1735

THE EFFECTS OF STREAM CHANNELIZATION ON BOTTOM DWELLING ORGANISMS

Phase 2 Report
"1975 Construction Season"

by

David C. Wyant
Research Engineer

(The opinions, findings, and conclusions expressed in this report are those of the author and not necessarily those of the sponsoring agencies.)

Virginia Highway & Transportation Research Council
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1736

SUMMARY

Three construction projects affecting streams are being monitored. On two of the projects, those affecting Meadow Run and Moores Creek, the streams are being monitored for flow, suspended solids, rainfall, and benthic populations. Construction has been completed on these projects and the monitoring program is being curtailed. The third project, which affects Simpson Creek, was added to the study in May 1975 to expand the monitoring program to include chemical parameters. Therefore, only the background data on this project are available at this time.

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BACKGROUND

This study was initiated in June 1974 as a result of growing concern in Virginia over the effects of channelization on the ecology of streams. Studies made in other states in the early fifties had indicated adverse effects from channelization. Several of these studies are cited in the Phase 1 Report on this present study.(1) In summary, these studies concluded that with increased sediment loads the benthic populations, the numbers of fish per acre, and the weight of fish per acre were reduced.

In 1973, the Committee on Water Quality Criteria to the Environmental Studies Board of the National Academy of Science, National Academy of Engineering released a report stating the need for further research on the consequences of eliminating riffles and pools in streams by channelization.(2) This report was followed by a Research Council publication in early 1974 that covered a survey of the Department of Highways and Transportation's erosion-siltation control program.(3) In the Council report, recommendations were made to the Department to minimize channel changes, to locate highways away from live streams, and to rehabilitate streams that had to be altered.

To provide information concerning the effects of any necessary channel changes, the work reported here was initiated.

OBJECTIVES

The objectives of this study, as stated in the working plan,(4) are the determination of the —

(1) percentages reduction of various benthic populations as a result of stream channelization;

(2) the downstream extent of the reduction of the benthic populations;

(3) the recovery time for the stream's ecology after the channelization;

(4) the relation of turbidity and/or suspended solids to the benthic insect population reductions.

SUMMARY OF PHASE 1 REPORT

In June 1974, two streams proposed for channelization by the Department were selected to be monitored. The first one, Meadow Run, is located in the Valley and Ridge Province of Virginia (Figure 1). Route 254 near Staunton was being relocated and had to cross Meadow Run. At the point of the crossing, a four-barrel box culvert was constructed in the dry and a new channel, above and below the box culvert, was cut to the culvert (Figure 2). Flow, rainfall, suspended solids, and benthic populations were determined from the first of June 1974 to the middle of October 1974.

The suspended solids values determined for ambient conditions after channelization were lower at every test station than the results obtained before channelization. This trend held true for all stations except station 2, which is 100 feet (30.5 meters) downstream from the channelized section, when a 0.1-inch (0.25 cm.) storm event occurred. On the day the stream was diverted through the new channel and box culvert the suspended solids at station 2 increased, on the average, 106 ppm over the ambient level. At one time during the initial flushing out day, the suspended solids level was as high as 534 ppm at this station.

At station 3, .25 mile (402 meters) downstream, the suspended solids increased on the average by 33 ppm over the average ambient level. However, during the flushing out period the suspended solids reached a maximum of 147 ppm at this lower station, which exceeds the Environmental Protection Agency's proposed limit of 80 ppm above the ambient level.

The second stream being monitored is Moores Creek near Route 29 south of Charlottesville (Figure 3). This stream is located in the Piedmont Province of Virginia and crosses Route 29 three times on the construction project. In addition, several of its tributaries cross the construction project. The same parameters were determined on this stream as on Meadow Run.

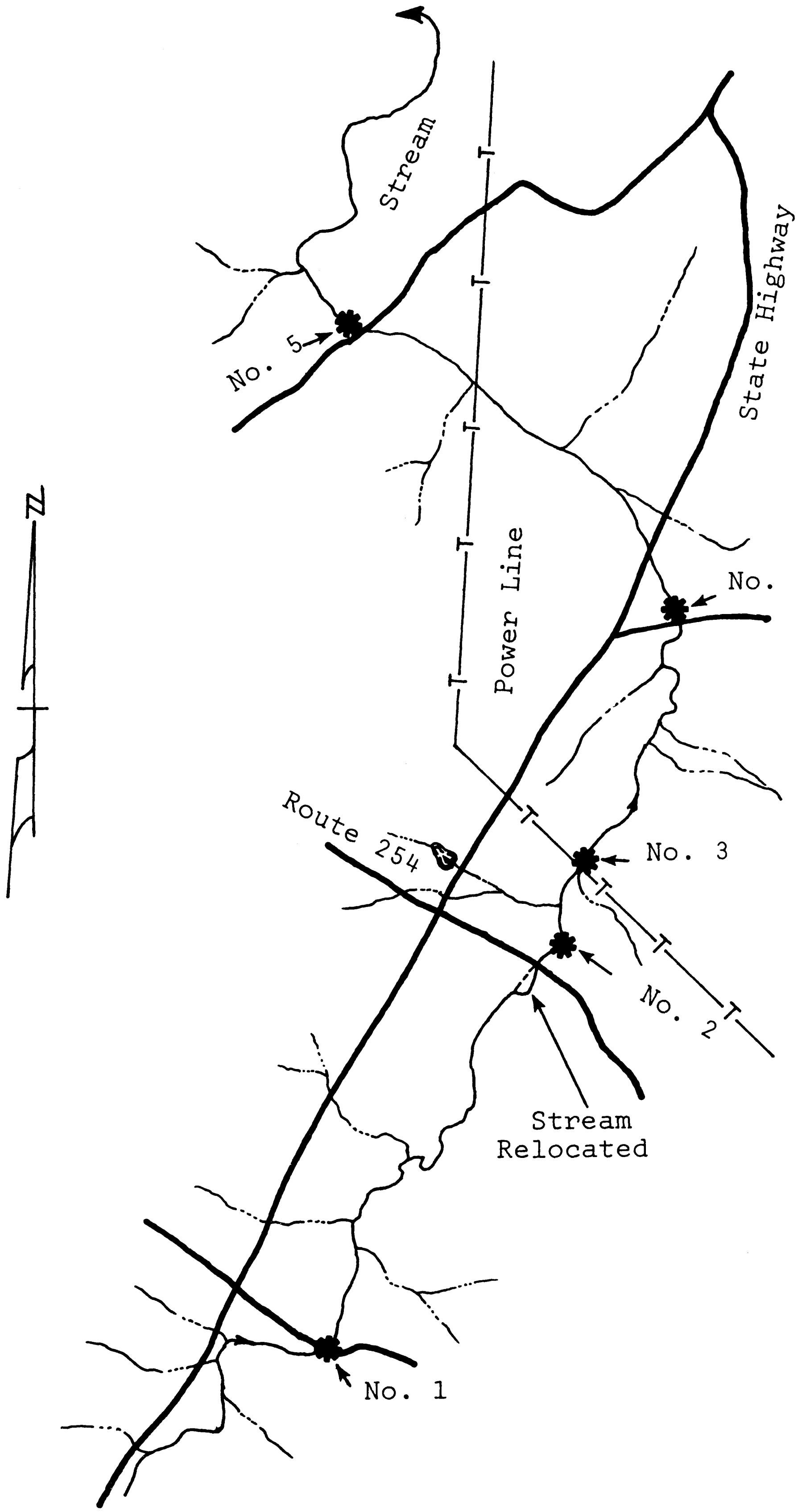

Figure 1. Meadow Run — Route 254 site.

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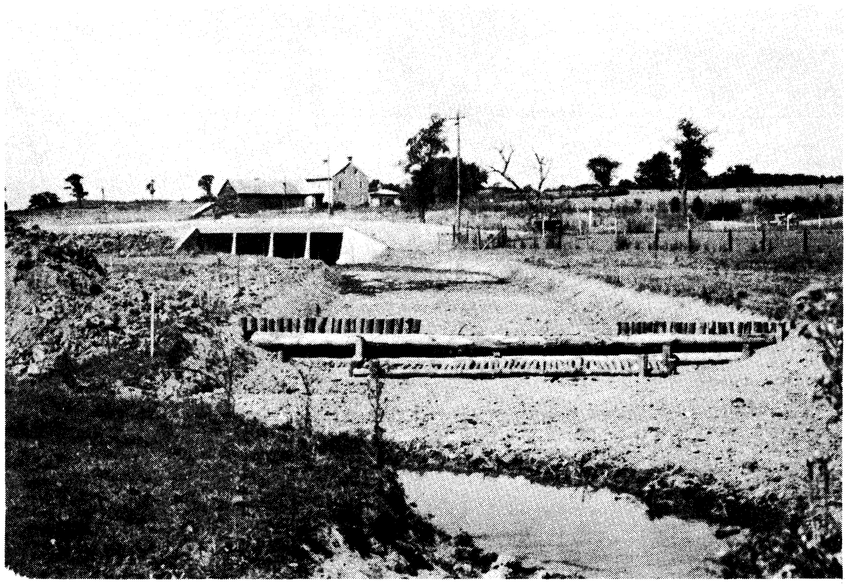


Figure 2. New channel.

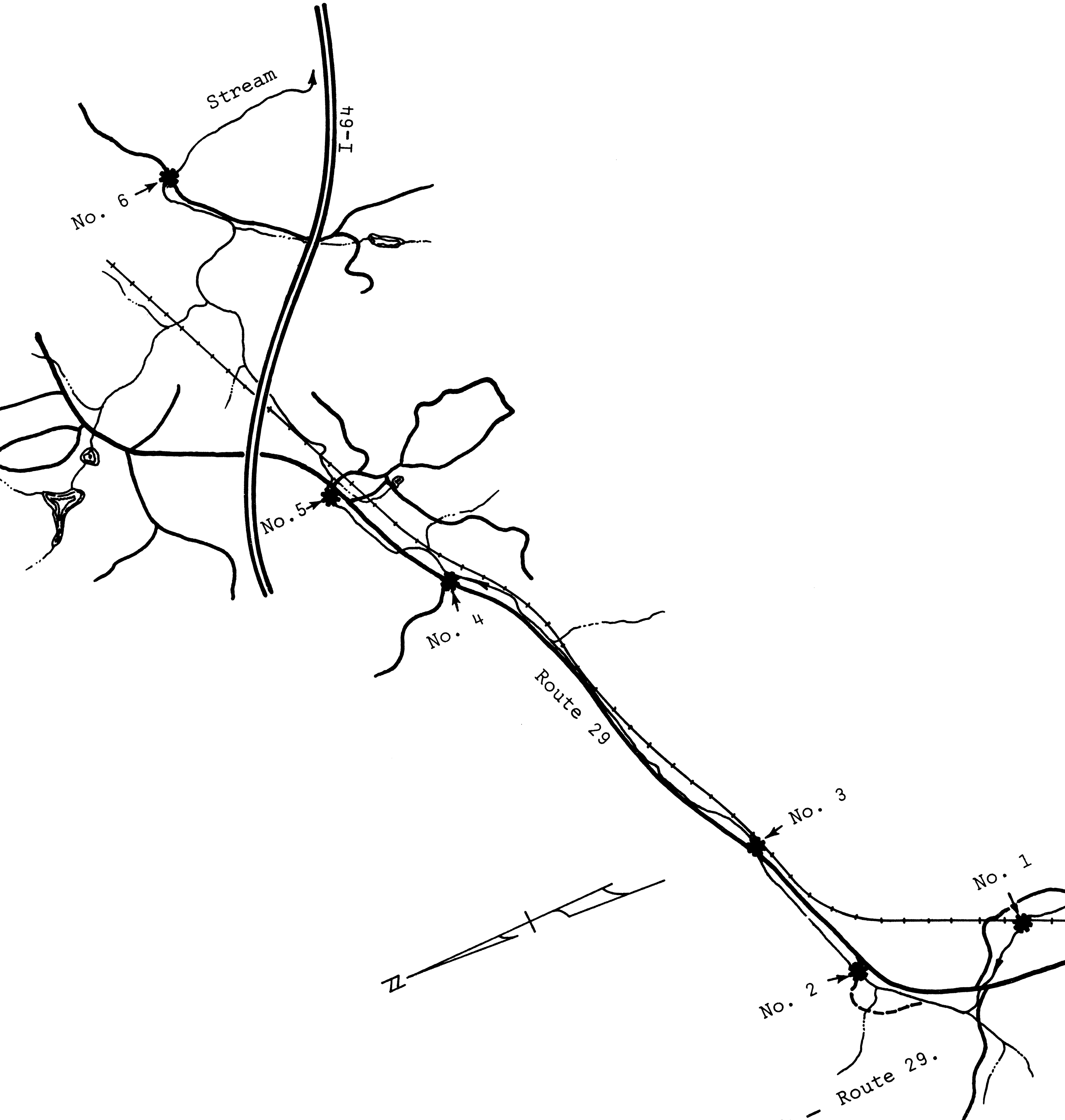


Figure 3. Moores Creek — Route 29.

The channel work conducted on this project was in the stream. Since the stream is essentially parallel to Route 29, most of the earthwork came down to the stream bank. Under ambient conditions the suspended solids were as high as 69 ppm just below the construction of a box culvert in the stream. During a 0.7-inch (1.8 cm.) storm event, the suspended solids below the box culvert reached 601 ppm. In addition, suspended solids of 363 ppm were recorded for the same storm event just below an area being filled. The fill material either came down to the stream bank or was spilt into the stream during the fill construction.

For the same storm event the suspended solids level was at the proposed EPA limit of 80 ppm at a distance 1.5 miles (2,414 meters) downstream (station 6) from the end of the construction project.

At the time of publication of the Phase 1 Report, only suspended solids, flow, and rainfall results were available. The benthic samples were not completely processed at that time, so the biological results were withheld for this report.

1975 SUMMARY

This section of the report covers three aspects of the study. First, the 1974 benthic population results are reported. Next the 1975 construction results minus the benthic population results for the year are given. The last aspect is the background research conducted on the Simpson Creek project, which was initiated in early 1975.

1974 Benthic Population Results

Sets of a modified Hester-Dendy, multi-plate artificial substrate were placed in Meadow Run and Moores Creek around the end of May 1974 at the stations shown on Figures 1 and 3. An additional set was placed at each station every two weeks until the latter part of October 1974. After each set of substrates was exposed to the aquatic environment for a period of six weeks, it was removed for processing and the identification of benthic organisms.

The numbers of organisms and genera collected on each five square foot (0.47 square meter) substrate at each station were determined. From these data the mean diversity, $\overline{D}$,[5] and the redundancy, R,[6] for each date and station sampled were ascertained.

The mean diversity indicates the average diversity among individual organisms, or the average "richness" in genera of the biological community. The mean diversity was determined as follows:

$$\bar{D} = \frac{1}{N}\left[\log_2 N! - \sum_{i=1}^{s} \log_2 n_i!\right]$$

where

N = total number of organisms,

n_i = number of organisms in the i^{th} genera, and

s = total number of genera.

Redundancy is a measure of the probability that an organism belongs to a specific genera. The value of redundancy can vary from zero to one. If R = 1.0, then all the organisms belong to the same genera; while if R = 0, each organism is from a different genera. Redundancy was calculated as follows:

$$R = \frac{\sum_{i=1}^{s} \log n_i! - s \log ({}^{N}/s)!}{\log (N - s + 1)! - s \log ({}^{N}/s)!}$$

Until the early 1970's no way was available to statistically evaluate changes in water quality parameters such as suspended solids, mean diversity, and redundancy over a long period of time. Harkins and Austin[5] developed a technique that provides a single index value from a set of indices. The index value derived is a unique distance value from a fixed reference point or condition. The condition chosen in this study is a "biological desert". The index value, or standardized distance (SD) as it is called in this study, indicates less favorable conditions at the stations by values close to zero.

Meadow Run — Route 254

Table 1 shows the mean diversity and redundancy index for the substrates collected from Meadow Run in 1974. Using the redundancy index, mean diversity, and number of genera shown in Table 1, and a weighted average suspended solids determined for each date, the standardized distance for stations 1 and 2 were calculated. Table 2 shows the results obtained with these four input parameters. The largest values of standardized distance for the dates are associated with the upstream (control) station, station 1. Since the values are correlated in time, paired t statistics were used to test for significant differences in the two stations (upstream and downstream of the stream alteration). The statistical tests indicated, on the average, that station 2 was significantly different 95.8% of the time from station 1. In other words, environmental degradation occurred downstream at station 2 after the four-barrel box culvert was opened.

An environmental damage index (SD_1 - SD_2) was determined and plotted versus time after the box culvert was opened (see Figure 4). As the index approaches zero, there is no difference between the upstream and downstream stations; in other words, no environmental damage is evident and the stream has recovered from the effects of channelization at station 2.

Figure 4 shows two straight lines, four open circle data points and one solid circle data point. The data points represent the environmental damage index for different days. From a linear regression analysis on the four open data points, the dashed line is obtained. As shown on Figure 4, it took 106 days after the new channel was opened for the channel to return to its original condition. This recovery rate is similar to the rate (92 days) that Poché obtained in his study for one test site.[7] From these results it seems the effects of building a box culvert in the dry reduce the benthic populations for 3 to 3½ months. Therefore, the drift and regrowth of organism occurs faster than previously thought by this researcher.

However, if all five data points in Figure 4 are regressed linearly, the solid line is obtained. The result from this analysis is not as favorable as the previous result. The recovery time determined for this line is 510 days, or 17 months. The data point at 72 days after opening of the box culvert (October 3, 1974) caused the curve to shift.

Table 1

Biological Analyses for Meadow Run

Redundancy Index	Mean Diversity	Number of Genera	Number of Organisms	Station Identification*
.3507	2.660	16	164.0	627 1
.8670	.683	17	919.0	627 2
.5128	1.659	10	611.0	627 3
.3903	2.776	21	257.0	627 4
.3531	2.493	13	68.0	627 5
.6253	1.697	16	293.0	712 2
.2678	3.101	19	206.0	712 3
.6331	1.626	17	560.0	712 4
.3434	2.401	12	113.0	712 5
.3456	2.872	20	327.0	725 2
.2446	3.388	23	195.0	725 3
.4336	2.902	32	970.0	725 4
.7607	1.149	21	1411.0	8 9 2
.2426	3.298	21	271.0	8 9 3
.1583	3.411	18	231.0	8 9 4
.2924	2.969	18	133.0	822 1
.5774	1.912	19	576.0	822 2
.3120	2.968	19	143.0	822 3
.4252	2.718	23	318.0	822 4
.2761	3.293	23	131.0	9 5 1
.5495	2.146	23	720.0	9 5 2
.1360	4.054	29	271.0	9 5 3
.4805	2.632	27	398.0	9 5 4
.1829	3.433	20	186.0	9 5 5
.3076	3.106	22	401.0	919 1
.4623	2.397	19	334.0	919 2
.4930	2.293	20	486.0	919 3
.3348	2.970	21	267.0	919 4
.2754	3.322	24	450.0	10 3 1
.7437	1.056	15	1733.0	10 3 2
.4110	2.800	24	370.0	10 3 3
.4541	2.566	23	499.0	10 3 4
.2481	2.981	16	235.0	10 3 5
.4160	2.710	22	318.0	1018 1
.6165	1.924	23	486.0	1018 2
.2844	3.482	29	707.0	1018 3
.6959	1.530	21	537.0	1018 4
.3708	2.773	20	380.0	1018 5

*The first four numbers indicate the month and day of the sample. The fifth number is the station of the sample indicated in Figure 1.

1708

Table 2

Water Quality Index — 1974
Meadow Run — Stations 1 and 2

Date	Station	Standardized Distance
8-22-74	1	18.111
	2	5.059
9- 5-74	1	23.179
	2	11.379
9-19-74	1	14.510
	2	9.859
10- 3-74	1	31.180
	2	5.203
10-18-74	1	20.310
	2	15.979

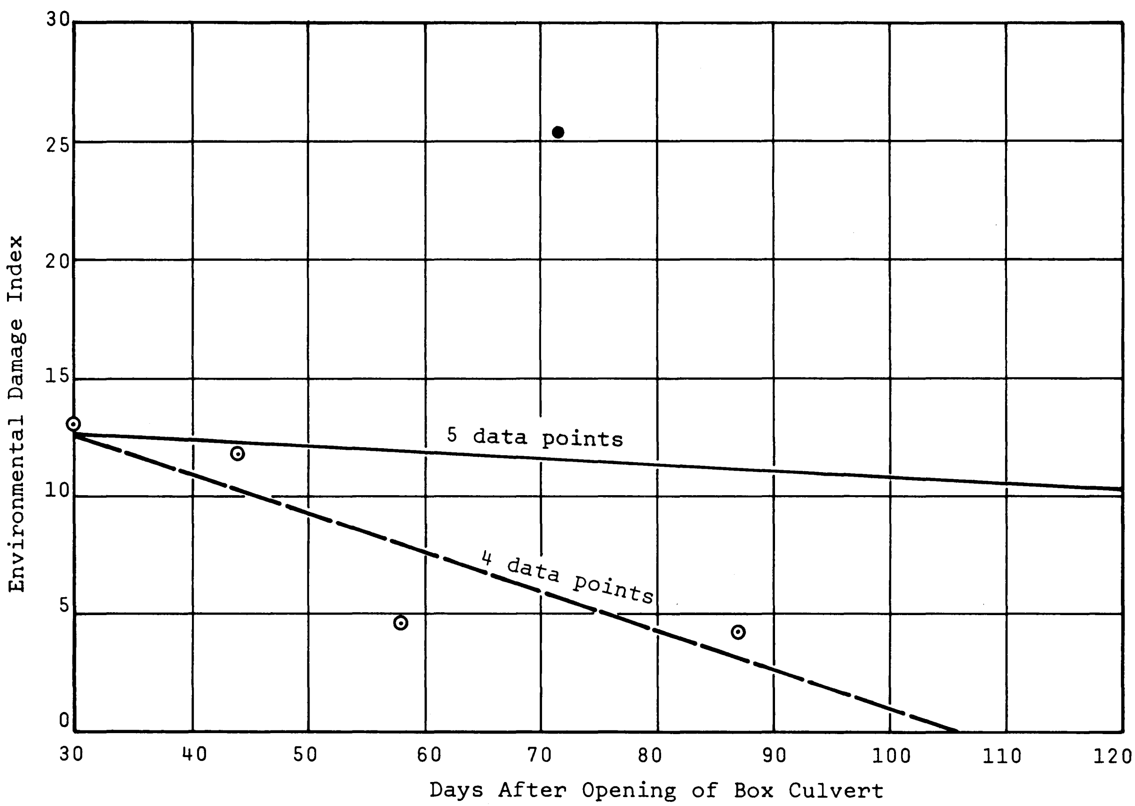
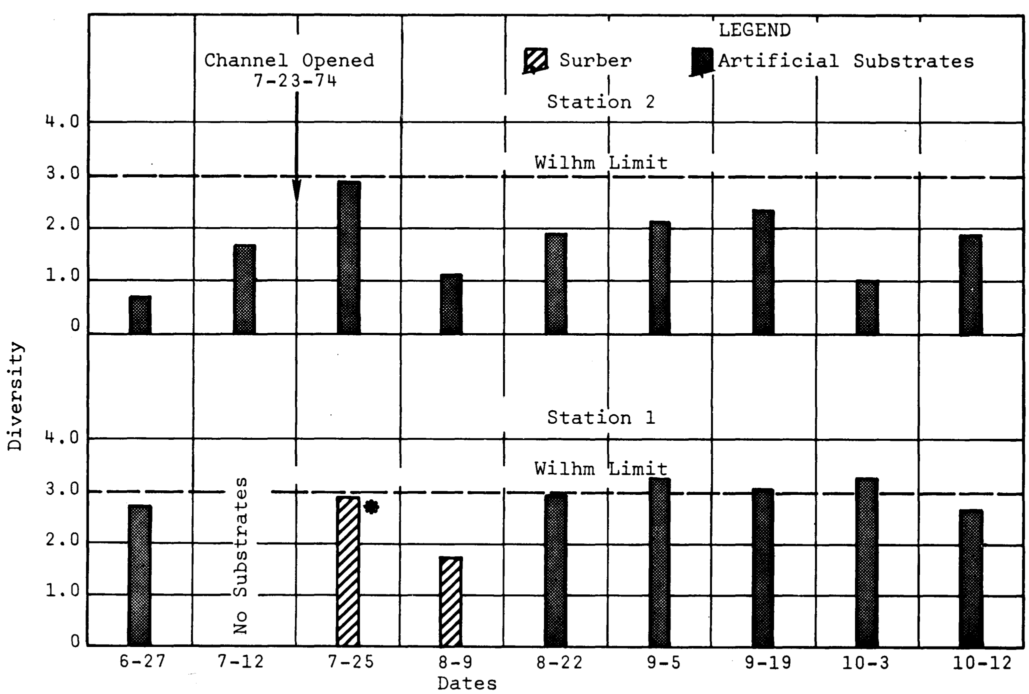


Figure 4. Rate of recovery at Meadow Run.

The data for stations 1 and 2 on October 3, 1974 (Tables 1 and 2), show 450 organisms and 24 genera for station 1, while station 2 has more organisms (1,733) but fewer genera (15), and thus a lower diversity than station 1 (Figure 5). Wilhm states that when the diversity is less than 3, the benthic population is approaching an unsatisfactory condition.[8] The horizontal dashed lines in Figure 5 indicate the lower limit of $\bar{D} = 3.0$. As shown, station 2 approached this limit only once (7-25-74), which indicates unsatisfactory conditions at all times. The diversity at station 2 was at its highest level (2.872) 2 days after opening of the channel, then dropped to around 1.0. Figure 5 also indicates that the mean diversity for station 2 increased until October 3, 1974, when it dropped to nearly 1.0 again.

Figure 6 shows the percentages of three tolerance classes of the organisms. The three tolerance classes are: (1) sensitive to pollution [S], (2) intermediate [I], and (3) tolerant to pollution [T]. The effects of pollutants on the number of organisms and genera are shown in Table 3.



* One square foot surber sample.

Figure 5. Diversity of Stations 1 and 2 at Meadow Run.

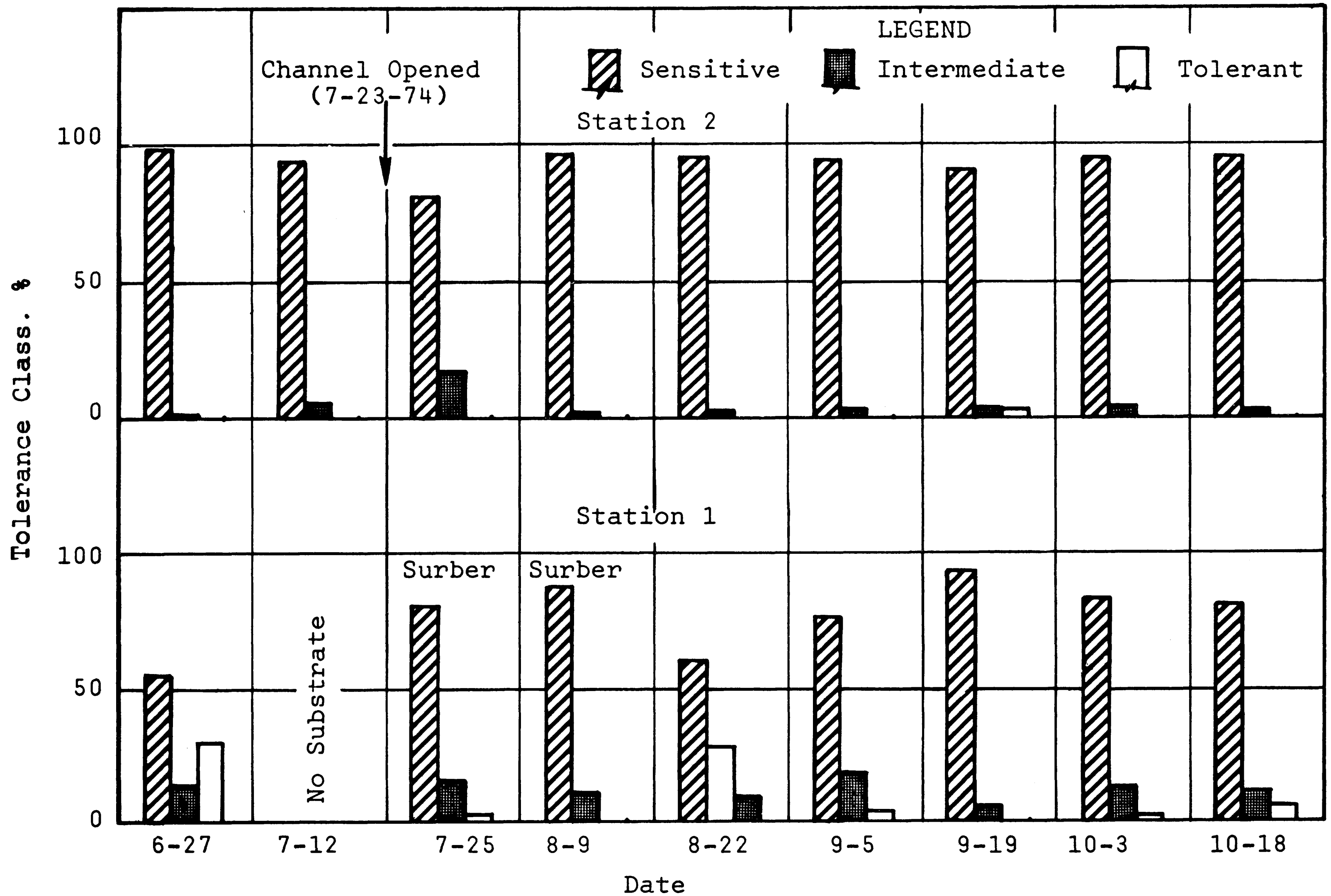


Figure 6. Tolerance classes at Meadow Run.

Table 3

Effects of Pollutants on Benthic Populations

Pollutants	No. of Organisms	No. of Genera
Toxic Substance	Reduce	Reduce
Temperature	Variable	Reduce
Silt	Reduce	Reduce
Nutrients Inorganic	Increase	Variable
Organic Waste	Increase	Reduce

Source: U. S. Environment Protection Agency

In Figure 6 the percentages for all classes for station 2 are nearly the same except those for the first sampling date after opening the new channel and box culvert. A higher percentage of the intermediate and lower percentage of the sensitive organisms were present at that time.

Figure 7 plots the number of genera and organisms per square foot versus time for stations 1 and 2. Table 3 and Figure 7, show no effects of silt after the channel change. From Figure 7, it seems possible that the increased temperature due to the wide channel (approximately 50 feet [15.2 meters]),no shade present on the channel banks, and the small volume of water in the channel may have affected the benthic populations. The number of organisms is quite variable while the number of genera decreases for most of the sampling dates after the channel opening during the summer months.

Figure 7 also shows the increase in organisms and the decrease in genera on October 3 as mentioned earlier. From Table 1, these conditions indicate an addition of organic waste to the stream. Between September 19 and October 3 the farmer owning the field bordering Meadow Run spread cow manure on the field, and probably the runoff from this field substantially increased the number of organisms and decreased the number of genera.

1752

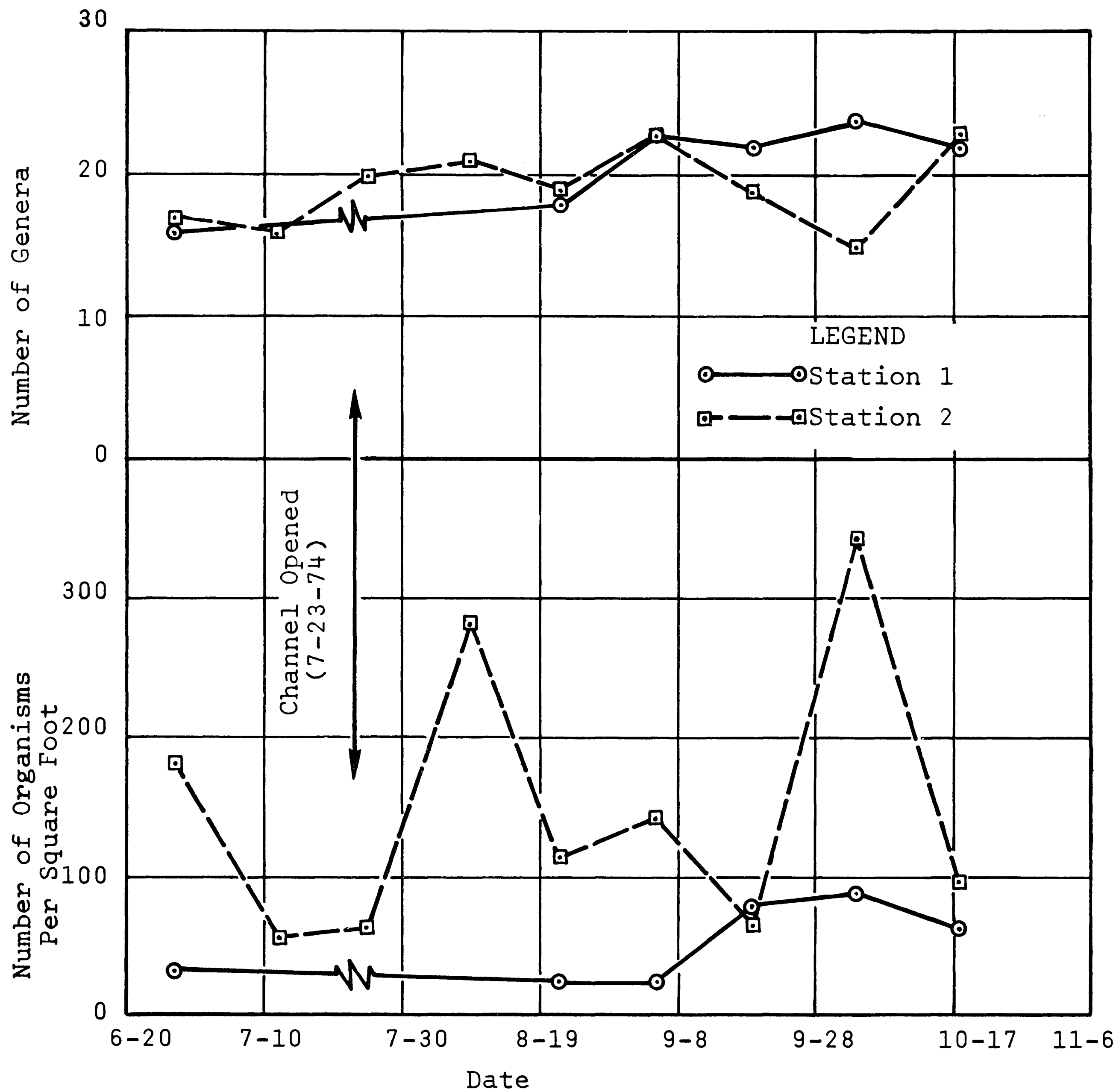


Figure 7. Number of organisms and genera for Meadow Run.

Station 1 had an acceptable water condition from August 22 to October 3 as defined by Wilhm (Figure 5). Silt from an upstream construction project may have affected the benthic population on June 27, since the tolerant class of organisms is larger than that for the other sampling dates (Figure 6). The construction occurred in and next to Meadow Run approximately 1 mile (1,609 meters) upstream from station 1.

On July 12 highway forces constructed wing walls to the bridge at station 1. In preparation for the concrete work, they removed the three substrates at station 1. The surbers for July 25 and August 9 and the substrate for August 22 may indicate some of the effects of the concrete on the benthic organisms. In Figure 5 the mean diversity is lower than the Wilhm limit. The intermediate class for August 22 is larger than it is for the other dates, and the sensitive class is smaller (Figure 6). From August 22 to September 19 the sensitive class increased, which indicates a decrease in the effects of the concrete work with time.

In summary, it seems that the four point line in Figure 4 is the better line, since the fifth point was influenced by organic waste. Therefore, the recovery time for a channel constructed in the dry is around 106 days.

Moores Creek — Route 29

Table 4 shows the mean diversity and redundancy index for the substrates collected from Moores Creek in 1974. As shown in Table 4, the mean diversity for the different sampling dates and stations exceeded Wilhm's limit of 3.0 only once. On August 21, 1974, station 1 had a mean diversity of 3.037, which indicates an acceptable water quality as defined by Wilhm.

The standardized distances for different combinations of stations were determined as was done on Meadow Run. Several conclusions can be drawn from the analyses. The water quality at station 1 was inferior to that at station 3 (below a box culvert construction) for 75% of the sampling dates. The poor water quality at station 1 is possibly due to infiltration of sewage from houses near the headwater of Moores Creek. In addition, two unaffected streams enter Moores Creek below station 1 and improve the water quality of station 3.

1754

Table 4

Biological Analyses for Moores Creek

Redundancy Index	Mean Diversity	Number of Genera	Number of Organisms	Station Identification
1.0000	1.181	4	5.0	711 1
0.3758	1.968	8	37.0	711 2
0.2566	2.523	11	61.0	711 3
0.1157	1.657	4	50.0	711 4
0.3489	2.543	13	43.0	711 5
0.3250	2.153	9	12.0	726 1
0.1219	2.647	11	28.0	726 2
0.3770	2.515	14	72.0	726 3
0.4953	1.066	4	82.0	726 4
0.5068	1.556	7	57.0	726 5
0.3475	1.889	7	22.0	726 6
1.0000	0.0	1	2.0	8 8 1
1.0000	0.0	0	0.0	8 8 2
0.0	0.862	3	3.0	8 8 3
0.2697	2.147	8	46.0	8 8 4
0.4954	2.254	13	50.0	8 8 5
0.2564	1.864	6	43.0	8 8 6
0.1810	3.037	16	41.0	821 1
0.3743	2.088	9	44.0	821 2
0.5307	1.601	7	33.0	821 3
0.4592	1.245	4	7.0	821 4
0.2141	2.884	14	68.0	821 5
0.0	1.381	5	5.0	821 6
0.1904	2.209	8	23.0	9 5 1
0.4015	2.561	15	61.0	9 6 2
0.1885	2.574	11	29.0	9 6 3
1.0000	0.0	0	0.0	9 6 4
0.5507	2.068	16	148.0	9 6 5
1.0000	1.151	4	6.0	9 6 6
0.2829	2.462	11	33.0	923 2
0.5125	1.464	5	8.0	923 3
0.2131	2.528	10	77.0	923 5
0.5910	1.774	11	71.0	10 1 2
0.7424	1.479	12	78.0	10 1 3
1.0000	0.0	1	1.0	10 1 4
0.3323	2.684	15	83.0	10 1 5
1.0000	0.864	3	5.0	10 1 6
1.0000	1.315	7	18.0	1028 1
0.3559	1.023	3	18.0	1028 2
0.5654	1.925	9	24.0	1028 3
1.0000	0.0	0	0.0	1028 4
0.2170	2.480	10	45.0	1028 5
1.0000	1.488	6	10.0	1028 6

The water quality at stations 4 and 5 is lower than that at station 1, because stations 4 and 5 were exposed to the total effects from the construction activities. In addition, several private pipes (storm water and sewage) enter the stream above these stations. However, the big contributor to the lower water quality was the bedload being moved by Moores Creek. During the sampling period many of the substrates were either partially or completely covered by silt. In several instances they were completely covered on the day of sampling. On the next sampling trip for substrates (two weeks later) the lost substrates would be visible because of the movement of the bedload.

1975 Results

Meadow Run — Route 254

Route 254 was under construction until August 1975, with construction activity near Meadow Run being only minimal during the year. Benthic, suspended solids, flow, and rainfall data were obtained on Meadow Run from April to November. Due to the limited amount of construction near Meadow Run, substrates were placed at station 1 and 2 every 6 weeks during the above months. The benthic population results are being processed and will be published in a later report.

The suspended solids results obtained indicate that the average values at stations 1 and 2 are the same as those prior to construction for ambient conditions (13 and 19 ppm, respectively). For storm events of 1.0 inch or less, the suspended solids decrease through the new channel (41 ppm above the channel to 22 ppm below the channel). The decrease is probably due to the greater width of the new channel, which is 50 feet (15.2 meters), as compared to 3 to 4 feet (0.9 to 1.2 meters) for the old channel. This widening thus created a shallower depth and slower velocity to the stream flow through the construction area. In addition, the wider channel, shallower water, and absence of shade shrubs on the stream banks created a condition that resulted in an increase in the water temperature. On July 18, when the air temperature was 28.9° C (84° F), the water temperature increased from 20.8° C (69.4° F) to 22.6° C (72.7° F) while passing through the new 600 foot (182.9 meter) channel. Although these results indicate an increase in water temperature through the wide channel, the temperature never exceeded the 27° C (81° F) maximum temperature for survival of most of the fish in the channelized section of Meadow Run.

Moores Creek — Route 29

The construction on Route 29 was completed by November 1975. Benthic, suspended solids, flow, and rainfall data were obtained on Moores Creek until the end of October. The benthic samples are being processed and will be reported at a later date.

The ambient suspended solids results are nearly identical or less than the 1974 results. For example, station 1 had an average suspended solids value of 30 ppm in 1974 and 16 ppm in 1975. Station 5 had an ambient suspended solids result of 15 ppm in 1974 and a value of 18 ppm in 1975.

Around the end of May 1975, an owner of land between stations 3 and 4 relocated Moores Creek for approximately 100 yards (91.4 meters) at that location. The excavation of the new channel left the banks vertical. After completion of the new channel, Moores Creek stayed muddy for days as it eroded the banks (Figure 8). The suspended solids results indicated an increase of 2,800 ppm through the new channel several days after the excavation was completed. At station 5, which was .50 mile (805 meters) downstream, the suspended solids load was 1,005 ppm.

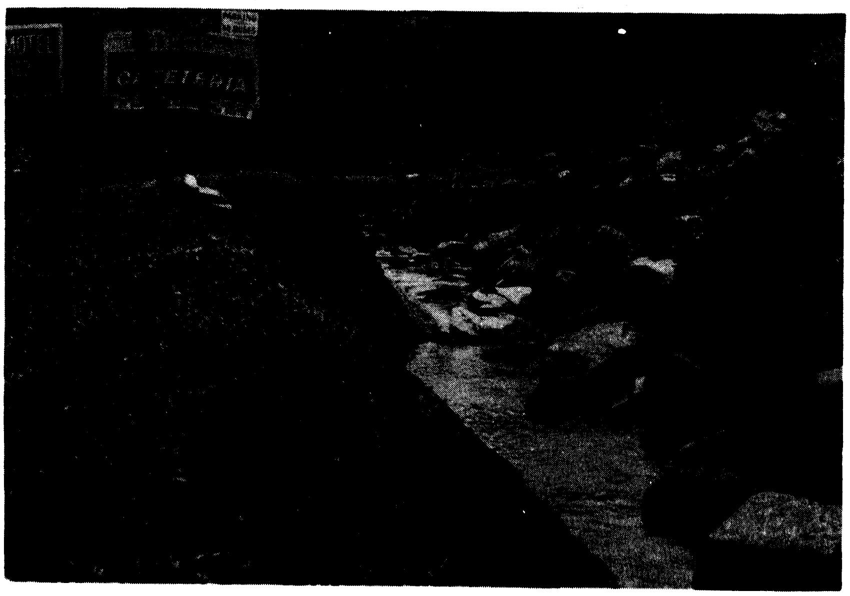


Figure 8. Eroded banks of private channel.

During the sampling period several 2-inch (5.1 cm.) storm events occurred, the first one coming approximately 1½ months after the new channel was opened. Table 5 shows the average suspended solids and flow at the 6 stations.

Table 5

Moores Creek — Route 29

2-inch (5.1 cm.) Storm Events

Measurements	Stations					
	1	2	3	4	5	6
Average Suspended Solids (ppm)	309	541	462	650	825	617
Flow (cfs)*	18		59	105	92	

*To convert from cfs to M^3/sec multiply by 0.028.

As shown in Table 5, the average suspended solids for 2-inch (5.1 cm.) storm events increased 188 ppm through the new channel ($S.S._{Sta.\ 4} - S.S._{Sta.\ 3}$). At station 5, the suspended solids value was 175 ppm higher than the value at station 4 just below the new channel. The higher value at station 5 resulted from several unprotected drop inlets in the median of Route 29 draining into Moores Creek below station 4.

Simpson Creek — I-64

In early May of 1975 the Research Council was notified by the Environmental Quality Division that a trout stream, Simpson Creek, had been scheduled to be relocated and channelized for 5,660 feet (1,725 meters) during the construction of I-64. Work on the project was planned to commence on September 2, 1975. Background data on Simpson Creek were collected from May to September at 6 stations (Figure 9). The sampling program for this project included the same parameters as were monitored on the previous two projects with the addition of several others, most of the them chemical parameters. A detailed description of the proposed program for Simpson Creek is given in the working plan.[9]

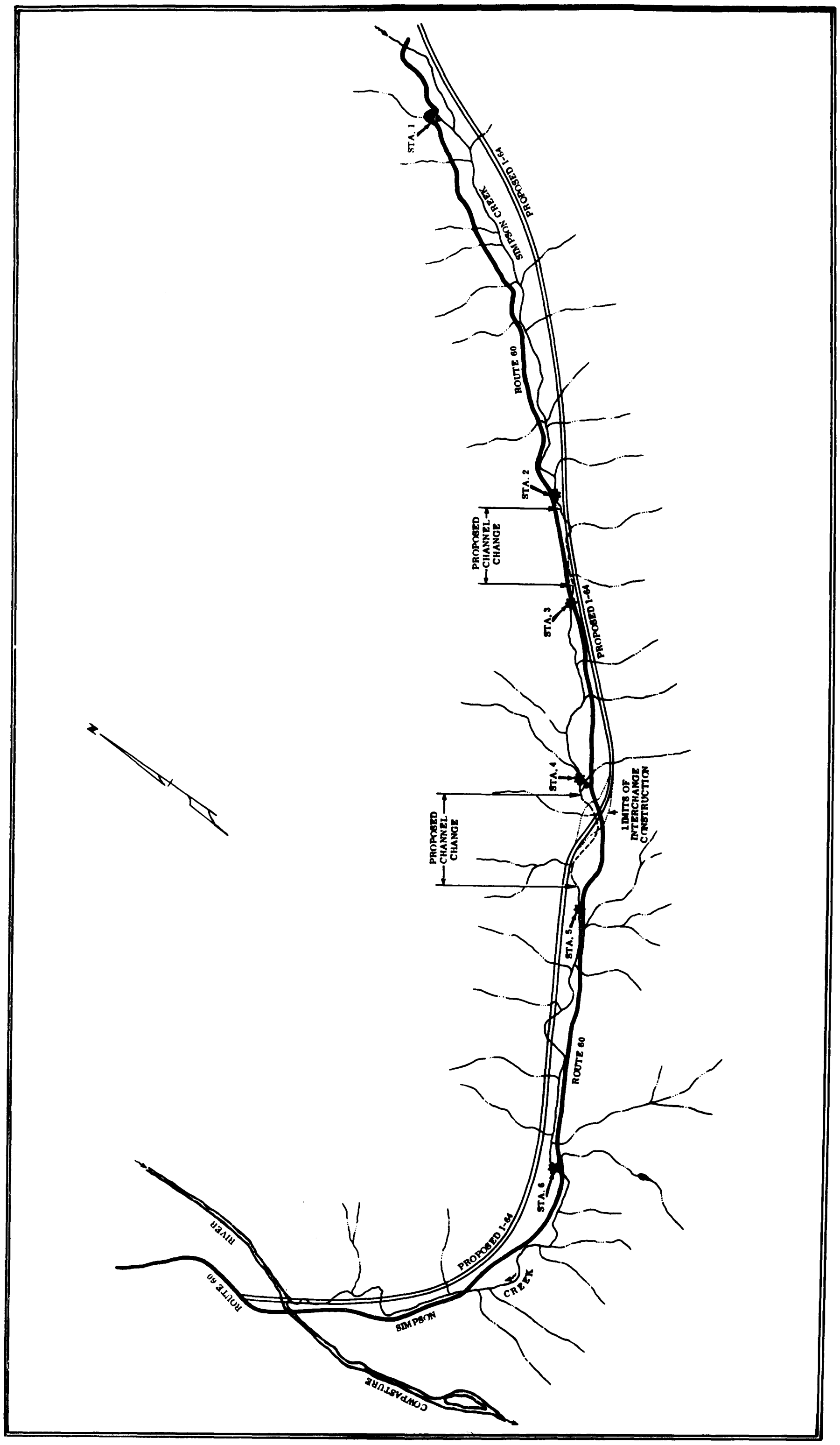


Figure 9. Simpson Creek — I-64.

The benthic population results are being processed and will be reported in an interim report (November 1976). Background results for other parameters indicated the stream to be of good water quality for trout, except for some pH results. The suspended solids results were low (0-20 ppm) at all the stations. The water temperature from May to September was several degrees below the survival limit for rainbow and brook trout, 24° C (75° F) and 23° C (73° F), respectively. In fact, the water temperature during the hottest months was near the 19° C (66° F) temperature necessary for trout growth. The pH of the water should range for trout from 6.5 to 8.5. After the initial instrument problems with the portable pH meter were resolved, the pH values were found to range from 5.7 to 8.3. Therefore, on some sampling days the headwaters of Simpson Creek have been found to be acidic.

RESEARCH PROPOSED FOR 1976

After the 1975 benthic population results are evaluated, it will be decided if further research on the Meadow Run project is necessary. If further work is warranted, suspended solids, temperature, flow, rainfall, and benthic population data will be obtained from April to November at stations 1 and 2 (Figure 1) every 6 weeks.

Research on the Moores Creek project will be curtailed in 1976. Construction activity on the project was completed in the fall of 1975. The same procedure used on Meadow Run in 1975 will be used on Moores Creek in 1976. One station (#1) above all previous construction and one (#5) below all construction will be monitored. Flow, suspended solids, rainfall, and benthic population data will be collected from April to November 1976.

Research on the Simpson Creek project will be continued, with the monitoring program being conducted as described in the working plan. Construction on the section of I-64 adjacent to Simpson Creek is scheduled to be completed around October 15, 1976. At that time the monitoring program will be curtailed as it was on the other two projects.

1760

RECOMMENDATIONS

1. It is recommended that every possible effort be made to effect channel relocations in the dry. As described earlier, the effects of dry channel construction on the benthic populations is less than was earlier thought. For this construction procedure, the recovery rate for a stream's ecology is around 3 to 3½ months.

2. It is recommended that an aquatic biologist supervise the Department's channel changes. With an expert in aquatic biology working with the contractor, the new channel should closely approximate the old one. In other words, the new channel should be approximately the same length and width, and have the same riffle-pool ratio. By approximating the old channel, the recovery rate for the stream's ecology should be accelerated.

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