THE IMPACT OF CONSTRUCTION OF VOGTLE ELECTRIC GENERATING PLANT ON THE AQUATIC MACROINVERTEBRATE POPULATIONS OF BEAVERDAM CREEK, JULY, 1973 THROUGH JUNE, 1978
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TABLE OF CONTENTS

	Page
LIST OF TABLES	ii
LIST OF FIGURES	iii
INTRODUCTION	1
RESULTS AND DISCUSSION	6
CONCLUSIONS	13
REFERENCES	15
TABLES	18
FIGURES	36

LIST OF TABLES

		Page
1.	Period Designation, Year and Month of Sampling, and Stations Sampled During Each Survey in Beaverdam Creek	18
2.	Aquatic Macroinvertebrate Fauna Collected at Stations in Beaverdam Creek With Special Reference to Significant Taxa	19
3.	Number of Significant Taxa at Each Station in Beaverdam Creek for Ekman Samples	24
4.	Number of Significant Taxa at Each Station in Beaverdam Creek for Dendy Samples	25
5.	Probability that Data are Normally Distributed for Ekman Samples	26
6.	Probability that Data are Normally Distributed for Dendy Samplers	27
7.	Tests of Homogeneity of Variances for LOG_{10} (N + 1), NTAXA, and HBAR from Ekman Samples	28
8.	Tests of Homogeneity of Variances for LOG_{10} (N + 1), NTAXA, and HBAR from Dendy Multiplate Samplers	29
9.	Results of Analysis of Variance for Ekman Samples	30
10.	Results of Analysis of Variance for Dendy Samples	31
11.	Physicochemical Data for Surveys from 1973 to 1978 on Beaverdam Creek	32
12.	Flow, Total Suspended Solids, and Suspended Sediment Discharge at Stations 3.0, 3.5, and 6.0 in Beaverdam Creek	33
13.	Estimated Bedload Discharge at Station 3.0 Using the Schoklitsch Formula	34
14.	Estimated Bedload Discharge at Stations 3.5 and 6.0 Using the Schoklitsch Formula	35

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LIST OF FIGURES

		Page
1.	Beaverdam Creek Sampling Stations	36

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INTRODUCTION

As required by Section 6.1.2.2 of the A. W. Vogtle Nuclear Plant Final Environmental Statement (March, 1974), an environmental study assessing the effect of plant construction activities on the resident aquatic fauna of Beaverdam Creek was begun by Environmental Affairs Center personnel on July 24, 1973. Aquatic macroinvertebrate populations were sampled during construction at approximately six-week intervals from July, 1973, through February, 1975. Sampling was discontinued from February, 1975, to May, 1976, while construction was halted. After construction resumed, sampling began in May, 1976, and continued through June, 1978. Quarterly visual inspections and water quality sampling will be conducted until the end of construction.

Section 4.3.2 of the FES suggested that construction activities could cause adverse effects on the Beaverdam Creek drainage basin receive runoff from the site. The FES further states that the major effect on the aquatic environment would result from the increased suspended particulate matter in the receiving waters.

Previous research suggested that increased suspended particulate matter from construction activities may affect aquatic fauna by habitat alteration, changing food availability (e.g. covering detritus), release of toxic substances, clogging of egg membranes and gills, smothering sessile benthic populations and inducing avoidance.[1, 2, 3] Several studies have shown that the number of organisms and species decreased downstream of sediment sources but recovered rapidly after the sediment load was reduced.[4, 5, 6, 7] In several cases, changes in species composition were noted with variable effects on numbers of individuals.[7, 8]

The purpose of this study was to determine the possible environmental effects of plant construction (erosion and siltation) on the aquatic macroinvertebrate community inhabiting Beaverdam Creek. The effects of siltation from access road construction and other land grading activities were also discussed.

METHODS

Beaverdam Creek is a fourth-order stream located in Burke County, Georgia, approximately six miles northwest of Girard and about 26 miles south-southeast of Augusta. The creek is approximately six miles in length and flows east-northeast to its confluence with the Savannah River. The area is characterized by rolling sandhills and mixed pine-hardwood association. The average yearly rainfall of the area is 39 inches (Bush Field, Augusta, National Oceanic and Atmospheric Administration). Two main tributaries of Beaverdam Creek are Daniels Branch, approximately five miles in length running southeast, and High Head Creek, one mile in length running northeast (figure 1).

Telfair Pond originated with the damming of Beaverdam Creek downstreem from the confluence of the three creeks. Seven sampling stations were located on Beaverdam Creek and Daniels Branch. The stations were designated: 2.0, 3.0, 3.5, 4.0, 6.0, 7.0, and 8.0. Stations 2.0, 3.0, and 6.0 were downstream of and could have been effected by construction. These stations were considered to be "unaltered habitats". Stations 4.0 and 8.0 were termed "altered habitats," as they were downstream of the site construction, but were affected by road construction prior to plant construction. Stations 3.5 and 7.0 were in areas unaffected by construction and, therefore, termed "control stations."

Station 2.0: Beaverdam Creek approximately 1.5 miles upstream from the Savannah River and 66.0 feet downstream from the wooden bridge on River Road. Predominant vegetation was hardwoods, low shrubs, and a few grasses. The substrate was composed of sand with scattered areas of detritus. The creek was about 33.0 feet with a depth from 1.5 feet to 5.0 feet.

Station 3.0: Beaverdam Creek approximately 1.5 miles upstream from the Savannah River and 33.0 feet supstream from the wooden bridge on River Road. Predominant vegetation was hardwoods, low shrubs, and a few grasses. The substrate was composed of sand and scattered areas of detritus. The creek width was about 33.0 feet with a depth from 0.6 feet to 3.0 feet.

Station 3.5: Beaverdam Creek approximately 1.6 miles upstream from the Savannah River and 33.0 feet above the confluence of Beaverdam Creek and an unnamed tributary draining sediment retention basin No. 1. Predominant vegetation was hardwoods, shrubs, and grasses. The creek was braided in the area of the station; therefore, one channel (6.0 feet wide and 1.5 to 4.0 feet deep) was chosen for sampling. The substrate was composed of sand and detritus.

Station 4.0: Unnamed tributary from sediment retention basin No. 1 approximately 1.6 miles upstream from the Savannah River and about 33.0 feet downstream of the access road. Predominant vegetation was cattails, willows, and low shrubs. Algae growth was prevalent at this station since this area was exposed to full sunlight most of the day. The creek width was about 6.0 feet and was from 0.3 to 1.0 feet deep with a substrate composed of sand and silt.

Station 6.0: Daniels Branch approximately 0.5 miles upstream from Telfair Pond and about 81.0 feet downstream from Telfair Plantation Road. Predominant vegetation was mixed hardwoods, low shrubs, and grasses. Stream substrate was composed of sand, gravel, and a few scattered areas of detritus. The creek was about 9.0 feet wide and 1.0 to 3.0 feet deep.

Station 7.0: Daniels Branch about 0.5 miles upstream from Telfair Pond and about 30.0 feet upstream from the confluence of Daniels Branch and the unnamed tributary which drained the area of sediment retention basin No. 2. The predominant vegetation was mixed hardwoods with a few shrubs and grasses. The creek was about 6.0 feet wide and 0.6 feet to 3.0 feet deep. The substrate was composed of sand and detritus.

Station 8.0: Unnamed tributary from sediment retention basin No. 2 approximately 0.5 miles upstream from Telfair Pond and about 9.0 feet upstream from its confluence with Daniels Branch. The predominant vegetation was mixed hardwoods with a few shrubs and grasses. The tributary was about 3.0 feet wide and 0.3 feet deep with a sand substrate.

In 1972 and early 1973, prior to the beginning of the study, an access road was built into the plant site. Stations 4.0 and 8.0 were located within 30.0 feet and 450 feet, respectively, of the access road. In September, 1977, a private logging operation upstream of Station 7.0 (a control), caused increased sediment loads resulting in reduced flow, braiding of the creek channel, and increased turbidity.

Aquatic macroinvertebrates were collected from Stations 2.0 through 4.0 and 6.0 through 8.0 at approximately six-week intervals from September, 1973, through February, 1975. All construction activities were suspended for the remainder of 1975 and the survey was discontinued. In 1976, construction resumed and the objectives of the sampling program were reevaluated. As a result, Stations 3.0, 4.0, 6.0, 7.0, and 8.0 were sampled in May, June, and August of 1976. Station 2.0 was discontinued because it was located within 90.0 feet of Station 3.0 and provided unneeded duplication. In March, 1977, sampling resumed at Stations 3.0, 4.0, 6.0, 7.0, and 8.0. At this time, Station 3.5 was added as an additional control in the vicinity of Stations 3.0 and 4.0. Station 8.0 was discontinued in July, 1977, because flooding caused the creek channel to move and the substrates were out of water. It was determined that it was futile for sampling to continue at Station 8.0 where flooding was common. Stations were sampled until June, 1978. Surveillance continues with a quarterly inspection and water quality sampling at each station.

On each sampling date, four Ekman grab samples (Ekman samples) and three Hester-Dendy multiplate samplers (Dendy samplers) were collected from each station. The Ekman samples were collected along a transect between banks. Ekman samples were washed in a No. 30 field screen and placed in liter jars. The three multiplate samplers were attached to an aluminum rod for easier handling. Immediately prior to removal from the water, the Dendy samplers were covered with nylon bags to prevent loss of macroinvertebrates. After retrieval, a replacement rod was placed at the station. All samples were preserved in ten percent formalin and transported to the laboratory.

In the laboratory, Ekman samples were stained with Rose-bengal and washed through a No. 30 U.S. standard soil sieve. Macroinvertebrates and detritus were brushed gently from artificial substrates and washed through a No. 30 sieve. Macroinvertebrates were sorted from detritus and sand using an illuminated magnifier and forceps. Identifications were made using a stereo-zoom microscope. Macroinvertebrates were identified to the lowest practical level.[9 through 14]

Macroinvertebrate data were arranged in groups according to sample date and assigned a seasonal period (table 1). The months used in each seasonal period may or may not correspond to traditional seasons, but the periods were incorporated to place the data in an order that would be familiar to the reader. In addition, combining data into periods provides "replicate" samples for analyzing the variance and distribution of the data.

Macroinvertebrate data from Ekman samples and Dendy samplers were stored on magnetic tape using the Southern Company Services, Inc., IBM computer system. The Shannon-Weiner diversity index (HBAR), total number of individuals (NUM-IND), and number of taxa (NTAXA) were tabulated using SAS 76.6. The Shannon-Weiner diversity index was calculated for each sample as:

$$HBAR = \sum_{i=1 \text{ to } T}^{T} Pr_i \log_2 (Pr_i)$$

Where T = Number of taxa (NTAXA) and

Pr_i = Proportion of individuals in the i-th taxa[15]

Water samples, instantaneous air and water temperature, pH, and dissolved oxygen, measurements were obtained during each collection of macroinvertebrates. The water samples were analyzed according to Standard Methods[16] by Georgia Power Company's Central Laboratory.

Beginning in April, 1976, instantaneous discharge measurements were made in Beaverdam Creek and Daniels Branch at Stations 3.0, 3.5, and 6.0. At each station, the creek was divided into equal segments across the stream. Width and depths of each segment were recorded and used to determine cross-sectional areas. Velocity measurements were made using a Gurley Hydrological Instrument's Inc., pygmy-type current meter. An instantaneous discharge was calculated from the cross-sectional area and mean velocity. Stations 4.0, 7.0, and 8.0 were braided; therefore, flow measurements were not made.

Samples for total suspended solids were collected using a depth-integrating suspended sediment wading-type sampler, U.S. DH-48. Two suspended sediment samples were collected at Stations 3.5 and 6.0, and one sample was collected in each segment of the creek at Station 3.0. Instantaneous suspended sediment load (tons per day) was calculated using average suspended sediment (mg/l) and instantaneous discharge.

In order to determine the amount of bedload discharge, a sample of the bed material was collected and analyzed for grain size. The Schoklitsch formula was used for bedload determinations.[17] The Schoklitsch formula is:

$$G_1 = 156.2\ S^{3/2}\ (Q_0 - Q_{01})$$

Where G_1 is the bedload in lbs/sec/ft

S is the slope

Q_0 is the stream discharge in ft^3/sec

Q_{01} is the critical discharge or flow responsible for sediment transport along the channel bed in ft^3/sec

$$Q_{01} = \frac{1.088\ D^{3/2}}{S^{7/6}}$$

Where D is the particle diameter in feet

The slope of the creek bed at Stations 3.0, 3.5, and 6.0 were obtained from USGS quadrangle maps.

A seasonal qualitative analysis of species composition of each station was made using the more frequent or "significant" taxa. This type of comparison makes use of the biological information on community composition which is not reflected in numbers of individuals, numbers of taxa,

and to a certain extent, taxonomic diversity indices. The objective is to base interpretations on those organisms that have a high probability of being collected during sampling and eliminate those which may be migrants from other localities or are too infrequent for statistical evaluation.[18]

The criteria for selection of "significant" taxa were those used by Chutter:[18]

1. Taxa composing five percent or more of the individuals in single samples, regardless of the number of samples in which they were found, and

2. Taxa found in more than half the samples collected in a period, regardless of their number.

The first criteria was evaluated using the total number of individuals excluding Oligochaetes and chironomids, since a preponderance of individuals in these two groups eliminated less numerous taxa. This criteria selected those taxa present in large numbers, but may be collected for a short period. The second criteria selects those taxa which may be present in low numbers but were collected with some frequency.

The statistical analysis considered the data in two parts: 1973 through 1974 and 1976 through 1978, due to changes in stations sampled and absence of data from most of 1975. The effect of year and month on the sample statistics could not be examined due to the variable frequency of sampling. Instead, the data were combined into three-month periods (approximating seasons) and analyzed for differences among stations. Variables analyzed were: Shannon-Weiner diversity index (HBAR); $\log_{10}$ transformation of the total number of individuals (LOG_{10} (N + 1)); and number of taxa (NTAXA). Assumptions of normality and homogeneity of variances were tested using the G-test and an approximation of the F-max test, respectively.[19] These sample statistics were generated using the KSLTEST procedure of SAS 76.6. An analysis of variance was performed on the sample statistics using the General Linear Models (GLM) procedure of SAS 76.6.[20] A two-way fixed effects model with replication was used to test for differences among stations and periods for HBAR, NTAXA, and LOG_{10} (N + 1). Type III estimable functions were used in computing sums of squares because of missing data and unequal numbers of observations. The statistical analysis and average values for HBAR, LOG_{10} (N + 1), and NTAXA are presented in Appendix A.

RESULTS AND DISCUSSION

Environmental components of each station, such as substrate type, stream width, stream depth, current velocity, and vegetation cover, affect its faunal composition. In order to determine the effects of perturbation,

the physical make-up of each station should be duplicated as closely as possible.[7] The Beaverdam Creek stations were chosen to monitor sediment-induced perturbations, but faunal differences due to other physical factors were present.

Table 2 lists the macroinvertebrate taxa and total numbers of individuals found at stations in Beaverdam Creek. The letter code ("E" = Ekman, "D" = Dendy samplers) represents the sampler type that the organism was collected by and occurs only where a particular taxa met the criteria for "signicance."

The "significant" taxa unique to the Ekman or Dendy samplers reflected the habitats sampled by these techniques. During the survey, some of the "significant" taxa were collected by either or both samplers, but the organisms were not collected in great enough numbers or frequency to meet the criteria for "significance" in both samplers.

One hundred and fifty-three taxa were collected in Beaverdam Creek during the study. The most abundant included Stenonema spp., Cheumatopsyche spp., Ceratopogonidae, Chironomidae, Oligochaeta, and Pelecypoda. Of the 153 taxa, 126 were considered "significant." Forty-two taxa were "significant" in Ekmans only and 27 taxa were "significant" in Dendy samplers only. Sixteen taxa were "significant" at all stations when one or both of the sampling techniques were considered. Fifteen taxa were "significant" at Station 4.0 only, and four taxa were "significant" only at Station 8.0. Generally, a majority of the remaining "significant" taxa were shared by Stations 2.0, 3.0, 3.5, 6.0, and 7.0 and occasionally Stations 4.0 and 8.0.

Table 3 shows the number of "significant" taxa in Ekman samples for each station. The greatest number of "significant" taxa recorded was 36 at Station 3.5 during the spring, 1977. The least number of "significant" taxa (4) recorded was at Stations 4.0 and 8.0. It is evident that there was an increase in the number of "significant" taxa after summer, 1974.

Those organisms that were "significant" in Ekman samples only were inhabitants of the sediment or in close association with the bed of the creek. Examples include: Baetisca spp., Hexagenia spp., Dromogomphus spp., Gomphus spp., Nectopsyche spp., Molanna spp., Tabanidae, and Corbicula spp., most of which are burrowers or live in leaf packs and debris feeding as predators, detritivores, or filter feeders.[10, 12, 21, 22]

Table 4 gives the number of "significant" taxa at each station for Dendy samples. The greatest number of "significant" taxa at any station was recorded at Station 6.0 (23) and the least at Station 3.0 (1). Station 2.0 had the highest mean number of "significant" taxa (15.4) and Station 8.0 had the lowest (6.4). Stations 3.0, 6.0, and 7.0 had consistently higher numbers of "significant" taxa throughout the survey. Station 4.0

had low numbers during the fall, 1973, and winter, 1974; increased to control station levels in the spring, 1974, through summer, 1977; and decreased again during winter through summer, 1978. Generally, the number of "significant" taxa at Station 8.0 remained low throughout the time of sampling. The "significant" taxa found only in the Dendy samplers typically inhabit undercut banks, sticks, and debris or the surface of logs and rocks. These organisms include: Acroneuria spp., Corydalus spp., Nigronia spp., Macronema spp., and others. These species are either predatory or collector filter feeders. A majority of the organisms that were "significant" at all stations were tolerant of widely fluctuating environmental conditions. Tolerant taxa include: Cheumatopsyche spp., Macronychus spp., Ceratopogonidae, Chironomidae, and Oligochaete.[7, 21]

The "significant" taxa present in either sample type at all stations except 4.0 and 8.0 were: Hexagenia spp., Phylocentropus spp., Nectopsyche spp., and Ectopria spp. The above taxa require a stable or firm substrate which was not present at either Station 4.0 or 8.0.[12, 14, 21, 23]

Access road construction in 1972 eliminated all terrestrial and aquatic vegetation in the area of Station 4.0. The creek substrate was covered with a thick layer of silt (0.5 to 3 feet deep) which was very unstable. The succession of vegetation and stabilization of the substrate throughout the study created a unique habitat. Due to the habitat, different organisms were "significant" at Station 4.0 when compared to the other stations. The majority of "significant" taxa at Station 4.0 required slow-moving current with abundant algae and macrophytic vegetation.[12, 21, 22, 24] These taxa included: Hydropyrus spp. (Ephydra), Nemotelus spp., Cladocera, Ostracoda, Berosus spp., Nymphyla spp., and Habrophleboides spp. After the substrate at Station 4.0 began to stabilize (post-road construction), the area became overgrown with cattails (Typha latifolia) and willows (Salix nigra). Due to the presence of full sunlight most of the day, algal growth was prevalent at this station. No sediment movements were observed in the area of Station 4.0 after the substrate became stabilized, which indicates that on-site construction activities had no significant effect on the station. Station 8.0 was affected by road construction in the same manner as Station 4.0 with heavy silt cover (0.5 to 1.5 feet), but trees and shrubs were not removed. The stream channel at Station 8.0 shifted a minimum of three times during the survey, usually after heavy rains and flooding. The relative lack of macroinvertebrate species at Station 8.0 was probably due to channel movement and lack of bank vegetation. The four "significant" taxa unique to Station 8.0 were: (1) Calopteryx spp., (2) Tipula spp., (3) Bittacomorpha spp., and (4) Trematoda organisms pre-

ferring areas of decaying vegetation and detritus.[20, 21, 23] The majority of the above taxa were not found in "significant" numbers prior to the last two sampling periods. The establishment of these taxa late in the sampling program and their habitat preferences indicated that the creek bed was stabilizing.

The unaltered stations (2.0, 3.0, and 6.0) shared a majority of the "significant" taxa found at the control stations. This indicates that the unaltered stations were not adversely affected by plant or access road construction. In addition, the "significant" taxa data show that the altered stations (4.0 and 8.0) were generally different from all other stations. The colonization of the "significant" taxa at Stations 4.0 and 8.0 indicated that each station was not receiving large quantities of sediment from on-site construction.

The number of "significant" taxa for Ekman samples, shown in table 3, suggested that Stations 4.0 and 8.0 were similar to the control station in the fall, 1974. The fluctuations in numbers of "significant" taxa found at the unaltered stations were very similar to Station 7.0 throughout the survey. Indicating that the numbers of fauna at the unaltered stations were not changed by road or plant construction activities. From the spring, 1977, Station 3.5 had higher numbers of "significant" taxa than the other stations. The increased numbers at Station 3.5 were probably indicative of the favorable habitat. Recovery of organisms at the altered stations (4.0 and 8.0) occurred within a short time after the stream bed stabilized. Rapid faunal recovery of impacted stations has been reported by Tebo,[4] Gammon,[5] Reed,[6] and Lenat, et al.[7] The Dendy data in table 4 is variable but does show Station 8.0 having had low numbers of "significant" taxa a majority of the time. The low numbers of "significant" taxa at Station 8.0 were probably due to the substrate of shifting sand.

An increase in the numbers of "significant" taxa at the altered stations occurred after summer, 1974. The fauna at the unaltered stations were similar to the controls throughout the study. It was recognized that the habitats at Stations 4.0 and 8.0 were changed and a majority of the "significant" taxa present were different from the other stations. The biological requirements of the taxa that were present demonstrated that the quality of habitat at Stations 4.0 and 8.0 did improve.

Since the Ekman samples were collected in a fixed-spatial design, the samples cannot be considered random. The assumption of spatial randomness is not applicable to the Dendy samplers since the entire sampler was counted. Results of the G and Fmax tests for HBAR, NTAXA, and Log_{10} (N + 1) collected in Ekman and Dendy samplers are presented in tables 5

through 8. The data were non-normal in many instances. A closer approximation of a normal distribution for total number of individuals was obtained using the following transformation:

$$LOG_{10}\ (N + 1) = \log_{10}\ (NUM\text{-}IND + 1)$$

The Fmax test demonstrated that the variances of the data were not homogeneous in specific cases (tables 7 and 8). Ekman samples obtained in 1973 through 1974 have significant differences among variances for LOG_{10} (N + 1) and NTAXA, but not for HBAR. Ekman samples collected during 1976 through 1978 showed significant differences among variances for NTAXA and HBAR values, but not for LOG_{10} (N + 1). Dendy samplers in 1973 through 1974 had significant differences among variances for LOG_{10} (N + 1) and NTAXA, but not for HBAR. Dendy samplers collected in 1976 through 1978 showed no significant deviation from the assumption of homogeneity for any variable.

An analysis of variance was completed recognizing that assumptions of normality and homoscedasticity were not met by the data. A two-way fixed effect model with replication was used to test for differences among stations and periods for HBAR, NTAXA, and LOG_{10} (N + 1) data. When no station-period interaction occurred and the variances of the data were homogeneous, further comparisons among mean values were made using the Bonferroni multiple comparison procedure.[25] Data obtained from Stations 2.0, 3.0, 3.5, 4.0, 6.0, 7.0, and 8.0 were used for this analysis.

The results of the analysis of variance are summarized in tables 9 and 10. Heterogeneous variances of station-period interaction precluded statistical comparisons among station means for LOG_{10} (N + 1) and NTAXA values for the 1973 to 1974. Multiple comparisons of station means for HBAR in 1973 to 1974 indicated that average values for the unaltered stations (2.0, 3.0, and 6.0) did not significantly differ from those obtained at the control station (7.0). Also, the mean values for the altered stations (4.0 and 8.0) were less than those obtained at the unaltered and control stations (see Appendix A-14).

Heterogeneous variances or station-period interaction also prevented statistical comparison among means from Dendy samplers collected during 1973 and 1974. Data obtained during 1976 to 1978 showed no significant differences among stations for LOG_{10} (N + 1) and HBAR. Significant station-period interaction ruled out further comparison among NTAXA for Dendy samplers collected in 1976 to 1978. No detectable differences were found among stations for data collected in 1976 through 1978.

The statistical analysis of Log_{10} (N + 1), NTAXA, and HBAR supported the previous conclusions based on species composition. The statistical analysis (Log_{10} (N + 1), NTAXA, and HBAR) for Ekman samples indicated that there were differences among stations, but these differences depend

upon the time of year the sample was taken. This was expected since environmental changes have a varying effect on different habitats and the populations which inhabit them. Although a rigorous statistical analysis was not feasible, it is evident that Ekman samples collected in 1973 and 1974 had fewer individuals and taxa at the stations affected by road construction (4.0 and 8.0 of table 7). Multiple comparison among stations for species diversity supported this, indicating that Stations 4.0 and 8.0 were less diverse than the control (7.0) and unaltered stations (2.0, 3.0, and 6.0). Log_{10} (N + 1), NTAXA, and HBAR were not noticeably lower at Station 4.0 during 1976 through 1978. This suggeted that this station had recovered from the impact of road construction by 1976.

Similar results were obtained from the Dendy samplers. Dendy samplers obtained during 1973 through 1974 had fewer individuals and NTAXA and lower HBAR at the altered stations compared to the control and unaltered stations. A statistical comparison among station means in 1973 through 1974 was not possible due to significant station-period interaction or heteorgeneous variances. Samples taken during 1976 through 1978 showed no significant differences among stations for LOG_{10} (N + 1) and HBAR. Differences among stations in NTAXA were significant but depended on the time of sampling. Thus, initial construction of the access road in 1972 adversely affected macroinvertebrates at Stations 4.0 and 8.0. Sampling during 1976 through 1978 indicated that these altered stations had recovered and were comparable in Log_{10} (N + 1) and NTAXA with stations unaffected by road construction.

Table 11 presents the mean, standard deviation, and coefficient of variation of physicochemical data collected from all stations and sampling dates. Seasonal divisions were not made.

Water temperatures at Stations 2.0, 3.0, 4.0, 6.0, and 8.0 were similar to those exhibited at Stations 3.5 and 7.0. Station 2.0 had the greatest variability (c.v. = 39.0%) in water temperature. The mean water temperatures for all stations ranged from a low of 17.3 C at Station 2.0 to a high of 19.5 C at Station 3.5.

Dissolved oxygen levels were within the same range for all stations. Stations 3.5 and 4.0 exhibited the greatest variation in dissolved oxygen with a coefficient of variation of 22.0 percent. The mean dissolved oxygen values ranged from a low of 7.6 mg/l (Station 4.0) to a high of 8.3 mg/l (Station 8.0).

Conductivity (μmhos/cm) values at the unaltered and altered stations were similar to those found at the control stations, except the variability was higher at Stations 3.0 and 4.0 (c.v. = 21.9% and 48.0%, respectively). The mean conductivity values for all stations ranged from a low of 35.6 μmhos/cm at Station 8.0 to a high of 86.0 μmhos/cm at Station 4.0.

Alkalinity values were similar for unaltered and control stations. Alkalinity values at Stations 4.0 and 8.0 varied more than the other stations (c.v. = 51.6% and 29.0%, respectively), while Station 2.0 had the least variation (c.v. = 10.2%). The values for alkalinity demonstrate the same general trends that were exhibited by conductivity with high mean value at Station 4.0 (35.4 mg/l) and a low mean value at Station 8.0 (13.9 mg/l).

The hardness values at Station 4.0 were higher than the control or other downstream stations. The greatest variation in hardness was exhibited at Stations 4.0 and 8.0 (c.v. = 52.0% and 77.3%, respectively), and Station 3.0 had the least variation (c.v. = 3.0%). Station 4.0 had the greatest mean hardness value (41.5 mg/l $CaCO_3$), while Station 8.0 had the lowest mean value (17.2 mg/l $CaCO_3$).

The unaltered and altered stations had approximately the same pH as the control stations throughout the study. Station 4.0 exhibited the greatest pH fluctuation (c.v. = 7.0%), while Station 3.5 showed the least variation (c.v. = 1.7%). The highest mean pH was obtained at Station 3.5 (7.2) and the lowest was at Station 8.0 (6.6).

Stations 4.0 and 8.0 exhibited greater turbidity than the control stations. Stations 2.0 and 3.0 were higher than and Station 6.0 was similar to the controls. Coefficients of variation for turbidity values were high at Stations 3.0 (161.0%), 4.0 (150.0%), and 8.0 (122.0%). Station 8.0 had the greatest mean value (33.8 NTU) and Station 3.5 had the lowest (3.0 NTU).

The total suspended solid data was similar to the turbidity data with Stations 4.0 and 8.0 having higher mean values than the other stations. The coefficient of variations for all stations were high with the lowest at Stations 3.0 and 3.5 (55.0% and 92.0%, respectively). Station 8.0 exhibited the greatest range (c.v. = 135.0%) in total suspended solids, while Station 3.0 showed the least (c.v. = 55.0%). The greatest mean value was obtained at Station 8.0 (45.6 mg/l) and Station 3.0 (5.48 mg/l) had the least.

Flow, total suspended solids, and suspended sediment discharge data are presented in table 12 for Stations 3.0, 3.5, and 6.0. It should be noted that Beaverdam Creek in the area of Station 3.5 was braided and only that portion of the stream that affected the Dendy and Ekman samples was monitored (approximately 15.0% to 20.0% of the total flow). Flow at Stations 3.0 and 3.5 did not fluctuate widely during the survey. However, at Station 6.0, flow was influenced by releases from sediment retention basin No. 2. The total suspended sediment data was used to calculate suspended sediment discharge. Suspended sediment discharge ranged from 0.12 to 0.82 tons/day at Station 3.0; 0.03 to 0.14 tons/day at Station 3.5; and 0.11 to 5.16 tons/day at Station 6.0. The high suspended sediment discharge at Station 6.0 on April 13, 1977, was probably due to high flow and high suspended solids for that date and would not be indicative of normal conditions.

Table 13 lists the results of the Schoklitsch formula applied to the data collected at Station 3.0. The estimated bedload discharges ranged from 140 tons/day on July 12 to 510 tons/day on May 7, 1976 and 1978, with an average value of 244 tons/day. It should be noted that these values are approximations.

Table 14 lists the results of the Schoklitsch formula applied to the data collected at Stations 3.5 and 6.0, respectively. The bedload discharges at Station 3.5 ranged from 5 tons/day to 16 tons/day. The bedload discharges at Station 6.0 ranged from 150 tons/day to 780 tons/day.

The physicochemical data (table 11) collected during the study were typical of natural waters and did not vary drastically from the control station data.[25, 27] Generally, conductivity, alkalinity, and hardness had the greatest variation at Stations 4.0 and 8.0. This was probably resulted from excavation on the plant site. Leaching of the soil components can cause differences in the stream chemistry.[27, 28] The mean turbidity was greater at Stations 4.0 and 8.0 (34.3 NTU and 46.0 NTU, respectively) but more variable at Station 3.0 (mean 5.6 NTU, c.v. of 130.0%).

Total suspended solids data had the greatest mean values at Stations 4.0 (30.6 mg/l) and 8.0 (53.5 mg/l) and the greatest variation at Station 7 (144.0%). Mean values for the other stations were a great deal lower ranging from 4.5 mg/l at Station 3.5 to a high of 15.8 mg/l at Station 6.0. It should be noted that the turbidity and total suspended solids data were extremely variable due to the nature of the drainage basin, the sediment input from access road and plant construction, and sampling variability. Table 12 shows low concentrations of suspended material at Stations 3.0, 3.5, and 6.0; therefore, it would be expected to have a small percentage of suspended load as compared to total sediment discharge. The data collected indicated the suspended sediment discharge to be less than one percent of the estimated total sediment discharge of Beaverdam Creek.

Most of the sediment discharge in Beaverdam Creek occurred as bedload movement. The bedload movement was characterized by sand particles rolling or tumbling along or near the streambed. This area was known as the unsampled zone.[29] Empiracal formulas must be used to estimate the amount of sediment discharge occurring within this unsampled zone. The most important factor in the amount of sediment discharge from Beaverdam Creek would be the influence of localized heavy rainfall. The resulting increased flow would increase the amount of bedload movement and greatly increase the amount of suspended materials.

CONCLUSIONS

Species composition at the unaltered stations were similar to the control stations throughout the study indicating that plant construction had little or no effect on the macroinvertebrate fauna of Beaverdam Creek.

Species composition at the altered stations (affected by access road construction) became increasingly similar to that of the control stations after the summer of 1974. This indicated that the altered stations recovered from access road construction and were not affected by plant construction.

The control stations generally had more taxa present than the altered stations due to the more stable substrate at the control stations.

Differences among stations for LOG_{10} (N + 1) and HBAR were not signficant during 1976 through 1978. This suggested that initial differences among stations were largely due to access road construction, and that plant construction had little impact on the indices used. Significant differences among stations for NTAXA values probably reflected differences in habitat at specific stations.

Physicochemical data showed differences in conductivity, alkalinity, and hardness between the control and unaltered and altered stations. The variation in values at Stations 4.0 and 8.0 were probably due to the exposed soils on the plant site.

Suspended sediment data indicated that most of the sediment discharge in Beaverdam Creek occurred as bedload. The on-site sediment retention basins would cause heavier particles to settle out and be deposited in the basin; therefore, the bedload movement results from natural phenomena and not plant construction.

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TABLE 1

PERIOD DESIGNATION, YEAR AND MONTH OF SAMPLING, AND STATIONS SAMPLED DURING EACH SURVEY IN BEAVERDAM CREEK (* = STATION 3.5 WAS SAMPLED).

Period	Year	Month	Station Sampled
Fall	73	9	2.0 - 8.0
	73	10	2.0 - 8.0
	73	11	2.0 - 8.0
Winter	74	1	2.0 - 8.0
	74	2	2.0 - 8.0
Spring	74	4	2.0 - 8.0
	74	5	2.0 - 8.0
Summer	74	7	2.0 - 8.0
	74	8	2.0 - 8.0
	74	9	2.0 - 8.0
Late Fall & Winter	74	11	2.0 - 8.0
	74	12	2.0 - 8.0
	75	2	2.0 - 8.0
Summer	76	5	3.0 - 8.0
	76	6	3.0 - 8.0
	76	8	3.0 - 8.0
Spring	77	3	3.0 - 8.0*
	77	4	3.0 - 8.0*
	77	5	3.0 - 8.0*
Summer	77	7	3.0 - 7.0*
	77	8	3.0 - 7.0*
	77	9	3.0 - 7.0*
Fall	77	11	3.0 - 7.0*
Spring	78	2	3.0 - 7.0*
	78	3	3.0 - 7.0*
Summer	78	4	3.0 - 7.0*
	78	6	3.0 - 7.0*

TABLE 2 (Page 1 of 5)

AQUATIC MACROINVERTEBRATE FAUNA COLLECTED AT STATIONS IN BEAVERDAM CREEK WITH SPECIAL REFERENCE TO"SIGNIFICANT" TAXA. (D = SIGNIFICANT TAXA COLLECTED IN DENDY SAMPLES: E = SIGNIFICANT TAXA COLLECTED IN EKMAN SAMPLES).

	Stations							Total
	2.0	3.0	3.5	4.0	6.0	7.0	8.0	Number
Ephemeroptera			E	E	E			18
Siphlonuridae			E					2
Ameletus spp.	E							1
Isonychia spp.	D	D	D		D/E	D	D	364
Baetidae		E		E	D/E	E		33
Baetis spp.	D	D/E	D/E		D/E	D/E	D/E	228
Centroptilum spp.	D							4
Pseudocloeon spp.	D/E					D/E		20
Heptageniidae		D			D			10
Heptagenia spp.								1
Stenacron spp.					D			10
Stenonema spp.	D/E	D	D/E	D	D/E	D/E		2469
Leptophlebiidae								1
Habrophlebiodes spp.				E				1
Leptophlebia spp.	D				D	E		6
Paraleptophlebia spp.	D	D		D				13
Ephemerellidae								
Ephemerella spp.	D/E	D/E	D/E	D/E	D	D/E	D	257
Tricorythidae								
Tricorythodes spp.	D/E	D	D/E	D	D	D/E		161
Neoephemeridae								
Neoephemera spp.	E		D/E		D	E		20
Caenidae			E					1
Brachycercus spp.		E	E					14
Caenis spp.	D	D	D/E	D/E	D/E	D/E		143
Baetiscidae								
Baetisca spp.		E	E					5
Ephemeridae								
Hexagenia spp.	E	E	E		E	E		32
Odonata								1
Zygoptera								2
Calopterygidae								1
Calopteryx spp.							D/E	4
Hetaerina spp.						D		10
Coenagrionidae								2
Argia spp.	D	D		D	D			40
Enallagma spp.								2
Ischnura spp.								2
Agrionidae								5
Anisoptera					D			1
Cordulegastridae								
Cordulegaster spp.								1

TABLE 2 (PAGE 2 OF 5)

	Stations							Total
	2.0	3.0	3.5	4.0	6.0	7.0	8.0	Number
Gomphidae	E		E		E	E		17
Dromogomphus spp	E	E	E	E	E	E	E	147
Gomphus spp.		E	E	E	E	E	E	45
Hagenius spp.								2
Ophiogomphus spp.						E		1
Progomphus spp.		E	E		E	E	E	14
Aeschnidae								
Aeschna spp.	D							2
Boyeria spp.		D						8
Libellulidae	E	E			D/E			9
Macromia spp.		E	E	E	E			16
Neurocordulia spp.								3
Somatochlora spp.								1
Orthemis spp.								1
Plecoptera		D		D	D	E	D/E	45
Taeniopterygidae								
Taeniopteryx spp.		D				E	E	10
Nemouridae				D				9
Pteronarcidae								
Pteronarcys spp.								1
Perlidae		D	D/E	D	D	D		25
Neoperla spp.								1
Paragnetina spp.	D	D	D	E		D	D	29
Acroneuria spp.	D	D	D	D	D	D	D	89
Perlesta spp.	D	D	D/E		D/E	D/E	D	181
Atoperla spp.				D				2
Perlinella spp.				E				3
Perlodidae								2
Isogenus spp.		D	D			D		6
Isoperla sp.p.		D	D/E		D			24
Hemiptera				E				1
Corixidae					E			3
Veliidae					E			1
Microvélia spp.				E	E			2
Megaloptera								
Corydalidae								
Chauloides spp.			D					6
Corydalus spp.	D	D	D	D	D	D	D	61
Nigronia spp.				D	D			11
Sialidae								
Sialis spp.	D/E	D/E	D/E	D	D/E	E		45

TABLE 2 (PAGE 3 OF 5)

	Stations							Total
	2.0	3.0	3.5	4.0	6.0	7.0	8.0	Number
Trichoptera			E	D	D/E			17
Philopotamidae								
Chimarra spp.	D	D			D	D		135
Psychomyiidae					D			5
Lype diversa		D	D		D		E	49
Polycentropodidae					D			7
Neureclipsis spp.	D/E	D/E	D		D			53
Polycentropus spp.	D/E	D/E	D	D	D/E			56
Phylocentropus spp.	E	E	E		D/E	E		150
Hydropsychidae		D/E	D/E	D/E	D	D/E	E	96
Diplectrona spp.				D				7
Cheumatopsyche spp.	D/E	D/E	D/E	D/E	D/E	D/E	D/E	1207
Hydropsyche spp.	D	E		D	D/E			26
H. incommoda	E	D		D/E	D	D/E		92
H. orris	D				D			5
Macronema spp.	D			D	D			21
Hydroptilidae				D/E	D			39
Brachycentridae	E		E					2
Brachycentrus spp.			E					8
Limnephilidae								
Pycnopsyche spp.			E			E		9
Neophylax spp.	E							2
Lepidostomatidae								
Lepidostoma spp.	E							2
Molannidae								
Molanna spp.		E	E	E				6
Leptoceridae								1
Ceraclea spp.			E		D			2
Mystacides spp.						D		1
Triaenodes spp.								1
Oecetis spp.	D/E	D/E	D/E		D/E			107
Nectopsyche spp.	E	E	E		E	E		125
Coleoptera				E				4
Dytiscidae								
Hydroporus spp.	E	E	E	D	D			16

TABLE 2 (PAGE 4 OF 5)

	Stations							Total
	2.0	3.0	3.5	4.0	6.0	7.0	8.0	Number
Elmidae								
Ancyronyx variegatus	D/E	D	D	D/E	D			63
Dubiraphia spp.						E		3
Macronychus spp.	D/E	D/E	D/E	D	D	D/E	D	327
Microcylloepus spp.			D					6
Stenelmis spp.	E	D/E	D/E	D/E		D/E	D	144
Psephenidae								
Ectopria spp.	E	D	D/E		D/E	D		44
Gyrinidae								
Dineutus spp.	D							7
Gyrinus spp.								1
Haliplidae								
Peltodytes spp.								3
Hydrophilidae								
Berosus spp.			E					1
Hydrochus spp.								1
Chrysomelidae								
Donacia spp.					E			1
Lepidoptera				E				1
Pyralidae								
Nymphula spp.				E				1
Diptera				E				3
Tipulidae			E	E	D		D/E	10
Eriocera fultonensis								1
Tipula spp.							D/E	23
Ceratopogonidae	D	D/E	E	D/E	D/E	D/E	D/E	1730
Atrichopogon spp.								3
Chironomidae	D/E	D/E	D/E	D/E	D/E	D/E	D/E	32757
Simulidae	E	D	E	D/E	D/E	D/E	D/E	183
Ptychopteridae								
Bittacomorpha spp.							E	1
Stratiomyidae								
Nemotelus spp.				D				1
Tabanidae		E		E	E	E		21
Hydrellia spp.								1
Psychodidae								1
Empididae	D/E	D/E	D/E	D/E	D	D/E	E	178
Ephydridae								
Hydropyrus spp. (*Ephydra*)				E				8

TABLE 2 (PAGE 5 OF 5)

	Stations							Total
	2.0	3.0	3.5	4.0	6.0	7.0	8.0	Number
Hydrozoa								
Hydra spp.	D/E	D			E			15
Turbellaria								
Planaridae	E	D/E	D/E	D/E	D/E	D/E		560
Rhynchocoela	E	E		E	E	D/E	E	83
Prostoma rubrum		D/E	D/E	D/E	D/E	D/E		827
Nematoda	E	E	E	D/E	D/E	D/E	E	974
Gordioidea			E					2
Oligochaeta	D/E	D/E	D/E	D/E	D/E	D/E	D/E	16545
Polychaeta								
Manyunkia spp.								1
Hirudinea	D	E	E	E	E	D	D	38
Cladocera				E				4
Ostracoda				D				3
Copepoda		E	E	D/E	D/E	D/E	E	83
Amphipoda	E		D/E	D		E	E	16
Collembola	E	E	E	E	E	E	E	560
Hydracarina	E	E	D/E	D	E			36
Acari				E				1
Mollusca								
Gastropoda	E	D/E	E	D/E	D/E	D/E	D/E	863
Ancylidae								
Lavapex spp.				E				7
Ferrissia spp.	E	D/E	D/E	D/E	D/E	E	E	166
Pelecypoda	D/E	E	E	D/E	D/E	D/E	D/E	6649
Corbicula sp.	E				E			2
Elliptio spp.	E					E	E	23
Trematoda							E	4

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TABLE 3

NUMBER OF SIGNIFICANT TAXA AT EACH STATION
IN BEAVERDAM CREEK FOR EKMAN SAMPLES.

	Station						
	2.0	3.0	3.5	4.0	6.0	7.0	8.0
Fall 1973	20	14	-	11	14	15	4
Winter 1974	11	10	-	4	12	19	7
Spring 1974	17	10	-	4	12	16	6
Summer 1974	14	14	-	9	10	15	8
Fall 1974	24	21	-	14	20	17	18
Summer 1976	-	17	-	13	9	15	11
Spring 1977	-	16	36	12	12	12	12
Summer 1977	-	17	25	21	20	8	-
Fall 1977	-	5	18	7	7	14	-
Spring 1978	-	7	10	5	7	9	-
Summer 1978	-	9	13	8	8	8	-

- = No data obtained.

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TABLE 4

NUMBER OF SIGNIFICANT TAXA AT EACH STATION
IN BEAVERDAM CREEK FOR DENDY SAMPLES.

	Station						
	2.0	3.0	3.5	4.0	6.0	7.0	8.0
Fall 1973	17	13	-	8	20	18	6
Winter 1974	15	16	-	6	5	10	12
Spring 1974	6	11	-	13	6	15	4
Summer 1974	18	17	-	18	18	11	5
Fall 1974	21	16	-	15	14	13	7
Summer 1976	-	20	-	17	10	9	6
Spring 1977	-	16	15	14	23	11	5
Summer 1977	-	11	17	15	16	9	-
Fall 1977	-	1	13	-	8	10	-
Spring 1978	-	10	8	9	5	8	-
Summer 1978	-	10	13	9	11	8	-
Mean Number	15.5	12.8	13.2	12.4	12.4	11.1	6.4

- = No data obtained.

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TABLE 5

PROBABILITY THAT DATA ARE NORMALLY DISTRIBUTED FOR EKMAN SAMPLES.

1973 - 1974

Station	LOG_{10} (N+1) P-G_1	P-G_2	NTAXA P-G_1	P-G_2	HBAR P-G_1	P-G_2
2.0	0.029	0.697	0.659	0.574	0.045	0.716
3.0	0.808	0.286	0.134	0.314	0.136	0.437
4.0	0.282	0.994	0.006	0.753	0.007	0.248
6.0	0.711	0.416	0.413	0.213	0.359	0.266
7.0	0.009	0.947	0.977	0.135	0.123	0.231
8.0	0.612	0.889	0.000	0.000	0.340	0.205
Maximum	0.808	0.994	0.977	0.753	0.359	0.716
Minimum	0.009	0.286	0.000	0.000	0.007	0.205

1976 - 1978

Station	LOG_{10} (N+1) P-G_1	P-G_2	NTAXA P-G_1	P-G_2	HBAR P-G_1	P-G_2
3.0	0.383	0.054	0.000	0.122	0.109	0.130
3.5	0.905	0.258	0.250	0.151	0.645	0.058
4.0	0.305	0.131	0.058	0.970	0.427	0.495
6.0	0.637	0.455	0.553	0.926	0.678	0.122
7.0	0.269	0.394	0.012	0.114	0.346	0.814
Maximum	0.905	0.841	0.553	0.970	0.678	0.814
Minimum	0.269	0.131	0.000	0.114	0.109	0.058

For α = 0.05, P > 0.95 indicates that the data are normally distributed.

VEGP - OLSER

TABLE 6

PROBABILITY THAT DATA ARE NORMALLY DISTRIBUTED FOR DENDY SAMPLERS.

1973 - 1974

Station	LOG_{10} P-G_1	(N+1) P-G_2	NTAXA P-G_1	NTAXA P-G_2	HBAR P-G_1	HBAR P-G_2
2.0	0.177	0.978	0.004	0.662	0.598	0.685
3.0	0.194	0.959	0.058	0.542	0.846	0.200
4.0	0.001	0.533	0.000	0.001	0.000	0.000
6.0	0.083	0.833	0.027	0.010	0.553	0.540
7.0	0.850	0.692	0.000	0.014	0.197	0.826
8.0	0.334	0.518	0.002	0.001	0.243	0.173
Maximum	0.850	0.978	0.058	0.662	0.846	0.685
Minimum	0.001	0.518	0.000	0.001	0.000	0.000

1976 - 1978

Station	LOG_{10} P-G_1	(N+1) P-G_2	NTAXA P-G_1	NTAXA P-G_2	HBAR P-G_1	HBAR P-G_2
3.0	0.000	0.054	0.660	0.881	0.789	0.586
3.5	0.000	0.000	0.822	0.921	0.906	0.440
4.0	0.179	0.373	0.021	0.083	0.107	0.874
6.0	0.001	0.295	0.665	0.525	0.014	0.495
7.0	0.041	0.829	0.795	0.445	0.752	0.996
Maximum	0.179	0.829	0.822	0.921	0.906	0.996
Minimum	0.000	0.000	0.021	0.083	0.014	0.440

For $\alpha = 0.05$, $P > 0.95$ indicates that the data are normally distributed.

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TABLE 7

TESTS OF HOMOGENEITY OF VARIANCES FOR LOG_{10} (N+1), NTAXA, NAD HBAR FROM EKMAN SAMPLES.

1973 - 1974

Station	N	LOG_{10} (N+1) $\bar{X}$	S^2	NTAXA $\bar{X}$	S^2	HBAR $\bar{X}$	S^2
2.0	44	1.44	0.20	5.82	13.08	1.58	0.56
3.0	48	1.38	0.30	5.19	10.37	1.34	0.58
4.0	48	0.91	0.49	2.25	3.38	0.47	0.37
6.0	48	1.31	0.22	3.92	4.16	1.12	0.35
7.0	48	1.38	0.18	4.60	6.80	1.23	0.41
8.0	48	0.98	0.21	2.69	2.99	0.91	0.35
Maximum S^2			0.49 N = 48		13.08 N = 44		0.58 N = 48
Minimum S^2			0.18 N = 48		2.99 N = 48		0.35 N = 48
Fmax			2.72*		4.37**		1.55 NS

* Significant for α = 0.05, variances not homogeneous
** Significant for α = 0.01, variances not homogeneous

1976 - 1978

Station	N	LOG_{10} (N+1) $\bar{X}$	S^2	NTAXA $\bar{X}$	S^2	HBAR $\bar{X}$	S^2
3.0	56	1.73	0.24	4.96	13.93	1.00	0.64
3.5	56	1.81	0.23	8.81	15.69	1.50	0.71
4.0	56	2.05	0.21	6.25	5.25	1.33	0.27
6.0	56	1.70	0.15	5.02	3.00	1.32	0.23
7.0	44	2.20	0.17	8.77	9.27	1.71	0.19
Maximum S^2			0.24 N = 56		15.69 N = 56		0.71 N = 56
Minimum S^2			0.15 N = 56		3.00 N = 56		0.19 N = 56
Fmax			1.60 NS		5.23**		3.74**

** Significant for α = 0.01, variances not homogeneous

TABLE 8

TESTS OF HOMOGENEITY OF VARIANCES FOR LOG_{10} (N+1), NTAXA, AND HBAR FROM DENDY SAMPLERS.

1973 - 1974

Station	N	$LOG_{10}(N+1)$ $\bar{X}$	S^2	NTAXA $\bar{X}$	S^2	HBAR $\bar{X}$	S^2
2.0	32	1.37	0.39	6.28	15.05	1.68	0.72
3.0	30	1.51	0.14	6.93	9.37	1.86	0.47
4.0	30	1.20	0.50	4.17	16.14	0.77	0.67
6.0	30	1.11	0.31	5.83	16.70	1.67	0.93
7.0	33	1.48	0.49	8.88	33.92	1.95	1.27
8.0	27	1.00	0.36	3.07	8.38	0.90	0.56
Maximum S^2		0.50 N = 30		33.92 N = 33		1.27 N = 33	
Minimum S^2		0.14 N = 30		8.38 N = 27		0.47 N = 30	
Fmax		3.57**		4.05*		2.70 NS	

* Significant for α = 0.05, variances not homogeneous
** Significant for α = 0.01, variances not homogeneous

1976 - 1978

Station	N	$LOG_{10}(N+1)$ $\bar{X}$	S^2	NTAXA $\bar{X}$	S^2	HBAR $\bar{X}$	S^2
3.0	33	1.62	0.40	7.21	14.11	1.39	0.60
3.5	33	1.72	0.34	8.48	18.95	1.60	0.80
4.0	39	1.62	0.25	6.92	12.76	1.62	0.40
6.0	36	1.71	0.41	9.00	21.60	1.71	0.60
7.0	41	1.57	0.41	8.17	10.90	1.53	0.59
Maximum S^2		0.41 N = 41		21.60 N = 36		0.80 N = 33	
Minimum S^2		0.25 N = 39		10.90 N = 41		0.40 N = 39	
Fmax		1.64 NS		1.98 NS		2.00 NS	

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TABLE 9

RESULTS OF ANALYSIS OF VARIANCE FOR EKMAN SAMPLES. THESE RESULTS ARE SUMMARIZED FROM ANOVA TABLES 3, 4, 7, 8, 11, AND 12 IN APPENDIX A.

1973-1974		1976-1978	
LOG_{10} (N+1)			
Source	P	Source	P
Station[1,2]	0.0001	Station[2]	0.0001
Period	0.0083	Period	0.0001
Station-Period	0.0015	Station-Period	0.0025
NTAXA			
Source	P	Source	P
Station[1]	0.0001	Station[1]	0.0001
Period	0.0015	Period	0.0055
Station-Period	0.5972	Station-Period	0.3632
HBAR			
Source	P	Source	P
Station[3]	0.0001	Station[1]	0.0001
Period	0.0053	Period	0.3359
Station-Period	0.6716	Station-Period	0.1659

1. Heterogeneous variances precludes comparison among mean values.

2. Significant station-period interaction precludes comparison among mean values.

3. Comparison among mean values indicate: 7 ≈ 2, 3, 6 > 4, 8, (see Appendix A, Table 14).

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TABLE 10

RESULTS OF ANALYSIS OF VARIANCE FOR DENDY SAMPLES. THESE RESULTS ARE SUMMARIZED FROM ANOVA TABLES 16, 17, 20, 21, 24, AND 25 IN APPENDIX A.

	1973-1974		1976-1978
LOG_{10} (N+1)			
Source	P	Source	P
Station[1,2]	0.0008	Station	NS (P < 0.1515)
Period	0.0001	Period	0.0002
Station-Period	0.0001	Station-Period	0.0001
NTAXA			
Source	P	Source	P
Station[1,2]	0.0001	Station[2]	0.005
Period	0.0116	Period	0.076
Station-Period	0.01	Station-Period	0.0002
HBAR			
Source	P	Source	P
Station[2]	0.0001	Station[1]	NS (P < 0.1245)
Period	0.0194	Period	0.0096
Station-Period	0.0593	Station-Period	0.0002

1. Heterogeneous variances precludes comparison among mean values.

2. Significant station-period interaction precludes comparison among mean values.

TABLE 11

PHYSICOCHEMICAL DATA FOR SURVEYS FROM 1973-1978 ON BEAVERDAM CREEK (MEAN ± STANDARD DEVIATION) / (COEFFICIENT OF VARIATION)

	Station						
	2.0	3.0	3.5	4.0	6.0	7.0	8.0
Water Temperature (^{o}C)	17.3 ± 6.7 / 39%	19.2 ± 6.5 / 34%	19.5 ± 6.6 / 34%	19.4 ± 7.0 / 36%	18.8 ± 6.3 / 34%	19.1 ± 6.1 / 32%	19.3 ± 7.0 / 36%
DO (mg/l)	8.0 ± 1.53 / 19%	7.9 ± 1.20 / 15%	7.7 ± 1.73 / 22%	7.6 ± 1.65 / 22%	8.0 ± 1.4 / 18%	8.0 ± 1.26 / 16%	8.3 ± 1.9 / 14%
Conductivity (μmhos/cm)	49.3 ± 4.6 / 9.3%	48.4 ± 10.6 / 21.9%	47.7 ± 3.3 / 6.9%	86.0 ± 41.0 / 48%	48.8 ± 4.3 / 9.0%	49.7 ± 5.84 / 12.0%	35.6 ± 6.2 / 17.0%
Alkalinity mg/l $CaCO_3$	21.8 ± 2.24 / 10.2%	22.1 ± 2.76 / 12.4%	22.7 ± 3.64 / 16.0%	35.4 ± 18.3 / 51.6%	20.4 ± 2.7 / 13.2%	21.6 ± 2.8 / 13.0%	13.9 ± 4.0 / 29.0%
Hardness mg/l $CaCO_3$	22.6 ± 2.0 / 8.0%	23.0 ± 2.69 / 3.0%	23.0 ± 1.9 / 8.0%	41.5 ± 21.7 / 52%	22.4 ± 3.4 / 15%	23.3 ± 3.4 / 15%	17.2 ± 13.3 / 77.3%
pH	6.9 ± 0.15 / 2.0%	7.0 ± 0.20 / 3.0%	7.2 ± 0.12 / 1.7%	6.8 ± 0.47 / 7.0%	6.9 ± 0.38 / 5.5%	6.9 ± 0.28 / 4.0%	6.6 ± 0.19 / 3.0%
Turbidity (NTU)	4.9 ± 5.2 / 106%	4.9 ± 7.9 / 161%	3.0 ± 1.6 / 54%	22.6 ± 33.9 / 150%	7.0 ± 3.6 / 51%	4.2 ± 2.62 / 63%	33.8 ± 41.4 / 122%
Total Suspended Solids (mg/l)	--	5.48 ± 3.0 / 55%	5.9 ± 5.4 / 92%	30.6 ± 40.5 / 132%	18.3 ± 22.0 / 120%	11.4 ± 14.9 / 130%	45.6 ± 61.5 / 135%
Number of samples	13	27	11	27	27	27	19

-- = No data obtained.

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TABLE 12

FLOW, TOTAL SUSPENDED SOLIDS, AND SUSPENDED SEDIMENT DISCHARGE AT STATIONS 3.0, 3.5, AND 6.0 IN BEAVERDAM CREEK.

	Station 3.0			Station 3.5			Station 6.0		
Date	Flow (CFS)	Total Suspended Solids (mg/ℓ)	Suspended Sediment Discharge (Tons/Day)	Flow (CFS)	Total Suspended Solids (mg/ℓ)	Suspended Sediment Discharge (Tons/Day)	Flow (CFS)	Total Suspended Solids (mg/ℓ)	Suspended Sediment Discharge (Tons/Day)
4/12/76	23.9	12.7	0.82	-	-	-	-	-	-
5/17/76	61.7	4.7	0.78	-	-	-	-	-	-
5/26/76	43.2	5.8	0.67	-	-	-	-	-	-
6/29/76	34.2	6.7	0.62	-	-	-	-	-	-
8/10/76	22.4	8.7	0.53	-	-	-	-	-	-
9/21/76	25.2	4.4	0.30	-	-	-	-	-	-
3/1/77	36.9	1.2	0.12	-	-	-	-	-	-
4/13/77	17.2	2.6	0.12	4.76	10.5	0.13	22.5	85.0	5.16
5/23/77	27.1	8.9	0.65	3.82	5.1	0.05	7.2	38.5	0.75
7/12/77	17.6	3.2	0.15	1.93	2.7	0.14	5.8	7.3	0.11
8/17/77	20.0	4.8	0.26	-	-	-	-	-	-
9/27/77	31.3	3.4	0.28	-	-	-	-	-	-
11/15/77	22.4	5.8	0.35	4.6	4.9	0.06	6.8	8.0	0.15
3/14/78	35.2	2.6	0.28	5.7	6.1	0.09	15.6	11.0	0.46
4/25/78	31.1	2.2	0.18	5.2	2.1	0.03	13.0	8.6	0.30

- = No data obtained.

NOTE: Station 3.5 was in one of the channels of the braided stream.

TABLE 13

ESTIMATED BEDLOAD DISCHARGE AT STATION 3.0 USING THE SCHOKLITSCH FORMULA.

Date	Stream Width (Ft.)	Q_0	D	Q_{01}	G_1	Estimated Bedload Discharge Tons/Day
4/12/76	28	23.9	0.575	0.24	0.14	170
5/17/76	32	61.7	0.464	0.18	0.37	510
5/26/76	31	43.2	0.473	0.18	0.26	350
6/29/76	29.5	34.2	0.503	0.20	0.20	260
8/10/76	30	22.4	0.469	0.18	0.13	175
9/21/76	30	25.2	0.544	0.22	0.15	195
4/13/77	37	17.2	0.593	0.26	0.10	165
5/23/77	33	27.1	0.462	0.18	0.16	230
7/12/77	31	17.6	0.411	0.15	0.11	140
9/27/77	32	31.3	0.554	0.23	0.19	260
11/15/77	32	22.4	0.563	0.23	0.13	185
3/14/78	32	35.2	0.394	0.14	0.21	290
4/25/78	31	31.1	0.384	0.13	0.19	250

Slope = 0.00114

NOTE: Because of the empirical nature of the formulas, the bedload discharges are not exact values, but approximations.

Symbols: Q_0 = Stream discharge ft^3/sec

D = Particle diameter (ft)

Q_{01} = Critical flow

G = Bedload

TABLE 14

ESTIMATED BEDLOAD DISCHARGE AT STATIONS 3.5 and 6.0 USING THE SCHOKLITSCH FORMULA.

Station 3.5

Date	Stream Width (Ft)	Q_0	D	Q_{01}	G	Bedload Discharge Tons/Day
4/13/77	13	4.8	0.448	0.17	0.03	15
5/23/77	12	3.8	0.470	0.19	0.02	10
7/12/77	12	1.9	0.387	0.14	0.01	5
11/15/77	12	4.6	0.392	0.14	0.03	13
3/14/78	12	5.7	0.474	0.19	0.03	16
4/25/78	12	5.2	0.438	0.17	0.03	15

Slope at Station 3.5 = 0.0011

Station 6.0

Date	Stream Width (Ft)	Q_0	D	Q_{01}	G	Bedload Discharge Tons/Day
4/13/77	24	22.5	0.533	0.06	0.07	780
5/23/77	21	7.2	0.561	0.06	0.24	220
7/12/77	18	5.8	0.491	0.05	0.19	150
11/15/77	20	6.8	0.636	0.07	0.23	200
3/14/78	20	15.6	0.586	0.07	0.52	450
4/25/78	20	13.0	0.643	0.08	0.44	420

Slope at Station 6.0 = 0.0036

NOTE: Because of the empirical nature of the formulas, the bedload discharges are not exact values, but are approximations.

Symbols: Q_0 = Stream discharge ft^3/sec

D = Particle diameter (ft)

Q_{01} = Critical flow

G = Bedload