AQUATIC HABITAT OF THE TIEKEL RIVER, SOUTHCENTRAL ALASKA, AND ITS UTILIZATION BY RESIDENT DOLLY VARDEN (SALVELINUS MALMA)

by

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A

THESIS

Presented to the Faculty of the University of Alaska

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MASTER OF SCIENCE

By

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ABSTRACT

The Tiekel River is a third order stream in southcentral Alaska and contains stream-resident Dolly Varden (*Salvelinus malma*) that are small in size. The purpose of this project was to compile baseline aquatic habitat data, determine which habitats were the most important to the Dolly Varden and should be protected from future development, and develop management recommendations. Habitat data suggested that the Tiekel River drainage contained a wide variety of habitats that could fulfill the life requirements for a number of fish species. Habitat suitability index graphs were constructed for the important habitat variables and should be used in the planning of future habitat alterations to assure that habitat quality does not suffer. The beaver ponds were found to have a greater probability of producing large fish than the stream habitats. Fish size was positively correlated with August water temperatures and chlorophyll *a* concentrations.

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INTRODUCTION

Journals and early records from miners and surveyors indicate that the Tiekel River did not contain a population of Dolly Varden until the early 1900's. Before this time the only fish species to inhabit the Tiekel River may have been the slimy sculpin (*Cottus cognatus*). Local resource managers believe that during the early part of this century Dolly Varden were transported from the nearby Little Tonsina River to the Tiekel River. Although not clearly documented, it is also believed that in the 1950's or 60's an unsuccessful attempt was made to introduce rainbow trout (*Salmo gairdneri*) to the Tiekel River. Presently the Tiekel River is known for its poor fishing and small fish. Even though the Tiekel is paralleled for most of its length by the Richardson Highway, its reputation keeps the fishing pressure to a minimum.

The Alaska Department of Fish and Game and the Bureau of Land Management sponsored a two part study of the Tiekel River's aquatic habitat and fish biology in hopes of finding out why the Tiekel River Dolly Varden were so small, and what could be done to increase the recreation value of the area. This thesis is based on the aquatic habitat portion of this study. The Bureau of Land Management sponsored the aquatic habitat portion of the study in hopes of:

1) Developing an aquatic habitat data base for the drainage.

2) Determining which habitats were important to the resident Dolly Varden.

3) Determining which habitats should be protected from future development and how they should be protected.

4) Developing specific management recommendations for the drainage.

The study on the biology of the Dolly Varden was done by Saree Gregory (1988).

The range of the Dolly Varden (Salvelinus malma) has been difficult to define in the past because of the confusion of this species with the arctic charr (Salvelinus alpinus) and bull trout (Salvelinus confluentus) (Morrow, 1980a). Morrow (1980b) concluded, from discriminant function analysis of meristic counts, that many previous accounts of arctic charr in northern Alaska and western Canada were in fact the northern form of Dolly Varden. Morrow concludes that the present range of the Dolly Varden in

North America extends from the arctic coast of Alaska south to southern British Columbia. Morrow (1980b) describes Dolly Varden north of the Alaska Range as the northern form and those south of the range to be the southern form, and native charr south of British Columbia to be bull trout and lake trout (Salvelinus namaycush). Armstrong and Morrow (1980) describe seven different life forms of Dolly Varden. These include: northern anadromous, northern lake resident, northern stream resident, northern spring resident, southern anadromous, southern stream resident, and southern stream-lake resident. The Dolly Varden of the Tiekel River are of the southern stream-resident form (Gregory, 1988).

A southern stream-resident population of Dolly Varden was described by Blackett (1973) in southeastern Alaska. He described these fish as smaller, earlier to mature, having a lower fecundity, and shorter lived than the anadromous Dolly Varden of nearby streams. Gregory (1988) found similar characteristics in the Tiekel River population of Dolly Varden. The average length of Dolly Varden in the Tiekel River is 150 mm and the population is a young one with high mortality rates after age four (Gregory, 1988).

STUDY AREA

The Tiekel River is a third-order tributary (1:63,360) of the Copper River in southcentral Alaska. The river is situated in a steep valley and is fed by groundwater, rain and snow runoff, and during the summer, runoff from glaciers. The Tiekel River parallels the Richardson Highway for about 20 miles between the towns of Glennallen and Valdez. The Tiekel River originates as Ernestine Creek high in the Chugach Mountains east of the Richardson Highway and flows west until it meets the highway near mile-post 62. At this point it becomes the Tiekel River and flows south along the highway until it joins the Tsina River near mile-post 47. From there the Tiekel flows east for 15 miles through a steep gorge before it joins the Copper River. The study area consists of the Tiekel River, its tributaries, and the associated beaver ponds above the Tsina confluence (Figure 1).

For the purpose of the study, the lotic habitats were broken down into five groups based on their major morphometric characteristics. These groups are referred to as habitat types. The five habitat types, their locations, and some characteristics that distinguish them from one another are:

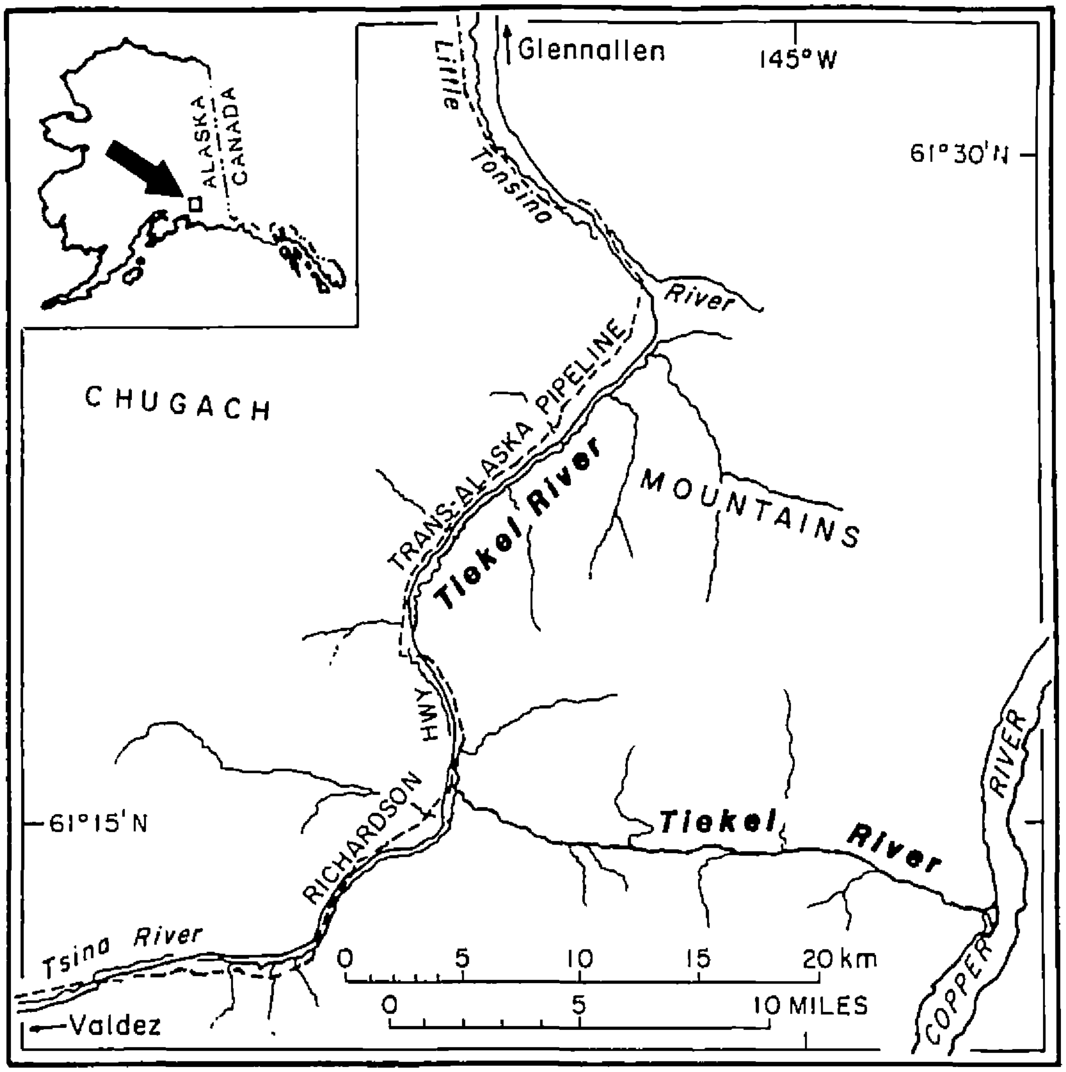

Figure 1. Tiekel River Drainage.

Wide-Banked Areas- This habitat type originates at the head of the Tiekel River and ends at about 60-mile Richardson Highway. This habitat type is characterized by having high water marks that are several times as wide as the stream width and by both sides of the stream usually being bordered by rock bars (Figure 2).

Upper Main River- This section starts at about 60-mile Richardson Highway and goes to 52-mile. This stretch is different from the wide-banked habitat type in that the high water marks are not much wider than the stream itself and usually one or both banks are vegetated (Figure 3).

Lower Main River- This section starts where the upper main river ends and goes to the end of the study area. This area has many of the same characteristics as the upper main river but differs, because of the high number of feeder streams in the area, in that it has a much greater discharge (Figure 4).

Feeder Streams- This habitat type includes all of those streams that feed the Tiekel within the study area. Their size and type of habitat they provide varies greatly (Figures 5, 6, and 7).

Figure 2. Wide-banked habitat type.

Figure 3. Upper main river habitat type.

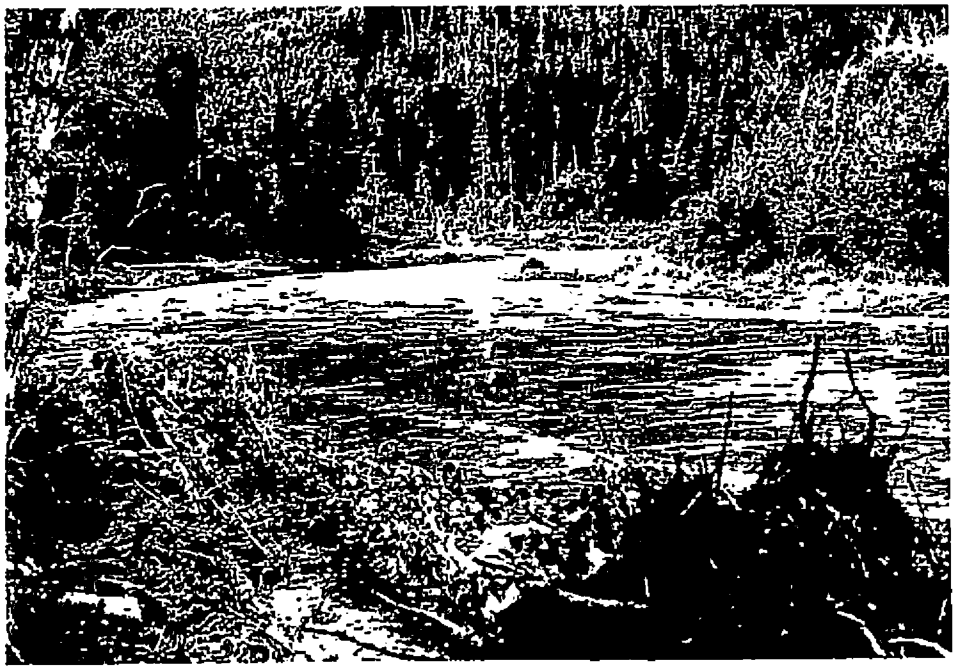

Figure 4. Lower main river habitat type.

Figure 5. Feeder stream habitat type.

Figure 6. Feeder stream habitat type.

Figure 7. Feeder stream habitat type.

Disturbed Areas- This includes all of those reaches where the stream channel has obviously been altered by human activity. There are three main types of disturbed areas. These include: bridge crossings, reaches where the road runs along side the river and the channel has been changed to accommodate the course of the road, and sections where dikes have been built to protect the highway from high water. These disturbed areas are found throughout the length of the study area.

MATERIALS AND METHODS

Tiekel River Hydrology

A staff gauge was established during the summer of 1985 at the 47-mile Richardson Highway bridge crossing. This staff gauge was resurveyed in the spring of 1986 and separate stage discharge relationship curves were developed for each year. A standard surveyor's level and stadia rod were used to determine the stream bottom profile and a Marsh McBirny electromagnetic water velocity meter was used in determining stream discharges. These discharges were calculated using the midsection method (Orth, 1983).

Description of Available Habitats

Lotic Habitats

Thirty six stream sampling reaches, each 30 meters long, were established and sampled during the summer of 1985 (Figure 8). The extent of the reach was delineated by measuring 30 meters along the wetted edge of the bank that was closest to the highway. In the wide-banked, upper main river, lower main river, and disturbed areas the

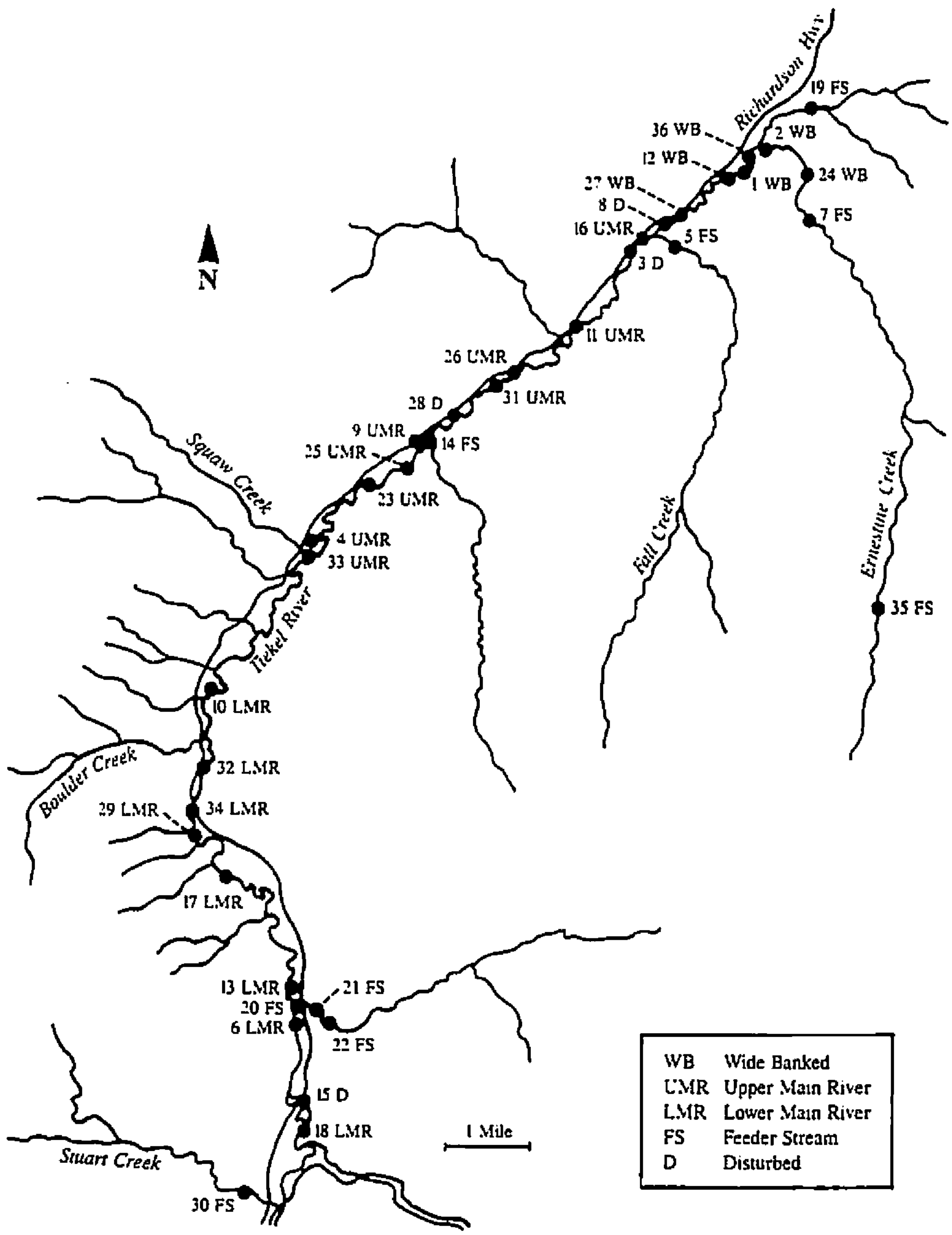

Figure 8. Locations of sample reaches from the lotic habitats.

sample reaches were randomly chosen by dividing the habitat type, on an aerial photo, into equal increments and assigning each increment a number. One of these increments was selected with a random numbers table and was then itself divided into ten equal increments with one again being randomly selected. This process was repeated until a 30 meter section of stream had been located on the aerial photo.

In the feeder-stream habitat type the sample reaches were chosen in a way to give a representative variety in the available types of habitats from the sample reaches. They were not chosen randomly because all of the feeder streams and their locations were not known to us. Most were too small to be shown on 1:63,360 maps. We had no way of assigning individual sites numbers and therefore no way of randomly selecting individual reaches.

The habitat types were sampled in a particular order and the cycle was repeated throughout the sampling period. The sampling period lasted from May 29 through September 29, 1985. More sample reaches were chosen from the upper main river and lower main river because these habitat types had the largest number of potential sample reaches and because they were quite variable. The disturbed areas were sampled the least because there was so little of this habitat type.

The data that were collected from each sample reach included: gradient, maximum depth, high water width, stream width, discharge, wetted area (cross-sectional area), mean velocity, temperature, turbidity, percent composition of substrate, percent embeddedness of substrate, percent cover, and percent composition of different water velocity and depth categories. A description of how each of these measurements was taken and recorded follows:

Gradient- The gradient was estimated using a "carpenter's water level". The construction and use of this device is described by LaPerriere and Martin (1986). The gradients were estimated to the nearest 0.1 percent.

Maximum Depth- Maximum depths were measured, for the water level at the time of sampling, to the nearest 0.1 meter on a top-setting rod which was used to hold the water velocity meter.

High Water Width- The distance between the high water marks was measured at a point that looked to be average for the sample reach. High water mark was defined as the highest point on the bank where there was evidence of water presence in the past. The measurement was made with a 30-meter tape and was recorded to the nearest meter.

Stream Width- The distance between the wetted edges on either side of the stream was taken at a point that looked to be an average distance for the sample reach. Measurements were made with a 30-meter tape to the nearest meter.

Discharge- The discharges were calculated using the midsection method (Orth, 1983). A Marsh McBirny, Price AA, or a Pygmy Gurley water velocity meter was used, depending on stream characteristics and equipment availability, to determine the velocities for the discharge calculations. Water velocity readings where taken at 0.6 total water depth. Discharges were calculated to the nearest 0.1 m^3/sec.

Wetted Area- Wetted areas (cross-sectional areas) were calculated by summing the fractional areas used in the midsection discharge calculations. These values were calculated to the nearest 0.1 m^2.

Mean Velocity- Mean velocities were calculated by dividing the total discharge by the wetted area. These values were calculated to the nearest 0.1 m/sec.

Temperature- Both air and water temperatures were measured with a mercury thermometer to the nearest 0.5 °C. The time of day was also recorded as a temperature reference.

Turbidity- Turbidities were measured in nephelometric turbidity units (NTU) to the appropriate significant figures (APHA et al., 1985) using a Hach portable turbidimeter model number 16800.

Percent Composition of Substrate- The substrates were grouped, according to Wentworth classification system (Table 1) (Orth, 1983), into boulder, cobble, pebble, gravel, sand, and silt. The percent composition measurement was made by eye for the entire sample reach and recorded to the nearest 10 percent.

Percent Embeddedness of substrate- The amount of fine material surrounding the larger material in the substrate

Table 1. Wentworth size classification system for substrate particles.

Classification	Particle size range (mm)
Boulder	> 256
Cobble	64 - 256
Pebble	16 - 64
Gravel	2 - 16
Sand	0.0625 - 2
Silt	0.0039 - 0.0625

was estimated to the nearest 10 percent for the entire sample reach. A substrate made up of cobble sized rocks with no sand or silt present would be given a zero percent embeddedness. A substrate made up of cobble where each rock is completely surrounded by sand or silt would be given a 100 percent embeddedness.

Percent Cover and Percent Composition of Velocity and Depth Categories- Diagrammatic maps were drawn of each 30-meter sample reach. These maps show an overhead view of the reach and are made up of polygons that represent different velocity and depth categories as well as available fish cover. For the diagrammatic mapping method, see Oswood and Barber (1982). Because the purpose of describing the existing habitats was to develop a broad data base, and because the type of information needed from this data could change in the future depending on the purpose of the inquiry, a general type of data that could be reinterpreted in the future was desired. For this reason diagrammatic maps were drawn. From these maps a wide range of habitat data are available. Pool-riffle ratios can be determined from these maps, even if several different definitions of pools are used. Transects can be made on the maps themselves to obtain data in the future. Names of specific habitat types (e.g. plunge pools, lateral scour pools etc.) as defined by Bisson et al. (1981) can be identified from these maps as well. The depth and water velocity categories used in the mapping were:

Slow Shallow- Water with a velocity less than 30 cm/sec (1 ft/sec) and less than 0.5 m (1.6 ft) deep.

Slow Deep- Water with a velocity less than 30 cm/sec (1 ft/sec) and with a depth equal to or greater than 0.5 m (1.6 ft) deep.

Fast Shallow- Water with a velocity equal to or greater than 30 cm/sec (1 ft/sec) and less than 0.5 m (1.6 ft) deep.

Fast Deep- Water with a velocity equal to or greater than 30 cm/sec (1 ft/sec) and with a depth equal to or greater than 0.5 m (1.6 ft) deep.

Very Fast- Water with a velocity equal to or greater than 100 cm/sec (3.3 ft/sec).

The velocity and depth categories of slow shallow, slow deep, fast shallow, and fast deep roughly correspond to the terms shallow and deep pools, riffles, and deep runs respectively (Oswood and Barber, 1982). The 100 plus cm/sec category was added to further describe the sample reaches and because I felt the Dolly Varden avoided this type of water except for movement up or down stream. The cover classifications used were: submerged forest debris, overhanging vegetation, and undercut banks. Diagrammatic maps are located in Appendix I.

Lentic Habitats

The lentic habitats include all of the standing water behind beaver dams. Sample sites were selected as whole beaver ponds. Eleven of the largest ponds, fairly evenly distributed along the study area, were selected as sample sites (Figure 9). Each of these ponds was mapped with 0.5 meter depth contours. The outline of each pond was drawn from aerial photographs using a camera lucida. Transects were then made of the pond, using a canoe, measuring depth every three meters. This depth data was then transferred to the outline drawing and the contours drawn. Seven to twenty five transacts were run depending on the size and shape of the pond. All of the depth data were gathered when the ponds were full (i.e. they had water to the top of the dam). Contour maps are located in Appendix II.

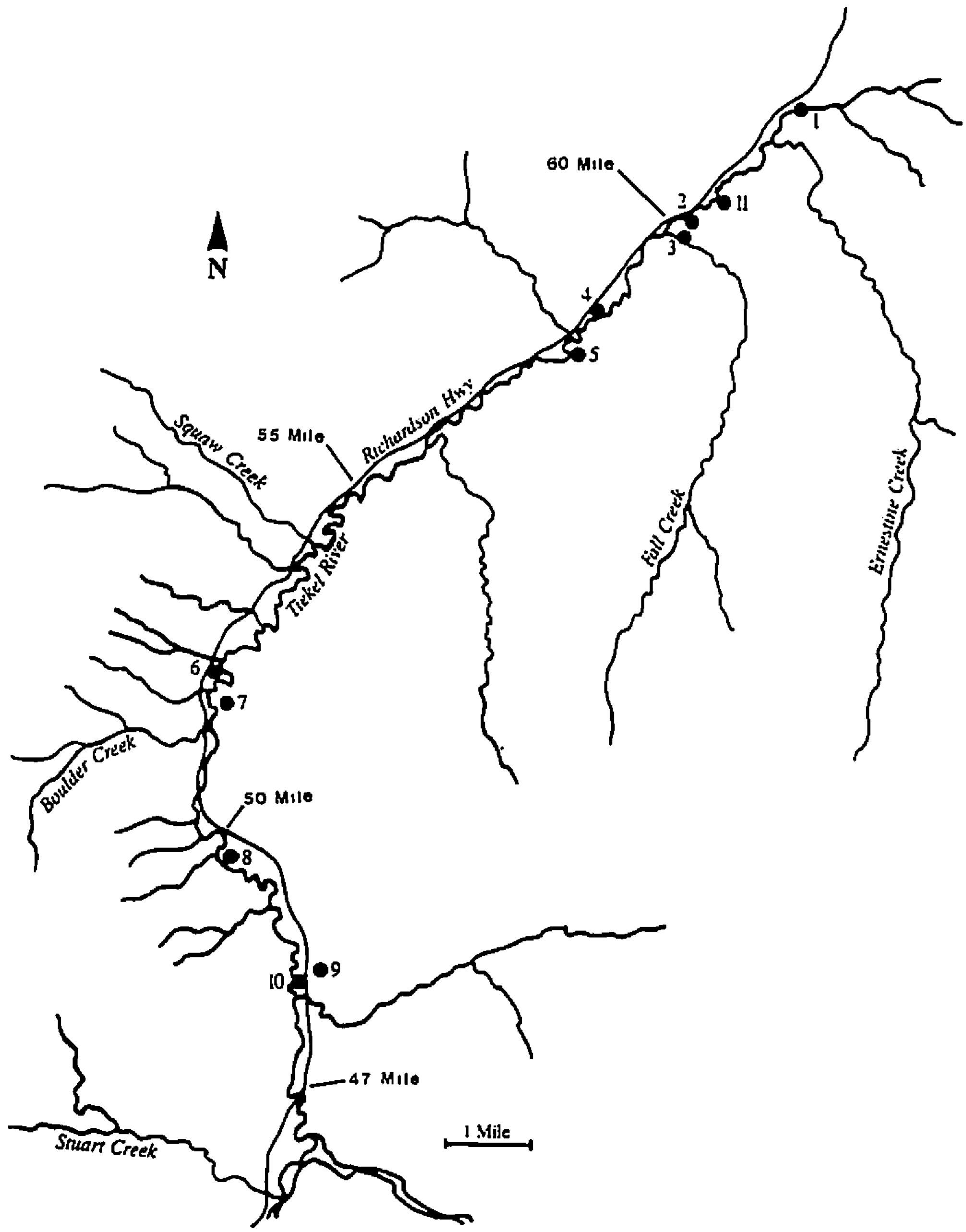

Figure 9. Locations of sample reaches from the lentic habitats.

Three times during the 1986 field season, water chemistry data were taken at each of the sample ponds, once in late May, once in mid July, and once in late August. Each time it took two to three days to gather this water chemistry data from all of the ponds. All measurements, unless otherwise stated, were taken over the deepest part of the pond at Ø.5 meter deep. These data included: temperature, dissolved oxygen (D.O.), turbidity, pH, alkalinity, and chlorophyll <u>a</u> concentrations. A description of how each of these measurements was taken and recorded follows:

Temperature- Temperatures were measured with a Yellow Springs Instruments (YSI) model 51 dissolved oxygen meter at the surface and bottom of each pond and recorded to the nearest Ø.5 $^{\circ}$C.

Dissolved oxygen- These measurements were taken using the same D.O. meter described above at both the surface and pond bottom. These data were recorded to the nearest Ø.1 mg/l.

Turbidity- Turbidities were measured in the same manner as in the stream sample reaches.

pH- Measurements were made with a Hach digital pH meter pH- Measurements were made with a Hach digital pH meter model 19000 and recorded to the nearest 0.1 pH unit.

Alkalinity- Alkalinities were measured using the Hach digital titration method. A Hach DR-EL/4 portable water chemistry lab was used.

Chlorophyll _a_- Samples were filtered through 0.3 um nominal pore-size glass fiber filters and were kept frozen over desiccant until processing. The chlorophyll _a_ concentrations were estimated using the fluorometric method (APHA et al., 1985) on a Turner Designs fluorometer at the University in Fairbanks. The concentrations were calculated to the nearest 0.01 ug/l.

Dolly Varden Use of Lotic Habitats

Fish were located throughout both field seasons using minnow traps, hoop nets, Fyke nets, electroshocking, angling, and by direct observation. Notes were taken on locations and times of all fish sightings. The life stages were broken down into young-of-the-year, adults, and spawning adults. Because the Dolly Varden in this system tended to be so small and because many of the fish mature at age two or three (Gregory, 1988), no effort was made in differentiating between habitat use by second-year fish that were not yet mature and mature fish.

Habitat Suitability Indices

To take a closer look at habitat use of the three life stages, young-of-the-year, adult, and spawning adults, suitability index graphs were developed for various habitat variables. Of the wide range of variables measured, graphs were developed only for those that made intuitive sense as well as showed some graphic relationship in a variable vs. catch-per-unit-effort or frequency of occurrence graph (USFWS, 1981).

Young-of-the-Year

Locations of young-of-the-year fish were made by electroshocking and by direct observation. The habitat variables were measured at the location where each fish was found. Measurements were not taken if we thought the location of the fish was influenced by our presence. The variables that were measured include: water depth, water velocity, substrate composition, turbidity, temperature, and cover use and type. A young-of-the-year fish was determined to be using cover if its proximity to cover, or location was influenced by nearby cover. The methodologies for taking and recording these measurements have previously been discussed. The habitat suitability index was calculated using the frequency of occurrence of fish in the different measurement ranges of each habitat variable. The highest frequency of occurrence was given a suitability index of one.

Adults

Observations were made of the exact positions of adult fish, just as for the young-of-the-year, using direct observation and angling. The habitat suitability index data came from catch-per-unit-effort data that were gathered during the first field season. These data consisted of the catch-per-minnow trap that was set over night in the different sample reaches. Catches from minnow traps were found to be representative of the actual size distribution of the Dolly Varden population found in the river (Gregory, 1988). The habitat data came from the separate habitat maps that were drawn of each sample reach as well as the other measurements that were taken at each site. The habitat that had the highest catch-per-unit-effort was given a suitability index of one.

Spawning Adults

Tributaries as well as the main river channel were searched during late September of both 1985 and 1986 for spawning Dolly Varden. Spawning locations and approximate fish densities were noted. The habitat data were gathered from the spawning redds themselves. These data included water depth, water velocity (measured at Ø.6 m), substrate composition, water temperature, and cover availability and type. Suitability index graphs for spawning fish were constructed in the same manner as for the young-of-the-year data.

Dolly Varden Use of Lentic Habitats

The data on the use of lentic habitats are mostly in the form of presence and absence information as well as length frequency data from trapping that was done throughout both field seasons in all of the sample ponds. Minnow traps, hoop nets, Fyke nets, and some gill nets were used in the ponds. Notes were also made as to pond location in relation to stream channel and how this could affect the accessibility of the pond to Dolly Varden.

Habitat Quality

A record of fish lengths was kept of all fish caught throughout the study. These measurements were taken to the nearest mm. Weights were attained from the fish caught during the second field season with a spring scale to the nearest five grams. From the length and weight data Fulton condition factors were calculated (Anderson and Gutreuter, 1983)

$$K = weight / (length^3 * 100,000)$$

Where: K = Fulton condition factor

Fulton type condition factor was used instead of LaCren, or others, because the line representing the $\log_{10}$ length-weight relationship of all Tiekel River Dolly Varden was not significantly different from the line representing X^3 growth (e.g. the shape of an organism does not change with growth) (Zar, 1984). This is an assumption that must be met in order for the Fulton condition factor to be valid. Both single and multiple regression analysis was used to look for relationships between habitat variables and fish condition (Zar, 1984). These relationships were used to determine which habitats were best for Dolly Varden.

RESULTS

Tiekel River Hydrology

The Tiekel River, upstream of the Tiekel-Tsina confluence, has a drainage area of 32,376 ha (80,000 acres). During the winter, the valley floor can have as much as 2.5 meters (eight feet) of snow on the ground (Personal Communication, Dave McCahn, 1986). At this time the river runs clear with turbidity as low as 0.8 NTU, and has a base flow of six m^3/sec (212 ft^3/sec CFS). It is not uncommon for parts of the river as well as parts of some of the beaver ponds to remain ice-free throughout the entire winter (Personal Communication, Dave McCahn, 1986). By the end of May most of the snow on the valley floor is usually gone and the river is still flowing low and clear. Discharge data for the summers of 1985 and 1986 (Figure 10) showed that the peak flow comes suddenly in late June to early July and decreases to pre-high water levels by mid-August. Mid-June flows for 1985 and 1986 were about 13 m^3/sec (458 CFS), the high flow for 1985 was 52 m^3/sec (1836 CFS) and 37 m^3/sec (1306 CFS) in 1986, and by late September the flows were down to about six m^3/sec (212 CFS). The high mid-summer flows are accompanied by silty waters, typical of glacial streams, with turbidities as

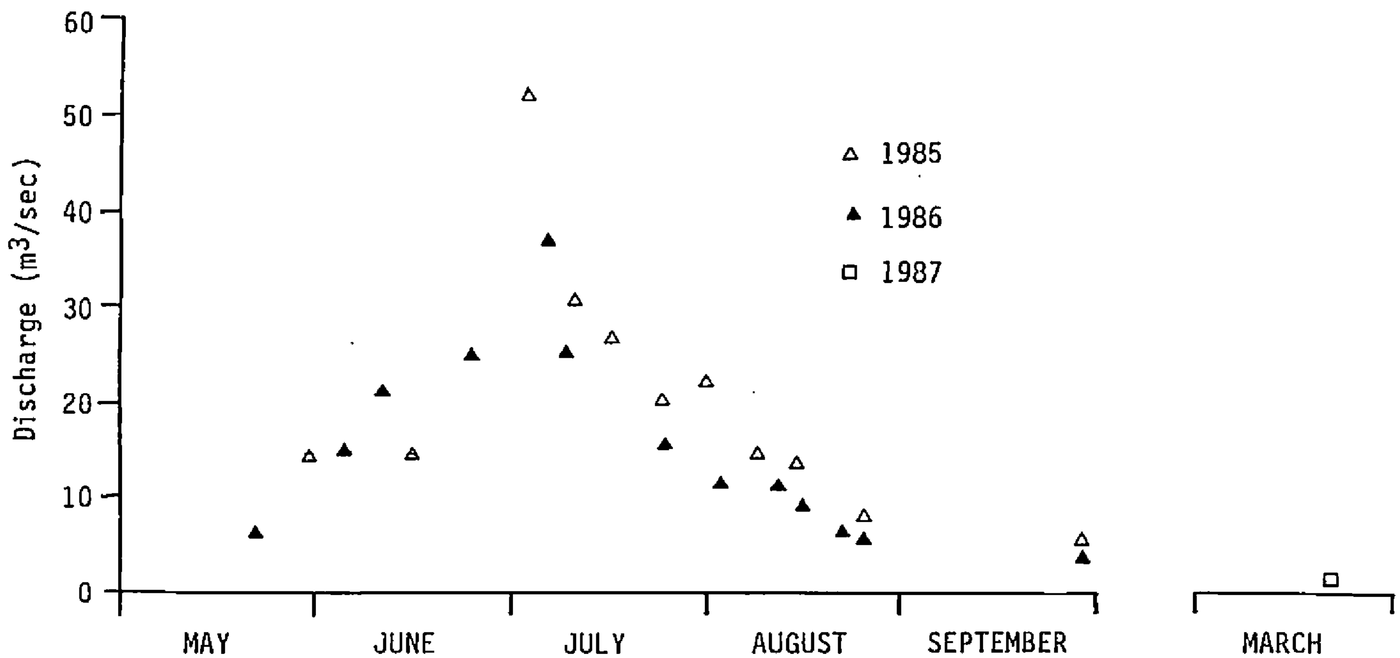

Figure 10. Tiekel River discharges measured at the 47-mile Richardson Highway bridge.

high as 21 NTU. Figure 11 presents the stage discharge relationship for the staff gauge from which the flows were calculated.

Description of Available Habitats

Lotic Habitats

Wide-Banked Areas- The stream reaches in this habitat type were characterized by having high water marks that were usually separated by a distance of several times that of the stream width. The mean distance between high water marks for this habitat type was 56 m (184 ft). One of the sample reaches had high water marks 130 m (427 ft) apart. Usually, in this habitat type, both banks were made up of rock bars with little or no vegetation. As a result, there were very little overhanging vegetation or undercut banks for the fish to use as cover. There was a relatively large amount, a mean of five percent of the total reach area, of submerged forest debris. This debris was mostly in the form of whole trees or root wads that had apparently been left behind after a high water event. This habitat type was also characterized by having large clean substrates. Cobble was the dominant substrate size averaging 77 percent of the total area of the sample

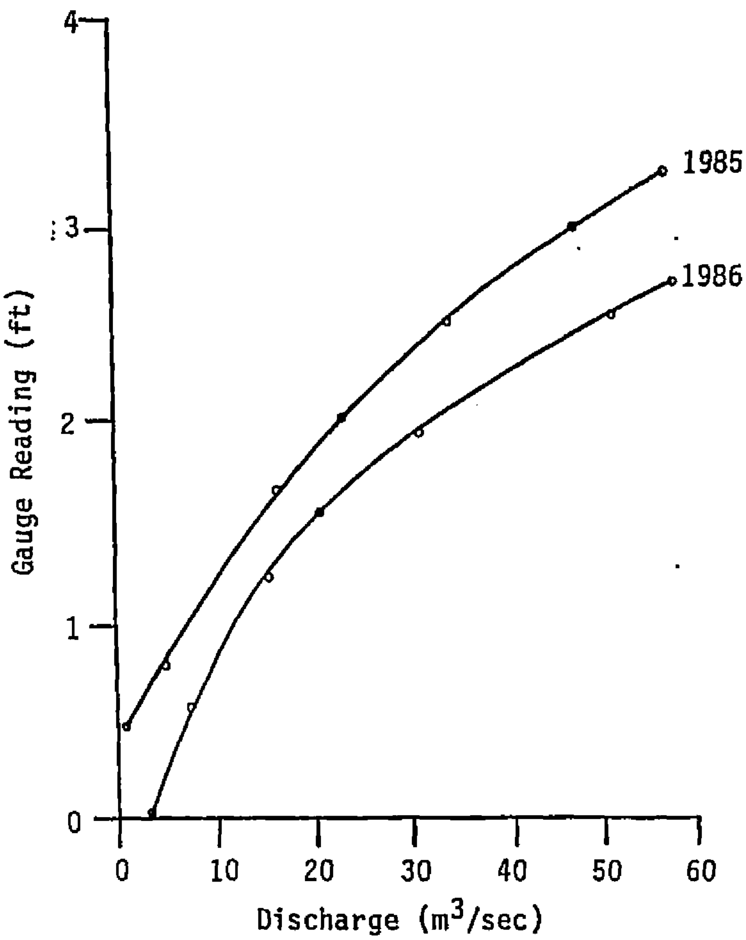

Figure 11. Stage discharge relationship for staff guage at the 47-mile Richardson Highway bridge crossing.

reaches. All of the sample reaches in this habitat type had a zero percent embeddedness. This habitat type had the steepest gradient, with a mean of 1.4 percent slope, and also was the shallowest. The average maximum depth was 0.7 m (2.3 ft) and the slow-deep and fast-deep categories together made up only 3 percent of the mean sample reach area.

The water in this section of the Tiekel River is almost entirely derived from Ernestine Creek. Because of Ernestine Creek's origins, the discharge and water clarity in this section are influenced by glacial melt. See Table 2 for a summary of habitat measurements from the sample reaches of the wide-banked habitat type and Appendix I for the individual habitat maps and other habitat data for each sample reach from all of the habitat types.

Upper Main River- The upper main river differed from the wide-banked area in that the highwater marks were only, on the average, 23 m (76 ft) apart. Usually one or both stream banks were vegetated. There was also some, although limited amounts, of overhanging vegetation and undercut banks. The substrates in this area were made up of finer materials than in the wide-banked area. Cobble substrate was the most abundant at 49 percent. Many

Table 2. Summary of the habitat measurements from the wide-banked habitat type.

Mean Habitat Measurements

Temperature and Hydrology		% Composition of Substrate	
Temperature:	5.5°C (41.9°F)	Sand:	0%
Gradient:	1.4 %	Gravel:	0%
Maximum Depth:	0.7 m (2.3 ft)	Pebble:	11%
Turbidity:	6.0 NTU	Cobble:	77%
% Embeddedness:	0%	Boulder:	12%
Highwater Width:	56 m (184 ft)		
Stream Width:	17 m (56 ft)		
Discharge:	3.9 m^3/sec (105.9 ft^3/sec)		
Wetted Area:	3.8 m^2 (40.9 ft^2)		
Mean Velocity:	1.0 m/sec (3.3 ft/sec)		

% Cover

Submerged Forest Debris:	5%
Overhanging Vegetation:	0%
Undercut Bank:	0%

% Composition of Depth and Velocity Categories

Slow Shallow:	24%
Slow Deep:	3%
Fast Shallow:	28%
Fast Deep:	0%
Very Fast:	45%

feeder streams entered the river in this area which made the average summer discharge in this habitat type about twice that of the wide-banked area. Like the wide-banked area, the fish cover in this habitat type was mostly in the submerged forest debris classification. Unlike the submerged forest debris in the wide-banked area, the majority of this debris was in the form of freshly fallen trees. Evidently, there was a large enough annual high water event to keep most of these trees from remaining in this section of the river from year to year. This habitat type also had a great deal more slough and backwater area than in the wide-banked area. These sloughs were mostly old river channels that, for the most part, are filled with local drainage rather than river water. These old channels, or oxbows, often contain beaver dams. See Table 3 for a summary of of the sample reach data for the upper main river habitat type.

Lower Main River- The lower river shared many of the same characteristics with the upper main river. One of the biggest differences was that the mean summer discharge in the lower main river was about twice that of the upper main river. The size of the substrates was also much different in this habitat type, with the sand being the most abundant at 41 percent. The pebble and cobble size

Table 3. Summary of the habitat measurements from the upper main river habitat type.

Mean Habitat Measurements

Temperature and Hydrology		% Composition of substrate	
Temperature:	5.2°C (41.4°F)	Sand:	8%
Gradient:	1.2%	Gravel:	5%
Maximum Depth:	1.2 m (3.9 ft)	pebble:	26%
Turbidity:	11 NTU	Cobble:	49%
% Embeddedness:	15%	Boulder:	12%
Highwater Width:	23 m (76 ft)		
Stream Width:	14 m (45 ft)		
Discharge:	7.5 m3/sec (264.9 ft3/sec)		
Wetted Area:	7.1 m^2 (76.4 ft^2)		
Mean Velocity:	1.1 m/sec (3.6 ft/sec)		

% Cover

Submerged Forest Debris:	4%
Overhanging Vegetation:	0%
Undercut Bank:	0%

% Composition of Depth and Velocity Categories

Slow Shallow:	14%
Slow Deep:	7%
Fast Shallow:	21%
Fast Deep:	13%
Very Fast:	45%

categories were also important, both combined representing over 20 percent of the total area. Sedimentation also became important in this habitat type. The amount of sedimentation influences the percent embeddedness which averaged 39 percent in this habitat type compared to 25 percent and zero percent in the upper main river and wide-banked area respectively. This increase in percent embeddedness may be a result of the decrease in the gradient from the upper reaches of the river to the lower. The average gradient of the lower main river habitat type was 0.7 percent while the gradient for the upper main river and wide-banked area are 1.2 percent and 1.4 percent respectively. See Table 4 for a summary of the sample reach data for the lower main river habitat type.

Feeder Streams- A wide variety of aquatic habitats were present in the feeder streams. The discharge, gradient, and amount and kind of cover varied from stream to stream. Three of the larger streams, Ernestine, Fall, and Stuart Creeks, resembled many of the reaches in the wide-banked areas. They were similar to that section of the river in that they had steep gradients, large substrates, shallow maximum depths, and the little in-stream cover that was available was in the form of submerged forest debris. All of these streams are partially glacial fed and were

Table 4. Summary of the habitat measurements from the lower main river habitat type.

Mean Habitat Measurements

Temperature and Hydrology		% Composition of Substrate	
Temperature:	5.6°C (42.1°F)	Sand:	41%
Gradient:	0.7%	Gravel:	0%
Maximum Depth:	1.4 m (4.6 ft)	Pebble:	26%
Turbidity:	12 NTU	Cobble:	25%
% Embeddedness:	39%	Boulder:	8%
Highwater Width:	36 m (118 ft)		
Stream Width:	21 m (69 ft)		
Discharge:	14.2 m^3/sec (501.5 ft^3/sec)		
Wetted Area:	15.0 m^2 (161.5 ft^2)		
Mean Velocity:	1.0 m/sec(3.3 ft/sec)		

% Cover

Submerged Forest Debris:	3%
Overhanging Vegetation:	1%
Undercut Banks:	0%

% Composition of Depth and Velocity Categories

Slow Shallow:	9%
Slow Deep:	7%
Fast Shallow:	17%
Fast Deep:	25%
Very Fast:	42%

therefore silty during most of the summer. There were also a large number of streams with summer discharges below 0.4 m^3/sec (14.1 CFS). The length of available habitat to the fish in these streams was usually quite small as most of them are too steep for fish passage until they reach the narrow river plain. Most of these small streams had smaller substrates with little substrate embeddedness. See Table 5 for a summary of the sample reach data of the feeder streams habitat type.

Disturbed Areas- As mentioned earlier, the disturbed areas can be broken down into the three groups: bridge crossings; reaches of the river where dikes had been built to protect the highway from highwater; and, reaches where the stream channel had been altered to accommodate the course of the highway. All of these groups had similar characteristics. Except for the amount of in-stream cover, the habitat characteristics in this habitat type were similar to those found in the wide-banked areas habitat type. The disturbed areas had very little cover, submerged forest debris averaged one percent compared to the wide-banked areas where submerged forest debris averaged five percent. The pools in this habitat type were usually small and confined to the edge of the stream. This habitat type also had the highest percentage of water

Table 5. Summary of the habitat measurements from the feeder streams habitat type.

Mean Habitat Measurements

Temperature and Hydrology		% Composition of Substrate	
Temperature:	5.3°C (41.5°F)	Sand:	22%
Gradient:	2.1%	Gravel:	2%
Maximum Depth:	0.8 m (2.6 ft)	pebble:	12%
Turbidity:	4.0 NTU	Cobble:	22%
% Embeddedness:	21%	Boulder:	42%
Highwater Width:	17 m (56 ft)		
Stream Width:	12 m (39 ft)		
Discharge:	2.2 m3/sec (77.7 ft3/sec)		
Wetted Area:	3.3 m^2 (35.5 ft^2)		
Mean Velocity:	0.6 m/sec (2.0 ft/sec)		

% Cover

Submerged Forest Debris:	9%
Overhanging Vegetation:	3%
Undercut Bank:	1%

% Composition of Depth and Velocity Categories

Slow Shallow:	19%
Slow Deep:	4%
Fast Shallow:	28%
Fast Deep:	18%
Very Fast:	31%

in the very fast classification at 56 percent and the largest percentage of substrate area in the boulder classification at 55 percent. See Table 6 for a summary of the sample reach data for the disturbed areas habitat type.

Lentic Habitats

The beaver ponds in the Tiekel River drainage offer a wide variety of habitats for the Dolly Varden that use them. Most of the ponds are built in old river channels. Some of these ponds were new and were built in places where beaver ponds had never existed in the past, some were new ponds that were built in places where older dams had previously existed but since failed, and some were ponds that have been in place for many decades. Most of the ponds retained an ice cover throughout the winter while some, evidently due to groundwater influx, had ice-free areas throughout the winter (Personal Communication, Dave McCahn, 1985). The water level in some of the ponds was low during the early summer before the runoff from the mountains began to raise the water in the river. Others were filled to the tops of the dams from the time the ice went out. All of the ponds were full during the middle part of the summer. In the fall when the water level

Table 6. Summary of the habitat measurements from the disturbed areas habitat type.

Mean Habitat Measurements

Temperature and Hydrology		% Composition of Substrate	
Temperature:	5.0°C (41.0°F)	Sand:	1%
Gradient:	0.7%	Gravel:	0%
Maximum Depth:	0.9 m (2.9 ft)	pebble:	6%
Turbidity:	4.4 NTU	Cobble:	37%
% Embeddedness:	6%	Boulder:	56%
Highwater Width:	21 m (69 ft)		
Stream Width:	20 m (66 ft)		
Discharge:	4.4 m^3/sec (155.4 ft^3/sec)		
Wetted Area:	5.0 m^2 (53.8 ft^2)		
Mean Velocity:	0.8 m/sec 2.6 ft/sec)		

% Cover

Submerged Forest Debris:	1%
Overhanging Vegetation:	0%
Undercut Bank:	0%

% Composition of Depth and Velocity Categories

Slow Shallow:	16%
Slow Deep:	5%
Fast Shallow:	18%
Fast Deep:	6%
Very Fast:	55%

dropped in the river, the water levels in some of the ponds again dropped. See Table 7 for a summary of some pond data and Appendix II for bathymetric maps of all of the sample ponds. For each pond, a physical location, some of the more important habitat variable measurements, and how some of these variable measurements changed over the summer follows:

Pond #1- This pond was an active beaver pond with a surface area of 1.81 ha (4.48 acre), mean depth of 0.80 m (2.62 ft), and a volume of 14,500 m^3 (510,000 ft^3). This pond had the largest surface area of the sample ponds and was found on the east side of the highway near mile 61.5 across from the Ernestine highway maintenance station. Its water source was the boggy area which drained the south side of the divide which separated the Little Tonsina and Tiekel drainages. Mosquito Creek was the main feeder stream of this pond. Groundwater may also have been an important water source since several terrestrial as well as underwater springs were evident. Pond #1 was comparatively old as indicated by the dense, overgrown dam and the emergent vegetation growing in the shallows.

The temperature in this pond varied throughout the summer with a May temperature of 4.0 C (39 F), a June temperature of 2.0 C (36 F), and a August temperature of 7.0 C (45 F). These low temperatures may have been a result of a high refill rate as well as the groundwater influence. The D.O. was above 11.0 mg/l throughout the summer as well as during our winter trip in March of 1987. The turbidity was fairly low throughout the summer, although just as the ice cover was leaving during May of 1986, the pond was very turbid. We were unable to make a measurement at that time but it looked to be well above 5.0 NTU. This may have been the result of an early algal bloom. Unfortunately chlorophyll a samples were not taken during this first field trip. The June, July, and August samples show very little change in chlorophyll a concentrations throughout the remainder of the summer averaging about 0.2 ug/l.

Pond #2- Pond #2 was an active pond which was situated on an old river channel east of the river near mile 60.5. This pond had a surface area of 0.42 ha (1.03 acre), a mean depth of 0.70 m (2.3 ft), and a volume of 2900 m^3 (102,000 ft^3). This pond was relatively new as indicated by the clean dam and rocky bottom and banks. There was a feeder stream which flowed in the old river channel, and throughout the summers of 1985 and 1986, this stream contained water.

Table 7. Summary of habitat variable measurements gathered from the lentic habitats throughout the study. S = Surface. B = Bottom.

	TEMPERATURE (°C)									DISSOLVED OXYGEN (mg/l)				
	MAY		JUNE		JULY		AUG		MAR	MAY	JUNE	JULY	AUG	MAR
	S	B	S	B	S	B	S	B	S					
Pond #1	4.0	4.0	2.0	2.0	5.0	5.0	7.8	6.1	0.4	11.0	12.5	11.3	11.2	11.8
Pond #2	6.0	5.0	4.0	4.0	5.0	6.0	5.5	5.5		11.8	12.0	11.4	11.0	
Pond #3	1.8	1.8	11.0	9.0	15.0	14.0	9.5	9.5	0.0	8.2	13.0	5.8	5.6	0.9
Pond #4	7.6	6.0	5.0	5.0	5.2	5.2	7.5	7.0	0.0	11.2	10.2	9.2	9.7	12.6
Pond #5	3.5	3.5	4.0	4.0	5.2	5.0	9.5	7.0		10.8	10.8	9.6	9.2	
Pond #6	3.0	3.0	13.0	13.0	14.0	14.0	11.2	11.2		8.5	9.0	8.5	8.6	
Pond #7	3.5	3.5	4.0	4.0	10.0	9.0	11.5	11.5		12.0	12.2	10.6	10.1	
Pond #8	3.0	3.0	10.5	8.5	13.0	10.0	11.0	11.0		6.8	8.6	7.6	7.7	
Pond #9	4.0	5.0	7.5	7.5	12.0	12.0	11.0	11.0	0.0	6.5	10.4	9.4	4.0	2.1
Pond #10	6.0	6.0	14.5	11.0	14.0	12.0	11.0	11.0	0.0	3.6	8.6	8.1	4.6	2.4
Pond #11							4.0	4.0	0.0					10.6

Table 7. (Continued), * = Dolly Varden present in feeder stream.

** = Limited amount of spawning habitat available, no fish seen using it.

	ALKALINITY (mg/l CaCO3)				CHOROPHYLL a (µg/l)				DOLLY VARDEN ABUNDANCE A=Abundant P=Present N=None	FISH ACCESSABILITY 1=Poor 2=Fair 3=Good	SPAWNING HABITAT S=Present N=None
	MAY	JUNE	JULY	AUG	MAY	JUNE	JULY	AUG			
Pond #1	40	47	16	41		0.19	0.12	0.30	A	1	S
Pond #2	28	39	35	43		0.21	0.31	0.14	N*	2	S
Pond #3	16	23	59	61		0.61	1.03	4.70	N	1	N
Pond #4	35	51	47	40		0.21	0.22	0.17	P	3	N
Pond #5	39	36	34	35		0.17	0.14	0.21	N	2	N
Pond #6	47	54	47	130		2.44	1.38	7.95	P	2	N**
Pond #7	48	28	38	67		0.26	1.54	1.64	A	3	N
Pond #8	39	43	38	37		0.52	1.73	2.77	A	3	N
Pond #9	22	27	29	39		0.81	0.73	4.26	P	1	N
Pond #10	9	28	38	47		2.04	0.68	6.93	N	2	N
Pond #11				32					A	2	S

Table 7. (Continued)

	pH				TURBIDITY (NTU)				Surface Area (ha)	Mean Depth (m)	Volume (m^3)
	MAY	JUNE	JULY	AUG	MAY	JUNE	JULY	AUG			
Pond #1	6.7	6.9	6.1	7.0		3.7	1.2	1.1	1.18	0.80	14,500
Pond #2	6.8	6.9	6.6	6.8		1.1	1.1	0.8	0.42	0.70	2,900
Pond #3	6.3	6.2	6.3	6.3		3.4	2.8	7.6	0.31	0.75	2,300
Pond #4	6.5	6.4	6.3	6.4		1.1	1.2	0.8	0.42	0.57	2,400
Pond #5	6.5	6.2	6.0	6.3		2.4	0.8	1.2	0.38	0.41	1,600
Pond #6	6.5	6.8	6.4	6.9		2.5	2.1	5.9	0.79	0.77	6,100
Pond #7	6.7	6.8	6.6	7.3		1.9	2.5	3.2	1.59	0.76	12,100
Pond #8	6.0	6.5	6.0	6.6		1.2	1.5	7.4	1.01	0.73	7,400
Pond #9	6.2	6.5	6.0	6.2		1.2	1.1	2.2	1.31	0.95	9,900
Pond #10	5.6	6.3	5.7	6.2		2.9	2.5	9.2	0.65	0.64	4,100
Pond #11				6.5				0.6	0.35	0.70	2,500

This pond remained cold and clear throughout the summer. The temperature in this pond was never recorded above 6.0 °C (43 °F) and the turbidity was never recorded above 1.1 NTU. This may have been a result of the high refill rate from the cold, clear water from its feeder stream. Chlorophyll a concentrations were relatively low throughout the summer with a high being recorded in July at 0.31 µg/l. Because of multiple layers of ice, no D.O. or temperature measurements could be taken during March of 1987.

Pond #3- Pond #3 was an active pond found on a slough on the east side of the river near the 60.3-mile turnout of the highway. This slough was an old stream channel and is bordered on its east side by the steep slopes of the river valley. The pond had a surface area of 0.31 ha (0.77 acre), a mean depth of 0.75 m (2.5 ft), and a volume of 2300 m^3 (82,000 ft^3). Upstream of this pond was a chain of other ponds which make up a large marshy area. This pond, as well as the other ponds in this chain, are very old.

The water was always a brown color with turbidities being low in the early summer (2.8 NTU) and higher in the fall

(7.6 NTU). This pond had a relatively low refill rate, particularly in the fall when the water temperatures reached 15°C (59°F). The chlorophyll _a_ concentrations measured as high as 4.7 µg/l in August. D.O. concentrations were measured at saturation levels during June (13 mg/l) and low (0.9 mg/l) in March. This was the lowest D.O. measurement recorded from any of the sample ponds. The bottom was made up of deep detritus deposits and smelled of sulfur gas throughout the summer.

Pond #4- This pond was located next to the highway, on the west side of the river, near mile-post 58. The dam which created this pond was fairly new although the area has had beaver activity for a long time. Possibly this was a new dam at the site of a older dam that had failed in the past. The surface area of this pond was 0.42 ha (1.05 acre), a mean depth of 0.57 m (1.9 ft), and a volume of 2400 m^3 (85,000 ft^3). This pond was fed from a stream which crossed the road from the west as well as a marshy area which received water during high flows of the river.

This pond remained cold and clear throughout the summer, with the exception of silty water conditions when the river was at peak discharges. The chlorophyll _a_ concentrations in this pond remained relatively low throughout the summer, peaking at 0.22 μg/l in July. D.O. measurements indicated that the water in this pond remained nearly saturated throughout the year, with the lowest reading in July at 9.2 mg/l and the highest in March at 12.2 mg/l. The clear water, new dam, high D.O. readings, and cold temperatures (never recorded above 7.0 °C (45 °F)) indicated that this pond had a relatively high refill rate.

Pond #5- This pond was located on the east side of the river at about mile 57.5 near the outside of a large meander. The surface area was 0.38 ha (0.94 acre), mean depth was 0.41 m (1.3 ft), and the volume was 1600 m^3 (55,000 ft^3). This pond was the shallowest of the sample ponds and about one quarter of the surface area was covered with fallen trees. Beavers had not wintered in this pond for a number of years. This was evident by the lack of fresh cuttings in the dam, lodge, and food cache.

This pond was fed mainly from a small stream which contained water throughout the summer of 1986. Because of the small volume of water and poor condition of the dam this pond probably had one of the fastest refill rates of the sample ponds. It therefore contained cold, clear water with low chlorophyll *a* concentrations throughout the summer. No measurements were taken from this pond between September and May.

Pond #6- Pond #6 was located near mile 52.5 on the east side of the highway between the highway and the river. This pond had a surface area of 0.79 ha (3.92 acre), mean depth of 0.77 m (2.5 ft), and a volume of 6100 m^3 (215,000 ft^3). This was an old, well-established pond that had been active throughout the study. It was fed by a small stream which flowed through a boggy area before entering the pond.

This pond had a relatively slow refill rate especially during the late summer when the small feeder stream was running low. Evidently as a result of the slow refill rate, this pond reached late summer temperatures as high as any of the sample ponds (14°C (57°F)) during July of 1986. This pond also attained one of the highest turbidity readings and the highest chlorophyll _a_ concentration measurement of all of the sample ponds. The turbidity in this pond reached 5.9 NTU and the chlorophyll _a_ concentration reached 7.95 µg/l in August of 1986. Again we were unable to take measurements from this pond during the winter field trip due to layered ice.

Pond #7- Pond #7 had the second largest surface area at 1.59 ha (3.29 acre) and was located on the east side of the river near mile 52. This pond had a mean depth of 0.76 m (2.5 ft), and a volume of 12,100 m^3 (426,000 ft^3).

The refill rate was relatively slow in this pond during the late summer. The highest turbidity reading was 3.2 NTU which was taken in August of 1986 and the highest temperature was 11.5°C taken at the same time. This pond was situated in an old river channel and was fed mostly from a boggy area which drained the east side of the river valley. No data were taken from this pond in March.

Pond #8- Pond #8 was located between the highway and the river near mile-post 50. It had a surface area of 1.01 ha (2.5 acre), a mean depth of 0.73 m (2.4 ft), and a volume of 7400 m^3 (261,000 ft^3). This pond had beaver activity and was quite old. It received water from a series of ponds which collected water from the boggy area along the edge of the river.

This pond had a slow refill rate during times of low water. At these times the water reached high temperatures and turbidities. In August of 1986 this pond had a water temperature of 11.0°C (52°F) and a turbidity of 7.4 NTU.

The chlorophyll a concentration during this same time was relatively low (2.77 µg/l). The D.O. concentrations in this pond were continually low with the highest measurement being 8.6 mg/l in June of 1986. Because of layered ice no D.O. measurements were taken in March.

Pond #9- This pond was separated from the river by the highway near mile 48.5, the pond being on the east side of the highway and the river on the west. This pond was very old but still had beaver activity. It had a surface area of 1.31 ha (3.2 acre), a mean depth of 0.95 m (3.1 ft), and a volume of 9900 m^3 (348,000 ft^3). This pond was fed from the drainage of several small streams as well as a boggy area on the east side of the road.

This pond had a relatively slow refill rate throughout most of the summer and therefore had high temperatures. The highest water temperature in this pond was recorded during July of 1986 (12.0°C (54°F)). During this same period the chlorophyll a concentration was high (4.26 µg/l), and the D.O. was low (4.0 mg/l). The highest turbidity measurement was also taken at this time (2.2 NTU). In March of 1987 the D.O. in this pond was measured at 2.1 mg/l.

Pond #10- This pond was located on the west side of the road, between the highway and the river, about 400 meters south of pond #9. The surface area of this pond was 0.65 ha (1.6 acre), mean depth was 0.64 m (2.1 ft), and the volume was 4100 m^3 (146,000 ft^3). This pond was relatively new and was on an old river channel. It received its water from the wet ground surrounding the river.

This pond was characterized by high water temperatures, low D.O., high turbidity, and high chlorophyll <u>a</u> concentrations. These indicate a slow refill rate. The highest recorded temperature was in August (14.0 °C (57 °F)). The highest turbidity and chlorophyll <u>a</u> concentrations were also in August (9.2 NTU) and (6.93 µg/l) respectively. This pond had beaver activity throughout the entire study. In March on 1987 the D.O. in this pond was low, recorded at 2.4 mg/l.

Pond #11- Pond #11 was located on the east side of the river near mile 62.5, between pond #1 and pond #2. The surface area of this pond was 0.35 ha (0.87 acre), the mean depth was 0.7 m (2.3 ft) ,and the volume was 2500 m^3 (5000 ft^3).

This pond was very unusual, in that it was really two separate ponds that were connected. They were separated by an old beaver dam that had become a dense soil dike with several deep openings in it. On the east side of the dike was the old pond which received its water from a series of ponds which drained a boggy area. On the west side of the dike was a new pond which received its water from a stream which flowed throughout the year. On the east side, or "warm" side, the pond was typical of the old ponds in the area. It had a deep detritus bottom, it was filling in from the edges, it had a slow refill rate and got quite warm in the summer. The west side of the pond, or "cold" side, was typical of the newer ponds in the drainage. It had a loose rocky bottom, the dam was new and allowed water to pass through, it had a good constant source of water, and the water was cold and clear throughout the summer. In July of 1985 the "warm" side of the pond had a recorded temperature of 14.0°C (57°F) while the "cold" side had a temperature of 6.0°C (42 °F). On August 8, 1985 the turbidity of the "warm" side was measured at 4.1 NTU while the "cold" side was measured at 1.5 NTU. The only chlorophyll a concentration measurements were taken on August 23, 1986. At this time the air temperature had started to drop for the summer and the water temperatures were similar to each other, 5.5°C

(42°F) for the "warm" side and 4.0°C (39°F) for the "cold" side. The chlorophyll a concentration for the "warm" side was measured at 0.25 µg/l while the "cold" side was measured at 0.18 µg/l. This difference was significant at the 95 percent confidence level. During March of 1987 the "cold" side was partially ice free due to the large inlet stream. The ice on the middle of the "cold" side was five cm (2 inches) thick while the ice on the "warm" side was 20 cm (8 inches) thick. The D.O. measurements were fairly similar with the "cold" side being 11.7 mg/l while the "warm" side was 10.6 mg/l.

Dolly Varden Use of Lotic Habitats

In the early part of the summer very few fish were found in the upper-most part of the river (the wide-banked habitat type) and the smaller feeder streams. By mid to late June, however, fish were found in all accessible waters of the Tiekel drainage. This indicated that the Dolly Varden were wintering in the larger parts of the river and reinhabiting the smaller sections of the stream each year. The extent of the overwintering areas are not known, but because the winter stream discharges were similar to those found in late September and large sections of the stream remain ice-free throughout the winter, overwintering sites may be abundant. A discussion of fish use of the different habitat types follows:

Wide-Banked Areas- Because this section of stream is shallow, particularly during low winter flows, it is doubtful that any Dolly Varden use this habitat type during the winter months. Some fish were found in this area as early as late May but the fish became much more abundant by late June. The Dolly Varden in this section were usually found in the small pools that were created by large boulders, at the edge of dropoffs, and where large debris piles (usually root wads and whole trees) were located in the stream channel. Boulders and submerged woody debris were the most obvious forms of cover used by the Dolly Varden in this section. Deep water, turbidity, and turbulent water surfaces were also used as cover. Basically, adult fish in this section of the stream were not seen unless forced or lured out of protective cover. Young-of-the-year fish were not found in this area, possibly due to the fact that there was no spawning witnessed in this section or in streams feeding this section.

Upper Main River- During the summers, the Dolly Varden used this section of the stream extensively. It was used by adults as well as young-of-the-year. The adults were usually associated with some sort of cover. It was possible, however, to see occasional fish in this section, usually as they took food from the surface. Spawning occurred in many of the streams that feed this section as well as in the main channel itself. Use of the main channel for spawning is probably limited as only one spawning redd with five to seven Dolly Varden was seen in the main channel during our field trips in late September. The reason for this limited amount of spawning may be the lack of substrates in the preferred gravel and sand size categories. Young-of-the-year Dolly Varden first appeared in this and other downstream sections of the river in mid-July. It may be that they do not emerge from the substrate until this time, since they become fairly easy to find thereafter. The young-of-the-year used the water along the edges of the channel and in the side channels where the velocities are near zero. They also preferred areas that provided some type of cover.

Lower Main River- Because of the greater maximum depth, area, and number of pools in this habitat type, this section of the stream may play an important role in providing overwintering habitat for the Dolly Varden. The adult Dolly Varden used this section during the summer and could be found in the many large pools as well as the small pools which were created by downed trees and large rocks. During mid-summer, Dolly Varden adults tended to be less dense in this habitat type than in the habitat types further up stream. No spawning was seen in this habitat type but some of the streams which feed the river in this section did contain spawning fish. Young-of-the-year fish were seen in this habitat type from mid-July on, along the stream edges and in the side channels where water velocities were near zero.

Feeder Streams- Two of the larger feeder streams, Ernestine and Boulder Creeks, showed little use by Dolly Varden throughout the year. Many of the smaller streams, most of which are unnamed, were used by adults and young-of-the-year during the summer and were used for spawning during the fall. Most of these streams contained fish up to the last accessible pool during the summer. The Dolly Varden used cover when available throughout the summer, but when spawning, the fish were easily visible. Some of the spawning redds were associated with cover but most were not. Two of the streams, one which crosses the highway at mile 59.5 and the other which enters the river from the east near mile-post 59, were crowded with spawning fish during the last week of September, 1986. In these crowded streams it was difficult to see which fish were actually associated with each redd as there were as many as two hundred fish crowding over two or three redds. In most of the other feeder streams where spawning occurred, the fish were much less numerous. Usually there were only two dominant and as many as four subordinate fish on each redd in these streams.

Disturbed Areas- Most of the disturbed areas were within the upper and lower main river habitat types. The adult Dolly Varden used these areas throughout the sampling periods. Due to the lack of pools and cover in this habitat type, the fish there were generally found in the small pools created by large rocks at the edge of the stream. Because of the high percentage of these reaches in the shallow-fast water category it is doubtful these areas are used as overwintering areas. There were very few side channels in this habitat type and little water in the 0-30 cm/sec velocity category. This resulted in little use by young-of-the-year fish.

Habitat Suitability Indices

Young-of-the Year

The habitat variables found to have a relationship with young-of-the-year use were: water velocity, dominant substrate type, water depth, and cover presence and type. Water velocity seemed to be the most important because its graph showed the narrowest preference (Figure 12) and because most of the other habitat variables important to this life stage are related to water velocity. Young-of-the-year fish showed a strong preference for zero velocity water. From zero, the line drops quickly to 10 cm/sec (0.33 ft/sec) where the suitability index is less than 0.1. From this point the line flattens out and extends to 40 cm/sec (1.3 ft/sec) where the suitability index is near zero. This portion of the line is probably biased towards the higher velocities since we measured average velocities of the water column above the fish due to instrumental design, and the micro-habitats around the fish were probably nearer to zero velocity due to frictional effects of the bottom substrates on the flowing water.

The preferred substrate classification for young-of-the-year Dolly Varden included sand and silt (Figure 13).

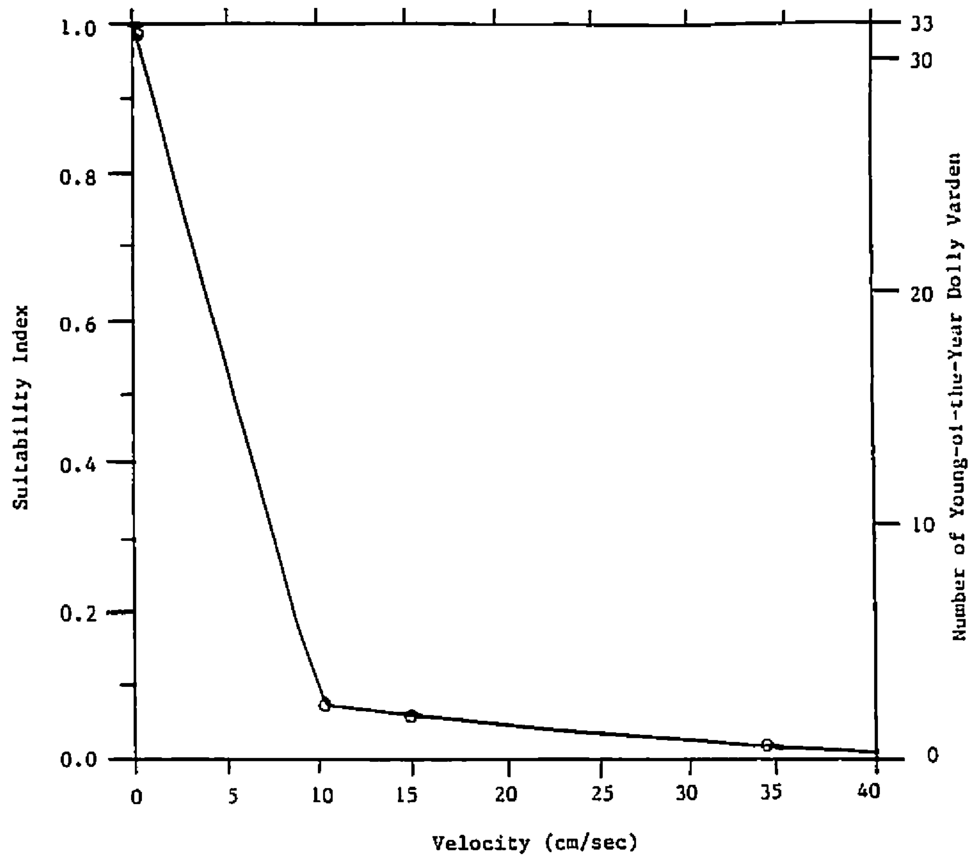

Figure 12. Habitat suitability indices and number of young-of-the-year Dolly Varden collected at various water velocity measurements.

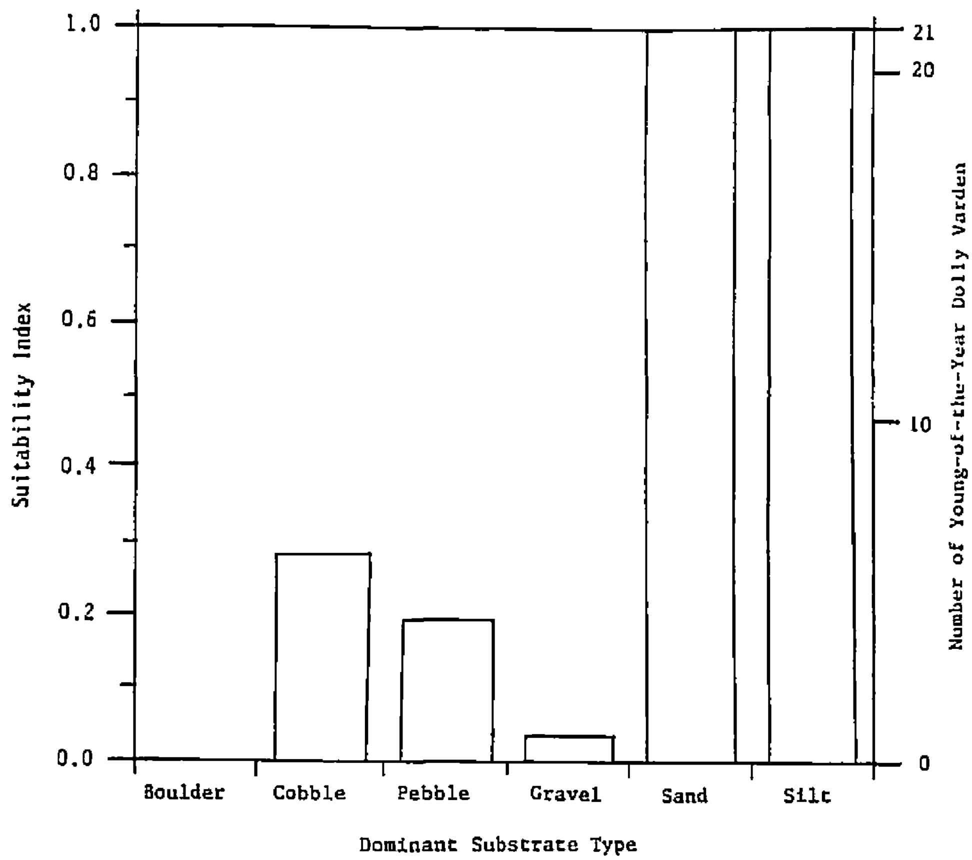

Figure 13. Habitat suitability indices and number of young-of-the-year Dolly Varden collected over several types of substrates.

Both sand and silt received a suitability index of 1.0. Cobble received a rating of 0.28, pebble 0.19, and gravel 0.03.

Young-of-the-year Dolly Varden showed a preference for water in the depth range of nine to 17 cm (0.6 ft) (Figure 14). This range rated a suitability index of 1.0. This depth appeared to be strongly favored as the curve is fairly steep on either side of this range. The young-of-the-year Dolly Varden showed a strong preference for cover, and and of the cover types submerged forest debris was the most preferred (Figure 15).

Adults

Ten habitat variables were used in constructing the suitability index graphs for the adult or post young-of-the-year Dolly Varden. Two of these, wetted area and stream width, dealt directly with the size of the stream. Both of these had narrow optimum ranges. The optimum wetted area was between eight and 11 m^2 (118 ft^2) (Figure 16). The largest wetted area considered in this suitability index graph was 30 m^2 (323 ft^2) which had a suitability index of 0.15. The optimum range for the stream width was between 14 and 17 m (46 and 56 ft)

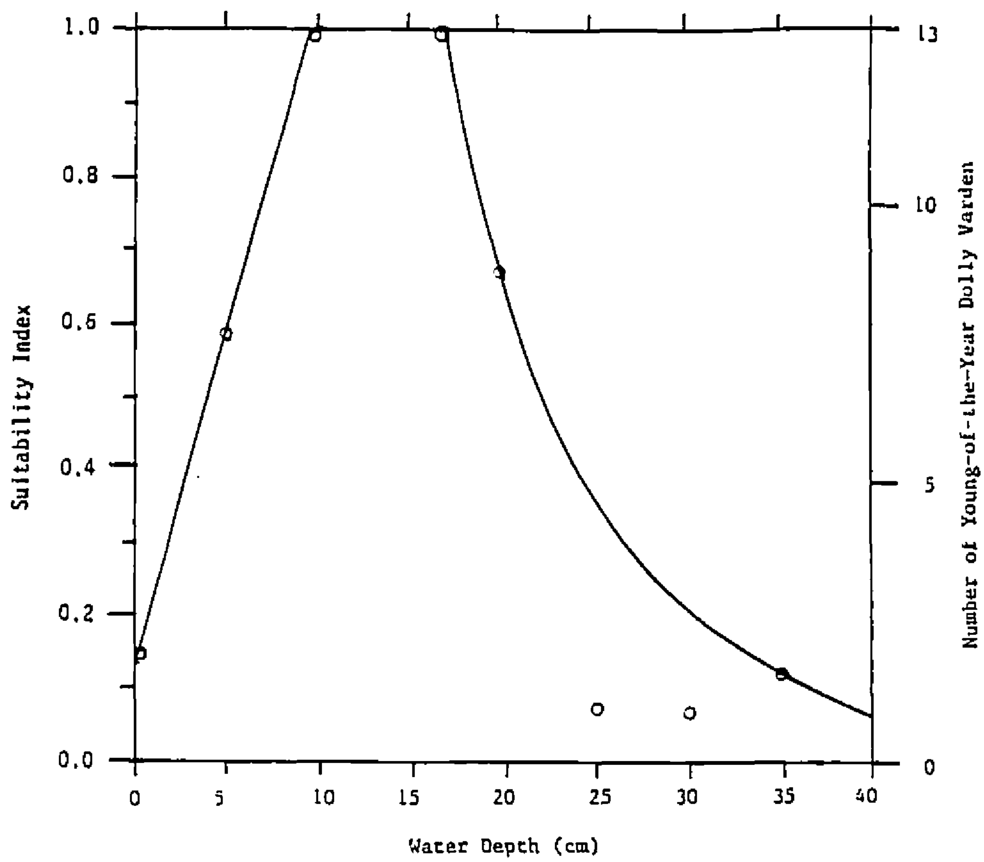

Figure 14. Habitat suitability indices and number of young-of-the-year Dolly Varden collected in various depths of water.

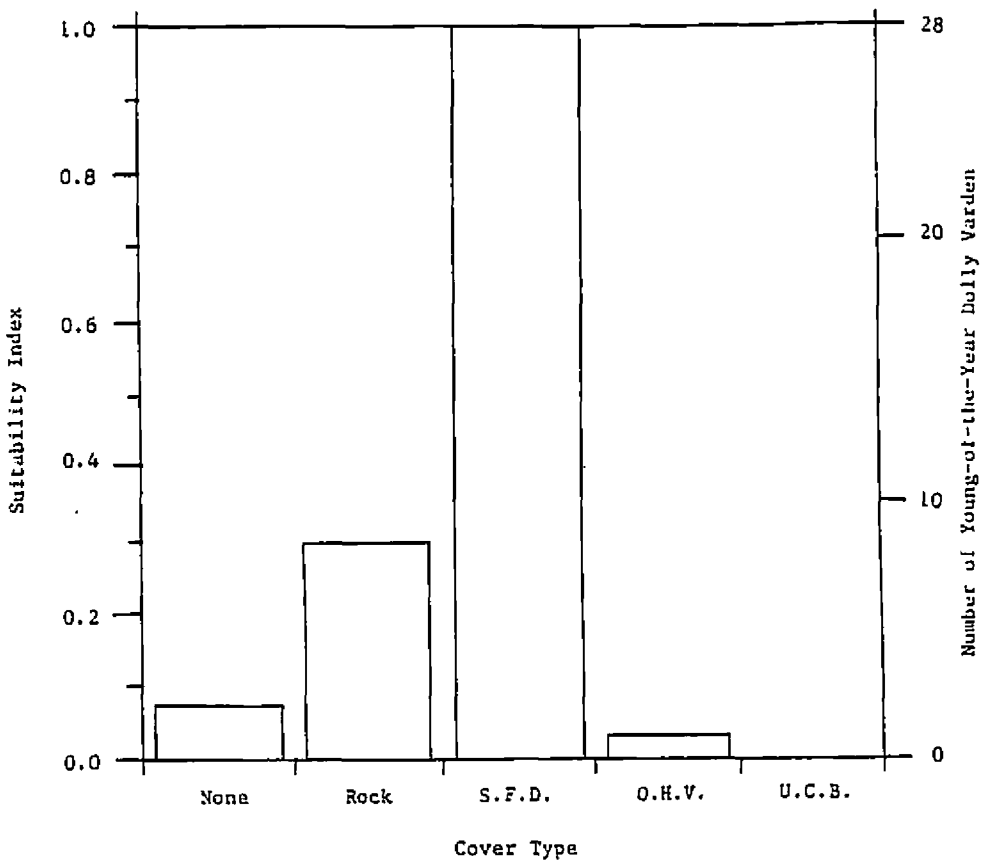

Figure 15. Habitat suitability indices and number of young-of-the-year Dolly Varden collected from various cover types. S.F.D = Submerged forest debris. O.H.V. = Overhanging vegetation. U.C.B. = Undercut banks.

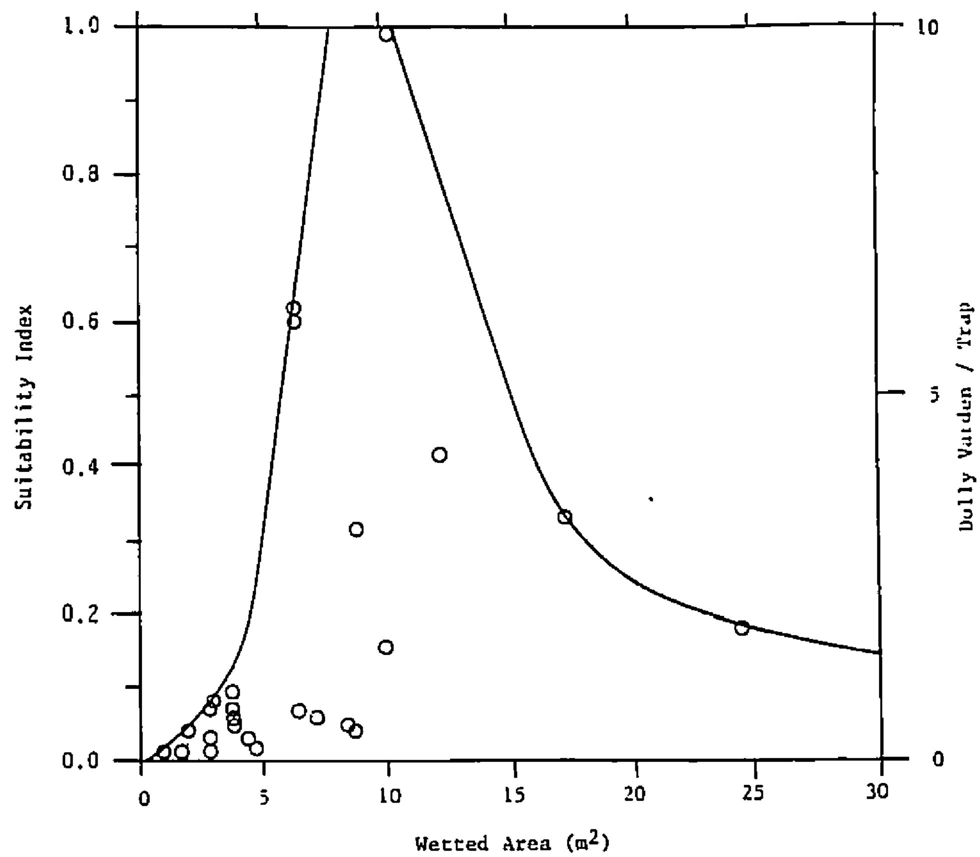

Figure 16. Habitat suitability indices and catch-per-unit-effort for adult Dolly Varden from stream reaches with various wetted areas.

(Figure 17). The largest width considered was 40 m (131 ft) which had a suitability index of 0.7.

Mean water velocity, percent pools, dominant substrate type, turbidity, percent embeddedness of substrate, maximum depth, and stream gradient were the other habitat variables used in adult Dolly Varden suitability index graphs. The mean water velocity graph started with a zero suitability index at 5.0 cm/sec (0.2 ft/sec), maintained a 1.0 index between 9.7 and 10.6 cm/sec (0.32 and 0.35 ft/sec) and again dropped to a suitability index of 0.42 at a mean velocity of 13 cm/sec (0.42 ft/sec) (Figure 18).

Percent pools, defined as the percent of the sample reach area in the slow deep water category, had a relatively wide optimum range. At zero percent pools the suitability index was at 0.81 which climbed to 1.0 between 6.5 and 14 percent pools, and then dropped to a suitability index of 0.23 at 30 percent pool area (Figure 19).

Of the four dominate substrate size classifications, pebble was the only one that rated a 1.0 suitability index. Boulder and cobble were next highest with 0.8 and 0.7 respectively with sand being the lowest at 0.4 (Figure 20). Silt was never the dominant substrate and therefore

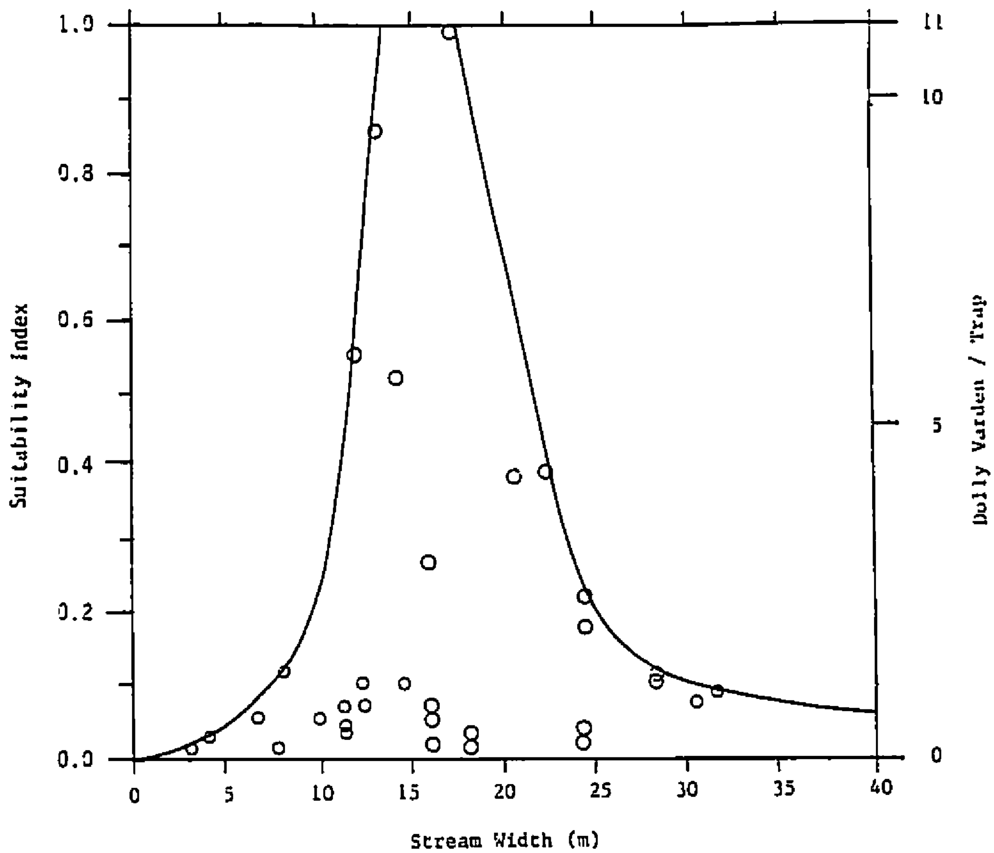

Figure 17. Habitat suitability indices and catch-per-unit-effort for adult Dolly Varden from stream reaches with various widths.

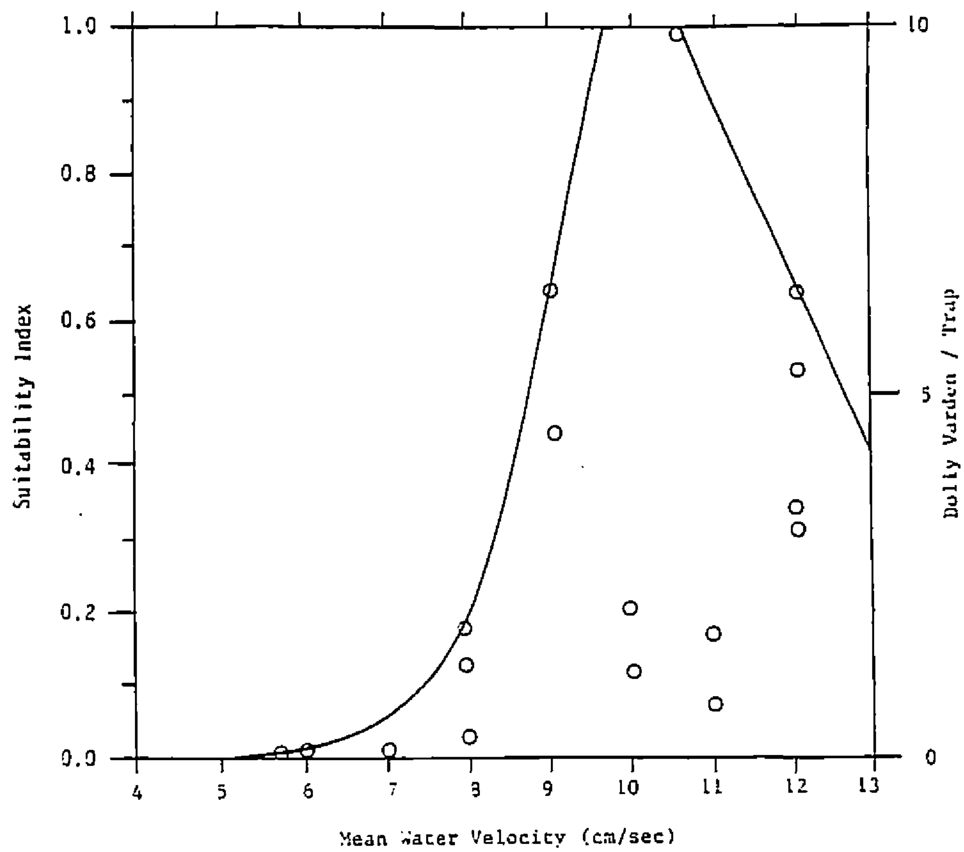

Figure 18. Habitat suitability indices and catch-per-unit-effort for adult dolly Varden from stream reaches with various mean water velocities.

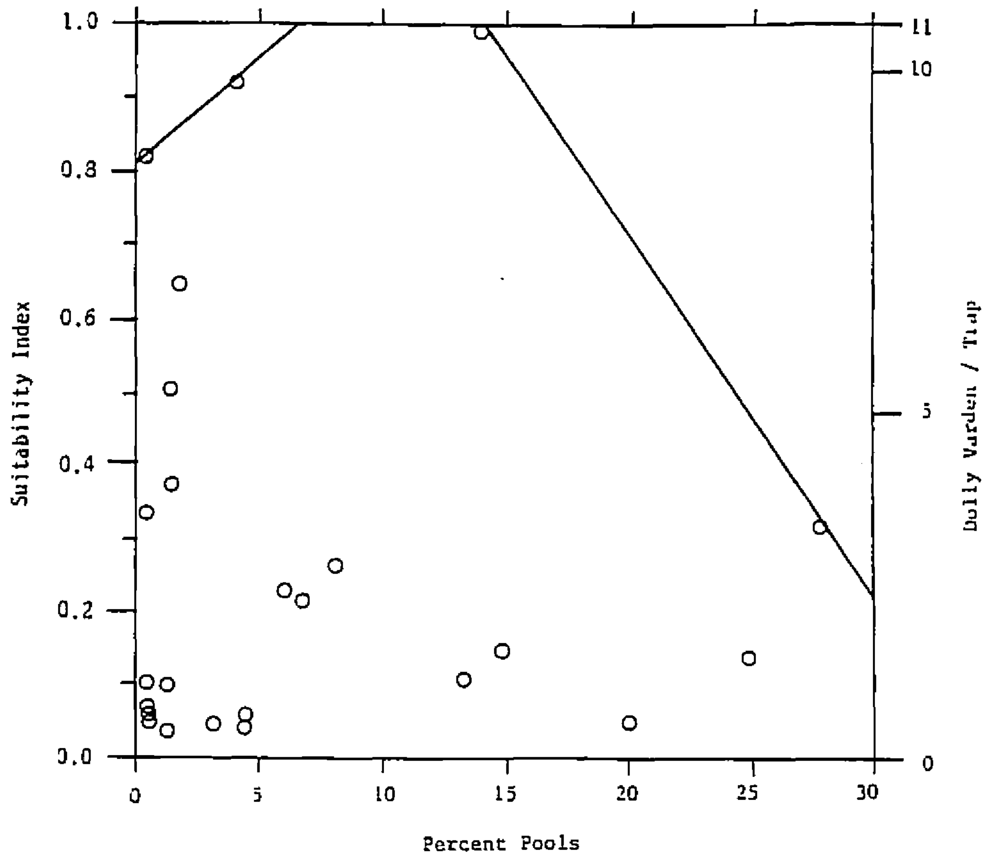

Figure 19. Habitat suitability indices and catch-per-unit-effort for adult Dolly Varden from stream reaches with varying amounts of pool area.

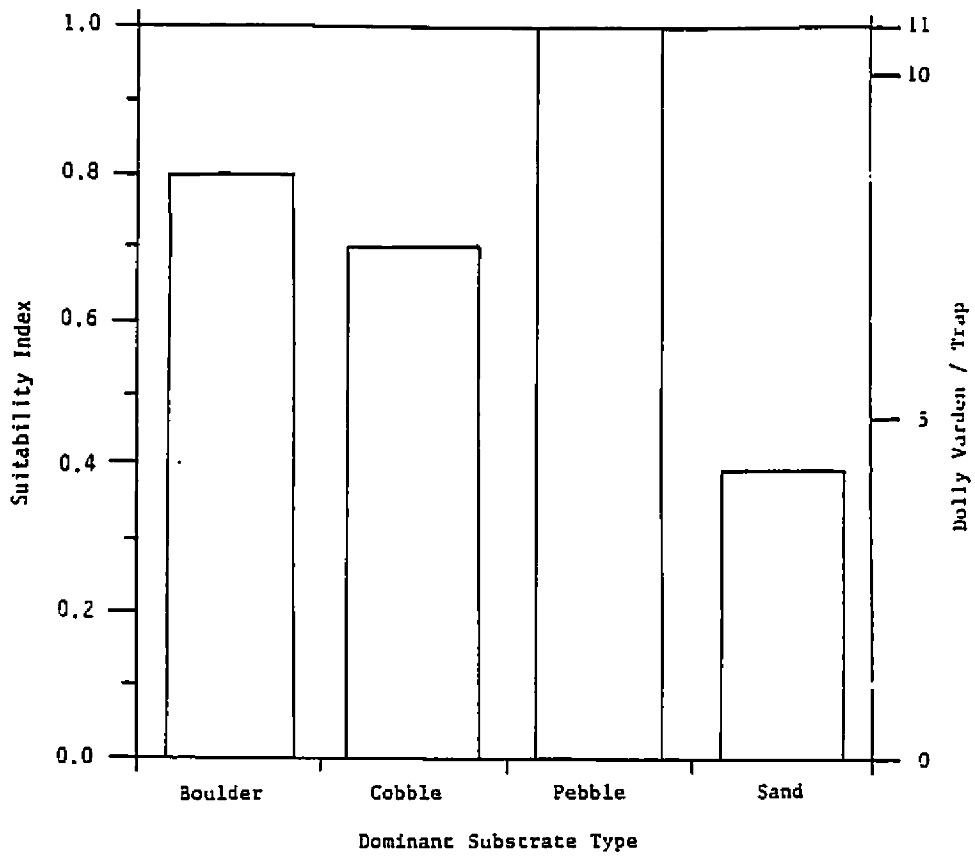

Figure 20. Habitat suitability indices and catch-per-unit-effort for adult Dolly Varden from stream reaches with different dominant substrate types.

not included in this suitability graph.

Turbidity was the only variable which had a suitability index curve showing a bimodal pattern (Figure 21). A suitability index of 1.0 was given to the turbidities from 0.0 to 3.5 NTU. The other high point in the curve was at a NTU reading of 17 which corresponded to a suitability index of 0.48.

Percent embeddedness of substrate showed a narrow optimum range between 12 and 18 percent with sharp declines in suitability index values on either side of this optimum (Figure 22).

The suitability index curve for maximum depth started with a suitability index of zero at a maximum depth of 0.25 m (0.8 ft) and the curve increased in slope until a suitability index of 0.5 at 0.55 m (1.8 ft) (Figure 23). From this point the slope steadily decreased until it reached the suitability index of one at a maximum depth of 1.65 m (5.4 ft).

The adult Dolly Varden appear to show a strong preference for streams with a slope between 0.5 and one percent (Figure 24). This was reflected in the stream gradient

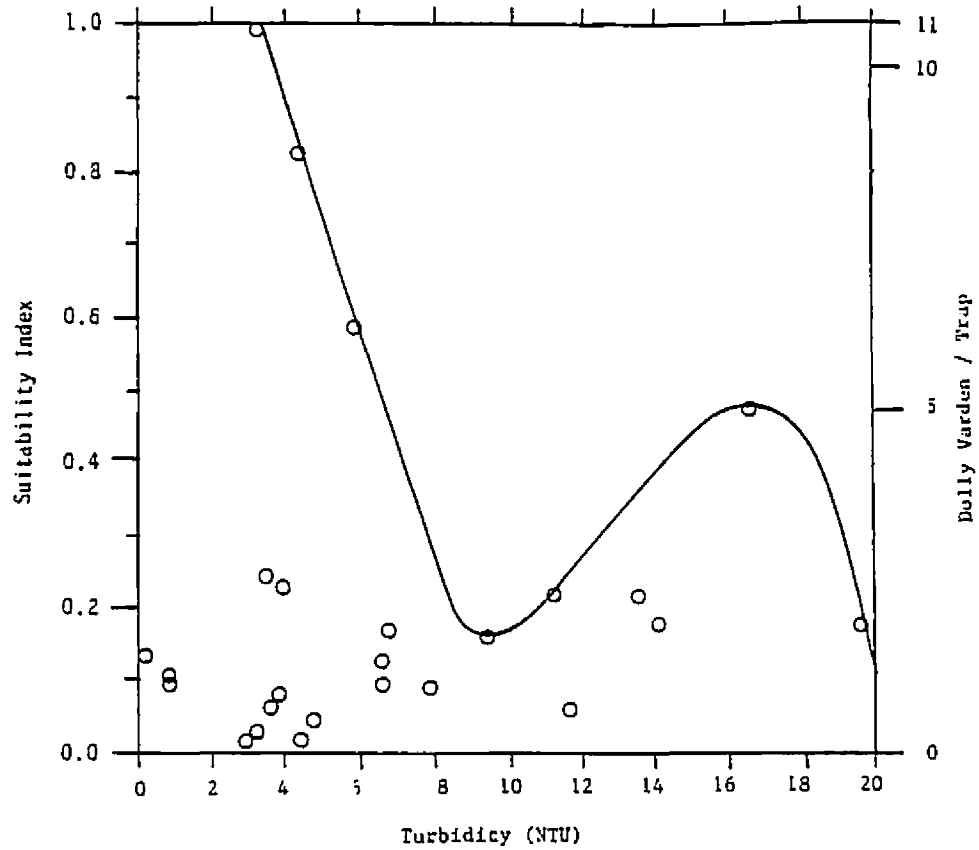

Figure 21. Habitat suitability indices and catch-per-unit-effort for adult Dolly Varden from stream reaches with various turbidities.

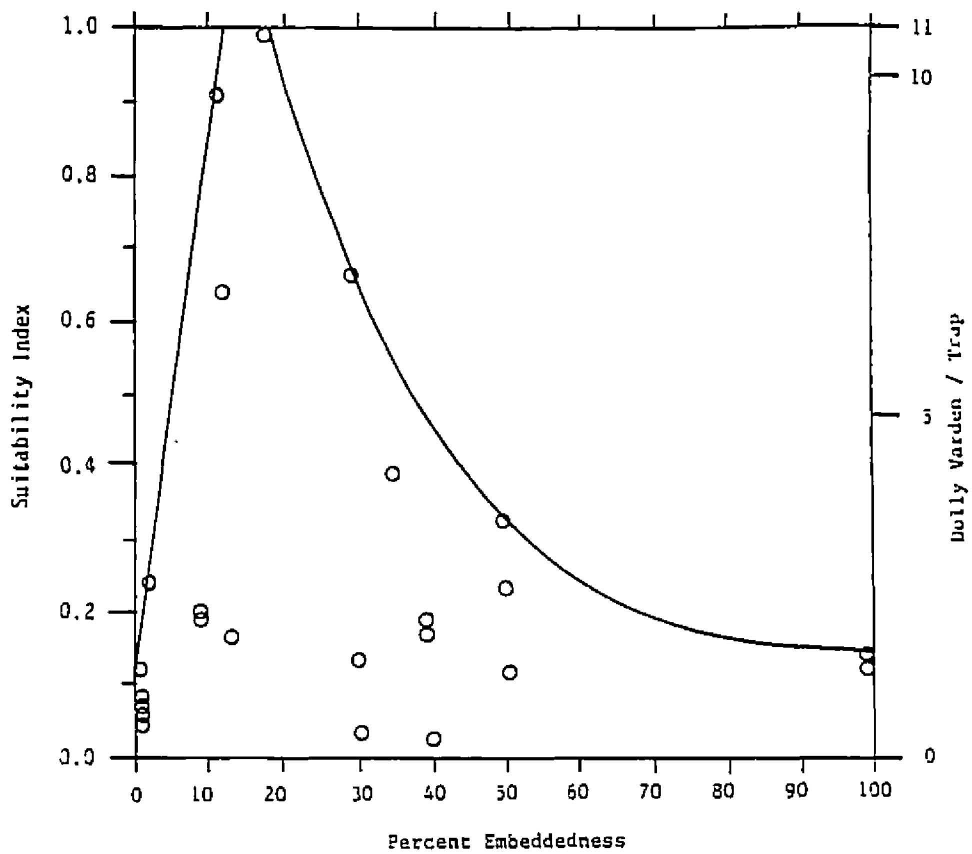

Figure 22. Habitat suitability indices and catch-per-unit-effort for adult Dolly Varden from stream reaches with various amounts of substrate embeddedness.

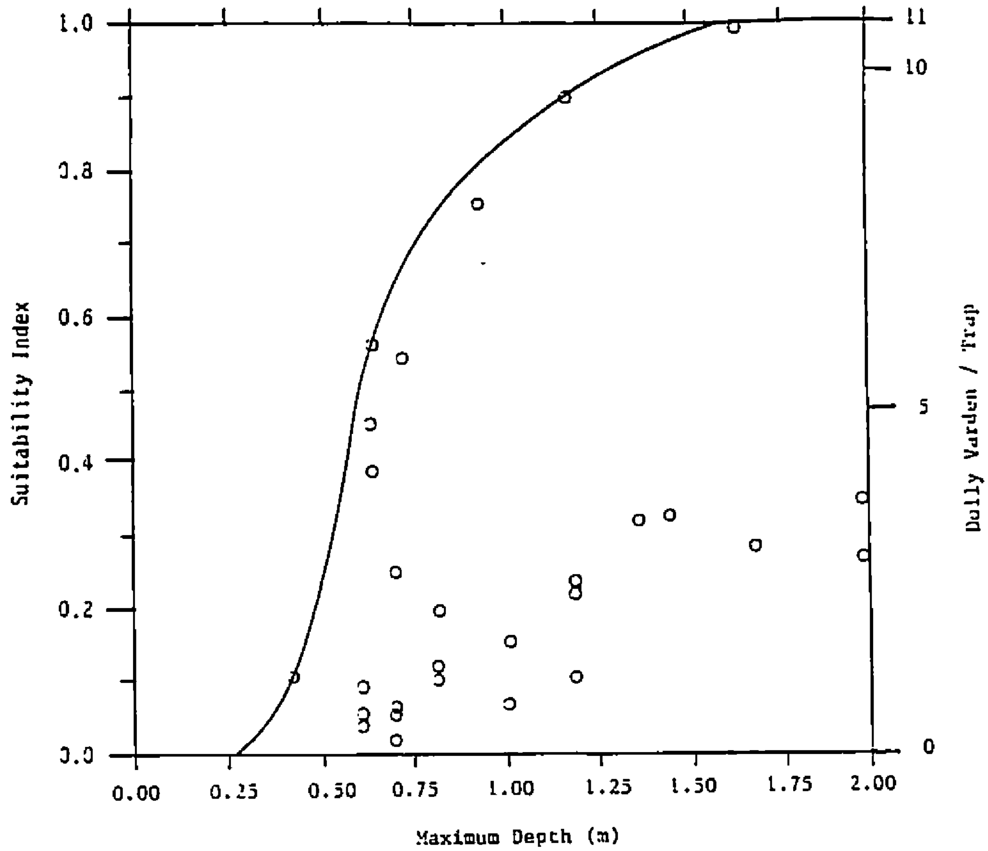

Figure 23. Habitat suitability indices and catch-per-unit-effort for adult Dolly Varden from stream reaches with various maximum depths.

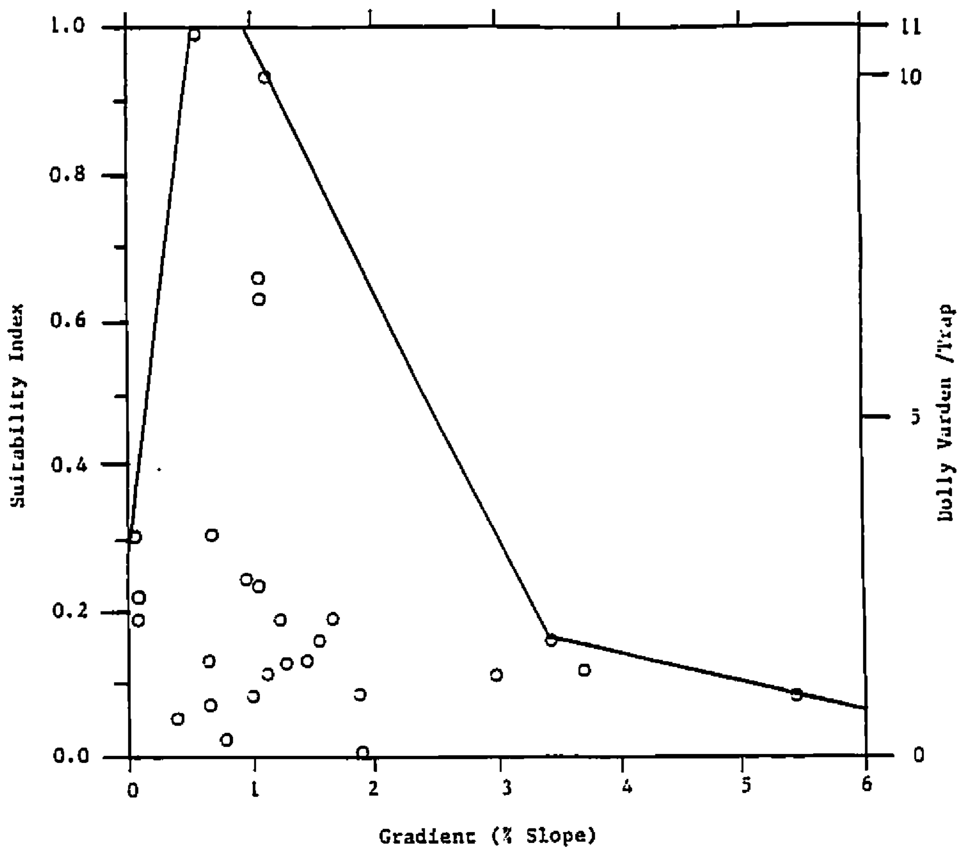

Figure 24. Habitat suitability indices and catch-per-unit-effort for adult Dolly Varden from stream reaches with various gradients.

suitability index graph. At zero percent slope the suitability index was Ø.3. After the optimum range, between Ø.5 and one percent slope, the line dropped steeply until it started to level off at a stream slope of 3.5 percent and a suitability index of Ø.15.

Spawning Adults

Four habitat variables were used in the development of suitability index graphs for the spawning requirements of the Dolly Varden. These variables were: water velocity, water depth, dominant substrate, and cover type and presence. Water velocity had the narrowest optimum range of the spawning suitability index graphs (Figure 25). This curve started with a suitability index of nearly Ø.1 at a water velocity of zero and rose sharply to a index of 1.Ø at a water velocity of 7.5 cm/sec (Ø.25 ft/sec). It remained at 1.Ø to a water velocity of 1Ø cm/sec (Ø.33 ft/sec) and then dropped off sharply again.

The water depth index graph had a steep line on the left side (shallowest depth) of the curve and more gradual slope on the right (increasing in depth) side of the curve (Figure 26). The optimum suitability index was between eight and 15 cm (Ø.3 and Ø.5 ft) deep and the lowest index

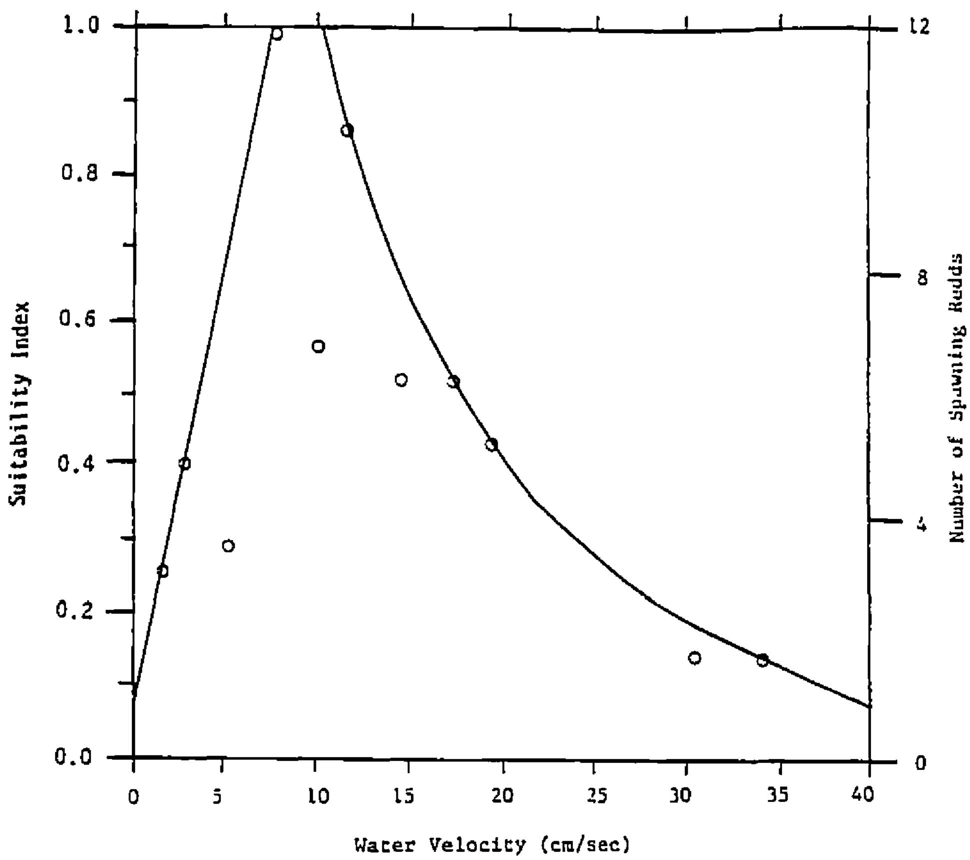

Figure 25. Habitat suitability indices and number of spawning redds located in water with various velocities.

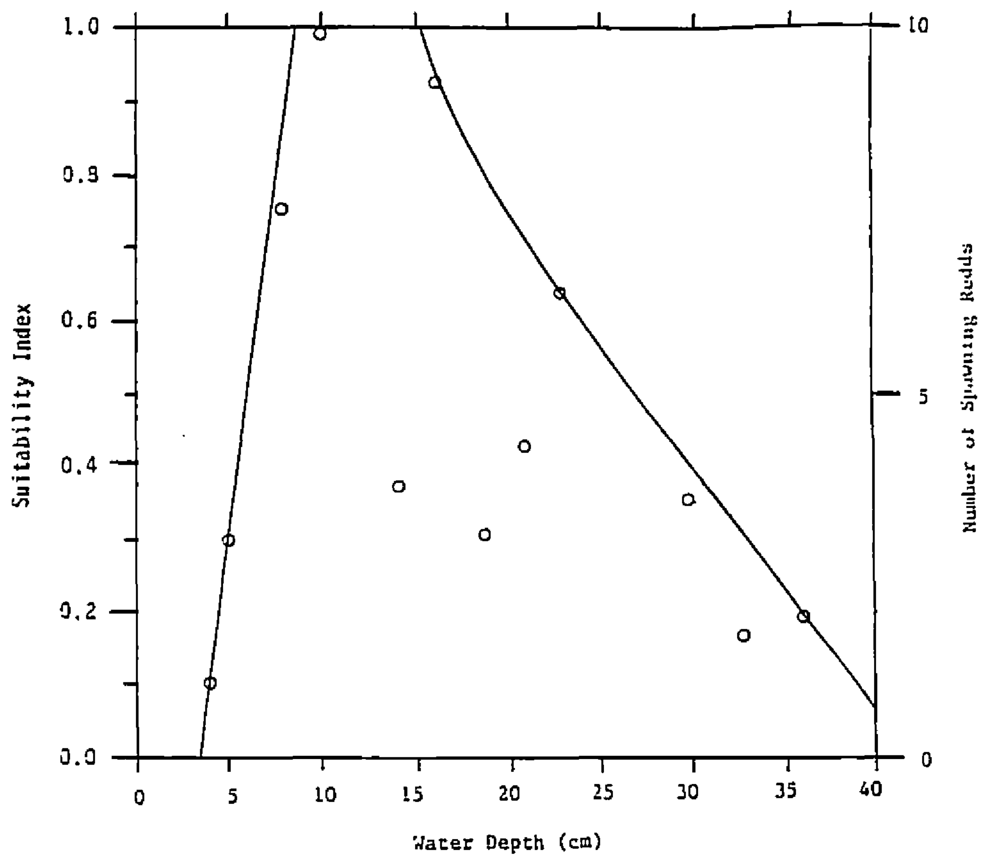

Figure 26. Habitat suitability indices and number of spawning redds in various water depths.

between zero and three cm (Ø.1 ft) in depth.

Gravel and sand were the two most important dominant substrate categories found in the spawning redds of the Dolly Varden (Figure 27). Gravel had a suitability index of 1.Ø and sand Ø.55. Pebble and cobble were also recorded as dominant substrates and had suitability indexes of Ø.38 and Ø.Ø9 respectively. Boulder and silt classifications were not found to be dominant substrates in any spawning redds and therefore received suitability indices of Ø.Ø.

Cover was apparently not preferred over non-cover areas in redd selection. The cover suitability index graph showed that both no cover and submerged forest debris rated a 1.Ø suitability index (Figure 28). Overhanging vegetations, undercut banks, and rocks appeared to be used only occasionally for cover when spawning.

Dolly Varden Use of Lentic Habitats

Some of the sample beaver ponds contained Dolly Varden and some did not. Generally, the ponds close to the river that were actively being used as overwintering ponds by beaver contained fish. A description of the Dolly Varden

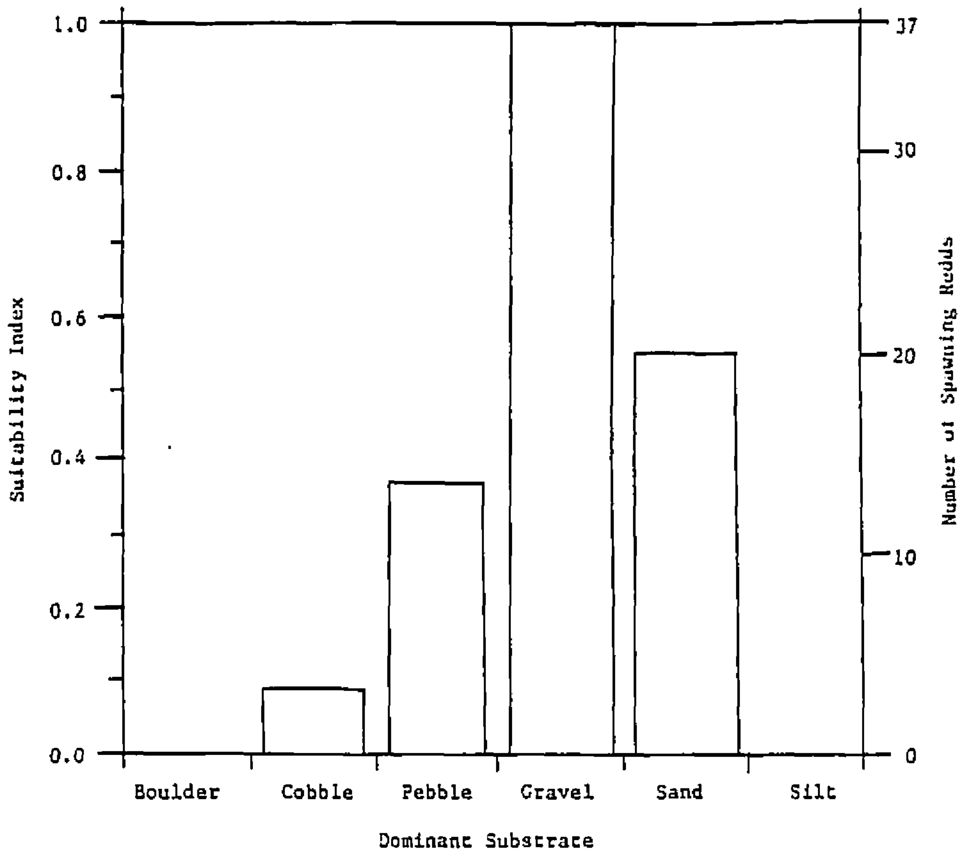

Figure 27. Habitat suitability indices and number of spawning redds on different substrates.

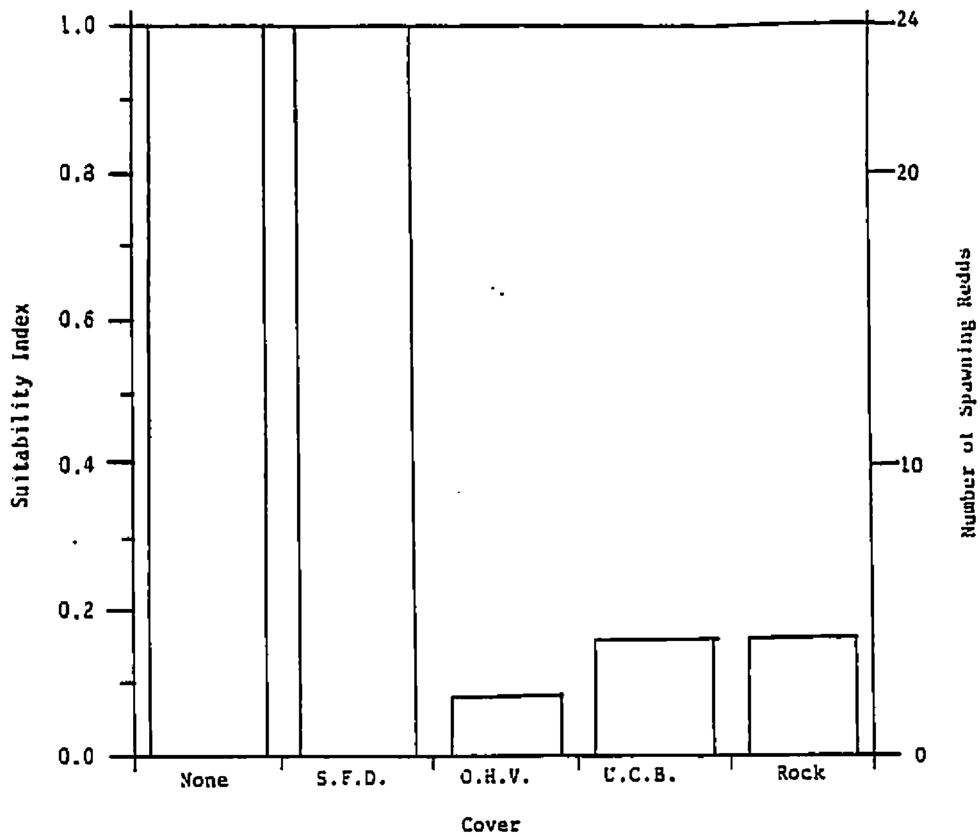

Figure 28. Habitat suitability indices and number of spawning redds associated with different cover types. S.F.D. = Submerged forest debris. O.H.V. = Overhanging vegetation. U.C.B. = Undercut bank.

use of the sample beaver ponds follows:

Pond #1- This pond contained fish of a variety of sizes. Because this pond was situated on Mosquito Creek and drained into Ernestine Creek, fish from the Tiekel River or Ernestine Creek must have moved upstream through a series of dams to gain access to the pond. This probably limited the number of fish that could enter the pond in a given year. The wide range in the sizes of fish was therefore probably a result of reproduction of pond #1 fish rather than migration of small fish in from the Tiekel River. During September of both field seasons I saw Dolly Varden spawning in Mosquito Creek. Dolly Varden in this pond appeared to be plentiful as they were easy to catch in traps as well as on rod and reel.

Pond #2- Pond #2 was situated within 40 m of the river but was not found to contain fish during the summer sampling period. Dolly Varden were found in the stream which feeds this pond, and were even seen spawning in this stream. Because this pond remains so cold and clear throughout the summer these fish may prefer to use the feeder stream as summer habitat and possibly only enter the pond during the winter months.

Pond #3- No fish were found at any time in this pond. Because of the turbid nature of this pond for most of the summer, it is possible that it contained a small population of fish that was undetectable. This pond is located about 400 m from the river which would make access from the river infrequent at best. The possibility of winter-kill also exists in this pond as late winter D.O. concentrations were measured at 0.9 mg/l.

Pond #4- This pond was situated very close to the river and took in river water during the July highwater event of 1986. This would indicate that the accessibility of this pond was relatively high; however only one Dolly Varden was found in this pond during the summer of 1986. Because of the clarity of the pond I am quite certain we did not miss the observation or capture of many fish in the pond.

Pond #5- This pond has not been used as an overwintering pond for beavers in many years. No fish were ever found in this pond even though it was only 20 meters from the river. It was possibly used during the summer by a limited number of fish as the dam was deteriorated which would have made access from the river possible.

Pond #6- The largest fish found during this study came from this pond. This pond also contained a wide variety of fish sizes. Evidently the population was relatively small as the catch per unit effort in this pond was consistently low compared to other areas. Access to this pond from the river appears to be difficult as it was about 400 m from the river and the outlet ran for several hundred meters through a series of small ponds before it reached the river. Although there is a possibility of reproduction in this pond as there is a small inlet stream, no spawning was ever observed in that stream.

Pond #7- This pond contained a large population of Dolly Varden with a wide variety of sizes present. The head of this pond was within 30 meters of the river and it probably receives river water annually. There were no feeder streams for spawning.

Pond #8- A large population of Dolly Varden, with a wide variety of sizes, was present in this pond. There were no spawning streams associated with this pond. The fish evidently came into this pond from the river as it was only a short distance from its head.

Pond #9- This pond contained a small population of large fish. All fish that entered the pond must have done so by upstream movement through a swampy outlet stream, 1000 m long, which had several beaver dams on it. There were no spawning streams associated with this pond.

Pond #10- No fish were found in this pond. Even though this pond was very close to the river it probably received very little river water. This was because the bank separating it from the river was relatively high. The consistently high water temperatures and stained water indicated little, if any, river water influence.

Pond #11. This pond contained a large population of relatively small fish. The feeder stream to this pond was used for spawning. Because of the distance from the river and the length and number of dams on the outlet stream, access from the river would have been difficult.

Habitat Quality

Fulton condition factors for Dolly Varden found in ponds #6 and #9, using the Tukey test for variance (Zar, 1984), were significantly higher at 95% probability than those of the other habitats sampled (Figure 29). They were not,

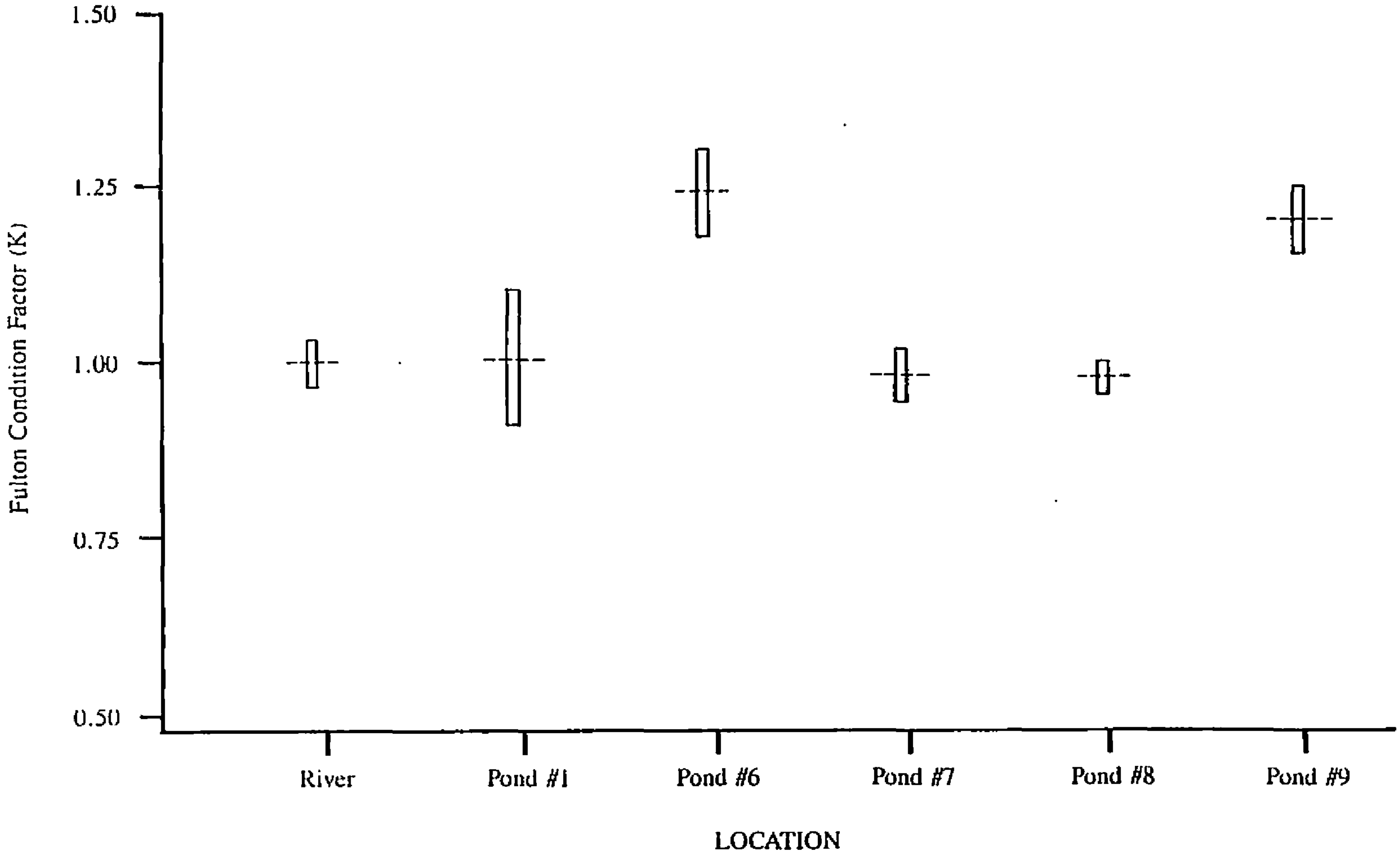

Figure 29. Mean Fulton condition factors, with 95% confidence limits, of Dolly Varden from the Tiekel River and five sample ponds.

however significantly different from each other.

When the separate habitat variables were regressed against the dependent variable, Fulton condition factor, chlorophyll _a_ concentrations and August water temperature (Table 8) showed relationships with r^2 values of 0.79 and 0.49 respectively. None of the relationships with the other variables had r^2 values above 0.24.

Table 8. August chlorophyll a concentrations, mean summer temperatures, and Fulton condition factors from sample ponds that contained Dolly Varden.

HABITAT	AUGUST CHLOROPHYLL a (µg/l)	MEAN SUMMER TEMPERATURE (°C)	FULTON CONDITON FACTOR (K)
POND #1	0.30	4.3	1.00
POND #6	7.95	10.3	1.24
POND #7	1.62	7.0	0.98
POND #8	2.77	8.1	0.97
POND #9	4.26	8.9	1.20

DISCUSSION

Tiekel River Hydrology

The discharge patterns of the Tiekel River throughout the summers of 1985 and 1986 were comparable, with the summer of 1985 having greater peak discharge than 1986 (Figure 10). In both years, the mid-May discharges were about three times that of base flow and increased sharply until they peaked in late June or early July. From this point the discharges dropped quickly until late August and then slowly continued to decline until late September.

Unlike many typical interior Alaska streams (Figure 30), the Tiekel did not respond to summer rain events with short term high discharges. Because there are gaps in the discharge data, up to 15 days, some peaks in discharge may have been missed. There are probably several factors which could account for the lack of short term peaks in the Tiekel River discharges. One of these would be the loose soils which allow the runoff from the steep mountains to be added to the ground water instead of being directly added to the River. The glacial input could also tend to stabilize the discharge of the Tiekel River. Glaciers tend to melt at a constant rate and do not cause

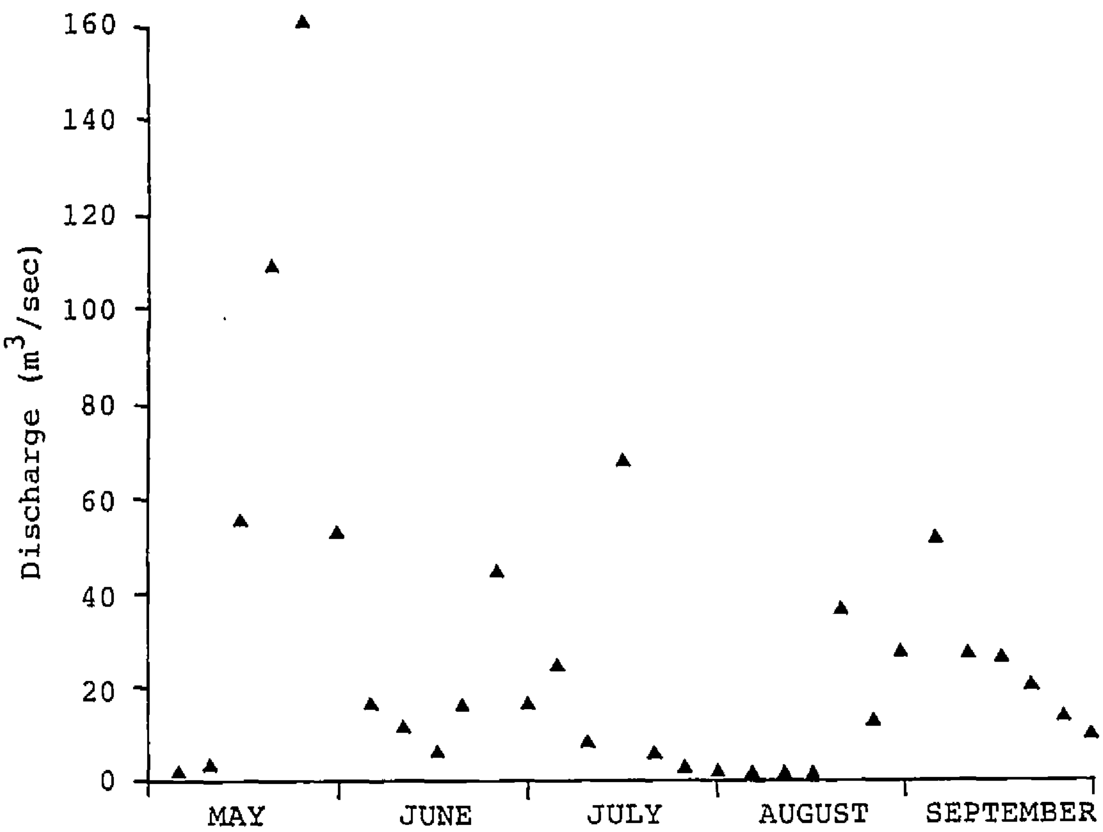

Figure 30. 1985 stream discharges for Hess Creek (tributary of Yukon River, Alaska)(USGS 1985).

short term peaks in stream flows. I feel the beaver activity in the Tiekel River drainage could also be keeping the river from showing high discharge peaks after short summer rain events. Apple (1985) found that beavers could successfully be used as part of a stream restoration program for streams in arid regions with loss of riparian habitat. In his study, relocated beavers were able to raise water tables, stabilize banks, fill in gullies, and increase production of riparian flora. Just as in Apple's study the extensive nature of the beaver ponds in the Tiekel drainage act as a buffer that attenuates the runoff peaks from rain events.

Description of Available Habitats

The Tiekel River main channel offers a wide range of aquatic habitats. The upper section of the river (Ernestine Creek) contains stream channels with high gradients (up to 1.6 percent), large clean substrates, and shallow water, whereas the lower end of the river contains stream reaches with low gradients, and deep, sand and silt-bottomed pools.

The streams that feed the Tiekel River offer a great diversity of aquatic habitats. Some of these streams are large and resemble reaches of the upper main channel. Others are large low gradient streams with deep slow moving water having abundant cover of various types. Still others are very small streams that offer fish only short distances of accessible habitat.

Beaver ponds in the Tiekel drainage offer both cold clear water as well as warm rich waters that can turn very turbid in late summer with primary production.

Because of the extreme variety of habitats found in the Tiekel River drainage the resident Dolly Varden can obtain all of their life requirements within the drainage. This is important as the gorge below the study area is thought to be an upstream barrier to fish migration, and therefore any fish leaving the drainage may not be able to return to the river.

Dolly Varden Use of Lotic Habitats

Dolly Varden were found throughout the accessible stream habitats in May with the exception of the uppermost reaches of the river and some of the smaller tributaries. By late June all accessible habitats were occupied by Dolly Varden. Young-of-the-year fish first appeared around the middle of July. These fish were found mostly in the lower main river along its edges and in side channels. The adult fish could be found mostly in pools where cover was available or where the water was turbid.

The feeder streams were used throughout the summer by adult fish. The confluence of these streams with the main river were used by young-of-the-year fish. In late September most of the feeder streams were probably used to some extent for spawning. Two of the streams were used extensively for this purpose. In these streams it was common to see hundreds of Dolly Varden in tight schools waiting to spawn.

Overwintering areas were not located as part of this study. However because low flows during late winter are similar to flows in late September when fish are dispersed throughout the river and because much of the river remains ice-free throughout the winter, overwintering areas may not be limited.

Habitat Suitability Indices

Young-of-the-Year

Four habitat variables were chosen for suitability indices for the young of the year Dolly Varden. These variables include: water velocity, water depth, dominant substrate type, and cover presence and type. Water velocity is probably the most critical of these variables as it had the narrowest preference range. Zero velocity water was strongly preferred. Besides a water velocity of zero, the suitability indices show a preference for 13 cm (0.4 ft) deep water, sand or silt substrates, an association with cover, and submerged forest debris as a cover type. Sand and silt may be the most preferred only because they are most commonly associated with zero velocity water. Cobble, pebble, and gravel may have shown some importance because they too may also be associated with low velocity water, or because they create pockets of low velocity water. Submerged forest debris may show up as the preferred cover type because it was the most abundant of the cover types measured. The young-of-the-year fish do show some use of areas with no cover. These fish were usually over silty substrates. Unlike most other salmonids the Dolly Varden fry tend to be rather sedentary

(Morrow, 1980) and blend in very well to silty substrates. Therefore the "no cover" category in the suitability index graph might be relabled "camouflage cover." Saunders and Smith (1962) found an increase in the amount of hiding cover resulted in survival of brook trout (*Salvelinus fontinalis*) fingerlings (age zero).

Adults

Nine separate habitat variables were used for suitability indices for the adult Dolly Varden. These include: wetted area, stream width, mean water velocity, percent pools, dominant substrate type, turbidity, percent embeddedness of substrate, maximum depth, and stream gradient. Two of these, wetted area and stream width, define a particular size of stream. The preferred ranges of these three variables correspond to that part of the Tiekel River in the lower end of the upper main river habitat type.

The optimum mean water velocity was between 9.7 and 10.6 cm/sec (0.3 and 0.35 ft/sec), percent pools between 6.5 and 14 percent, pebble was the most important dominant substrate class, percent embeddedness between 12 and 18 percent, maximum depth at 1.65 m (5.4 ft) and greater, and stream slope between 0.5 and 1.0 percent. Turbidity had a bimodal pattern. One peak was at a turbidity of zero NTU with a suitability index of 1.0 and the other was at 17 NTU with a suitability index of 4.8. This bimodal curve may be explained by our observations that the adult Dolly Varden both preferred low turbidity, as long as cover was available, but used the turbidity as a type of cover when other cover was not available. The importance of pool area and cover availability is not only demonstrated in the suitability index curves of this study but also in other studies. Lewis (1969) found water velocity and amount of cover to be the two most important factors in determining trout abundance in a Montana stream. In a Canadian coastal stream, the abundance of brook trout over the age of one was found to double after the addition of dams, velocity deflectors, and cover (Saunders and Smith, 1962). In the laboratory conditions small brook trout selected deep areas or areas that were shaded (Gibson and Power, 1975).

Spawning Adults

Water velocity, water depth, dominant substrate, and cover type and presence were the four habitat variables used in developing the suitability indices for the spawning requirements. These suitability indices demonstrate the preference for locating spawning redds where mean water velocities were between 7.5 and 10 cm/sec (0.25 and 0.3 ft/sec). Smith (1973) examined 122 brook trout redds and found the mean water velocity was 11.2 cm/sec (0.4 ft/sec) which is slightly above the optimum range for the Tiekel River Dolly Varden. The Tiekel River Dolly Varden also show a preference for redd location in water depths between eight and 15 cm (0.26 and 0.5 ft) and where gravel and coarse sand are the dominant substrate types. The depths of water over the spawning redds were much less for the Tiekel River Dolly Varden than for the brook trout looked at by Smith. The mean depth of water over the redds of the brook trout was 46 cm (1.5 ft) (Smith, 1973) while the depth receiving the highest suitability index rating for the Tiekel fish was between eight and 15 cm (0.26 and 0.5 ft). The high percentage of sand in the spawning redds is far different than what would be expected to be found in optimum spawning substrates. Studies have indicated that fry emergence rate is higher in course substrates than in finer substrates (Shelton, 1955, Dill and Northcote, 1970). Hausle and Coble (1976) found that the presence of sand in the gravel surrounding the eggs reduced fry emergence. Why then do the Tiekel River Dolly Varden select substrates that are dominated by sand to build their spawning redds? One answer may be that the sand found in the Tiekel River spawning redds is quite course and allows adequate passage of water through it to the eggs. The Dolly Varden may also be placing the redds in places where there is upwelling water which could make up for the low amount of interspace between substrate particles by forcing more water through them. Webster and Eiriksdottir (1976) found brook trout to select redd sites directly above upwelling areas in laboratory conditions. Cover did not appear to be an important factor in spawning redd placement.

Dolly Varden Use of Lentic Habitats

Six of the eleven sample beaver ponds contained populations of Dolly Varden. Pond #4 contained a very small number of fish even though it was quite close to the river. Ponds #1 and #11 contained populations that have access to spawning streams and had large populations of fish of varied sizes. Ponds #7 and #8 contained large populations of fish with a varied size distribution that did not have access to spawning habitat. Both of these ponds are close to the river and probably receive fish from the river on a regular basis. Ponds #6 and #9 are both old ponds that are considerable distance from the river and both contain small populations of relatively large Dolly Varden.

Habitat Quality

Habitat quality can be expressed in many ways. For the purpose of this study, two expressions will be used. The habitat quality of a stream reach increases as the amount of favorable habitat increases. Favorable habitat has habitat variable measurements that show high suitability index values for the different life stages of Dolly Varden. Because different variables were measured in the stream habitats than in the pond habitats only stream habitats can be compared with this definition. Habitat quality can also be evaluated by measuring the condition (weight to body-length ratio) of the fish that live in that habitat. By looking at the condition of fish as a measure of habitat quality, pond and stream habitats can be compared.

A perfect, or high quality, habitat can be described by combining the information from the suitability index curves. For the young-of-the-year life stage this habitat would be described as areas where the water had a zero, or near zero, velocity, a depth between 9 and 17 cm (0.3 and 0.6 ft), a substrate consisting of sand or silt, and with submerged forest debris as a cover type. This description fits much of the stream edge in the upper and especially the lower main river habitat types. This also describes many of the side channels and sloughs found on the lower river, and the confluence of several of the feeder streams with the main stream in the upper and lower main river habitat types.

Quality habitat would be described for the adult Dolly Varden as stream reaches where the wetted area was between eight and 11 m^2 (86 ft^2), stream width was between 13 and 18 m (42 and 59 ft), mean water velocity was between nine and 11 cm/sec (0.3 and 0.36 ft/sec), percent pools were between five and 15, dominant substrate type was pebble, stream gradient was between 0.5 and 1.0%, percent embeddedness of substrate was between 10 and 20, maximum depth was greater than 1.25 m (4.1 ft), and the turbidity was below 4 NTU. Six of these index values match the means of the habitat variable measurements of the upper main river habitat type (Table 3). The number of these indices with values that match the means for the other habitat types are: two for wide-banked areas, four for lower main river, one for feeder streams, and two for disturbed areas (Tables 2, 4, 5, and 6). This would indicate that the upper main river habitat type tended to be of higher quality for adult Dolly Varden than the other habitat types.

Quality spawning habitat could be described as those areas where the water velocity was between seven and 11 cm/sec (0.2 and 0.36 ft/sec), depth was between eight and 16 cm (0.26 and 0.5 ft), gravel substrates, and submerged forest debris were present. This describes many of the small feeder streams throughout the drainage. Often this type of habitat is limited to the lower sections of these streams (often less than 30 meters) due to the steep gradient where these streams come off the valley walls.

Only one spawning redd was found in the main river channel. This apparent disuse of the main river channel as spawning habitat may be a result of the lack of gravel and coarse sand in the substrates. Although these substrates are present in the main channel, during late fall the low water levels leave much of the finer substrates dry.

The results of the length-weight condition factor data suggest pond #6 and pond #9 are of higher quality than the other ponds and the stream habitats. Pond #6 and #9 had Dolly Varden with statistically higher condition factors than the other ponds and stream habitats. Because the single regression analysis shows chlorophyll a to explain 79% of the variation in condition factors between habitats, and August temperature to explain 49% of the variation, these two variables appeared to be good predictors of habitat quality. Ponds #3 and #10 had August water temperatures and chlorophyll a concentrations as high or higher than ponds #6 and #9. This would indicate that these habitats, ponds #3 and #10, were of as high quality of habitat as ponds #6 and #9. If these ponds were of such high quality, then why did they not contain Dolly Varden? One reason might be that they are inaccessible to the natural introduction of Dolly Varden. Another reason might be that they have water conditions that make them uninhabitable to Dolly Varden. One possibility could be low early spring D.O. concentrations. This may be responsible for the lack of fish in pond #3 as it had a late March D.O. concentration of only 0.9 mg/l.

CONCLUSIONS

The water in the Tiekel River runs low and clear from late August to mid-May. In late June or early July the river reaches its peak discharge which is accompanied by turbid waters (20+ NTU). From its peak, the discharge slowly drops until late August when the river is again running low and clear. A wide variety of aquatic habitats exists in the Tiekel River drainage.

There are two types of Dolly Varden populations within the drainage; those that live in the stream habitats and those that are confined to beaver ponds. The fish that live in the stream habitats use the entire stream system throughout the summer. The young-of-the-year fish are found in the feeder streams and in the lower sections of the river. They prefer zero or near zero velocity water that is near 13 cm (0.4 ft) deep. They also prefer sand and silt substrates as well as an association with cover.

The adult fish evidently spend the winter in the lower reaches of the river and inhabit all accessible stream habitats during the summer. The highest densities of adult Dolly Varden were found in stream reaches with mean water velocities around 10 cm/sec (0.3 ft/sec), where the pool area was between seven and 14 percent, pebble as the dominant substrate class, maximum depths greater than 1.6 m (5.2 ft), and stream slopes between 0.5 and 1.0 percent.

The Dolly Varden use most of the feeder streams as well as the main river channel for spawning. A majority of the spawning is done in two small feeder streams. The Dolly Varden showed a preference for locating spawning redds in water with velocities between 7.5 cm/sec (0.25 ft/sec) and 10 cm/sec (0.33 ft/sec). They also preferred water depths between eight and 15 cm (0.26 and 0.5 ft) where gravel and course sand was the dominant substrate type.

Some of the beaver ponds in the drainage contained populations of Dolly Varden and some did not. Generally the ponds closest to the river contained the most fish. Three of the sample ponds had tributary streams that were used for spawning. Each of the ponds had its own water quality characteristics. The ponds that contained the highest August water temperatures and the highest chlorophyll _a_ concentrations also contained the largest and heaviest fish.

RECOMMENDATIONS

Further Research

This study succeeded in describing most of the important habitats utilized by the resident Dolly Varden in the Tiekel River drainage. One important piece of information not found in this study was the type, or types of habitats used for overwintering. Because much of the river remains ice-free throughout the winter, these habitats would be relatively easy to locate. I believe overwintering habitat data is necessary for completing the habitat utilization description of these fish and should be obtained in any further research concerning the Tiekel River fishery.

One other important aspect of the Dolly Varden biology and habitat use not effectively measured was the accessibility of beaver ponds to the fish. It appeared that many of the ponds were separated by extensive fish barriers from the river while others were relatively easily accessed. Whether or not Dolly Varden from the river can enter and exit these ponds at will is an important consideration in looking at the habitat available to these fish. This question could be answered with a series of extensive site-specific tagging studies. The biggest problem in designing a study of this sort would be in finding a suitable tag for such small fish. Thin flexible plastic tags (Floy tag FTSL-73) were used with little success in the fish biology study of the Tiekel River (Gregory, 1988). The problem encountered with using these tags was high tag loss and possible physical effect of the tags on the small fish. Freeze branding and new methods of externally visible coded implants may be suitable for this purpose.

One management strategy for increasing the number of Dolly Varden, in the size range that would be attractive to anglers, would be to periodically relocate fish from the river into some of the more productive ponds. Before fish could be relocated, research must be done to determine how many fish these ponds could support. Currently, the most productive ponds, ponds #6 and #9, have relatively few fish. There are several ponds in the drainage, which currently do not contain Dolly Varden populations, that have high August water temperatures and high chlorophyll *a* concentrations. This indicates that they may be able to produce fish with relatively high condition factors. This process could not create enough large fish to make the Tiekel River a famous trophy fish producer, but it could significantly add to the total number of large fish available in the drainage.

The possible introduction of salmon species to the Tiekel River drainage would depend on their being able to negotiate the gorge at the lower end of the river. The theory that this gorge is an upstream barrier to fish migration should be tested. This could be accomplished by an intensive hydrological study of the gorge or by the introduction of smolt salmon above the gorge and recording their return progress.

The Tiekel River drainage not only offers researchers an opportunity to study an interesting population of stream-resident Dolly Varden, without the confusing presence of other anadromous charr, but also offers a look at the process of natural selection in general, and how a population of charr has changed to adapt to a new environment in a relatively short period of time (80 to 90 years). Because the present stock of Dolly Varden in the Tiekel River is thought to be a derivative of the Little Tonsina River stock, differences in the two populations might be attributed to adaptation of the original Little Tonsina transplants to the different environment of the Tiekel River. These population differences are many. We witnessed not only differences in physical appearance but also in population biology, behavioral characteristics, and habitat utilization. There is also a population of Dolly Varden in Tsina Lake. Tsina Lake is a body of water near the head of the Tsina River which is a tributary of the Tiekel River. The fish in this lake are also presumably ancestors of the Little Tonsina River stock. These fish have a very different physical appearance than both the Little Tonsina and Tiekel River fish and are probably lake-resident fish that spawn in the lake itself.

An understanding of the relationships between these three populations of charr would greatly add to the knowledge of charr speciation, stock separation, and fish evolution. This situation might also be suitable for the evaluation of new techniques of analysis of genetic comparisons between stocks.

Management

Low Profile

The Tiekel River drainage is currently a highly accessible area that is full of recreational opportunities. These opportunities include: hiking, rafting and canoeing, fishing for the resident Dolly Varden, hunting, camping, and sightseeing. The drainage is full of spectacular scenery and is inhabited by a number of wildlife species that can easily be viewed from the highway, during hikes along the river, or from canoe or raft. Presently this area is being appreciated mostly for its hunting and the scenery it provides travelers of the Richardson Highway. This means that during most of the year very few people are leaving the highway and visiting the river. This is also one of the area's greatest assets, being able to walk for miles along the river's edge and not see another person. Maintaining the area for the above recreational activities would be "low profile" management, i.e., managing the resource to maintain its present qualities.

Maintaining the area's present qualities does not mean non-active management. There are a number of potential activities that may occur in the future that will need to be adequately designed and monitored to protect the current condition of the drainage. These include: road repairs and alterations, development of private lands along the river, and construction associated with pipelines and other utility projects that use the Tiekel drainage as a corridor.

For the good of the resident Dolly Varden as well as the integrity of the whole drainage, the beaver activity should not be allowed to decline as a result of any future development. This could be accomplished by allowing structures to only be built on existing high ground and not by filling low areas to create high ground. Also alterations of tributary streams that result in the permanent unsuitability of these streams as beaver pond sites, should not be allowed. Any construction activity in the area that might result in an increase in beaver activity would probably also benefit the Dolly Varden as long as fish passage is not affected.

The suitability index graphs developed in this study should be used in the designing of projects that will alter the aquatic habitat. The suitability index graphs rank habitat variable measurements as to the quality of habitat they provide for the three life stages of Dolly Varden. Aquatic habitats should not be altered in a way that results in a reduction in the suitability index rating of a given habitat variable. If the habitat alteration is carried out, without the reduction in any suitability indices, then the quality of the habitat for Dolly Varden has not been reduced. These habitat suitability index curves can also be used in designing projects to improve existing habitats.

High Profile

"High profile" management includes management options that would result in major changes in the habitat or change the types of recreational options in the area. Because the Tiekel River drainage is so accessible to the public it may be a desired result of management activities to greatly increase the use of this area. One management option that has been considered is the development of the Tiekel River as a floating stream (Personal Communication, Mike Scott, 1986). Currently the river is used by some floaters, mostly kayakers. Because of the number of log jams and "sweepers" along the river, portages have to be made and the river is not as safe as it could be if some of this debris was removed. The removal of log jams and "sweepers" as well as the development of larger turn-outs along the road may be part of future management plans to increase the use of the river. Log jams and sweepers can be removed without reducing the quality of habitat if the total amount of in-stream cover is not reduced. Again the habitat suitability index curves should be used as a guide to habitat quality.

The availability of such a wide variety of aquatic habitats also makes the successful introduction of different sport fish species a possibility. The successful introduction of Pacific salmon would depend on their ability to negotiate the gorge at the lower end of the river. The successful introduction of a salmon run to the Tiekel River could benefit the recreational as well as commercial opportunities of the southcentral region of Alaska. Recreationally, the addition of another salmon stream to the area would take some fishing pressure off the other, more heavily fished, streams. It might also benefit the current population of Dolly Varden in the Tiekel River by making more food available to them in the form of salmon eggs, fry, and possibly greater primary production as the result of nutrient input from salmon carcasses. Commercially, the addition of another salmon stream to the area would not only add fish to the general Copper River stock, but by doing so, take pressure off the rest of the separate spawning stocks throughout the Cooper River Drainage.

The stocking of non-salmon species could also have benefits to the recreational use of the area. The introduction of rainbow trout (*Salmo gairdneri*) or Arctic grayling (*Thymallus arcticus*) would probably add to the recreational use of the area even if trophy sized fish were never available.

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APPENDIX I

Individual habitat maps and other habitat data for each sample reach from all habitat types.

⟵ Direction of Water Flow

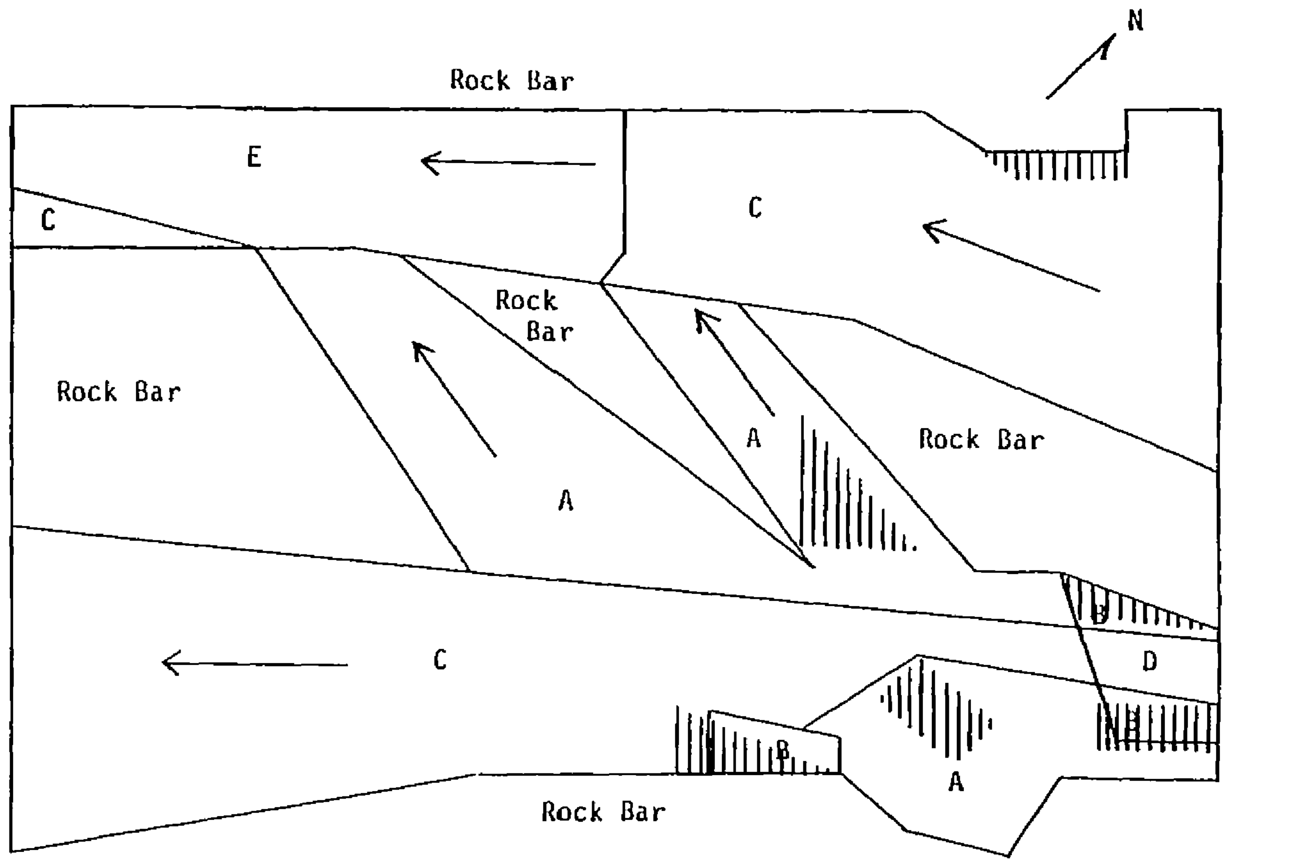
A Slow - Shallow

B Slow - Deep

C Fast - Shallow

D Fast - Deep

E Very Fast



Submerged Forest Debris

Scale 1/178

Location:	60.5-mile Richardson Hwy	Maximum Depth:	0.7 m (2.3 ft)	Flow:	1.5 m^3/sec (53.0 ft^3/sec)
Date Sampled:	6/2/85	Turbidity:	6.0 NTU	Wetted Area:	2.9 m^2 (31.2 ft^2)
Highwater Width:	125 m (410 ft)	% Embeddedness:	0%	Mean Velocity:	0.54 m/sec (1.8 ft/sec)
Stream Width:	16 m (53 ft)	Substrate:	100% Cobble		

Sample Reach #1, Wide-Banked Areas

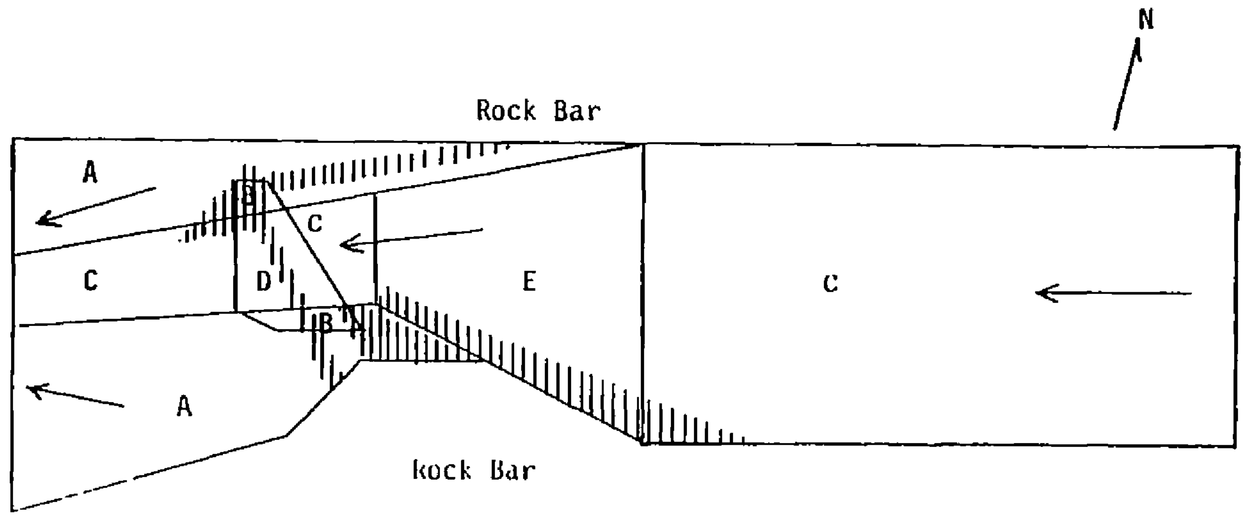
A Slow - Shallow

B Slow - Deep

C Fast - Shallow

D Fast - Deep

E Very Fast



Scale 1/178

Submerged Forest Debris

Location:	61.5-mile Richardson HWY	Maximum Depth:	0.6 m (2.0 ft)	Flow:	1.2 m^3/sec (42.4 ft^3/sec)
Date Sampled:	6/3/85	Turbidity:	5.5 NTU		
Highwater Width:	38 m (125 ft)	% Embeddedness:	0%	Wetted Area:	2.0 m^2 (21.5 ft^2)
Stream Width:	8 m (26 ft)	Substrate:	100% Cobble		
Gradient:	1.2%			Mean Velocity:	0.6 m/sec (2.0 ft/sec)

Sample Reach #2, Wide-Banked Areas

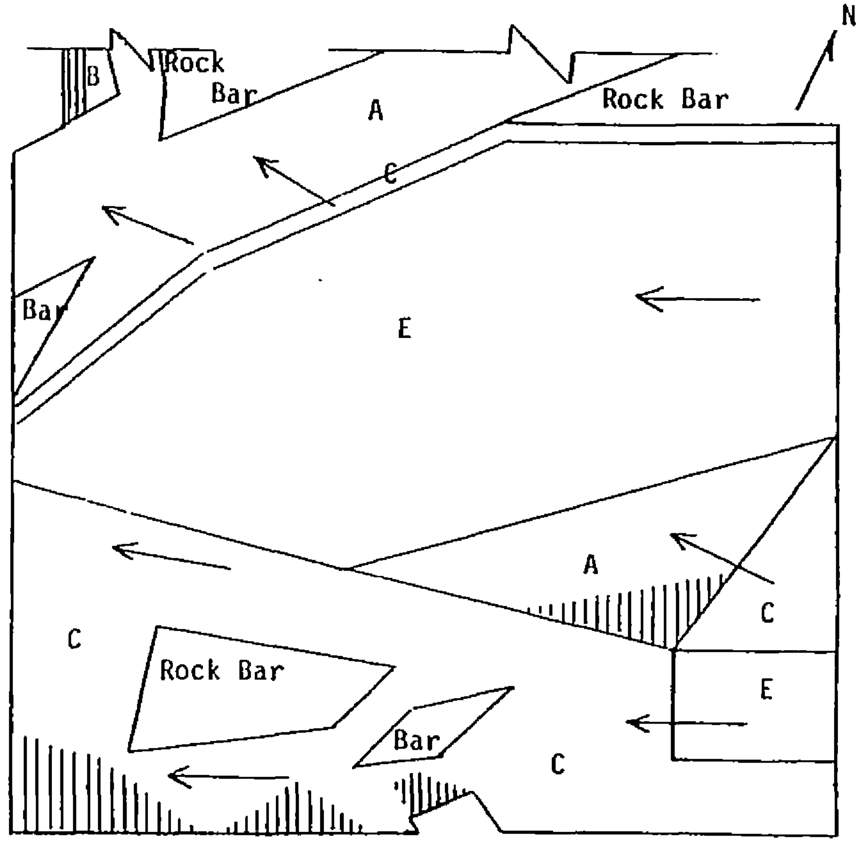
A Slow - Shallow
D Fast - Deep

B Slow - Deep
E Very Fast

C Fast - Shallow

Submerged Forest Debris

Scale 1/267



Location:	60.5-mile Richardson HWY
Date Sampled:	6/29/85
Air Temperature:	25.0°C (77.0°F)
Water Temperature:	6.0°C (42.8°F)
Highwater Width:	130 m (427 ft)
Stream Width:	31 m (102 ft)
Gradient:	1.4%
Maximum Depth:	0.8 m (2.6 ft)
% Embeddedness:	0%

Substrate: 30% Pebble, 60% Cobble, 10% Boulder

Flow: 4.3 m^3/sec (151.9 ft^3/sec)

Wetted Area: 3.3 m^2 (35.5 ft^2)

Mean Velocity: 1.3 m/sec (14.1 ft/sec)

Sample Reach #12, Wide-Banked Areas

A Slow - Shallow

B Slow - Deep

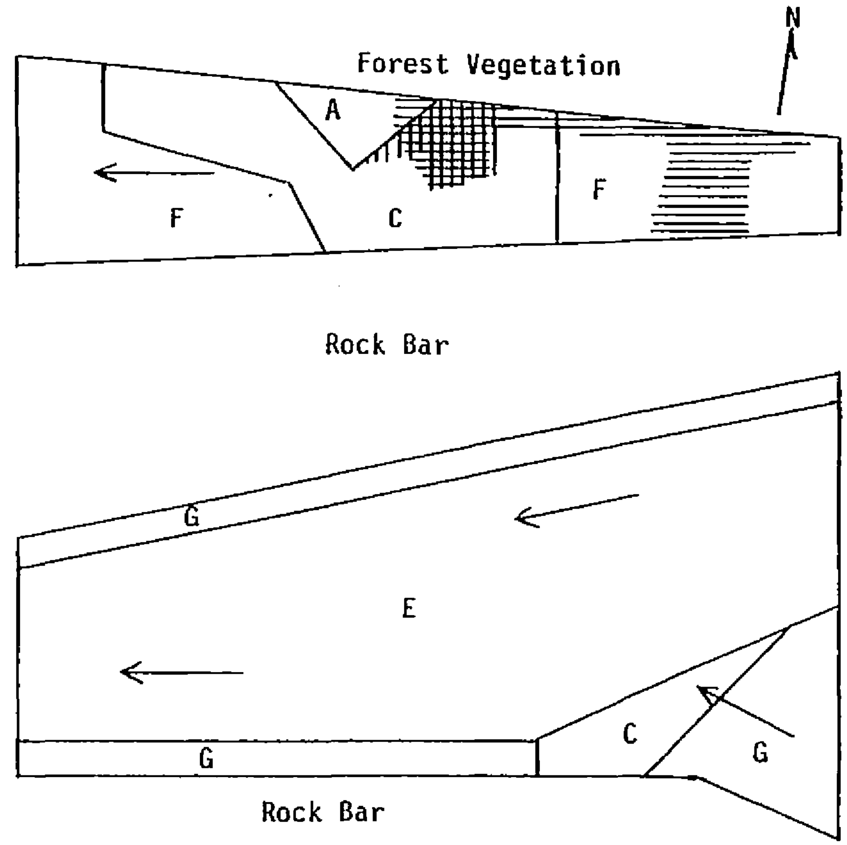
C Fast - Shallow

D Fast - Deep

E Very Fast

F 30% A
70% C

G 50% A
50% C



Submerged Forest Debris

Overhanging Vegetation

Scale 1/267

Location:	61.8-mile Richardson HWY
Date Sampled:	7/27/85
Air Temperature:	11.5°C (57.7°F)
Water Temperature:	4.0°C (39.2°F)
Highwater Width:	40 m (131 ft)
Stream Width:	15 m (49 ft)
Gradient:	1.4%
Maximum Depth:	0.7 m (2.3 ft)
Turbidity:	7.4 NTU
% Embeddedness:	0%

Substrate: 20% Pebble
60% Cobble
20% Boulder

Flow:	4.4 m^3/sec (155.4 ft^3/sec)
Wetted Area:	4.0 m^2 (13.1 ft^2)
Mean Velocity:	1.1 m/sec (3.6 ft/sec)

Sample Reach #24, Wide-Banked Areas

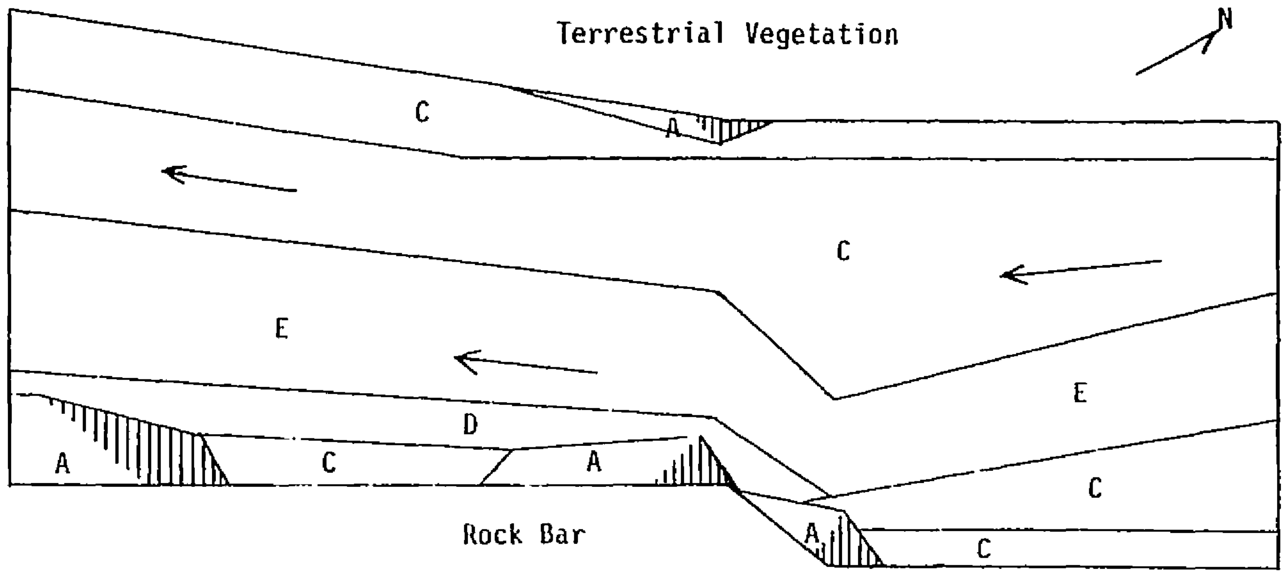
A Slow - Shallow

B Slow - Deep

C Fast - Shallow

D Fast - Deep

E Very Fast



Scale 1/178

Submerged Forest Debris

Location:	61-mile Richardson HWY	Maximum Depth:	0.6 m (2.0 ft)	Flow:	7.4 m^3/sec
Date Sampled:	8/9/85	Turbidity:	6.2 NTU		(261.3 ft^3/sec)
Air Temperature:	23.0°C (73.4°F)	% Embeddedness:	0%	Wetted Area:	6.2 m^2
Water Temperature:	8.0°C (46.4°F)	Substrate:	10% Pebble		(66.7 ft^2)
Highwater Width:	50 m (164 ft)		60% Cobble	Mean Velocity:	1.2 m/sec
Stream Width:	11 m (36 ft)		30% Boulder		(3.9 ft/sec)

Sample Reach #27, Wide-Banked Areas

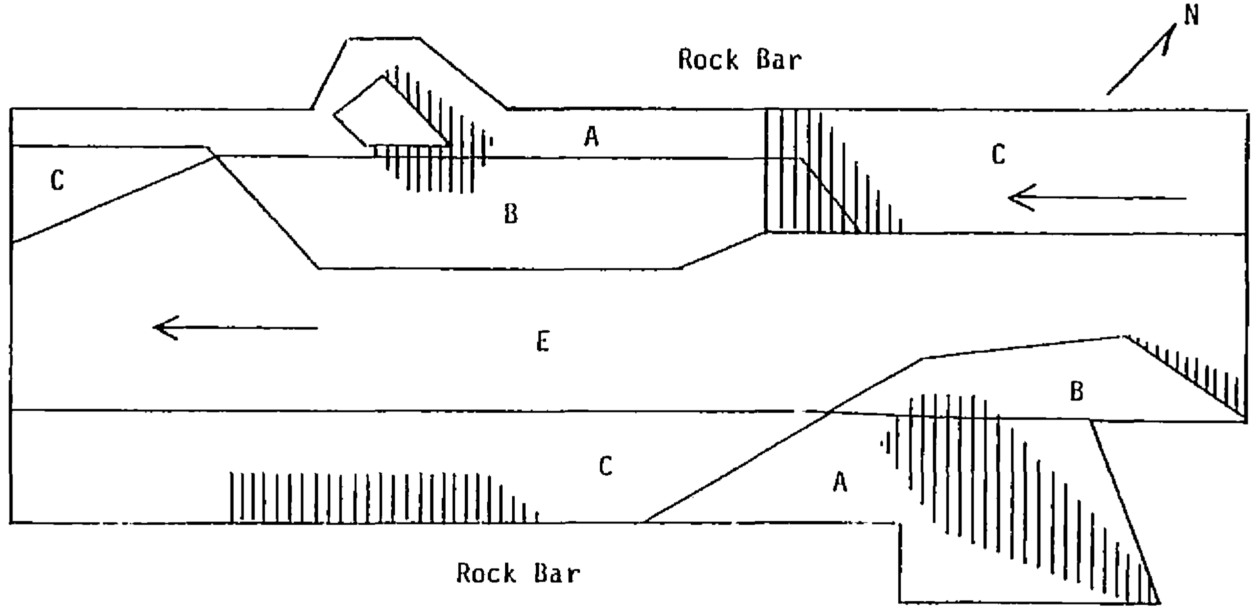
A Slow - Shallow

B Slow - Deep

C Fast - Shallow

D Fast - Deep

E Very Fast



Scale 1/178

Submerged Forest Debris

Location:	60.3-mile Richardson HWY	Maximum Depth:	0.7 m (2.3 ft)	Flow:	4.3 m^3/sec (151.9 ft^3/sec)
Date Sampled:	6/14/85	Turbidity:	5.0 NTU	Wetted Area:	4.1 m^2 (44.1ft^2)
Air Temperature:	14.0°C (57.2°F)	% Embeddedness:	0%	Mean Velocity:	1.0 m/sec (3.2 ft/sec)
Water Temperature:	4.0 °C (39.2°F)	Substrate:	80% Cobble 20% Boulder		
Highwater Width:	85 m (279 ft)	Gradient:	1.6%		
Stream Width:	10 m (33 ft)				

Sample Reach #36, Wide-Banked Areas

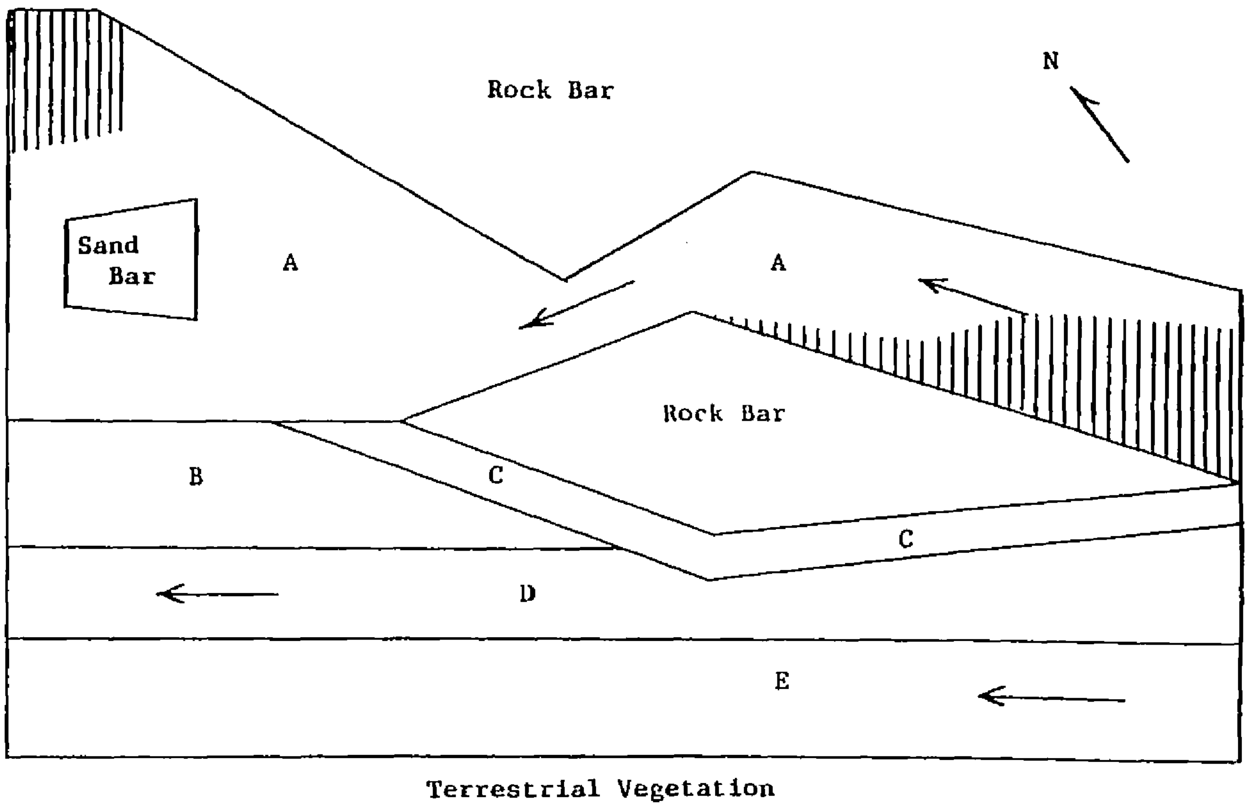
A Slow - Shallow

B Slow - Deep

C Fast - Shallow

D Fast - Deep

E Very Fast

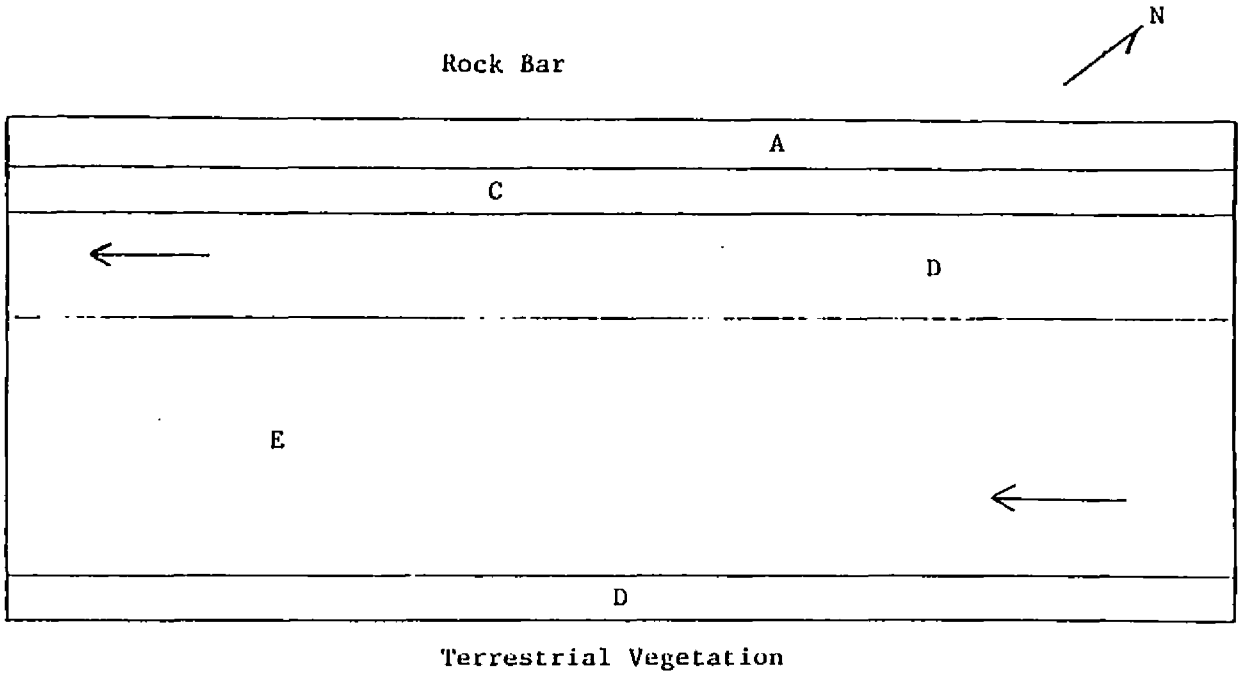


Submerged Forest Debris

Scale 1/178

Location:	54.0-mile Richardson HWY	Maximum Depth:	1.3 m (4.3 ft)	Flow:	9.2 m^3/sec
Date Sampled:	6/12/85	Turbidity:	15.0 NTU		(324.9 ft^3/sec)
Air Temperature:	16.0°C (60.8°F)	% Embeddedness:	40%	Wetted Area:	8.1 m^2
Water Temperature:	4.0°C (39.2°F)	Substrate:	25% Sand		(87.2 ft^2)
Highwater Width:	36 m (118 ft)		25% Gravel	Mean Velocity:	1.1 m/sec
Stream Width:	13 m (43 ft)		10% Pebble		(3.6 ft/sec)
Gradient:	1.0%		40% Cobble		

Sample Reach #4, Upper Main River



A Slow - Shallow

B Slow - Deep

C Fast - Shallow

D Fast - Deep

E Very Fast

Scale 1/178

Location:	55.5-mile Rich. HWY	Maximum Depth:	1.0 m (3.3 ft)	Flow:	7.4 m^3/sec (261.3 ft^3/sec)
Date Sampled:	6/16/85	Turbidity:	17.0 NTU		
Air Temperature:	16.0°C (60.8°F)	% Embeddedness:	10%	Wetted Area:	6.2 m^2 (66.7 ft^2)
Water Temperature:	4.0°C (39.2°F)	Substrate:	50% Cobble		
Highwater Width:	13 m (42 ft)		50% Boulder	Mean Velocity:	1.2 m/sec (3.9 ft/sec)
Stream Width:	12 m (39 ft)				
Gradient:	0.7%				

Sample Reach #9, Upper Main River

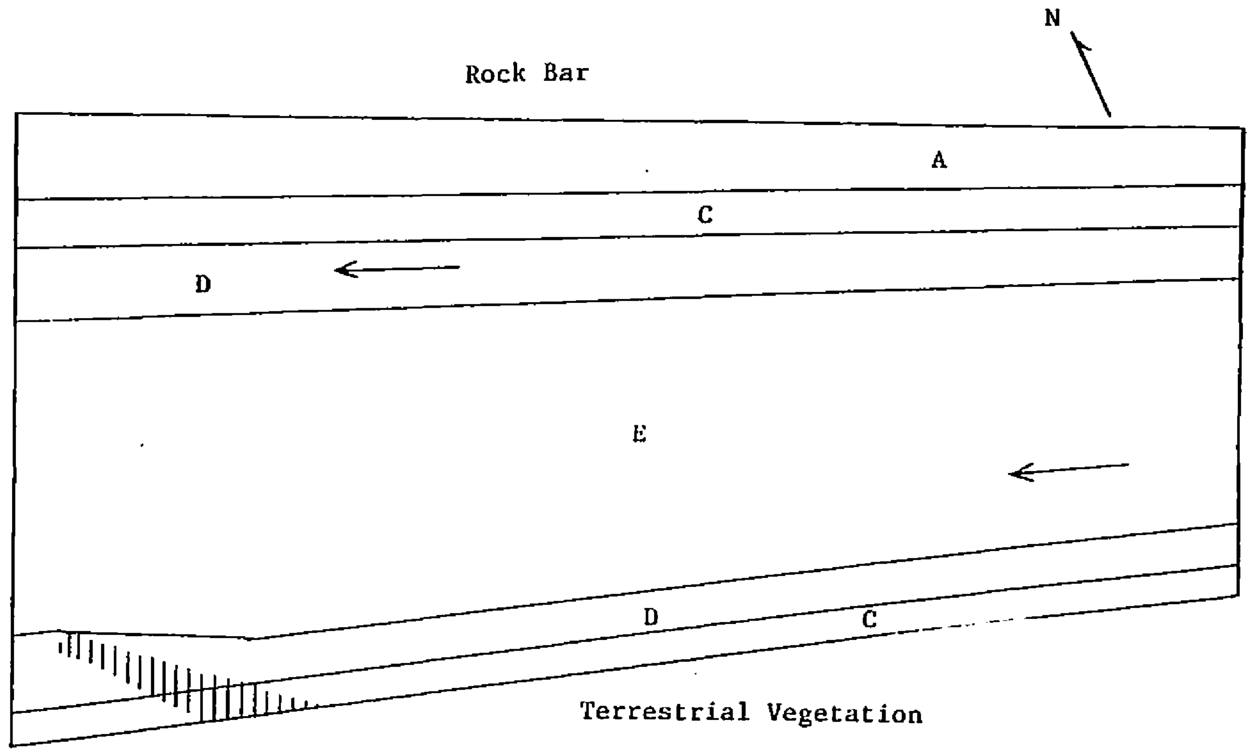
A Slow - Shallow

B Slow - Deep

C Fast - Shallow

D Fast - Deep

E Very Fast



Sumerged Forest Debris

Scale 1/178

Location:	58-mile Rich. HWY
Date Sampled:	6/29/85
Air Temperature:	20.0°C (68.0°F)
Water Temperature:	4.0°C (39.2°F)
Highwater Width:	20 m (66 ft)

Stream Width:	13 m (43 ft)
Gradient:	1.7%
Maximum Depth:	1.0 m (3.3 ft)
% Embeddedness:	10%
Substrate:	50% Pebble
	50% Cobble

Sample Reach #11, Upper Main River

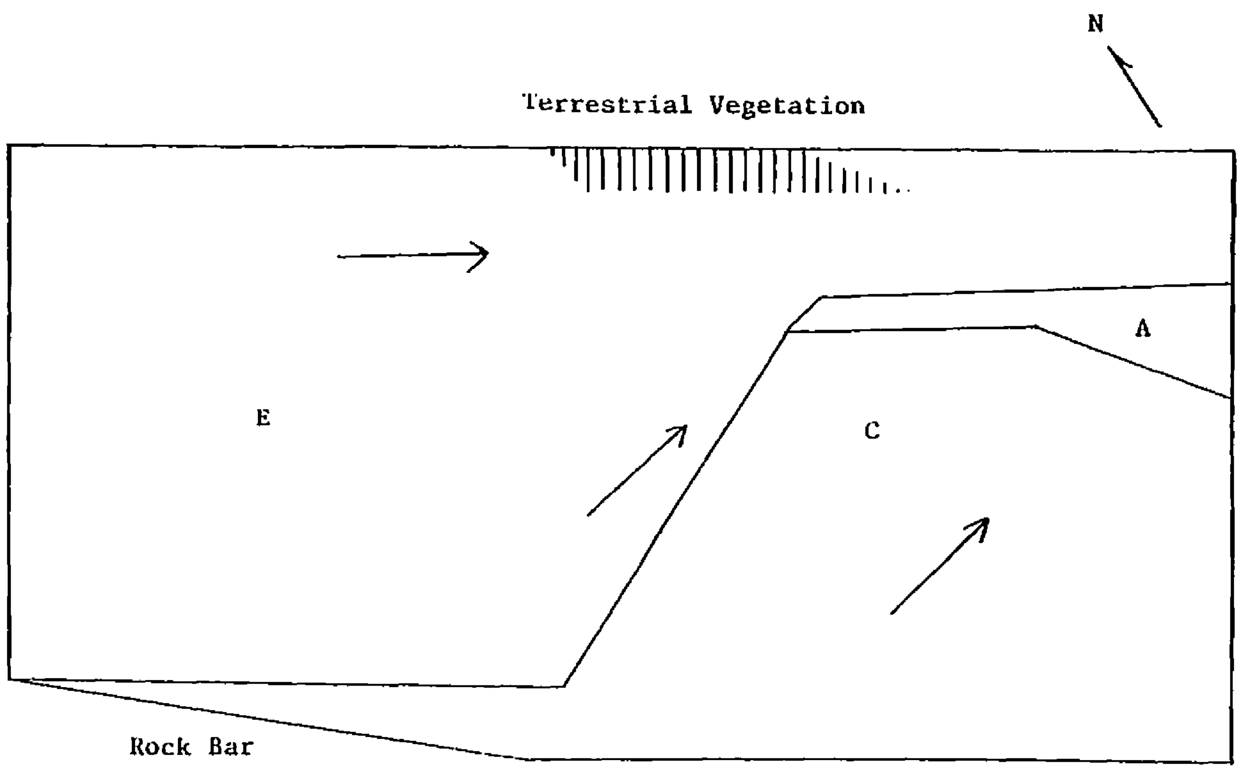
A Slow - Shallow

B Slow - Deep

C Fast - Shallow

D Fast - Deep

E Very Fast

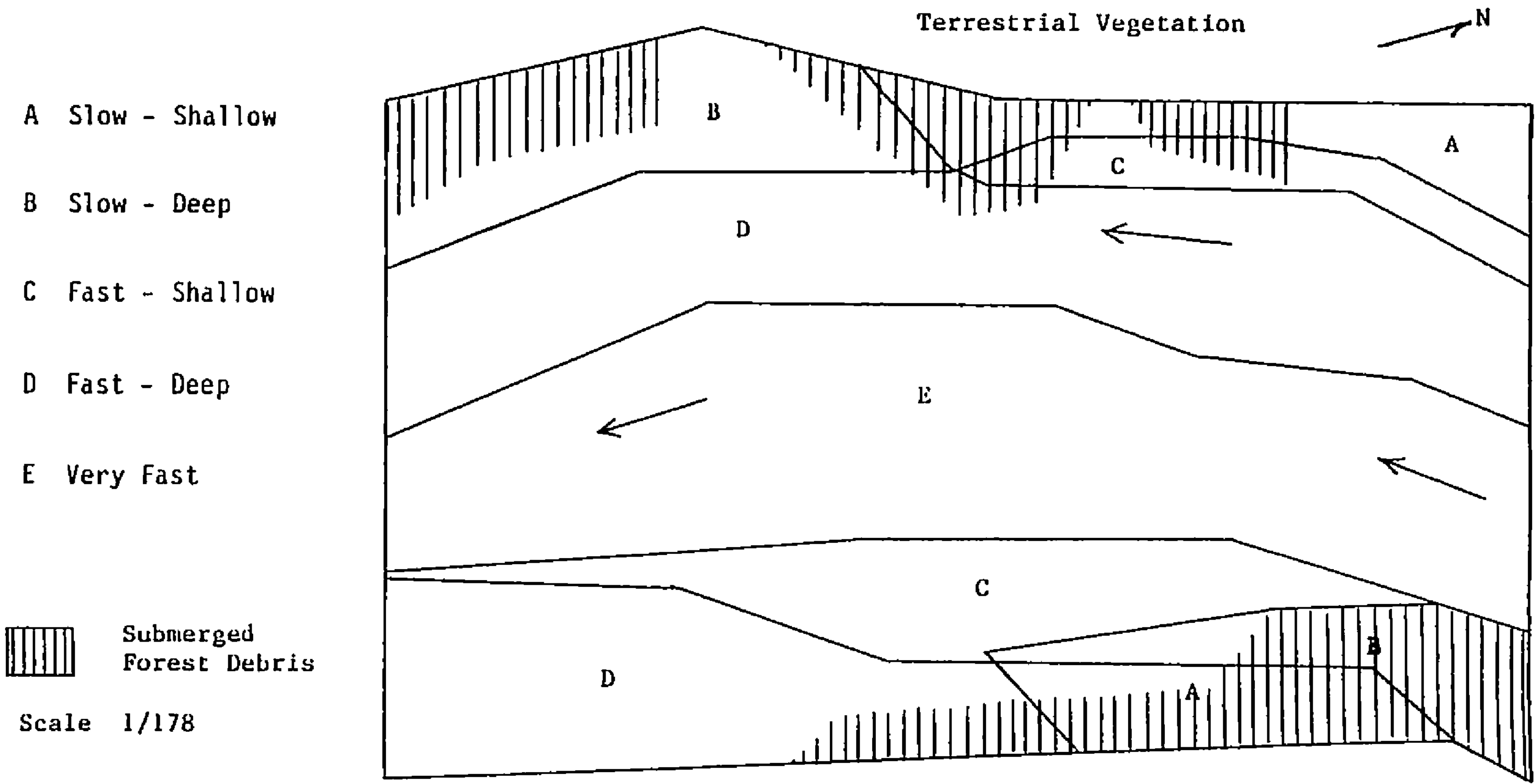


Submerged Forest Debris

Scale 1/178

Location:	59-mile Rich. HWY	Maximum Depth:	1.2 m (3.9 ft)	Flow:	8.7 m^3/sec (307.2 ft^3/sec)
Date Sampled:	7/16/85	Turbidity:			
Highwater Width:	30 m (98 ft)	% Embeddedness:	0%	Wetted Area:	6.9 m^2 (74.2 ft^2)
Stream Width:	16 m (53 ft)	Substrate:	70% Cobble		
Gradient:	1.5%		30% Boulder	Mean Velocity:	1.3 m/sec (4.3 ft/sec)

Sample Reach #16, Upper Main River



Location:	55-mile Rich. HWY	Highwater Width:	26 m (85 ft)	Turbidity:	3.5 NTU
Date Sampled:	7/25/85	Stream Width:	17 m (56 ft)	% Embeddedness:	14%
Air Temperature:	24.5°C (76.1°F)	Gradient:	0.5%	Substrate:	20% Sand
Water Temperature:	5.5°C (41.9°F)	Maximum Depth:	1.8 m (5.9 ft)		60% Cobble
					20% Boulder

Sample Reach #23, Upper Main River

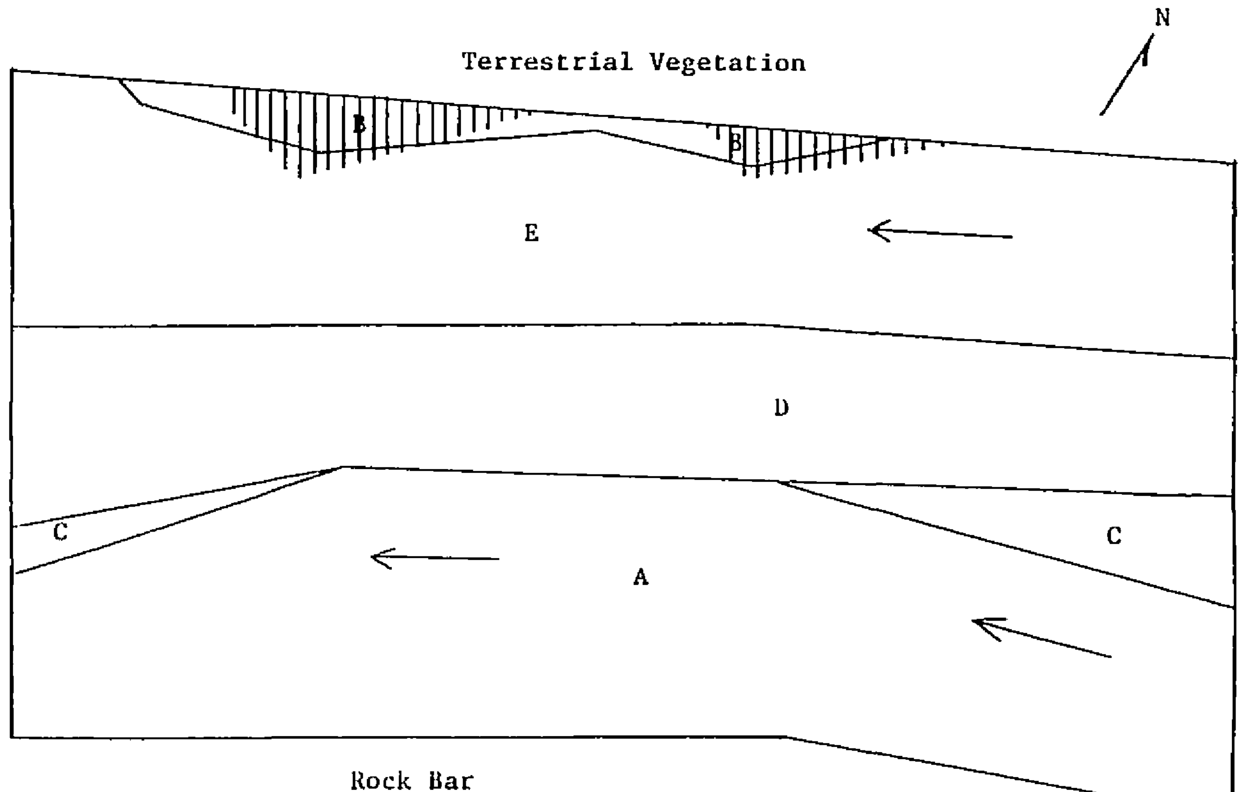
A Slow - Shallow

B Slow - Deep

C Fast - Shallow

D Fast - Deep

E Very Fast

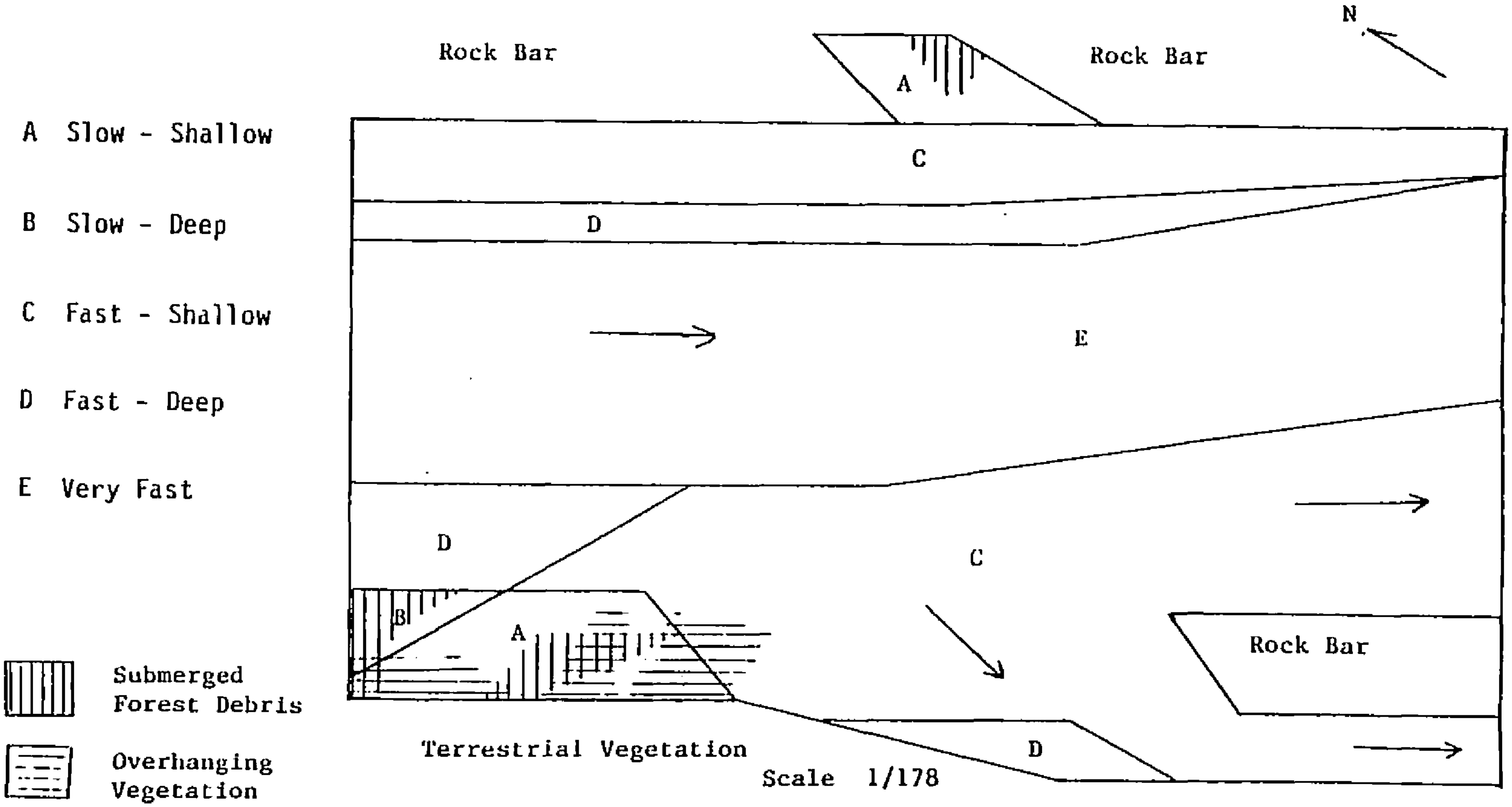


Submerged Forest Debris

Scale 1/178

Location:	56-mile Rich. HWY	Highwater Width:	19 m (62 ft)	% Embeddedness:	10%
Date Sampled:	7/27/85	Stream Width:	16 m (53 ft)	Substrate:	25% Sand
Air Temperature:	16.0°C (60.8°F)	Maximum Depth:	1.4 m (4.6 ft)		50% Pebble
Water Temperature:	5.0°C (41.0°F)	Turbidity:	4.1 NTU		25% Cobble

Sample Reach #25, Upper Main River



Location:	58.5-mile Rich. HWY	Maximum Depth:	1.2 m (3.9 ft)	Flow:	7.2 m^3/sec
Date Sampled:	8/9/85	Turbidity:	4.5 NTU		(254.3 ft^3/sec)
Air Temperature:	14.0°C (57.2°F)	% Embeddedness:	10%	Wetted Area:	7.2 m^2
Water Temperature:	6.0°C (42.8°F)	Substrate:	10% Gravel		(77.5 ft^2)
Highwater Width:	24 m (79 ft)		60% Pebble	Mean Velocity:	1.0 m/sec
Stream Width:	15 m (49 ft)		20% Cobble		(3.3 ft/sec)
Gradient:	0.7 NTU		10% Boulder		

Sample Reach #26, Upper Main River

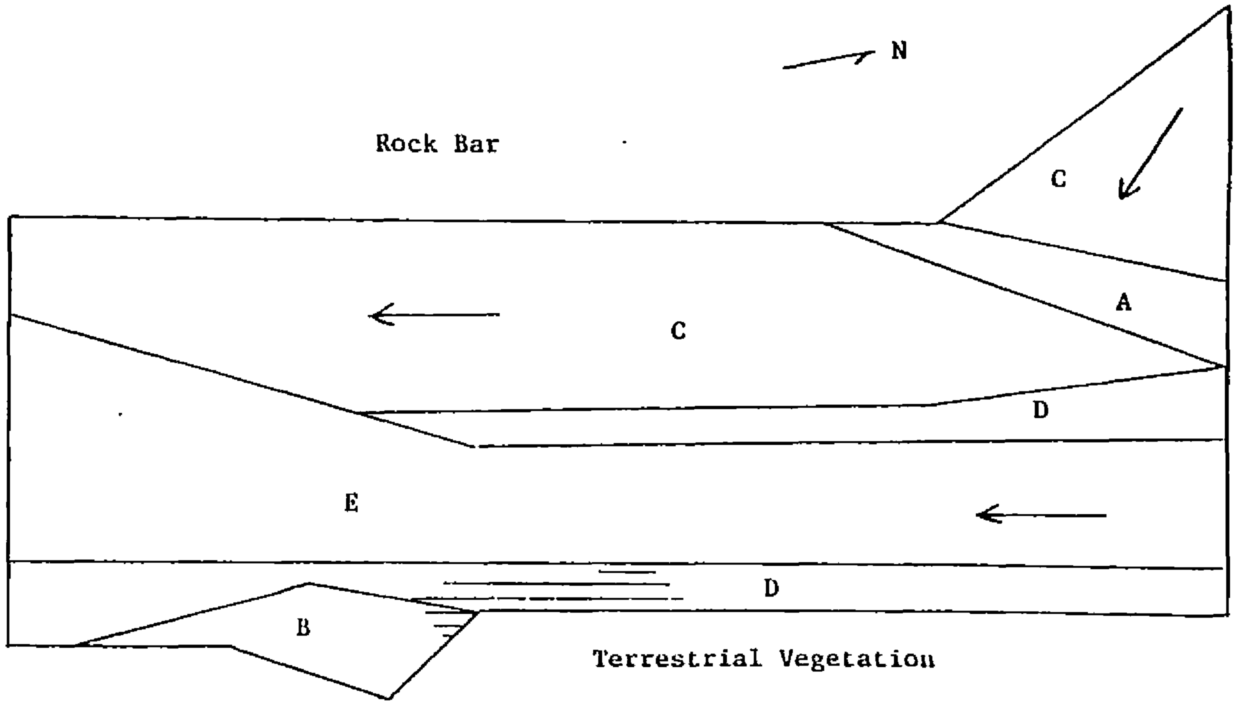
A Slow - Shallow

B Slow - Deep

C Fast - Shallow

D Fast - Deep

E Very Fast



Overhanging Vegetation

Scale 1/178

Location:	58-mile Rich. HWY	Stream Width:	9 m (30 ft)	Turbidity:	9.6 NTU
Date Sampled:	8/13/85	Gradient:	3.2%	Substrate:	10% Gravel
Air Temperature:	15°C (59°F)	Maximum Depth:	0.7 m (2.3 ft)		10% Pebble
Water Temperature:	6.0°C (42.8°F)	% Embeddedness:	10%		80% Cobble
Highwater Width:	20 m (66 ft)				

Sample Reach #31, Upper Main River

A Slow - Shallow

B Slow - Deep

C Fast - Shallow

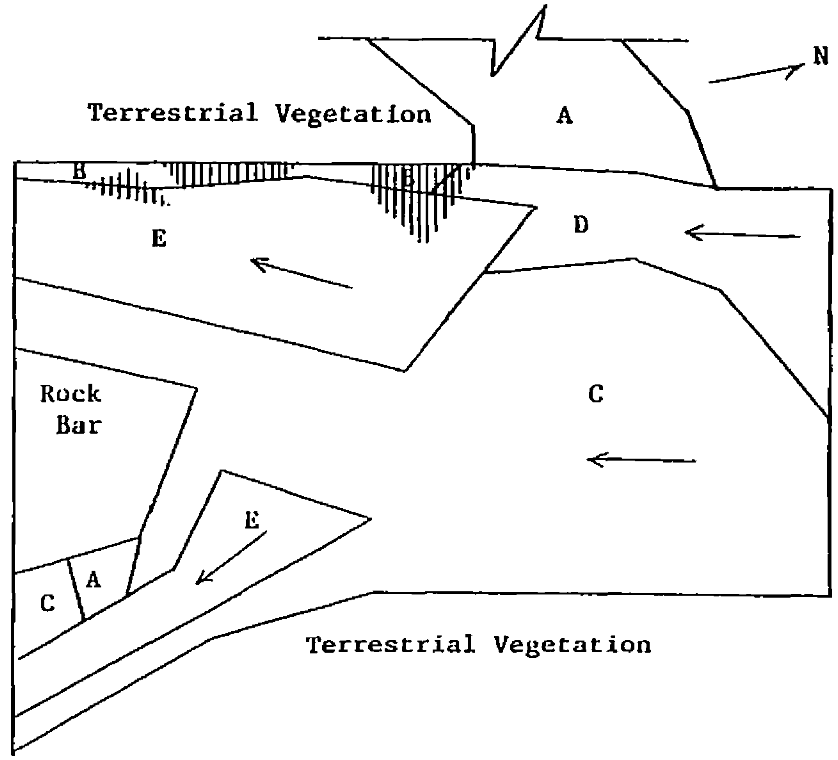
D Fast - Deep

E Very Fast

Submerged Forest Debris

Scale 1/267

Location:	53-mile Rich. HWY
Date Sampled:	8/14/85
Air Temperature:	12.0°C (53.6°F)
Water Temperature:	7.0°C (44.6°F)
Highwater Width:	18 m (59 ft)
Stream Width:	18 m (59 ft)
Gradient:	0.2%
Maximum Depth:	1.0 m (3.3 ft)
Turbidity:	3.9 NTU
% Embeddedness:	30%



Substrate: 50% Pebble
50% Cobble

Wetted Area: 7.0 m^2 (75.3 ft^2)

Mean Velocity: 0.7 m/sec (2.3 ft/sec)

Flow: 5.2 m^3/sec (186.6 ft^3/sec)

Sample Reach #33, Upper Main River

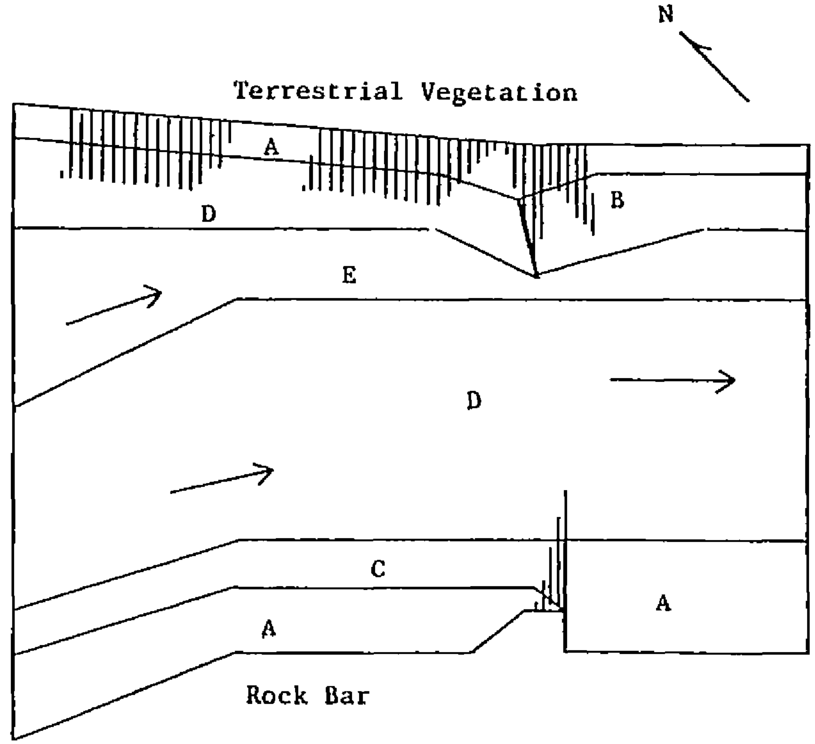
A Slow - Shallow
D Fast - Deep

B Slow - Deep
E Very Fast

C Fast - Shallow

Submerged Forest Debris

Scale 1/267



Location:	48-mile Rich. HWY
Date Sampled:	6/14/85
Air Temperature:	16.0°C (60.8°F)
Water Temperature:	4.0°C (39.2°F)
Highwater Width:	28 m (100 ft)
Stream Width:	19 m (62 ft)
Gradient:	0.4%
Maximum Depth:	2.0 m (7 ft)
Turbidity:	14.5 NTU
% Embeddedness:	50%

Substrate: 80% Sand
20% Pebble

Flow:	14.2 m^3/sec (501.5 ft^3/sec)
Wetted Area:	16.7 m^2 (179.8 ft^2)
Mean Velocity:	0.9 m/sec (3.0 ft/sec)

Sample Reach #6, Lower Main River

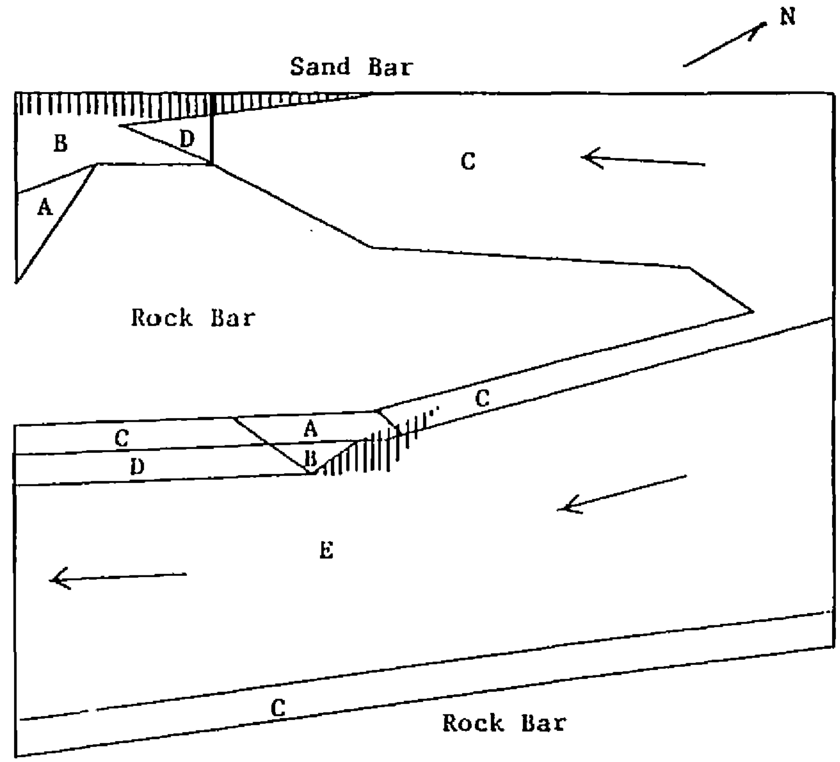
A Slow - Shallow

B Slow - Deep

C Fast - Shallow

D Fast - Deep

E Very Fast



Submerged Forest Debris

Scale 1/267

Location:	52.5-mile Rich. HWY
Date Sampled:	6/17/85
Air Temperature:	11.5°C (52.7°F)
Water Temperature:	3.5°C (38.3°F)
Highwater Width:	45 m (148 ft)
Stream Width:	24 m (79 ft)
Gradient:	0.6%
Maximum Depth:	0.8 m (2.6 ft)
Turbidity:	13.0 NTU
% Embeddedness:	5%

Substrate: 10% Sand
30% Pebble
60% Cobble

Sample Reach #10, Lower Main River

A Slow - Shallow

B Slow - Deep

C Fast - Shallow

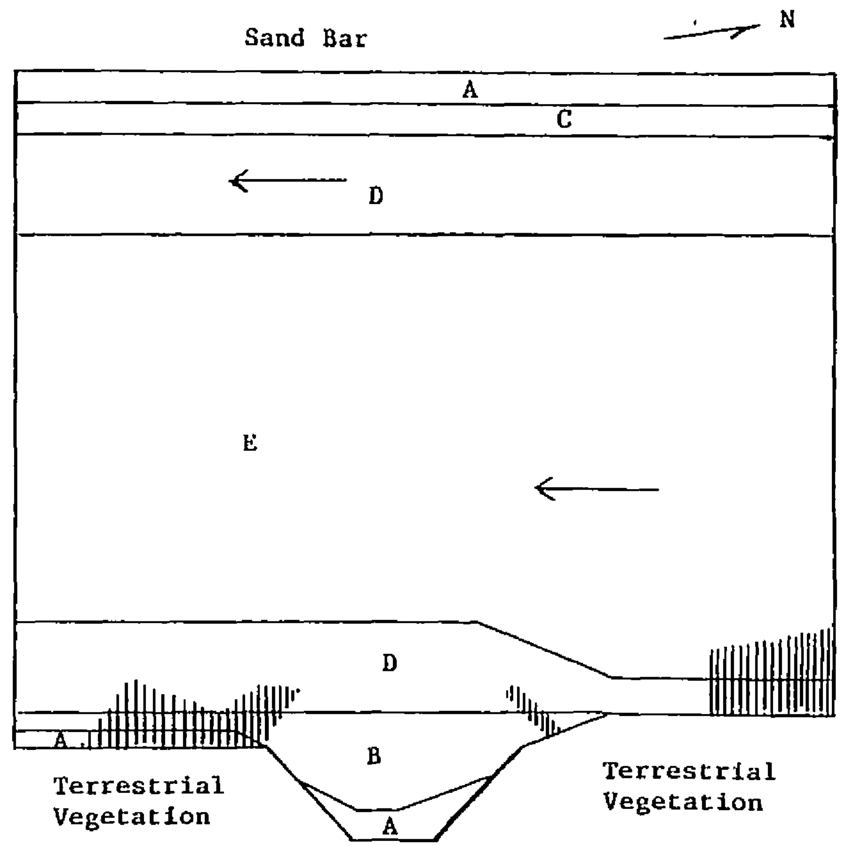
D Fast - Deep

E Very Fast

Submerged Forest Debris

Scale 1/267

Location:	48.5-mile Rich. HWY
Date Sampled:	7/9/85
Air Temperature:	15.0°C (59.0°F)
Water Temperature:	5.0°C (41.0°F)
Highwater Width:	35 m (115 ft)
Stream Width:	25 m (82 ft)
Gradient:	0.1%
Maximum Depth:	1.7 m (5.6 ft)
Turbidity:	20 NTU
% Embeddedness:	100%



Substrate: 100% Sand

Flow: 24.3 m^3/sec (858.1 ft^3/sec)

Wetted Area: 23.4 m^2 (251.9 ft^2)

Mean Velocity: 1.0 m/sec (3.3 ft/sec)

Sample Reach 13, Lower Main River

A Slow - Shallow
D Fast - Deep

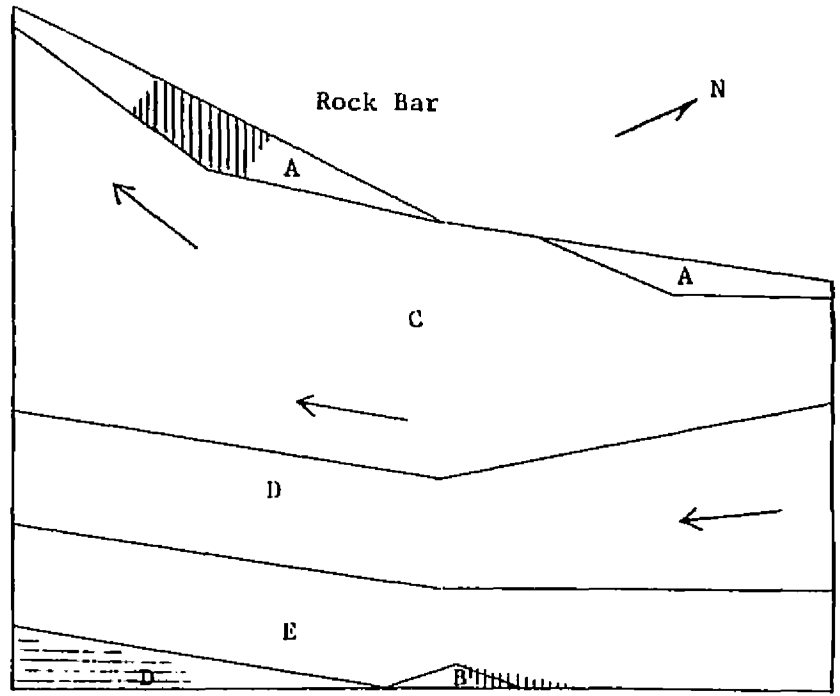
B Slow - Deep
E Very Fast

C Fast - Shallow

Submerged Forest Debris

Overhanging Vegetation

Scale 1/267



Terrestrial Vegetation

Location:	49.5-mile Rich. HWY
Date Sampled:	7/26/85
Air Temperature:	20.5°C (68.9°F)
Water Temperature:	7.5°C (45.5°F)
Highwater Width:	36 m (118 ft)
Stream Width:	21 m (69 ft)
Gradient:	0.1%
Maximum Depth:	1.3 m (4.3 ft)
Turbidity:	7.6 NTU
% Embeddedness:	30%

Substrate: 40% Sand
40% Pebble
20% Cobble

Sample Reach #17, Lower Main River

A Slow - Shallow

B Slow - Deep

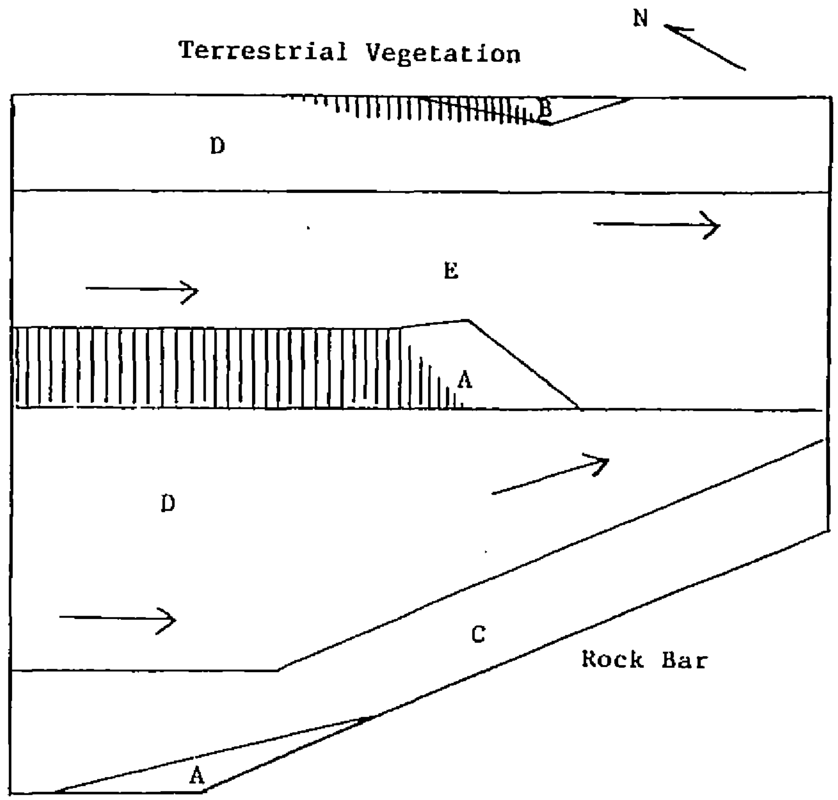
C Fast - Shallow

D Fast - Deep

E Very Fast

Submerged Forest Debris

Scale 1/267



Location:	47-mile Rich. HWY
Date Sampled:	7/17/85
Air Temperature:	30.0°C (86°F)
Water Temperature:	7.0°C (44.6°F)
Highwater Width:	54 m (177 ft)
Stream Width:	27 m (89 ft)
Gradient:	2.3%
Maximum Depth:	1.3 m (4.3 ft)
Turbidity:	21.5 NTU
% Embeddedness:	15%

Substrate: 50% Pebble
50% Cobble

Sample Reach #18, Lower Main River

A Slow - Shallow

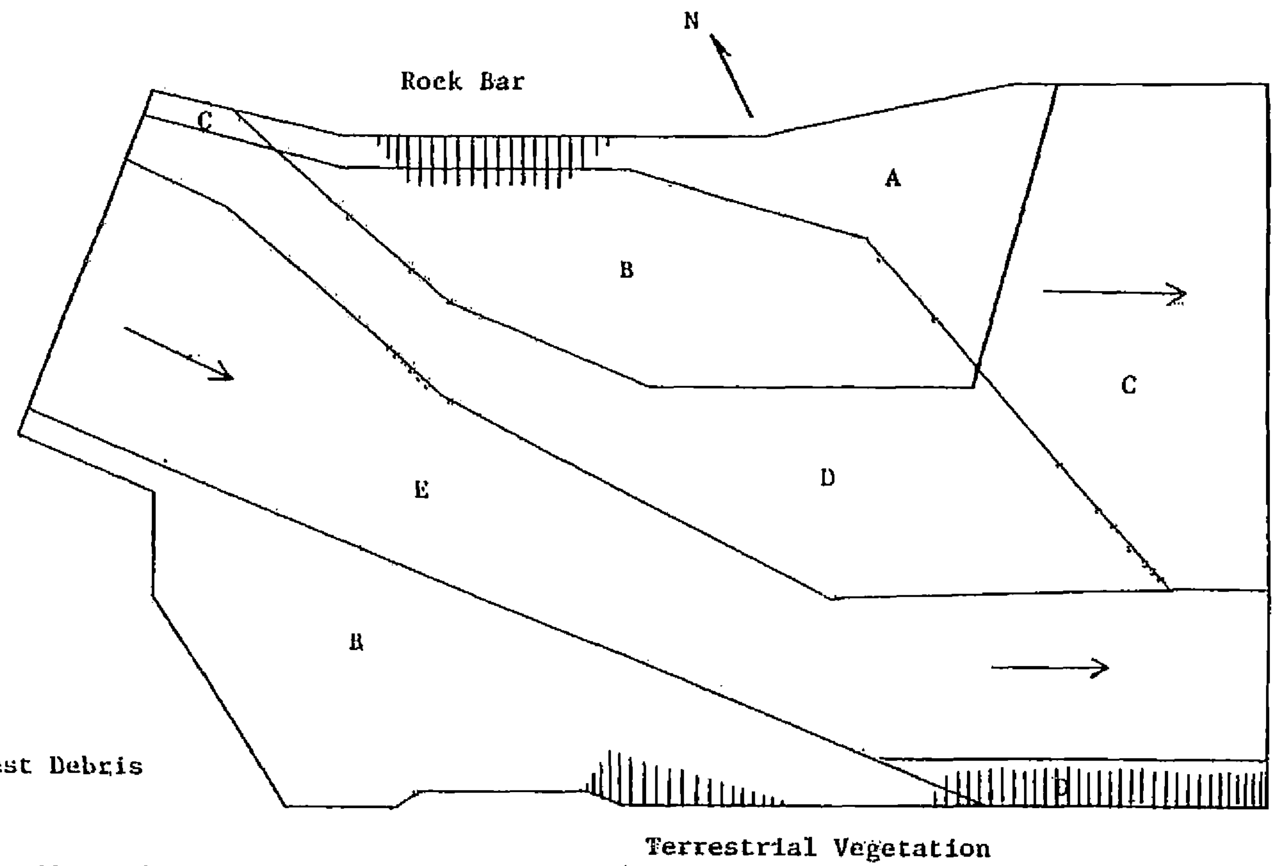
B Slow - Deep

C Fast - Shallow

D Fast - Deep

E Very Fast

Submerged Forest Debris



Scale 1/178

Location:	51-mile Rich. HWY	Stream Width:	16 m (53 ft)		
Date Sampled:	8/10/85	Maximum Depth:	2.0 m (6.6 ft)	Substrate:	20% Sand
Air Temperature:	12.5°C (54.5°F)	Turbidity:	3.9 NTU		20% Pebble
Water Temperature:	6.0°C (42.8°F)	% Embeddedness:	50%		60% Cobble
Highwater Width:	26 m (85 ft)	Gradient:	0.9%		

Sample Reach #29, Lower Main River

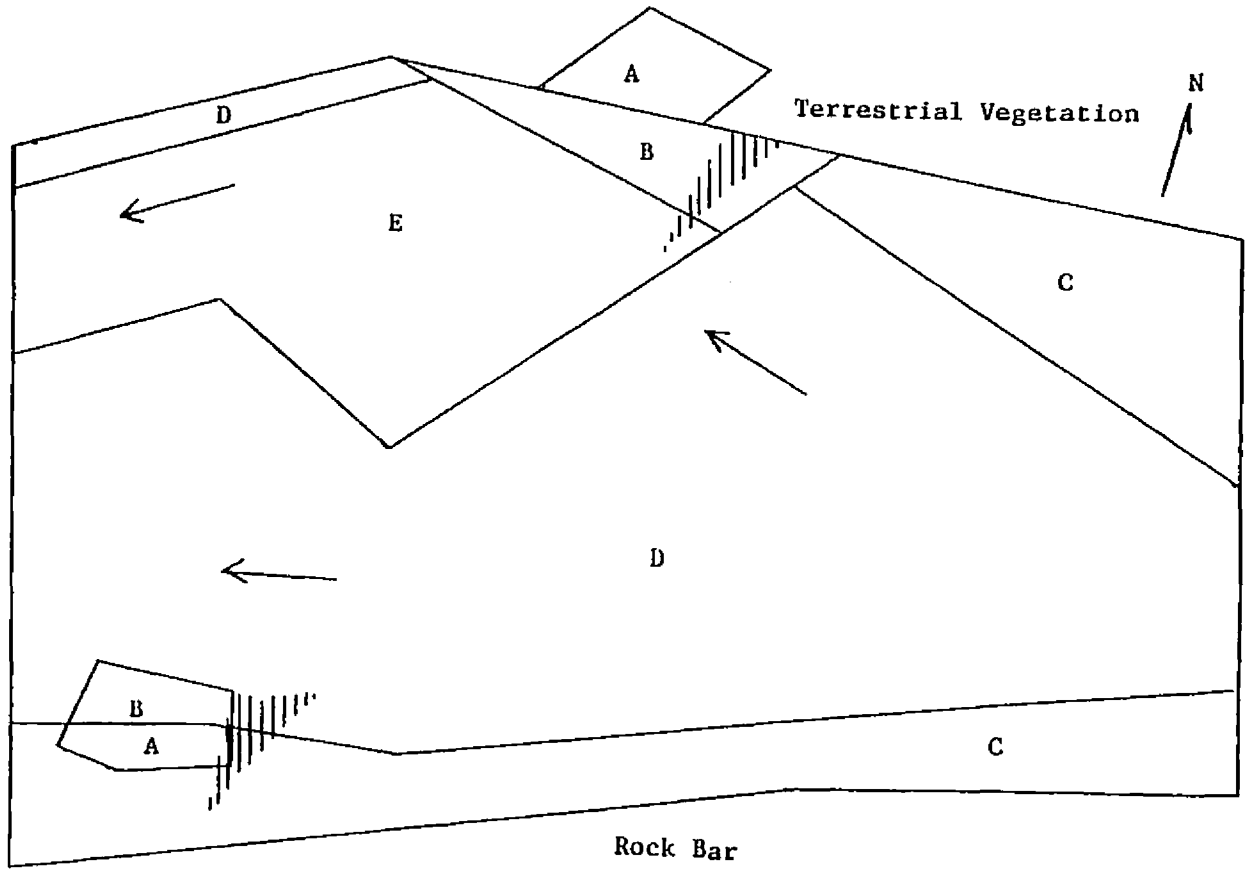
A Slow - Shallow

B Slow - Deep

C Fast - Shallow

D Fast - Deep

E Very Fast



Submerged Forest Debris

Scale 1/178

Location:	52-mile Rich. HWY	Maximum Depth:	1.2 m (3.9 ft)	Flow:	8.5 m^3/sec (300.2 ft^3/sec)
Date Sampled:	8/13/85	Turbidity:	12.0 NTU	Wetted Area:	7.4 m^2 (79.7 ft^2)
Air Temperature:	13.0°C (55.4°F)	% Embeddedness:	20%	Mean Velocity:	1.2 m/sec (3.9 ft/sec)
Water Temperature:	5.5°C (41.9°F)	Substrate:	50% Sand		
Highwater Width:	30 m (98 ft)		25% Pebble		
Stream Width:	20 m (66 ft)		25% Cobble		

Sample Reach #32, Lower Main River

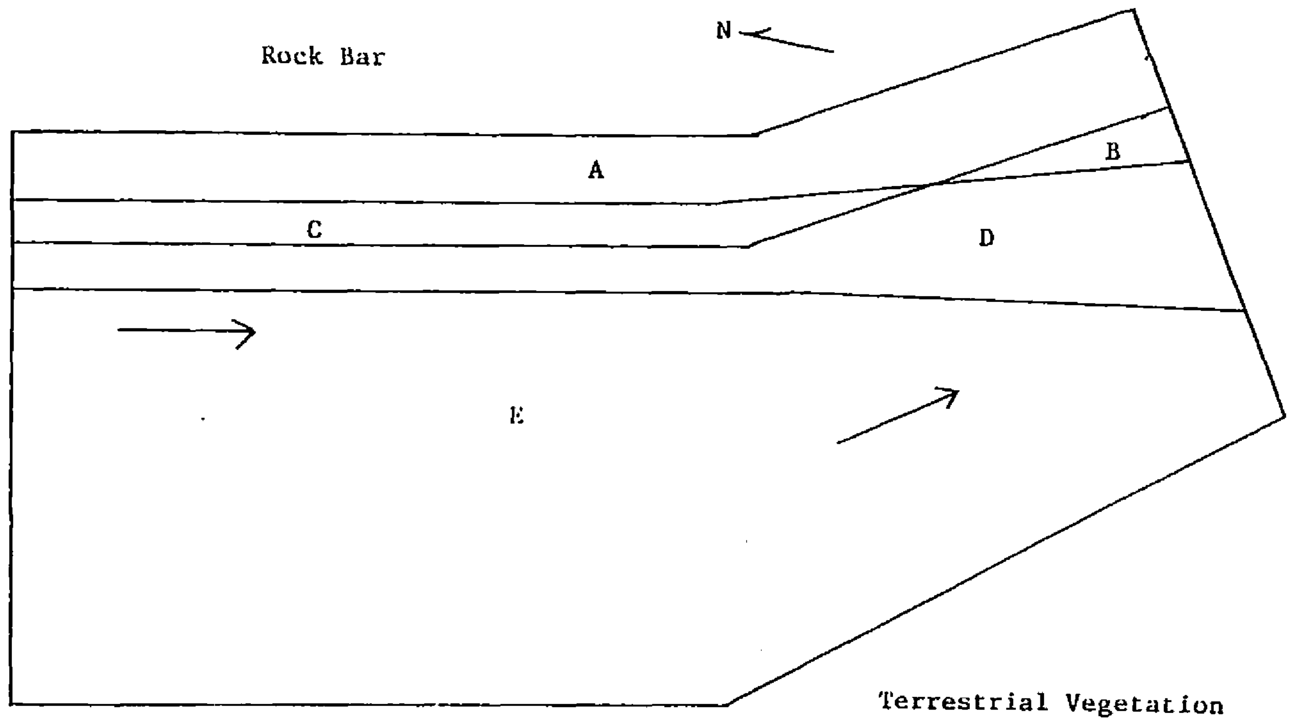
A Slow - Shallow

B Slow - Deep

C Fast - Shallow

D Fast - Deep

E Very Fast



Scale 1/178

Location:	50.5-mile Rich. HWY	Maximum Depth:	1.2 m (3.9 ft)	Flow:	9.7 m^3/sec
Date Sampled:	8/14/85	Turbidity:	5.0 NTU		(342.6 ft^3/sec)
Air Temperature:	15.0°C (59.0°F)	% Embeddedness:	40%	Wetted Area:	13.0 m^2
Water Temperature:	6.0°C (42.8°F)	Substrate:	25% Sand		(139.9 ft^2)
Highwater Width:	35 m (115 ft)		25% Cobble	Mean Velocity:	0.8 m/sec
Stream Width:	15 m (49 ft)		50% Boulder		(2.6 ft/sec)

Sample Reach #34, Lower Main River

A Slow - Shallow

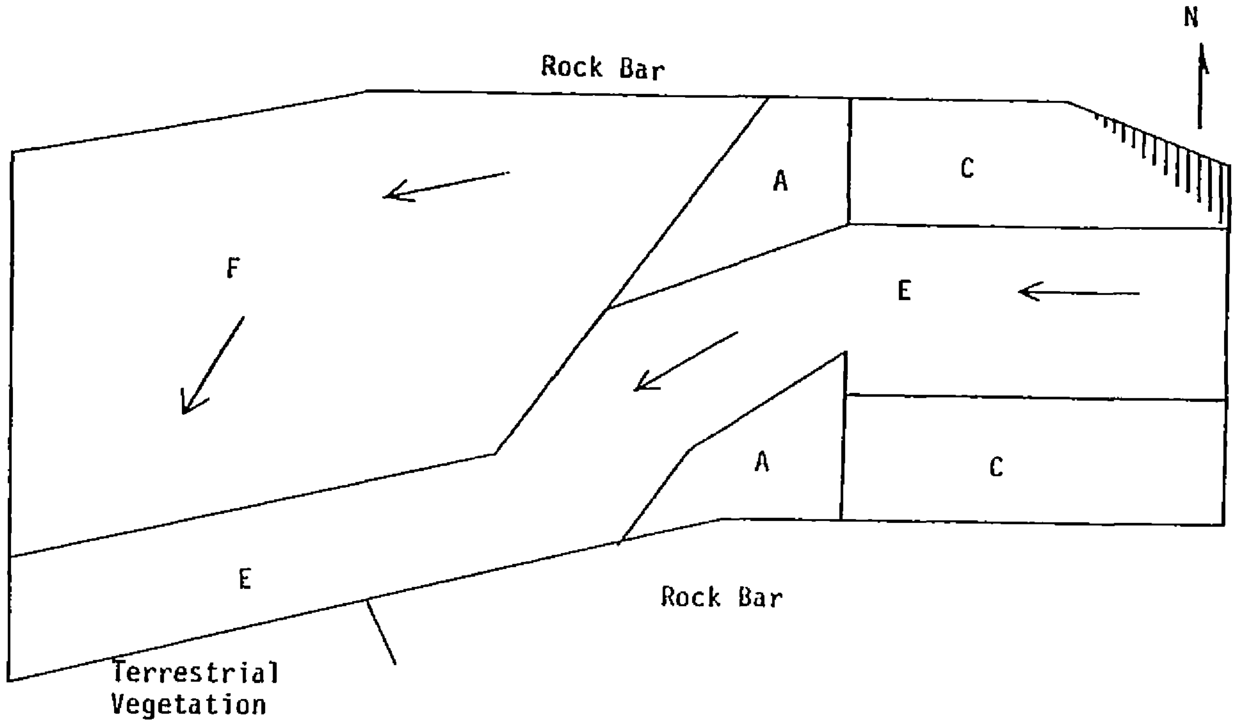
B Slow _ Deep

C Fast - Shallow

D Fast - Deep

E Very Fast

F 50% A
50% C



Scale 1/178

Submerged Forest Debris

Location:	60-mile Rich. HWY	Gradient:	1.8%		
Date Sampled:	6/13/85	Maximum Depth:	0.6 m (2.0 ft)		
Air Temperature:	16.0°C (60.8°F)	Turbidity:	4.7 NTU	Flow:	1.8 m^3/sec (63.6 ft^3/sec)
Water Temperature:	5.0°C (41.0°F)	% Embeddedness:	0%		
Highwater Width:	19 m (62 ft)	Substrate:	30% Cobble	Wetted Area:	2.2 m^2 (23.7 ft^2)
Stream Width:	11 m (36 ft)		70% Boulder	Mean Velocity:	0.8 m/sec (2.6 ft/sec)

SAmple Reach #5, Feeder Streams

A Slow - Shallow

B Slow - Deep

C Fast - Shallow

D Fast - Deep

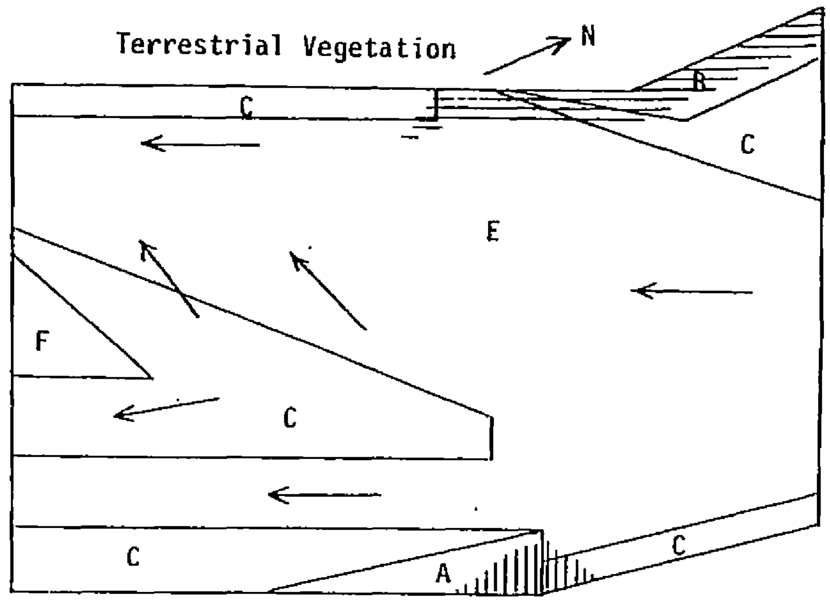
E Very Fast

F 70% C
30% A

Submerged Forest Debris

Overhanging Vegetation

Scale 1/267



Location:	62-mile Rich. HWY
Date Sampled:	6/15/85
Air Temperature:	9.0°C (48.2°F)
Water Temperature:	3.0°C (37.4°F)
Highwater Width:	20 m (65.6 ft)
Stream Width:	18 m (59 ft)
Gradient:	1.0%
Maximum Depth:	.6 m (2.0 ft)
Turbidity:	4.4 NTU
% Embeddedness:	0%

Substrate: 30% Cobble
70% Boulder

Flow:	3.9 m^3/sec (137.7 ft^3/sec)
Wetted Area:	4.7 m^2 (50.6 ft^2)
Mean Velocity:	0.8 m/sec (2.6 ft/sec)

Sample Reach #7, Feeder Streams

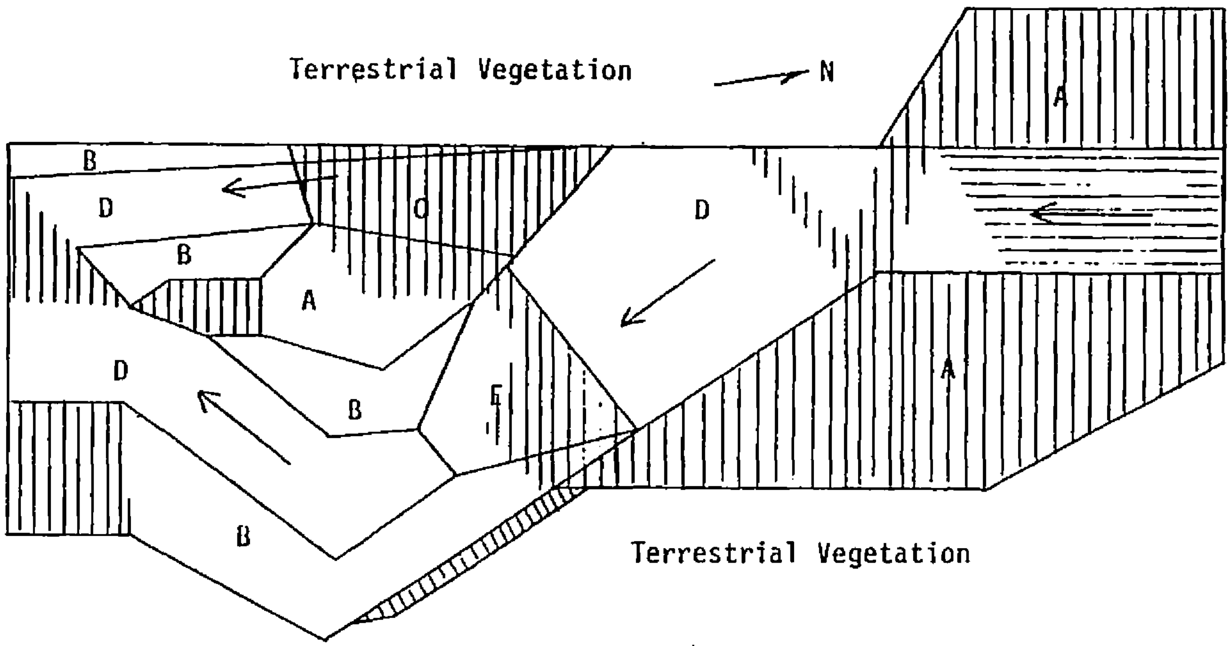
A Slow - Shallow

B Slow - Deep

C Fast - Shallow

D Fast - Deep

E Very Fast



Scale 1/178

Submerged Forest Debris

Overhanging Vegetation

Undercut Bank

Location:	56-mile Rich. HWY	Highwater Width:	4 m (13 ft)	Turbidity:	1.7 NTU
Date Sampled:	7/12/85	Stream Width:	4 m (13 ft)	% Embeddedness:	50%
Air Temperature:	12.0°C (53.6°F)	Gradient:	0.4%	Substrate:	50% Sand
Water Temperature:	5.5°C (41.9°F)	Maximum Depth:	1.2 m (3.9 ft)		50% Pebble

Sample Reach #14, Feeder Streams

A Slow - Shallow

B Slow - Deep

C Fast - Shallow

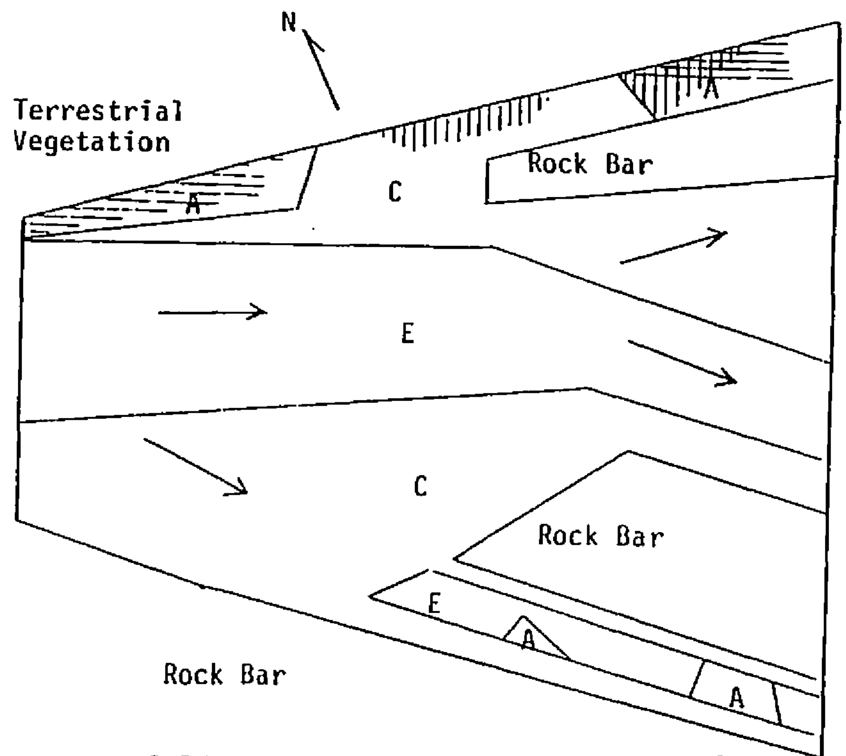
D Fast - Deep

E Very Fast

Submerged Forest Debris

Overhanging Vegetation

Scale 1/400



Location:	45-mile Rich. HWY	Gradient:	3.5%	Flow:	3.8 m^3/sec (134.2 ft^3/sec)
Date Sampled:	8/13/85	Maximum Depth:	0.7 m (2.3 ft)	Wetted Area:	3.2 m^2 (34.4 ft^2)
Air Temperature:	16.0°C (60.8°F)	Turbidity:	7.5 NTU	Mean Velocity:	1.2 m/sec (3.9 ft/sec)
Water Temperature:	6.0°C (42.8°F)	% Embeddedness:	0%		
Highwater Width:	30 m (98 ft)	Substrate:	40% Pebble 60% Cobble		
Stream Width:	35 m (115 ft)				

Sample Reach #19, Feeder Streams

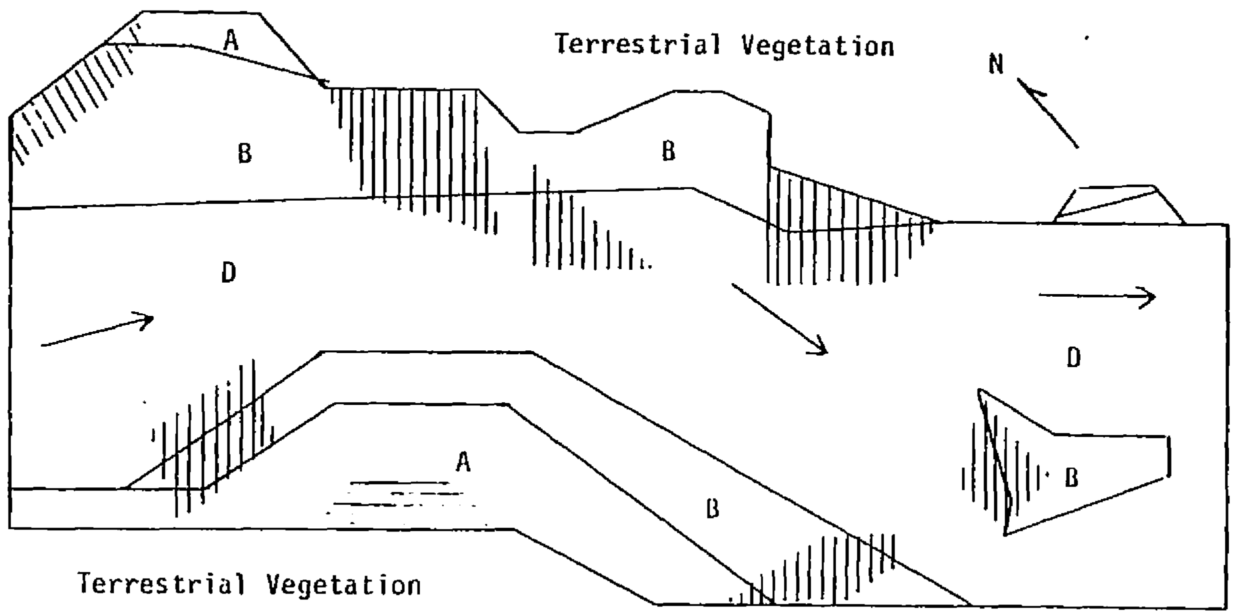
A Slow - Shallow

B Slow - Deep

C Fast - Shallow

D Fast - Deep

E Very Fast



E 100+ cm/sec
(3.3+ ft/sec)

Scale 1/178

Submerged Forest Debris   Overhanging Vegetation   Overhanging Bank

Location:	48-mile Rich. HWY	Maximum Depth:	1.3 m (4.3 ft)	Flow:	1.8 m^3/sec (63.6 ft^3/sec)
Date Sampled:	7/24/85	Turbidity:	1.2 NTU		
Air Temperature:	14.0°C (57.2°F)	% Embeddedness:	100%	Wetted Area:	4.1 m^2 (44.1 ft^2)
Water Temperature:	5.5°C (41.9°F)	Substrate:	80% Sand		
Highwater Width:	11 m (36.1 ft)		20% Gravel	Mean Velocity:	0.4 m/sec (1.3 ft/sec)
Stream Width:	11 m (36.1 ft)				
Gradient:	0.4%				

Sample Reach #20, Feeder Streams

A Slow - Shallow

D Fast - Deep

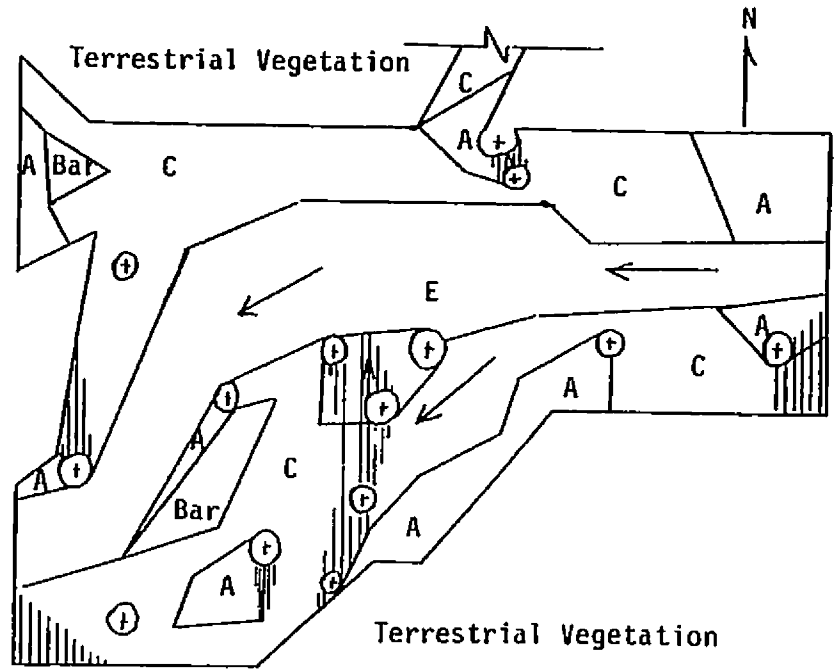
B Slow - Deep

E Very Fast

Fast - Shallow

Live Standing Trees

Submerged Forest Debris



Scale 1/267

Location:	48-mile Rich. HWY
Date Sampled:	7/24/85
Air Temperature:	12.0°C (53.6°F)
Water Temperature:	6.5°C (43.7°F)
Highwater Width:	21 m (69 ft)
Stream Width:	21 m (69 ft)
Gradient:	5.4%
Maximum Depth:	0.6 m (2.0 ft)
Turbidity:	1.4 NTU
% Embeddedness:	0%

Substrate: 95% Cobble
5% Boulder

Flow:	1.8 m^3/sec (63.6 ft^3/sec)
Wetted Area:	4.1 m^2 (44.1 ft^2)
Mean Velocity:	0.4 m/sec (1.3 ft/sec)

Sample Reach #21, Feeder Streams

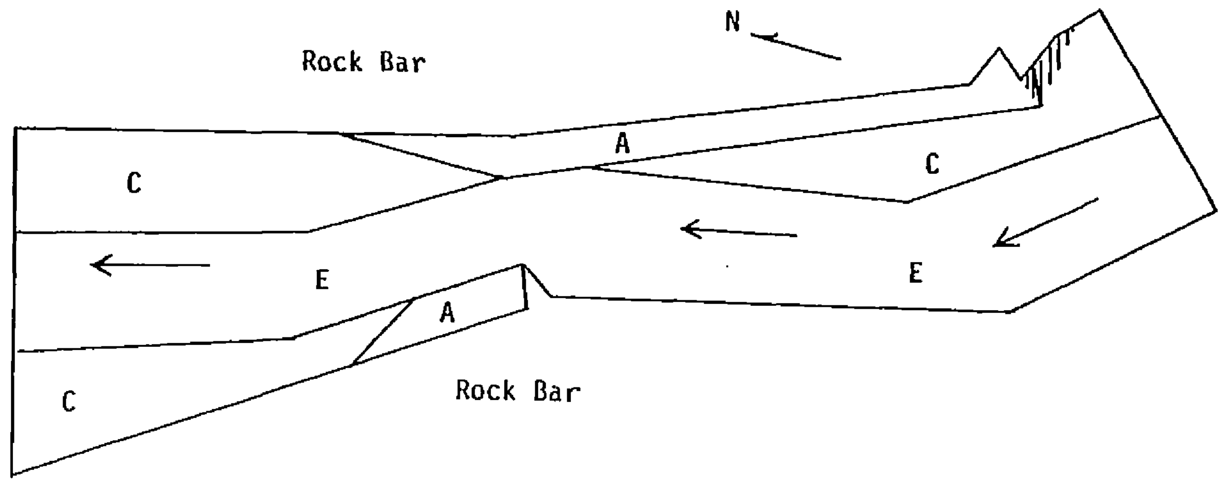
A Slow - Shallow

B Slow - Deep

C Fast - Shallow

D Fast - Deep

E Very Fast



Scale 1/178

Submerged Forest Vegetation

Location:	48-mile Rich. HWY	Gradient:	2.8%	Flow:	1.8 m^3/sec (63.6 ft^3/sec)
Date Sampled:	7/24/85	Maximum Depth:	0.4 m (1.3 ft)	Wetted Area:	4.1 m^2 (44.1 ft^2)
Air Temperature:	12.0°C (53.6°F)	Turbidity:	1.4 NTU	Mean Velocity:	0.4 m/sec (1.3 ft/sec)
Water Temperature:	6.5°C (43.7°F)	% Embeddedness:	0%		
Highwater Width:	12 m (39 ft)	Substrate:	30% Cobble 70% Boulder		
Stream Width:	7 m (23 ft)				

Sample Reach #22, Feeder Streams

A Slow - Shallow

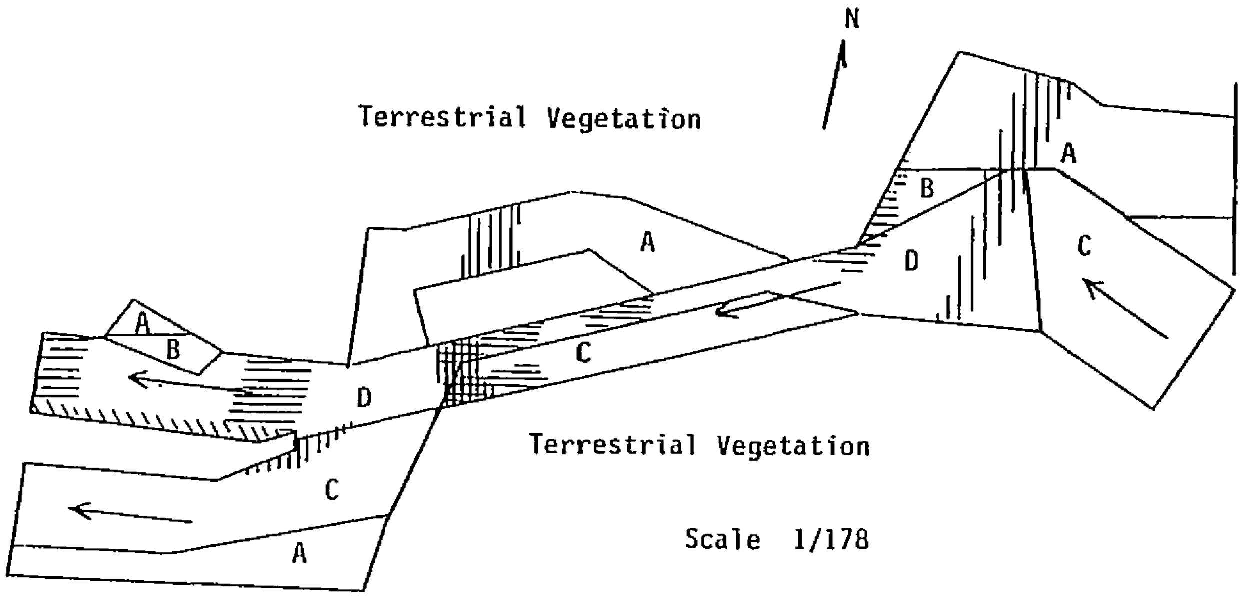
B Slow - Deep

C Fast - Shallow

D Fast - Deep

E Very Fast

E 100+ cm/sec
(3.3+ ft/sec)



Submerged Forest Debris

Overhanging Vegetation

Undercut Bank

Location:	62-mile Rich. HWY
Date Sampled:	7/14/85
Air Temperature:	27.0°C (80.6°F)
Water Temperature:	5.0°C (41.0°F)
Highwater Width:	3 m (10 ft)
Stream Width:	3 m (10 ft)
Gradient:	1.8%

Maximum Depth:	0.7 m (2.3 ft)
Turbidity:	2.5 NTU
% Embeddedness:	40%
Substrate:	60% Sand
	20% Pebble
	20% Boulder

Flow:	0.4 m^3/sec (14.1 ft^3/sec)
Wetted Area:	0.9 m^2 (9.7 ft^2)
Mean Velocity:	0.4 m/sec (1.3 ft/sec)

Sample Reach #30, Feeder Streams

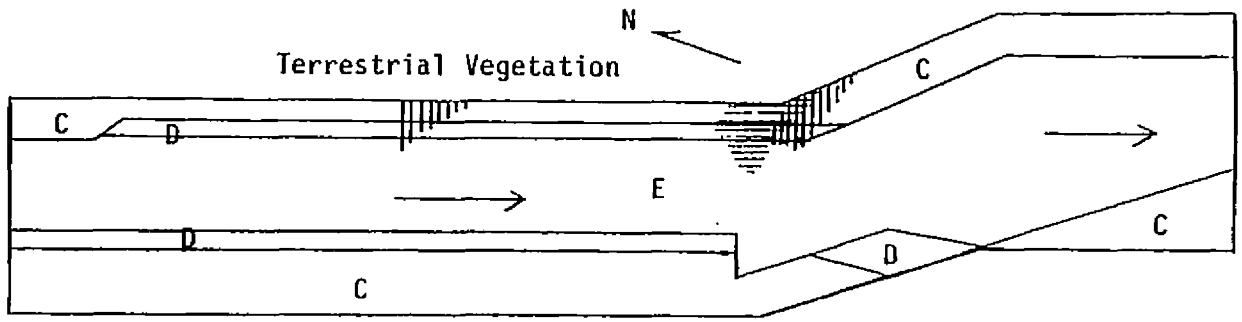
A Slow - Shallow

B Slow - Deep

C Fast - Shallow

D Fast - Deep

E Very Fast



Scale 1/178

E 100+ cm/sec
(3.3+ ft/sec)

Location: Head waters of Ernestien Cr

Date Sampled: 7/31/85

Air Temperature: 14.0°C (57.2°F)

Water Temperature: 4.5°C (40.1°F)

Highwater Width: 35 m (115 ft)

Stream Width: 5 m (16 ft)

Maximum Depth: 0.7 m (2.3 ft)

Turbidity: 11.0 NTU

% Embeddedness: 0%

Substrate: 10% Cobble
90% Boulder

Sample Reach #35, Feeder Streams

A Slow - Shallow

B Slow - Deep

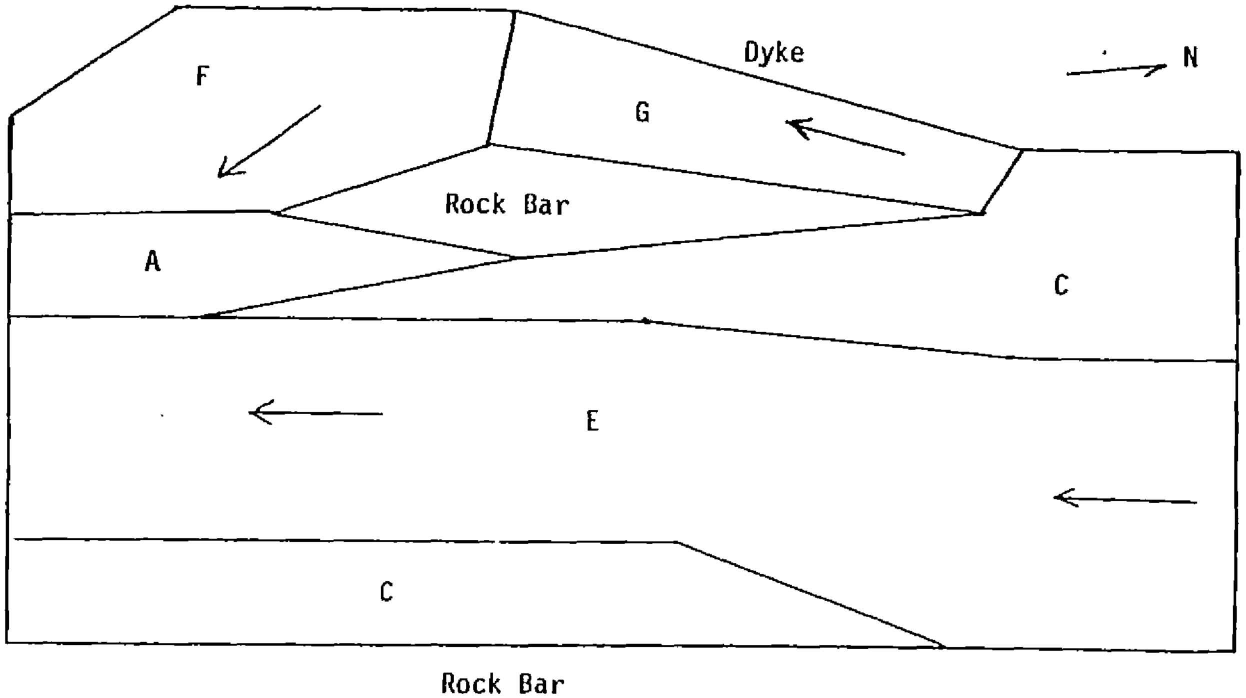
C Fast - Shallow

D Fast - Deep

E Very Fast

F 50% A
50% Exposed Rock

G 80% A
20% Exposed Rock



Scale 1/178

Location:	59.5-mile Rich. HWY	Maximum Depth:	0.8 m (2.6 ft)	Flow:	5.8 m^3/sec (204.8 ft^3/sec)
DateSampled:	6/15/85	Turbidity:	4.0 NTU	Wetted Area:	5.8 m^2 (62.4 ft^2)
Air Temperature:	12.0°C (53.6°F)	% Embeddedness:	0%	Mean Velocity:	1.0 m/sec (3.3 ft/sec)
Water Temperature:	4.0°C (39.2°F)	Substrate:	20% Cobble		
Highwater Width:	20 m (66 ft)		80% Boulder		
Stream Width:	16 m (53 ft)				

Sample Reach #3, Disturbed Areas

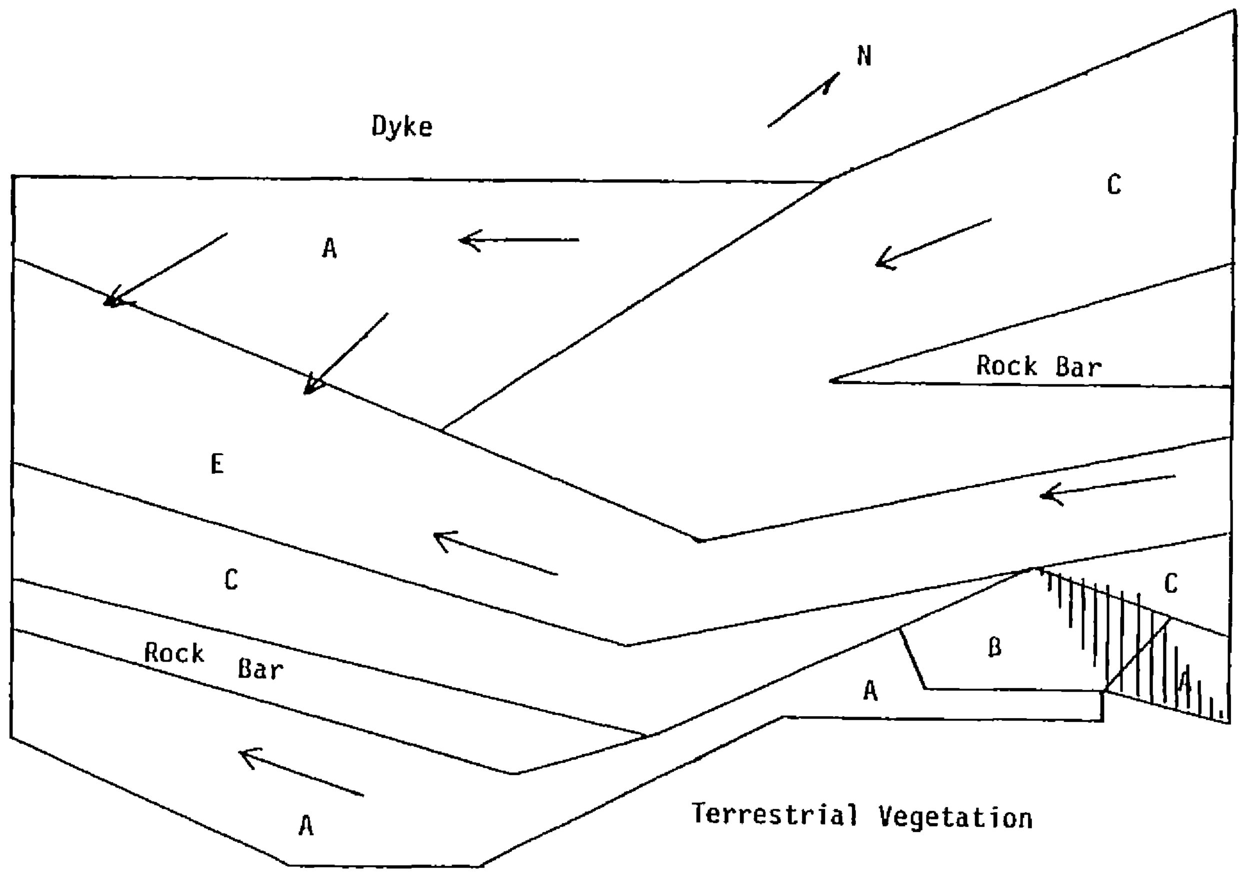
A Slow - Shallow

B Slow - Deep

C Fast - Shallow

D Fast - Deep

E Very Fast



Submerged Forest Debris

Scale 1/178

Location:	60.5-mile Rich. HWY	Maximum Depth:	0.6 m (2.0 ft)	Flow:	1.8 m^3/sec ($63.6\ ft^3$/sec)
Date Sampled:	6/4/85	Turbidity:	2.7 NTU	Wetted Area:	2.9 m^2 ($31.2\ ft^2$)
Highwater Width:	23 m (76 ft)	% Embeddedness:	0%	Mean Velocity:	0.6 m/sec (2.0 ft/sec)
Stream Width:	23 m (76 ft)	Substrate:	100% Cobble		
Gradient:	1.3%				

Sample Reach #8, Disturbed Areas

A Slow - Shallow

B Slow - Deep

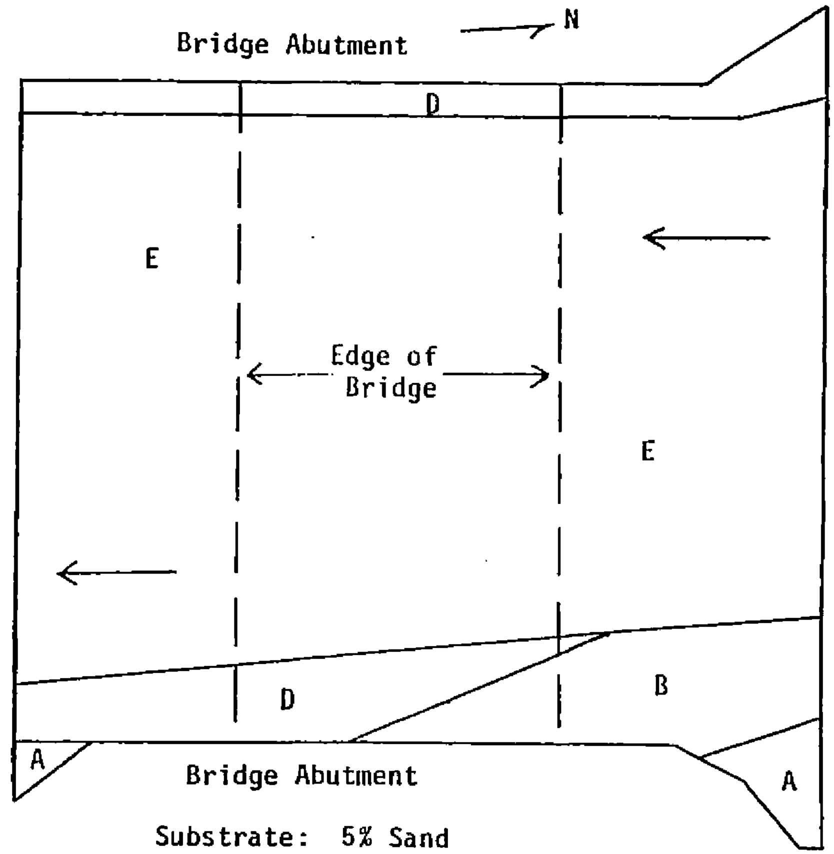
C Fast - Shallow

D Fast - Deep

E Very Fast

Scale 1/267

Location:	47-mile Rich. HWY
Date Sampled:	6/30/85
Air Temperature:	12.0°C (53.6°F)
Water Temperature:	6.0°C (42.8°F)
Highwater Width:	25 m (82 ft)
Stream Width:	25 m (82 ft)
Maximum Depth:	1.5 m (4.9 ft)
Gradient:	0.1%
% Embeddedness:	5%



Substrate: 5% Sand
5% Cobble
90% Boulder

Sample Reach #15, Disturbed Areas

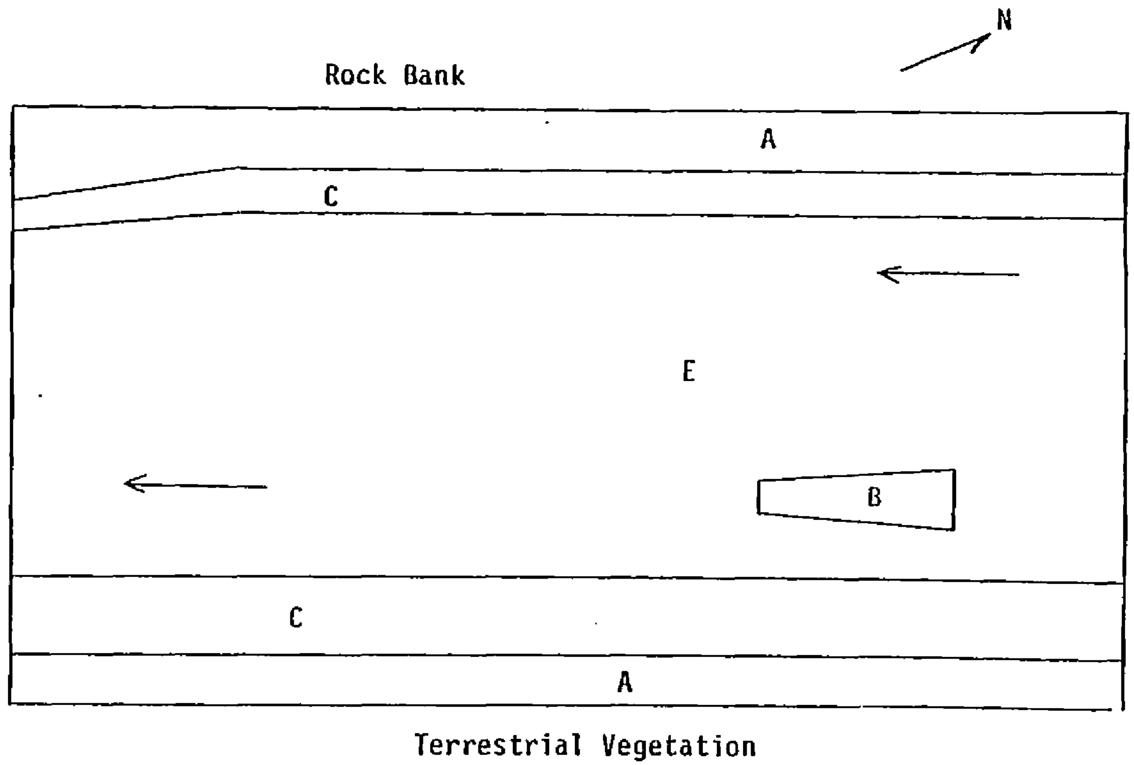
A Slow - Shallow

B Slow - Deep

C Fast - Shallow

D Fast - Deep

E Very Fast



Scale 1/178

Location:	58-mile Rich. HWY	Maximum Depth:	0.6 m (2.0 ft)	Flow:	5.6 m^3/sec (197.8 ft^3/sec)
Date Sampled:	8/10/85	Turbidity:	6.6 NTU	Wetted Area:	6.2 m^2 (66.7 ft^2)
Air Temperature:	18.5°C (67.2°F)	% Embeddedness:	20%	Mean Velocity:	0.9 m/sec (3.0 ft/sec)
Water Temperature:	5.0°C (41.0°F)	Subsrate:	25% Pebble		
Highwater Width:	15 m (49 ft)		25% Cobble		
Stream Width:	15 m (49 ft)		50% Boulder		
Gradient:	0.7%				

Sample Reach #28, Disturbed Areas

APPENDIX II

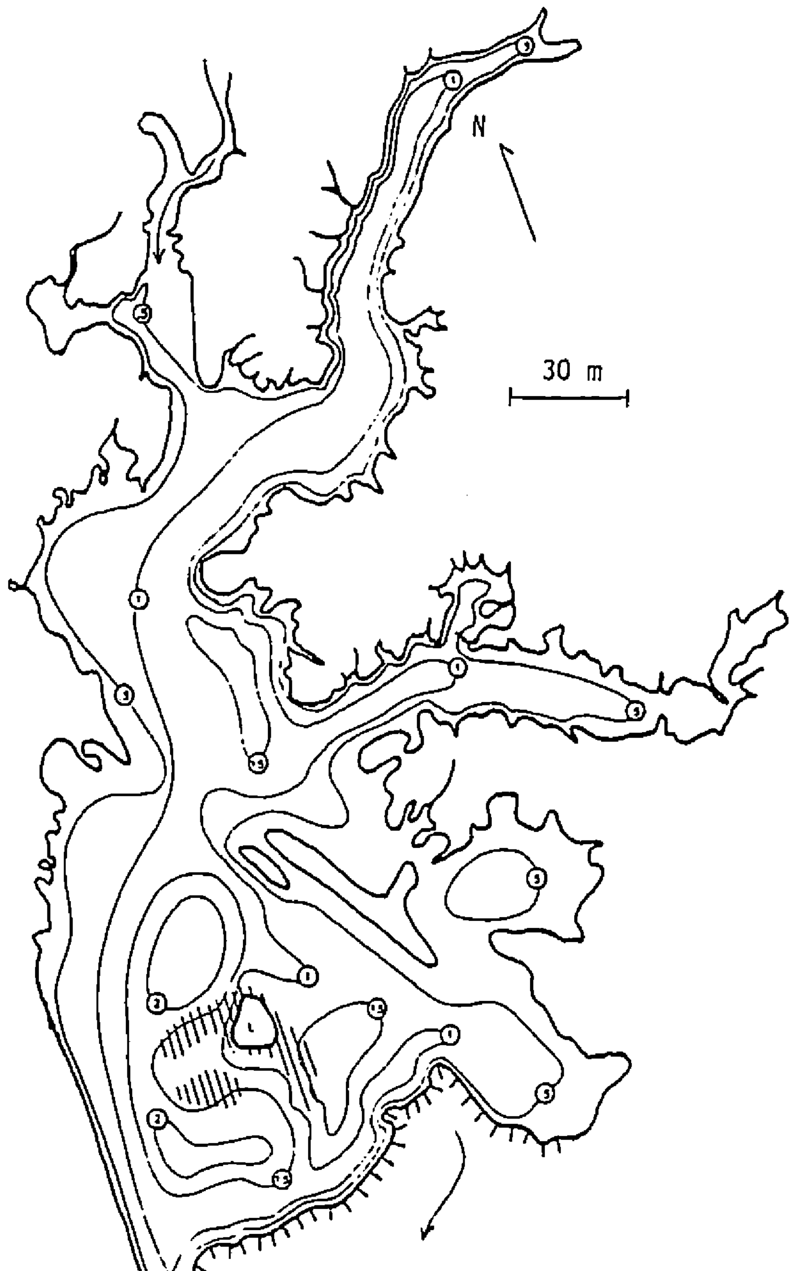
Bathymetric maps of all sample ponds.

L Beaver lodge

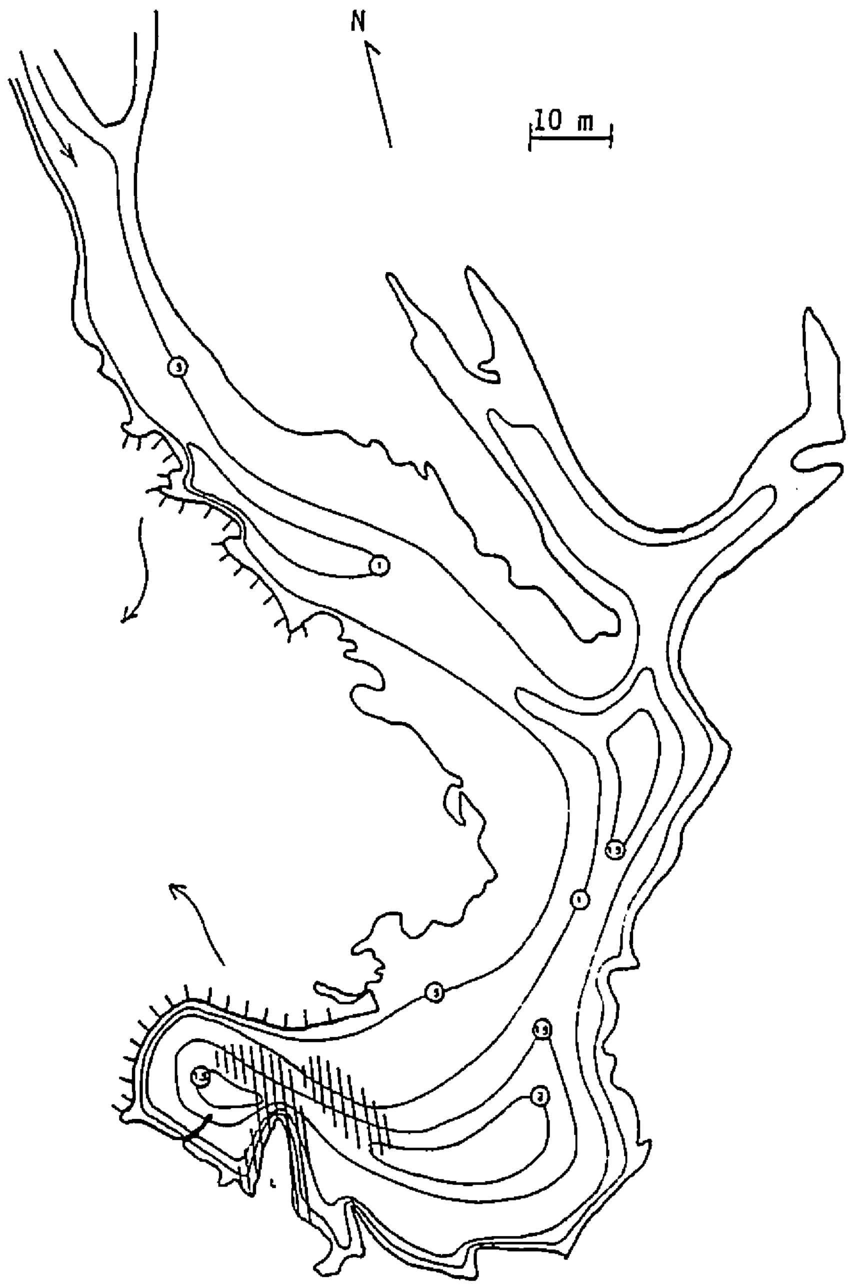
Beaver Dam

← Direction of Water Flow

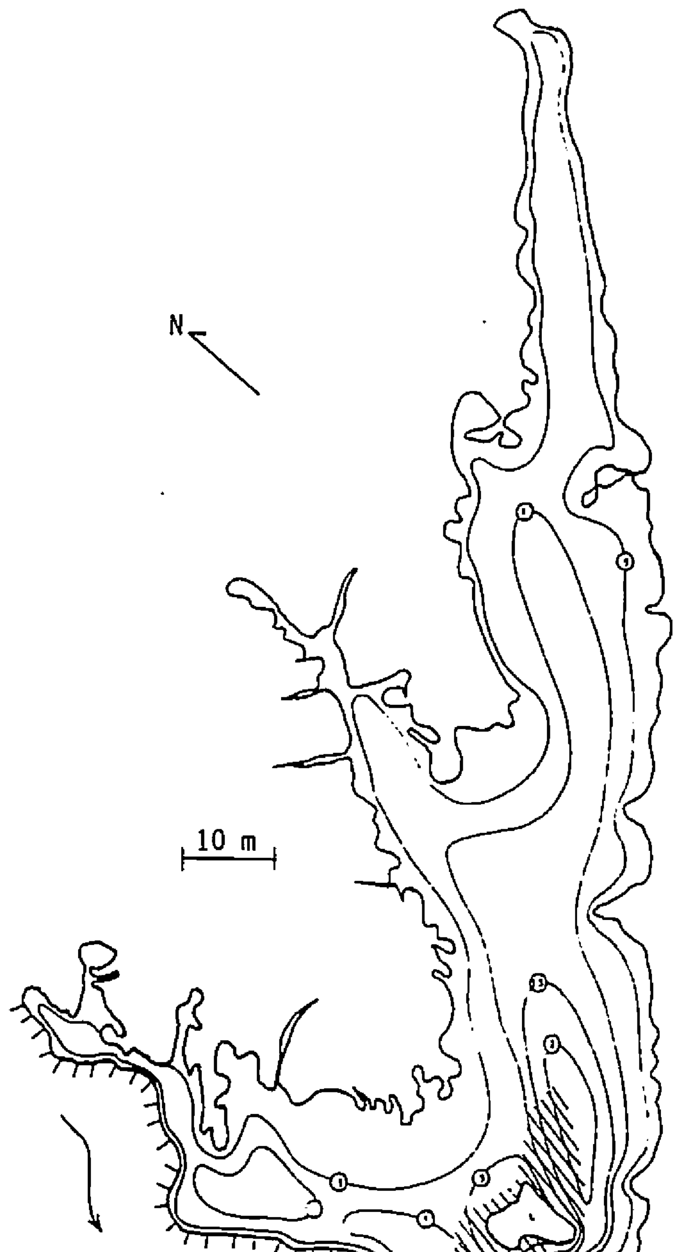
Submerged Woody Debris



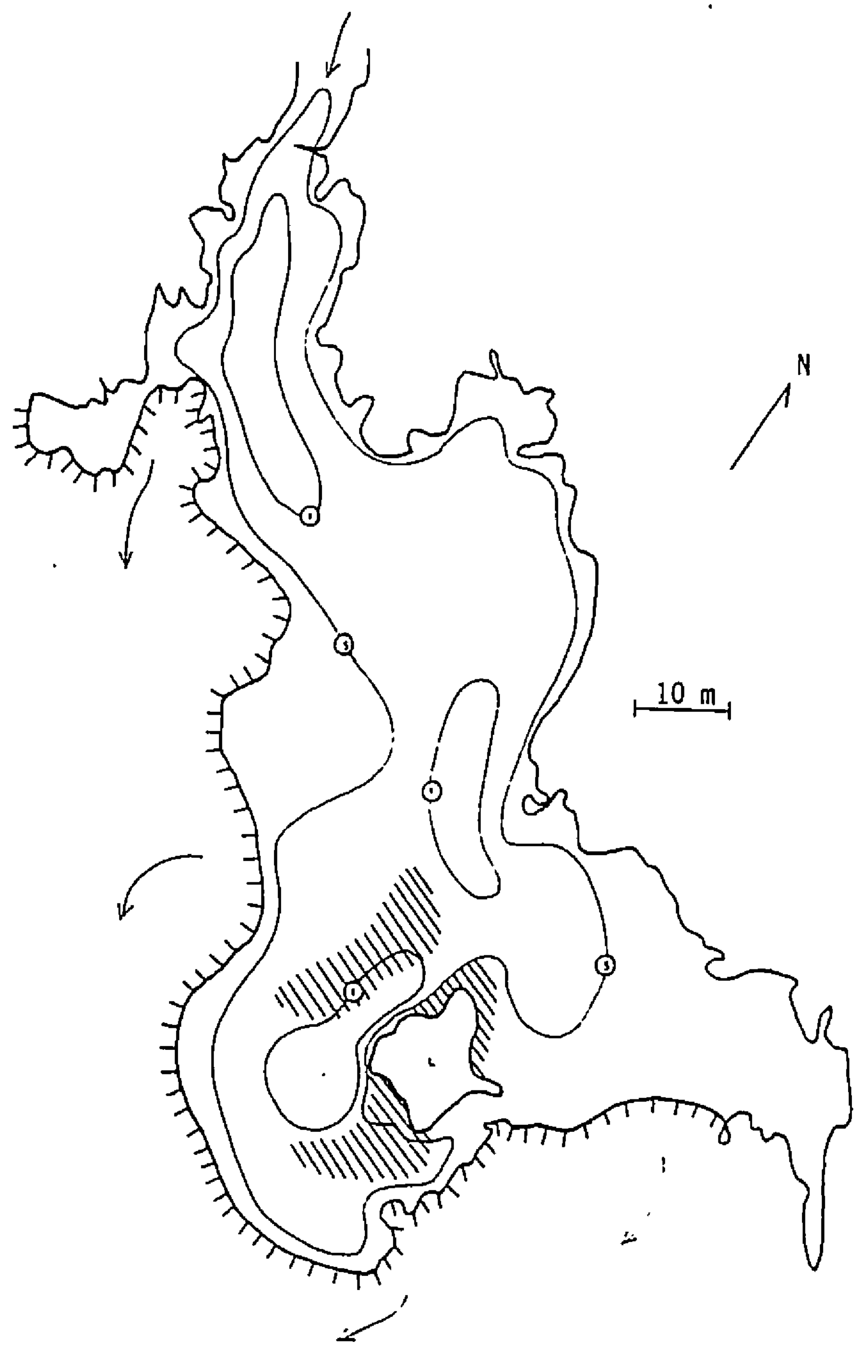
Pond #1



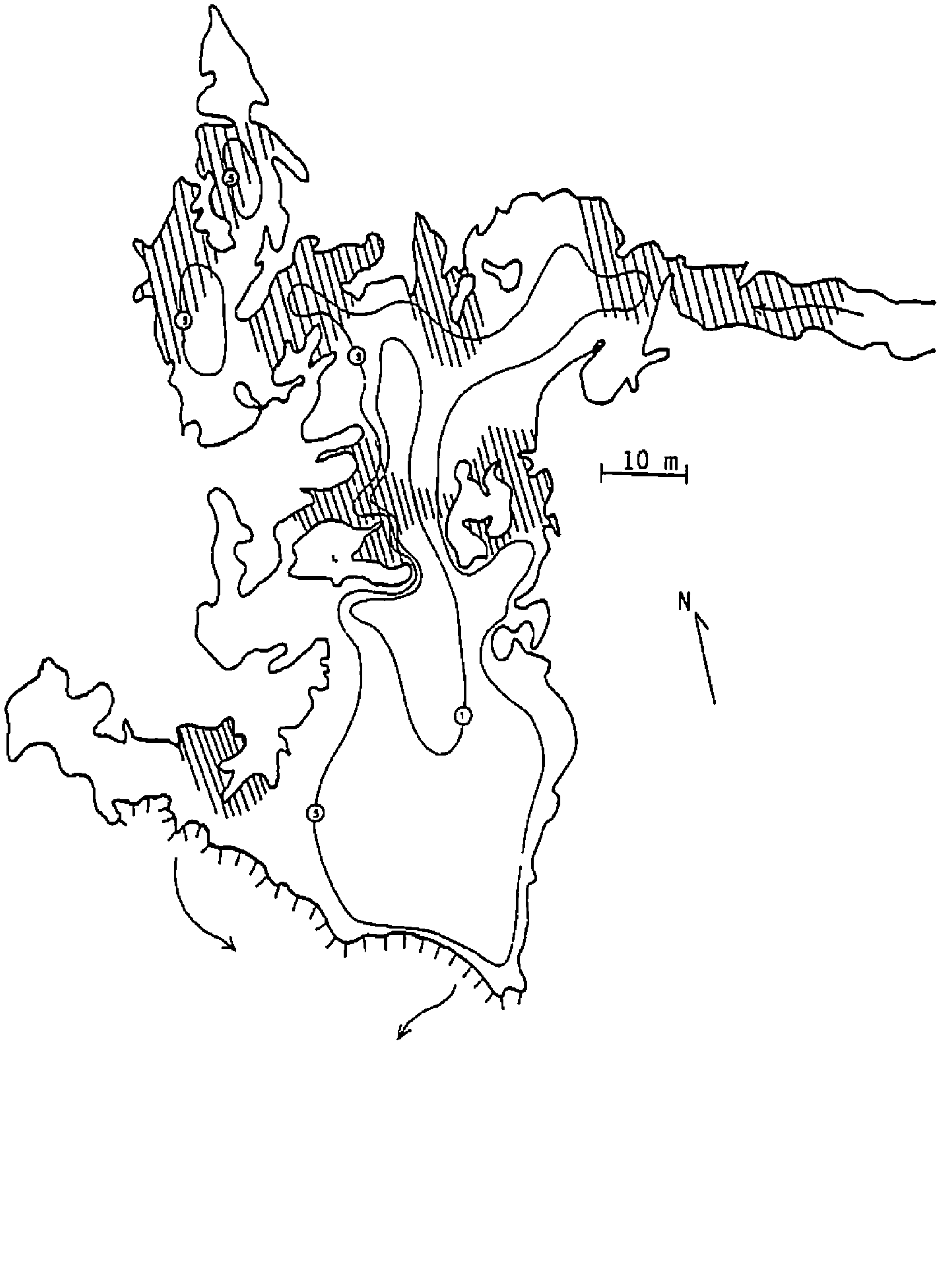
Pond #2



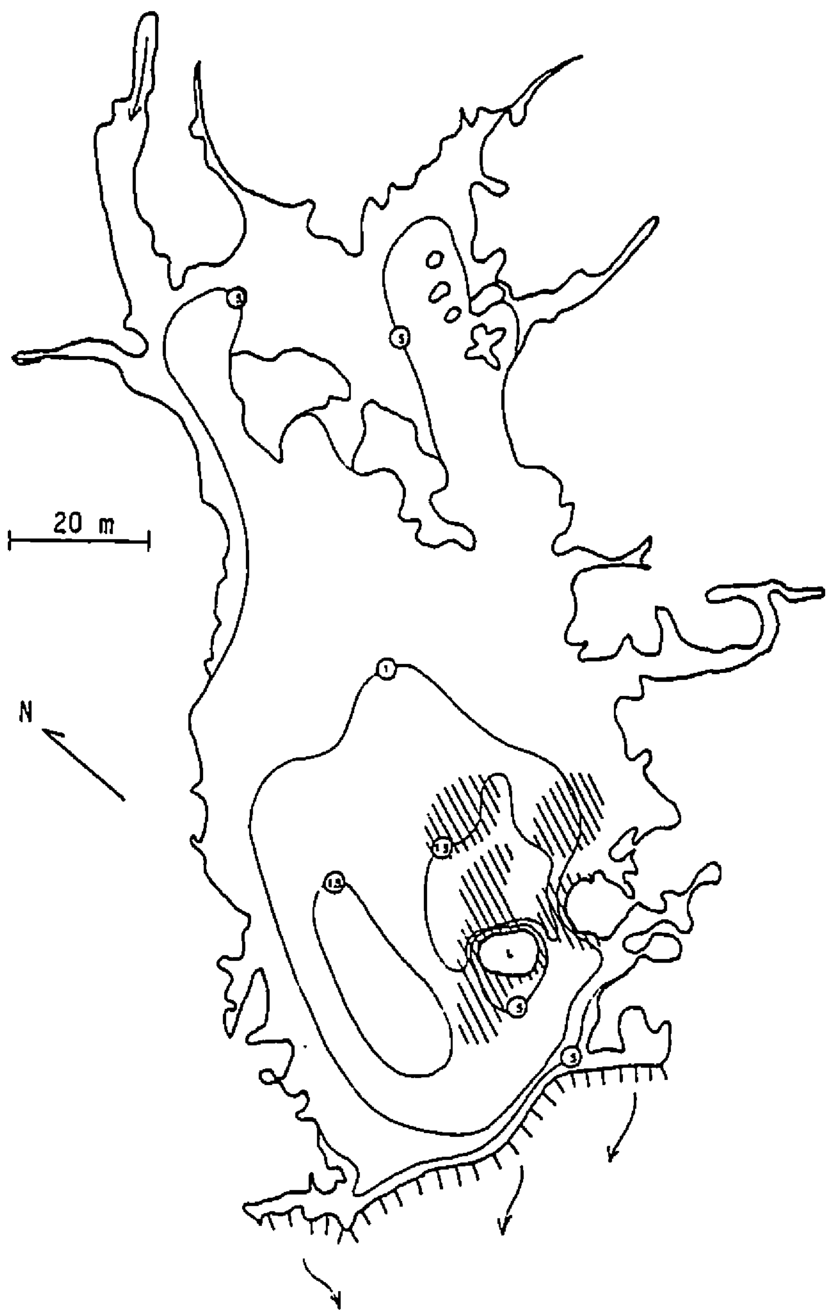
Pond #3



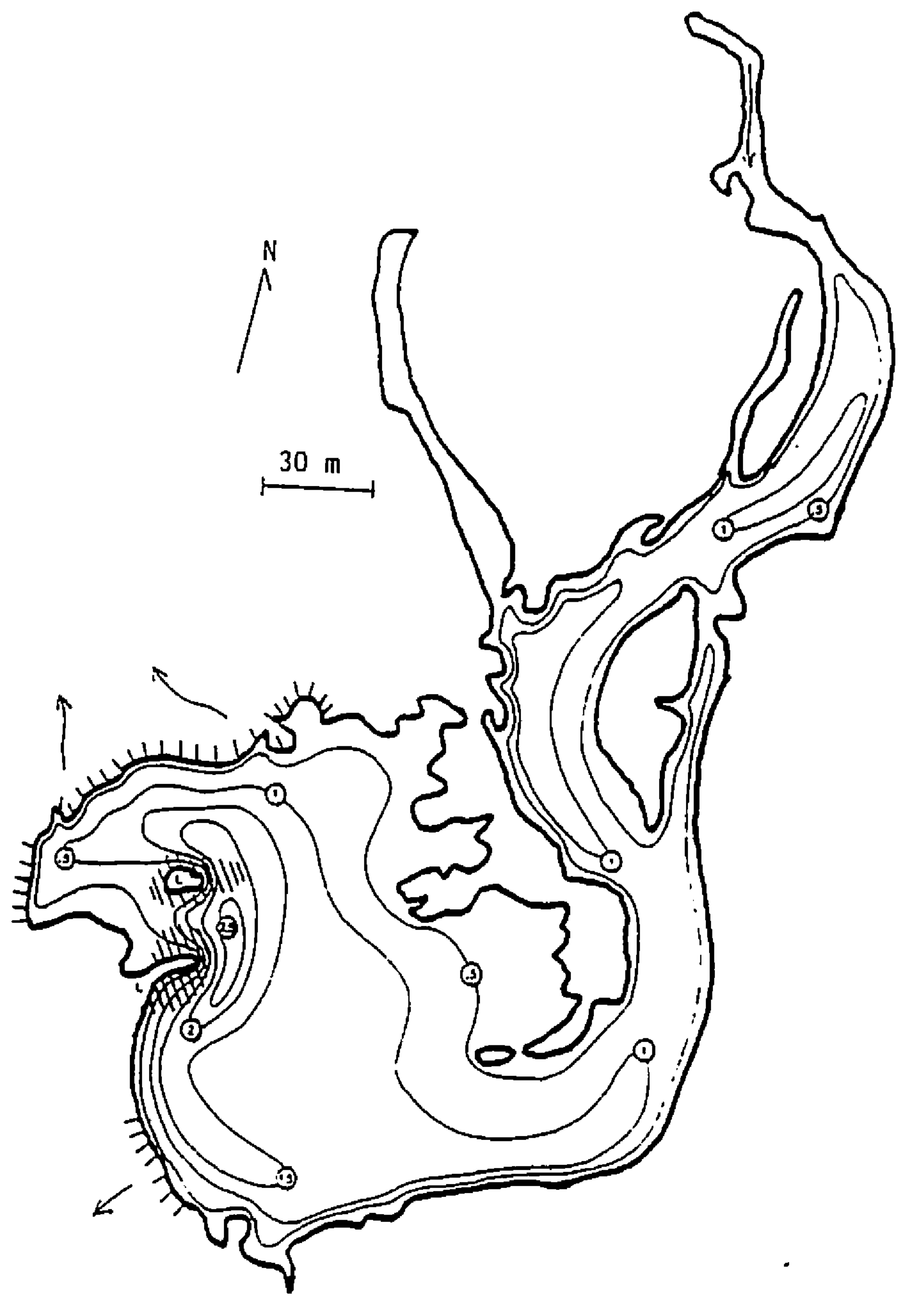
Pond #4



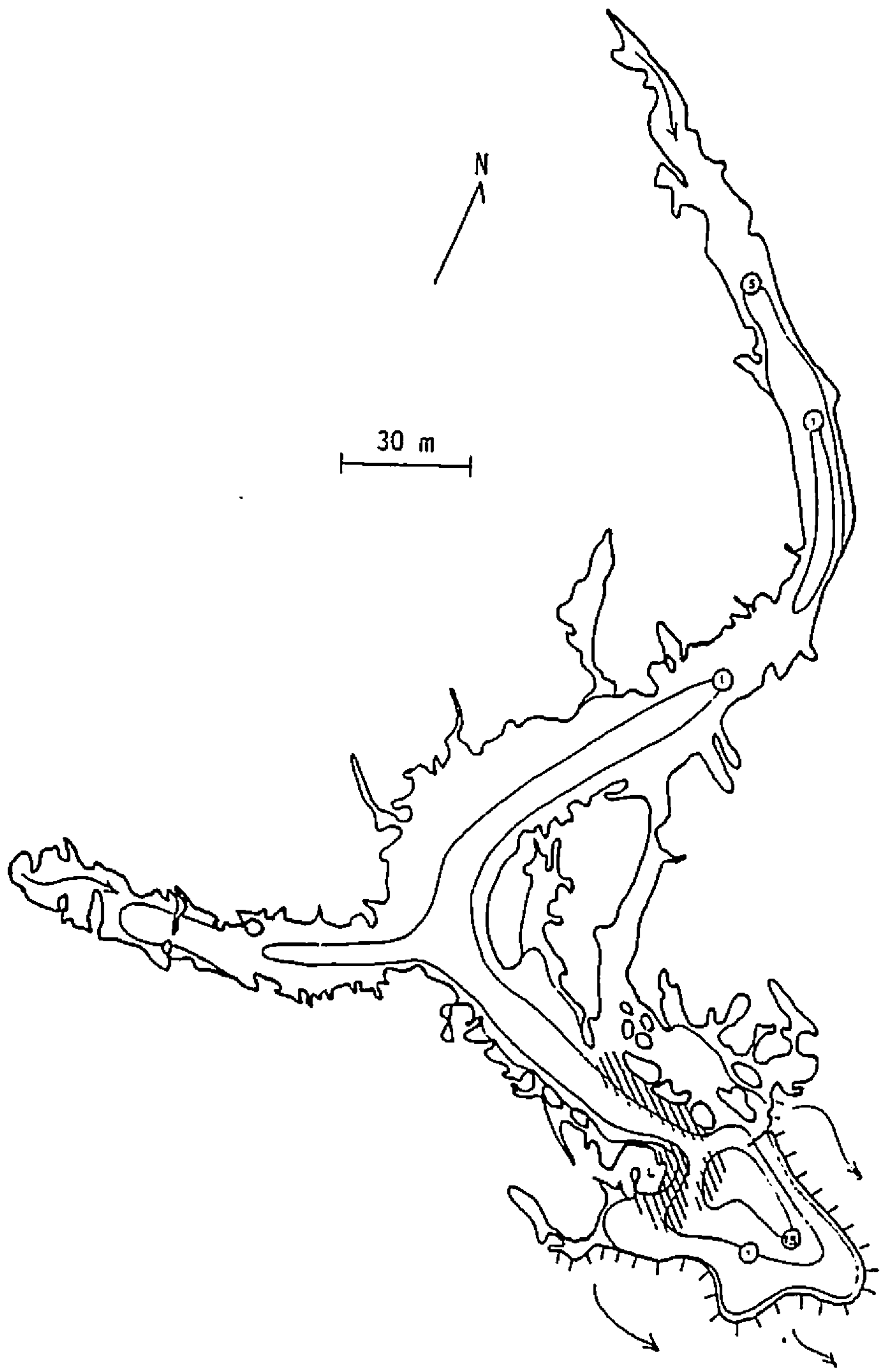
Pond #5



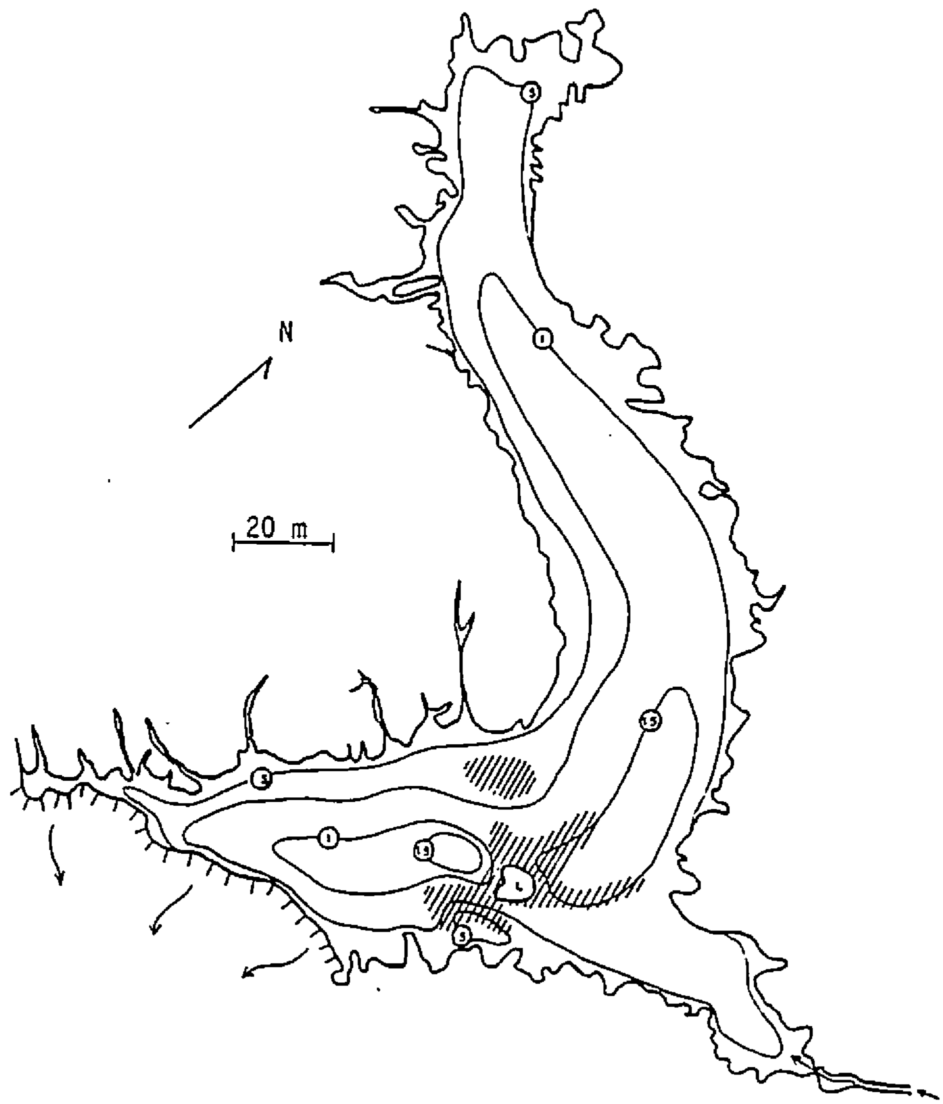
Pond #6



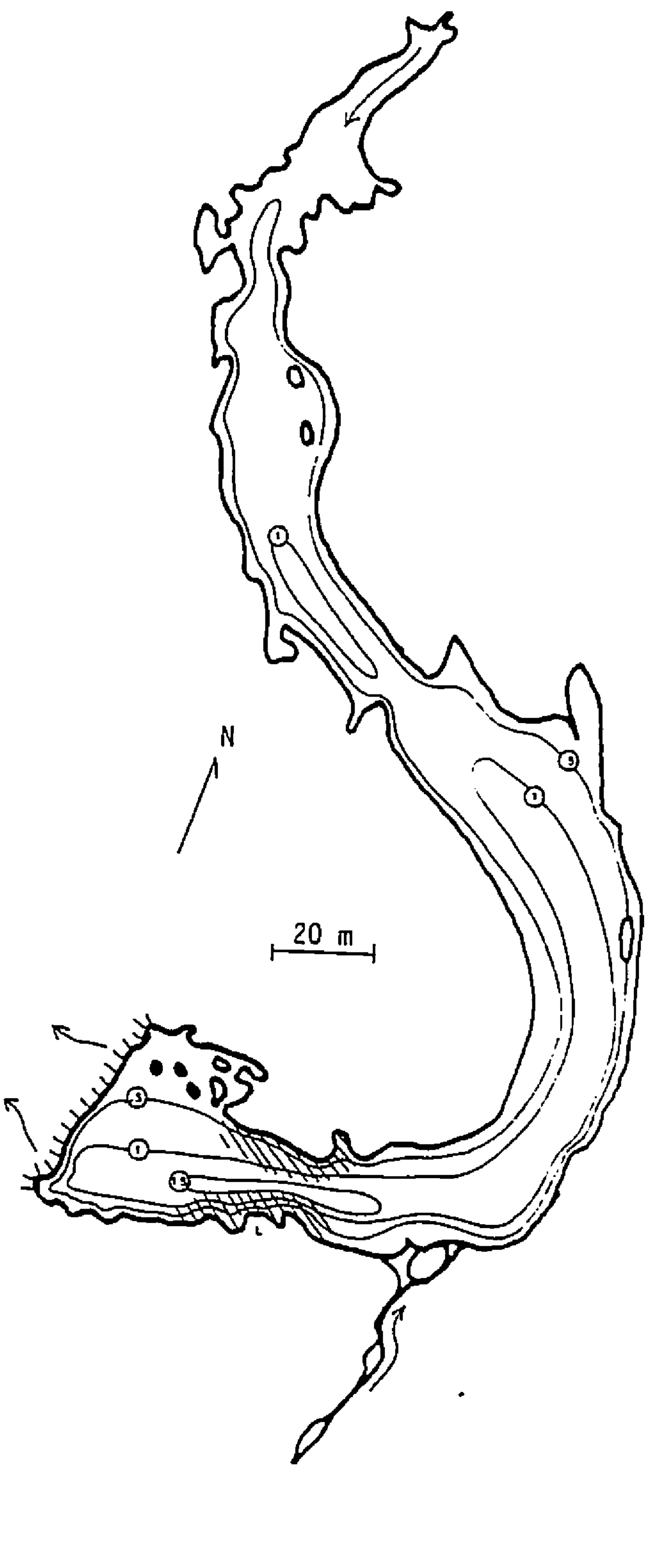
Pond #7



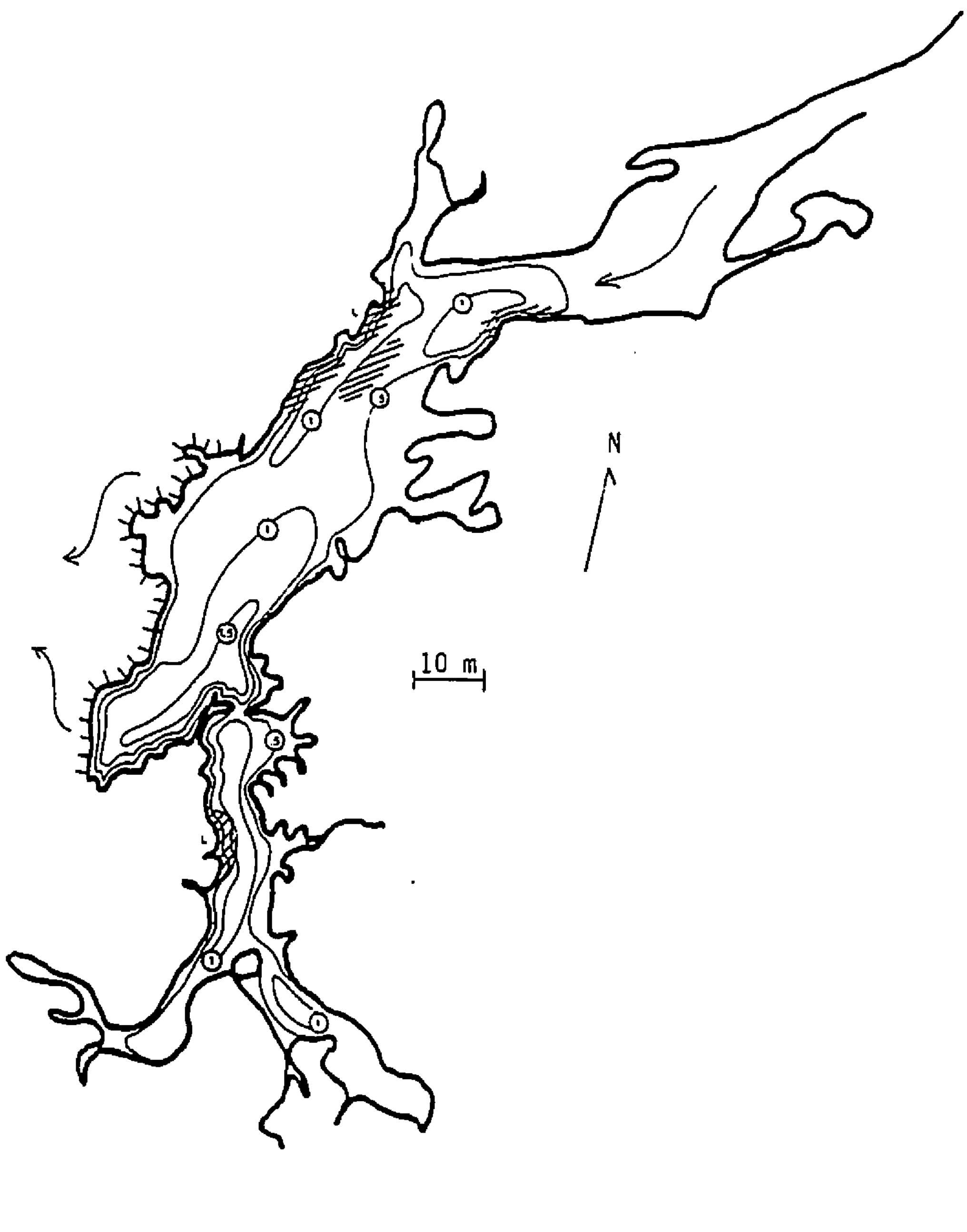
Pond #8



Pond #9



Pond #10



Pond #11