop Creek Reaches 09 and 10 - These reaches make up the portion of South Fork Bishop Creek between South Lake and the South Fork diversion. The 6.3-mile stretch of stream consists of a mixture of two fundamentally different types of habitat. The most abundant type (Reach 09) of habitat is a moderate-gradient situation typical of Reach 07. The second type (Reach 10) is very-low-gradient, open valley meadow stream of a type that occurs in Bishop Creek only in this reach. These meadow areas contain wide, deep pools, quiet deep runs, and occasional riffles. Substrates are generally sand or gravel. To characterize relationships between discharge and fish habitat in the two stream types, Transect Area 10 is in the meadow area downstream from both the Tyee Lakes Bridge and the highway crossing and Transect Area 09 is in the higher-gradient section just downstream of the Tyee Lakes Bridge.

Transect Selection:

One hundred and five transects were selected on Bishop Creek in the field by a team including representatives from the U.S. Forest Service and the California Department of Fish and Game. The distribution among habitat types on Bishop Creek is shown on Table 2.

Transect Measurements:

All measurements on Bishop Creek were made in October and November of 1984 at nominal flows of 30 cfs, 15 cfs, and 5 cfs.

All transects were sampled with the following methods: Two permanent headstakes were established, one on each bank, to define a cross-sectional transect line perpendicular to the streamflow. Sampling stations along the transect line were established at appropriate intervals to ensure that at least 15 stations were under water at low flow on Bishop Creek. The elevation of the streambed at each sampling station, relative to a bench mark (one of the headstakes), was measured using standard surveying equipment and techniques.

The substrate type for the cell represented by each station was assessed visually and assigned to categories of dominant and subdominant particle size. Cover information was recorded for each cell as the percentages of object cover, overhead cover, and velocity cover within it. Velocity cover was defined as an area of reduced velocity due to the obstruction of normal flow by streambed objects.

Stream depth and velocity were measured at each station for all discharge rates at all study sites. Velocity was measured directly at each station using a Marsh-McBirney hydrostatic flow meter placed 0.6 of the distance down the water column for station depths less than 2.5 feet, and 0.2 and 0.8 of the distance for all other station depths. In the latter case, an average value of the two readings was used to represent the mean column velocity. Depth was determined indirectly for each station by measuring the elevation of the water surface at each discharge and subtracting the known streambed elevation for each station.

The amount of water flowing through the study reaches during periods of sampling (calibration discharge rates) were determined from the measured depths and velocities for a single transect having morphological characteristics that permitted an accurate estimate of discharge (such as a uniform bedrock or cobble

TABLE 2 DISTRIBUTION OF HABITAT TYPES AMONG TRANSECTS ON BISHOP CREEK. WITHIN A REACH, ALL TRANSECTS OF THE SAME TYPE WERE WEIGHED EQUALLY, AND THE TOTAL WEIGHT OF TRANSECTS OF THE SAME TYPE WAS DETERMINED BY THE PERCENTAGE OF FEET OF THAT HABITAT TYPE AS DETERMINED FROM TABLE 1. HIGH GRADIENT CASCADE WAS TREATED AS THOUGH IT DID NOT CONSTITUTE HABITAT AND HAD NO WEIGHTED USABLE AREA, SINCE NO TRANSECTS WERE PLACED THROUGH IT.

Transect #	01	02	03	04	05	06	07	08/11	09/10
1	LGC	Ru	LGC	P	P	P	Ri	P	LGC
2	P	Ru	Ru	P	P	P	Ru	P	Ri
3	P	LGC	Ru	P	P	P	MGC	LGC	LGC
4	P	LGC	P	LGC	LGC	P	MGC	Ru	Ru
5	Ru	Ru	P	LGC	LGC	Ru	LGC	Ri	Ri
6	LGC	P	P	Ru	Ri	Ru	Ri	Ru	Ru
7	Ri	P	Ru	Ru	Ru	LGC	LGC	Ru	Ru
8	Ru	P	Ru	Ru	Ru	MGC	P	Ru	MGC
9	P	LGC	LGC	LGC*	MGC	MGC	P	MGC	Ri
10	Ri	LGC	Ru	P	Ru	MGC		MGC	Ri
11	P		LGC	P	LGC			MGC	Ru
12	P			P	Ri			P	Ru
13								P	Ru
14									Ru
15									MGC
16									Ru

P = Pool, Ru = Run, Ri = Riffle, LGC = Low Gradient Cascade, MGC = Medium Gradient Cascade. No transects were put through High Gradient Cascade because of the impossibility of hydraulic simulation modeling.

* Dropped from the analysis because of very complex changes in water surface elevations across the transects.

substrate). A permanent staff gauge was established for the study reach and monitored as depth and velocity readings were collected for each transect.

Data Adjustments:

One requirement of the IFG4 hydraulic simulation model is a uniform water surface elevation across the full extent of the transect line. The model uses this single water surface elevation to calculate depth at each station by subtracting the measured bed elevations. Because of the complex nature of many Sierran streams, water frequently exhibits a non-uniform elevation as it passes a line perpendicular to streamflow. Rocks and boulders in the stream may create several levels of water surface elevation. The extreme case of this phenomenon is a cascade, where a high-gradient stream passing through an uneven assortment of boulders results in large differences in water surface elevation. Other habitat types, such as runs and riffles, also sometimes exhibit non-uniform water surface elevations, although less frequently.

One approach to satisfying the model's uniform water surface elevation requirement is to break the transect line into a series of connected lines essentially following a uniform path across the stream. The primary disadvantage of this approach is that the transect line over which a uniform water surface elevation was measured at the first discharge rate will, in many cases, not exhibit a uniform elevation at the second or third discharge rate.

The approach used in the Bishop Creek study to overcome non-uniform water surface elevations was to establish a transect line straight across the stream channel and to adjust the measured bed elevations at certain stations along the line, in order to indicate water depths as accurately as possible for all stations at all flows, assuming a single uniform water surface elevation for each flow. Of the 105 transects used in the analysis, only one (Reach 04, T9) had water surface elevations so variable it was dropped from the analysis. No other adjustments were made to the input data.

In order to produce an index of the amount of habitat available in a stream, the variations in depth and velocity with flow that are the output of the hydraulic simulation must be input, along with indices of habitat utilization, into a version of the habitat model (HABTAT) of USFS.

An interagency group has recently finished a preference study for salmonids in East-side Sierra Nevada streams. A preliminary report (Aceituno et al. 1985) was published in January, and a final version was being readied for publication in November 1985 (Aceituno et al. unpublished). EA was furnished a draft copy of the preference curves in the final report (Appendix A) by its authors. Four versions of each of these curves were furnished, corresponding to four conditions of object and overhead cover in a stream: no cover, object cover only, overhead cover only, and a combination of object and overhead cover.

Once the hydraulic simulations for each transect were complete, for the Bishop Creek data, the simulated depths and velocities were evaluated using the HABTAT model modified by EA (called the HABSIM model) to accept habitat suitability functions specific to four different cover types (no cover, overhead cover, object cover, and a combination of object and overhead cover). The data constituting the cover-specific curves were obtained from Appendix A of the final draft of the interagency study on streams of the eastern Sierra Nevada (Aceituno et al. unpublished). The data, with one exception, consisted of the four cover-type curves for each of four life stages (adult, juvenile, fry, and spawning) of brown and rainbow trout, with respect to depth and velocity. These curves are included as Attachment 1. For adult rainbow trout, the report used single curves for depth and velocity of rainbow trout taken from Bovee (1978).

It appears that, except for the data from Bovee (1978), the researchers made random observations of water depths and velocities in the streams where preference observations were made. These randomly chosen observations were used to adjust the cover-specific suitability functions to take into account the relative availability of various depths and velocities, and the functions are thus "preference curves" rather than utilization curves.

Weighted Usable Area and Percent Usable Area:

The results of the PHABSIM Studies are reported both as Weighted Usable Area (WUA) expressed as square feet per 1,000 linear feet of stream, and as Percent Usable Area (PUA) expressed as percent of total surface area consisting of Weighted Usable Area to correspond to the approach used by Oak Ridge National Laboratory in their tests of the Instream Flow Incremental Methodology (Loar et al. 1985).

Fish Populations:

Fish populations were sampled in all of the reaches used for instream flow transects in Bishop Creek in October and November of 1984, and in Reaches 01, 02, 03, 04, 05, and 08 (the diverted reaches) plus Reach 07 (undiverted reach upstream from Intake No. 2) in November of 1985.

Block nets were positioned at the upstream and downstream ends of the site to insure no movement in or out of the study area during the sampling period. Sampling was conducted by a crew of 3 or 4 biologists with a Smith-Root Mark VII backpack electrofisher. Block or rock salt was placed upstream of the sample site. Three independent passes were made through each sampling site. A constant level of sampling effort was maintained in each pass by monitoring electrofisher on-time and duration of the sampling effort. During each pass all shocked fish were collected by dip net, weighed on a volumetric basis (assuming an equivalence of one gram of wet fish tissue weight to one milliliter of water displaced), measured for fork length, and removed temporarily from the study reach.

The length of each reach sampled is shown in Table 3, along with electrofishing data from Deinstadt et al, 1985. The number of fish captured was converted to the number of fish estimated in the reach using the Zippin (1958) technique. This in turn was converted to pounds per acre, pounds per mile, and total numbers per mile.

Condition Factor:

In 1984, groups of fish were weighed together, preventing calculation of condition (plumpness). In 1985, however, all fish were weighed individually and condition was calculated for all fish captured as $(100{,}000 * g)/(\text{Forklength (mm)})^3$ (Anderson and Gutreuter, 1983)

Additional fish were captured in December 1985 in Reaches 01, 05, and 08 and were weighed to greater precision using a triple beam balance. In this supplemental study both standard and fork lengths were measured as well, and condition factors were calculated as functions of both.

Stream flows:

None of the study reaches in any of the streams was gauged at the time those studies were done, but the Southern California Edison Company Regional Hydrographer was able to make reasonable estimates of the mean monthly flows for 1983, 1984, and 1985 in all reaches of Bishop Creek. These estimates were subsequently used to calculate mean annual monthly minimum WUA and PUA for each reach in order to compare effects of variation in WUA and PUA on existing fish populations.

TABLE 3. LENGTH OF STUDY REACHES SAMPLED BY ELECTROFISHING ON BISHOP CREEK.

Reach	Year	Length Sampled (ft)	Source
01	1984	308	EA Engineering
02	1984	246	EA Engineering
03	1984	270	EA Engineering
04	1984	310	EA Engineering
05	1984	322	EA Engineering
06	1984	330	EA Engineering
07	1984	140	EA Engineering
08	1984	275	EA Engineering
09	1984	325	EA Engineering
10	1984	285	EA Engineering
11	1984	154	EA Engineering
01	1985	319	EA Engineering
02	1985	320	EA Engineering
03	1985	310	EA Engineering
05	1985	295	EA Engineering
06	1985	254	EA Engineering
07	1985	240	EA Engineering
08	1985	273	EA Engineering
1	1981	243	Deinstadt et al 1985
2	1981	240	Deinstadt et al 1985
3	1984	300	Deinstadt el al 1985
4	1984	260	Deinstadt et al 1985
5	1984	270	Deinstadt et al 1985
SF1	1984	324	Deinstadt et al 1985
SF2	1984	276	Deinstadt et al 1985
SF3	1984	272	Deinstadt et al 1985
SF4	1984	300	Deinstadt et al 1985

RESULTS

Density of Fish in Bishop Creek:

Figures 4, 5, and 6 show the number of brown trout, of all sizes per mile, pounds of brown trout per acre, and pounds of brown trout per mile for Bishop Creek in 1981, 1984, and 1985. EA electrofished in late October and November (shown as November on those figures) in both 1984 and 1985 and nearly one hundred percent of the catch was brown trout. Deinstadt et al. (1985) electrofished in April, June, and July, when large numbers of stocked catchable rainbow trout were present, and they captured a number of these as well. Deinstadt's rainbow trout data are not reported here.

Size Distributions of Fish in Bishop Creek:

Figures 7, 8, and 9 show the size distribution of brown trout in Bishop Creek in 1984 and 1985.

Length-Weight Relationships of Brown Trout in Bishop Creek:

The regressions of weight on fork length in Bishop Creek by reach for the October/November 1985 data are shown in Figure 10. These regressions do not differ significantly from one another, and the single regression based on all data points is shown in Figure 11. A similar regression of weight on fork length for the weight data taken in December 1985 using a triple beam balance is shown in Figure 12. The slopes and intercepts are similar but the scatter is less in Figure 12 because of the greater precision of using the triple-beam balance over that of measuring volumetric displacement. Figure 13 illustrates the same relationship based on standard length, which results in an identical slope.

Condition of Brown Trout in Bishop Creek:

Figure 14 illustrates the fork length condition factors of brown trout captured in October and November 1985 and weighed volumetrically. There is a great deal of variability in the data, but a general decrease in the value of the condition factor with size is noticeable, particularly in the pooled data to which a linear least squares line is fit in Figure 15. Despite the scatter, these data are approximately normally distributed with a mean fork length condition factor of 1.13 (Figure 16). A comparison among the reaches is shown in Figure 17.

Table 4 shows that there are significant differences in condition factors among the reaches, with fish in Reach 03 (below the Coyote Creek confluence) in better condition than those in any other reach except 04, just upstream, and those in Reach 07 (above the Intake No. 2 diversion) in better condition than those in Reach 6, downstream from it, and in Reach 08, downstream from a similar diversion on the south fork.

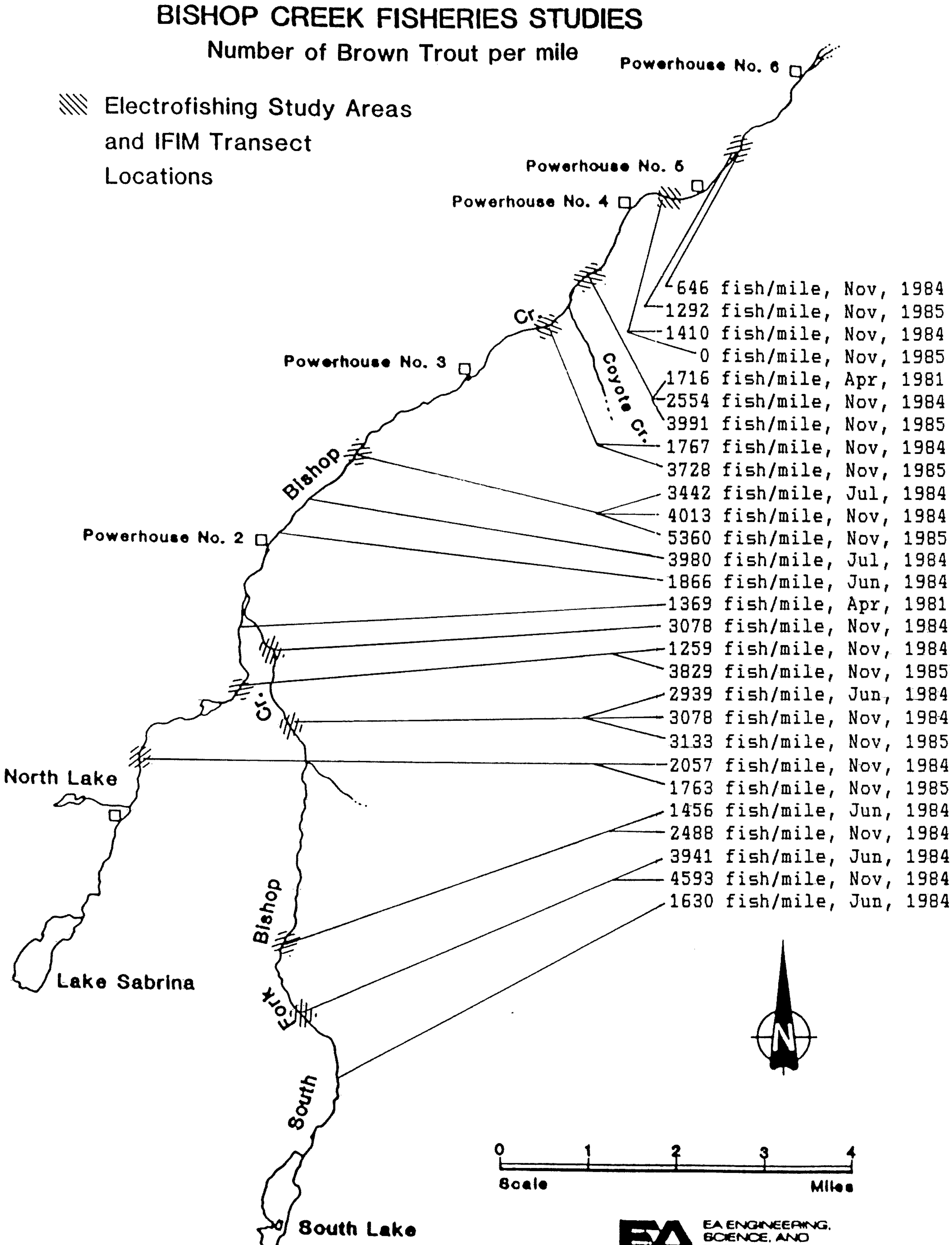


Figure 4. Number of brown trout per mile in Bishop Creek. Data from EA Engineering, Science, and Technology, Inc. (November 1984, 1985), and Deinstadt et al. 1985 (other dates).

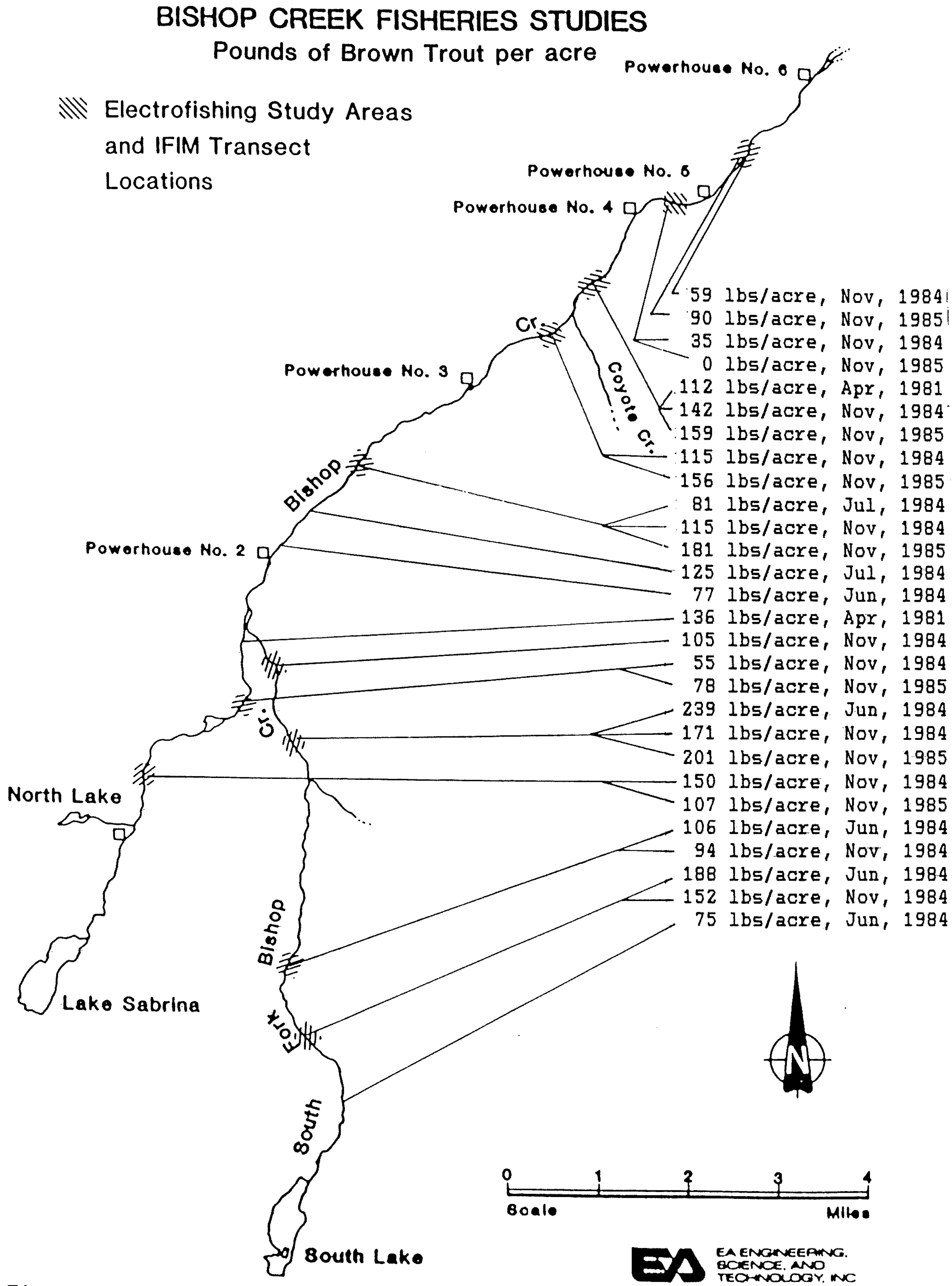


Figure 5. Pounds of brown trout per acre in Bishop Creek. Data from EA Engineering, Science, and Technology, Inc. (November 1984, 1985), and from Deinstadt et al. 1985 (other dates).

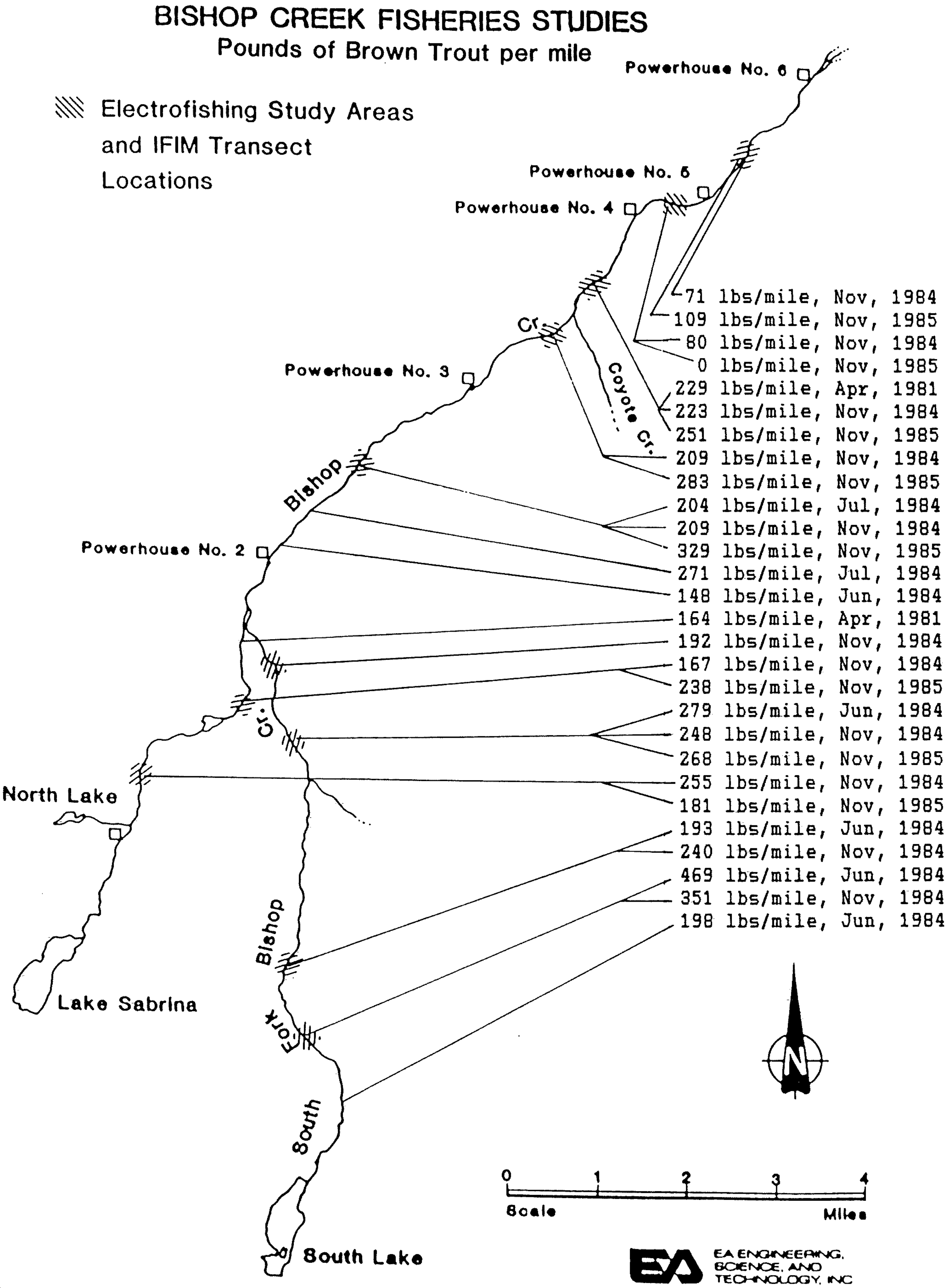


Figure 6. Pounds of brown trout per mile in Bishop Creek. Data from EA Engineering, Science, and Technology, Inc. (November 1984, 1985), and from Deinstadt et al. 1985 (other dates).

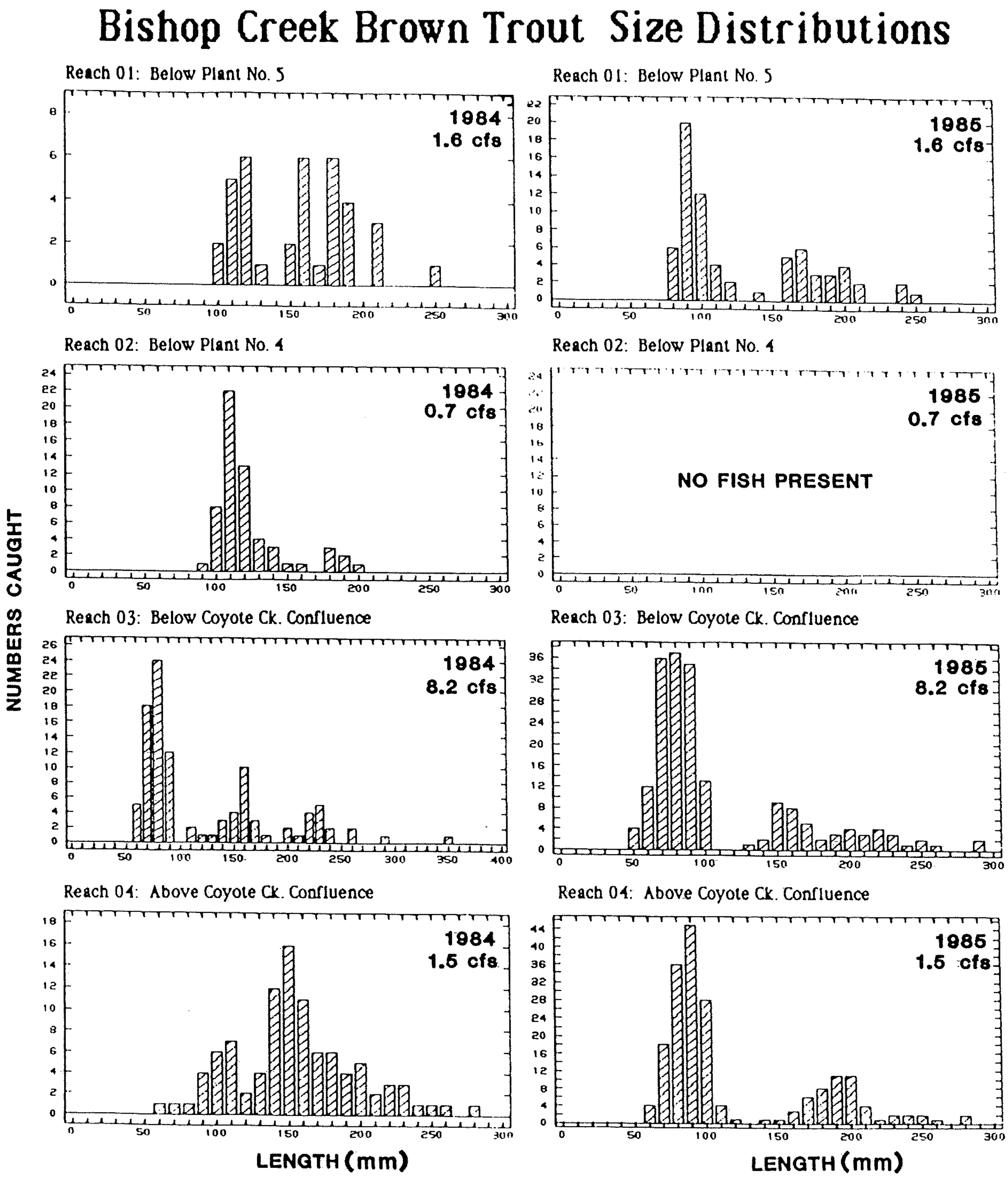


Figure 7. Length-frequency distributions of brown trout for the four lowest diverted reaches of Bishop Creek. Data collected in October and November by EA Engineering, Science, and Technology, Inc. Flows listed are normal year mean annual flows.

Bishop Creek Brown Trout Size Distributions

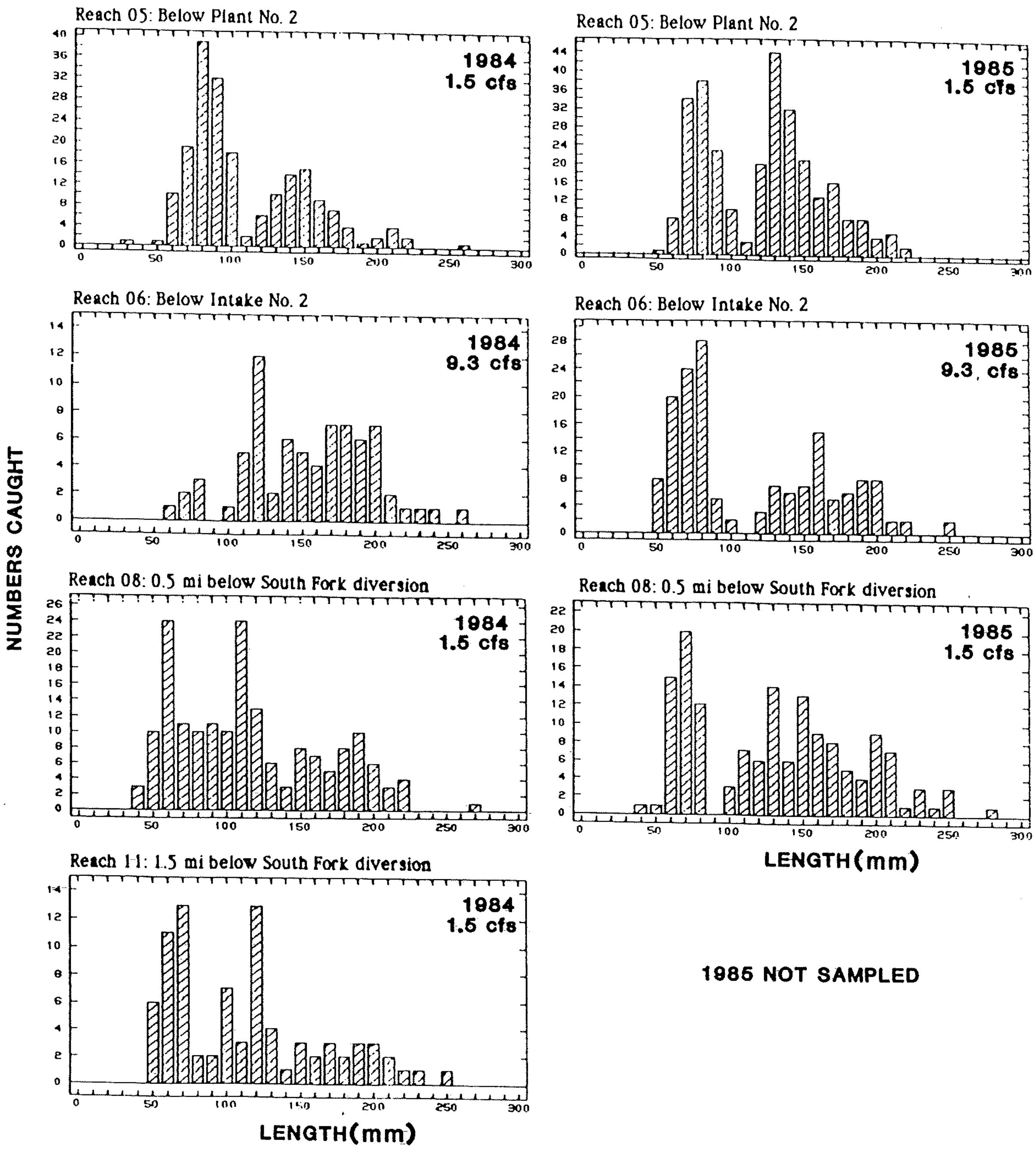


Figure 8. Length-frequency distributions of brown trout for the four upper diverted reaches of Bishop Creek. Data collected in October and November by EA Engineering, Science, and Technology, Inc. Flows listed are normal year mean annual flows.

Bishop Creek Brown Trout Size Distributions

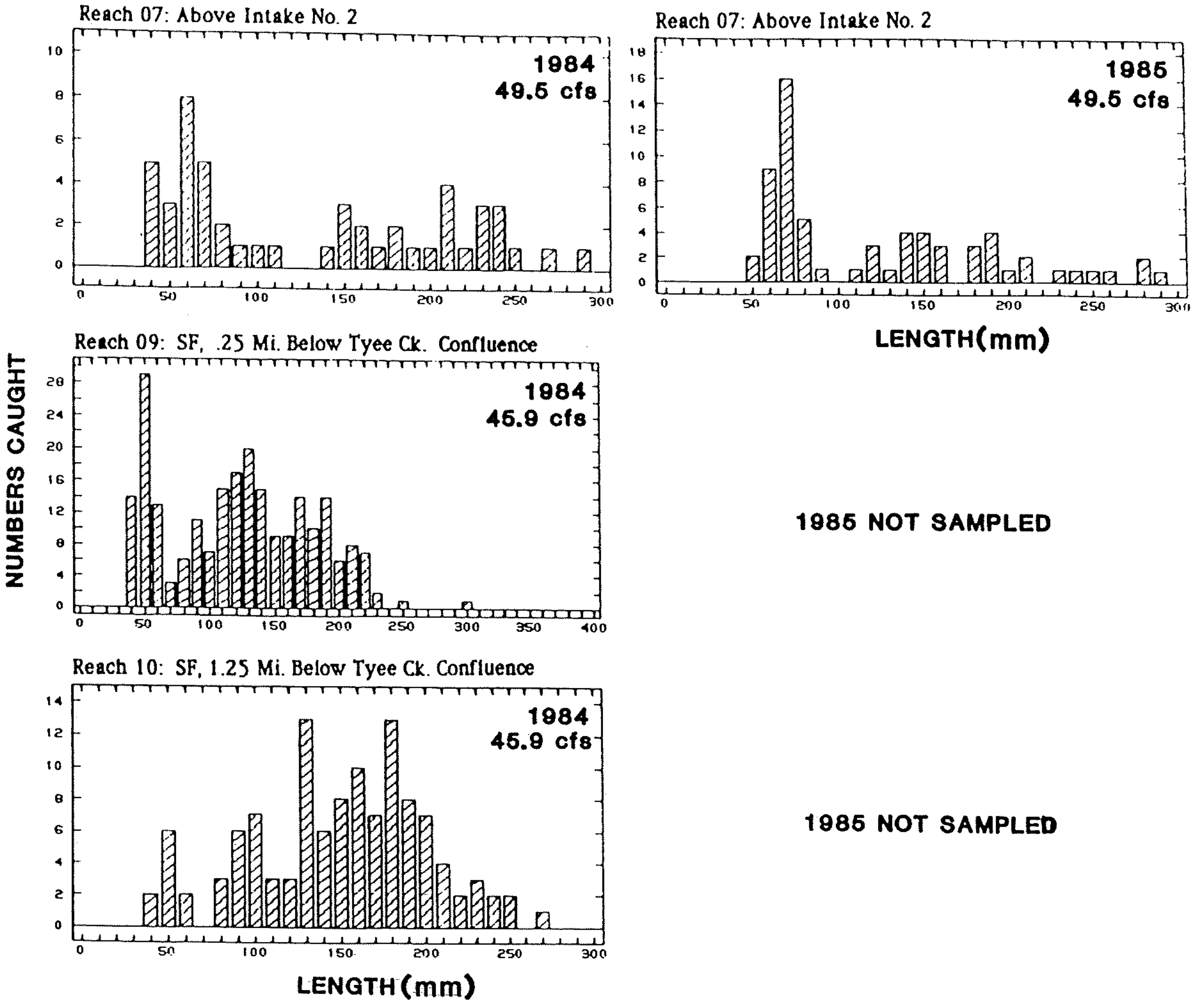


Figure 9. Length-frequency distributions of brown trout for regulated but not diverted reaches of Bishop Creek. Data collected in October and November by EA Engineering, Science, and Technology, Inc. Flows listed are normal year mean annual flows.

Bishop Creek Brown Trout Length-Weight Relationships

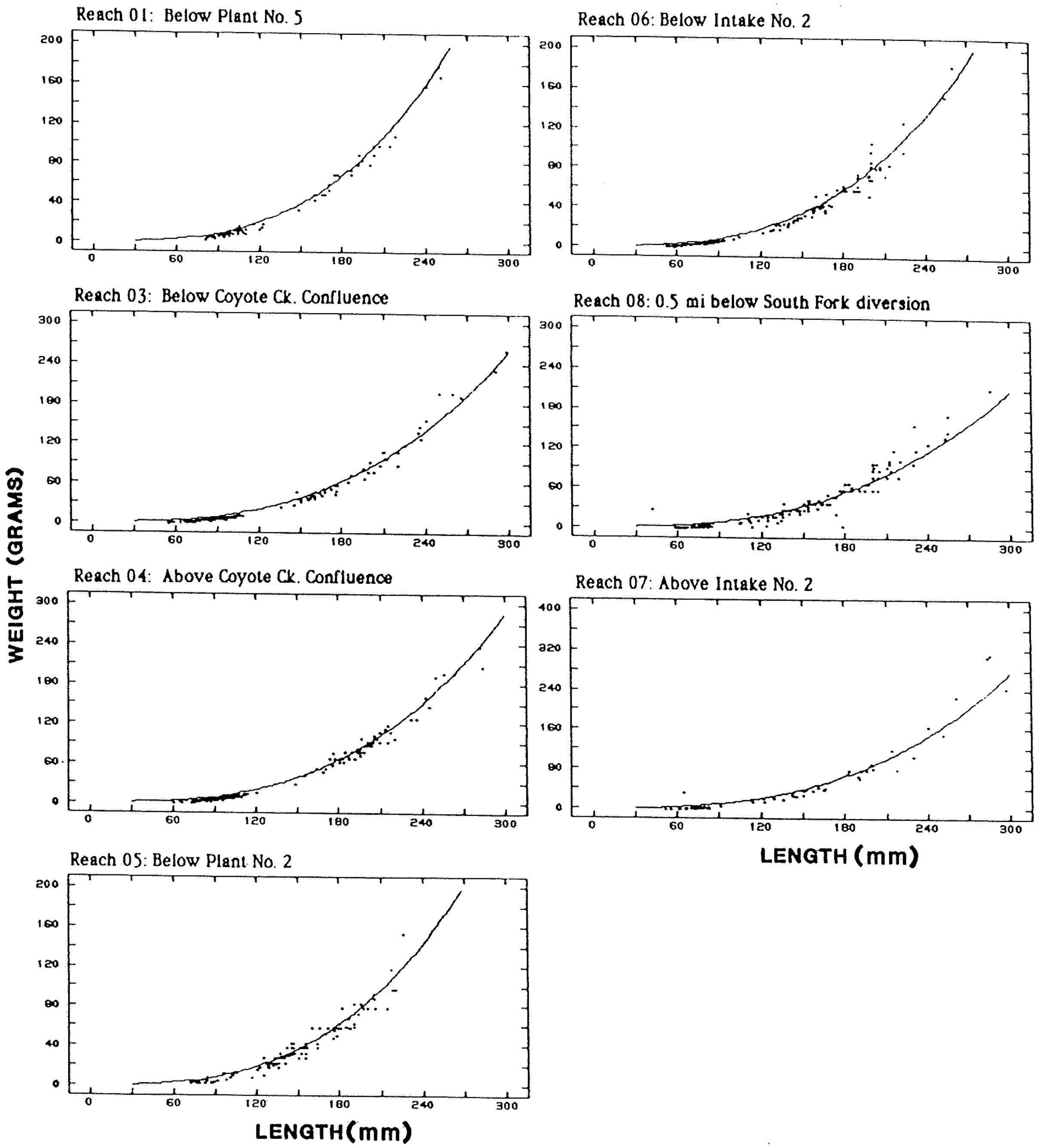


Figure 10. Length-weight regressions of brown trout caught in October and November 1985, in 6 diverted and 1 regulated reach of Bishop Creek. Data collected by EA Engineering, Science, and Technology, Inc.

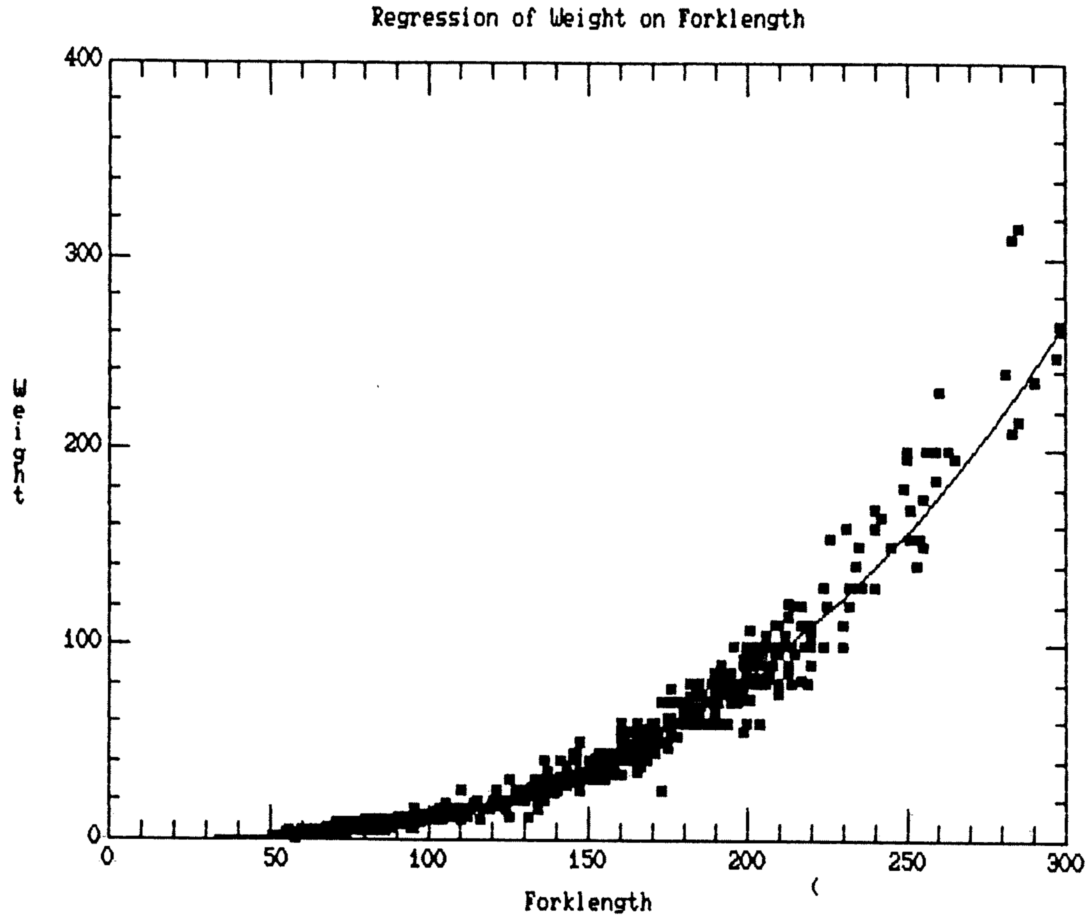


Figure 11. Regression of weight on forklength for brown trout captured in Reaches 01, 03, 04, 05, 07, and 08 of Bishop Creek in October and November 1985. Slope = 2.87, intercept = 10.79, r^2 = 0.98.

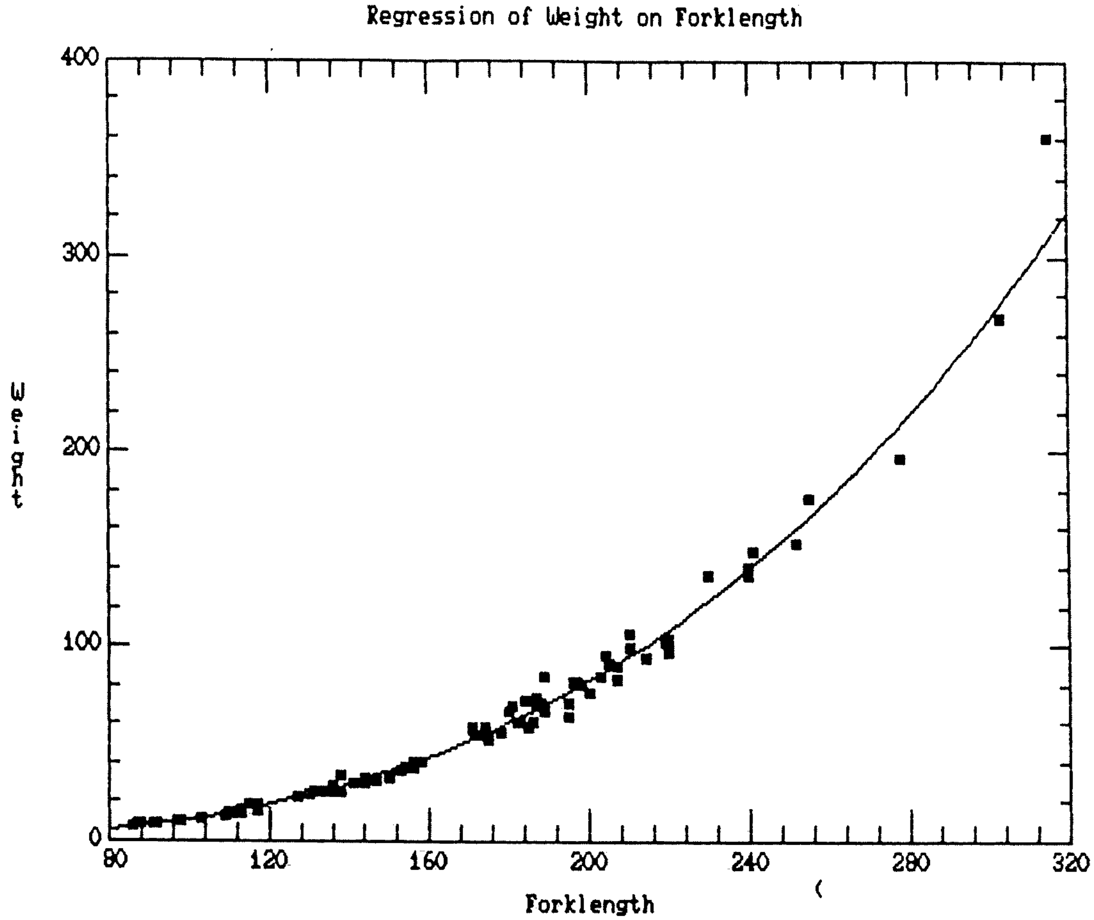


Figure 12. Regression of weight on forklength for brown trout captured in Reaches 01, 05, and 08 of Bishop Creek on December 20, 1985. Slope = 2.91, intercept = -11.0277, $r^2 = 0.99$.

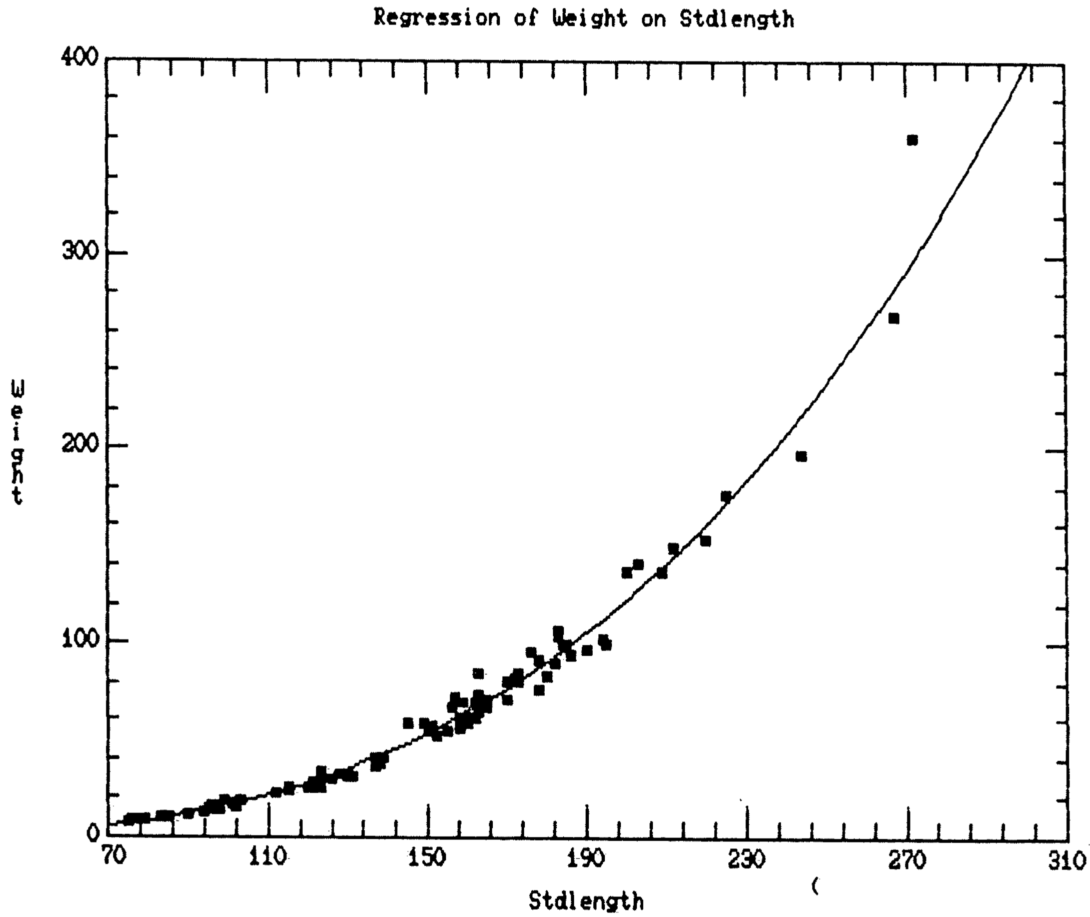


Figure 13. Regression of weight on standard length for brown trout captured in Reaches 01, 05, and 08 of Bishop Creek on December 20, 1985. Slope = 2.91, intercept = -10.60, r^2 = 0.99.

Bishop Creek Brown Trout Condition Factors

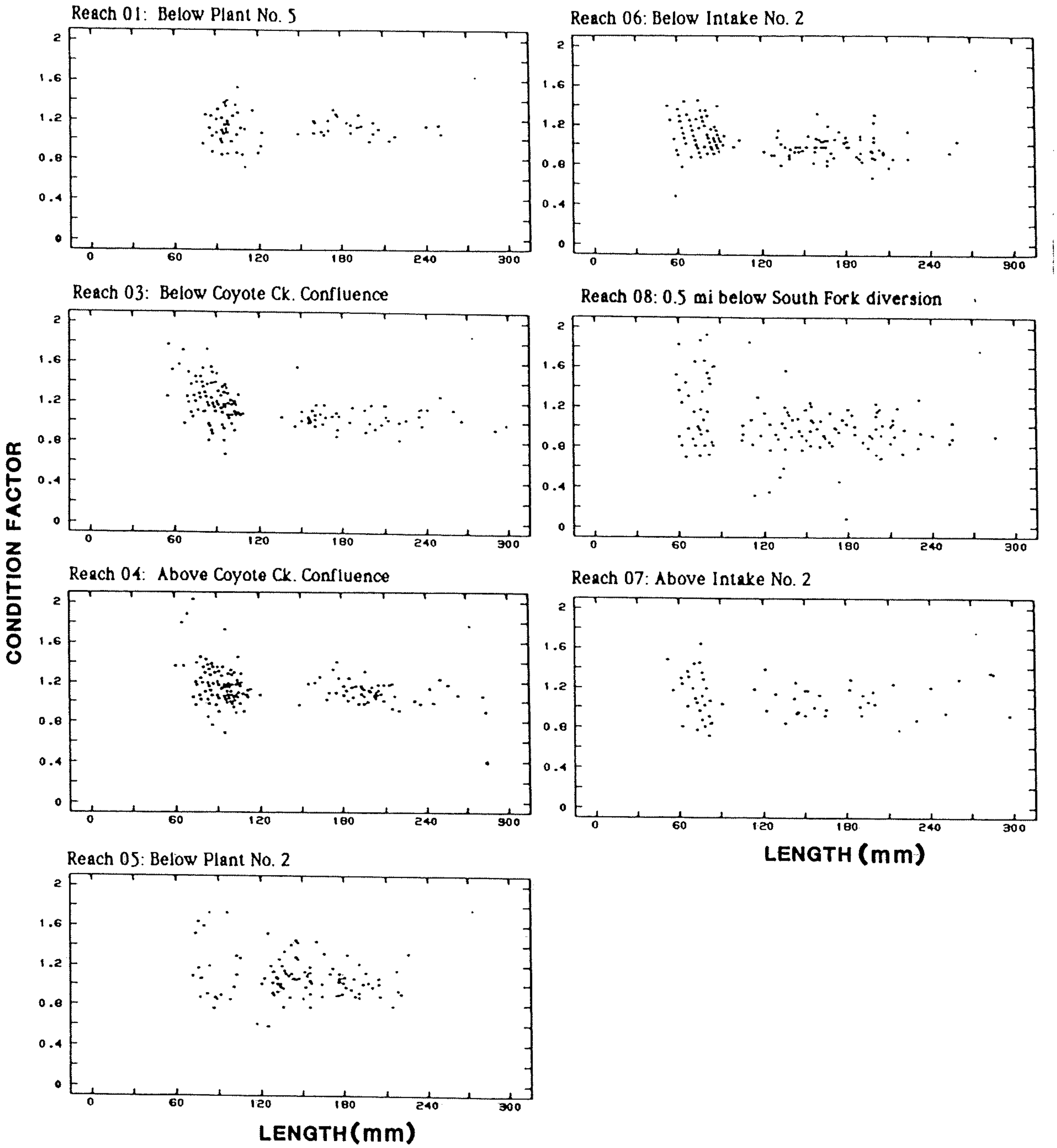
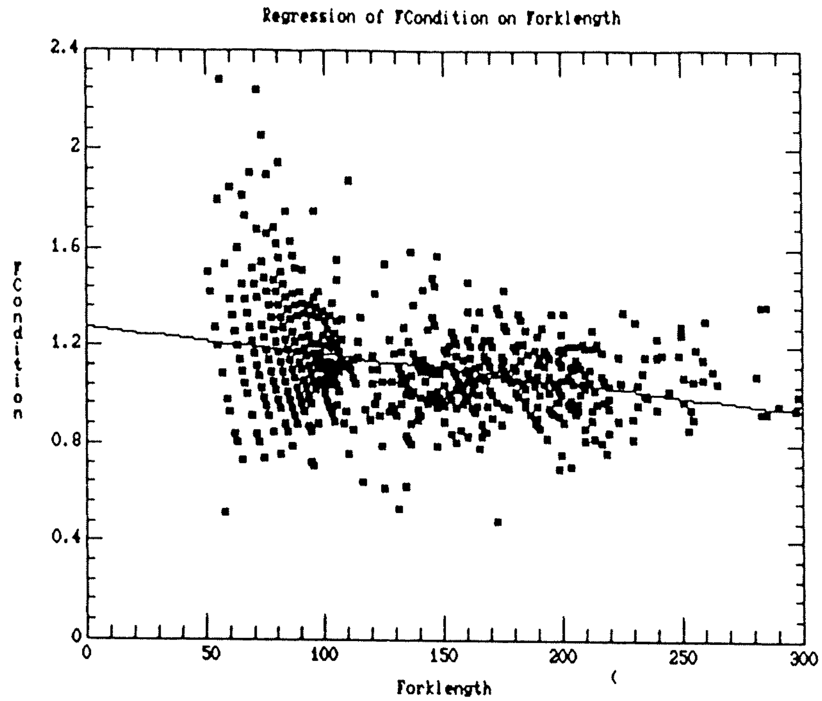


Figure 14. Condition factors (100,00 * g/forklength (mm)^3) for brown trout captured in Bishop Creek in Octoaber and November of 1984 and 1985.



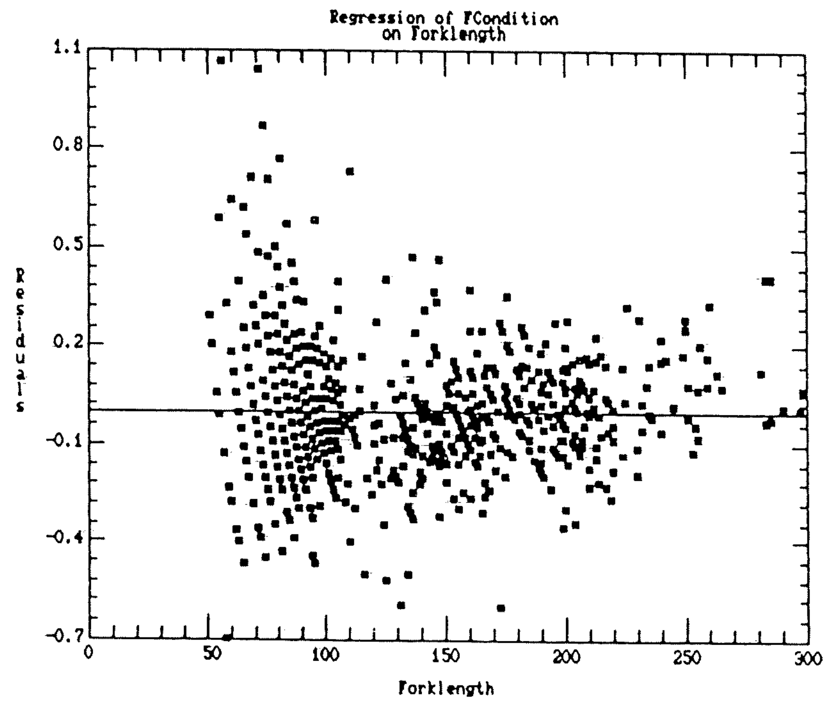


Figure 15. Condition factors (100,000 * g/forklength (mm)^3) for brown trout captured in Bishop Creek in October and November 1985.

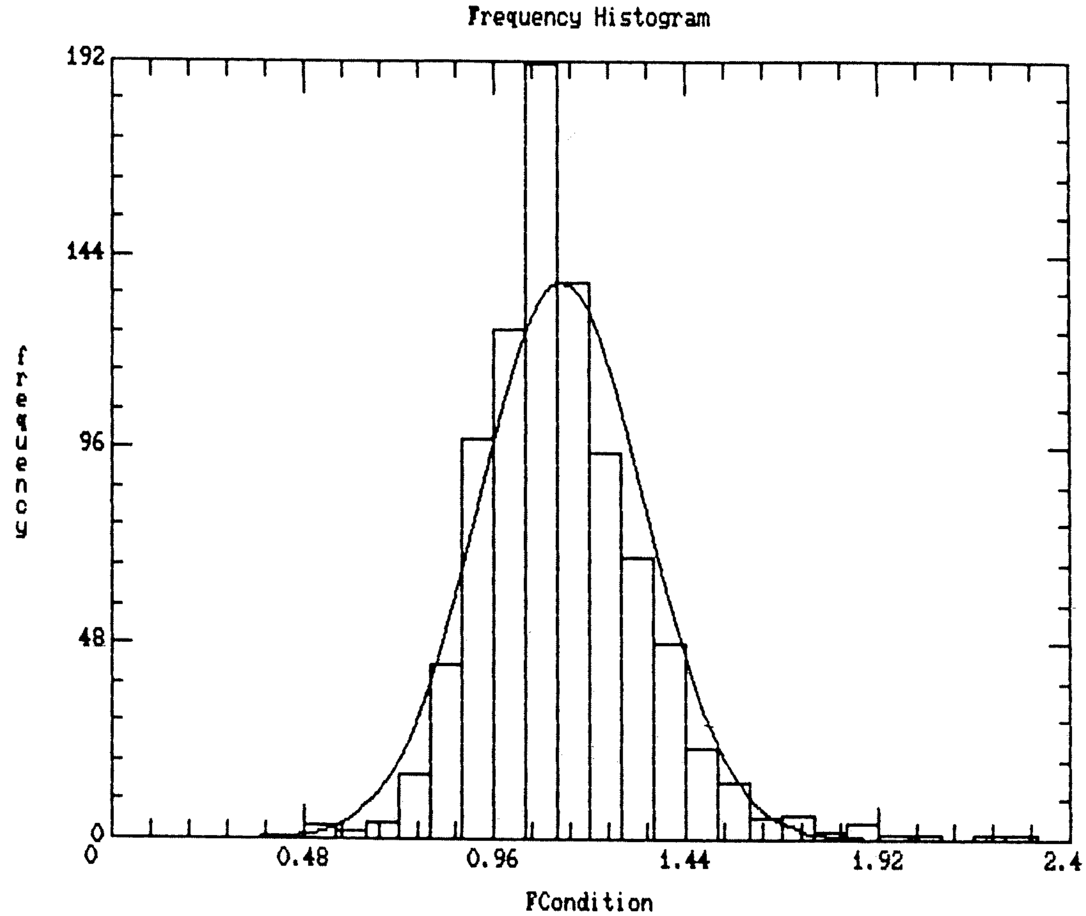


Figure 16. Frequency distribution of forklength condition factor for brown trout caught in Bishop Creek in October and November 1985. The mean of the superimposed normal distribution is 1.1302 with a standard deviation of 0.21.

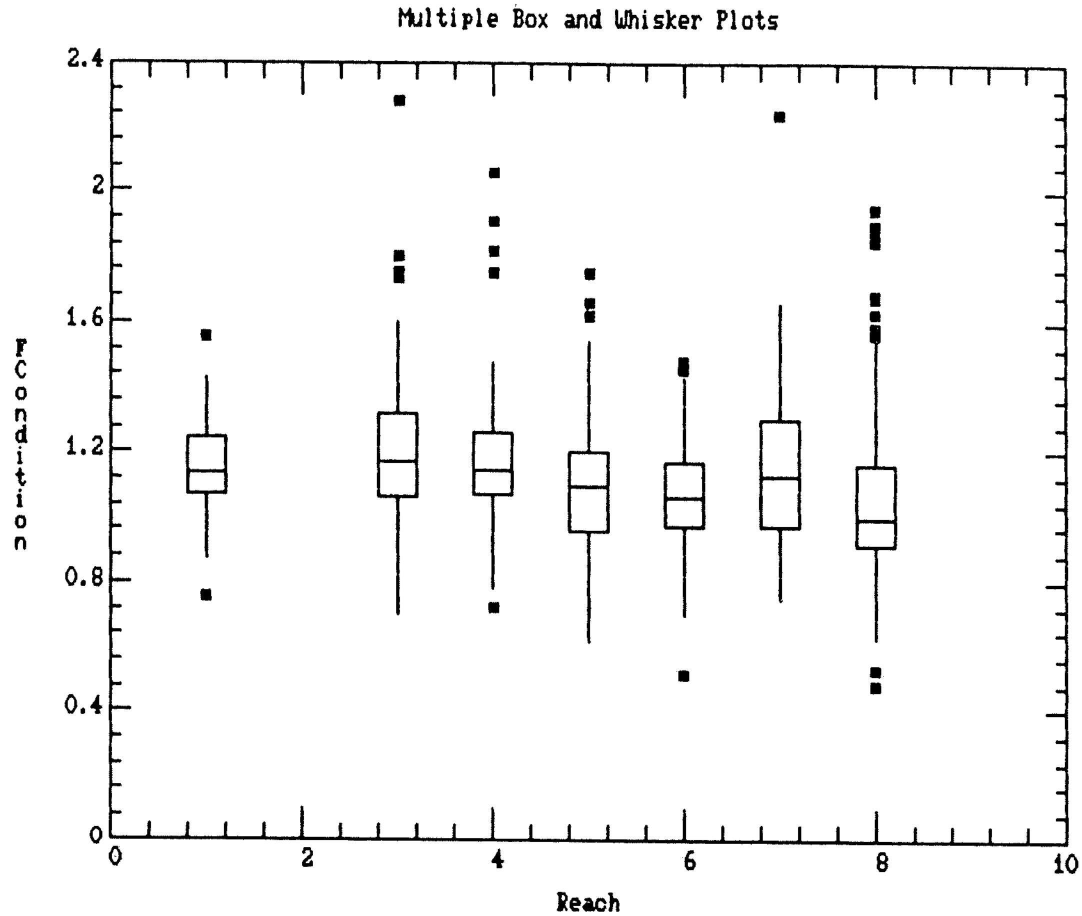


Figure 17. Box and whisker plot of condition factor (100,000 * g/forklength (mm) for brown trout captured in Bishop Creek Reaches 01, 03, 04, 05, 06, 07, and 08 in October and November 1985. Center lines are the median values which range from 1.0 for Reach 08 to 1.17 for Reach 03. The central box covers the range containing the middle 50% of the data values, between the upper and lower quartiles.

TABLE 4 RESULTS OF 1-TAILED "T" TESTS OF FORK LENGTH CONDITION FACTOR OF BROWN TROUT CAPTURED IN BISHOP CREEK IN OCTOBER AND NOVEMBER 1985

	Reach						
	01	03	04	05	06	07	08
Reach							
01	-	NS	NS	NS	<.001	NS	NS
03	0.02	-	NS	<.001	<.001	.039	<.01
04	NS	NS	-	.002	<.001	NS	<.001
05	NS	NS	NS	-	NS	NS	NS
06	NS	NS	NS	NS	-	NS	NS
07	NS	NS	NS	NS	.005	-	.013
08	NS	NS	NS	NS	NS	NS	-

Note: Numbers are the probabilities of being incorrect in assuming that the condition of fish in the reach listed on the left-hand side of the table are better than those across the top. Thus, there is a 3.9% chance (P = 0.039) that the fish in Reach 03 are not in better condition than those in Reach 07. NS means that the probability of being incorrect is >5%.

A similar treatment of the December 1985 data, in which weights were obtained using a triple beam balance, shows a similar decline in condition factor with size, but much less scatter of the data (Figure 18). The mean value of fork length condition factor for these fish was 1.049 (Figure 19), and for standard length condition factor, 1.58 (Figure 20). Figure 21 shows the relationship of fork length condition factor among Reaches 01, 05, and 08 in December 1985. The fish in Reach 01 are in significantly better condition than those in Reach 08.

Weighted Usable Area:

The basic results of this analysis consist of curves relating Weighted Usable Area (WUA) to flow in each stream reach. Graphs of these results are shown in Attachment 2. Three curves are shown for each life stage (adult, fry, juvenile, and spawning), and these represent the 3 complete simulations done for each of the three measured flows.

In order to simplify the data presentation, we have aggregated all of these curves into a single curve for each reach for brown trout (Figure 22) and a single curve for each reach for rainbow trout (Figure 23). The aggregation uses a minimum number of assumptions and produces a dimensionless scale of WUA versus discharge. The absolute magnitudes of the curves are meaningless, since all peak at a value of 1.0, but the location of the peaks and the rates of change, features often used as the basis of instream flow recommendations, are retained. The aggregation was done as follows:

1. For each species, each life stage, and each reach, the 3 curves resulting from the three one-flow hydraulic simulations were averaged, to produce a single average relationship between WUA and flow for each life stage and each reach.

2. The resulting average curves were then each normalized to a scale of 0-1, by dividing the entire curve by its maximum value.

3. For each reach, the averaged normalized curve for adults, fry, and juveniles of each species were averaged.

4. The resulting species- and reach-specific curves were then normalized again, producing a single curve for each reach peaking at a value of 1.0.

Existing Monthly Flows and Weighted Usable Area in Bishop Creek

Figure 24, 25, and 26 show the monthly average flows in the diverted reaches of Bishop Creek for normal, wet, and dry years.

Figures 27-32 show the mean monthly flows and corresponding adult brown trout Weighted Usable Area for 1983, 1984, and 1985.

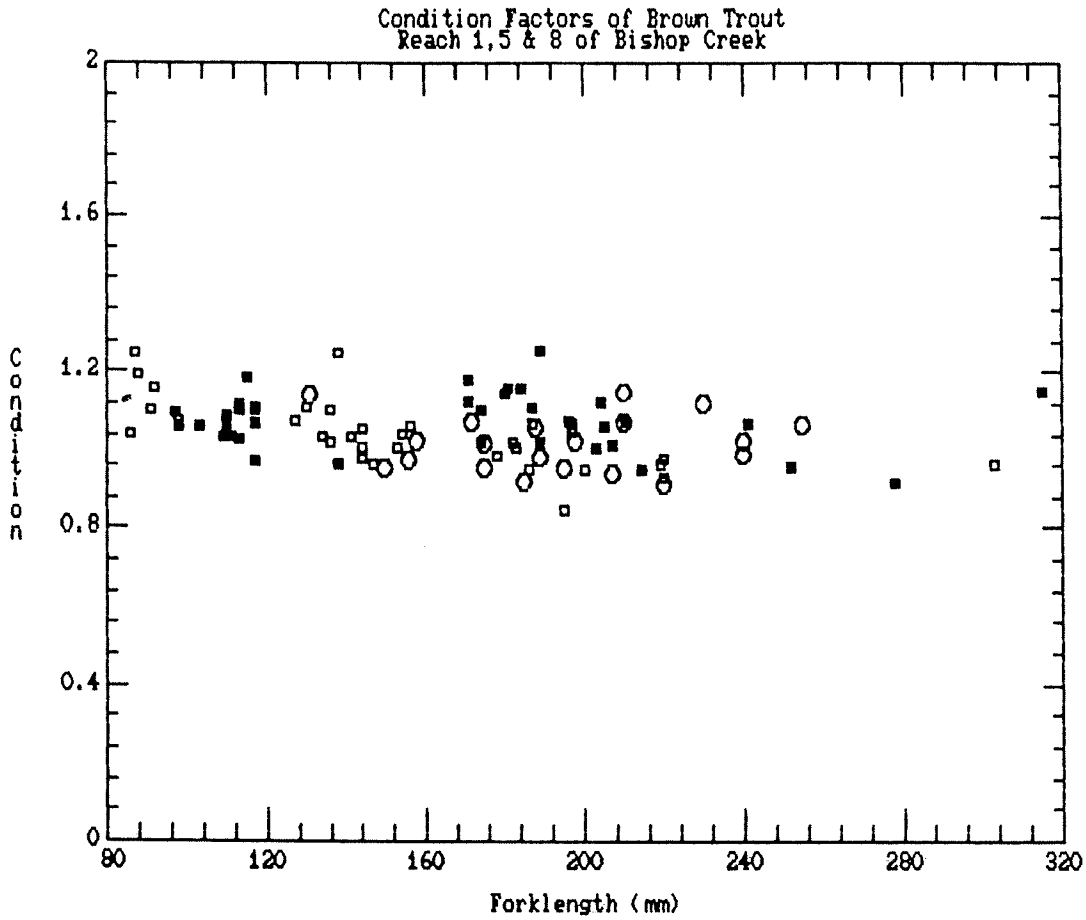
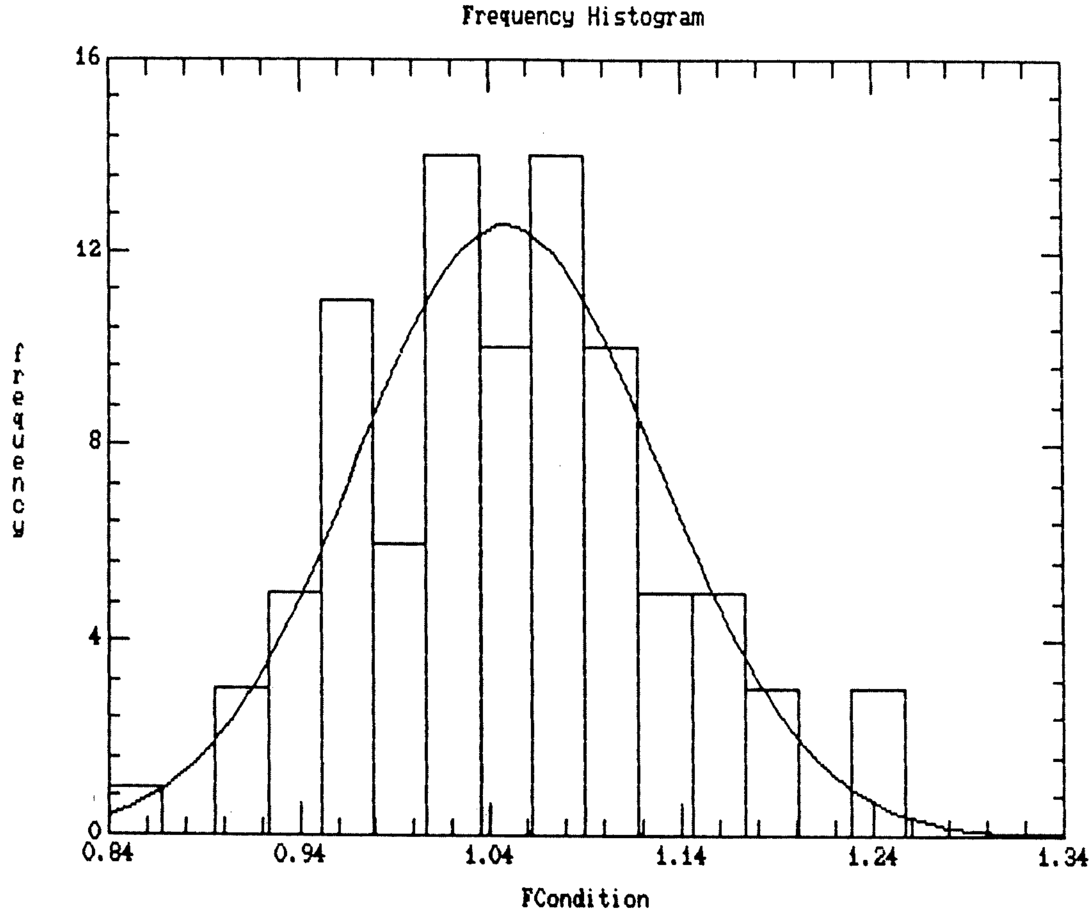
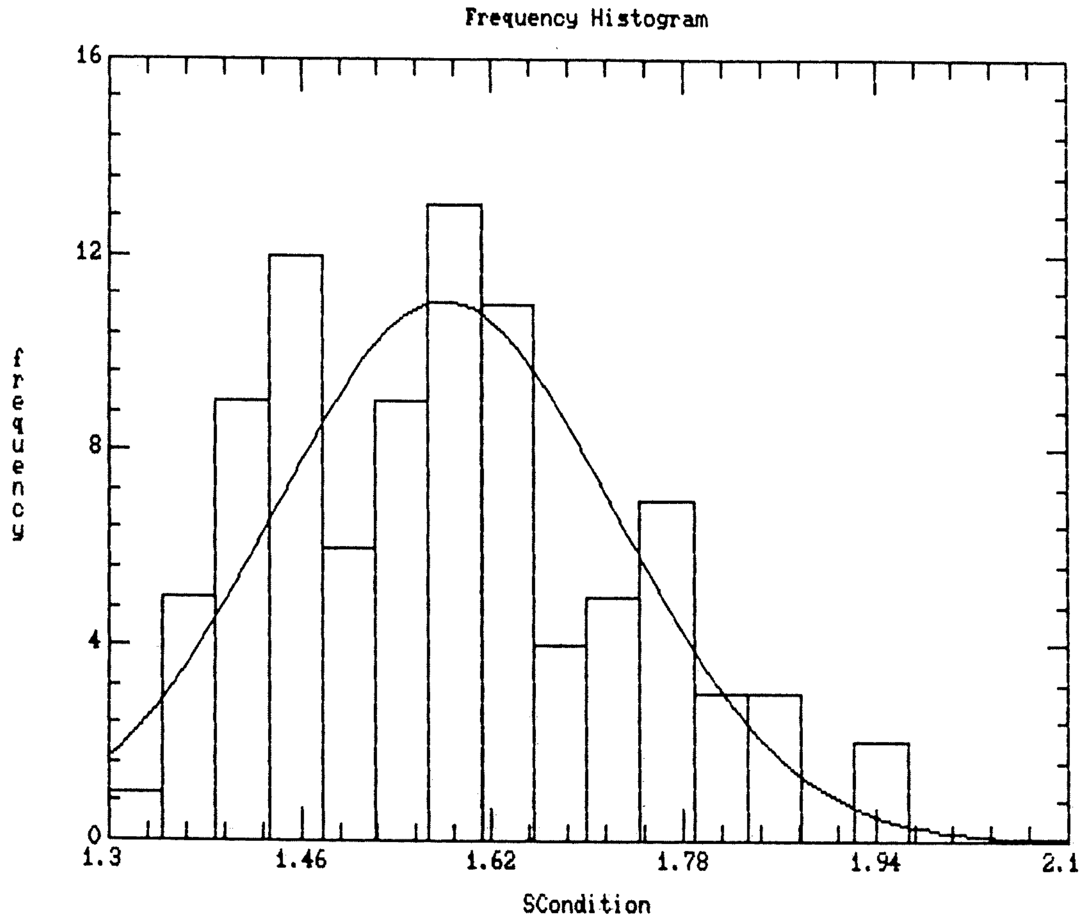


Figure 18. Condition factors (100,000 * g/forklength (mm)^3) for brown trout captured in Bishop Creek on December 20, 1985, in Reach 01 (▪) between plants 5 and 6, Reach 05 (▫) between Plants 2 and 3, and Reach 08 (○) just below the South Fork diversion.



ESTIMATED PARAMETERS: 1.0488 0.079316
CHI*2 GOODNESS-OF-FIT STATISTIC = 5.6484 WITH 6 DEGREES OF FREEDOM
PROBABILITY OF A LARGER VALUE = 0.4637

Figure 19. Normal distribution superimposed on frequency distribution of forklength condition factors for fish captured on December 20, 1985 in Reaches 01, 05, and 08 of Bishop Creek. Mean condition is 1.0488 ± 0.079 (sd).



ESTIMATED PARAMETERS: 1.5809 0.1444
CHI*2 GOODNESS-OF-FIT STATISTIC = 10.793 WITH 7 DEGREES OF FREEDOM
PROBABILITY OF A LARGER VALUE = 0.14791

Figure 20. Normal distribution superimposed on frequency distribution of standard length condition factor for fish captured on December 20, 1985, in Reaches 01, 05, and 08 of Bishop Creek. Mean standard length condition factor is 1.581 ± 0.144 (sd).

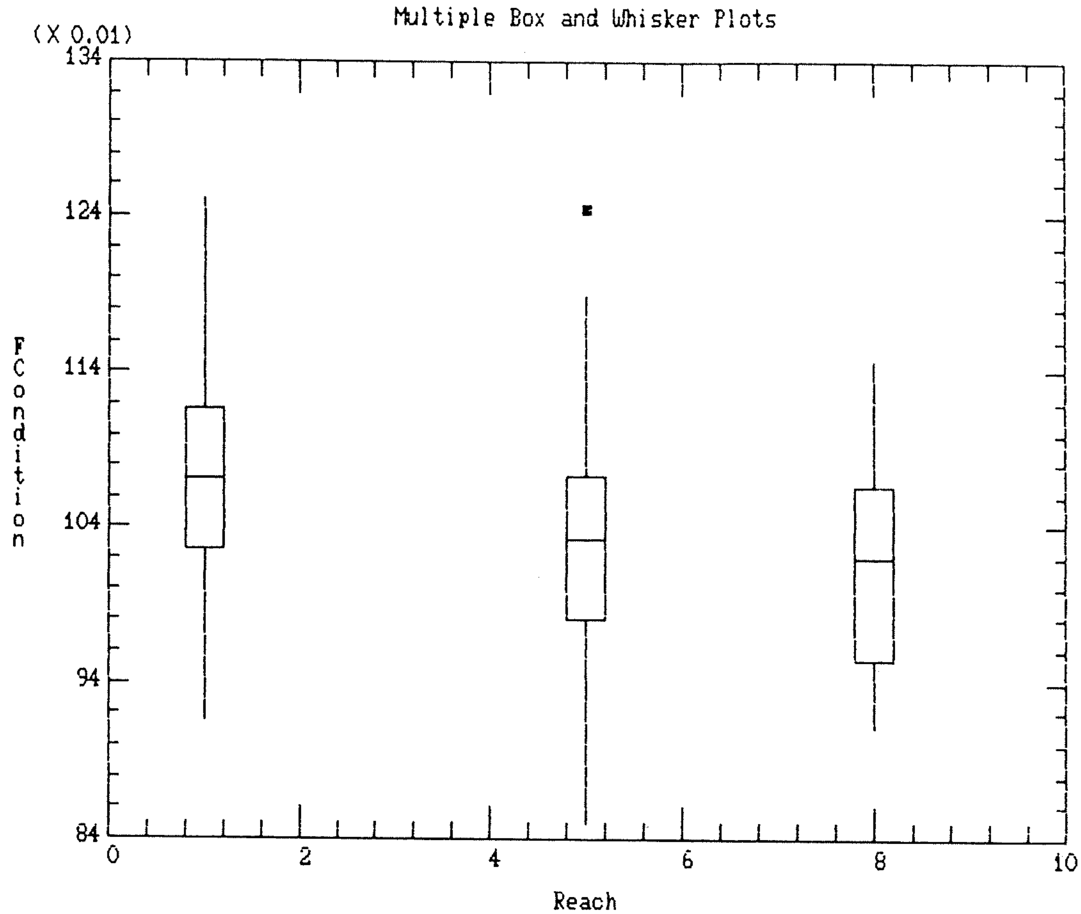


Figure 21. Box and whisker plot of condition factor (100,000 * g/forklength (mm)^3) for brown trout captured in Bishop Creek reaches 01, 05, and 08 in December 1985. Center lines are the median values. The central box covers the range containing the middle 50% of the data values, between the upper and lower quartiles.

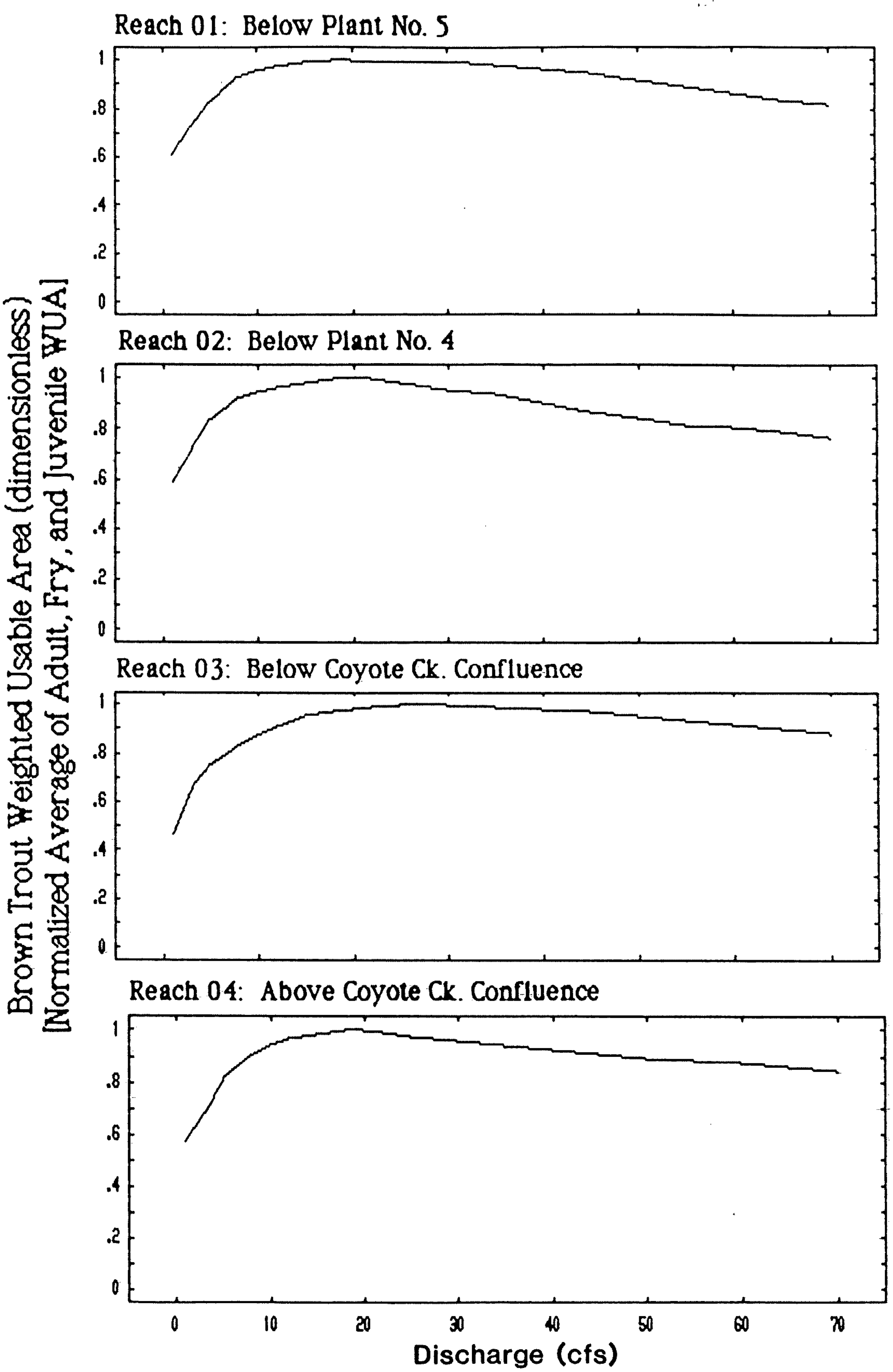


Figure 22. Normalized mean Weighted Usable Area as a function of discharge for brown trout adults, juveniles, and fry in Bishop Creek.

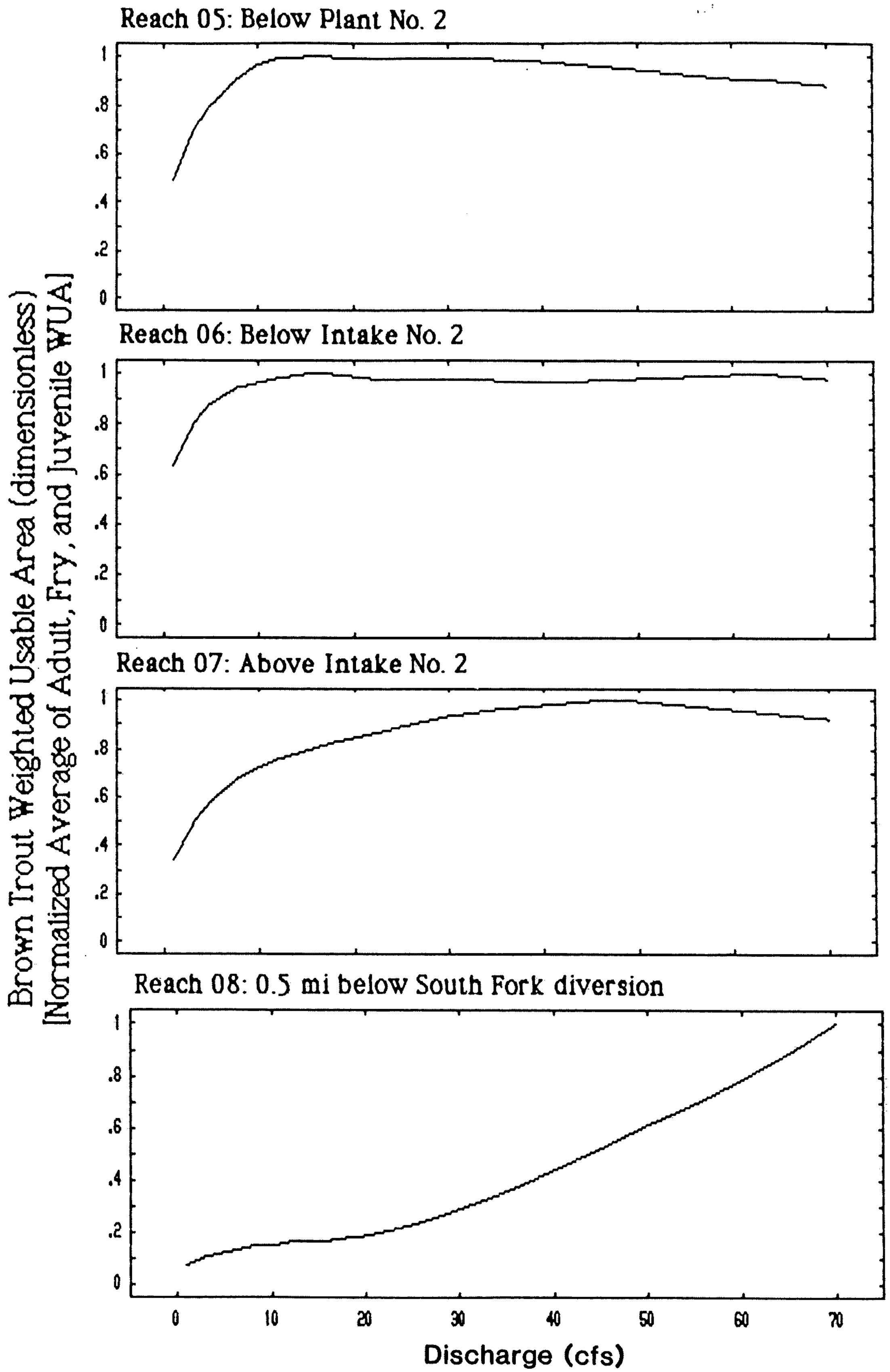


Figure 22. (continued)

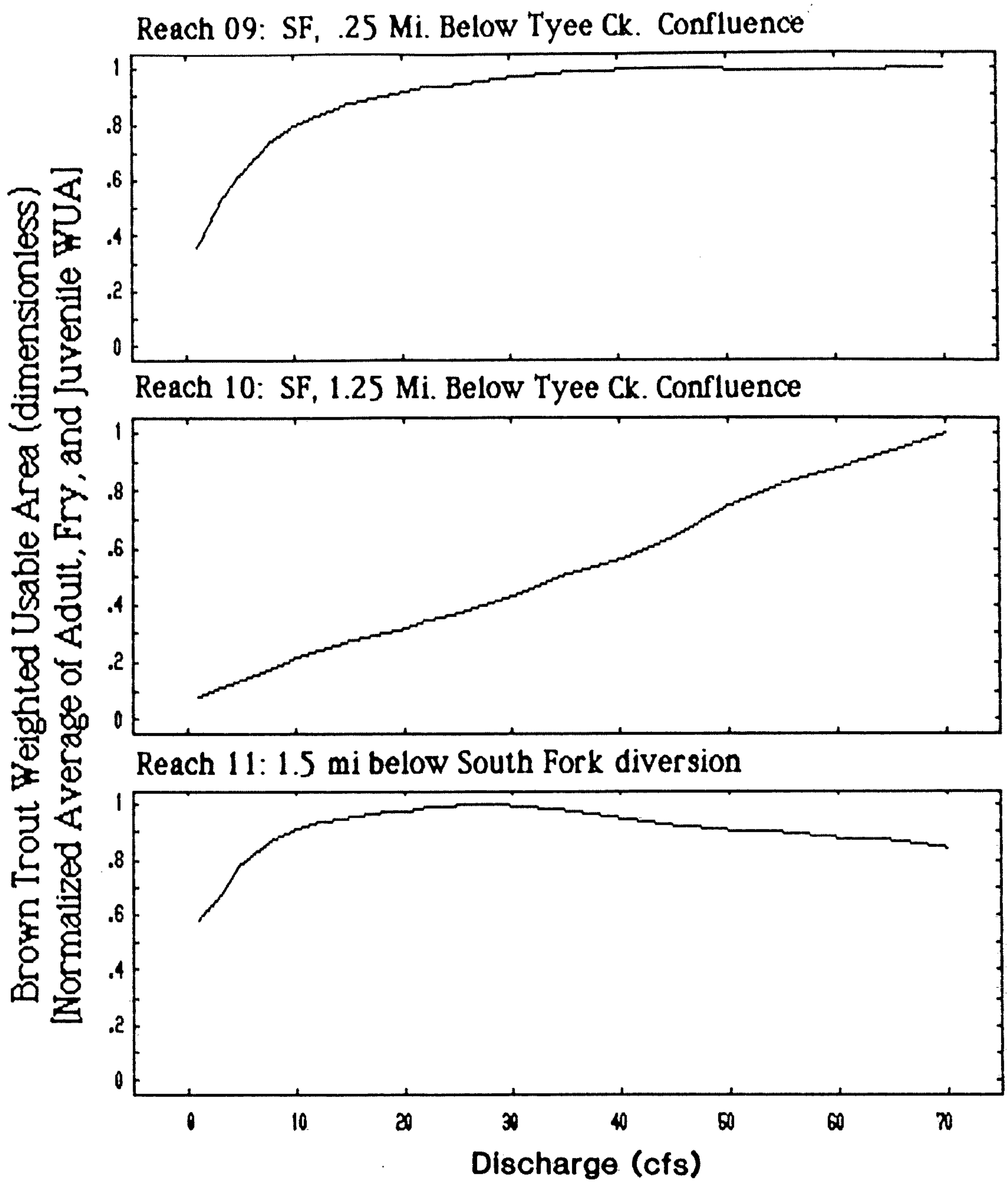


Figure 22. (continued)

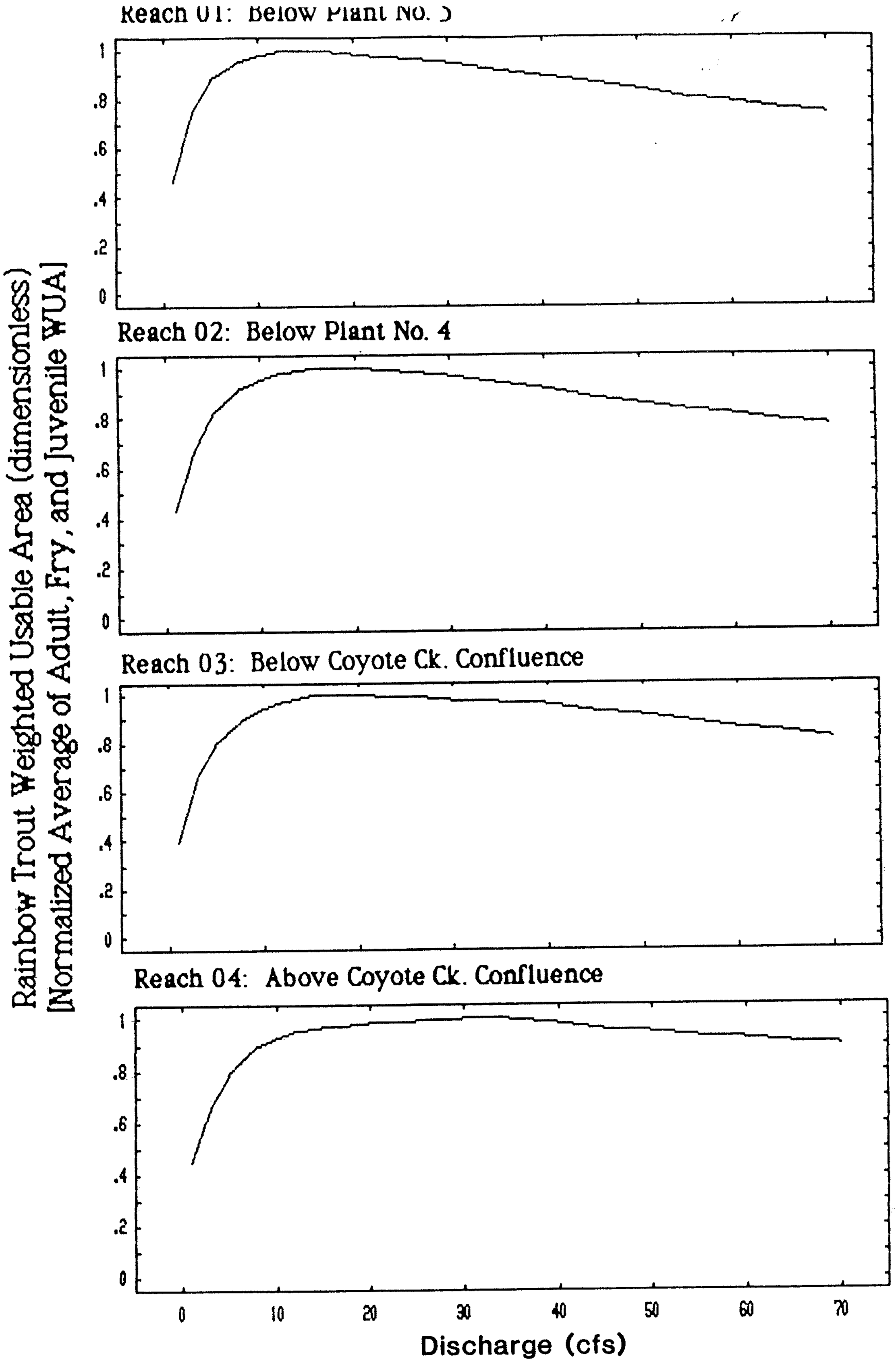


Figure 23. Normalized mean Weighted Usable Area as a function of discharge for rainbow trout adults, juveniles, and fry in Bishop Creek.

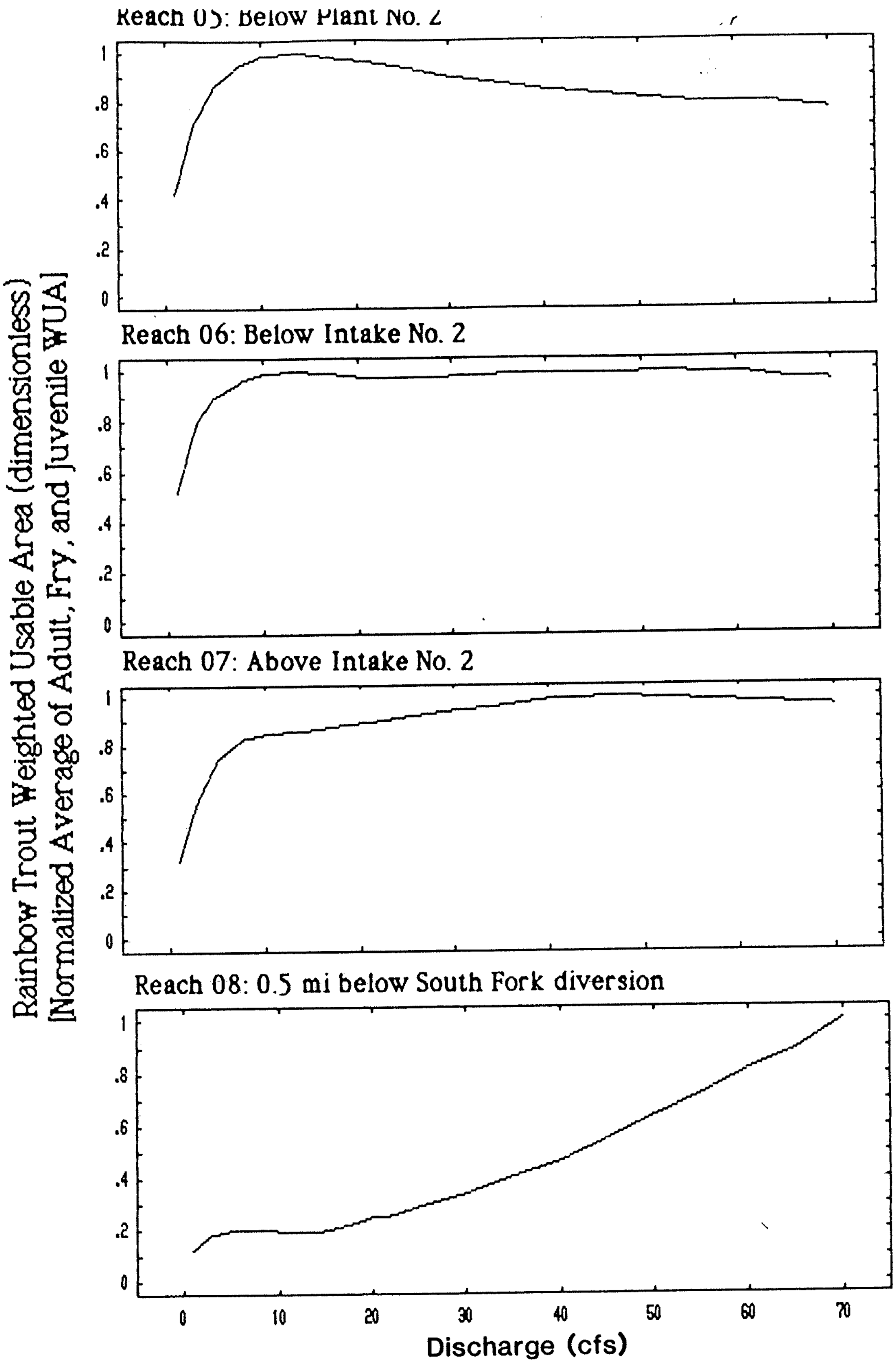


Figure 23. (continued)

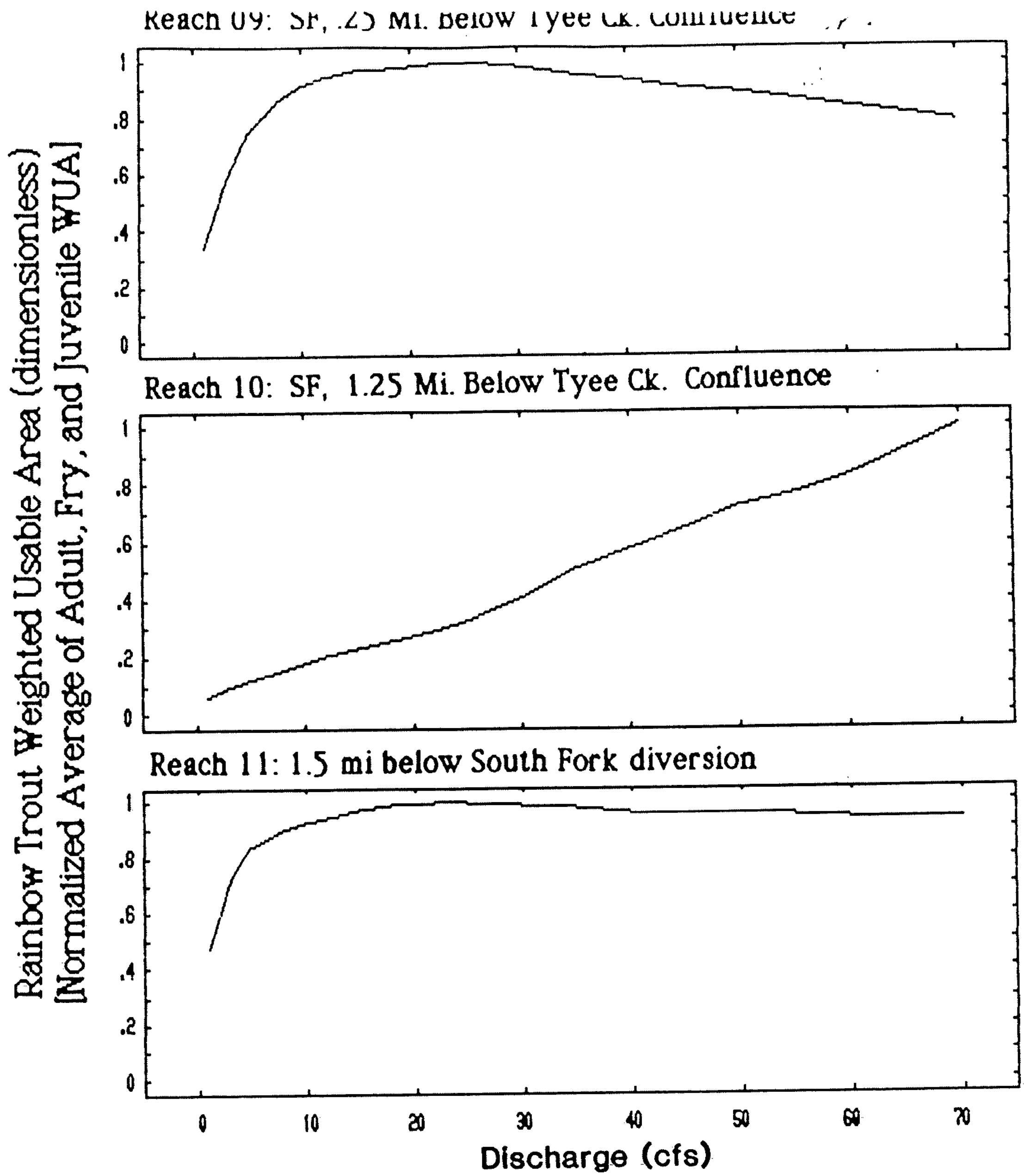
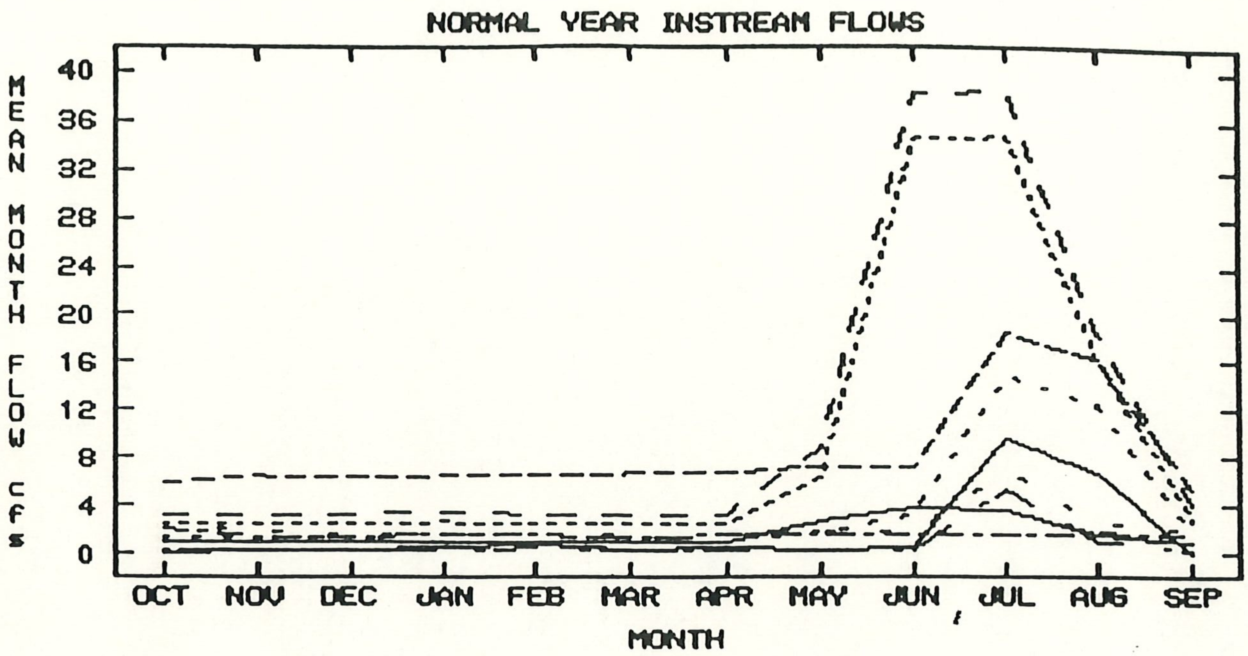


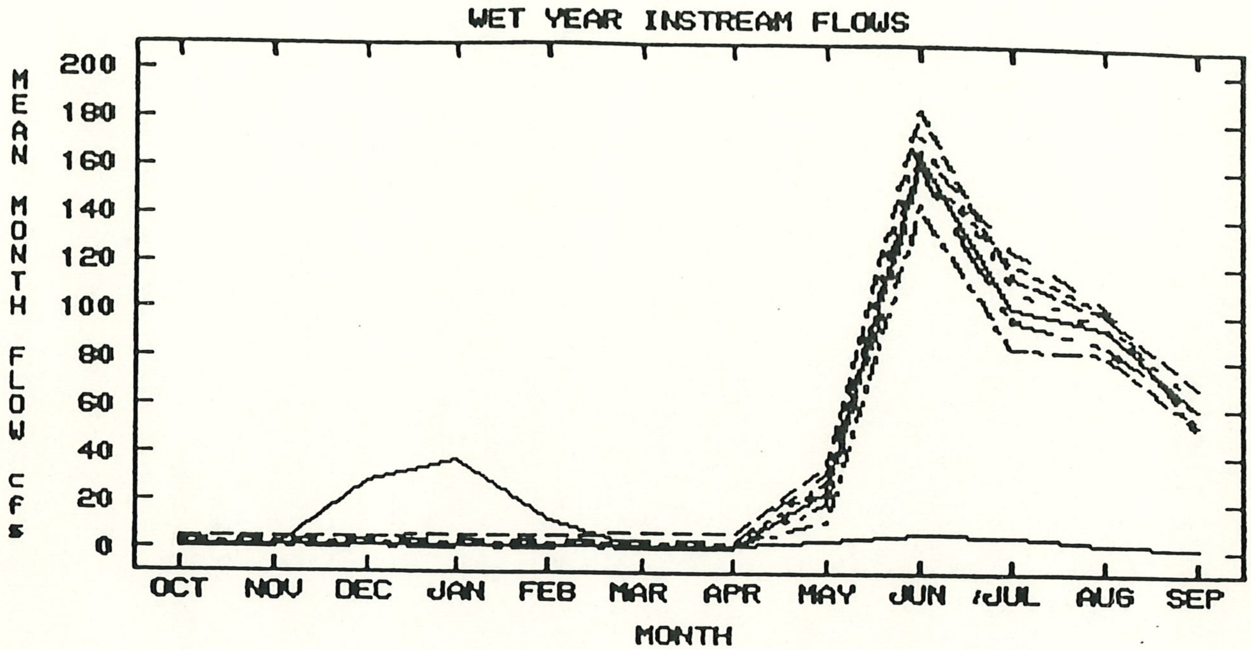
Figure 23. (continued)



Monthly flows in DIVERTED sections of Bishop Creek...Normal Year, 1979

Study Reach / Month	08 South Fork (cfs)	06 North Fork (cfs)	08+06 Main above 2 (cfs)	05 Main below 2 (cfs)	04 Main below 3 (cfs)	03 Main above 4 (cfs)	Main below 4 (cfs)	02 Main above 5 (cfs)	01 Main below 5 (cfs)
October	.8	2.4	3.2	2.0	1.3	5.8	2.0	.2	.1
November	.8	2.4	3.2	1.4	1.4	6.4	1.9	.2	.3
December	.8	2.4	3.2	1.4	1.4	6.2	1.6	.2	.3
January	.9	2.6	3.4	1.5	1.5	6.4	1.6	.2	.4
February	.8	2.4	3.2	1.5	1.5	6.4	1.5	.4	.7
March	.8	2.4	3.2	1.4	1.3	6.6	1.6	.2	.2
April	.8	2.4	3.2	1.5	1.5	6.6	.8	.2	.4
May	2.6	6.2	8.8	1.5	1.7	7.2	1.8	.2	.2
June	3.7	34.5	38.2	1.5	3.2	7.1	1.8	.3	.4
July	3.6	34.8	38.4	1.6	14.9	18.5	6.8	5.3	9.7
August	1.6	16.2	18.4	1.7	12.5	16.2	2.6	1.0	6.8
September	1.0	2.8	3.8	1.5	1.4	5.2	1.9	.2	.1
Mean Annual	1.5	9.3	10.9	1.5	3.6	8.2	2.2	.7	1.6
Jul,Aug,Sep	2.1	17.9	20.2	1.6	9.6	13.3	3.8	2.2	5.5

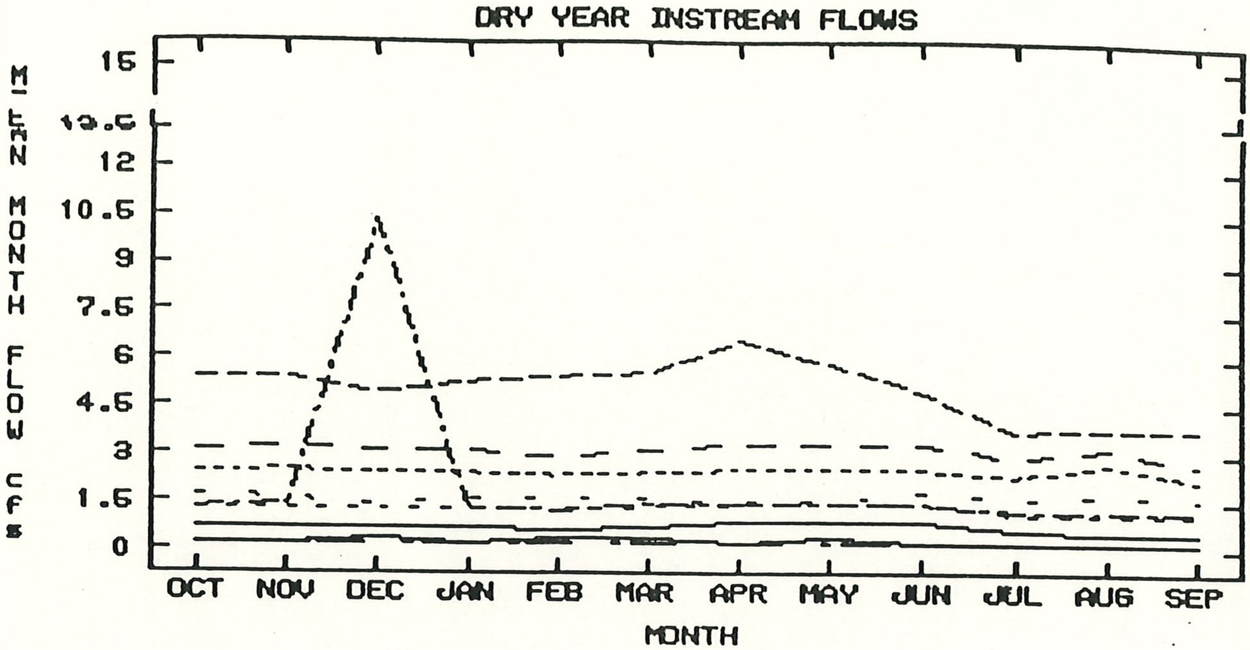
Figure ~~3.6~~ 24 Distribution of mean monthly flows in diverted sections of Bishop Creek in a normal year.



Monthly flows in DIVERTED sections of Bishop Creek...Wet Year, 1978

Study Reach	08	06	08+06	05	04	03		02	01
Month	South Fork (cfs)	North Fork (cfs)	Main above 2 (cfs)	Main below 2 (cfs)	Main below 3 (cfs)	Main above 4 (cfs)	Main below 4 (cfs)	Main above 5 (cfs)	Main below 5 (cfs)
October	.8	2.4	3.2	1.3	1.2	4.6	1.7	.2	.1
November	.7	2.4	3.1	1.3	1.3	5.0	1.8	.2	.2
December	.7	2.4	3.1	1.4	1.4	5.0	1.7	.2	28.0
January	.7	2.4	3.1	1.4	1.4	5.2	1.5	.2	36.5
February	.7	2.3	3.0	1.4	1.4	5.5	1.5	.2	12.0
March	.7	2.3	3.0	1.4	1.4	6.7	1.7	.2	.3
April	.8	2.4	3.2	1.4	1.4	6.4	1.7	.2	.3
May	3.7	28.3	32.0	11.7	26.5	35.6	19.9	18.8	24.9
June	6.5	160.3	166.8	143.6	173.8	182.7	160.2	159.2	164.2
July	6.0	119.4	125.4	84.9	109.3	113.9	97.6	96.1	101.3
August	2.2	100.6	102.8	83.0	95.0	99.2	85.4	87.0	94.1
September	1.6	52.2	53.8	53.6	65.3	69.8	61.7	60.2	60.6
Mean Annual	2.1	39.8	41.9	32.2	40.0	45.0	36.4	35.2	43.5
Jul,Aug,Sep	3.3	90.7	94.0	73.8	89.9	94.3	81.6	81.1	85.3

Figure ~~3.7~~ 25 Distribution of mean monthly flows in diverted sections of Bishop Creek in a wet year.



Monthly flows in DIVERTED sections of Bishop Creek...Dry Year

Study Reach	08	06	08+06	05	04	03		02	01
Month	South Fork (cfs)	North Fork (cfs)	Main above 2 (cfs)	Main below 2 (cfs)	Main below 3 (cfs)	Main above 4 (cfs)	Main below 4 (cfs)	Main above 5 (cfs)	Main below 5 (cfs)
October	.7	2.4	3.1	1.3	1.3	5.4	1.7	.2	.2
November	.7	2.5	3.2	1.4	1.3	5.4	1.6	.2	.2
December	.7	2.4	3.1	10.3	1.3	4.9	1.4	.2	.3
January	.7	2.4	3.1	1.3	1.3	5.2	1.6	.2	.2
February	.6	2.3	2.9	1.2	1.2	5.4	1.6	.2	.3
March	.7	2.4	3.1	1.4	1.3	5.5	1.6	.2	.3
April	.8	2.5	3.3	1.4	1.4	6.5	1.5	.2	.2
May	.8	2.5	3.3	1.4	1.4	5.8	1.5	.2	.3
June	.8	2.5	3.3	1.4	1.4	4.9	1.8	.2	.2
July	.6	2.3	2.9	1.2	1.1	3.7	1.6	.2	.2
August	.5	2.7	3.2	1.2	1.1	3.8	1.7	.2	.2
September	.5	2.2	2.7	1.2	1.1	3.8	1.6	.2	.2
Mean Annual	.7	2.4	3.1	2.1	1.3	5.0	1.6	.2	.2
Jul,Aug,Sep	.5	2.4	2.9	1.2	1.1	3.8	1.6	.2	.2

Figure ~~3.8~~ 26 Distribution of mean monthly flows in Bishop Creek in a dry year.

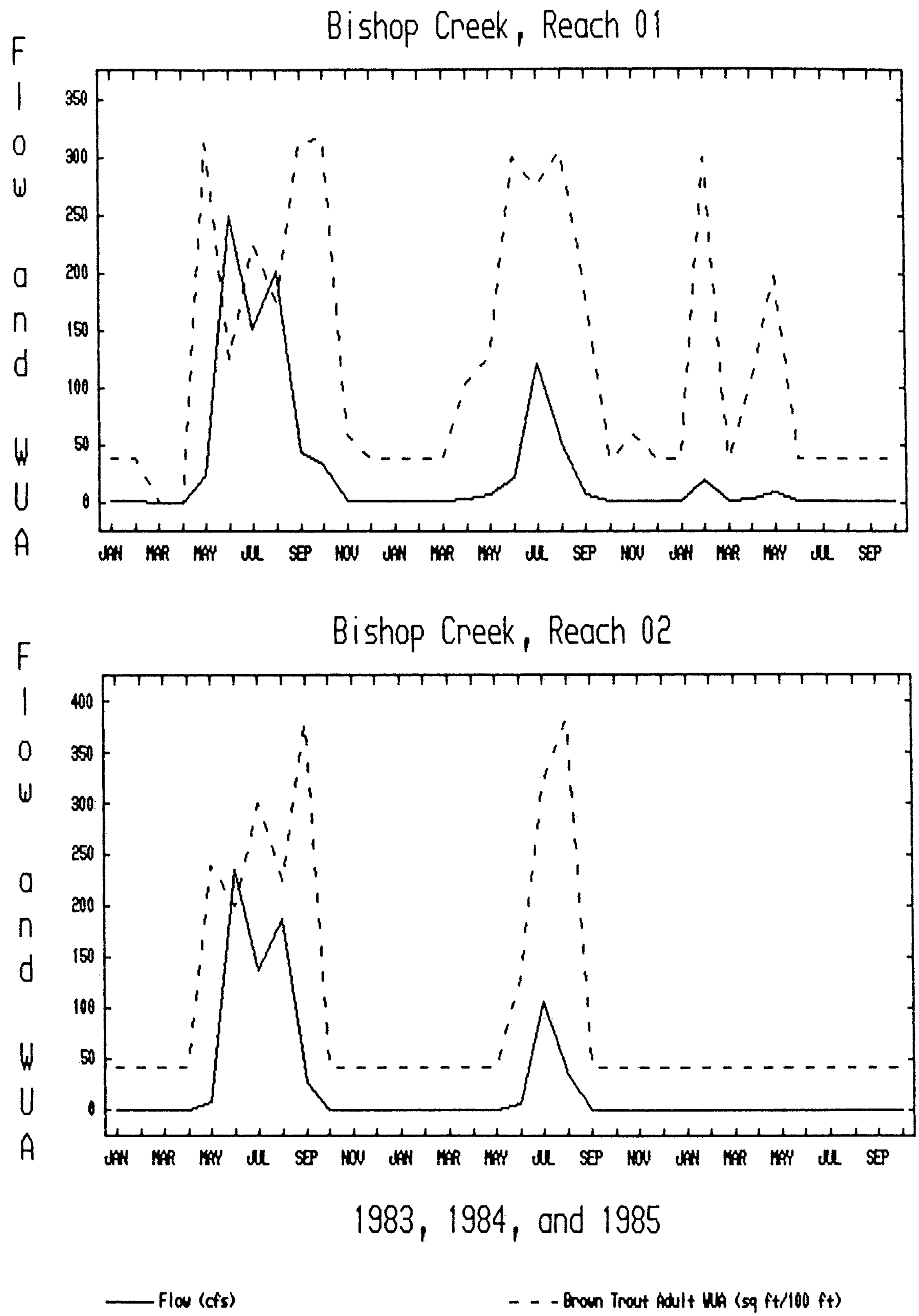


Figure 27. Brown trout adult Weighted Usable Area and mean monthly flow in Reaches 01 and 02 of Bishop Creek.

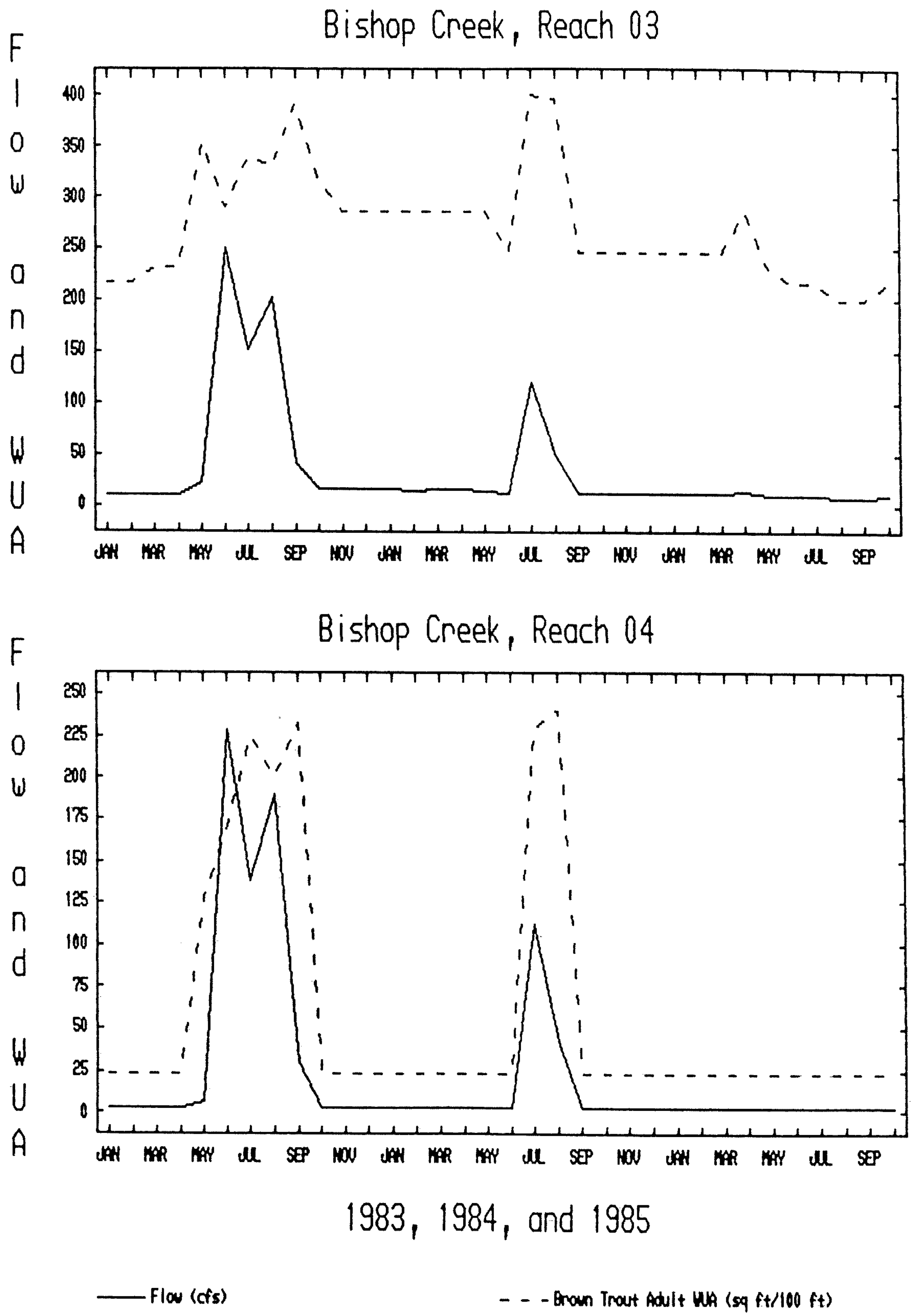


Figure 28. Brown trout adult Weighted Usable Area and mean monthly flow in Reaches 03 and 04 of Bishop Creek.

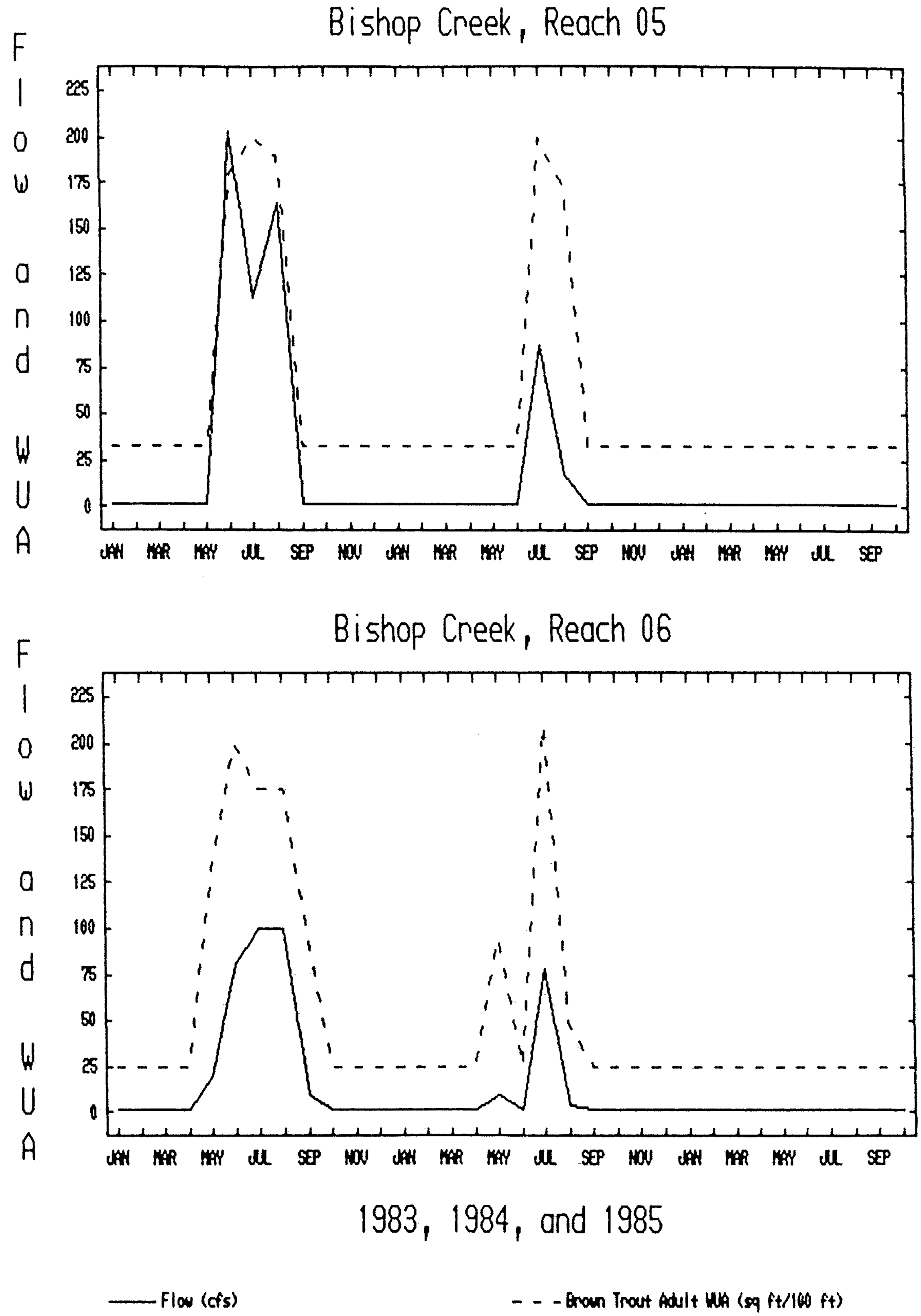


Figure 29. Brown trout adult weighted usable area and mean monthly flow in Reaches 05 and 06 of Bishop Creek.

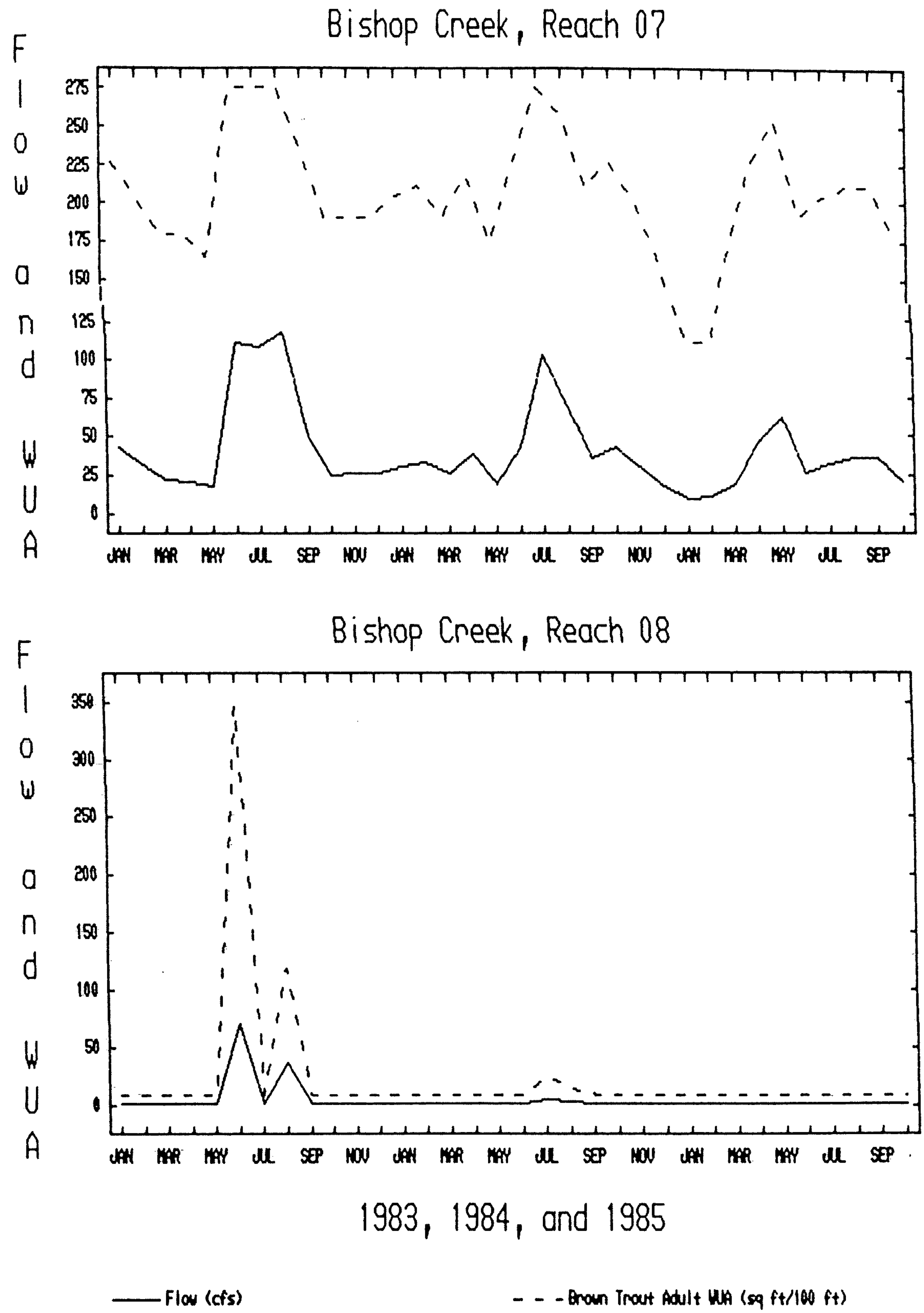


Figure 30. Brown trout adult weighted usable area and mean monthly flow in Reaches 07 and 08 of Bishop Creek.

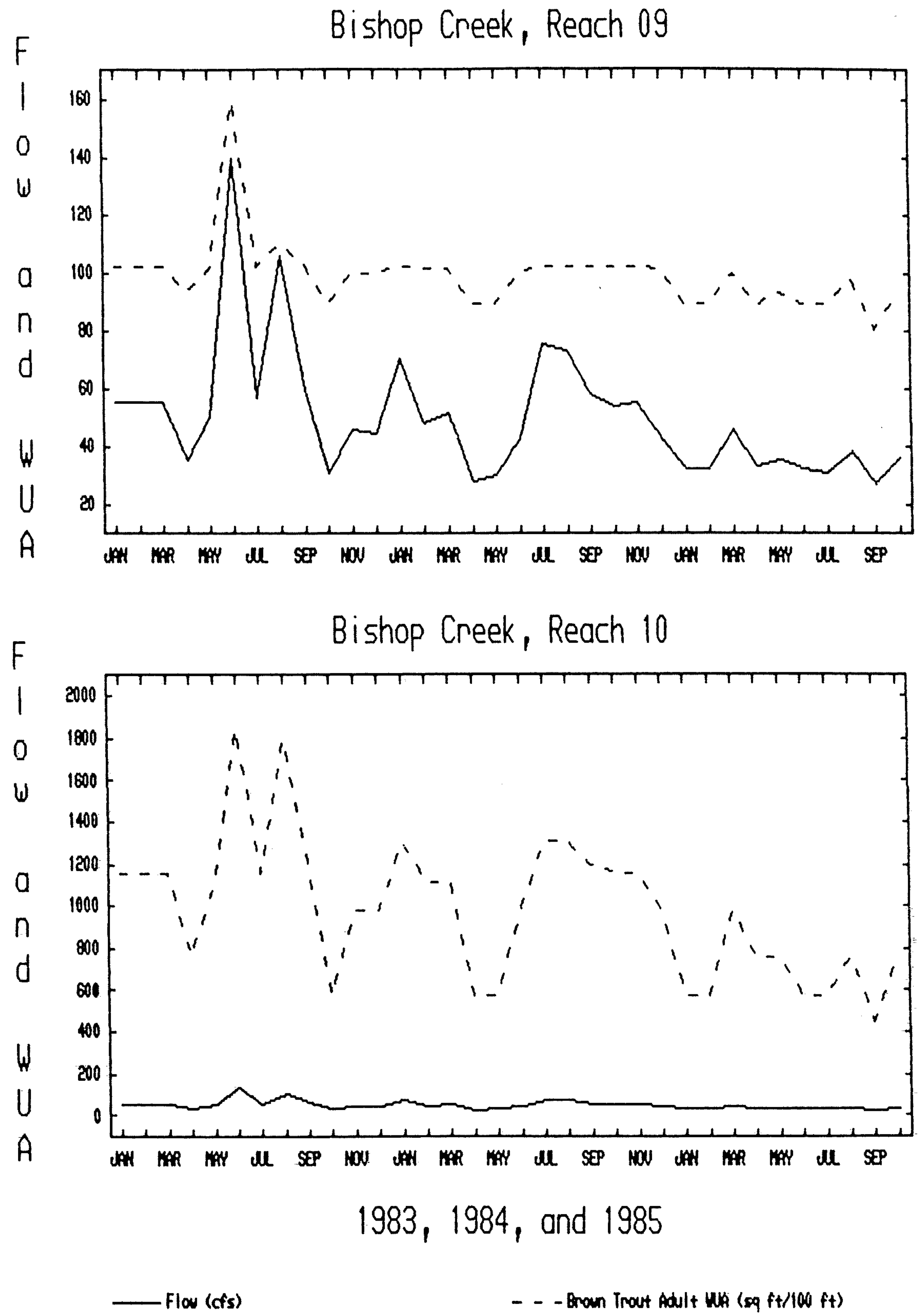


Figure 31. Brown trout adult Weighted Usable Area and mean monthly flow in Reaches 09 and 10 of Bishop Creek.

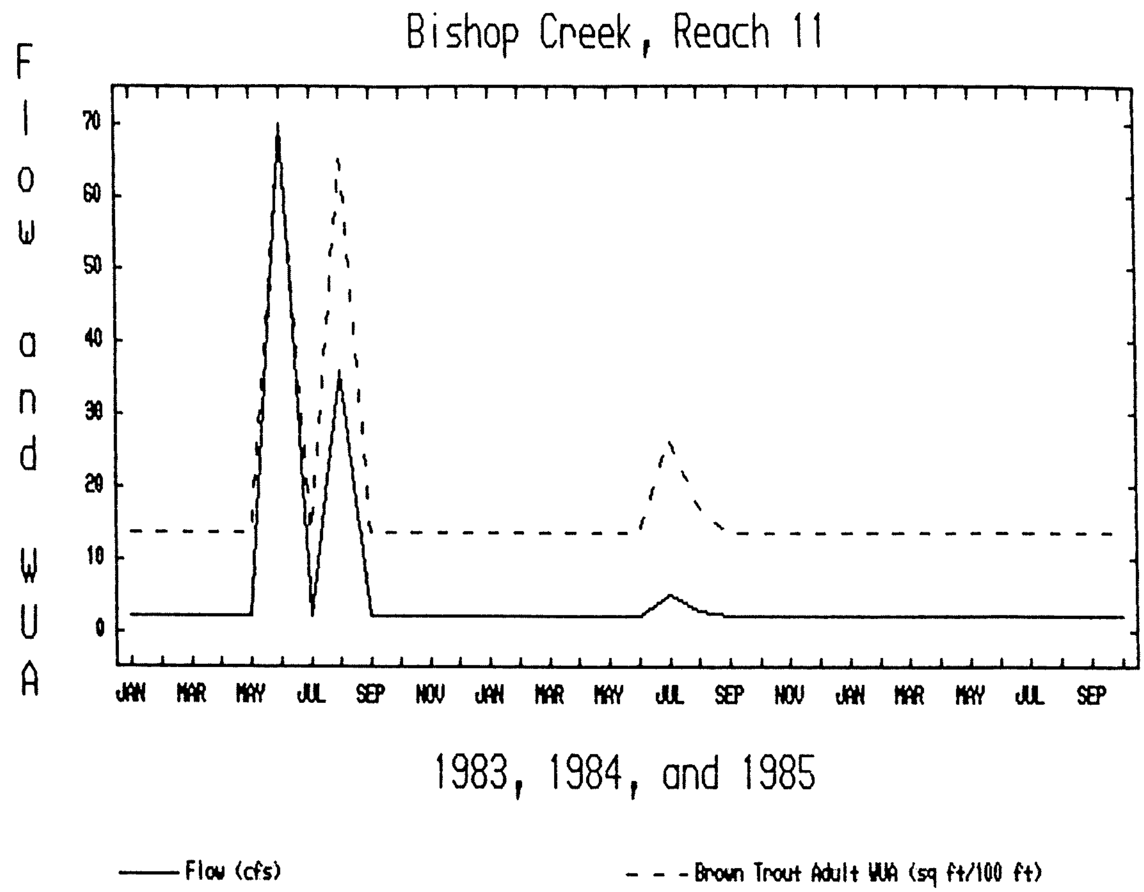


Figure 32. Brown trout adult Weighted Usable Area and mean monthly flow in Reach 11 of Bishop Creek.

Effects of Altering Flows on Weighted Usable Area

Figures 33-39 illustrate the existing normal year average Weighted Usable Area for brown trout adults, juveniles, and fry in all of the diverted reaches of Bishop Creek, along with the change in WUA that would result from additional releases of 5-30 cfs. Figures 40-46 illustrate the same results for rainbow trout. These are summarized in Figures 47-50, which show percent change in mean Weighted Usable Area for each reach for brown and rainbow trout as functions of flow.

Cross-Sections and Water Surface Elevations

Graphs of cross sections and the water surface elevations at each of the measured flows on Bishop Creek are shown in Attachment 3.

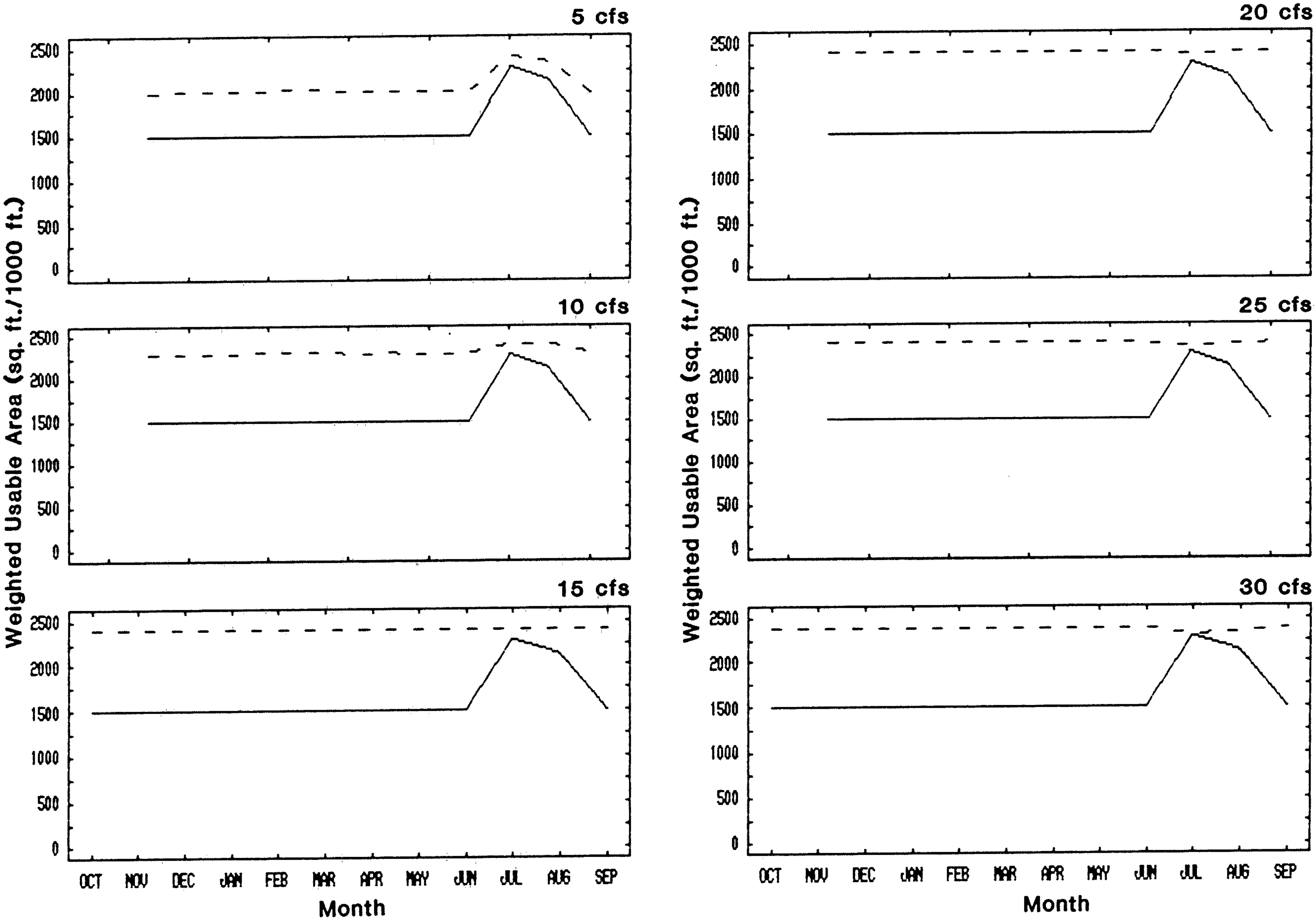


Figure 33. Existing (solid line) normal year monthly average Weighted Usable Area (WUA) for brown trout adults, fry and juveniles in Reach 01 of Bishop Creek, and the change in WUA that would result from additional releases of 5–30 cfs.

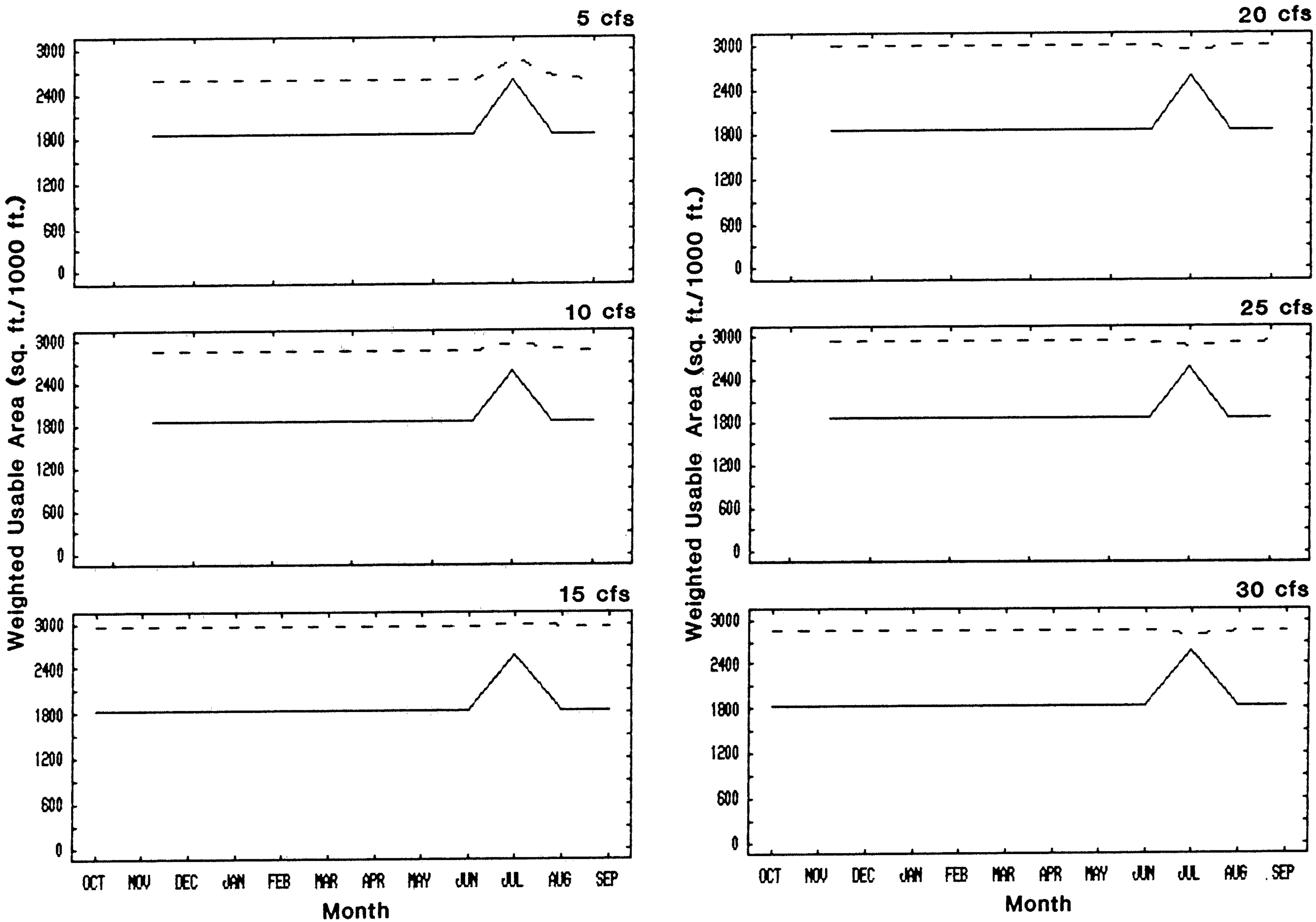


Figure 34. Existing (solid line) normal year monthly average Weighted Usable Area (WUA) for brown trout adults, fry and juveniles in Reach 02 of Bishop Creek, and the change in WUA that would result from additional releases of 5-30 cfs.

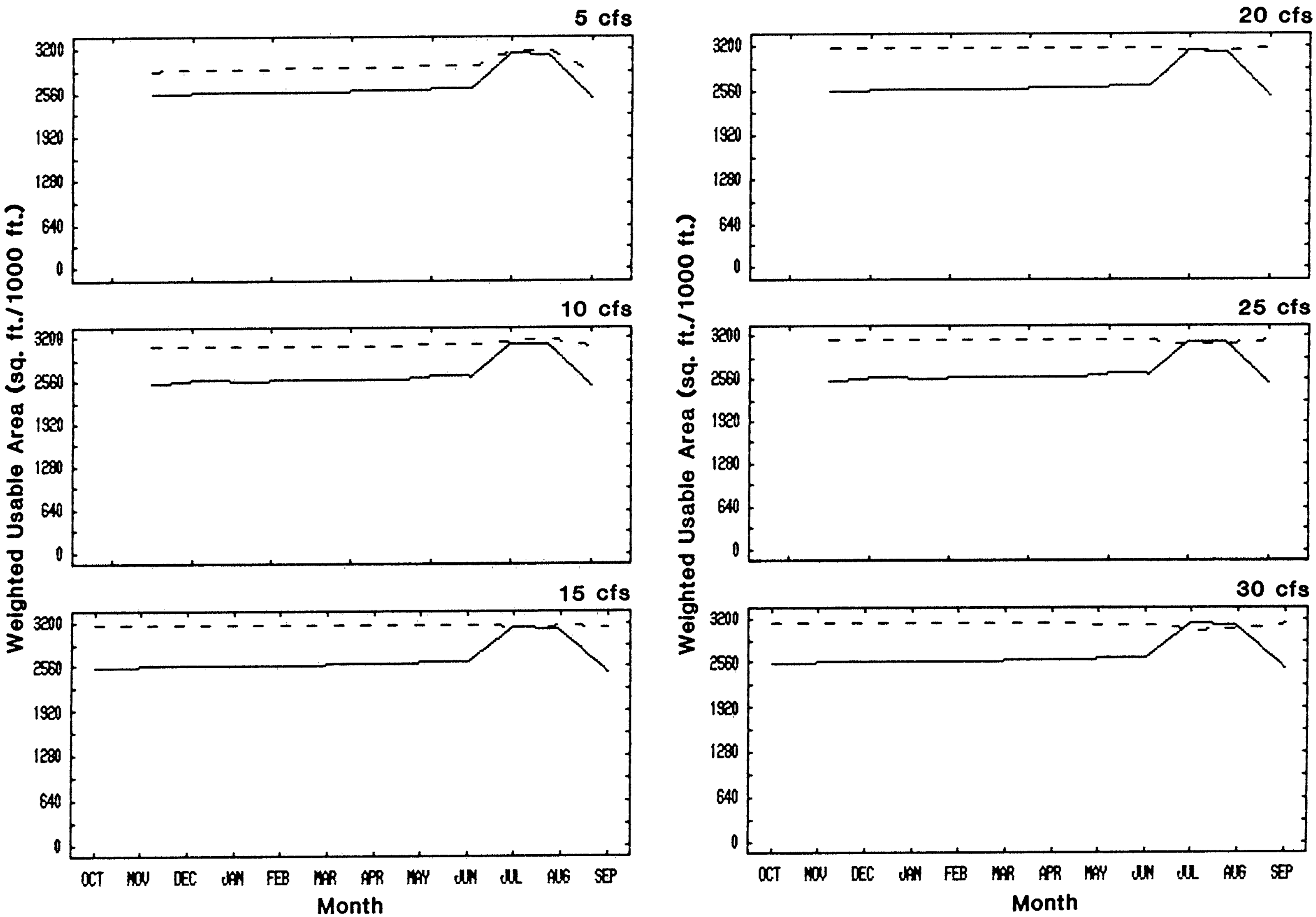


Figure 35. Existing (solid line) normal year monthly average Weighted Usable Area (WUA) for brown trout adults, fry and juveniles in Reach 03 of Bishop Creek, and the change in WUA that would result from additional releases of 5-30 cfs.

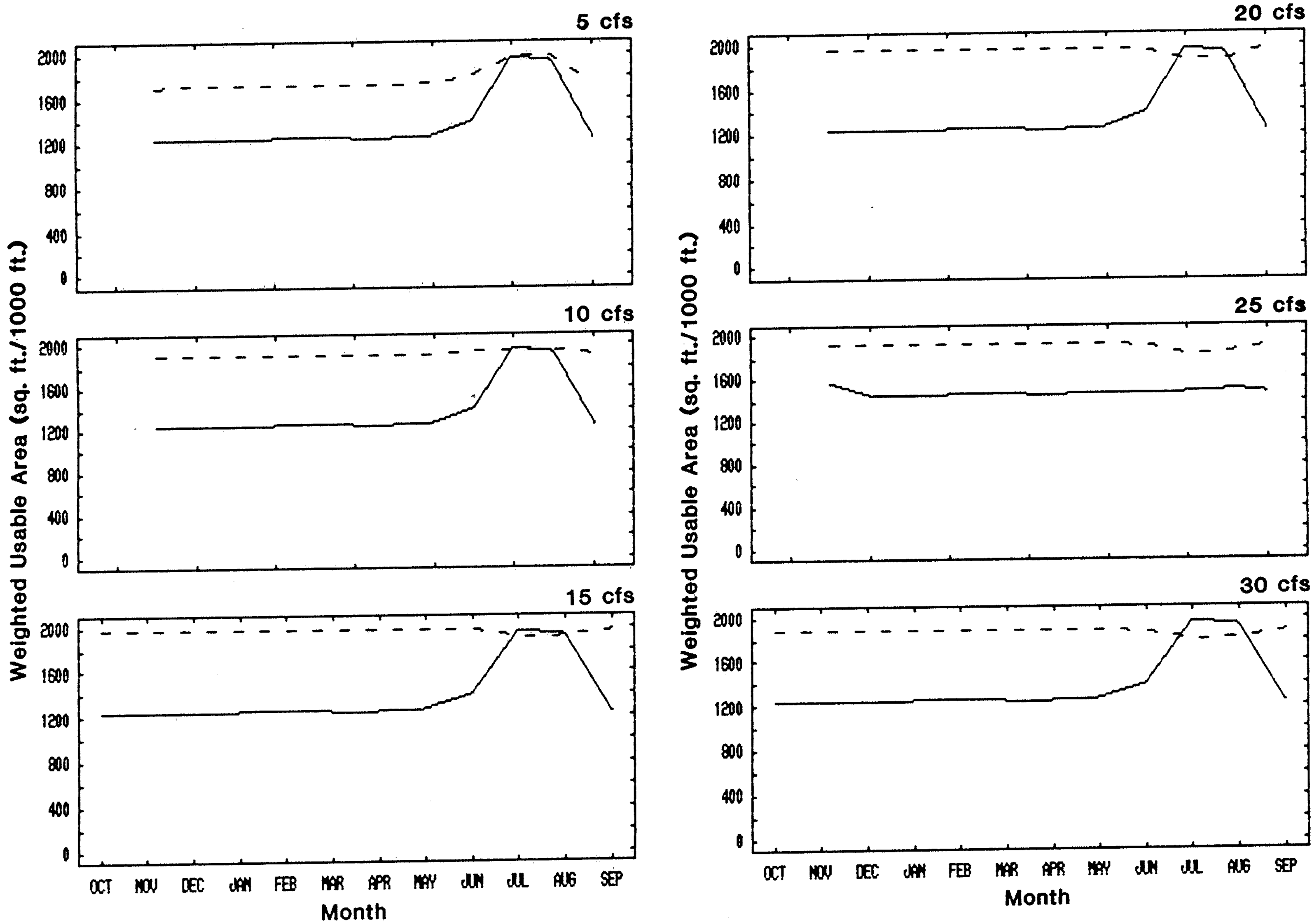


Figure 36. Existing (solid line) normal year monthly average Weighted Usable Area (WUA) for brown trout adults, fry and juveniles in Reach 04 of Bishop Creek, and the change in WUA that would result from additional releases of 5-30 cfs.

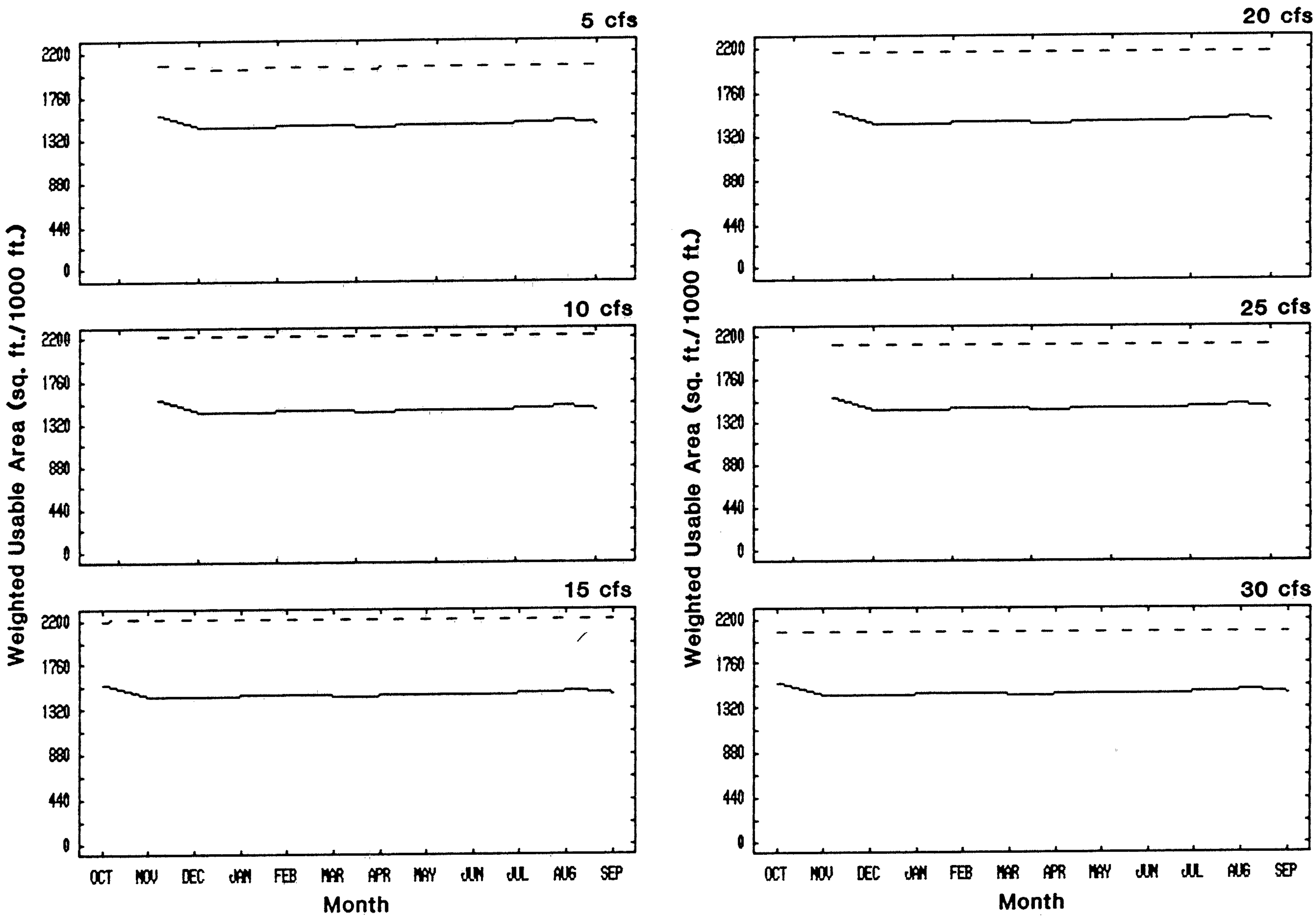


Figure 37. Existing (solid line) normal year monthly average Weighted Usable Area (WUA) for brown trout adults, fry and juveniles in Reach 05 of Bishop Creek, and the change in WUA that would result from additional releases of 5-30 cfs.

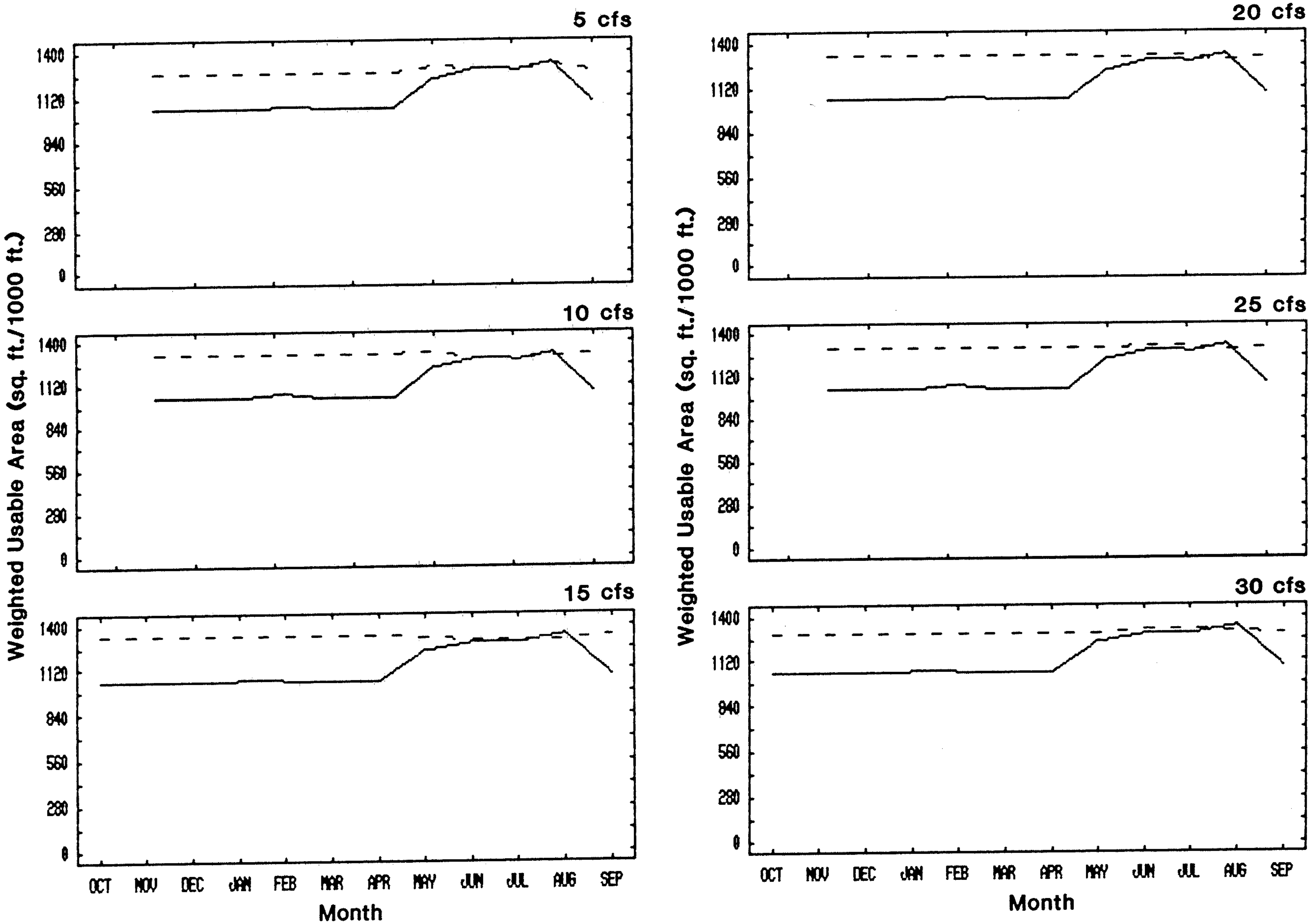


Figure 38. Existing (solid line) normal year monthly average Weighted Usable Area (WUA) for brown trout adults, fry and juveniles in Reach 06 of Bishop Creek, and the change in WUA that would result from <u>additional</u> releases of 5-30 cfs.

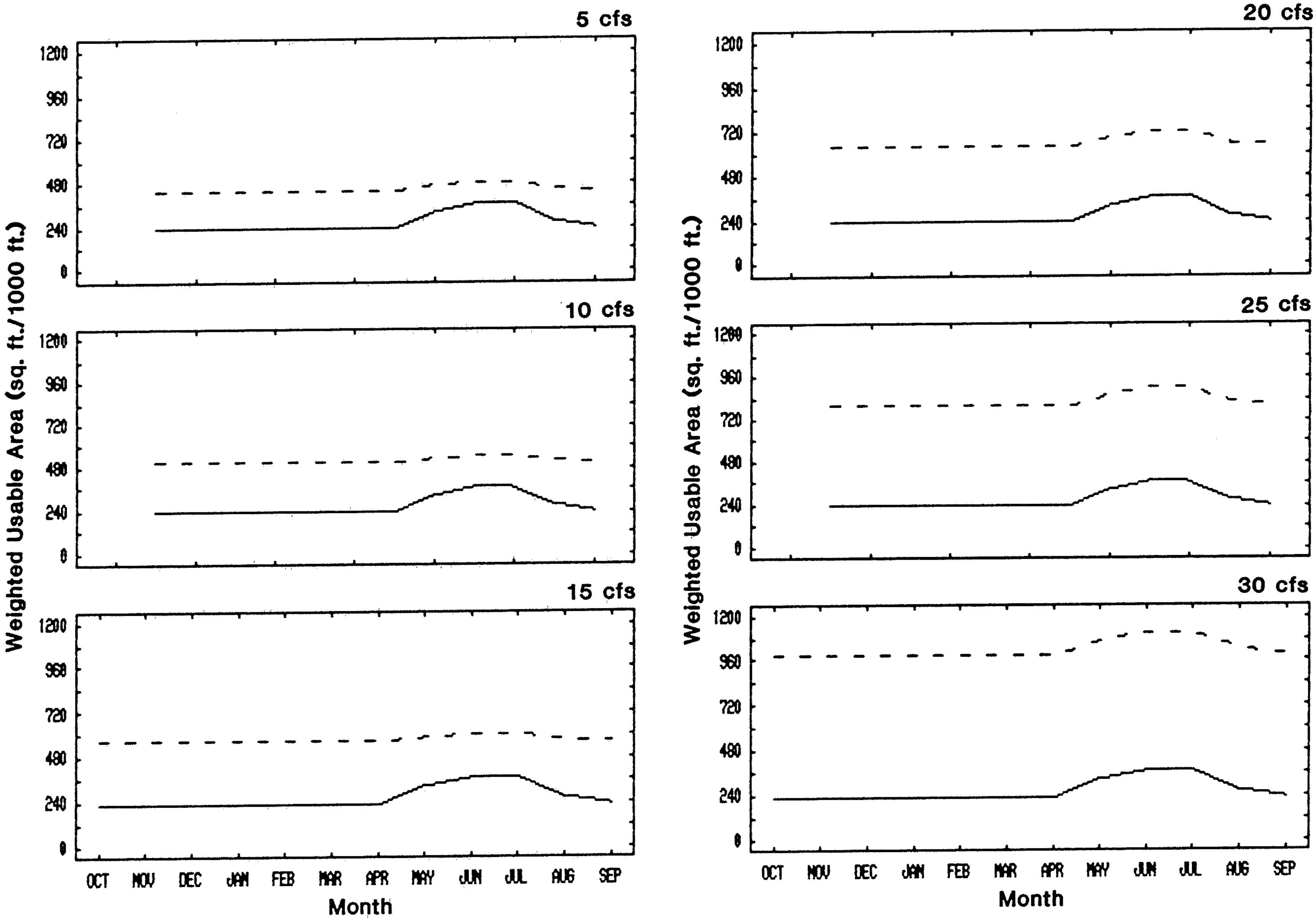


Figure 39. Existing (solid line) normal year monthly average Weighted Usable Area (WUA) for brown trout adults, fry and juveniles in Reach 08 of Bishop Creek, and the change in WUA that would result from additional releases of 5-30 cfs.

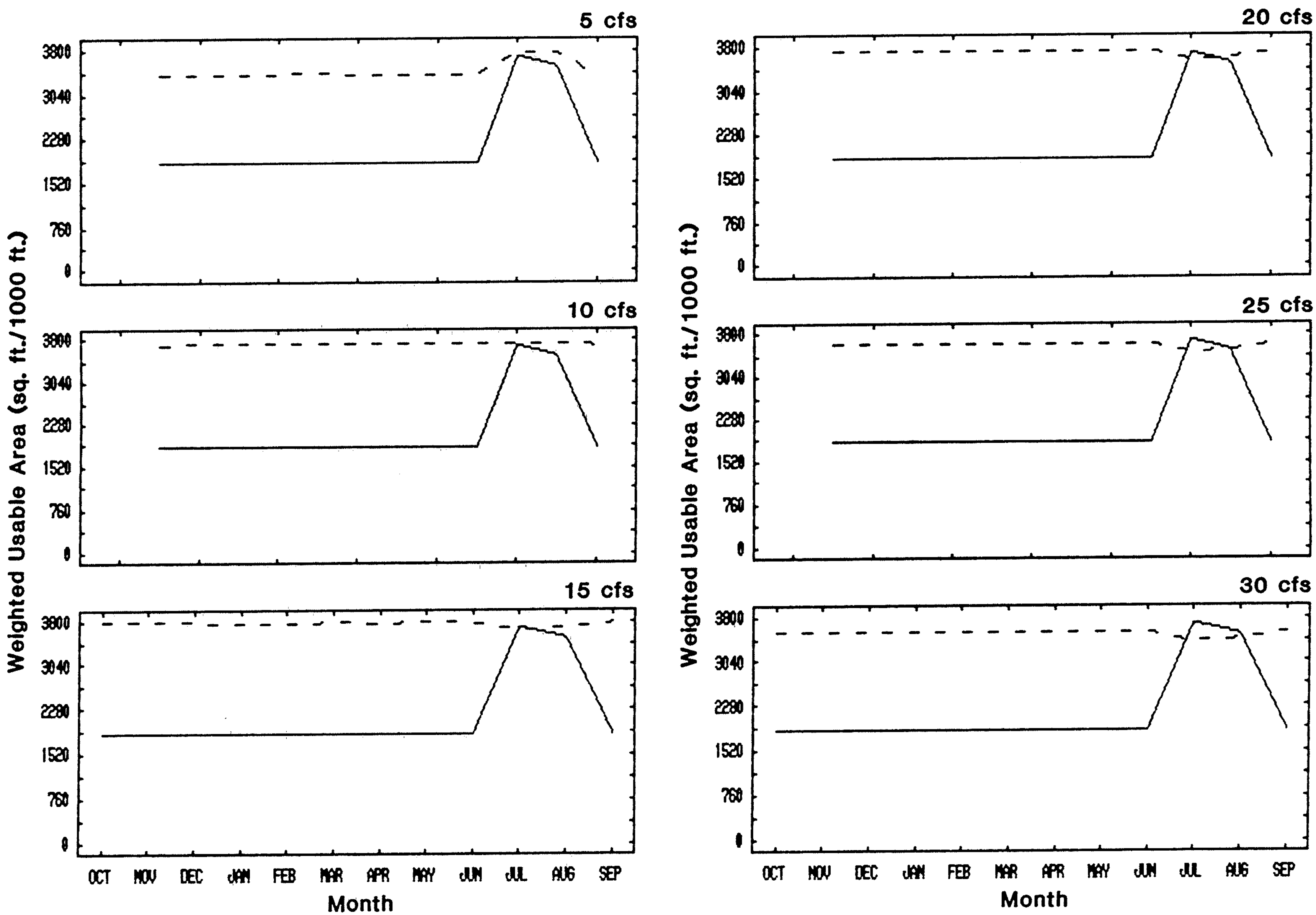


Figure 40. Existing (solid line) normal year monthly average Weighted Usable Area (WUA) for rainbow trout adults, fry and juveniles in Reach 01 of Bishop Creek, and the change in WUA that would result from <u>additional</u> releases of 5–30 cfs.

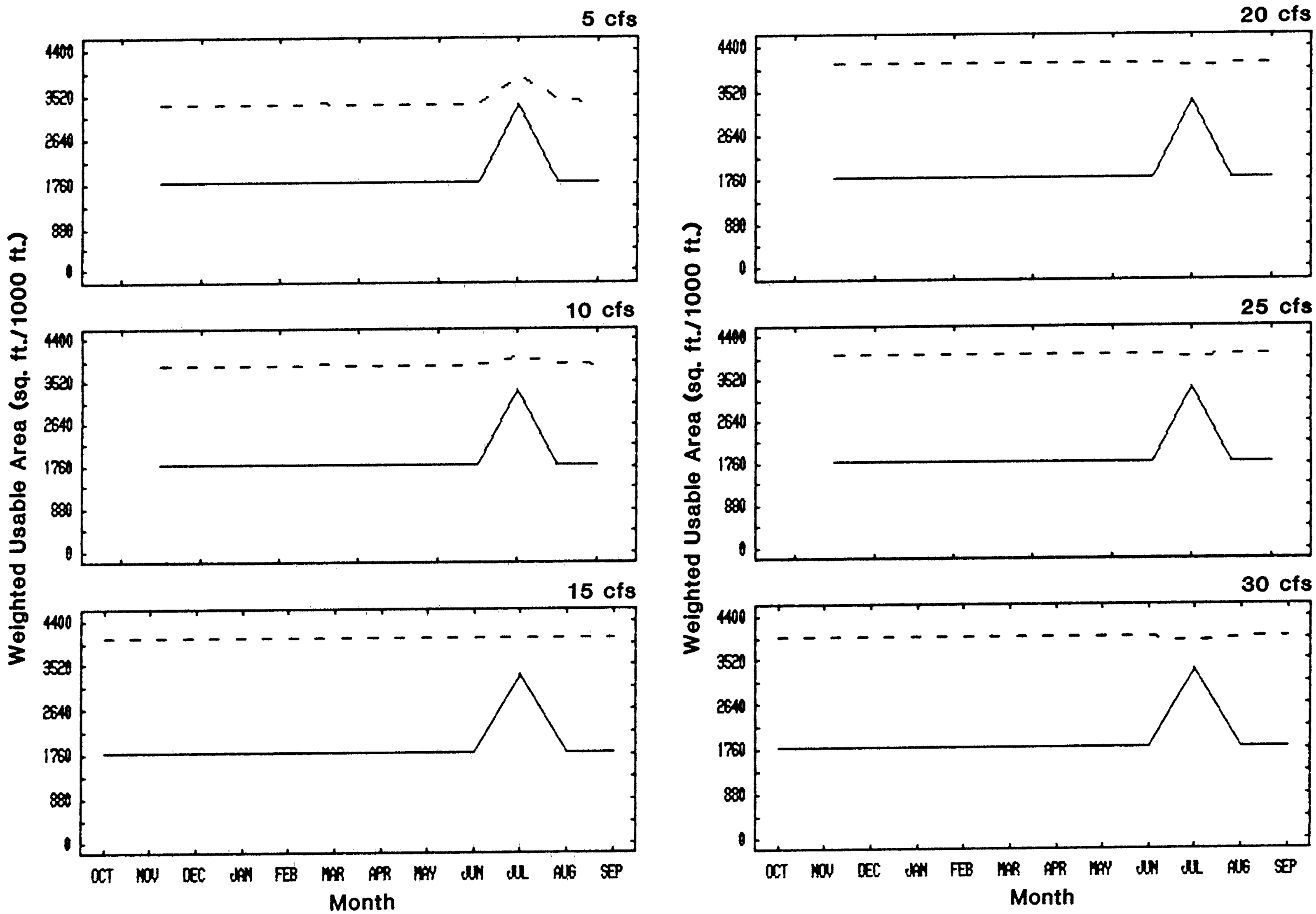


Figure 41. Existing (solid line) normal year monthly average Weighted Usable Area (WUA) for rainbow trout adults, fry and juveniles in Reach 02 of Bishop Creek, and the change in WUA that would result from <u>additional</u> releases of 5-30 cfs.

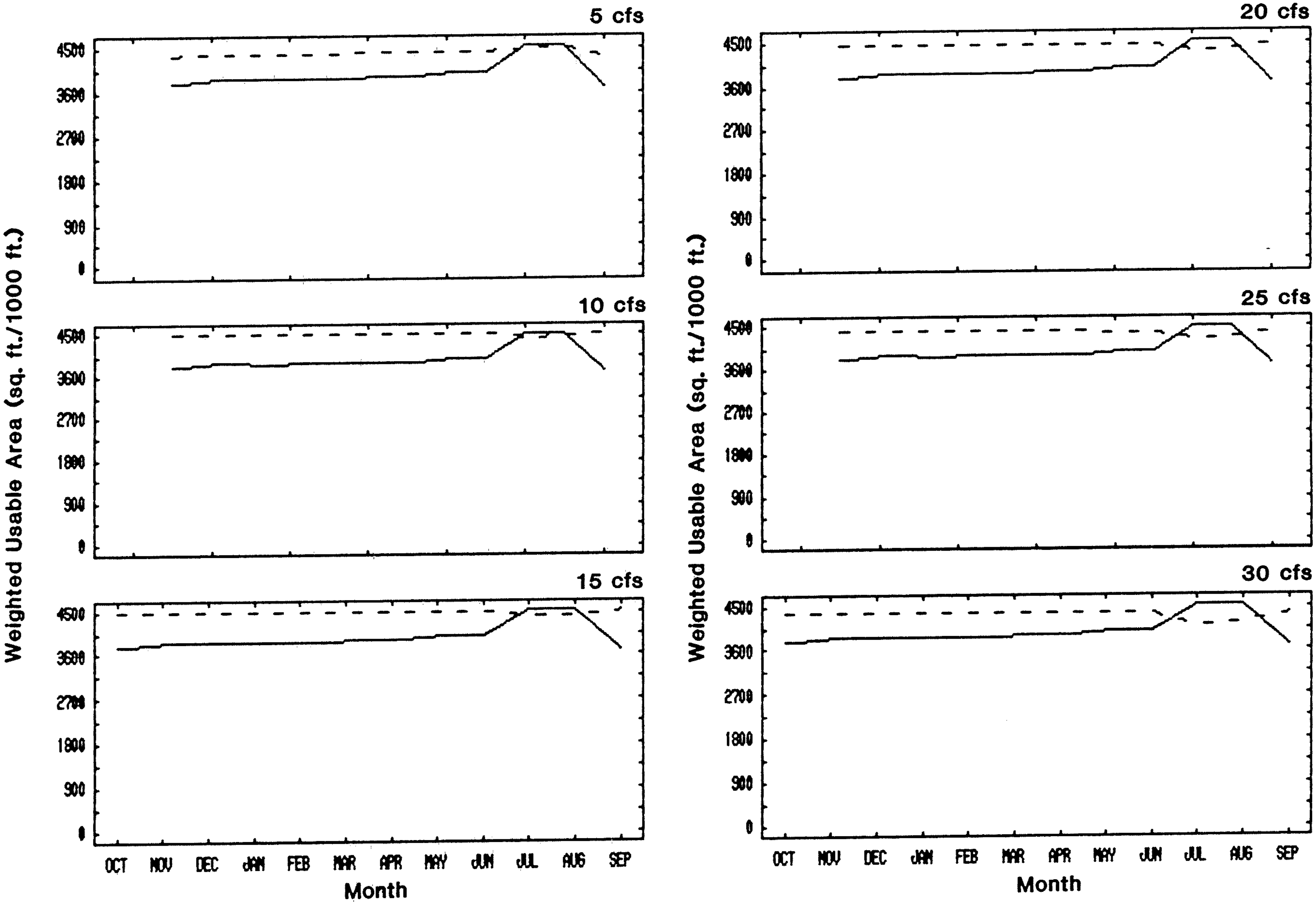


Figure 42. Existing (solid line) normal year monthly average Weighted Usable Area (WUA) for rainbow trout adults, fry and juveniles in Reach 03 of Bishop Creek, and the change in WUA that would result from additional releases of 5-30 cfs.

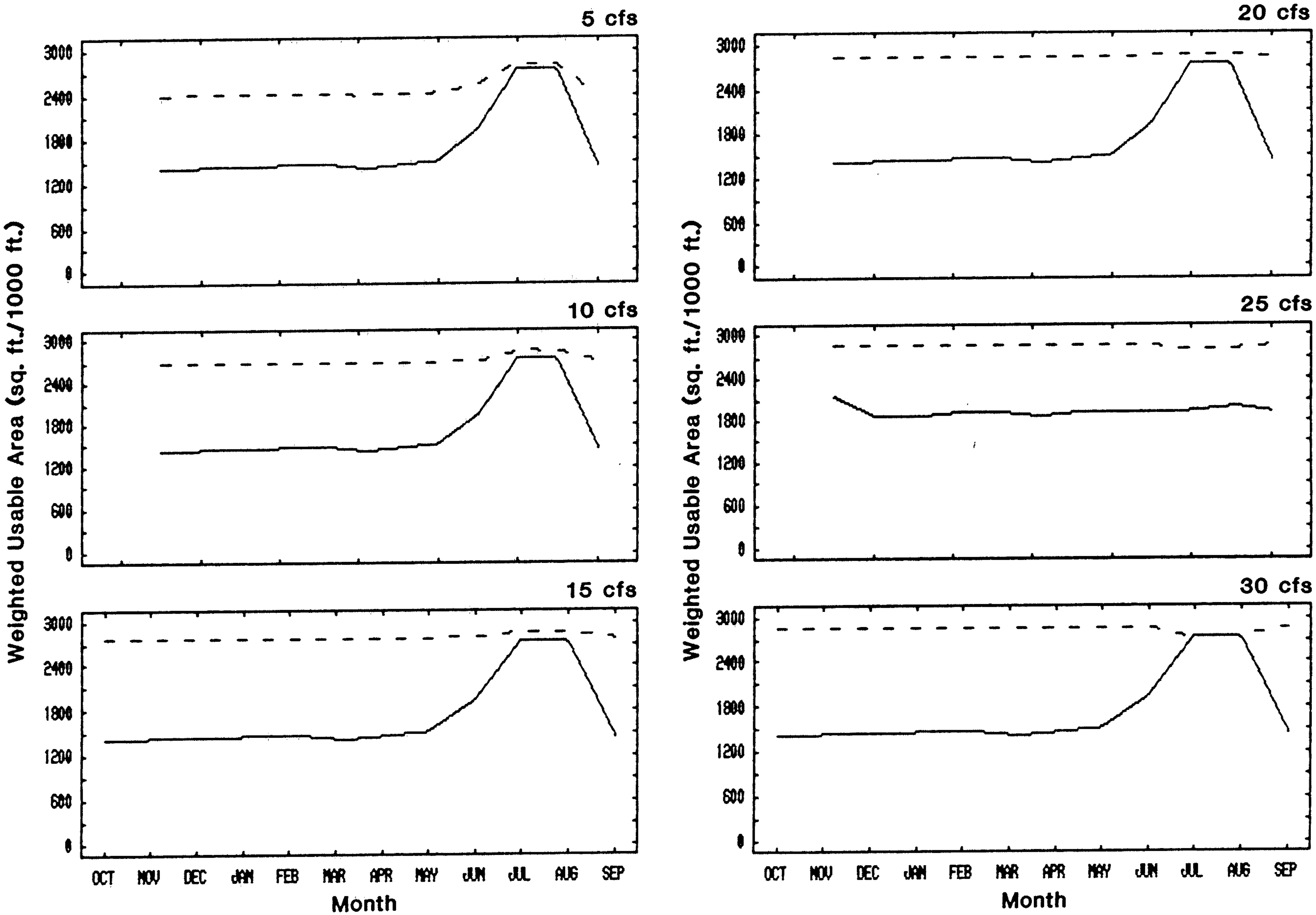


Figure 43. Existing (solid line) normal year monthly average Weighted Usable Area (WUA) for rainbow trout adults, fry and juveniles in Reach 04 of Bishop Creek, and the change in WUA that would result from <u>additional</u> releases of 5-30 cfs.

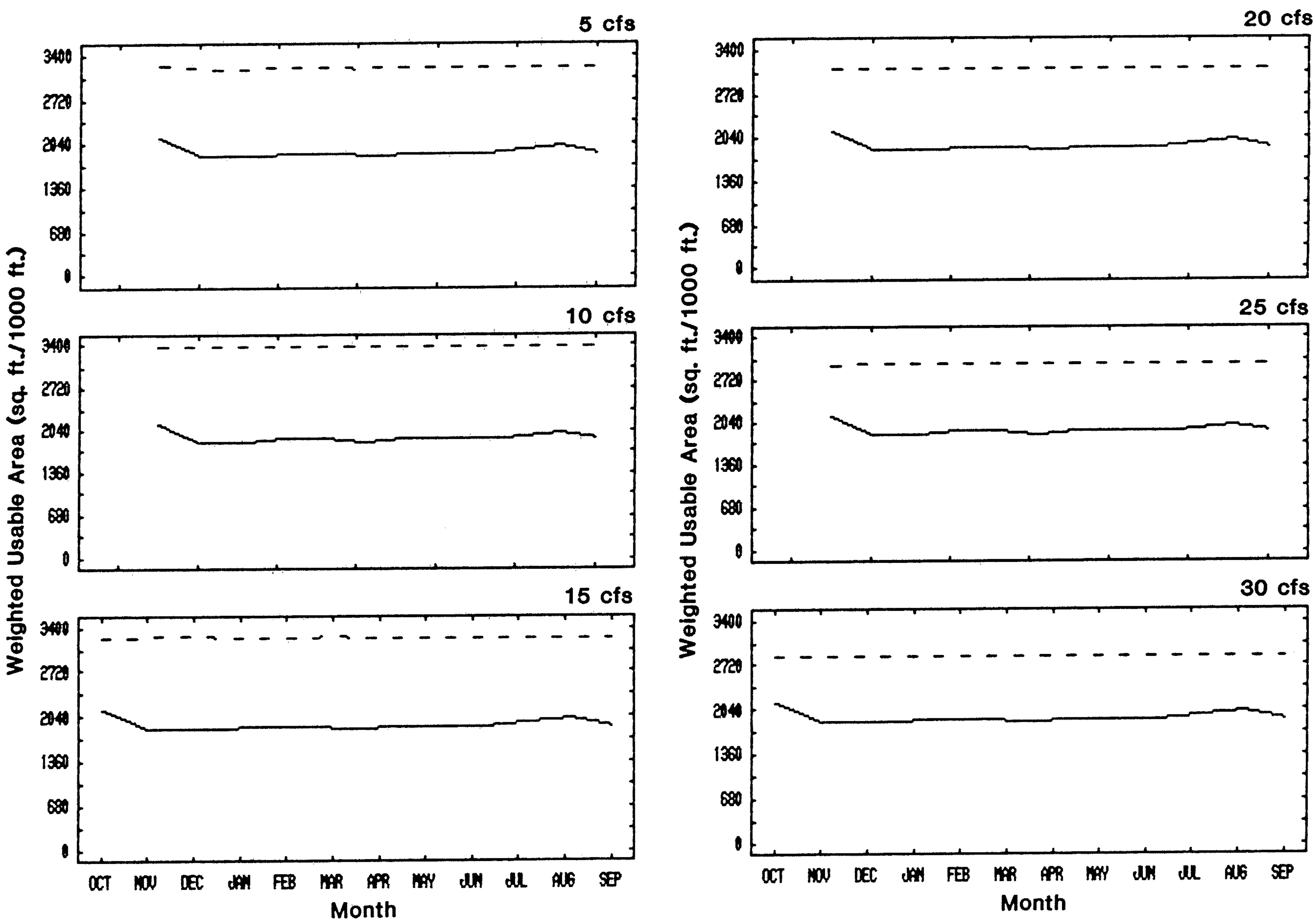


Figure 44. Existing (solid line) normal year monthly average Weighted Usable Area (WUA) for rainbow trout adults, fry and juveniles in Reach 05 of Bishop Creek, and the change in WUA that would result from additional releases of 5–30 cfs.

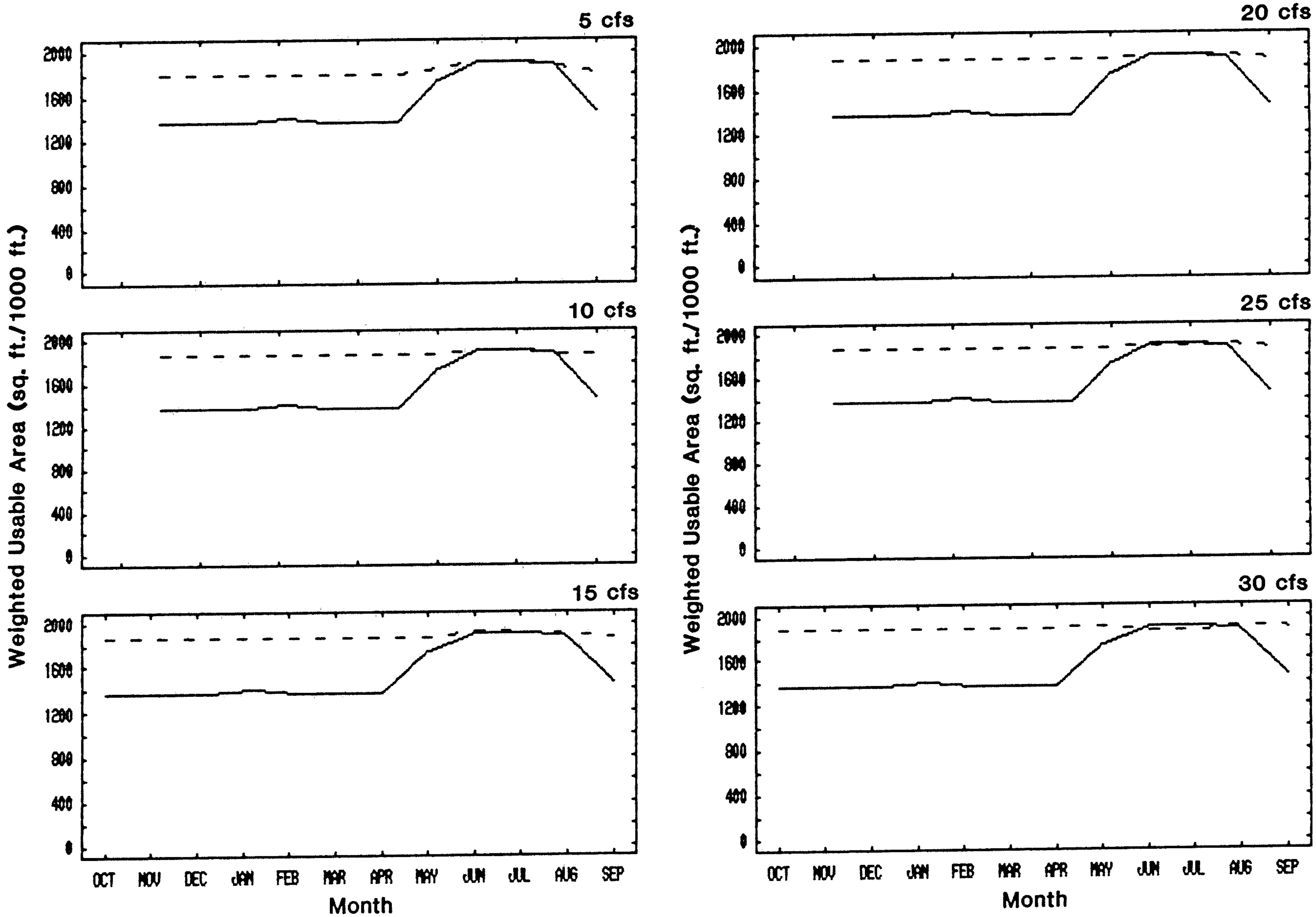


Figure 45. Existing (solid line) normal year monthly average Weighted Usable Area (WUA) for rainbow trout adults, fry and juveniles in Reach 06 of Bishop Creek, and the change in WUA that would result from additional releases of 5–30 cfs.

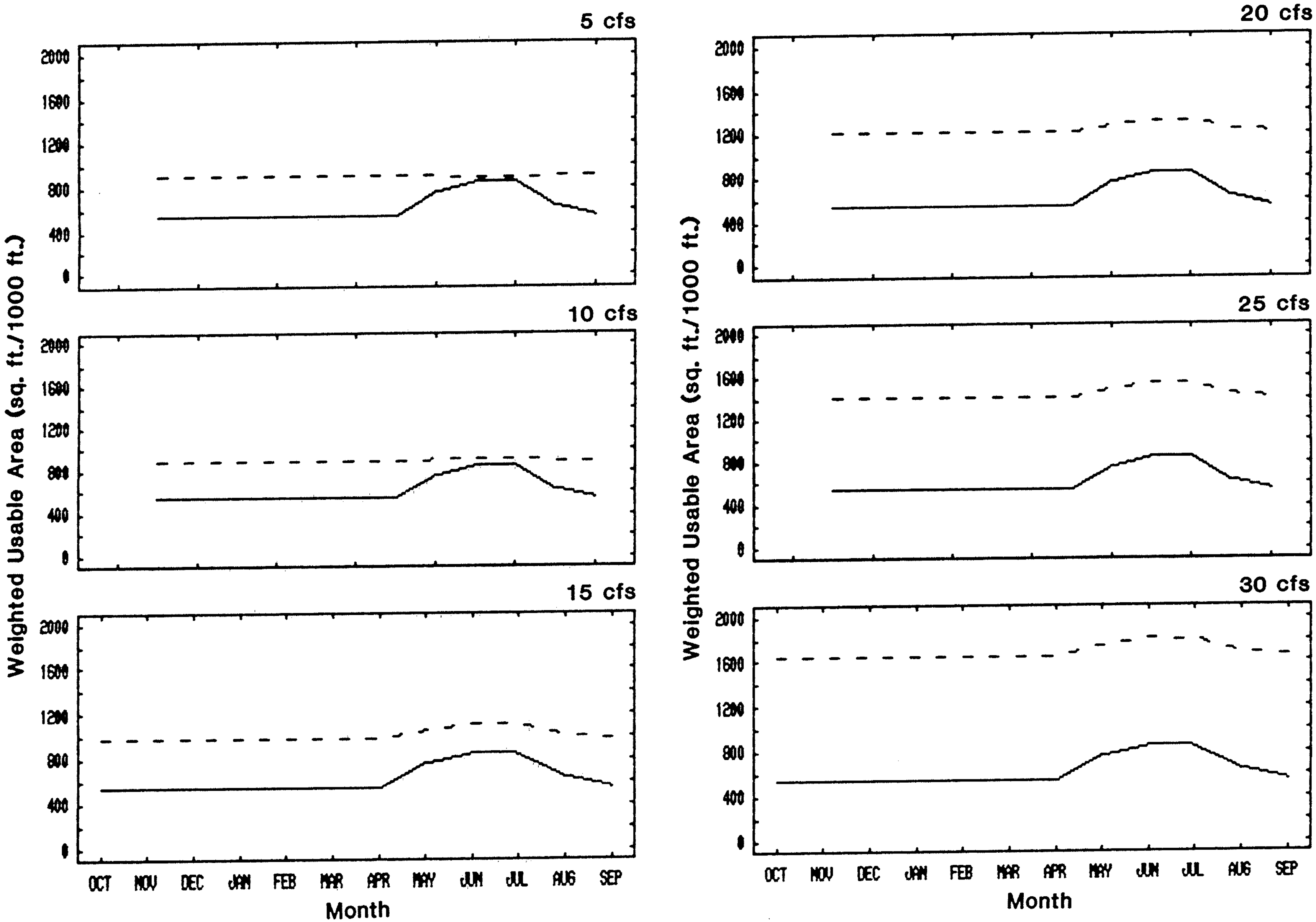


Figure 46. Existing (solid line) normal year monthly average Weighted Usable Area (WUA) for rainbow trout adults, fry and juveniles in Reach 08 of Bishop Creek, and the change in WUA that would result from <u>additional</u> releases of 5-30 cfs.

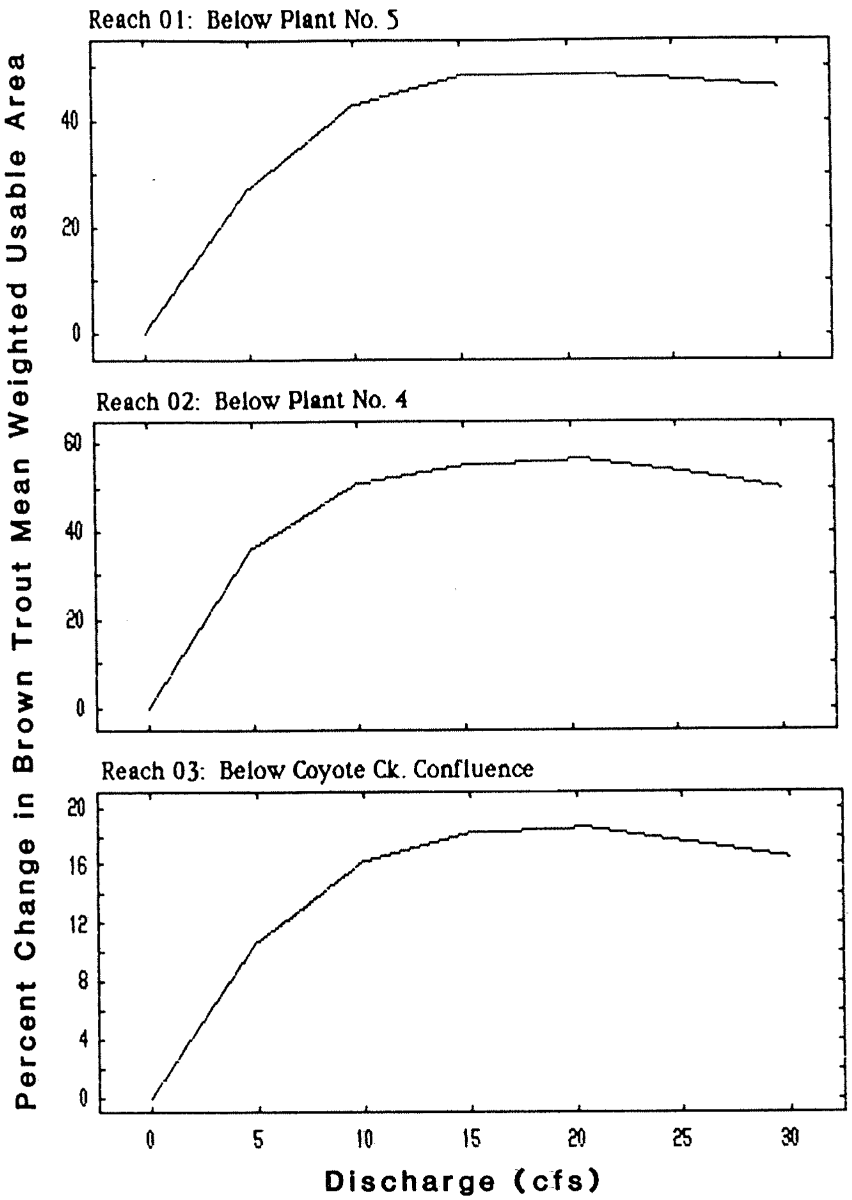


Figure 47. Percent change in mean annual mean (adult, fry, juvenile) brown trout Weighted Usable Area in Reaches 01, 02, and 03 of Bishop Creek as functions of releases in excess of current releases.

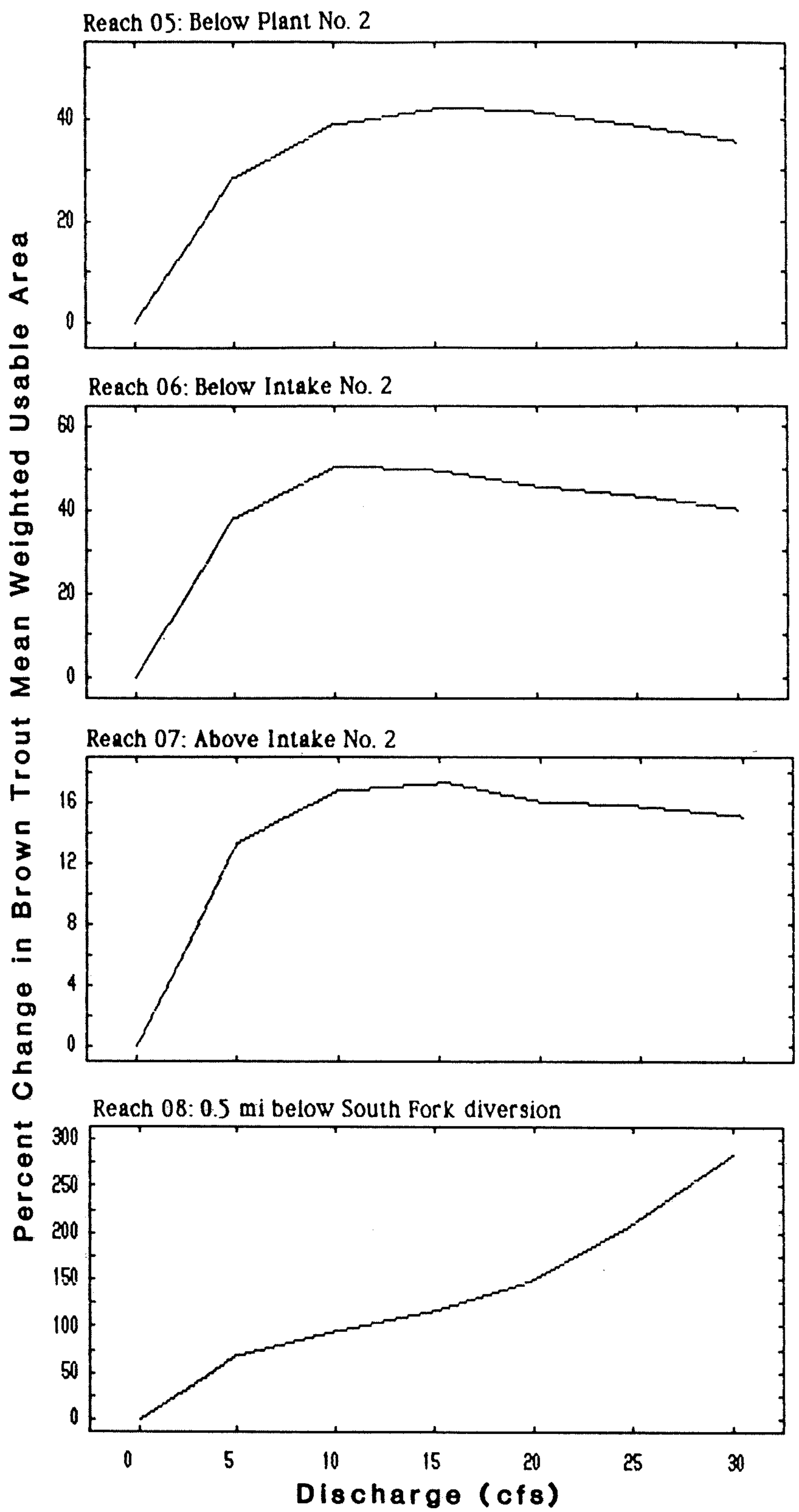


Figure 48. Percent change in mean annual mean (adult, fry, juvenile) brown trout Weighted Usable Area in Reaches 04, 05, 06, and 08 of Bishop Creek as functions of releases in excess of current releases.

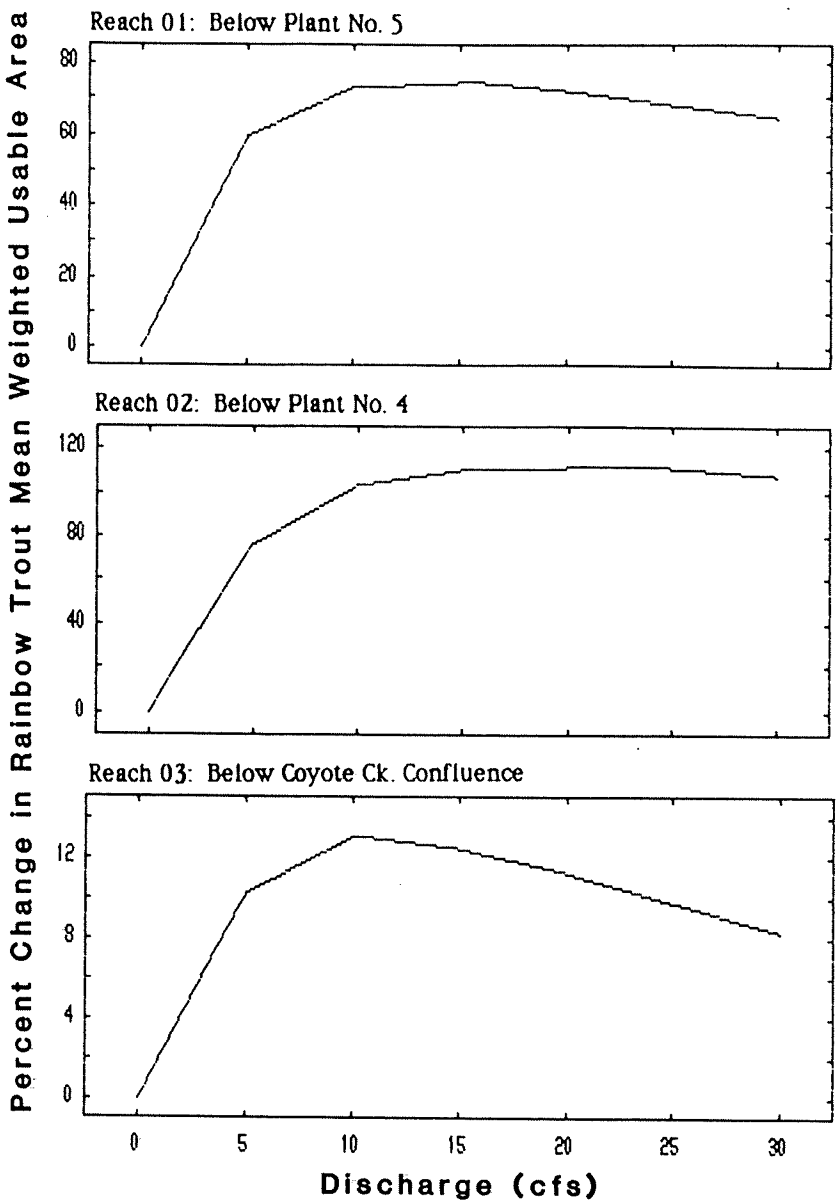


Figure 49. Percent change in mean annual mean (adult, fry, juvenile) rainbow trout Weighted Usable Area in Reaches 01, 02, and 03 of Bishop Creek as functions of releases in excess of current releases.

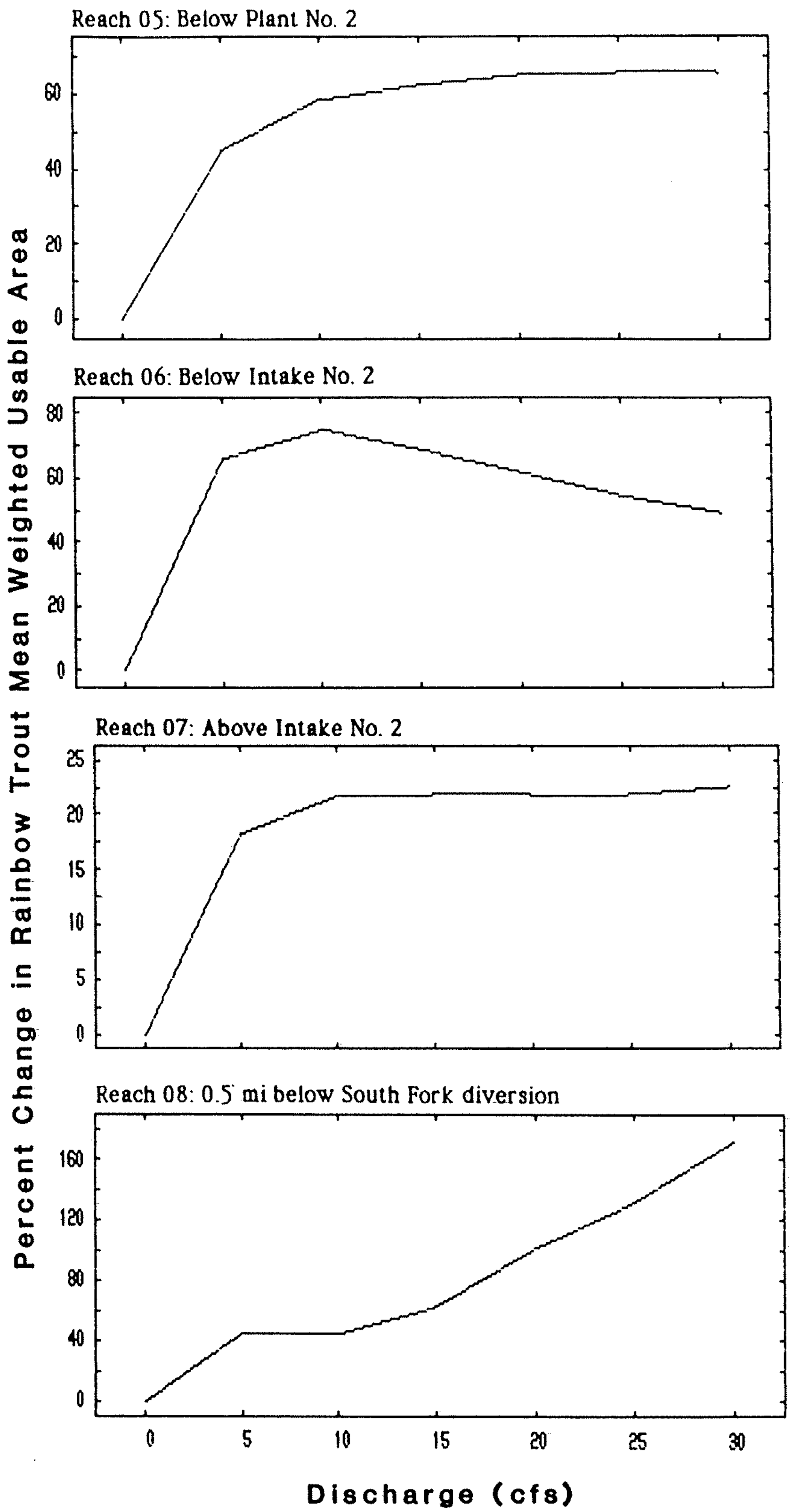


Figure 50. Percent change in mean annual mean (adult, fry, juvenile) rainbow trout Weighted Usable Area in Reaches 04, 05, 06, and 08 of Bishop Creek as functions of releases in excess of current releases.

DISCUSSION

Bishop Creek, having been under its present state of diversion and regulation for over 50 years represents a remarkable test situation in which to examine the effects of hydroelectric projects on fish populations. It also offers an opportunity to evaluate the ability of indices of habitat quality such as Weighted Usable Area (WUA) to describe or reflect variations in fish populations in regulated and diverted streams.

Bishop Creek is the antithesis of the undisturbed natural stream. On the middle fork between Lake Sabrina and the Intake No. 2 diversion and on the south fork between South Lake and the South Fork diversion the stream is undiverted but heavily regulated, having flows maintained year around at approximately 50 cfs. Below these two diversions, nearly all the water is routinely removed, and the principle sources of flow are side hill runoff which occurs primarily in May through September with flows lower than 1 cfs common in many reaches throughout the autumn and winter. Fishing pressure is high in both the diverted and undiverted reaches above Plant No. 3 (Reaches 05-11) but probably very low in the lower reaches.

Throughout the summer the California Department of Fish and Game stocks prodigious numbers of adult rainbow trout in all reaches upstream from Plant No. 3 (182,303 in 1983; 172,020 in 1984; 187,121 in 1985). If we assume an average resident adult (>150mm) population of brown trout of about 1000 per mile as shown from the 1984 and 1985 electrofishing, the 29 miles of Bishop Creek above Plant No. 5 are annually stocked with over 6 times as many catchable rainbow trout as their resident adult population of brown trout. Occasionally a few hatchery brown trout adults are stocked as well. One thousand nine hundred and sixty were stocked in Reach No. 7 during 1984. Also in response to the flooding in late 1982, in 1983 102,000 rainbow trout fingerlings and 42,600 brown trout fingerlings were stocked in the undiverted reaches below South Lake and Lake Sabrina.

This report has been prepared in response to Federal Energy Regulatory Commission relicensing requirements and is directed at the question of how much water should be released from the hydroelectric intake structures to maintain instream flows beneficial to Bishop Creek fisheries. The question is not a simple one to answer. There are many ways to calculate appropriate instream flows but little evidence that any of them produce meaningful results (Morhardt, in press). Consequently, the studies on Bishop Creek have gone beyond the implementation of the technique currently required by the California Department of Fish and Game (the U. S. Fish and Wildlife Service PHABSIM model) to look directly at the effects of prolonged diversion, stocking and recreational fishing on the resident brown trout population, and have examined the relationship between the output of the PHABSIM model and existing populations.

Significance of Brown Trout Size Distributions in Bishop Creek

The length-frequency distributions of brown trout shown in Figures 7 and 8 are generally consistant with a hypothesis that brown trout are reproducing and growing in all reaches of Bishop Creek. The source of juveniles making up the young-of-the year size group in each reach could be either spawning within the reach, or seeding from reaches upstream. Functionally it makes little difference because whatever their source, the fish are growing and maturing in all reaches. It should be noted that the young-of-the-year fish in these samples were not stocked, but were spawned in Bishop Creek. The most recent stocking of brown trout fingerlings occurred in 1983 (21,300 in both the middle fork and south fork above the first diversion point). To the extent that these stocked fish survived, they appear in the second peak on the length frequency histograms for 1984, and in the third peak for 1985.

Each of the reaches had its own size distribution characteristics which we interpret as follows:

Reach 01 below Plant No. 5: Apparently only fish 1 and 2 years old were present. The 1985 size distribution appears normal with the expected large numbers of young-of-the-year and smaller numbers of older fish; the 1984 sample appears deficient in young of year.

Reach 02 below Plant No. 4: The 1984 sample appears deficient in adults. No fish were present in 1985 suggesting that the stream bed dried up completely during the summer of 1985.

Reach 03 above Plant No. 4 below the Coyote Creek confluence: The distribution of life stages appears normal for both years. The fish grew more slowly than those immediately upstream and downstream, probably because of the colder water from Coyote Creek.

Reach 04 between Plant No. 3 and the Coyote Creek confluence: This reach was deficient in young of year in 1984, but the distribution appeared normal in 1985. The flooding of 1982 may have depleted the adults enough that spawning was at reduced levels until autumn of 1984.

Reach 05 below Plant No. 2: The size distributions appear normal in 1984 but there are more adults than expected in relation to numbers of juveniles in 1985. Juvenile numbers are the same in 1985 as in 1984, suggesting a better survival of adults than in the previous year.

Reach 06 below South Fork Diversion: Very low numbers of juveniles were present in 1984, and the low total numbers captured probably contributed to the absence of clear peaks. In 1985 the size distribution appears normal.

Reach 08, 0.5 miles below the South Fork Diversion: Relatively even distributions suggest either better adult survival or lower recruitment than normal.

Reach 11 below South Fork Diversion: This erratic distribution is probably the result of the low total number of fish caught.

Condition of Fish in Bishop Creek

Growth rates in the lowest reaches of Bishop Creek between Plants No. 4 and 6, and above the Coyote Creek Confluence in 1984, were noticably higher than in any of the reaches upstream. The mean size of the young-of-the-year in these reaches was about 100 mm, whereas in all reaches upstream mean young-of-the-year lengths were closer to 75mm. To assure that the differences in length were attributable to growth, we sampled scales from a few fish in Reach 01 and Reach 05 for age determination. In Reach 01, two brown trout 114 and 117 mm long were in their first year and serveral brown trout between 200 and 300 mm were in their second year. In Reach 07, one brown trout 85 mm long was in its first year, another 139 mm long was in its second year, another 219 mm long was in its third year, and one 303 mm long was in its fourth year. The increased growth rates in the lower reaches are probably attributable to a combination of relatively low fish densities and possibly to higher summer water temperatures.

Length-Weight regressions: We have reported the relationships between length and weight because U.S. Forest Service comments indicated that the results would be useful in their analysis of the electrofishing data. We, however, have been unable to find data from other studies with which to make a comparison.

Condition Factors: The condition of fish in Bishop Creek appears to be good based on Fulton-type condition factors (calculated using the technique of Anderson and Gutreuter, 1983). The mean value of fork length condition factor for fish captured in October and November 1985 was 1.13 $\pm$ sd 0.21; and for fish captured December 20, was 1.05 $\pm$ sd 0.08. These are as good or better than the condtion factors of 0.99-1.08 observed in adult brown trout fed maximum rations for 35-42 days at temperatures of 3.8C to 9.5C (Elliott 1975) or those of 0.95 - 1.08 observed by Mesick (1984) in adult brown trout fed maximum rations for 60 days at temperatures of 14.5C. They are also better than those observed by Ellis and Gowing (1957) in a study comparing natural sections of a Michigan stream with another section enriched with food (0.88-1.06). We converted the data of Needham et al. (1945) on Brown Trout in Convict Creek to Forklength condition factor and found that they had observed conditions with a mean value of 0.819, much less good than the fish in Bishop Creek.

The substantial scatter in condition factor in Figure 15, particularly in fish of small size, is probably due to random measurement error resulting from difficulty in visually estimating amount of water displaced in a graduated cylinder.

The curvilinear patterns in the scatter plot for the shortest fish is the result of reading the graduated cylinder to the nearest ml. Figure 18 shows the decrease in scatter resulting from the use of a triple-beam balance for weighing the fish.

The differences in condition factors among reaches shown in Figures 17 and 21, and identified in Table 6, indicate that fish in the undiverted reach above Intake No. 2 are in better condition than in the reaches immediately below the diversions into Intake 2 on both forks. So are those in Reach 4 (above the Coyote Creek confluence), and in Reach 3 below the Coyote confluence, and those in Reach 01 are in better condition than those in Reach 06. The trends from Table 6 appear to be that the lower the elevation and the more water in the stream, the better the condition of the fish. The mean condition values for all reaches, however, are quite good. For example, the mean value of the condition factor in Reach 08, the reach with the lowest condition factors, is 1.06. This value is at the high end of condition factors from the literature. It appears, therefore, that brown trout throughout Bishop Creek are in good condition, and those in some of the reaches are in extremely good condition, even, as in the case of Reach 01, under conditions of heavy diversion.

<u>Comparison of Bishop Creek Brown Trout Populations With Those of Other Eastern Sierra Streams:</u>

The California Department of Fish and Game has recently completed a comprehensive survey of fish populations in streams of the Owens River basin (Deinstadt et al. 1985) and this study provides the most suitable available benchmark for comparison with fish populations in Bishop Creek. Figure 51a shows the relationship between numbers of adult (>150mm) brown trout per mile for Bishop Creek (open squares) and all other streams sampled by Deinstadt et al. (1985) in the eastern Sierra, as a function of mean annual flow. (Flow data are from either Southern California Edison Company for Bishop Creek or from the City of Los Angeles gauging stations closest to Deinstadt's sampling points.) Two things about these data are noteable: although most of the data points occur in the lower left hand corner at low flows and low fish densities, one group of data points shows relatively low populations at high flows, and another set shows very high populations at low flows. All of the data points with high mean annual flows (greater than 100 cfs) come from the Owens River below Pleasant Valley Dam, and all of the remaining data (at relatively low flows) showing more than 2000 adults per mile come either from the Bishop Creek Canal, from the diverted section of the Owens River Gorge below Crowley Lake, or from Hot Creek and the adjacent reach of Mammoth Creek. None of these stream sections bear much resemblance to Bishop Creek and other canyon and alluvial streams on the east side of the Sierra. The Owens River below Pleasant Valley Dam is an order of magnitude larger than any of the other streams, and below Crowley Lake is heavily regulated with large quantities of aquatic plants. Bishop Creek

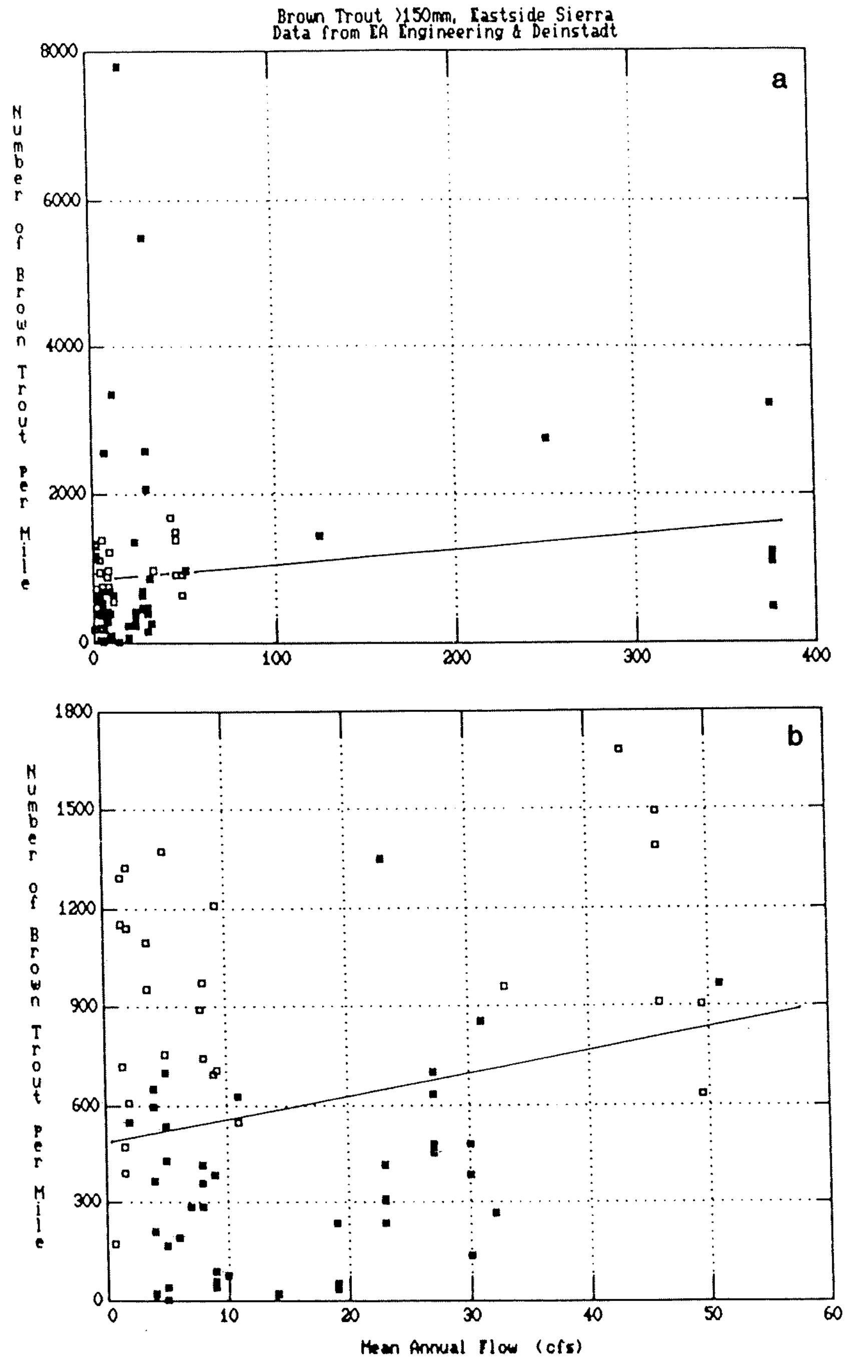


Figure 51. Relationship between number of adult brown trout per mile and mean annual flow in eastside Sierra streams. Open squares are for Bishop Creek. The lower figure is an enlargement of the lower left-hand corner of the upper figure. Note that with few exceptions, Bishop Creek has higher populations than other streams with the same mean annual flows.

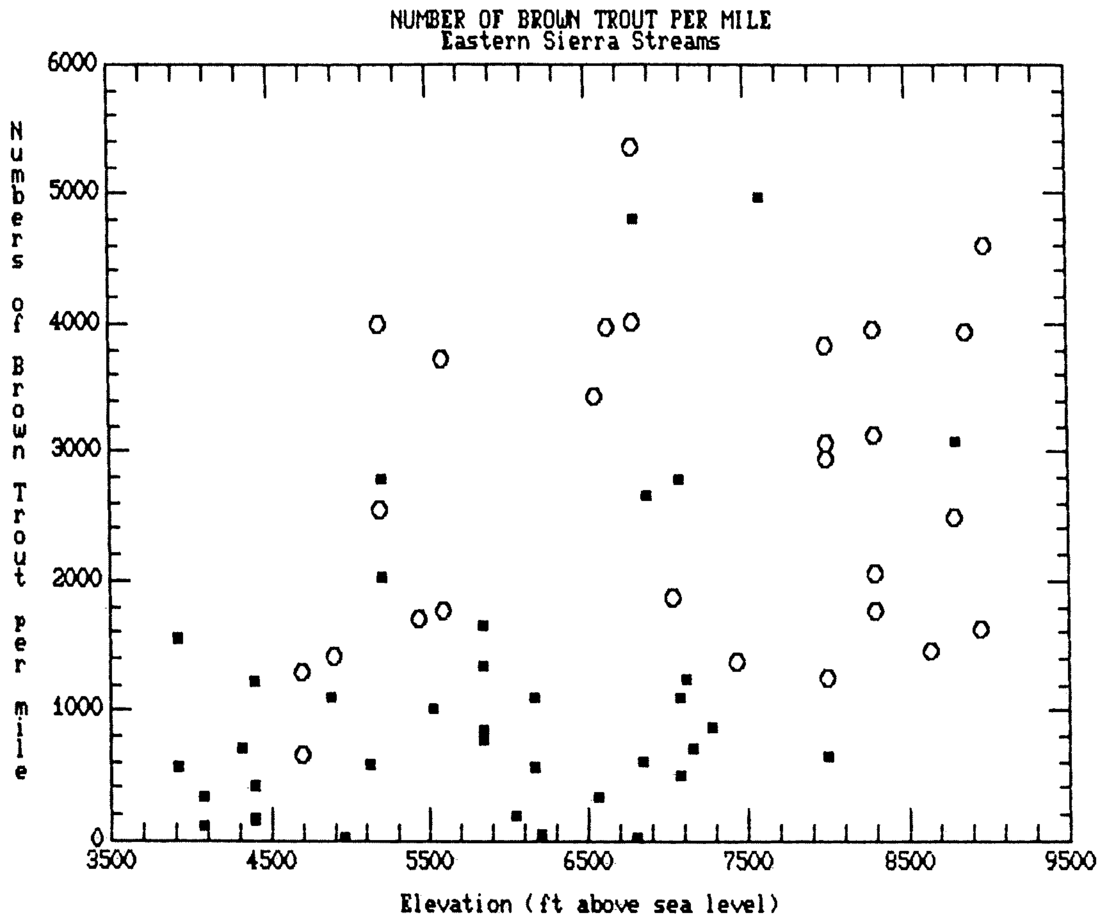


Figure 52. Number of brown trout per mile in Bishop Creek (open circles) and the other eastern sierra streams studied by Deinstadt et al., 1985 (closed squares) plotted against elevation. Excluded from the analysis were Hot Creek, the Mammoth Creek station just upstream from Hot Creek, Bishop Creek Canal, and the Owens River.

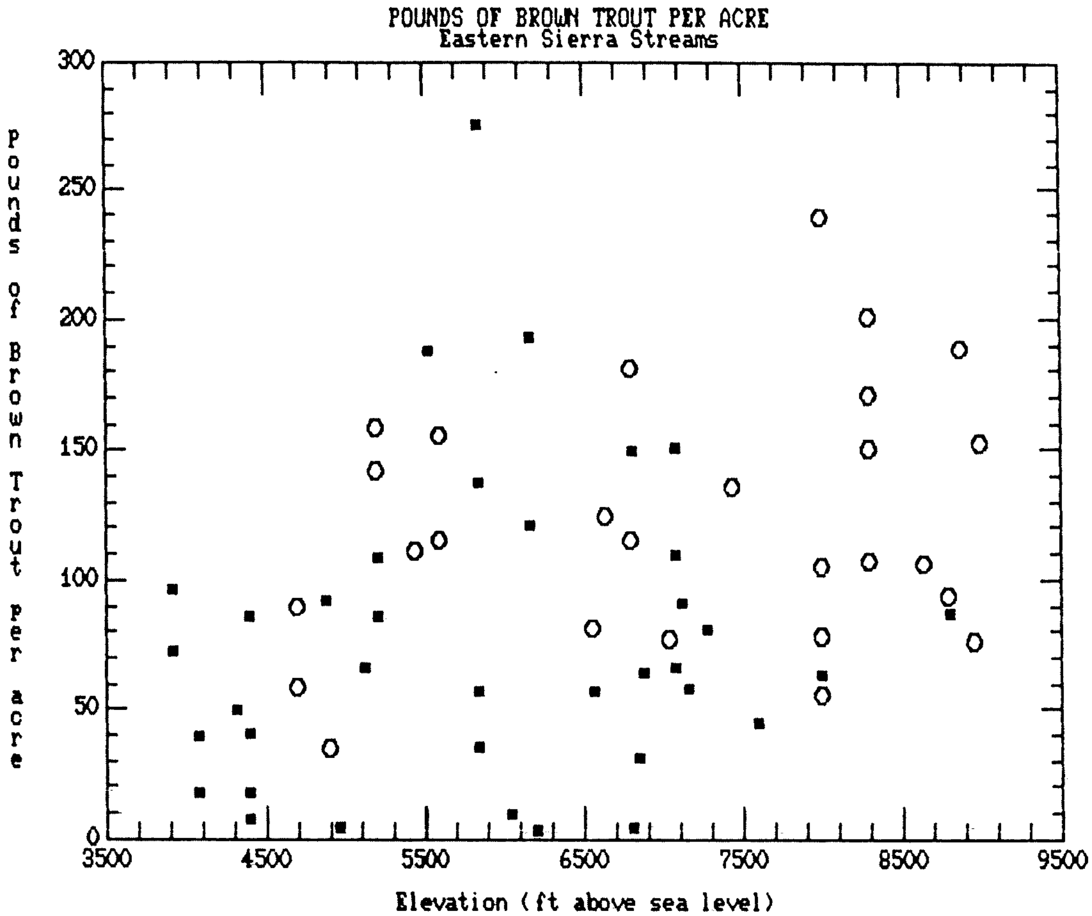


Figure 53. Pounds of brown trout per acre in Bishop Creek (open circles) and the other eastern sierra streams studied by Deinstadt et al., 1985 (closed squares) plotted against the mean monthly January flow. Excluded from the analysis were Hot Creek, the Mammoth Creek station just upstream from Hot Creek, Bishop Creek Canal, and the Owens River.

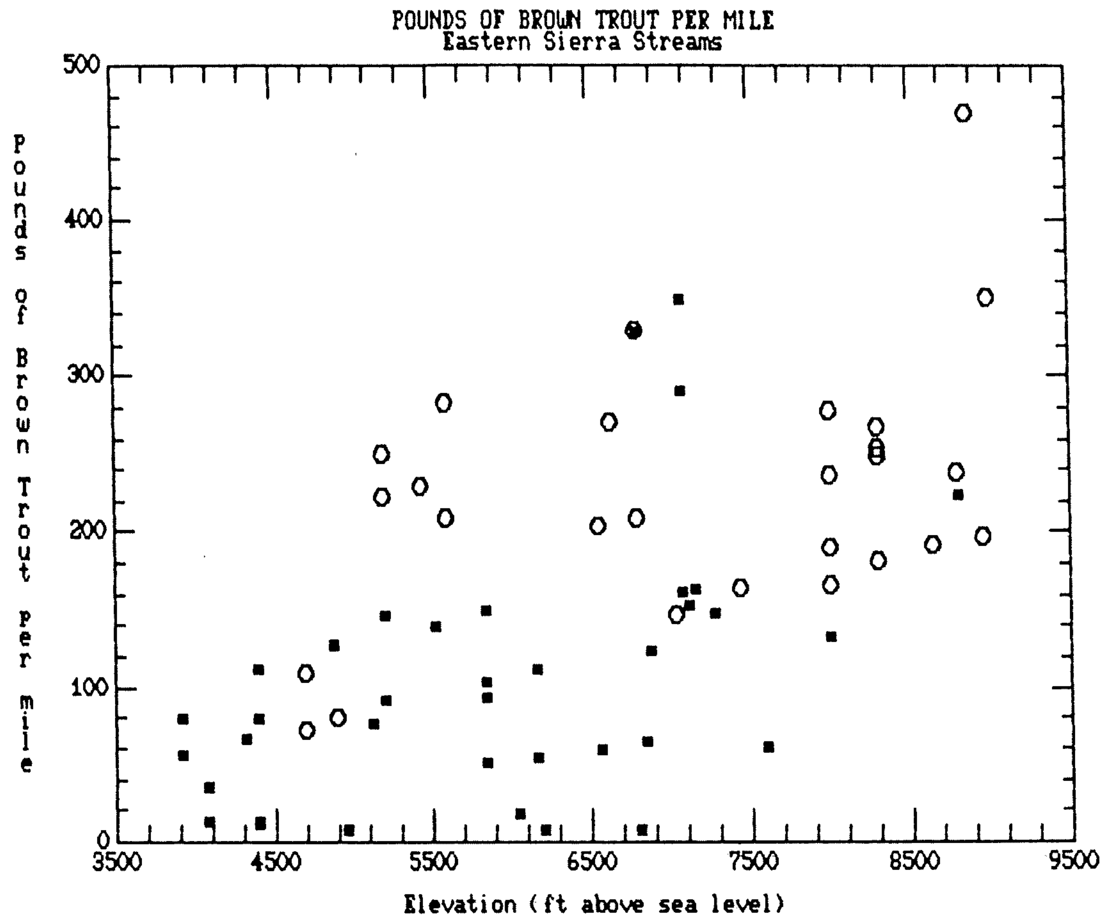


Figure 54. Pounds of brown trout per mile in Bishop Creek (open circles) and the other eastern sierra streams studied by Deinstadt et al., 1985 (closed squares) plotted against elevation. Excluded from the analysis were Hot Creek, the Mammoth Creek station just upstream from Hot Creek, Bishop Creek Canal, and the Owens River.

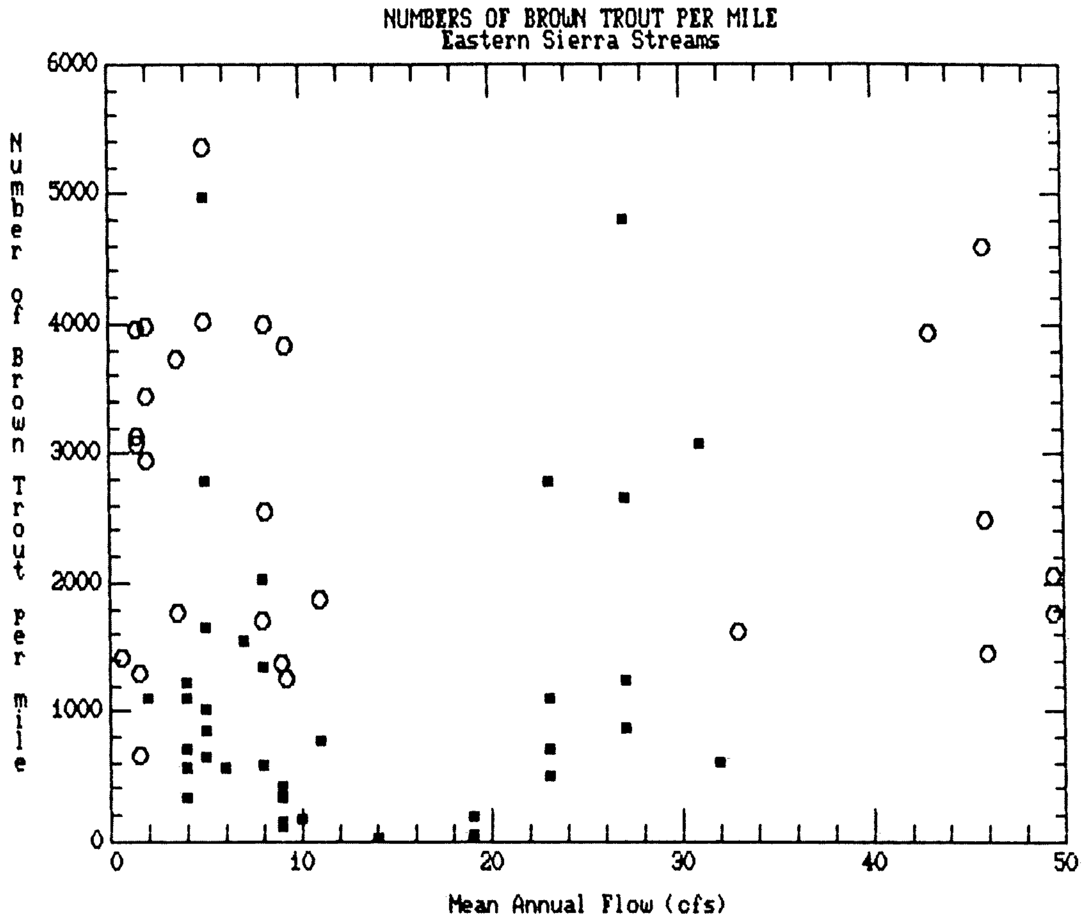


Figure 55. Number of brown trout per mile in Bishop Creek (open circles) and the other eastern sierra streams studied by Deinstadt et al., 1985 (closed squares) plotted against the mean annual flow. Excluded from the analysis were Hot Creek, the Mammoth Creek station just upstream from Hot Creek, Bishop Creek Canal, and the Owens River.

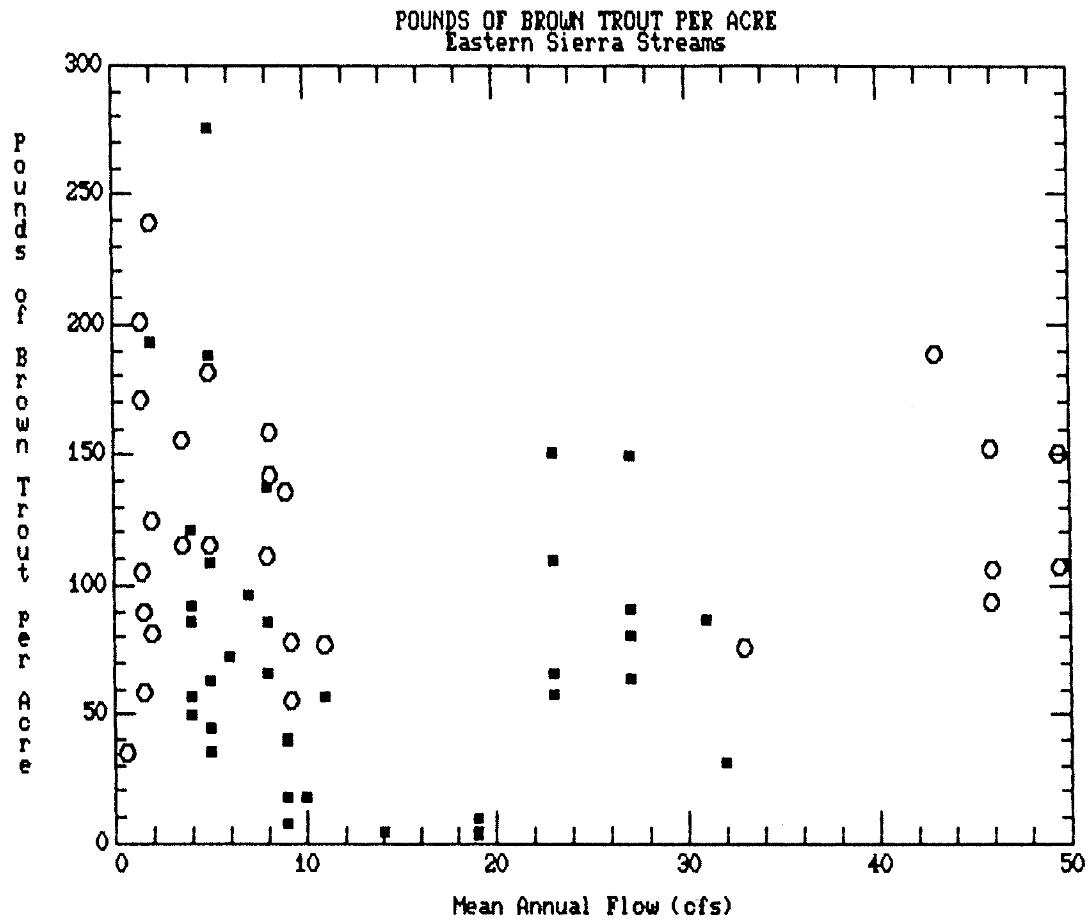


Figure 56. Pounds of brown trout per acre in Bishop Creek (open circles) and the other eastern sierra streams studied by Deinstadt et al., 1985 (closed squares) plotted against the mean annual flow. Excluded from the analysis were Hot Creek, the Mammoth Creek station just upstream from Hot Creek, Bishop Creek Canal, and the Owens River.

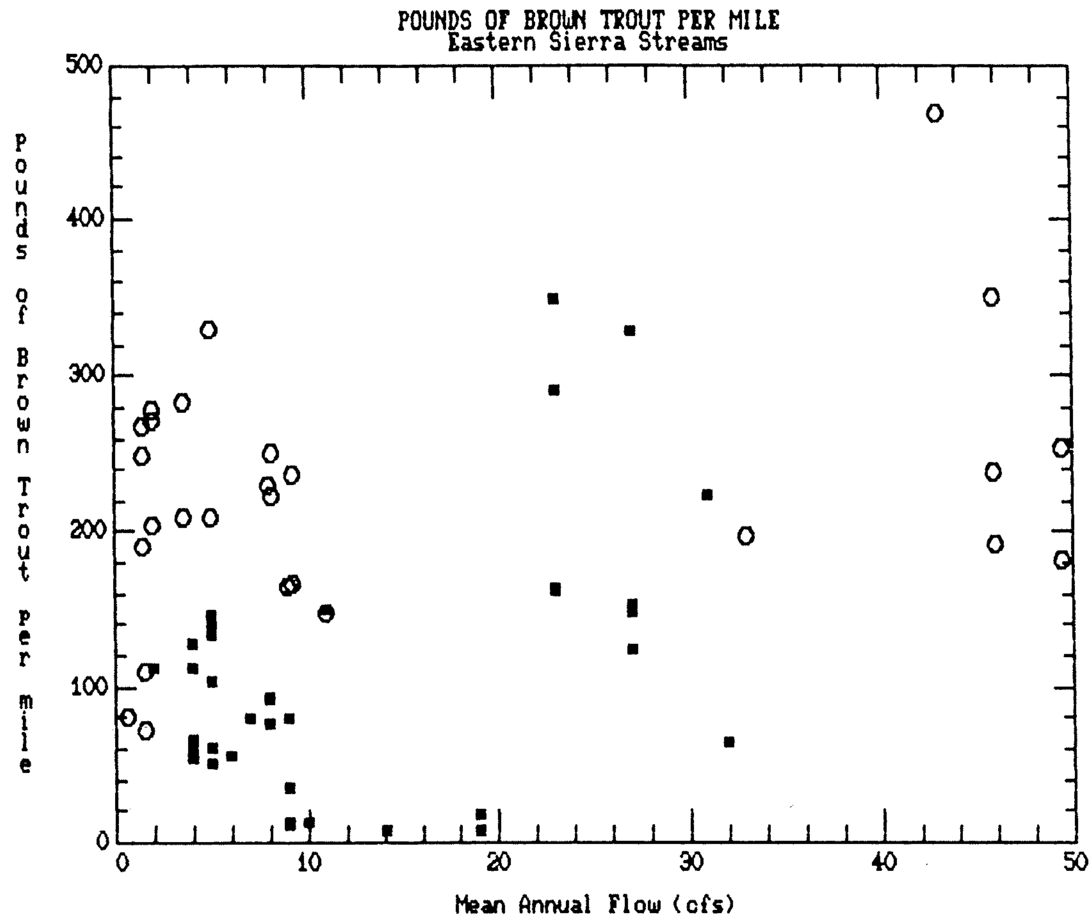


Figure 57. Pounds of brown trout per mile in Bishop Creek (open circles) and the other eastern sierra streams studied by Deinstadt et al., 1985 (closed squares) plotted against the mean annual flow. Excluded from the analysis were Hot Creek, the Mammoth Creek station just upstream from Hot Creek, Bishop Creek Canal, and the Owens River.

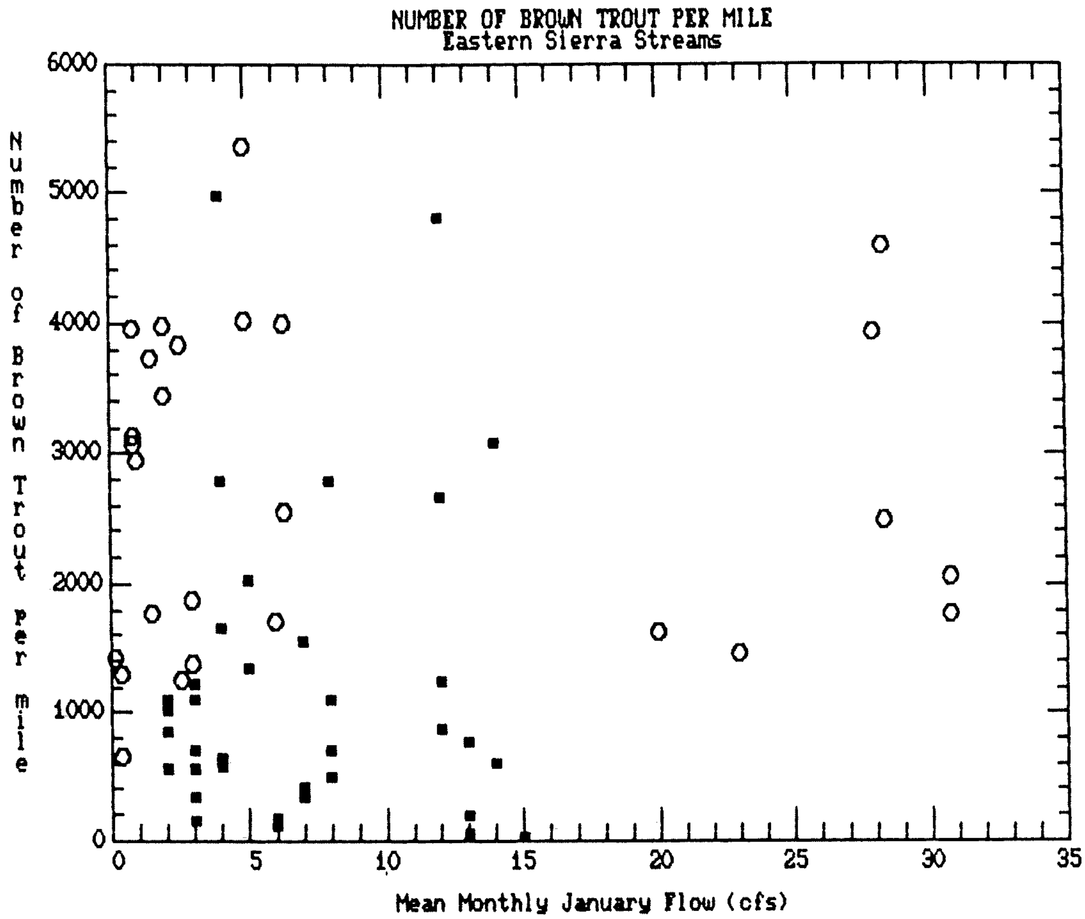


Figure 58. Number of brown trout per mile in Bishop Creek (open circles) and the other eastern sierra streams studied by Deinstadt et al., 1985 (closed squares) plotted against the mean monthly January flow. Excluded from the analysis were Hot Creek, the Mammoth Creek station just upstream from Hot Creek, Bishop Creek Canal, and the Owens River.

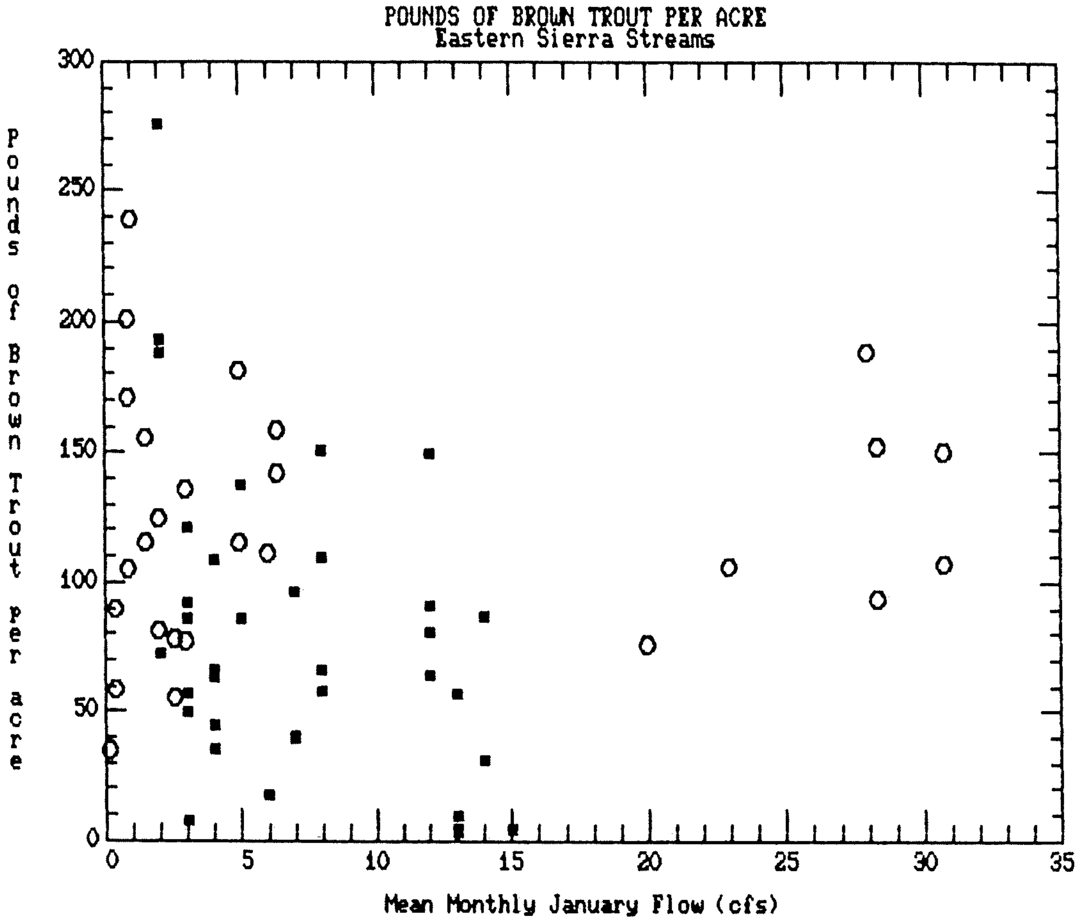


Figure 59. Pounds of brown trout per acre in Bishop Creek (open circles) and the other eastern sierra streams studied by Deinstadt et al., 1985 (closed squares) plotted against the mean monthly January flow. Excluded from the analysis were Hot Creek, the Mammoth Creek station just upstream from Hot Creek, Bishop Creek Canal, and the Owens River.

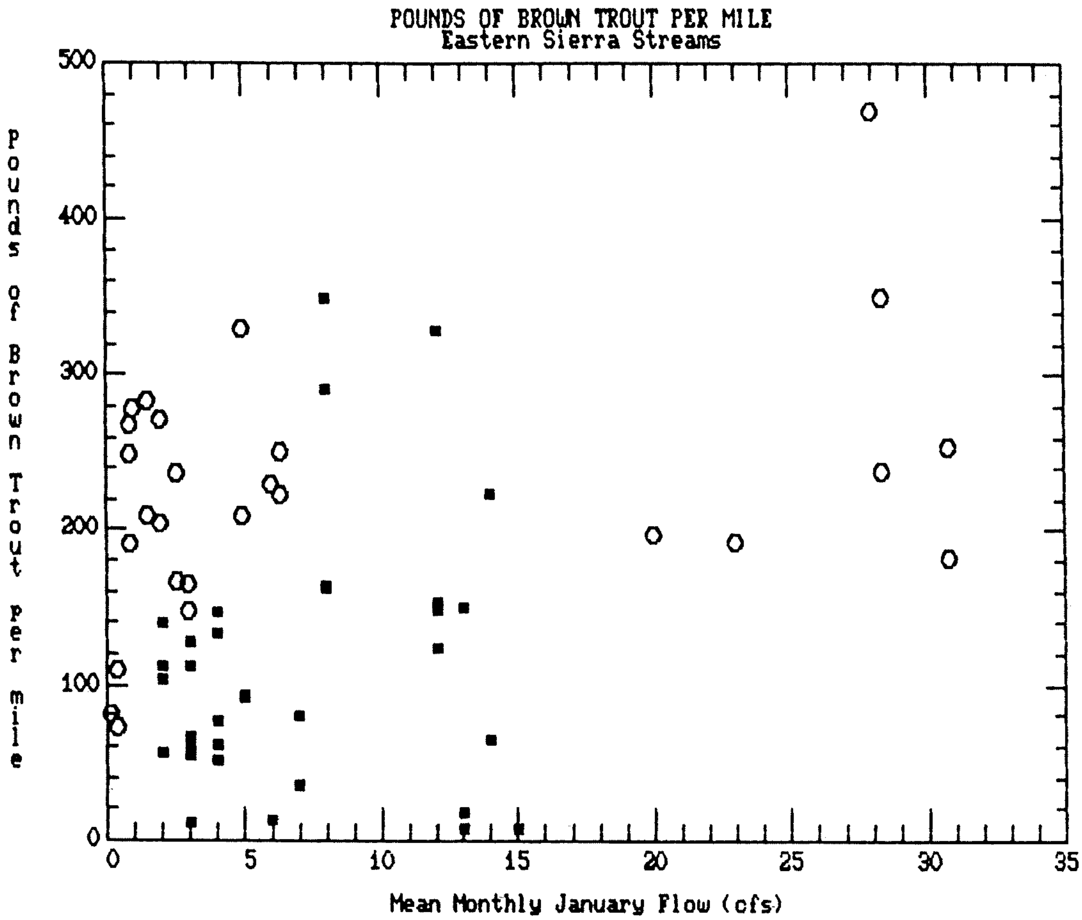


Figure 60. Pounds of brown trout per mile in Bishop Creek (open circles) and the other eastern sierra streams studied by Deinstadt et al., 1985 (closed squares) plotted against the mean monthly January flow. Excluded from the analysis were Hot Creek, the Mammoth Creek station just upstream from Hot Creek, Bishop Creek Canal, and the Owens River.

Canal is a man-made low gradient ditch, much of it with emergent aquatic vegetation and Hot Creek is infused with a large supply of nutrients flowing out of the Hot Creek fish hatchery. The lowest station on Mammoth Creek is near the Hot Creek confluence and its populations are probably influenced by the proximity to Hot Creek as well. Figure 51b shows an enlargement of the lower lefthand corner of Figure 51a, eliminating data from the unusual reaches listed above. Inspection of Figure 51b shows that Bishop Creek has, in general, more adult brown trout per mile than the other eastern Sierra streams studied by Deinstadt et al. 1985. Figures 52, 53 and 54, show the same data plotted as a function of elevation, again showing that Bishop Creek produces as many or more brown trout per mile, pounds of brown trout per acre, and pounds of brown trout per mile , as other eastern Sierra streams.

Figures 55, 56 and 57, show these same data (numbers of brown trout per mile, pounds of brown trout per acre and pounds of brown trout per mile for eastside Sierran streams) as functions of mean annual flow, and Figures 58, 59, and 60 show the same data plotted against mean monthly January flow (the lowest flows of the year usually occur in January in the unregulated streams). Bishop Creek equals or exceeds most of the other streams in fish production.

Statistical analysis of the data in Figures 55-60 show that:

1. Bishop Creek has significantly higher populations of brown trout, whether measured as numbers per mile, pounds per acre, or pounds per mile, than other eastern Sierra streams (99% confidence level). This difference occurs whether or not the seven data points on Bishop Creek representing mean January flows of 20 cfs or greater are included.

2. There are no significant differences (95% confidence level) in brown trout population sizes in Bishop Creek by any of the three population measures used, between reaches with January flows greater than 20 cfs (the regulated sections) those with January flows less than 7 cfs (the diverted sections).

We conclude from these data that Bishop Creek is better than most other eastern Sierra streams in its ability to maintain high standing crops of brown trout. The fishing pressure, diversions, and heavy stocking of catchable rainbow trout have not caused brown trout populations to become atypically low, and the relatively high continuous flows in the regulated reaches have not resulted in higher standing crops than in the diverted reaches. Because the mean annual and mean January flows shown on Figures 55-60 are for the period of record rather than for the time immediately preceeding population sampling it is not reasonable to use these data to determine if the fish populations are correlated with flows. Regression analysis of population size and recent flows on Bishop Creek follows.

Relationship Between Flow And Numbers of Brown Trout in Bishop Creek

To test the possibility that brown trout standing crops are correlated with flow in Bishop Creek, we plotted population size (pounds per acre and numbers per mile) against the mean monthly flow in the sampled reaches for the twelve months previous to the sample period, and against the minimum monthly average flow in the twelve months preceeding the sample period, and examined the regressions statistically.

The result of these regressions are shown in Figures 61 and 62. There is no statistically significant correlation between flow and standing crop of brown trout.

Relationship Between Weighted Usable Area and Brown Trout Numbers in Bishop Creek.

The purpose of the U.S. Fish and Wildlife Service PHABSIM/HABTAT model is to produce a response variable, Weighted Usable Area (WUA), which reflects habitat quality. If fish populations are limited by habitat availabilty, then WUA shuld be correlated with fish population size. The most basic assumption used when applying the model to diverted streams is that diversion will cause fish populations to be limited by habitat. Consequently, in diverted streams, the model can be considered valid only if WUA is correlated with population size.

In order to test this assumption, and hence the validity of the model, we plotted pounds of brown trout per acre and numbers of brown trout per mile versus mean fry WUA for the 12 months preceeding population measurement (Figure 63) and fry WUA for the month with the lowest WUA of the preceeding 12 months (Figure 64). We also plotted population versus mean juvenile WUA (Figure 65) and minimum juvenile WUA (Figure 66), mean adult WUA (Figure 67) and minimum adult WUA (Figure 68), and the mean of the mean fry, juvenile and adult WUA (Figure 69) as well as the mean of the minimum, fry, juvenile and adult WUA (Figure 70).

None of the correlations were significant at the 95% confidence level (F-test), and all but one of them was negative. This analysis does not support the validity of Weighted Usable Area as calculated using the Suitability Index curves supplied by Aceituno et al. (unpublished) as a descriptor of habitat quality in Bishop Creek.

Relationship Between Percent Usable Area and Brown Trout Numbers in Bishop Creek.

Another approach to validating Weighted Usable Area as an indicator of habitat quality is to produce a WUA-dependent variable, Percent Usable Area (PUA) for regression against standing crop. Percent Usable Area is the percentage of the total area represented by WUA, and was used in an extensive

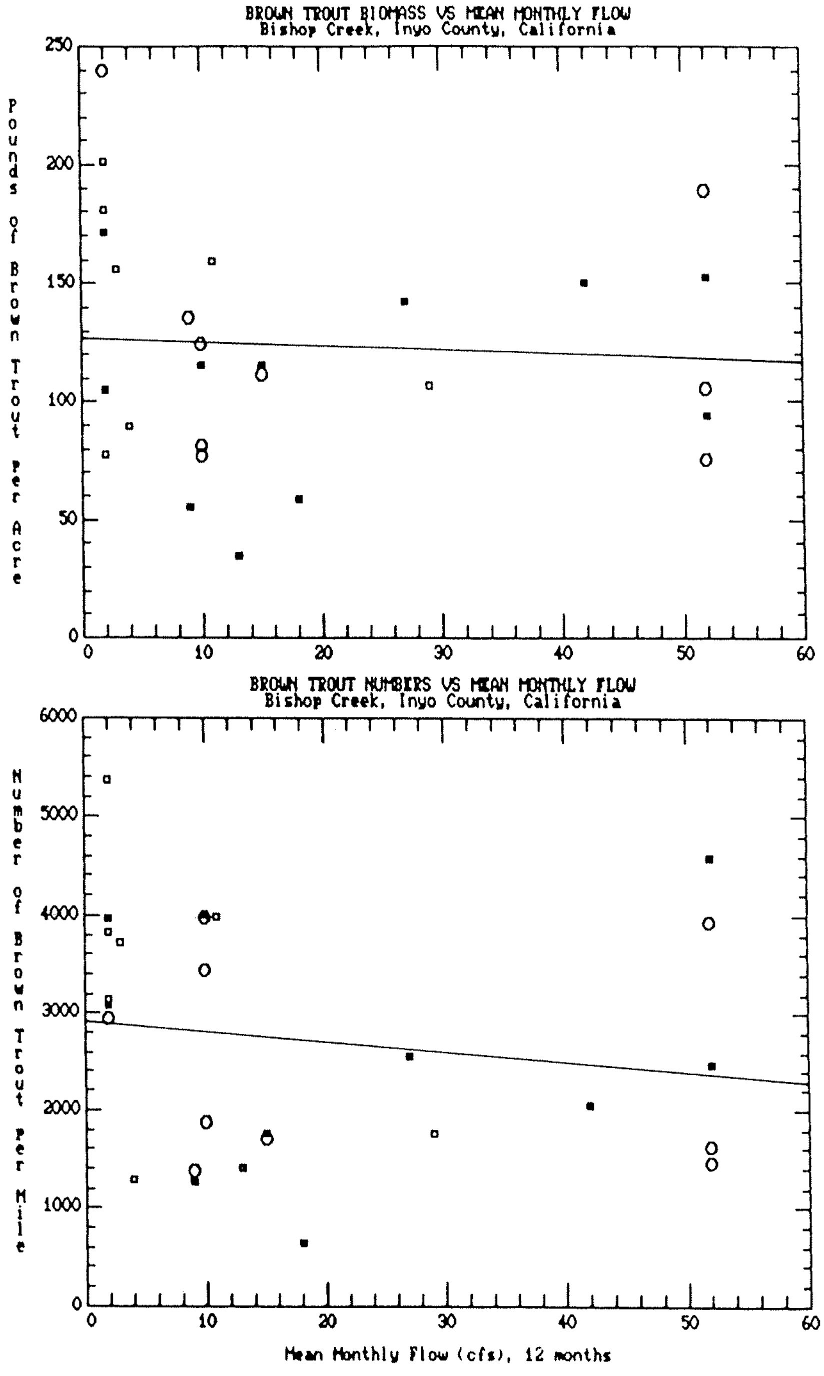


Figure 61. Pounds of brown trout per acre and numbers of brown trout per mile in Bishop Creek plotted against mean monthly average flow (cfs) for the preceeding 12 months. Data are from EA Engineering, Science, and Technology, Inc. 1984 (closed squares), 1985 (open squares), and Dienstadt et al., 1985 (open circles).

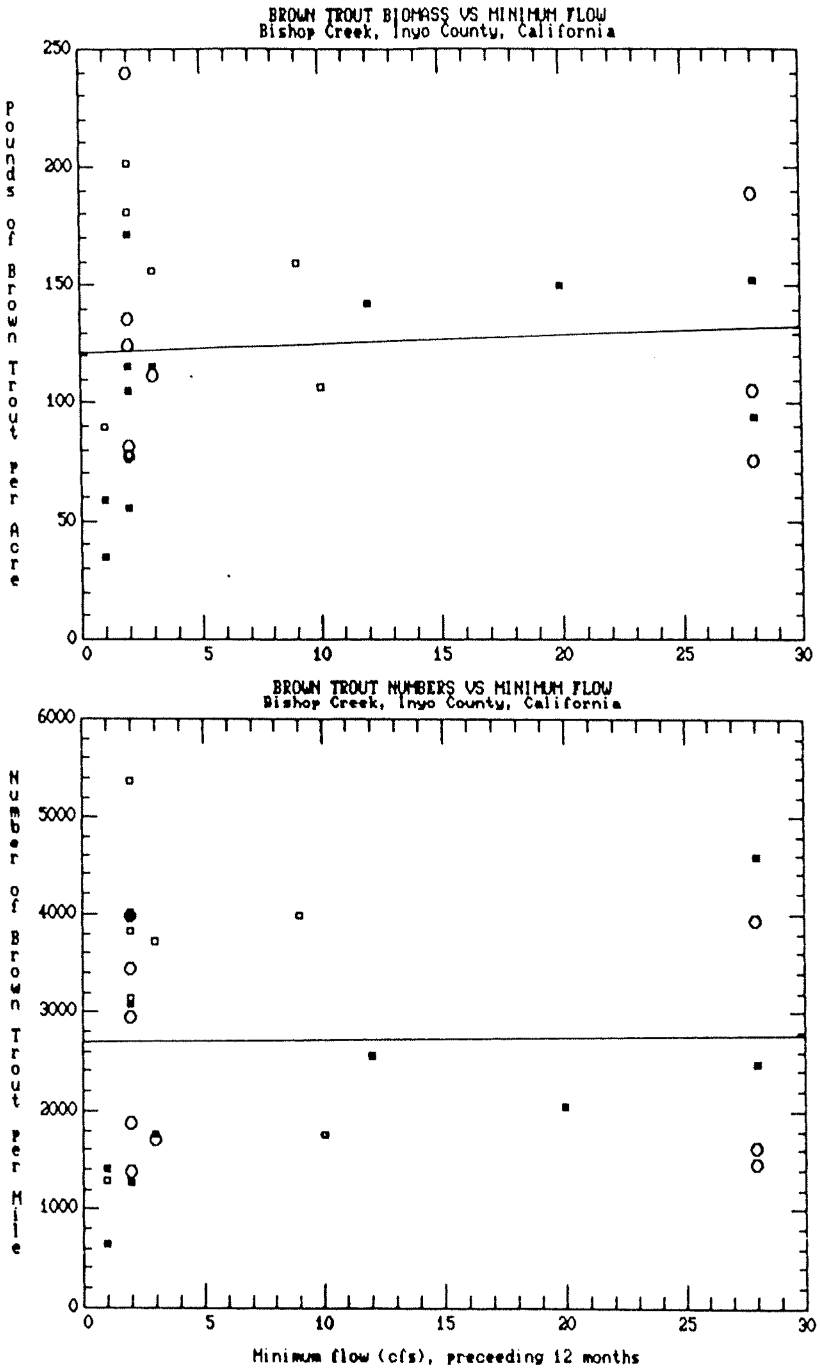


Figure 62. Pounds of brown trout per acre and numbers of brown trout per mile in Bishop Creek plotted against minimum monthly average flow (cfs) for the preceeding 12 months. Data are from EA Engineering, Science, and Technology, Inc. 1984 (closed squares), 1985 (open squares), and Dienstadt et al., 1985 (open circles).

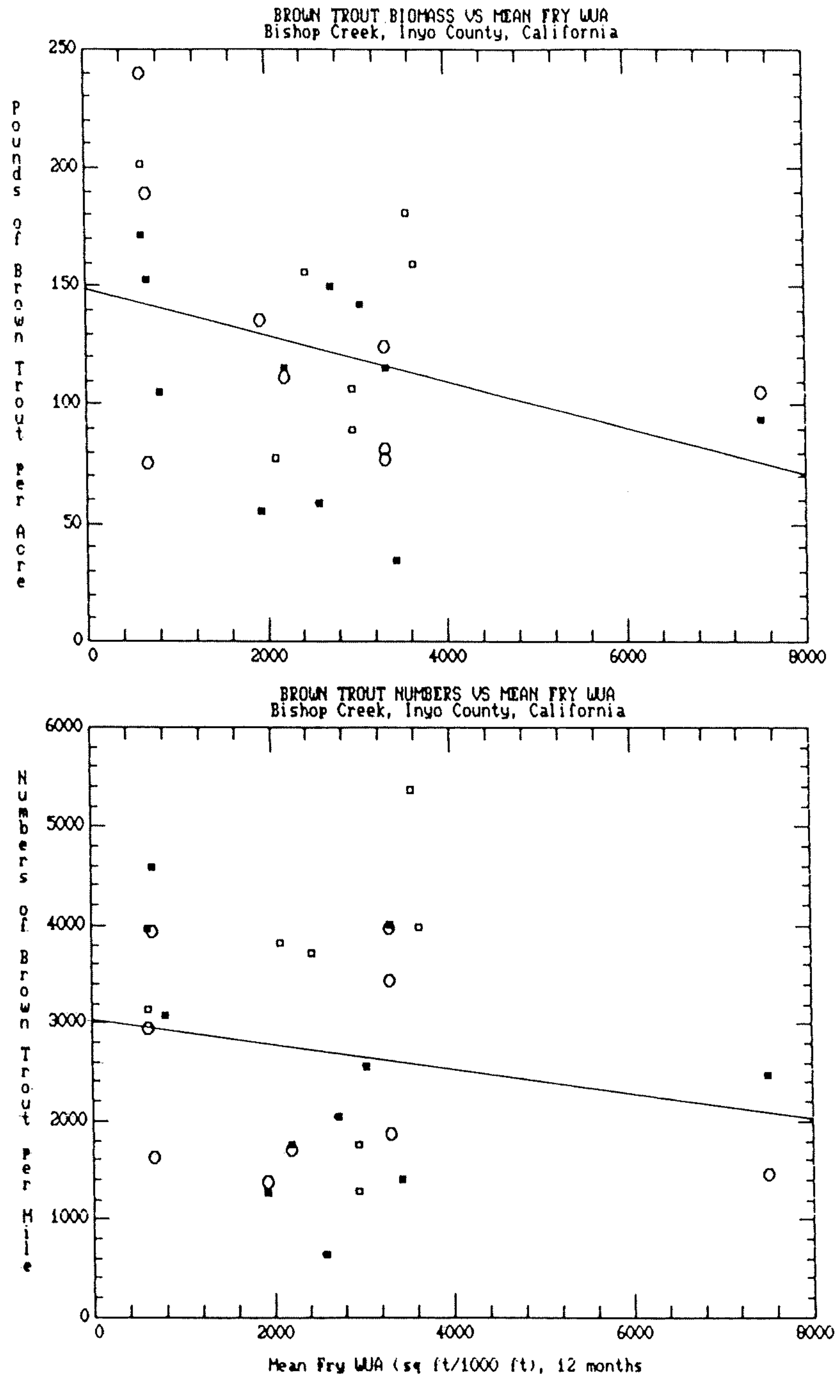


Figure 63. Pounds of brown trout per acre and numbers of brown trout per mile in Bishop Creek plotted against mean fry Weighted Usable Area for the preceeding 12 months. Data are from EA Engineering, Science, and Technology, Inc. 1984 (closed squares), 1985 (open squares), and Dienstadt et al., 1985 (open circles).

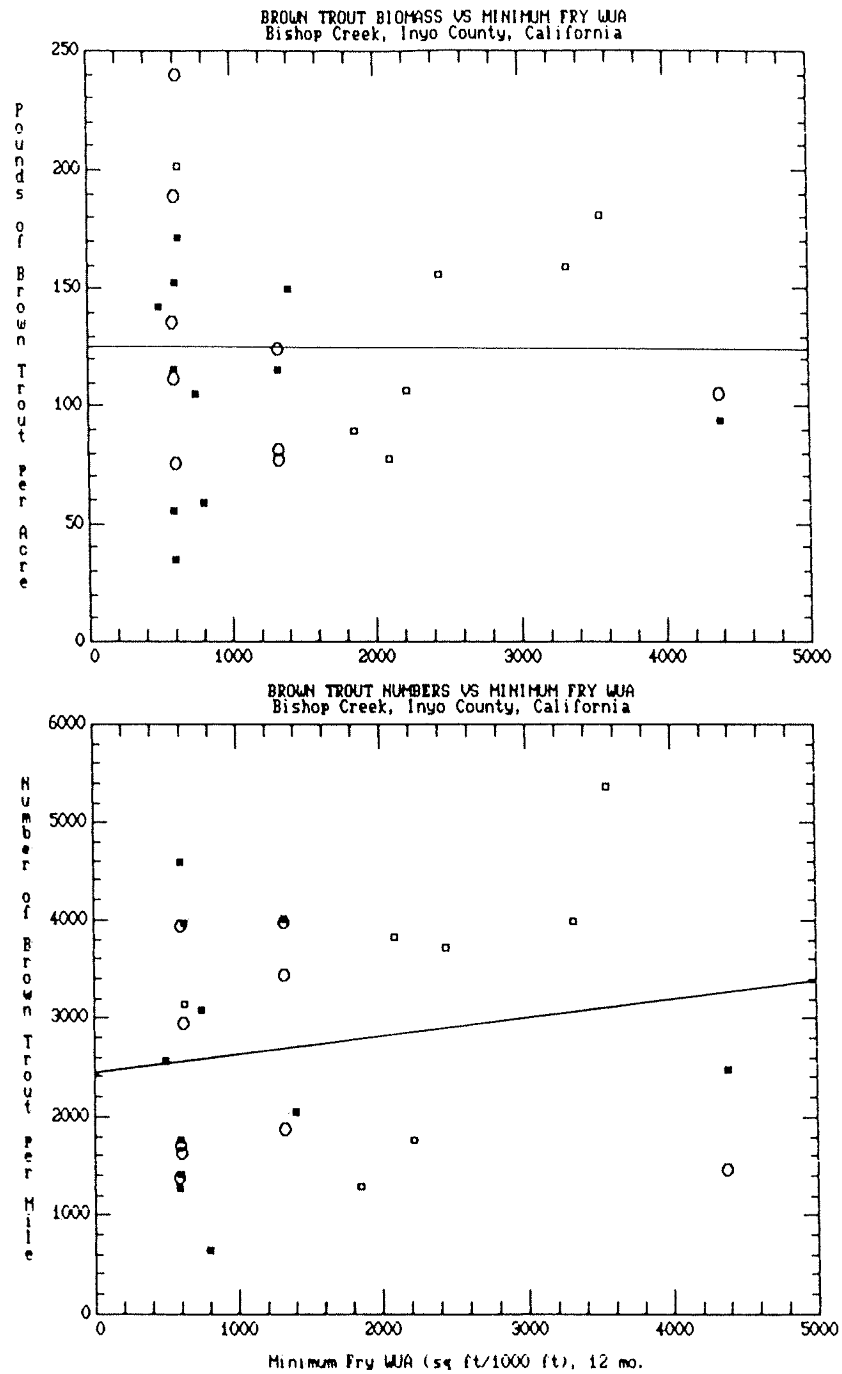


Figure 64. Pounds of brown trout per acre and numbers of brown trout per mile in Bishop Creek plotted against minimum fry Weighted Usable Area for the preceeding 12 months. Data are from EA Engineering, Science, and Technology, Inc. 1984 (closed squares), 1985 (open squares), and Dienstadt et al., 1985 (open circles).

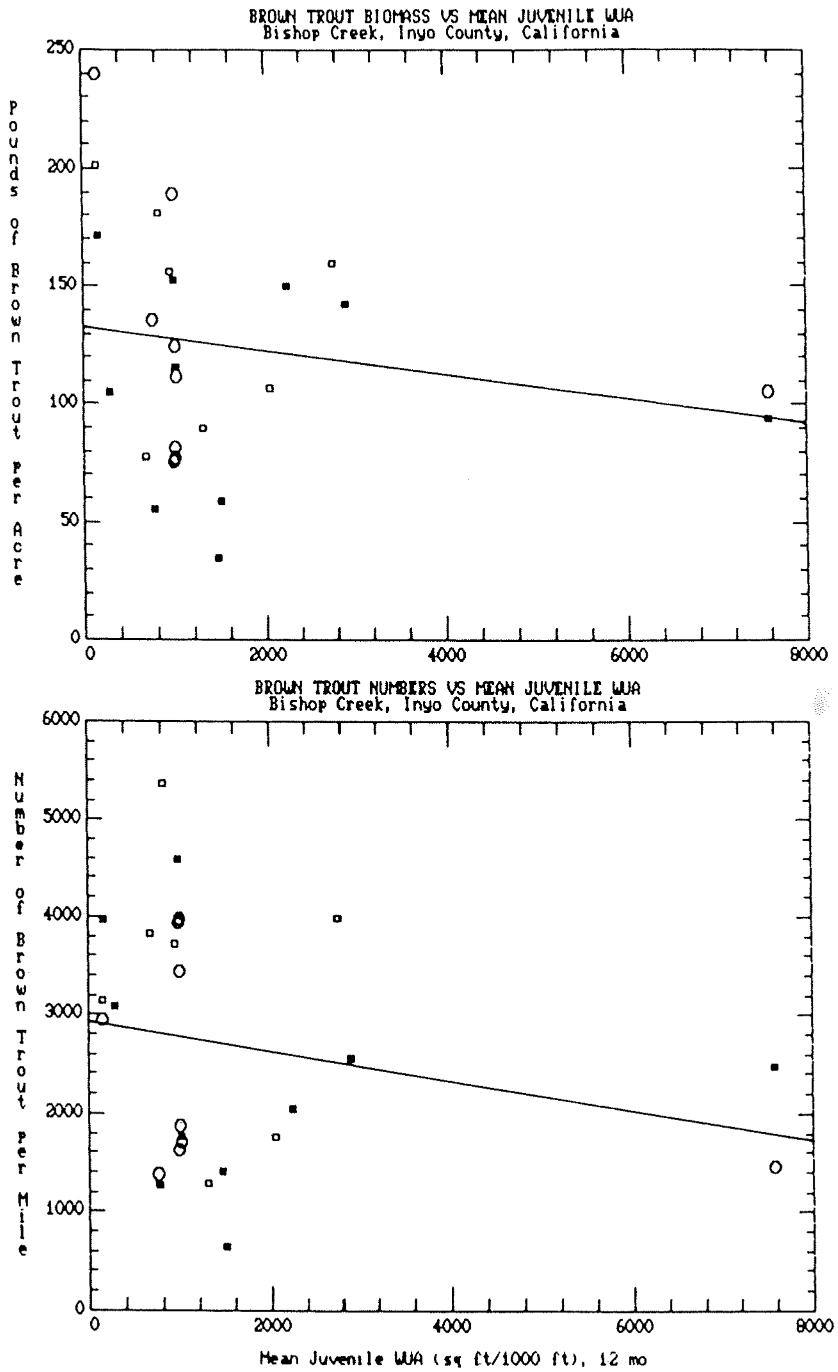


Figure 65. Pounds of brown trout per acre and numbers of brown trout per mile in Bishop Creek plotted against mean juvenile Weighted Usable Area for the preceeding 12 months. Data are from EA Engineering, Science, and Technology, Inc. 1984 (closed squares), 1985 (open squares), and Dienstadt et al., 1985 (open circles).

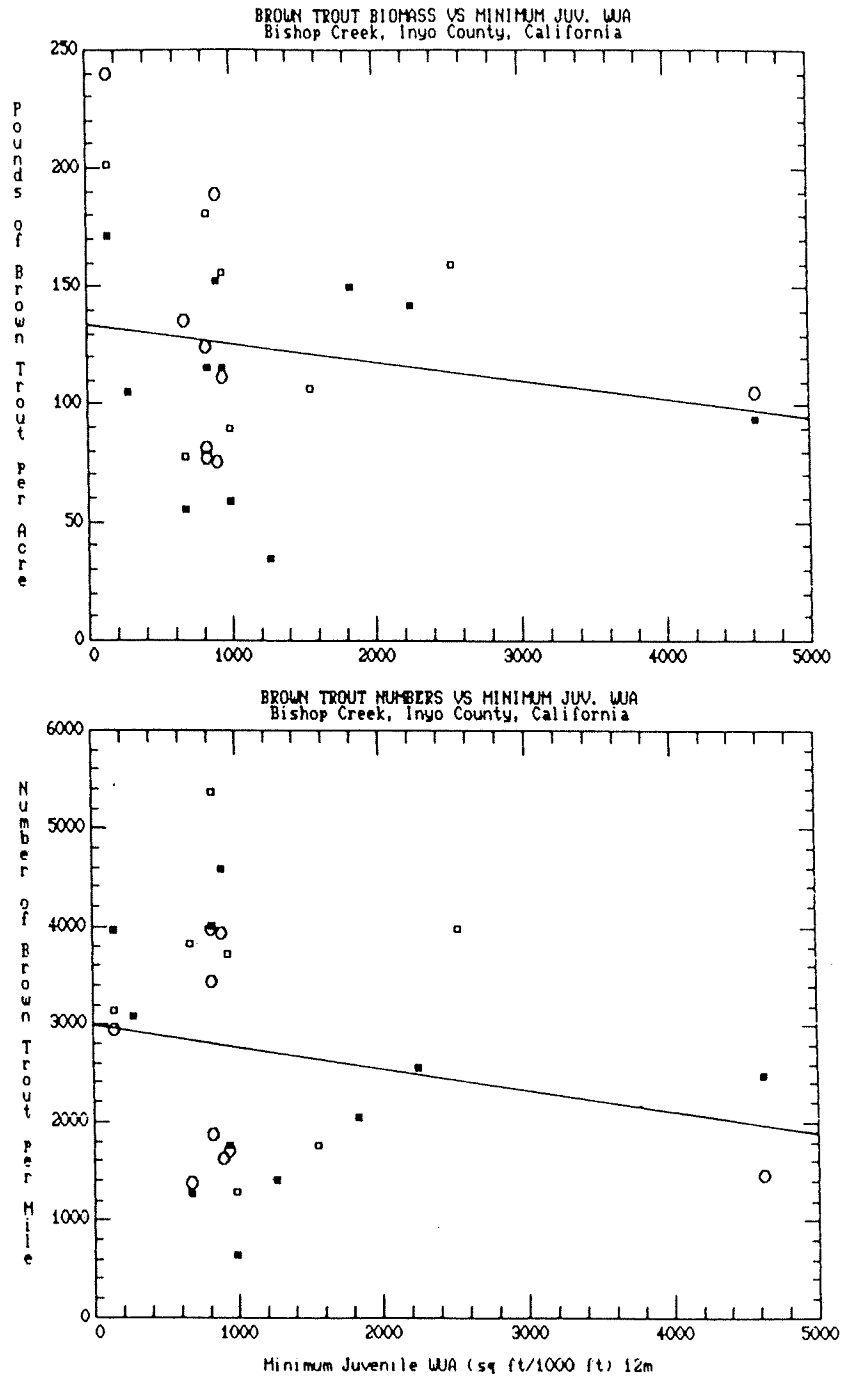


Figure 66. Pounds of brown trout per acre and numbers of brown trout per mile in Bishop Creek plotted against minimum adult Weighted Usable Area for the preceeding 12 months. Data are from EA Engineering, Science, and Technology, Inc. 1984 (closed squares), 1985 (open squares), and Dienstadt et al., 1985 (open circles).

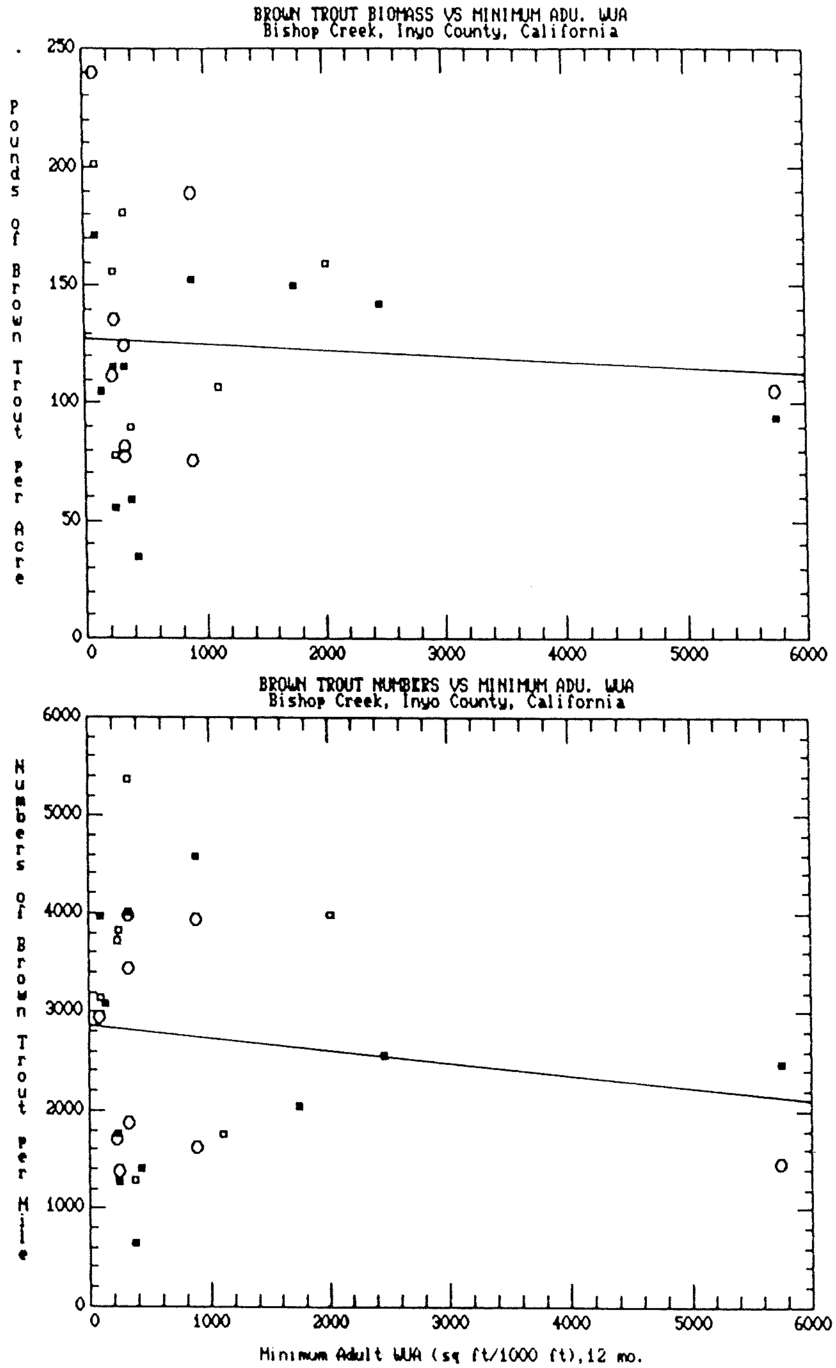


Figure 67. Pounds of brown trout per acre and numbers of brown trout per mile in Bishop Creek plotted against minimum adult Weighted Usable Area for the preceeding 12 months. Data are from EA Engineering, Science, and Technology, Inc. 1984 (closed squares), 1985 (open squares), and Dienstadt et al., 1985 (open circles).

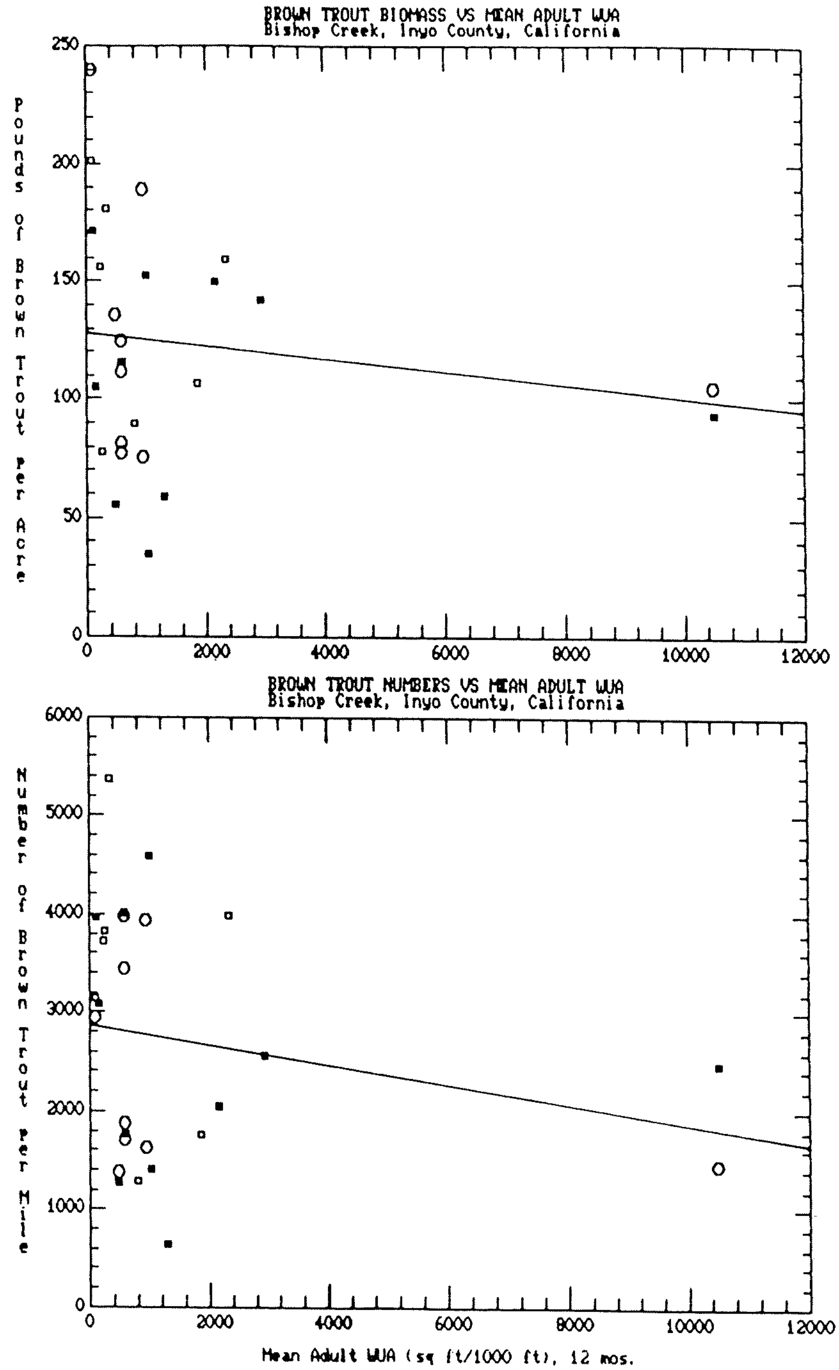
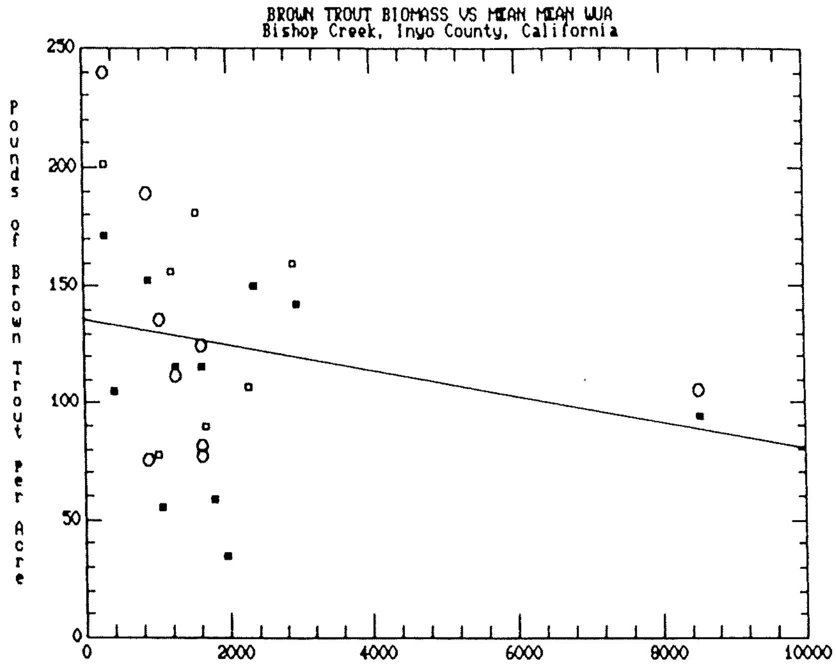


Figure 68. Pounds of brown trout per acre and numbers of brown trout per mile in Bishop Creek plotted against mean adult Weighted Usable Area for the preceeding 12 months. Data are from EA Engineering, Science, and Technology, Inc. 1984 (closed squares), 1985 (open squares), and Dienstadt et al., 1985 (open circles).



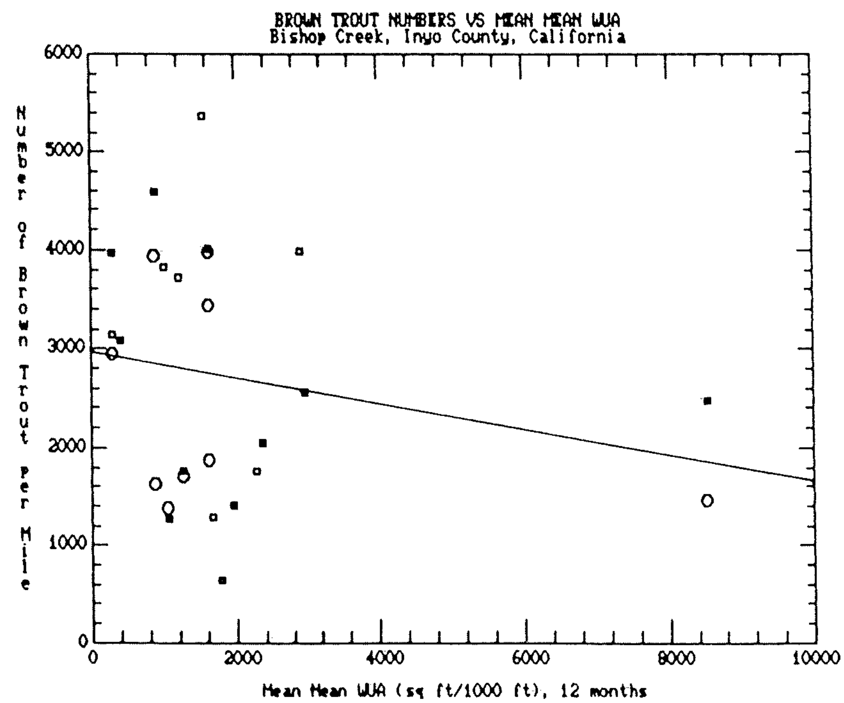


Figure 69. Pounds of brown trout per acre and numbers of brown trout per mile in Bishop Creek plotted against the mean Weighted Usable Area for the preceeding 12 months calculated as the mean of the adult, juvenile, and fry WUA. Data are from EA Engineering, Science, and Technology, Inc. 1984 (closed squares), 1985 (open squares), and Dienstadt et al., 1985 (open circles).

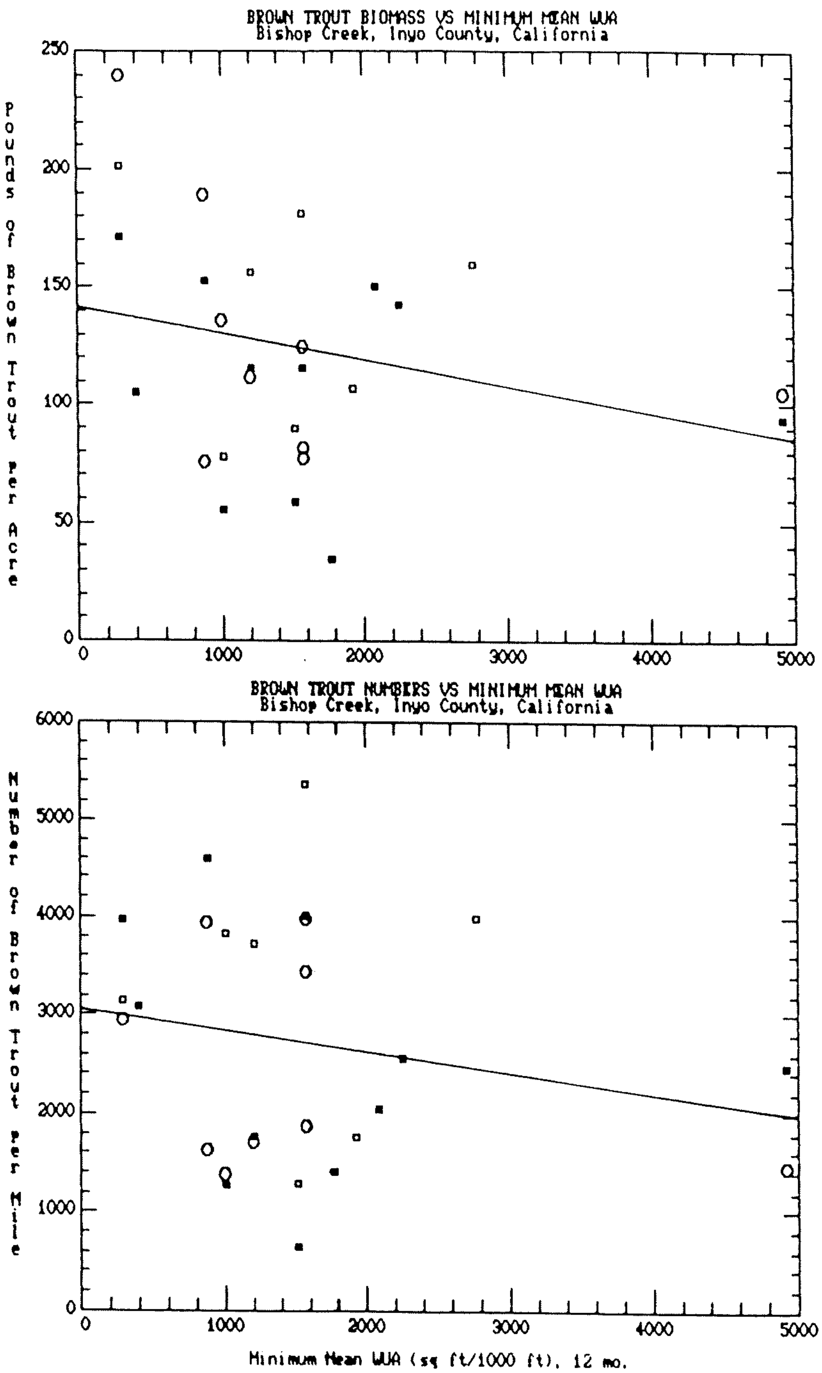


Figure 70. Pounds of brown trout per acre and numbers of brown trout per mile in Bishop Creek plotted against the minimum monthly Weighted Usable Area for the preceeding 12 months calculated as the mean of the adult, juvenile, and fry WUA. Data are from EA Engineering, Science, and Technology, Inc. 1984 (closed squares), 1985 (open squares), and Dienstadt et al., 1985 (open circles).

TABLE 5. CORRELATION MATRICES OF POUNDS OF BROWN TROUT PER ACRE (LBSPERACRE), POUNDS OF BROWN TROUT PER MILE (LBSPERMILE) AND NUMBER OF BROWN TROUT PER MILE (NUMPERMILE) VERSUS THE MEAN AND MINIMUM ADULT, JUVENILE, FRY, AND MEAN [OF ADULT, JUVENILE, OR FRY] WEIGHTED USABLE AREA AND PERCENT USABLE AREA FOR THE PRECEDING 12 MONTHS FOR ALL AVAILABLE DATA (TOP MATRIX), ALL DATA COLLECTED BY EA ENGINEERING, SCIENCE, AND TECHNOLOGY, INC. IN 1984 AND 1985 (BOTTOM MATRIX), AND ALL EA DATA EXCEPT THOSE FROM REACH 10, THE AREAS WITH THE HIGHEST WUA AND PUA.

CORRELATION MATRIX

	Lbsperacre	Lbspermile	Numpermile	Min12AWUA	Mean12AWUA	Min12JWUA	Mean12JWUA	Min12FWUA	Mean12FWUA	Min12MWUA	Mean12MWUA	Min12APUA	Mean12APUA	Min12JPUA	Mean12JPUA	Min12FPUA	Mean12FPUA	Min12MPUA	Mean12MPUA
Lbsperacre	1.00000	.73531	.56977	-.07670	-.14655	-.17695	-.18578	-.01399	-.33715	-.25717	-.21834	-.04073	-.13079	-.12057	-.15475	.08681	-.24459	-.18094	-.17789
Lbspermile	.73531	1.00000	.74696	.03322	-.04898	-.06020	-.08434	.07038	-.25044	-.14341	-.11885	-.00670	-.10084	-.14289	-.16234	-.00390	-.35684	-.24773	-.20089
Numpermile	.56977	.74696	1.00000	-.15115	-.21668	-.20057	-.22999	.17927	-.17538	-.19475	-.21589	-.17855	-.26358	-.26069	-.29473	.11665	-.27787	-.28028	-.28825
Min12AWUA	-.07670	.03322	-.15115	1.00000	.98455	.97316	.98286	.69513	.79524	.92348	.96178	.97499	.96880	.90498	.94031	.59297	.70452	.83119	.91960
Mean12AWUA	-.14655	-.04898	-.21668	.98455	1.00000	.96051	.99047	.70415	.83421	.92902	.98204	.94563	.97671	.87990	.93875	.59558	.73609	.82688	.93202
Min12JWUA	-.17695	-.06020	-.20057	.97316	.96051	1.00000	.98737	.74170	.87042	.97586	.97419	.96046	.95533	.95199	.96177	.65545	.79576	.90361	.94795
Mean12JWUA	-.18578	-.08434	-.22999	.98286	.99047	.98737	1.00000	.73323	.87581	.96656	.99273	.95643	.97697	.92419	.96290	.63649	.79221	.88152	.95652
Min12FWUA	-.01399	.07038	.17927	.69513	.70415	.74170	.73323	1.00000	.80512	.78996	.76508	.67211	.68785	.69884	.70356	.94174	.74349	.72992	.73745
Mean12FWUA	-.33715	-.25044	-.17538	.79524	.83421	.87042	.87581	.80512	1.00000	.95230	.92175	.77448	.82321	.81970	.84649	.71665	.91427	.87526	.89123
Min12MWUA	-.25717	-.14341	-.19475	.92348	.92902	.97586	.96656	.78996	.95230	1.00000	.97753	.90977	.92415	.93029	.94302	.70498	.87651	.92936	.95312
Mean12MWUA	-.21834	-.11885	-.21589	.96178	.98204	.97419	.99273	.76508	.92175	.97753	1.00000	.93053	.96446	.90474	.95014	.66226	.82831	.88436	.95808
Min12APUA	-.04073	-.00670	-.17855	.97499	.94563	.96046	.95643	.67211	.77448	.90977	.93053	1.00000	.97667	.95563	.97097	.62581	.75321	.88716	.94711
Mean12APUA	-.13079	-.10084	-.26358	.96880	.97671	.95533	.97697	.68785	.82321	.92415	.96446	.97667	1.00000	.93574	.98171	.63310	.79562	.89089	.97326
Min12JPUA	-.12057	-.14289	-.26069	.90498	.87990	.95199	.92419	.69884	.81970	.93029	.90474	.95563	.93574	1.00000	.98189	.70664	.86584	.97238	.96686
Mean12JPUA	-.15475	-.16234	-.29473	.94031	.93875	.96177	.96290	.70356	.84649	.94302	.95014	.97097	.98171	.98189	1.00000	.68586	.86638	.95622	.99239
Min12FPUA	.08681	-.00390	.11665	.59297	.59558	.65545	.63649	.94174	.71665	.70498	.66226	.62581	.63310	.70664	.68586	1.00000	.78564	.76286	.72118
Mean12FPUA	-.24459	-.35684	-.27787	.70452	.73609	.79576	.79221	.74349	.91427	.87651	.82831	.75321	.79562	.86584	.86638	.78564	1.00000	.95301	.91142
Min12MPUA	-.18094	-.24773	-.28028	.83119	.82688	.90361	.88152	.72992	.87526	.92936	.88436	.88716	.89089	.97238	.95622	.76286	.95301	1.00000	.96598
Mean12MPUA	-.17789	-.20089	-.28825	.91960	.93202	.94795	.95652	.73745	.89123	.95312	.95808	.94711	.97326	.96686	.99239	.72118	.91142	.96598	1.00000

All data from EA Engineering and Deinstadt et al., 1985.

CORRELATION MATRIX

	Lbsperacre S	Lbspermile S	Numpermile S	Min12AWUA	Mean12AWUA	Min12JWUA	Mean12JWUA	Min12FWUA	Mean12FWUA	Min12MWUA	Mean12MWUA	Min12APUA	Mean12APUA	Min12JPUA	Mean12JPUA	Min12FPUA	Mean12FPUA	Min12MPUA	Mean12MPUA
Lbsperacre S	1.00000	.82386	.68030	.20908	.00202	.00147	-.06139	.28026	-.24923	-.10690	-.12657	.21426	.00811	.05006	-.02640	.31522	-.12379	-.02926	-.05800
Lbspermile S	.82386	1.00000	.84499	.14916	-.10469	-.04371	-.14864	.31725	-.28650	-.15670	-.20967	.09288	-.17145	-.11866	-.22310	.19491	-.35463	-.23883	-.27902
Numpermile S	.68030	.84499	1.00000	-.02077	-.26031	-.14605	-.26025	.44593	-.15070	-.16412	-.24397	-.05895	-.30153	-.20269	-.31101	.31107	-.24546	-.24178	-.30485
Min12AWUA	.20908	.14916	-.02077	1.00000	.95358	.91301	.91215	.15750	.41343	.77296	.82059	.99155	.91545	.88508	.85765	.20789	.44249	.73548	.76978
Mean12AWUA	.00202	-.10469	-.26031	.95358	1.00000	.93193	.96929	.08604	.50826	.83534	.89681	.95735	.98088	.92733	.93799	.17293	.56757	.82592	.87037
Min12JWUA	.00147	-.04371	-.14605	.91301	.93193	1.00000	.98225	.33227	.68765	.94566	.95387	.91299	.90100	.96209	.92173	.38314	.66785	.88057	.88078
Mean12JWUA	-.06139	-.14864	-.26025	.91215	.96929	.98225	1.00000	.24326	.67657	.93435	.96832	.92112	.95442	.97036	.96378	.31977	.70060	.90496	.92602
Min12FWUA	.28026	.31725	.44593	.15750	.08604	.33227	.24326	1.00000	.55925	.46143	.35167	.17210	.10591	.33355	.24354	.94609	.50439	.42598	.32703
Mean12FWUA	-.24923	-.28650	-.15070	.41343	.50826	.68765	.67657	.55925	1.00000	.87576	.83520	.43819	.51304	.66550	.64347	.57260	.88640	.79164	.75333
Min12MWUA	-.10690	-.15670	-.16412	.77296	.83534	.94566	.93435	.46143	.87576	1.00000	.98421	.78293	.81988	.91784	.88689	.50863	.82828	.93030	.91006
Mean12MWUA	-.12657	-.20967	-.24397	.82059	.89681	.95387	.96832	.35167	.83520	.98421	1.00000	.83556	.88713	.93881	.93096	.41384	.81565	.93504	.94143
Min12APUA	.21426	.09288	-.05895	.99155	.95735	.91299	.92112	.17210	.43819	.78293	.83556	1.00000	.94236	.91636	.89657	.24986	.50888	.78374	.81939
Mean12APUA	.00811	-.17145	-.30153	.91545	.98088	.90100	.95442	.10591	.51304	.81988	.88713	.94236	1.00000	.94699	.97372	.22916	.64523	.87537	.92111
Min12JPUA	.05006	-.11866	-.20269	.88508	.92733	.96209	.97036	.33355	.66550	.91784	.93881	.91636	.94699	1.00000	.98319	.45331	.76689	.95352	.95784
Mean12JPUA	-.02640	-.22310	-.31101	.85765	.93799	.92173	.96378	.24354	.64347	.88689	.93096	.89657	.97372	.98319	1.00000	.38185	.78302	.95529	.97899
Min12FPUA	.31522	.19491	.31107	.20789	.17293	.38314	.31977	.94609	.57260	.50863	.41384	.24986	.22916	.45331	.38185	1.00000	.64611	.56844	.47275
Mean12FPUA	-.12379	-.35463	-.24546	.44249	.56757	.66785	.70060	.50439	.88640	.82828	.81565	.50888	.64523	.76689	.78302	.64611	1.00000	.91706	.89062
Min12MPUA	-.02926	-.23883	-.24178	.73548	.82592	.88057	.90496	.42598	.79164	.93030	.93504	.78374	.87537	.95352	.95529	.56844	.91706	1.00000	.98823
Mean12MPUA	-.05800	-.27902	-.30485	.76978	.87037	.88078	.92602	.32703	.75333	.91006	.94143	.81939	.92111	.95784	.97899	.47275	.89062	.98823	1.00000

All data except Reach 10 from EA Engineering.

CORRELATION MATRIX

	Lbsperacre S	Lbspermile S	Numpermile S	Min12AWUA	Mean12AWUA	Min12JWUA	Mean12JWUA	Min12FWUA	Mean12FWUA	Min12MWUA	Mean12MWUA	Min12APUA	Mean12APUA	Min12JPUA	Mean12JPUA	Min12FPUA	Mean12FPUA	Min12MPUA	Mean12MPUA
Lbsperacre S	1.00000	.80308	.68118	-.01524	-.13067	-.11031	-.15249	.14322	-.26639	-.17579	-.18099	.05327	-.11280	-.03567	-.11660	.24574	-.17446	-.09505	-.14119
Lbspermile S	.80308	1.00000	.83620	.13946	.03223	.03189	-.00511	.29999	-.12751	-.04013	-.02444	.11790	-.03249	-.05834	-.10811	.20793	-.27652	-.16976	-.13891
Numpermile S	.68118	.83620	1.00000	-.06573	-.15185	-.13981	-.17950	.32378	-.14592	-.15251	-.16369	-.08690	-.21929	-.20428	-.26733	.27013	-.24613	-.24119	-.25663
Min12AWUA	-.01524	.13946	-.06573	1.00000	.97657	.96546	.97791	.56756	.79375	.91762	.95657	.96317	.97508	.84946	.91305	.39218	.60601	.75354	.89296
Mean12AWUA	-.13067	.03223	-.15185	.97657	1.00000	.94188	.98616	.57098	.83124	.91445	.98018	.89639	.97174	.78754	.88962	.37556	.61963	.71898	.88870
Min12JWUA	-.11031	.03189	-.13981	.96546	.94188	1.00000	.98149	.62714	.87617	.97905	.96639	.95244	.96396	.92585	.95551	.48931	.73419	.86069	.94405
Mean12JWUA	-.15249	-.00511	-.17950	.97791	.98616	.98149	1.00000	.60788	.88007	.96390	.99254	.92797	.98406	.86762	.94107	.44190	.70926	.81022	.93963
Min12FWUA	.14322	.29999	.32378	.56756	.57098	.62714	.60788	1.00000	.73914	.68993	.65005	.50846	.53477	.54688	.54869	.92080	.63713	.59064	.60553
Mean12FWUA	-.26639	-.12751	-.14592	.79375	.83124	.87617	.88007	.73914	1.00000	.94964	.92279	.73687	.82042	.77817	.83023	.60695	.86506	.82305	.88817
Min12MWUA	-.17579	-.04013	-.15251	.91762	.91445	.97905	.96390	.68993	.94964	1.00000	.97029	.89581	.93361	.90824	.94156	.56454	.82583	.89321	.95731
Mean12MWUA	-.18099	-.02444	-.16369	.95657	.98018	.96639	.99254	.65005	.92279	.97029	1.00000	.88978	.96409	.83570	.91789	.47550	.73891	.80113	.93382
Min12APUA	.05327	.11790	-.08690	.96317	.89639	.95244	.92797	.50846	.73687	.89581	.88978	1.00000	.95486	.93130	.94698	.40579	.65149	.83394	.91028
Mean12APUA	-.11280	-.03249	-.21929	.97508	.97174	.96396	.98406	.53477	.82042	.93361	.96409	.95486	1.00000	.89416	.96624	.40249	.70820	.83371	.95384
Min12JPUA	-.03567	-.05834	-.20428	.84946	.78754	.92585	.86762	.54688	.77817	.90824	.83570	.93130	.89416	1.00000	.97198	.54297	.82450	.96451	.95008
Mean12JPUA	-.11660	-.10811	-.26733	.91305	.88962	.95551	.94107	.54869	.83023	.94156	.91789	.94698	.96624	.97198	1.00000	.49450	.82461	.94118	.98890
Min12FPUA	.24574	.20793	.27013	.39218	.37556	.48931	.44190	.92080	.60695	.56454	.47550	.40579	.40249	.54297	.49450	1.00000	.69618	.63289	.55302
Mean12FPUA	-.17446	-.27652	-.24613	.60601	.61963	.73419	.70926	.63713	.86506	.82583	.73891	.65149	.70820	.82450	.82461	.69618	1.00000	.93625	.88437
Min12MPUA	-.09505	-.16976	-.24119	.75354	.71898	.86069	.81022	.59064	.82305	.89321	.80113	.83394	.83371	.96451	.94118	.63289	.93625	1.00000	.95218
Mean12MPUA	-.14119	-.13891	-.25663	.89296	.88870	.94405	.93963	.60553	.88817	.95731	.93382	.91028	.95384	.95008	.98890	.55302	.88437	.95218	1.00000

All data from EA Engineering.

validation study in North Carolina (Loar, et al., 1985). The correlations between PUA and population, and the correlation coefficients (r) for both are shown in Table 5 for the entire data set and two subsets. The top matrix includes all the population data shown on Figures 61-70; the bottom matrix excludes the data of Deinstadt et al. 1985 (the open circles on Figures 61-70); and the middle matrix excludes both Deinstadt's data and EA's data from the single measurement at Reach 10. In all instances all correlation coefficients are insignificant at the 95% confidence level. The test excluding Deinstadt's data was done because we were less sure of the WUA and PUA at the time of sampling than for our own data. The test excluding Reach 10 was done because this point is so for separated from the rest of the data that it could have exerted a disproportionate influence. The results, however, show that its inclusion makes little difference in the results.

We conclude, therefore, that the evidence at hand does not support the validity of the PHABSIM/HABTAT model for Bishop Creek using the Suitability Index curves supplied by Aceituno et al. (unpublished).

Suitability Index Curves: The analysis presented in this report is based on unpublished Suitability Index curves provided to EA by the U.S. Fish and Wildlife Service as the final work product of a joint agency data collection and analysis program (Aceituno et al. unpublished). The California Department of Fish and Game, however, is continuing to analyze the data that resulted in these curves, and does not yet consider them final (Gary Smith, personal communication 23 January 1986). The curves, presented in Attachment 1, are much less smooth than previously published curves (cf Bovee, 1982) and many of them reflect extreme changes in habitat suitability over very narrow ranges of velocity and depth. For example, the adult brown trout curves show the suitability ranging from 0.5 to 1.0 under conditions of object cover over a velocity range of 0.2 feet per second, and the juvenile brown trout depth suitability under conditions of object cover ranges from 0.13 to 1.0 over a depth range of 0.2 feet. It is difficult for us to envision a biological mechanism that would result in such an extreme sensitivity on the part of the fish to these small changes in physical habitat.

Some of the curves also show certain sensitivities to the presence and type of cover which do not make intuitive sense to us. For example, with object cover only, juvenile brown trout are shown by the curves to find a depth of 1.5 feet ideal, but if overhead cover is present as well, the depth of 1.5 feet has a suitability of only 0.44, unless the object cover is removed, resulting in a suitability of 0.89. We can see no obvious mechanism that would render habitat less than half as good when overhead cover was added and then would return it to a suitability of 0.89 just by taking away the object cover.
It is also unclear whether the appropriate assumptions were met for conversion of the habitat utilization data to habitat

preference data. While the division of the utilization frequency distributions by the frequency of available habitat makes some intuitive sense, it produces unrealistic preference curves unless the utilization distribution is influenced by a lack of sufficient ideal habitat. In other words, it is important to know if the observed fish were where they were because they found the habitat optimal, or because it was the best habitat available even though sub-optimal. This judgement cannot be made on the basis of differences in the frequency distributions of fish observations and random habitat observations. It is necessary to determine the absolute amount of habitat relative to the absolute numbers of fish. If there is more of every kind of habitat than could be occupied by the total number of fish, the frequency distributions of velocity and depth where fish were observed are the proper data for development of suitability index curves. Only when a particular type of habitat is completely occupied by fish, should it be reasonable to correct utilization data for preference. The data from the preliminary report (Aceituno et al. 1985) suggest that there was a great deal more habitat of every type than needed by fish, and therefore the correction for preference appears to have been unnecessary. The data needed to test this hypothesis appear to exist, but have not been released by the agencies because they are continuing to analyze them (Gary Smith, personal communication, January 23, 1986). Consequently, the calculations of Weighted Usable Area as functions of flow in this report must be considered preliminary and subject to revision. Similarly, the tests of WUA and PUA as descriptors of habitat quality and as predictors of standing crop should be redone using any new Suitability Index curves that result from additional analysis of the agency data set.

Calculations of Weighted Usable Area

The three curves on each of the graphs in Attachment 2 represent the WUA resulting from three separate one-flow IFG4 hydraulic simulations on each reach. All three curves were run because it is unknown which of the one-flow simulations produces the most accurate hydraulic simulations at other than the measured flows. We felt that if the three curves differed much from one another, more work should be done in determining which of the curves was appropriate. For the adults and the juveniles, the three curves were nearly identical in most cases. The three fry curves and three spawner curves were not as similar to one another, but were usually close together at flows less than 20 cfs. Because of the similarity of the curves, we did no further analysis, and took the mean of the three curves as the WUA for each life stage.

Techniques for Arriving at Appropriate Instream Flow Releases in Bishop Creek

There are many approaches in the literature for arriving at appropriate instream flow releases using curves of WUA versus flow (see Morhardt, in press, for a discussion of some of them). We have used several of them here, but caution the reader that

1) the Suitability Index curves used to calculate the WUA appear to us to have been inappropriately derived in some cases and 2) neither WUA nor PUA calculated using these curves was significantly correlated with standing crop of brown trout in Bishop Creek in 1984 and 1985, suggesting either that habitat as measured by WUA or PUA was not limiting, or that the SI curves are not valid.

Mean Weighted Usable Area for Three Life Stages

One simple way of determining the effect of flow on WUA is to normalize the curves of WUA plotted against flow, so that they all have a range from 0-1. This allows the percentage of the maximum WUA to be read directly from the curve at each flow. Figures 22 and 23 do this for the average of adult, juvenile, and fry curves (from Attachment 2) for rainbow and brown trout. Average values were used in order to take into account equally the amount of habitat for each of these three life stages. The spawning life stage was omitted because the approach used for transect selection on Bishop Creek does not result in a meaningful sample of spawning habitat, and because spawning habitat does not appear to be limiting.

From these curves, it can be seen, for example, that for nearly all of the diverted reaches (01, 02, 04, 05, 06, 11) a flow in the channel of 5 cfs results in greater than 50% of the maximum possible habitat and a flow of 10 cfs results in greater than 90% of the maximum possible habitat averaged over the three life stages. The two exceptions are Reach 03 (below the Coyote Creek confluence) for which a flow of 10 cfs results in about 88% of the maximum habitat for brown trout, and Reach 08, just below the South Fork diversion, in which a flow of 10 cfs results in only 15% of the maximum modeled habitat for brown trout and only 20% for rainbow trout. In the regulated but undiverted reaches 07 and 09, the existing regulated flows (around 40 cfs) produce over 90% of the maximum possible habitats, but in Reach 10 in a meadow along the South Fork, they produce only about half of the maximum amount modeled at 70 cfs.

In the two atypical reaches (08 and 10), the WUA increases steadily over the ranges of flows tested. In the case of Reach 08, the absolute WUA at 10 cfs (as shown in Attachment 2) is relatively low, and its steady increase is apparently brought about by the gradual filling of the floodplain as flows increase. In the case of Reach 10, the absolute value of the WUA is relatively high at 10 cfs, but it continues to increase with flow to an order of magnitude greater than the maximum for most of the other reaches.

Time Series Analysis

Using the average WUA curves (obtained by averaging all of the adult, juvenile, and fry curves of Attachment 2 separately for brown and rainbow trout) it is possible to show how releases of various amounts from the intake structures along Bishop Creek would alter WUA from its present condition. Figures 33-46 show how WUA would compare to existing WUA for releases of 5, 10, 15, 20, 25 and 30 cfs from each of the diversion structures. During most of the year in all diverted reaches except the atypical Reach 08, the release of 5 cfs would make a significant improvement over existing habitat, and the release of 10 cfs would achieve nearly maximum WUA. In other words, 10 cfs added to the existing accretion flows would result in nearly maximum possible average habitat for adults, fry, and juveniles of both brown and rainbow trout.

Figures 47-50 present these same data in a slightly different way: they show the percent change from the existing average mean annual habitat for each reach as a function of flow.

Maximizing the Minimum WUA

Bovee (1982) suggests an alternative technique for selecting the optimum WUA from curves of three life stages. He does it by creating a habitat optimization matrix and from that picking as optimum the flow which maximizes the habitat in least supply. The technique is more accurately applied using graphs rather than numerical matrices and can be done readily for all reaches of Bishop Creek for brown and rainbow trout directly from the figures in Attachment 4. According to this reasoning process, the functional relationship of WUA versus flow that is most meaningful, is the line delineated by the lowest of the curves at any flow. Figure 71 illustrates how this works for the brown trout data from Reach 02. The results of applying this technique are generally similar to those of using the mean of the three curves. For most of the diverted reaches, over 90% of the maximum possible habitat is achieved with flows of about 10 cfs.

Habitat Ratio:

Bovee (1982) also suggests adjusting the amount of juvenile and fry habitat to reflect the absolute amount of habitat required by these life stages to result in an adult population that could be supported by the adult habitat at the flows chosen. In his example, he multiplied juvenile habitat by 1.5 and fry habitat by 5.0 prior to applying the least-maximum-habitat approach. He suggests a series of ways of arriving at the correct multiplication factors ranging from professional opinion to complex population modeling based on a knowledge of the appropriate ratios of fry and juvenile habitat to adult habitat.

Bishop Creek absolute values of fry and juvenile habitat are similar to those of adult habitat at flows in the vicinity of 10 cfs. The practical result of adjusting fry and juvenile habitat upward in ratios similar to those used by Bovee would be to drop consideration of fry habitat entirely, and concentrate principally on adult habitat. The results of using the adult

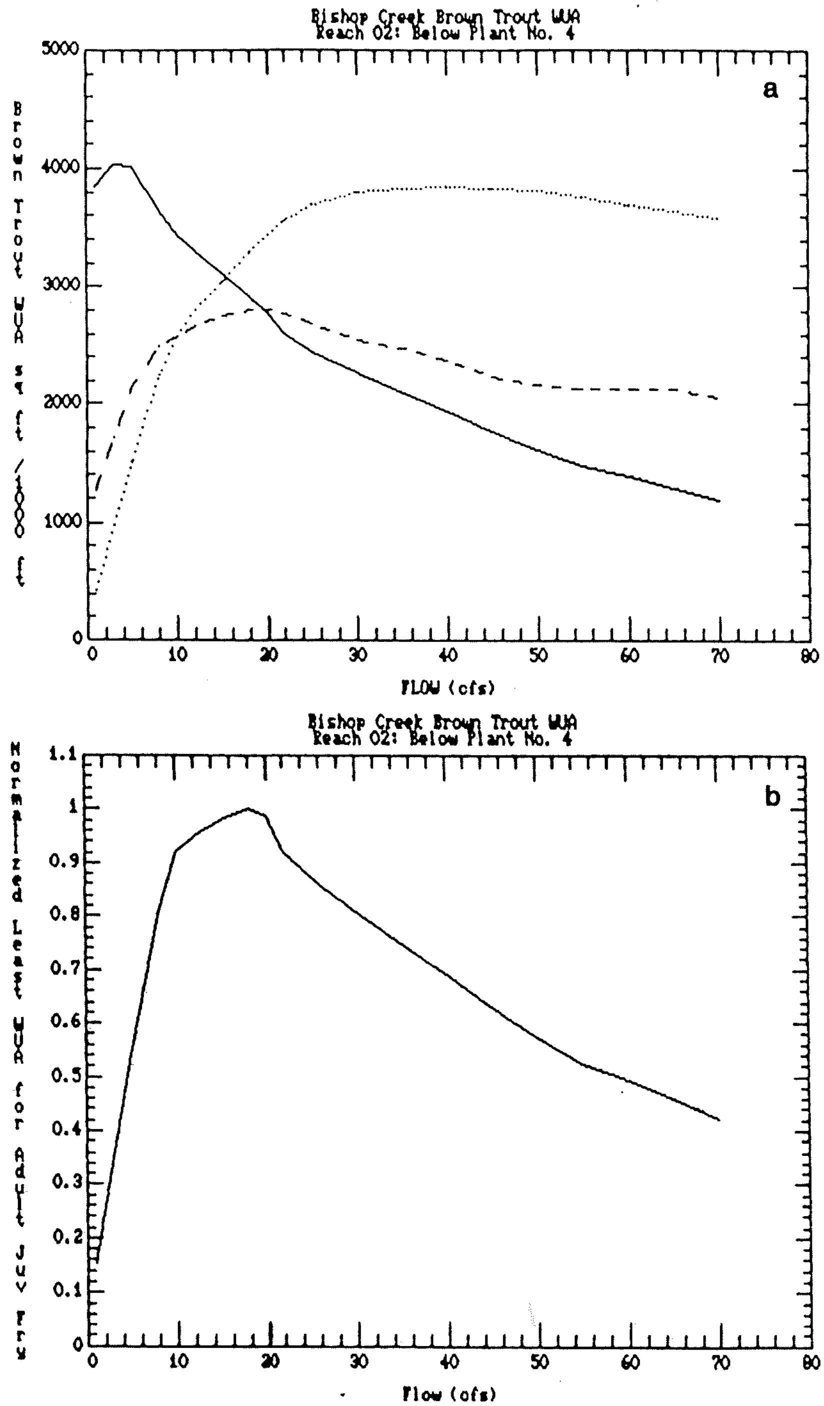


Figure 71. Illustration of how to apply Bovee's maximize-least-habitat technique to the data in Attachment 4.

a. The curve maximizing the least habitat follows along all three curves sequentially: the adult curve (dots) from 0-10cfs, the juvenile curve (dashes) between 10-20 cfs, and the fry curve (solid line) between 20 and 70 cfs.

b. When this curve is extracted and normalized to 1.0, it can be seen that maximum habitat occurs at 18 cfs, and 90% of maximum occurs at 10 cfs.

habitat curves alone can be determined visually from the curves in either Attachment 2 or Attachment 4.

In all reaches adult WUA peaks, if at all, above 30 cfs. Figure 72 shows as an illustration, the normalized curves for adult brown trout WUA for reaches 01-05. A flow of 10 cfs results in about half of the maximum adult habitat, and a flow of 20 cfs, the approximate break point on the curves, results in greater than 80% of the maximum adult habitat.

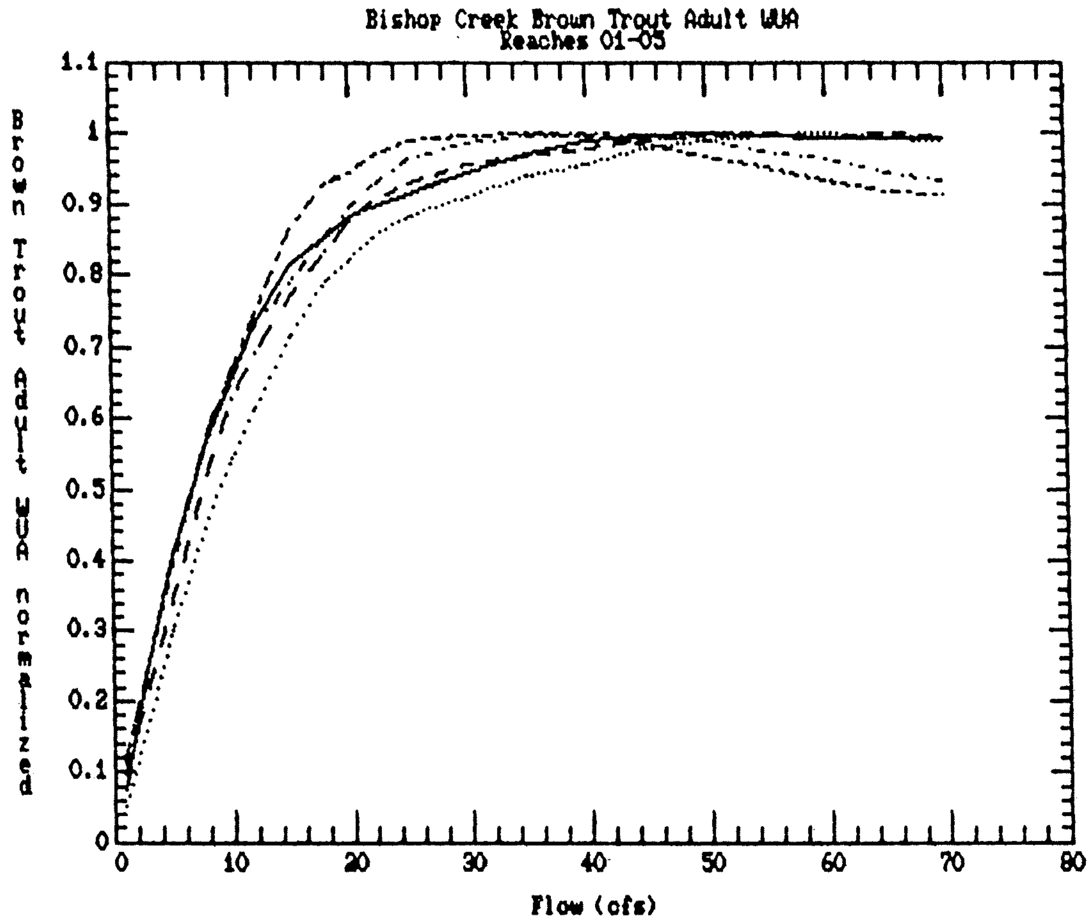


Figure 72. Normalized brown trout adult weighted usable area for reaches 01-05 plotted against flow.

habitat curves alone can be determined visually from the curves in either Attachment 2 or Attachment 4.

In all reaches adult WUA peaks, if at all, above 30 cfs. Figure 72 shows as an illustration, the normalized curves for adult brown trout WUA for reaches 01-05. A flow of 10 cfs results in about half of the maximum adult habitat, and a flow of 20 cfs, the approximate break point on the curves, results in greater than 80% of the maximum adult habitat.

Conclusions and Recommendations

If one accepts the hypothesis that trout populations in Bishop Creek are limited by the physical habitat described by the WUA index, and if one accepts the assumptions and techniques used in developing the Suitability Index curves, it follows that the curves of WUA versus flow should be used to determine appropriate instream flows. Depending on the approach taken in analyzing these curves, the maximum habitat for trout in Bishop Creek occurs in most reaches at flows of between 15-35 cfs. If one were willing to accept something less than maximum obtainable habitat, then one might conclude that suitable flows range from 5 to 20 cfs.

However, there is evidence that trout populations in much of Bishop Creek are not limited by physical habitat as characterized using the WUA index, possibly because the Suitability Index curves are inappropriate, or possibly because the distributions of depth and velocity are sufficient under present conditions in most reaches and the fish are limited by something else such as overhead cover or food availability. Consequently, we have a considerable reluctance to base instream flow recommendations directly on the output of the present WUA model. Instead, it is our opinion that the Bishop Creek project should be used as a test system for rigorously determining the effects of hydroelectric diversions in the eastern Sierra on fish populations. Specifically, we believe that most of the current diversions should remain in place for three to five more years to allow:

1. Continued monitoring of fish populations to determine the year-to-year variability

2. Expanded monitoring of fish populations to determine spatial heterogeneity, particularly with regard to macro habitat features such as cascades, pools, and riffles

3. Rigorous experimental determination of microhabitat preference so that Suitability Index curves accurately portray preference. This study should include additional analysis of the agency microhabitat data base (Aceituno et al., unpublished) and experimental studies in sections of Bishop Creek and possibly in artificial channels as well.

4. Monitoring of food resources to determine source, magnitude, and timing of food availability

5. Evaluation of the extent and cause of winter mortality, including studies to determine the effect, if any, of winter anchor ice formation

6. Evaluation of the effect of cover, and the effectiveness of cover manipulation in enhancing fish populations

7. Evaluation of the impact of fishing pressure on resident brown trout populations

During the course of these studies, a site-specific model describing spatial and temporal variations in fish populations and conditions should be developed and should be designed to predict the effects on fish and invertebrates of subsequent flow increases. The model should have, as its response variable, a measurable quantity--probably standing crop of brown trout.

Following this initial 5-year study, flows should be increased by 5 cfs and maintained at this level for five more years, while the monitoring and modeling studies continue. Flows should then be increased to 10 cfs for another 5 years. If these increases in flow result in significant increases in fish production, the studies should be continued with flows of 15 cfs for 5 years. At that time, it is likely to be desirable to experiment with reductions in winter flow to offset power losses from increased summer releases, and it will also be important to evaluate the economic value of fish population increases as compared to economic values of lost power generation.

At the end of this 18-20 year period, the results should be carefully evaluated to determine whether the appropriate response is an increase or a decrease in instream releases, and whether continued studies would be useful.

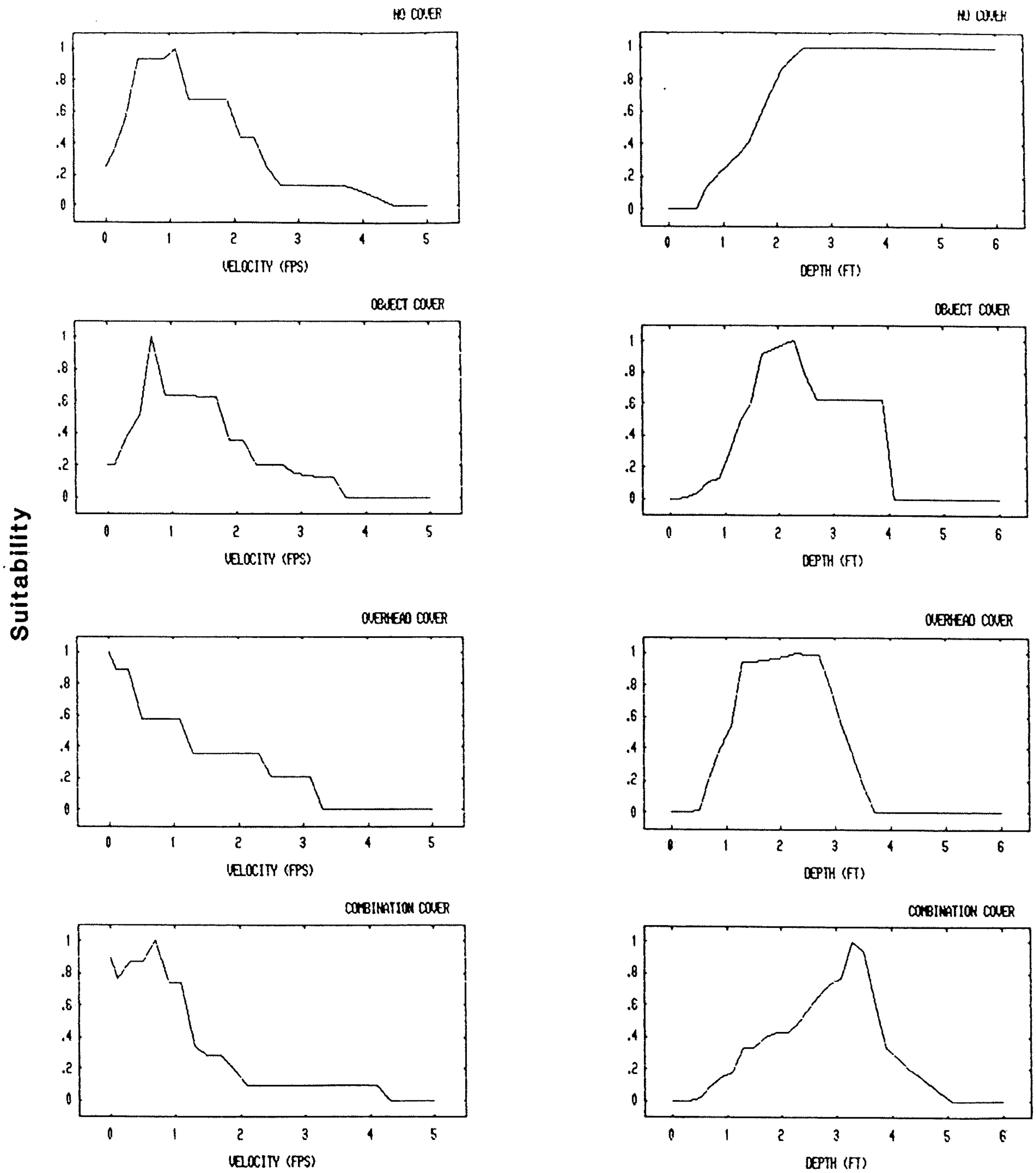
This proposal has both advantages and disadvantages, but seems to us far superior to basing a fixed flow (or flow regime) recommendation on an extremely uncertain model.

ATTACHMENT 1

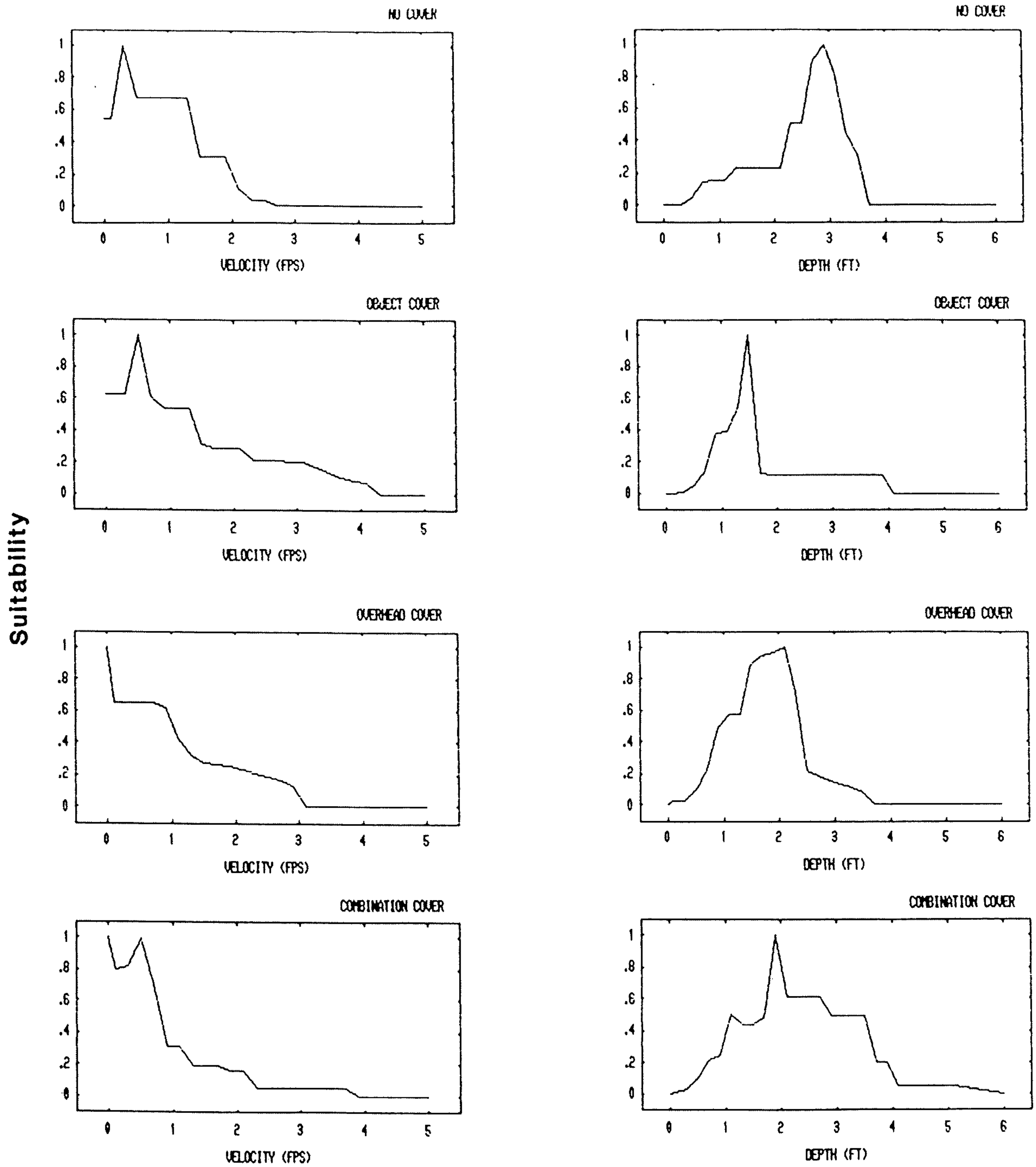
Habitat Preference Curves plotted from data supplied by M. Aceituno, U.S. Fish and Wildlife Service, for use on the Bishop Creek Project instream flow studies. The data are from Appendix A of Aceituno et al., unpublished, and represent utilization data corrected for habitat availability.

Adult Brown Trout Suitability Index Curves

(from Aceituno et al, unpublished)

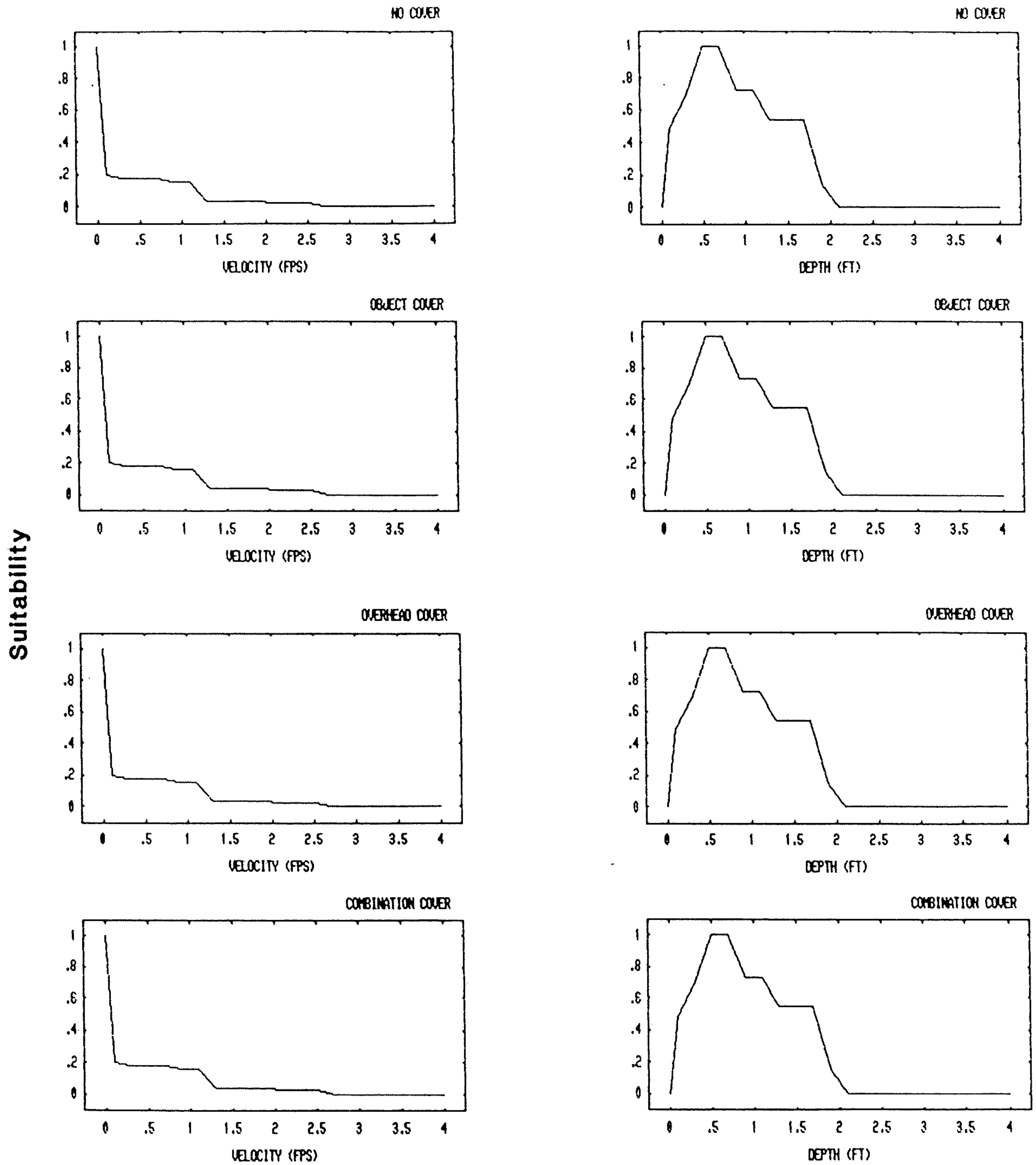


Juvenile Brown Trout Suitability Index Curves
(from Aceituno et al, unpublished)



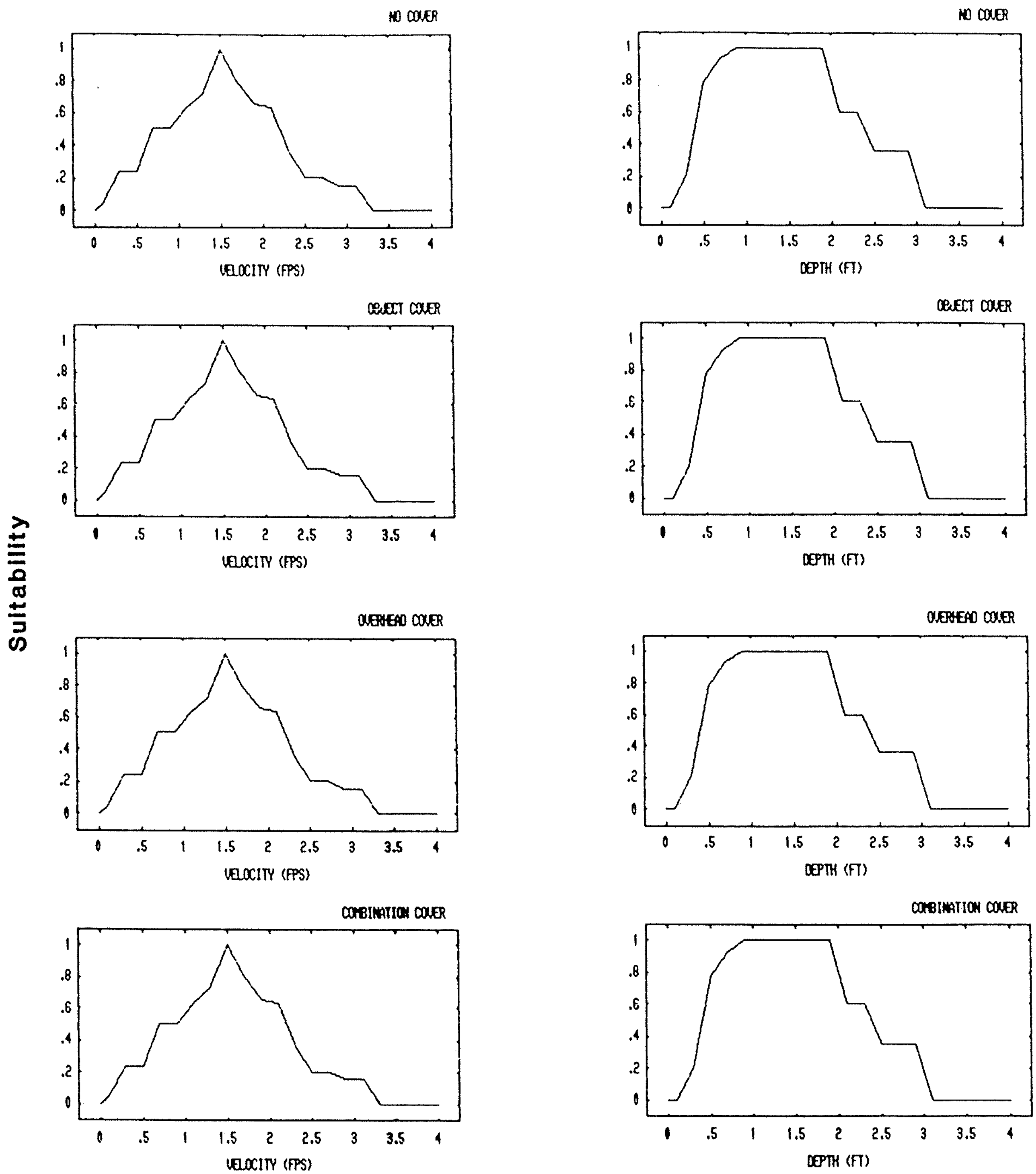
Fry Brown Trout Suitability Index Curves

(from Aceituno et al, unpublished)



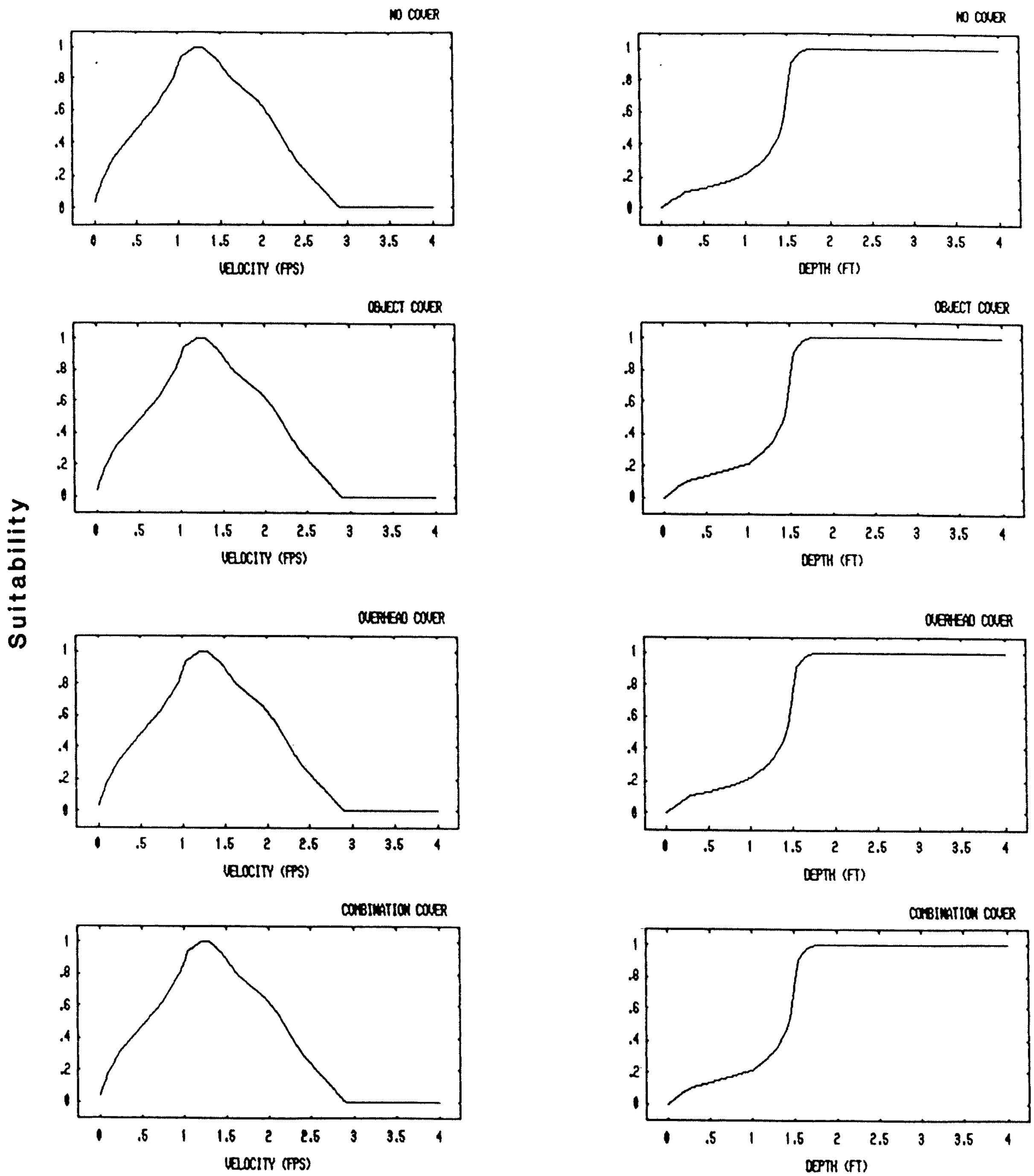
Spawning Brown Trout Suitability Index Curves

(from Aceituno et al, unpublished)



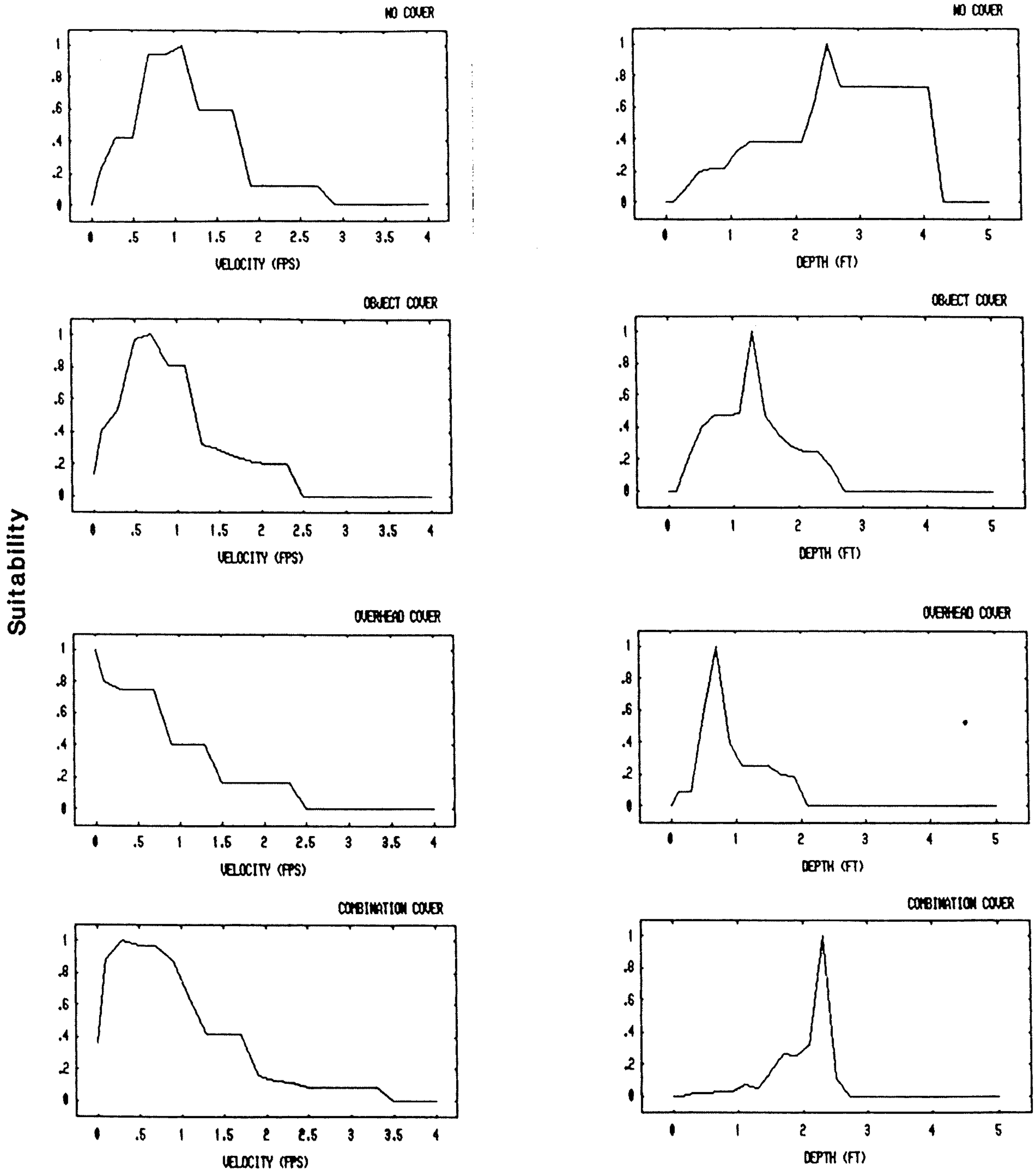
Adult Rainbow Trout Suitability Index Curves

(from Aceituno et al, unpublished)

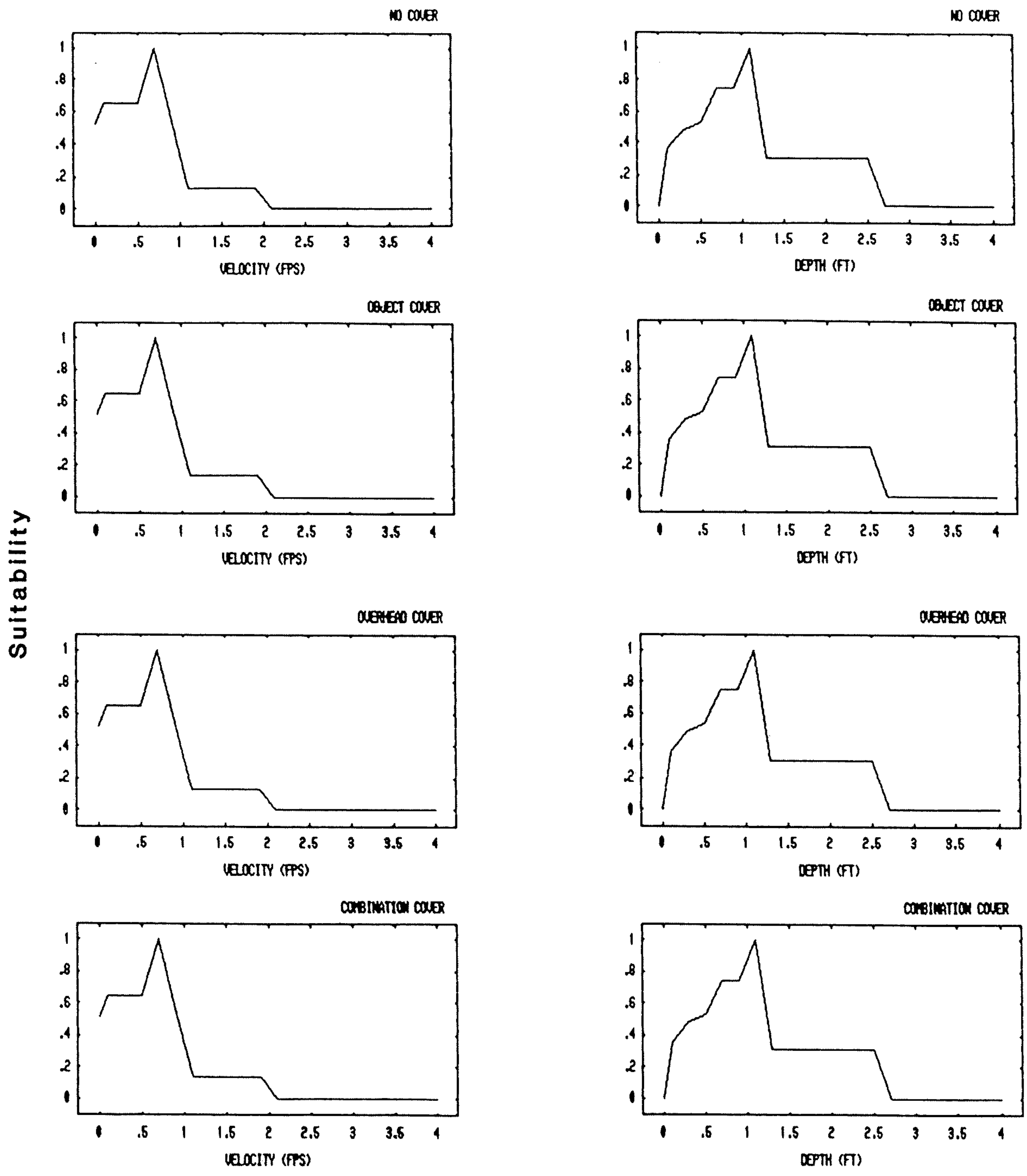


Juvenile Rainbow Trout Suitability Index Curves

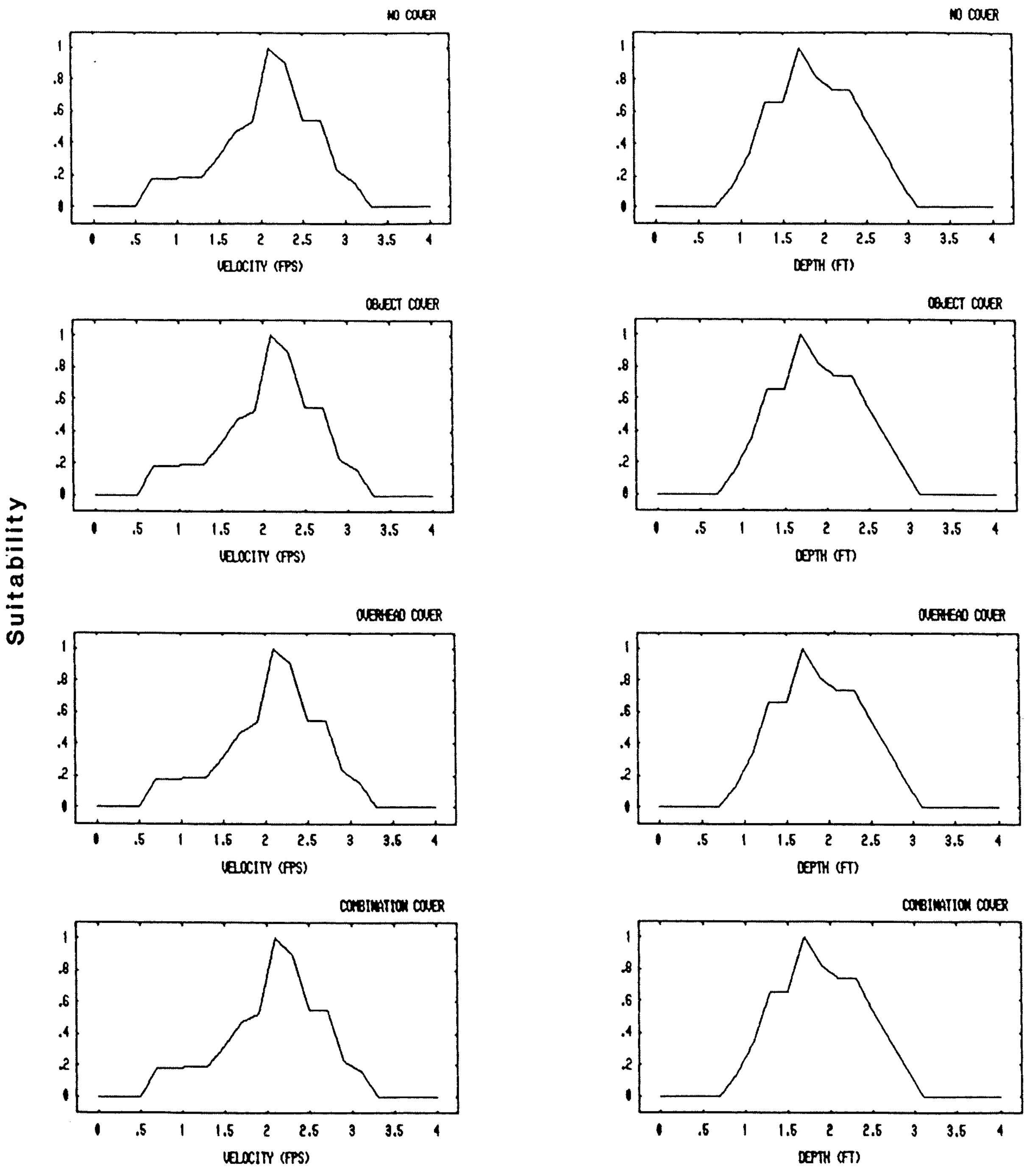
(from Aceituno et al, unpublished)



Fry Rainbow Trout Suitability Index Curves
(from Aceltuno et al, unpublished)



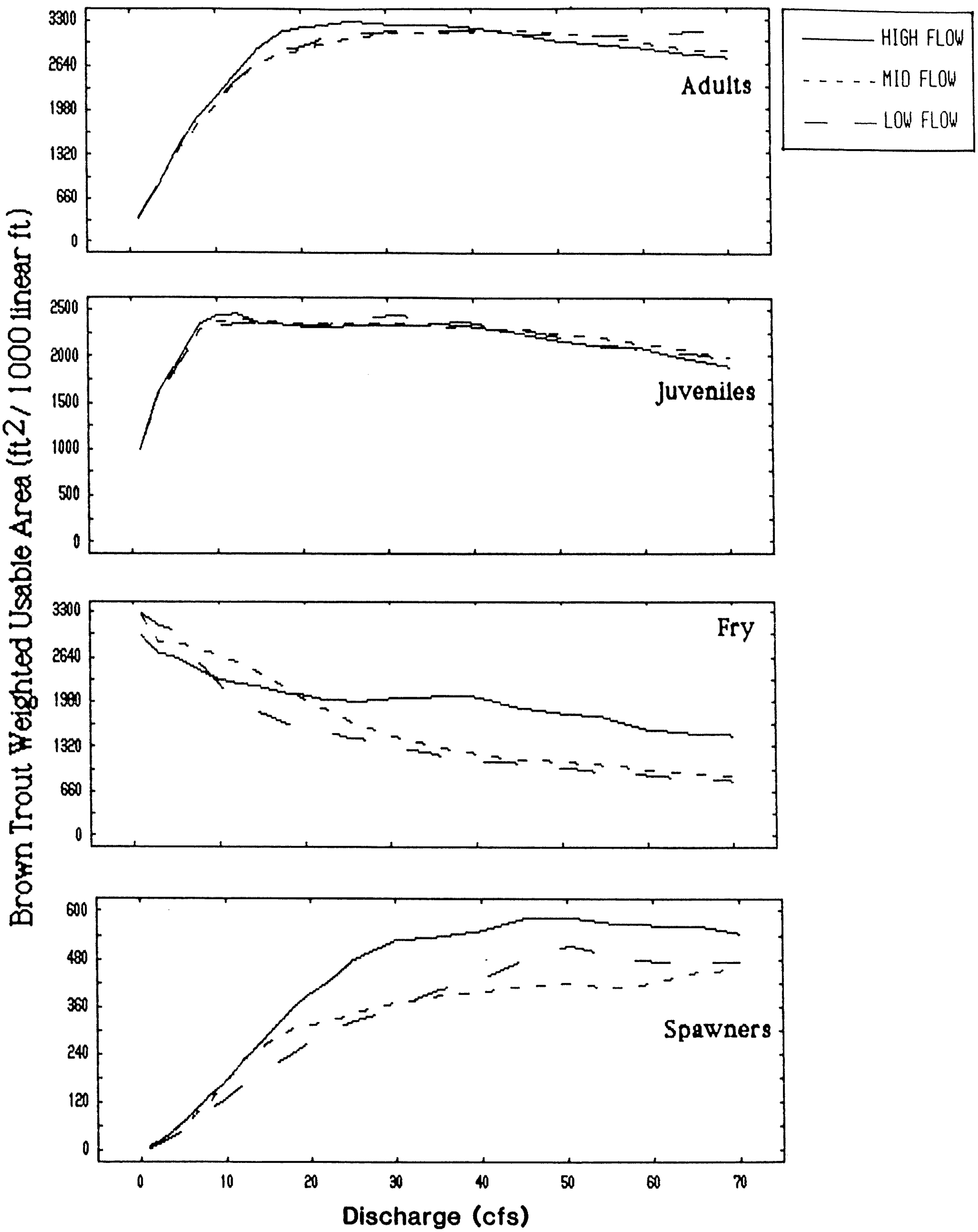
Spawning Rainbow Trout Suitability Index
(from Aceituno et al, unpublished)



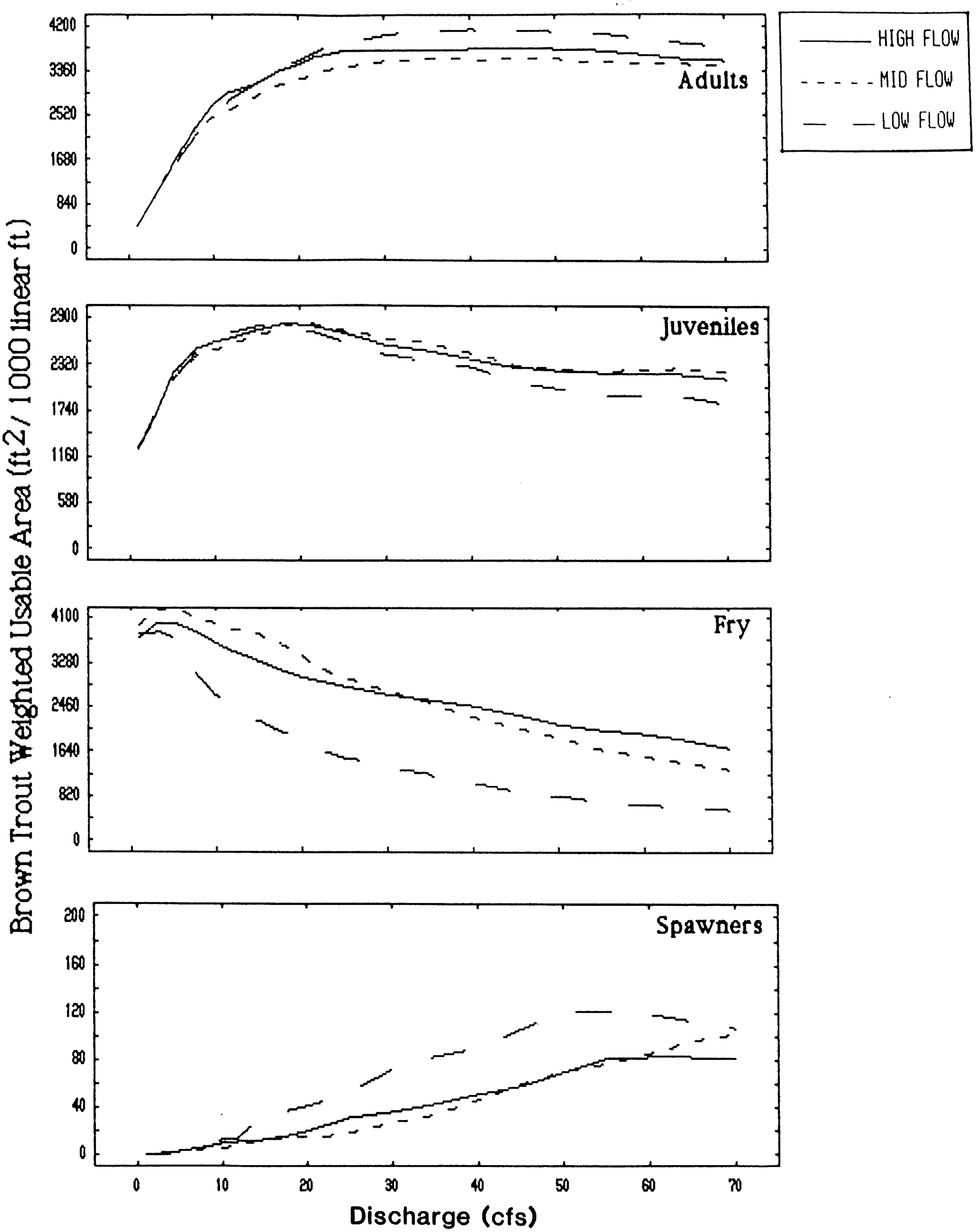
ATTACHMENT 2

Absolute Weighted Usable Area in Bishop Creek
for brown and rainbow trout

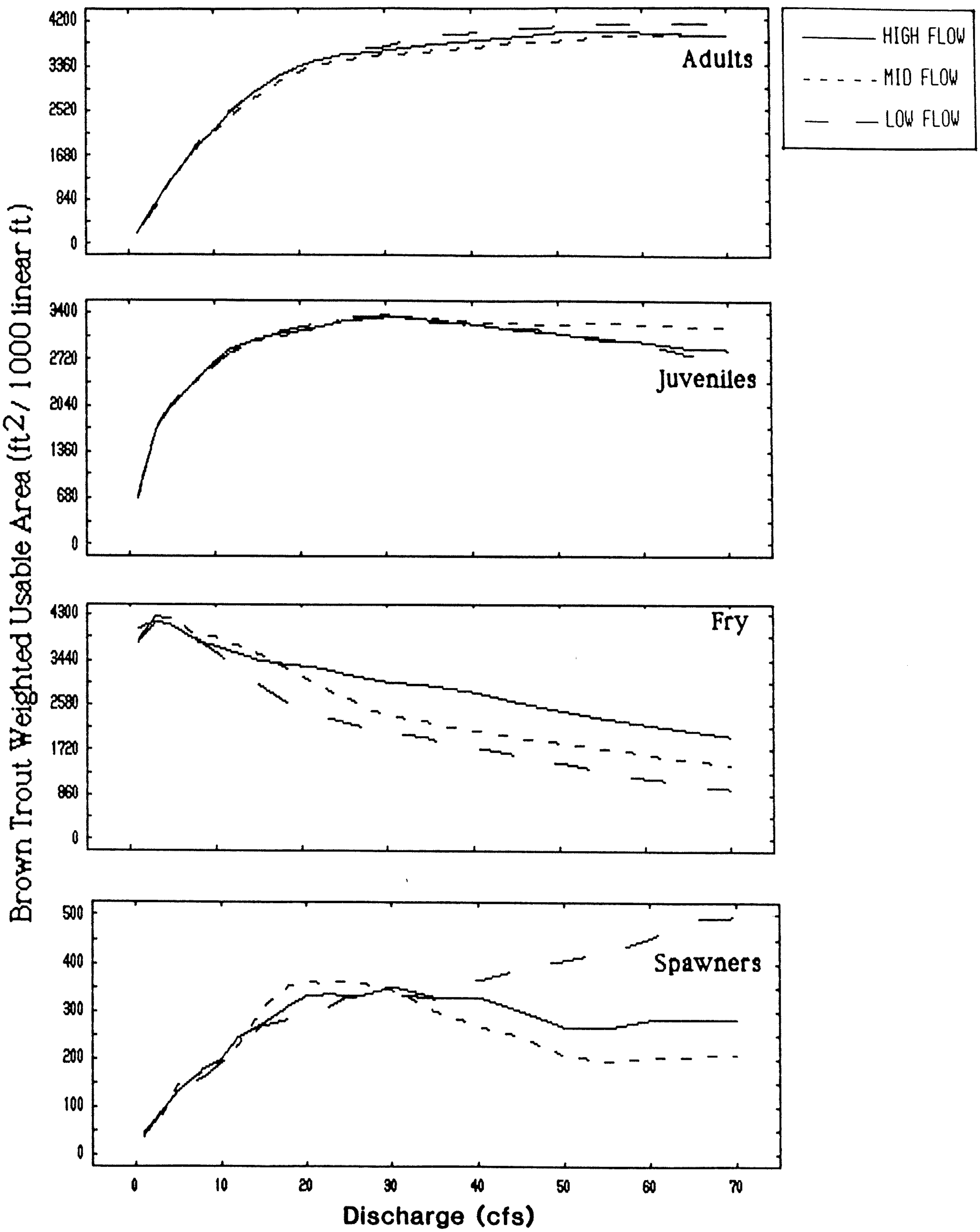
Reach 01: Below Plant No. 5

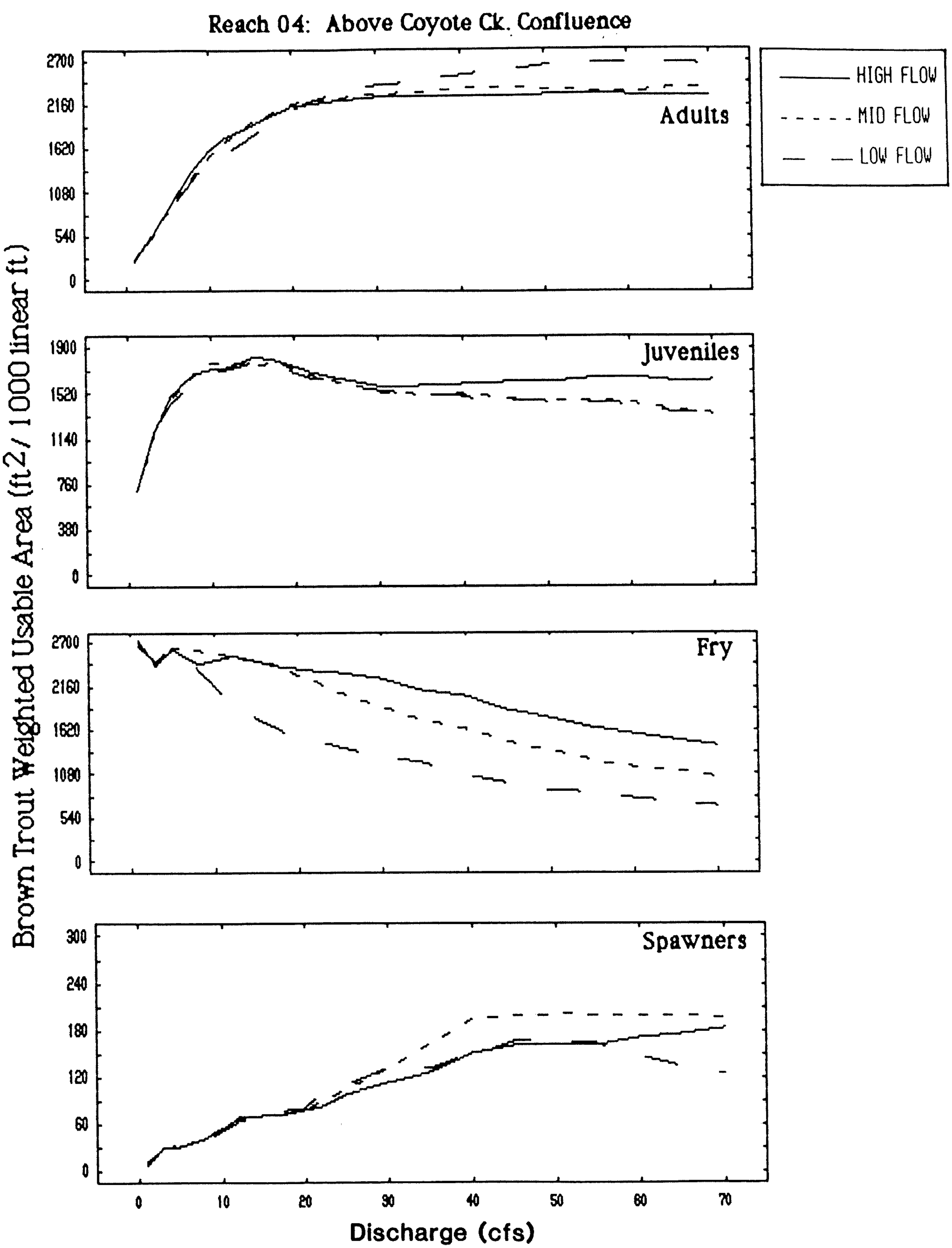


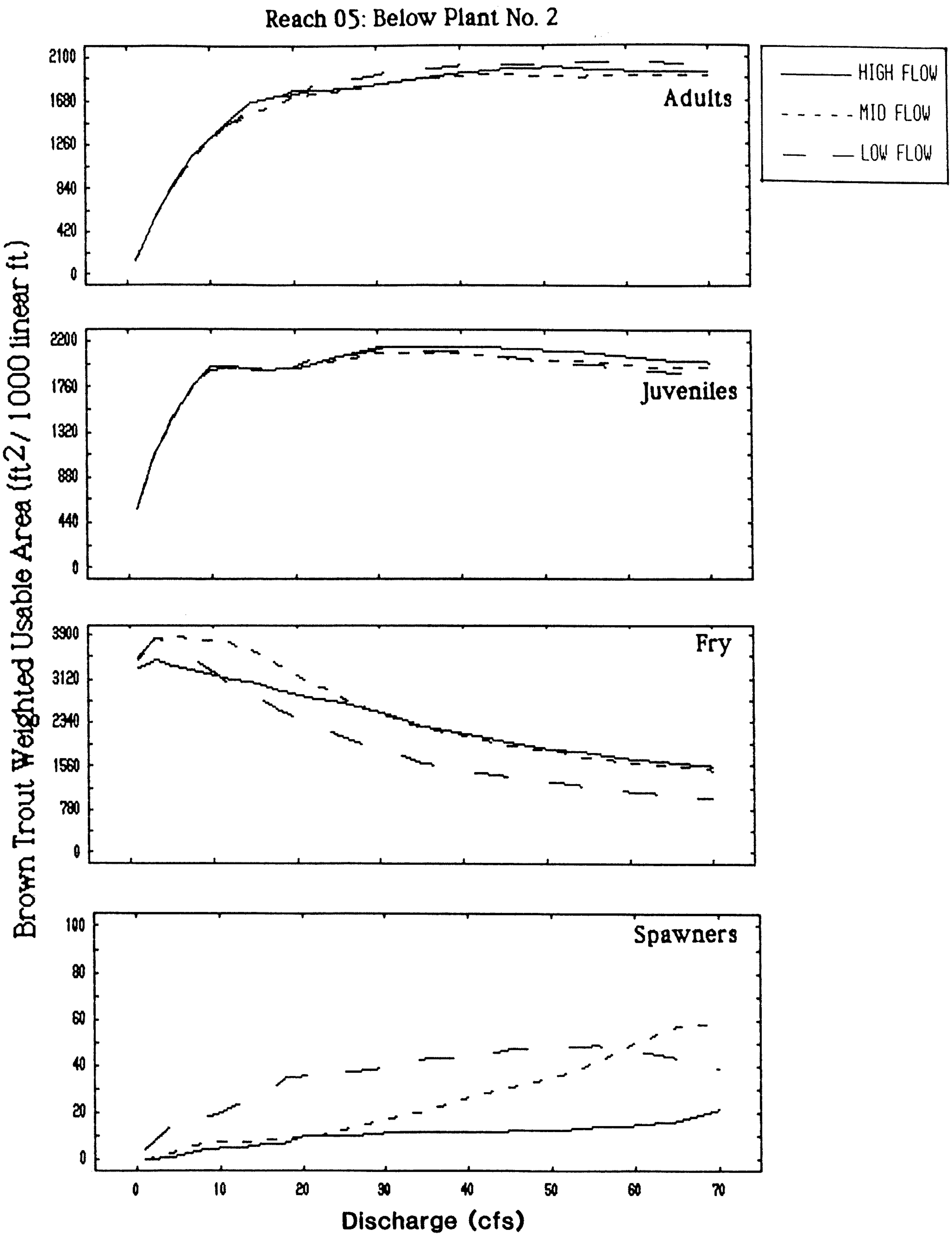
Reach 02: Below Plant No. 4



Reach 03: Below Coyote Ck. Confluence

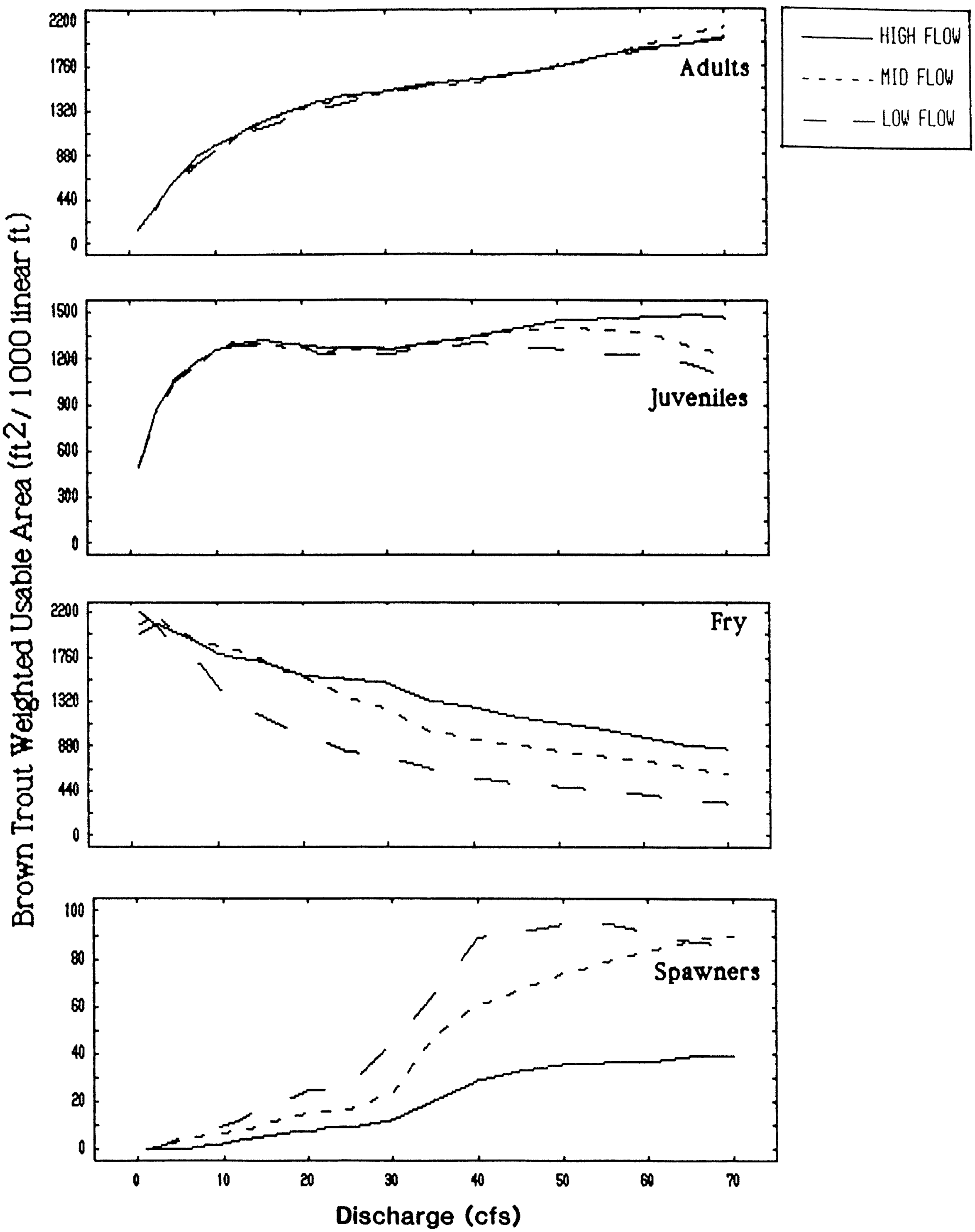


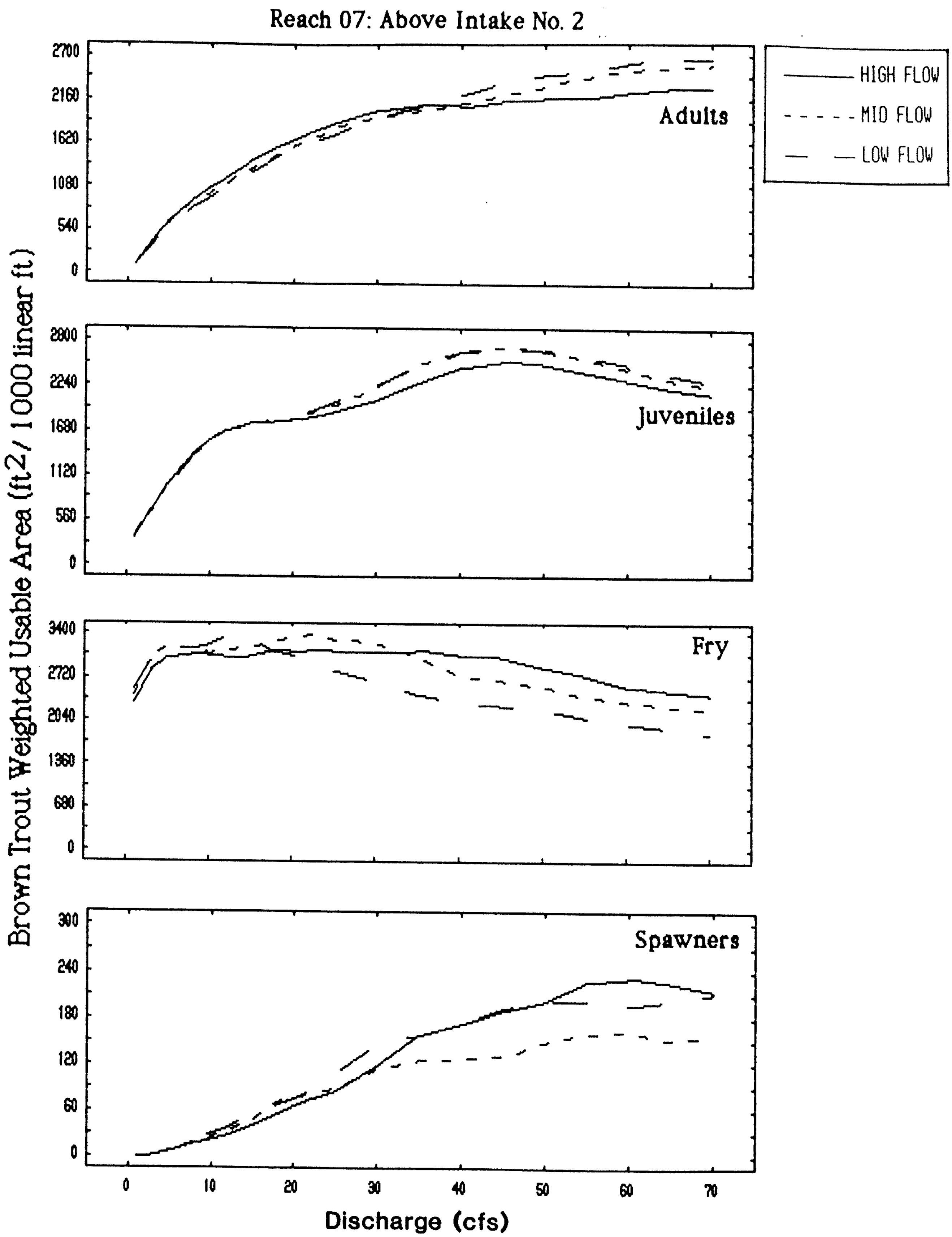

Reach 04: Above Coyote Ck. Confluence
HIGH FLOW
MID FLOW
LOW FLOW
Adults
Juveniles
Fry
Spawners
Brown Trout Weighted Usable Area (ft2 / 1000 linear ft)
Discharge (cfs)
2700
2160
1620
1080
540
0
1900
1520
1140
760
380
300
240
180
120
60
10
20
30
40
50
60
70



Reach 05: Below Plant No. 2
HIGH FLOW
MID FLOW
LOW FLOW
Adults
Juveniles
Fry
Spawners
Brown Trout Weighted Usable Area (ft2/ 1000 linear ft)
Discharge (cfs)

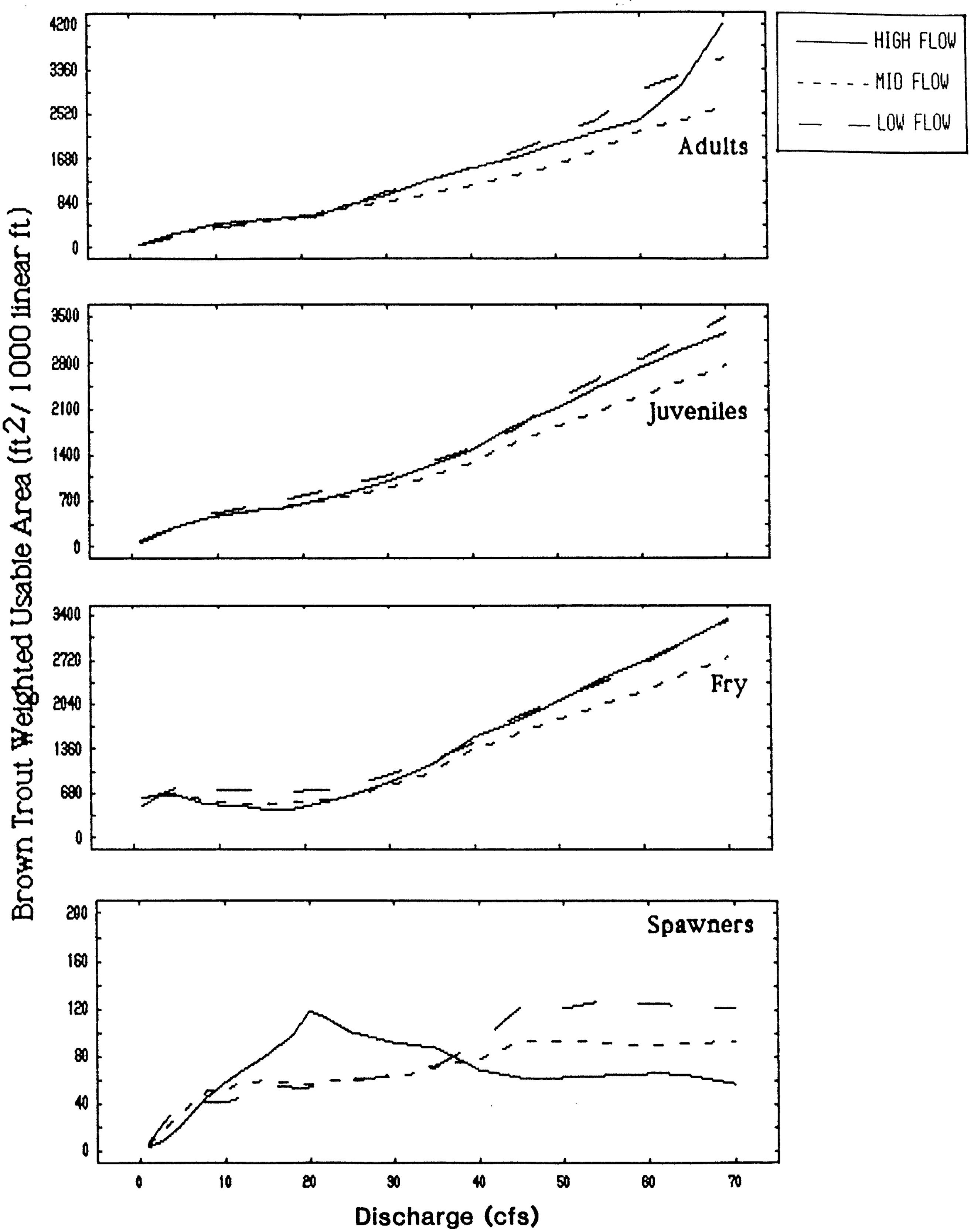
Reach 06: Below Intake No. 2



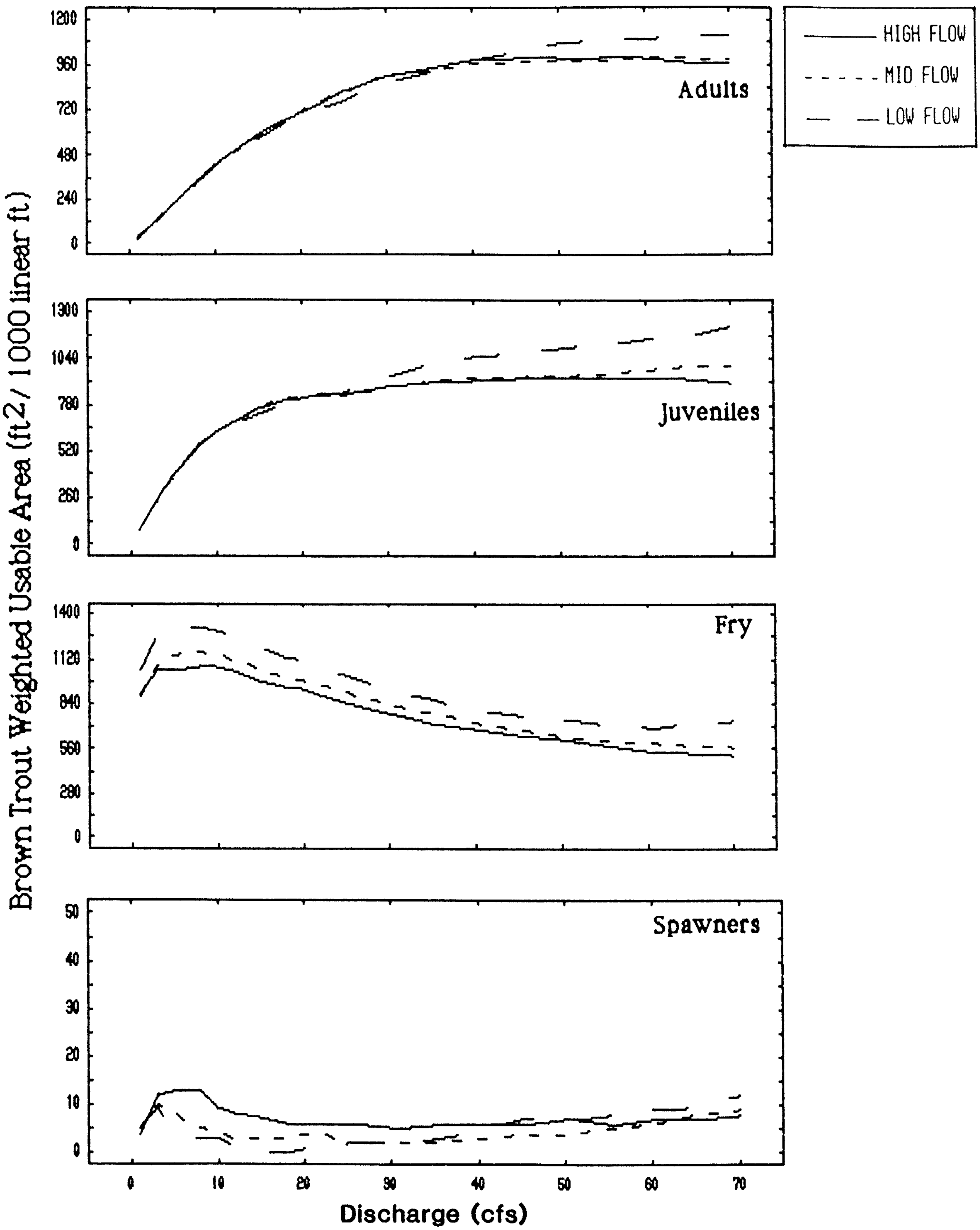


Reach 07: Above Intake No. 2
HIGH FLOW
MID FLOW
LOW FLOW
Adults
Juveniles
Fry
Spawners
Brown Trout Weighted Usable Area (ft2/ 1000 linear ft)
Discharge (cfs)

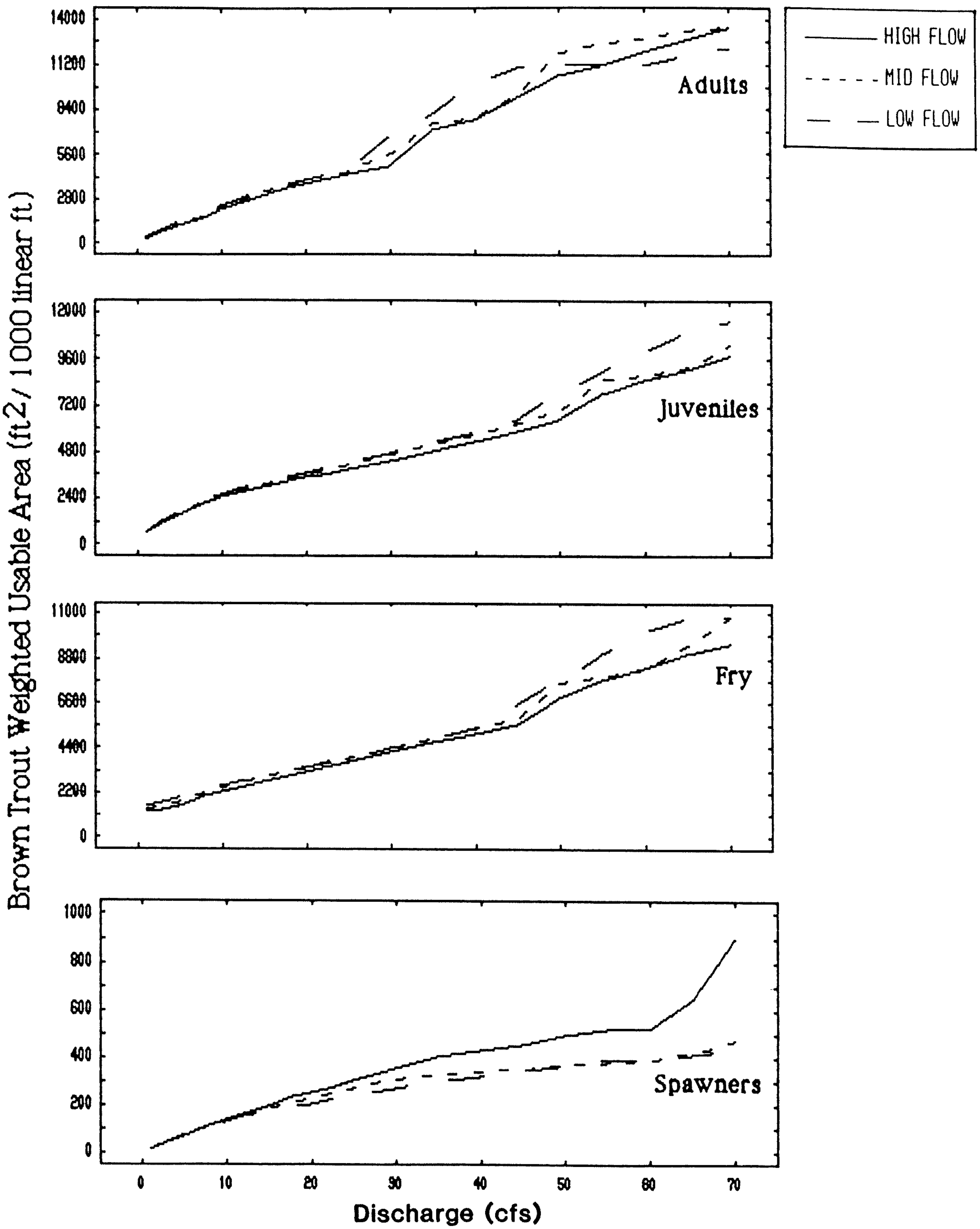
Reach 08: 0.5 mi below South Fork diversion



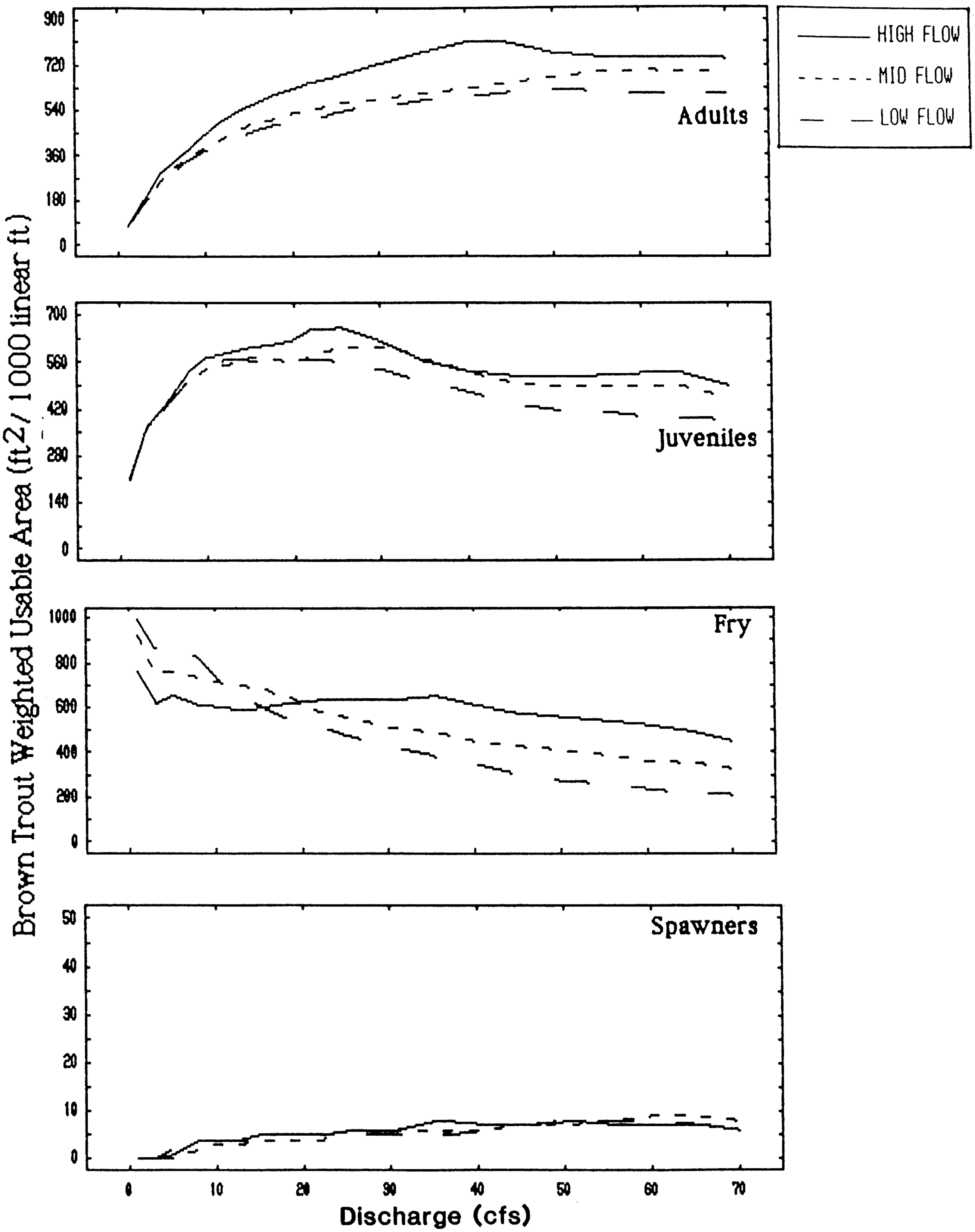
Reach 09: SF, .25 Mi. Below Tyee Ck. Confluence

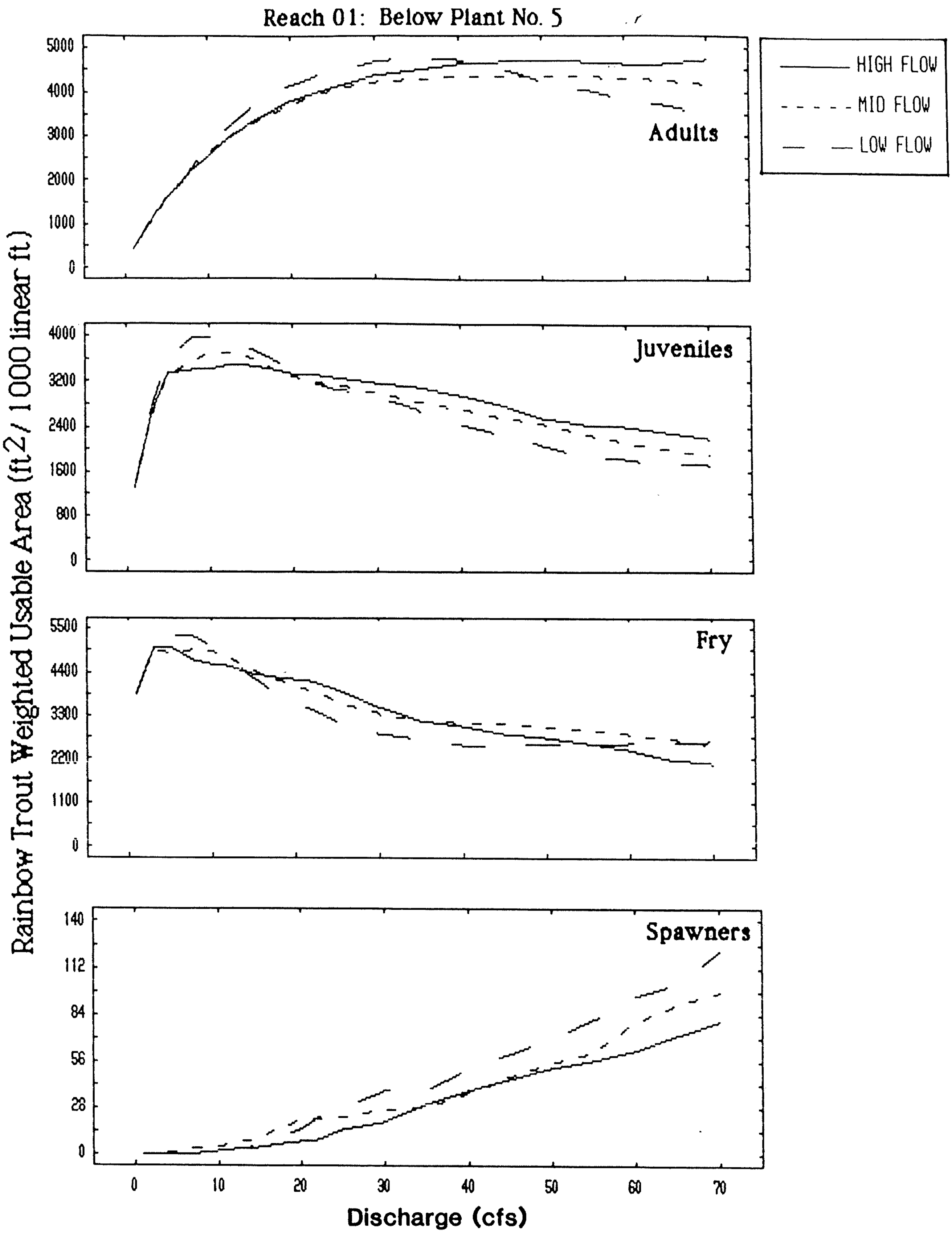


Reach 10: SF, 1.25 Mi. Below Tyee Ck. Confluence



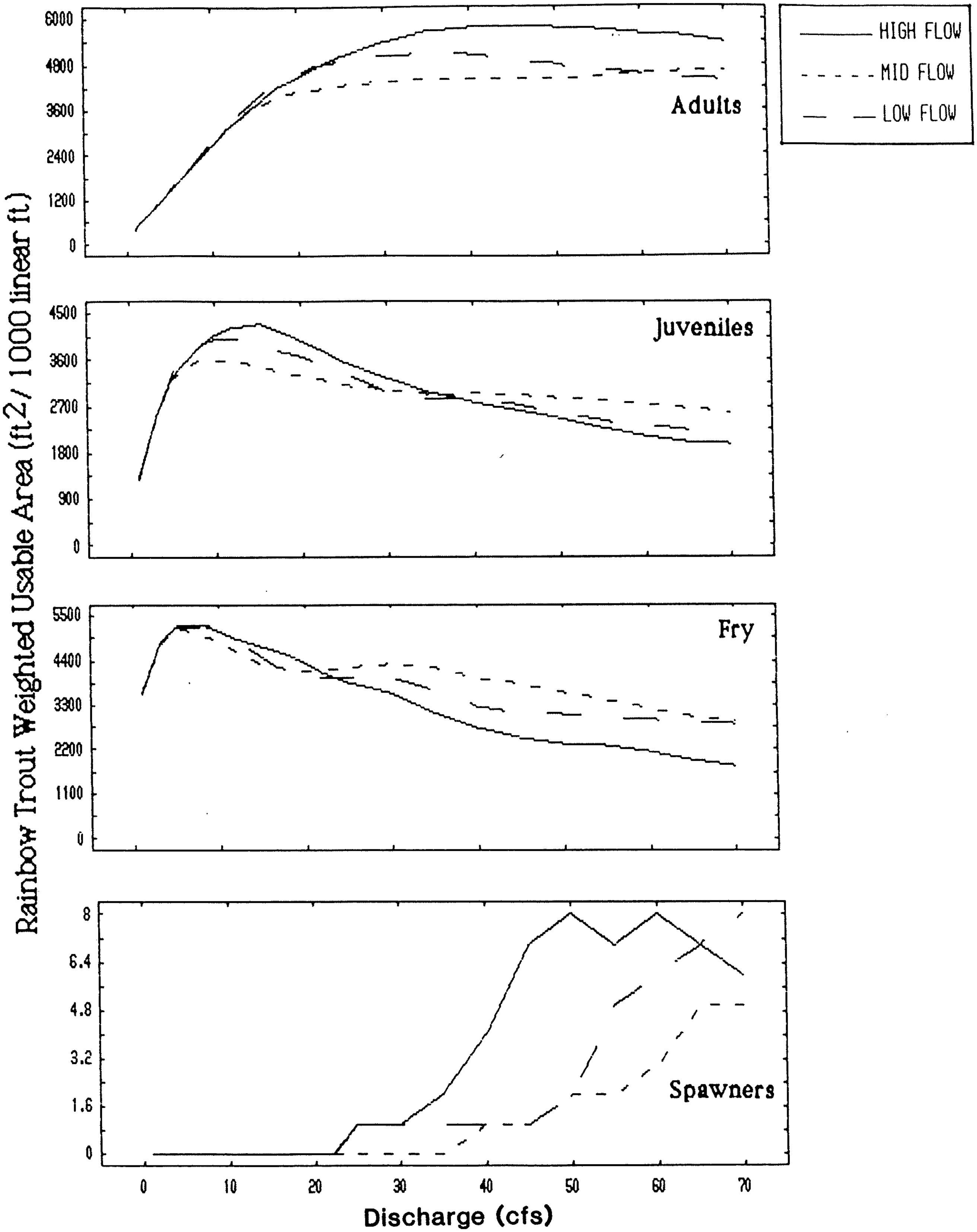
Reach 11: 1.5 mi below South Fork diversion



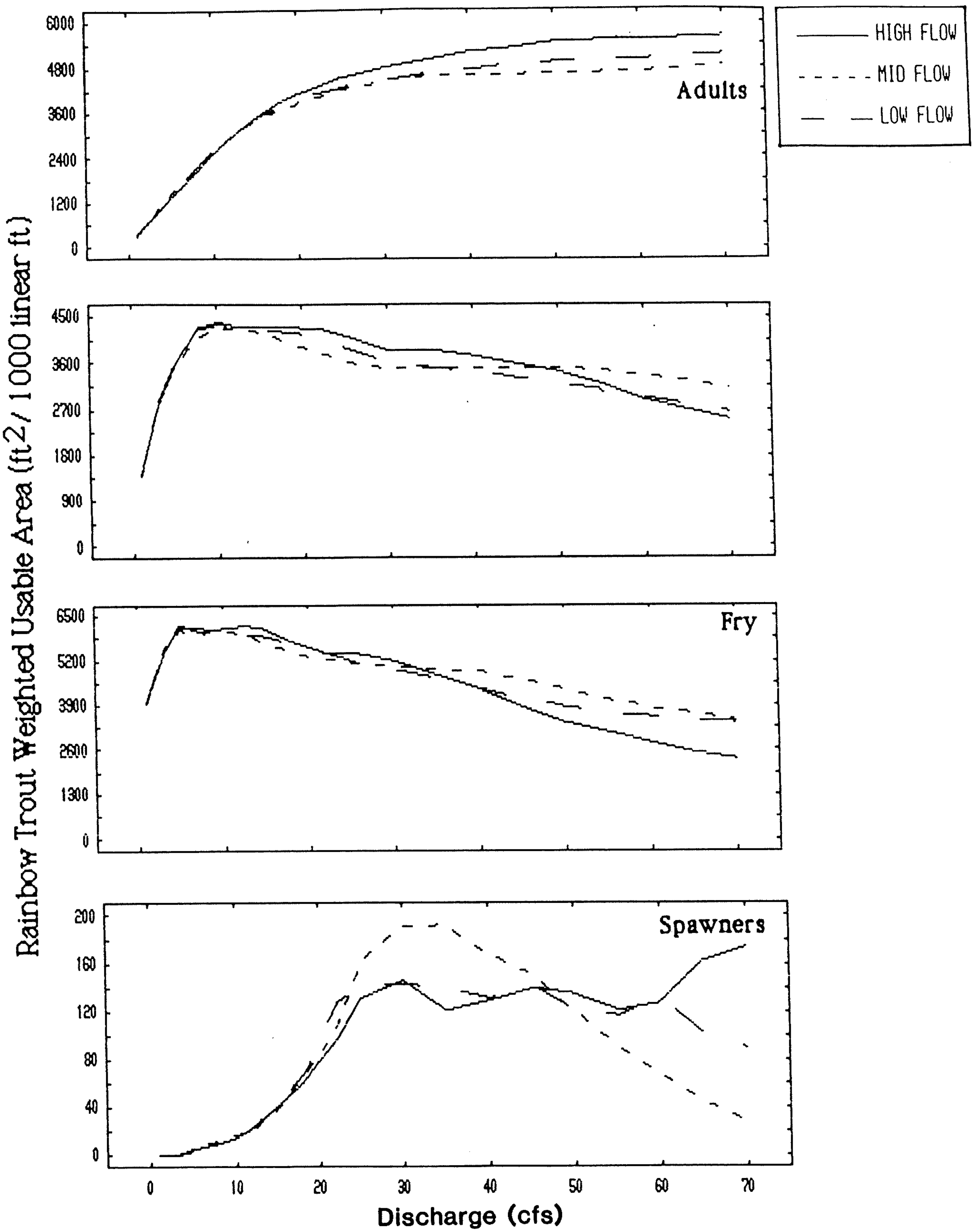


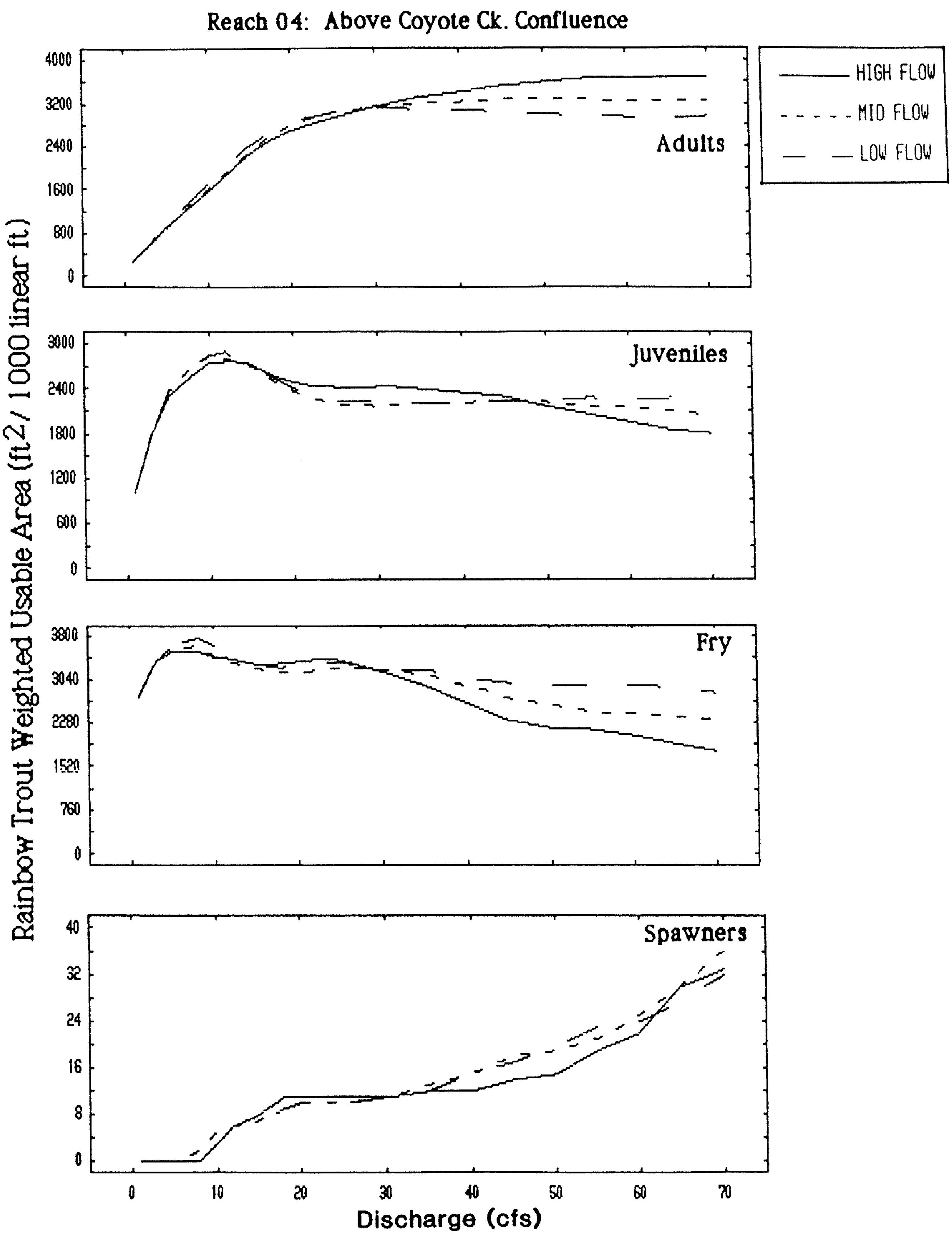
Reach 01: Below Plant No. 5
HIGH FLOW
MID FLOW
LOW FLOW
Rainbow Trout Weighted Usable Area (ft2/1000 linear ft)
Adults
5000
4000
3000
2000
1000
0
Juveniles
4000
3200
2400
1600
800
0
Fry
5500
4400
3300
2200
1100
0
Spawners
140
112
84
56
28
0
0
10
20
30
40
50
60
70
Discharge (cfs)

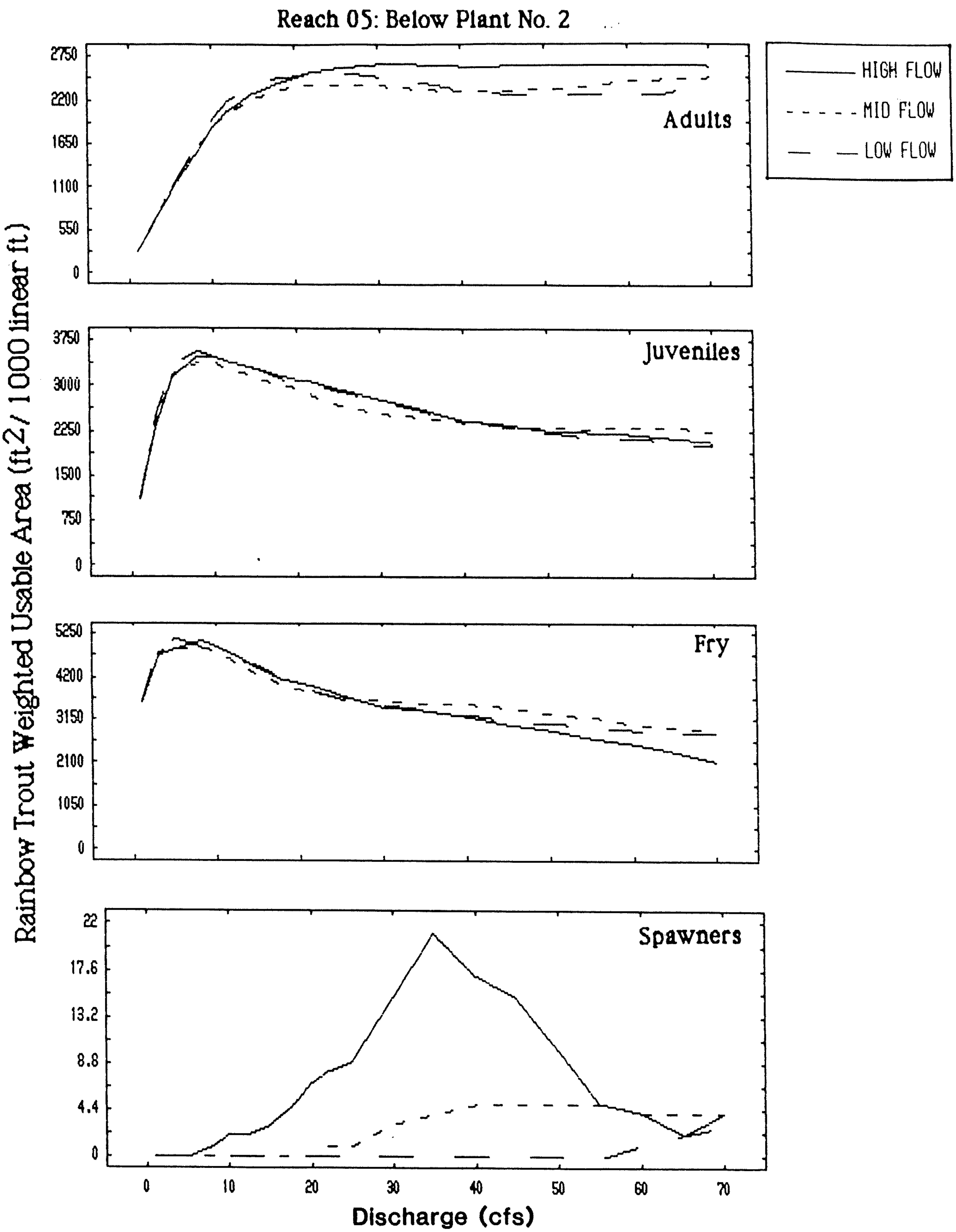
Reach 02: Below Plant No. 4

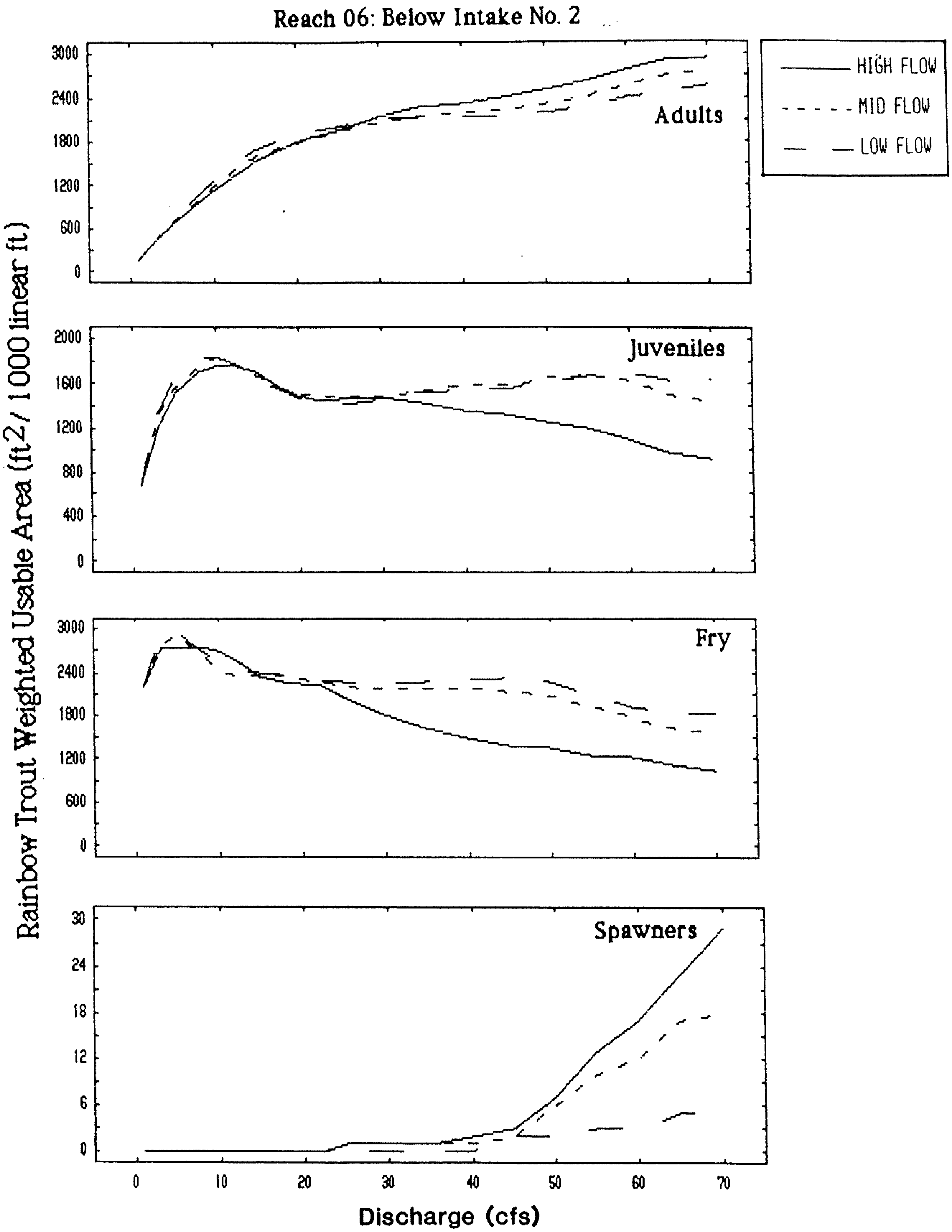


Reach 03: Below Coyote Ck. Confluence

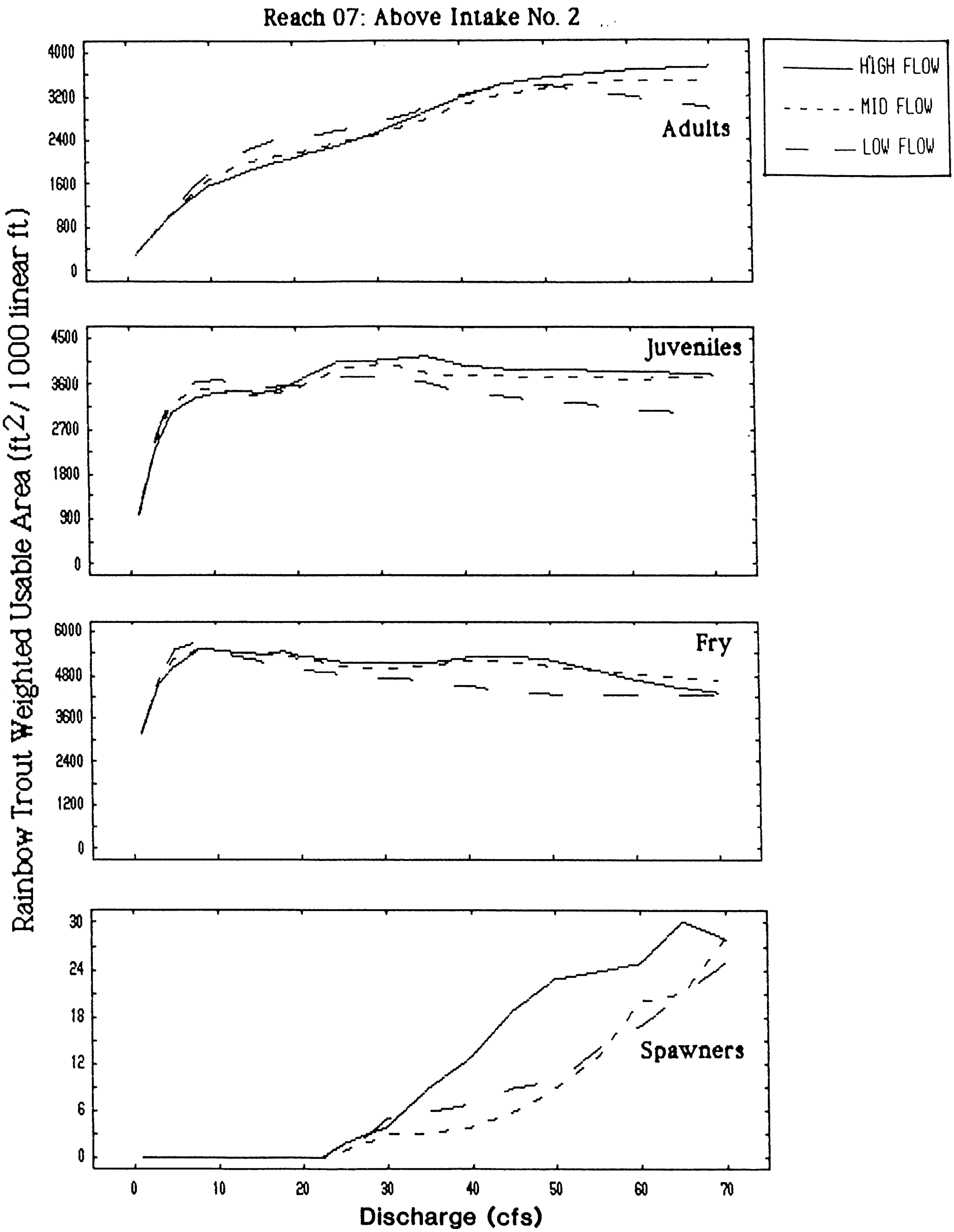



Reach 04: Above Coyote Ck. Confluence
HIGH FLOW
MID FLOW
LOW FLOW
Adults
Juveniles
Fry
Spawners
Rainbow Trout Weighted Usable Area (ft2 / 1000 linear ft.)
Discharge (cfs)

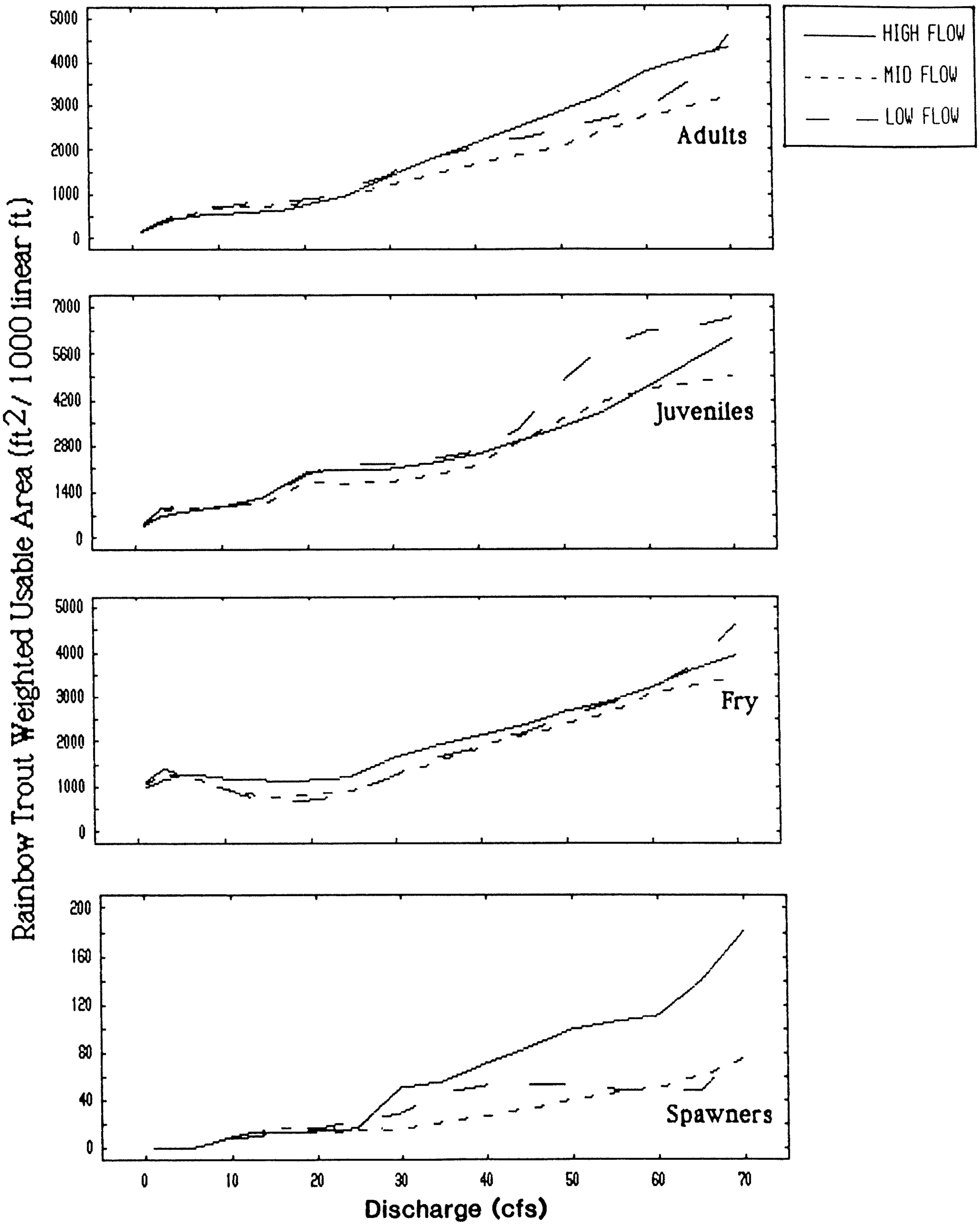

Reach 05: Below Plant No. 2
HIGH FLOW
MID FLOW
LOW FLOW
Adults
Juveniles
Fry
Spawners
Rainbow Trout Weighted Usable Area (ft2/ 1000 linear ft.)
Discharge (cfs)
2750
2200
1650
1100
550
0
3750
3000
2250
1500
750
0
5250
4200
3150
2100
1050
0
22
17.6
13.2
8.8
4.4
0
0
10
20
30
40
50
60
70



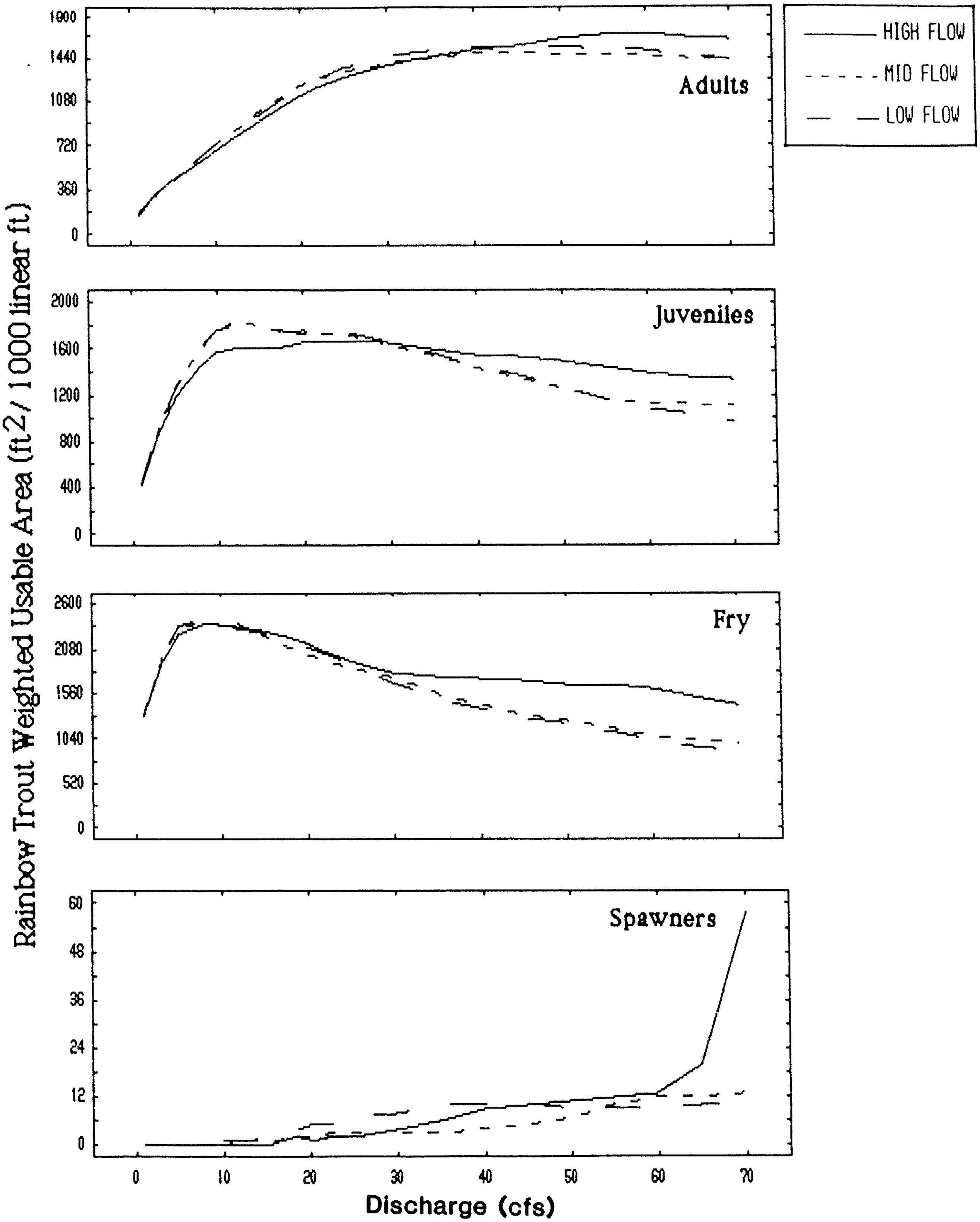
Reach 06: Below Intake No. 2
HIGH FLOW
MID FLOW
LOW FLOW
Adults
Juveniles
Fry
Spawners
Rainbow Trout Weighted Usable Area (ft2 / 1000 linear ft.)
3000
2400
1800
1200
600
0
2000
1600
1200
800
400
0
30
24
18
12
6
0
0
10
20
30
40
50
60
70
Discharge (cfs)


Reach 07: Above Intake No. 2
HIGH FLOW
MID FLOW
LOW FLOW
Adults
Juveniles
Fry
Spawners
Rainbow Trout Weighted Usable Area (ft2 / 1000 linear ft)
Discharge (cfs)
4000
3200
2400
1600
800
0
4500
3600
2700
1800
900
0
6000
4800
3600
2400
1200
0
30
24
18
12
6
0
0
10
20
30
40
50
60
70

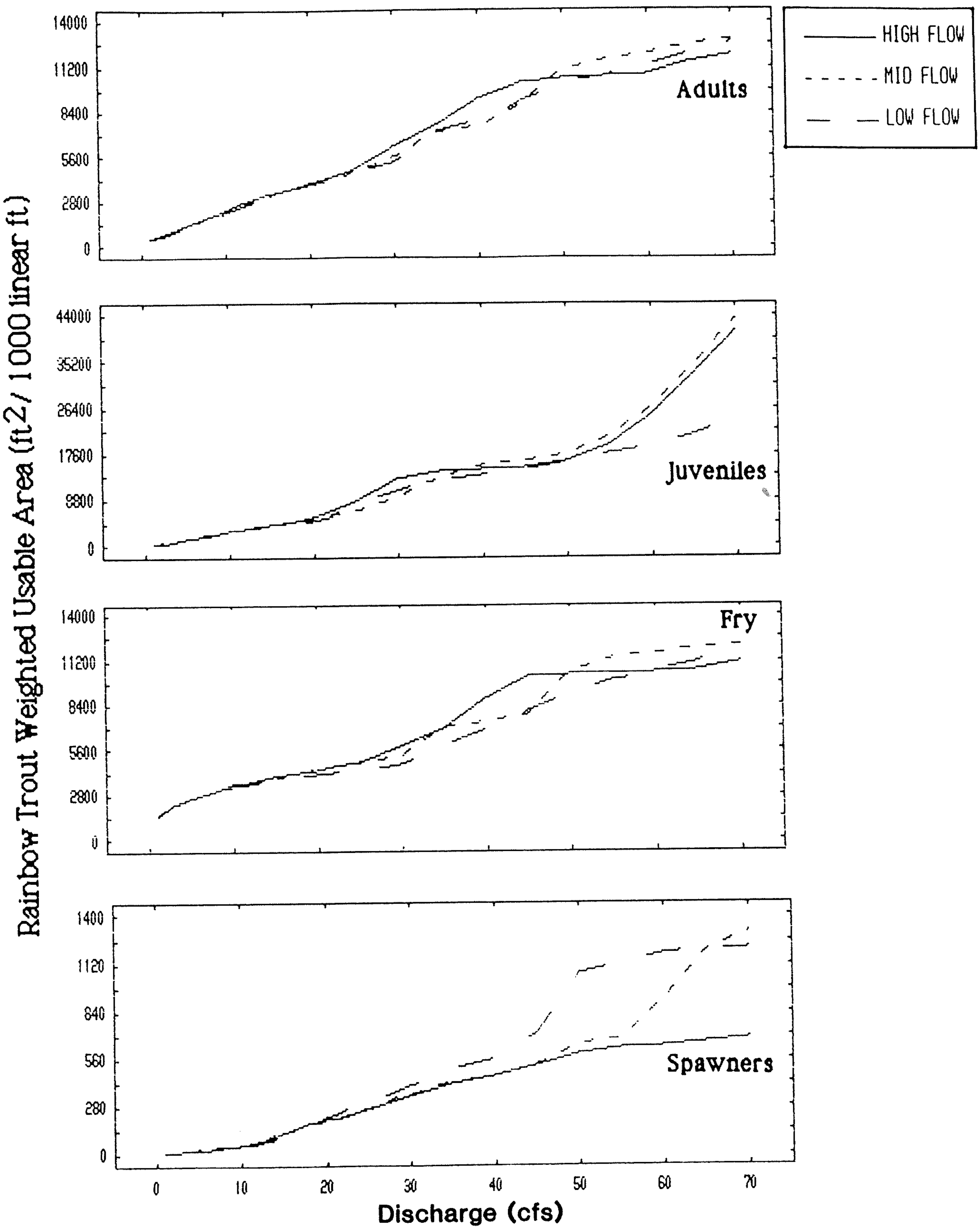
Reach 08: 0.5 mi below South Fork diversion



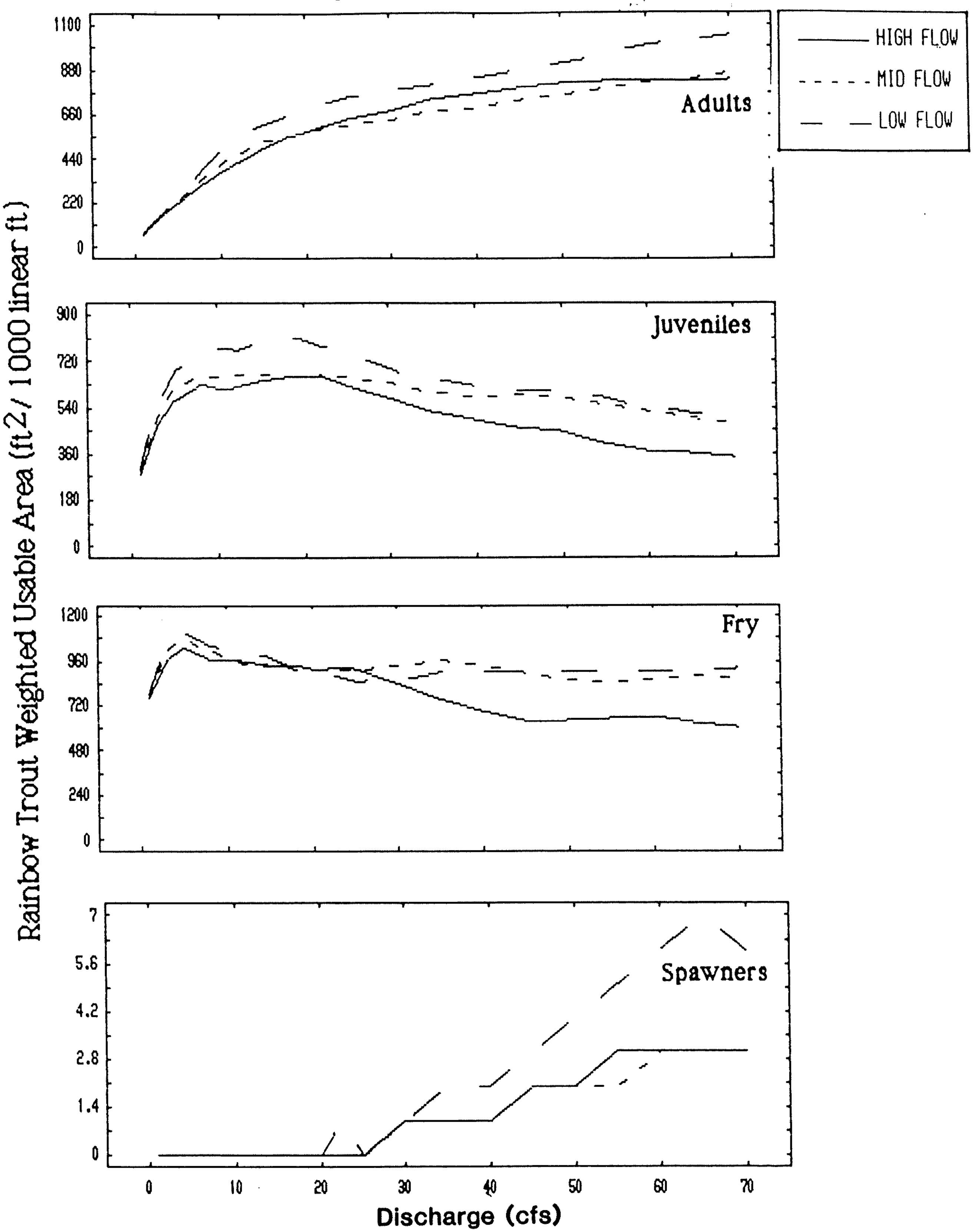
Reach 09: SF, .25 Mi. Below Tyee Ck. Confluence



Reach 10: SF, 1.25 Mi. Below Tyee Ck. Confluence

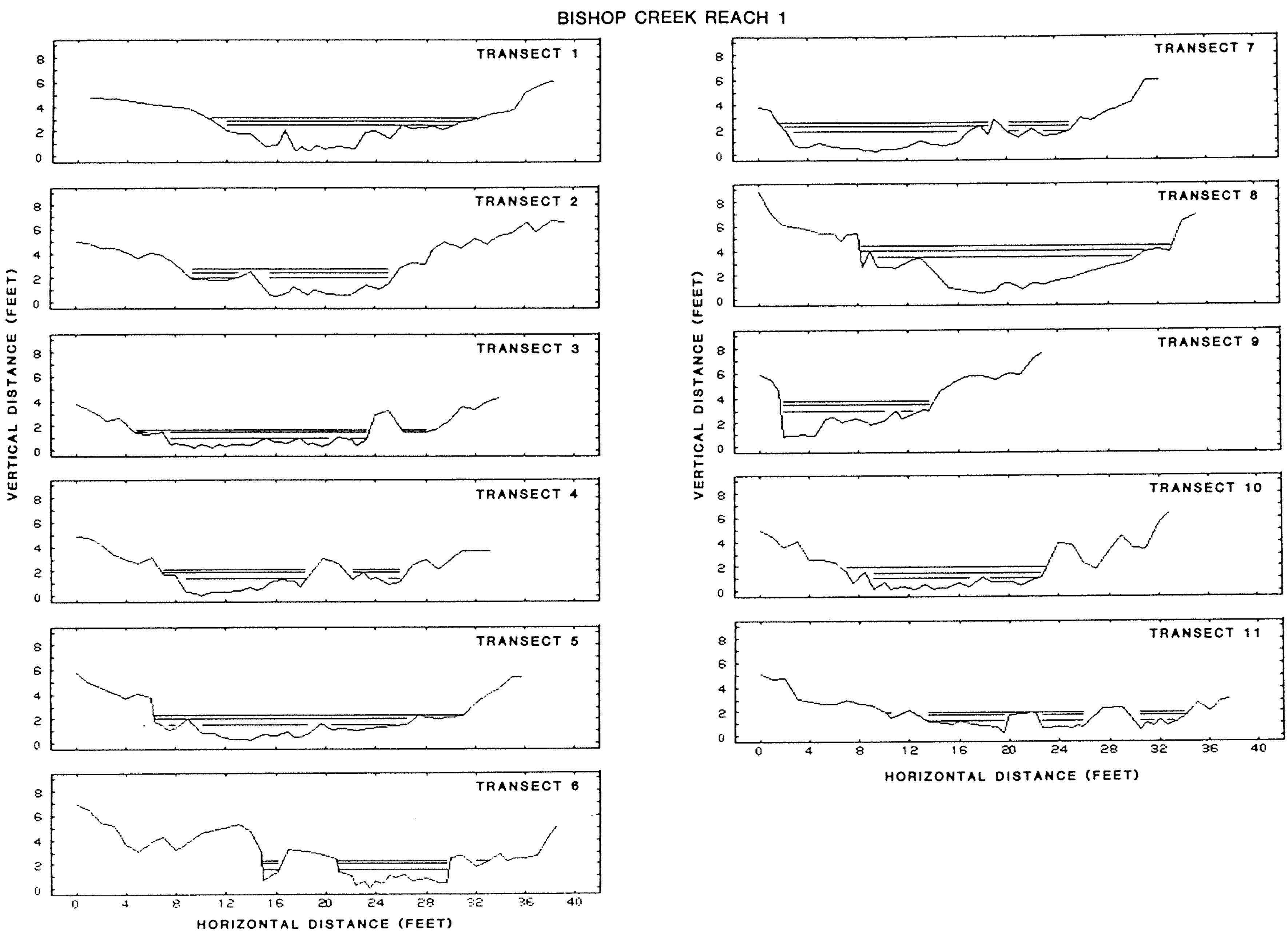


Reach 11: 1.5 mi below South Fork diversion



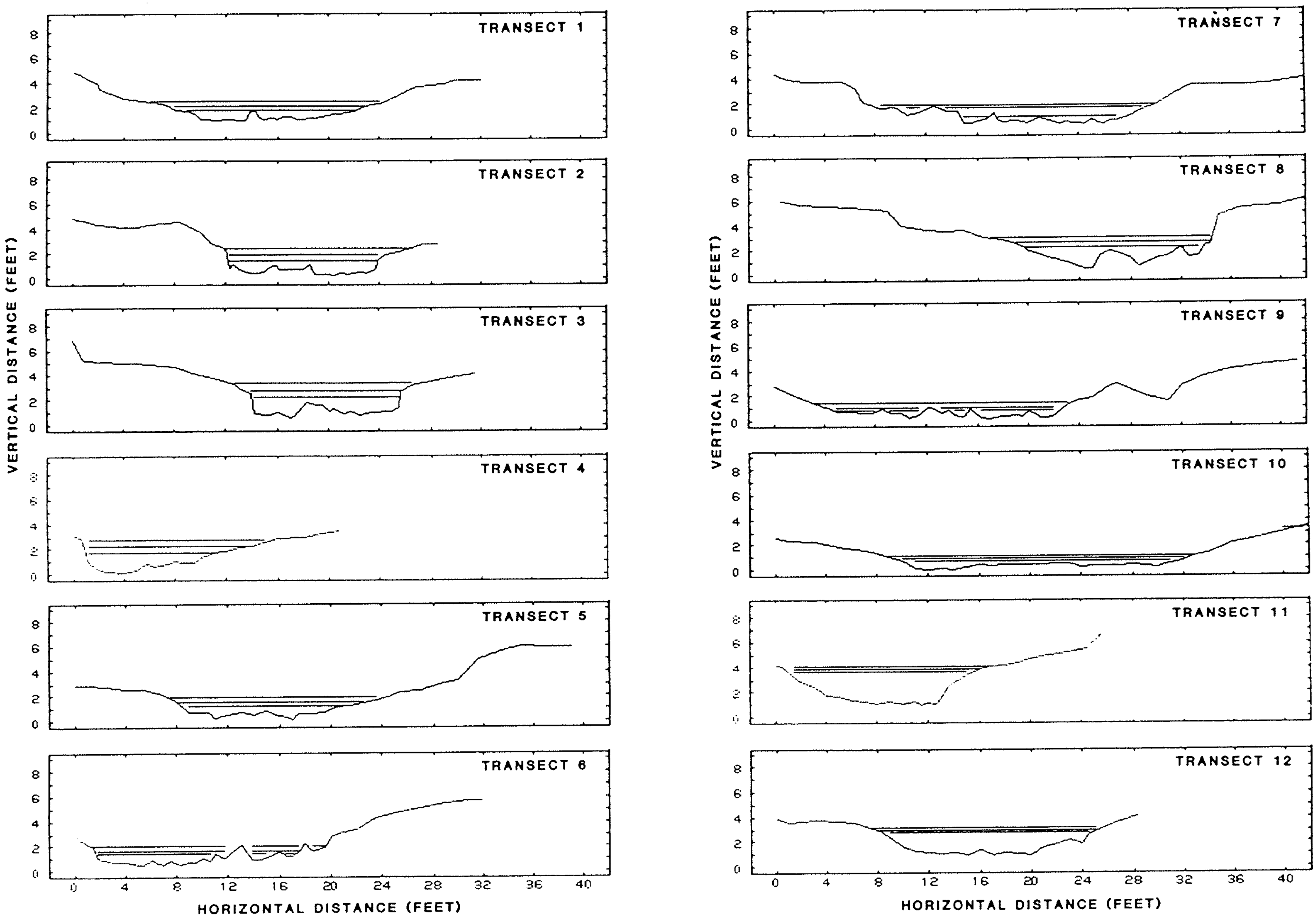
ATTACHMENT 3

Cross sections and water surface elevations
at the three measured flows on Bishop Creek

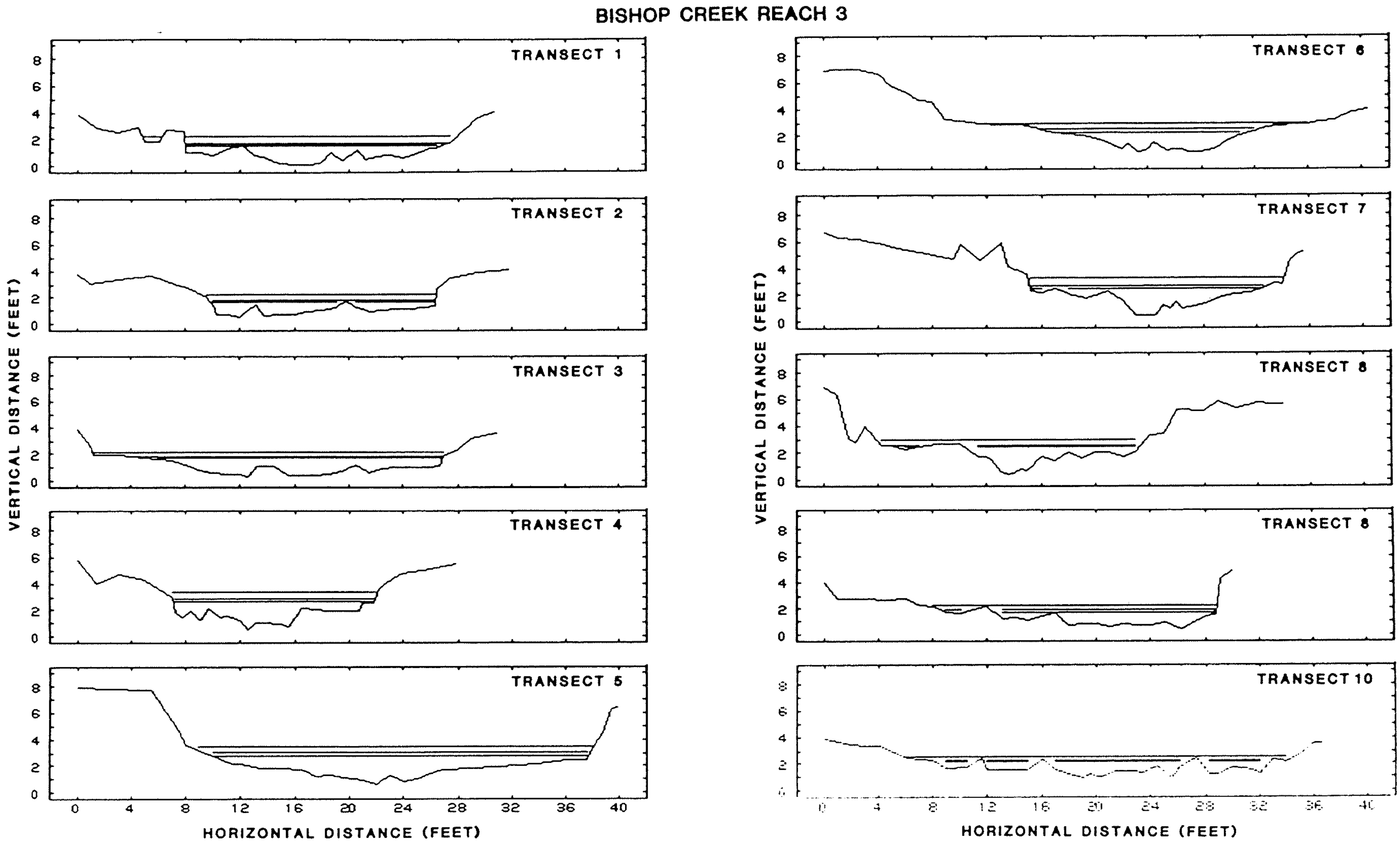


Cross-sectional profiles and water surface elevations at the measured flows.

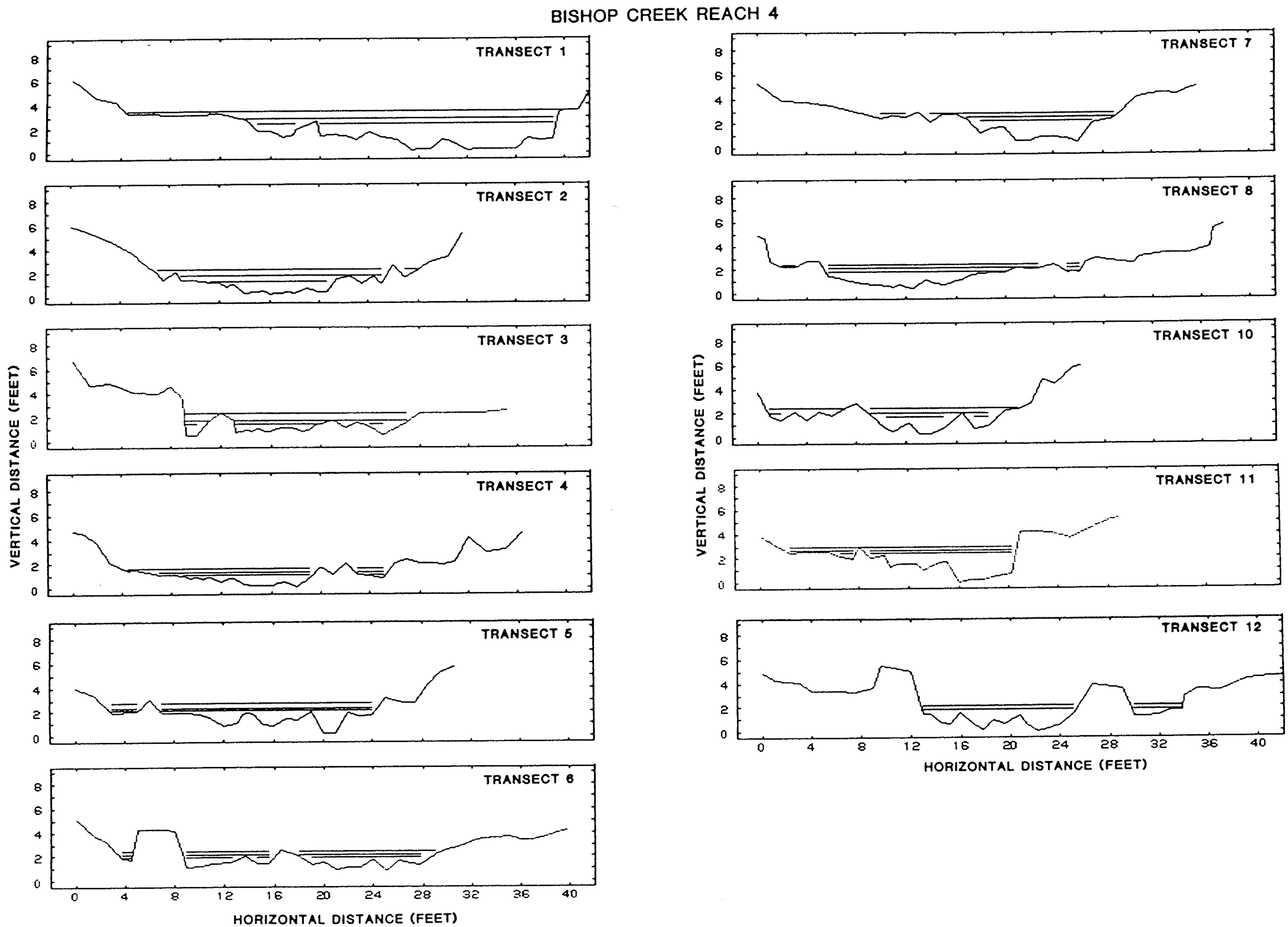
BISHOP CREEK REACH 2



Cross-sectional profiles and water surface elevations at the measured flows.

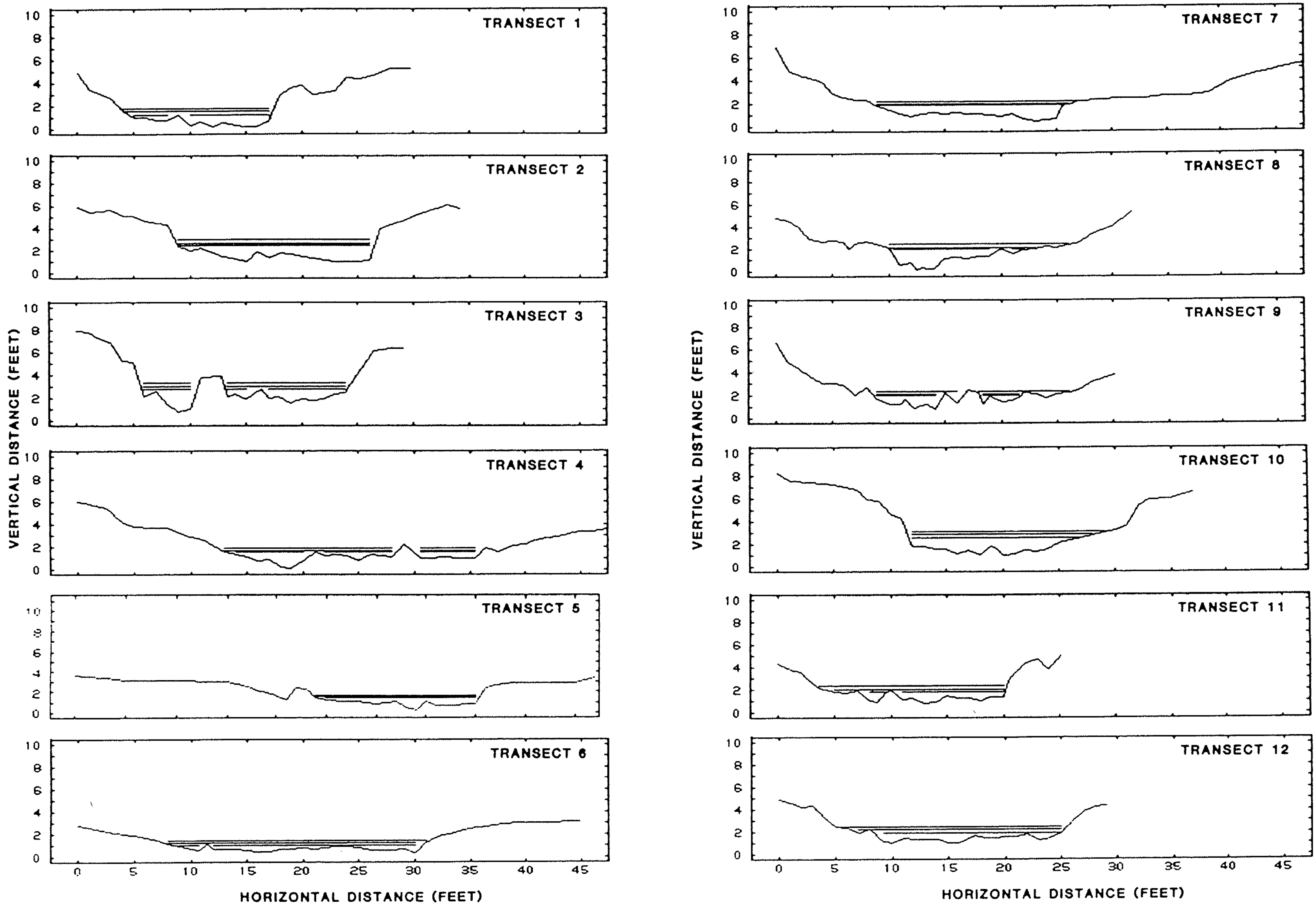


Cross-sectional profiles and water surface elevations at the measured flows.

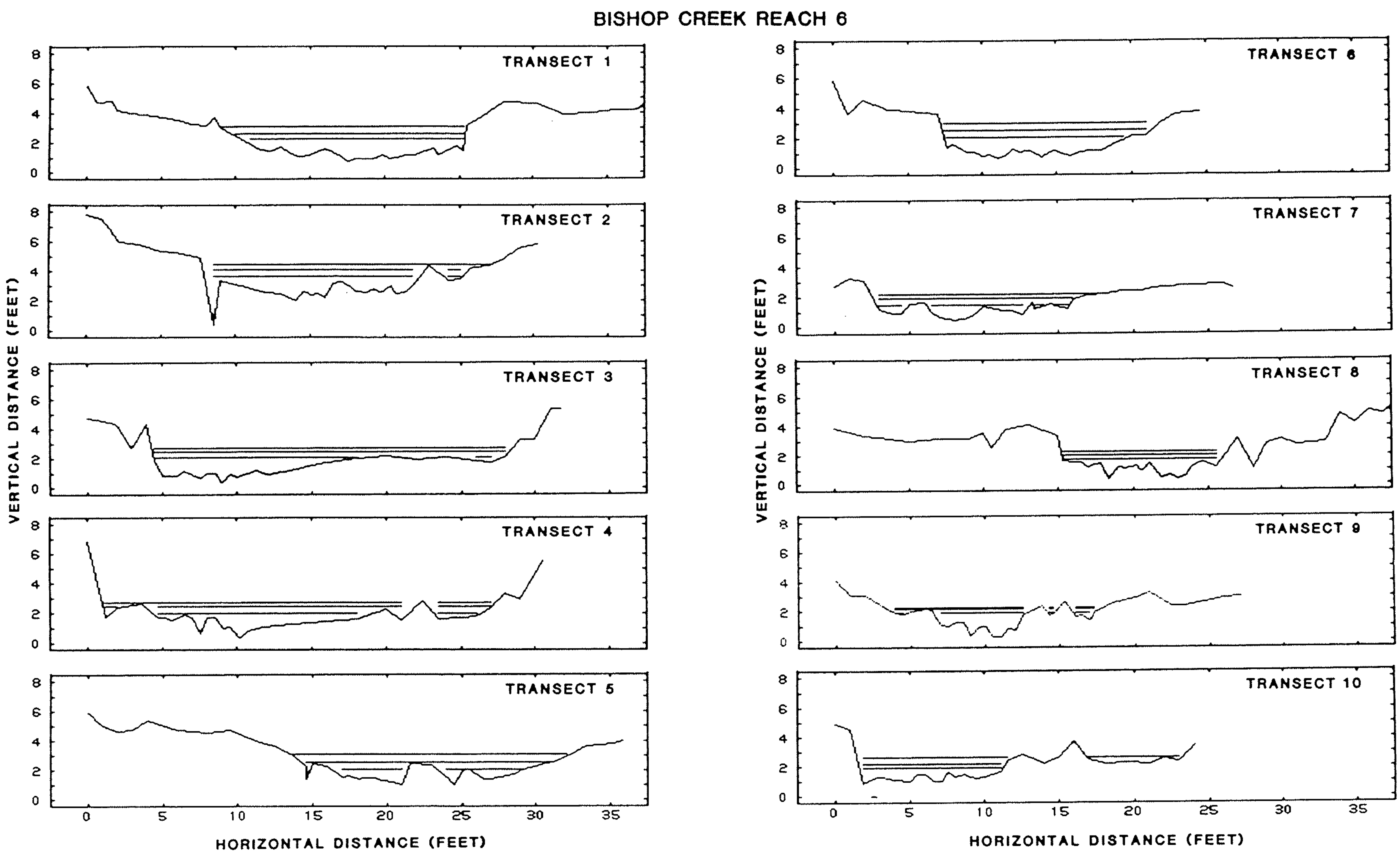


Cross-sectional profiles and water surface elevations at the measured flows.

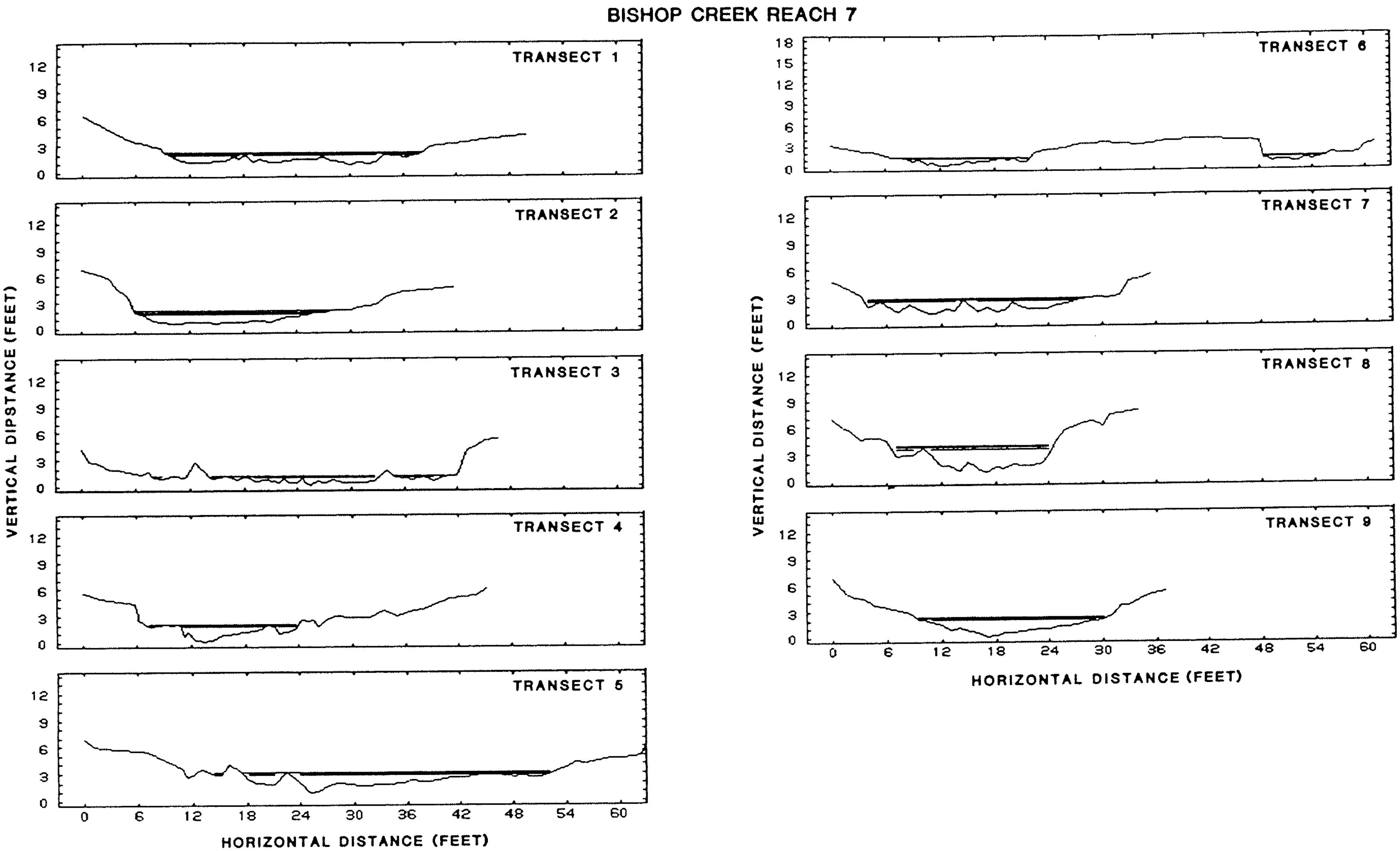
BISHOP CREEK REACH 5



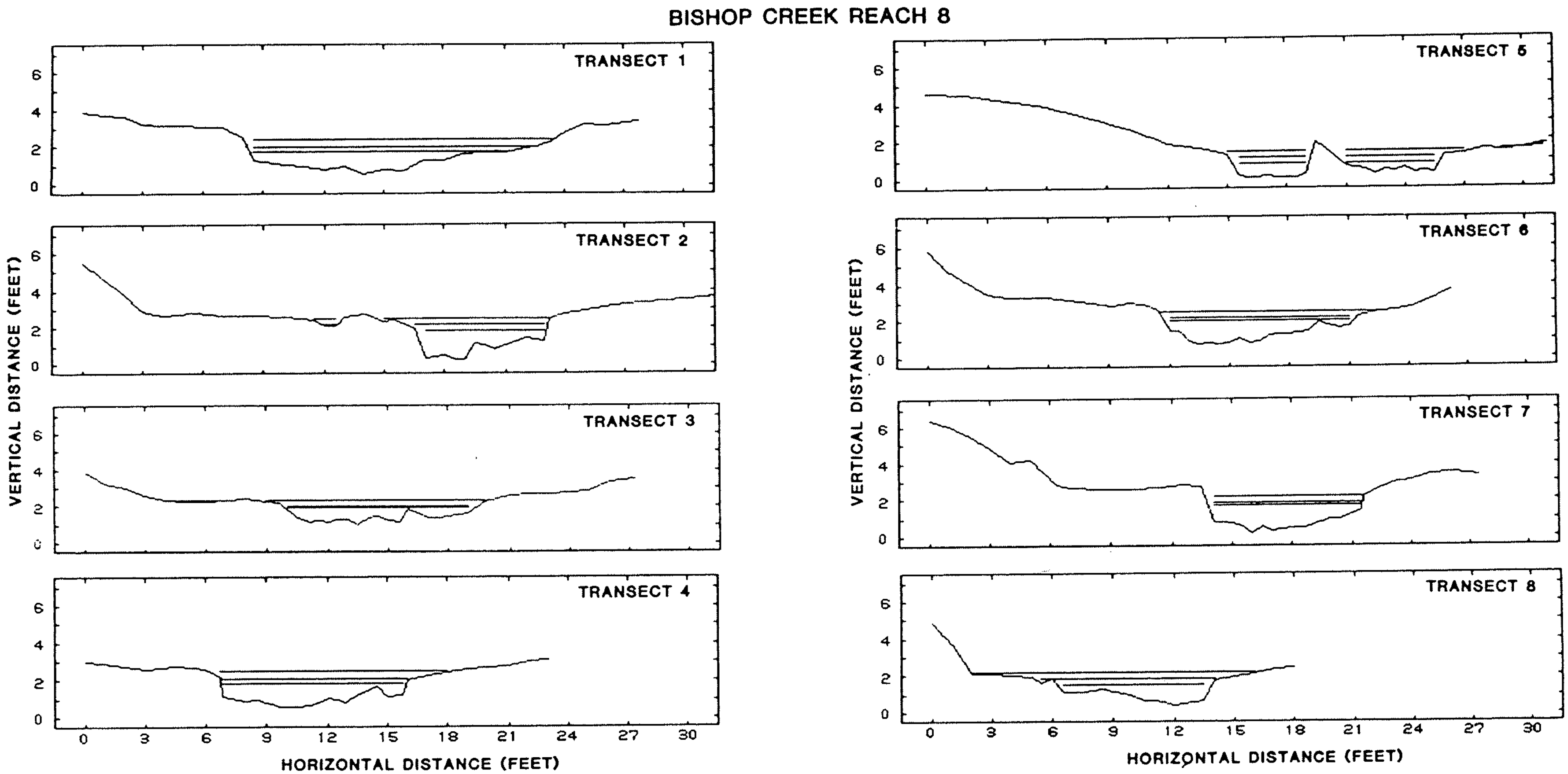
Cross-sectional profiles and water surface elevations at the measured flows.



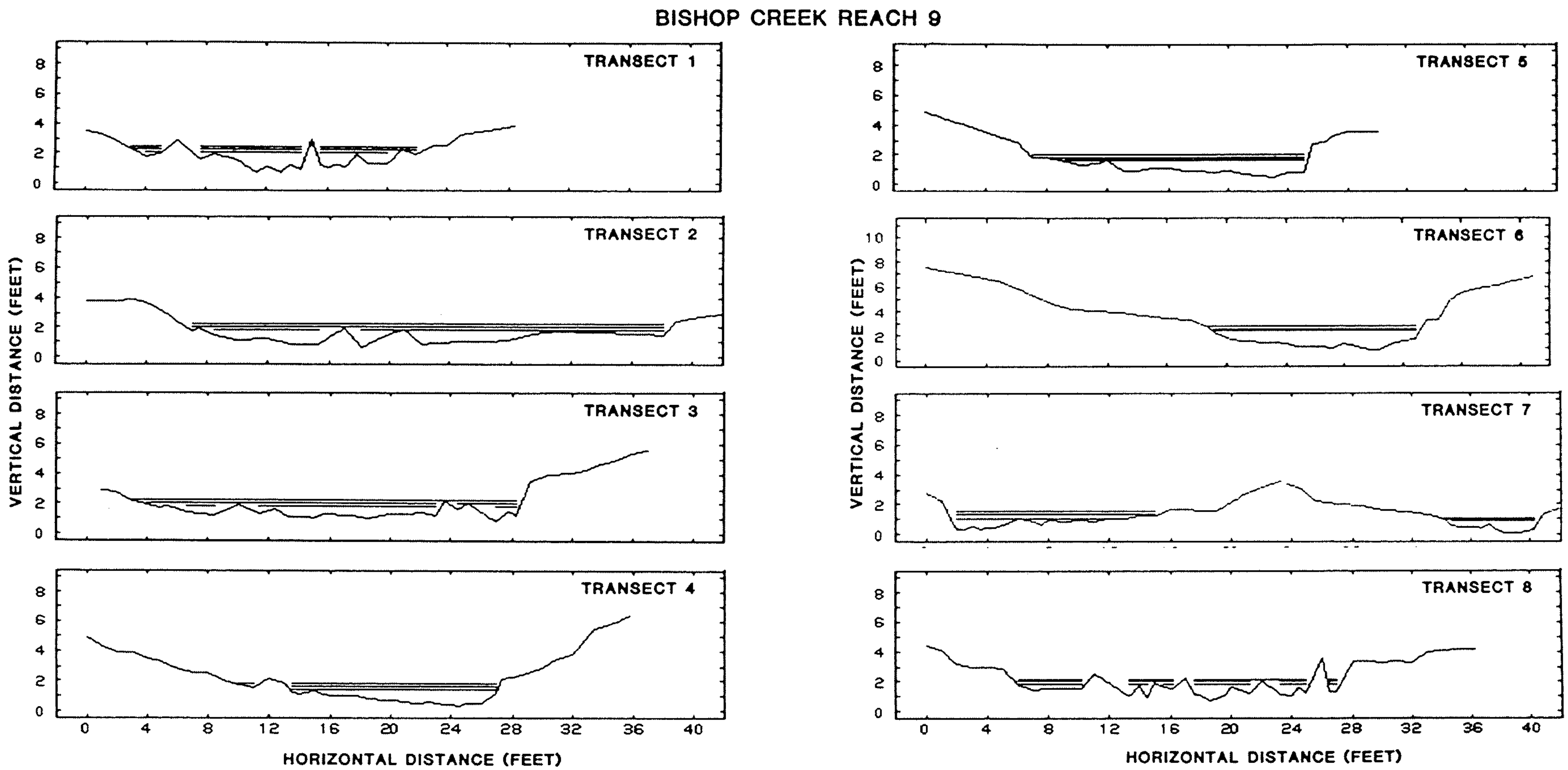
Cross–sectional profiles and water surface elevations at the measured flows.



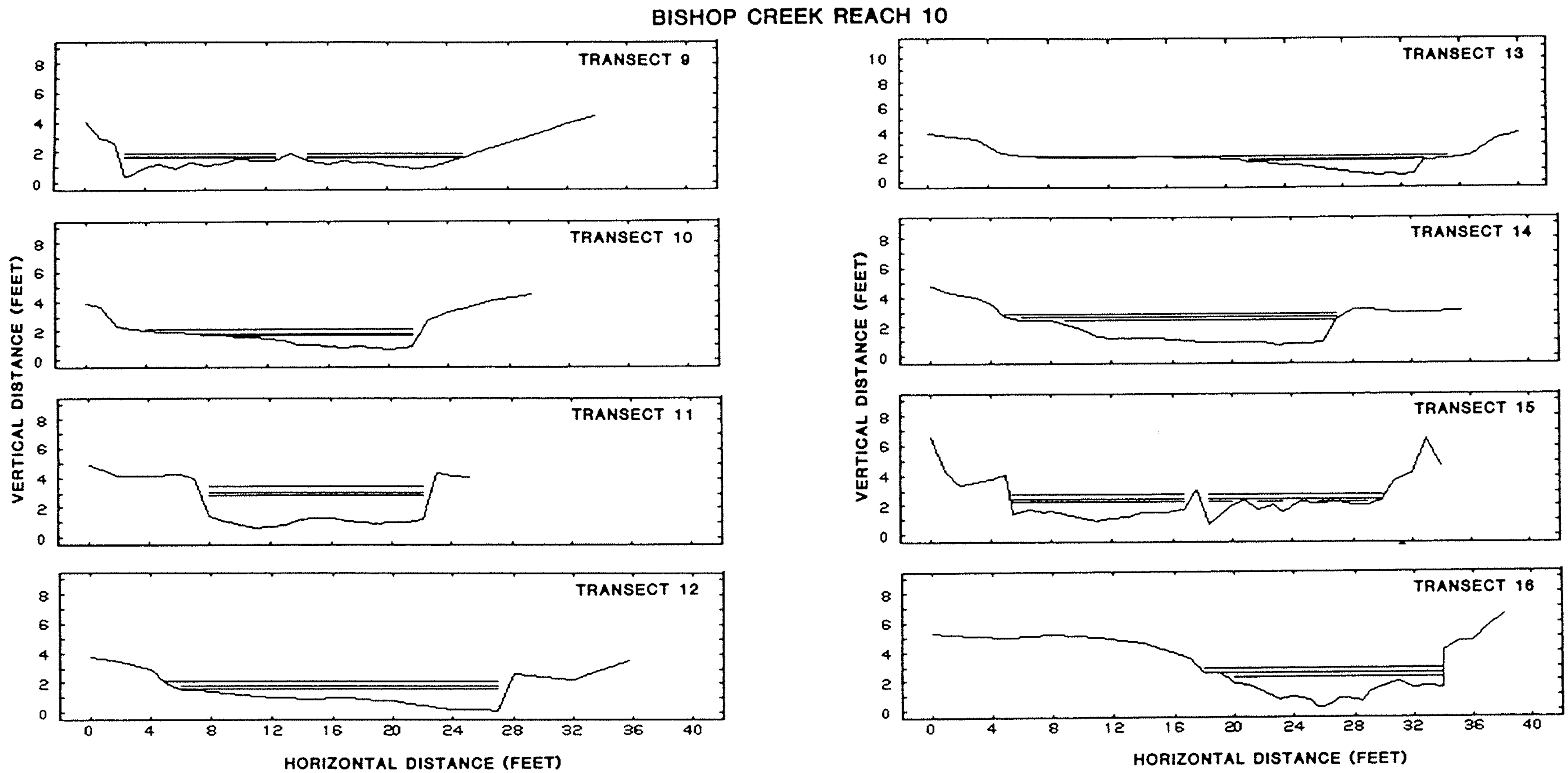
Cross-sectional profiles and water surface elevations at the measured flows.



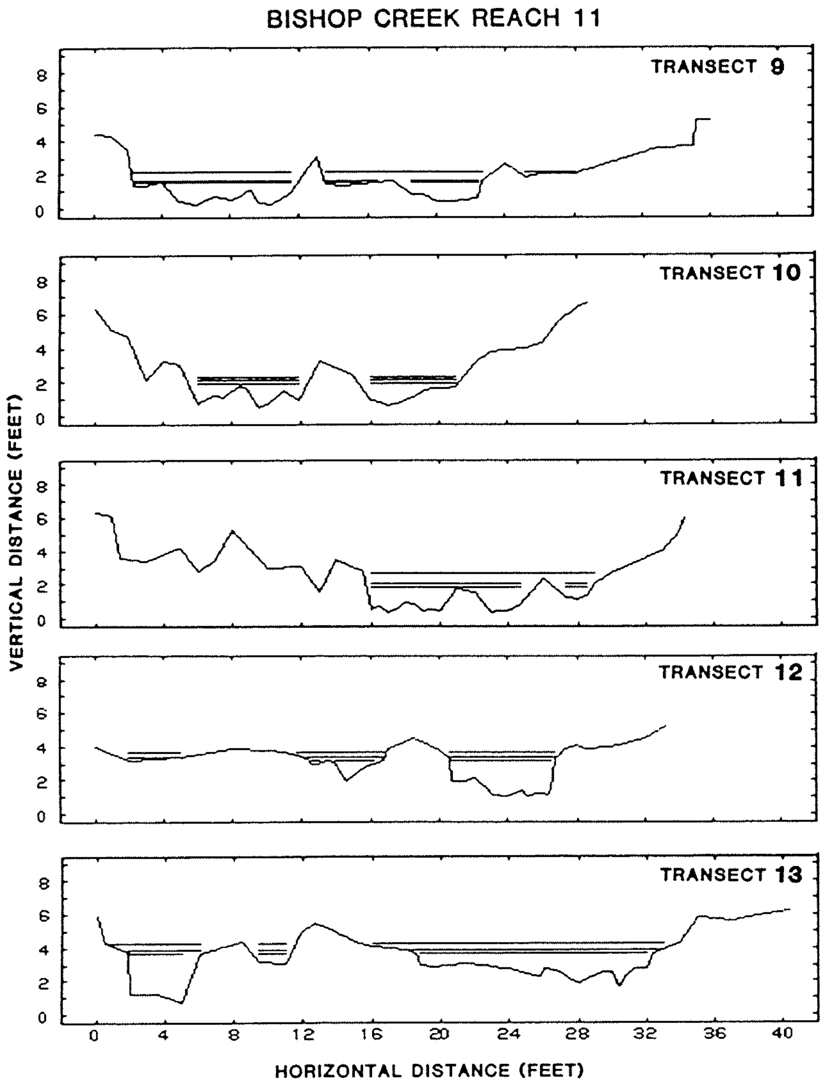
Cross-sectional profiles and water surface elevations at the measured flows.



Cross-sectional profiles and water surface elevations at the measured flows.



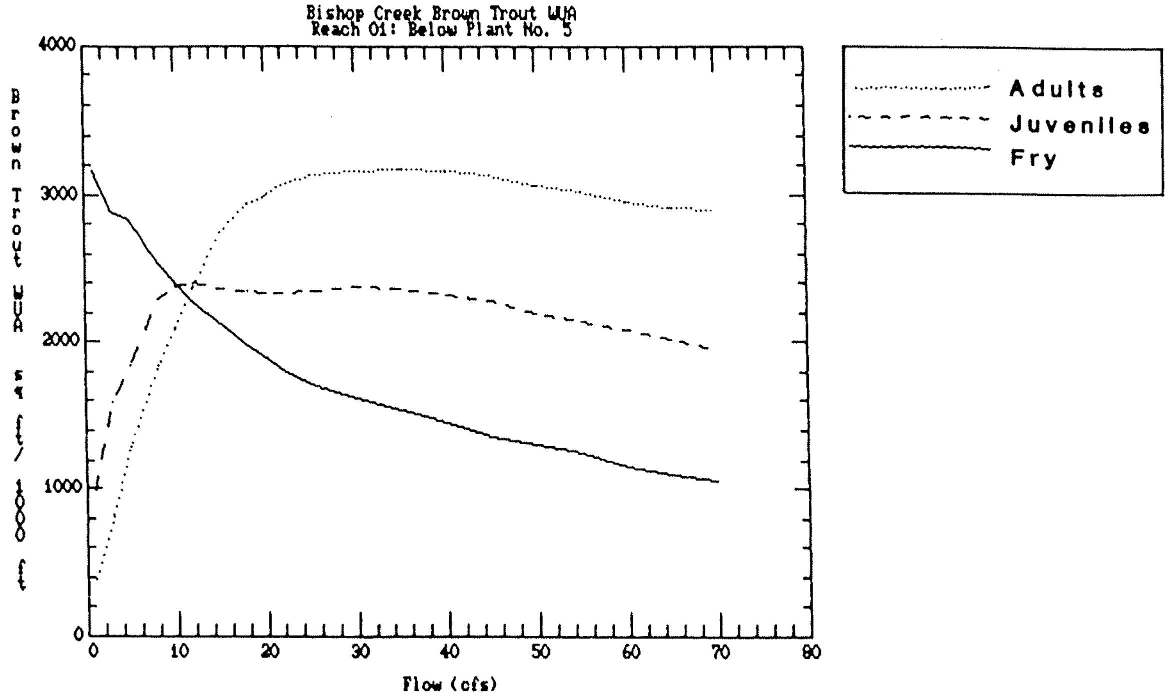
Cross-sectional profiles and water surface elevations at the measured flows.

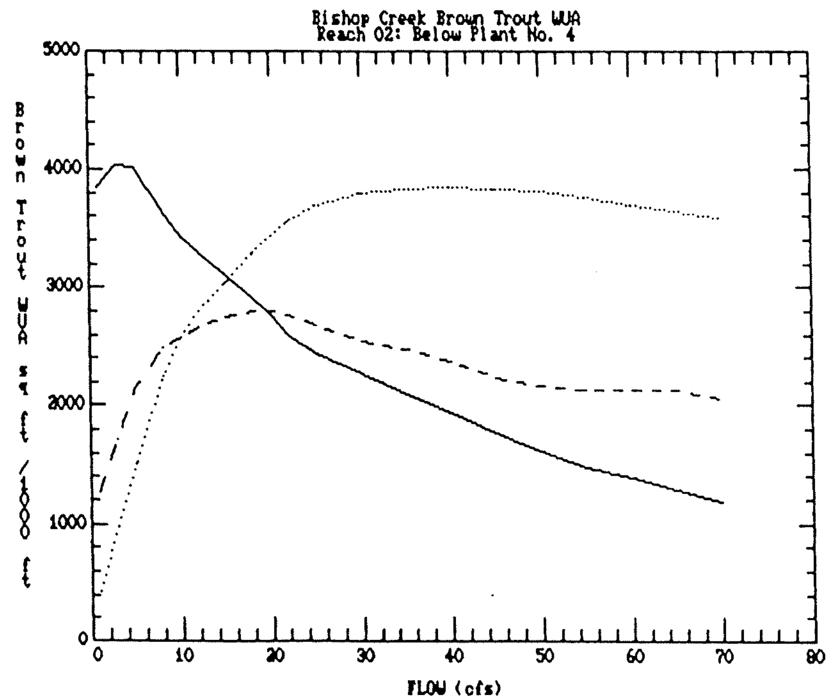


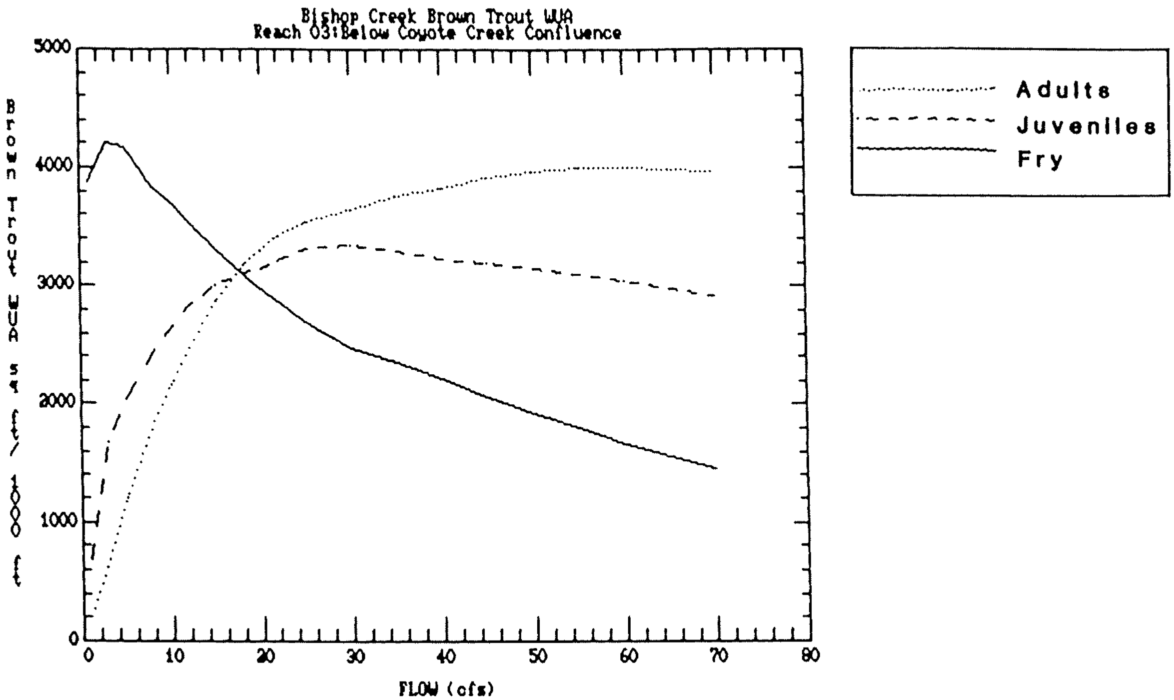
Cross-sectional profiles and water surface elevations at the measured flows.

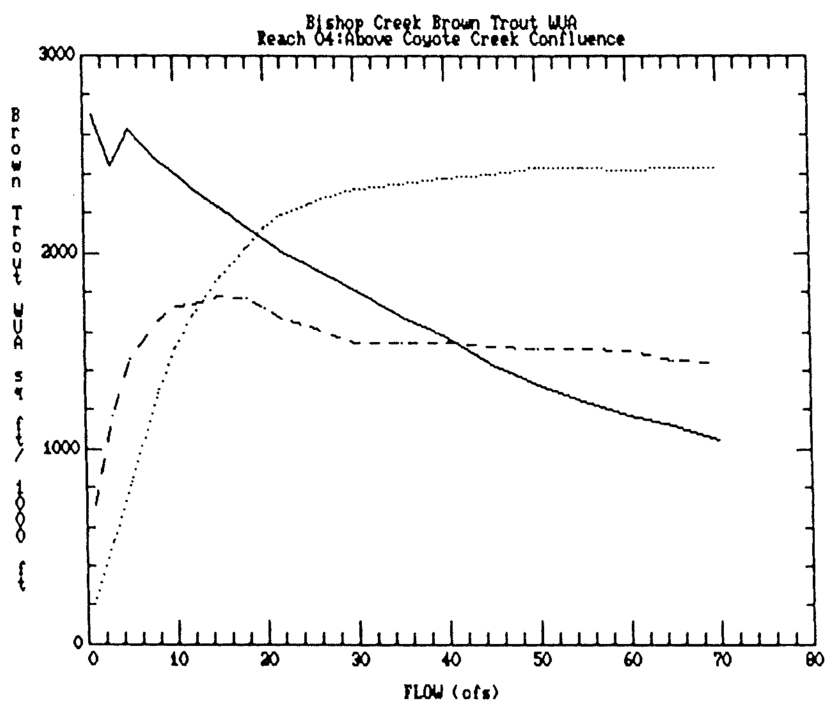
ATTACHMENT 4

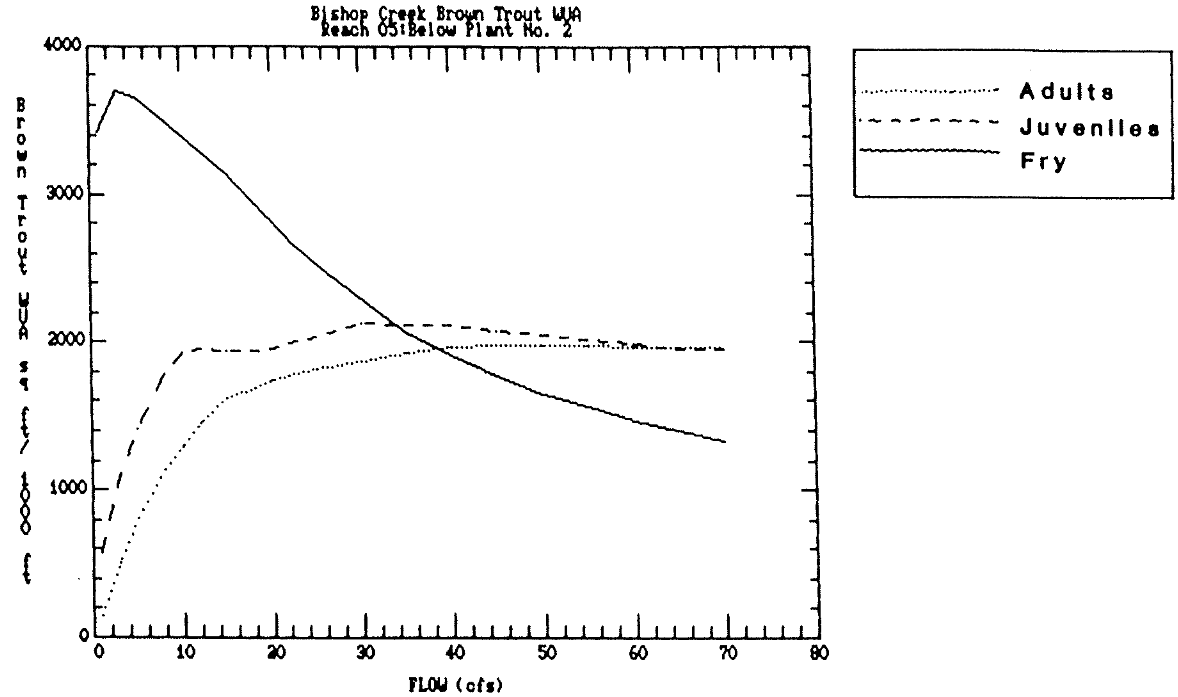
Plots of adult, fry, and juvenile brown and rainbow trout WUA for the eleven study reaches of Bishop Creek.

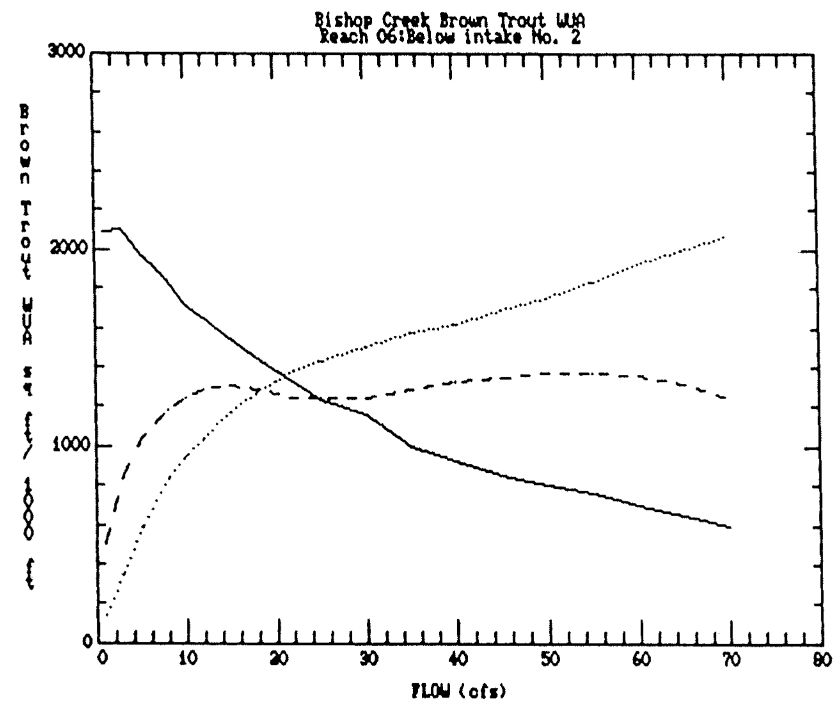

Bishop Creek Brown Trout WUA
Reach 01: Below Plant No. 5
Brown Trout WUA sq ft/ 1000 ft
Flow (cfs)
Adults
Juveniles
Fry

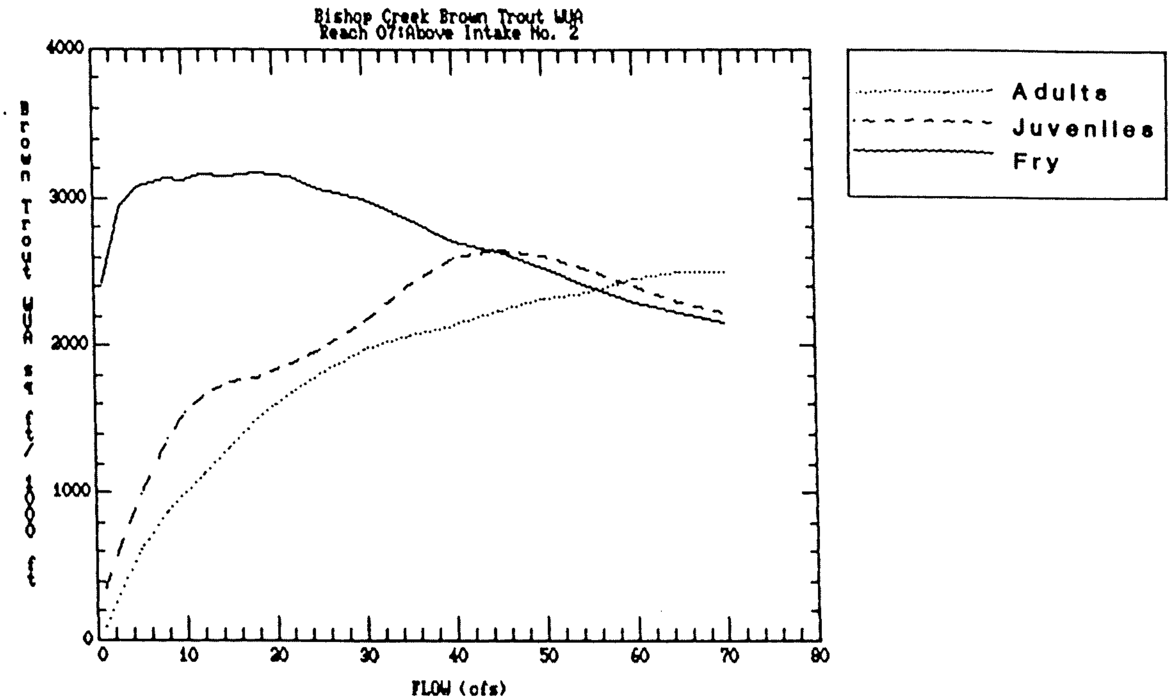

Bishop Creek Brown Trout WUA
Reach 02: Below Plant No. 4
Brown Trout WUA sq ft /1000 ft
FLOW (cfs)

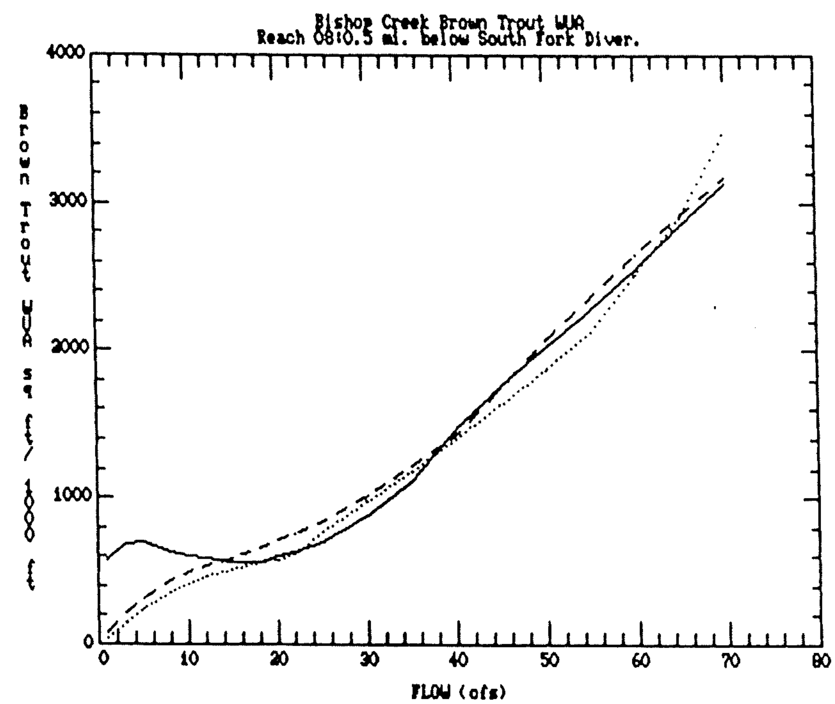

Bishop Creek Brown Trout WUA
Reach 03:Below Coyote Creek Confluence
Brown Trout WUA sq ft/ 1000 ft
FLOW (cfs)
Adults
Juveniles
Fry

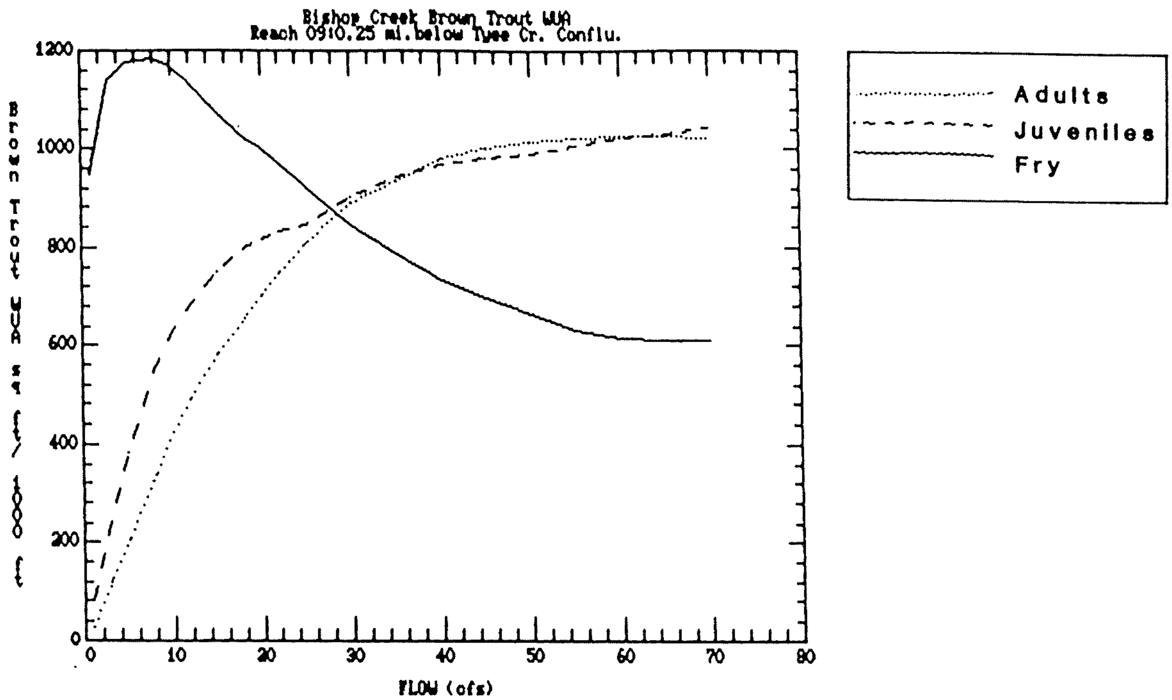

Bishop Creek Brown Trout WUA
Reach 04:Above Coyote Creek Confluence
Brown Trout WUA sq ft/ 1000 ft
FLOW (cfs)

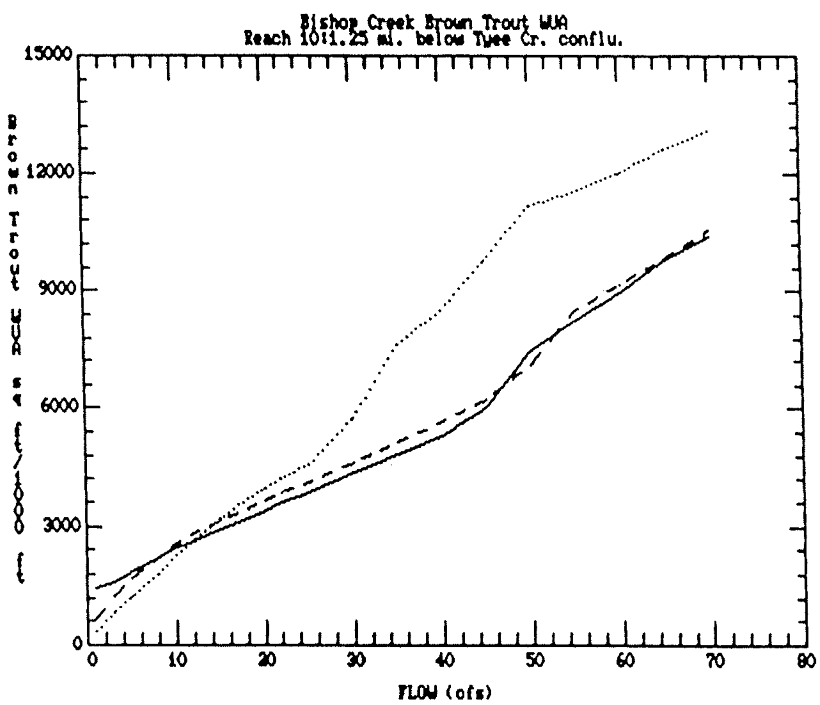

Bishop Creek Brown Trout WUA
Reach 05:Below Plant No. 2
Brown Trout WUA sq ft/ 1000 ft
4000
3000
2000
1000
0
0
10
20
30
40
50
60
70
80
FLOW (cfs)
Adults
Juveniles
Fry

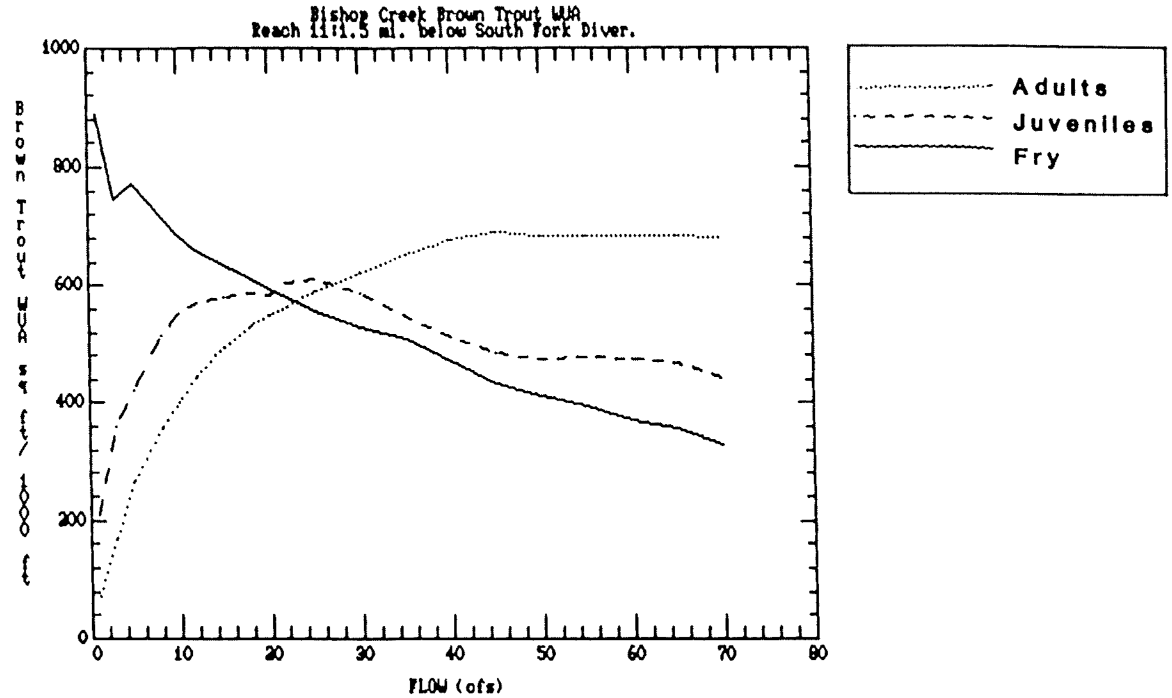

Bishop Creek Brown Trout WUA
Reach 06:Below intake No. 2
Brown Trout WUA sq ft/ 1000 ft
3000
2000
1000
0
0
10
20
30
40
50
60
70
80
FLOW (cfs)


Bishop Creek Brown Trout WUA
Reach 07:Above Intake No. 2
Brown Trout WUA sq ft/1000 ft
FLOW (cfs)
Adults
Juveniles
Fry
0
1000
2000
3000
4000
0
10
20
30
40
50
60
70
80


Bishop Creek Brown Trout WUA
Reach 08:0.5 mi. below South Fork Diver.
Brown Trout WUA sq ft/1000 ft
FLOW (cfs)
0
1000
2000
3000
4000
0
10
20
30
40
50
60
70
80

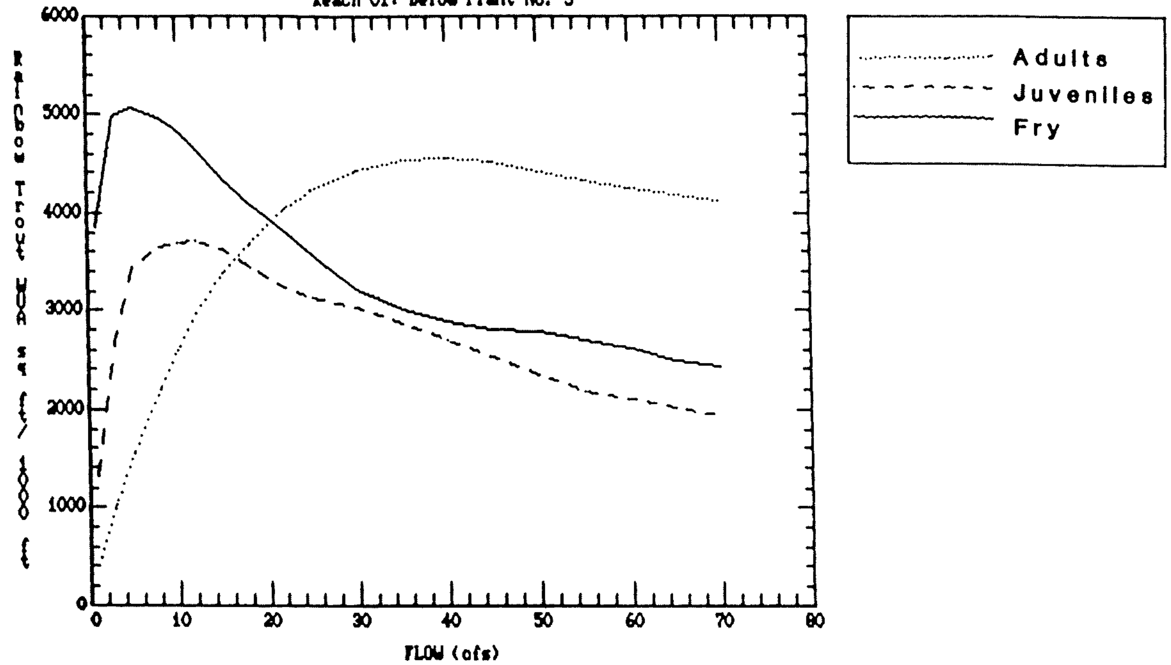

Bishop Creek Brown Trout WUA
Reach 09:0.25 mi. below Tyee Cr. Conflu.
Brown Trout WUA sq ft/ 1000 ft
FLOW (cfs)
0
200
400
600
800
1000
1200
0
10
20
30
40
50
60
70
80
Adults
Juveniles
Fry


Bishop Creek Brown Trout WUA
Reach 10:1.25 mi. below Tyee Cr. conflu.
Brown Trout WUA sq ft/1000 ft
FLOW (cfs)
0
3000
6000
9000
12000
15000
0
10
20
30
40
50
60
70
80

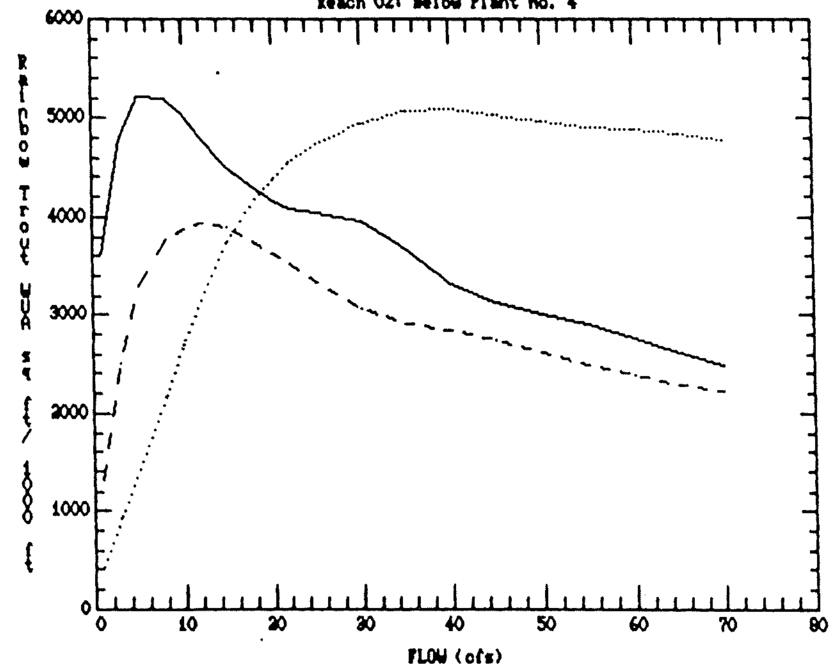


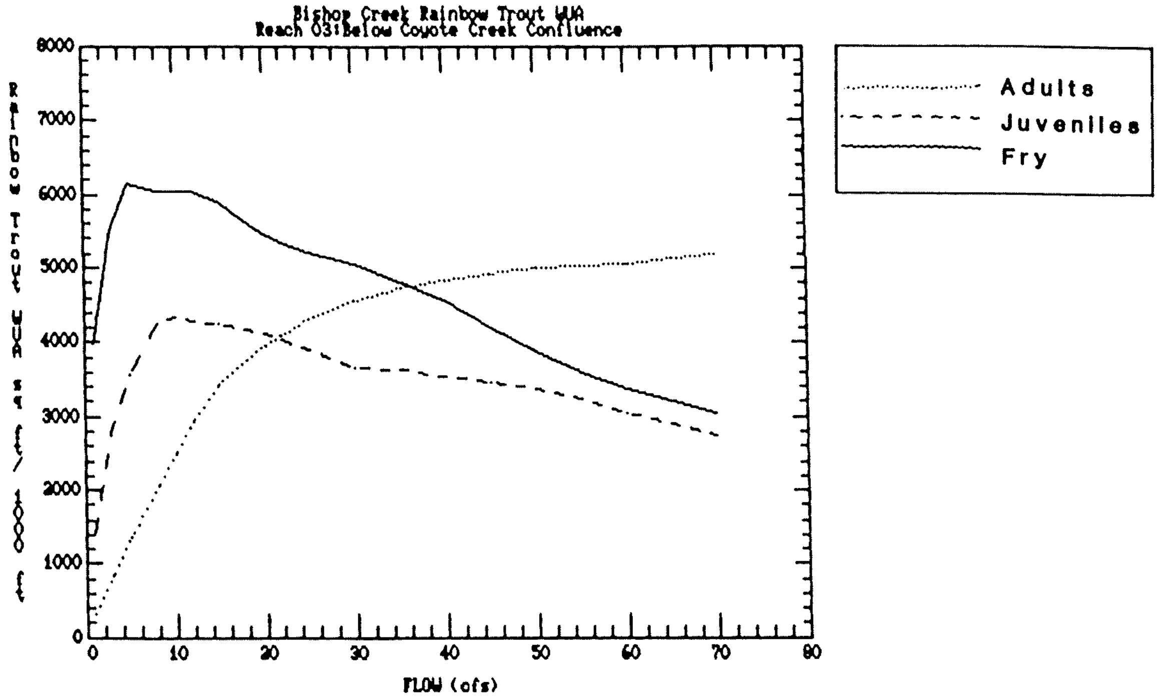
Bishop Creek Brown Trout WUA
Reach 11:1.5 mi. below South Fork Diver.
Brown Trout WUA sq ft/ 1000 ft
FLOW (cfs)
0
200
400
600
800
1000
0
10
20
30
40
50
60
70
80
Adults
Juveniles
Fry

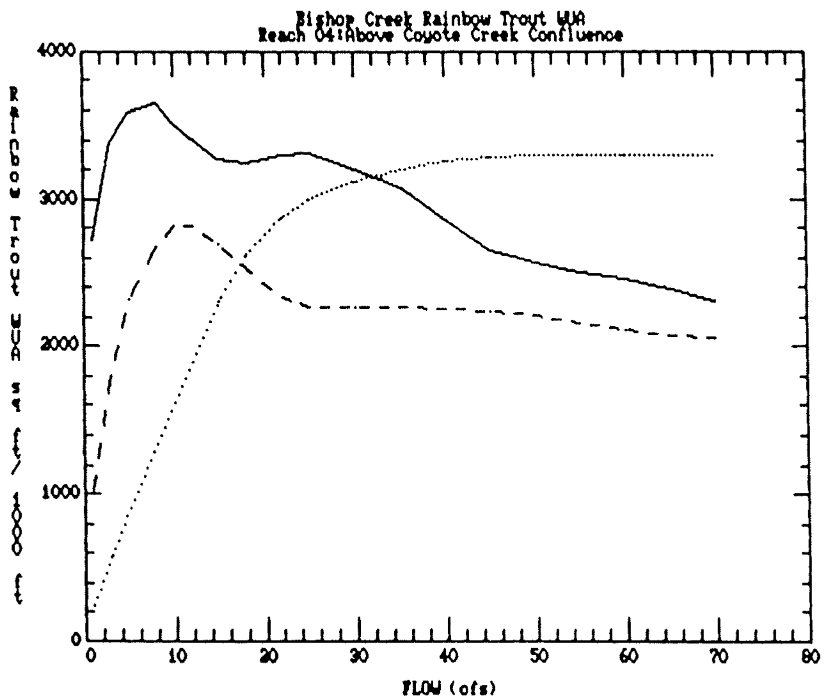
Bishop Creek Rainbow Trout WUA
Reach 01: Below Plant No. 5

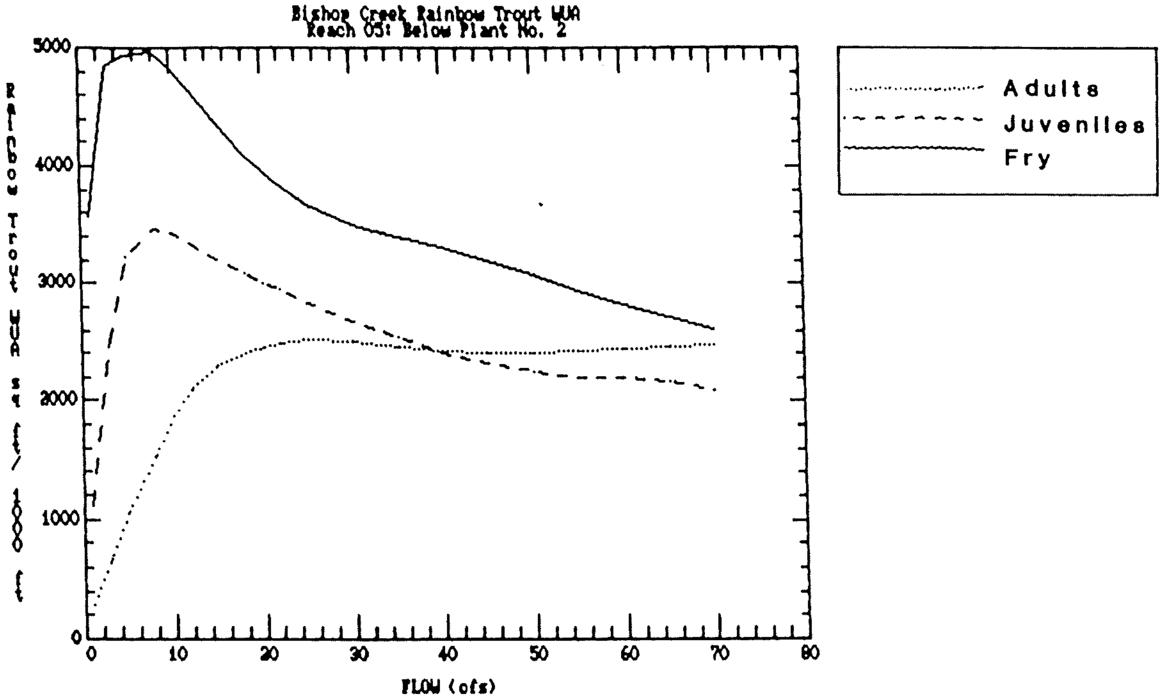


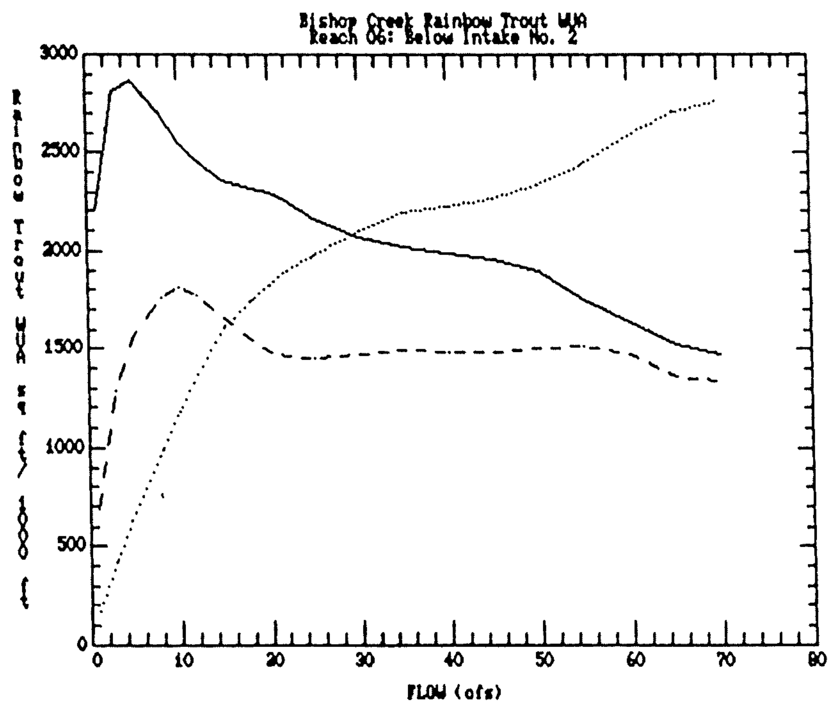
Bishop Creek Rainbow Trout WUA
Reach 02: Below Plant No. 4

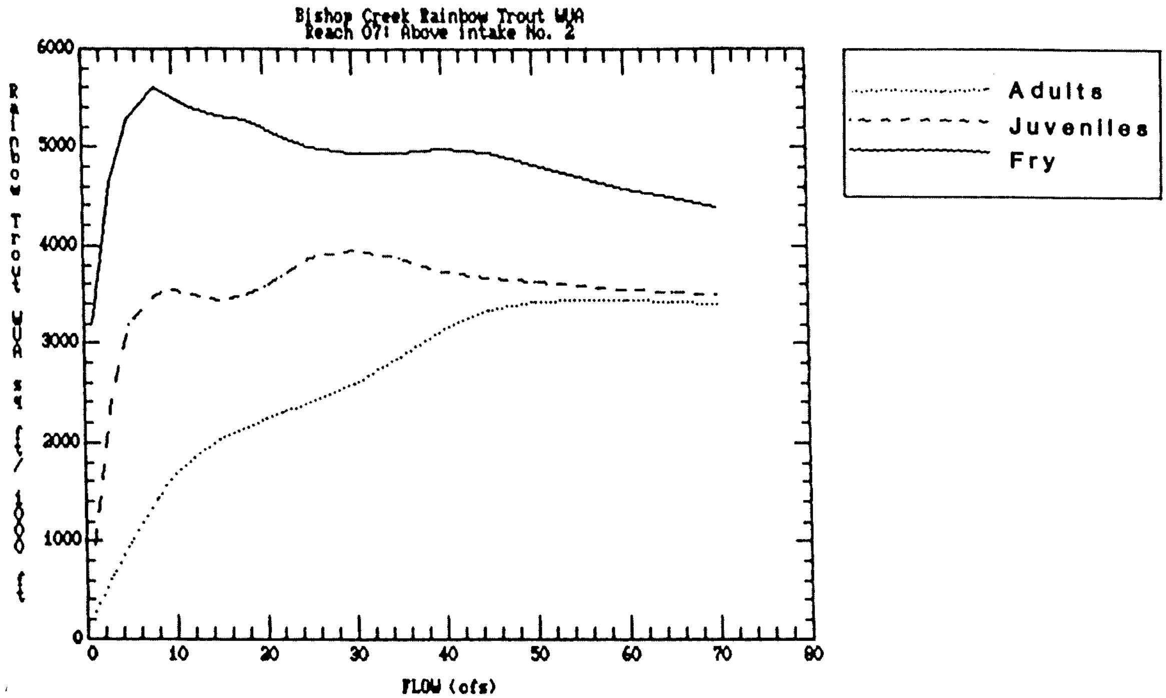


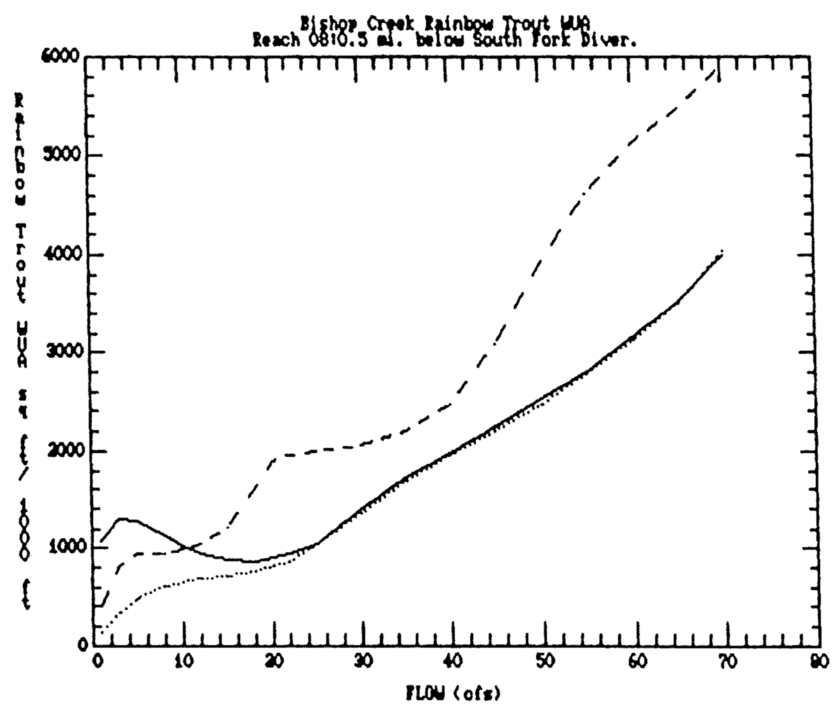

Bishop Creek Rainbow Trout WUA
Reach 03:Below Coyote Creek Confluence
Rainbow Trout WUA sq ft/1000 ft
FLOW (cfs)
Adults
Juveniles
Fry

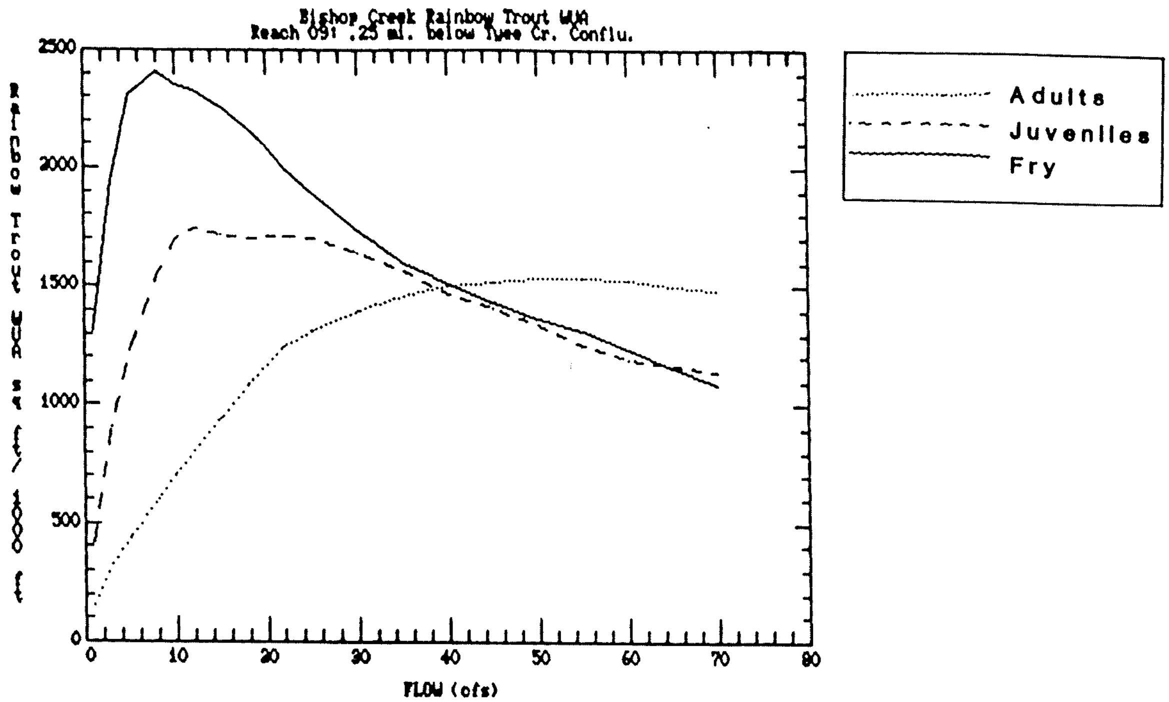

Bishop Creek Rainbow Trout WUA
Reach 04:Above Coyote Creek Confluence
Rainbow Trout WUA sq ft/1000 ft
FLOW (cfs)

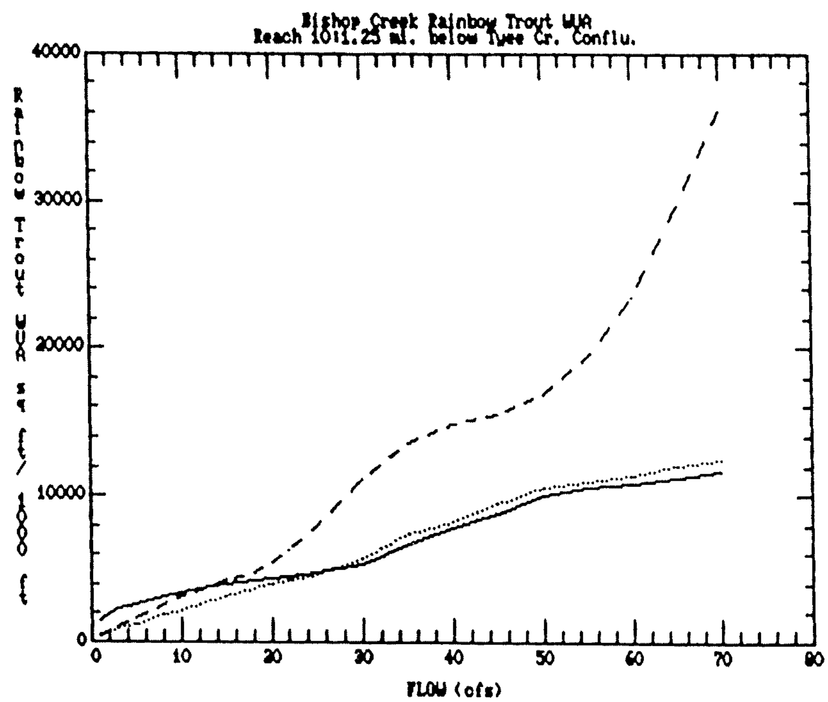

Bishop Creek Rainbow Trout WUA
Reach 05: Below Plant No. 2
Rainbow Trout WUA sq ft/ 1000 ft
FLOW (cfs)
Adults
Juveniles
Fry

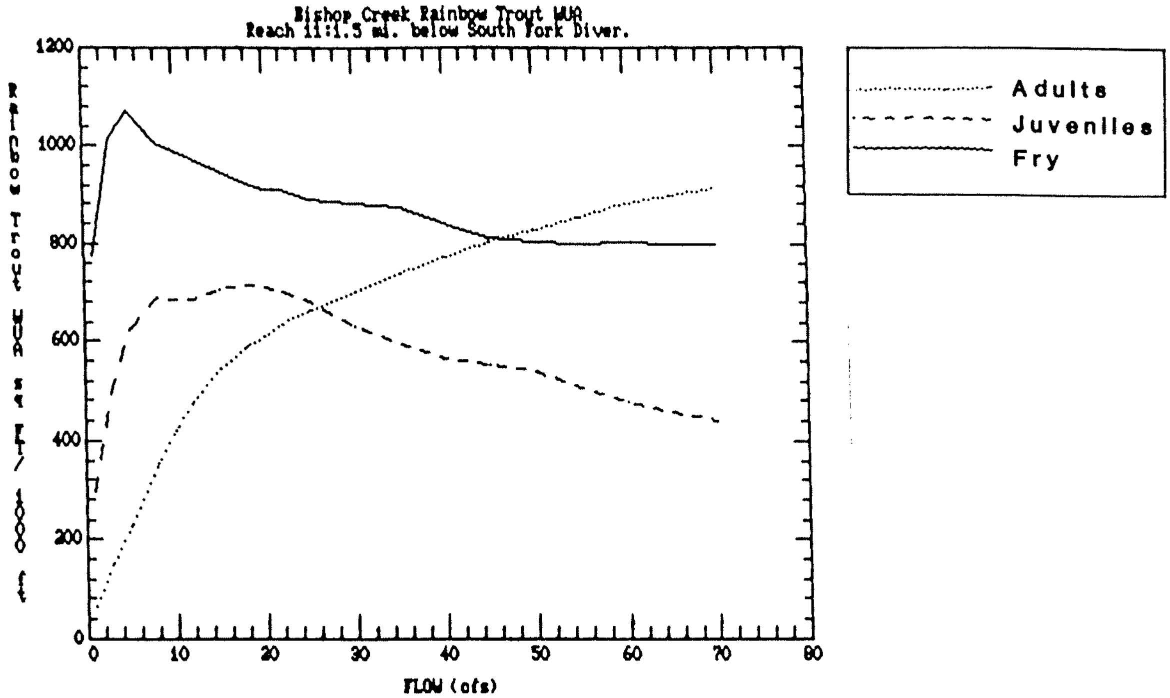

Bishop Creek Rainbow Trout WUA
Reach 06: Below Intake No. 2
Rainbow Trout WUA sq ft/ 1000 ft
FLOW (cfs)


Bishop Creek Rainbow Trout WUA
Reach 07: Above intake No. 2
Rainbow Trout WUA sq ft / 1000 ft
FLOW (cfs)
Adults
Juveniles
Fry


Bishop Creek Rainbow Trout WUA
Reach 08:0.5 mi. below South Fork Diver.
Rainbow Trout WUA sq ft / 1000 ft
FLOW (cfs)


Bishop Creek Rainbow Trout WUA
Reach 09: .25 mi. below Tyee Cr. Conflu.
Rainbow Trout WUA sq ft / 1000 ft
FLOW (cfs)
Adults
Juveniles
Fry


Bishop Creek Rainbow Trout WUA
Reach 10:1.25 mi. below Tyee Cr. Conflu.
Rainbow Trout WUA sq ft / 1000 ft
FLOW (cfs)


Bishop Creek Rainbow Trout WUA
Reach 11:1.5 mi. below South Fork Diver.
Rainbow Trout WUA sq ft/ 1000 ft
FLOW (cfs)
Adults
Juveniles
Fry
0
200
400
600
800
1000
1200
0
10
20
30
40
50
60
70
80

REFERENCES

Aceituno, M.E., G.E. Smith, G. Ging, and D.M. Ward. Unpublished. Appendix A, Habitat Preference Criteria for Eastern Sierra Nevada Streams: Family Salmonidae. 19 pages.

Anderson, R.O. and S.J. Gutreuter. 1983. Length, Weight, and Associated Strucural Indices. Chapter 15 (pages 283-300) in Nielsen, L.A. and D.L. Johnson, eds. Fisheries Techniques. American Fisheries Society, Bethesda, Maryland. 468 pages.

Bovee, K.D. 1978. Probability of Use Criteria for the Family Salmonidae. Instream Flow Information Paper 4. USDI Fish. Wildl. Serv. FWS/OBS-78/07. 80 pages.

Deinstadt, J.M., D.R. McEwan, D.M. Wong. 1985. Survey of fish populations in streams of the Owens River drainage: 1983-1984. California Department of Fish and Game Inland Fisheries Administrative Report No. 85-2. 102 pages.

Elliott, J.M. 1975. The growth rate of brown trout fed on maximum rations. J. Animal. Ecology 44:805-821.

Ellis, R.J. and J. Gowing. 1957. Relationship between food supply and condition of wild brown trout in a Michigan stream. Limn. Ocean 2:299-308.

Loar, J.M., M.J. Sale, G.F. Cada, D.K. Cox, R.M. Cushman, G.K. Eddlemon, J.L. Elmore, A.J. Gatz, P. Kanciruk, J.A. Solomon, and D.S. Vaughan. 1985. Application of habitat evaluation models to to Southern Appalachian trout streams. Oak Ridge National Laboratory, Environmental Sciences Division, Publication No. 2383 (ORALL/TM-9323), 310 pages.

Mesick, C.F. 1984. Emigratory Behavior of Arizona and brown trout as a means to regulate population numbers in response to environmental changes. Unpublished doctoral dissertation. The University of Arizona. 41 pp.

Morhardt, J.E., D.F. Hanson, and P.J. Coulston. 1983. Instream Flow: Increased accuracy through habitat mapping. pages 1294-1313 in Volume III, Waterpower '83: International Conference on Hydropower Proceedings.

Morhardt, J. Emil. In Press. Instream Flow Methodologies: Report of Research done under RP 2194-2. Electric Power Research Institute. Palo Alto, CA.

Zippin, C. 1958. The removal method of population estimation. J. Wildl. Mgmt. 22(1):82-90.