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Cumulative Effects of Micro-Hydro Development on the Fisheries of the Swan River Drainage, Montana

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CUMULATIVE EFFECTS OF MICRO-HYDRO DEVELOPMENT ON THE FISHERIES OF THE SWAN RIVER DRAINAGE, MONTANA

First Annual Progress Report

(covering field season July-November 1982)

submitted By

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Cumulative Impact Study of Micro-Hydro
Sites, Swan River, Montana

1983

EXECUTIVE SUMMARY

This fisheries study is to determine the potential cumulative biological and economic effects of 20 small or "micro"-hydro-electric facilities (less than 5 megawatts) proposed to to be constructed on tributaries to the Swan River, a 1738 square kilometer (671 square mile) drainage located in northwestern Montana. The study addresses portions of measure 1204 (b) (2) of the Northwest Power Planning Council's Columbia River Basin Fish and Wildlife Program.

Aerial pre-surveys conducted during 1982 identified 102 stream reaches that may support fish populations in the Swan drainage between Swan and Lindbergh lakes. These reaches were located in 49 tributary streams and constituted 416 kilometers (258 miles) of potential fish habitat. Construction of all proposed small hydro projects would divert water from 54 kilometers (34 miles) or about 13 percent of the tributary system. Only two of the 20 proposed hydro sites did not support trout populations and most were populated by migratory bull trout and westslope cutthroat trout.

Potential cumulative habitat losses that could result from dewatering of all proposed project areas were predicted using a stream reach classification scheme involving stream gradient, drainage area, and fish population data. Preliminary results of this "worst case" analysis indicate that 23, 19 and 6 percent of the high quality rearing habitat for cutthroat, bull, and brook trout respectively would be lost.

A total of 206 bull trout redds were located in a survey of 196 kilometers (122 miles) of potential spawning habitat located in 27 tributaries. Ninety-five percent of the bull trout redds were found in 25 kilometers (16 miles) of habitat located in six tributaries. Twenty percent of all bull trout redds were located in diversion reaches of proposed microhydro projects, indicating that dewatering of project areas could result in a substantial cumulative loss of spawning habitat used by migratory bull trout.

A significant negative relationship ($r = 0.75$, $p<.01$) was observed between juvenile bull trout density and percentage of fine material (<2mm) in the streambed. This indicated that increased sediment delivery to tributaries resulting from construction of micro-hydro projects may have a negative influence on rearing capacity of the drainage for juvenile bull trout. The relationships between land use activities, streambed composition and trout density will continue to be investigated in cooperation with the US. Forest Service in an attempt to develop models to predict the cumulative effect of strearnbed sedimentation.

The replicability of habitat surveys between crews was tested on two streams. Average between-rew measurement errors were lowest (less than 16% error) for overhead cover, substrate, channel debris, and several width and depth measurements. Between-crew errors were unacceptably large (more than 40% error) for stream features, instream cover, and channel stability.

Fish population estimation techniques were compared in sections of five streams. Two-sample removal estimates and mark-recapture estimates produced similar results and were more effective techniques than the three-sample removal or snorkel count methods. The two-sample removal method was recommended for routine use because less time was required to obtain a reliable population estimate.

ACKNOWLEDGEMENTS

We would like to express our appreciation to the many people who contributed to the successful completion of the first year of this study. Steve Bartelt, Pat Clancey and Lani Horris served ably as field crew leaders. They shared the responsibility of collecting much of the field data and compiling it in the office. Bob Braund, Bill Swaney, John Wachsmuth, and Steve Glutting assisted in field activities. Fred Nelson of the Montana Department of Fish, Wildlife and Parks in Bozeman assisted in the WEtP instream flow analysis and Alex Hoar of the U.S. Fish and Wildlife Service in Billings aided in the IFGI instream flow analysis. Tom Berggren of the Bonneville Power Administration provided helpful statistical advice, particularly in regards to fish population estimation. Personnelatthe Swan River Youth Forest Camp provided a location and assisted in establishing our field camp.

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INTRODUCTION

Interest in developing small scale hydropower generating facilities in the Pacific Northwest has increased dramatically since the passage of the Public Utility Regulatory Policies Act (PURPA) by Congress in 1978. Section 210 of PURPA created a strong incentive to develop such resources by mandating that utilities must offer to purchase power generated by small hydro facilities at a favorable price known as "full avoided cost". Full avoided cost is generally known as the amount it would cost the utility would pay to generate or acquire electricity at present day costs. Private entrepreneurs have responded to this guaranteed market and favorable price schedule by proposing hundreds of small hydro projects throughout the region.

Preliminary permits have been issued by the Federal Energy Regulatory Commission (FERC) to study the feasibility of at least 50 proposed small scale or "micro" hydro sites in northwestern Montana during the past two years. Twenty of these preliminary permits have been issued for projects proposed in the Swan River drainage at or above Swan Lake. Preliminary FERC permits allow an 18 month to three-year period for the prospective developer to collect environmental, engineering, and economic data to be used in applying for a license (or licensing exemption) to develop the project, At the time of this writing, these projects were still in the preliminary study phase. No applications for licenses or licensing exemptions had been filed with the FERC.

The development of micro-hydra projects on tributaries to the Swan River could impact trout populations within diversion reaches as well as in areas downstream from project sites. Possible fisheries impacts due to project construction and operation could result from a host of factors including stream dewatering, temperature changes, increased siltation rates, turbine entrainment, and the creation cf barriers to upstream migration. The construction of a number of micro-hydro facilities in a single river drainage like the Swan could have significant cumulative effects on both resident and migratory fish species.

The Northwest Power Planning Council (1982) recognized the potentially harmful cumulative effects of small hydro development (less than 5 megawatts) on fish and wildlife resources within individual river basins. In accordance, the Council recommended Measures 1204 (b) (1) and (2) to insure that the potential cumulative effects of existing and proposed multiple hydroelectric developments within a single river drainage are addressed by federal project operators and regulators, and encourage the development of criteria and methods to use in assessing cumulative fisheries impacts of multiple hydroelectric developments.

This study addresses portions of Measure 1204 (b) (2) in the Columbia River Basin Fish and Wildlife Program. The purpose of the study is to design, develop and apply methods to determine the potential cumulative effects on both migratory and non-migratory trout populations of the Swan River drainage that could result from extensive small-scale or "micro" hydro development (less than 5 megawatts). These impacts will be expressed in both biological and economic terms.

The study is divided into two phases as &scribed in the study proposal by Graham and Leathe (1982). The first phase involves the collection of a drainage-wide data base consisting of fish population and stream habitat data to be used in the develop ment of cumulative impact models and criteria to be used in evaluating potential fisheries impacts of proposed micro-hydro developments. Methods used for determining fish population size, instream flow needs, and stream habitat quality will also be described and evaluated. The second study phase involves the collection of economic and use data to enable the results of the biological assessment to be expressed in economic terms.

This study is timely since very little published information exists that describes the potential fisheries impacts of small high-head hydroelectric facilities. Further, we are not aware of any studies to date that have considered the potential cumulative biological and economic effects of a number of these hydro projects on the fishery resource of a river drainage. The methods developed for determining fish population size, recommended minimum flow, and physical habitat characteristics have for the most part been developed and applied to 11.76 low gradient rivers and streams. Such methods have infrequently been used and evaluted in high gradient reaches of small mountain streams which are typical locations for micro-hydro sites.

This document summarizes the results of the first field season. The conclusions drawn must be considered tentative as they may be revised during the study period as more data becomes available relative to impact analysis. This report will focus primarily on evaluation of methods of estimating fish populations, instream flow, and the physical habitat characteristics of proposed micro-hydro sites as well as preliminary description of impact models and criteria. Cooperation of study efforts with the Flathead National Forest in regards to sediment production modeling has been initiated through an associated study also funded by the BPA. This coordination will allow all forms of land disturbance to be incorporated into the cumulative effects model(s).

DESCRIPTION OF STUDY AREA

The Swan River is located in northwestern Montana, west of the Continental Divide (Figure 1). The river flows north from its headwaters in the Mission and Swan mountains and enters Flathead Lake near the town of Bigfork Montana which is 23 river kilometers downstream from Swan Lake. Several peaks in the Mission (to the west) and Swan (to the east) mountain ranges exceed 2,743

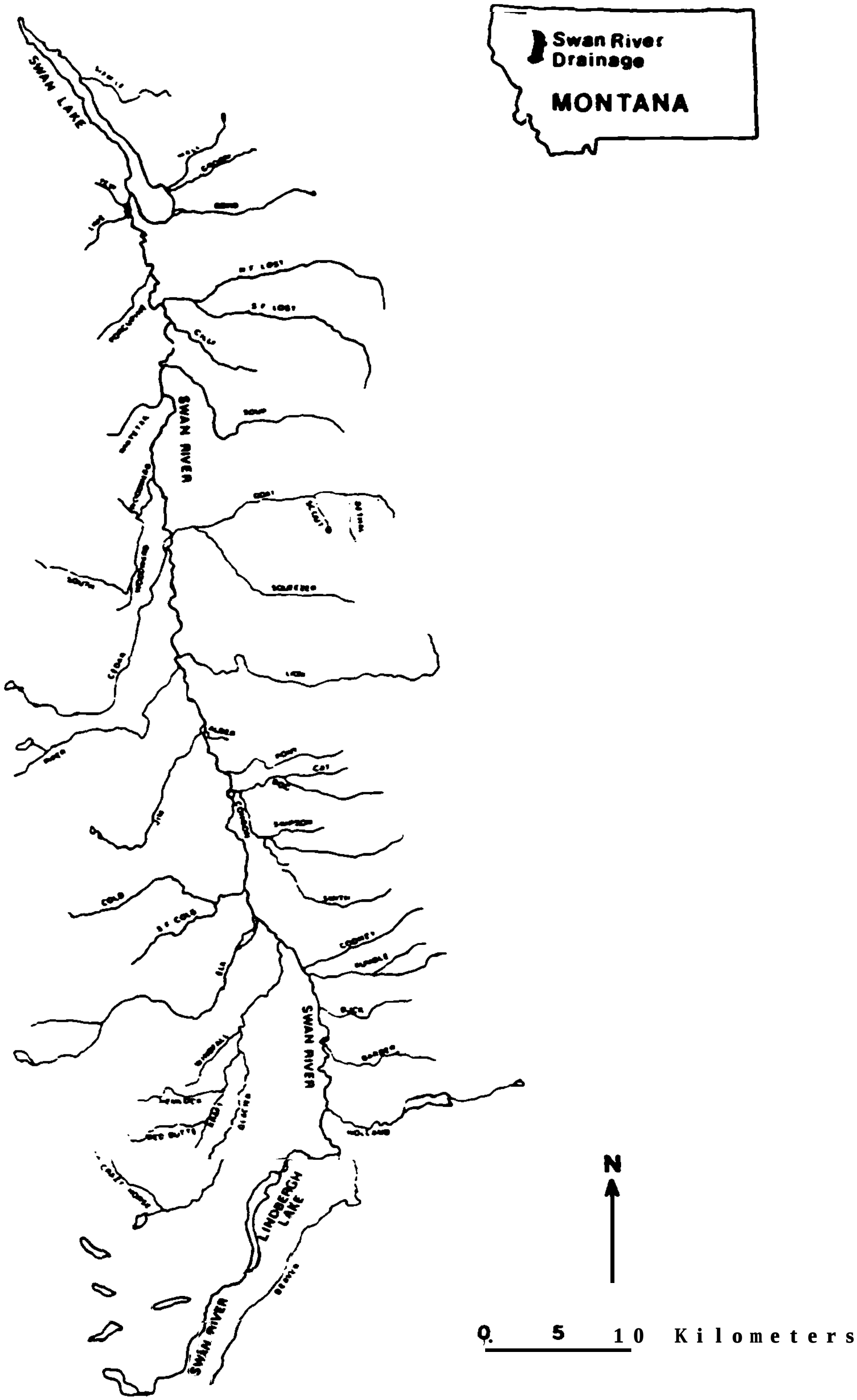

Figure 1. Map of the Swan River drainage, Montana.

meters (9,000 feet). The Flathead River drains Flathead Lake and flows into the Clark Fork River which eventually leaves Montana and enters the Pend Oreille River system in northern Idaho.

The Swan River has a drainage area of 1,738 km^2 measured at the outlet of Swan Lake and flows through a heavily forested glaciated valley that is relatively flat and five to ten kilometers wide. The average drop for the 83 km river section between Lindbergh and Swan lakes is 4.5 meters per kilometer which is equivalent to a 0.4 percent gradient. Lateral channel movement and subsequent bank erosion in this river section have resulted in the presence of excessive amounts of channel debris and numerous log jams which limit recreational floating use.

The Swan River has mean annual flows of 165 cfs at a gauging point 6.4 km downstream from Lindbergh Lake and 1,168 cfs immediately downstream from Swan Lake (USGS 1981). Peak discharges typically occur in June (Figure 2) and are determined by the amount and rate of snowmelt in this mountainous watershed. Streamflows in the largest tributaries Woodward, Elk, Glacier, and Lion creeks) ranged between 19 and 69 cfs during September of 1982. Peak spring flows in the river and tributaries are usually 15 to 30 times larger than low flows measured in the fall.

The Swan River meanders for about 20 kilometers below Swan Lake before entering a high gradient canyon section immediately upstream from Flathead Lake. The high gradient section is very popular among whitewater floating enthusiasts and is also the site of a 4.1 megawatt hydroelectric facility constructed in 1902 and currently operated by the Pacific Power and Light Company (Graham et al. 1981). A fish ladder was constructed to enable migratory westslope cutthroat trout, bull trout and kokanee salmon from Flathead Lake to pass over the 12-foot high concrete diversion dam and access the Swan River drainage. However, this ladder did not become operative to migrating trout until 1959 (Domrose 1974). Historical use of the passage facility has been limited (Graham et al.1981), probably because of design flaws and the length of time required to render to the ladder operative. Consequently, the fisheries within the Swan drainage can be considered to be isolated from the remainder of the Flathead drainage.

Numerous high mountain lakes and valley lakes and potholes are scattered throughout the Swan River drainage (Figure 1). swan Lake is the largest and has a surface area of 1,085 hectares. Lindbergh Lake (294 hectares) and Holland Lake (165 hectares) are the two other major lakes and are located in the upper portion of the drainage. The fisheries of these two subdrainages are assumed to be independent from the remainder of the Swan drainage. Since there were no proposed micro-hydro sites in these drainages they will not be considered in the cumulative fisheries impact assessment.

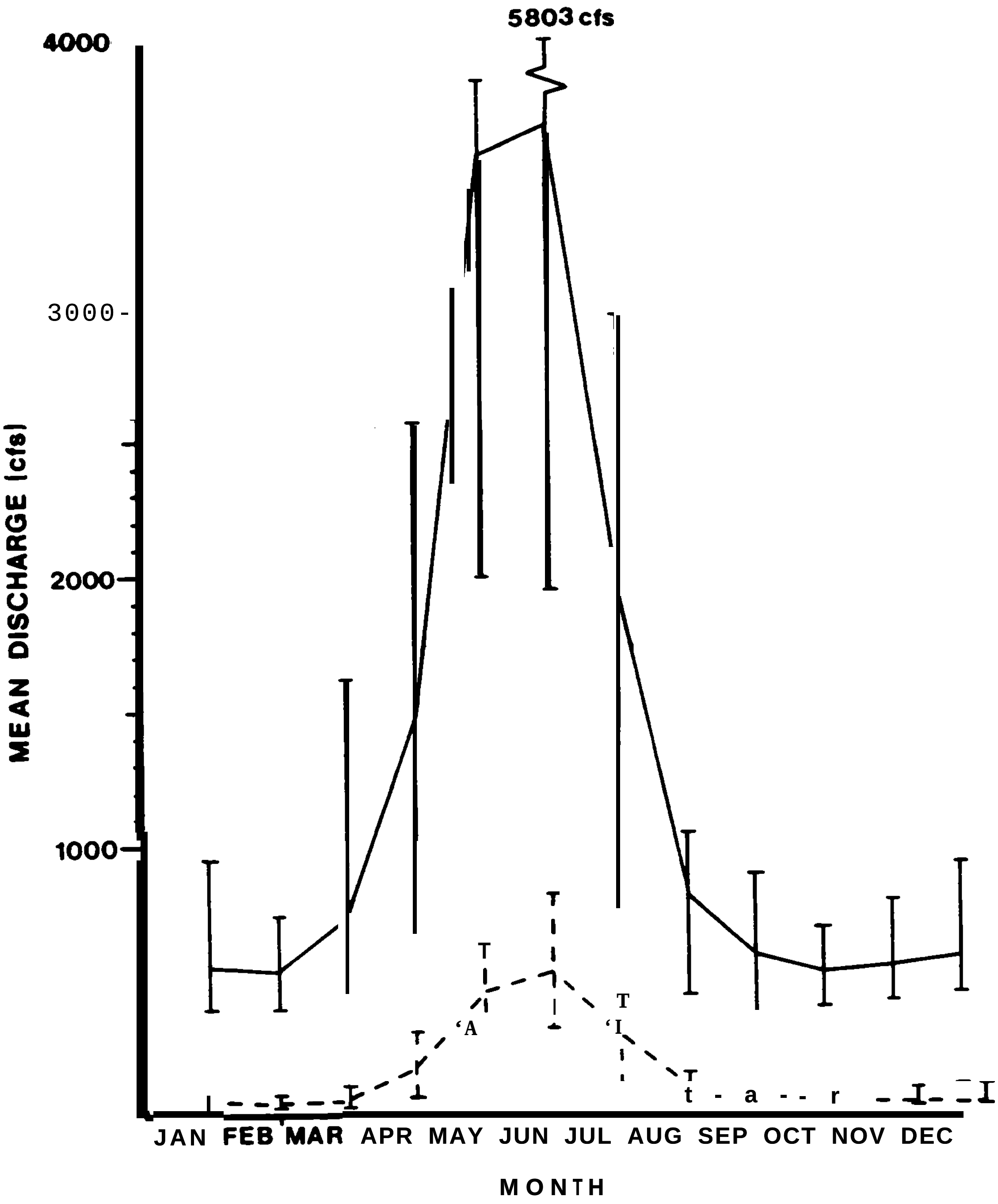

Figure 2. Average and ranges of mean monthly flows in the Swan River immediately below Swan Lake (solid line) and at Condon (broken line) for the years 1972 through 1982.

All of the proposed micro-hydro facilities in the Swan River drainage are high head projects located on mountain streams (Figure 3) and have installed capacities ranging between 100 kilowatts and 1.5 megawatts (Table 1). Water would be diverted into 12 to 20 inch diameter penstocks by the construction of three-foot high diversion dams in the stream. The diverted water would be transported thousands of feet downstream in penstocks and released through high-pressure jets which would drive an impulse turbine (Pelton wheel) to generate electricity at the powerhouse before being returned to the stream. Stream gradients within the proposed diversion reaches ranged between three and 21 percent.

Tributaries to the Swan River support resident and migratory populations of westslope cutthroat trout (Salmo clarki lewisi) and bull trout (Salvelinus confluentus) as well as resident brook trout (Salvelinus fontinalis) and small numbers of rainbow trout (Salmo gairdneri). The Swan River is classified as having a Class II fishery resource (high priority) with tributary streams rated Class III (substantial fisheries resource value) by the Montana Department of Fish, Wildlife and Parks and the U.S. Fish and Wildlife Service (1980).

Cutthroat and bull trout in the Swan River system display life history traits similar to those described in detail by Graham et al. (1980) and Fraley et al. (1981) for the upper Flathead River system. This includes migration of adult fish from Swan Lake to spawning tributaries in the Swan River drainage where juvenile fish spend two to three years prior to emigrating downstream to the lake where maturity is attained. Cutthroat trout densities are usually largest in smaller, higher elevation streams in the Swan drainage (Domrose 1974, and this study). The westslope cutthroat trout is currently listed as a fish species of "special" concern in Montana because of its limited distribution in the state, plus the fact that it has been extirpated from a large portion of its native range in the interior regions of the United States (Holton 1980; Behnke 1979).

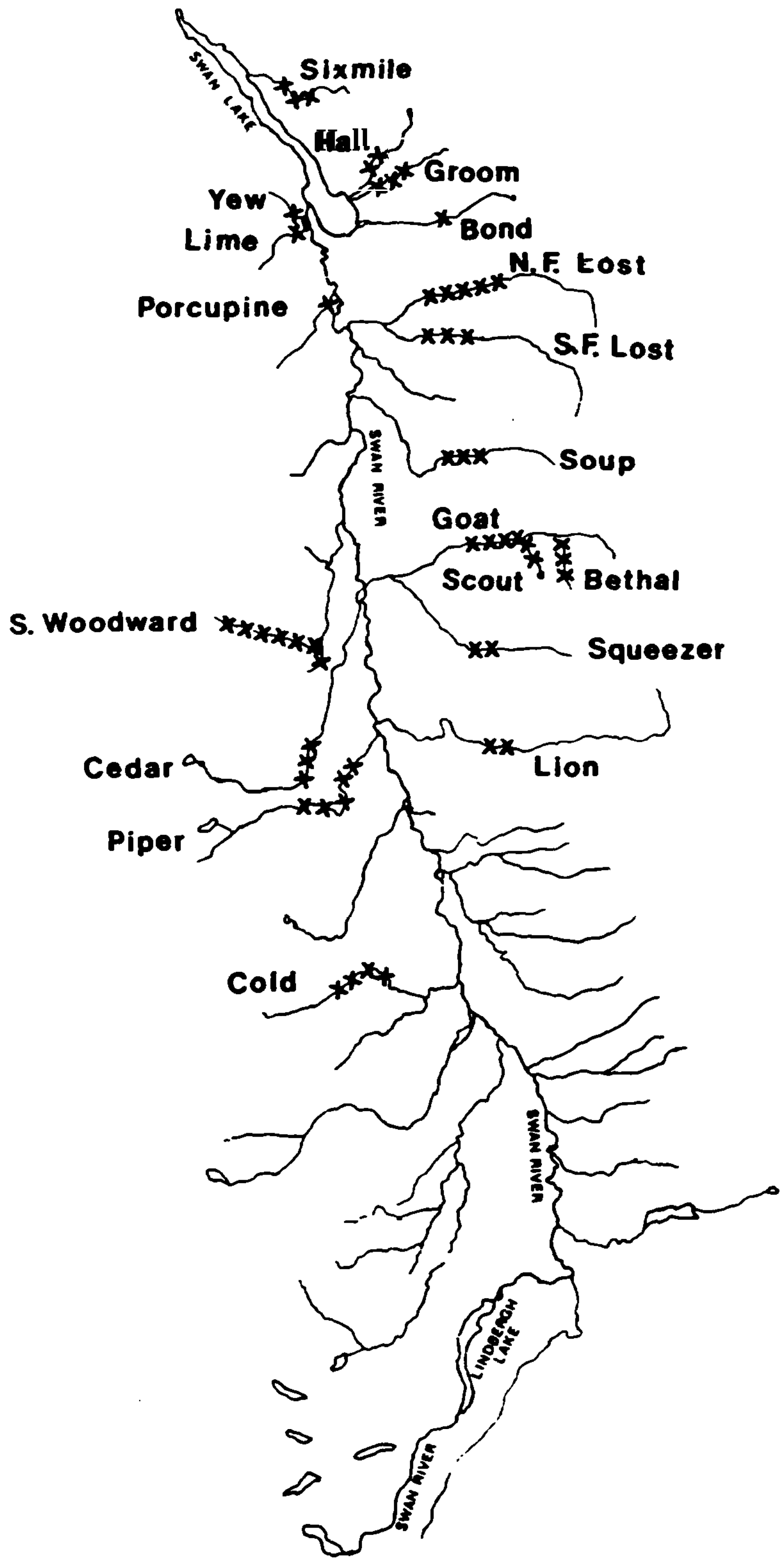

Figure 3. Map of the Swan River drainage, Montana depicting proposed locations of 20 micro-hydro sites.

Table 1. Information pertaining to proposed micro-hydroelectric facilities in the Swan River drainage, Montana.

Project No.	Project name	Length of penstock (ft)	Diameter of penstock (in)	Installed capacity (kw)
5093*	Yew Creek	4,200	12	100
5095*	Bond Creek	3,700	20	300
5097*	Lime Creek	3,400	12	100
5098	Hall Creek	5,100	16	400
5105*	Sixmile Creek	3,900	16	150
5517	Scout Creek	5,000	not stated	407
5518	Goat Creek	12,200	NS	430
5519	S. Fork Lost Creek	11,800	NS	291
5520	Soup Creek	8,200	NS	377
5521*	Porcupine Creek	4,800	14	259
5522	Bethal Creek	9,200	12	263
5523*	No. Fork Lost Creek	13,250	12	184
5524	Piper Creek	17,000	14	624
5525	Cedar Creek	11,500	12	377
5556	So. Fork Woodward Cr.	18,000	16	1411
5557	Squeezer Creek	7,000	16	604
5558	Cold Creek	16,000	16	929
5559	Lion Creek	5,000	16	352
5733	Groom Creek	7,600	14	376
5783*	Trib. to S. Fork Woodward Creek	2,750	16	2-100

* Preliminary permit surrendered.

METHODS

HABITAT ANALYSIS

Standard USGS topographic maps (1:24,000 scale) were used to delineate stream order, potential reach breaks, and reach drainage areas in tributaries to the Swan River at or above Swan Lake. Tributary streams were divided into one-kilometer sections (beginning at their mouths) to facilitate the location of important stream features and ground survey sites.

Aerial pre-surveys were conducted for all streams in the drainage using a helicopter technique similar to that developed in British Columbia (Chamber lin 1981, 1980a) and which has been uss in other parts of the Flathead River Basin (Fraley and Graham 1981). Each survey was initiated at the downstream end of the tributary. A trained observer narrated key habitat characteristics, locations of stream features, and the locations of potential reach breaks into a tape recorder while the helicopter proceeded upstream. Reaches were defined as being stream sections having "a repetitious sequence of physical processes and habitat types" (Chamber lin 1981). Thus, changes in channel gradient and stream habitat uniformity were important factors considered in defining reach boundaries.

Each aerial stream survey was terminated when streamflow and channel gradient thresholds MO.5 cfs and/or >25% gradient) deemed necessary to support resident trout were exceeded. It is likely that the kilometer of potential trout habitat was overestimated using the minimum flow criterion since aeriai surveys were conducted during mid-Septenber. Available hydrologic information indicate that these creeks were at base flow during this time, however, absolute minimum flows occur during late winter. January flows during 1983 in several streams in the Swan drainage were generally 30 to 45 percent lower than flows measured in mid-September (U.S. Geological Survey, unpublished data).

Final reach boundaries, significant habitat features (log jams, waterfalls, wasted banks, etc.), and recommended ground survey sections were located as the helicopter proceeded downstream to the mouth of the stream. Approximately 25 kilometers of stream length were surveyed per hour using this technique involving both up and downstream passes. Tape recorded information was later transcribed onto off ice forms (Table 2).

Stream habitat surveys were conducted by crews of two technicians on one or two kilometer-long sections of selected reaches. A number of habitat variables including feature (pool, riffle, run, pocket water, cascade), f lcw character, debr is presence and stability, and channel splitting were measured at each of 40 sampling stations selected by random pacing Intesive measurements of other habitat variables were made at 15 of the 40 randomly selected stations using a line transect method similar to

Table 2. Aerial survey form utilized in reach delineation in the Swan River drainaoe during 1982.

AERIAL STREAM SURVEY REPORT

Stream: ________________ Reach No.: ________ Stream km: ____ to ____

Date: ________________ Time: ________ Observer: ________

REACH CHARACTERISTICS

Upper bank slope: ________ % Mass wasting potential: ________

Valley flat width: ________ (m) Stream pattern: ________

Flow characteristics: ________ Channel width: ________ (m)

Channel debris: ________ Floodplain debris: ________

Fish migration barriers -

Types: Locations:

Spawning potential:

Bull trout: ________ Cutthroat: ________

Portion of reach that should be surveyed for bull trout redds:

Km ________ to ________

General comments

Substrate: ________ Canopy: ________

Trout cover: ________ D-90: ________

Suggested habitat survey section: Km ________ to ________.

Important stream features (Description and location):

that described by Herrington and Dunham (1967) and modified by Shepard and Graham (19831. Measured variables included water depth, dominant and subdominant substrate types, instream and overhead trout cover, wetted width, channel width, substrate embeddedness substrate composition and D-90. Channel stability was evaluated for the reach using a procedure employed by the Northern Region of the U.S. Forest Service (U.S. Department of Agriculture, Forest Service 1975). Streamflow was measured at one point within the survey section using either a Gurley Type AA or a pygmy current meter. A typical habitat. survey for one reach required two man-days of field effort. Detailed stream reach and fish population data was then entered into the Montana Interagency Stream Fishery Data Storage System described by Holton et al. (1981) .

FISH POPULATIONS

Tributaries

In most cases, fish population estimates were made in representative sections between 100 and 150 meters in length within each reach. These sections were blocked on the downstream end using quarter-inch mesh nylon netting or hardware cloth. Upstream ends were block& by either a natural waterfall or by a block net.

Populations of fish larger than 75 millimters total length were estimated using either a two-sample method, or occasionally a three-sample method described by Seber (1973). Each sample consisted of an intensive downstream pass through the blocknetted section using electrofishing gear. Most electrofishing was conducted by a crew of two technicians (one shocker, one netter) using a Coffelt BP-1C gas-powered backpack electrofishing unit. Accessible large (i.e. more than 15 cfs) streams were electrofished using bank electrofishing gear consisting of a llO-volt Homelite generator and a Coffelt WP-2C variable voltage pulsator. Fish collected during each pass were held until the completion of the experiment.

Two-sample estimates were considered to be adequate for the dominant species within each section when the following criteria were met:

$\hat{p} \geq .50$ and $\hat{N} \geq 50$, or
$\hat{p} \geq .60$ and $\hat{N} \leq 50$,

where $\hat{p}$ was the probability of capture and $\hat{N}$ was the fish population estimate. The probability of capture ($\hat{p}$) was calculated as:

$$\hat{p} = \frac{\text{“1} - \text{“2}}{\text{“1}}$$

where: n_1 = number of fish 275 mm total length in first sample, and
n_2 = number of fish 275 mm total length in second sample.

When one of the above criteria was met the resulting calculated confidence intervals were considered to be satisfactory based on the rough guide provided by equation 7.33 in Seber (1973). When neither of the above criteria were met, a third electrofishing pass was made and a three-sample estimate was calculated using Equations 7.24 and 7.23 in Seber (1973). Three-sample estimates were necessitated in only two of the 29 mult-sample estimates made on tributary streams during 1982. Variance of two-sample estimates was calculated using Equation 7.30 in Seber (1973).

Mark-recapture population estimates were obtained for two large tributary reaches having flows of 35 and 69 cfs. A single marking run was made in a 300 to 350 m long section that was not blocked on either end Marked fish were distributed by hand throughout the section and allowed to redistribute for three full days prior to the recapture run. Small fish (100 to 225 mm) were tagged with Floy FTF-69 fingerling tags which were attached to the fishes' body at the base of the first anterior ray of the dorsal fin. Larger fish were tagged with Floy anchor tags.

Population size ($\hat{N}$) and variance ($\hat{V}[\hat{N}]$) for mark-recapture estimates were calculated according to Seber (1973).

$$N = \frac{(n_1 + 1)(n_2 + 1)}{m_2 + 1} - 1 \text{ and}$$

$$i(N) = \frac{(n_1 + 1)(n_2 + 1)(n_1 - m_2)(n_2 - m_2)}{(m_2 + 1)^2 (m_2 + 2)}$$

where: n_1 = number of fish $\geq$75 mm total length marked,
$n2$ = number of fish $\geq$75 mm total length in the recapture sample, and
m^2 = number of marked fish in the recapture sample.

Swan River

Fish population estimates were attempted in three sections of the Swan River during the fall of 1982. The most upstream section was 457 meters in length and was located immediateiy below the outlet of Cygnet Lake. Two marking runs were made using electrofishing gear carried ir a small boat. Marked fish were distributed by hand throughout the section and allowed five full days to redistribute prıcr to the single recapture run. The population estimate was calculated for fish larger than 75 mm total length as described above.

A six-kilometer section of the mid-Swan River lying between the Salmon Prairie and Piper Creek bridges was also electrofished to determine fish population levels. A total of six complete and two partial marking runs were made during October. Two recapture runs were made in early November after allowing a 12-day period for redistribution of marked fish throughout the section.

A four kilometer section of the Swan River lying between Lost Creek and the Porcupine Creek bridge immediately upstream from Swan Lake was electrofished in mid-October. Population estimation efforts on this section were abandoned since only four trout were captured. This inefficiency was probably related to the sluggish nature of the river and the presence of numerous large, deep pools in this section.

Methods Comparison

Various fish population estimation techniques were compared in 90 to 120 m long blocknetted sections of five creeks to evaluate the effectiveness of the two-sample method and to explore the possibility of employing snorkel counts to estimate fish abundance. In a given section, two downstream electrofishing passes were made using a gas-powered backpack electrofishing unit after an upstream snorkel count was made by each of two observers the previous day. A two-sample estimate was calculated from this information and the fish were marked and redistributed throughout the section. After a three or four day redistribution period, a single downstream pass was made in the section and this information was used to calculate the mark-recapture estimate as well as the three-sample estimate using formulae described above.

FLOWGAUGING

Continuous water level recorders were installed within or near the diversion areas of proposed micro-hydro sites on South Fork Lost, Soup, Squeezer, Lion, Piper and Cold creeks during November. Vertical four-inch diameter slotted steel standpipes were driven approximately two feet into streambeds using a semi-portable tripod-type pile driver powered by an electric motor. Standpipes were capped with a threaded iron platform upon which Belfort Type FW-1 water level recorders were mounted. The platform and recorders were covered with a locking steel cap and staff gauges were attached to the standpipes. The Squeezer Creek recorder was installed by attaching the standpipe to a bridge abutment.

INSTREAM FLOW MEASUREMENTS

The amount of reserved instream flow required to preserve existing fish populations was determined using the wetted perimeter method described by Nelson (198Oa). Three or more cross-section transects were established in riffle and run features within the proposed diversion areas of 12 creeks. Water surface elevations at each transect were measured relative to an establ ished benchmark at medium, medium-low, and low flow using a Lietz C3A automatic engineers level and a stadia rod. Streamflow measurements were made at one or more transects within each creek at each flow level using either a Gurley Type AA or a Pygmy current meter depending upon current velocity and discharge.

Streamflow information was used to develop a logarithmic stage-discharge relationship for each transect. Channel profile measurements were made at each transect during the low-flow period. Stage, discharge, and channel profile data were input into the WETP computer program described by Nelson (1980a) on the Montana State University computer system. This program calculated stage discharge relationships which were used in conjunction with channel profile data to yield predictions of wetted perimeter at various flows. Wetted perimeter is defined as the amount of stream bottom (in feet) in contact with water at a given cross-sectional transect.

Wetted perimeter-discharge curves were also produced using the IFG1 computer program described by Milhous (1978). This approach involved the use of the Manning equation which was calibrated using measurements of discharge, water level, and the channel profile at each transect at a single flow. The IFGl computer program was accessed at the US. Fish and Wildlife Service regional office in Billings, Montana.

Composite wetted perimeter-discharge curves for each creek were then plotted and visually examined for the presence of inflection points (Figure 4). In this example (Figure 4), it can be seen that the amount of wetted stream bottom in riffles diminishes rapidly as streamflow drops below the inflection point flow of six cubic feet per second. Riffle areas serve as key production areas for the aquatic invertebrates upon which stream dwelling trout feed, hence accelerated dewatering of these areas would decrease the food supply and thus lower the carrying capacity for trout (Nelson 198Ob, Montana Department Fish, Wildlife and Parks 1981). Losses in wetted riffle area may also result in decreases in bank cover and living space for trout.

The wetted perimeter method has been validated in several southwestern Montana trout rivers (Nelson 198Ob). Preliminary results from an ongoing study indicate that it accurately reflected losses in rainbow trout carrying capacity in a small stream (C. Randolph, Montana Cooperative Fisheries Research Unit, personal communication).

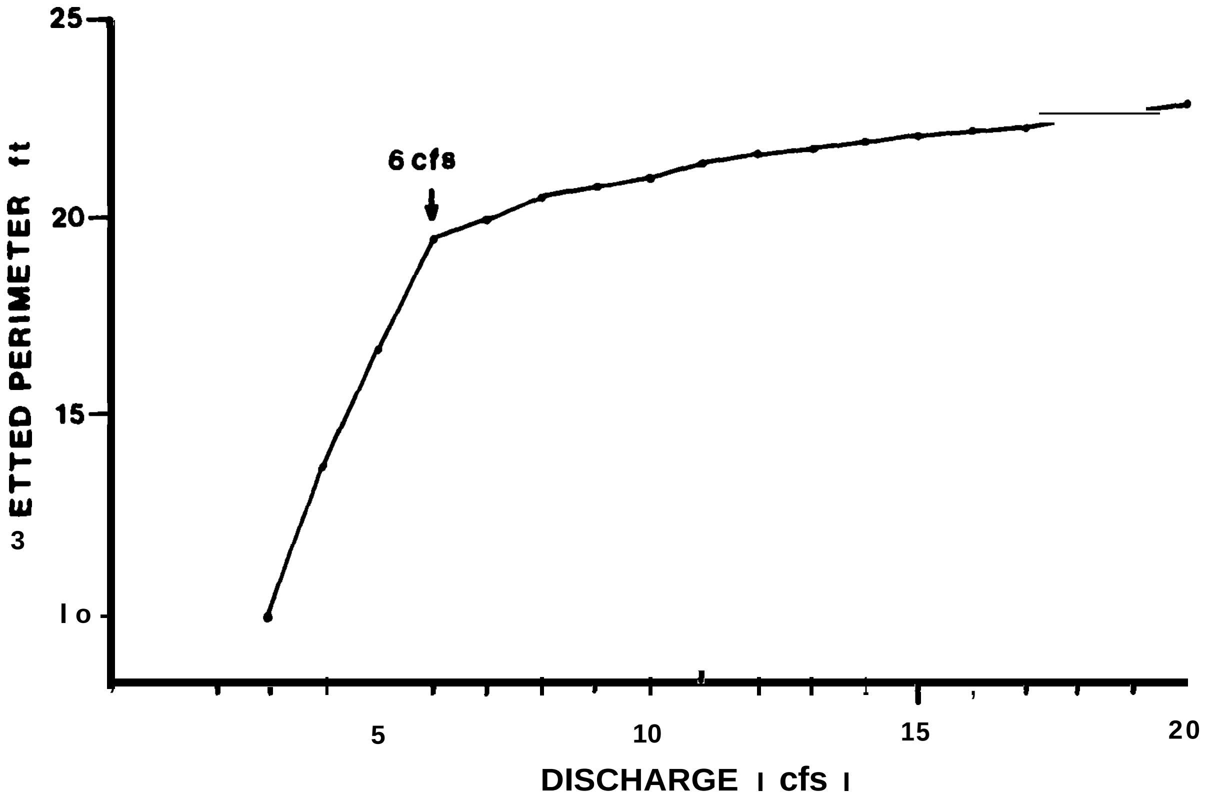

Figure 4. Example wetted perimeter versus discharge relationship for a composite of three riffle cross-section transects within the proposed diversion area of a micro-hydro site on the South Fork of Lost Creek.

BULL TROUT SPAWNING SURVEY

A drainage-wide bull trout spawning site census was conducted during October. Preliminary surveys on Squeezer Creek, an important spawning tributary, indicated that bull trout spawning activity was confined to the month of September. Ground survey crews walked a total of 196 km (122 miles) of potential spawning habitat located in 27 tributaries.

Potential bull trout spawning habitat was identified using aerial reach survey information. Graham et al. (1981) reported that most bull trout spawnirq in the upper Flathead River drainage occurred in large higher-order stream reaches having low gradients (usually less than three percent) and relatively high percentages of preferred gravel and cobble spawning substrate.

Bull trout redds were for the most part easily recognized by trained survey personnel since these large fish (usually a minimum of 400 mm total length at maturity) spawn during the low flow period when water clarity is excellent. Spawning activity results in the formation of a depression or pit at the upstream end of the redd. At the downstream end of the redd a pile of "clean" or recently disturbed loosely packed gravel covers the incubating eggs as described byReiser andBjornn (1979).

Fctential bull trout redds were recorded by survey personnel as either definite, probable or possible using criteria described by Shepard et al. (1982). Only those redds classified as "definite" or "probable"were included in the final count.

RESULTS AND DISCUSSION

METHODS ANALYSIS

One of the objectives of this study was to evaluate methods used for determining physical habitat characteristics, fish population size, and reserved instream flow at proposed micro-hydro sites. Such an evaluation is important in identifying advantages and shortcomings of various methods and recommending procedures for determining potential impacts of micro-hydro developments.

Habitat Analysis

The replicability of habitat surveys was assessed by two *crews* surveying the same section on two tributary streams during early September (Table 3). Channel gradients in the sections of Lion and Cold creeks were 5.7 and 5.0 percent and discharges were 14 and 38 cfs, respectively. Average between-creek measurement errors were calculated according to Beamish and Fournier (1981).

For the two streams combined, the average between-crew measurement errors were lowest for total overhead cover (overall average error 6%) and for four width and depth measurements (nine percent). Relatively low combined between-crew average measurement errors were also noted for five substrate variables (16%) and for channel debris (12%). Excessively high combined average measurement errors were observed for stream features (71%). irstream cover (42%), and channel stability (42%). Measurement errors were likely due to observer bias and differences in transect locations.

Attempts will be made during the next field season to minimize between-crew errors in measurements of stream feature, instream cover, and channel stability. Much of the error in determining stream feature is probably related to observer bias and high channel gradients. Error in channel stability rating was due to observer bias and can be improved by more intensive training of survey personnel.

Instream cover is widely considered to be an important factor influencing trout density in streams (Fraley and Graham 1981, Binns and Eiserman 1979, Reiser and Bjornn 1979). Unfortunately, instream cover is also one of the most difficult habitat variables to estimate and is subject to a large degree of observer bias. Attempts will be made to improve cover estimates made by survey crews in the Swan drainage by establishing more rigorous criteria for defininginstream cover than those employed during 1982.

Comparisons between habitat survey crews will be expanded during 1983. Habitat surveys may be repeated for reaches surveyed during 1982 using refined techniques. More intensive measurements of substrate embeddedness, pool frequency and pool habitat will also be made.

Table 3. Comparison of physical habitat measurements made by two survey crews on two tributaries to the Swan River during early September, 1982.

Parameters	Lion Creek Crew 1	Lion Creek Crew 2	Lion Creek Mean error	Cold Creek Crew 1	Cold Creek Crew 2	Cold Creek Mean error
Channel Measurements						
Wetted width (m)	8.0	8.5	6%	8.9	8.4	6%
Channel width (m)	12.8	13.0	2%	11.4	11.7	3%
Mean depth (cm)	29	33	13%	32	29	10%
Maximum depth (cm)	145	120	19%	80	89	11%
Channel splitting (%)	0	23	200%	3	10	108%
Channel stability rating	56	94	51%	46	65	34%
Substrate Measurements						
Fines (%)	9	13	36%	5	5	0%
Gravel (%)	38	34	11%	20	19	5%
Cobble (%)	26	32	21%	30	44	38%
Boulder-bedrock (%)	27	21	25%	44	32	32%
D-90 (cm)	80	83	4%	81	85	5%
Habitat Measurements						
Feature:						
Pool (%)	30	15	100%	10	15	40%
Riffle-run (%)	36	65	57%	26	62	82%
Pocketwater-cascade(%)	34	20	52%	64	23	94%
Cover:						
Instream cover (%)	47	29	47%	62	43	36%
(logs & debris)	(53%)	(34%)	(43%)	(58)	(33)	(55%)
(boulders)	(47%)	(66%)	(34%)	(42)	(67)	(46%)
Overhead cover:						
within 1 meter(%)	---	22	---	48	42	13%
undercut bank (%)	---	25	---	33	23	36%
Total overhead(%)	91	87	4%	57	63	10%
Debris (%)	68	60	13%	83	75	10%
Stable debris (%)	89	83	7%	73	90	21%

Fish Population Estimation

Comparisons of the snorkeling and electrofishing techniques for estimating population size for fish larger than 75 mm total length are presented in Table 4. In general, snorkelers observed only about 50 percent of the total fish populations in these blocknetted sections of streams. Shepard and Graham (1983) also found that snorkel counts usually underestimated trout abundance in tributaries to the Flathead River. They concluded that the accuracy of snorkel estimates was influenced fish species, water temperature and clarity, streamflow, and trout cover.

The inaccuracy of snorkel counts may have been due to habitat complexity (turbulent water, large substrate and shallow depth) in these small, high gradient streams. For unknown reasons, the efficiency of snorkel counts did not improve in the relatively low-qradient meadow section of Squeezer Creek. Three-sample and mark-recapture estimates were not obtained for the Squeezer Creek section due to difficulties encountered in maintaining block nets.

There was good agreement between two-sample and mark-recapture estimates (Table 4). Calculated 95 percent confidence intervals overlapped in all five instances where these two methods were compared. Two- and three-sample confidence intervals overlapped in four of five cases, however, overlap occurred in only two of the five comparisons made between three-sample and mark-recapture techniques. These results indicated that the assumption of a constant probability of capture was not satisfied beyond two samples, therefore the three-sample method was the least effective of the electrofishing techniques tested. The two-sample method is recommended since it was comparable to mark-recapture estimates, but required less field time to complete.

Instream Flow

Wetted perimeter-discharge relationships generated using the WETP computer model (Nelson 198Oa) are presented for proposed hydro site diversion areas on Soup and Choat creeks in Figures 5 and 6. Recommended minimum flows determined using this method were similar or higher than base level streamflows observed during the fall and winter of 1982 (Figures 5 and 6). This suggests that natural fall and winter streamflows may already be below optimum levels for supporting trout. Withdrawal of water for power production during these months could have detrimental effects on overwintering trout populations by reducing available habitat via dewatering and ice build-up.

The WETP and IFGl computer models produced composite wetted perimeter-discharge curves having similar shapes (Appendix Al through A6). With the exception of Lion Creek (Appendix A3), both methods yielded similar predictions of wetted perimeter at various flows. However, the shape of the curves is considered to be more important than the accuracy of wetted perimeter estimates because

Table 4. Summary of fish population estimation methods comparisons conducted on tributaries to the Swan River, Montana durina the period July throuqh September, 1982. Ninety-five percent confidence intervals are in parentheses and all estimates are for fish 75 mm and larger.

Creek	Flow (cfs)	Gradient (%)	Species	Snorkel estimate #1	Snorkel estimate #2	Two-sample estimate	Three-sample estimate	Mark-recapture estimate
Groom	5.6	7.1	Cutthroat	24	18	51(±1)	42(±4)	53(±4)
SOUP	6.9	11.6	Cutthroat	17	27	69(±5)	77(±5)	71(±5)
S.F. Lost	13.3	4.4	Cutthroat	5	8	12(±2)	10(±1)	13(±1)
			Bull trout	6	6	24(±5)	18(±18)	39(±10)
Bethal	6.7	9.9	Bull trout	10	5	21(±1)	22(±1)	22(±1)
Squeezer	19.3	2.5	Bull trout	11	13	27(±6)	---	---
			Brook trout	14	12	24(±6)	---	---

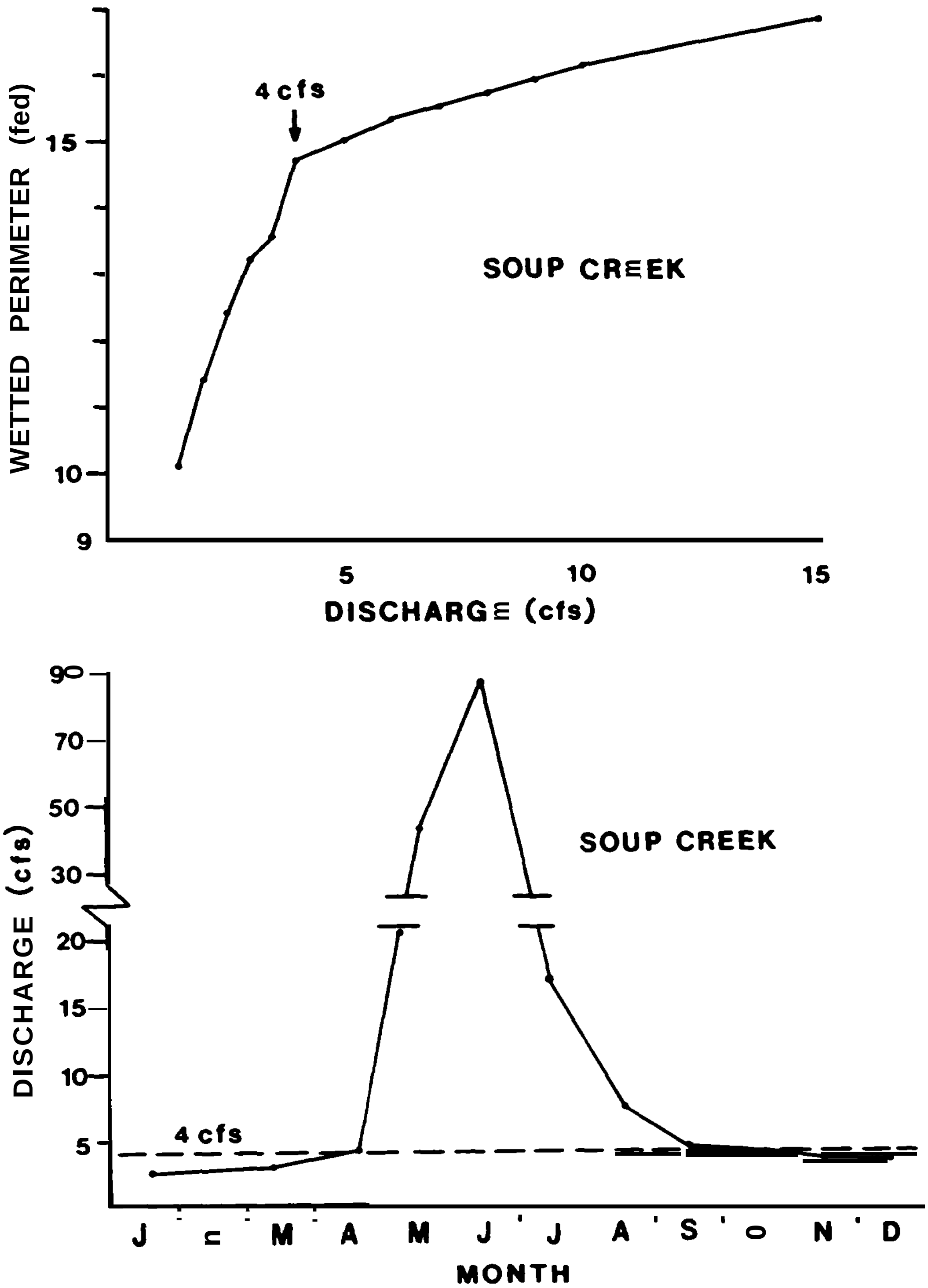

Figure 5. Wetted perimeter versus discharge for a composite of three riffle cross-sections in Soup Creek (upper diagram), and annual hydrograph for 1982 from unpublished U.S. Geological Survey data (lower diagram).

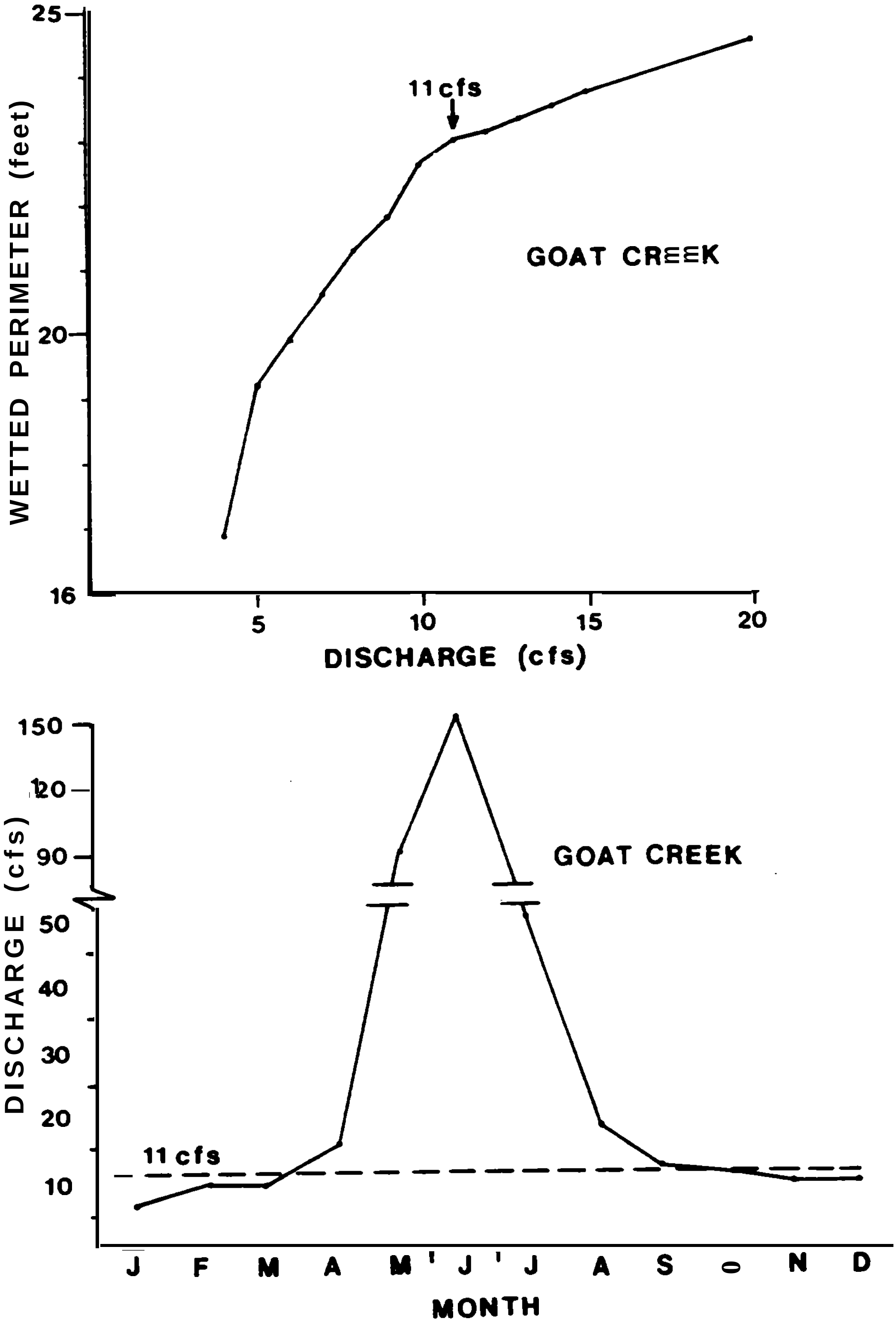

Figure 6. Wetted perimeter versus discharge for a composite of four riffle cross-sections in Goat Creek (upper diagram), and annual hydrograph for 1982 from unpublished vs Geological Survey data (lower diagram).

the method relies on the selection of one or more inflection points that reflect relative rates of loss of wetted perimeter. Reasons for the discrepancy observed between the two methods for Lion Creek are unknown

Inflection points were usually more easily recognized on curves generated by the WETP model (Appendix Al through A6). The IFGl method frequently produced smooth curves having less well defined inflection points. Using the curves generated by the WETP model as standards, it did not appear that calibration of the IFGl program at medium flow or at low flow made a consistent difference. In some cases, the IFGl model calibrated at medium flow produced curves that more closely approximated those generated by the WETP model, while in other cases, the reverse was true.

If the wetted perimeter approach is to be used in determining reserved minimum streamflow for small hydro sites, it is recommended that a method that utilizes stage-discharge data be employed. Single-flow techniques that use the Manning equation to predict discharge at alternate stages are subject to substantial error. This error results from the assumptions that the channel roughness coefficient (Manning's “n") and energy slope remain constant at all flows. Bovee and Milhous (1978) demonstrated that these "constants" (especially the roughness coefficient) vary considerably with flow and can cause substantial error in stage-discharge predict ions.

The WETP model uses only stage-discharge information whereas the IFG1 model can use either single-flow (Manning equation) information or stage-discharge data. The WETP model was simpler to use because it calculated average wetted perimeter at various discharges for each transect as well as for a composite of all transects. Using the IFGl method, composite data had to be derived by interpreting and averaging plotted transect data. As was mentioned previously, inflection points were more easily recognized on perimeter-discharge curves generated by the WETP model.

Elydraulic simulation methods involving field stage-discharge measurements can be more time consuming than single-flow simulation techniques. This can be especially true if discharge data for the stream in question is not available from a streamflow monitoring agency such as the U.S. Geological Survey. Increased field effort is probably justified by the resultant increased accuracy of stage-discharge predictions and the ability to predict wetted perimeter over a wider range of flows. Bovee and Milhous (1978) recommended that single-flow simulation models be extrapolated between 0.4 and 2.5 times the calibration flow. Stage-discharge relationships based on two or more points can be extrapolated to 40 percent of the lowest calibration flow and 2.5 times the highest calibration flow (Bovee and Milhous 1978). Stage discharge information should be gathered at three or more different flows at each transect. This approach reduces the potential for error that could result from the construction of stage-discharge relationships based on only one or two calibration flows.

Results of our 1982 studies indicate that the location of crass-section transects in riffle and runs adequately represented the habitat of proposed hydro sites. Riffles, runs and pocket water comprised an average of 76 percent of stream habitat within the 20 proposed diversion areas. Composite wetted perimeter-discharge curves generated for all habitat types (riffle, pool, runs) were similar to those generated for only riffle cross-sections in a southwest Montana stream (Montana Department Fish, Wildlife and Parks 1981). However, the degree of similarity between riffle and composite feature wetted perimeter-discharge relationships was not as high for rivers in Southwest Montana (Nelson 1980b).

CUMULATIVE IMPACT DATA BASE

A sound data base that describes existing resources is an essential element to the process of analyzing the potential cumulative effects of development activities within a drainage basin. In order to construct this data base, the tributaries to the Swan River and Swan Lake were divided into reaches by aerial survey. Selected reaches were then ground surveyed to describe existing fish populations, physic.1 habitat, and spawning use by migratory bull trout.

Aerial Survey and Hydro Site Locations

Helicopter survey crews identified 102 tributary reaches that may support trout populations. These reaches comprised approximately 416 kilometers (258 miles) of potential fish habitat and were located on 49 named tributaries located between the out lets of Swan and Lindbergh lakes.

Tributary reaches were divided into gradient and drainage area categories to enable subsampling from the 102 reaches to develop a drainage-wide data base. The stream reaches identified during the aerial survey were grouped into 10 gradient-drainage area categories although two of these categories contained only one or two reaches (Table 5). Numbers of reaches and stream kilometers were relatively evenly distributed among gradient-drainage area classes with the exception that few large medium-gradient (3.1 to 6%) and medium-high (6.1 to 13%) gradient reaches were found. The largest number of reaches (22 reaches) were small medium-high gradient drainage segments (Table 5) whereas the most stream kilometers (92 km) were found in large low gradient (0 to 3%) reaches (Table 6).

Project description information that accompanied notices of issuance of preliminary permits from the Federal Energy Regulatory Commission was used to pinpoint proposed locations of the 20

Table 5. Number of reaches in various gradient-drainage area categories in the Swan River drainage. Percent of total number of reaches is in parentheses.

Gradient	Drainage area (km²)		
	0-20	21-50	>50
0-3%	5 (4%)	14 (14%)	15 (15%)
3.1-6%	12 (12%)	12(12%)	2 (2%)
6.1-13%	22 (22%)	6 (5%)	1 (1%)
>13%	13 (13%)	----	----

Table 6. Number of stream kilometers having potential fish habitat in various gradient-drainage area categories in the Swan River drainage. Percent of total is in parentheses.

Gradient	Drainage area (km²)		
	0-20	21-50	>50
0-3%	14.5 (4%)	50.5 (12%)	92.2(22%)
3.1-6%	46.6 (11%)	55.6 (13%)	13.8(3%)
6.1-13%	66.8 (16%)	33.6 (8%)	1.5(1%)
>13%	40.5 (10%)	----	----

proposed micro-hydro sites in the Swan drainage. Based on this information it was found that about 54 kilometers of tributary streams would be diverted for power production if all sites were developed. This equates to about 13 percent of the total length of the tributary system. Most of the proposed diversions would be located in medium and medium-high gradient reaches (Table 7). More than 20 percent of the stream reaches within certain gradient-drainage area classes would be diverted.

Fish Populations

Tributaries

Fish population estimates were made during 1982 within the diversion areas of all 20 proposed micro-hydro sites. Cutthroat trout or bull trout were the dominant species in 12 of these areas, while brook trout dominated at only two sites (Table 8). The remainder of the sites were either populated by relatively even numbers of two or more species or did not support fish.

Fish were absent in project areas on Lime and Scout creeks. These were small, high gradient streams (Table 8). The upper portions of two other proposed projects (Bethal and Lion creeks) were also devoid of fish due to the presence of steep cascade subsections that prevent upstream fish movement. Sculpins were present at many of the project locations but their numbers were not estimated. Rainbow trout were observed in small numbers at a few sites.

Fish population estimates were also obtained in eleven stream reaches that did not contain proposed micro-hydro sites. Most of these sections were located in the downstream ends of large tributaries. Gradients in these sections were less than those within proposed hydro sites and most ranged between C.6 and 2.5 percent (Table 9). Fish species composition in these reaches was different than for the hydro sites. Cutthroat trout or bull trout were clearly dominant in only three reaches while brook trout were the dominant species in six reaches (Table 9). Small populations of rainbow trout were found in two reaches.

Populations of trout in tributary streams were comprised mostly of small resident fish or of juvenile populations of migratory species. Cutthroat trout populations were comprised mostly of fish less than 250 millimeters total length (Appendix A7). It is not known if these populations were entirely comprised of resident fish or if some of these were juvenile adfluvial fish that will emigrate to Swan Lake to attain maturity. Upstream and downstream fish traps will be installed in selected streams during the spring of 1983 to determine use by migratory cutthroat trout.

Tributary populations of bull trout and brook trout were also comprised of small fish, less than 250 millimeters total length (Appendix A8 and A9). While brook trout are considered to be a

Table 7. Number of stream kilometers within various gradient-drainage area categories that would be diverted by 20 proposed micro-hydro developments in the Swan River drainage. Percentage of total available kilometers within each category is in parentheses.

	Drainage area		
Gradient	O-20	21-50	>50
o - x	----	2.0 (4%)	0.1 (<1%)
3.1-6%	0.2 (<1%)	15.5 (282)	2.6 (19%)
6.1-13%	9.3 (142)	18.0 (54%)	----
>13%	4.7 (12%)	----	----

Table 8. Fish species composition and population density within the diversion areas of 20 proposed micro-hydro sites located on tributaries to the Swan River, Montana.

				No. fish ≥75mm per 100 m			
Creek	Date	Flow (cfs)	Gradient (%)	Cutthroat trout	Bull trout	Brook trout	Rainbow trout
Bethal (upper)	8/16/82		8.5		No Fish		
(lower)	8/26/82	6.7	8.5	---	25	---	---
Bond	8/13/82	10	15.5	28	---	33	---
Cedar	9/2/82	3.5	10.8	92	---	---	---
Cold	9/9/82	31	6.0	P[c]	90	P[c]	---
Goat	8/9/82	15	4.8	---	16	---	---
Groom[a]	9/1/82	5.6	11.7	57	---	---	---
Hall	8/19/82	4.7	15.2	46	---	8	---
Lime	8/24/82	0.7	15.8		No Fish		
Lion (upper)	9/14/82	---	5.6		No Fish		
(lower)	9/15/82	14	5.6	---	36	---	---
N. Fork Lost	8/31/82	12	4.3	34	33	P	---
Piper	8/26/82	16	6.9	22	---	26	---
Porcupine	8/23/82	7.2	8.7	---	---	48	---
Scout	9/13/82	2.7	21.9		No Fish		
Sixmile	8/17/82	4.9	3.3	41	---	---	---
Soup[a]	8/26/82	6.9	11.5	84	---	---	---
S. Fork Lost[b]	9/2/82	13	3.0	9	31	---	---
S. Woodward	9/1/82	8.9	11.4	4	---	---	---
Squeezer	8/11/82	19	10.3	4	40	---	---
Trib to S. Woodward	9/7/82	7.9	11.2	P	---	P	---
Yew	8/24/82	1.8	9.6	21	---	P	---

a/ Average of two estimates.
b/ Average of three estimates.
c/ "P" indicates species was present but in small numbers.

Table 9. Fish species composition and population density within selected stream reaches not proposed for micro-hydro development in the Swan River drainaqe, Montana.

Creek	Date	Flow (cfs)	Gradient (%)	No. fish ≥75 mm per 100 m			
				Cutthroat trout	Bull trout	Brook trout	Rainbow trout
Cedar	9/30/82	16	1.4	11	P[a/]	69	---
Cold	9/22/82	28	0.6	---	P	19	---
Elk	10/18/82	35	1.7	---	85	7	4
Glacier	9/28/82	22	1.3	---	---	28	6
Goat	9/30/82	9.7	1.6	4	16	11	---
Lion	9/20/82	19	0.9	1	33	13	---
Piper	9/20/82	6.9	1.8	8	16	61	P
South Fork Cold	9/15/82	2.5	8.9	50	---	---	---
South Fork Cold	9/21/82	3.4	1.6	P	P	51	---
Squeezer	9/9/82	---	2.5	---	27	58	---
Woodward	9/27/82	69	1.0	P	30	189	P

a/ "P" indicates species was present but in small numbers.

resident species, several of the streams electrofished during 1982 are known to be important spawning and rearing areas for migratory bull trout from Swan Lake. Large bull trout ranging between 410 and 610 millimeters in total length were captured in electrofishing sections in Squeezer and Gold creeks during August and September. These fish were in spawning condition and were probably upstream migrants from Swan Lake.

Channel gradient appeared to be an important factor influencing fish species composition (Figure 7). Brook trout were present in all gradient classes but maximum densities were found in low gradient (0-3%) reaches. Bull trout were most abundant in reaches having gradients of six percent or less. Cutthroat trout were the dominant species in reaches where channel gradient exceeded six percent.

Patterns of spatial segregation among juvenile steelhead trout and cutthroat trout similar to what we observed between cutthroat and brook trout in the Swan drainage have been &served in other river drainages (Hanson 1977, Hartman and Gill 1968). This indicates that cutthroat trout inhabit less accessible headwater areas due to an inability to compete successfully with other species in downstream areas. Griffith (1972) reported that brook trout predominated in low gradient (less than three or four percent) downstream sections while cutthroat trout were more abundant in higher gradient. upstream sections of several Idaho streams.

Swan River

Fish population estimates were attempted in three sections of the Swan River between the outlet of Cygnet Lake (a small lake located immediately downstream from Lindbergh Lake) and Swan Lake. This was done to determine use of the Swan River by migratory cutthroat trout and bull trout. Portions of the North, Middle and South Forks of the Flathead River are believed to support significant populations of fluvial westslope cutthroat trout (Shepard et al. 1982, Fraley et al. 1981). These fish spawn and rear as juveniles in tributary streams prior to emigrating downstream into the rivers where maturity is attained. If a similar situation exists in the Swan drainage, impacts of proposed micro-hydro developments on spawning and rearing success of fluvial and adfluvial (migratory between streams and lakes) fish stocks in tributaries could have detrimental effects on downstream fisheries.

The upper section of the Swan River (below Cygnet Lake) contained small populations of rainbow and brook trout (Table 10). These populations were comprised of small fish, less than 280 mm in total length (Appendix A10 and A11), and estimates were calculated for fish 75 millimeters (total length) and larger. Lesser numbers of northern squawfish, mountain whitefish, longnose

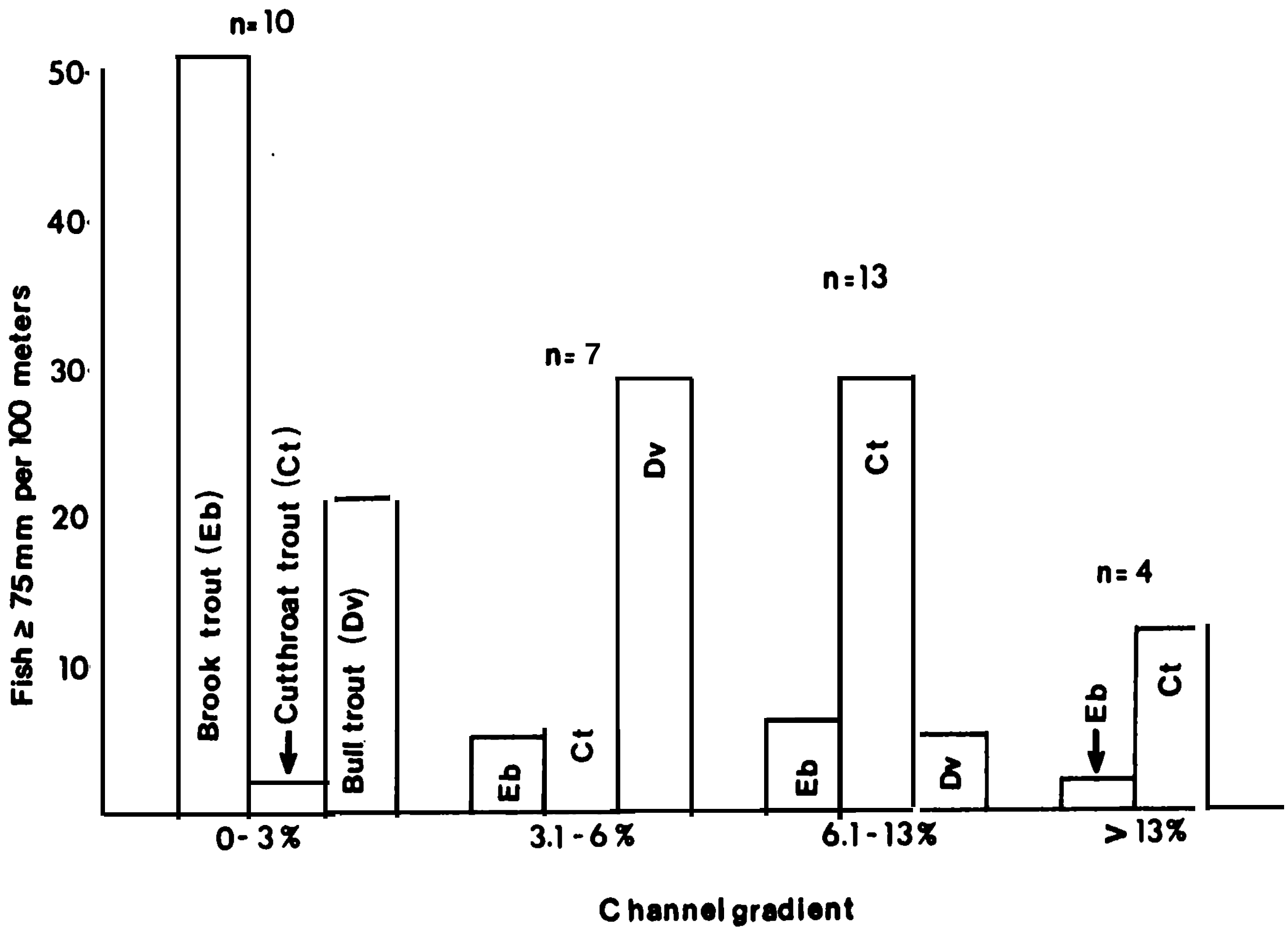

Figure 7. Population density (number of fish 75 mm and larger per 100 meters of stream) of brook, cutthroat and bull trout in relation to channel gradient in tributaries to the Swan River during 1982. Number of electrofishing sections (n) is indicated for each gradient class.

Table 10. Summary of electrofirhing results for two sections of the Swan River located between Cygnet Lake and Swan Lake.

	Fish per kilaneter			
River section	Rainbow trout	Brook trout	Bull trout	Mountain whitefish
Below Cygnet Lake				
Number Marked (≥75mm)	50	34	---	---
Number in recapture sample (≥75mm)	31	32	---	---
Nunber of recaptures (≥75mm)	16	12	---	---
Population estimate (±95% CI)	210 (±50)	190 (±60)	---	---
Salmon Prairie Bridge to Piper Creek Bridge				
Nunber marked (≥150mm)	149	85	25	186
Nunber in recaoture sample (≥150mm)	44	53	3	3
Number of recaptures (≥150mm)	5	4	0	0
Po(±95% iCI)estimate	(±129)	(±117)	---	---

suckers, cutthroat trout, largescale suckers and sculpins were also collected. No bull trout were found.

The fish population in the middle section of the Swan River between the Salmon Prairie and Piper Creek bridges comprised mostly of rainbow trout, brook trout, and mountain whitefish (Table 10). Due to low trout densities and gear inefficiency, the resultant population estimates for trout 150 millimeters and longer (total length) were bracketed within exceedingly large confidence limits. Rainbow trout ranged up to 502 millimeters (19.8 inches) and brook trout were up to 269 millimeters (10.6 inches; (Appendix Al2 and All). The bull trout collected were mostly juvenile fish with the exception of four mature individuals (526 to 576 mm) captured during October (Appendix Al0). These fish were likely returning to Swan Lake following their spawning migration to tributary streams.

Dense schools of mountain whitefish in spawning condition were frequently encountered in the Salmon Prairie to Piper Creek section during 'October, but not in November. Mature whitefish ranged between 225 and 347 millimeters total length (Appendix Al3). The small number of cutthroat trout collected (only two) indicated that a river-dwelling population did not exist in this section. Sculpins were commonly found and small numbers of long-nose suckers, largescale suckers and redside shiners were also collected.

Bull Trout Spawning

A total of 206 bull trout redds were located in the 196 km (122 miles) of potential spawning habitat surveyed in 27 tributaries. Redds were identified in eight tributaries although only one redd was located in each of two tributaries (Table 111. Ninety-five percent of the spawning activity occurred in 25 km (16 miles) of spawning habitat scattered in the North and South Forks of Lost Creek, Goat Creek, Squeezer Creek, Lion Creek and Elk Creek (Figure 8).

Maximum redd densities were found in Reach 2 of Elk Creek (7.8 redds per kilometer) and in Reach 1 of Lion Creek (6 redds per kilometer; Table 11). The most concentrated spawning use occurred in Elk Creek where 44 redds were found in a one-kilometer section. Only a single bull trout redd was located in Cold Creek despite the fact that this creek supported the largest population of juvenile bull trout observed in any stream during 1982 (Table 8). It is possible that spawning sites in Cold Creek were not recognized due to the turbulent nature of this high gradient large stream.

Table 11. Number and density of redds located within principal bull trout spawning areas in the Swan River drainage during 1982.

Creek	Reach	Gradient (%)	No. DV redds found	No. DV redds per kilometer
Cedar	01	1.4	1	0.1
Cold	02	5.0	1	0.1
Elk	02	1.8	56	7.8
Goat	01	0.5	1	0.8
	02	1.6	14	3.8
	03	4.6	18	3.3
Squeezer	01	2.5	41	6.3
Lion	01	0.9	60	6.0
	02	5.7	3	0.3
N.F. Lost	01	3.6	9	1.2
S.F. Lost	02	4.4	2	0.3

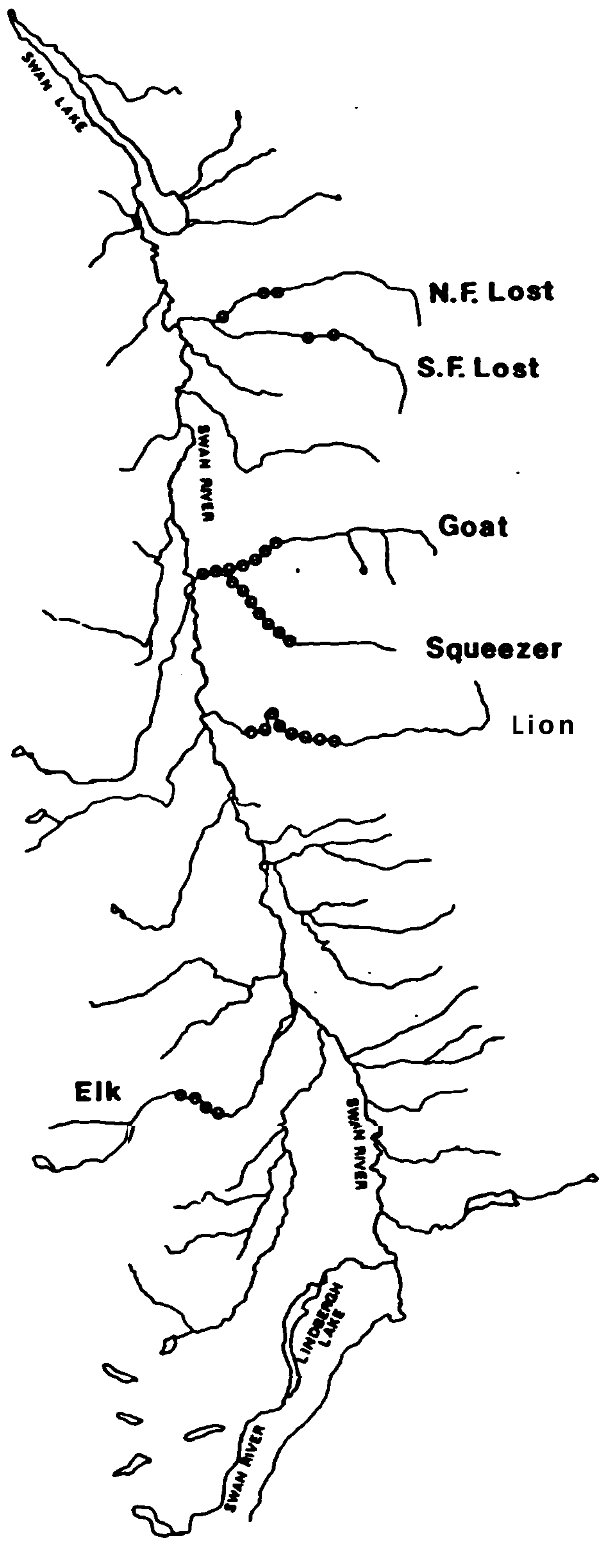

Figure 8. Location of the most intensively utilized bull trout spawning areas in the Swan River drainage during 1982. Circles indicate either individual redds or areas of concentrated use.

CUMULATIVE IMPACT ASSESSMENT

In the present analysis two main factors will be considered in the assessment of the potential cumulative fisheries impacts of full development of the 20 proposed micro-hydro sites in the Swan River drainage. Our cumulative impact assessment will focus on the potential impacts of dewatering of diversion areas and the introduction of fine sediment to tributary systems as a result of construction activities. These two factors pose the most recognizable and quantifiable threats to resident and migratory trout populations in tributaries to the Swan River. Additional factors such as water temperature may be added at a later date as the study progresses.

Dewatering

In the present analysis a "worst case" scenario was used to analyze the potential impacts of dewatering the diversion areas of the 20 proposed micro-hydro sites. This approach was simplistic because it was assumed that all diversion areas would be totally dewatered at some point in time which would result in the loss of fish populations within these sections. The establishment of minimum flow stipulations for each project by resource management agencies would likely prevent such a "worst case" scenario from occurring.

At the present time a more refined model that incorporates incremental losses in trout carrying capacity resulting from flow reductions cannot be constructed due to the lack of applicable experimental data. The relationship between carrying capacity for trout and amounts of wetted perimeter and/or weighted usable area needs to be quantified for one or more representative high-gradient mountain streams to provide such information.

Dewatering Impacts on Resident and Juvenile Trout

Accurate predictions of the potential amount of tributary fish habitat that would be lost through dewatering depend on the acquisition of a reliable data base. About one half of the necessary information needed for this data base for the Swan drainage was collected during 1982. Hence the following results must be considered to be preliminary and subject to change upon the acquisition of more data.

The first step in developing a model to determine the potential cumulative impact of the total dewatering of proposed diversion reaches involved partitioning all tributary reaches into channel gradient-drainage area categories. Channel gradient was used as a classifying variable because it appeared to influence fish species composition and abundance (Figure 7). Drainage area was used to classify reaches within gradient categories because we felt that it was a less biased estimator than stream order for describing stream size.

Stream order has been significantly correlated with trout densities in tributaries to the Flathead Rivers (Fraley and Graham 1981). However, methods for determining stream order vary and are subject to interpretational bias. For instance, Platts (1979) identified first-order streams as those which were the first recognizable drainages on two-inches-to--mile maps. Lotspeich and Platts (19821 redefined first order streams as those with "sufficient continuous flow to support aquatic biota at all seasons".

In the second step of model construction, fish population information was combined with data on reach length for tributary reaches surveyedduring1982. This informationwas used to determine the amount of stream habitat (in kilometers) sampled during 1982 within various gradient-drainage area categories that support4 none, low, medium and high density populations of resident and/or migratory trout. We then calculated the percentage of stream kilometers sampled during 1982 that supported various trout population levels within each gradient-drainage area category. An example of these calculations for cutthroat trout is presented in Table 12.

In the third step, the calculated percentages of stream kilometers supporting various trout population levels within each gradient-area category were multiplied by the total kilometers of available habitat within each category. The product of this operation was the predicted amount of stream habitat (in kilometers) within each gradient-area category that supported specified trout population levels.

The results of the third step of the dewatering model for cutthroat trout are presented in Table 13. The total of 36.2 kilometers of high quality cutthroat trout habitat and much of the medium quality habitat was found to occur in medium-high gradient (6.1 to 13%) reaches. These totals may be underestimated since a substantial amount of potential habitat (46.6 km) in small (0 to 20 km^2) medium-low gradient (3.1 to 6%) reaches has yet to be sampled (Table 12).

The final step of the model involves the determination of the amount of trout habitat of varying quality that occurred in potential hydro-site diversion areas. The results for the cutthroat model indicate that 23 percent of the high quality cutthroattrouthabitat in the Swan drainage may be dewatered by full development of all proposed micro-hydro sites (Table 13). lesser percentages of medium and low quality cutthroat habitat could be dewatered and the overall potential habitat loss was calculated to be 16 percent. Similar calculations indicate a potential dewatering loss of 19 and 6 percent of medium and high quality bull and brook trout habitat.

Table 12. Estimated amounts of stream habitat (number of reaches and stream kilometers) by gradient and draInage size class supporting specified numbers of cutthroat trout in tributaries to the Swan River sampled during 1982.

Gradient	Drainage area(km²)	Available habitat km/no. reaches	Sampled in 1982 km/no. reaches	Cutthroat trout population levels in reaches sampled[a/] High density km/% of km sampled	Medium density km/% of km sampled	Low density km/% of km sampled	None km/% of km sampled
0 - 3%	0-20	14.5/5	0/0	--/--	--/--	--/--	--/--
	20.1-50	50.5114	5.5/2	--/--	--/--	5.5/100%	--/--
	>50	92.2/15	54.7/7	--/--	--/--	23.2/42%	31.5/58%
3.1-6%	O-20	46.6/12	0/0	--/--	--/--	--/--	--/--
	20.1-50	55.6/12	28.7/4	--/--	7.3/25%	16.0/56%	5.4/19%
	>50	13.8/2	9.5/1	--/--	--/--	--/--	9.5/100%
6.1-13%	O-20	66.8/22	29.6/5	8.1/45%	5.7/32%	1.0/6%	3.0/17%
	20.1-50	3[illegible]	[illegible]	5.[illegible]/17%	13.0/44%	11.5/39%	--/--
	>50	1.5/1	0/0	--/--	--/--	--/--	--/--
>13%	O-20	40.5/13	9.5/3	--/--	4.0/42%	--/--	5.5/58%
	20.1-50	None					
	>50	None					

a/ Fish density classes were defined as follows:
High - more than 50 fish ≥75 mm per 100 m.
Medium - 26 to 50 fish ≥75 mm per 100 m.
Low - 1 to 25 fish >75 mm per 100 m.
NOM - none captured.

Table 13. Predicted total amounts of stream habitat (in kilometers) in various channel gradient-drainage size classes supporting specified numbers of cutthroat trout in tributaries to the Swan River.

Gradient	Drainage area(km²)	Available habitat(km)	Cutthroat trout population level[a/] High density	Medium density	Low density	None
0-3%	0-20	14.5	?	?	?	?
	20.1-50	50.5	---	---	50.5	---
	>50	92.2	---	---	39.1	53.1
3.1-6%	0-20	46.6	?	?		?
	20.1-50	55.6	---	14.1	31.0	10.5
	>50	13.8	---	---	---	13.8
6.1-13%	0-20	66.8	30.4	21.4	3.7	11.3
	20.1-50	33.6	5.8	14.8	13.1	---
	>50	1.5	?	?	?	?
>13%	0-20	40.5	---	17.1	---	23.4
Total available			36.2km	67.4km	137.4km	112. lkm
Potential amount diverted			8.3km	7.9km	23.4km	13.1
Percent diverted			23%	12%	17%	12%

a/ Fish density classes were defined as follows:
High - more than 50 fish 275 mm per 100 m.
Medium - 26 to 50 fish ≥75 mm per 100 m.
Low - 1 to 25 fish ≥75 mm per 100 m.
None - none captured.

Dewatering Impacts on Bull Trout Spawning

The potential cumulative effects of dewatering on bull trout spawning was determined by plotting redd locations in relation to the locations of proposed micro-hydro sites. Of the seven major bull trout spawning areas identified during the 1982 spawning survey, only one (Elk Creek) would not be directly influenced by proposed hydro sites. Twenty percent of the 206 bull trout redds found during 1982 were located within the proposed diversion areas, indicating a potential substantial loss of bull trout spawning habitat if full development and dewatering occurred.

Bull trout spawning activity occurred in the lower portions of proposed diversion reaches on Coat and Sgueezer creeks (Figure 9) and on Lion Creek (Appendix A14). Potential dewatering impacts on bull trout spawning at these sites could be lessened by relocating proposed powerhouses further upstream. However, dewatering losses of juvenile bull trout rearing habitat located upstream from spawning areas must also be considered. Bull trout spawning in the North and South Forks of Lost Creek (Appendix A15) and in Cold Creek occurred within and even upstream from proposed hydro sites.

Sediment Production

The effects of increased fine sediment levels in streambeds on various life stages of stream dwelling salmonids has been extensively documented and reviewed (Bjornn et al. 1977; Adams and Beschta 1980; Reiser and Bjornn 1979; Crouse et al. 3981). Increased levels of fine sediment resulting from land disturbance can affect egg and embryo survival, fry emergence, and growth and survival of juvenile salmonids. Construction activities related to micro-hydro site development may contribute significant amounts of fine sediment to stream channels. Many of these construction activities would be carried out in steep terrain and in riparian areas in close proximity to stream channels.

To predict the potential cumulative impacts of fine sediment on stream biota in the Swan drainage, we are attempting to adapt a method that is currently being developed in Idaho (Stowell et al., unpublished). This method involves the development of two models that are used sequentially to predict changes in amounts of streambed sediment and the subsequent response of salmonid populations.

To employ this method one must first develop a habitat response model that describes the relationship between amounts of fine materials in streambeds (measured as percent composition, substrate embeddedness, or a related parameter) and the existing sediment yield above natural levels (Figure 10). Our habitat survey information for reaches surveyed during 1982 and 1983 will provide streambed substrate data to be used in the construction of the habitat response model. The sediment yield information will be

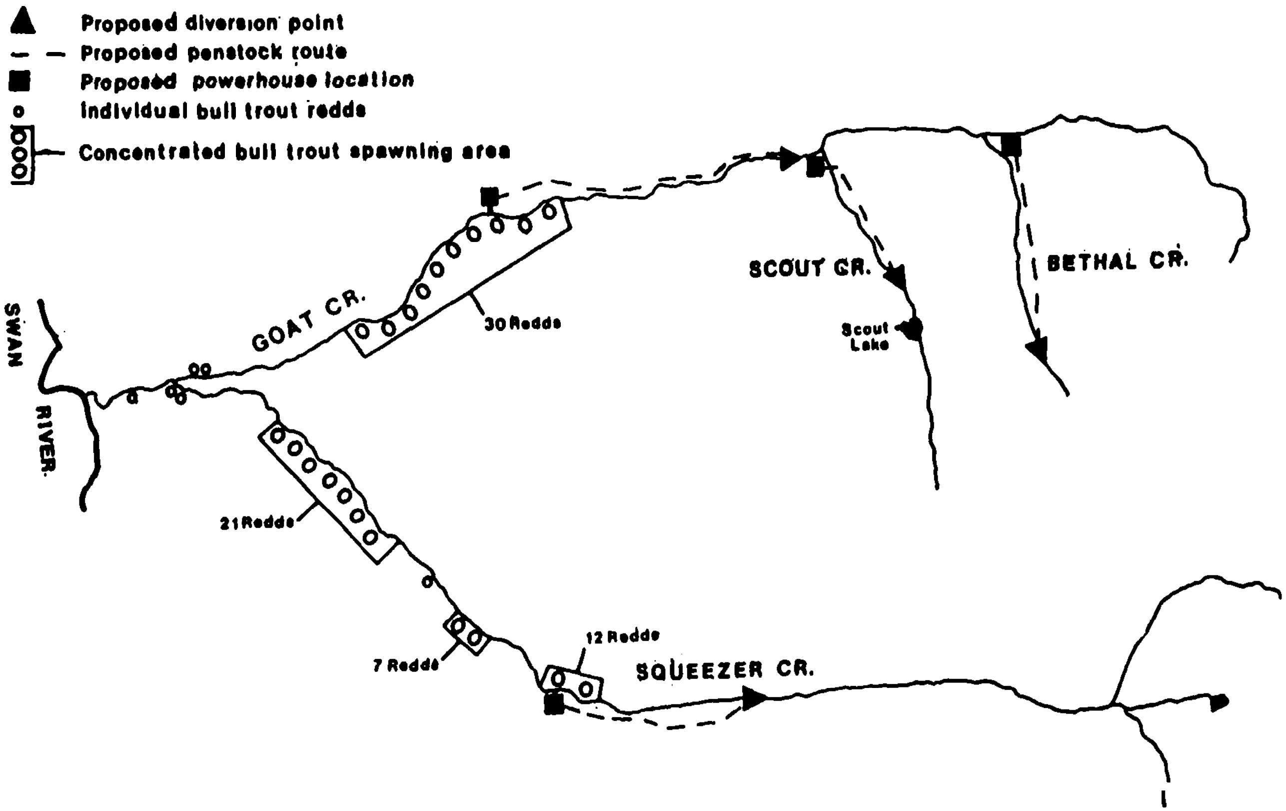

Figure 9. Locations of bull trout spawning sites (redds) found in the fall of 1982 in relation to proposed micro-hydro sites in the Coat snd Squeezer Creek drainages.

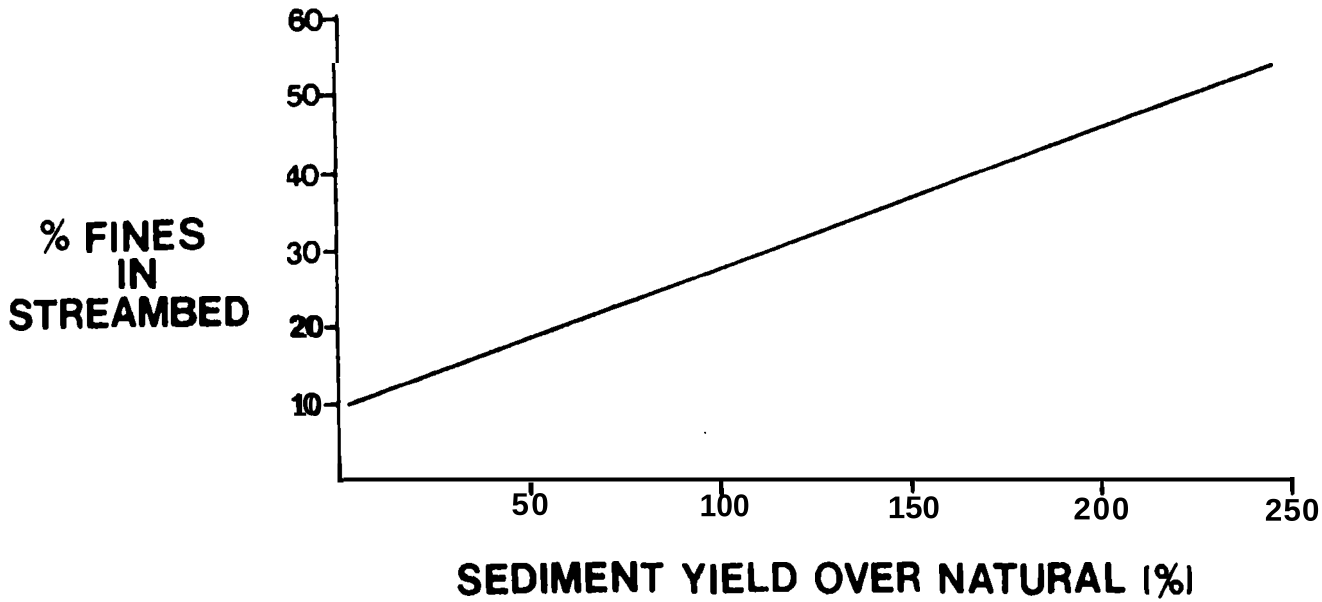

Figure 10. Hypothetical habitat response model suggested for use in sediment impact modeling.

a product of a companion study recently funded by the Bonneville Rower Administration. A EPA-funded fisheries biologist working out of the Swan Lake Ranger District of the Flathead National Forest is currently working with Forest Service hydrologists and soil scientists to generate needed sediment yield data.

The estimation of sediment yield for a given reach or drainage involves the determination of the land area occupied by various land types as well as the amount and timing of land use disturbance within each landtype. Sediment yield coefficients (tons per acre of landtype per year) are then used to predict natural and existing rates of sediment delivery to the stream. Flathead National Forest personnel have completed a landtype mapping program for the Swan drainage (US Department of Agriculture, Flathead National Forest 1980). Sediment yield coefficients have also been developed for various landtypes and are currently being used in the development of the Forest Plan for the Flathead National Forest as required by the National Forest Management Act.

A second model is needed to describe the response of fish populations to altered amounts of sediment in the streambed. Fish response can be measured in terms of rearing capacity and/or embryo survival and emergence. We obtained statistically significant relationships between trout populations (rearing capacity) and amounts of fine sediment for tributaries to the Swan River sampled during 1982. A significant non-linear negative relationship ($r = -0.75$; $p < .01$) was found to exist between the density of juvenile bull trout (fish 75 mm and larger per square meter) and percentages of fine sediment (less than 2 mm) in the streambeds of 14 reaches sampled during 1982 (Figure 11). The reverse was true for brook trout. A significant positive relationship ($r = 0.79$; $p < .01$; Figure 12) was observed for brook trout, indicating' that these fish were much more tolerant of fine sediment than were bull trout. No significant relationship was observed for cutthroat trout since extremely wide variations in population density were observed in streams having small amounts of fine material.

To determine the potential impacts on fish populations of sediment production resulting from the construction of a micro-hydro site one would first determine the existing sediment loading rate in relation to natural levels for the stream reach in guestion. The next step involves plotting proposed roads, penstock, and powerhouse locations within the reach on landtype maps. The predicted amount of sediment delivered to the reach as a result of construction activities is then determined using sedinent production coefficients and predicted amounts of disturbed land within specific landtypes. Existing and predicted sediment yields for the reach would then be expressed as percentages of natural sediment yield and entered into the habitat response model (Figure 10).

The results of the habitat response model would be interpreted as the response of an average stream channel to increasing

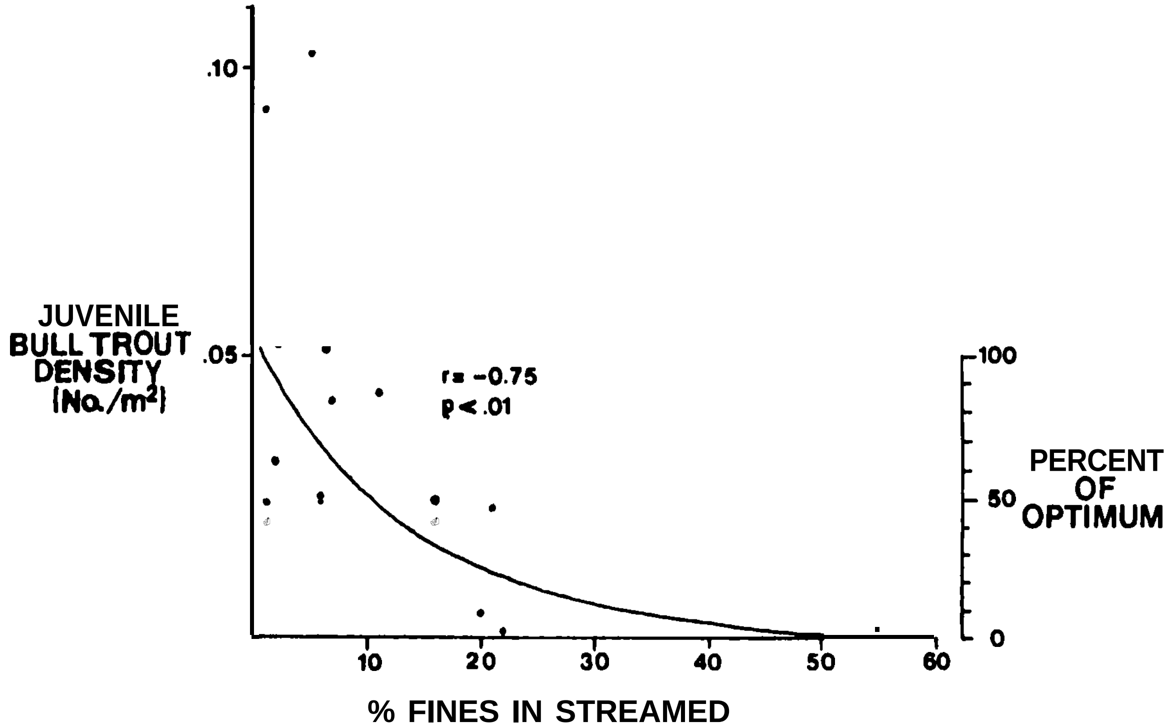

Figure 11. Relationship between density of juvenile bull trout (fish 75 mm and larger per ssquare meter of stream surface area) and percentage of fine material (2mm and less) in the substrate of 14 tributary reaches sampled in the Swan River drainage during 1982.

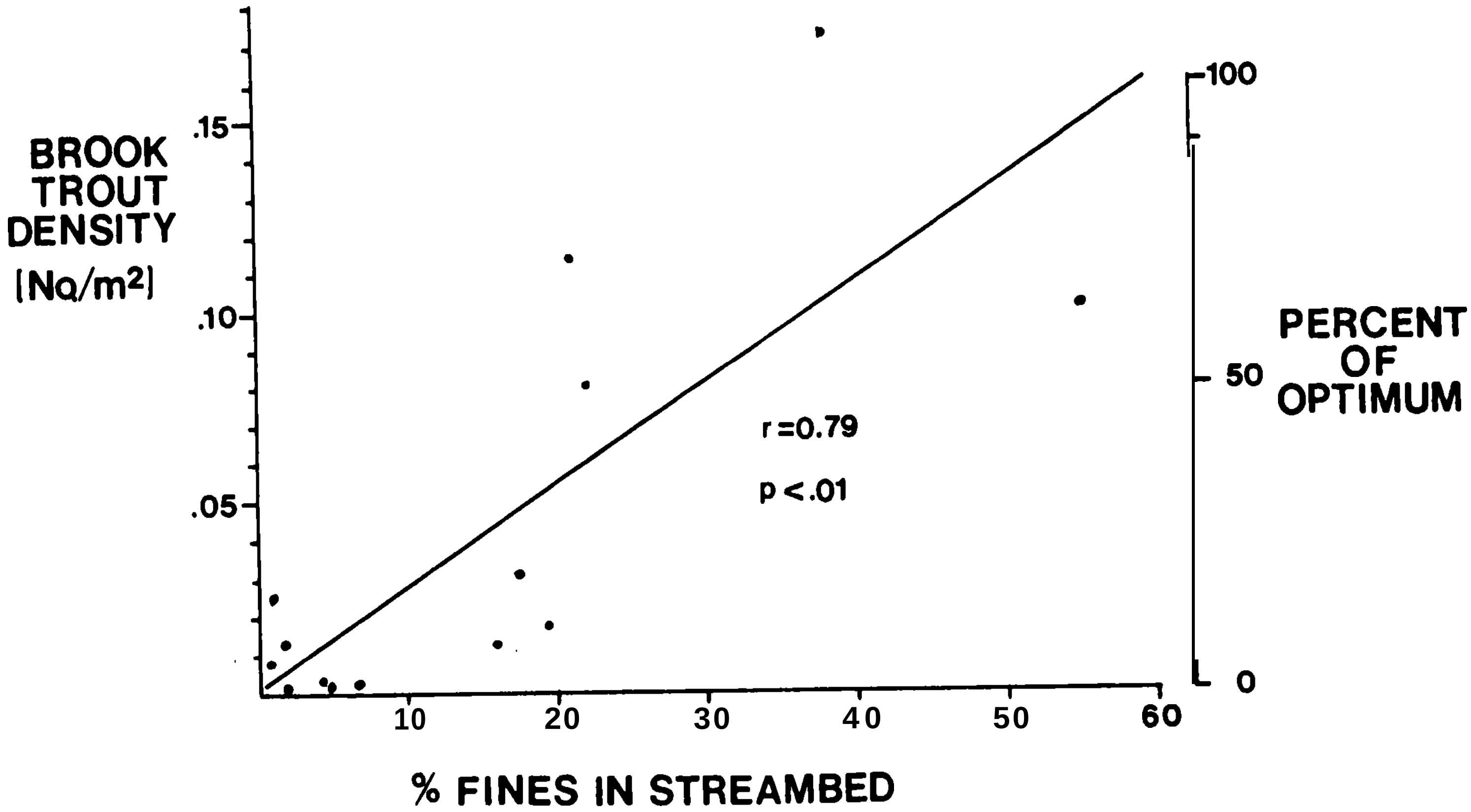

Figure 12. Relationship between density of brook trout (fish 75 mm and larger per square meter of stream surface area) and percentage of fine material (2mm and less) in the substrate of 14 tributary reaches sampled in the Swan River drainage during 1982.

(or decreasing) sediment yield. Changes in percentage of fine material in the streambed predicted by the habitat response model would then be entered into fish response models to predict changes in fish carrying capacity. Cooperative efforts will continue during the next year to develop the habitat response model and refine the fish response models.

PRELIMINARY FISHERIES IMPACT EVALUATION CRITERIA

The following major criteria should be considered when evaluating potential fisheries impacts of proposed micro-hydro developments on tributary streams.

1. Fish Populations - The species composition and density of fish populations in the vicinity of potential micro-hydro sites are basic factors to be considered in the site evaluation process. Many of the proposed sites in the Swan drainage supported moderate (26 to 50 fish per 100 meters) or high (more than 50 fish per 100 meters) density populations of westslope cutthroat trout and bull trout. Only two sites were completely devoid of fish. Substantial trout populations were found in diversion areas having channel gradients as large as 15 percent.

   Special emphasis should be placed on fish species having high management priority. Westslope cutthroat trout are a high priority native subspecies in Montana due to genetic considerations. Pull trout are a priority species due to the migratory nature of this native species and its potential for growth to trophy size.

2. Life History - Detailed life history information for fish species of interest is necessary to fully evaluate potential hydro impacts. Basic life history patterns (resident versus migratory) will determine the scope of potential impacts. Impacts on resident species would be more localized than those on migratory species. Timing of spawning, size of spawning fish, and (for migratory species) the size of emigrating smolts and the timing of migration are important life history characteristics.

3. Dewatering - Potential dewatering of thousands of feet of stream channel resulting from the diversion of water for power production is a most important consideration. Adequate instream flow must be maintained to ensure sufficient amounts of spawning, rearing, and over-wintering habitat for resident and migratory fish species. Our results indicate that in general, dewatering to below base flow levels (i.e. flow levels observed during October or November) would result in unacceptable losses of trout rearing habitat as indexed

by wetted perimeter. Passage flows for spawning fish may be specified using transect information and width-&p&h criteria employed in Oregon (Thompson 1972).

4. Upstream passage - Measures to provide adequate upstream passage conditions for migratory and resident fish include the provision of adequate passage flows as well as the installation of fishways at diversion sites. Migratory bull trout in the Swan drainage utilized proposed diversion reaches having average channel gradients of up to six percent. Limited spawning use by migratory bull trout was observed upstream from proposed diversion points. Movements of resident cutthroat trout and juvenile bull trout in tributaries to the Swan River are probably less extensive because of the relatively high-qradient reaches they inhabited and the small size of resident fish. Resident Gila trout (*Salmo gilae*) moved less than 0.1 km on the average in small New Mexico streams and seldom passed log structures that were 0.5 m or taller (Rinne 1982). Falls and cascades of 0.5 m or taller were commonplace (an average of at least 10 per kilometer) within proposed diversion areas in the Swan drainage.

   Most upstream fish passage facilities for Swan hydro projects would therefore need to be designed to accommodate localized movements of small resident fish. Vertical slot fishways are probably best suited to these small streams since they accommodate a wide range of flow conditions without the need for adjustment (British Columbia Ministry of Environment 1980). Design considerations for various fishways are available in a handout published by the National Marine Fisheries Service (undated).

5. Downstream passage - Fish screening devices must be installed at diversion sites where necessary to prevent mortality or injury to juvenile or resident salmonids migrating downstream F&commended screen mesh size depends on the size of downstream migrating fish Screen openings of no more than 0.125 inch (3.2 mm) in the narrow direction are recommended for fry (<59 mm total length), whereas openings of 0.25 inch (6.4 mm) are recommended for fingerlings (>60 mm; National Marine Fisheries Service 1982). Screen openings of no more than 0.10 inch (2.5 mm) are specified by the British Columbia Ministry of Environment (1980).

   Most juvenile adfluvial westslope cutthroat and bull trout in the Flathead drainage emigrate as one to three year old fingerlings (Fraley et al. 19811, hence screen openings of no more than 0.25 inch (6.4 mm) should prevent entry of these fish into penstocks and subsequent turbine mortality. Turbine mortality for entrained fish would probably be 100 percent since most projects would use impulse turbines which are propelled by high speed water jets directed through high pressure nozzles.

Criteria describing approach velocities, screen material, screen location, and required amounts of wetted screen are detailed by the National Marine Fisheries Service (1982) and B.C. Ministry of Environment (1980). Various designs for screening facilities are described in the latter publication.

6. Sediment -- Construction of roads, penstock routes, diversion structures, and powerhouses may result in the addition of substantial amounts of fine sediment to the stream. Many of these facilities would be built in steep terrain and in close proximity to the stream. Most projects would have buried penstocks which would require the clearing of about a 40-foot right-of-way for pipe burial.

   To minimize sedimentation problems, adequate buffer strips should be maintained between penstock routes, roads and the stream. Penstock placement above ground would likely result in lower rates of sedimentation, however, visual impacts and potential disruption of wildlife travel corridors may preclude this option. Penstock routes should employ existing roadways when possible and all disturbed areas should be mulched and revegetated as soon as possible to achieve stabilization. Steep slopes can also be covered with woven cloth mesh material to increase stabilization and sediment-filtering cloth can be installed in critical areas to intercept fine sediment from runoff water. Extra precautions should be taken when hydro sites are located upstream from important fish spawning and rearing areas.

   Problems may also be encountered with the accumulation of gravel and sediment on the upstream side of diversion structures. Periodic flushing of this accumulated material may be necessary, however, this activity should be carefully planned and monitored to prevent harmful effects on stream biota in downstream areas.

7. Temperature - Temperature alterations could occur within diversion areas as a result of transporting substantial amounts of water downslope in buried pipelines. Summer temperatures within dewatered reaches would likely be elevated due to decreased flows and water velocity as well as reductions in amounts of shading by riparian vegetation. Some increase in summer water temperature may enhance trout growth and aquatic productivity.

although it may also alter fish species composition. The influence of summer water temperature on trout populations in the Swan drainage will be more intensively examined during the 1983 field season.

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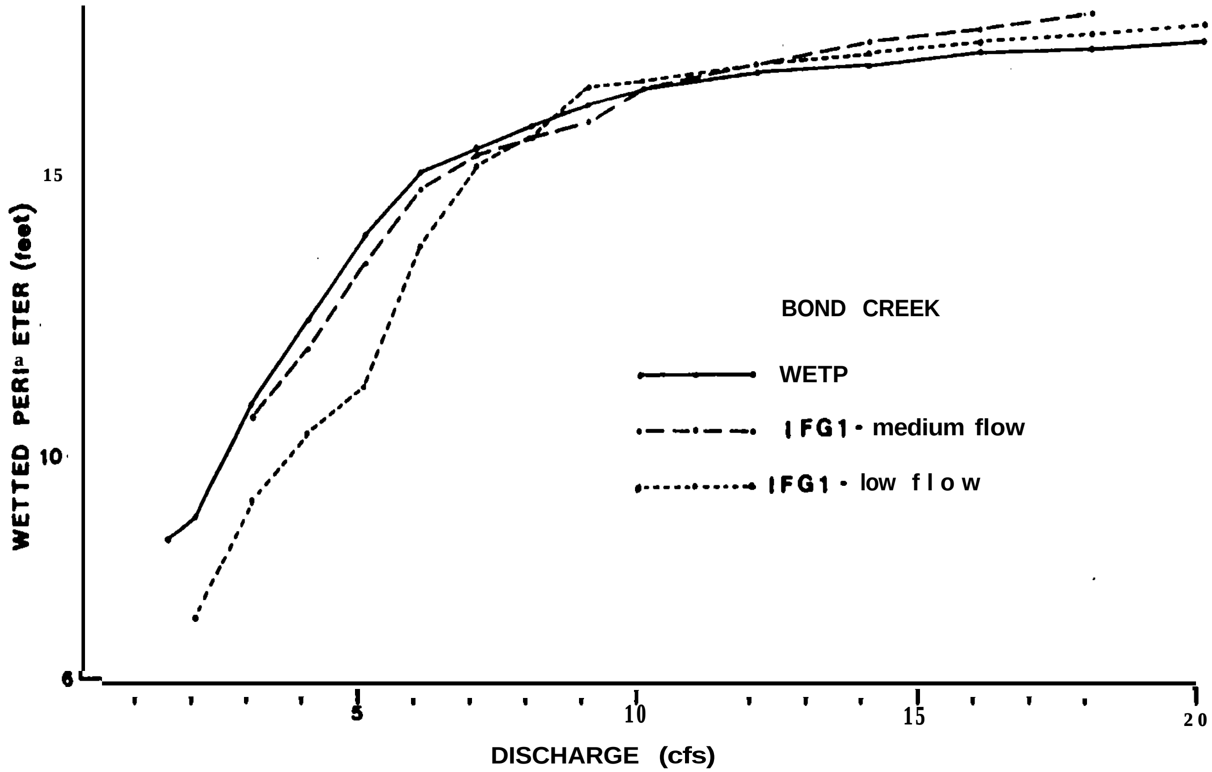
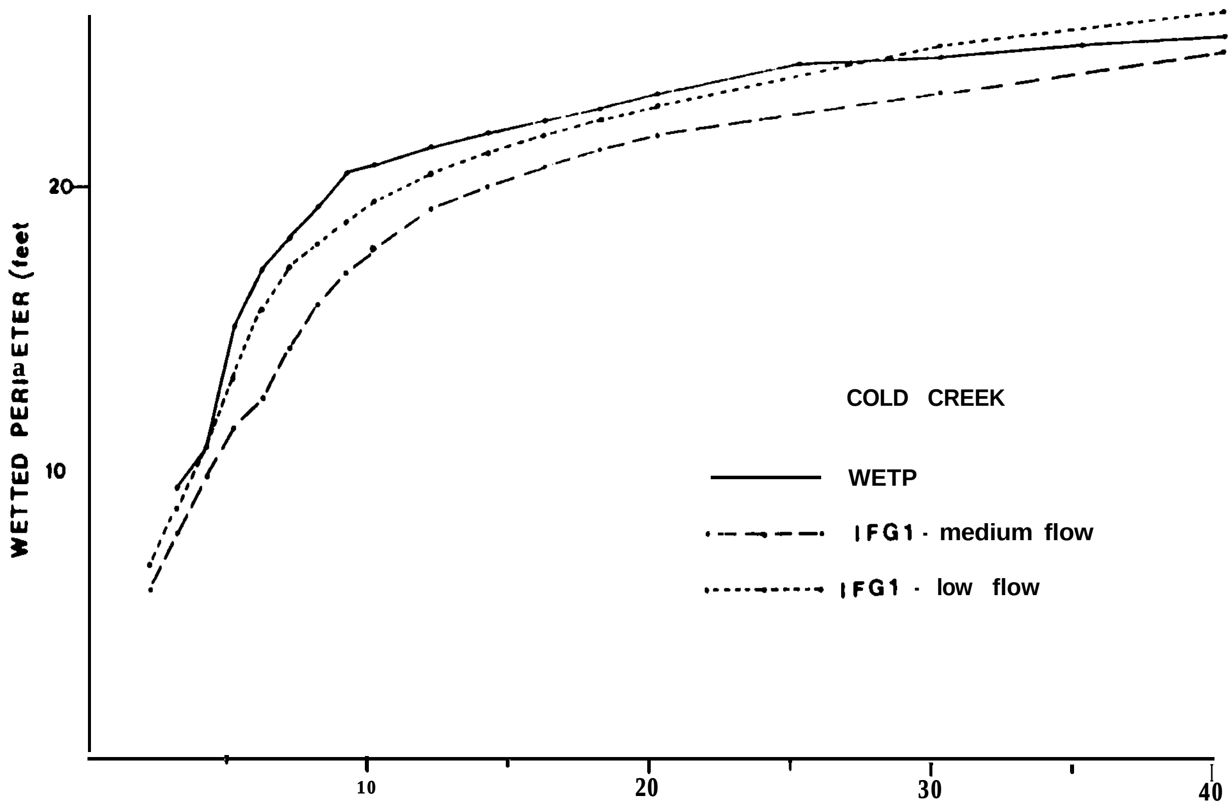
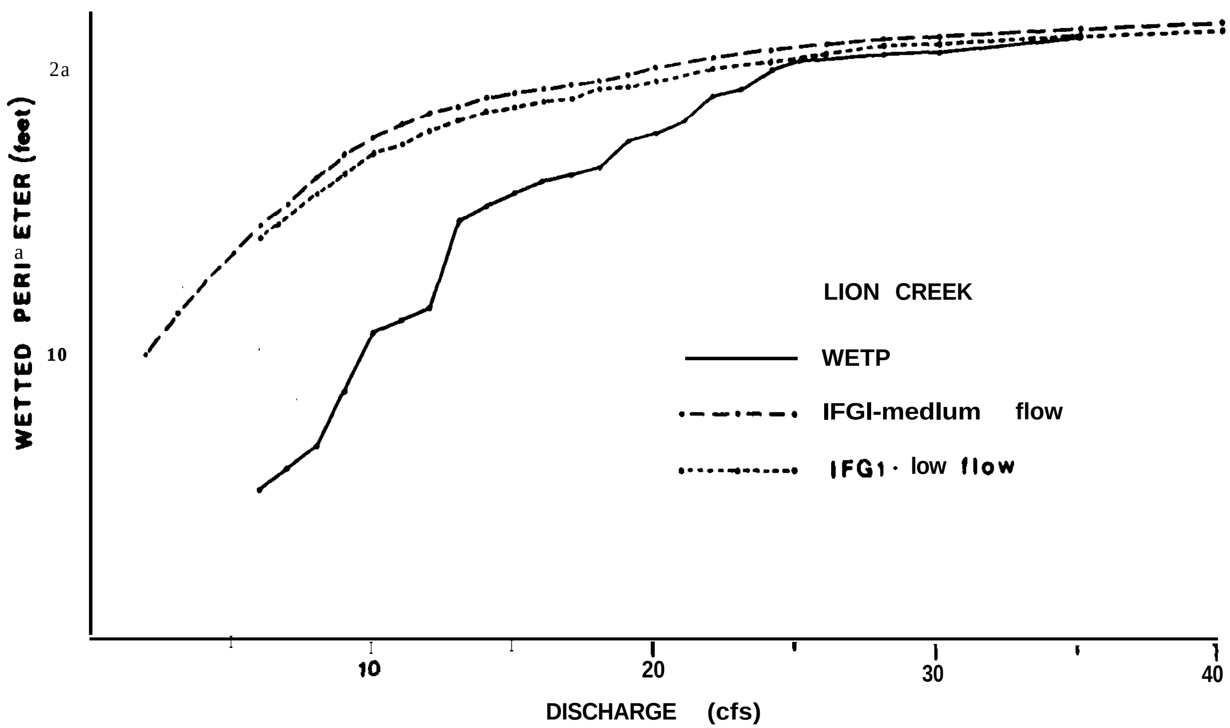
APPENDIX A



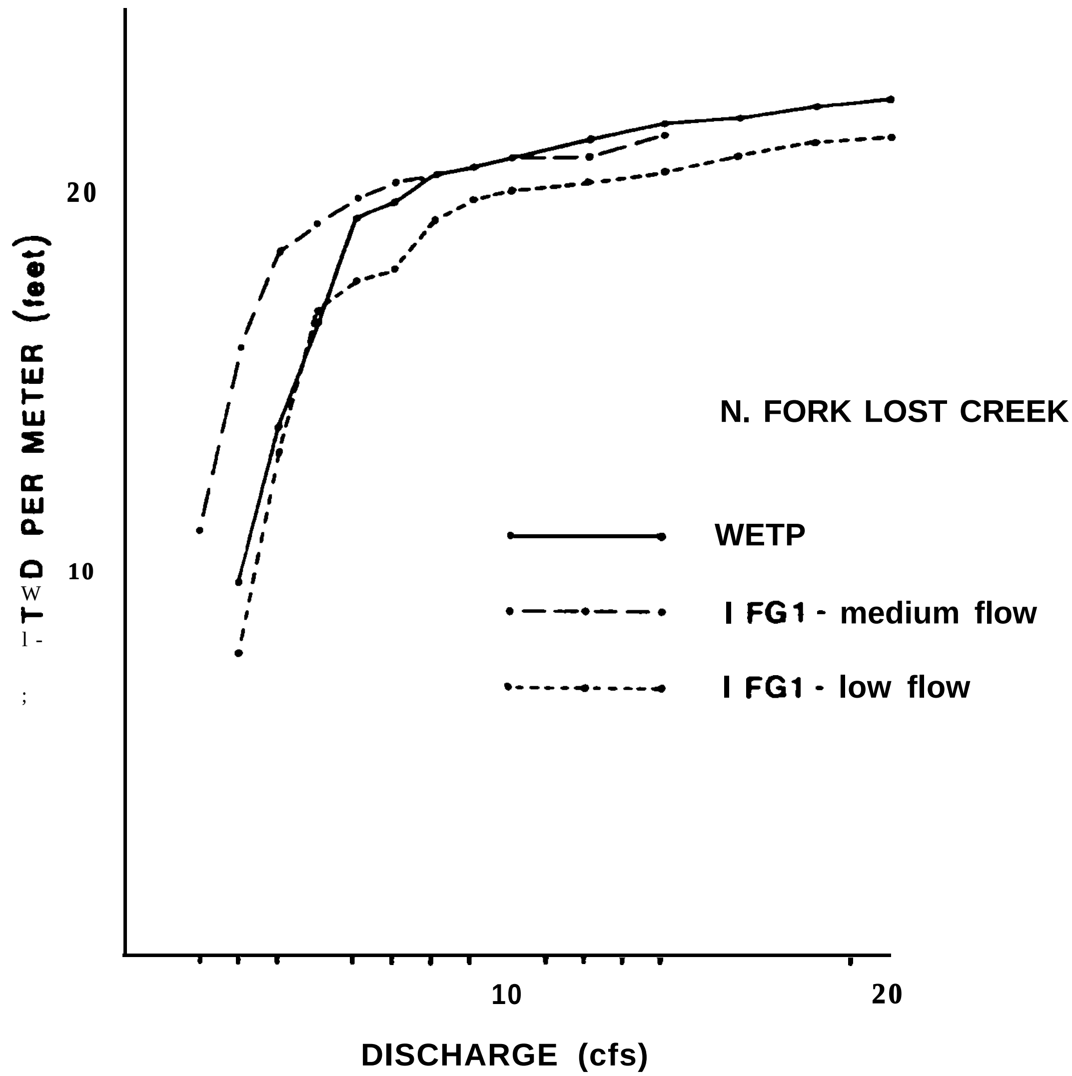
Appendix Al. Composite wetted perimeter to discharge relationship for three riffle cross sections on Bond Creek during 1982. Curves were generated using either the WETP computer model or the IFGl model calibrated at medium flow (6.6 cfs) or low flow (3.9 cfs)



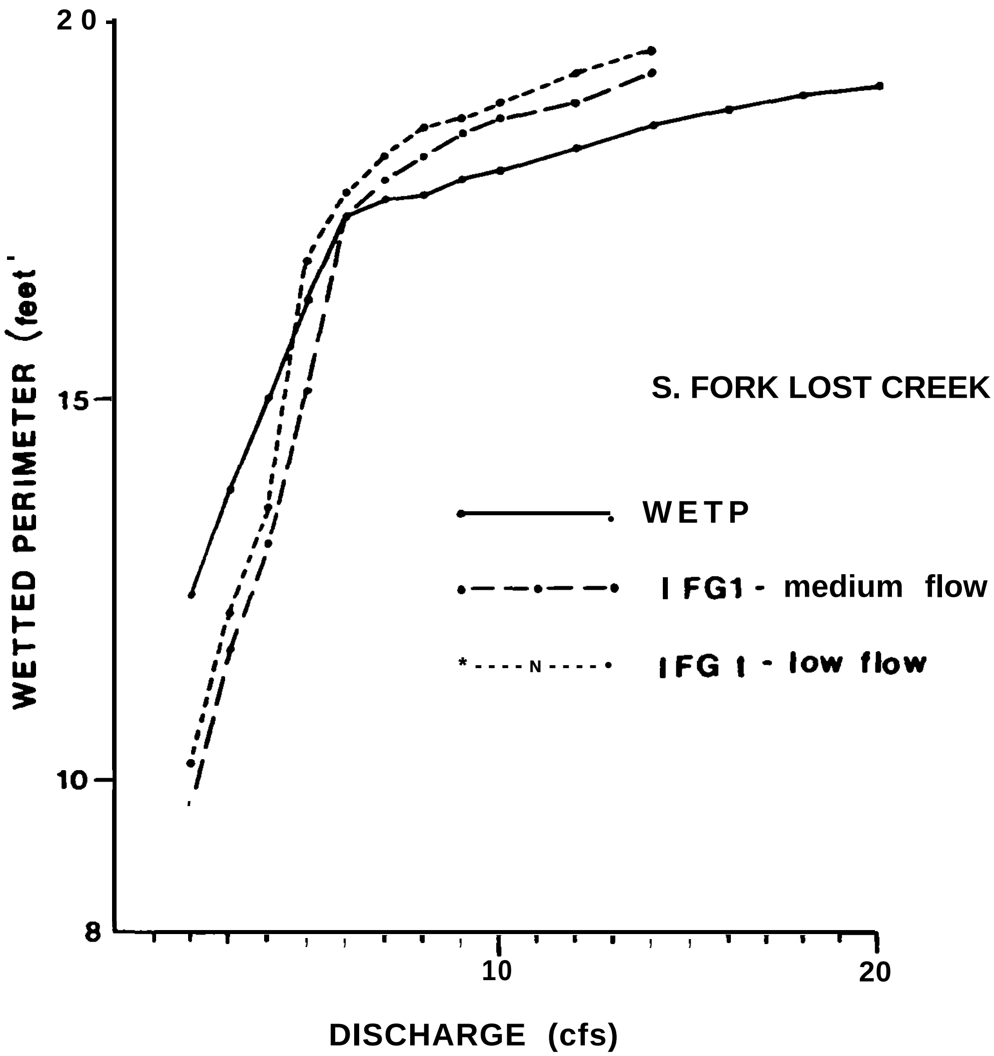
Apendix A2. Composite wetted perimeter to discharge relationship for three riffle cross sections on Cold Creek during 1982. Curves were generated using either the WETP computer model or the LFG1 model calibrated at medium flow (54 cfs) or low flow (20 cfs).



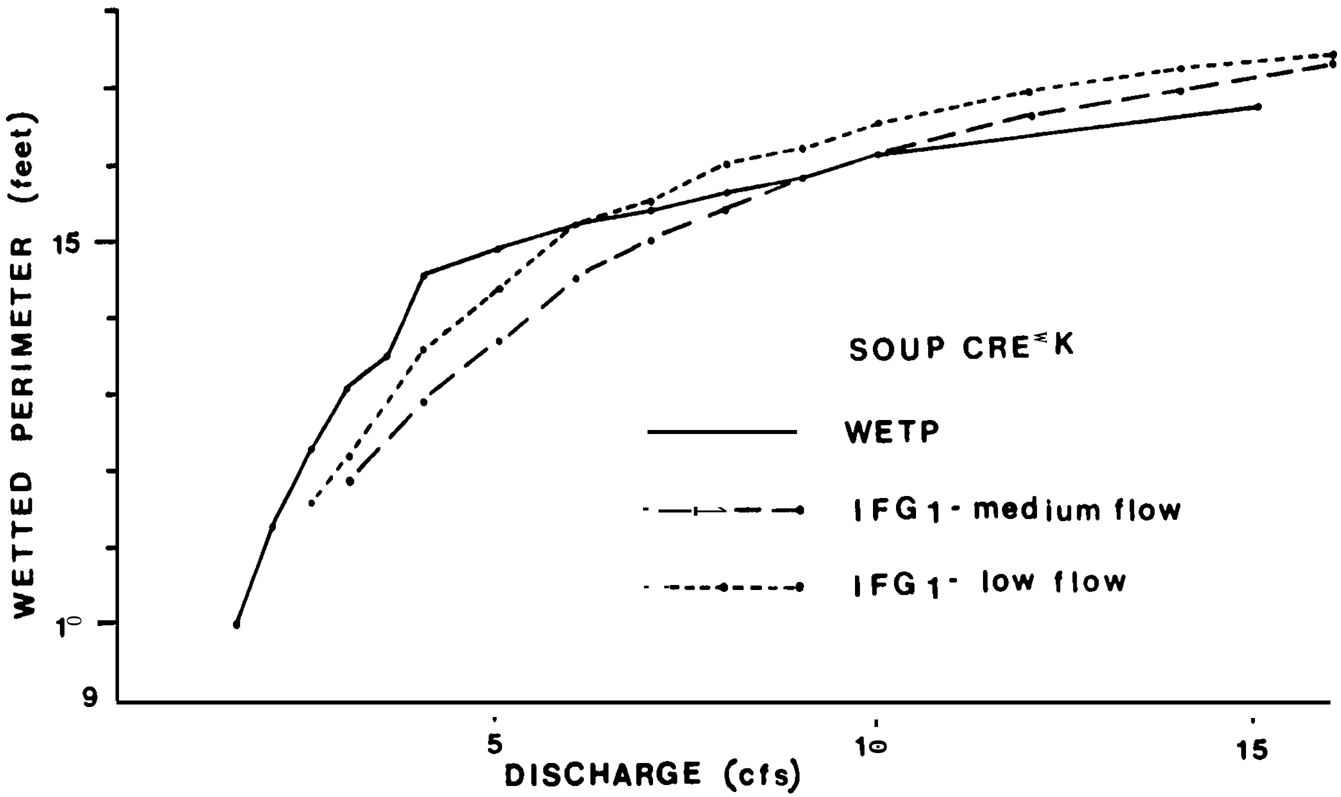
Appendix A3. Composite wetted perimeter to discharge relationships for three riffle cross sections on Lion Creek during 1982. Curves were generated using either the WETP computer model or the IFG1 model calibrated at medium (49 cfs) or low (38 cfs) flow.



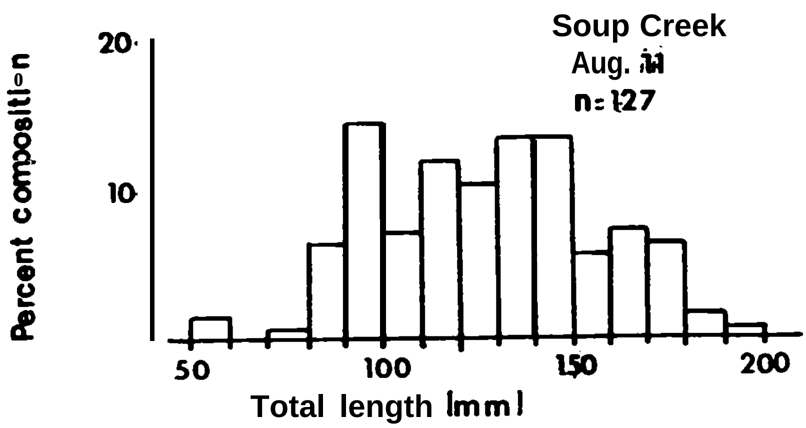
Appendix A4. Composite wetted perimeter to discharge relationships for three riffle cross sections on the North Fork of Lost Creek during 1982. Curves were generated using either the WETP computer model or the IFG1 model calibrated at medium (8.4 cfs) or low (7.5 cfs) flow.

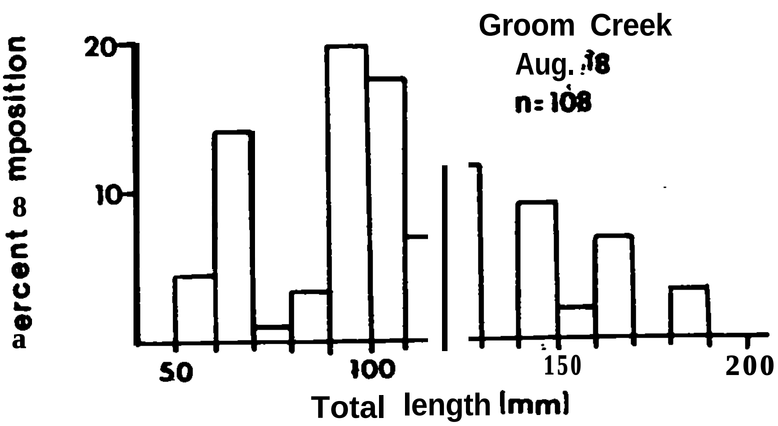


Appendix A5. Composite wetted perimeter to discharge relationships for three riffle cross sections on the South Fork of Lost Creek during 1982. Curves were generated using either the WETP computer model calibrated at medium (15.8 cfs) or low (10.9 cfs) flow.

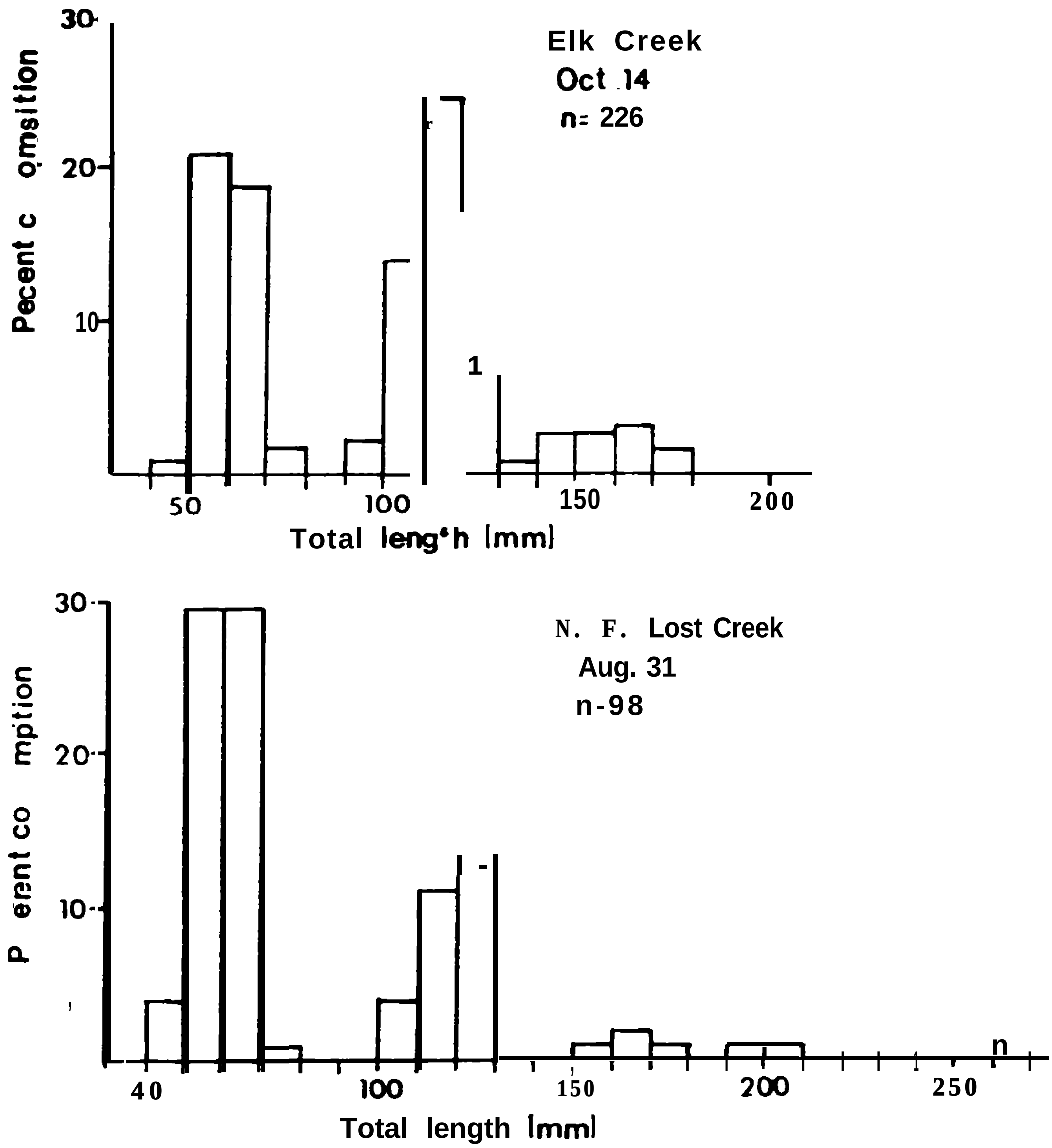


Appendix A6. Composite wetted perimeter to discharge relationship for three riffle cross sections on Soup Creek during 1982. Curves were generated using either the WETP computer model or the IFG1 model calibrated at medium flow (5.2 cfs) or low flow (3.8 cfs).

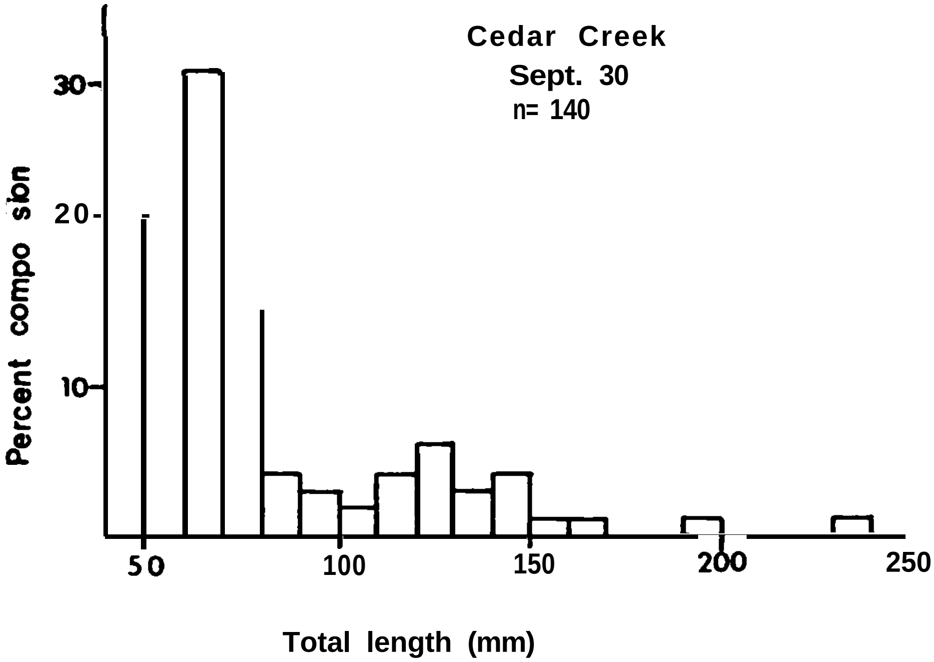


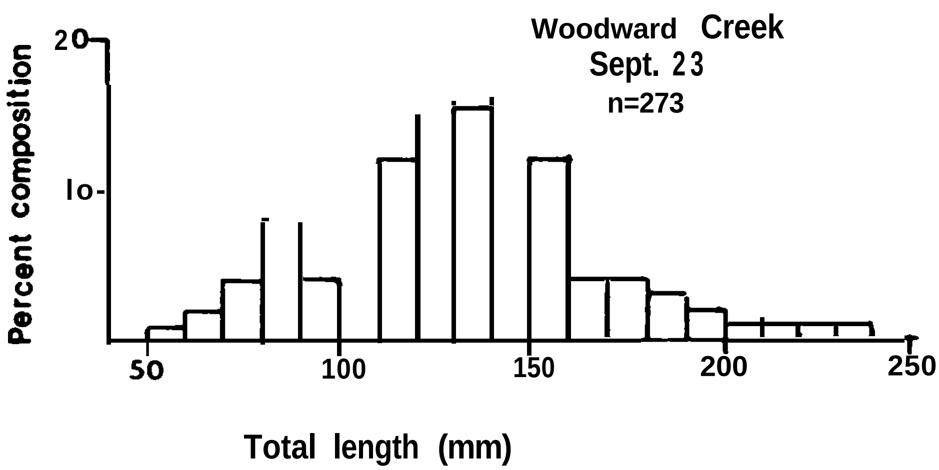


Appendix A7. Length frequency diagrams for cutthroat trout captured by electrofishing in Soup Creek and Groom Creek during 1982.

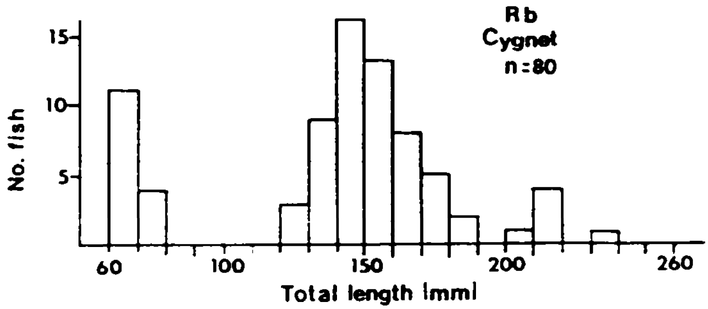


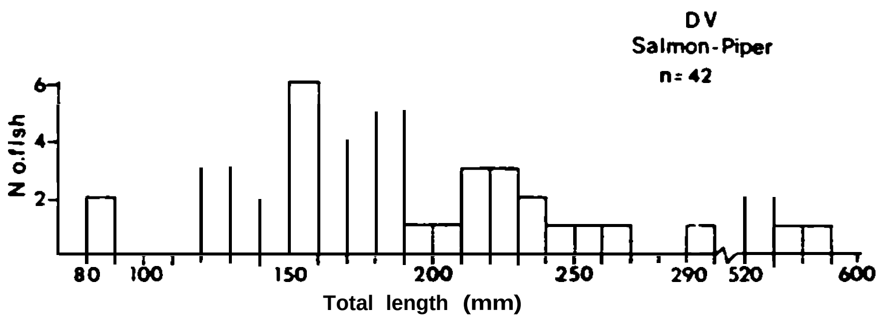
Appendix A8. Length frequency diagrams for juvenile bull trout captured by electrofishing in Elk Creek and the North Fork of Lost Creek during 1962.



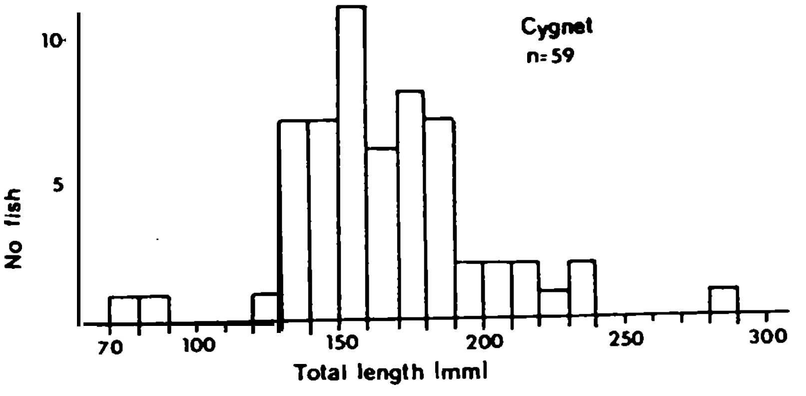


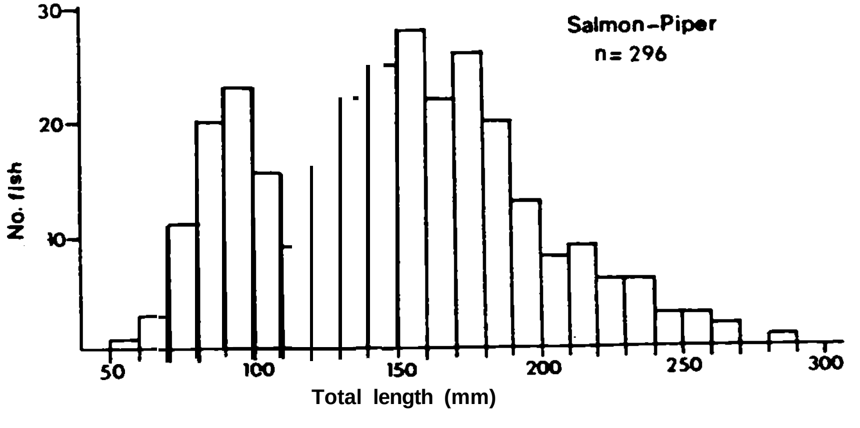
Appendix A9. Length frequency diagrams for brook trout captured by electrofishing in Cedar Creek and Woodward Creek during 1982.



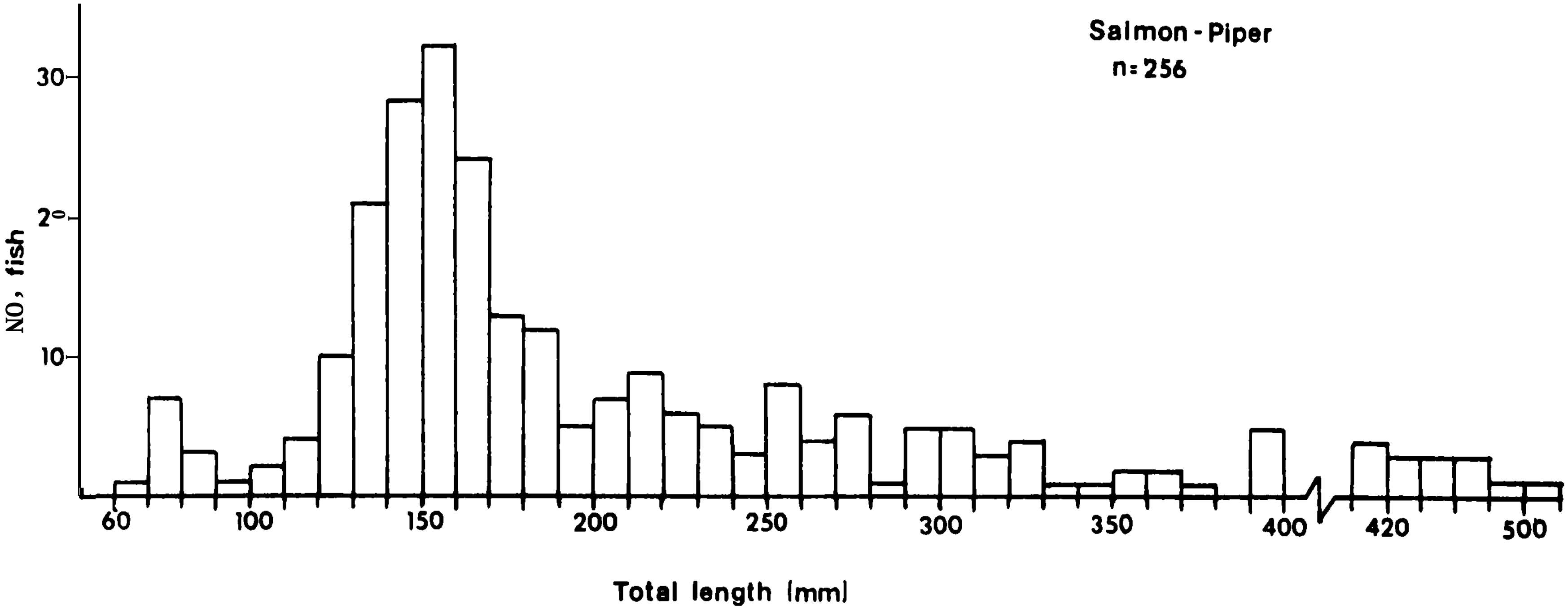


Appendix A10. Lenqtb frequency diagrams for rainbow trout captured during 1982 in an electrofishing section on the upper Swan River belov Cygnet Lake and for bull trout captured by electrofishing in the middle section of the Swan River between the Salmon Prairie and Piper Creek bridges.

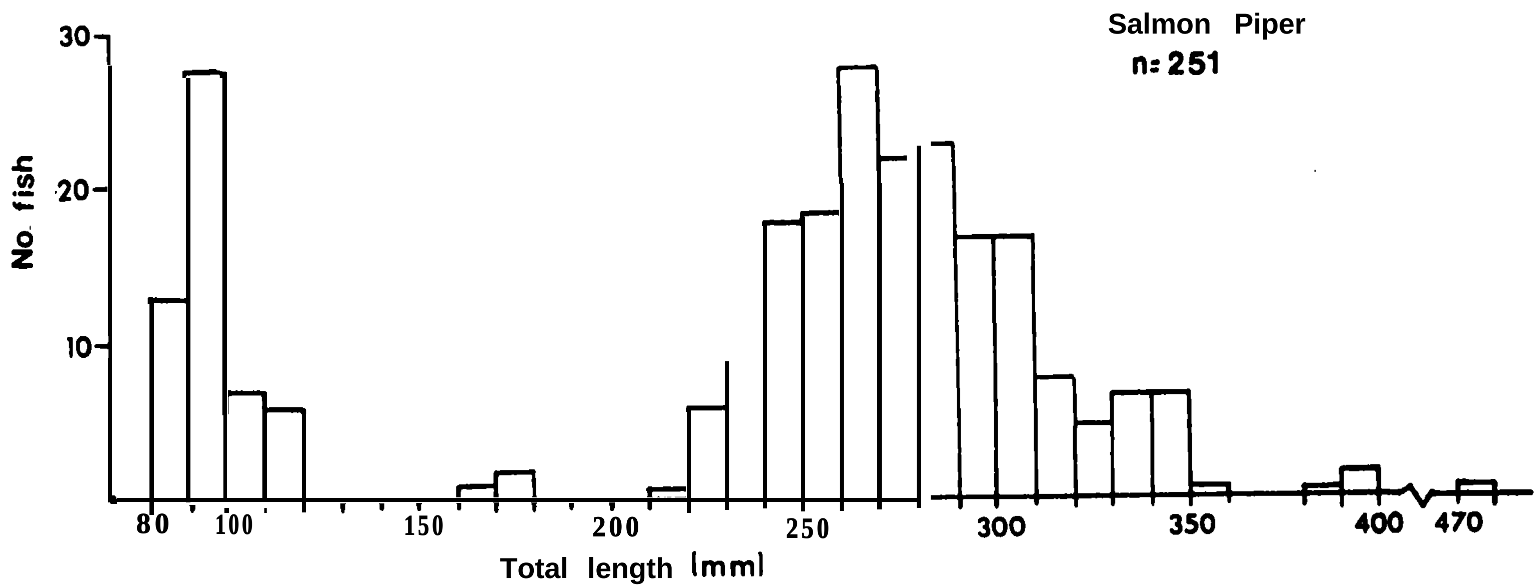




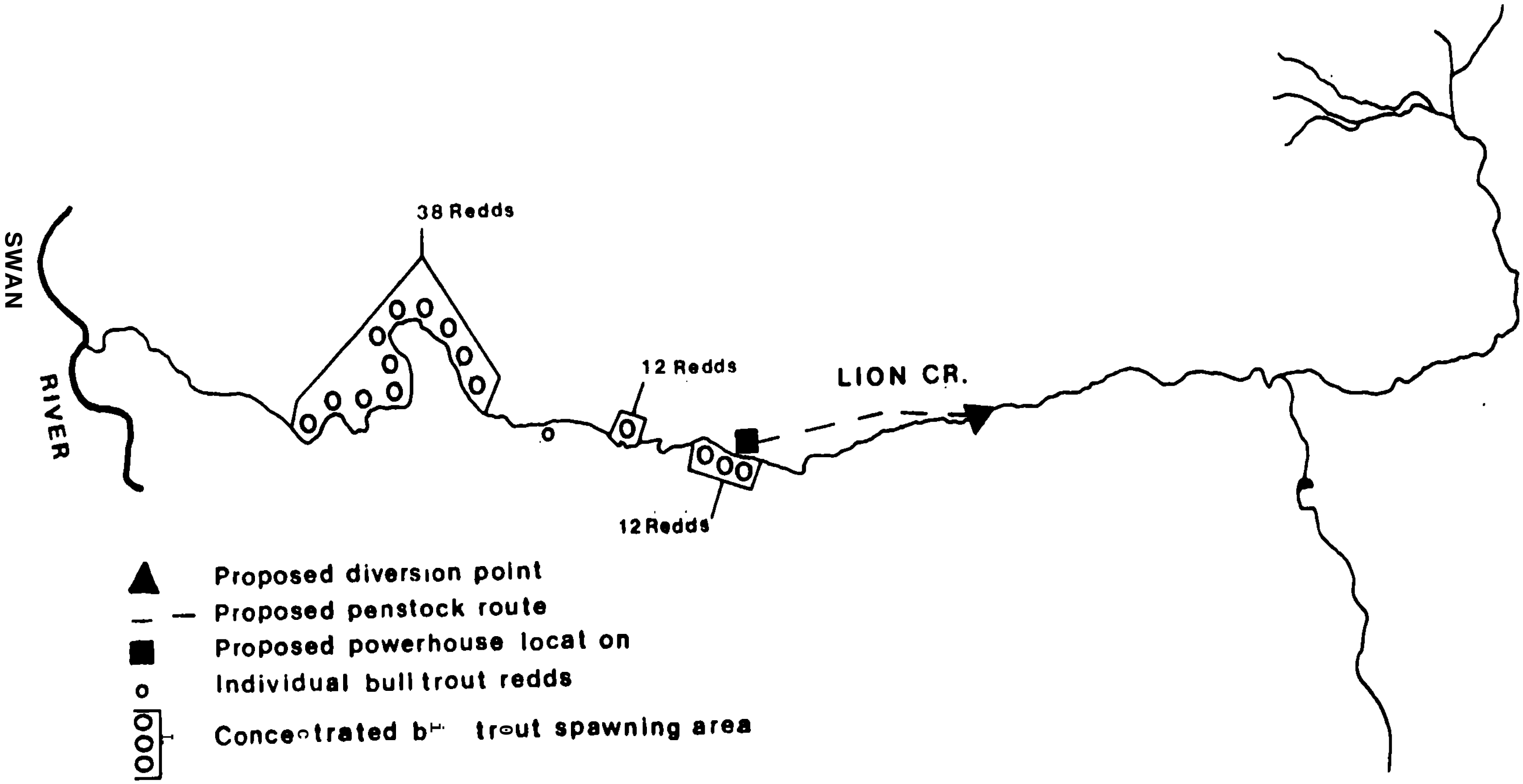
Appendix All. Length frequency diagram for brook trout captured during 1982 by electrofishirq in a section of the upper Swan River below Cygnet Lake and in the middle Swan River between the Salmon Prairie and Piper Creek bridges.



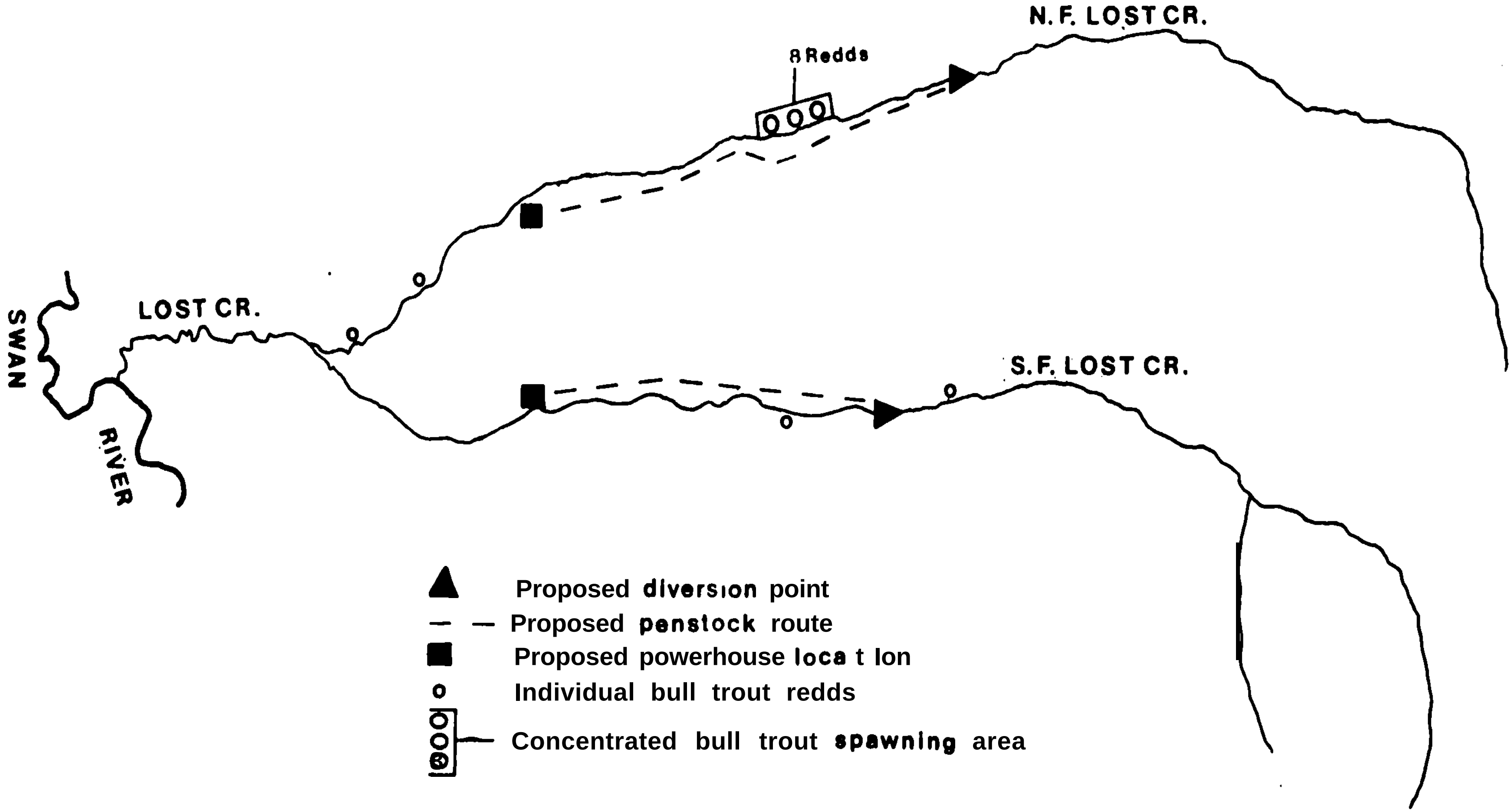
Appendix A12. Length frequency diagram for rainbow trout captured by electrofishing during fall 1982 on a section of the middle Swan River between the Salmon Prairie and Piper Creek bridges.



Appendix Al3. Length frequency diagram for mountain whitefish captured by electrofishing during fall 1982 on the middle section of the Swan River between the Salmon Prairie and Piper Creek bridges.



Appendix A14. Locations of bull trout spaw ing sites redds) found in the fall of 1982 in re tion to a proposed micro hydro site o Lion Creek.



Appendix A15. Locations of bull trout spawning sites (redds) found in the fall of 1982 in relation to proposed micro-hydro sites on the North and South Fork of Lost Creek.

WATERS REFERRED TO:

Water	
Flathead Lake	07-6400-03
Lindbergh Lake	07-7260-03
Swan Lake	07-9000-05
Bethal Creek	07-0260-10
Bond Creek	07-0480-01
Cedar Creek	07-0740-01
Cold Creek	07-0860-01
Elk Creek	07-1340-01
Glacier Creek	07-1700-01
Goat Creek	07-1720-01
Groom Creek	07-1820-01
Ball Creek	07-1860-01
Lime Creek	---
Lion Creek	07-2420-01
North Fork Lost Creek	07-3200-01
Piper Creek	07-3440-01
Porcupine Creek	07-3520-10
Scout Creek	07-3880-10
Sixmile Creek	07-3960-01
Soup Creek	07-4020-01
South Fork Cold Creek	07-4080-01
South Fork Lost Creek	07-4200-01
South Fork Woodward Creek	---
Squeezer Creek	07-4340-01
Swan River Section 01	07-4560-01
Swan River Section 02	07-4580-01
Woodward Creek	07-5100-01
Yew Creek	07-5160-10