TENNESSEE VALLEY AUTHORITY

Resource Group
Water Management

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CLINCH RIVER REMEDIAL INVESTIGATION
TASK 9 - BENTHIC MACROINVERTEBRATES

DISCLAIMER

Prepared by
Edwin M. Scott, Jr.

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ACKNOWLEDGMENTS

Many Tennessee Valley Authority (TVA) associates were involved with this task of the Clinch River Remedial Investigation Project. Jack Milligan, as the project coordinator, and Anita Masters, the originator of the benthic macroinvertebrate workplan, and others on the project team initiated the scope and planning for this study, and dialogue with Oak Ridge National Laboratory (ORNL) personnel. Dan Levine (ORNL) provided locations to be sampled. The fieldwork was accomplished by the author and contractors Suzie Jones and Susan Rone of Fish and Wildlife Associates. Richard Graves scheduled the use of vehicles, boats, gear, and contractors necessary to complete the field assignment. Richard Clapp maintained the boat, motor, and trailer used in the study, and made an emergency field repair of the outboad motor. Wendel Pennington, Pennington and Associates, provided the laboratory processing and identification of the benthic samples. Bob Terry and Gladys Hassell provided data management and basic analysis. Dave Kinney, Harold Pratt, Anita Masters, and Tom McDonough all contributed to the benthic index community analysis program used for TVA's Reservoir Vital Signs Monitoring Program that was applied to data collected in this report. Ken Tennessen and Steve Ahlstedt provided information about the relative tolerance of certain benthic invertebrates. David Varnell provided chemical analysis of sediments containing an unusual substance found in an embayment of the Clinch River during the course of field sampling.

INTRODUCTION

This report summarizes the results of Task 9 of the TVA/Department of Energy (DOE) Interagency Agreement supporting DOE's Clinch River Remedial Investigation. Species lists and densities (numbers/m^2) of benthic macroinvertebrates sampled at 16 sites in the Clinch River and Poplar Creek embayments of upper Watts Bar Reservoir near Oak Ridge, Tennessee, in March, 1994, are presented and briefly discussed. Data are also analysed to assess and compare quality of benthic communities at each site, according to methods developed for TVA's Reservoir Vital Signs Monitoring Program.

Results of this study will be incorporated with other program tasks in a comrehensive report prepared by Oak Ridge National Laboratory in 1995, which will, in part, assess the effect of sediment contaminants on benthic macroinvertebrate communities in Watts Bar Reservoir.

METHODS

Sixteen sample sites in upper Watts Bar Reservoir, eight in Clinch River and eight in Poplar Creek embayments, were identified for benthic macroinvertebrate sampling (Figures 1-6). Sites were selected on the basis of sediment accumulation determined by ORNL core samples. Dan Levine and Clint Rash accompanied TVA employees to locate sample sites to ensure agreement between macroinvertebrate samples collected by TVA and sediment core samples collected by ORNL.

At each site, ten Ponar dredge samples were collected from an anchored boat. Taking all samples from one small area is a departure from standardized TVA Vital Signs Monitoring, which collects ten samples from equally spaced intervals along a line-of-sight transect across the width of a reservoir. Global Positioning System (GPS) coordinates were obtained at each sampling location with a hand-held Magellan device.

Ponar samples were collected over a two week period beginning March 15, 1994. During this time the elevation of Watts Bar reservoir remained at winter pool, and certain benthic macroinvertebrates had not begun emerging as winged adults (mayflies, midges, etc.). Samples taken near shallow shorelines were from areas continually wetted by reservoir waters.

In collecting Ponar dredge samples, the dredge was lowered from the boat until it reached the bottom. As the dredge was subsequently retrieved, the jaws of the dredge closed, grabbing a 0.06 m^2 chunk of the substrate (Figure 7A). The dredge was raised to the boat with a gas powered winch, and its contents were dumped into a washdown tray (Figure 7B). River water sprayed on the sample washed finer particles of silt,

sand and clay through a 533 um mesh sorting screen (Masters and Wales 1994). Larger items (woody debris, rocks, etc.) were sprayed clean and discarded. Benthic organisms and remaining materials were transferred to sample jars and preserved in 10 percent buffered formalin. Most samples could be contained in a single pint jar, but at some locations, accumulations of detritus necessitated quart jars. Abiotic data recorded for each sample included depth, percent distance from left descending bank, and the percent composition of the two predominant substrate components (silt, clay, sand, etc.).

Laboratory processing of the samples was performed by Pennington and Associates, Cookeville, Tennessee. There benthic organisms were removed from remaining debris and substrate, counted, and identified to the lowest practical taxon consistent with the requirements of the TVA Vital Signs Monitoring Program. Data were transmitted back to TVA on computer diskettes. TVA data management associates in Norris merged the biotic data with abiotic data in the TVA mainframe computer data base and produced standard tables of macroinvertebrate densities by sample site.

Benthic community quality was determined by an analysis program developed for TVA's Vital Signs Monitoring Program (Dycus and Meinert 1994). Six benthic community measurements were calculated from data collected at each site as follows:

1. Taxa Richness--The number of different taxa present. An increase in total taxa or taxa richness is used to indicate better conditions than low taxa richness.
2. Long-lived Species--The number of taxa (Corbicula, Hexagenia, mussels, and snails present. These organisms are long-lived and their presence indicates conditions which allow long-term survival.
3. EPT--The number of different taxa within these orders (Ephemeroptera-mayflies, Plecoptera-stoneflies, Tricoptera-caddisflies).

Higher numbers of this metric indicate good water quality conditions in streams. A similar use is incorporated here despite expected lower numbers in reservoirs than in streams.

4. Proportion as Chironomidae--The percent of the total organisms in the sample that are chironomids. A higher proportion indicates poor conditions.
5. Proportion as Tubificidae--The percent of the total organisms present that are tubificids. A higher proportion indicates poor conditions.
6. Proportions as Dominant Taxa--The percent of total organisms present that are members of the dominant taxon. This metric is used as an evenness indicator. A large proportion comprised of one or two taxa indicates poor conditions.

For each metric, scoring criteria were developed for inflow zones of TVA mainstream (run-of-river) reservoirs based on results of surveys conducted 1991-1993 (Table 2). Benthic data collected in the present study were compared to the criteria to score each metric 1, 3, or 5, with a score of 5 representing the highest quality, and a score of 1 indicating the poorest. Metric scores were then summed to yield the benthic community index, which categorized a community as follows:

Benthic Community Index	Benthic Community Quality
6 - 10	Poor
16 - 20	Fair
26 - 30	Good

RESULTS AND DISCUSSION

Benthic community quality of the Clinch River Remedial Investigation sites was categorized as generally poor to fair relative to expectations developed by TVA for inflow zones of mainstream Tennessee River reservoirs (Table 2). Six sites rated poor, six rated fair, three rated intermediate between poor and fair, and the best site rated between fair and good, based on community indices ranging from 8 to 22.

The depressed quality evident in this study is not unlike results of other studies in the area. The Clinch River inflow zone of Watts Bar Reservoir had a poor benthic community, as did the Tennessee River inflow zone (Dycus and Meinert 1994). Benthic communities at both sites suffered from lack of taxa richness, EPT taxa, long-lived species, and evenness of dominant taxa. Density of benthic organisms in the Clinch River inflow was 145 organisms/m^2, represented by 16 taxa. Dominant taxa were Corbicula fluminea (49 percent), Pseudochironomus sp. (18 percent), and Tubificidae (18 percent).

Primary shortcomings of the present study area communities were low numbers of long-lived taxa and EPT taxa, and high percentages of tubificids. The former two metrics agree with TVA's Vital Signs Monitoring results, but that study showed lower taxa richness than expected for a mainstream reservoir inflow. Differences in results could be due to sample site differences, as mentioned in Methods section of this report.

Clinch River Sites

Ponar samples were taken from overbank areas at eight locations in the Clinch River between miles 1.0 and 20.5. The two lowermost stations

were more lacustrine in nature, being located in more permanent backwaters of Watts Bar Reservoir than those at mile 9 and above. Benthic community quality was rated poor to fair among seven of the eight sites, as index values ranged from 8 to 20 (Table 2). The best site rated fair to good with an index of 22.

Mile 1.0

Samples were taken from the overbank area along the left descending bank at Kingston, Tennessee (Figure 1). Average sampling depth was 9.6 feet. The main substrate components were silt and detritus. Due to the volume of detritus encountered at this site, quart jars were frequently needed to contain rinsed samples.

A fair benthic community was found at this site, indicated by an index of 18 (Table 2). This was among the better benthic communities identified in the study. Although the site received highest scores for two metrics, including taxa richness (12.4) and dominant taxa (53.4 percent), low scores were assigned for average abundance of long-lived taxa (1.2 per sample) and percentage of chironimids (40.6). Average EPT taxa per sample (1.1) and percent tubificid worms (16.4) were considered in the intermediate range.

By far, this site had the highest density of benthic organisms (3,910/m^2) and the highest diversity (36 taxa, Table 3). The three most abundant taxa were Hexagenia limbata (832/m^2), Procladius sp. (742/m^2), and Musculium transversum (753/m^2).

Mile 3.7

Samples at this site were taken from the overbank along the right descending bank (Figure 2) from depths averaging 3.6 feet. As at CRM

1.0, silt and detritus were dominant substrate components at CRM 3.7. Detritus in the form of decaying leaves was very abundant at CRM 3.7, and often two quart jars were required to contain single, washed samples.

An index of 16 indicated a fair benthic community at CRM 3.7 (Table 2). High scores for taxa richness (9.7) and percent dominant taxa (56.0) were offset by low scores for long-lived taxa (1.1) and excessive percentages of chironomids and tubificids (49.9 and 33.2, respectively). EPT taxa averaged 1.0 per sample.

This site had the second highest density of benthic macroinvertebrates (2,355/m^2) and total taxa (24) (Table 3). The three most abundant taxa were tubificids Branchiura sowerbyi (580/m^2) and the chironomids Procladius sp. (512/m^2) and Chironomus sp. (313/m^2).

Mile 6.7

Samples were collected from the channel of the Young Creek embayment near its mouth on the south bank of the Clinch River (Figure 3). Average depth sampled was 14.1 feet, and the substrate was primarily silt.

This site had the best benthic community of all sites sampled. With an index of 22, it was rated fair to good (Table 2). Highest scores were assigned for taxa richness (12.6), tubificid abundance (5.2 percent), and percent dominant taxa (66.3). As in virtually all samples of this study, long-lived taxa were depressed at CRM 6.7, relative to inflow zones of mainstream TVA reservoirs. EPT taxa and chironomid metrics were given intermediate rankings.

Like the other lower stations of the Clinch River, benthic invertebrate abundance was relatively high (2,151/m^2) and 29 taxa were found (Table 3). Fingernail clams (Sphaeriidae) and burrowing mayflies (Hexagenia limbata) were the two most abundant taxa, with densities of

765 and 655 individuals/m^2, respectively. As high densities of these taxa indicate good benthic community quality, low densities of tubificids are 'good' indicators, also. At CRM 6.7 density of tubificid worms (two taxa) was only 84/m^2.

Mile 9.0

Dredge samples were taken in shallow water near the right descending bank (Figure 3). Water depths averaged two feet. The predominant substrate component was sand, with lesser amounts of silt.

The benthic community at CRM 9.0 was among the poorest identified in the present study. It shared the second lowest benthic index (10) with two Poplar Creek sites (Table 2). Four metrics rated low, including long-lived taxa (0.5), EPT taxa (0.2), percent tubificids (75.9), and percent dominant taxa (83.8). Taxa richness and percent chironomid metrics fell into the intermediate ranking.

Overall density of benthic macroinvertebrates (550/m^2) and taxa diversity (16), were notably less along the sandy, shallow, right bank at CRM 9.0 than other Clinch River sites previously discussed (Table 3). By far the most abundant taxon was Tubificidae, at 72.2 percent of the total sample (397/m^2). No other taxon exceeded 8 percent of the sample.

Mile 11.0

Samples were collected near the left descending bank (Figure 4) in water depths averaging one foot. Predominant substate particles were silt and sand.

The benthic community at this site was rated poor to fair, according to an index of 12 (Table 2). Absence of long-lived taxa and near absence of EPT taxa (0.1) along with excessive percentages of tubificids (84.5) were evidence of a depressed benthic community. The excessive abundance

of tubificids also resulted in a low score for the dominant taxa metric. Ironically, a high score was associated with the relatively low percent chironomid (8.3) metric, but it can be explained by the overwhelming dominance of tubificids. Taxa richness overall received an intermediate ranking.

Total macroinvertebrate benthic density (1,589 organisms/m^2) at CRM 11.0 represented 20 taxa (Table 3). Over 85 percent of organisms collected were tubificid worms of three taxa. The third most abundant taxon was Chironomus sp. (78/m^2).

Mile 14.5

Ponar dredge samples were taken from the Grassy Creek embayment on the right descending bank of the Clinch River (Figure 4). Average depth of sampling was 6.5 feet. The substrate was characterized by silt, sand, and lesser amounts of clay.

A peculiar substance was found in the sediments at this site. During washdown of dredge samples, globules of dry, white powder appeared in the silt and sand (Figure 5A). The powder globules floated to the surface and dispersed into a milky cloud, which was also visible on the river's surface (Figure 5B). The white powder was found in most samples at the CRM 14.5 site, and was not limited to the deeper creek channel of the overbank. Propwash dislodged powder from the overbank substrate in depths of approximately one foot over a fairly large part of the Grassy Creek embayment.

A sample of the substrate containing white powder was sent to TVA's Environmental Laboratory in Chattanooga for analysis. Analytical chemist David Varnell reported test results as follows: the sample was treated as a sediment and analyzed using methods described in the EPA

SW846 manual. Analysis for semi-volatile organics detected no target list compounds amenable to the GC/MS method 8270 nor were any compounds identified by the spectral library search. Four TCLP regulated metals were found, but at levels well below potential hazardous concentrations. Sediment core samples taken at CRM 14.5 did not contain noticeable amounts of the unknown white substance (Dan Levine, ORNL, personal communication).

The benthic macroinvertebrate community was apparently unharmed by the unknown material in the substrate. It was the second best community identified in the study, and received an index of 20 (Table 2). Metrics for taxa richness and percent dominant taxa were assigned high scores, but the tubificid metric scored low. The remaining metrics were given intermedite scores.

Total density of benthic macroinvertebrates at this site was 1,201 organisms/m^2, containing 32 identified taxa (Table 3). Over half the sample was comprised of tubificid worms (3 taxa). A diverse assortment of chironomids (15 taxa) accounted for 23 percent of the total sample. The two most frequently encountered chironomid taxa were the genera Cryptochironomus sp. and Procladius sp.

Mile 19.0

Ponar samples were taken in the mouth of a small, unnamed tributary entering the Clinch River near CRM 19. Sampling depth averaged 3.8 ft., and the predominant substrate components were clay and silt with lesser amounts of sand.

All but one community metric indicated a poor quality benthic assemblage at this site, shown by an index of 8 (Table 2). The only metric that did not score low was percent chironomids (16.7), and it was

dictated by the overwhelming dominance of tubificids (77.4 percent). Long-lived taxa (0.3) and EPT taxa (0.1) were among the lowest observed in this study, as was taxa richness (4.6).

Overall benthic macroinvertebrate density (471/m^2) was the lowest found in the Clinch River sites (Table 3). Twenty taxa were identified, the most abundant being Tubificidae (315/m^2). Following in abundance were two chironomids, Polypedilum sp. and Dictrotendipes sp., which had much lower densities (30 and 23/m^2, respectively).

Mile 20.5

Near shoreline samples were taken from the left descending bank in the vicinity of CRM 20.5 (Figure 5). The sustrate was sand and silt with lesser amounts of sand. Average depth sampled was 1.2 ft.

The benthic community at this site was very similar to that found at CRM 19.0. An index of 8 also was determined for CRM 20.5, and all metrics received identical scores (Table 2). Average taxa richness was slightly less at this site, and EPT taxa were absent.

Thirteen taxa had a combined density of 622 individuals/m^2 (Table 3). Over 76 percent of the organisms sampled were Tubificidae. The second most abundant taxon was the chironomid Polypedilum sp. (98/m^2).

Poplar Creek Sites

Eight sites were sampled in the Poplar Creek Embayment of Watts Bar Reservoir between Poplar Creek Mile (PCM) 0.5 and PCM 8.0 (Figures 4 and 6). All but the two lowermost stations were amidst the complex of buildings associated with the K25 Gaseous Diffusion Plant. Sampling depths ranged from less than 1 ft. to 18 ft. depending on location of sediment accumulation. Benthic communities at all Poplar Creek sites rated in the poor to fair categories. Deficiencies were found in long-lived taxa and EPT taxa, relative to expectations for mainstream Tennessee River reservoir inflow zones.

Mile 0.5

Ponar samples were taken in an average depth of 3 ft. along the left descending bank of Poplar Creek (Figure 4). The substrate was almost exclusively silt.

Abundance of benthic organisms was generally less than Clinch River sites. One of the better benthic communities found in the Poplar Creek embayment, this site was rated fair, based on an index of 16 (Table 2). Taxa richness (10.8) was higher at PCM 0.5 than the other seven sites in Poplar Creek, and a high score was given to that metric. Another high score was given for low percentage of dominant organisms (61). But low scores were assigned for three metrics, including long-lived taxa (0.2), EPT taxa (0.4), and percent tubificids (60.1).

Total benthic invertebrate density (961/m^2) included 32 taxa (Table 4). Two tubificid taxa were most frequently encountered, Tubificidae (453/m^2) and Branchiura sowerbyi (150/m^2). Following them in abundance were Chironomus sp. (60/m^2) and Bezzia sp. (52/m^2).

Mile 1.0

Dredge samples at this site were taken from the deepest part of the creek channel approximately twenty percent from the left descending bank (Figure 4). Average sampling depth was 16.3 ft. The substrate was almost exclusively fine silt.

With a benthic index of 18, this site appeared to have the healthiest community of the Poplar Creek sites, but still only was rated fair (Table 2). It scored high for just one metric, the relatively low percentage of dominant taxa (68.0). All other metrics were scored in the intermediate range, except the long-lived metric which rated low.

Total density of benthic macroinvertebrates at PCM 1.0 was 421 individuals/m^2, represented by 24 taxa (Table 4). Three dominant taxa were Bezzia sp. (90/m^2), Hexagenia limbata (88/m^2), and Tubificidae (60/m^2).

Mile 2.9

Samples were collected from near the right descending bank (Figure 6) at an average depth of 1.5 ft. The substrate was mostly silt with some clay.

A poor to fair benthic community was identified at this site by an index of 12 (Table 2). Like the majority of Poplar Creek sites, PCM 2.9 was rated poor for long-lived taxa, EPT taxa, and tubificid metrics (0.2, 0.3, and 68.1, respectively). Fair scores were assigned for the remaining three metrics.

Twenty-eight taxa were collected at this site with a total density of 614 organisms/m^2 (Table 4). Over half the sample was composed of tubificid worms (3 taxa). Eleven chironomid taxa were identified with Chironomus sp. (58/m^2) and Cryptochironomus sp. (32/m^2) more

frequently occurring. Three EPT taxa were found, namely Caenis sp., Eurylophella sp., and Hexagenia limbata, but none were abundant.

Mile 4.3

Silt, clay, and detritus were the predominant substrate components found in Ponar samples taken along the left descending bank at PCM 4.3 (Figure 6). Average sampling depth was approximately one foot.

The benthic community was rated poor (index=10) at this shallow site (Table 2). Low scores were assigned for four of the six metrics (taxa richness, long-lived taxa, EPT taxa, and percent tubificids). The remaining two metrics (chironomids and dominant taxa) received intermediate scores.

Benthic community abundance and composition at PCM 4.3 was similar to that of PCM 2.9, except fewer taxa were identified (Table 4). The total density (573 organisms/m^2) was represented by 17 taxa. Again over half the commuity was composed of tubificid worms. Chironomids were the next most abundant group, but were only half as diverse (6 taxa) as at PCM 2.9. No EPT taxa were found.

Mile 5.1

Ponar samples were collected along the right descending bank at PCM 5.1 (Figure 6). Average sampling depth was 1.7 ft, and the substrate was mostly silt, along with lesser amounts of clay.

Conditions for benthic organisms were slightly better at PCM 5.1 than the previous two sites. An index of 14 placed this benthic community in the poor to fair range (Table 2). Measurements of taxa richness and percent dominance met highest expectations for mainstream Tennessee River reservoir inflow zones (8.9 and 65.3, respectively). But all other metrics scored lower.

Overall abundance (981 organisms/m^2) was slightly greater at PCM 5.1 than the other Poplar Creek sites (Table 4), and 27 taxa were identified. Three dominant taxa included Tubificidae (400/m^2), Tribelos sp. (173/m^2), and Polypedilum sp. (122/m^2).

Mile 6.0

Samples were taken along the left descending bank near PCM 6.0 (Figure 6). Average sample depth was 1.6 ft. The substrate was predominantly silt with lesser amounts of clay.

This site supported one of the best benthic communities found in Poplar Creek. With an index of 16, the community at this site was rated fair (Table 2). Like PCM 5.1, this site's benthos scored high for taxa richness and percent dominance (10.2 and 63.0, respectively). The EPT metric was scored intermediately, but the remaining metrics were assigned low scores.

Overall density of benthic macroinvertebrates (977/m^2) was high at PCM 6.0, relative to other Poplar Creek sites (Table 4). Twenty-seven taxa were identified. The three dominant taxa were Polypedilum sp. (330/m^2), Tubificidae (193/m^2), and Hexagenia limbata (138/m^2). Fourteen chironomid taxa were identified.

Mile 7.0

Samples were taken along the right descending bank from depths averaging 0.6 ft. Substrate components were clay and silt. (Figure 6)

A poor benthic community was identified by an index of 8 at PCM 7.0, the poorest site sampled in Poplar Creek (Table 2). All metrics indicated poor benthic quality, except percent dominance (77.1), which rated fair. Taxa richness (4.1) and long-lived taxa (0.2) were the lowest found in Poplar Creek. Average EPT taxa was only 0.1.

Density of benthic macroinvertebrates was greatly reduced at this site (262 organisms/m^2, Table 4)). Eighteen taxa were identified. Three dominant taxa included Tubificidae (108/m^2), Polypedilum sp. (65/m^2), and Tribelos sp. (22/m^2). The single EPT taxon identified was the plecopteran family Capniidae.

Mile 8.0

Samples from sand, silt, and clay substrates were collected from shallow depths along the right descending bank at PCM 8.0 (Figure 6). Average sampling depth was 0.85 ft.

The uppermost site on Poplar Creek also was found to have a poor benthic community (index=10, Table 2). Lowest scores were assigned for all but the percent dominant taxa metric (67.6), which scored high.

Benthic macroinvertebrate density (192/m^2) was the lowest of all sites in the study (Table 4). Only 14 taxa were identified. Three dominant taxa included Tubificidae (65/m^2), Polypedilum sp. (40/m^2), and Tribelos sp. (17/m^2). No EPT taxa were found.

LITERATURE CITED

Dycus, D. L., and D. L. Meinert, 1994. "Tennessee Valley Reservoir and Stream Quality - 1993, Summary of Vital signs and Use Suitability Monitoring." TVA, Water Management, Chattanooga, Tennessee.

Masters, A. E., and A. K. Wales, 1994. "Tennessee Valley Reservoir and Stream Quality - 1993, Benthic Macroinvertebrate Community Results, Reservoir Vital Signs Monitoring. TVA, Water Management, Chattanooga, Tennessee.

Table 1. Reservoir benthic macroinvertebrate metrics and scoring criteria developed for Tennessee Valley mainstream reservoir inflow sites, (Dycus and Meinert 1994).

Benthic Community Metrics	Scoring Criteria 5	3	1
Taxa richness	>8.0	5.2 - 8.0	<5.2
Long-lived species	>1.9	1.3 - 1.9	<1.3
EPT (mayfly, stonefly, caddisfly)	>1.4	0.6 - 1.4	<0.6
% Chironomidae	<10	10 - 30	>30
% Tubificidae	<11	11 - 25	>25
% Dominant taxa	<70	70 - 80	>80

Table 2. Macroinvertebrate community metric observations and scores, index values, and site ratings for 16 sites in Clinch River and Poplar Creek embayments of Watts Bar Reservoir, March 1994.

	Taxa		Long-lived		EPT		Chironomids		Tubificids		Dominance		Index	Rating
Clinch River mile:														
1.0	12.4	5	1.2	1	1.1	3	40.6	1	16.4	3	53.4	5	18	FAIR
3.7	9.7	5	1.1	1	1.0	3	50.0	1	33.2	1	56.0	5	16	FAIR
6.7	12.6	5	1.2	1	1.2	3	20.0	3	5.2	5	66.3	5	22	FAIR/GOOD
9.0	5.7	3	0.5	1	0.2	1	21.1	3	75.9	1	83.8	1	10	POOR
11.0	7.4	3	0.0	1	0.1	1	8.3	5	84.5	1	85.1	1	12	POOR/FAIR
14.5	12.2	5	1.4	3	0.9	3	23.3	3	63.9	1	65.3	5	20	FAIR
19.0	4.6	1	0.3	1	0.1	1	16.7	3	77.4	1	86.3	1	8	POOR
20.5	3.7	1	0.7	1	0.0	1	16.4	3	76.3	1	91.5	1	8	POOR
Poplar Creek mile:														
0.5	10.8	5	0.2	1	0.4	1	18.7	3	60.1	1	61.0	5	16	FAIR
1.0	6.7	3	1.2	1	1.3	3	10.5	3	12.0	3	68.0	5	18	FAIR
2.9	7.8	3	0.2	1	0.3	1	18.6	3	68.2	1	71.5	3	12	POOR/FAIR
4.3	5.0	1	0.2	1	0.0	1	23.8	3	52.3	1	79.4	3	10	POOR
5.1	8.9	5	0.6	1	0.5	1	47.6	1	43.6	1	65.3	5	14	POOR/FAIR
6.0	10.2	5	0.9	1	0.7	3	45.9	1	28.5	1	63.0	5	16	FAIR
7.0	4.1	1	0.2	1	0.1	1	32.6	1	40.8	1	77.1	3	8	POOR
8.0	4.8	1	0.7	1	0.0	1	41.5	1	35.5	1	67.6	5	10	POOR

Table 3. Densities (number/m^2) of benthic macroinvertebrate taxa from eight sites in the Clinch River embayment of upper Watts Bar Reservoir, March 1994.

Taxon	CRM 1.0	CRM 3.7	CRM 6.7	CRM 9.0	CRM 11.0	CRM 14.5	CRM 19.0	CRM 21.0
Nematoda	13	8	3	7	37	10	23	2
Oligochaeta								
Haplotaxida								
Enchytraeidae	.	.	.	.	.	2	.	.
Lumbricidae	.	.	.	.	.	.	.	.
Naididae	.	.	.	.	.	.	.	.
Dero sp.	2	.	.	.	.	.	.	.
Nais sp.	7	13	.	.	.	2	.	.
Nais communis	.	.	.	.	8	.	.	.
Tubificidae	552	580	72	397	1140	653	315	475
Branchiura sowerbyi	2	110	12	.	12	20	13	.
Limnodrilus hoffmeisteri	22	2	.	40	200	95	8	.
Lumbriculida								
Lumbriculidae	.	.	.	.	.	.	.	.
Hirudinea	.	.	2	.	.	.	.	.
Crustacea								
Isopoda								
Asellidae								
Caecidotea sp.	.	.	.	.	.	.	.	2
Eucopepoda								
Cyclopidae	.	.	3	.	.	.	.	.
Macrocyclops albidus	2	.	.	.	.	.	.	.
Podocopa								
Candoniidae								
Candona sp.	2	.	.	.	.	.	.	.
Cyclocyprididae								
Cyclocypris sp.	.	7	5	.	.	.	.	.
Insecta								
Collembola	7	.	.	.	.	.	.	.
Plecoptera								
Capniidae	.	.	.	.	.	.	.	.
Odonata								
Coenagrionidae								
Argia sp.	.	.	.	.	.	.	.	.
Gomphidae								
Gomphus sp.	.	.	.	.	.	.	.	.
Libellulidae	3	.	.	.	.	.	.	.
Ephemeroptera								
Caenidae								
Caenis sp.	.	.	3	.	.	.	.	.
Ephemerellidae								
Eurylophella sp.	.	.	.	.	2	3	.	.
Ephemeridae								
Hexagenia limbata	832	177	655	3	.	40	3	.
Heteroptera								
Corixidae	.	.	.	.	2	.	.	.
Trichocorixa sp.	.	.	.	.	17	.	.	.

Table 3. continued.

Taxon	CRM 1.0	CRM 3.7	CRM 6.7	CRM 9.0	CRM 11.0	CRM 14.5	CRM 19.0	CRM 21.0
Trichoptera								
Leptoceridae								
Mystacides sp.	2	.	.	.	.	.	.	.
Oecetis sp.	.	.	.	.	.	.	.	.
Megaloptera								
Sialidae								
Sialis sp.	.	.	.	.	.	.	.	.
Diptera								
Ceratopogonidae								
Bezzia sp.	12	8	25	.	10	67	.	.
Chaoboridae								
Chaoborus punctipennis	10	10	7	.	.	.	.	.
Chironomidae	.	.	3	7	.	.	3	.
Ablabesmyia annulata	235	68	130	.	.	18	.	.
Ablabesmyia sp.	.	.	.	.	.	.	.	.
Axarus sp.	.	.	.	3	7	8	.	.
Brillia sp.	3	.	.	.	.	.	.	.
Chaetocladius sp.	.	.	.	3	.	2	.	.
Chironomus sp.	308	313	25	28	78	35	7	.
Cladotanytarsus sp.	.	13	.	2	.	3	.	.
Coelotanypus tricolor	47	10	.	.	.	2	.	.
Cricotopus sp.	.	.	.	.	.	3	5	3
Cricotopus tremulus gp.	.	.	.	.	.	.	.	2
Cryptochironomus sp.	117	78	12	7	8	72	10	10
Dicrotendipes sp.	.	.	.	13	2	2	23	2
Diplocladius cultriger	.	.	.	.	.	.	2	.
Einfeldia sp.	.	.	.	.	.	.	.	.
Epoicocladius sp.	95	2	15	.	.	8	.	.
Glyptotendipes sp.	.	.	.	.	.	.	2	.
Harnischia sp.	.	.	3	.	.	.	.	.
Microtendipes sp.	.	.	.	8	.	.	3	.
Pagastiella sp.	.	.	10	.	.	.	.	.
Parakiefferiella sp.	.	.	.	.	.	.	.	.
Paralauterborniella sp.	.	.	.	.	.	7	.	.
Parametriocnemus lundbecki	.	.	.	.	.	.	7	.
Phaenopsectra sp.	.	.	.	.	.	.	.	.
Polypedilum sp.	78	160	.	22	23	5	30	98
Polypedilum halterale	.	.	.	.	.	.	.	.
Procladius sp.	742	512	187	.	5	57	.	.
Pseudochironomus sp.	.	2	.	.	.	22	5	.
Rheocricotopus sp.	.	.	.	.	.	.	.	.
Rheotanytarsus sp.	.	7	.	.	.	.	3	.
Tanytarsus sp.	10	33	2	3	2	10	.	2
Tribelos sp.	13	.	2	2	.	28	.	.
Dolichopodidae	.	.	.	.	.	.	.	.
Empididae								
Hemerodromia sp.	3	.	.	.	.	.	2	.
Stratiomyidae	.	.	.	.	.	.	.	.
Tabanidae	.	.	.	.	.	.	.	.
Chrysops sp.	3	.	.	.	.	.	.	.

Table 3. continued.

Taxon	CRM 1.0	CRM 3.7	CRM 6.7	CRM 9.0	CRM 11.0	CRM 14.5	CRM 19.0	CRM 21.0
Tipulidae	.	.	.	.	.	.	.	.
Limnophila sp.	.	.	.	.	.	.	.	.
Tipula sp.	.	.	.	.	.	.	.	.
Coleoptera								
Elmidae								
Dubiraphia sp.	2	.	13	.	8	.	2	.
Optioservus sp.	.	.	3	.	.	.	.	.
Promoresia sp.	3	.	.	.	.	.	.	.
Hydrophilidae	.	.	.	.	.	.	.	.
Ptilodactylidae								
Anchytarsus bicolor	7	.	.	.	.	.	.	.
Arachnoidea								
Hydrachnellae	3	.	.	.	2	5	.	.
Hygrobatidae								
Atractides sp.	.	.	17	.	3	.	.	.
Krendowskiidae								
Krendowskia similis	.	.	2	.	.	.	.	.
Unionicolidae								
Neumania sp.	.	.	25	.	23	.	.	.
Unionicola sp.	2	3	10	.	.	.	.	.
Gastropoda								
Mesogastropoda								
Hydrobiidae	.	.	.	.	.	3	.	.
Pleuroceridae								
Pleurocera canaliculata	2	.	.	.	.	.	.	2
Basommatophora								
Lymnaeidae	.	.	.	.	.	.	.	2
Planorbidae	.	.	.	.	.	.	.	.
Bivalvia								
Unionoida								
Unionidae								
Anodonta imbecillis	.	.	.	.	.	3	.	.
Quadrula pustulosa pustulosa	2	.	.	.	.	.	.	.
Veneroida								
Corbiculidae								
Corbicula fluminea	7	2	5	5	.	8	5	20
Sphaeriidae	.	127	765	.	.	3	.	.
Musculium transversum	753	110	135	.	.	3	.	2
Pisidium sp.	.	.	.	.	.	2	.	.
Pisidium compressum	.	.	.	.	.	.	.	.
Number of samples	10	10	10	10	10	10	10	10
Sum	3910	2355	2151	550	1589	1201	471	622
Number of species	36	24	29	16	20	32	20	13
Number of ept taxa	2	1	2	1	1	2	1	0
Sum of area	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60

Table 4. Densities (number/m^2) of benthic macroinvertebrate taxa from eight sites in the Poplar Creek embayment of upper Watts Bar Reservoir, March 1994.

Taxon	PCM 0.5	PCM 1.0	PCM 2.9	PCM 4.3	PCM 5.1	PCM 6.0	PCM 7.0	PCM 8.0
Nematoda	8	3	25	35	22	12	13	5
Oligochaeta								
Haplotaxida								
Enchytraeidae	.	.	.	.	.	.	.	2
Lumbricidae	.	.	.	.	.	2	2	.
Naididae	3	2	.	2	.	.	.	.
Dero sp.	.	2	8	.	.	.	.	.
Nais sp.	5	.	.	.	.	.	.	.
Nais communis	.	.	.	.	.	.	.	.
Tubificidae	433	60	327	267	400	193	108	65
Branchiura sowerbyi	150	3	40	40	23	53	.	10
Limnodrilus hoffmeisteri	.	13	23	27	55	32	12	17
Lumbriculida								
Lumbriculidae	13	.	.	.	.	.	2	.
Hirudinea	.	2	.	.	2	.	.	.
Crustacea								
Isopoda								
Asellidae								
Caecidotea sp.	.	.	.	.	.	.	.	.
Eucopepoda								
Cyclopidae	.	.	.	.	.	.	.	.
Macrocyclops albidus	.	.	.	.	.	.	.	.
Podocopa								
Candoniidae								
Candona sp.	.	.	.	.	.	.	.	.
Cyclocyprididae								
Cyclocypris sp.	.	.	.	.	.	.	.	.
Insecta								
Collembola	.	.	.	.	.	.	.	.
Plecoptera								
Capniidae	.	.	.	.	.	.	2	.
Odonata								
Coenagrionidae								
Argia sp.	.	.	.	2	2	.	.	.
Gomphidae								
Gomphus sp.	.	.	.	.	2	2	.	.
Libellulidae	.	.	.	.	.	.	.	.
Ephemeroptera								
Caenidae								
Caenis sp.	.	30	3	.	.	.	.	.
Ephemerellidae								
Eurylophella sp.	2	3	2	.	2	2	.	.
Ephemeridae								
Hexagenia limbata	7	88	2	.	18	138	.	.
Heteroptera								
Corixidae	2	.	7	.	.	.	.	.
Trichocorixa sp.	.	.	.	.	.	.	.	.

Table 4. continued.

Taxon	PCM 0.5	PCM 1.0	PCM 2.9	PCM 4.3	PCM 5.1	PCM 6.0	PCM 7.0	PCM 8.0
Trichoptera								
Leptoceridae								
Mystacides sp.	.	.	.	.	.	.	.	.
Oecetis sp.	3	.	.	.	.	.	.	.
Megaloptera								
Sialidae								
Sialis sp.	.	.	.	.	.	2	.	.
Diptera								
Ceratopogonidae								
Bezzia sp.	52	90	12	25	32	77	2	5
Chaoboridae								
Chaoborus punctipennis	.	3	.	.	.	.	.	.
Chironomidae	2	.	.	.	5	2	..	.
Ablabesmyia annulata	.	10	.	.	3	.	.	.
Ablabesmyia sp.	.	.	.	2	.	.	.	.
Axarus sp.	.	.	2	.	8	2	15	.
Brillia sp.	.	.	.	.	.	.	.	.
Chaetocladius sp.	2	.	.	.	.	2	.	.
Chironomus sp.	60	2	58	55	38	25	2	7
Cladotanytarsus sp.	15	.	.	.	.	.	.	.
Coelotanypus tricolor	.	.	.	.	.	.	.	.
Cricotopus sp.	3	.	3	.	7	5	3	.
Cricotopus tremulus gp.	.	.	.	.	.	.	.	.
Cryptochironomus sp.	43	5	32	.	22	17	.	2
Dicrotendipes sp.	2	3	3	.	.	.	.	.
Diplocladius cultriger	.	.	.	.	.	.	.	.
Einfeldia sp.	.	.	.	.	2	.	.	.
Epoicocladius sp.	.	.	.	.	.	.	.	.
Glyptotendipes sp.	2	.	2	2	.	2	.	.
Harnischia sp.	2	5	2	.	.	.	.	.
Microtendipes sp.	.	.	.	.	.	3	.	.
Pagastiella sp.	15	.	.	.	.	5	.	.
Parakiefferiella sp.	.	.	2	.	.	.	.	.
Paralauterborniella sp.	.	.	.	.	.	3	.	.
Parametriocnemus lundbecki	.	.	.	.	.	.	.	.
Phaenopsectra sp.	.	.	.	.	13	.	.	.
Polypedilum sp.	20	.	23	35	122	330	65	40
Polypedilum halterale	.	.	3	.	.	.	3	.
Procladius sp.	7	15	.	2	2	2	.	.
Pseudochironomus sp.	.	.	.	.	.	.	.	.
Rheocricotopus sp.	2	.	.	.	.	.	.	.
Rheotanytarsus sp.	.	.	.	.	.	.	.	.
Tanytarsus sp.	13	.	.	.	.	8	.	.
Tribelos sp.	.	5	10	27	173	17	22	17
Dolichopodidae	.	.	2	.	.	.	.	.
Empididae								
Hemerodromia sp.	.	.	.	.	.	.	.	.
Stratiomyidae	.	.	.	2	.	.	.	.
Tabanidae	.	.	.	.	.	2	.	.
Chrysops sp.	.	.	.	.	.	.	.	.

Table 4. continued.

Taxon	PCM 0.5	PCM 1.0	PCM 2.9	PCM 4.3	PCM 5.1	PCM 6.0	PCM 7.0	PCM 8.0
Tipulidae	.	.	.	.	3	.	.	.
Limnophila sp.	.	.	.	.	.	.	2	.
Tipula sp.	.	.	.	.	.	.	.	2
Coleoptera								
Elmidae								
Dubiraphia sp.	22	10	8	.	7	32	2	.
Optioservus sp.	.	.	.	.	.	.	.	.
Promoresia sp.	.	.	.	.	.	.	.	.
Hydrophilidae	.	.	.	2	.	.	.	.
Ptilodactylidae								
Anchytarsus bicolor	.	.	.	.	.	.	.	.
Arachnoidea								
Hydrachnellae	27	.	2	.	.	.	.	.
Hygrobatidae								
Atractides sp.	.	3	.	.	.	.	.	.
Krendowskiidae								
Krendowskia similis	.	.	.	.	.	.	.	.
Unionicolidae								
Neumania sp.	.	.	.	.	.	.	.	.
Unionicola sp.	.	2	.	.	.	.	.	.
Gastropoda								
Mesogastropoda								
Hydrobiidae	.	.	.	.	.	.	.	.
Pleuroceridae								
Pleurocera canaliculata	.	.	.	.	.	.	.	.
Basommatophora								
Lymnaeidae	.	.	.	.	.	.	.	.
Planorbidae	.	.	.	.	.	.	.	2
Bivalvia								
Unionoida								
Unionidae								
Anodonta imbecillis	.	.	.	.	.	.	.	.
Quadrula pustulosa pustulosa	.	.	.	.	.	.	.	.
Veneroida								
Corbiculidae								
Corbicula fluminea	2	5	2	3	3	7	3	15
Sphaeriidae	17	.	7	.	5	.	2	.
Musculium transversum	5	57	2	.	.	.	.	.
Pisidium sp.	2	.	2	.	2	.	2	.
Pisidium compressum	20	.	.	.	.	.	.	.
Number of samples	10	10	10	10	10	10	10	10
Sum	961	421	614	573	981	977	262	192
Number of species	32	24	28	17	27	27	18	14
Number of ept taxa	3	3	3	0	2	2	1	0
Sum of area	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60

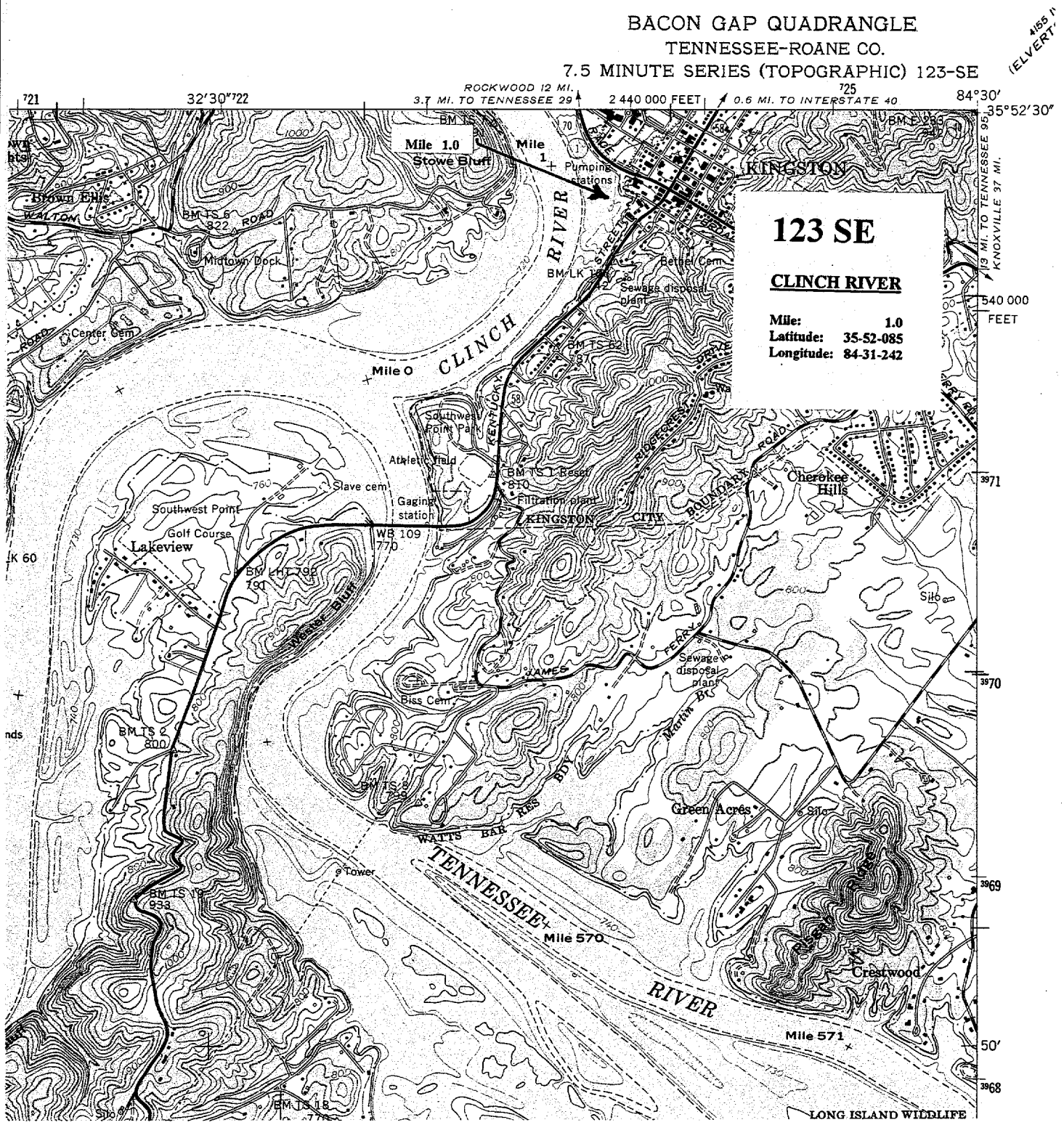


Figure 1. Location of benthic macroinvertebrate sampling at Clinch River mile 1.0, Watts Bar Reservoir, March 1994.

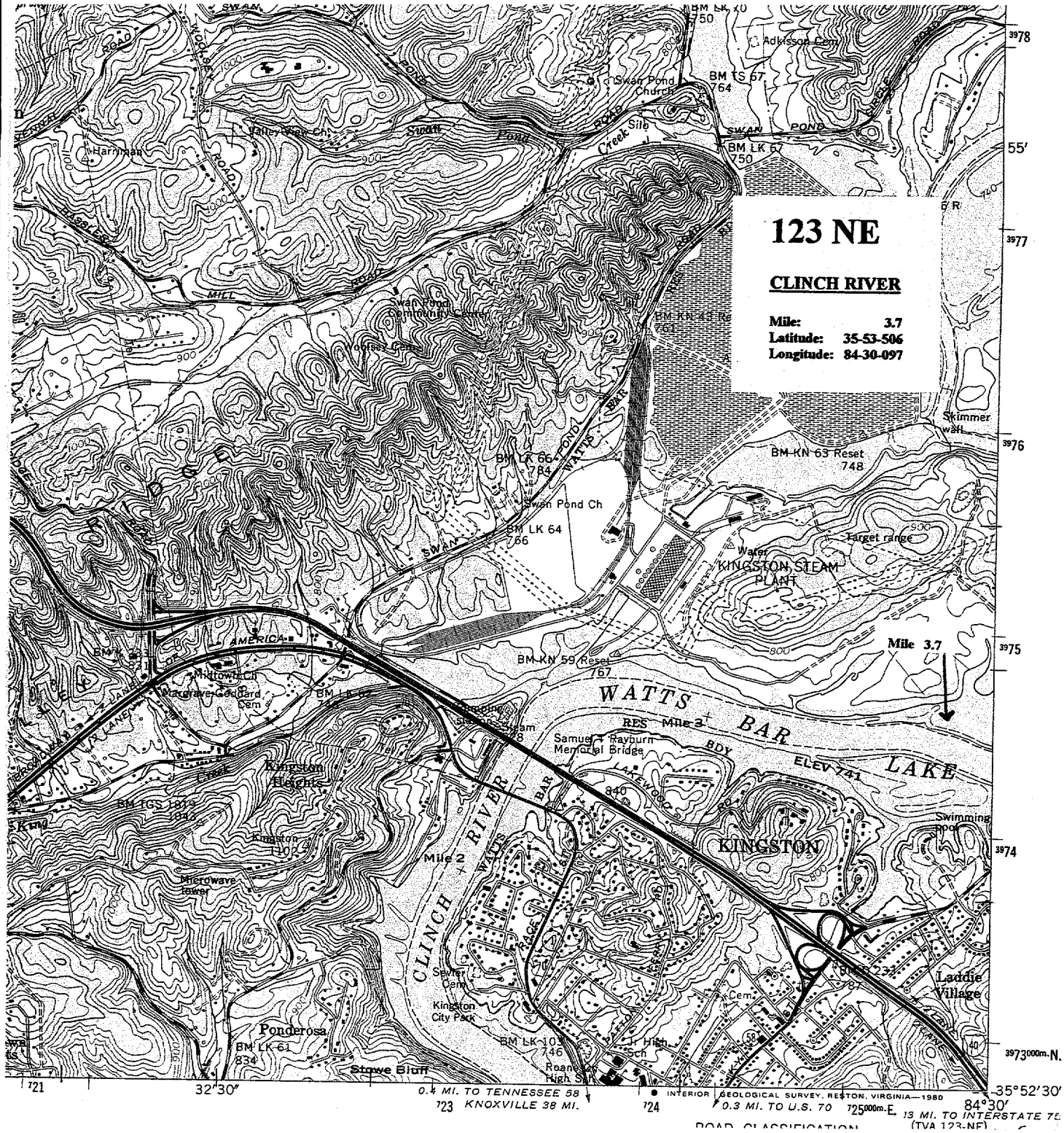


Figure 2. Location of benthic macroinvertebrate sampling at Clinch River mile 3.7, Watts Bar Reservoir, March 1994.

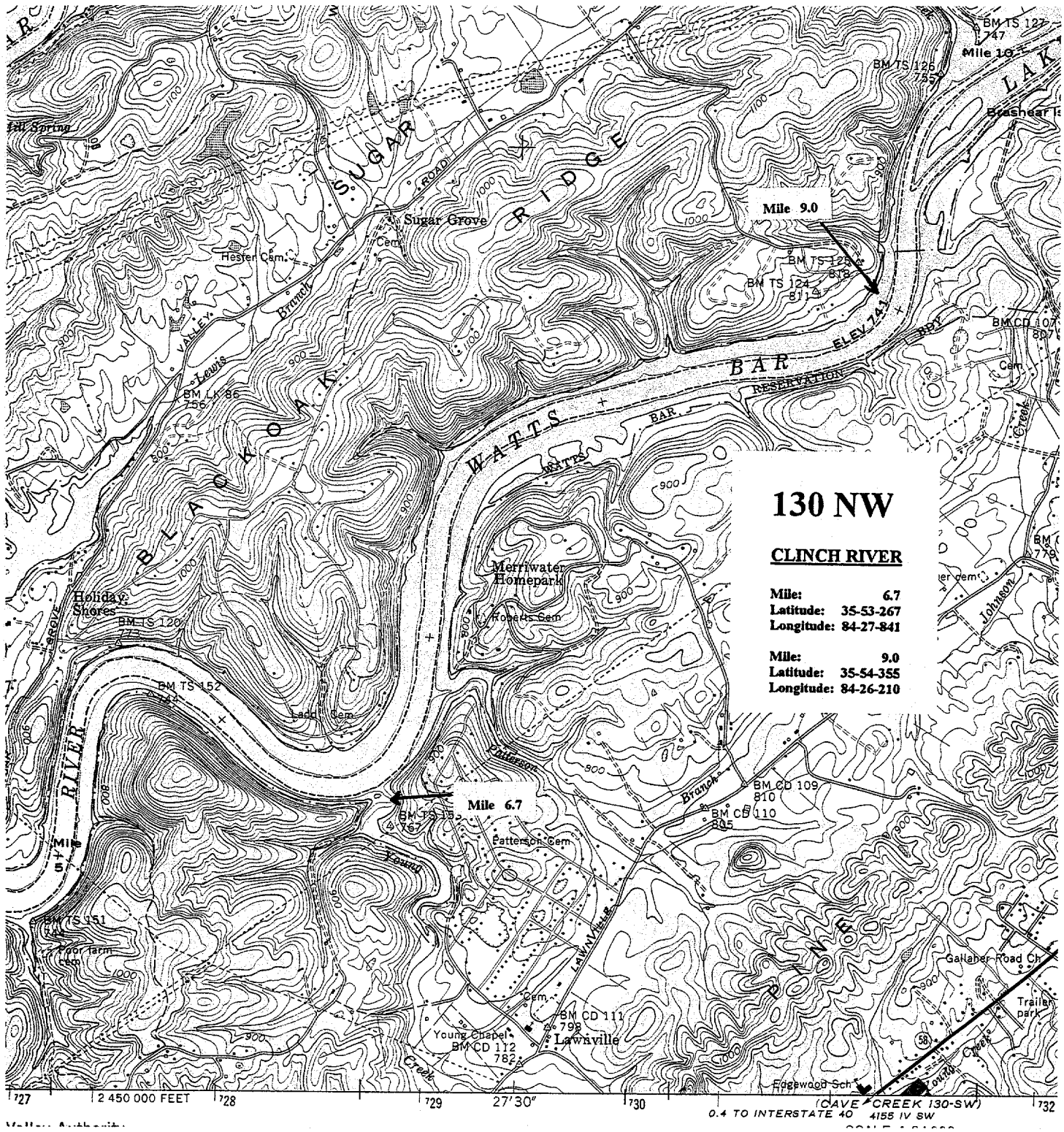


Figure 3. Locations of benthic macroinvertebrate sampling at Clinch River miles 6.7 and 9.0, Watts Bar Reservoir, March 1994.

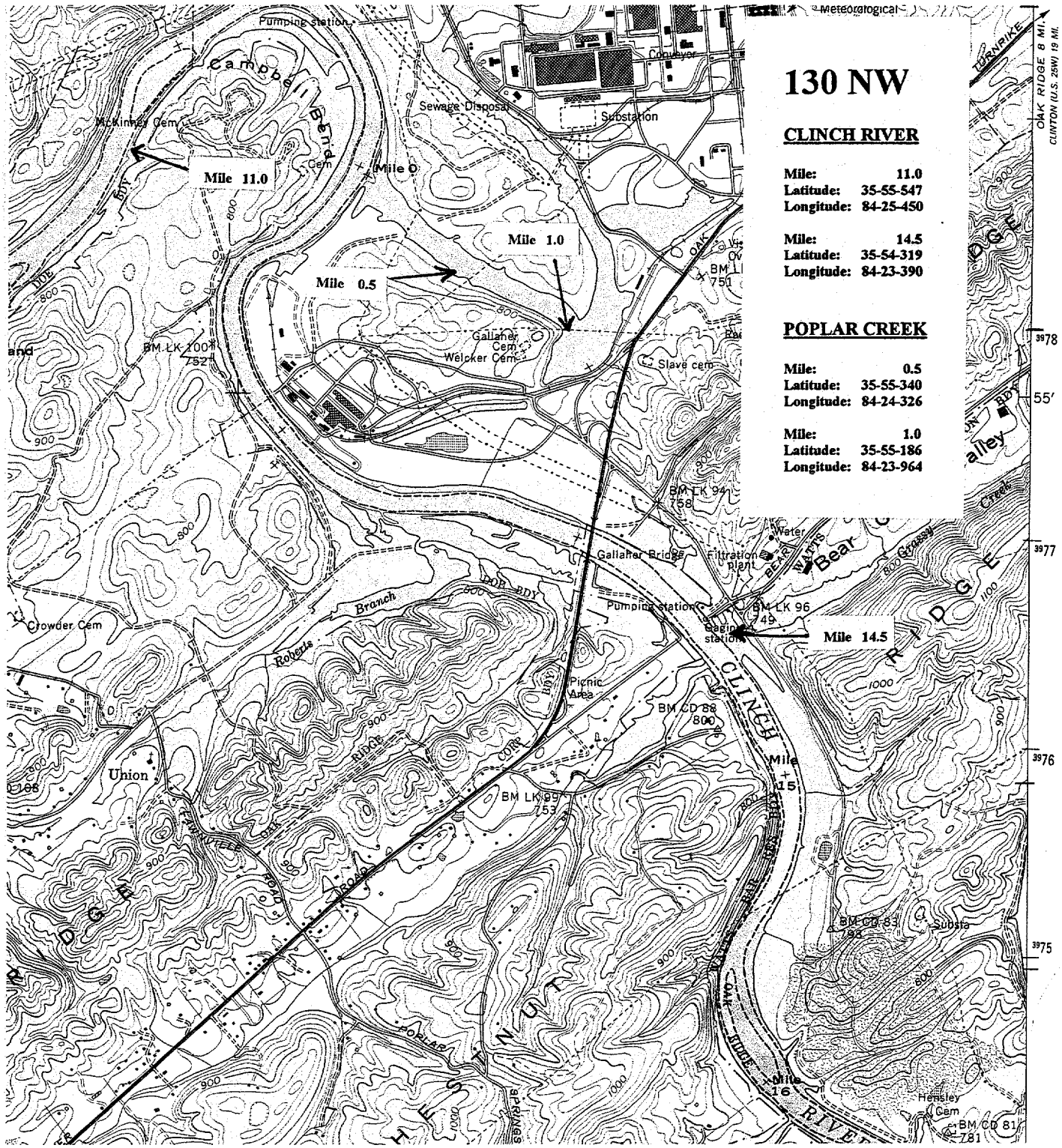


Figure 4. Locations of benthic macroinvertebrate sampling at Clinch River miles 11.0 and 14.5 and Poplar Creek miles 0.5 and 1.0, upper Watts Bar Reservoir, March 1994.

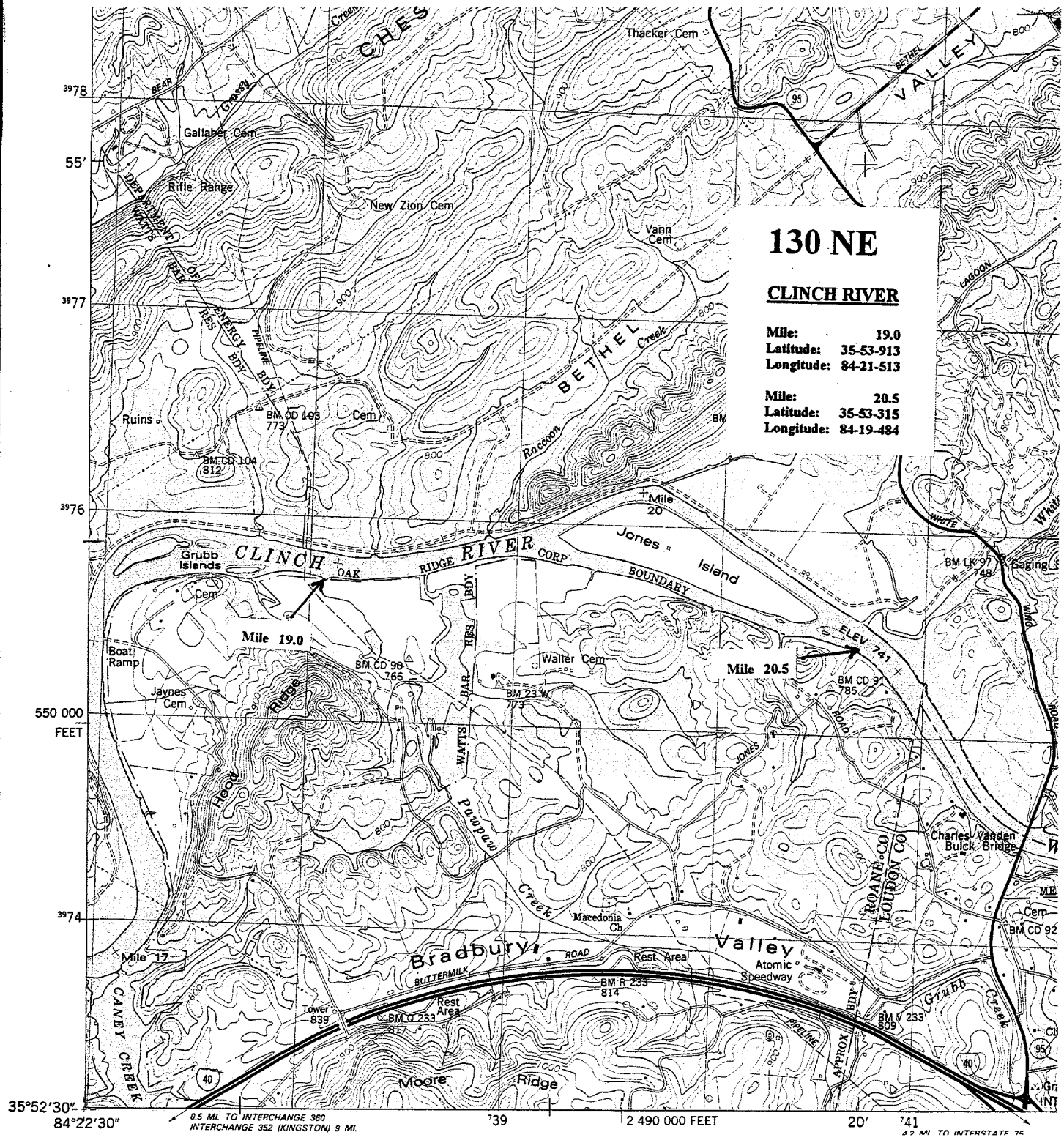


Figure 5. Locations of benthic macroinvertebrate sampling at Clinch River miles 19.0 and 20.5, Watts Bar Reservoir, March 1994.

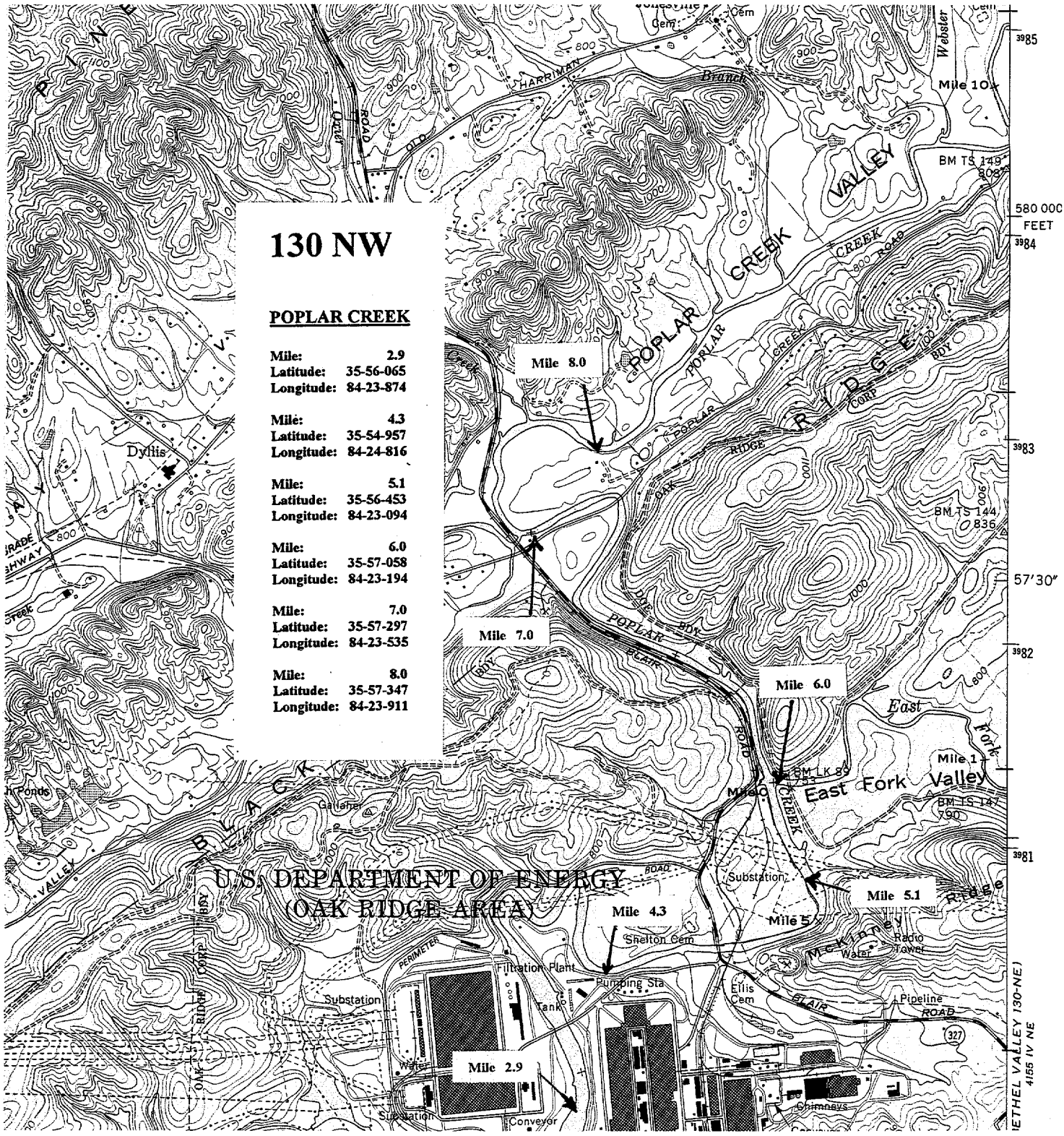
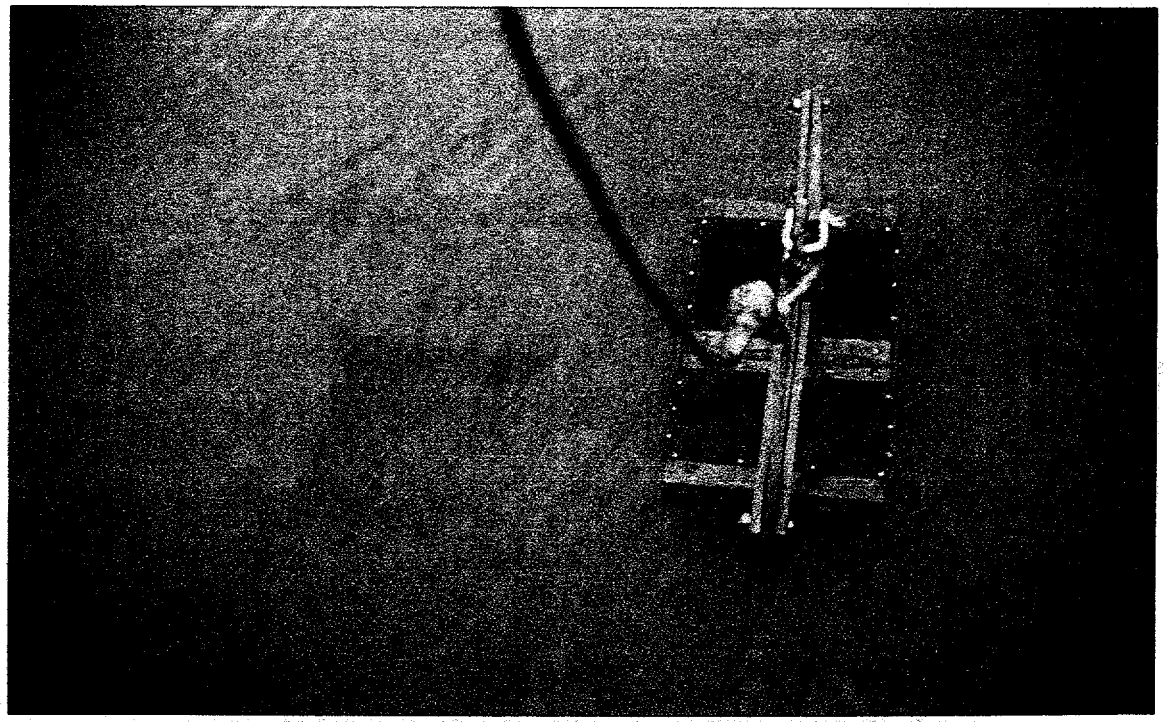


Figure 6. Locations of benthic macroinvertebrate sampling at Poplar Creek miles 2.9 to 8.0, Watts Bar Reservoir, March 1994.



A

B

Figure 7. Ponar dredge in use (A) and washdown of sample (B), DOE benthic macroinvertebrate study, March 1994.

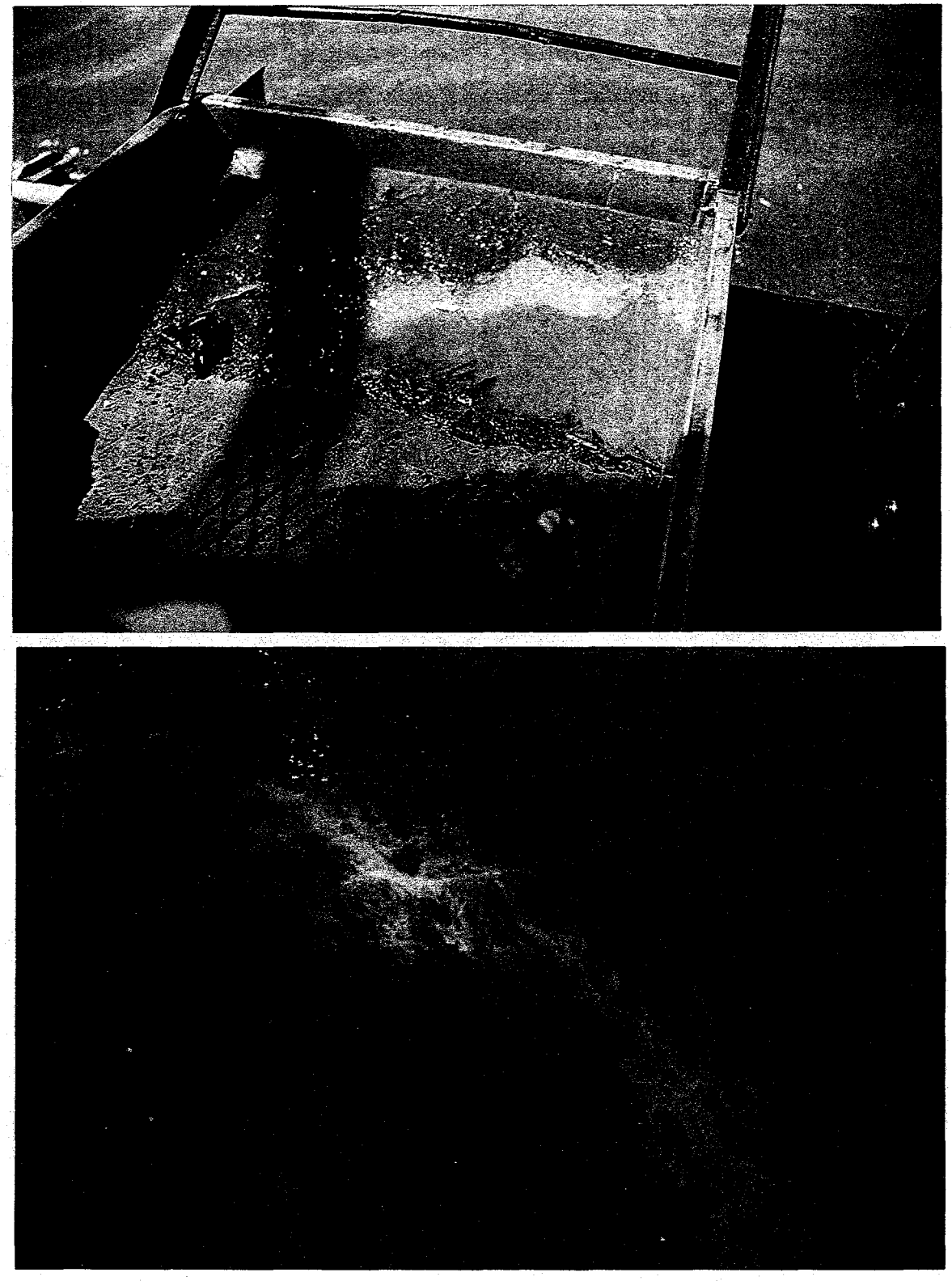


Figure 8. Unknown substance encountered in ponar dredge samples at Clinch River mile 14.5, March 1994, in washdown tray (A) and on water surface (B).