Stress and Recovery of Aquatic Organisms as Related to Highway Construction along Turtle Creek, Boone County, West Virginia

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ENGLISH-METRIC CONVERSION

[The following factors may be used to convert the English units published herein to the International System of Units (SI)]

Multiply English units	by	to obtain SI units
	Length	
inches (in.)	25.4	millimeters (mm)
	.0254	meters (m)
feet (ft)	.3048	meters (m)
miles (mi)	1.609	kilometers (km)
	Area	
acres	4047	square meters (m^2)
	.4047	hectares (ha)
	.4047	square hectometer (hm^2)
	.004047	square kilometers (km^2)
square miles (mi^2)	2.590	square kilometers (km^2)
	Volume	
cubic yards (yd^3)	0.7646	cubic meters (m^3)
	Flow	
cubic feet per second (ft^3/s)	28.32	liters per second (L/s)
	.02832	cubic meters per second (m^3/s)
	Mass	
short ton	0.9072	metric ton (t)

STRESS AND RECOVERY OF AQUATIC ORGANISMS AS RELATED TO HIGHWAY CONSTRUCTION ALONG TURTLE CREEK, BOONE COUNTY, WEST VIRGINIA

By JAMES L. CHISHOLM and SANFORD C. DOWNS

ABSTRACT

During and after construction of Appalachian Corridor G, a divided, four-lane highway, five benthic invertebrate samples were collected at each of four sites on Turtle Creek, and, for comparative purposes, three samples were collected at each of two sites on Lick Creek, an adjacent undisturbed stream. Diversity index, generic count, and total count initially indicated severe depletion or destruction of the benthos of Turtle Creek, but, within 1 year after highway construction was completed, the benthic community of Turtle Creek was similar to that of Lick Creek. The greatest degradation occurred near the headwaters of Turtle Creek because of erratic movement of sediment resulting from high streamflow velocity. Diversity indices ranged from 0 to 3.41 near the headwaters in the original channel, but only from 0.94 to 2.42 farther downstream in a freshly cut channel. The final samples from Turtle Creek, which were similar to those taken from Lick Creek at the same time, had generic counts of 10 at the most upstream site and 16 near the mouth. A total of 147 organisms was found near the headwaters, whereas a total of 668 was found near the mouth of the stream. The total number of organisms collected at each site was proportional to the drainage area upstream from the site. As a result of tributary inflow from unaltered drainage areas and organism drift, rapid repopulation and stabilization of the benthic community occurred. Channel relocation, bank recontouring, and reseeding also accelerated the recovery of the benthic community.

INTRODUCTION

During 1973–74, the suspended-sediment yield of the Coal River and its tributaries was 1,200,000 tons of sand, silt, and clay (Bader, Chisholm, Downs, and Morris, 1977), 800 tons per square mile per year. During the same period, Turtle Creek, a tributary to the Little Coal River and the construction route of Appalachian Corridor G, a divided, four-lane highway, yielded 34,000 tons of suspended sediment, or 1,400 tons per square mile per year.

The construction of the highway, which was begun in 1972, necessitated the removal of most vegetation and the development of large cuts and fills along the narrow Turtle Creek Valley. Almost 60 percent of the stream channel was relocated to accommodate the new highway. As a result, vast quantities of disturbed soil were exposed to erosion. The high sediment yield of Turtle Creek provided an ideal situation for observing the impact of massive sediment transport and channel relocation on the benthic invertebrate organisms of this stream. Samples were collected for this purpose from 1973 to 1975.

To assist in evaluating the data collected from Turtle Creek, a control basin of similar topographic and geologic setting was investigated concurrently. Lick Creek, a small, virtually unaltered stream adjacent to Turtle Creek, was chosen for this purpose.

This report summarizes the results of the biological studies as empirically related to sediment movement along the bed of Turtle Creek during the construction and postconstruction phase of Appalachian Corridor G.

ACKNOWLEDGMENT

The authors wish to express their appreciation to Mr. Merrill W. Nelson, Division Administrator, West Virginia Division Office, Federal Highway Administration, for furnishing detailed construction plans and data related to Appalachian Corridor G.

DESCRIPTION OF TURTLE CREEK AND LICK CREEK BASINS

Turtle Creek is located in Boone County, W. Va., and flows northeastward to the Little Coal River at Danville (fig. 1). It was so named because of the turtle-shaped limestone concretions along its bed (Krebs and Teets, 1915, p. 31). Turtle Creek has a drainage area of 11.8 square miles and a stream-channel gradient of 460 feet over 6.9 miles, averaging 66 feet per mile. The mean annual discharge of Turtle Creek is 15.8 ft^3/s (cubic feet per second).

The cultivation of gardens and a few acres of corn and tobacco constitutes the only agricultural activity in the basin. With the exception of a few gas wells, mineral-resource extraction is virtually nonexistent.

The most significant change of the topographic features of this basin came about as a result of the construction of Appalachian Corridor G. That required excavating more than 3⅓ million cubic yards of earth, clearing and grubbing 250 acres, and dismantling 60 structures. Stabilizing cuts and fills required mulching and seeding 108 acres.

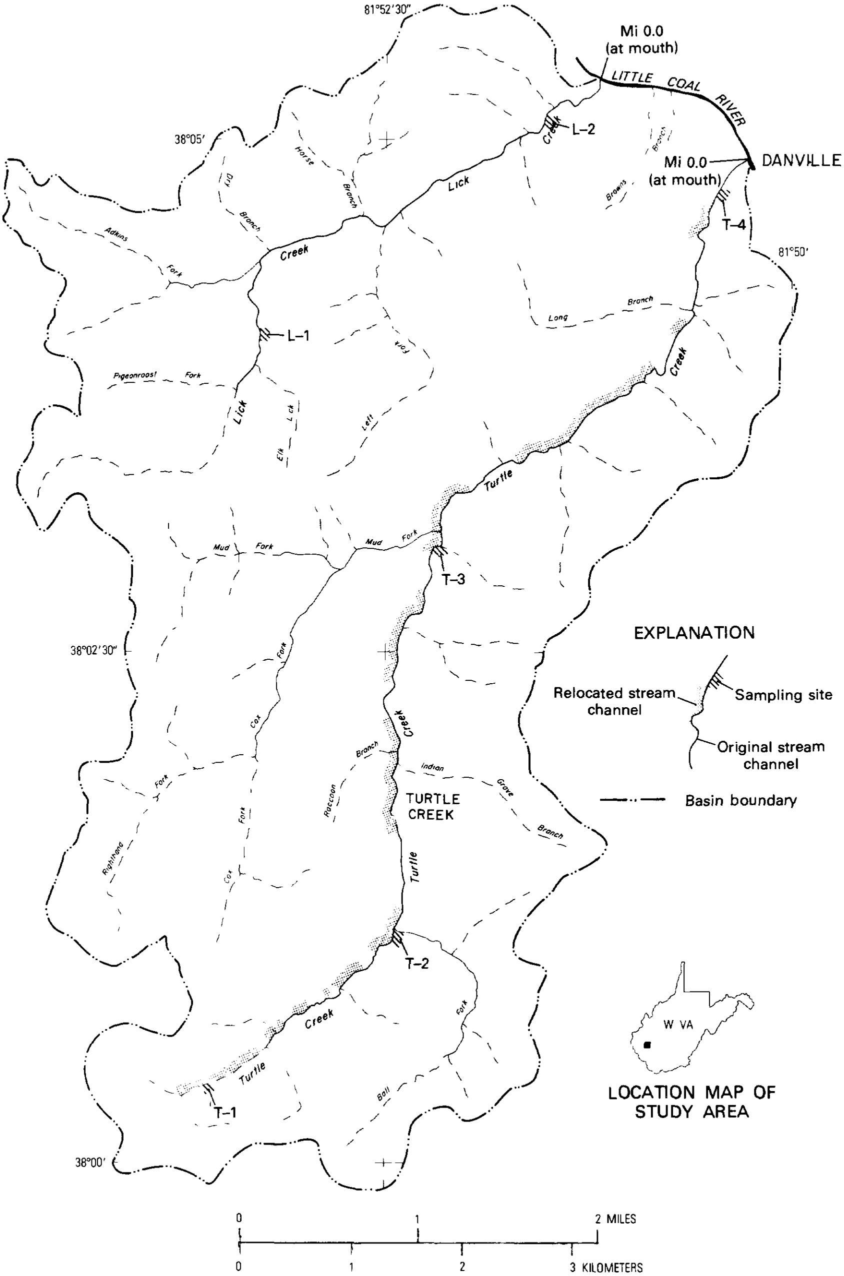

FIGURE 1. — Turtle Creek and Lick Creek basins, West Virginia.

Lick Creek flows northeastward to the Little Coal River, about a mile downstream from the mouth of Turtle Creek. The drainage area of Lick Creek is 5.5 miles, and its stream-channel gradient is 580 feet over 4.6 miles, averaging 126 feet per mile. The mean annual flow of Lick Creek is 7.38 ft^3/s.

Cultural activities in the Lick Creek basin are similar to those in the Turtle Creek basin. With the exception of its steeper channel gradient, the Lick Creek basin has virtually the same topographic and geologic features as those of the Turtle Creek basin.

GEOLOGY OF TURTLE CREEK AND LICK CREEK BASINS

Both Turtle Creek and Lick Creek are underlain by the Kanawha Formation of Pennsylvanian age. The alluvium in both basins is derived from rocks of the Kanawha Formation. According to Cardwell, Erwin, and Woodward (1968), the Kanawha Formation is composed of "sandstone (approximately 50 percent), shale, siltstone, and coal. Contains several marine zones. Becomes more shaly westward in the subsurface* * *."

In September 1973, the authors observed some recently exposed boulders beside a cut on the right-of-way of Corridor G approximately half a mile southwest of the head of the Turtle Creek drainage. Of particular interest were some black boulders 3 to 4 feet in diameter composed of shale, which appeared to be weathering very rapidly, breaking down into small chips that separated along the bedding plane. Further weathering probably reduced the chips to silt-to-clay-sized particles in a short time, the entire process probably taking only a few months.

Under natural conditions this process may have occurred slowly because the shale was weathered only from surfaces at the outcrops. However, the process was accelerated when large masses of the material were exposed in cuts during road construction. Consequently, large amounts of fine material became available to the stream during a short time.

STUDY METHODS

PHYSICAL AND CHEMICAL QUALITY SAMPLING METHODS

Dissolved oxygen, pH, and specific conductance were measured in situ with portable field instruments at the time of benthic invertebrate sampling. Samples were collected and analyzed in accordance with the methods prescribed by the U.S. Geological Survey (Brown, Skougstad, and Fishman, 1970). Turbidity measurements were made of raw water samples by the nephelometric method, and values are reported in NTU (nephelometric turbidity units).

Suspended-sediment samples were collected at various stages of stream discharge in an effort to estimate sediment discharge from

Turtle Creek. Sediment samples were collected in accordance with the methods prescribed by the U.S. Geological Survey (Guy and Norman, 1970).

BENTHIC INVERTEBRATE SAMPLING METHODS

Benthic invertebrate samples were collected along a 300-foot reach of stream at each sampling site by two people for a 45-minute period. An effort was made to sample at least three pools and three riffles at each of the sites. For this report, a riffle is defined as an obstruction on the streambed that creates a broken or disturbed water surface and that forms a slower moving pool or body of water just upstream from the obstruction. A pool is defined as the body of water impounded by the riffle control.

Because the purpose of the sampling was to evaluate the total benthic environment rather than any specific habitat, riffles, pools, loose rocks, sand, permanent streambed, and leaf debris were examined for organisms.

In riffles, samples were collected with the D-frame dip net mounted with a 0.210 mm mesh Nitex[1] net shown in figure 2. The net was used to catch organisms that washed off a rock as it was picked from the streambed for examination. The net was held downstream to catch organisms dislodged when the sample area was physically disturbed. Organisms found clinging to rocks were removed with biological forceps and placed in a vial of 70-percent ethanol.

In pools where there were few or no loose rocks, the net was scraped along the bottom of the bed to dislodge and trap organisms. All materials thus collected were transferred to a sorting screen made of the same material as the dip net. The organisms were removed from the sorting screen and placed in a vial of preservative.

In areas of sand or silt deposits, garden trowels were used to scoop up and transfer the bottom material to the sorting screen. The dip net was held downstream from the sampling site to prevent the loss of organisms.

DIVERSITY INDEX

According to Lium (1974), "Diversity, or the evenness of distribution of insects, gives some indication of the aquatic environmental condition of a stream." Diversity was computed at the genus level, by season, for each sampling site by the approximation:

$$\text{Diversity index, } D = -\Sigma PI \log_2 PI$$

where PI is the probability of occurrence of the Ith species. The prob-

[1] The use of the brand name in this report is for identification purposes only and does not imply endorsement by the U.S. Geological Survey.

FIGURE 2. — D-frame dip net used to collect benthic invertebrate samples.

ability (*PI*) is equal to *NI/NS*, where *NI* is the number of individuals in each species and *NS* is the total number of individuals in all species.

"When the assemblage consists of a single species, $D = 0$, and no more information can be gained when a random individual is identified, D increases as the number of species increases and is greatest when all species are equally abundant" (Lium, 1974, p. 382).

Because it increases as community complexity increases, diversity may be considered as an indicator of the stream's ability to support a varied benthic community.

GENERIC COUNT DEFINED

The total number of different genera within any one sample is defined as the generic count. Generally, the higher the generic count the greater the diversity and complexity of the benthic community structure.

TOTAL COUNT DEFINED

The total number of organisms collected as a part of any one sample is defined as the total count of that sample. Total count alone does not provide an adequate means of assessing the biological condition of a stream, but it is useful when considered with generic count and diversity index.

EVALUATION OF DATA

For the purpose of this report it is assumed that the benthic invertebrate community of Lick Creek is responsive only to natural stresses. Therefore, diversity index, generic count, and total count of each sample are a measure of the response of Lick Creek only to natural changes. It is further assumed that had there been no highway construction, samples from Turtle Creek would at all times have been similar to samples from Lick Creek. It follows that the less the similarity of samples from the two creeks, the greater the impact of highway construction, and the more similarity, the smaller the impact.

SELECTION AND DESCRIPTION OF SAMPLING SITES

SELECTION OF SITES

Sampling sites were selected to lessen the effect of channel-gradient and drainage-area differences between the two streams. For example, the drainage area of site T–2 is approximately equal to that of site L–2. The problem of differences in channel gradient was not entirely surmounted. However, because Lick Creek has the steepest channel gradient, any resulting flushing of organisms biases the data in favor of Turtle Creek. This perhaps lessens the possibility of overstating the extent of degradation of Turtle Creek.

Stream-channel relocation was considered in site selection. Sites T–2 and T–3 are in relocated channels, whereas, sites T–1 and T–4 are in the original channel. This placement of sites allowed a comparison of community development in a previously sterile environment (relocated channel) to that in a degraded environment (original channel).

DESCRIPTIONS OF SITES

Site T–1. — Turtle Creek, 7.1 miles upstream from mouth; lat 38°00′27″, long 081°53′25″; drainage area, 0.63 mi^2.

Site T–1 is located in a section of the original streambed. Just upstream from the site, 600 feet of streambed was relocated during the winter of 1972 to accommodate the new highway. One million four hundred thousand cubic yards of earth was excavated upstream from this site, and 51 acres was cleared and grubbed. An assortment of native plant life along the banks provides shade during part of the day. Ground-water discharge to the stream at this site is indicated by the brownish appearance of precipitating iron and manganese at times of low runoff (fig. 3).

FIGURE 3.—Sampling site T–1. Iron precipitation causes water to appear brown. The sky-light reflection of bluish hues is indicative of the water-saturated condition of the sediment at this site.

Site T–2.—Turtle Creek, 5.7 miles upstream from mouth; lat 38°01'08", long 081°52'28"; drainage area, 2.84 mi^2.

Site T–2 is located near the midpoint of a 1,700-foot reach of relocated streambed, which was completed in September 1973. The width of the new bed is 15 feet. Recontouring the adjacent slopes necessitated removing all vegetation from both banks of Turtle Creek at this site. As a result of reseeding, a sparse coverage of *Sericea lespedeza*, locally referred to as "Ethiopian vetch," (E. E. Harris, oral commun., 1974) was established by October 1973. Between this site and site T–1, 206,000 cubic yards of earth was excavated, and 44 acres was cleared and grubbed. Cumulative excavation from the headwaters to site T–2 totals 1,633,000 cubic yards. As shown in figure 4, the water is relatively free of turbidity, and iron and manganese have precipitated.

FIGURE 4. — Sampling site T–2. Precipitation of iron from upstream sources is virtually complete at this point; yellow blooms of newly planted Ethiopian vetch can be seen in the upper center of the photograph.

Site T–3. — Turtle Creek, 3.2 miles upstream from mouth; lat 38°02′57″, long 081°52′12″; drainage area, 4.84 mi².

Site T–3 is located near the upstream end of a 2,500-foot reach of relocated streambed 20 feet wide. The site is 0.1 mile upstream from the mouth of Mud Fork. All vegetation was removed from both banks at the time of initial excavation during July 1973, but, by September 1974, a sparse coverage of "Ethiopian vetch" had been established, as shown by the yellow flowers in figure 5. Between this site and T–2, 234,148 cubic yards of earth was excavated, or, from the headwaters to this site, a cumulative total of 1,867,000 cubic yards. A sediment retention dam was built across the stream about 300 feet upstream from this site, and its effectiveness is demonstrated by the transparency of the water during low flow (fig. 5).

Site T–4. — Turtle Creek, 0.2 mile upstream from mouth; lat 38°04′19″, long 081°50′35″; drainage area, 11.80 mi².

Site T–4 is located between two culverts in a section of the original channel just downstream from a 0.3-mile reach of stream that was relocated in June 1973. Highway construction required excavating

FIGURE 5. — Sampling site T–3. Sky-light reflection and transparency of water are indicative of the low turbidity of the stream. Small boulders and cobbles along the banks and streambed serve as a substrate for benthic organisms.

1,490,570 cubic yards of earth and clearing and grubbing 88 acres between this site and T–3. Cumulative excavation from the headwaters to site T–4 totals 3,357,570 cubic yards. In figure 6, the green vegetation on the right side of the stream is native, whereas that on the left side results from sediment-control efforts.

Site L–1. — Lick Creek, 2.7 miles upstream from mouth; lat 38°05′05″, long 081°51′31″; drainage area, 1.43 mi^2.

The natural channel configuration of this reach is virtually undisturbed. At this site several small pools and riffles prevail, and the bed consists of sand, rounded cobbles, and flat sandstone outcrops. The site is heavily shaded by overhanging deciduous trees, and the banks are heavily fringed with wildflowers, ferns, and grasses. Figure 7 shows the extreme transparency of the water, fallen leaves, moss on the rocks, and alternating areas of shade and sunlight. All of these conditions are undoubtedly associated with stream productivity.

Site L–2. — Lick Creek, 0.5 mile upstream from mouth; lat 38°05′05″, long 081°51′32″; drainage area, 5.50 mi^2.

The natural channel configuration of this reach is undisturbed, with the exception of a bridge at the downstream end of the sampling site.

FIGURE 6. — Sampling site T–4. The new highway cut showing red-brown stains on the rocks, Ethiopian vetch along the left bank, and sand bars can be seen in this photograph.

FIGURE 7. — Sampling site L–1. Areas of sunlight and shade, moss-covered rocks, diversity of plant life, and streambed sediments are all indicative of the unspoiled or natural conditions extant at this site.

FIGURE 8. — Sampling site L–2. Native vegetation along both banks creates a pattern of alternating sunlight and shade on the stream.

The streambed consists of sand, gravel, and cobbles. The sampling site is partly shaded by overhanging trees, and the banks are covered with shrubs and grasses, as shown in figure 8.

FIGURE 9. — Reddish-orange colored water caused by iron precipitation of groundwater inflow into Turtle Creek midway between sites T–1 and T–2. Note sediment retention dam across channel and Ethiopian vetch on right bank.

FIGURE 10. — Sediment deposit of silt and clay, 8 to 10 inches deep at the downstream end of site T–1.

FIGURE 11. — Turtle Creek streambed 0.25 mile upstream from site T–2. Sediment deposition at this point was promoted by a retention dam a few hundred feet downstream. Ethiopian vetch is barely discernible on the newly graded hillside.

RESULTS AND DISCUSSION

WATER CHEMISTRY OF TURTLE CREEK AND LICK CREEK

When Turtle and Lick Creeks were sampled during September 1973 for the Coal River basin investigation, it became apparent that the water chemistry was similar (Bader and others, 1977). As shown in table 1, water in both streams is soft and alkaline. Calcium and sulfate are the major dissolved constituents.

As indicated by several measurements of specific conductance, the concentration of dissolved solids in Turtle Creek was generally higher than in Lick Creek during the early phases of the study. Later, as highway construction neared completion, the concentration of dissolved solids in Turtle Creek diminished. Calcium chloride, a wetting agent used to minimize dust, was frequently applied during the early and middle phases of construction. This agent, which is extremely soluble, is readily leached and may account for some of the higher conductance values.

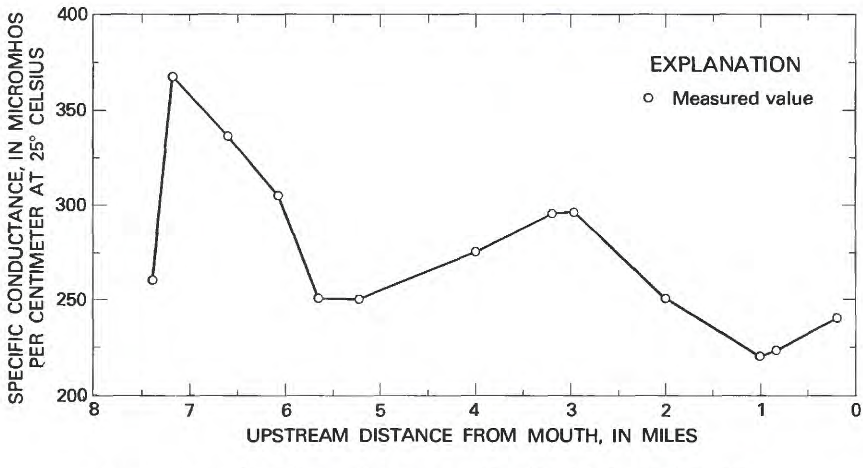

FIGURE 12.—Specific-conductance profile of Turtle Creek, fall 1974.

As shown in figure 12, the values of specific conductance in Turtle Creek indicated significant variations in water quality. Some of the marked changes, as shown between mile 8.0 and 7.0, result from the inflow of mineralized ground water having relatively high concentrations of dissolved iron, calcium, and sulfate. The iron readily precipitates upon exposure to the atmosphere and causes the stream to become turbid and to appear reddish-orange colored. (See figure 9.) This is commonly observed along small streams in the Coal River basin that drain from areas of active or recent excavation.

TABLE 1. — *Chemical and microbiological analyses of Turtle Creek and Lick Creek*

[Leaders (. . .) indicate no data]

Date	Discharge (ft^3/s)	Total aluminum (Al) ($\mu g/L$)	Total iron (Fe) ($\mu g/L$)	Total manganese (Mn) ($\mu g/L$)	Dissolved calcium (Ca) (mg/L)	Dissolved magnesium (Mg) (mg/L)	Dissolved sodium (Na) (mg/L)	Dissolved potassium (K) (mg/L)	Dissolved sulfate (SO_4) (mg/L)	Dissolved chloride (Cl) (mg/L)	Hardness (Ca, Mg) (mg/L)	Specific conductance (micromhos at 25°C)	pH	Temperature (°C)	Turbidity (NTU)	Dissolved oxygen (mg/L)	Fecal coliforms (colonies per 100 mL)	Fecal streptococci (colonies per 100 mL)
Site T–1																		
9–20–73	<0.1	...	...	...	...	...	...	...	...	...	...	390	8.0	13.0	5	14.0	...	...
11–15–73	.1	...	...	...	...	...	...	...	...	...	...	400	7.9	12.5	2	10.5	...	...
5–9–74	1.0	...	...	...	...	...	...	...	...	...	...	340	7.6	16.0	2	9.6	...	...
9–18–74	.5	...	...	...	...	...	...	...	...	...	...	300	9.2	22.5	15	...	...	...
11–19–75	1.0	...	...	...	...	...	...	...	...	...	...	210	7.5	7.0	1	13.1	...	...
Site T–2																		
9–19–73	.1	...	...	...	...	...	...	...	...	...	...	385	7.0	20.0	4	11.7	...	...
11–15–73	.5	...	...	...	...	...	...	...	...	...	...	295	8.9	14.0	3	13.2	...	...
5–9–74	1.0	...	...	...	...	...	...	...	...	...	...	270	7.6	...	4	8.9	...	...
9–18–74	1.0	...	...	...	...	...	...	...	...	...	...	340	8.8	...	2	...	...	...
11–19–75	2.5	...	...	...	...	...	...	...	...	...	...	200	8.0	6.5	..	12.1	...	...
Site T–3																		
9–19–73	<.1	...	...	...	...	...	...	...	...	...	...	280	7.3	20.0	6	12.5	...	...
11–15–73	.5	...	...	...	...	...	...	...	...	...	...	240	8.3	17.0	4	12.0	...	...
5–9–74	1.5	...	...	...	...	...	...	...	...	...	...	215	7.6	17.5	3	8.9	...	...
9–18–74	2.0	...	...	...	...	...	...	...	...	...	...	320	8.7	...	2	...	...	...
11–19–75	3.0	...	...	...	...	...	...	...	...	...	...	130	8.0	12.5	1	11.0	...	...
Site T–4																		
9–20–73	1.0	...	...	...	...	...	...	...	...	...	...	290	8.0	21.0	5	12.0	...	...
9–26–73	.63	2500	6700	300	26	11	...	...	50	12	110	310	8.3	27.5	30	9.3	730	...
11–15–73	1.0	...	...	...	...	...	...	...	...	...	...	295	8.0	15.5	3	12.2	...	...
4–11–74	36	400	460	80	15	4.1	2.0	1.4	23	1.7	54	120	7.3	11.0	3	10.8	140	16
5–9–74	4.0	...	...	...	...	...	...	...	...	...	...	180	7.5	15.0	6	9.8	...	...
9–18–74	3.5	...	...	...	...	...	...	...	...	...	...	200	9.2	...	2	...	...	...
11–19–75	5.0	...	...	...	...	...	...	...	...	...	...	160	8.1	12.0	1	12.0	...	...
Site L–1																		
5–8–74	2.5	...	...	...	...	...	...	...	...	...	...	100	7.6	18.0	50	9.4	...	...
9–18–74	.5	...	...	...	...	...	...	...	...	...	...	95	8.5	...	..	...	...	...
11–19–75	1.0	...	...	...	...	...	...	...	...	...	...	80	8.2	11.5	1	13.6	...	...
Site L–2																		
9–26–73	.37	100	1400	230	12	4.8	...	...	17	5.9	50	180	7.2	26.0	4	7.8	1100	100
4–11–74	18	300	300	30	5.3	3.0	1.5	1.4	17	1.1	26	90	7.3	10.5	2	10.6	140	20
5–8–74	1.0	...	...	...	...	...	...	...	...	...	...	90	7.6	15.5	2	9.0	...	...
9–18–74	1.5	...	...	...	...	...	...	...	...	...	...	150	8.1	21.0	..	...	...	...
11–19–75	2.5	...	...	...	...	...	...	...	...	...	...	90	8.1	11.0	1	10.2	...	...

RESPONSE OF BENTHIC INVERTEBRATES TO SEDIMENT DEPOSITION AND TRANSPORT

Beginning in the fall of 1973, four sets of benthic invertebrate samples were collected every 4 to 5 months at four sites on Turtle Creek. Another sample was collected about 10 months after highway construction and reseeding were completed.

The following discussion describes the response of the benthic invertebrates of Turtle Creek to sediment deposition (table 2) and transport down the main stem. The results are discussed for each site individually, and are shown collectively in tables 3 and 4.

TABLE 2.—*Suspended-sediment discharge for Turtle Creek at Danville (site T-4)*

Date	Time	Discharge (ft^3/s)	Concentration (mg/L)	Tons per day
Sep. 29, 1973	1745	250	11,100	7,490
Oct. 30, 1973	1500	50	1,240	167
Jan. 10, 1974	1415	500	2,900	3,920
Aug. 23, 1974	1120	1.0	14	.04
Nov. 19, 1975	1400	5.0	2	.03

SITE T-1

Excavation upstream from this site began during the fall of 1972. During the following year, deposition of silt and clay eventually covered the streambed to a depth of 8 to 10 inches, as shown in figure 10. The sample collected in the fall of 1973 had a diversity index of 0.92, a generic count of 7, and consisted of 4 crayfish (Decapoda), 2 damselflies (Odonata), and 1 common crane fly (Diptera), for a total count of 7. As a result of ground-water discharge, the sediment deposit at this site remained saturated during low streamflow (fig. 3).

Heavy rains during the early spring scoured most of the finer sediment and left about half an inch of clay and sand on the original rock bed. As shown in figure 13, the bed had returned to a near-normal riffle-pool configuration, with sufficient detritus to reestablish and support a benthic community.

The sample collected during the winter of 1973 yielded only two crayfish; the sample had a diversity index of 0. This augmented degradation resulted from continued sediment deposition, which buried the organisms to a depth sufficient to isolate them from the free-flowing, aerated water, which contained 10.5 mg/L of dissolved oxygen. As a result, benthic invertebrates were seemingly eliminated.

By the following spring (1974), this reach of the stream had made dramatic progress toward rebuilding the biological community. The new complexity of the benthic community was indicated by the spring sample, which had a total count of 59 insects and 2 crayfish, a generic count of 15, and a diversity index of 3.41. As shown in figure 14*A*,

TABLE 3. — *Distribution of benthic invertebrates*

[Values in organisms per sample]

		Annelida (aquatic earthworm)	Decapoda (crayfish)	Diptera (trueflies)	Trichoptera (caddis flies)	Ephemeroptera (mayflies)	Plecoptera (stoneflies)	Megaloptera (dobsonflies)	Odonata (dragonflies)	Hemiptera (bugs)	Coleoptera (beetles)	Collembola (springtails)	Hydracarina (water mites)	Basommatophora (snails)
Site T–1														
Fall	1973	...	4	1	...	...	...	...	2	...	...	...	...	...
Winter	1973	...	2	...	...	...	...	...	...	...	...	...	...	...
Spring	1974	...	2	11	1	29	11	...	2	5	...	...	...	...
Fall	1974	2	4	3	...	6	...	...	12	...	1	...	...	...
Winter	1975	1	6	...	37	3	1	1	...	...	...	...	...	...
Site T–2														
Fall	1973	...	5	4	1	11	...	8	8	2	5	...	...	...
Winter	1973	...	...	16	...	...	...	...	...	...	1	...	...	...
Spring	1974	...	2	7	...	42	7	...	...	...	...	...	...	...
Fall	1974	...	...	13	1	13	...	1	...	...	1	...	...	...
Winter	1975	1	1	22	51	3	9	2	...	...	...	...	...	...
Site T–3														
Fall	1973	...	6	9	27	69	...	...	...	1	...	...	...	...
Winter	1973	...	...	5	41	21	...	...	...	...	...	...	2	...
Spring	1974	...	...	3	1	20	2	...	...	...	1	...	...	...
Fall	1974	...	2	3	...	36	...	...	...	1	1	...	...	...
Winter	1975	...	12	...	92	50	4	...	...	...	5	...	...	3
Site T–4														
Fall	1973	5	10	83	9	15	...	...	1	...	...	...	...	...
Winter	1973	...	...	6	10	52	...	2	...	...	...	...	...	...
Spring	1974	...	...	128	...	62	...	1	...	2	...	1	...	...
Fall	1974	...	6	...	4	7	...	11	2	1	2	...	...	...
Winter	1975	1	3	7	150	69	4	7	...	...	1	...	...	6
Site L–1														
Spring	1974	...	4	...	...	27	1	...	2	...	1	...	...	...
Fall	1974	...	1	3	8	11	...	...	2	3	2	...	...	...
Winter	1975	...	2	4	65	32	2	...	...	...	37	...	...	...
Site L–2														
Spring	1974	...	3	3	9	71	7	...	...	...	14	...	...	...
Fall	1974	...	1	15	2	4	...	...	4	...	...	...	1	2
Winter	1975	...	2	3	97	49	9	...	2	...	5	...	...	10

seven taxonomic orders were represented. Many of the genera were those that are known to thrive on sand and rock streambeds under well-aerated, free-flowing water. In particular, several genera of the midges (Diptera) and mayflies (Ephemeroptera) were present, representing climbers, bottom sprawlers, burrowers, free rangers of rapid water, and clingers. The family Simuliidae (Diptera), which, according to Smith (1896, p. 341), prefers a habitat of swiftly flowing water, rocks, and vegetable matter, was represented. Eleven stonefly nymphs (Plecoptera) were found. According to Pennak (1953, p. 500), stonefly

TABLE 4. — *Benthic invertebrate taxa of*

	Prospora (aquatic earthworms)	Lumbriculidae	Opisthopora (aquatic earthworms)	Haplotaxidae *Haplotaxis*	Rhynchobdellida (leeches)	Glossiphonidae *Placobdella*	Decapoda (crayfish)	Astacidae	*Orconectes*	*Cambarus*	Diptera (true flies)	Tipulidae *Tipula*	*Limnophila*	*Eriocera*	*Dactylolabis*	Simuliidae	*Simulium*	Chironomidae *Ablabesmyia*	*Heterotrissocladius*
Site T–1																			
Fall 1973									X			X							
Winter 1973									X										
Spring 1974								X								X		X	X
Fall 1974		X						X											
Winter 1975						X													
Site T–2																			
Fall 1973									X				X						
Winter 1973																			
Spring 1974										X		X							
Fall 1974														X				X	
Winter 1975		X								X		X		X					
Site T–3																			
Fall 1973									X										
Winter 1973																			
Spring 1974																		X	
Fall 1974									X										
Winter 1975												X							
Site T–4																			
Fall 1973				X					X										
Winter 1973												X							
Spring 1974																	X		
Fall 1974															X				
Winter 1975		X							X			X							
Site L–1																			
Spring 1974									X										
Fall 1974								X											
Winter 1975										X		X							
Site L–2																			
Spring 1974												X							
Fall 1974								X		X		X							
Winter 1975									X			X							

Turtle Creek and Lick Creek, 1973–1975

Polypedilum	*Rheotanytarsus*	*Chironomus*	*Glyptotendipes*	*Orthocladius*	*Pentaneura*	*Tanytarsus*	*Diamesa*	*Paratendipes*	*Tendipes*	Ceratopogonidae *Forcipomyia*	*Probezzia*	Empididae *Hemerodromia*	Rhagionidae *Atherix*	Trichoptera (caddis flies)	Limnephilidae *Pycnopsyche*	Hydropsychidae *Cheumatopsyche*	*Hydropsyche*	*Diplectrona*	Philoptamidae *Sortosa*	Rhyacophilidae *Rhyacophila*	Psychomyiidae *Polycentropus*
Site T–1 — Continued																					
X	X														X						
								X													
				X			X									X	X				
Site T–2 — Continued																					
		X														X					
		X																			
			X	X																	
X				X						X	X	X				X					
				X	X							X				X	X				
Site T–3 — Continued																					
		X														X					
		X														X					
																X					
				X																	
				X	X	X										X	X				
Site T–4 — Continued																					
		X															X				
		X														X	X				
	X			X																	
							X					X				X	X				
				X	X							X				X	X				
Site L–1 — Continued																					
				X												X			X		
	X												X			X	X	X	X	X	
Site L–2 — Continued																					
	X															X	X		X		X
								X	X			X									
					X											X		X			

TABLE 4. — *Benthic invertebrate taxa of Turtle*

	Ephemeroptera (mayflies)	Baetidae *Baetis*	*Ephemerella*	*Paraleptophlebia*	Heptageniidae *Epeorus*	*Stenonema*	Leptophlebiidae *Leptophlebia*	Siphlonuridae *Isonychia*	Ephemeridae *Caenis*	*Ephemera*	Plecoptera (stoneflies)	Nemouridae *Nemoura*	*Allocaphia*	Perlodidae *Isoperla*	*Isogenus*	Perlidae *Acroneuria*	Peltoperlidae *Peltoperla*	Megaloptera (dobsonflies)	Corydalidae *Corydalus*	Sialidae *Sialis*
Site T-1—Continued																				
Fall 1973																				
Winter 1973																				
Spring 1974		X	X	X	X	X						X		X						
Fall 1974		X																		
Winter 1975						X	X	X							X				X	
Site T-2—Continued																				
Fall 1973			X			X			X										X	
Winter 1973																				
Spring 1974		X	X	X	X	X						X		X						
Fall 1974		X				X													X	
Winter 1975		X	X			X							X		X				X	
Site T-3—Continued																				
Fall 1973		X				X		X	X											
Winter 1973						X														
Spring 1974			X		X	X								X						
Fall 1974		X																		
Winter 1975			X			X		X	X				X			X				
Site T-4—Continued																				
Fall 1973		X				X		X												
Winter 1973						X		X											X	
Spring 1974		X			X			X												X
Fall 1974		X				X		X											X	
Winter 1975						X		X					X			X			X	
Site L-1—Continued																				
Spring 1974		X	X	X		X		X	X					X						
Fall 1974		X				X			X	X										
Winter 1975						X		X		X					X					
Site L-2—Continued																				
Spring 1974		X	X	X	X	X						X		X	X		X			
Fall 1974						X			X											
Winter 1975						X		X	X	X			X							

Creek and Lick Creek, 1973–1975 — Continued

Odonata (dragonflies, damselflies)	Calopterygidae *Calopteryx*	Gomphidae *Progomphus*	Libellulidae	Aeschnidae *Boyeria*	*Aeshna*	Hemiptera (true bugs)	Gerridae *Gerris*	*Trepobates*	Veliidae *Microvelia*	*Rhagovelia*	Gelastocoridae *Gelastocoris*	Coleoptera (beetles)	Hydrophilidae *Laccobius*	*Tropisternus*	Dytiscidae *Loccophilus*	Psephenidae *Psephenus*	Gyrinidae *Dineutus*	Elmidae *Optioservus*	Dryopidae *Helichus*	Collembola (springtails)	Isotomidae *Isotomurus*	Hydracarina (water mites)	Basommatophora (snails)	Physidae *Physa*	Lymnacidae *Lymnaea*
Site T–1 — Continued																									
	X						X		X																
	X												X												
Site T–2 — Continued																									
	X	X									X			X	X	X									
														X											
																X									
Site T–3 — Continued																									
									X															X	
																	X								
								X										X							
																X			X					X	X
Site T–4 — Continued																									
			X																						
							X														X				
							X											X							
																X								X	X
Site L–1 — Continued																									
				X												X									
					X			X		X						X									
																X									
Site L–2 — Continued																									
																X		X							
	X				X																	X		X	
	X															X								X	

FIGURE 13. — Sampling site T–1 showing riffle-pool configuration of streambed.

nymphs "occur in debris, masses of leaves and algae, and under stones * * * in general, they are found only where there is an abundance of oxygen." This observation of Pennak well describes the streambed and dissolved-oxygen content of the water at site T–1 during the spring sampling.

The source of organisms for recolonization of this site was not determined. It is likely, however, that many of the organisms were washed downstream from the two small branches of Turtle creek, which converge 0.1 mile upstream from the site. The heavy rains of January and February 1974 were probably important factors in rapidly transporting organisms to the site.

By the fall of 1974, a thin cover of silt had been deposited on the bed and rocks. This resulted in a decrease of both diversity and total count, as compared to the previous spring. Only four genera of organisms were represented in this sample.

Based on organism diversity index and generic count, the 1975 sample indicated a remarkable improvement in the benthic invertebrate community compared with the samples collected during 1973. (See table 5.) Perhaps the most significant change was the large percentage of caddis flies (Trichoptera) in the 1975 sample.

A total of 147 organisms were collected at this site; the median diversity index of the five samples was 1.58.

TABLE 5. — *Summary of diversity indices and count data for Turtle Creek*

		Diversity index	Generic count	Total count
		Site T–1		
Fall	1973	0.92	2	7
Winter	1973	.00	1	2
Spring	1974	3.41	15	61
Fall	1974	1.58	4	28
Winter	1975	2.20	10	49
		Site T–2		
Fall	1973	3.22	14	44
Winter	1973	.32	2	17
Spring	1974	2.95	11	58
Fall	1974	2.91	12	29
Winter	1975	2.61	15	89
		Site T–3		
Fall	1973	2.14	7	112
Winter	1973	1.24	4	69
Spring	1974	2.42	7	27
Fall	1974	.94	5	43
Winter	1975	2.05	16	166
		Site T–4		
Fall	1973	1.26	7	123
Winter	1973	1.48	7	70
Spring	1974	1.72	9	194
Fall	1974	3.15	11	33
Winter	1975	1.78	16	248

SITE T–2

From the fall of 1973 through the following spring, the streambed consisted of a gravel, mud, and sand mixture (fig. 15). During this period, however, the bed was undergoing a fairly constant transition to coarser materials.

The first benthic invertebrate sample, which was collected at this site during the fall of 1973, revealed a well-diversified population. The sample had a diversity index of 3.22 and a generic count of 14. Many of the organisms typically found on sandy and rocky streambeds were represented. Eight mayflies (*Stenonema*), which are considered bottom sprawlers, and seven damselflies (Odonata) were found. The remainder of the sample consisted of true bugs (Hemiptera), beetles (Coleoptera), craneflies (Diptera), and dobsonflies (Megaloptera). *Psephenus*, commonly called the riffle beetle, was present in the sample. According to Pennak (1953, p. 613) riffle beetles "commonly occur

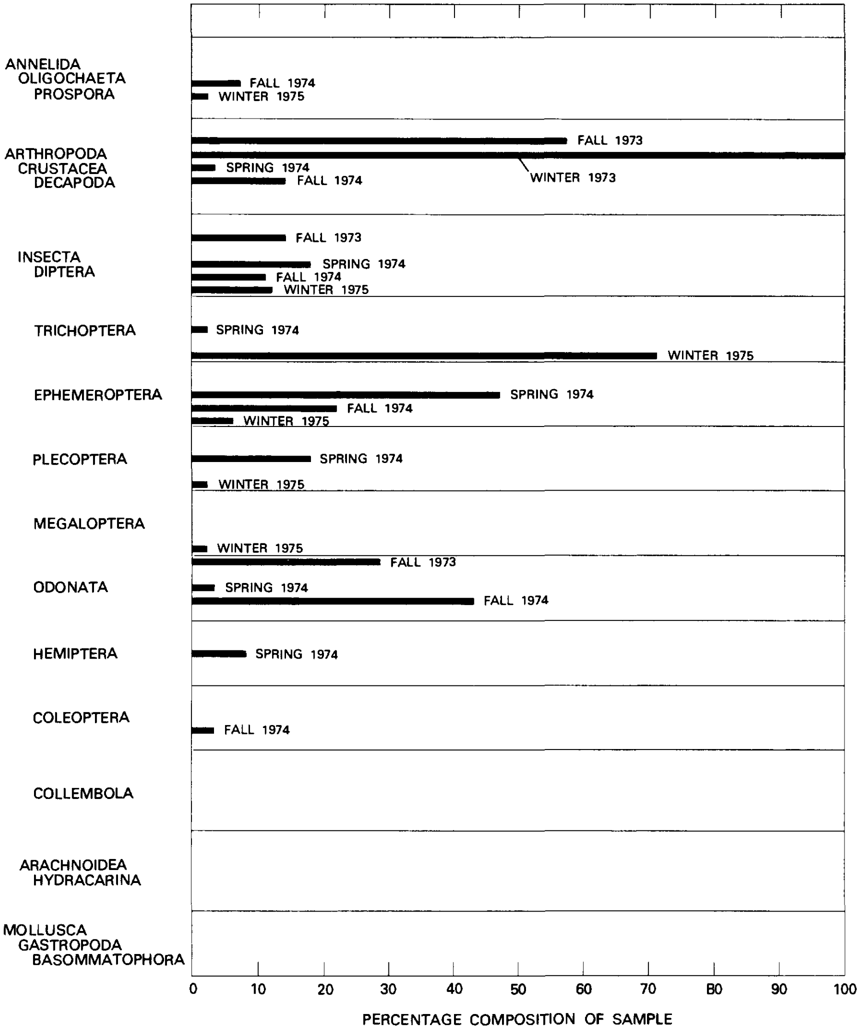

FIGURE 14*A*. — **Benthic invertebrate distribution in Turtle Creek, site T–1.**

on rocky or gravel bottoms * * * in streams where the water is shallow and swift." This sample is very similar to the sample collected at site T–1 in the spring of 1974.

By the winter of 1973, much of the sand and gravel substrate had been flushed downstream, and the sample taken at this time revealed the degrading impact of streambed alteration upon the benthic community. The sample had a diversity index of 0.32 and a generic count of 2; only beetles (Coleoptera) and midges (Diptera) were contained in the sample.

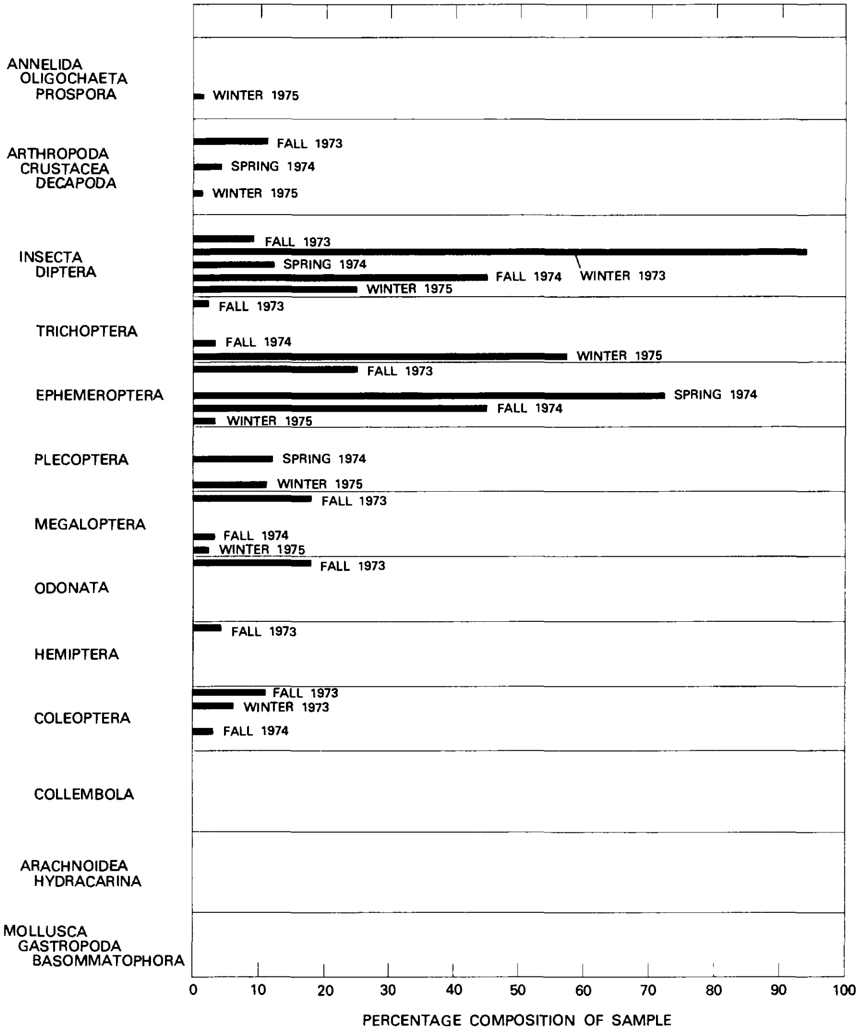

FIGURE 14*B*. — Benthic invertebrate distribution in Turtle Creek, site T–2.

The heavy rains of January 1974 scoured the sediment substrate. By the fall of 1974 the streambed had completely reverted to its preconstruction morphology of clean, white and grey, sandstone cobbles and loose gravel (fig. 4), even though large quantities of sand still remained in the channel 0.25 mile upstream from the site (See fig. 11.) The sample collected during the spring of 1974 indicated that a different group of organisms had established a new type of benthic community structure. This sample had a generic count of 11 and a diversity index of 2.95. The sample consisted mostly of mayflies

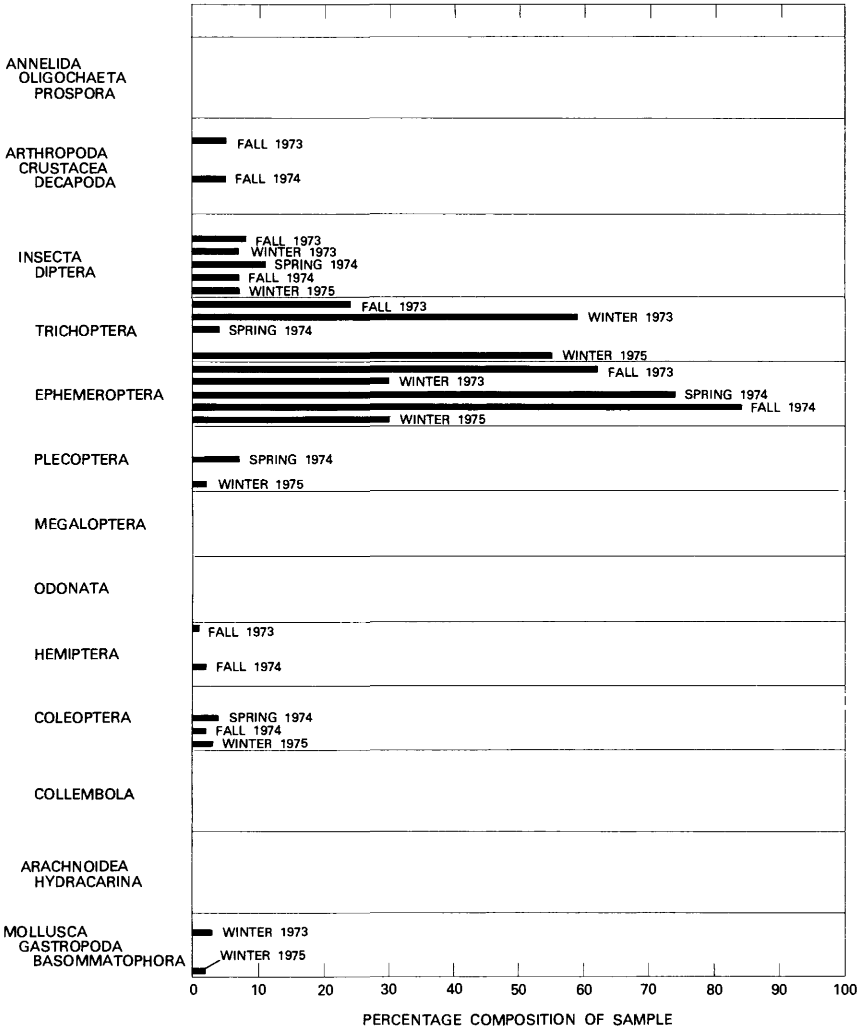

FIGURE 14*C*. — Benthic invertebrate distribution in Turtle Creek, site T–3.

(Ephemeroptera) and a few midges (Diptera), stoneflies (Plecoptera), and crayfishes (Decapoda). Even though the diversity index of this sample was almost as high as that of the fall sample, there was great dissimilarity in the composition of the two communities. (See fig. 14*B*.) The early dominance of mayfly nymphs at this site may indicate that they are among the first benthic invertebrates to repopulate a given reach of freshly cut streambed with the onset of stabilization.

Hynes (1972, p. 266) reports a new channel cut for a stream near Philadelphia contained *Simulium* (black fly) within a week followed

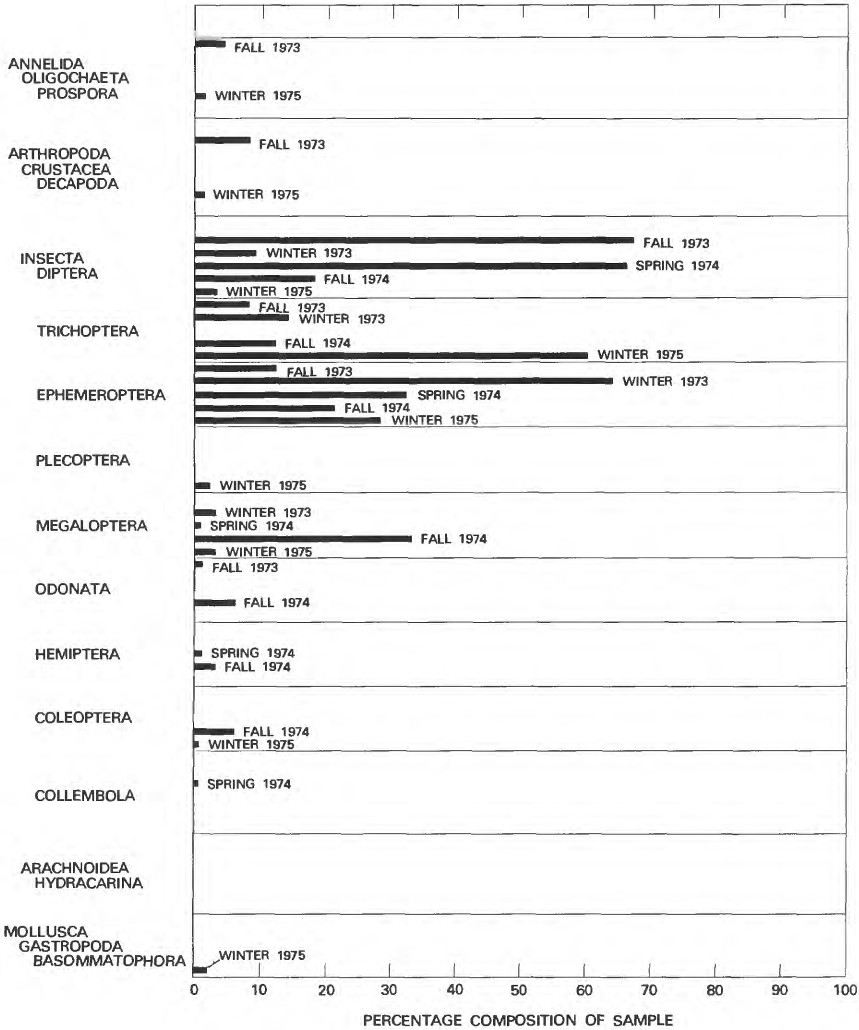

FIGURE 14*D*. — Benthic invertebrate distribution in Turtle Creek, site T–4.

rapidly by *Baetis* (mayfly) and *Stenonema* (mayfly). This is similar to the repopulation of site T–2, as indicated by the spring sample. Drift, resulting from the gentle spring rains of March, April, and May, introduced organisms to the site from small tributaries.

The sample collected during the fall of 1974 had a diversity index of 2.91 and a generic count of 12 but contained only 29 organisms.

The final sample collected at site T–2 indicated the diversity and population had stabilized. Eighty-nine organisms, the highest count obtained at this site, were recovered from the sample that had a diver-

FIGURE 15.—Sampling site T–2 showing streambed consisting of gravel, sand, and mud during fall 1973.

sity index of 2.61. As at site T–1, caddis flies (Trichoptera) were the dominant organisms in the sample, indicative of uniform repopulation trends from the headwater to this site.

A total of 237 organisms were collected at this site during the study; the median diversity index of the five samples was 2.91. As shown in figure 16, this site had the highest median diversity index of all sites on Turtle Creek. The authors believe that streambed construction and landscaping were conducive to rapid recolonization and community development at this site.

SITE T–3

The composition of the streambed changed from gravel and cobble to small boulders, sand, and silt from the fall of 1973 (fig. 5) to the fall of

1974. However, the samples collected at this site indicated that the benthic diversity remained more stable during and after highway construction than it did at any of the other sites on Turtle Creek. (See fig. 16.)

During 1972, the aquatic habitat of this reach of Turtle Creek was destroyed because of relocation of the stream channel. The new streambed was quickly repopulated by tributary inflow and downstream drift.

The sample collected during the fall of 1973 had a total count of 112 organisms and a diversity index of 2.14. The sample contained genera of the order of mayflies (Ephemeroptera), caddis flies (Trichoptera), midges (Diptera), and crayfish (*Orconectes virilis*). As at site T--2, the mayflies were the first to repopulate the relocated channel.

During the winter of 1973 the site was sampled again. That sample had both a lower diversity index (1.24) and a lower total count (112) than the fall sample. The major change in community structure resulted from a dominance of mayflies during the fall to a dominance of caddis flies during the winter. There were no visible changes in the streambed sediment that would indicate a habitat more suitable for caddis flies than mayflies.

The sample contained the first snails (Gastropoda) that were encountered during the study. The particular snail (*Physa*) found at this site "occurs in greatest abundance where there is a moderate amount of aquatic vegetation and organic debris," (Pennak, 1953, p. 681).

The sample collected during the spring of 1974 showed a marked improvement in diversity index, as compared with the one collected in the

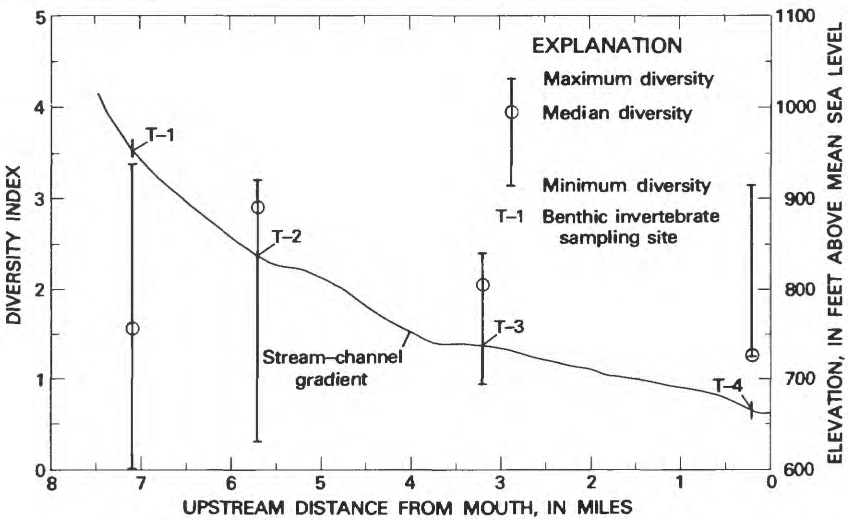

FIGURE 16. — Stream-channel gradient and diversity-index range of Turtle Creek.

previous winter. It had a diversity of 2.42 and a generic count of 7 but a total count of only 27 organisms. The dominant organisms of the benthic community were mayflies (Ephemeroptera), midges (Diptera), and stoneflies (Plecoptera).

Because of heavy sediment deposition at this site during the summer of 1974 (fig. 17), the benthic invertebrate diversity was markedly diminished, as indicated by the fall 1974 sample. The diversity index of this sample was 0.94, and its generic count was 5. However, its total population was actually greater than that of the previous sample and consisted mostly of free-ranging *Baetis* (mayflies) (Pennak, 1953, p. 514).

The site is downstream from several undisturbed tributaries;

FIGURE 17.—Sampling site T–3 during August 1974, showing sediment deposition on streambed.

repopulation of this site by mayflies (Ephemeroptera) might have resulted from organism drift.

The winter of 1975 sample again confirmed that the benthic community remained relatively stable during construction and postconstruction at site T–3. The dominant organisms were caddis flies (Trichoptera).

During the study, a total of 417 organisms were collected at this site; the median diversity index of the five samples was 2.05 (fig. 16).

SITE T–4

During the fall of 1973 the rock and cobble bed was covered with silt and clay to a depth of about 10 inches (fig. 18). During the winter the

FIGURE 18. — Sampling site T–4 during September 1973.

bed showed evidence of reverting to its original riffle-pool morphology. A flood during January 1974 augmented this process.

All indigenous vegetation was removed from the left bank during the summer of 1973, but reseeding had established a moderate to dense coverage of "Ethiopian vetch" by August 1974. Also, sand bars along both banks had replaced mucky silt and clay (fig. 19). The downstream section of this site is shaded until noon by trees growing on the right bank.

Diversity indices for this site varied rather widely, from 1.26 to 3.15; generic counts varied from 7 to 16, and the total counts varied from 70 to 248. Generally, values of all three were lowest during the early stages of the study and were highest during the fall of 1974 and the winter of 1975. As shown by figure 14*D*, this site demonstrated a striking example of generic shift from a dominance of midges (Diptera) in the fall of 1973 to mayflies (Ephemeroptera) in the winter and back to midges (Diptera) in the spring of 1974.

FIGURE 19.—Sampling site T–4 during August 1974.

The sample collected during the fall of 1973 had a diversity index of 1.26, the lowest from this site. It contained a relatively high number (83) of midge larvae (Diptera). These midge larvae, or blood-worms, were found embedded in the thick, mucky bottom layer of silt and clay such as that shown in figure 11. Ten crayfish (*Orconectes*) were found at this site, representing the highest number of crayfish found in any sample during the investigation.

The winter sample had a slightly higher diversity index but a total count of about half of the previous sample. However, the greatest difference between fall and winter samples was the marked change from a dominance of *Chironomus* (Diptera) in the fall to that of mayflies (Ephemeroptera) in the winter. Many *Chironomus* inhabit sluggish streams with a deficiency of dissolved oxygen and a muddy bottom (Pennak, 1953, p. 650). The mucky deposition on the streambed during the summer was conducive to the presence of *Chironomus*.

Because of bed scouring, conditions probably favored benthic invertebrate diversification by the spring of 1974. The spring sample contained five types of mayflies (Ephemeroptera) and three types of the order Diptera.

The fall 1974 sample indicated biological diversification. Though the total count was less than any of the three previously collected samples at site T–4, its diversity index (3.15) was much greater. Eleven different genera were present, and many of these were representative or indicative of higher forms commonly associated with free-flowing streams having low sediment concentrations.

Although the final sample collected at site T–4 had a lower diversity (1.78) than the preceding sample, it had a generic count of 16 and a total count of 248 organisms. Like all of the other sites sampled along Turtle Creek during the winter of 1975, site T–4 yielded a predominance of caddis flies.

During the study a total of 668 organisms was collected at this site, and the mean diversity index of the five samples was 1.88.

LICK CREEK — STUDY-CONTROL STREAM

Beginning in the spring of 1974, three benthic invertebrate samples were collected at each of the two sampling sites on Lick Creek. The following discussion briefly describes the analytical results of these samples for the individual sites.

SITE L–1

The samples collected during the spring and fall of 1974 had low total counts but high diversity indices. The spring sample contained a much larger percentage of mayflies (Ephemeroptera) than the fall sample. Caddis flies (Trichoptera), which constituted almost 30 percent of the fall sample, were not present in the spring sample. (See fig. 20*A*.)

However, the sample collected during the winter of 1975 contained 65 caddis flies (Trichoptera) and 32 mayflies (Ephemeroptera) and had a diversity index of 2.64. The sample contained 142 organisms and had a generic count of 14 — the highest generic count recorded for Lick Creek (table 6).

The three samples collected at site L–1 yielded a total of 207 organ-

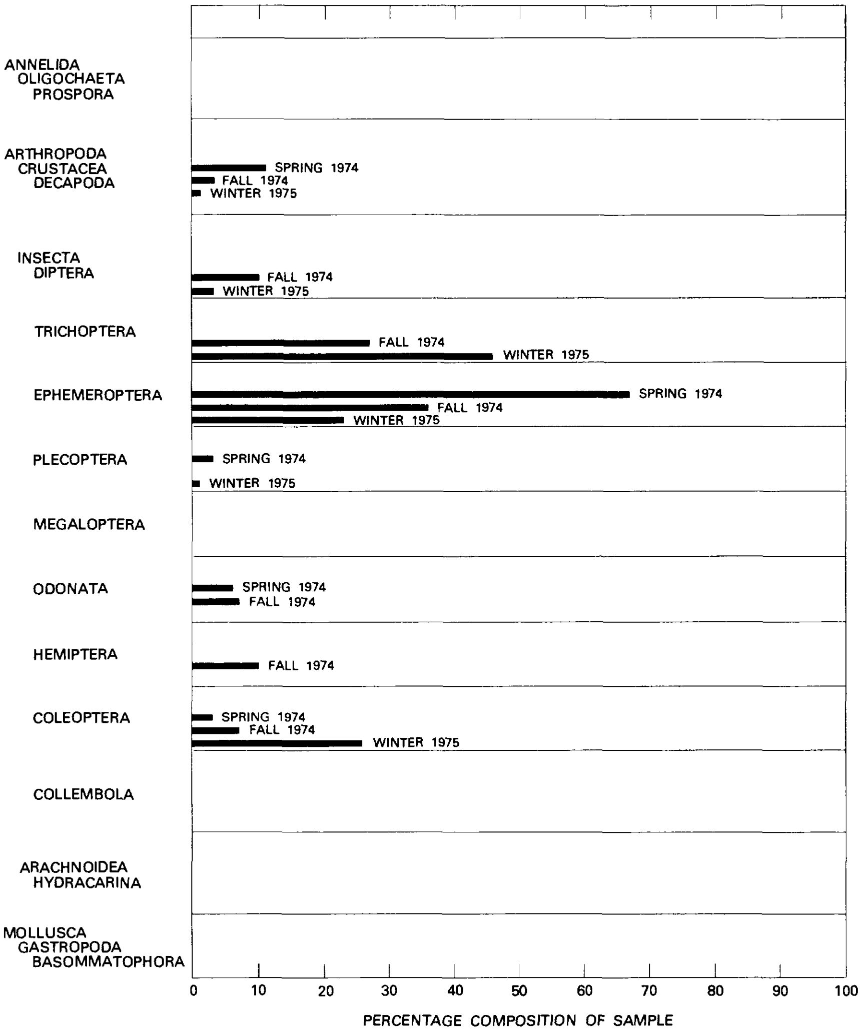

FIGURE 20*A*. — Benthic invertebrate distribution in Lick Creek, site L–1.

TABLE 6. — *Summary of diversity indices and count data for Lick Creek*

		Diversity index	Generic count	Total count
		Site L-1		
Spring	1974	2.26	10	35
Fall	1974	3.13	11	30
Winter	1975	2.64	14	142
		Site L-2		
Spring	1974	3.04	18	107
Fall	1974	2.80	9	29
Winter	1975	2.14	13	177

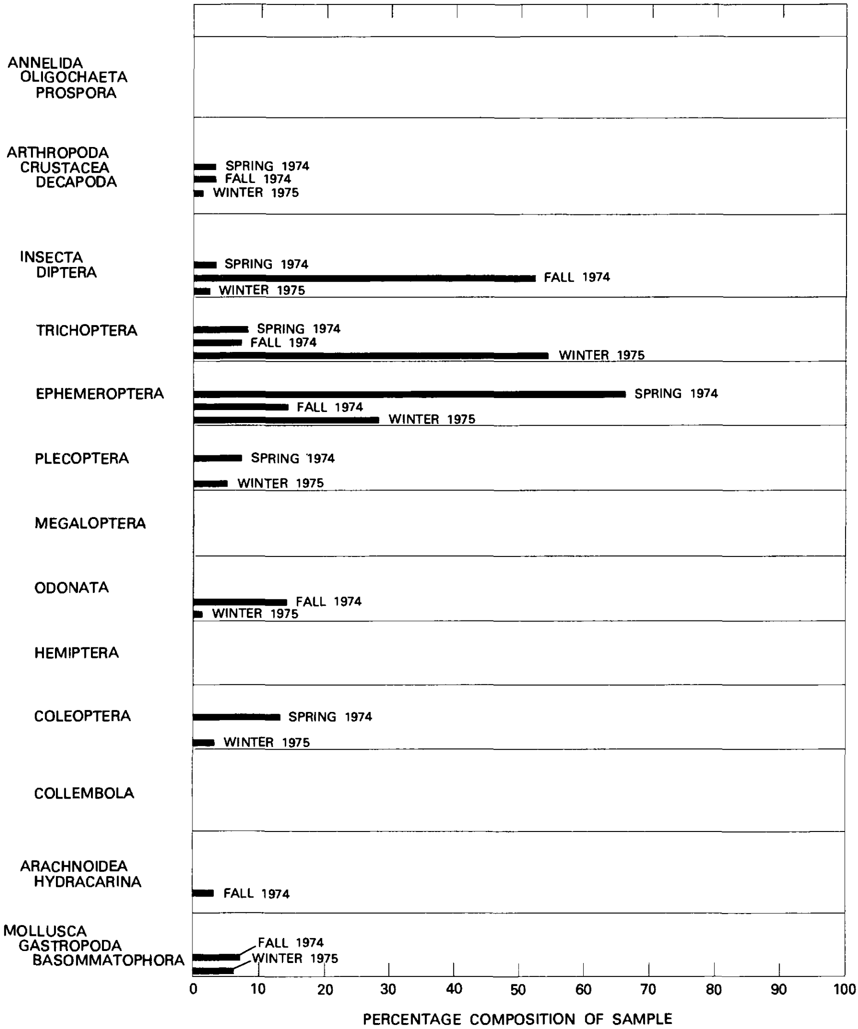

FIGURE 20*B*. — Benthic invertebrate distribution in Lick Creek, site L-2.

isms and a mean diversity index of 2.68.

It is emphasized that neither sediment transport nor deposition was visually or otherwise related to the changes observed in generic distribution of the benthic invertebrates; the changes may be cyclic.

The highest total count observed at site L–1 was less than the highest count observed at site L–2. The steeper channel gradient at site L–1 results in an increased flow velocity that may periodically dislodge organisms, thereby reducing total counts. This probably explains the smaller total population at site L–1 observed shortly after the spring rains.

Because the drainage area upstream from this site is virtually in its natural state, it was assumed that these samples depicted the "normal condition" for site L–1.

SITE L–2

The biological community at this site was well diversified and highly populated during the spring of 1974, and the sample collected at this time had the highest generic count obtained for Lick Creek. One hundred seven organisms were present in the spring sample. The benthic invertebrate community structure was similar but more complex than that found at site L–1 at the same time.

By the fall of 1974, the benthic invertebrate population had greatly decreased, but its diversification had remained high (2.80). As at site L–1, a generic shift away from a predominance of mayflies (Ephemeroptera) in the spring occurred. (See fig. 20*B*.) In this case, the shift produced a dominance of crane flies (Diptera).

The final sample taken at site L–2 contained 97 caddis flies (Trichoptera) and 49 mayflies (Ephemeroptera). The sample had a diversity index of 2.14, contained 177 organisms, and had a generic count of 13.

The three samples collected at this site yielded a total of 133 organisms and had a mean diversity index of 2.66 (fig. 21).

EFFECT OF DRAINAGE AREA UPON TOTAL POPULATION

Higher total counts were obtained at sites T–3 and T–4 than at T–1 and T–2 and varying kinds of benthic invertebrates were frequently found at T–3 and T–4 during subsequent visits. The authors attributed the higher total count (and diversification) at sites T–3 and T–4 to tributary inflow and organism drift. If this is true, there should be some correlation between inflow from undamaged tributaries and organism count.

To test this hypothesis, all total counts for each site were arithmetically averaged and plotted against cumulative drainage area. The sites farthest downstream and, therefore, those having the largest drainage area, yielded the greatest arithmetic mean number of organisms. This was true for both Turtle Creek and Lick Creek, and the resulting curves shown in figure 22 also point out that population variation from the headwaters to the mouth of Turtle Creek was much greater than that for Lick Creek. Drainage area is significant to the extent that tributary inflow, which increases with drainage area, provides a source of seed organisms to a degraded main stem.

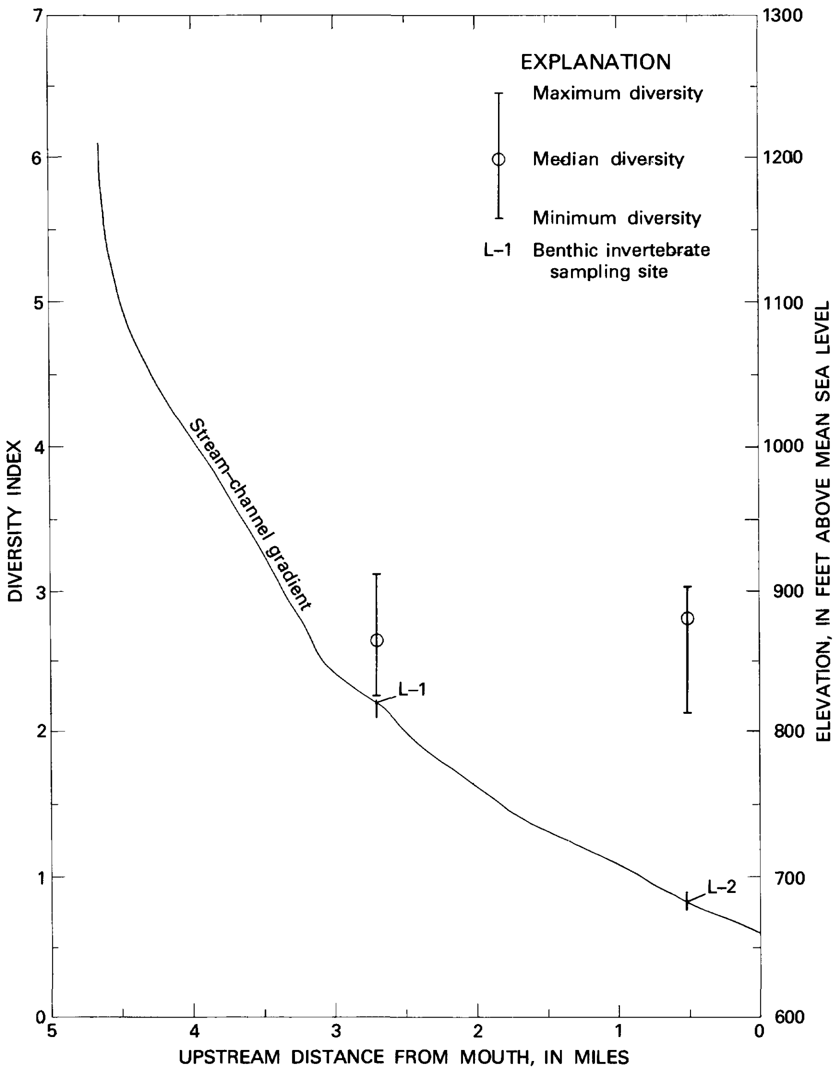

FIGURE 21. — Stream-channel gradient and diversity-index range of Lick Creek.

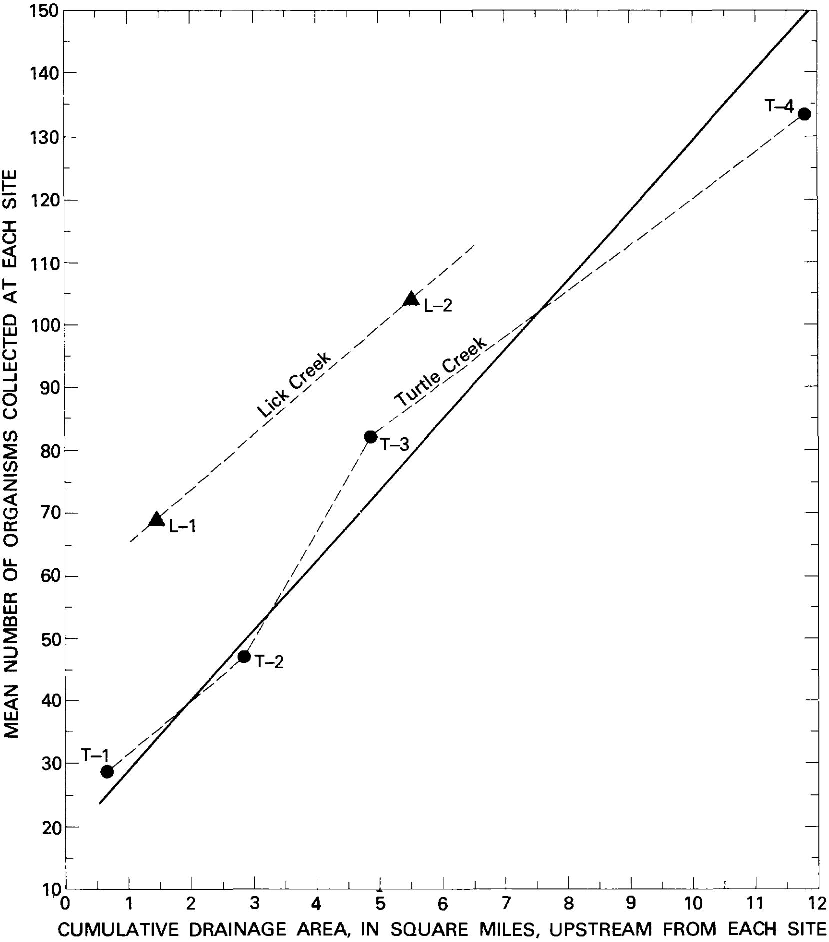

FIGURE 22. — Relationship between drainage area and total count.

CONCLUSIONS

Massive sediment transport and channel relocation along the mainstem of Turtle Creek, generated by the construction of a super highway, Appalachian Corridor G, destroyed or severely damaged the stream's benthic invertebrate community.

The greatest benthic damage, which was observed about 18 months after initial excavation, occurred in the upper reaches of the stream, where channel gradient is greatest and tributary input of benthic organisms is least. In these reaches of relatively high flow velocities, dramatic habitat alteration occurred quickly presumably because of the erratic movement of large loads of sediment. For example, diversity indices ranged from 0 to 3.41 at site T–1, near the headwaters, and the number of organisms found was only one-third that found at sites T–3 and T–4. Despite rapid streambed alteration, site T–2, which was in a reach of relocated stream channel, had the highest median diversity index of all sites on Turtle Creek.

In the downstream reaches of the stream, where the channel gradient is less and the drainage area greater, the range of diversity indices was less than half that of upstream reaches. As drainage area increased progressively downstream by four times, the total number of organisms increased proportionately, but the range of diversity indices was halved. At sites T–3 and T–4, the sediment movement was less erratic, and, instead of entire communities being quickly destroyed, certain organisms were preferentially eliminated from the changing environment.

Repopulation and organism diversification of both old and new channels of Turtle Creek came about quickly. Within a year after construction was completed and vegetation had helped stabilize and lessen the release of sediment, the population and diversification of the benthic invertebrates of Turtle Creek were similar to those of Lick Creek — the control stream. The final samples (winter 1975) from Turtle Creek had a mean generic count of 14.5, whereas the final samples from Lick Creek had a mean generic count of 13.5. The benthic diversities of the two streams during the final sampling were also similar. The median diversity of Turtle Creek was 2.82, and that of Lick Creek was 2.39. Organism drift and organism inflow from undamaged tributaries were the major methods by which damaged reaches of Turtle Creek were repopulated.

If projects involving large-scale excavations, such as the construction of Appalachian Corridor G, can bypass a relatively large part of the headwater reaches of streams, a source of seed organisms would remain available to promote repopulation of the downstream reaches. Though highway construction necessitated major alteration of the upper main stem of Turtle Creek, the small but unaltered tributaries to this reach of the stream were a significant source of the organisms that promoted development of new benthic communities.

In the absence of data collected prior to excavation activities, concurrent data collection on a control stream may be the only means by which a reasonable assessment of habitat alteration can be made.

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