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INSTREAM OVERHEAD BANK COVER AND
TROUT ABUNDANCE IN TWO MICHIGAN STREAMS

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INSTREAM OVERHEAD BANK COVER AND TROUT ABUNDANCE IN TWO MICHIGAN STREAMS

By

Michael David Enk

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ABSTRACT

INSTREAM OVERHEAD BANK COVER AND TROUT ABUNDANCE IN TWO MICHIGAN STREAMS

By

Michael David Enk

The relationship between abundances of instream bank cover and trout was examined in 2.4km of the hardwater Pigeon River, Otsego County, and in 4.5km of the softwater Salmon Trout River, Marquette County. Each study area was divided into 100-m reference stations. Trout populations were inventoried by mark-and-recapture electrofishing in July and October, 1976. During 1976 summer low flow, the length of stream bank qualifying as overhead concealment for trout was measured in 12 of the stations on the Pigeon River and 18 of the stations on the Salmon Trout River. Overhead bank cover included all submerged undercut banks, overhanging vegetation, and log cover not closer than 15cm to the stream bed and forming overhangs at least 9cm wide.

In the Pigeon River, harboring brook and brown trout, total length of overhead bank cover accounted for 88% of the variation in July number of trout $\geq$150mm long and 72% of the variation in July biomass of trout 150-399mm long. For October brook trout $\geq$150mm, bank cover abundance explained 68% of variation in numerical density and 65% of variation in biomass. Brown trout had redistributed

themselves for spawning in October, and at that time, population parameters were poorly correlated with bank cover abundance.

In 2.6km of the Salmon Trout River where brook trout were the only salmonid (passage of anadromous fish blocked by a falls), length of overhead bank cover explained up to 83% of the variation in numerical densities and up to 69% of the variation in standing crops of brook trout $\geq$150mm present in July. In October, abundance of cover accounted for 78% of the variation in numerical density and 88% of the variation in biomass of brook trout $\geq$150mm.

In combined analyses of Pigeon and Salmon Trout River data, length of bank cover accounted for up to 81% of the variation in July and October trout populations. These strong correlations between indices of cover and trout abundances suggest that availability of instream bank cover is essential to the production of larger brook and brown trout. Bank cover appeared to be the major factor limiting trout populations in both streams, despite differences in fish species composition, water hardness, and hydrologic characteristics.

Dedicated to Mrs. Anthony J. Bohte

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INTRODUCTION

Habitat needs of stream salmonids have long been of interest to biologists, fishery managers, and anglers concerned with this resource. Several approaches have been used to investigate possible relationships between physical parameters of streams and trout populations. The most complicated have involved multiple regression of a large number of stream variables onto some measure of trout abundance.

In a survey of 112 stream segments in Michigan and Wisconsin, Hendrickson, Knutilla, and Doonan (1972a) evaluated the relationships between trout populations and 29 hydrologic parameters, including channel characteristics, streamflow characteristics, and water quality. They found that trout populations seemed to be limited chiefly by stream temperature, hardness of water, bed materials, instream vegetation, variability of streamflow, and discharge per unit drainage area. However, all correlation coefficients for single hydrologic parameters with trout populations were less than 0.5, suggesting that populations in a heterogeneous sampling of streams are not dominated by any single hydrologic characteristic. But when sample size was restricted to stream segments within certain limits of hardness or temperature, for example, higher multiple correlation coefficients resulted. Abundance of fish cover showed poor correlation with trout populations in that study, but the cover values were only visual estimates.

Using multiple regression analysis, White, Hansen, and Alexander (1976) further demonstrated the importance of streamflow stability to trout populations in Midwestern U. S. streams. In the Northwestern U. S., Platts (1976) also examined the influence of stream variables in controlling fish populations of 38 streams. Coefficients of determination (r^2) for each of his 20 variables with salmonid populations were less than 0.4 in all cases.

Although valuable, the multi-variate approach often fails to examine in enough detail each of the variables used. The measurement procedures and criteria are often subjectively established, and the stream variables themselves are hydrologically interrelated and by no means independent. Variation in trout populations along one stream section where water quality and many hydrologic characteristics remain fairly constant might be explained largely by one major limiting factor. This factor, in many cases, may be shelter or protective cover (Elser, 1968; Lewis, 1969; O'Connor and Power, 1976).

For stream salmonids, habitat differentiation and selection of resting microhabitat are governed by water velocity, turbulence, and cover conditions which include light, water depth, concealment, visual/tactile reference points, and spatial limits (Kalleberg, 1958; Chapman, 1966; Baldes and Vincent, 1969). Baldes and Vincent (1969) also found that the resting microhabitat serves as the hub or focal point for the radius of movement of the fish to other types of microhabitat. Since spatial requirements increase with age and size of fish, the amount of resting microhabitat with adequate cover characteristics may regulate the density of salmonid populations in streams (Kalleberg, 1958; Chapman, 1966; Allen, 1969).

According to Onodera (1962), as trout fingerlings grow larger, they begin selecting definite places of residence under objects which cover them from enemies. However, a stream affords only a limited number of shelters for fingerlings, and therefore Onodera suggested that the number of available shelters controls the survival of fingerlings; excess populations are eliminated by flood, competition, and predation. The stream's carrying capacity for trout would be determined in this case primarily by the amount of suitable cover.

Much has been learned about the habitat requirements of salmonids through detailed studies of microhabitat preferences. Although microhabitats are almost always associated with some type of shelter, salmonid cover needs are known to vary seasonally, diurnally, by fish species, and by fish size (Saunders and Smith, 1955; Kalleberg, 1958; Hartman 1963, 1965; Chapman, 1966; Gibson and Keenleyside, 1966; McCrimmon and Kwain, 1966; Butler and Hawthorne, 1968; Allen, 1969; Chapman and Bjornn, 1969; Lewis, 1969; Hunt, 1971; Griffith, 1972; Wesche, 1973; Bustard and Narver, 1975a). Undercut banks, overhanging vegetation, submerged objects (logs, stumps, tree roots, boulders), floating debris, water depth and turbulence are all known to provide cover for fish in streams (Giger, 1973; White, 1973).

Brook and brown trout show especially strong preference for overhead concealment cover along the stream margin (Hartman, 1963; Gibson and Keenleyside, 1966; Baldes and Vincent, 1969; Lewis, 1969). Furthermore, Kalleberg (1958) and P. W. DeVore and R. J. White (unpublished) observed that larger stream salmonids frequently darted from midstream cover to shoreline cover (rather than vice-versa) when frightened or disturbed. Wesche (1973) conducted a detailed study of trout cover preferences in two Wyoming streams and reported that 85% of all brown trout $\geq$152mm used undercut banks for cover instead of rubble-boulder areas.

The value of overhead instream shelter along the bank has been further demonstrated by the success of stream improvement work that included installation of additional bank cover (Tarzwell, 1938; Hale, 1969 in White,1973; Hunt, 1971; Boreman, 1974; White, 1975; Cooper and Wesche, 1976). Trout populations increased in manipulated areas with the larger size groups of fish usually responding the most. Also, Boussu (1954) showed that removal of brush cover and overhanging banks from experimental sections in a Montana stream caused decreases in trout populations, with losses being greatest for larger fish.

Although the importance of streambank cover to salmonids is widely recognized, criteria for defining and measuring cover have neither been clearly established nor consistently applied in the literature. This is due partly to the diversity of cover needs among various salmonid species and its complexity within mixed salmonid populations.

In the West, withdrawal of water from streams for agricultural and urban use has damaged fisheries and led to the development of many new methods for assessing the quality and quantity of available fish habitat (Kraft, 1972; Wesche, 1973; Stalnaker and Arnette, 1976; Bartschi, 1976; Cooper, 1976; Nickelson, 1976; Tennant, 1976; Waters, 1976). While most of these techniques can adequately describe the loss of fish habitat resulting from flow reduction, they make no attempt to set guidelines for determining the specific attributes of fish cover. Most of the procedures use descriptive variables or subjective rating systems for cover evaluation.

One notable exception is the work of Wesche (1973, 1976). His cover rating system utilizes criteria derived from intensive studies of trout cover preferences. The length of overhead bank cover meeting certain criteria is the most important component of his cover rating formula for "catchable" brown trout. These cover ratings were also found to be highly correlated with trout biomass in several streams. Hunt (1971) had reported that the length of bank having permanent overhead cover appeared to limit brook trout populations in 1.6km of a Wisconsin Creek. Although Hunt's criteria for bank cover were slightly different than Wesche's, both researchers obtained indices of the total length of streambank which afforded overhead shelter for fish. They included only bank cover which was at or below the water surface. Streamside vegetation that is more than a fraction of a meter above the water surface is believed to be of little value as concealment cover for trout (White, 1973).

The present study was undertaken to further test the validity of relationships between bank cover and stream trout abundance as proposed by Hunt (1971) and Wesche (1976). Specifically, the objective was to investigate the possible correlation of trout populations with length of streambank cover in two Michigan streams. These streams were widely separated geographically and had different species compositions, hydrologic characteristics, and dissolved salts concentrations. The Wesche (1973) criteria for determining overhead bank cover were chosen for use in this study because they were based on actual observations of cover usage and had been proven applicable at 11 study sites on four streams (Wesche, 1976).

DESCRIPTION OF STUDY AREA

Pigeon River

General Location and Setting

The Pigeon River rises in a cedar swamp at the north edge of a prominent glacial moraine just northeast of the city of Gaylord in the northern part of Michigan's Lower Peninsula (Hendrickson et al., 1973a). The river then flows generally northward for about 70km through coniferous swamp, birch-aspen forests, and hardwood swamp. It drops about 180m from its source to its mouth at Mullet Lake in Cheboygan County (Figure 1).

Most of the river flows over glacial till or outwash but downstream sections traverse limestone outcrops (Hendrickson and Doonan, 1970). As much of it lies within State Forest land, the Pigeon River is fairly remote from major roads and other development.

Water Quality and Discharge

The water is hard (160-220mg/l $CaCO_3$) and pH ranges from 7.5-8.5 (Hendrickson et al., 1973a).

Due to a large component of groundwater inflow in the headwaters region, discharge is generally uniform in the upper Pigeon River and water temperatures remain relatively cool in summer and warm in winter (Hendrickson et al., 1973a; Benson, 1953a). Records from a U. S. Geological Survey Gaging Station at the DNR Pigeon

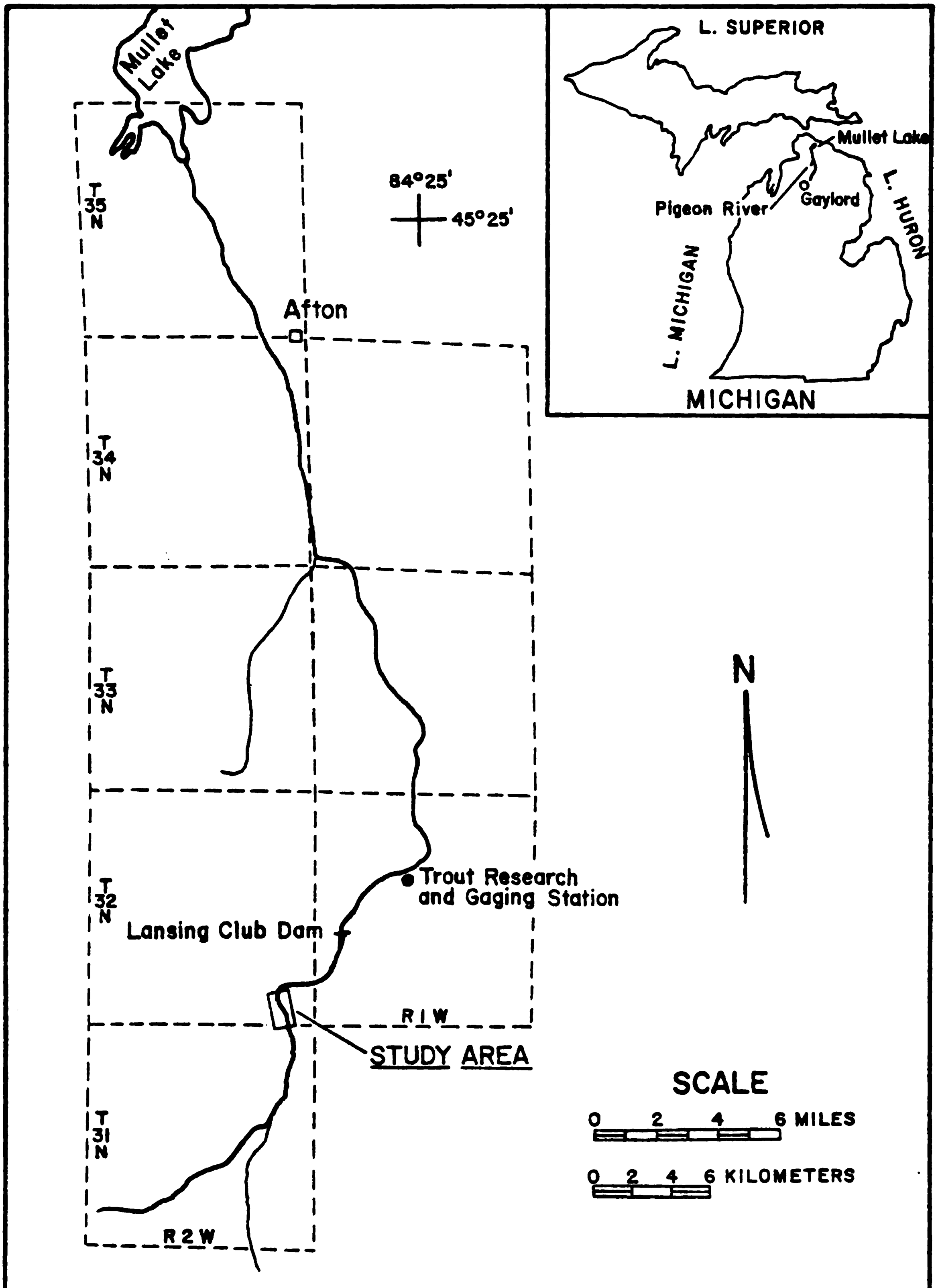

Figure 1. The Pigeon River.

River Headquarters located about 12km downstream from the study area show a 25-year (1950-1975) average discharge of 2.19m^3/sec.

Resident Fishes

Nearly all of the Pigeon River supports brook and brown trout (*Salvelinus fontinalis* and *Salmo trutta*). Certain areas also contain rainbow trout (*Salmo gairdneri*). Suckers (Catostomidae), sculpins (Cottidae), minnows (Cyprinidae), and darters (Percidae) are present throughout the river. A few other non-trout species are also found in the lower stretches of the stream (Benson, 1953a).

Specific Location and Dimensions

The study area on the Pigeon River lies in Otsego County in Sections 25 and 36 of Township 32 North, Range 2 West, and Section 1 of Township 31 North, Range 2 West (Figure 1). This portion lies in the upper quarter of the river's length, about 12km upstream from the DNR Trout Research-USGS Gaging Station and about 7km above the Lansing Club Dam. The closest town, Vanderbilt (population: ca. 600), is about 16km west of the study area.

The study section consists of 2.4km of river extending upstream from the Old Vanderbilt Road bridge (Figure 2). Here, the stream ranges from 7.5-14m in width, the banks are low, and depth of the channel at its deepest cross-sectional point varies from 40-120cm at the base flow. A few small spring drainages empty into the river along the study area.

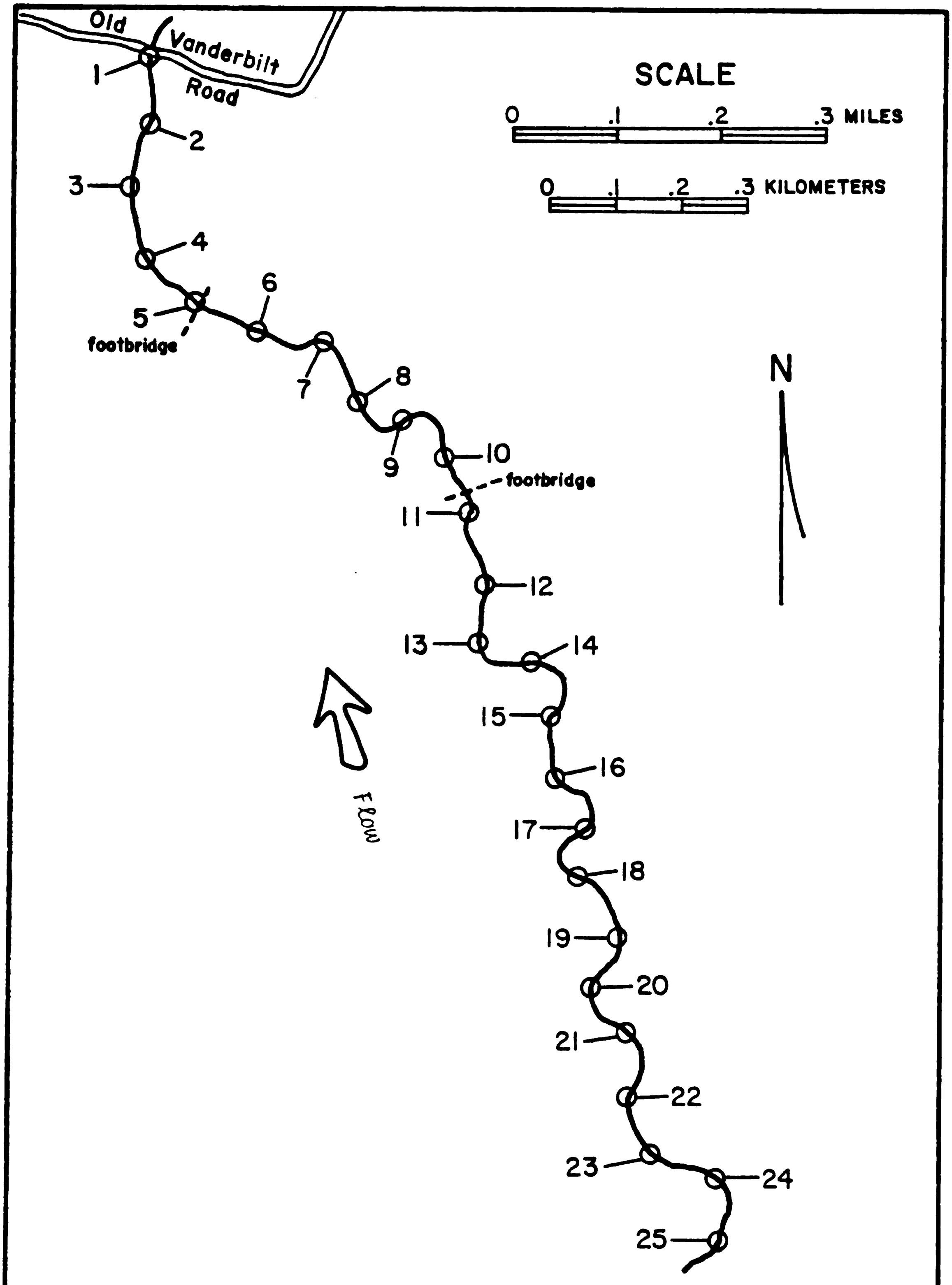

Figure 2. Pigeon River study area.
(Numbers refer to station markers.)

Bed Materials

Sand and gravel are the major components of the stream bed, but silt and muck occur in areas near the banks.

Fishing Pressure

Anglers were occasionally encountered by the author in the Pigeon River study area. Indirect evidence of fishing pressure, such as beverage and bait containers, was rarely seen. However, the landowner displays a sign allowing access to fisherman, and the total amount of fishing that occurred in the study area during 1976 is unknown.

Salmon Trout River

General Location and Setting

The Salmon Trout River originates as two small branch streams in the southeastern portion of the Huron Mountains in Marquette County in the Upper Peninsula of Michigan (Figure 3). From the junction of these two branches, the river flows generally northeastward for about 20 stream kilometers and enters Lake Superior. The headwaters and central portion of the stream flow primarily through northern hardwood forest. The lower portion winds through mixed coniferous-hardwood swamp.

The river has three major waterfall areas: Upper Falls, Middle Falls, and Lower Falls. A small dam and elongate impoundment exist on the river about 1km upstream from Lower Falls. Nearly all of the river is remote from public roads, and most of it lies within the boundaries of the Huron Mountain Club.

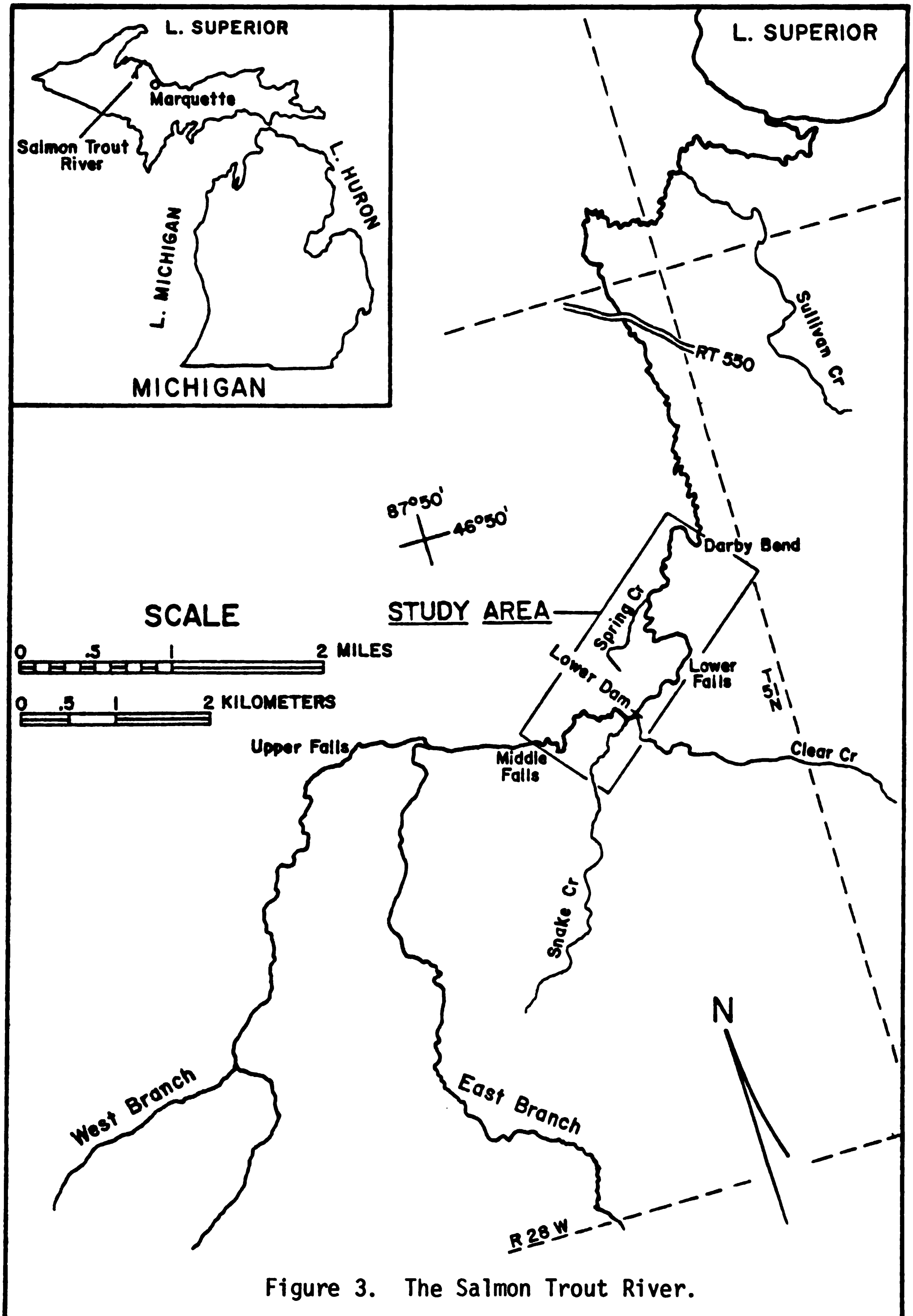

Figure 3. The Salmon Trout River.

Water Quality and Discharge

Chemically, the water is soft--only 62mg/l $CaCO_3$--with a pH of around 7.6 (Hendrickson, Knutilla, and Doonan, 1973b). Outcroppings of crystalline bedrock in this part of the Upper Peninsula help to explain the softness of streams in the area. These rocks provide very little soluble material for mineralization of water entering streams such as the Salmon Trout River (Hendrickson et al., 1973b).

Mean discharge of the river in Section 12, Township 51 North, Range 28 West (Darby Bend area) was reported by Hendrickson et al. (1973b) to be $1.50m^3$/sec. Because large areas of Precambrian bedrock in the western part of the Upper Peninsula are exposed or are covered only with a thin layer of glacial deposits, conditions are poor for stable groundwater flow (Hendrickson et al., 1973b). Consequently, streams in this area, including the Salmon Trout River, are characterized by wider temperature fluctuations, greater streamflow variability, and much greater floodflows than coldwater streams in the Lower Peninsula. High, eroded banks and deeply-scoured pools along much of the Salmon Trout River are the result of tremendous flooding that occurs during snowmelt and springtime runoff from the surrounding hills.

Fishes

Below Lower Falls, the resident fish population of the Salmon Trout River is composed primarily of brook trout, sculpins, minnows, darters, and a few rainbow trout. This part of the river, however, is used heavily by migratory fish from Lake Superior for seasonal spawning activity. In winter and spring, steelhead (rainbow trout), suckers, and burbot (*Lota lota*) enter the river to spawn. In late summer and continuing into fall, lake-run (coaster) brook trout move into the lower section of the river up to Lower Falls to spawn. Also in fall, chinook salmon (*Oncorhynchus tschawytscha*), coho salmon (*Oncorhychus kisutch*), and brown trout make spawning runs into the lower Salmon Trout River.

Above the insurmountable Lower Falls-Sheet Rock Falls area, lake migrants are excluded from the stream, and the fish population consists of brook trout, sculpins, minnows, and an occasional brook stickleback (*Eucalia inconstans*).

The Huron Mountain Club conducts an annual stocking of legal-sized brook trout in the Salmon Trout River. The fish are usually stocked in early summer at various locations along the river, including several sites in the study area.

Specific Location, Dimensions, and Bed Materials

The study area begins at a point about 100m below a deep pool called Darby Bend and extends upstream about 6km to the base of Middle Falls (Figure 3). This portion of the river lies in Sections 12, 13, and 14 of Township 51 North, Range 28 West. Three small tributaries--Spring Creek, Clear Creek, and Snake Creek--join the river along the study area. The closest town, Big Bay (population: ca. 250), is about 9km east of the study area.

Three basic subdivisions of the study area are described in the following table. Station marker locations are shown in Figure 4.

TABLE 1.--Description of Salmon Trout River study area.

Station Marker Boundaries	Channel Width	Thalweg Depth (base flow)	Bed Materials
1-20	6-17m	21-180cm	Generally sand and gravel, larger rubble in some areas.
34-40	7-22m	18-110cm	Gravel and rubble with sand intermixed.
40-60	5-12m	24-150cm*	Sand and muck in Lower Dam impoundment; gravel, sand, and occasionally rubble upstream from marker 50.

*Water depth in Stations 40-50 is regulated by the height of stop-logs in Lower Dam but usually does not exceed 150cm.

Fishing Pressure

Fishing in the study area is basically limited to members of the Huron Mountain Club and their guests. Trespassers occasionally enter club property and also fish this part of the river. Most of the study area between station markers 42 and 59 has been designated a "catch-and-release" section by the Huron Mountain Club, meaning that all trout caught are supposed to be returned to the stream immediately. The rate of angler harvest from the river is probably somewhat less than from other streams in the area which are open to the public.

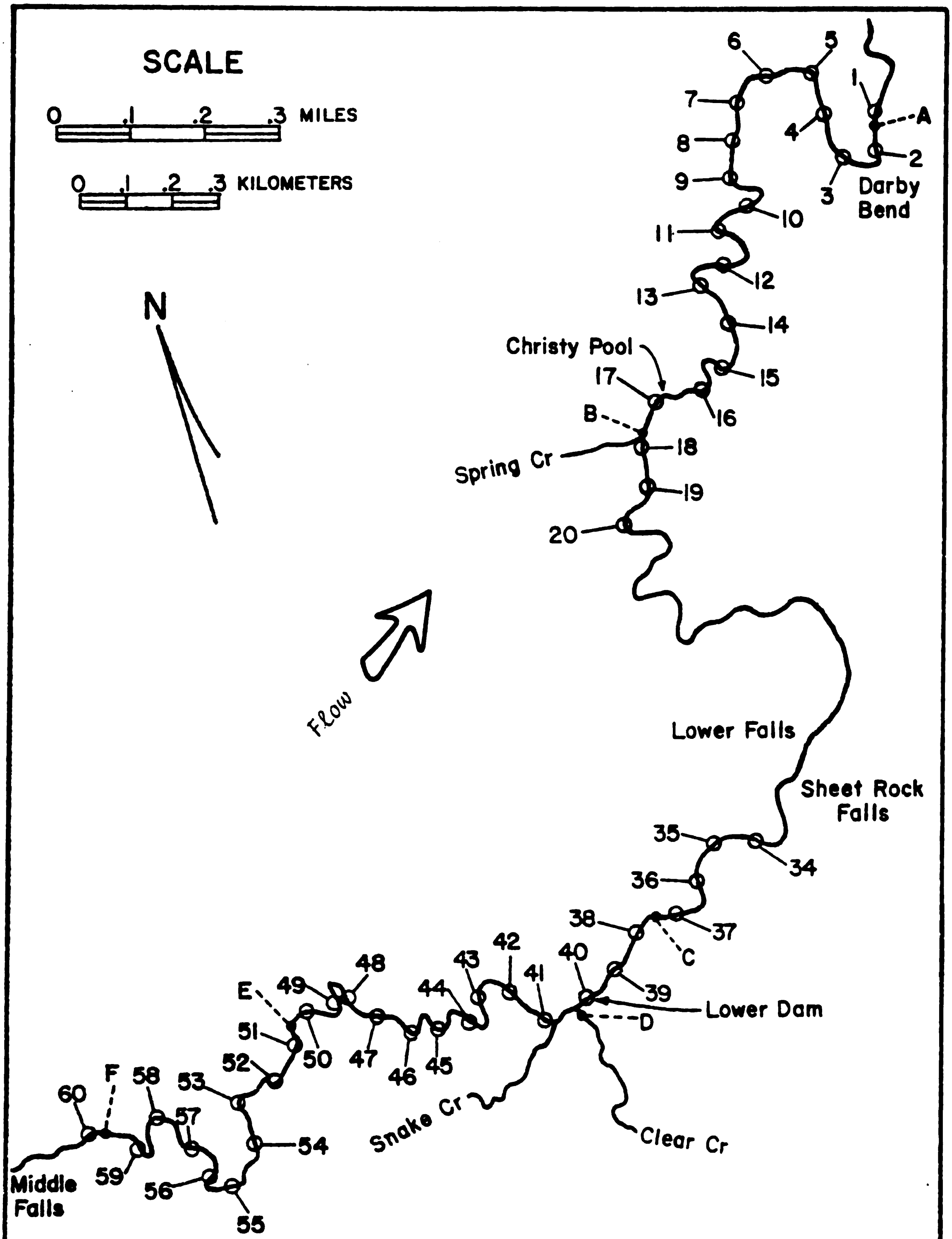

Figure 4. Salmon Trout River study area. (Numbers refer to station markers, letters to discharge sites.)

METHODS AND MATERIALS

Preparation of Study Area

Both the Pigeon River and the Salmon Trout River study areas were initially divided into reference stations by tying brightly-colored flagging to streamside trees at intervals of approximately 100m along the streams. The stations were measured off with a 30-m plastic clothesline marked in meters. Station markers were numbered in the upstream direction and each station was given the number of the marker at its downstream end. Station locations on the two streams are shown in Figures 2 and 4.

Estimation of Trout Populations

Electrofishing Procedure

Mark-and-recapture electrofishing was conducted to inventory trout populations. Two complete sweeps of each study area were made for each inventory.

The electrofishing unit consisted of a 2.1-m plastic boat carrying a gasoline-powered 250-VDC, 1.75-kw generator (Pow-R-Gard Model 1736 DCV). Two spring-loaded retracting reels, each containing 7.6m of electrical cord, were mounted on opposite sides of the boat's bow and wired to the positive pole of the generator. The two capture electrodes were attached to the free ends of the reel cords. Each electrode consisted of a 135-cm fiberglass handle with a head of 4.8mm stainless steel rod bent into a diamond shape about 25cm long. For the grounding electrode,which trailed behind the boat, brass window screening was fastened to the bottom of an 80x30x5cm styrofoam float and connected to the negative pole of the generator.

In operation, the electrofishing boat was pulled upstream while two men with capture electrodes swept the channel, jabbed into areas of fish cover, and poked along stream banks. Often, the two electrofishers worked together on one side of the channel, with one moving to the upstream end of log jam, pool, or undercut bank and sweeping downstream with his electrode toward the other man at the lower end. As fish were drawn to the electrodes, they were netted and transferred to a tub of river water carried in the boat. After a 100-m station had been electrofished, the team either stopped to process the catch or, if few fish had been taken, they placed a dividing net in the collection tub and continued electrofishing upstream through the next station.

During processing, fish captured in each station were anesthetized with tricaine methane sulfonate (MS-222), measured, weighed, and examined for finclip markings. On the first or marking run, the bottom tip of the caudal fin was clipped on every fish. After processing, the fish were held in the stream in a live box until revived from anesthesia, then carried back to the downstream end of the station in which they were captured, and released. This step helps to facilitate the proper redistribution of fish in each station. On the second or recapture run, fish were carefully examined for caudal fin clips during processing, and this time the upper tip of the caudal was clipped to ensure against double-counting of fish that may swim upstream past the team's position overnight. Separate records were kept for each 100-m station.

Trout population inventories were conducted in July and October on the Pigeon River. The marking run for the first inventory was made July 18-19, 1976, and the recapture run July 21-22. For the fall inventory, a marking run was made on October 7-8, with the recapture run on October 16-17.

The first trout population inventory on the Salmon Trout River began with a marking run June 3-8, 1976. Because of equipment failure, the recapture run could not be made until July 1. On the basis of experience gained during the marking run, it was decided that the section of stream from Christy Pool upstream to Lower Falls (Figure 4) would not be electrofished again, owing to treacherous bed materials (large, slippery rubble), the difficulty of portaging equipment around Lower Falls, and the sparseness of trout populations in that area. Therefore, valid population estimates were made only for Stations 1-17 and 36-59 during the first inventory. Both runs of the fall electrofishing inventory for the Salmon Trout River were conducted during October 2-7 in Stations 1-19 and 34-59.

For purposes of future growth analyses, special finclip markings were made on fish of the youngest age group (as judged by length-frequency distribution and appearance) during the electrofishing in both streams. In the Pigeon River, Age-0 trout were given a left ventral (LV) fin clip during the October inventory. In the Salmon Trout River, Age-1 fish captured below Lower Falls in the June-July electrofishing were given an adipose (A) fin clip. Those caught above Lower Falls were given an adipose and right ventral (ARV) fin clip. During the fall inventory on the Salmon Trout River, all Age-0 trout were given a left ventral (LV) fin clip, and any hatchery trout (identified by color markings and size) caught were given a left pectoral (LP) fin clip.

Calculation of Estimates

Population estimates were calculated according to the Schaefer modification of the Petersen formula (Regier and Robson, 1967):

$$\hat{P} = \left[\frac{m(r + u + 1)}{(r + 1)}\right] - 1$$

where $\hat{P}$ = estimated population,

m = number of fish marked during first run,

r = number of marked fish recaptured during second run, and

u = number of unmarked fish captured during second run.

Efficiency of capture by electrofishing tends to increase with total length of fish up to about 250mm, at which point it levels off (Schuck, 1945; Cooper and Lagler, 1956; McFadden, 1961). In order to minimize the error caused by this size-selectivity of electrofishing gear, separate population estimates were made for the fish of each 50-mm length interval from 100mm to 250mm. Fish longer than 250mm were grouped for population estimates. No estimates were made for fish smaller than 100mm because of the extremely low recapture rate for these fish.

Estimates for each size class were made for the entire Pigeon River study area and for three separate sections within the Salmon Trout River study area: the sections between Darby Bend and Lower Falls, Lower Falls and Lower Dam, and Lower Dam and Middle Falls. These total population estimates were then partitioned into the individual stations within the study areas on the basis of the relative proportions of the sums of m + u for each station. The same procedure was used in combining the data for brook and brown trout in the Pigeon River, then segregating the two species after calculation of a total population estimate for each size class. Cooper (1952) found no difference in the catchability and rate of recapture between brook and brown trout. Similarly, the Salmon Trout River data for stocked and wild brook trout were combined for the calculation of a total population estimate, and the two groups were subsequently separated out during the partitioning of the total into individual stations. This method of combining data and then subdividing total estimates is more accurate because it allows the use of larger individual units in the estimations, especially the number of recaptured fish, upon which the method is based, and probable errors decrease accordingly (Cooper, 1952).

Estimates of trout biomass in each station were computed as the product of the number and average weight of fish in each size class, the biomasses of the various size classes then totaled. Average weights for each size class were calculated separately for brook and brown trout.

In the Pigeon River, several very large brown trout ($\geq$500mm) were captured, and these fish were simply added to the final population and biomass estimates for the station in which they were taken. A single rainbow trout, about 250mm long, was caught in Station 20 but was not entered in the estimate tables because brook and brown trout were the primary focus of this study.

In the Salmon Trout River, a few large migratory steelhead (rainbow trout) were caught below Lower Falls during the first inventory. These fish were not included in the population estimates but are listed in Appendix A, Table A1. Separate calculations were made for the sparse population of smaller rainbow trout present below Lower Falls and the results are also given in Table A1.

During fall electrofishing, many young-of-the-year coho salmon, several adult coho, and two adult brown trout were caught below Lower Falls (see Appendix A, Table A2); because these are not considered resident stream fish, they are not included in the population estimates. Also encountered were several large, obviously lake-run (coaster) brook trout, but since spawning migrants and resident brook trout could not always be positively distinguished, all were included in the population and biomass estimates. Brook trout stocked by the Huron Mountain Club were mistakenly not finclipped as arranged, and therefore had to be identified by their hatchery coloration and size (230-350mm). These fish were omitted from the final population estimates.

Confidence intervals were calculated for population estimates according to the procedure outlined by Davis (1964). In this method, the proportion of recaptures to total catch in the second run [r/(r + u)] determines the appropriate distribution, Poisson or binomial, to be used in deriving 95% confidence limits for the true proportion of marked fish in the population. Then, by reference to the proper table or graph given in Ricker (1975) or Adams (1951), upper and lower limits for r can be obtained and these values used to calculate upper and lower 95% limits for the population estimates of each size class. The new estimates are then partitioned into individual stations in the same manner as the original or best estimate. In any case, the lower population limit for a particular size class of fish in a station can never be less than the total number of fish (m + u) of that size caught in that station. If a calculated lower limit was less than the sum of m + u, it was simply disregarded and the lower limit was given as the value m + u. Finally, confidence intervals for trout biomass were computed by multiplying the upper and lower population limits in each station by the average weight of fish in the corresponding size group.

Habitat Studies

In order to study conditions in the two rivers at a time when fish cover would most likely be at a minimum, habitat measurements were made during summer low flow. Cooper and Wesche (1976) implied that trout populations were limited by stream carrying capacity at the lowest flow which occurs in the stream for an extended period of time, in keeping with Liebig's law of the minimum (Odum, 1971). Habitat measurements were made on August 7-21 at the Pigeon River and from August 30-September 13 at the Salmon Trout River.

Streamflow Discharge Measurements

Initially, discharge measurement sites were established so that stream flow could be monitored for the duration of the summer study period. Discharge measurements were made by stretching a tape measure across the river perpendicular to the direction of flow, and measuring the average water velocity at 30-cm increments along the tape with a Gurley pigmy current meter. For each 30-cm width interval, the product of average velocity x average depth x width was computed to derive an individual discharge value. All of the interval products were then summed to obtain total discharge through the cross section being considered.

A single discharge measurement was made on August 10 at Old Vanderbilt Road (station marker 1) on the Pigeon River. The height of the water was also recorded at that time. Because good records were available from the USGS gaging station further downstream, no additional discharge measurements were necessary, but height of the river at the road bridge was noted daily to check stability of flow during the habitat studies.

Discharge was measured on August 31 at five strategic locations on the Salmon Trout River and at one place on Clear Creek near its confluence (Figure 4). Clear Creek is the largest tributary in the study area. The flow of water in nearby Snake Creek was too slight to be accurately gauged with our equipment. Specific cross-sectional sites for discharge measurements were selected on the basis of uniformity of flow and substrate. Also recorded at each site was the height of the river at the time of discharge measurement and periodically thereafter during the summer study, again, to detect any changes in stream flow.

Mapping and Bank Cover Measurements

Since it was impossible to make detailed habitat measurements of the entire study area on either river in the time available, stations to be studied were chosen on the basis of the first population inventory results. The objective was to obtain a set of stations on each river--12 on the Pigeon and 18 on the Salmon Trout--with the greatest possible variety of trout abundance. However, certain stations on the Salmon Trout River were intentionally excluded from the selection because they contained large, deep, unwadable pools where habitat measurement would not have been possible and population estimates were not reliable. Also, the first six stations above Lower Dam were removed from consideration due to the pond-like nature of the stream in that area.

In order to obtain accurate measurements of channel and thalweg lengths, and to graphically represent the path of the thalweg and the locations of various kinds of cover, detailed maps of the selected study stations were constructed by a standard compass traverse procedure (Compton, 1962). In the traverse, a series of points were surveyed by measuring the direction and distance from one point in the stream to a second point upstream, and from the second to a third and so on. A compass was used to determine bearing of the stream channel and a 30-m calibrated vinyl clothesline was used to measure distances from point to point as well as stream widths along the traverse. After a suitable scale had been chosen, the maps themselves were drawn in the field on graph paper using the ruled lines as a north-south/east-west grid for plotting bearings. Once a station had been mapped, the path of the thalweg was sketched in while walking along the deepest part of the channel. The actual water depth along the thalweg was also recorded on the map.

The most important part of the habitat studies involved the measurement of overhead bank cover, which was defined in this study as solid or nearly-solid overhead cover not closer to the bed than 15cm and extending at least 9cm from the bank in water that is at least 15cm deep. These criteria for usable bank cover were developed by Wesche (1973, 1976) who reported that trout were never found in overhead bank cover less than 9cm wide, and that 92% of all trout sampled were found in water depths of at least 15cm.

To determine if an area of bank cover met these requirements, a special gauge constructed of wooden doweling and plexiglas was fitted along the outer edge of the cover. This gauge had a measuring arm which was 9cm wide and 15cm high. If the gauge could be fitted beneath an area of potential bank cover, the length or streamside perimeter of that cover was measured. The gauge was continuously inserted along the edge of the cover as the researcher moved upstream, so that only that portion of bank cover which satisfied the above criteria would be included in the length measurement. However, individual cover lengths less than 15cm were deemed insignificant and disregarded. No attempt was made to measure the actual width of bank cover greater than 9cm wide.

In both rivers, there were basically three main types of overhead bank cover: undercut banks, overhanging vegetation, and log cover. These were measured and recorded separately. The length of suitable undercut bank was easily determined by contouring a tape measure along that portion of bank under which the special gauge would fit. Overhanging vegetation consisted of tree branches and roots (primarily speckled alder, Alnus rugosa) extending into the water from the bank. If this mat of vegetation was solid or nearly-solid and continuous from the bank to its outer edge in the stream, the gauge was fitted along it and the length which qualified as overhead bank cover was determined with a tape measure. Log cover included only those single logs, deadfalls, or log jams which were firmly lodged against the bank. If any of these fulfilled the requirements for overhead bank cover, the length of their outer edge or streamside perimeter was measured. In many cases, only a portion of the log cover met the criteria and was included in the length measurement. As a final step, the three types of overhead bank cover were sketched in at their approximate locations on the individual station maps. Other conspicuous instream objects were also added to the maps to help indicate the relative location of bank cover.

RESULTS AND DISCUSSION

Pigeon River

Population Estimates

The Pigeon River was generally favorable for electrofishing. Its hard water was conductive of electricity and there were few places where water was too deep to be waded. However, several very large log jams were present in the study area, and these were difficult to electrofish effectively. As a result, populations may have been slightly underestimated in certain stations, but in general, I feel the data provide an accurate description of the trout population.

July standing crops of brook and brown trout $\geq$100mm in length in the Pigeon River study area are shown by station in Tables 2-5. At that time, no Age-I trout were smaller than 100mm, and no Age-0 trout were as large as 100mm. Confidence intervals for the total number and biomass of trout in each station and in each size class have been included in the tables. These confidence intervals represent the totals of individual confidence limits derived for each size class of fish within each station.

For brook trout, fish in the 150-199mm size class comprise the majority of total biomass, with few fish reaching lengths greater than 250mm. Biomass of brown trout is spread over a much greater range of size groups. Whether measured in numbers or

TABLE 2.--Population (number) of brook trout in the Pigeon River in July, 1976.

Sta	Total Length (mm)				Total	95% CI
	100-149	150-199	200-249	250-299		
1	25	22			47	35-67
2	29	24		1	54	41-78
3	2	9	1		12	10-16
4	32	31	1	2	66	51-94
5	20	7	1		28	21-43
6	18	18			36	27-51
7	5	9			14	11-19
8	7	15			22	18-30
9	5	9	1		15	12-21
10	5	5	3		13	9-19
11,12	5	44	1		50	41-64
13	18	40			58	45-78
14	11	16			27	21-38
15	5	22	3		30	23-40
16	5	15			20	16-27
17	5	29	1		35	28-46
18	14	37	3		54	43-74
19	11	33	1	1	46	37-62
20	5	27			32	25-41
21	7	16			23	18-31
22	7	46	3		56	45-73
23	5	18	6		29	22-40
24	11	18	1	1	31	25-43
Total	257	510	26	5	798	624-1095
95% CI	174-414	425-630	20-46	5-5	624-1095	

TABLE 3.--Biomass (kg) of brook trout in the Pigeon River in July, 1976.

Sta	Total Length (mm)				Total	95% CI
	100-149	150-199	200-249	250-299		
1	0.64	1.07			1.71	1.31-2.33
2	0.74	1.16		0.21	2.11	1.69-2.86
3	0.05	0.44	0.11		0.60	0.52-0.83
4	0.82	1.50	0.14	0.34	2.80	2.31-3.80
5	0.51	0.34	0.08		0.93	0.72-1.40
6	0.46	0.87			1.33	1.03-1.81
7	0.13	0.44			0.57	0.46-0.74
8	0.18	0.73			0.91	0.76-1.20
9	0.13	0.44	0.14		0.71	0.60-1.01
10	0.13	0.24	0.45		0.82	0.57-1.24
11,12	0.13	2.13	0.11		2.37	1.98-3.05
13	0.46	1.94			2.40	1.91-3.12
14	0.28	0.78			1.06	0.83-1.43
15	0.13	1.07	0.36		1.56	1.19-2.11
16	0.13	0.73			0.86	0.71-1.12
17	0.13	1.41	0.07		1.61	1.31-2.10
18	0.36	1.80	0.41		2.57	2.03-3.51
19	0.28	1.60	0.07	0.17	2.12	1.76-2.77
20	0.13	1.31			1.44	1.14-1.80
21	0.18	0.78			0.96	0.76-1.25
22	0.18	2.23	0.33		2.74	2.19-3.59
23	0.13	0.87	0.60		1.60	1.21-2.27
24	0.28	0.87	0.12	0.17	1.44	1.23-1.94
Total	6.59	24.75	2.99	0.89	35.22	28.22-47.28
95% CI	4.44-10.56	20.61-30.56	2.28-5.27	0.89-0.89	28.22-47.28	

TABLE 4.--Population (number) of brown trout in the Pigeon River in July, 1976.

Sta	Total Length (mm)									Total	95% CI
	100-149	150-199	200-249	250-299	300-349	350-399	400-449	450-499	>500 (length)		
1		4				3		1		8	6-10
2	2	6	3	3	4					18	13-24
3		6	2	3	3	1				15	11-19
4		4	3	3	3	1	1			15	11-20
5		4		4	1	3				12	9-15
6		7	2	1	1	1				12	10-15
7		4	2		1					7	5- 9
8	2	2	2			3	1			10	7-13
9		4	2		1		4			11	8-14
10		2				1			1(630)	4	4- 4
11,12		11	2	3		6		1	2(537,635)	25	20-31
13	2	11	2	4		3	2	1		25	19-33
14		6	2	4	1	5		1		19	15-23
15		7		3			1			11	9-14
16		9		1		1	1			12	11-14
17		7	2			5	2			16	13-21
18		9	3	1	3	5	2			23	19-30
19	5	15	2	3		4	1	1		31	24-41
20		11		4	1	4	1			21	17-26
21		11	2	5		4	1			23	18-29
22	2	20	2	4	1	1				30	24-38
23		11	2	4	5	4	1	1		28	22-35
24		13	2	3		4	1			23	18-29
Total	13	184	37	53	25	59	19	6	3	399	313-507
95% CI	7-20	154-229	20-57	39-67	20-30	46-72	18-23	6-6	3-3	313-507	

TABLE 5.--Biomass (kg) of brown trout in the Pigeon River in July, 1976.

Sta	Total Length (mm)									Total	95% CI
	100-149	150-199	200-249	250-299	300-349	350-399	400-449	450-499	≥500		
1		0.20				1.83		1.04		3.07	2.41- 3.74
2	0.05	0.31	0.32	0.59	1.38					2.65	1.92- 3.48
3		0.31	0.22	0.59	0.84	0.44				2.40	1.76- 3.03
4		0.20	0.32	0.59	0.95	0.46	0.90			3.42	2.76- 4.21
5		0.20		0.79	0.27	1.58				2.84	2.06- 3.60
6		0.36	0.22	0.20	0.30	0.59				1.67	1.50- 1.87
7		0.20	0.22		0.27					0.69	0.54- 0.85
8	0.05	0.10	0.22			1.61	0.71			2.69	2.01- 3.34
9		0.20	0.22		0.37		2.68			3.47	2.65- 4.30
10		0.10				0.48			2.30	2.88	2.88- 2.88
11,12		0.56	0.22	0.59		3.02		1.10	5.00	10.49	9.58-11.45
13	0.05	0.56	0.22	0.79		1.50	1.58	0.87		5.57	4.63- 7.33
14		0.31	0.22	0.79	0.30	2.52		1.80		5.94	5.07- 6.79
15		0.36		0.59			0.85			1.80	1.55- 2.10
16		0.46		0.20		0.45	0.92			2.03	1.98- 2.13
17		0.36	0.22			2.81	1.31			4.70	3.97- 6.12
18		0.46	0.32	0.20	0.98	2.73	1.47			6.16	5.12- 8.08
19	0.11	0.77	0.22	0.59		2.01	0.78	0.90		5.38	4.42- 6.46
20		0.56		0.79	0.41	2.04	0.81			4.61	3.80- 5.47
21		0.56	0.22	0.98		1.95	0.89			4.60	3.71- 5.54
22	0.05	1.02	0.22	0.79	0.27	0.47				2.82	2.33- 3.40
23		0.56	0.22	0.79	1.65	2.08	0.66	1.17		7.13	5.87- 8.43
24		0.67	0.22	0.59		1.88	0.68			4.04	3.15- 4.96
Total	0.31	9.39	4.04	10.05	7.99	30.45	14.24	6.88	7.30	91.05	75.67-109.56
95% CI	0.16- 0.46	7.89- 11.72	2.15- 6.14	7.66- 13.17	6.41- 9.60	23.65- 37.20	13.57- 17.09	6.88- 6.88	7.30- 7.30	75.67- 109.56	

biomass, trout abundance varies considerably among the 24 stations. Cooper (1952) also reported extensive variation in the density of trout populations between small adjacent portions of the Pigeon River in the DNR research area.

July biomass totals for brook and brown trout in the Pigeon River are depicted graphically in Figure 5. Although they are less numerous than brook trout in all but two stations, brown trout comprise more than half of the total biomass in all stations. This greater biomass of brown trout is due mainly to the larger body size which they attain. A few large brown trout in a station contribute a substantial portion of the total biomass. Again, the wide fluctuations in trout biomass from station to station can be seen, but there is also a general trend toward greater biomass in the upstream portion of the study area.

October standing crops of trout in the study area are given in Tables 6-9, along with the corresponding confidence intervals. The most notable changes from summer standing crops are the decrease in total number and biomass of 150-199mm brook trout, and the large-scale recruitment of brook trout and especially brown trout into the 100-149mm size class. Most of the reduction in brook trout biomass from summer to fall is probably caused by angling mortality. According to Cooper (1953), brook trout in the Pigeon River are more susceptible than brown trout to angling and suffer a higher rate of exploitation. He reports that 75% of the standing crop of legal-sized brook trout is removed by anglers each season, while only

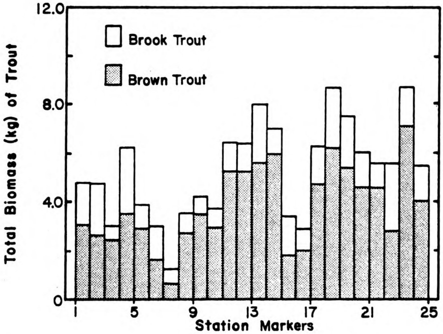

Figure 5. Biomass of trout in the Pigeon River in July, 1976.

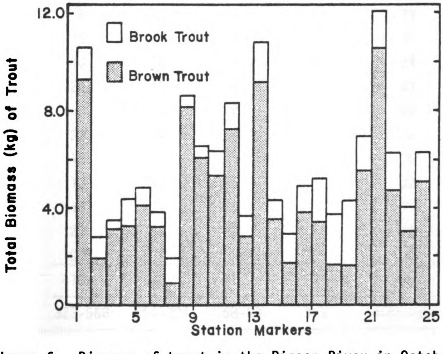

Figure 6. Biomass of trout in the Pigeon River in October, 1976.

TABLE 6.--Population (number) of brook trout in the Pigeon River in October, 1976.

Sta	Total Length (mm)				Total	95% CI
	100-149	150-199	200-249	250-299		
1	28	17	2		47	37-63
2	8	17			25	20-33
3	13	5			18	14-24
4	18	10	2	1	31	25-42
5	13	8	2		23	19-31
6	15	8			23	19-30
7	15	13	2		30	25-40
8	8	8			16	13-21
9	15	5			20	16-26
10	18	5	2	1	26	21-35
11	28	8	3		39	30-52
12	15	8	3		26	21-34
13	31	15	5		51	40-68
14	5	12	2		19	16-26
15	15	13	3		31	25-41
16	10	10	3	1	24	19-32
17	26	17	6		49	39-65
18	28	32	2		62	49-83
19	23	34	8		65	52-86
20	18	13	5		36	29-49
21	13	19	5		37	30-50
22	15	17	5		37	30-49
23	20	5	5		30	23-40
24	20	7	6		33	26-44
Total	418	306	71	3	798	638-1064
95% CI	323-568	254-394	58-99	3-3	638-1064	

TABLE 7.--Biomass (kg) of brook trout in the Pigeon River in October, 1976.

Sta	Total Length (mm)				Total	95% CI
	100-149	150-199	200-249	250-299		
1	0.43	0.80	0.13		1.36	1.11-1.81
2	0.12	0.80			0.92	0.75-1.20
3	0.20	0.23			0.43	0.34-0.56
4	0.28	0.47	0.14	0.22	1.11	0.95-1.42
5	0.20	0.37	0.17		0.74	0.65-1.00
6	0.23	0.37			0.60	0.51-0.77
7	0.23	0.61	0.15		0.99	0.85-1.32
8	0.12	0.37			0.49	0.42-0.64
9	0.23	0.23			0.46	0.37-0.59
10	0.28	0.23	0.34	0.16	1.01	0.90-1.33
11	0.43	0.37	0.24		1.04	0.81-1.37
12	0.23	0.37	0.27		0.87	0.69-1.13
13	0.47	0.70	0.46		1.63	1.29-2.17
14	0.08	0.56	0.16		0.80	0.68-1.09
15	0.23	0.61	0.32		1.16	0.91-1.53
16	0.15	0.47	0.32	0.18	1.12	0.88-1.42
17	0.40	0.80	0.58		1.78	1.44-2.34
18	0.43	1.50	0.17		2.10	1.71-2.80
19	0.35	1.59	0.74		2.68	2.14-3.55
20	0.28	0.61	0.52		1.41	1.15-1.91
21	0.20	0.89	0.48		1.57	1.28-2.11
22	0.23	0.80	0.54		1.57	1.27-2.08
23	0.31	0.23	0.48		1.02	0.80-1.37
24	0.31	0.33	0.56		1.20	0.98-1.58
Total	6.42	14.31	6.77	0.56	28.06	22.88-37.09
95% CI	4.94-8.69	11.89-18.44	5.49-9.40	0.56-0.56	22.88-37.09	

TABLE 8.--Population (number) of brown trout in the Pigeon River in October, 1976.

Sta	Total Length (mm)									Total	95% CI
	100-149	150-199	200-249	250-299	300-349	350-399	400-449	450-499	>500 (length)		
1	5	3		1		3	3		3(512,535,555)	18	14-25
2	18	5	3	1	1	1				29	23-41
3	3	2	5	1	1	1			1(500)	14	12-21
4	8	5	3		3	1	1			21	16-29
5	10	3	3	1	1	1	1		1(542)	21	17-30
6	46	7	3		1	1		1		59	46-81
7	3	2	2	1	1					9	8-14
8	10		2	3		1	1		2(650,685)	19	16-27
9	31		5	1		3	3	1		44	34-61
10	18	3	3		1		1	3		29	22-40
11	23		2			1			3(530,537,640)	29	24-39
12	5	2	3			1	1		1(517)	13	11-18
13	8	7			3	6	3		1(586)	28	22-39
14	26	5	2	1	1		3			38	30-52
15	15	7	6			1				29	24-39
16	13	3	3	1	1		3			24	18-34
17	26	3	8	1	1				1(540)	40	31-55
18	23	5	3				1			32	25-42
19	20	5	6	1	1					33	26-45
20	46	13	10	1			1		1(602)	72	57-98
21	28	7	11	4	1	7	3		1(503)	62	49-86
22	31	10	5	4	3				1(515)	54	42-74
23	18	3	16		1		1			39	30-55
24	20	3	13	1	6	1		1		45	35-63
Total	454	103	117	23	27	29	26	6	16	801	632-1108
95% CI	349-619	83-133	91-162	20-41	23-48	25-50	20-32	5-7	16-16	632-1108	

TABLE 9.--Biomass (kg) of brown trout in the Pigeon River in October, 1976.

Sta	Total Length (mm)									Total	95% CI
	100-149	150-199	200-249	250-299	300-349	350-399	400-449	450-499	≥500		
1	0.06	0.18		0.22		1.66	2.51		4.64	9.27	7.81-11.52
2	0.20	0.31	0.29	0.22	0.34	0.51				1.87	1.66- 3.17
3	0.03	0.12	0.48	0.28	0.32	0.58			1.28	3.09	3.00- 4.55
4	0.09	0.31	0.29		1.22	0.58	0.78			3.27	2.67- 4.83
5	0.11	0.18	0.29	0.20	0.36	0.52	0.67		1.76	4.09	3.92- 5.38
6	0.52	0.43	0.29		0.39	0.64		0.92		3.19	2.90- 4.63
7	0.03	0.12	0.19	0.19	0.38					0.91	0.91- 1.66
8	0.11		0.19	0.56		0.54	0.68		6.08	8.16	7.95- 9.21
9	0.35		0.48	0.19		1.92	2.12	1.00		6.06	4.53- 8.54
10	0.20	0.18	0.29		0.38		0.85	3.43		5.33	3.99- 7.09
11	0.26		0.19			0.65			6.16	7.26	7.20- 8.09
12	0.06	0.12	0.29			0.44	0.60		1.26	2.77	2.66- 3.38
13	0.09	0.43			0.95	2.84	2.61		2.24	9.16	7.42-12.25
14	0.29	0.31	0.19	0.19	0.40		2.16			3.54	2.68- 5.10
15	0.17	0.43	0.58			0.57				1.75	1.56- 2.70
16	0.15	0.18	0.29	0.16	0.41		2.58			3.77	2.72- 5.41
17	0.29	0.18	0.77	0.28	0.26				1.62	3.40	3.08- 4.40
18	0.26	0.31	0.29				0.77			1.63	1.41- 1.87
19	0.22	0.31	0.58	0.16	0.32					1.59	1.37- 2.40
20	0.52	0.80	0.96	0.25			0.69		2.32	5.54	5.10- 6.61
21	0.31	0.43	1.06	0.81	0.34	3.90	2.39		1.31	10.55	8.67-14.95
22	0.35	0.61	0.48	0.81	0.82				1.58	4.65	3.88- 6.10
23	0.20	0.18	1.54		0.40		0.64			2.96	2.47- 4.18
24	0.22	0.18	1.25	0.22	1.67	0.62		0.90		5.06	4.38- 7.35
Total	5.09	6.30	11.26	4.74	8.96	15.97	20.05	6.25	30.25	108.87	93.94-145.37
95% CI	3.92-6.93	5.06-8.14	8.76-15.60	4.14-8.47	7.69-16.10	13.75-27.66	15.26-24.83	5.11-7.39	30.25-30.25	93.94-145.37	

25% of the legal-sized brown trout stock is taken by anglers annually. Nyman (1970) also reported that brook trout in some Newfoundland streams had a much higher catchability than brown trout.

In Figure 6, October biomass totals are shown for all stations in the study area. As in July, brown trout strongly dominate the biomass figures, but in fall, trout biomass appears to vary even more radically from station to station than in summer. During the October inventory, it was observed that most of the trout were in spawning condition and that many were near areas which appeared to be spawning habitat. Concentration of fish in scattered areas of suitable spawning substrate may help to explain the more clumped fall distribution. Also, a greater number of very large brown trout ($\geq$500mm) were captured in the study area during the October electrofishing. It is believed that many of these large fish were spawning migrants, perhaps from the Lansing Club Pond. Older trout in some streams are thought to be more abundant in downstream areas during most of the year and then to move upstream temporarily in the fall to spawning grounds (McFadden and Cooper, 1962). In October, large brown trout occurred erratically in the research area, adding considerable biomass to the stations in which they were captured and further contributing to the irregularity of the fall biomass distribution.

Habitat Studies

On August 10, 1976, discharge of the Pigeon River at the Old Vanderbilt Road bridge was 1.42m^3/sec, and depth of the water at mid-channel was 58cm. Mean discharge further downstream at the USGS gaging station was reported to be 1.61m^3/sec for the same date. Moderate precipitation on the night of August 11 caused a slight rise in water level; mid-channel river depth at the road bridge on August 12 was 61cm. No significant precipitation occurred for the remainder of the summer study period, and fluctuations in river height at the bridge were only 1-2cm. USGS records indicated that the Pigeon River remained at summer low flow for the duration of the cover measurement studies.

Maps of the 12 stations selected (see p. 25 for selection procedure) for cover measurement are given in Appendix B. Log jams and fallen trees provided the majority of trout cover in the Pigeon River study area. Alders, hardwoods, and cedars occurred along much of the stream bank. Frequently, alder branches and roots protruded into the water and provided measurable bank cover. In several stations, the river flowed through intermittent meadow where undercut banks and grassy overhangs afforded excellent trout cover. Channel and thalweg lengths, as well as total measurements of the three types of cover, are given for the selected stations in Table 10.

Population-Bank Cover Relationships

A series of simple correlation analyses was made to discern possible relationships between trout abundance and amount of overhead bank cover in the 12 selected stations. Various trout population parameters were considered separately as dependent variables.

TABLE 10.--Habitat measurements from 12 study stations on the Pigeon River.

Sta No.	Channel Length (m)	Thalweg Length (m)	Length (m) of Overhead Bank Cover			
			Undercut Bank	Overhanging Vegetation	Log Cover	Total
3	100.6	105.0	4.0	0.0	43.3	47.3
4	105.0	108.8	3.8	0.8	50.9	55.5
5	101.2	103.8	3.9	5.1	31.9	40.9
6	101.2	104.4	30.9	7.3	7.8	46.0
9	103.8	106.2	20.6	6.1	5.8	32.5
10	100.6	103.8	7.4	8.3	15.5	31.2
13	110.0	115.0	10.0	9.2	32.0	51.2
14	105.0	108.1	15.1	9.4	24.4	48.9
19	108.8	113.8	2.3	8.9	68.0	79.2
20	97.5	99.4	4.7	9.6	59.2	73.5
21	101.2	106.9	9.2	13.6	33.6	56.4
22	106.2	110.0	4.6	9.2	47.3	61.1

Total length of bank having overhead cover was the independent variable in each case. Resulting r and r^2 values and their significance levels are given in Table 11. The non-random selection of stations for habitat study did not introduce positive bias into the analysis because the objective of selection was to obtain a sample with the greatest possible variety of trout abundance. By forcing population parameters to have high variability, this procedure actually tends to produce conservative correlation coefficients.

For July populations, all parameters involving numbers of trout $\geq$150mm long showed significant correlation with length of bank cover (Table 11). Abundance of trout less than 150mm in length, however, was not significantly related to bank cover. Furthermore, the number of brown trout $\geq$150mm long was found to be more strongly correlated ($r = 0.812$) with the amount of bank cover than was the number of brook trout $\geq$150mm long ($r = 0.665$).

Relationships between overhead bank cover and the two species of trout are shown in Figure 7. The greater association of brown trout with bank cover may be due in part to competitive advantages enjoyed by the species. Nyman (1970) reported that although brook and brown trout have similar ecological demands, brown trout in some Newfoundland streams were larger and dominated niches having the most favorable cover conditions.

The highest correlation between trout abundance/station and bank cover/station is obtained when the total number of brook and brown trout $\geq$150mm is considered (Table 11). On the basis of a

TABLE 11.--Correlation coefficients (r) and coefficients of determination (r^2) for trout population variables (Y) and total length (m) of overhead bank cover/ station (X) in the Pigeon River.

Dependent Variables (Y)	July 1976		October 1976	
	r	r^2	r	r^2
No. all trout 100-149mm/sta	0.128	0.016	0.340	0.116
No. brook trout ≥150mm/sta	0.665*	0.442	0.822**	0.676
No. brown trout ≥150mm/sta	0.812**	0.659	0.449	0.202
No. all trout ≥150mm/sta	0.756**	0.572	0.792**	0.627
No. all trout ≥150mm/sta-- Stations 13 and 22 excluded	0.938**	0.880	--	--
Biomass all trout 100-149mm/sta	0.114	0.013	0.360	0.130
Biomass brook trout ≥150mm/sta	0.617*	0.381	0.804**	0.646
Biomass brown trout ≥150mm/sta	0.448	0.201	-0.164	0.027
Biomass brown trout 150-399mm/sta	0.734**	0.539	0.127	0.016
Biomass all trout ≥150mm/sta	0.627*	0.393	0.021	0.001
Biomass all trout 150-399mm/sta	0.847**	0.717	0.376	0.141

*Indicates significance at the 5% level.

**Indicates significance at the 1% level.

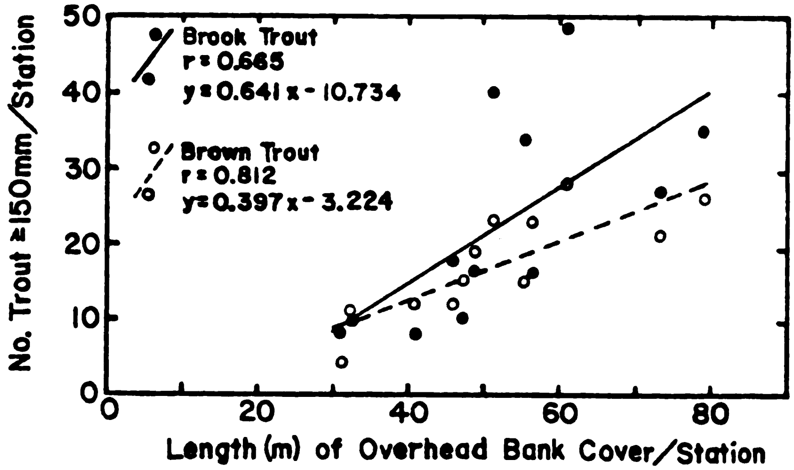

Figure 7. Relationship between July brook and brown trout abundances and bank cover in the Pigeon River.

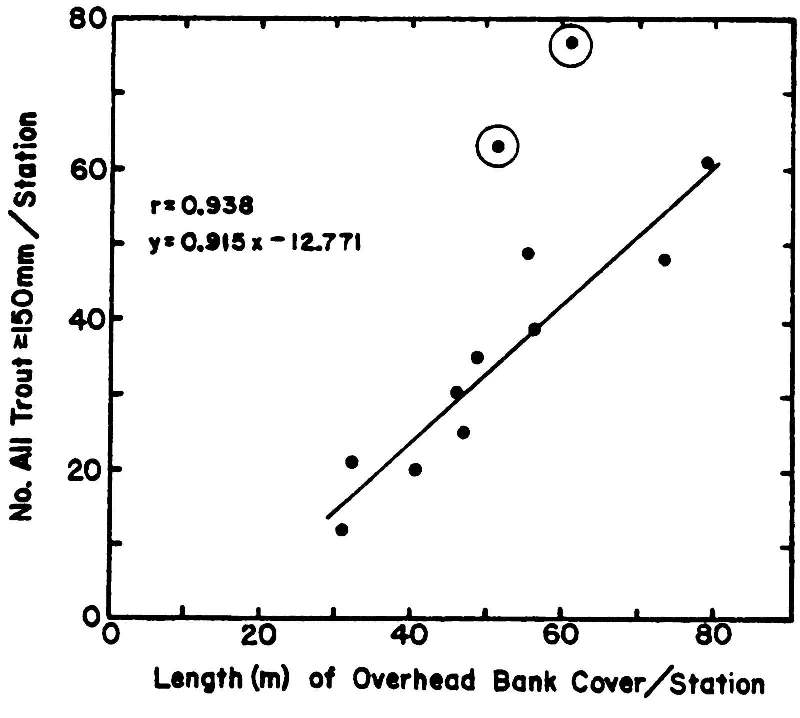

Figure 8. Relationship between July total trout abundance and bank cover in the Pigeon River. (Circled points have been excluded from the correlation analysis.)

statistical test for significance (α = 0.05) of outlying observations (Grubbs and Beck, 1972), the points for Stations 13 and 22 can be excluded from the correlation analysis. As shown in Figure 8, the remaining ten points form a strong linear relationship with $r = 0.938$. The resulting r^2 value indicates that 88% of the variation in abundance of trout $\geq$150mm in the Pigeon River can be accounted for by the length of overhead bank cover.

Hunt (1971) reported that the number of brook trout greater than 152mm in a Wisconsin creek was highly correlated ($r = 0.815$) with the length of permanent bank cover, which he defined as streambank providing at least 15.2cm of overhang in 30.5cm of water. This correlation remained high ($r = 0.809$) even after extensive artificial creation of cover had increased the average amount of bank cover by more than 400%/station. Furthermore, Lewis (1969) demonstrated that cover was the single most important factor accounting for variation in numbers of brown trout 178mm or larger in pools of a Montana stream. According to Lewis's description, cover included brush, overhanging vegetation, undercut banks, and other areas providing shelter for larger fish.

Correlations between July trout biomass/station and bank cover/station are given in Table 11 and shown in Figures 9 and 10. Biomass of trout less than 150mm was not related to length of overhead bank cover. However, biomass of brook trout $\geq$150mm was significantly correlated with cover. The total biomass/station value will be influenced heavily by the presence of any very large trout.

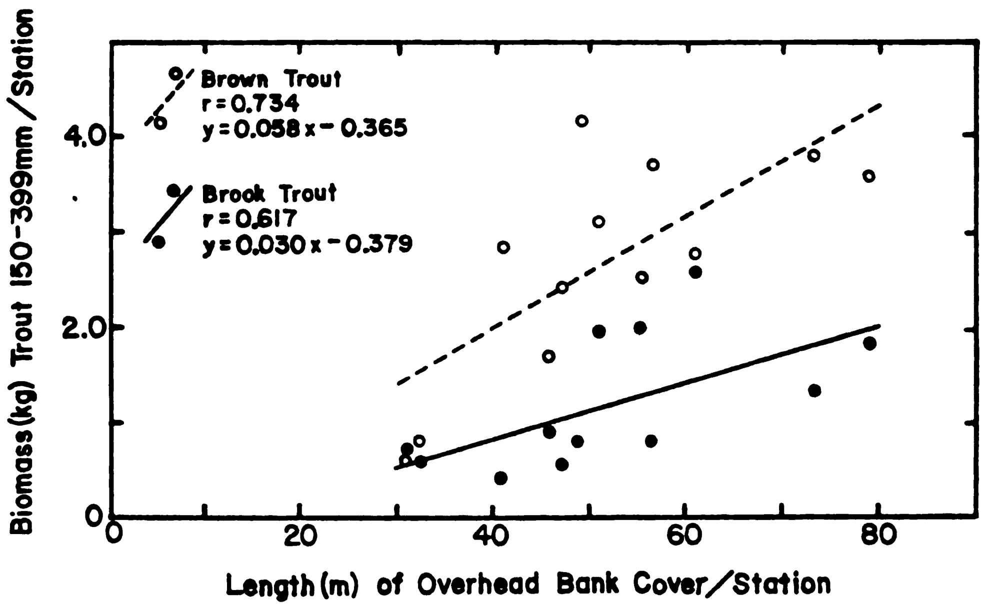

Figure 9. Relationship between July standing crops of brook and brown trout and bank cover in the Pigeon River.

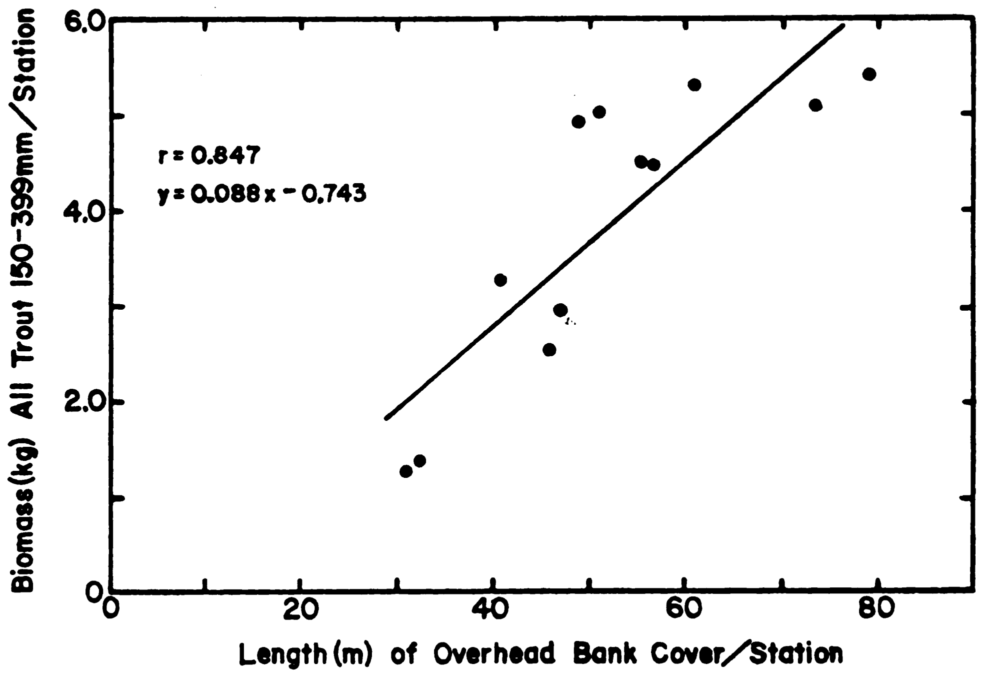

Figure 10. Relationship between July total standing crop of trout and bank cover in the Pigeon River.

Since larger browns may reside near study station boundaries and occupy sizeable home ranges which can extend into an adjacent station, the stations in which they are captured may not accurately reflect their total cover requirements. Large trout also seem to travel greater distances when frightened by electricity, hence their true stations of residence may in some cases be less certain. Perhaps if stations of greater length had been used, the biomass variability due to large brown trout might not have been so great.

These interferences are believed in part to explain the poor correlation between biomass of brown trout $\geq$150mm and abundance of bank cover. If, however, all brown trout 400mm or longer are omitted from the biomass totals, the correlation between brown trout biomass/station and bank cover/station becomes highly significant ($r = 0.734$). Also, by excluding brown trout $\geq$400mm from the totals for biomass of all trout $\geq$150mm (there were no brook trout $\geq$400mm), a very high correlation with bank cover is obtained (Figure 10). Thus, about 72% of the variation in biomass of all trout 150-399mm in the Pigeon River can be accounted for by the length of overhead bank cover.

Stewart (1970 in Hunt, 1971) analyzed physical characteristics of 41 study sections in a small Colorado trout stream and found that a combination of hiding and protective shelter was highly correlated with the distribution and density (biomass/station) of brook trout. According to Wesche (1976), a linear relationship existed between the mean cover rating for a stream section and the standing crop of trout present. His cover rating formula involved one component for the length of overhead bank cover, another component for the area of stream having a water depth of at least 15cm with a substrate diameter of 7.6cm of more (rubble-boulder), and a preference factor for "catchable" and "subcatchable" trout. In the present study, "rubble-boulder" areas were not measured because of the low preference of larger ($\geq$152mm) brook and brown trout for this type of cover.

Relationships between October trout populations and bank cover are also summarized in Table 11 and depicted in Figures 11 and 12. As previously mentioned, brown trout appear to redistribute themselves extensively in the fall for spawning. This may explain the lack of significant correlation between any of the October brown trout population parameters and the amount of bank cover. Brook trout, on the other hand, displayed an even stronger relationship with bank cover in fall than in summer. Both number and biomass of brook trout $\geq$150mm were highly correlated with the length of overhead bank cover (Figures 11 and 12). One possible explanation for increased brook trout association with bank cover during this period was the apparent decrease in brown trout occupation of the preferred sites in their search for more appropriate spawning habitat.

In an attempt to test for possible interactions between brook and brown trout in their use of cover, a series of tests for correlation was run, using various population density parameters as X

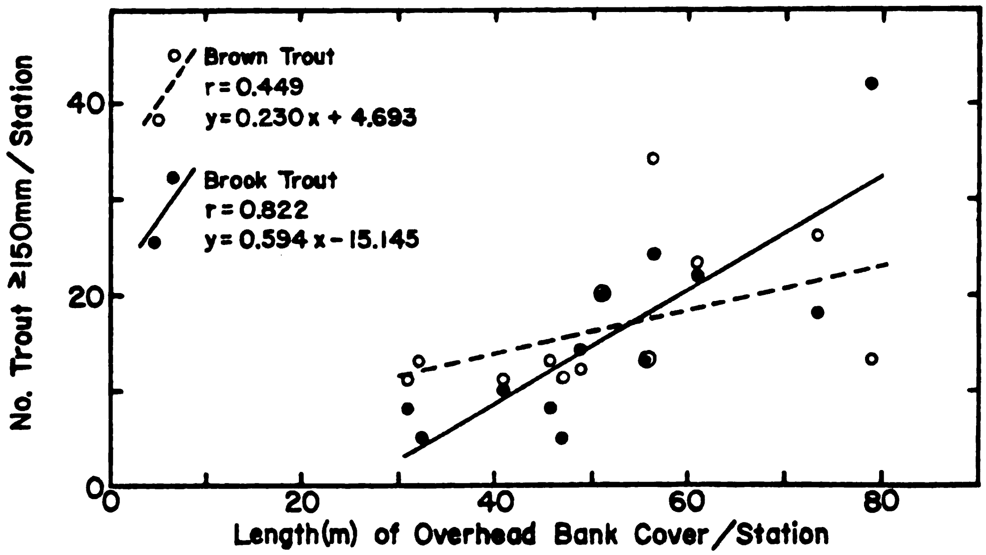

Figure 11. Relationship between October brook and brown trout abundances and bank cover in the Pigeon River.

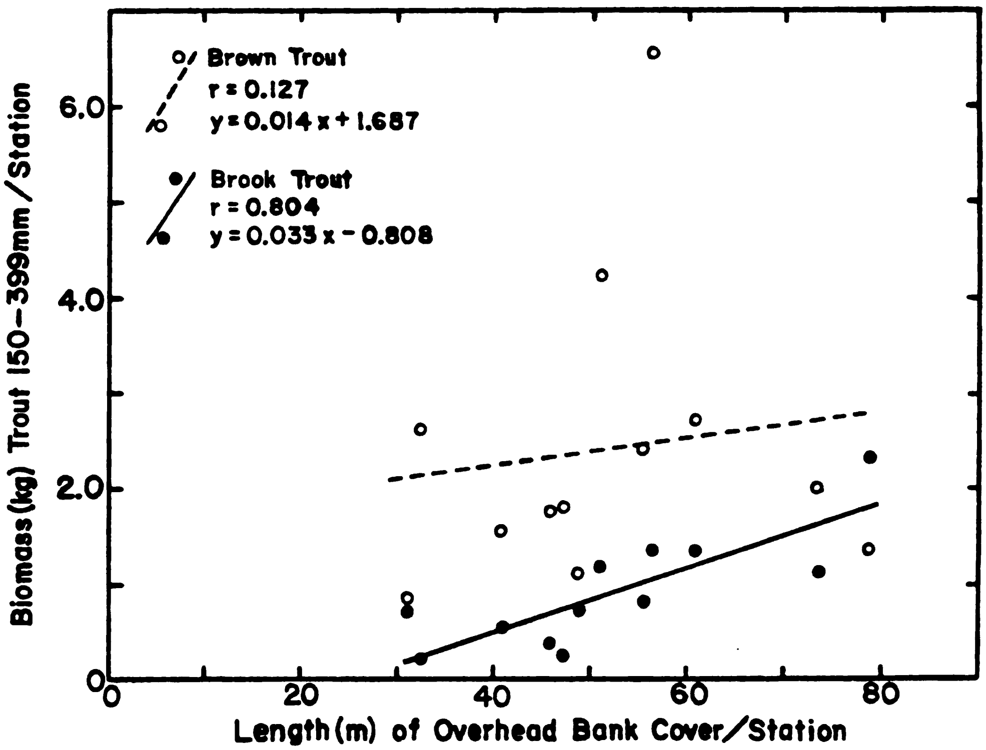

Figure 12. Relationship between October standing crops of brook and brown trout and bank cover in the Pigeon River.

and Y variables. No significant relationships could be demonstrated between brook trout population parameters (abundance, biomass, or trout/cover density, i.e., number or biomass of trout/length of overhead bank cover) and brown trout/cover density. However, because both brook and brown trout showed significant correlation in June with length of bank cover, there was also a positive correlation ($r = 0.764$) between number of brook trout $\geq$150mm/station and number of brown trout $\geq$150mm/station. Such a relationship did not exist for the October trout populations.

Multiple regression was also used to test the importance of brown trout/cover density as a second variable in accounting for variation in brook trout abundance when length of overhead bank cover served as the first variable. The analysis revealed that brown trout/cover density was not a significant variable in the regression equation ($\alpha = 0.05$). It should be acknowledged, however, that the above tests were only crude evaluations based on station totals and not on individual cases of cover usage by the two species. Therefore, the possibility of meaningful interaction between brook and brown trout in regard to utilization of cover has certainly not been eliminated.

Salmon Trout River

Population Estimates

Although the softness of the water made electrofishing less effective in the Salmon Trout River, I feel that the majority of study stations were sufficiently sampled for the computation of reliable population estimates. However, deep water prevented electrofishing in certain areas of Stations 2, 15, 19, 39, and 55, and estimates may therefore be incomplete or deceptively low for these stations. A series of five long, unwadable pools made electrofishing nearly impossible in Station 11, which probably explains why no brook trout were captured there.

Results and confidence intervals for the July brook trout inventory of the Salmon Trout River are given in Tables 12-15. The sparseness of the brook trout population below Lower Falls (Table 12) is immediately apparent. There are fewer than ten trout ≥100mm in nearly all stations, and few of these fish exceed 250mm in length. Above Lower Falls (Table 13), the population of wild brook trout increases, but again, there are very few fish larger than 250mm. Trout in the 100-149mm size group comprise the vast majority of the population. As shown in Figure 13, July biomass totals for brook trout vary considerably from station to station throughout the study area. Above Lower Falls, the lowest biomass (0.21kg) was found in Station 51, while Station 47 contained the greatest biomass of brook trout (3.44kg).

October brook trout abundances are given in Tables 16-19. Data for the study area below Lower Falls (Tables 16 and 18) include any Lake Superior spawning immigrants (coaster brook trout) present at the time of the fall inventory. Because of these fish, brook trout populations were noticeably increased over summer levels in several stations. Above Lower Falls, the total population of brook trout ≥100mm increased from July to October, primarily because of

TABLE 12.--Population (number) of wild brook trout in the Salmon Trout River below Lower Falls in July, 1976.

Sta	Total Length (mm)					Total	95% CI
	100-149	150-199	200-249	250-299	300-349		
1	1	2	2			5	3-10
2	1	2	2			5	3-10
3	3					3	2-7
4		4	3			7	4-13
5	1					1	1-2
6				1	1	2	2-3
7	1		2			3	2-6
8	3			3		6	4-13
9	4	4		1		9	6-19
10		2				2	1-4
11							
12	1	2	2	1	1	7	5-13
13	1		3	1		5	4-10
14	1		2			3	2-6
15		4	2			6	3-11
16,17	10	11	3	3		27	16-57
Total	27	31	21	10	2	91	58-184
95% CI	21-62	15-58	12-42	8-20	2-2	58-184	

TABLE 13.--Population (number) of wild brook trout in the Salmon Trout River above Lower Falls in July, 1976.

Sta	Total Length (mm)				Total	95% CI
	100-149	150-199	200-249	250-299		
36	42	1			43	23-94
37	11	3			14	9-31
38	90	5	1		96	52-209
39	45	5			50	28-109
40,41	35	10	4		49	35-75
42,43	26	12		1	39	29-56
44	4	10	8	1	23	15-41
45,46	13	15	8		36	25-60
47	22	16	18		56	37-97
48	9	3	2		14	10-22
49	13	1	2		16	12-25
50	9	9	2		20	15-32
51	11				11	8-16
52	35	10			45	33-65
53	9	1			10	8-15
54	37	7			44	32-63
55	28	10	2		40	28-60
56	20	3			23	17-33
57	61	15			76	56-110
58	46				46	34-66
59	52	9			61	45-88
Total	618	145	47	2	812	551-1367
95% CI	415-1025	110-229	24-111	2-2	551-1367	

TABLE 14.--Biomass (kg) of wild brook trout in the Salmon Trout River below Lower Falls in July, 1976.

Sta	Total Length (mm) 100-149	150-199	200-249	250-299	300-349	Total	95% CI
1	0.02	0.12	0.20			0.34	0.18-0.68
2	0.02	0.12	0.18			0.32	0.17-0.65
3	0.07					0.07	0.05-0.16
4		0.24	0.38			0.62	0.37-1.17
5	0.02					0.02	0.02-0.05
6				0.21	0.30	0.51	0.50-0.71
7	0.02		0.33			0.35	0.19-0.70
8	0.07			0.64		0.71	0.47-1.44
9	0.09	0.24		0.17		0.50	0.36-0.98
10		0.12				0.12	0.06-0.24
11							
12	0.02	0.12	0.30	0.24	0.42	1.10	0.89-1.77
13	0.02		0.35	0.23		0.60	0.49-1.20
14	0.02		0.30			0.32	0.17-0.64
15		0.24	0.30			0.54	0.27-1.01
16,17	0.23	0.65	0.50	0.74		2.12	1.28-4.26
Total	0.60	1.85	2.84	2.23	0.72	8.24	5.47-15.66
95% CI	0.48-1.42	0.89-3.43	1.62-5.65	1.76-4.44	0.72-0.72	5.47-15.66	

TABLE 15.--Biomass (kg) of wild brook trout in the Salmon Trout River above Lower Falls in July, 1976.

Sta	Total Length (mm)				Total	95% CI
	100-149	150-199	200-249	250-299		
36	0.98	0.06			1.04	0.57-2.27
37	0.26	0.18			0.44	0.32-0.98
38	2.10	0.30	0.10		2.50	1.47-5.35
39	1.05	0.30			1.35	0.84-2.94
40,41	0.66	0.52	0.36		1.54	1.03-2.62
42,43	0.49	0.62		0.18	1.29	1.00-1.81
44	0.08	0.52	0.75	0.33	1.68	1.13-3.00
45,46	0.24	0.78	0.87		1.89	1.20-3.61
47	0.41	0.83	2.20		3.44	2.02-6.96
48	0.17	0.16	0.17		0.50	0.32-0.87
49	0.24	0.05	0.34		0.63	0.41-1.29
50	0.17	0.47	0.23		0.87	0.61-1.55
51	0.21				0.21	0.15-0.30
52	0.66	0.52			1.18	0.85-1.72
53	0.17	0.05			0.22	0.18-0.35
54	0.70	0.36			1.06	0.77-1.52
55	0.53	0.52	0.20		1.25	0.84-2.03
56	0.38	0.16			0.54	0.39-0.75
57	1.15	0.78			1.93	1.42-2.84
58	0.86				0.86	0.64-1.24
59	0.98	0.47			1.45	1.08-2.12
Total	12.49	7.65	5.22	0.51	25.87	17.24-46.12
95% CI	8.24-21.12	5.84-12.18	2.65-12.31	0.51-0.51	17.24-46.12	

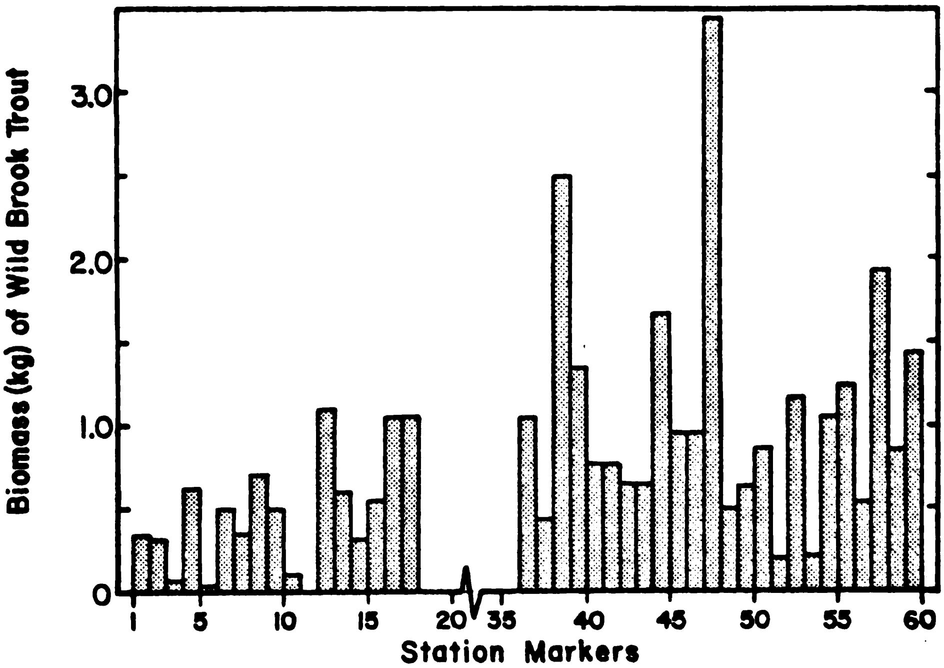

Figure 13. Biomass of wild brook trout in the Salmon Trout River in July, 1976.

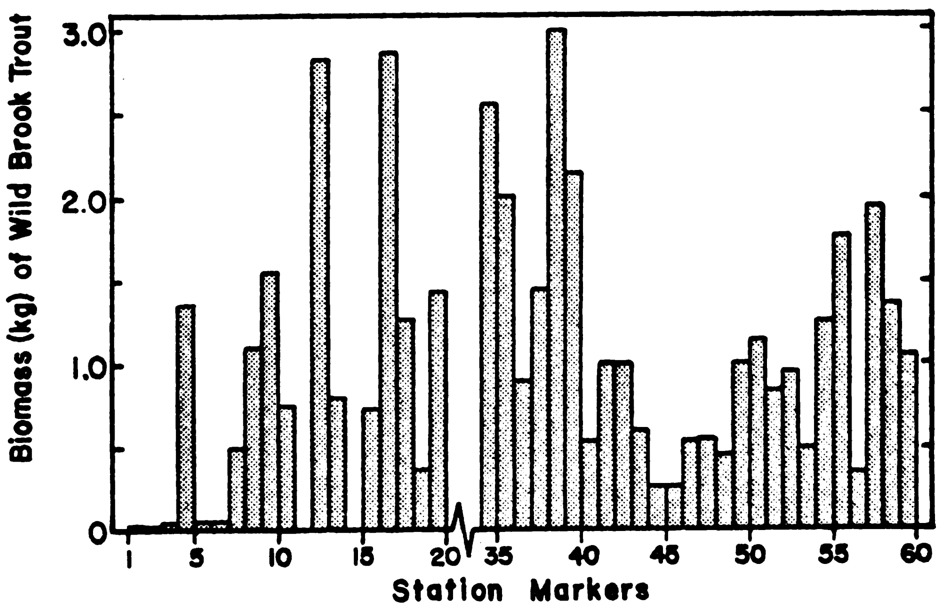

Figure 14. Biomass of wild brook trout in the Salmon Trout River in October, 1976.

TABLE 16.--Population (number) of wild brook trout in the Salmon Trout River below Lower Falls in October, 1976.

Sta	Total Length (mm) 100-149	150-199	200-249	250-299	300-349	>350 (length)	Total	95% CI
1	2						2	1-5
2	2						2	1-5
3	4						4	2-10
4	2	4	4		2		12	4-23
5	6						6	4-14
6	6						6	4-14
7	2		4				6	2-12
8	2			4			6	3-12
9	2		4	4			10	4-19
10	9	7		2			18	8-37
11								
12	4	4		2	2	2(350,449)	14	7-27
13			4	2			6	2-11
14	2						2	1-5
15	4		4	2			10	4-21
16	9	4	14		4		31	12-58
17	4	7	4	2			17	6-33
18	6	7					13	6-26
19	4	4	14				22	7-40
Total	70	37	52	18	8	2	187	78-372
95% CI	39-169	10-64	14-88	9-34	4-15	2-2	78-372	

TABLE 17.--Population (number) of wild brook trout in the Salmon Trout River above Lower Falls in October, 1976.

Sta	Total Length (mm)				Total	95% CI
	100-149	150-199	200-249	250-299		
34	52	34	2		88	59-148
35	44	28			72	49-120
36	33	9			42	29-67
37	62	12			74	52-117
38	89	32	2		123	84-200
39	35	23	5		63	42-107
40	16	6			22	16-32
41,42	9	15	6	3	33	21-51
43	23		3		26	18-38
44	9	3			12	9-17
45	9	3			12	9-17
46	25	3			28	21-39
47	21	5			26	20-37
48	14	5			19	14-27
49	18	5		3	26	18-38
50	41	6	3		50	36-72
51	44	3			47	35-67
52	32	3	3		38	27-54
53	25	2			27	20-38
54	35	3	6		44	30-65
55	58	9	6		73	52-106
56	14	3			17	12-24
57	58	18	3		79	57-114
58	30	20			50	37-73
59	41	9			50	38-71
Total	837	259	39	6	1141	805-1739
95% CI	618-1219	170-439	15-71	2-10	805-1739	

TABLE 18.--Biomass (kg) of wild brook trout in the Salmon Trout River below Lower Falls in October, 1976.

Sta	Total Length (mm)						Total	95% CI
	100-149	150-199	200-249	250-299	300-349	>350		
1	0.02						0.02	0.01-0.05
2	0.02						0.02	0.01-0.05
3	0.04						0.04	0.02-0.11
4	0.02	0.18	0.46		0.07		1.36	0.52-2.56
5	0.06						0.06	0.04-0.15
6	0.06						0.06	0.04-0.15
7	0.02		0.48				0.50	0.13-0.89
8	0.02			1.07			1.09	0.54-1.92
9	0.02		0.46	1.07			1.55	0.66-2.73
10	0.10	0.31		0.33			0.74	0.31-1.42
11								
12	0.04	0.18		0.53	0.62	1.46	2.83	2.10-4.18
13			0.40	0.40			0.80	0.30-1.50
14	0.02						0.02	0.01-0.05
15	0.04		0.31	0.37			0.72	0.28-1.39
16	0.10	0.18	1.46		1.14		2.88	1.08-4.92
17	0.04	0.31	0.59	0.33			1.27	0.43-2.34
18	0.06	0.31					0.37	0.13-0.68
19	0.04	0.18	1.20				1.42	0.41-2.39
Total	0.72	1.65	5.36	4.10	2.46	1.46	15.75	7.02-27.48
95% CI	0.39-1.81	0.45-2.83	1.44-9.07	2.05-7.68	1.23-4.63	1.46-1.46	7.02-27.48	

TABLE 19.--Biomass (kg) of wild brook trout in the Salmon Trout River above Lower Falls in October, 1976.

Sta	Total Length (mm)				Total	95% CI
	100-149	150-199	200-249	250-299		
34	0.71	1.71	0.14		2.56	1.59-4.62
35	0.60	1.41			2.01	1.29-3.62
36	0.45	0.45			0.90	0.58-1.54
37	0.85	0.60			1.45	0.97-2.44
38	1.22	1.61	0.17		3.00	1.91-5.25
39	0.48	1.15	0.51		2.14	1.35-3.96
40	0.25	0.27			0.52	0.37-0.76
41,42	0.14	0.66	0.74	0.46	2.00	1.00-3.30
43	0.37		0.23		0.60	0.35-0.90
44	0.14	0.13			0.27	0.20-0.38
45	0.14	0.13			0.27	0.20-0.38
46	0.40	0.13			0.53	0.39-0.73
47	0.33	0.22			0.55	0.43-0.79
48	0.22	0.22			0.44	0.34-0.63
49	0.29	0.22		0.50	1.01	0.55-1.55
50	0.65	0.27	0.21		1.13	0.74-1.67
51	0.70	0.13			0.83	0.61-1.18
52	0.51	0.13	0.31		0.95	0.57-1.40
53	0.40	0.09			0.49	0.35-0.69
54	0.56	0.13	0.56		1.25	0.69-1.99
55	0.92	0.40	0.46		1.78	1.15-2.73
56	0.22	0.13			0.35	0.25-0.49
57	0.92	0.80	0.23		1.95	1.34-2.89
58	0.48	0.88			1.36	1.01-2.01
59	0.65	0.40			1.05	0.80-1.50
Total	12.60	12.27	3.56	0.96	29.39	19.03-47.40
95% CI	9.33-18.33	8.01-20.99	1.37-6.49	0.32-1.59	19.03-47.40	

recruitment of young fish into the 100-149mm size class. However, the October total biomass of brook trout above Lower Falls was remarkably similar to the July total. Addition of Stations 34 and 35 to the fall inventory accounted for the greater total biomass in October. As in summer, fish in the 100-149mm size group comprised the bulk of the fall population.

October biomass totals for all stations sampled are shown in Figure 14. The presence of coaster brook trout obviously inflated the fall biomass in Stations 1-19. Above Lower Falls, the patterns of biomass distribution in October were roughly similar to those observed in July, with the notable exception of Station 47, which had far less biomass than in July. In order to facilitate electrofishing during the fall inventory, the water level at Lower Dam was drawn down considerably, leaving no water beneath a large log jam in Station 47. This temporary loss of a major cover area is believed to have accounted for the lower autumn biomass in the station, as most of the brook trout captured there during the July inventory were taken from beneath this log jam.

Habitat Studies

The results of discharge measurements made on August 31, 1976, at six sites (Figure 4) along the Salmon Trout River are given in Table 20. Note that the incoming flow of Clear Creek provides most of the increase in discharge from site E to site C on the river. No significant changes in discharge were detected from site C downstream to site A. Water levels recorded periodically at each discharge

TABLE 20.--Streamflow discharge (cubic meters per second) at 6 sites along the Salmon Trout River on August 31, 1976 (Site locations are shown in Figure 4).

Site of Measurement	Nearest Station Marker	Discharge (cms)
A	1	0.77
B	18	0.79
C	37	0.79
D*	40	0.16
E	50	0.54
F	60	0.53

*Clear Creek

site fluctuated less than 1.5cm during the two weeks of summer study. No precipitation occurred during this time. Therefore, the river remained at summer baseflow for the duration of the habitat measurements.

As previously described, 18 stations for mapping and cover analysis on the Salmon Trout River were selected on the basis of diversity of trout abundance. Finished maps are given in Appendix C. Total lengths of each of the three major types of bank cover are given by station in Table 21. Channel and thalweg lengths for each station have also been included in the table.

Below Lower Falls, where the stream flowed primarily through mature hardwood forest, most stations had steep banks with little cover in the form of overhanging vegetation. Substantially undercut

TABLE 21.--Habitat measurements from 18 study stations on the Salmon Trout River.

Sta No.	Channel Length (m)	Thalweg Length (m)	Length (m) of Overhead Bank Cover			
			Undercut Bank	Overhanging Vegetation	Log Cover	Total
3	99.4	106.2	3.0	0.0	13.6	16.6
5	96.2	99.4	13.0	1.1	8.1	22.2
6	101.2	104.4	8.2	4.0	7.6	19.8
7	101.9	103.8	3.0	2.9	1.7	7.6
8	105.0	108.8	3.6	2.7	13.1	19.4
10	101.2	106.9	9.6	2.0	8.8	20.4
13	96.2	100.0	5.8	1.7	6.9	14.4
14	105.0	113.8	9.4	0.0	1.0	10.4
36	92.5	95.6	8.4	4.1	3.5	16.0
38	94.4	96.2	13.8	3.1	17.1	34.0
47	98.8	101.2	1.1	7.7	43.7	52.5
48	102.5	109.4	3.5	9.7	1.5	14.7
50	108.1	115.0	0.9	5.2	9.6	15.7
51	99.4	103.8	0.0	0.9	6.6	7.5
52	120.0	132.5	5.8	0.8	20.3	26.9
53	110.6	116.9	1.1	0.5	2.9	4.5
54	111.9	123.8	10.4	3.8	11.6	25.8
57	106.2	110.6	17.8	10.6	13.7	42.1

banks occurred in some areas. Logs artificially fastened against the bank provided additional shelter in several stations. Between Lower Falls and Lower Dam, undercut banks and log cover occurred erratically in small amounts, and overhanging vegetation was more abundant. Above Lower Dam, the stream meandered for a considerable distance through alder meadow where overhanging roots and branches, undercut banks, and infrequent log jams constituted the majority of fish cover. Hardwoods again began to encroach upon the stream around Station 52, but all three major types of bank cover continued to occur throughout the study area above that point.

Population-Bank Cover Relationships

Correlation analyses similar to those performed on Pigeon River data were also done on data from the Salmon Trout River. Brook trout population parameters were used as dependent variables while abundance of overhead bank cover served as the independent variable. Correlation coefficients (r) and coefficients of determination (r^2) for these analyses are presented in Table 22.

Relationships between July number of brook trout $\geq$150mm and bank cover are significant at the 1% confidence level when all stations are considered, as well as when only stations above Lower Falls or Lower Dam are considered. However, the eight stations below Lower Falls contain sparse populations of brook trout and generally detract from the strength of the correlation (Figure 15). If only the eight selected stations above Lower Dam are considered,

TABLE 22.--Correlation coefficients (r) and coefficients of determination (r^2) for trout population variables (Y) and total length (m) of overhead bank cover/station (X) in the Salmon Trout River.

Dependent Variables (Y)	July 1976		October 1976	
	r	r^2	r	r^2
No. brook trout $\geq$150mm/sta--all stations included	0.822**	0.676	0.495*	0.245
No. brook trout $\geq$150mm/sta--stations above Lower Falls only	0.851**	0.724	0.452	0.204
No. brook trout $\geq$150mm/sta--stations above Lower Dam only	0.909**	0.826	0.518	0.268
No. brook trout $\geq$150mm/sta--stations above Lower Falls only, excluding #38 and #47	--	--	0.882**	0.778
Biomass brook trout $\geq$100mm/sta--all stations included	0.870**	0.757	0.442	0.195
Biomass brook trout $\geq$100mm/sta--stations above Lower Falls only	0.944**	0.891	0.390	0.152
Biomass brook trout $\geq$100mm/sta--stations above Lower Dam only	0.963**	0.927	0.367	0.135
Biomass brook trout $\geq$100mm/sta--stations above Lower Falls only, excluding #38 and #47	--	--	0.863**	0.745
Biomass brook trout $\geq$150mm/sta--all stations included	0.738**	0.545	0.383	0.147
Biomass brook trout $\geq$150mm/sta--stations above Lower Falls only	0.787**	0.619	0.447	0.200
Biomass brook trout $\geq$150mm/sta--stations above Lower Dam only	0.829*	0.687	0.491	0.241
Biomass brook trout $\geq$150mm/sta--stations above Lower Falls only, excluding #38 and #47	--	--	0.939**	0.882

*Indicates significance at the 5% level.

**Indicates significance at the 1% level.

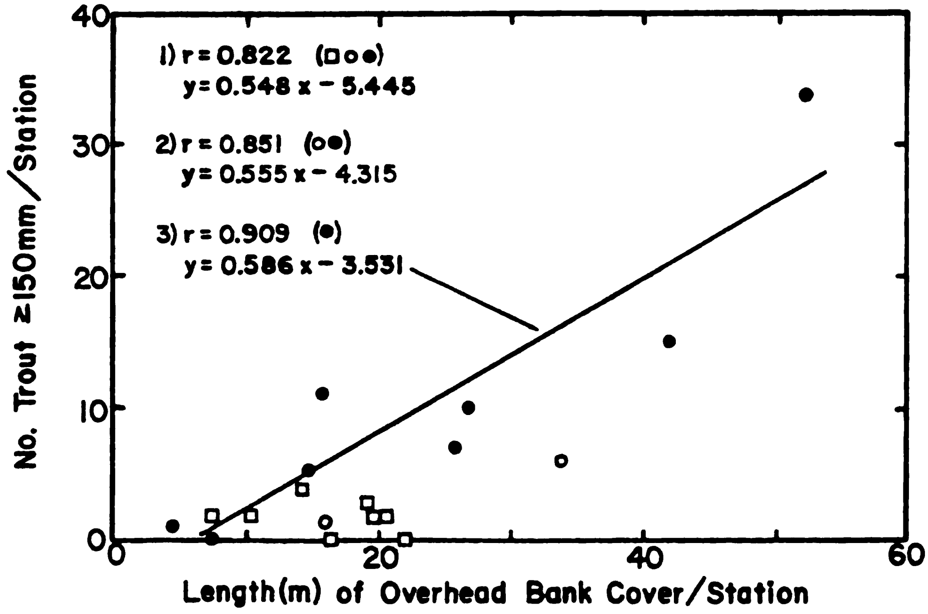

Figure 15. Relationship between July brook trout abundance and bank cover in the Salmon Trout River. (□ - stations below Lower Falls; ○ - stations between Lower Falls and Lower Dam; ● - stations above Lower Dam)

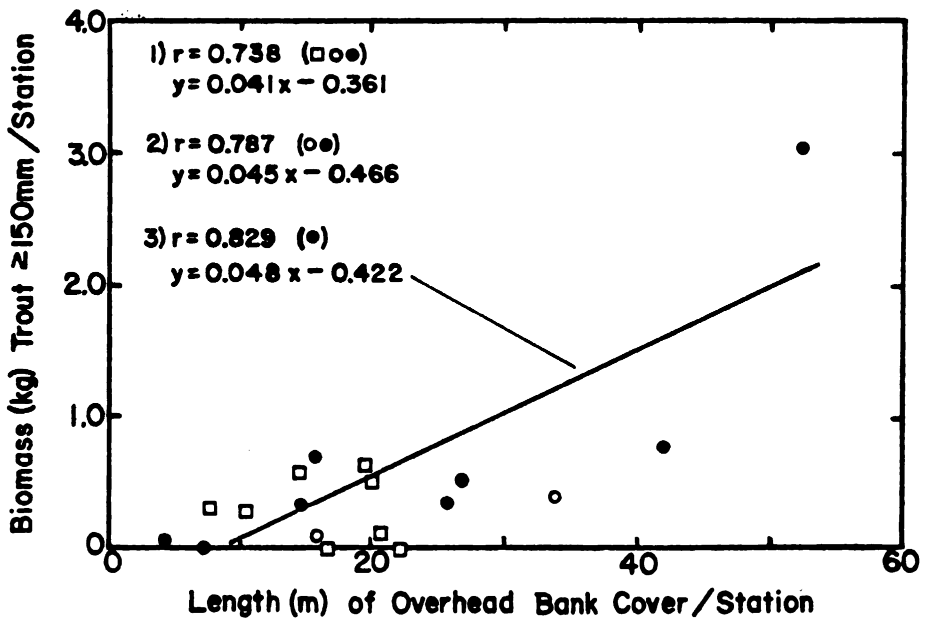

Figure 16. Relationship between July standing crop of brook trout and bank cover in the Salmon Trout River. (□ - stations below Lower Falls; ○ - stations between Lower Falls and Lower Dam; ● - stations above Lower Dam)

the highest correlation (r = 0.909) between bank cover and abundance of brook trout $\geq$150mm is obtained. This is an even stronger relationship than that reported by Hunt (1971) between permanent bank cover and abundance of brook trout greater than 152mm, for which r was 0.815.

July biomass totals for brook trout $\geq$100mm and $\geq$150mm were also highly correlated with abundance of bank cover (Table 22, Figure 16). Above Lower Falls, brook trout in the 100-149mm size group comprise nearly half of the total July biomass, which may explain why a greater correlation coefficient is obtained when biomass of trout $\geq$100mm (instead of $\geq$150mm) is plotted against length of overhead bank cover. Correlations between brook trout biomass and bank cover also tend to improve as stations below Lower Dam are excluded from the analysis.

Results of bank cover correlation tests for October brook trout population parameters are also given in Table 22. Correlation coefficients are very low when all stations are included or when all stations above Lower Falls or Lower Dam are included. The presence of coaster brook trout in stations below Lower Falls confounds the October population data and probably explains the poor results obtained in analyses involving these stations. Correlations between cover and trout populations in stations above Lower Falls are depressed by the effects of Stations 38 and 47. The points for these two stations, circled in Figures 17 and 18, deviate most substantially from expected points and may be excluded from the analysis

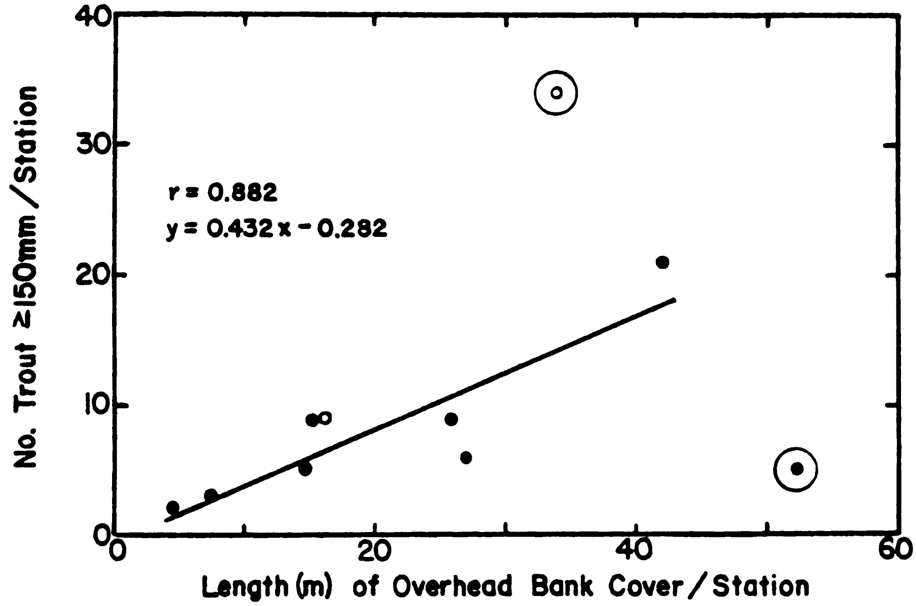

Figure 17. Relationship between October brook trout abundance and bank cover in the Salmon Trout River. (○ - stations between Lower Falls and Lower Dam; ● - stations above Lower Dam. Circled points have been excluded from the correlation analysis.)

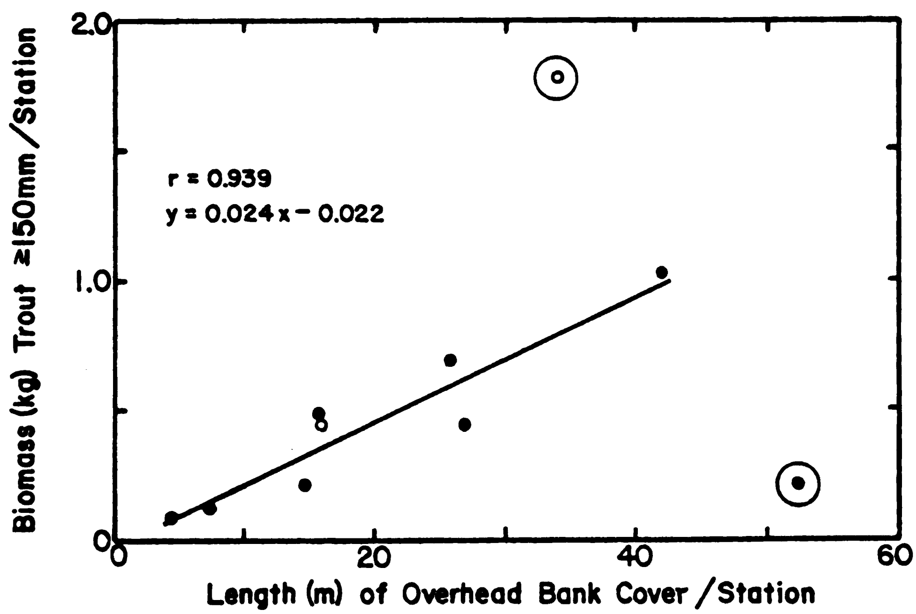

Figure 18. Relationship between October standing crop of brook trout and bank cover in the Salmon Trout River. (○ - stations between Lower Falls and Lower Dam; ● - stations above Lower Dam. Circled points have been excluded from the correlation analysis.)

according to the "outlier" significance test ($\alpha = 0.05$) of Grubbs and Beck (1972). In addition, there are experimental reasons for doubting the validity of cover measurements for Stations 38 and 47. A huge crib of logs from a former logging dam is lodged against the bank in Station 38, forming a vast area of fish cover which was probably underestimated by the method of cover measurement used in this study. Because a large number of trout were obtained from this device during the July inventory, an especially intense electrofishing effort was made around these logs during the October inventory. The result was a high population estimate for a station having a good deal of unmeasured cover. On the other hand, most of the measured cover in Station 47 was rendered unuseable to fish during the October inventory because of the lowered water level, as described previously (p. 62).

Points for the remaining eight stations above Lower Falls describe a close relationship between overhead bank cover and both measures of brook trout density (Figures 17 and 18). Abundance of overhead bank cover/station accounts for about 78% of the variation in number of trout $\geq$150mm/station and more than 88% of the variation in biomass of trout $\geq$150mm/station. By October, more brook trout have been recruited from the 100-149mm size group into the 150-199mm group, and as a result, stronger correlation with bank cover is obtained when biomass of trout $\geq$150mm (instead of $\geq$100mm) is used as the dependent variable.

Combined Analysis: Pigeon and Salmon Trout Rivers

Although these two rivers differ markedly in many respects, the possibility of a continuous relationship between cover and trout abundance in both streams demanded investigation. In comparison, the Pigeon is the larger of the two rivers, having an 80% greater baseflow discharge in the study area than the Salmon Trout River. Furthermore, the Pigeon River, which contains brook and brown trout, generally has more overhead bank cover/station as well as greater numbers and biomass of trout/station than the Salmon Trout River above Lower Falls, where brook trout are the only salmonid present.

In Figure 19, the relationship between July trout abundance and bank cover in both the Pigeon and Salmon Trout Rivers is depicted. The resulting r value--0.869--suggests a strong correlation, and the coefficient of determination indicates that about 76% of the variation in abundance of trout $\geq$150mm in both rivers can be explained by abundance of overhead bank cover. Stations below Lower Falls on the Salmon Trout River were not included in the analysis because of the inconsequential numbers of brook trout and the possibly confounding effects of anadromous salmonids there.

Biomass of trout in July also proved to be highly correlated ($r = 0.901$) with length of overhead bank cover in a combined analysis of the two study streams (Figure 20). In this test, only trout 150-399mm in length were entered into the biomass totals in order to avoid the distortion caused by very large brown trout in the Pigeon River, as explained previously. According to the r^2-value for this relationship, length of overhead bank cover accounts for

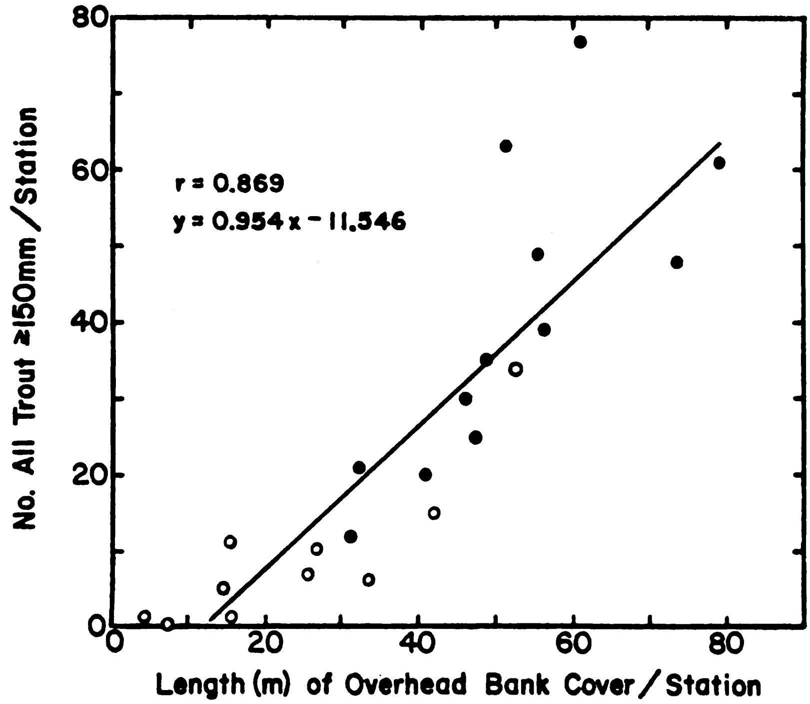

Figure 19. Relationship between July total trout abundance and bank cover in the Pigeon River (●) and the Salmon Trout River above Lower Falls (○).

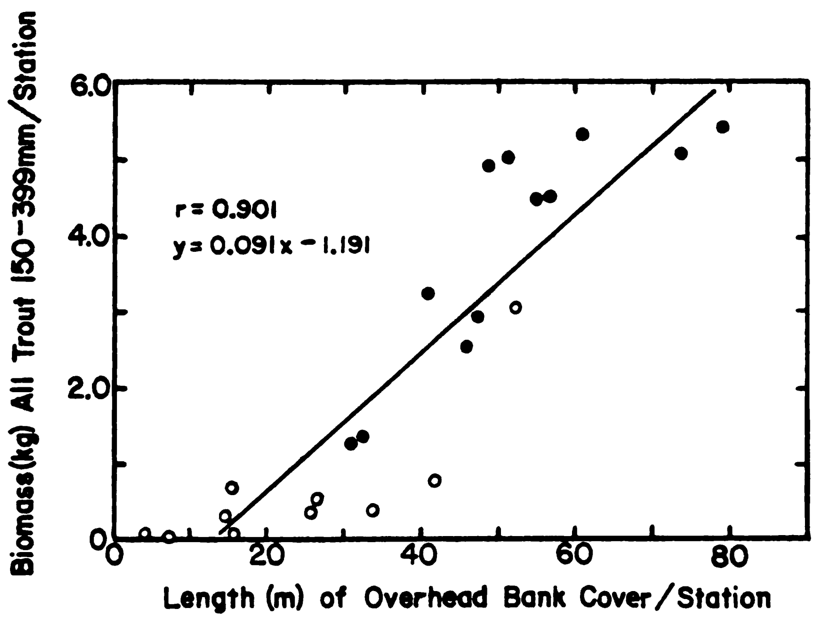

Figure 20. Relationship between July total standing crop of trout and bank cover in the Pigeon River (●) and the Salmon Trout River above Lower Falls (○).

81% of the variation in biomass of trout 150-399mm long in both rivers.

Several complications arise when attempts are made to correlate October population parameters with length of bank cover in the two streams. Biomass totals for the Pigeon River are severely disrupted by the redistribution of spawning brown trout, while relationships in the Salmon Trout River are clouded by the effects of Stations 38 and 47. The only strong correlation derived for October trout data from both streams was between length of overhead bank cover/station and total number of trout $\geq$150mm/station, in all Pigeon River stations and all Salmon Trout River stations above Lower Falls except #38 and #47. The r value for this analysis was 0.897. Considering only October brook trout populations in the Pigeon River stations and Salmon Trout River stations above Lower Falls (excluding #38 and #47), an r of 0.800 was obtained for the correlation of biomass of trout $\geq$150mm with length of bank cover.

The existence of a bank cover-trout abundance relationship that is continuous throughout study stations from two very different Michigan streams is remarkable. It suggests that despite major differences in water chemistry and flow regimes, quantity of streambank shelter is still the principal limiting factor of trout density in many areas of both these rivers. However, hasty speculation concerning means of boosting trout populations in these streams should be avoided. It may not be possible, for example, to raise the trout carrying capacity of the Salmon Trout River to Pigeon River levels by increasing the amount of bank cover beyond the highest observed cover abundances. Other environmental factors, such as severe winters, lack of spawning habitat, or floods, might limit the population before it could fill the increased cover capacity. Nevertheless, these results suggest that under conditions existing in the study areas during 1976, the length of overhead bank cover played a major role in regulating trout abundance. It would seem that some enlargement of trout populations may be possible by augmenting bank cover in stations having little shelter of this kind. According to Hunt (1976), the mean number of legal-sized brook trout in one section of Lawrence Creek, Wisconsin, increased by over 190% and the mean biomass of legal-sized brook trout increased nearly 180% during the six years following addition of bank cover/wing deflectors to that stream section.

Other factors may also have affected stream carrying capacity and trout populations in the study streams. According to Platts (1976), it is the proper combination of many conditions that is significant in producing a fishery resource. Benson (1953b) felt that ground water seepage, by determining the location and number of suitable spawning areas, was an important condition limiting trout production in many parts of the Pigeon River. Certainly, availability of spawning sites and variation in reproductive success may influence trout abundance in the Pigeon and Salmon Trout Rivers. McFadden and Cooper (1962) found a positive relationship between standing crops of fish and water conductivity in six Pennsylvania streams, such that hardness and specific conductance might be interpreted as measures of water fertility and biological productivity of trout streams. According to these criteria, the hard water of the Pigeon River, with its high specific conductance (380 micromhos), would be presumed more "fertile" than the soft, poorly-conductive (130 micromhos) water of the Salmon Trout River. One important factor that can have a crucial effect on trout populations is angler-caused mortality (Schuck, 1945; Cooper, 1952, 1953; McFadden, 1961; McFadden and Cooper, 1962, 1964; Gard and Seegrist, 1972). Stations on the two streams used in this study are undoubtedly subjected to differential fishing pressures. Although spring flooding occurs in both rivers, the Salmon Trout River is known to experience severe high water during spring snowmelt. These floods may have devastating effects on fish populations as well as fish cover. Late winter or spring floods can destroy eggs and alevins incubating in spawning redds, subject adult fishes to harmful if not lethal stresses, and seriously reduce the macrofauna food supply (Needham and Jones, 1959; Elwood and Waters, 1969; Mundie, 1969; Seegrist and Gard, 1972).

Interspecific competition may also have an important influence on stream trout populations. The sympatric occurrence of brook and brown trout in the Pigeon River study area raises questions concerning the significance of ecological interactions in population regulation. In the Salmon Trout River below Lower Falls, seasonal invasion by spawning migrants from Lake Superior, as well as temporary occupation of the river by their offspring, may seriously limit resident trout populations. Furthermore, the introduction of legal-sized hatchery trout into the Salmon Trout River could have important effects on the growth and reproduction of wild trout (Allen, 1962).

In this study, the significance of specific habitat features other than total length of bank cover was not investigated. Water velocities beneath cover were not measured, although it has been clearly demonstrated that the selection and use of microhabitats by salmonids is governed heavily by current velocity (Chapman, 1966; Wickham, 1967 in Stalnaker and Arnette, 1976; Baldes and Vincent, 1969; Giger, 1973; Wesche, 1973; Banks, Mullan, Wiley, and Dufek, 1974 in Stalnaker and Arnette, 1976). Proximity of cover to the thalweg or to principal lines of drift, which may have important implications for feeding efficiency (Everest and Chapman, 1972; Jenkins, 1969), was also not measured. Another unmeasured habitat variable was the number, size, and depth of pools, which several researchers have reported to be highly related to the production of larger trout (Tarzwell, 1937; Shetter, Clark, and Hazzard, 1949; Hunt, 1971).

Because all these factors and others can influence the abundance and distribution of trout in streams, it is not difficult to understand why abundance of overhead bank cover fails to account for all the observed variability in trout density in the Pigeon and Salmon Trout Rivers. In view of all other influences, it is remarkable that bank cover abundance alone can account for a major portion (55-88%) of the variability in numbers and biomass of trout $\geq$150mm in both separate and combined analyses of the two streams.

Now that the major significance of overhead bank cover to brook and brown trout has been demonstrated, the mechanisms by which this type of fish cover might act upon stream carrying capacity should be examined. First and foremost, overhead bank cover provides concealment and protection from predators (Giger, 1973; White, 1973). Saunders and Smith (1962) felt that availability of suitable hiding places was a dominant factor in delimiting the carrying capacity of a Prince Edward Island stream for older trout. They found a significant increase in the percent survival of fingerling brook trout and a marked increase in the number of Age-II trout following alterations which increased the number of hiding places. The observations of Gibson and Keenleyside (1966), McCrimmon and Kwain (1966), and Butler and Hawthorne (1968) indicated that the strong preferences of trout for overhanging cover was due to their photonegative responses which caused them to seek security in shaded areas. Bank cover can also provide shelter from swift currents. Hartman (1963) reasoned that summer association of brown trout with cover, shade, and regions of moderate water velocity may serve primarily for the development of an efficient feeding strategy. Brook trout are also known to rest in covered or shaded areas from which they may emerge to snatch food, but where they can also quickly retreat into dark corners when alarmed (Gibson and Keenleyside, 1966).

According to Baldes (1968 in Giger, 1973), the number and diversity of microhabitats is directly proportional to the potential carrying capacity of the stream environment. Since salmonid microhabitats are almost always associated with cover (Kalleberg, 1958; Hartman, 1963, 1965; Wickham, 1967 in Stalnaker and Arnette, 1976; Baldes and Vincent, 1969), it is certainly possible that the amount of overhead bank cover may limit to some degree the number of suitable microhabitats, and thus greatly influence the carrying capacity of the stream for brook and brown trout. In other words, because of territoriality and competition for a limited number of favorable positions, the amount of territory with sufficient cover may regulate maximum densities of salmonid populations in streams (Allen, 1969; Lewis, 1969). Furthermore, log jams, overhanging vegetation, and other items of instream overhead bank cover often provide greater visual isolation, which reduces territory size and may allow the density of fish to increase (Kalleberg, 1958; Chapman, 1966; Allen, 1969).

Finally, Hunt (1969) proposed another means by which stream-bank cover might affect trout abundance. He felt that increases in a trout population after habitat improvement which involved installation of permanent bank cover were largely the result of increased overwinter survival. Maciolek and Needham (1952) noted that severe winter conditions cause extremely high mortalities of trout, and other researchers have observed that salmonids in general display a strong preference in winter for stream banks with overhanging or submerged cover (Needham and Jones, 1959; Bustard and Narver, 1975b). This close association with cover is believed to be a mechanism for gaining shelter from currents and remaining in suitable reaches of stream over winter (Hartman, 1963). Bustard and Narver (1975a) found evidence that low overwinter survival of coho salmon and rainbow trout in one stream reflected low availability of suitable winter cover along the stream bank. Clearly, winter is a critical time for stream salmonids--a period when harsh environmental conditions and severe physiological stresses can greatly reduce fish populations. The availability of stable overhead bank cover may indeed become crucial to trout survival during this time.

SUMMARY AND CONCLUSIONS

Possible relationships between instream overhead bank cover and abundance of brook and/or brown trout were investigated on 2.4km of the Pigeon River and on 4.5km of the Salmon Trout River in Michigan's Lower and Upper Peninsulas, respectively. These streams differed in chemical content, hydrologic charactersitics, and fish species composition.

Numerous study stations, each about 100m long, were established on both rivers. Mark-and-recapture electrofishing was used to determine trout populations in July and October of 1976.

During August and September, when both rivers were at summer low flow, measurements were made of discharge and habitat characteristics. Maps showing channel width, thalweg location, thalweg depth, and bank cover were drawn for 12 Pigeon River stations and 18 Salmon Trout River stations. The length of overhead bank cover as defined by Wesche (1973, 1976) was measured in these stations. Bank cover was classified into three types: undercut banks, overhanging vegetation, and log cover.

In nearly all Pigeon River stations, brown trout were less numerous than brook trout, yet comprised the majority of the biomass. Total trout biomass/station in July ranged from 1.26-8.73kg. During October, trout were distributed more erratically, apparently for spawning. While number and biomass of legal-sized brook trout declined from July to October, total trout biomass/station in October ranged from 1.90-12.12kg.

Log jams and fallen trees comprised the majority of overhead bank cover in the Pigeon River. In many stations, however, undercut banks and overhanging vegetation provided substantial bank cover.

In Pigeon River stations, total length of overhead bank cover accounted for 44% of the variation in July number of brook trout $\geq$150mm, 66% of the variation in July number of brown trout $\geq$150mm, and 88% of the variation in July number of all trout $\geq$150mm. Length of bank cover also explained 38% of the variation in July biomass of brook trout $\geq$150mm. A significant relationship between bank cover and July biomass of brown trout $\geq$150mm could only be obtained by excluding fish $\geq$400mm in length from the analysis, thereby yielding an r^2 of 0.54. The length of overhead bank cover/ station explained 72% of the variation in July biomass of all trout 150-399mm/station.

For October brook trout $\geq$150mm in the Pigeon River, bank cover abundance accounted for 68% of the variation in numerical density and 65% of the variation in biomass. Interferences resulting from upstream spawning migration are believed to explain the lack of significant correlation between length of bank cover and number or biomass of brown trout $\geq$150mm in October.

In the Salmon Trout River, brook trout populations were very sparse below Lower Falls. The greatest July brook trout biomass/station in this area was 1.10kg. A few small rainbow trout and several very large lake-run rainbows were also present. Above Lower Falls, brook trout were more abundant, but there were few fish exceeding 250mm in length. Total biomass/station in July ranged from 0.22-3.44kg.

In October, the presence of spawning immigrants from Lake Superior increased the number and biomass of brook trout below Lower Falls. Brook trout biomass/station ranged from 0-2.88kg. Several large coho salmon, two large brown trout, and numerous fingerling cohos and browns were also present. Above Lower Falls, October brook trout biomass/station ranged from 0.27-3.00kg.

Log cover was the predominant type of overhead bank cover in the Salmon Trout River, but was much less abundant than in the Pigeon River. Undercut banks and overhanging vegetation were also present in much of the study area.

Correlations between brook trout abundance and length of bank cover in the Salmon Trout River were generally stronger when stations below Lower Falls were omitted from the analysis. For July populations of brook trout $\geq$150mm, total length of overhead bank cover accounted for 72-83% of variation in number and 62-69% of variation in biomass in stations above Lower Falls. For October brook trout $\geq$150mm, bank cover abundance explained 78% of the variation in number and 88% of the variation in biomass, again in stations above Lower Falls.

Several strong correlations between amount of bank cover and trout abundance were demonstrated in combined analyses of Pigeon River and Salmon Trout River data. Length of bank cover accounted for 76% of the variation in July number of all trout ≥150mm, 81% of the variation in July biomass of all trout 150-399mm, and 80% of the variation in October number of all trout ≥150mm in the Pigeon River and Salmon Trout River above Lower Falls.

These results indicate that overhead bank cover provides an important element in the habitat of brook and brown trout larger than 150mm. The strong correlations between abundances of cover and trout suggest that bank cover is the major factor limiting trout populations in both streams, despite differences in chemical, biological, and hydrological characteristics.

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LITERATURE CITED

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APPENDICES

APPENDIX A

RAINBOW TROUT, BROWN TROUT, AND COHO SALMON IN THE SALMON TROUT RIVER IN 1976

TABLE A1.--Estimates of rainbow trout populations in the Salmon Trout River in 1976

Total Length	100-149mm		150-199mm		200-249mm		≥250mm (length)
Month	Jun	Oct	Jun	Oct	Jun	Oct	Jun
Sta							
1		1					
2	1						
3		1	1				
4		1	1				
5		1					1(587)
6	1						
7							
8	1	3				1	3(270,405,618)
9			1				
10			1				
11							
12			3				
13	1						
14							
15	1					1	
16,17	1		5	2		1	
18							
19		3		1			
Total	6*	10	12	3*	0	3*	4*

*Actual number of fish captured

TABLE A2.--Estimates of brown trout and coho salmon populations in the Salmon Trout River in October, 1976

Sta	Brown Trout (Total Length)	Coho Salmon--Total Length		
		100-149mm	150-199mm	≥200mm (length)
1	1(103)	16		
2		29		
3		24		
4		73		
5	1(540)	90		1(605)
6		24		
7		69	1	
8		24		
9		102		1(530)
10		24		
11		106		1(577)
12		8		
13		33		
14	1(645)	16		
15		53		
16		53		2(350,570)
17		81		
18		29		
19		16		
Total	3*	870	1*	5*

*Actual number of fish captured

APPENDIX B

HABITAT MAPS FOR TWELVE STATIONS

ON THE PIGEON RIVER, MICHIGAN

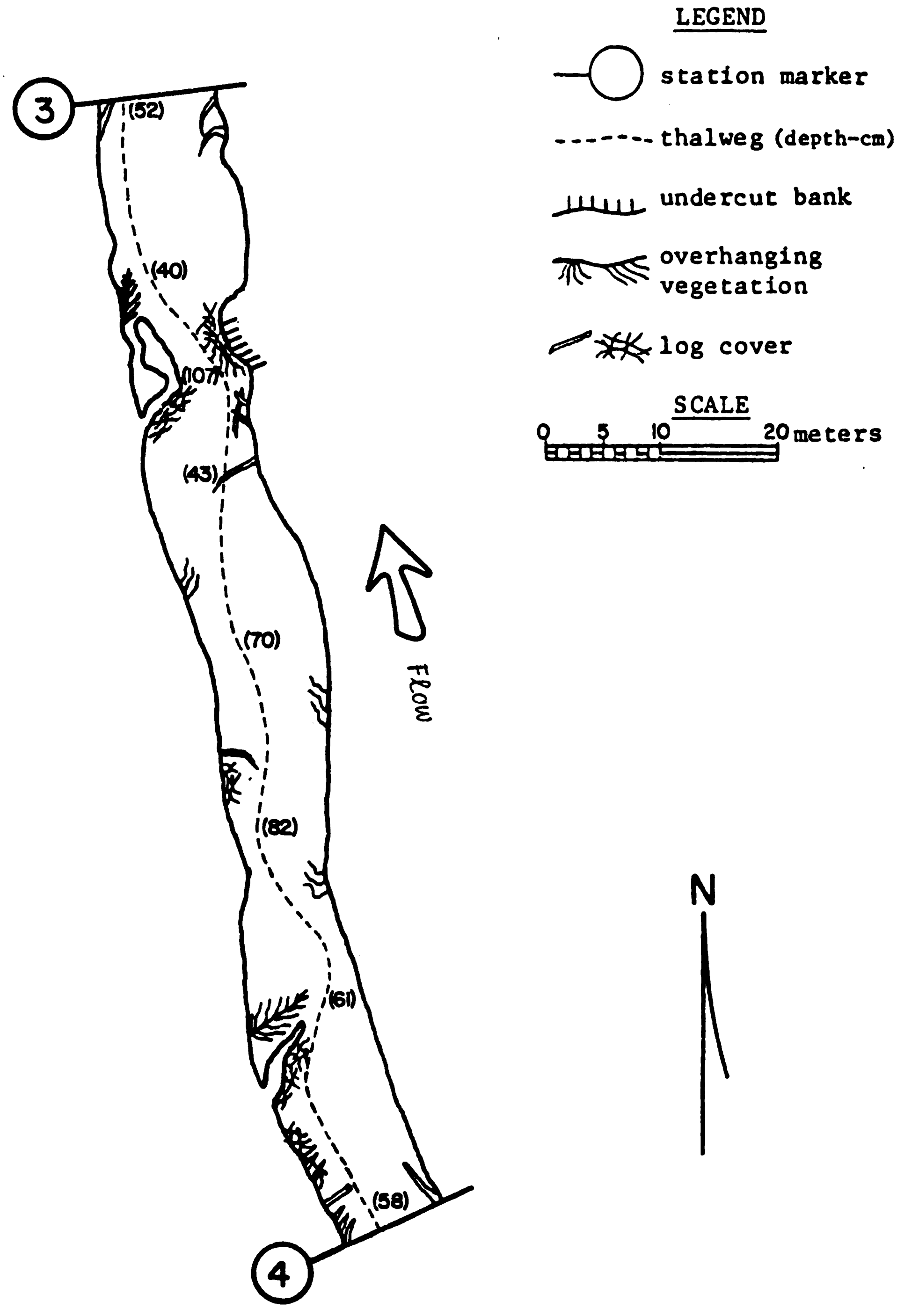

Figure B1. Pigeon River Station 3.

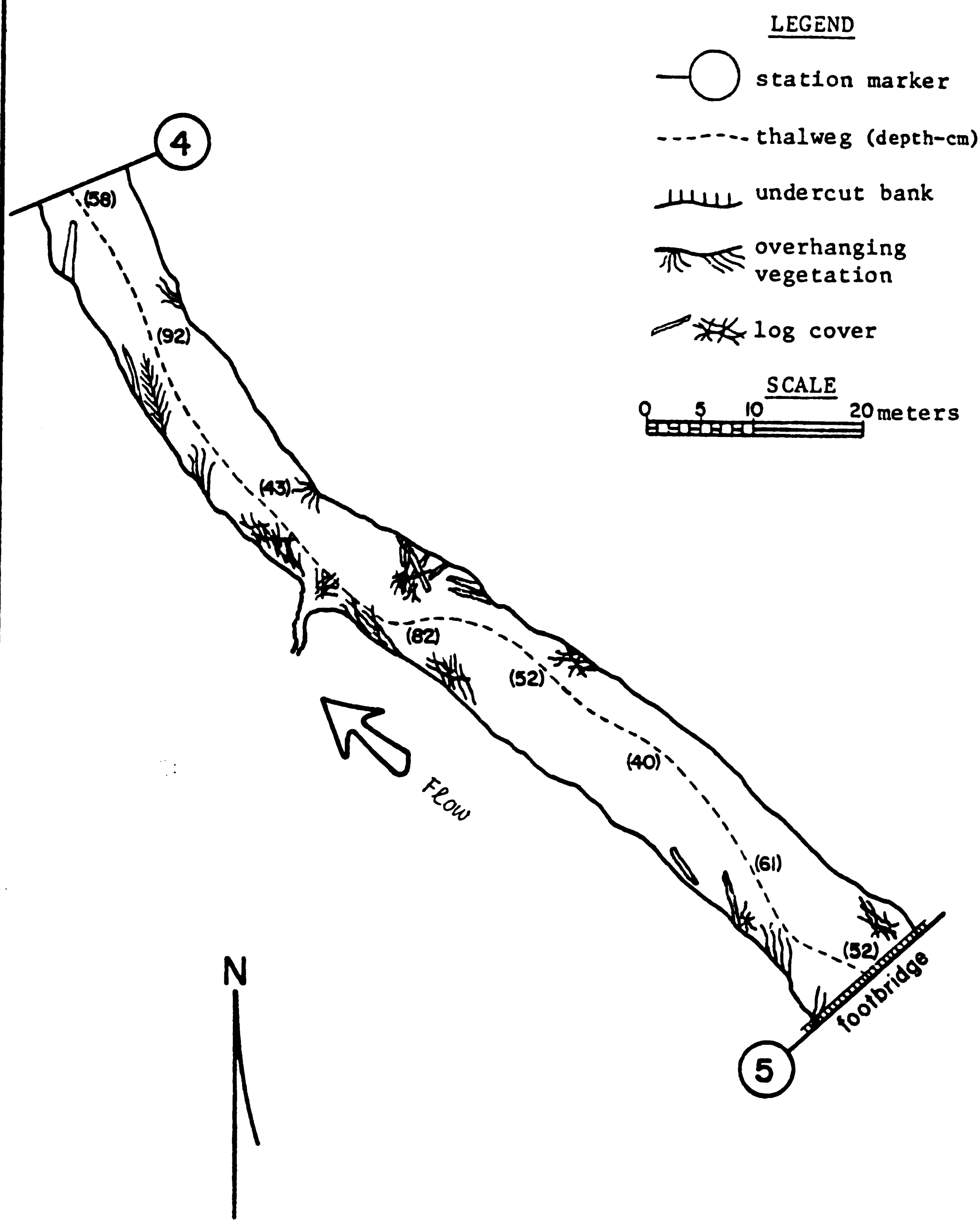

Figure B2. Pigeon River Station 4.

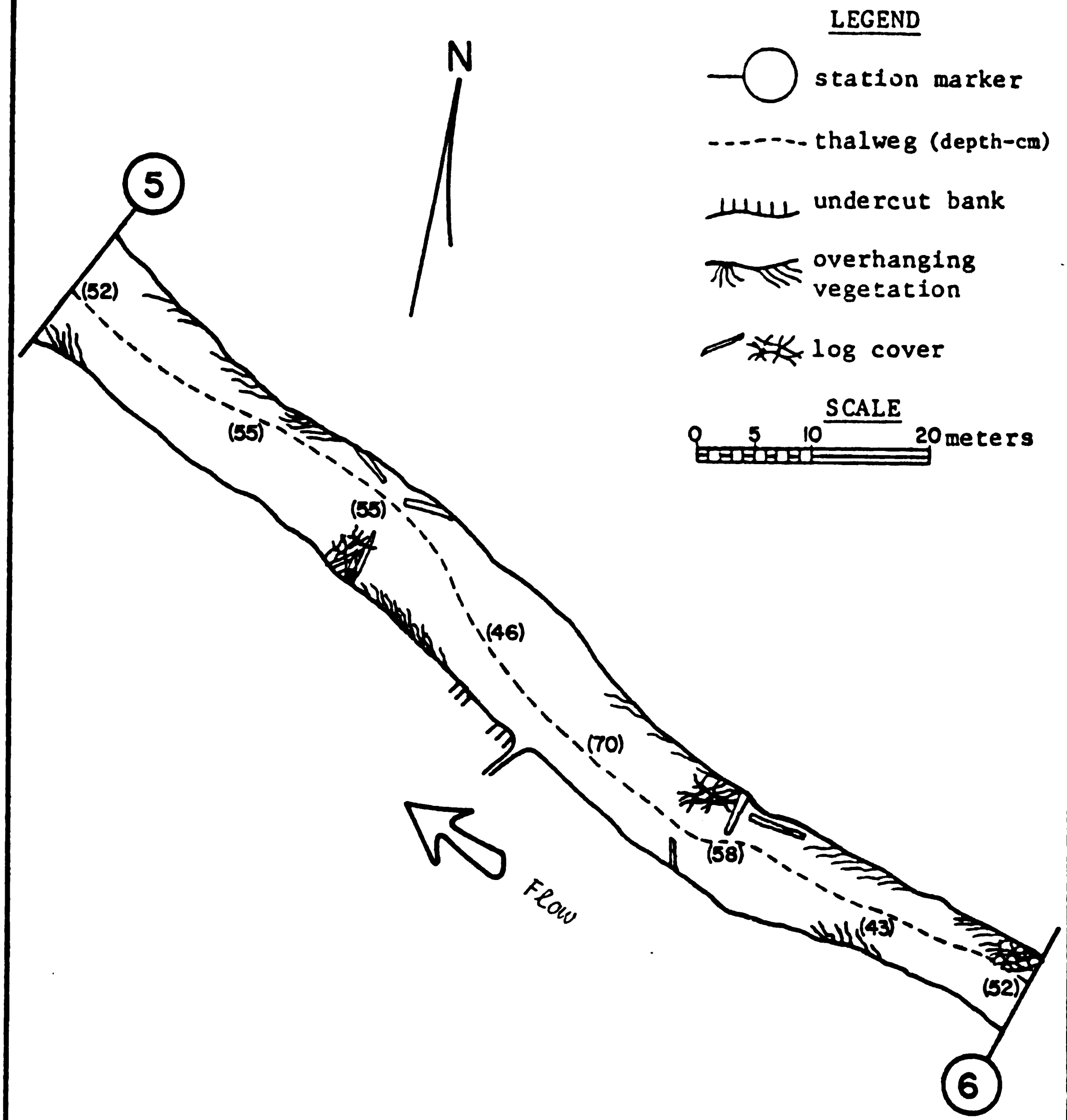

Figure B3. Pigeon River Station 5.

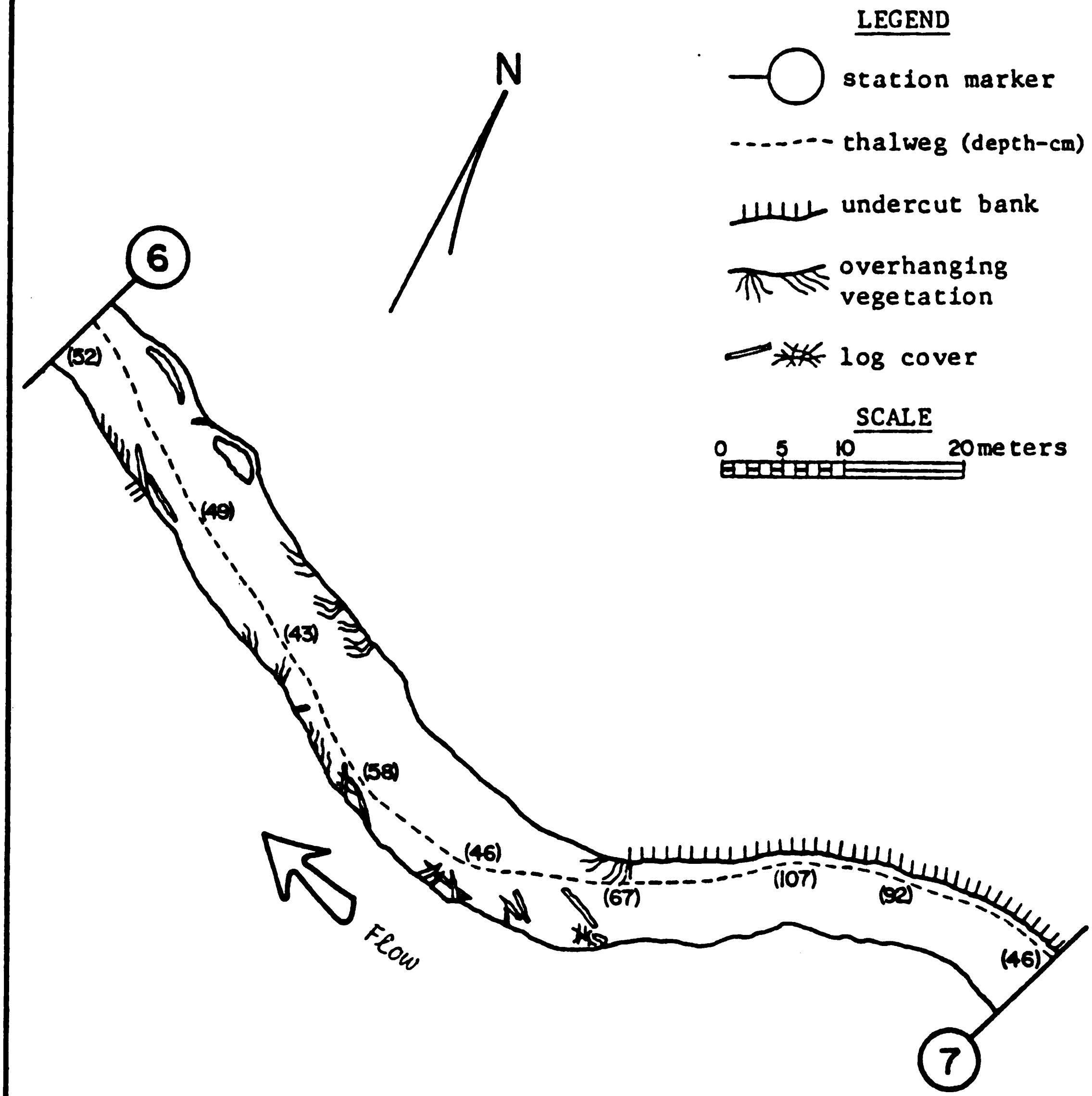

Figure B4. Pigeon River Station 6.

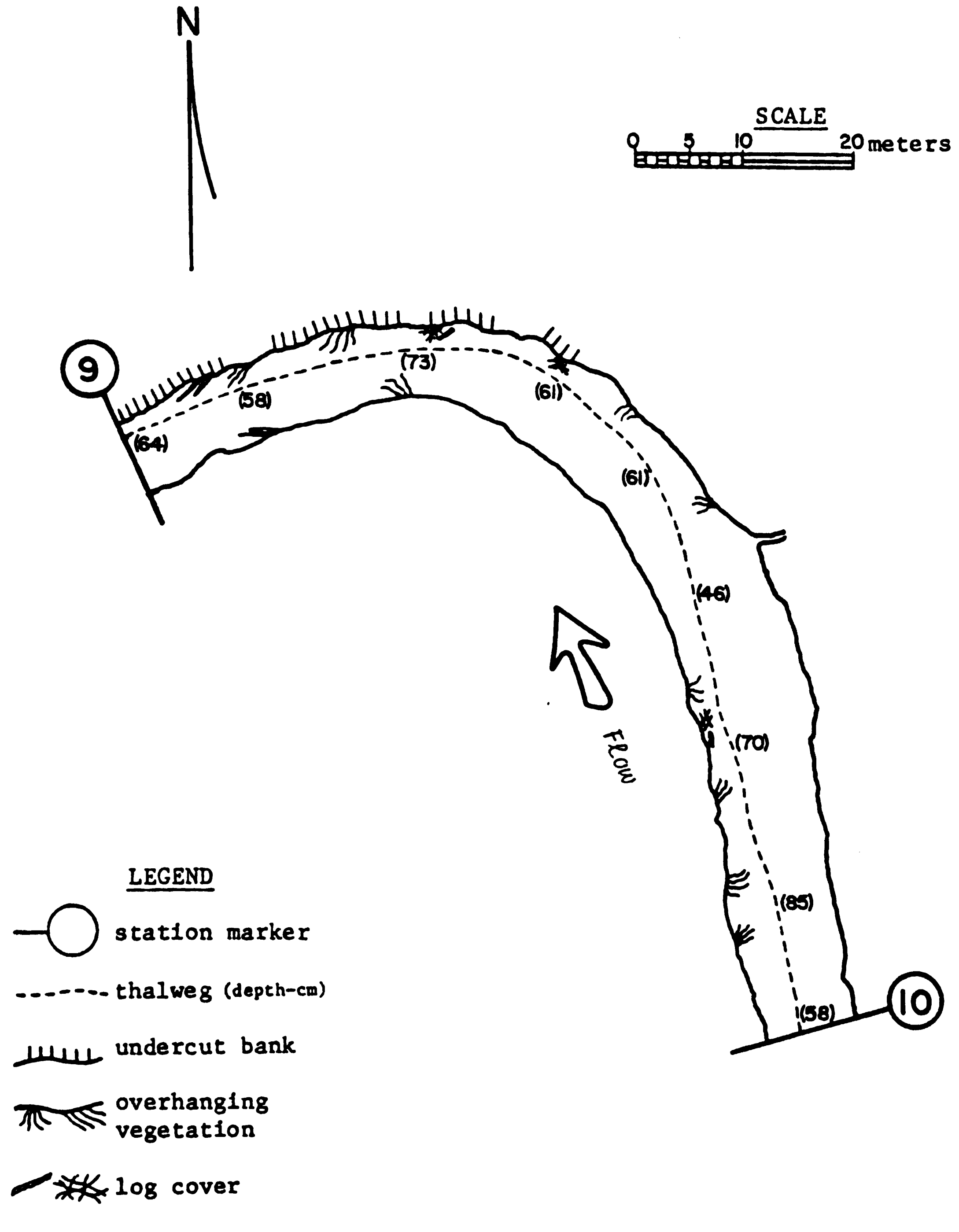

Figure B5. Pigeon River Station 9.

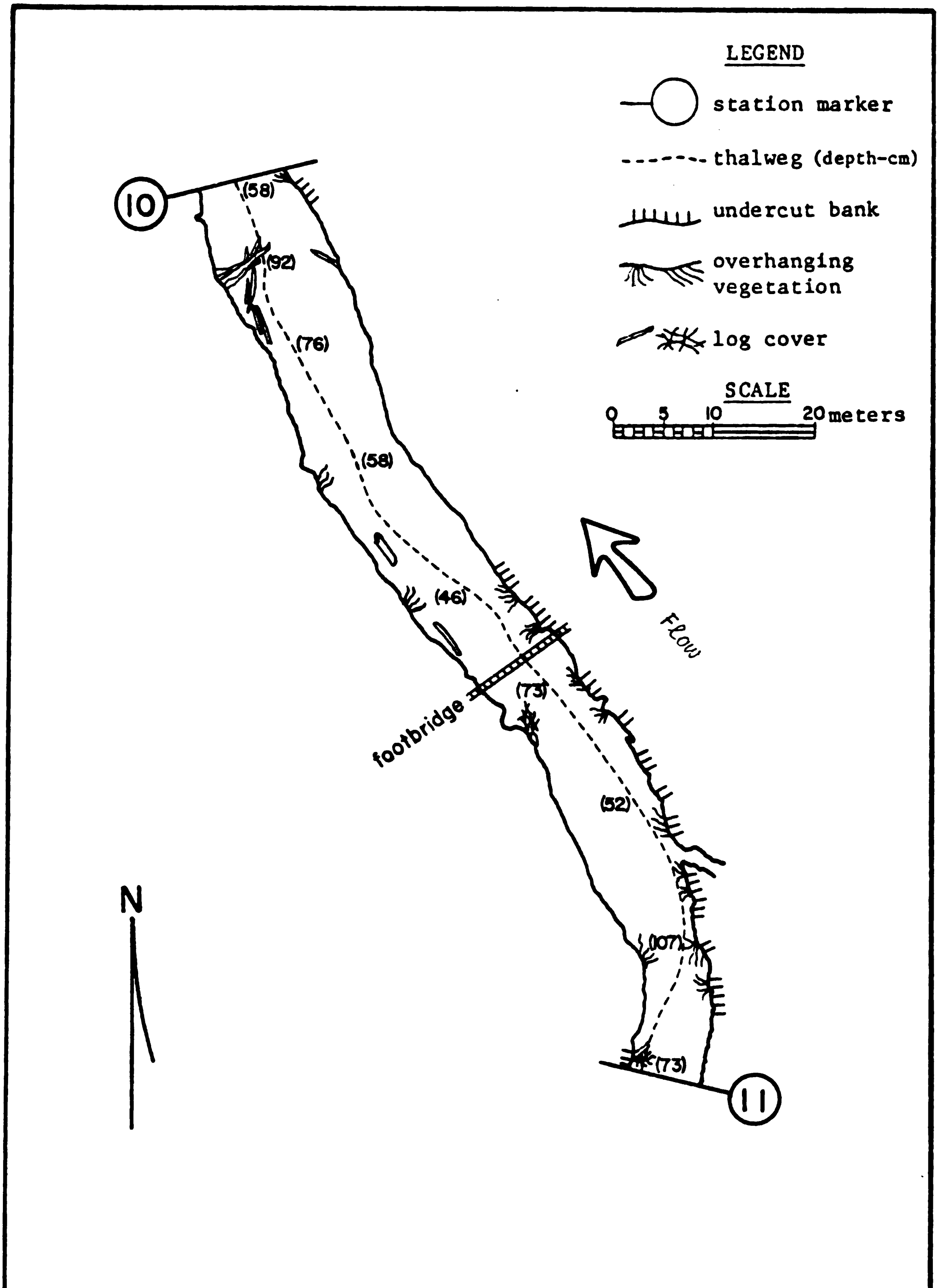

Figure B6. Pigeon River Station 10.

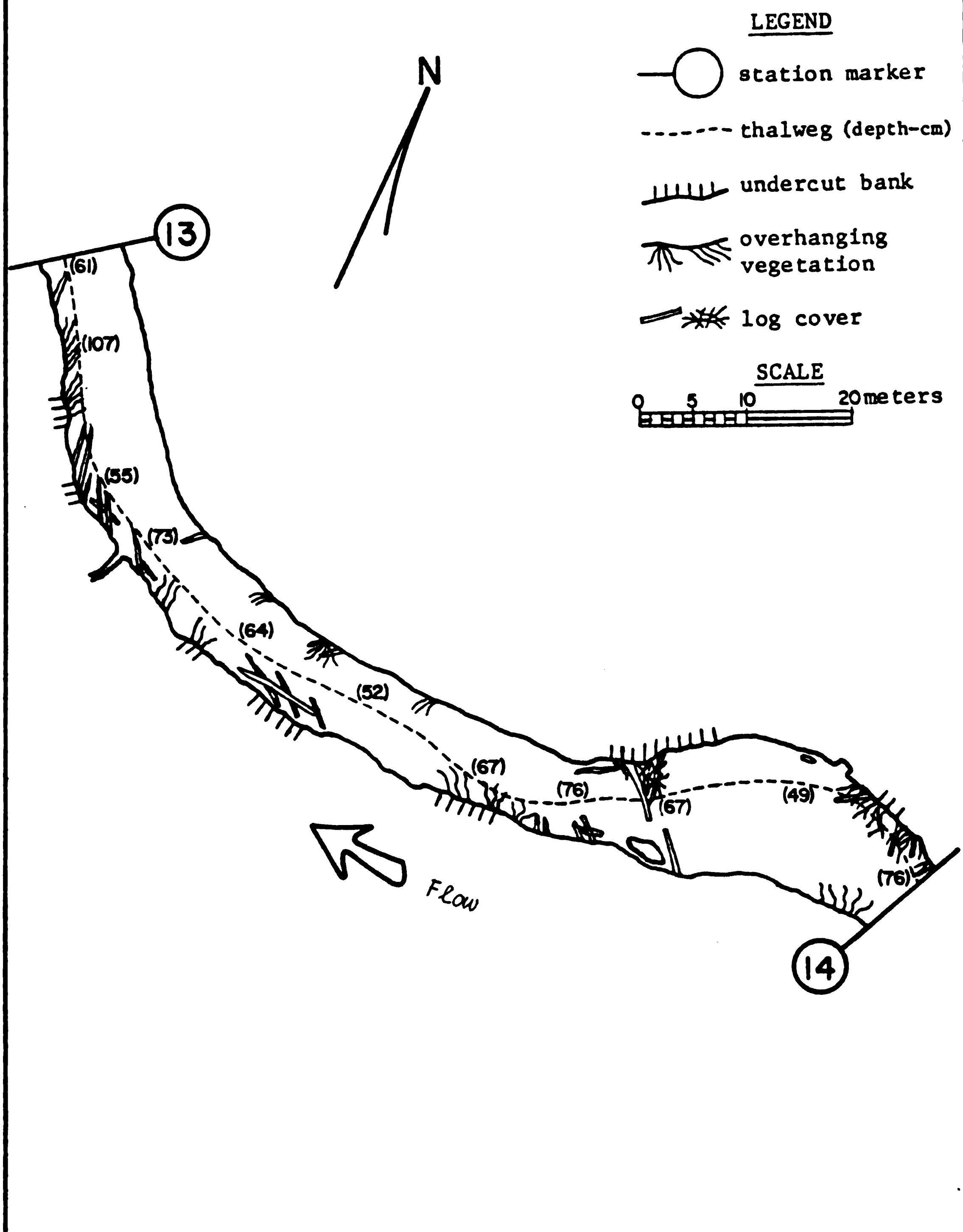

Figure B7. Pigeon River Station 13.

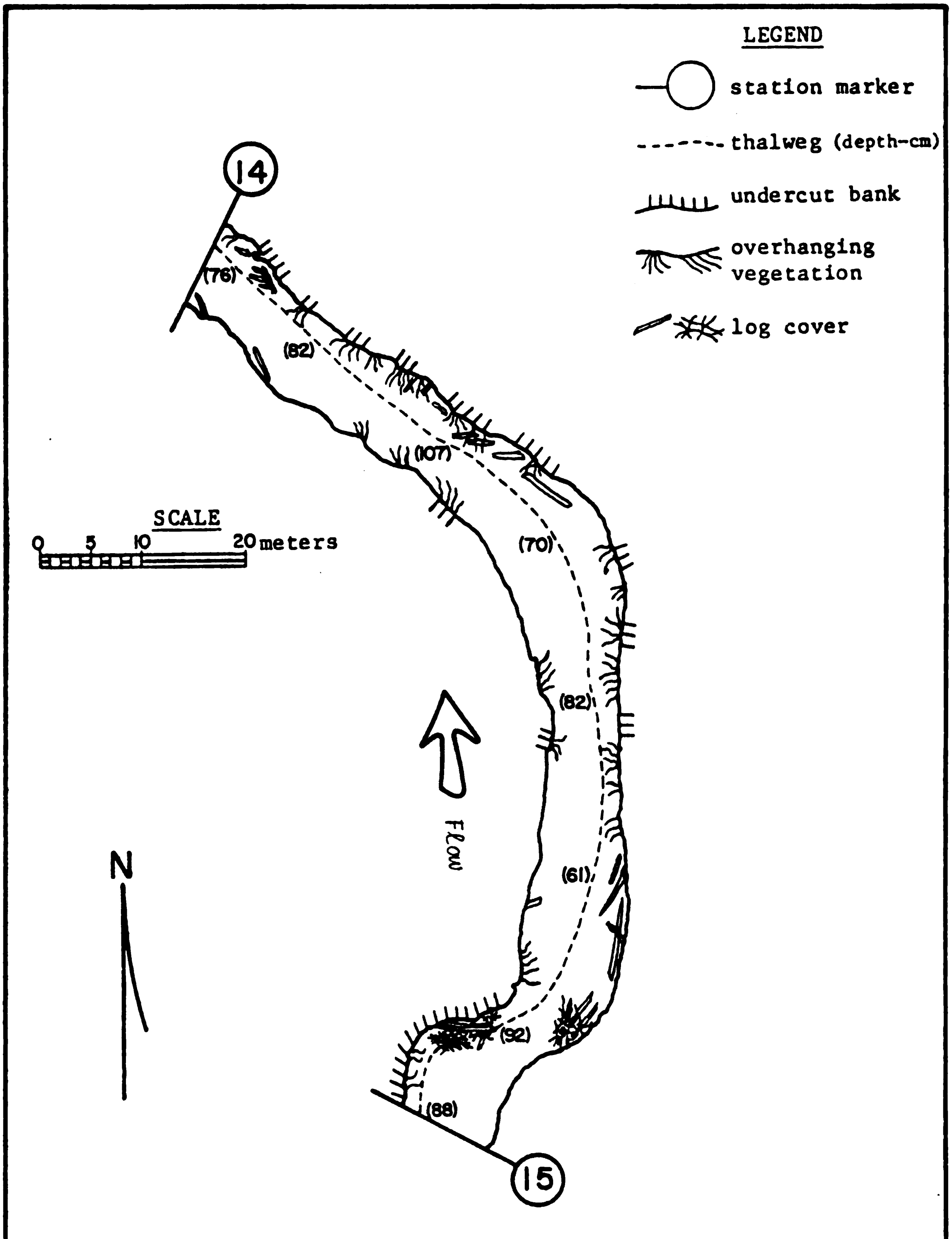

Figure B8. Pigeon River Station 14.

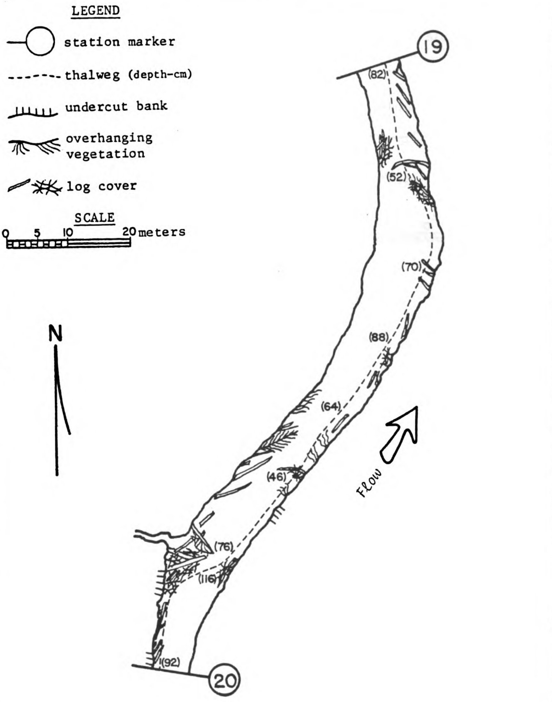

Figure B9. Pigeon River Station 19.

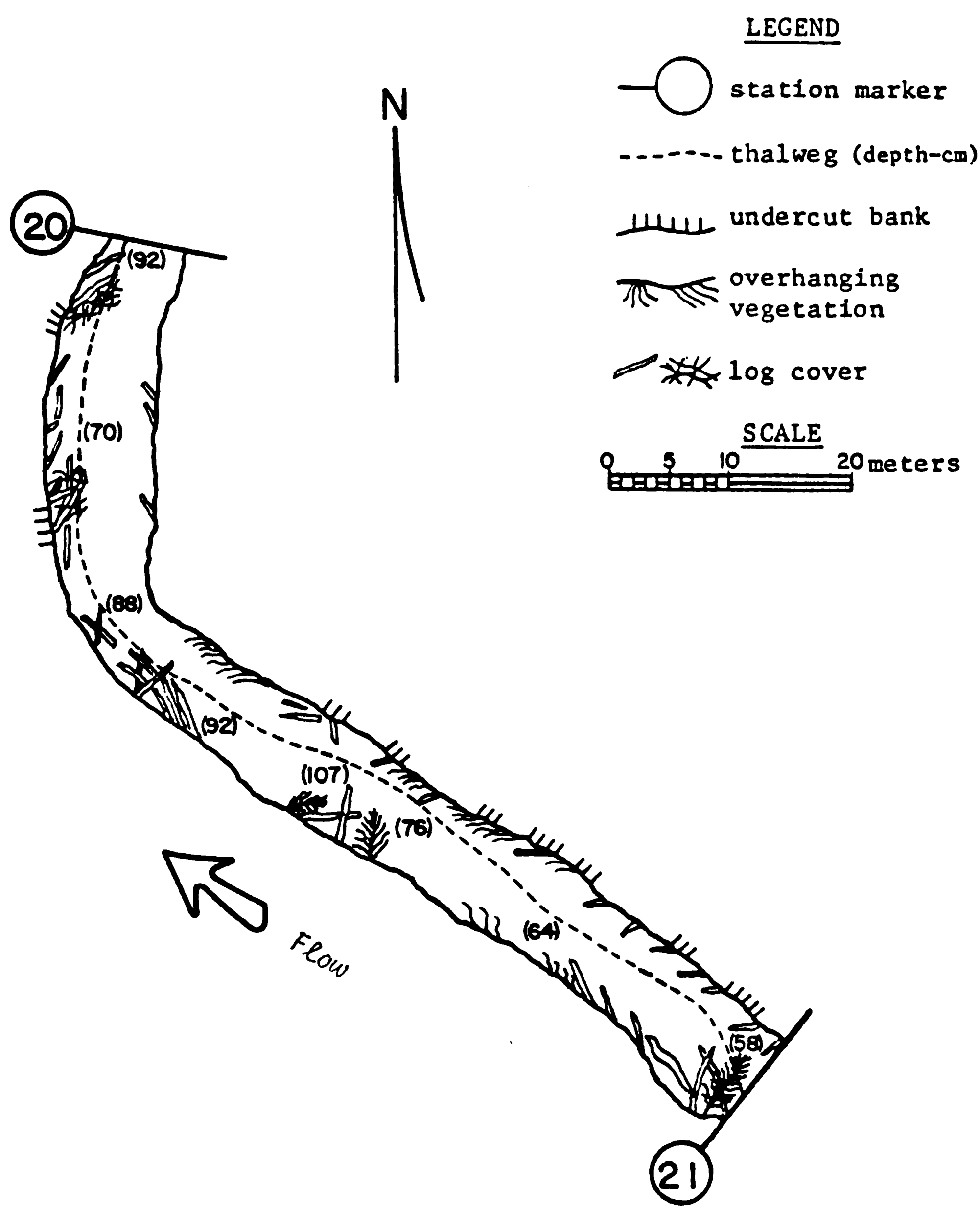

Figure B10. Pigeon River Station 20.

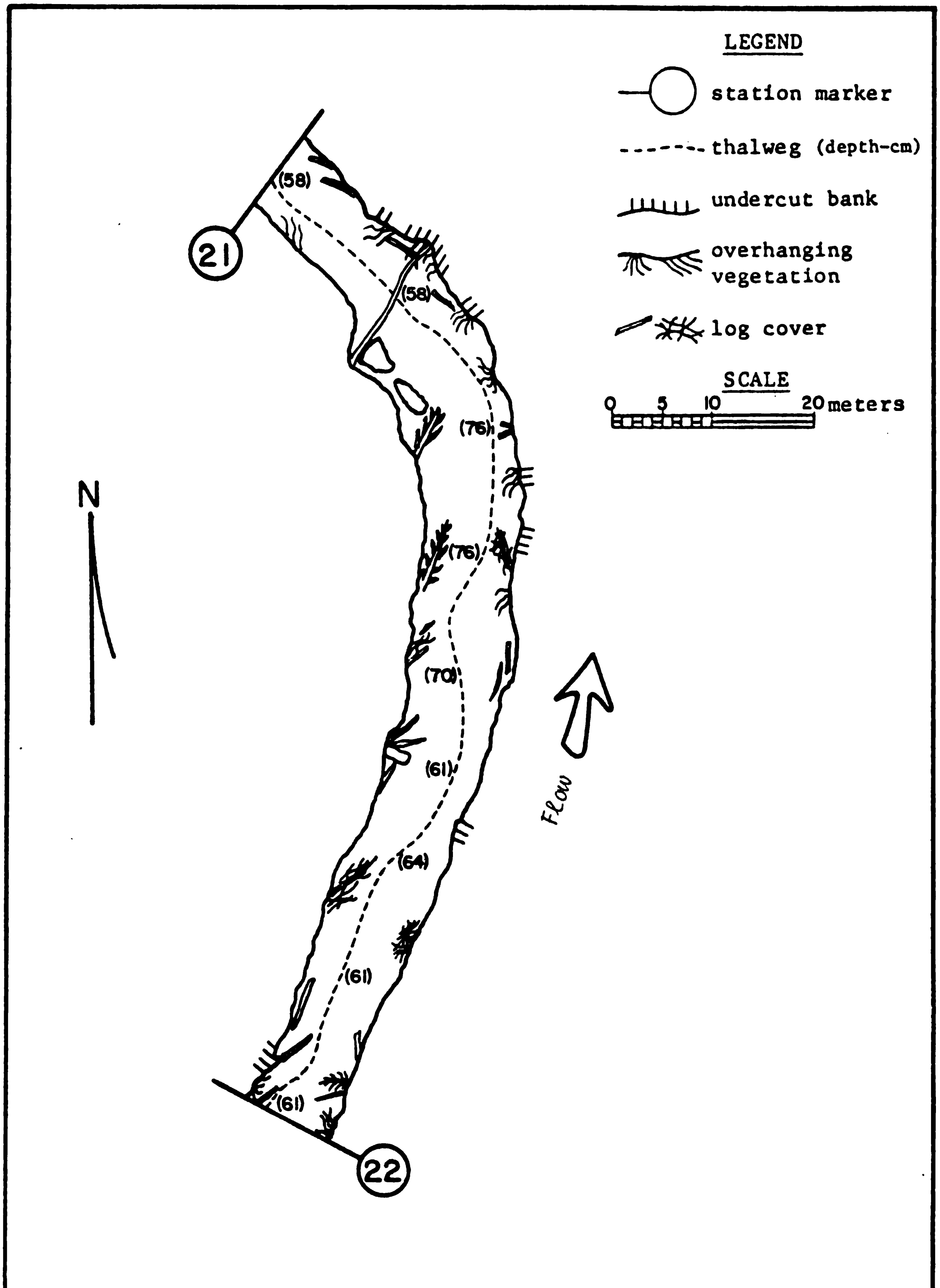

Figure B11. Pigeon River Station 21.

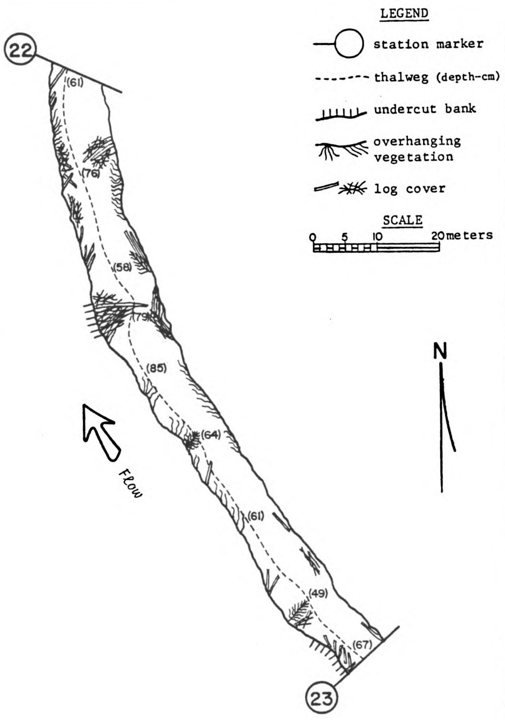

Figure B12. Pigeon River Station 22.

APPENDIX C

HABITAT MAPS FOR EIGHTEEN STATIONS ON THE SALMON TROUT RIVER, MICHIGAN

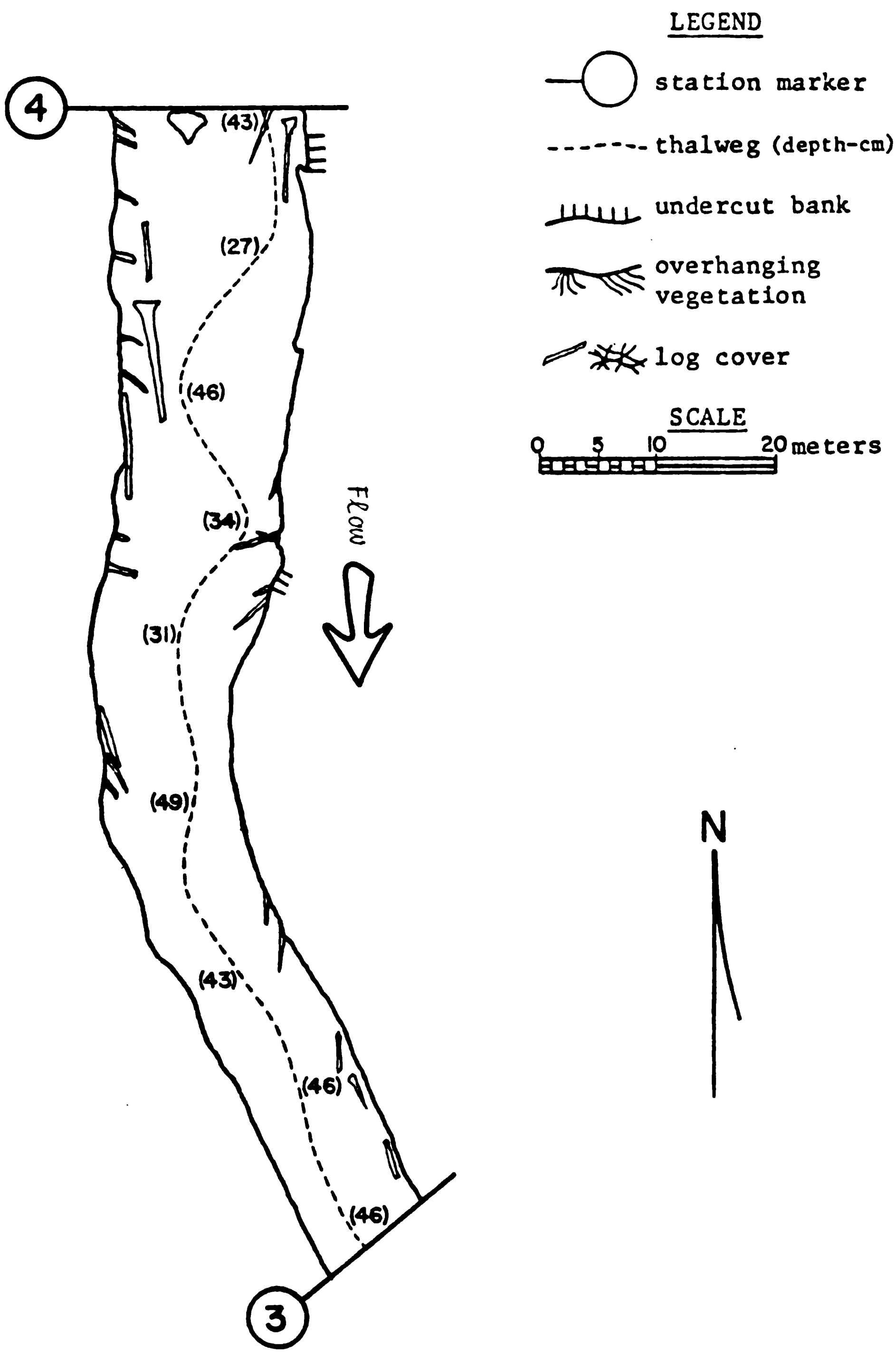

Figure C1. Salmon Trout River Station 3.

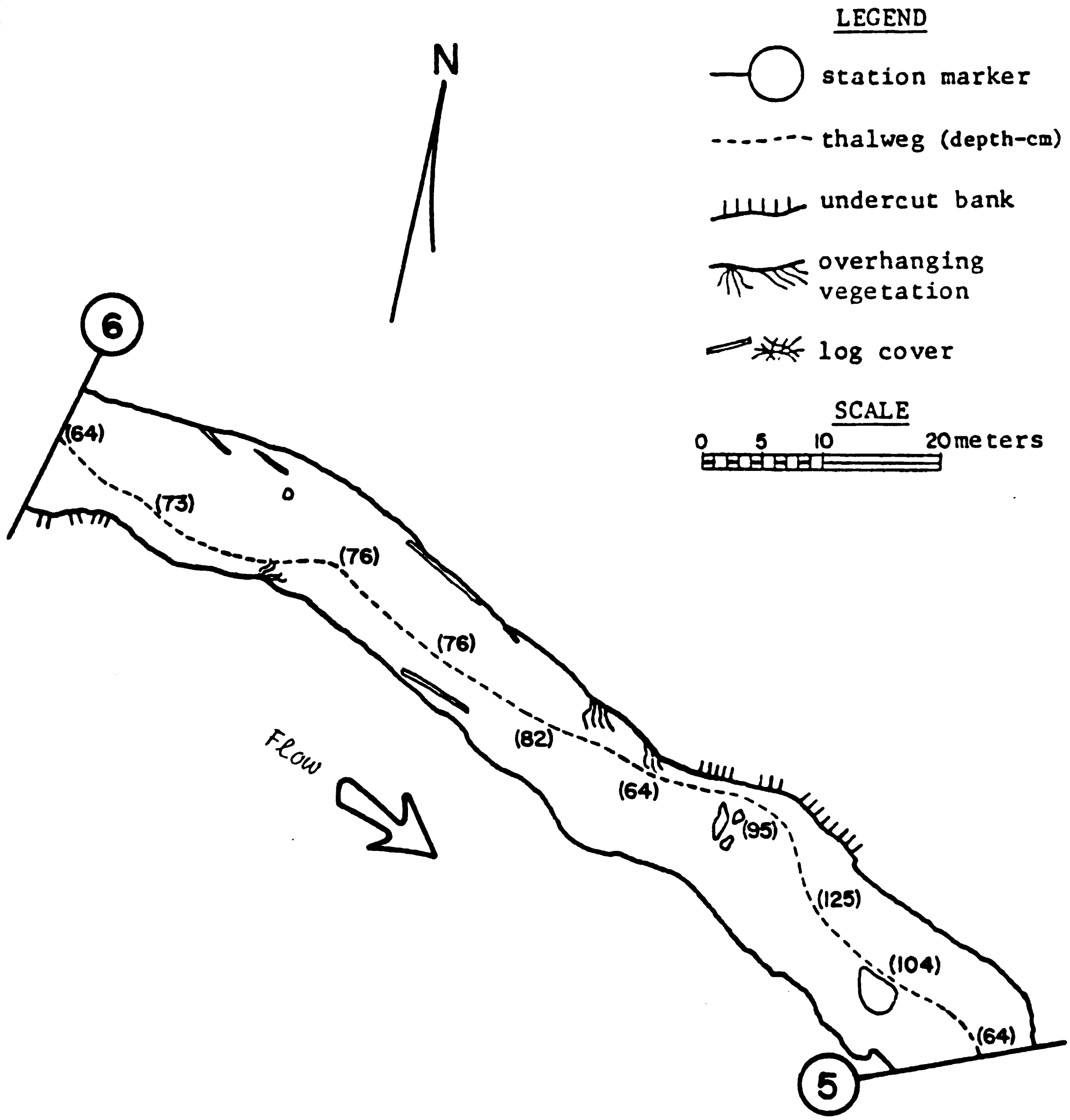

Figure C2. Salmon Trout River Station 5.

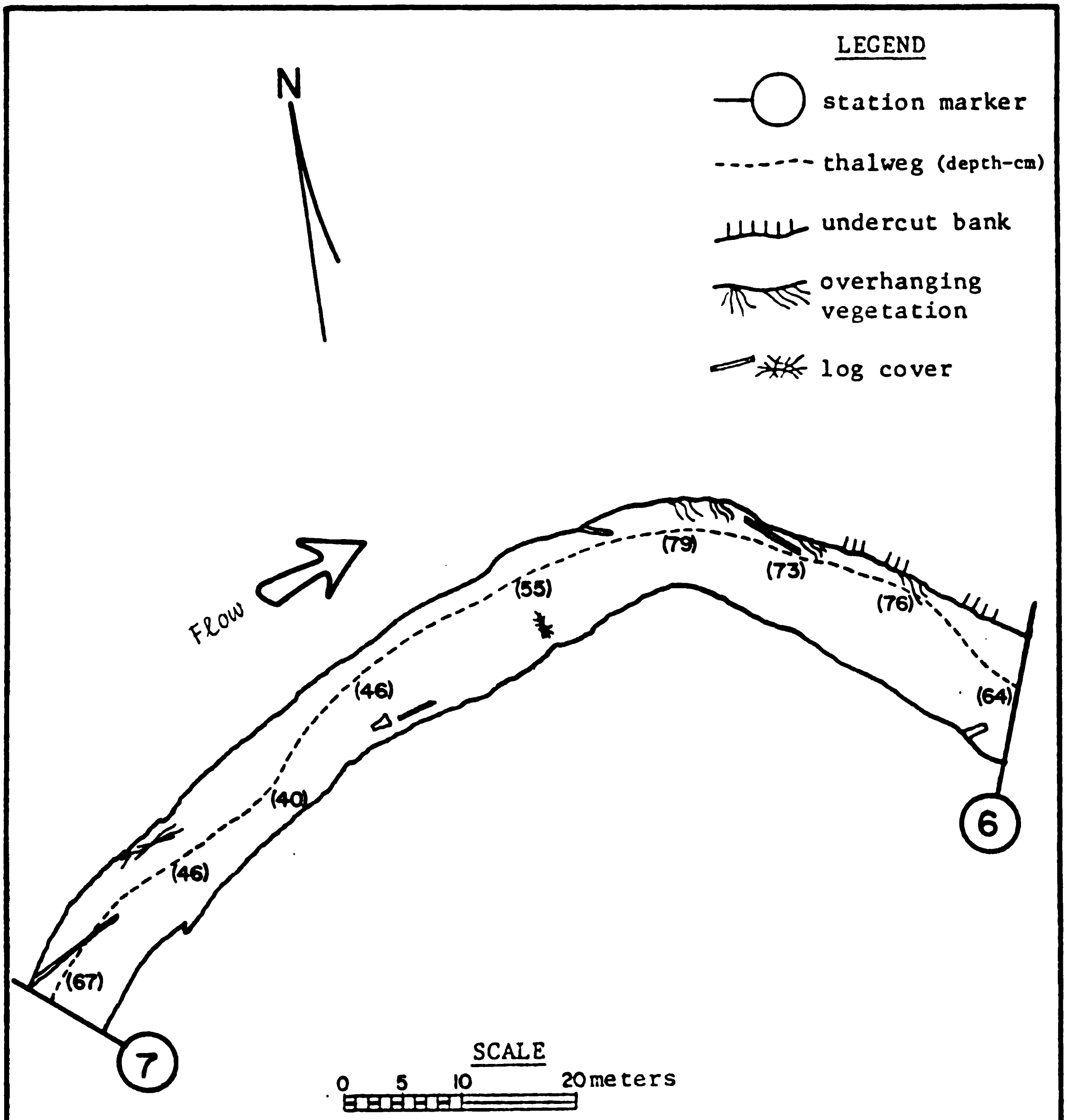

Figure C3. Salmon Trout River Station 6.

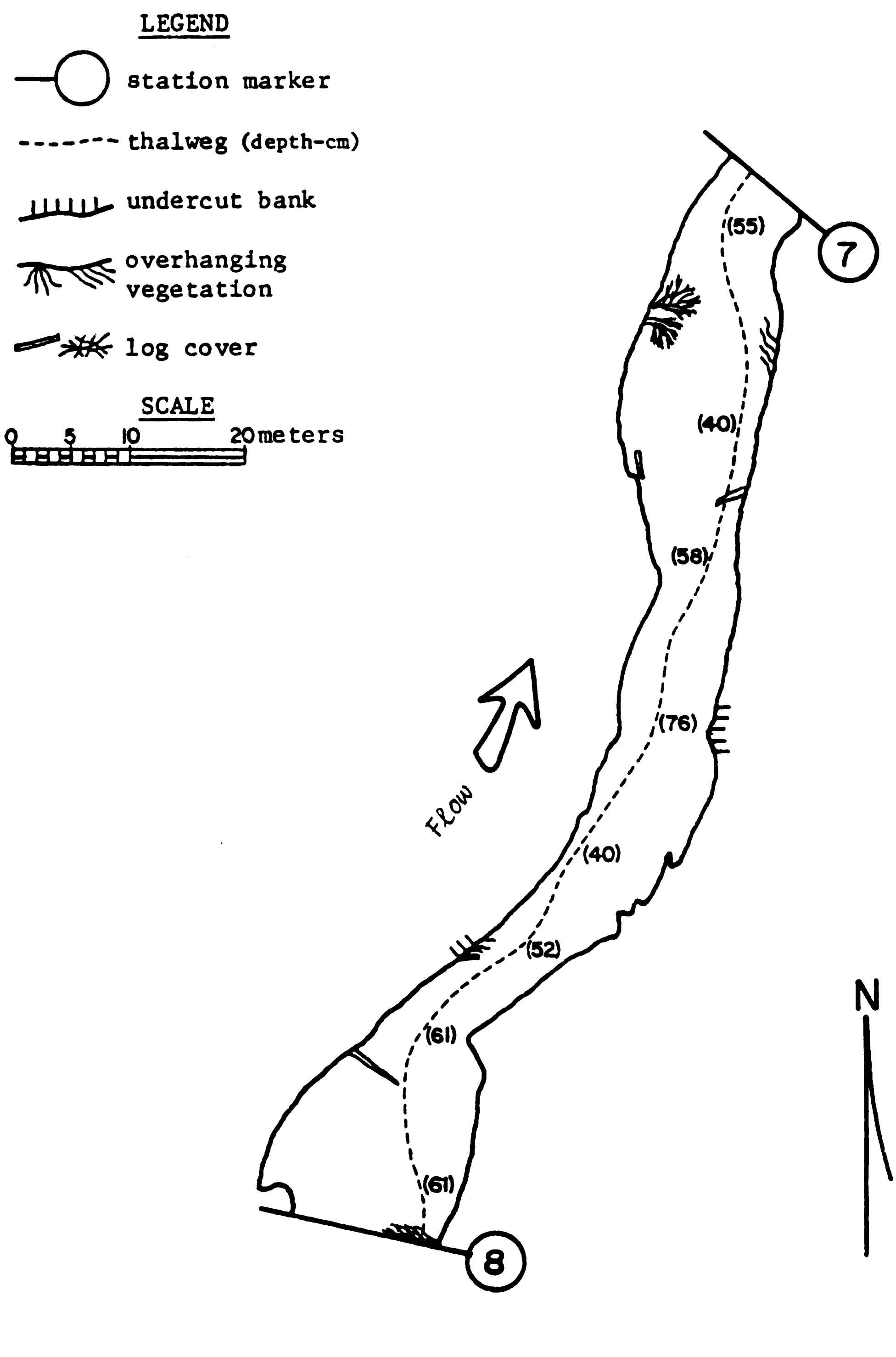

Figure C4. Salmon Trout River Station 7.

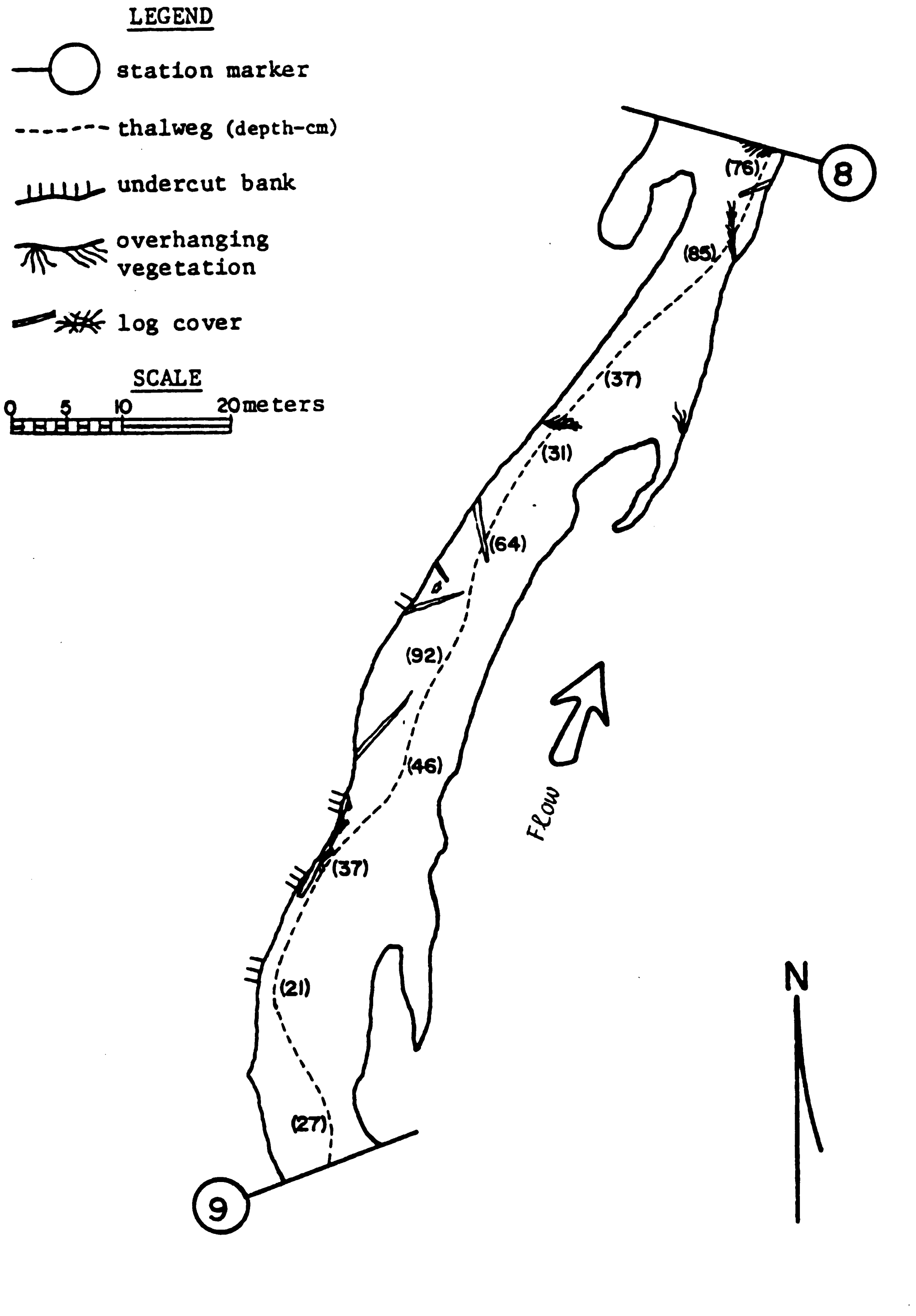

Figure C5. Salmon Trout River Station 8.

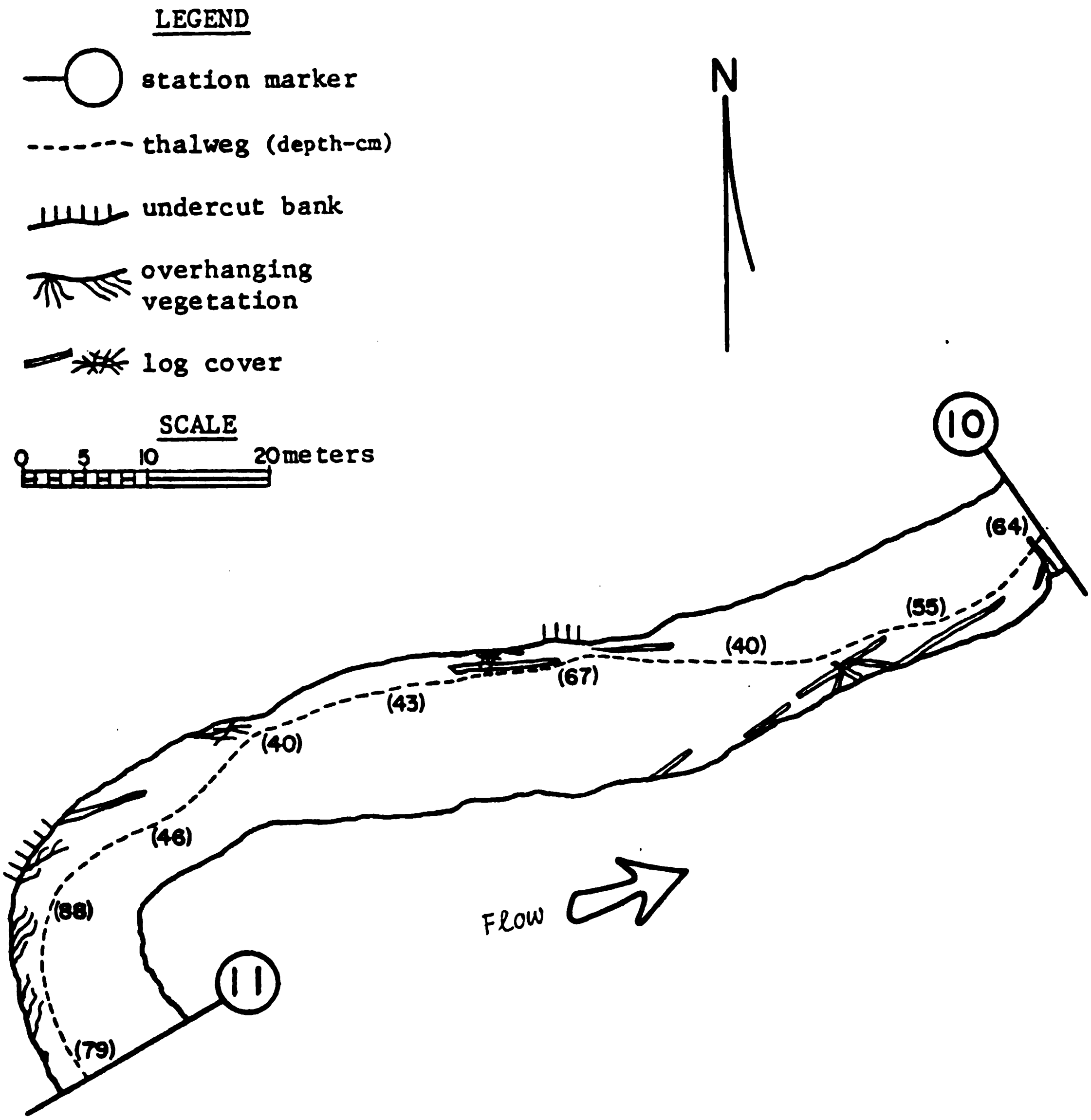

Figure C6. Salmon Trout River Station 10.

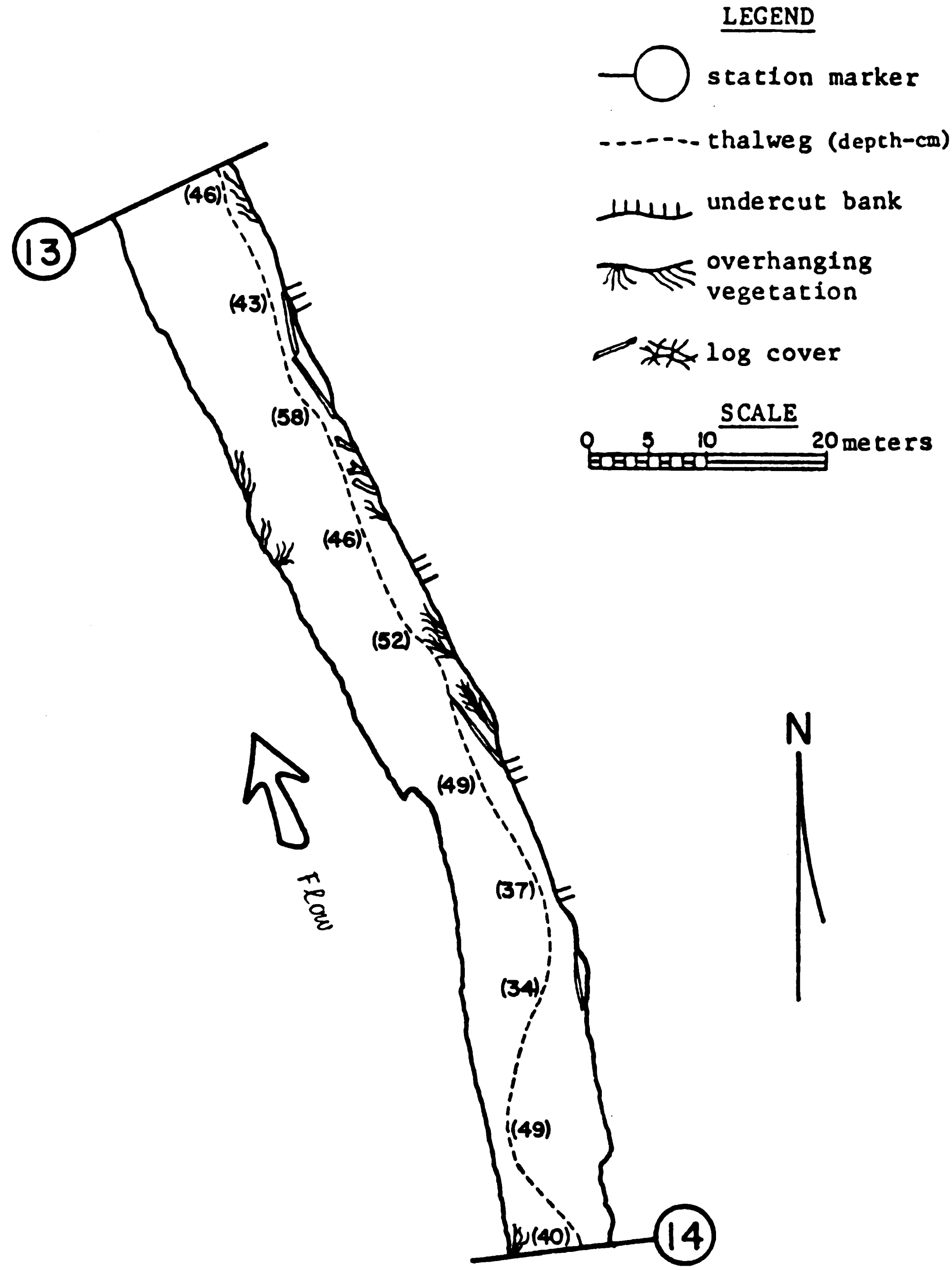

Figure C7. Salmon Trout River Station 13.

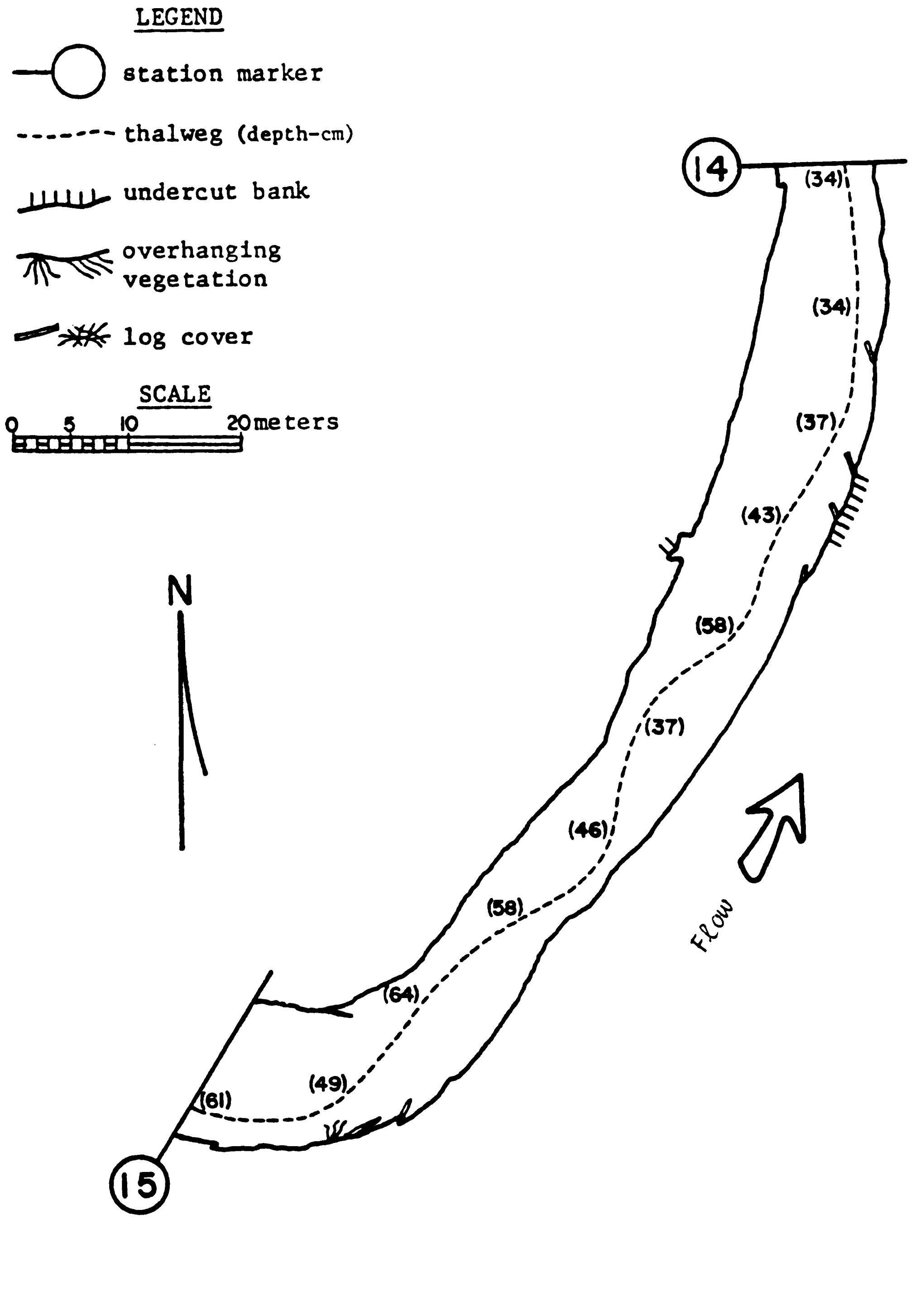

Figure C8. Salmon Trout River Station 14.

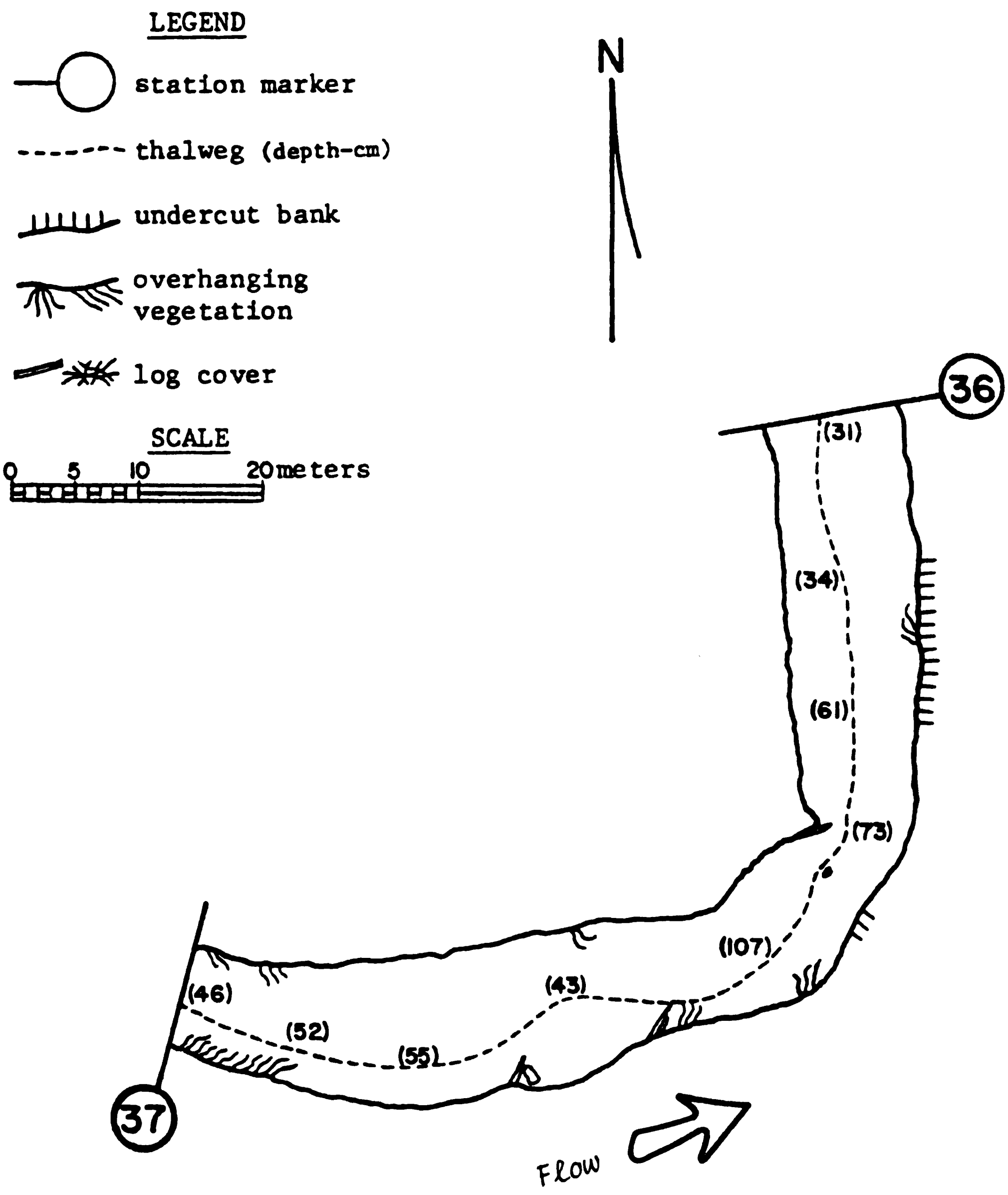

Figure C9. Salmon Trout River Station 36.

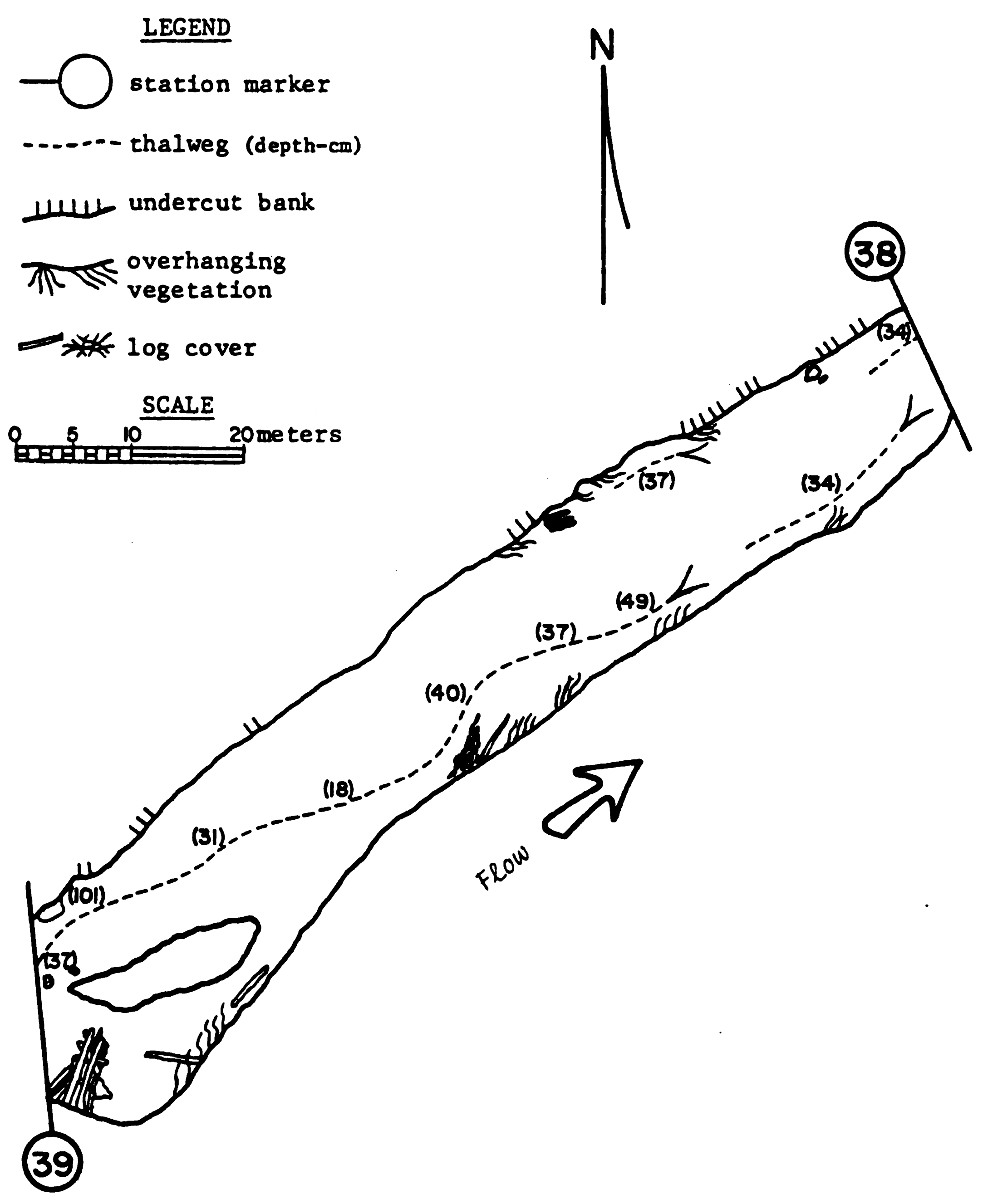

Figure C10. Salmon Trout River Station 38.

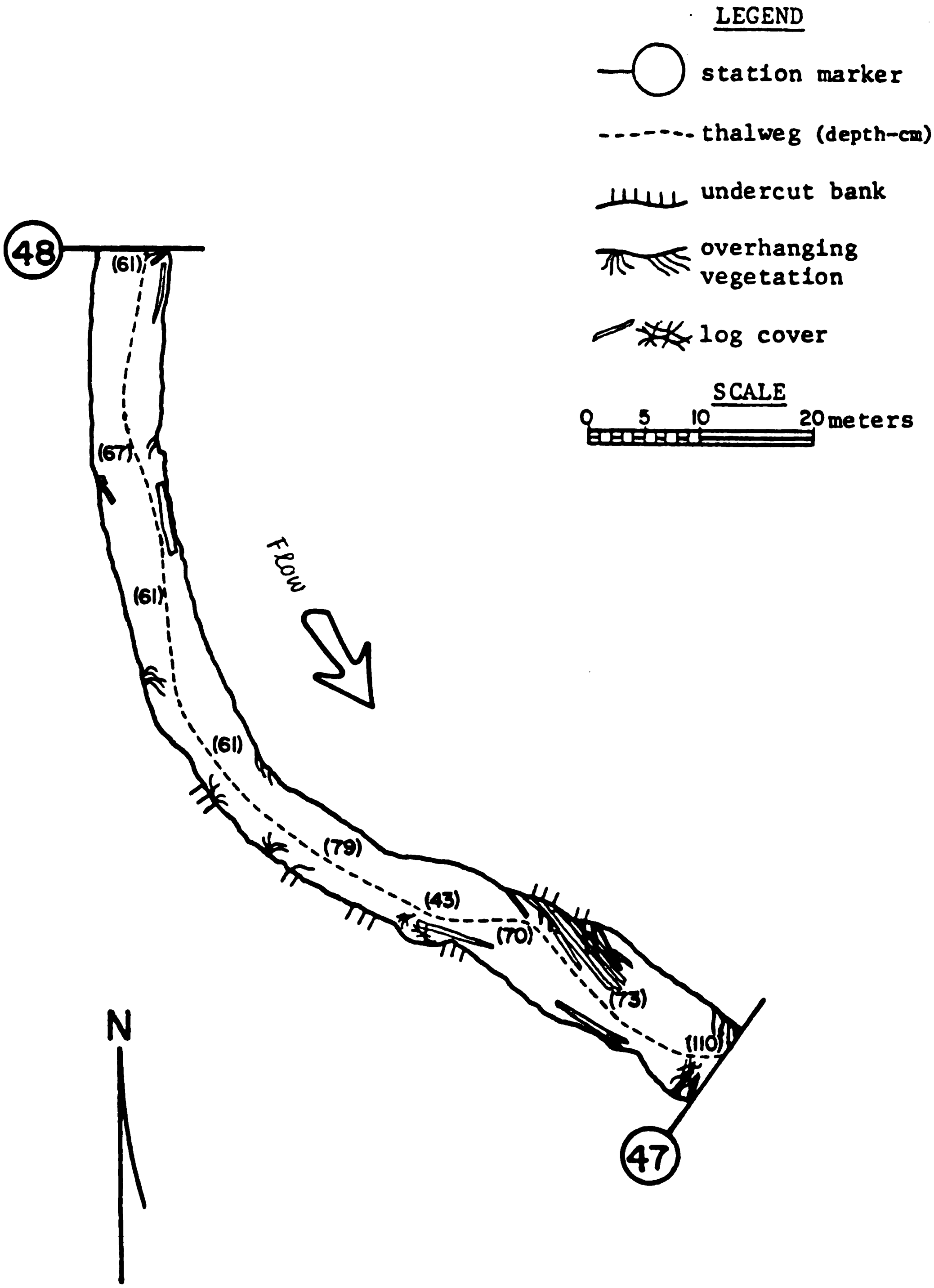

Figure C11. Salmon Trout River Station 47.

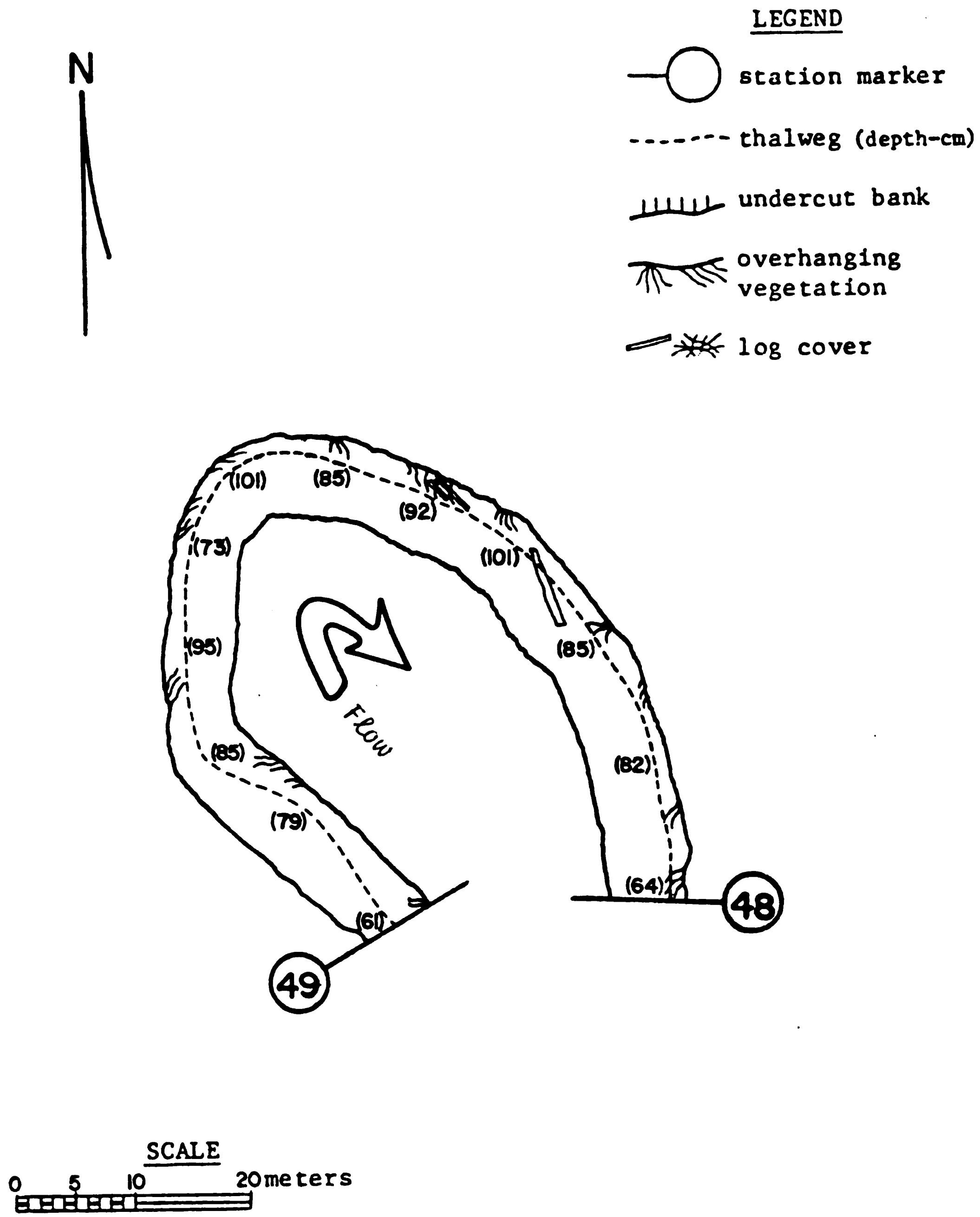

Figure C12. Salmon Trout River Station 48.

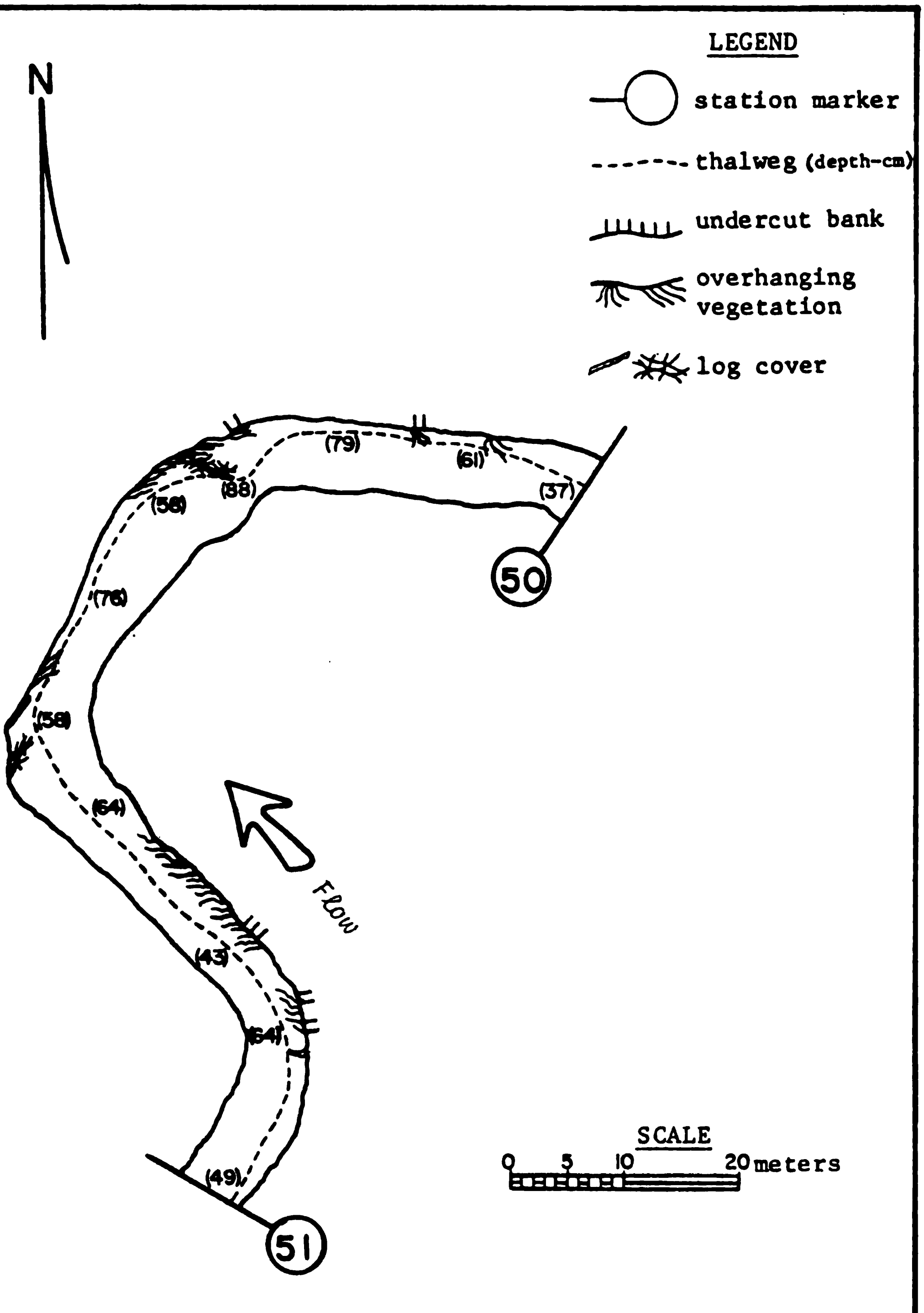

Figure C13. Salmon Trout River Station 50.

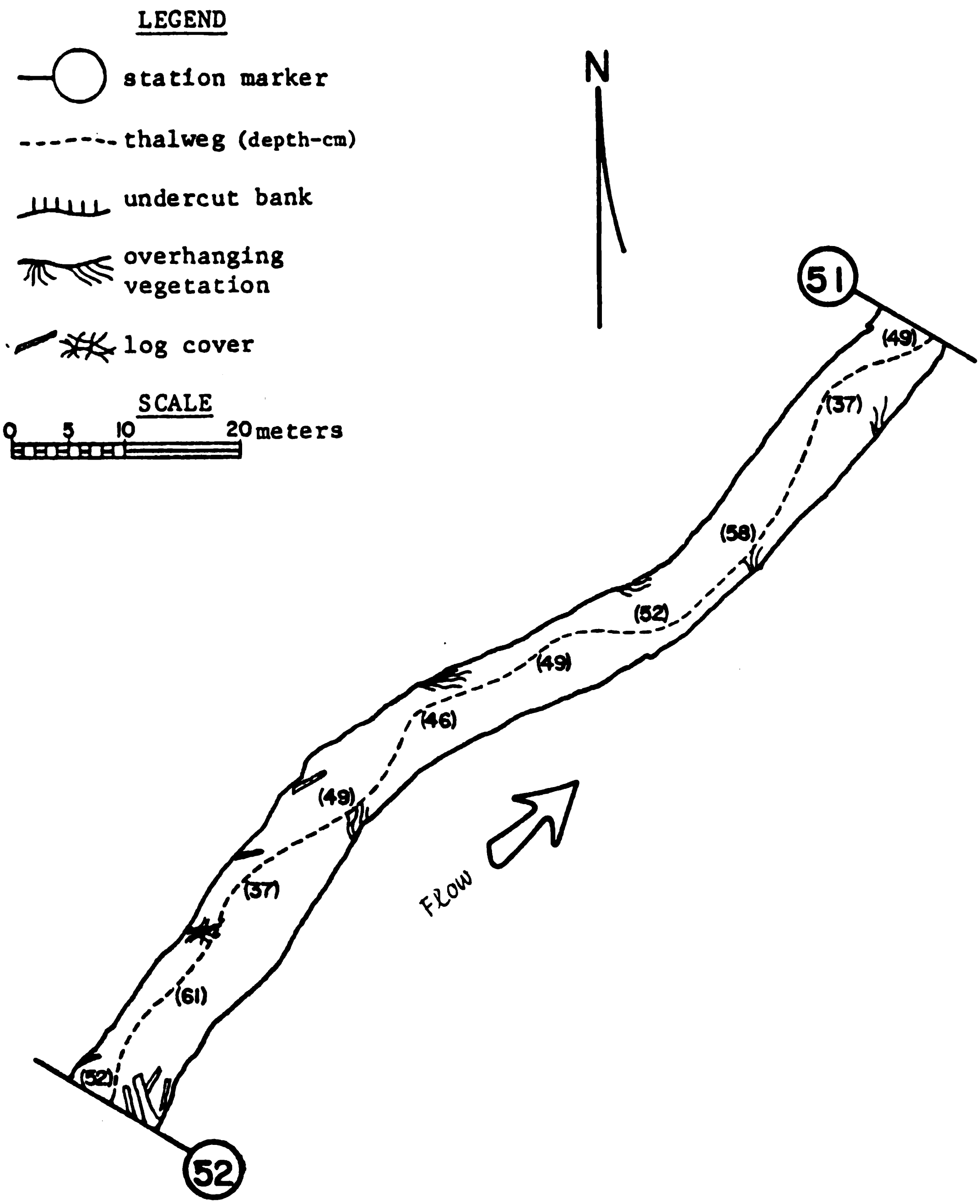

Figure C14. Salmon Trout River Station 51.

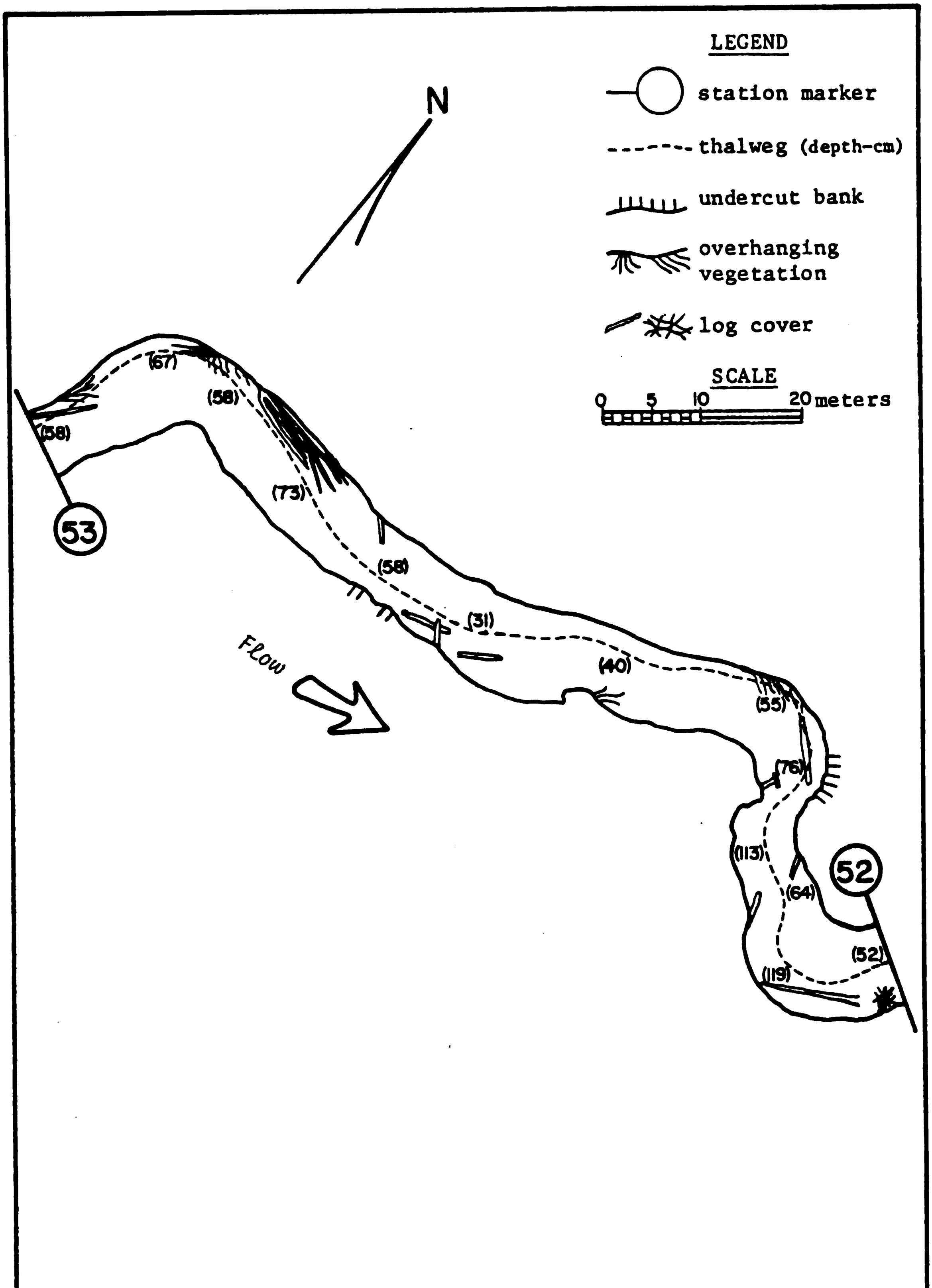

Figure C15. Salmon Trout River Station 52.

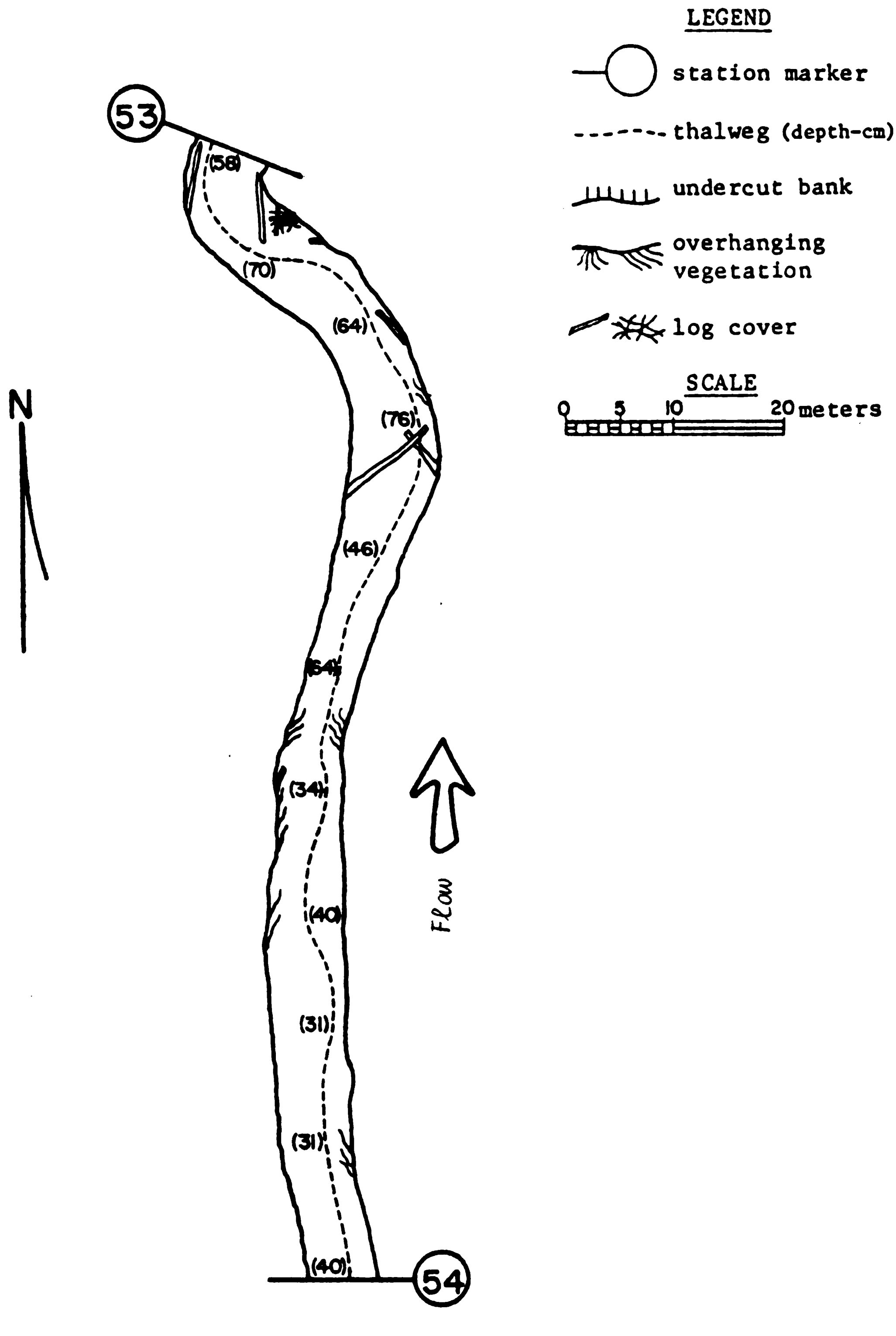

Figure C16. Salmon Trout River Station 53.

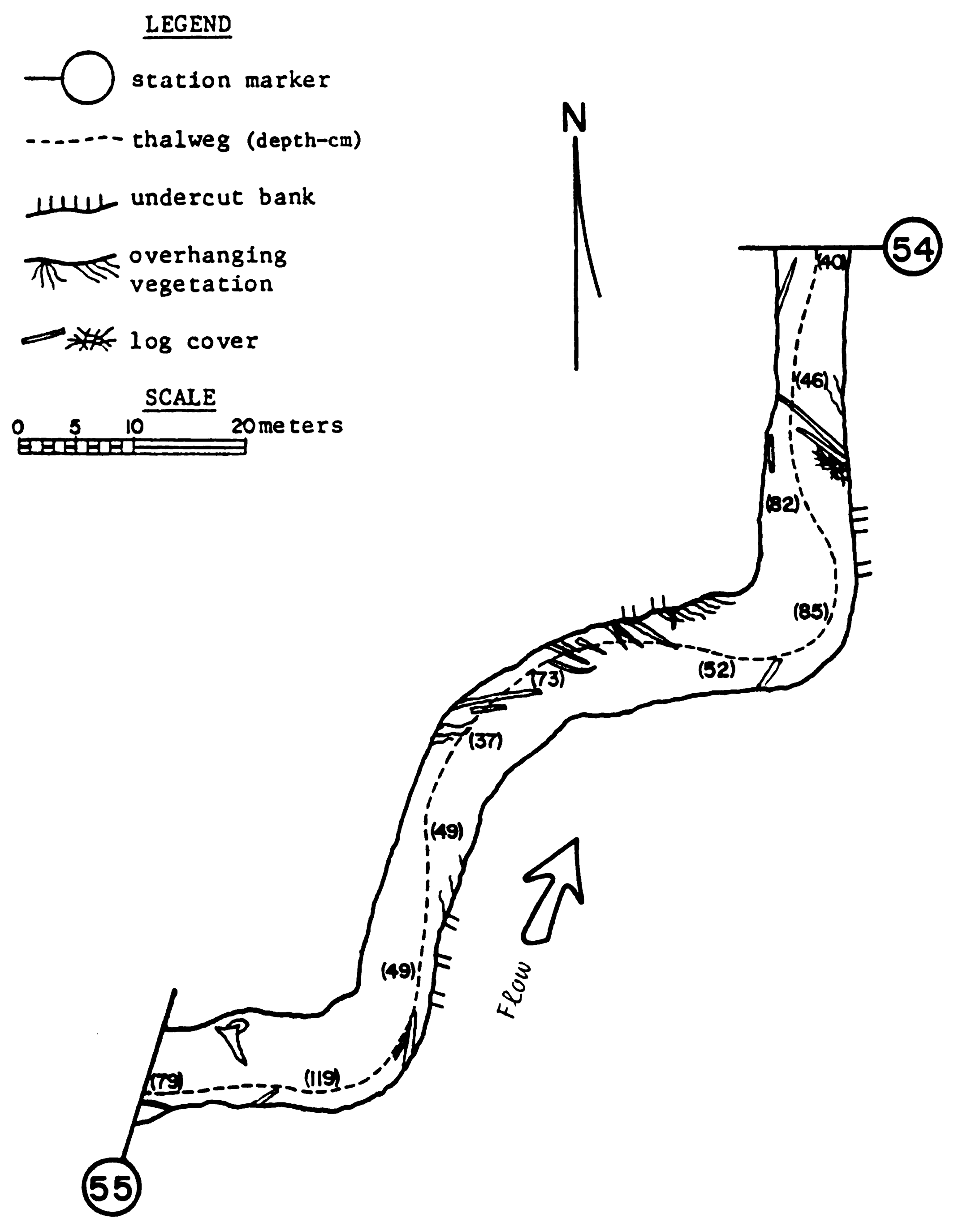

Figure C17. Salmon Trout River Station 54.

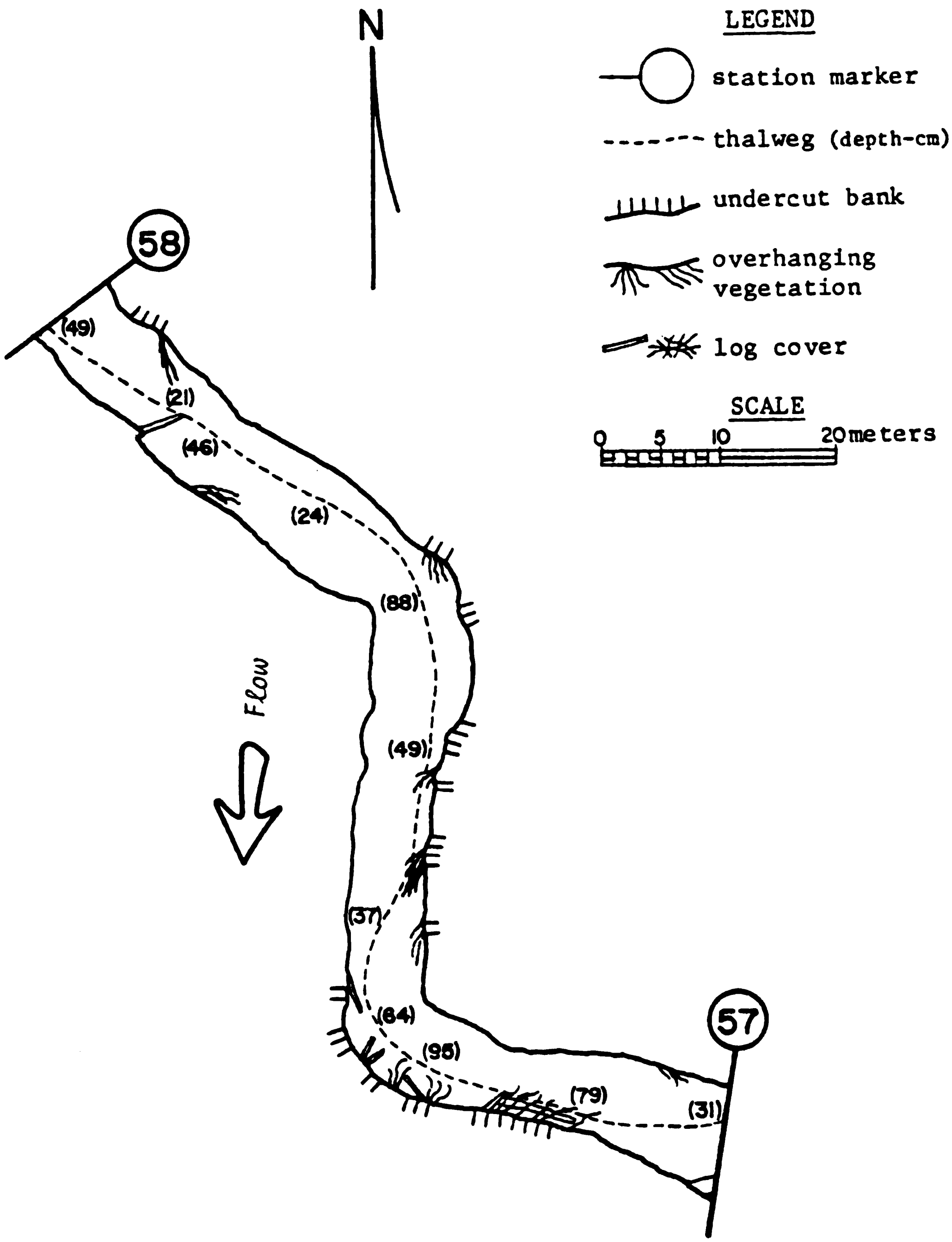

Figure C18. Salmon Trout River Station 57.