SULTAN RIVER PROJECT

FERC PROJECT NO. 2157

EVALUATION OF INSTREAM FLOWS FOR THE SULTAN RIVER FROM CULMBACK DAM TO THE DIVERSION DAM

PUBLIC UTILITY DISTRICT NO. 1

OF

SNOHOMISH COUNTY

WASHINGTON

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ENGINEERS AND CONSULTANTS

EICHER ASSOCIATES, INC.

ECOLOGICAL AND ENVIRONMENTAL

ANALYSIS AND PLANNING

OCTOBER 1980

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3110

October 31, 1980

Mr. W. G. Hulbert, Jr., Manager
Public Utility District No. 1
of Snohomish County
P. O. Box 1107
Everett, Washington 98206

Gentlemen:

Subject: Sultan River Instream Flow Study

We herewith submit our evaluation of instream flows as related to fish resources in the Sultan River from Culmback Dam to the City of Everett diversion dam.

This study was conducted using methods established by the Cooperative Instream Flow Service Group (IFG) of the U. S. Fish and Wildlife Service.

Field aspects of this study were coordinated through Michael Wert of Eicher Associates, Inc., with assistance from Federal, State, and private parties. The computer analysis was conducted by John Haapala of R. W. Beck and Associates; and the evaluation of results and the preparation of this report was a cooperative effort of Eicher and Beck staff.

Very truly yours,

R. W. BECK AND ASSOCIATES

A. Richard Griffith
Executive Engineer

EICHER ASSOCIATES, INC.

G. J. Eicher
President

MW/JH/ARG/rhl-A16

SULTAN RIVER PROJECT

EVALUATION OF INSTREAM FLOWS FOR THE SULTAN RIVER
FROM CULMBACK DAM TO THE DIVERSION DAM

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SUMMARY

The proposed Stage II hydroelectric development of the Sultan River Project will significantly alter the flow regime in approximately seven miles of the Sultan River between the existing Culmback Dam and City of Everett diversion dam. An evaluation of the impacts this flow reduction will have on fish resources in the Sultan River was conducted by the Public Utility District No. 1 of Snohomish County. The incremental method, established by the U. S. Fish and Wildlife Service's Instream Flow Service Group (IFG), was used to evaluate alterations in availability of habitat for life stages of selected species of fishes in response to incremental changes in river discharge. The study was a multi-disciplined cooperative effort involving members of various agencies, companies and interest groups. Field methods and computer analyses were conducted according to literature published by the IFG staff.

The IFG incremental method involves measurement of hydraulic parameters at a representative river section at three discharges. These data were used as input into a hydraulic model that simulates hydraulic parameters over a wide range of discharges. The resulting hydraulic simulation was then interfaced with a computer model which incorporates habitat criteria for life stages of selected fish species. The final result shows the weighted usable habitat area in square feet per 1,000 linear feet of stream for each fish life stage as a function of river discharge. Habitat criteria were those published by the U. S. Fish and Wildlife Service based on fish habitat studies conducted primarily in Pacific Northwest streams. Species examined were rainbow (*Salmo gairdneri*), cutthroat (*Salmo clarki*) and winter-run steelhead trout (*Salmo gairdneri*).

The primary objectives of the study were to:

1. Evaluate changes in usable habitat of various life stages of selected species as related to incremental changes in river discharge.

2. Compare historic river discharges to those expected under proposed power operation and assess the respective usable habitat available to selected species during relevant months.

3. Provide a foundation for negotiating compensation or mitigation measures in the Sultan River between Culmback Dam and the water return pipeline.

To accomplish the second objective, a comparative analysis of historic and proposed power project flows was conducted. To simplify discussion, monthly 1 in 2 year (median) flows were used to depict representative flow conditions under historic and proposed project flow regimes. These are flows which will be, or have been, equalled or exceeded 50% of the time.

Under the proposed power project operation, flows from Culmback Dam (minimum 20 cfs) will be significantly augmented during portions of the year by natural inflows between Culmback and the diversion dam. Thus, fish habitat near Culmback Dam will differ from that near the diversion dam. Habitat availability is therefore discussed for these two areas separately. Flows representing the vicinity of the diversion dam, for practical purposes, can be expected within two to three miles upstream of that point while flows representing the vicinity of Culmback Dam can be expected within approximately two miles of that dam. These two areas are subsequently referred to as simply near the diversion dam or near Culmback Dam.

The proposed flow regime will provide little trout spawning habitat near Culmback Dam and will reduce such habitat near the diversion dam to approximately 20% of that with pre-Culmback flows. Because steelhead spawning habitat is limited at proposed project flows, provision of upstream fish passage at the diversion dam is not recommended. Increasing discharges by even minimal increments above proposed project releases would cause lost power costs vastly in excess of fish production benefits.

Adult trout habitat would be reduced near Culmback Dam under the proposed flow regime. However, near the diversion dam local inflows increase the proposed project flows enough to provide trout habitat largely comparable to or greater than that with pre-Culmback flows.

Proposed project flows would generally provide more winter-run steelhead rearing habitat than historic flows. Rearing habitat for cutthroat and rainbow trout would be less or greater than that available at historic flows depending on location and season. It is apparent from the results of this study that the most feasible use of the reach between Culmback Dam and the City of Everett diversion dam would be rearing of winter-run steelhead, rainbow and cutthroat trout.

SECTION I

INTRODUCTION

1. AUTHORIZATION

This study was authorized and funded by the Public Utility District No. 1 of Snohomish County. It constitutes a part of the environmental impact assessment of the Sultan River Hydroelectric Project, FERC Project No. 2157.

2. BACKGROUND

Plans for hydroelectric development on the Sultan River call for diversion of water from Culmback Dam (RM 16.5) to a point approximately nine miles downstream as shown in Figure 1. Water diversion is of particular concern to water resource and fish and wildlife managers. This study was designed to address the impacts of flow reduction in the upper Sultan River (downstream of Culmback Dam) on life stages of selected species of fishes.

Impact evaluation requires comparison of historic flows with those anticipated under power operation. The Sultan River annual median flow at Culmback Dam is 740 cfs. Under proposed power operation a minimum of 20 cfs will be released to the diverted river channel via the dam outlet works (RM 16.5). This flow will be augmented by natural inflows or increased to assure flows in the immediate vicinity of the diversion dam (RM 9.7) of at least 30 cfs. If local inflows between Culmback Dam and the diversion dam are not sufficient to meet the 30 cfs requirement the Culmback Dam release would be increased.

Ideally the question to be answered is how will a change in the river's flow regime affect the productivity of fishes. Unfortunately, state of the art methods cannot address this question directly. Indirectly, however, the question can be approached by determining the change in habitat available to various life stages of fish with incremental changes in river discharge. This relationship between habitat availability and river discharge is the basis of the method used in this study and is referred to as a three point incremental methodology (Bovee and Milhous, 1978). The method has been developed by the U. S. Fish and Wildlife Service's Cooperative Instream Flow Service Group (IFG), Fort Collins, Colorado.

3. OBJECTIVES

The primary objectives of this study were to:

a. Evaluate changes in usable habitat available to various life stages of selected fish species as related to incremental changes in river discharge.

b. Compare historic river discharges to those expected under proposed power operation and assess the respective usable habitat available for life stages of resident rainbow, cutthroat and winter-run steelhead trout.

c. Provide a foundation for negotiating compensation or mitigation measures in the Sultan River between Culmback Dam and the water return pipeline.

4. PARTICIPANTS

This study was conducted by a multi-disciplined cooperative team comprised of representatives from various agencies, companies, and interest groups. Table I-1 lists alphabetically the participants' names, whom they represent and their role.

TABLE I-1

SULTAN RIVER PROJECT

Participants in the Sultan River Gorge Instream Flow Study
June - September, 1980

Name	Representing	Discipline	Role in Study
Bradbury, Alex	Washington Dept. of Game	Biologist	2
Eicher, George	Eicher Associates	Biologist	3
Engman, Gary	Washington Dept. of Game	Biologist	3
Farley, Paul	Parametrix	Water Quality Specialist	2
Griffith, Dick	R. W. Beck and Associates	Hydraulic Engineer	4,6,7
Haapala, John	R. W. Beck and Associates	Hydraulic Engineer	3,4,6,7
Mead, Richard	Parametrix	Surveyor	2
Riley, Kevin	Parametrix	Surveyor	2
Smith, Marvin	Pacific Helicopters	Pilot	3
Somers, David	Tulalip Tribes	Biologist	2
Tutmark, Greg	Washington Dept. of Game	Biologist	3
Wampler, Phil	U.S. Fish & Wild. Service	Biologist	8
Weller, Chris	R. W. Beck and Associates	Biologist	3,5,6,7
Wert, Michael	Eicher Associates	Biologist	1,2,5,6,7,8

Key to Study Roles

1. Project Coordinator
2. Field Work (data collection)
3. Field Support
4. Data Analysis
5. Data Analysis Support
6. Evaluation of Results
7. Report Write Up
8. Study Site Selection

SECTION II

METHODOLOGY

1. OVERVIEW OF THE INCREMENTAL METHODOLOGY

The IFG incremental methodology is designed to quantify potential habitat available for each life history stage of a fish species as a function of stream discharge (Bovee and Milhous, 1978). The major components of this method are: (1) field measurement of stream channel characteristics using a multiple transect approach; (2) hydraulic simulation to determine the spatial distribution of combinations of depths and velocities with respect to substrate under alternative flow regimes; (3) application of habitat suitability criteria to determine weighting factors; and (4) calculation of weighted usable area (gross habitat index) for the simulated streamflows based on physical characteristics of the stream (Trihey, 1980).

2. STUDY SITE SELECTION

Documentation of streamflow-habitat relationships for an entire stream is often impractical due to time and financial constraints. For this reason it is necessary to select study sites which characterize the entire stream. This can be accomplished through either one of two approaches with the incremental methodology; (1) critical reach concept, and (2) representative reach concept.

The critical reach concept requires prior knowledge of the dynamics of the fish population in the stream. Due to the inaccessible nature of the Sultan River gorge, previous biological information is limited. For this reason the representative reach concept was used. This concept is appropriate when the limiting life stage of a fish population is not known with any certainty. It does not assume a single type of habitat is controlling the population but that the importance of a particular area varies with time as well as discharge (Bovee and Milhous, 1978). The major assumption is that the stream segment from which the study reach is selected is fairly homogeneous.

In order to determine major stream habitat types (pools, riffles, runs) in the section of river under consideration, a preliminary helicopter survey was conducted by the Washington Department of Game and Eicher Associates. Final site selection was determined by an additional helicopter survey of the river. Due to limitations of upstream and downstream access a single site was required that included representative proportions of overall stream habitat types.

3. DATA COLLECTION

Data were collected using the methodology described by Bovee and Milhous, 1978. The method involves: 1) Determining transects which characterize the reach; 2) Surveying the location and elevation of transect headstakes located at the end of each transect; 3) Measuring substrate, depth and velocity at vertical stations along each transect; 4) Measuring water surface elevation at each transect; and 5) Measuring discharge at one of the transects, usually the one with the most continuous, homogeneous bottom contour.

Transects were selected through the joint effort of a hydraulic engineer and fish biologists to accurately characterize hydraulic and fish habitat conditions. All surveying was done by professional land surveyors. Physical stream measurements were obtained using equipment and methods described in Bovee and Milhous, 1978. The current meter used was a Gurley model 622.

Due to deep pools and swift currents, a drift boat was used at some transects. The stern of the boat was guided along the downstream side of the particular transect using a 1/4-inch cable attached near the headstake at each end of the transect. Transects were marked by a braided nylon rope which was marked with alligator clips at predetermined vertical distances from the left bank headstake. The "verticals" varied for each transect depending on changes in depth, degree of bottom slope, substrate and velocity.

The incremental method provides predictive weighted usable habitat values down to 40% below the lowest flow actually measured. Below the 40% range results vary with respect to the quality of data collected. The proposed release from Culmback Dam is 20 cfs. This flow applies only to the vicinity of Culmback Dam and does not include natural inflows between it and the diversion dam whose 40-year mean is 60 cfs. During August (driest month) the mean inflow is 10 cfs. For this reason, field measurements were conducted at flows providing an allowable extrapolation of weighted usable habitat down to 30 cfs, the combined release and mean dry-month inflow quantity. The lowest of the three flows measured in this study was 75 cfs.

The other flows used in the study were 178 cfs and 352 cfs. The values of these two flows were determined by approximately doubling the preceding lower flow measured. This procedure provided a relatively good spread of data points for the regression analysis.

4. DATA ANALYSIS

If the velocity distributions and water depths are measured for a flow, data can be used directly without analytical procedure to estimate hydraulic parameters. However, because of limited field resources and the wide range of discharges of interest, it was necessary to estimate hydraulic parameters for unmeasured discharges.

Physical Habitat Simulation System (PHABSIM) is a set of computer simulation programs developed by the Cooperative Instream Flow Service Group to simulate the physical stream habitat. PHABSIM computer models were used to extend the analysis to unmeasured discharges. The two main computer programs used were a hydraulic simulation model which calculates depth of flow and mean column velocity data to be used in the other main program, the habitat simulation model. The data analysis using the PHABSIM programs was performed on the R. W. Beck and Associates HP 3000 computer.

a. Hydraulic Simulation

The two alternative hydraulic models available in the PHABSIM system are IFG-2 and IFG-4. The IFG-2 (WSP) program is a computer adaption of the Water and Power Resources Service's Water Surface Profile Computation Method B. IFG-2 uses the Bernoulli and Manning equations to perform a step-backwater analysis.

The IFG-4 model employs an approach that differs from the energy balance method used in the IFG-2 model. IFG-4 uses a rating curve approach to correlate discharge with water surface elevation and with mean column velocity using a log-log linear fit. The log-log linear relationship is automatically calculated by the program from the measured data. This relationship is then used to calculate hydraulic parameters at other flows. IFG-4 processes one cross-section at a time independent of upstream or downstream hydraulic conditions.

The IFG-4 model was used for hydraulic simulation in this study because tests have shown it almost always produces better results than IFG-2 and it is the model recommended by the Instream Flow Service Group. The main advantages of IFG-4 are that it is not necessary to estimate Manning's "n" in the channel or vary the "n" coefficients with discharge. IFG-4 does not require transects to be set at hydraulic controls and is capable of handling reaches with rapidly varied flow.

b. Habitat Simulation

The PHABSIM program used to simulate the instream microhabitat is called HABTAT. HABTAT partitions the stream into a series of rectangular cells, the length and width of which are determined by the reach length and the cross-sectional stationing, as entered in the hydraulic simulation. Each cell is evaluated for its habitat suitability for various life stages and species, based on:

(1) Fixed characteristics of the cell, such as substrate,
(2) variable characteristics of the cell, such as depth and velocity, and
(3) probability of use criteria for each species and life stage.

c. Calculation of Weighted Usable Area

The quality of fish habitat is a deterministic function of streamflow. A composite suitability value can be determined for each fish species and life stage for a combination of hydraulic and physical conditions encountered in the stream reach. The conditions to be measured are depth and velocity of flow, channel geometry and substrate. For a given increment of each parameter, a weighting function was determined from published suitability of use curves (Bovee, 1978). Composite suitability values were then calculated for each cell of each cross-section.

The mean weighted usable area (WUA) determined from this calculation is defined as the total surface area of the stream reach having a certain combination of hydraulic conditions multiplied by the composite suitability value for that combination. The weighted usable area at a given discharge is the summation of the calculated values for every cell of each cross-section. The shape of the weighted usable area versus discharge curve is a function of the channel form and the distribution of hydraulic conditions throughout the study reach.

5. TEMPERATURE

Methods and objectives address only physical aspects such as flows, substrates and depths. Not considered are other influences on spawning and rearing such as temperature, chemical characteristics and food production which could have decisive effects. It has been forecast that water issuing from Culmback Dam will be quite cold during the growth season. This will inhibit growth of fish directly as well as food production. The effect will diminish in summer with downstream progression to the diversion dam.

SECTION III

RESULTS

1. SELECTION OF REPRESENTATIVE STUDY SITE

Preliminary stream habitat surveys determined the composition of this segment of river to consist of approximately 60% run-riffle habitat and 40% pool habitat. The habitat for the segment of the Sultan River under consideration is summarized in Figure 2. The selected study site was judged to contain these habitat types in the approximate proportions existing for the entire river segment. Figure 3 shows the transect locations at the study site in relation to stream habitat types.

2. HYDRAULICS

Results of the hydraulic calculations showed a close agreement between measured and simulated water surface elevations and flow velocities. Field measurements were made for three separate discharges and compared to simulated results for the same discharges at each cross-section. The calculated water surface elevations agreed with recorded data to within 0.02 feet which is the desired accuracy. Most of the simulated cell velocities agreed with measured data to within 0.2 feet per second, well within desired limits.

The close agreement between measured and simulated values gives confidence when extending the analysis to estimate hydraulic parameters at discharges not measured.

The computer output from the IFG-4 hydraulic simulation program contained in Appendix A can be categorized as either measured or simulated values. The field measured data, including the X-Y coordinates, substrate values and segment velocities are shown on pages headed "calibration details for cross-section". Manning "n" values were used only with one or zero recorded velocities in a segment and were obtained by calibration from the IFG-2 program. The simulated water depths and velocities are shown on pages headed "computational details for cross-section". Simulated velocities can be compared to recorded velocities of the corresponding discharge to determine the goodness of fit of the calibration.

3. HABITAT SUITABILITY

Habitat suitability was studied for four life stages and three species of fish. For each species and life stage, the weighted usable area was calculated for discharges ranging from 20 to 1,500 cfs. Shown are the weighted usable area for fry, juvenile and adult life stages of cutthroat, rainbow and winter-run steelhead trout. Curves are plotted on a log-log scale and weighted usable area is presented as square feet per thousand feet of stream length. The study area was approximately 700 feet long. A figure showing weighted usable areas calculated for spawning of all three species is also presented. Spawning curves have been grouped together because the calculated weighted usable areas for this life stage are significantly less than for others. Calculated weighted usable areas of less than 100 square feet per thousand feet were considered insignificant and are not shown. Appendix B contains the complete computer listing of available habitat in square feet per thousand feet of stream and as a percentage of gross stream surface area.

The IFG methodology does not quantify stream productivity or maximum sustainable fish populations. The weighted usable areas are an indication of relative habitat suitability at various discharges.

a. Winter-Run Steelhead Trout

As shown in Fig. 4, the weighted usable area available to winter-run steelhead trout fry and juveniles at 20 cfs is greater than that experienced at the average annual flow of 740 cfs. Habitat for adults, however, is greatly reduced at 20 cfs and is maximum at approximately 250 cfs. Adult habitat at 740 cfs is 32% of that available at 250 cfs. Adult habitat at 100 cfs is comparable to that available at 740 cfs.

b. Rainbow Trout

As shown in Fig. 5, the weighted usable area available to rainbow trout fry and juveniles at 20 cfs compared to that available at 740 cfs is 65% and 53% respectively. Approximately 100% of fry and juvenile habitat available at 740 cfs is available at 50 cfs. At 20 cfs adult habitat availability is reduced by approximately 50% from that at 740 cfs. Adult habitat at 45 cfs is comparable to that present at 740 cfs. The diminished availability of juvenile and fry habitat at flows between 100 and 400 cfs is likely due to increased velocity and depth at these intermediate flows. Flows exceeding 400 cfs rise above the bank and form low velocity shallows in many areas. Shallows formation was observed at flows exceeding 400 cfs at the study site.

c. Cutthroat Trout

As shown in Fig. 6, the maximum weighted usable area available to cutthroat trout fry occurs at 100 cfs. Fry habitat available at 20 cfs is comparable to that occurring at approximately 180 cfs and greater than that occurring at 740 cfs. Maximum juvenile habitat occurs at 100 cfs. Juvenile habitat available at 20 cfs is comparable to that occurring at 300 cfs and slightly greater than that occurring at 740 cfs. Maximum adult habitat occurs at 150 cfs. Adult habitat at 20 cfs is approximately 50% of that occurring at 740 cfs.

d. Spawning Habitat

As shown in Fig. 7, the maximum weighted usable spawning areas for winter-run steelhead, rainbow and cutthroat trout occur at 700, 500 and 500 cfs, respectively. Spawning habitat for all three species is nonexistent or slight at 20 cfs. It should be noted that the range of weighted usable spawning area in Fig. 7 is less than that presented for other life stages of all fishes by one order of magnitude.

SECTION IV

DISCUSSION OF RESULTS

1. PRE-CULMBACK AND PROJECT FLOW REGIME

The proposed project minimum flow constraints are presented in Volume I, Exhibit H of the Sultan River Project, Stage II, FERC License Application (Public Utility District No. 1 of Snohomish County, 1979). The minimum flow requirements throughout the year are 20 cfs immediately downstream from Culmback Dam and 30 cfs in the immediate vicinity of the diversion dam (upstream of fish water return line). These minimum flows, however, will be augmented by local inflow such that the minimum flows will be present only for limited periods of the year.

Figures 8 and 9 present the daily flow frequencies for pre-Culmback flows at Culmback dam site and proposed project flows at the diversion dam. These figures indicate the probability that a specified flow on a given day of the year will be equalled or exceeded. For example, the curves marked 90 indicate the flows that will be equalled or exceeded 90 percent of the time, or in 9 of 10 years. The flow frequencies were derived by rank ordering the flows for each day of the 40-year record and selecting the flows corresponding to the desired exceedance probabilities. A 10-day moving average was used to smooth the curves. Figures 8 and 9 are presented to show the range and variability of the daily flows. The flow frequencies are based on the daily data which was summarized into monthly averages and presented in Volume III of the FERC License Application Environmental Report Appendices (Public Utility District No. 1 of Snohomish County, 1979).

Table IV-1 presents the monthly 1 in 2 year flow frequency for three locations on the Sultan River. The flows are based on data presented in Volume III of the FERC License Application Environmental Report Appendices (Public Utility District No. 1 of Snohomish County, 1979). The values represent the average monthly discharges that will be equaled or exceeded an average of one in two years.

A set of flows was selected as most representative of the average monthly flow conditions for each location. The 1 in 2 year (median) monthly flows were considered more representative of average conditions than mean flows because of the special flow regime created downstream of Culmback Dam by the operation of the reservoir. The usual 20 cfs controlled releases are interrupted by infrequent but relatively very high flows when the reservoir is spilling. These spills significantly affect the mean flow but have no effect on the 1 in 2 year flows.

To remove the significant biasing effect of uncontrolled discharge and provide a common basis for comparison, the 1 in 2 year flows were selected as most representative of average flow conditions at all three locations.

To evaluate the effects of the power project flow regime on fish habitat availability, the historic (pre-Culmback) flow regime must be known. The curve representing the median monthly flow to Culmback Dam (total Spada basin inflow) is representative of historic flows between Culmback and the diversion dam. Inflow in this area is relatively insignificant as compared to the historic river discharge and varies on the average from an additional 10% during wet months to 5% during dry months. However, in relation to the power project flow regime they become more significant due to the reduced volume. Proposed median monthly releases from Culmback Dam vary only from 20 to 21 cfs. The median monthly flows at the diversion dam, however, exceed 70 cfs for October through June and exceed 30 cfs for July through September (Table IV-1).

Because of inflow between Culmback Dam and the diversion dam, habitat availability is discussed separately for the vicinities of Culmback Dam and the diversion dam under proposed power project operation. Flows representing the vicinity of the diversion dam, for practical purposes, can be expected within 2 to 3 miles upstream of the diversion dam while flows representing the vicinity of Culmback Dam can be expected within approximately two miles downstream of Culmback Dam. These two areas are subsequently referred to as near the diversion dam or near Culmback Dam.

2. HABITAT EVALUATION OF PRE-CULMBACK AND POWER PROJECT FLOW REGIMES

The incremental method provides a prediction of the weighted usable area for life stages of fishes over a range of flows. The study focuses only on those flows that represent the monthly 1 in 2 year historic flows, project flows and flows which provide maximum available habitat all for specific months relevant to individual life stages of fishes in consideration.

Tables IV-2, IV-3 and IV-4 summarize the relative habitat suitability and energy costs of instream flows for juvenile, adult and spawning life stages, respectively, of winter-run steelhead, rainbow and cutthroat trout. Common trends occurred between juveniles and fry of each species. For this reason, habitat availability will not be discussed in detail for both fry and juveniles. In general, flows which would provide maximum habitat availability for juveniles would also do so for fry.

a. Winter-Run Steelhead

Proposed project flows would provide greater steelhead fry habitat than historic flows. Based on Sultan River Studies by the Washington Department of Game and Snohomish County PUD (1980), steelhead fry emerge from spawning gravels between early June and mid-August. Although steelhead are currently absent above the diversion dam, it is likely that June through October are the months to consider when discussing relationships of steelhead rearing habitat with river discharge. The historic 1 in 2 year average monthly flows range from 150 to 840 cfs for these months. The 1 in 2 year average monthly flows under proposed power project conditions for this same time interval would range from 20 to 21 cfs immediately below Culmback Dam and 30 to 68 cfs at the diversion dam. The weighted usable area available to fry at 20 cfs (near Culmback Dam) is greater than that provided at flows exceeding 100 cfs. The weighted usable area related to the 30 to 68 cfs range near the diversion dam is the greatest amount available under the entire range of flows examined.

Proposed project flows generally would provide greater steelhead juvenile habitat than historic flows. While juveniles utilize the Sultan River downstream of the diversion dam throughout the year, June through September are most important for fish growth. Proposed power project 1 in 2 year monthly average flows range between 20 cfs just below Culmback Dam to 70 cfs at the diversion dam for June through September. The historic 1 in 2 year annual flow is 740 cfs. The weighted usable juvenile habitat area at 20 cfs is 147% of that occurring at 740 cfs. Maximum juvenile habitat is available at 80 cfs. During June the 1 in 2 year average flow would be 68 cfs at the diversion dam under proposed project conditions. This flow would provide nearly 2-1/2 times more habitat than the historic 1 in 2 year average for June (840 cfs). Similar comparisons of flows for July and September show more habitat available under proposed project conditions than under historic conditions. During August, the 1 in 2 year average flow at the diversion dam (30 cfs) under project conditions would provide 80% of the habitat normally available at historic August flows (150 cfs).

Proposed project flows near Culmback Dam would reduce suitable habitat for adult winter-run steelhead trout. Proposed project flows would provide suitable adult habitat near the diversion dam comparable to that occurring under historic flows. Adult winter-run steelhead utilize the Sultan River from December through May (WDG and Snohomish County PUD, 1980). The historic 1 in 2 year average monthly flows for this period range from 600 to 1,050 cfs. The 1 in 2 year monthly proposed project flows at the diversion dam during this time period would range from 77 to 120 cfs. Adult habitat available under this range of proposed project flows is comparable to that available under historic 1 in 2 year flows for December through May.

Proposed project flows near Culmback Dam would provide no suitable spawning habitat for winter-run steelhead trout. Availability of spawning habitat near the diversion dam at project flows is reduced compared to that under historic flows. Spawning generally occurs from April through May in the upper reaches of the Sultan River currently accessible to steelhead. The historic 1 in 2 year average monthly flows for this period range from 830 to 980 cfs. Maximum availability of spawning habitat occurs at approximately 700 cfs. The 1 in 2 year flow for April and May, under proposed project conditions, at the diversion dam is approximately 90 cfs. This flow would provide 15% and 20% of the available spawning habitat occurring in a relatively small area near the diversion dam at the historic April and May flows of 830 and 980 cfs, respectively.

b. Rainbow Trout

Proposed project flows near Culmback Dam would provide reduced juvenile rainbow trout rearing habitat as compared to historic flows. The 1 in 2 year average monthly project flows near the diversion dam would provide slightly greater or comparable juvenile rearing habitat for October through June compared to that of historic flows. Proposed project flows from July through September would provide less juvenile habitat than do historic flows. June through September are particularly important juvenile rearing months as they are generally considered the most biologically productive. During August, the month of lowest flow, the 1 in 2 year average flow near the diversion dam under proposed project conditions would be 30 cfs. This flow would provide 60% of the juvenile habitat available during the historic 1 in 2 year average August flow of 150 cfs. The 1 in 2 year average flow (project) for June near the diversion dam would provide close to maximum juvenile habitat available for the entire range of flows studied and is not equalled by any of the historic 1 in 2 year average monthly flows.

Proposed project flows near Culmback Dam would provide reduced adult rainbow trout rearing habitat compared to that available at historic flows. The 1 in 2 year average monthly project flows near the diversion dam would provide greater adult habitat than that provided at the historic 1 in 2 year flows from October through June. Historic flows from July through September provide greater adult habitat than that provided under proposed project flows during this same period. The 1 in 2 year historic flow for September (240 cfs) provides the maximum adult habitat available at any flows examined. The 1 in 2 year September flow under proposed project conditions at the diversion dam is 35 cfs. This flow would provide approximately 35% of the adult habitat available at 240 cfs.

Proposed flows near Culmback Dam provide very little suitable spawning habitat for rainbow trout. Spawning habitat near the diversion dam under proposed project flows is reduced compared to that available at historic flows. Rainbow trout generally spawn from April through June. The 1 in 2 year proposed project flows occurring near the diversion dam during this period would range from 68 to 93 cfs and would provide approximately 20% of the spawning habitat at the corresponding monthly historic flows.

c. Cutthroat Trout

Juvenile cutthroat trout utilize the Sultan River throughout the year. The 1 in 2 year proposed project flows from October through July would provide greater juvenile cutthroat trout rearing habitat than do historic flows. July through September are important growth months as flows decrease and the abundance of food generally increases. The 1 in 2 year historic monthly flows for August and September are 150 and 240 cfs, respectively. The 1 in 2 year proposed project flows near the diversion dam for August and September would provide approximately 55% and 90% of the juvenile habitat available at the respective historic monthly flows.

Adult cutthroat trout utilize the Sultan River throughout the year. Proposed project flows near Culmback Dam would reduce the availability of adult cutthroat trout habitat from that provided at historic flows. The 1 in 2 year monthly proposed project flows for October through June near the diversion dam would provide more adult habitat than that provided at corresponding historic flows. Proposed project flows near the diversion dam during July, August and September would provide adult habitat which is 65%, 35% and 40% of that occurring at corresponding monthly historic 1 in 2 year flows.

Proposed project flows near Culmback Dam would provide very little cutthroat trout spawning habitat during the April and May spawning months. Proposed project flows near the diversion dam would provide approximately 20% of the spawning habitat available at the historic April and May 1 in 2 year flows.

3. ANNUAL COST OF LOST ENERGY

Release of water from Culmback Dam in excess of the proposed 20 cfs will result in a loss of generating power at the power plant downstream. Each additional 10 cfs continuously released equals approximately $400,000 per year in lost energy. While additional releases may improve conditions for the life stages of some fishes near Culmback Dam, local inflows below the dam will augment the proposed 20 cfs release so that flows near the diversion dam will provide, in some instances, comparable or greater weighted usable habitat than that available at historic flows. Tables IV-2, IV-3 and IV-4 summarize the energy costs associated with additional flow releases at Culmback Dam.

TABLE IV-1

SULTAN RIVER PROJECT

Monthly 1 in 2 Year Flows

	Pre-Culmback Flow at Culmback Dam Site (cfs)	Proposed Project Flow at the Diversion Dam (cfs) (1)	Proposed Project Flow Released from Culmback Dam (cfs) (2)
January	770	110	20
February	680	92	20
March	600	77	20
April	830	92	20
May	980	93	20
June	840	68	20
July	380	38	20
August	150	30	21
September	240	35	21
October	670	81	20
November	910	110	20
December	1,050	120	20

(1) The proposed minimum flow requirement at the diversion dam is 30 cfs throughout the year.

(2) The proposed minimum flow release requirement from Culmback Dam is 20 cfs throughout the year.

TABLE IV-2
SULTAN RIVER PROJECT
RELATIVE HABITAT SUITABILITY AND
ENERGY COSTS OF INSTREAM FLOWS
FOR THE JUVENILE LIFE STAGE

Flow Condition	Winter Steelhead			Rainbow			Cutthroat			Annual Cost of Energy Lost (Dollars Per Year)
	WUA (2)	% of Maximum	% of WUA at Historic Flow	WUA (2)	% of Maximum	% of WUA at Historic Flow	WUA (2)	% of Maximum	% of WUA at Historic Flow	
Maximum(1)	16,000	100		3,700	100		11,000	100		
Historic (740 cfs)	6,600	41	100	3,200	86	100	5,100	45	100	Not Estimated
50	15,000	94	227	3,200	86	100	7,800	71	153	1,200,000
40	13,000	81	197	2,500	68	78	7,000	64	137	800,000
30	12,000	75	182	1,900	51	59	6,300	57	124	400,000
20	9,700	61	147	1,700	46	53	5,100	46	100	0

(1) - Maximum weighted usable area occurs at 80 cfs for winter steelhead, 80 cfs for rainbow and 100 cfs for cutthroat trout.
(2) - Weighted usable area in square feet per 1,000 feet of stream.

TABLE IV-3
RELATIVE HABITAT SUITABILITY AND
ENERGY COSTS OF INSTREAM FLOWS FOR THE
ADULT LIFE STAGE

	Winter Steelhead			Rainbow			Cutthroat			Annual Cost of Energy Lost	
Flow Condition	WUA (3)	% of Maximum	% of WUA at Historic Flow	WUA (3)	% of Maximum	% of WUA at Historic Flow	WUA (3)	% of Maximum	% of WUA at Historic Flow	Rainbow and Cutthroat (Dollars Per Year)	Winter-Run Steelhead (Dollars Per Year)
Maximum(1)	11,000	100		22,000	100		14,000	100			
Historic(2)	3,500	32	100	9,200	42	100	6,700	48	100	Not Estimated	
50	1,800	16	51	9,400	43	102	6,700	48	100	1,200,000	600,000
40	1,100	10	31	8,200	37	89	6,000	43	90	800,000	400,000
30	530	5	15	6,800	31	74	4,800	34	72	400,000	200,000
20	270	2	8	4,700	21	51	3,700	26	55	0	0

(1) - Maximum weighted usable area occurs at 250 cfs for winter steelhead, 200 cfs for rainbow and 150 cfs for cutthroat trout.
(2) - Pre-Culmback discharges averaged 890 cfs for the December through May adult winter-run steelhead use and 740 cfs for the annual use by rainbow and cutthroat trout.
(3) - Weighted usable area in square feet per 1,000 feet of stream.

TABLE IV-4
RELATIVE HABITAT SUITABILITY AND
ENERGY COSTS OF INSTREAM FLOWS FOR THE
SPAWNING LIFE STAGE

Flow Condition	Winter Steelhead WUA (1)	Winter Steelhead % of Maximum	Winter Steelhead % of WUA at Historic Flow	Rainbow WUA (1)	Rainbow % of Maximum	Rainbow % of WUA at Historic Flow	Cutthroat WUA (1)	Cutthroat % of Maximum	Cutthroat % of WUA at Historic Flow	Annual Cost of Energy Lost (4) (Dollars Per Year) Wtr. Steelhead	Annual Cost of Energy Lost (4) (Dollars Per Year) Rainbow	Annual Cost of Energy Lost (4) (Dollars Per Year) Cutthroat
Maximum(2)	1,900	100		1,200	100		860	100				
Ave. for Spawning Mos.(3)	1,600	84	100	690	58	100	510	59	100			
50	62	3	4	43	4	6	190	22	37	400,000	300,000	200,000
40	39	2	2	13	1	2	71	8	14	270,000	200,000	130,000
30	13	1	1	13	1	2	10	1	2	130,000	100,000	67,000
20	0	0	0	12	1	2	23	3	5	0	0	0

(1) - Weighted usable area in square feet per 1,000 feet of stream.
(2) - Maximum weighted usable area at 700 cfs for winter steelhead, 500 cfs for rainbow and 500 cfs for cutthroat.
(3) - Pre-Culmback discharges averaged 830 cfs for the February through May winter steelhead spawning season, 940 cfs for the April through June rainbow trout spawning season, and 960 cfs for the April through May cutthroat trout spawning season.
(4) - For flows applicable to months of spawning only.

SECTION V

CONCLUSIONS

1. The proposed 1 in 2 year monthly flows near Culmback Dam (20-21 cfs) will not provide meaningful amounts of suitable spawning habitat for winter-run steelhead, rainbow or cutthroat trout. Including local inflow, the proposed flows would provide winter-run steelhead spawning habitat in a relatively small area near the diversion dam at 15-20% of that available at pre-Culmback flows. Rainbow and cutthroat trout spawning habitat at project flows near the diversion dam would be reduced to 20% of that available at pre-Culmback flows.

2. The proposed 1 in 2 year monthly project flows would provide greater winter-run steelhead and cutthroat trout juvenile habitat from October through July than do pre-Culmback flows. Including local inflow, the proposed flows would provide juvenile steelhead habitat near the diversion dam at 80% and 110% of that available during the respective months of August and September under pre-Culmback flows. Near the diversion dam, the proposed project flows would provide less juvenile cutthroat trout habitat than was available at historic flows for these same months. Juvenile rainbow trout habitat near Culmback Dam would be reduced at proposed monthly project flows as compared to pre-Culmback flows. Proposed project flows near the diversion dam would provide more juvenile rainbow trout habitat than that available at pre-Culmback flows from October through June but less from July through September.

3. Proposed 1 in 2 year monthly project flows near Culmback Dam would provide less adult rainbow and cutthroat trout habitat than that available at pre-Culmback flows. Adult steelhead habitat would be greatly reduced in this area at proposed project flows. Near the diversion dam local inflows increase proposed project released flows to levels that would provide adult winter-run steelhead habitat comparable to that available at pre-Culmback flows. Proposed project flows near the diversion dam would provide more adult rainbow and cutthroat trout habitat than that available at pre-Culmback flows from October through June and less than that available at pre-Culmback flows from June through September.

4. Discharges above proposed project release of 20 cfs entail large costs of lost energy at even minimal increments. Each additional 10 cfs of flow reduces annual power revenues by approximately $400,000.

5. Due to the small amount of winter-run steelhead spawning habitat at proposed project flows, construction of an upstream fish passage facility at the diversion dam is not recommended.

6. It is apparent that the most feasible use of the reach between Culmback Dam and the City of Everett diversion dam would be the rearing of winter-run steelhead, rainbow and cutthroat trout. The addition of steelhead fry or advanced fry would constitute an enhancement measure over present conditions as these fish currently do not exist in this section of the Sultan River.

SECTION VI

REFERENCES

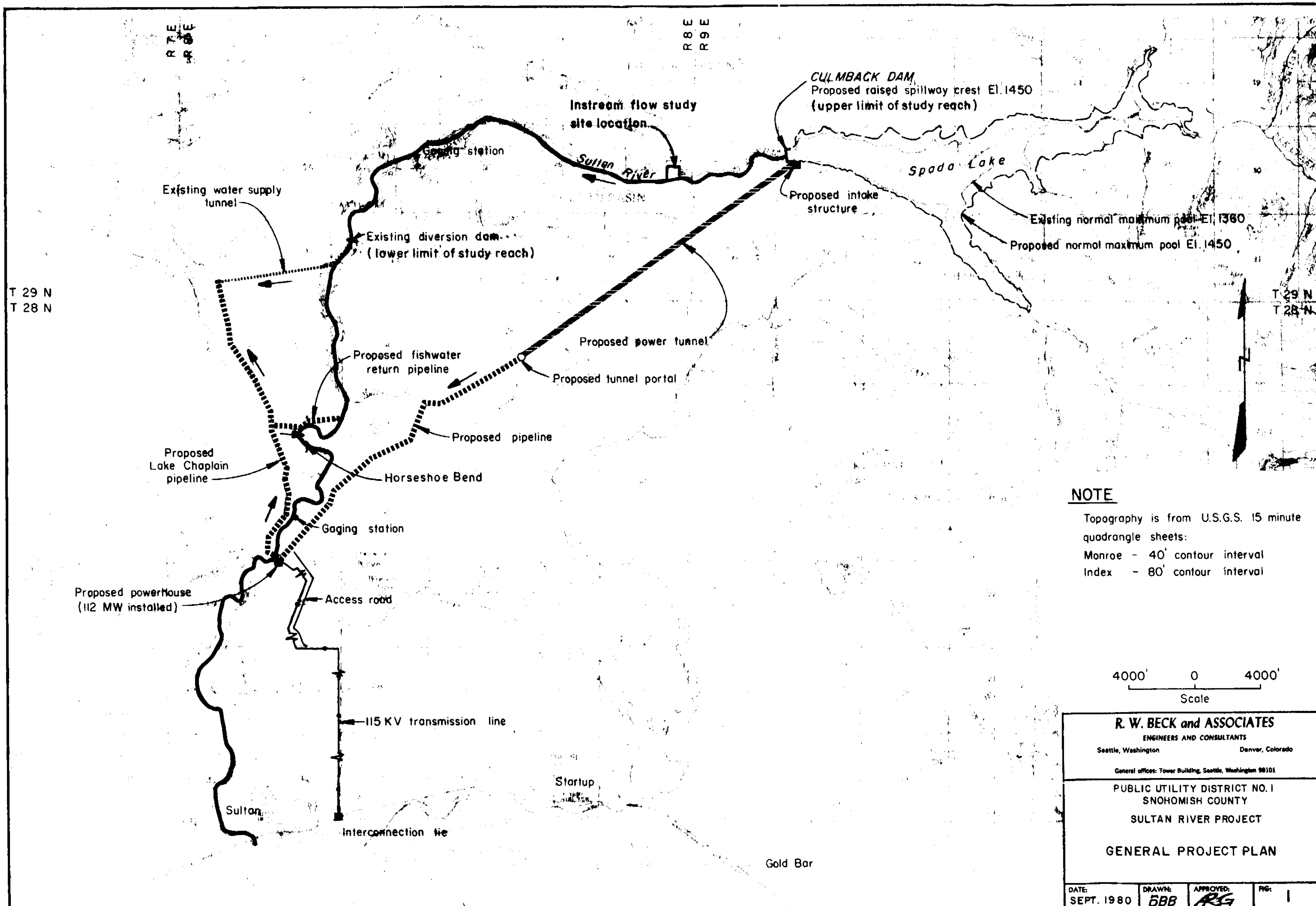
1. Bovee, K. D. Probability of Use Criteria for the Family Salmonidae; Instream Flow Information Paper No. 4, Cooperative Instream Flow Service Group, Fort Collins, Colorado; January 1978.

2. Bovee, K. D. and R. T. Milhous. Hydraulic Simulation of Instream Flow Studies: Theory and Techniques; Instream Flow Information Paper No. 5, Cooperative Instream Flow Service Group, Fort Collins, Colorado; June 1978.

3. Public Utility District No. 1 of Snohomish County and City of Everett. Sultan River Project - Stage II, Environmental Report Appendices; Volume I and III; FERC Project No. 2157, 1979.

4. Trihey, E. W. The IFG Incremental Methodology; Cooperative Instream Flow Service Group, Fort Collins, Colorado; 1980.

5. Washington Department of Game and Snohomish County Public Utility District No. 1. Annual Report: Sultan River Project - Stage II, Fish and Wildlife Resource Studies; 1980.



NOTE

Topography is from U.S.G.S. 15 minute quadrangle sheets:

Monroe - 40' contour interval

Index - 80' contour interval

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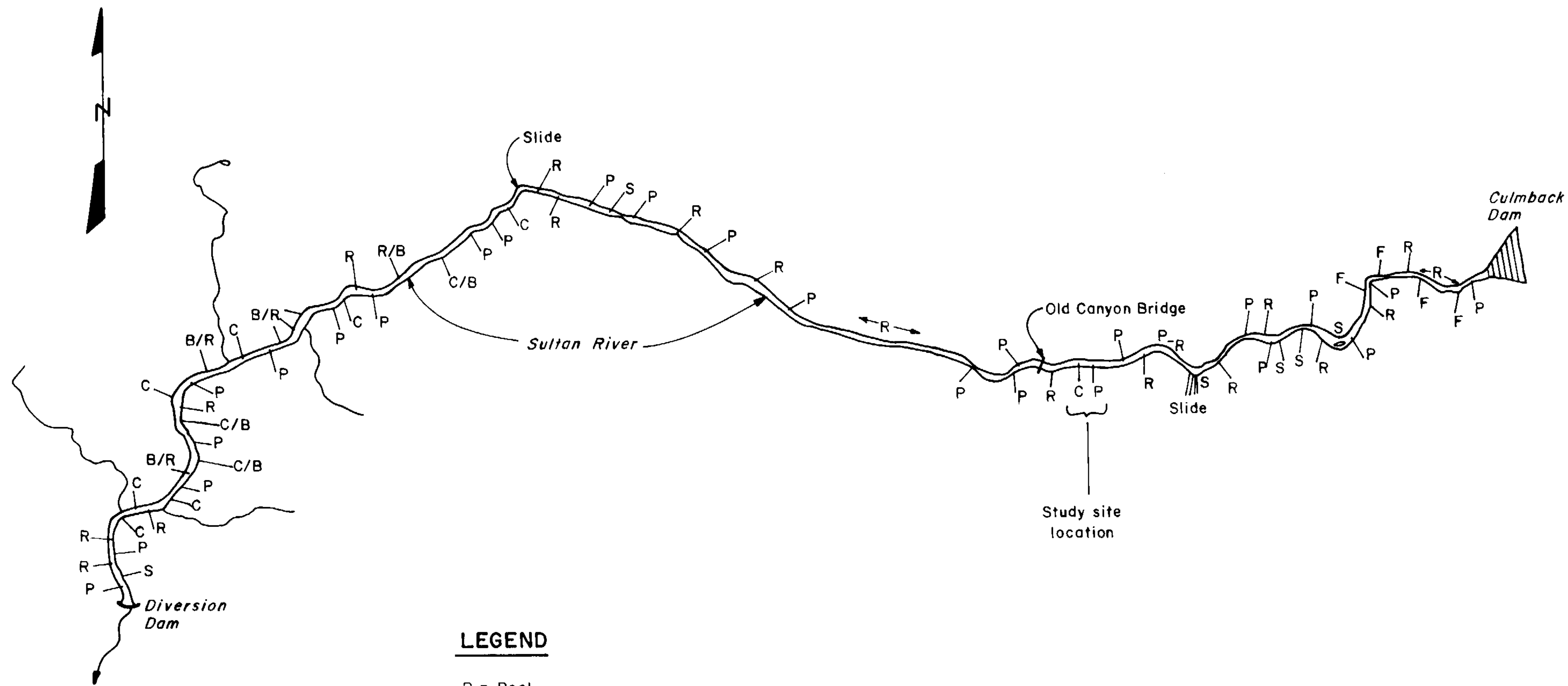
GENERAL PROJECT PLAN

DATE:	DRAWN:	APPROVED:	FIG:
SEPT. 1980	BBB	RSG	1



LEGEND

P = Pool
R = Riffle
C = Cobble run
S = Sandbar
B = Boulder
F = Falls

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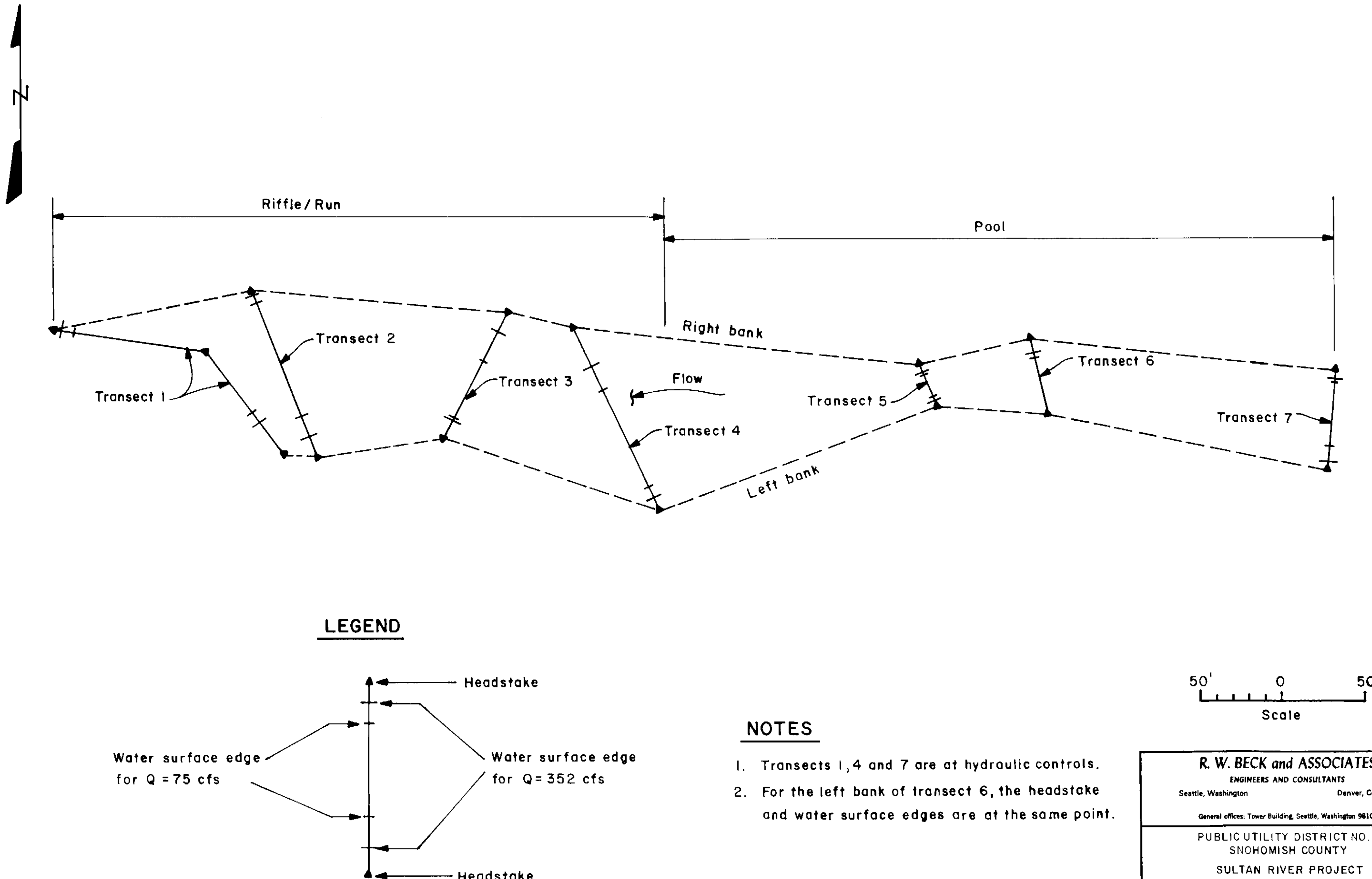
PUBLIC UTILITY DISTRICT NO. 1 SNOHOMISH COUNTY SULTAN RIVER PROJECT			
SULTAN RIVER HABITAT MAP			
DATE: SEPT. 1980	DRAWN: BBB	APPROVED: ARG	FIG: 2



NOTES

1. Transects 1, 4 and 7 are at hydraulic controls.
2. For the left bank of transect 6, the headstake and water surface edges are at the same point.

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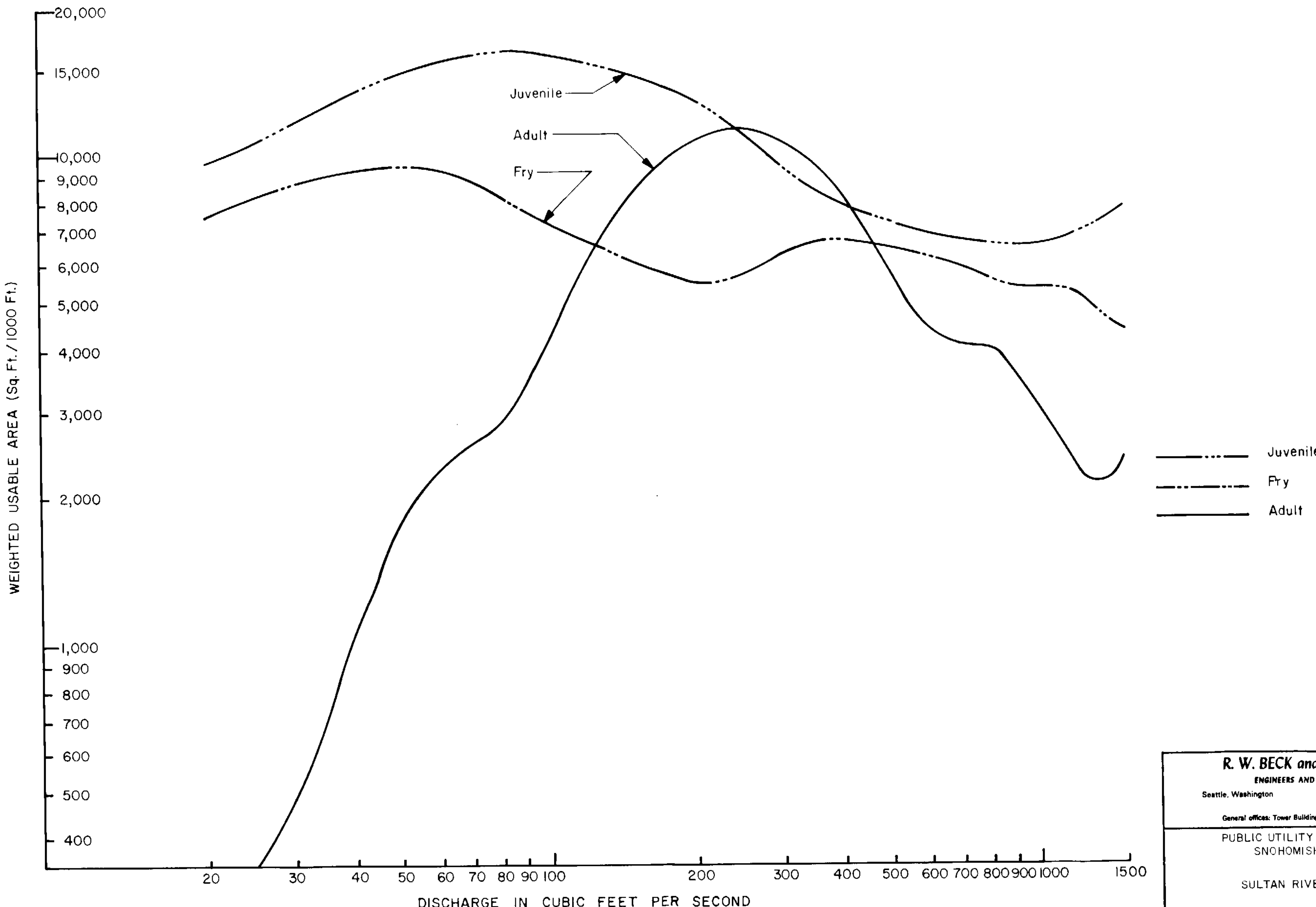
TRANSECT MAP

DATE:	DRAWN:	APPROVED:	FIG:
SEPT. 1980	RBR	[illegible]	3



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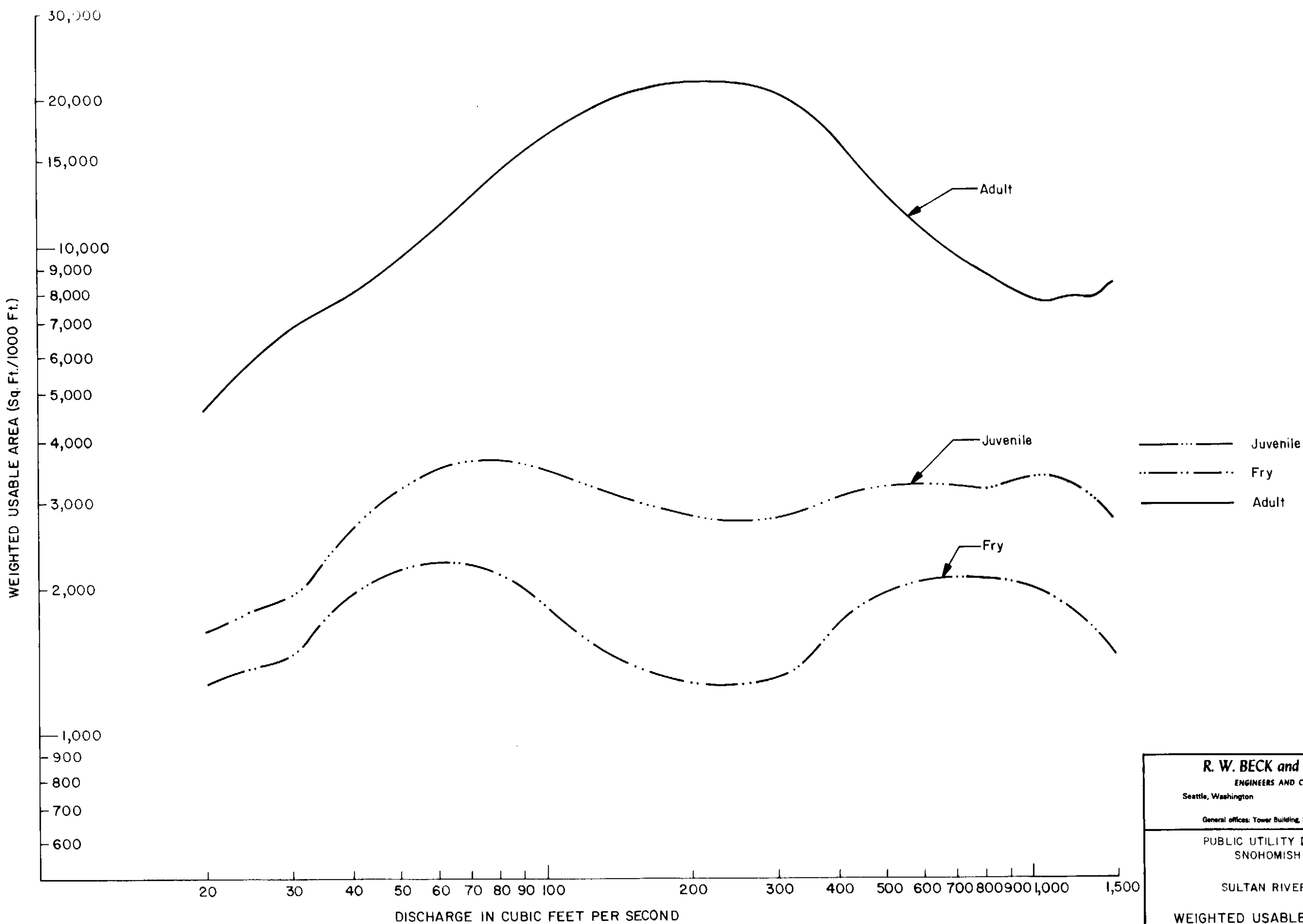
SULTAN RIVER PROJECT

WEIGHTED USABLE HABITAT AREA FOR WINTER STEELHEAD

DATE: SEPT. 1980	DRAWN: EMG	APPROVED:	FIG: 4



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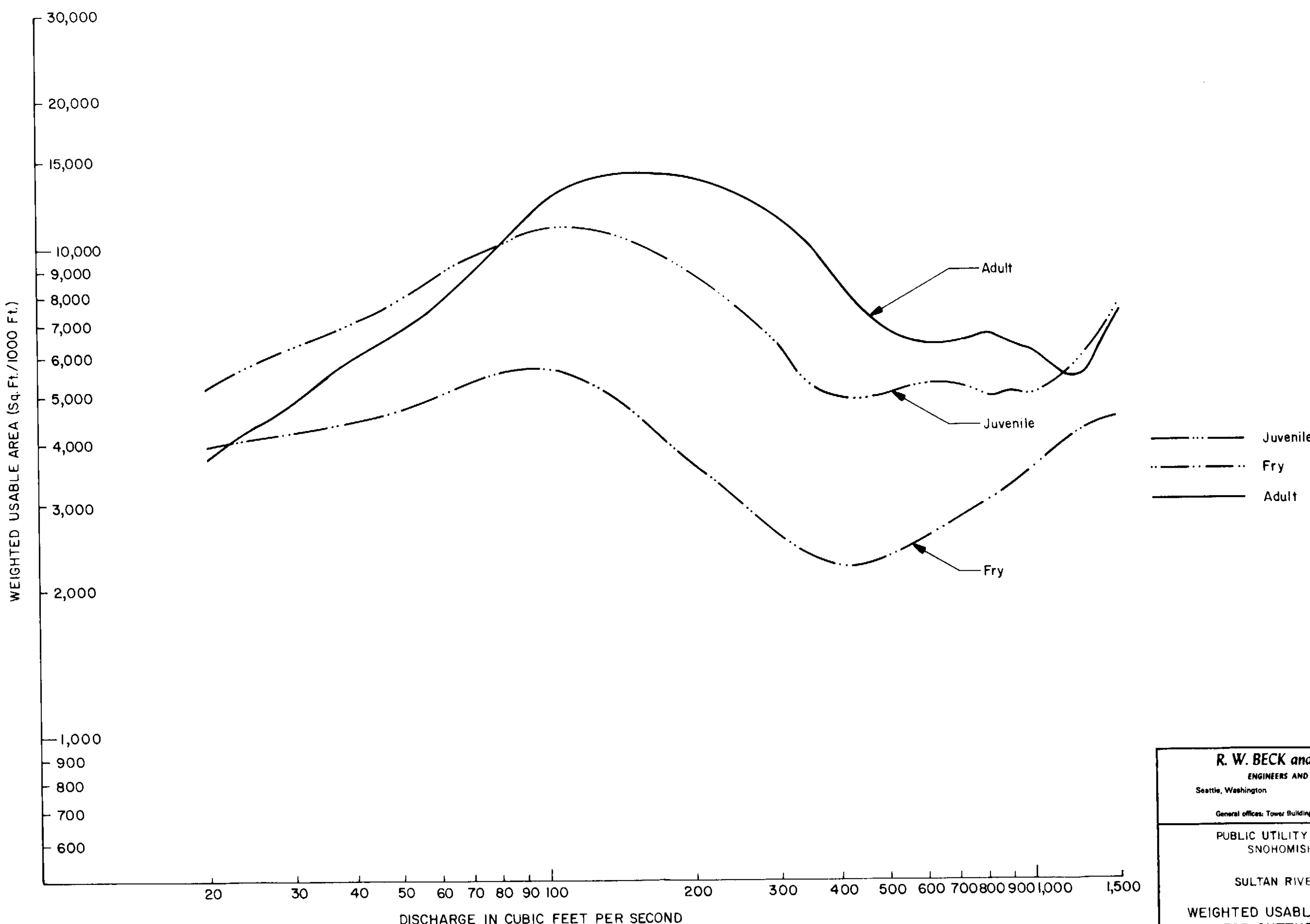
SULTAN RIVER PROJECT

WEIGHTED USABLE HABITAT AREA FOR RAINBOW TROUT

DATE:	DRAWN:	APPROVED:	FIG:
SEPT. 1980	myd	ARG	5



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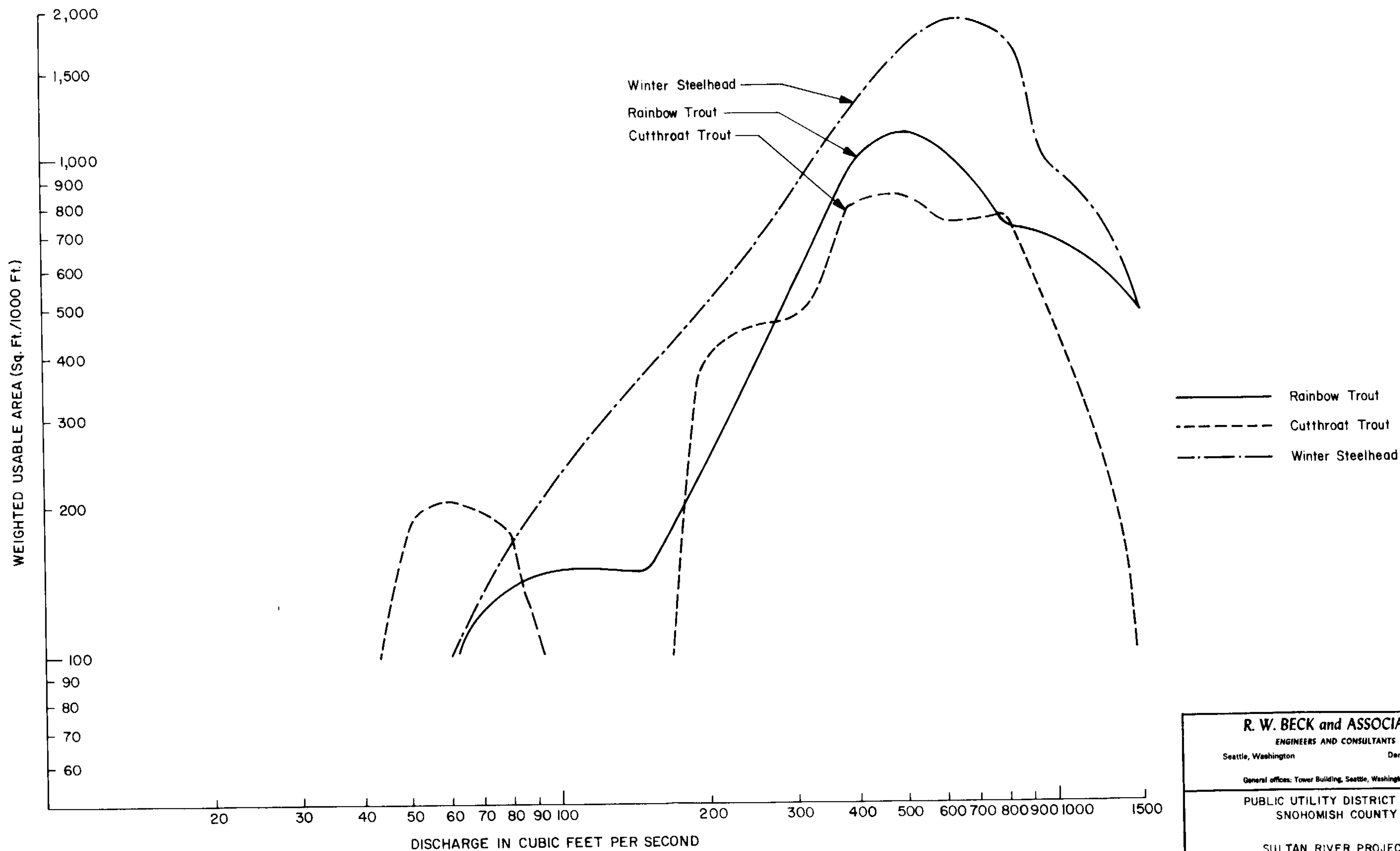
WEIGHTED USABLE HABITAT AREA
FOR CUTTHROAT TROUT

DATE:	DRAWN:	APPROVED:	FIG:
SEPT. 1980	myd	ARG	6



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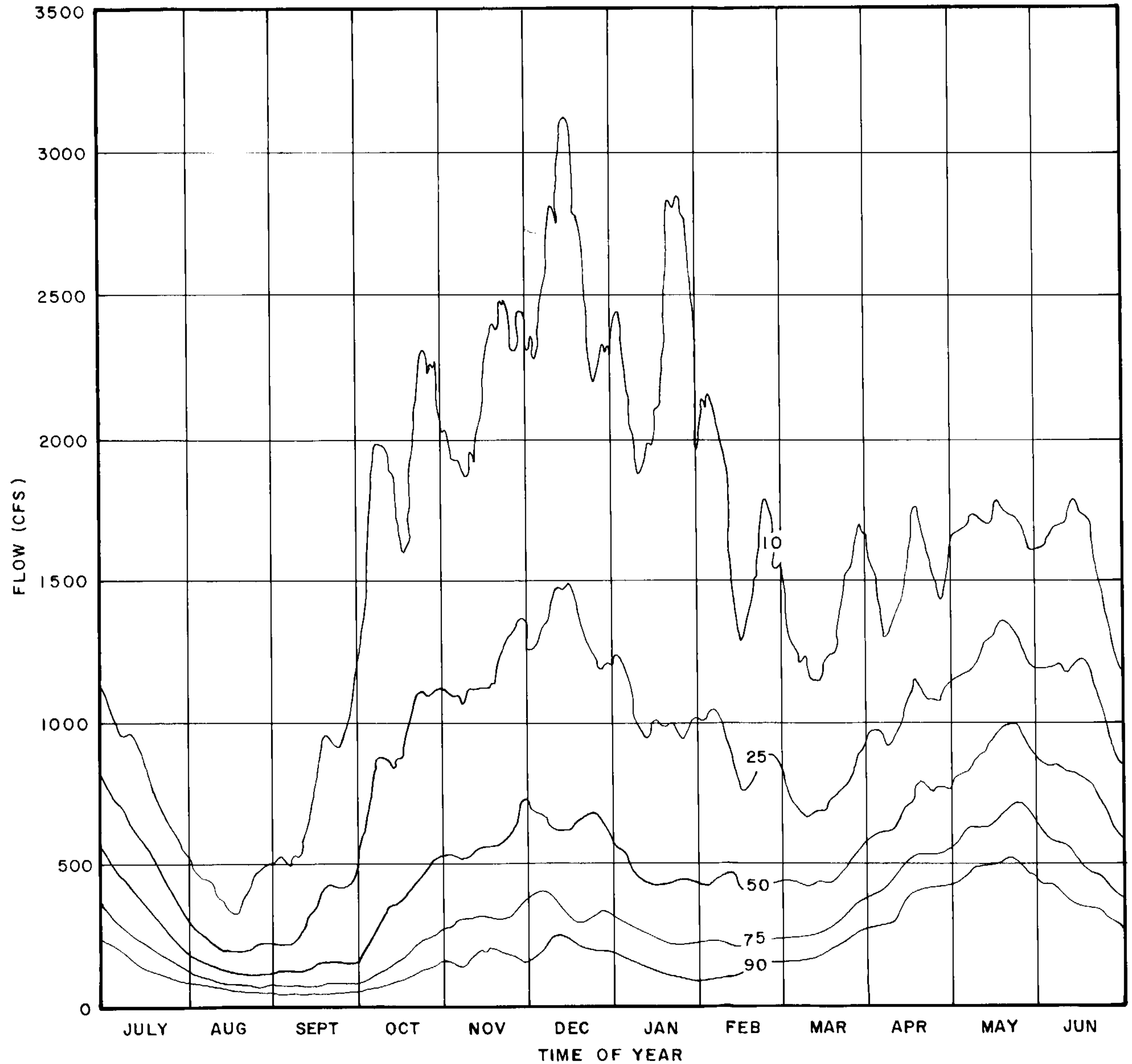
SULTAN RIVER PROJECT

WEIGHTED USABLE HABITAT AREA
FOR SPAWNING

DATE:	DRAWN:	APPROVED:	FIG:
SEPT. 1980	myd	ARG	7



NOTES

1. Curves represent probabilities in per cent that flow will be equalled or exceeded.

2. Curves are based on a 10-day moving average.

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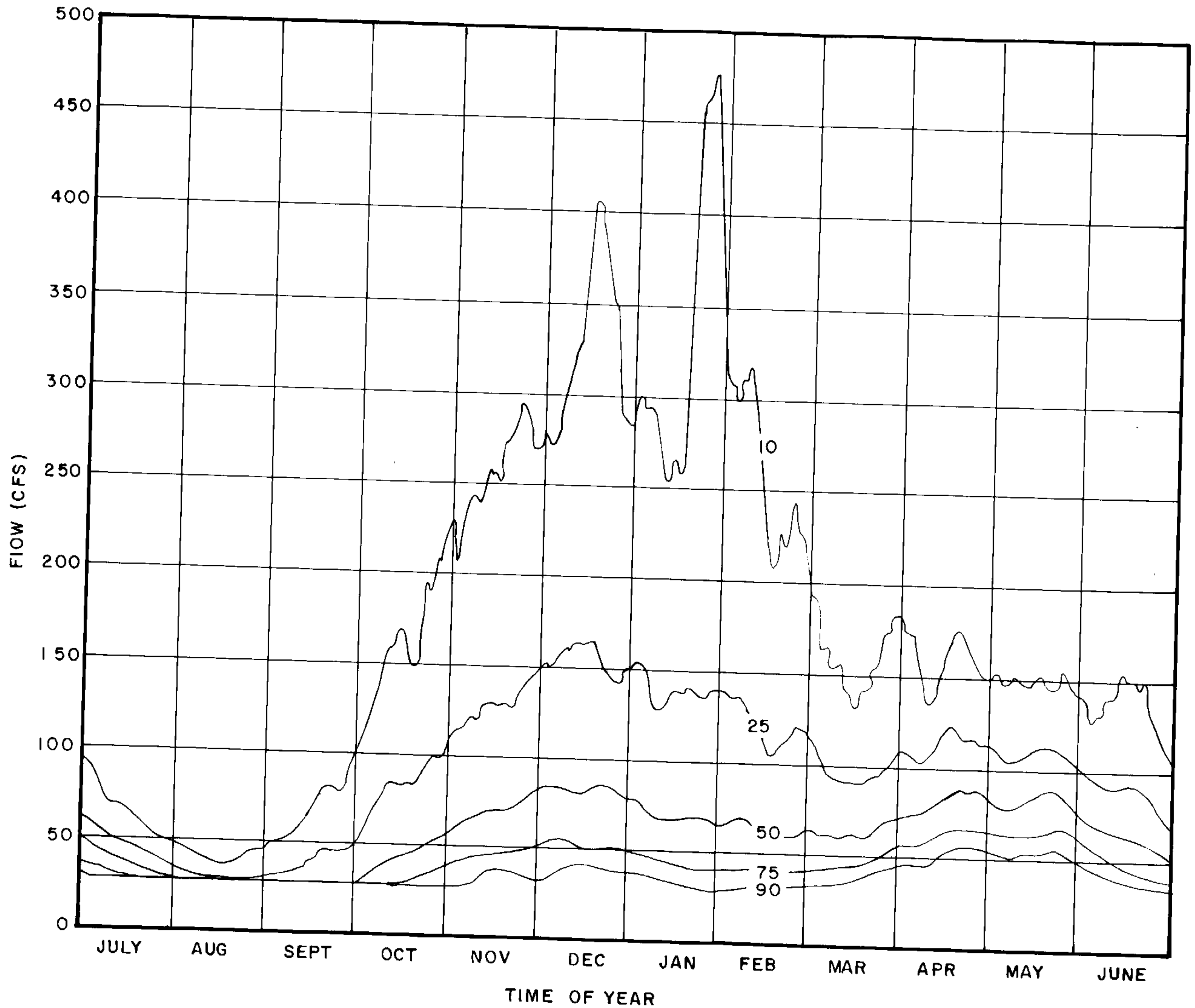
SULTAN RIVER PROJECT

PRE-CULMBACK FLOW FREQUENCY AT CULMBACK DAM SITE

DATE:	DRAWN:	APPROVED:	FIG:
NOV. 1980	BBB	ARG	8



NOTES

1. Curves represent probabilities in per cent that flow will be equalled or exceeded.

2. Curves are based on a 10-day moving average.

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SULTAN RIVER PROJECT

PROPOSED PROJECT FLOW FREQUENCY AT THE DIVERSION DAM

DATE: | DRAWN: | APPROVED: | FIG:

APPENDIX A

HYDRAULIC SIMULATION OUTPUT

CALIBRATION DETAILS FOR CROSS-SECTION 1.

X	Y	SUBSTRATE VALUE	MANNINGS N	N OBS	CORR COEF	SEGMENT VELOCITIES 1	2	3
.0	98.3	6.4	.100	0	.00	.00	.00	.00
28.2	94.2	6.4	.060	1	.00	1.13	.00	.00
32.0	93.8	5.7	.200	2	1.00	1.69	1.03	.00
35.2	93.6	6.4	.200	2	1.00	2.19	1.50	.00
38.3	93.9	5.5	.400	2	1.00	2.59	1.50	.00
42.6	92.1	6.6	.500	3	.96	1.56	.56	.30
49.2	91.3	6.6	.310	3	.98	2.11	1.60	.91
53.3	91.1	6.4	.370	3	1.00	2.12	1.46	.83
61.4	90.8	6.5	.280	3	1.00	3.09	1.80	1.02
67.1	94.0	7.0	.026	1	.00	4.04	.00	.00
71.4	92.4	7.0	.100	3	1.00	2.90	2.08	1.23
75.4	96.6	7.0	.300	0	.00	.00	.00	.00
84.3	93.0	7.0	.120	3	.76	.58	.56	.93
89.4	92.6	7.0	.110	3	.38	1.32	1.50	1.44
96.2	92.3	6.5	.180	3	.93	3.18	2.53	1.03
105.1	92.6	6.5	.600	3	1.00	1.79	.62	.21
111.8	92.7	6.5	.340	3	1.00	1.87	1.03	.46
115.8	92.8	7.0	.210	3	1.00	3.55	1.53	.66
120.6	93.0	7.0	.130	3	.98	1.72	.90	.53
130.4	93.0	7.0	.290	3	.94	1.27	.54	.35
142.0	93.7	7.0	.300	2	1.00	2.33	1.44	.00
146.9	93.1	7.0	.400	2	1.00	1.56	.58	.00
166.9	96.0	7.0	.100	0	.00	.00	.00	.00
COMPUTED DISCHARGE						529.	217.	70.

COMPUTATIONAL DETAILS FOR CROSS SECTION 1.
Q= 75.0 CFS, WSEL= 93.58

STATION	N	DEPTH	AREA	VELOCITY
38.3	.40	.74	2.6	.00
42.6	.50	1.88	12.4	.27
49.2	.31	2.38	9.7	.92
53.3	.37	2.63	21.3	.83
61.4	.28	1.39	6.9	.99
67.1	.03	.59	1.9	.00
71.4	.10	.59	.7	1.23
75.4	.30	.29	.4	.00
84.3	.12	.78	4.0	.85
89.4	.11	1.13	7.7	1.45
96.2	.18	1.13	10.0	1.10
105.1	.60	.93	6.2	.20
111.8	.34	.83	3.3	.46
115.8	.21	.68	3.3	.63
120.6	.13	.58	5.7	.50
130.4	.29	.29	2.8	.32
142.0	.30	.24	.9	.00
146.9	.40	.24	.8	.16
166.9	.10	.00	.0	.00

VELOCITY ADJUSTMENT FACTOR= .98375921
DISCHARGE USED TO CALCULATE VELOCITIES WAS 70.1 CUSECS

COMPUTATIONAL DETAILS FOR CROSS SECTION 1.
Q= 178.0 CFS, WSEL= 94.25

STATION	N	DEPTH	AREA	VELOCITY
.0	.10	.02	.0	.00
28.2	.06	.25	.9	.16
32.0	.20	.55	1.7	1.02
35.2	.20	.50	1.5	1.48
38.3	.40	1.25	5.4	1.48
42.6	.50	2.55	16.8	.67
49.2	.31	3.05	12.5	1.48
53.3	.37	3.30	26.7	1.40
61.4	.28	1.85	10.5	1.84
67.1	.03	1.05	4.5	1.11
71.4	.10	.92	1.6	1.99
75.4	.30	.62	1.9	.00
84.3	.12	1.45	7.4	.65
89.4	.11	1.80	12.2	1.40
96.2	.18	1.80	16.0	2.09
105.1	.60	1.60	10.7	.66
111.8	.34	1.50	6.0	1.00
115.8	.21	1.35	6.5	1.61
120.6	.13	1.25	12.2	.97
130.4	.29	.90	10.4	.65
142.0	.30	.85	4.1	1.42
146.9	.40	.57	4.5	.57
166.9	.10	.00	.0	.00

VELOCITY ADJUSTMENT FACTOR= .98759094
DISCHARGE USED TO CALCULATE VELOCITIES WAS 217.0 CUSECS

COMPUTATIONAL DETAILS FOR CROSS SECTION 1.
Q= 352.0 CFS, WSEL= 94.89

STATION	N	DEPTH	AREA	VELOCITY
.0	.10	.34	1.6	.00
28.2	.06	.89	3.4	.99
32.0	.20	1.19	3.8	1.73
35.2	.20	1.14	3.5	2.24
38.3	.40	1.89	8.1	2.65
42.6	.50	3.19	21.0	1.43
49.2	.31	3.69	15.1	2.24
53.3	.37	3.94	31.9	2.20
61.4	.28	2.49	14.2	3.11
67.1	.03	1.69	7.3	2.71
71.4	.10	1.24	2.9	3.02
75.4	.30	.94	4.4	.00
84.3	.12	2.09	10.6	.54
89.4	.11	2.44	16.6	1.40
96.2	.18	2.44	21.7	3.60
105.1	.60	2.24	15.0	1.76
111.8	.34	2.14	8.5	1.93
115.8	.21	1.99	9.5	3.51
120.6	.13	1.89	18.5	1.68
130.4	.29	1.54	17.8	1.17
142.0	.30	1.49	7.3	2.39
146.9	.40	.89	11.0	1.60
166.9	.10	.00	.0	.00

VELOCITY ADJUSTMENT FACTOR= 1.02389276
DISCHARGE USED TO CALCULATE VELOCITIES WAS 529.2 CUSECS

KNOWN Q= 352. COMPUTED Q= 440.

KNOWN Q= 178. COMPUTED Q= 234.

KNOWN Q= 75. COMPUTED Q= 105.

CALIBRATION DETAILS FOR CROSS-SECTION 2.

X	Y	SUBSTRATE VALUE	MANNINGS N	N OBS	CORR COEF	SEGMENT VELOCITIES 1	2	3
.0	96.6	5.7	.200	0	.00	.00	.00	.00
18.2	94.4	5.7	.062	1	.00	1.07	.00	.00
22.5	94.1	5.5	.220	2	1.00	1.35	.91	.00
25.0	94.0	5.9	.250	2	1.00	2.15	1.53	.00
27.8	93.4	5.8	.300	2	1.00	1.32	.72	.00
31.0	92.5	5.3	.260	3	.58	1.27	.29	.35
36.7	92.9	5.3	.380	3	.90	.72	.61	.22
41.9	92.5	6.2	.190	3	.98	1.35	.77	.50
47.6	91.6	6.7	.100	3	1.00	2.21	1.75	1.21
51.6	91.5	6.9	.080	3	.99	3.15	2.03	1.41
58.0	90.1	5.8	.300	3	.96	1.55	.71	.44
64.2	90.3	7.0	.120	3	.96	2.40	2.00	1.19
66.5	90.7	7.0	.120	3	1.00	2.29	1.74	1.15
70.1	91.4	6.0	.290	3	.99	2.04	.87	.38
73.2	92.0	6.8	.070	3	1.00	2.72	1.87	1.27
81.5	92.2	6.5	.070	3	.96	2.18	1.72	.90
87.0	92.1	6.5	.160	3	.94	1.50	1.10	.36
95.9	93.5	7.0	.119	1	.00	.54	.00	.00
105.0	99.8	7.0	.200	0	.00	.00	.00	.00
		COMPUTED DISCHARGE				440.	234.	105.

COMPUTATIONAL DETAILS FOR CROSS SECTION 2.
Q= 75.0 CFS, WSEL= 93.81

STATION	N	DEPTH	AREA	VELOCITY
25.0	.25	.20	.4	.00
27.8	.30	.86	2.7	.33
31.0	.26	1.11	6.3	.26
36.7	.38	1.11	5.8	.24
41.9	.19	1.76	10.0	.47
47.6	.10	2.26	9.0	1.20
51.6	.08	3.01	19.2	1.35
58.0	.30	3.61	22.4	.40
64.2	.12	3.31	7.6	1.21
66.5	.12	2.76	9.9	1.14
70.1	.29	2.11	6.5	.36
73.2	.07	1.71	14.2	1.23
81.5	.07	1.66	9.1	.92
87.0	.16	1.01	9.0	.39
95.9	.12	.15	.1	.28
105.0	.20	.00	.0	.00

VELOCITY ADJUSTMENT FACTOR= .98019619
DISCHARGE USED TO CALCULATE VELOCITIES WAS 105.0 CUSECS

COMPUTATIONAL DETAILS FOR CROSS SECTION 2.
Q= 178.0 CFS, WSEL= 94.48

STATION	N	DEPTH	AREA	VELOCITY
.0	.20	.04	.0	.00
18.2	.06	.23	1.0	.22
22.5	.22	.43	1.1	.90
25.0	.25	.78	2.2	1.52
27.8	.30	1.53	4.9	.72
31.0	.26	1.78	10.1	.53
36.7	.38	1.78	9.3	.48
41.9	.19	2.43	13.8	.83
47.6	.10	2.93	11.7	1.70
51.6	.08	3.68	23.5	2.13
58.0	.30	4.28	26.5	.82
64.2	.12	3.98	9.2	1.83
66.5	.12	3.43	12.3	1.70
70.1	.29	2.78	8.6	.93
73.2	.07	2.38	19.7	1.91
81.5	.07	2.33	12.8	1.54
87.0	.16	1.68	14.9	.88
95.9	.12	.49	.7	.61
105.0	.20	.00	.0	.00

VELOCITY ADJUSTMENT FACTOR= .99351314
DISCHARGE USED TO CALCULATE VELOCITIES WAS 233.9 CUSECS

COMPUTATIONAL DETAILS FOR CROSS SECTION 2.
Q= 352.0 CFS, WSEL= 95.11

STATION	N	DEPTH	AREA	VELOCITY
.0	.20	.36	2.1	.00
18.2	.06	.86	3.7	.94
22.5	.22	1.06	2.7	1.34
25.0	.25	1.41	4.0	2.13
27.8	.30	2.16	6.9	1.31
31.0	.26	2.41	13.8	.90
36.7	.38	2.41	12.6	.82
41.9	.19	3.06	17.5	1.28
47.6	.10	3.56	14.3	2.22
51.6	.08	4.31	27.6	3.03
58.0	.30	4.91	30.5	1.41
64.2	.12	4.61	10.6	2.50
66.5	.12	4.06	14.6	2.30
70.1	.29	3.41	10.6	1.94
73.2	.07	3.01	25.0	2.66
81.5	.07	2.96	16.3	2.29
87.0	.16	2.31	20.6	1.68
95.9	.12	.81	1.9	.86
105.0	.20	.00	.0	.00

VELOCITY ADJUSTMENT FACTOR= .99183555
DISCHARGE USED TO CALCULATE VELOCITIES WAS 440.0 CUSECS

KNOWN Q= 352. COMPUTED Q= 353.

KNOWN Q= 178. COMPUTED Q= 180.

KNOWN Q= 75. COMPUTED Q= 71.

CALIBRATION DETAILS FOR CROSS-SECTION 3.

X	Y	SUBSTRATE VALUE	MANNINGS N	N OBS	CORR COEF	SEGMENT VELOCITIES 1	2	3
.0	96.9	8.0	.100	0	.00	.00	.00	.00
17.0	93.8	8.0	.200	2	1.00	3.11	2.97	.00
20.1	92.9	8.0	.040	3	.99	4.24	3.26	1.95
25.0	90.4	6.0	.060	3	1.00	3.70	2.79	2.02
28.5	90.6	6.0	.050	3	.97	3.87	3.19	1.80
31.8	94.8	7.0	.020	1	.00	4.89	.00	.00
35.8	92.9	6.0	.030	3	.99	4.04	3.18	2.03
40.0	92.9	6.3	.040	3	.94	2.78	2.43	1.41
42.7	92.4	6.4	.050	3	.89	2.93	2.71	1.41
45.1	93.0	6.2	.040	3	1.00	3.63	2.59	1.50
47.4	93.3	5.6	.100	3	.99	2.13	1.29	.44
49.7	93.6	5.7	.200	2	1.00	1.95	.30	.00
55.0	93.9	5.8	.200	2	1.00	.77	.31	.00
62.0	94.8	5.8	.100	0	.00	.00	.00	.00
65.8	94.7	5.7	.100	0	.00	.00	.00	.00
84.0	99.1	5.7	.100	0	.00	.00	.00	.00
		COMPUTED DISCHARGE				353.	180.	71.

COMPUTATIONAL DETAILS FOR CROSS SECTION 3.
Q= 75.0 CFS, WSEL= 93.93

STATION	N	DEPTH	AREA	VELOCITY
.0	.10	.07	.0	.00
17.0	.20	.58	1.8	2.65
20.1	.04	2.28	11.2	1.90
25.0	.06	3.43	12.0	1.91
28.5	.05	1.67	4.4	1.78
31.8	.02	.52	1.1	.00
35.8	.03	1.03	4.3	1.97
40.0	.04	1.28	3.5	1.40
42.7	.05	1.23	3.0	1.44
45.1	.04	.78	1.8	1.45
47.4	.10	.48	1.1	.44
49.7	.20	.18	1.0	.02
55.0	.20	.02	.0	.08
62.0	.10	.00	.0	.00

VELOCITY ADJUSTMENT FACTOR= .95105086
DISCHARGE USED TO CALCULATE VELOCITIES WAS 71.2 CUSECS

COMPUTATIONAL DETAILS FOR CROSS SECTION 3.
Q= 178.0 CFS, WSEL= 94.68

STATION	N	DEPTH	AREA	VELOCITY
.0	.10	.44	2.1	.00
17.0	.20	1.33	4.1	3.08
20.1	.04	3.03	14.8	3.21
25.0	.06	4.18	14.6	2.93
28.5	.05	2.04	6.5	3.01
31.8	.02	.89	3.3	.00
35.8	.03	1.78	7.5	3.16
40.0	.04	2.03	5.5	2.26
42.7	.05	1.98	4.7	2.39
45.1	.04	1.53	3.5	2.60
47.4	.10	1.23	2.8	1.18
49.7	.20	.93	4.9	.29
55.0	.20	.39	2.4	.31
62.0	.10	.00	.0	.00

VELOCITY ADJUSTMENT FACTOR= 1.03803724
DISCHARGE USED TO CALCULATE VELOCITIES WAS 175.6 CUSECS

COMPUTATIONAL DETAILS FOR CROSS SECTION 3.
Q= 352.0 CFS, WSEL= 95.39

STATION	N	DEPTH	AREA	VELOCITY
.0	.10	.79	6.9	.00
17.0	.20	2.04	6.3	3.18
20.1	.04	3.74	18.3	4.46
25.0	.06	4.89	17.1	3.75
28.5	.05	2.69	8.9	4.17
31.8	.02	1.54	6.2	2.63
35.8	.03	2.49	10.4	4.23
40.0	.04	2.74	7.4	3.02
42.7	.05	2.69	6.5	3.29
45.1	.04	2.24	5.1	3.78
47.4	.10	1.94	4.5	2.34
49.7	.20	1.64	8.7	2.07
55.0	.20	1.04	7.3	.80
62.0	.10	.64	2.4	.53
65.8	.10	.34	1.0	.59
84.0	.10	.00	.0	.00

VELOCITY ADJUSTMENT FACTOR= 1.02053175
DISCHARGE USED TO CALCULATE VELOCITIES WAS 357.9 CUSECS

CALIBRATION DETAILS FOR CROSS-SECTION 4.

X	Y	SUBSTRATE VALUE	MANNINGS N	N OBS	CORR COEF	SEGMENT VELOCITIES 1	2	3
.0	98.8	4.5	.100	0	.00	.00	.00	.00
13.0	95.0	4.5	.104	1	.00	.91	.00	.00
16.9	94.1	4.5	.100	2	1.00	1.19	.69	.00
18.9	94.1	8.0	.100	2	1.00	1.75	.95	.00
20.6	93.9	7.5	.050	3	.85	.77	.72	.31
28.8	92.0	6.4	.080	3	.92	1.89	1.63	.85
33.0	90.5	6.0	.110	3	.99	1.94	1.27	.87
37.0	89.5	6.5	.240	3	1.00	1.21	.82	.49
40.0	90.1	7.0	.180	3	.98	2.12	.97	.52
42.8	93.4	7.0	.040	3	1.00	2.90	1.87	1.10
48.6	93.5	7.0	.080	3	.95	1.05	.68	.54
54.7	92.0	6.7	.040	3	.98	3.60	2.91	1.83
61.6	94.9	7.0	.037	1	.00	3.11	.00	.00
67.3	93.2	7.0	.060	3	.96	1.91	1.47	.70
74.3	93.1	5.7	.070	3	.99	1.56	1.13	.62
79.9	95.3	7.0	.040	1	.00	1.29	.00	.00
82.9	95.5	5.6	.038	1	.00	1.01	.00	.00
90.4	95.7	5.5	.130	1	.00	.15	.00	.00
94.8	96.0	5.9	.100	0	.00	.00	.00	.00
119.5	100.0	5.9	.100	0	.00	.00	.00	.00
		COMPUTED DISCHARGE				398.	180.	67.

COMPUTATIONAL DETAILS FOR CROSS SECTION 4.
Q= 75.0 CFS, WSEL= 94.24

STATION	N	DEPTH	AREA	VELOCITY
13.0	.10	.07	.0	.00
16.9	.10	.14	.3	.34
18.9	.10	.24	.4	.44
20.6	.05	1.29	10.6	.34
28.8	.08	2.99	12.6	.89
33.0	.11	4.24	17.0	.84
37.0	.24	4.44	13.3	.48
40.0	.18	2.49	7.0	.49
42.8	.04	.79	4.6	1.07
48.6	.08	1.49	9.1	.51
54.7	.04	1.12	6.0	1.84
61.6	.04	.52	1.8	.00
67.3	.06	1.09	7.7	.72
74.3	.07	.57	1.7	.62
79.9	.04	.00	.0	.00

VELOCITY ADJUSTMENT FACTOR= .98022244
DISCHARGE USED TO CALCULATE VELOCITIES WAS 66.9 CUSECS

COMPUTATIONAL DETAILS FOR CROSS SECTION 4.
Q= 178.0 CFS, WSEL= 95.13

STATION	N	DEPTH	AREA	VELOCITY
.0	.10	.06	.0	.00
13.0	.10	.58	2.2	.18
16.9	.10	1.03	2.1	.70
18.9	.10	1.13	1.9	.96
20.6	.05	2.18	17.8	.58
28.8	.08	3.88	16.3	1.43
33.0	.11	5.13	20.5	1.34
37.0	.24	5.33	16.0	.82
40.0	.18	3.38	9.5	1.09
42.8	.04	1.68	9.7	1.90
48.6	.08	2.38	14.5	.75
54.7	.04	1.68	11.6	2.77
61.6	.04	1.08	6.1	.75
67.3	.06	1.98	13.8	1.31
74.3	.07	1.01	5.2	1.08
79.9	.04	.00	.0	.00

VELOCITY ADJUSTMENT FACTOR= 1.00770872
DISCHARGE USED TO CALCULATE VELOCITIES WAS 180.8 CUSECS

COMPUTATIONAL DETAILS FOR CROSS SECTION 4.
Q= 352.0 CFS, WSEL= 95.98

STATION	N	DEPTH	AREA	VELOCITY
.0	.10	.49	1.6	.00
13.0	.10	1.43	5.6	.72
16.9	.10	1.88	3.8	1.20
18.9	.10	1.98	3.4	1.77
20.6	.05	3.03	24.8	.88
28.8	.08	4.73	19.9	2.06
33.0	.11	5.98	23.9	1.91
37.0	.24	6.18	18.5	1.23
40.0	.18	4.23	11.8	2.02
42.8	.04	2.53	14.7	2.93
48.6	.08	3.23	19.7	1.01
54.7	.04	2.53	17.5	3.76
61.6	.04	1.93	11.0	2.14
67.3	.06	2.83	19.8	2.07
74.3	.07	1.78	10.0	1.63
79.9	.04	.58	1.7	1.47
82.9	.04	.38	2.8	1.22
90.4	.13	.14	.6	.25
94.8	.10	.00	.0	.00

VELOCITY ADJUSTMENT FACTOR= 1.01270966
DISCHARGE USED TO CALCULATE VELOCITIES WAS 396.2 CUSECS

KNOWN Q= 352. COMPUTED Q= 373.

KNOWN Q= 178. COMPUTED Q= 188.

KNOWN Q= 75. COMPUTED Q= 73.

CALIBRATION DETAILS FOR CROSS-SECTION 5.

X	Y	SUBSTRATE VALUE	MANNINGS N	N OBS	CORR COEF	SEGMENT VELOCITIES 1	2	3
.0	99.2	8.0	.100	0	.00	.00	.00	.00
6.0	95.4	8.0	.117	1	.00	.58	.00	.00
7.0	95.0	8.0	.168	1	.00	.72	.00	.00
9.0	93.0	8.0	.010	3	.99	2.43	.94	.35
11.0	75.6	4.0	.020	3	1.00	1.90	1.12	.60
13.0	75.2	4.0	.080	3	1.00	2.11	1.15	.50
15.0	74.7	4.0	.080	3	1.00	2.06	1.15	.48
17.0	74.8	4.0	.030	3	1.00	2.14	1.16	.42
20.0	94.4	8.0	.020	3	1.00	.95	.46	.21
28.2	99.0	8.0	.100	0	.00	.00	.00	.00
		COMPUTED DISCHARGE				373.	188.	73.

COMPUTATIONAL DETAILS FOR CROSS SECTION 5.
Q= 75.0 CFS, WSEL= 94.25

STATION	N	DEPTH	AREA	VELOCITY
7.0	.17	.62	.8	.00
9.0	.01	9.95	19.9	.34
11.0	.02	18.85	37.7	.60
13.0	.08	19.30	38.6	.50
15.0	.08	19.50	39.0	.49
17.0	.03	9.72	29.0	.43
20.0	.02	.00	.0	.00

VELOCITY ADJUSTMENT FACTOR= 1.00005719
DISCHARGE USED TO CALCULATE VELOCITIES WAS 73.6 CUSECS

COMPUTATIONAL DETAILS FOR CROSS SECTION 5.
Q= 178.0 CFS, WSEL= 95.17

STATION	N	DEPTH	AREA	VELOCITY
6.0	.12	.09	.0	.00
7.0	.17	1.17	2.3	.14
9.0	.01	10.87	21.7	1.00
11.0	.02	19.77	39.5	1.13
13.0	.08	20.22	40.4	1.13
15.0	.08	20.42	40.8	1.10
17.0	.03	10.57	31.7	1.08
20.0	.02	.39	.5	.48
28.2	.10	.00	.0	.00

VELOCITY ADJUSTMENT FACTOR= .99789689
DISCHARGE USED TO CALCULATE VELOCITIES WAS 183.6 CUSECS

COMPUTATIONAL DETAILS FOR CROSS SECTION 5.
Q= 352.0 CFS, WSEL= 96.07

STATION	N	DEPTH	AREA	VELOCITY
.0	.10	.33	.4	.00
6.0	.12	.87	.9	.49
7.0	.17	2.07	4.1	.46
9.0	.01	11.77	23.5	2.35
11.0	.02	20.67	41.3	1.89
13.0	.08	21.12	42.2	2.14
15.0	.08	21.32	42.6	2.12
17.0	.03	11.47	34.4	2.24
20.0	.02	.83	2.5	.93
28.2	.10	.00	.0	.00

VELOCITY ADJUSTMENT FACTOR= 1.00358299
DISCHARGE USED TO CALCULATE VELOCITIES WAS 377.9 CUSECS

CALIBRATION DETAILS FOR CROSS-SECTION 6.

X	Y	SUBSTRATE VALUE	MANNINGS N	N OBS	CORR COEF	SEGMENT VELOCITIES 1	2	3
.0	97.8	4.3	.426	1	.00	.49	.00	.00
2.0	86.8	4.3	.030	3	.97	.57	.43	.26
5.0	86.8	4.3	.060	3	1.00	1.22	.65	.33
10.0	86.6	4.3	.040	3	1.00	1.57	.85	.48
12.0	86.2	5.0	.050	3	.98	1.42	.88	.40
13.0	86.2	6.5	.272	1	.00	1.29	.00	.00
14.0	85.8	8.0	.040	3	1.00	1.41	.67	.35
15.0	89.0	8.0	.189	1	.00	1.52	.00	.00
16.0	88.2	8.0	.040	3	1.00	1.47	.75	.34
18.0	89.5	8.0	.030	3	1.00	1.53	.87	.48
20.0	88.2	8.0	.040	3	1.00	1.39	.77	.37
22.0	88.3	8.0	.040	3	1.00	1.46	.75	.41
23.0	86.6	8.0	.040	3	.99	1.33	.76	.35
24.0	88.2	8.0	.040	3	.99	1.49	.88	.41
26.0	88.3	8.0	.040	3	1.00	1.29	.78	.41
28.0	87.5	4.0	.040	3	.99	.97	.55	.37
30.0	88.0	4.0	.060	3	1.00	.73	.47	.28
33.0	88.1	8.0	.050	3	1.00	.67	.34	.20
34.0	92.5	8.0	.020	3	.93	.65	.52	.27
36.0	94.3	8.0	.134	1	.00	.52	.00	.00
46.2	102.1	8.0	.100	0	.00	.00	.00	.00
			COMPUTED DISCHARGE			341.	158.	73.

COMPUTATIONAL DETAILS FOR CROSS SECTION 6.
Q= 75.0 CFS, WSEL= 94.25

STATION	N	DEPTH	AREA	VELOCITY
.0	.43	3.73	5.0	.00
2.0	.03	7.45	22.4	.21
5.0	.06	7.55	37.8	.26
10.0	.04	7.85	15.7	.37
12.0	.05	8.05	8.1	.33
13.0	.27	8.25	8.3	.89
14.0	.04	6.85	6.9	.27
15.0	.19	5.65	5.7	.96
16.0	.04	5.40	10.8	.27
18.0	.03	5.40	10.8	.38
20.0	.04	6.00	12.0	.30
22.0	.04	6.80	6.8	.32
23.0	.04	6.85	6.9	.28
24.0	.04	6.00	12.0	.33
26.0	.04	6.35	12.7	.33
28.0	.04	6.50	13.0	.28
30.0	.06	6.20	18.6	.22
33.0	.05	3.95	4.0	.15
34.0	.02	.88	1.7	.23
36.0	.13	.00	.0	.00

VELOCITY ADJUSTMENT FACTOR= .79992766
DISCHARGE USED TO CALCULATE VELOCITIES WAS 71.1 CUSECS

COMPUTATIONAL DETAILS FOR CROSS SECTION 6.
Q= 178.0 CFS, WSEL= 95.19

STATION	N	DEPTH	AREA	VELOCITY
.0	.43	4.19	6.4	.00
2.0	.03	8.39	25.2	.38
5.0	.06	8.49	42.4	.62
10.0	.04	8.79	17.6	.83
12.0	.05	8.99	9.0	.76
13.0	.27	9.19	9.2	1.09
14.0	.04	7.79	7.8	.67
15.0	.19	6.59	6.6	1.22
16.0	.04	6.34	12.7	.70
18.0	.03	6.34	12.7	.83
20.0	.04	6.94	13.9	.71
22.0	.04	7.74	7.7	.74
23.0	.04	7.79	7.8	.68
24.0	.04	6.94	13.9	.78
26.0	.04	7.29	14.6	.71
28.0	.04	7.44	14.9	.55
30.0	.06	7.14	21.4	.44
33.0	.05	4.89	4.9	.34
34.0	.02	1.79	3.6	.43
36.0	.13	.44	.5	.47
46.2	.10	.00	.0	.00

VELOCITY ADJUSTMENT FACTOR= .91583477
DISCHARGE USED TO CALCULATE VELOCITIES WAS 168.0 CUSECS

COMPUTATIONAL DETAILS FOR CROSS SECTION 6.
Q= 352.0 CFS, WSEL= 96.10

STATION	N	DEPTH	AREA	VELOCITY
.0	.43	4.65	7.9	.00
2.0	.03	9.30	27.9	.57
5.0	.06	9.40	47.0	1.17
10.0	.04	9.70	19.4	1.49
12.0	.05	9.90	9.9	1.43
13.0	.27	10.10	10.1	1.25
14.0	.04	8.70	8.7	1.32
15.0	.19	7.50	7.5	1.44
16.0	.04	7.25	14.5	1.43
18.0	.03	7.25	14.5	1.47
20.0	.04	7.85	15.7	1.36
22.0	.04	8.65	8.7	1.38
23.0	.04	8.70	8.7	1.32
24.0	.04	7.85	15.7	1.48
26.0	.04	8.20	16.4	1.27
28.0	.04	8.35	16.7	.91
30.0	.06	8.05	24.2	.71
33.0	.05	5.80	5.8	.63
34.0	.02	2.70	5.4	.67
36.0	.13	.90	2.1	.81
46.2	.10	.00	.0	.00

VELOCITY ADJUSTMENT FACTOR= .97992746
DISCHARGE USED TO CALCULATE VELOCITIES WAS 331.2 CUSECS

CALIBRATION DETAILS FOR CROSS-SECTION 7.

X	Y	SUBSTRATE VALUE	MANNINGS N	N OBS	CORR COEF	SEGMENT VELOCITIES 1	2	3
.0	100.3	6.0	.100	0	.00	.00	.00	.00
7.2	96.3	6.0	.099	1	.00	.35	.00	.00
9.2	96.4	6.0	.066	1	.00	.58	.00	.00
11.2	96.2	6.0	.074	1	.00	.85	.00	.00
12.2	95.6	6.0	.073	1	.00	1.19	.00	.00
13.2	95.2	6.0	.067	1	.00	1.56	.00	.00
14.2	94.8	6.0	.100	2	1.00	1.35	.31	.00
15.2	94.5	6.0	.100	2	1.00	1.91	1.23	.00
16.2	94.2	6.0	.200	2	1.00	2.13	1.44	.00
17.2	93.8	6.0	.040	3	.99	2.03	1.23	.56
19.2	93.5	6.0	.050	3	.97	1.92	1.41	.69
21.2	93.0	6.0	.030	3	.99	2.36	1.91	1.32
23.2	92.3	6.0	.040	3	1.00	2.41	1.82	1.23
25.2	92.2	6.0	.050	3	1.00	2.54	1.80	1.13
27.2	91.7	6.0	.050	3	.99	2.57	1.74	1.25
29.2	91.4	6.0	.060	3	.95	2.59	1.49	1.13
31.2	91.5	6.0	.060	3	1.00	2.78	1.79	1.19
33.2	91.3	6.0	.070	3	1.00	2.58	1.75	1.10
35.2	91.1	6.0	.090	3	1.00	2.51	1.58	.88
37.2	91.2	6.5	.070	3	.98	2.23	1.50	1.13
39.2	91.3	6.5	.060	3	1.00	2.14	1.64	1.11
41.2	91.5	6.0	.070	3	1.00	1.76	1.37	.99
43.2	91.8	6.0	.070	3	1.00	1.49	1.15	.88
45.2	92.3	5.5	.060	3	.97	1.30	1.00	.85
47.2	93.1	6.0	.070	3	.95	1.09	.93	.58
49.2	93.1	6.0	.070	3	.99	1.26	.80	.56
50.2	93.5	6.0	.080	3	.98	1.18	.63	.40
51.2	93.6	6.0	.080	3	1.00	1.07	.63	.36
52.2	93.8	6.0	.050	3	.99	.79	.58	.34
58.0	101.4	6.0	.100	0	.00	.00	.00	.00
		COMPUTED DISCHARGE				351.	176.	79.

COMPUTATIONAL DETAILS FOR CROSS SECTION 7.
Q= 75.0 CFS, WSEL= 94.39

STATION	N	DEPTH	AREA	VELOCITY
15.2	.10	.09	.1	.00
16.2	.20	.39	.4	.91
17.2	.04	.74	1.5	.57
19.2	.05	1.14	2.3	.72
21.2	.03	1.74	3.5	1.34
23.2	.04	2.14	4.3	1.23
25.2	.05	2.44	4.9	1.13
27.2	.05	2.84	5.7	1.22
29.2	.06	2.94	5.9	1.07
31.2	.06	2.99	6.0	1.16
33.2	.07	3.19	6.4	1.09
35.2	.09	3.24	6.5	.88
37.2	.07	3.14	6.3	1.10
39.2	.06	2.99	6.0	1.12
41.2	.07	2.74	5.5	.99
43.2	.07	2.34	4.7	.87
45.2	.06	1.69	3.4	.83
47.2	.07	1.29	2.6	.60
49.2	.07	1.09	1.1	.54
50.2	.08	.84	.8	.38
51.2	.08	.69	.7	.35
52.2	.05	.29	.1	.35
58.0	.10	.00	.0	.00

VELOCITY ADJUSTMENT FACTOR= .99896115
DISCHARGE USED TO CALCULATE VELOCITIES WAS 78.6 CUSECS

COMPUTATIONAL DETAILS FOR CROSS SECTION 7.
Q= 178.0 CFS, WSEL= 95.51

STATION	N	DEPTH	AREA	VELOCITY
12.2	.07	.16	.1	.00
13.2	.07	.51	.5	.51
14.2	.10	.86	.9	.32
15.2	.10	1.16	1.2	1.25
16.2	.20	1.51	1.5	1.46
17.2	.04	1.86	3.7	1.18
19.2	.05	2.26	4.5	1.28
21.2	.03	2.86	5.7	1.86
23.2	.04	3.26	6.5	1.80
25.2	.05	3.56	7.1	1.79
27.2	.05	3.96	7.9	1.83
29.2	.06	4.06	8.1	1.69
31.2	.06	4.11	8.2	1.87
33.2	.07	4.31	8.6	1.77
35.2	.09	4.36	8.7	1.58
37.2	.07	4.26	8.5	1.60
39.2	.06	4.11	8.2	1.62
41.2	.07	3.86	7.7	1.37
43.2	.07	3.46	6.9	1.17
45.2	.06	2.81	5.6	1.05
47.2	.07	2.41	4.8	.86
49.2	.07	2.21	2.2	.85
50.2	.08	1.96	2.0	.70
51.2	.08	1.81	1.8	.65
52.2	.05	.86	1.1	.56
58.0	.10	.00	.0	.00

VELOCITY ADJUSTMENT FACTOR= 1.00051852
DISCHARGE USED TO CALCULATE VELOCITIES WAS 180.2 CUSECS

COMPUTATIONAL DETAILS FOR CROSS SECTION 7.
Q= 352.0 CFS, WSEL= 96.66

STATION	N	DEPTH	AREA	VELOCITY
.0	.10	.18	.1	.00
7.2	.10	.31	.6	.38
9.2	.07	.36	.7	.46
11.2	.07	.76	.8	.60
12.2	.07	1.26	1.3	1.06
13.2	.07	1.66	1.7	1.43
14.2	.10	2.01	2.0	1.32
15.2	.10	2.31	2.3	1.90
16.2	.20	2.66	2.7	2.12
17.2	.04	3.01	6.0	2.08
19.2	.05	3.41	6.8	2.02
21.2	.03	4.01	8.0	2.40
23.2	.04	4.41	8.8	2.43
25.2	.05	4.71	9.4	2.55
27.2	.05	5.11	10.2	2.51
29.2	.06	5.21	10.4	2.42
31.2	.06	5.26	10.5	2.72
33.2	.07	5.46	10.9	2.57
35.2	.09	5.51	11.0	2.51
37.2	.07	5.41	10.8	2.16
39.2	.06	5.26	10.5	2.16
41.2	.07	5.01	10.0	1.76
43.2	.07	4.61	9.2	1.48
45.2	.06	3.96	7.9	1.27
47.2	.07	3.56	7.1	1.14
49.2	.07	3.36	3.4	1.22
50.2	.08	3.11	3.1	1.12
51.2	.08	2.96	3.0	1.05
52.2	.05	1.43	3.1	.81
58.0	.10	.00	.0	.00

VELOCITY ADJUSTMENT FACTOR= 1.00082468
DISCHARGE USED TO CALCULATE VELOCITIES WAS 346.7 CUSECS

APPENDIX B

HABITAT SIMULATION OUTPUT

Q VS. AVAILABLE HABITAT AREA PER 1000 FEET OF STREAM FOR WINTER STEELHEAD, CLEAR WATER, S=.001

Q	FRY	JUVENILE	ADULT	SPAWNING	INCUBATE
20.00	7541.21	9650.61	266.39	.00	2568.36
30.00	8855.28	11677.68	534.59	12.62	3784.22
40.00	9247.52	13153.79	1059.78	38.78	4928.47
50.00	9408.12	14574.59	1829.65	61.75	5954.51
60.00	9237.98	15762.90	2340.82	98.19	6922.66
80.00	8325.08	16312.31	2861.29	168.01	8315.75
100.00	7383.22	15971.38	4117.47	227.15	9482.04
150.00	6095.32	14495.94	8374.97	375.93	11716.22
200.00	5450.58	12867.82	10647.33	509.14	13368.27
250.00	5453.01	10927.20	10726.85	668.00	14693.61
300.00	6158.63	9485.56	10603.53	837.80	16022.21
400.00	6691.07	7930.29	8061.51	1217.11	18244.34

Q VS. AVAILABLE HABITAT AREA AS A PERCENTAGE OF THE GROSS AREA FOR WINTER STEELHEAD, CLEAR WATER, S=.001

Q	GROSS	FRY	JUVENILE	ADULT	SPAWNING	INCUBATE
20.	30962.	24.36	31.17	.86	.00	8.30
30.	34703.	25.52	33.65	1.54	.04	10.90
40.	36512.	25.33	36.03	2.90	.11	13.50
50.	37857.	24.85	38.50	4.83	.16	15.73
60.	39190.	23.57	40.22	5.97	.25	17.66
80.	41640.	19.99	39.17	6.87	.40	19.97
100.	43296.	17.05	36.89	9.51	.52	21.90
150.	46662.	13.06	31.07	17.95	.81	25.11
200.	49255.	11.07	26.12	21.62	1.03	27.14
250.	51394.	10.61	21.26	20.87	1.30	28.59
300.	54241.	11.35	17.49	19.55	1.54	29.54
400.	56992.	11.74	13.91	14.14	2.14	32.01

Q VS. AVAILABLE HABITAT AREA PER 1000 FEET OF STREAM FOR WINTER STEELHEAD, CLEAR WATER, S=.001

Q	FRY	JUVENILE	ADULT	SPAWNING	INCUBATE
500.00	6375.14	7314.87	5719.50	1400.11	19613.00
600.00	6079.60	6860.23	4387.30	1806.65	19587.93
700.00	5760.68	6610.07	4281.27	1907.94	19678.55
740.00	5677.99	6557.48	4309.78	1868.12	19744.46
800.00	5607.12	6559.02	4051.92	1721.30	19778.40
900.00	5567.86	6755.72	3472.12	1304.41	19807.29
1000.00	5381.64	6603.00	2990.24	946.86	19499.45
1100.00	5321.83	6855.24	2629.33	861.72	19484.50
1200.00	5195.43	7126.67	2278.06	785.52	19379.35
1300.00	4915.27	7284.30	2150.81	700.98	19201.28
1400.00	4533.21	7313.64	2233.35	603.54	18997.83
1500.00	4364.14	7852.51	2444.08	490.20	18945.55

Q VS. AVAILABLE HABITAT AREA AS A PERCENTAGE OF THE GROSS AREA FOR WINTER STEELHEAD, CLEAR WATER, S=.001

Q	GROSS	FRY	JUVENILE	ADULT	SPAWNING	INCUBATE
500.	58844.	10.83	12.43	9.72	2.38	33.33
600.	60441.	10.06	11.35	7.26	2.99	32.41
700.	61852.	9.31	10.69	6.92	3.08	31.82
740.	62375.	9.10	10.51	6.91	3.00	31.65
800.	63121.	8.88	10.39	6.42	2.73	31.33
900.	64278.	8.66	10.51	5.40	2.03	30.81
1000.	62753.	8.58	10.52	4.77	1.51	31.07
1100.	63703.	8.35	10.76	4.13	1.35	30.59
1200.	64506.	8.05	11.05	3.53	1.22	30.04
1300.	65193.	7.54	11.17	3.30	1.08	29.45
1400.	65793.	6.89	11.12	3.39	.92	28.88
1500.	68963.	6.33	11.39	3.54	.71	27.47

Q VS. AVAILABLE HABITAT AREA PER 1000 FEET OF STREAM FOR RAINBOW TROUT, CLEAR WATER, S=.001

Q	FRY	JUVENILE	ADULT	SPAWNING	INCUBATE
20.00	1269.88	1649.33	4687.90	12.19	1952.60
30.00	1474.24	1940.99	6755.48	12.96	2990.89
40.00	1973.99	2497.17	8158.80	12.83	3913.81
50.00	2160.23	3165.12	9433.26	42.61	4708.61
60.00	2265.96	3554.91	10983.62	89.55	5405.84
80.00	2100.61	3685.55	13963.11	136.74	6514.02
100.00	1826.97	3458.02	16293.96	148.11	7362.74
150.00	1360.51	3033.05	20554.56	148.99	8793.10
200.00	1268.71	2835.34	21725.54	246.31	9450.17
250.00	1344.90	2678.94	21221.26	477.06	9988.50
300.00	1272.48	2716.27	20551.64	555.78	10561.69
400.00	1708.93	3034.46	16807.26	974.49	11714.69

Q VS. AVAILABLE HABITAT AREA AS A PERCENTAGE OF THE GROSS AREA FOR RAINBOW TROUT, CLEAR WATER, S=.001

Q	GROSS	FRY	JUVENILE	ADULT	SPAWNING	INCUBATE
20.	30962.	4.10	5.33	15.14	.04	6.31
30.	34703.	4.25	5.59	19.47	.04	8.62
40.	36512.	5.41	6.84	22.35	.04	10.72
50.	37857.	5.71	8.36	24.92	.11	12.44
60.	39190.	5.78	9.07	28.03	.23	13.79
80.	41640.	5.04	8.85	33.53	.33	15.64
100.	43296.	4.22	7.99	37.63	.34	17.01
150.	46662.	2.92	6.50	44.05	.32	18.84
200.	49255.	2.58	5.76	44.11	.50	19.19
250.	51394.	2.62	5.21	41.29	.93	19.44
300.	54241.	2.35	5.01	37.89	1.02	19.47
400.	56992.	3.00	5.32	29.49	1.71	20.55

Q VS. AVAILABLE HABITAT AREA PER 1000 FEET OF STREAM FOR RAINBOW TROUT, CLEAR WATER, S=.001

Q	FRY	JUVENILE	ADULT	SPAWNING	INCUBATE
500.00	2006.93	3511.71	12903.41	1168.19	11715.44
600.00	2035.06	3258.68	10875.88	1015.90	11312.48
700.00	1848.18	3120.16	9410.79	843.66	10913.19
740.00	1925.62	3148.74	9167.77	789.85	10791.74
800.00	2065.28	3175.87	8854.53	731.50	10607.99
900.00	2059.88	3269.03	8442.37	707.49	10379.26
1000.00	1964.06	3316.86	7761.31	671.52	10175.76
1100.00	1909.03	3279.94	7604.00	645.63	10121.36
1200.00	1815.68	3255.48	7714.15	614.38	10098.66
1300.00	1693.94	3130.39	7743.00	566.91	10096.70
1400.00	1539.39	2876.37	7767.82	518.95	10071.38
1500.00	1427.79	2720.03	8226.06	488.73	10151.18

Q VS. AVAILABLE HABITAT AREA AS A PERCENTAGE OF THE GROSS AREA FOR RAINBOW TROUT, CLEAR WATER, S=.001

Q	GROSS	FRY	JUVENILE	ADULT	SPAWNING	INCUBATE
500.	58844.	3.41	5.97	21.93	1.99	19.91
600.	60441.	3.37	5.39	17.99	1.68	18.72
700.	61852.	2.99	5.04	15.22	1.36	17.64
740.	62375.	3.09	5.05	14.70	1.27	17.30
800.	63121.	3.27	5.03	14.03	1.16	16.81
900.	64278.	3.20	5.09	13.13	1.10	16.15
1000.	62753.	3.13	5.29	12.37	1.07	16.22
1100.	63703.	3.00	5.15	11.94	1.01	15.89
1200.	64506.	2.81	5.05	11.96	.95	15.66
1300.	65193.	2.60	4.80	11.88	.87	15.49
1400.	65793.	2.34	4.37	11.81	.79	15.31
1500.	68963.	2.07	3.94	11.93	.71	14.72

Q VS. AVAILABLE HABITAT AREA PER 1000 FEET OF STREAM FOR CUTTHROAT TROUT,CLEAR WATER S=.001

Q	FRY	JUVENILE	ADULTS	SPAWNING	INCUBATE
20.00	3972.32	5121.44	3720.83	23.10	2088.08
30.00	4223.24	6291.94	4825.81	10.23	3048.62
40.00	4408.49	7044.42	5979.41	71.31	3870.81
50.00	4629.95	7808.30	6748.24	191.39	4585.69
60.00	5030.31	8847.15	7896.18	205.89	5203.08
80.00	5515.79	10239.17	9931.23	169.48	6112.50
100.00	5630.04	10995.12	12526.39	79.77	6820.22
150.00	4548.37	10414.14	14235.83	70.36	8068.54
200.00	3603.81	8722.59	13096.90	391.34	8745.24
250.00	3048.22	7914.05	12827.72	464.69	9270.88
300.00	2559.42	6835.87	11565.47	472.95	9887.55
400.00	2201.83	4845.49	8250.03	787.15	11052.98

Q VS. AVAILABLE HABITAT AREA AS A PERCENTAGE OF THE GROSS AREA FOR CUTTHROAT TROUT,CLEAR WATER S=.001

Q	GROSS	FRY	JUVENILE	ADULTS	SPAWNING	INCUBATE
20.	30962.	12.83	16.54	12.02	.07	6.74
30.	34703.	12.17	18.13	13.91	.03	8.78
40.	36512.	12.07	19.29	16.38	.20	10.60
50.	37857.	12.23	20.63	17.83	.51	12.11
60.	39190.	12.84	22.58	20.15	.53	13.28
80.	41640.	13.25	24.59	23.85	.41	14.68
100.	43296.	13.00	25.40	28.93	.18	15.75
150.	46662.	9.75	22.32	30.51	.15	17.29
200.	49255.	7.32	17.71	26.59	.79	17.75
250.	51394.	5.93	15.40	24.96	.90	18.04
300.	54241.	4.72	12.60	21.32	.87	18.23
400.	56992.	3.86	8.50	14.48	1.38	19.39

Q VS. AVAILABLE HABITAT AREA PER 1000 FEET OF STREAM FOR CUTTHROAT TROUT,CLEAR WATER S=.001

Q	FRY	JUVENILE	ADULTS	SPAWNING	INCUBATE
500.00	2369.85	4608.16	6253.23	855.31	11108.87
600.00	2539.20	5208.21	6273.69	731.30	10833.89
700.00	2748.64	5205.42	6742.68	775.52	10540.08
740.00	2866.65	5107.31	6760.58	795.84	10460.92
800.00	2995.25	4959.15	6723.54	750.28	10354.84
900.00	3294.62	4996.59	6291.60	575.09	10166.54
1000.00	3420.11	4948.54	6032.49	465.49	9926.35
1100.00	3682.67	5202.77	5620.58	311.27	9842.94
1200.00	3968.42	5568.48	5381.73	273.61	9800.10
1300.00	4253.90	6089.06	5420.35	209.25	9768.95
1400.00	4397.52	6788.42	6405.96	134.67	9713.65
1500.00	4429.76	7591.55	7432.61	70.18	9797.36

Q VS. AVAILABLE HABITAT AREA AS A PERCENTAGE OF THE GROSS AREA FOR CUTTHROAT TROUT,CLEAR WATER S=.001

Q	GROSS	FRY	JUVENILE	ADULTS	SPAWNING	INCUBATE
500.	58844.	4.03	7.83	10.63	1.45	18.88
600.	60441.	4.20	8.62	10.38	1.21	17.92
700.	61852.	4.44	8.42	10.90	1.25	17.04
740.	62375.	4.60	8.19	10.84	1.28	16.77
800.	63121.	4.75	7.86	10.65	1.19	16.40
900.	64278.	5.13	7.77	9.79	.89	15.82
1000.	62753.	5.45	7.89	9.61	.74	15.82
1100.	63703.	5.78	8.17	8.82	.49	15.45
1200.	64506.	6.15	8.63	8.34	.42	15.19
1300.	65193.	6.53	9.34	8.31	.32	14.98
1400.	65793.	6.68	10.32	9.74	.20	14.76
1500.	68963.	6.42	11.01	10.78	.10	14.21