FLEMING CREEK DEMONSTRATION PROJECT

PRE-BMP REPORT

Natural Resources and
Environmental Protection Cabinet

Kentucky Division of Water
Water Quality Branch
Nonpoint Source Section
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PRE-BMP REPORT

INTRODUCTION

The Fleming Creek Water Quality Special Project was initiated by a group of local land owners concerned about the water quality of Fleming Creek. They formed the Fleming Creek Water Quality Committee which was dedicated to assessing the needs and interests of all local citizens. Early on in project development, this committee coordinated with local farmers and government agencies and represented the farmers. As the project evolved, the Community Farm Alliance (CFA) became the principal grassroots coordinating organization.

The principal land use within the Fleming Creek watershed is livestock production. Approximately eighty-five animal feedlots are located here, of which at least sixty are dairy operations. This high density of farm animals has resulted in water quality degradation. In response to the pollution problem and the local interest in remedying the problem, the U.S. Department of Agriculture (USDA) requested and received funding for animal waste pollution control for the watershed.

In FFY 1992, USDA allocated $200,000 through the Agricultural Conservation Program (ACP) for the purpose of providing cost-share monies for animal waste management systems. USDA awarded another $17,500 to the project for the installation of constructed wetland. During FFY 1994 farmers within the Fleming Creek watershed received $152,000 in USDA Water Quality Incentive Program (WQIP) funds for the implementation of non-structural agricultural BMPs. The WQIP money is being used for items such as animal exclusion (from streams) and manure management, as well as for agronomic activities. It is anticipated that state funds will also be allocated to this project for the construction of animal waste management systems pursuant to a recently passed cost-share program (H.B. 377). Further, an application was submitted to the National Forum on Nonpoint Source Pollution (a private organization dedicated to finding solutions for nonpoint source pollution control) by DOW soliciting additional funds for animal waste management systems. AT present the National Forum has not informed the Division as to their decision.

Kentucky Division of Water, Nonpoint Source Section received U.S. EPA 319 funds during FFY 1991, 1992, and 1993 for the purpose of documenting and demonstrating the effectiveness of the BMPs in improving water quality within the Fleming Creek watershed. The main pollutants of concern are nutrients and fecal coliforms. In order to fulfill project water quality monitoring objectives a three phased sampling approach is being employed.

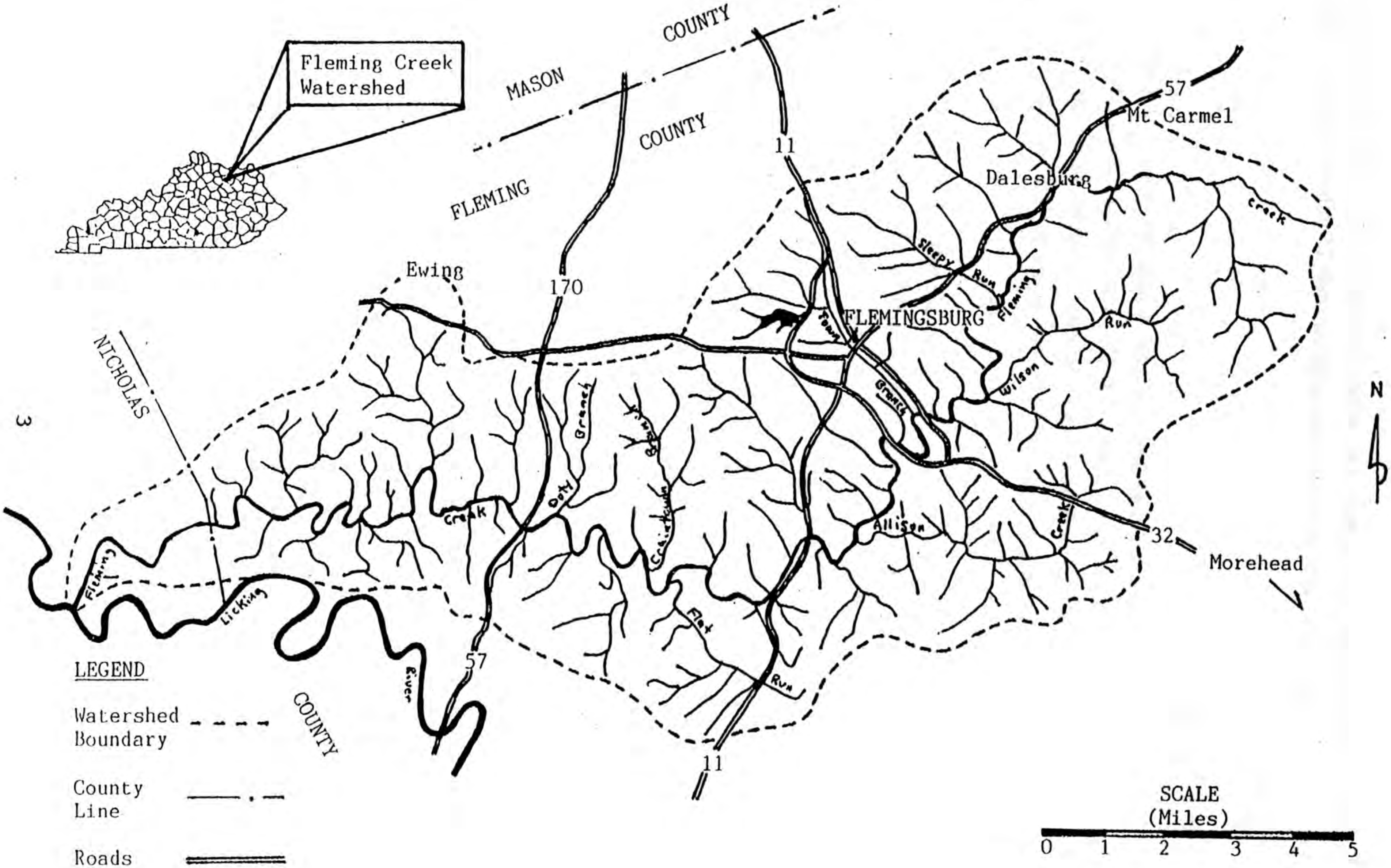
Phase I involves a pre-BMP and post-BMP bacteriological/water quality survey on a watershed-wide basis. Phase II consists of long-term physicochemical water sampling at selected locations, and Phase III employees biological sampling. Specific monitoring objectives of this project include: 1) a determination of water quality conditions prior to the installation of animal waste BMPs within the watershed (pre-BMP), and 2) documentation of changes in water quality as a result of this BMP installation (post-BMP). The details of the water quality data collection for this project are outlined under the water quality Monitoring Program section.

Land used data is being collected by the Kentucky Division of Conservation. This information is being used for the purpose of establishing a correlation between land use activities (i.e. livestock production) and water quality. Refer to the Land Use Tracking section under for specific information concerning this topic.

Farm field days will be held at selected operations to demonstrate the benefit of BMPs to vicinity farmers. It is envisioned that an increased number of farmers will then incorporate BMPs on their operations. In addition, CFA has initiated an educational project, funded in-part through U.S. EPA 319 monies, designed to promote conservation of water resources throughout the Fleming Creek watershed. Not only will school students be taught about conservation, they will be used as an outreach tool to help enlighten the local farming community.

FIGURE 1

STUDY AREA MAP



STUDY AREA DESCRIPTION

Location Information:

The Fleming Creek watershed is contained almost entirely within Fleming County, in northeastern Kentucky (Figure 1). However, a short reach at the mouth, flows into Nicholas County. Flemingsburg, the largest town within Fleming County, is situated in the eastern portion of the watershed. This community lies approximately 23 miles northwest of Morehead, Kentucky.

Geologic Information:

The Fleming Creek drainage lies primarily within the Bluegrass and Outer Bluegrass physiographic regions (Quarterman and Powell 1978). The landscape is characterized by gently sloping ridgetops and steep and moderately steep hillsides. Elevations within the watershed range from 580 feet above MSL at the mouth to 800 feet above MSL in the headwaters.

The geology is unique in that it varies dramatically within a short distance. The uppermost headwaters of Fleming Creek transect the Upper Devonian and Lower and Middle Silurian systems (Morris 1965). However, the major portion of the remaining watershed overlies Ordovician rock (Peck 1969).

The Upper Devonian system is characterized by a dark gray to black, highly carbonaceous stratum known as the Ohio Shale. The Lower and Middle Silurian systems are comprised of clayey shale and alternating limestone and shale layers of the Crab Orchard and Brassfield Formations. The Ordovician system is dominated by limestones. As is characteristic of certain limestones, some places along Fleming Creek are karstic and sinkholes are common in these areas.

Soils Information:

Most of the soils on the ridgetops and hillsides within the study area are formed from residual limestones, siltstones and shales, and overlie clayey subsoils (SCS 1992). Soil types found in these areas include the Lowell, Beasley, Faywood and Shrouts. Some ridgetop soils here were formed with a silty mantle of loess over clay weathered from residual limestones, siltstones and shales. Associated soil types at such locations are the Sandview, Nicholason and Crider. In addition, soils on certain steep hillsides were weathered from interbedded limestones, siltones and shales (Eden, Faywood and Cynthiana soil types). These steep hillside soils tend to be a shallower than other soils in the watershed.

Hydrologic Information:

The Fleming Creek drainage flows generally from east to west where it confluences with the Licking River (RMI 106.9) in northeastern Nicholas County. It's mainstem is 39 miles long, draining an area of 61,670 acres (DOW 1984). The average gradient drop for this stream is 7.7 feet per mile. According to Proctor, Davis, and Ray (no date), the estimated seven day, ten year low flow (7Q10) within the mainstem at RMI 12.2 near Hilltop, KY is 0.39 ft^3/s, however Sullavan (1980) derived a 7Q10 of 0.0 ft^3/s at this point.

Land Use Information:

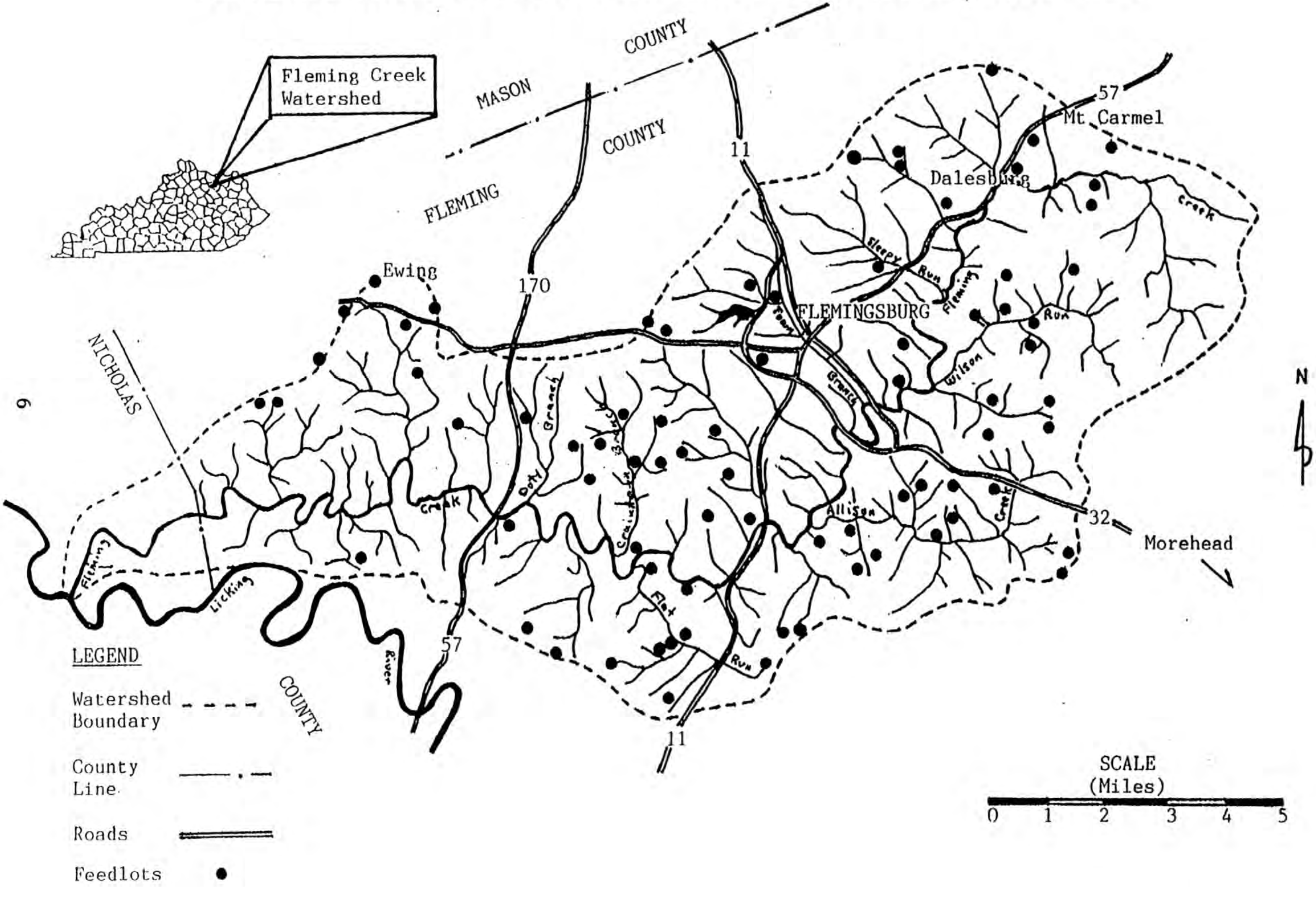
The predominant land use within the Fleming Creek watershed is agriculture. Thirty-one percent (19,118 acres) of the watershed area is used for cropland with corn and tobacco being the principal row crops. Another 59 percent (36,385 acres) of the watershed is managed for hayland and pasture, primarily to support dairy operations (Figure 2). Based on the average number of milk cows on farms, Fleming County ranks in the top three in total number of dairy cows statewide. (KY Dept. Ag. 1990-91)

The bulk of the animal waste pollution within the project area is likely caused from dairy feedlots. The total dairy cow population in Fleming County exceeds 10,000 head, with the average herd size being 50 cows. Approximately 48,500 total head of cattle occur in this county. Moreover, an estimated 1,700,000 ft^3 of animal waste has the potential to be washed into area streams annually from dairies alone. (SCS 1992)

Nine percent (5,500 acres) of the remaining land within the

FIGURE 2

LOCATION OF FEEDLOTS WITHIN THE FLEMING CREEK WATERSHED



watershed is wooded, and only one percent (617 acres) is urban. The town of Flemingsburg accounts for the majority of the county's population with just over 2800 people.

As of February 1993, there were eleven facilities within the Fleming Creek watershed permitted by DOW. Five of these were point source dischargers, and four were No Discharge Operational Permitted animal waste management facilities. The other two permits (both no discharge) involve a restaurant and a catch basin for Kentucky Stone Company limestone quarry. There have been several more animal waste management facilities installed since February 1993.

There have been several more animal waste management facilities installed since February 1993.

Other operations of interest are a stockyard adjacent to Town Branch, and the Carpenter Landfill next to Fleming Creek proper southeast of Flemingsburg. For a time, there was local controversy over the landfill for accepting out-of-state garbage and for exceeding permit boundaries. The site was closed in July 1992 (DOW 1992).

Only operations which will or may contribute to nutrient or bacteria loads will be of significant importance to this project. Those facilities include the Flemingsburg Sewage Treatment Plant, Farmers Stockyard and the land application sites. A Notice of Violation was issued against the stockyard in December 1992. As a result, the owners of this facility agreed to remove large piles of manure and to implement a manure collection system.

FIGURE 3

LAND USE TRACKING ZONES WITHIN THE PROJECT AREA

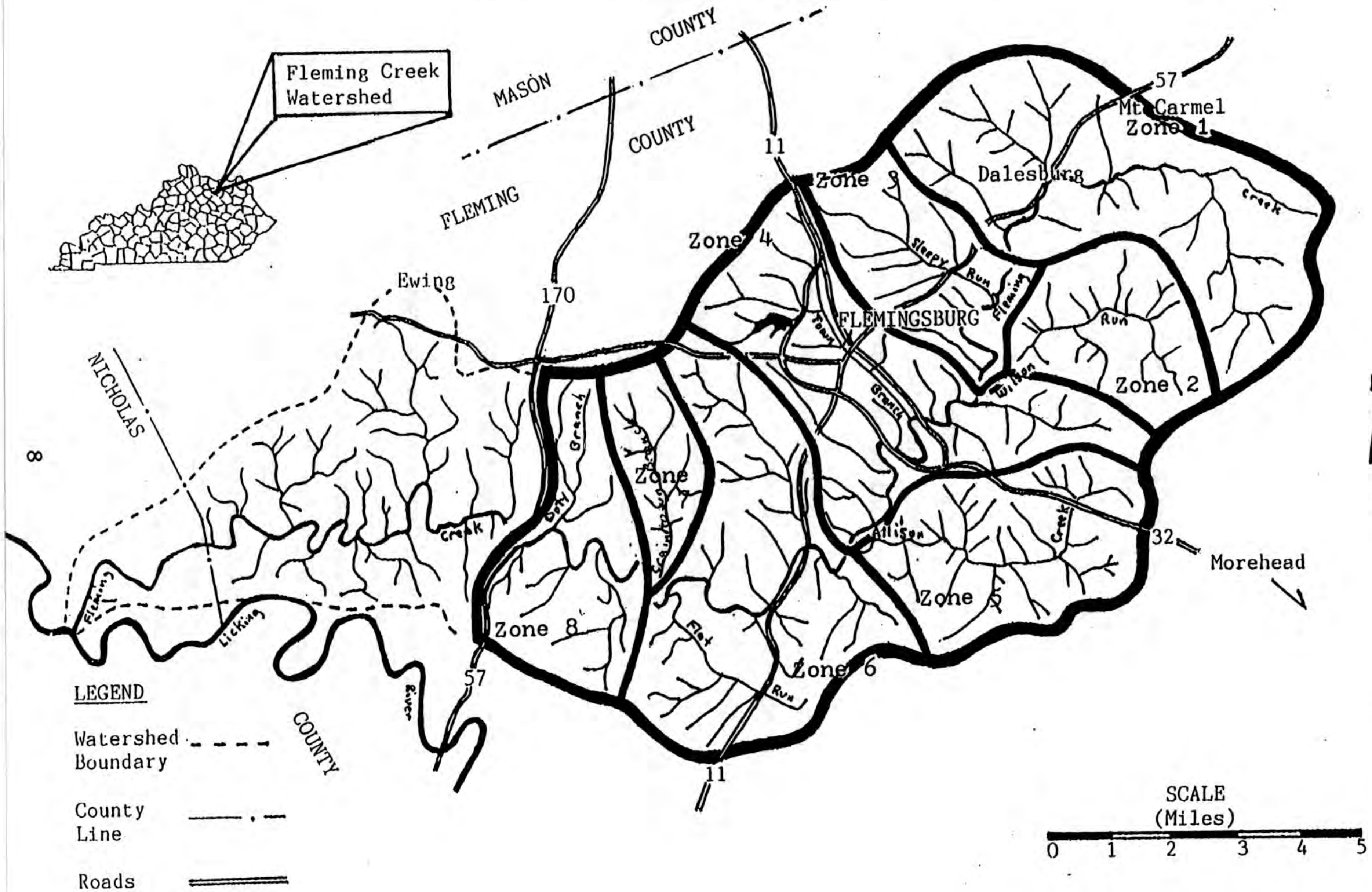
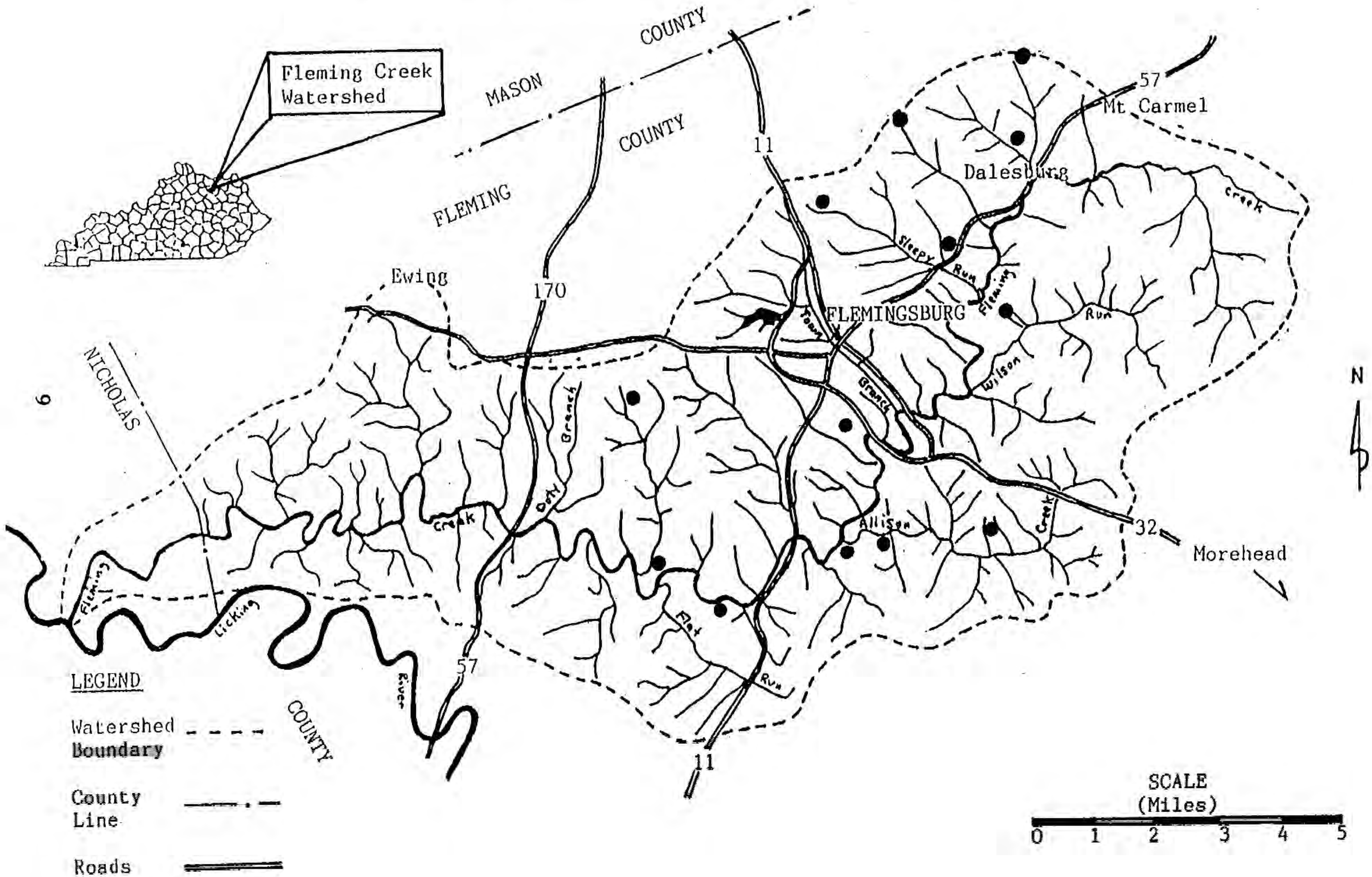


FIGURE 4

ANIMAL WASTE MANAGEMENT SYSTEMS INSTALLED WITHIN THE PROJECT AREA



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As for stream uses, Jones (1970) reported that Fleming Creek receives heavy fishing pressure, especially from the mouth to about 20 miles upstream. Angler success was reported fair to good for game species. Moreover, according to KDFWR (no date), both muskie and walleye may occur at the mouth of Fleming Creek. Another significant stream use is that of municipal water supply from upper Town Branch.

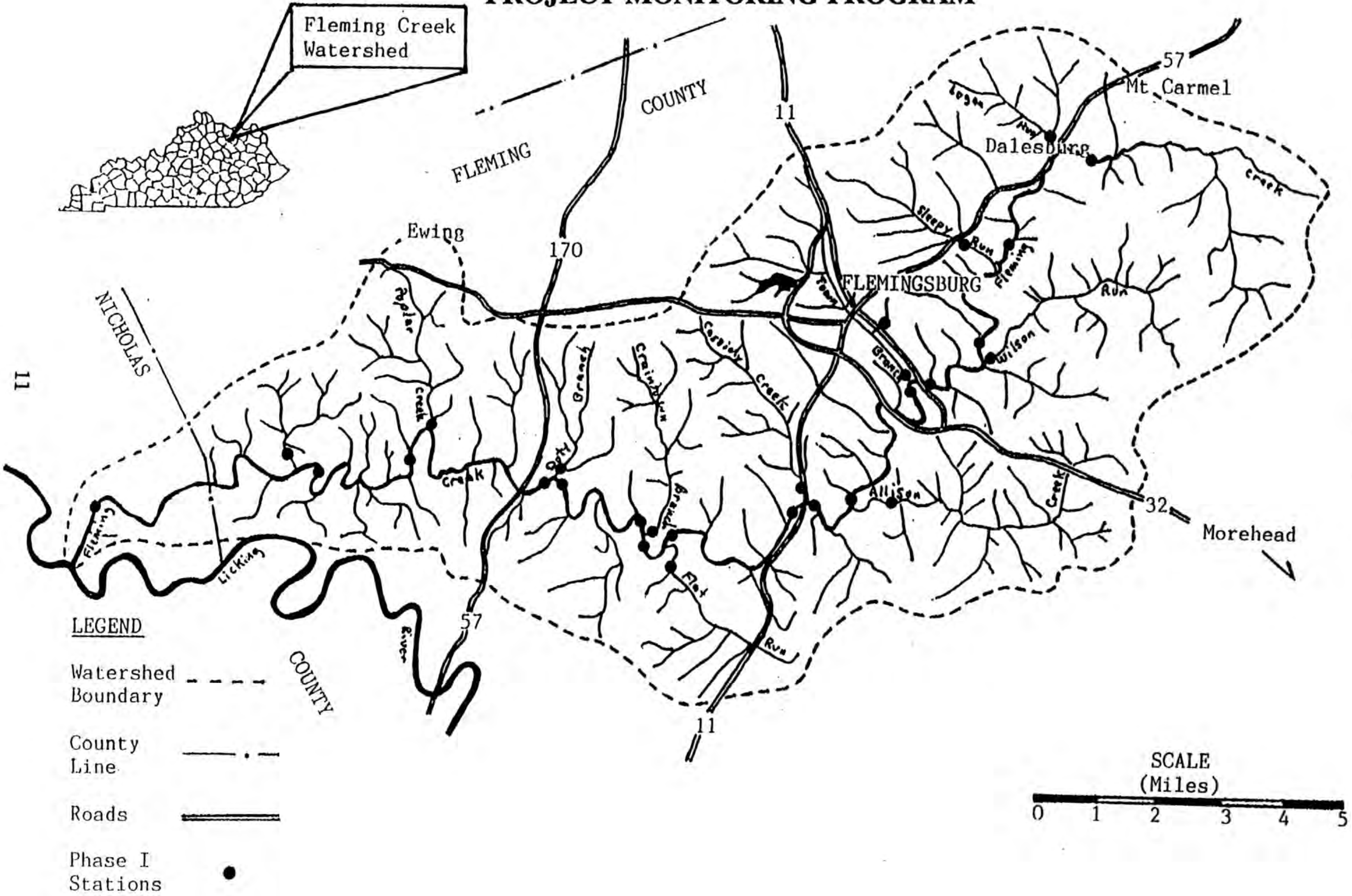
LAND USE TRACKING

The Kentucky Division of Conservation has the responsibility of tracking pertinent land use activities within the Fleming Creek watershed. The U.S. Natural Resource Conservation Service is also providing land use information. The project area was divided into eight zones for compiling the data (Figure 3). This was accomplished in order to derive correlations between land management activities within certain sub-watersheds of particular interest and individual water quality monitoring stations. Hence, progress, or lack thereof, can be monitored on a sub-watershed by sub-watershed basis with respect BMP effectiveness. Regionalizing the project area in this manner will also assist in targeting remaining problem areas within the Fleming Creek watershed in need of additional BMPs. Specific types of land use data being compiled within each zone includes:

1) location of feedlots (Figure 2);
2) feedlots within 100 feet of a stream;
3) location of animal waste management systems installed as a result of USDA cost-share funding and those installed through other means (Figure 4);
4) number of animals-broken out by beef cattle, dairy cattle, swine, sheep, etc. (Appendix 2);
5) tons of animal waste produced per unit time (Appendix 2);
6) agronomic activities-broken out by crop and acreage (Appendix 3);
7) tons of fertilizer applied (Appendix 3); and
8) location of straight-pipes, package plants, problem on-site waste water treatment systems and similar items which could have an influence on the water quality monitoring program (as known).

FIGURE 5

STATION LOCATIONS FOR PHASE I OF THE FLEMING CREEK PROJECT MONITORING PROGRAM



WATER QUALITY MONITORING PROGRAM

Methodology:

The Nonpoint Source (NPS) Section of the Kentucky Division of Water (DOW) has been gathering physicochemical, bacteriological and biological data designed to target the worst animal waste pollution problems within the Fleming Creek watershed and to establish general pre-BMP conditions. Monitoring will continue after the installation of animal waste BMPs to document and demonstrate water quality improvements resulting from BMP implementations. Specific responsibilities of the NPS Section includes: coordination of monitoring activities with other agencies; implementation of water quality monitoring activities; and documentation of water quality changes as a result of BMP installation.

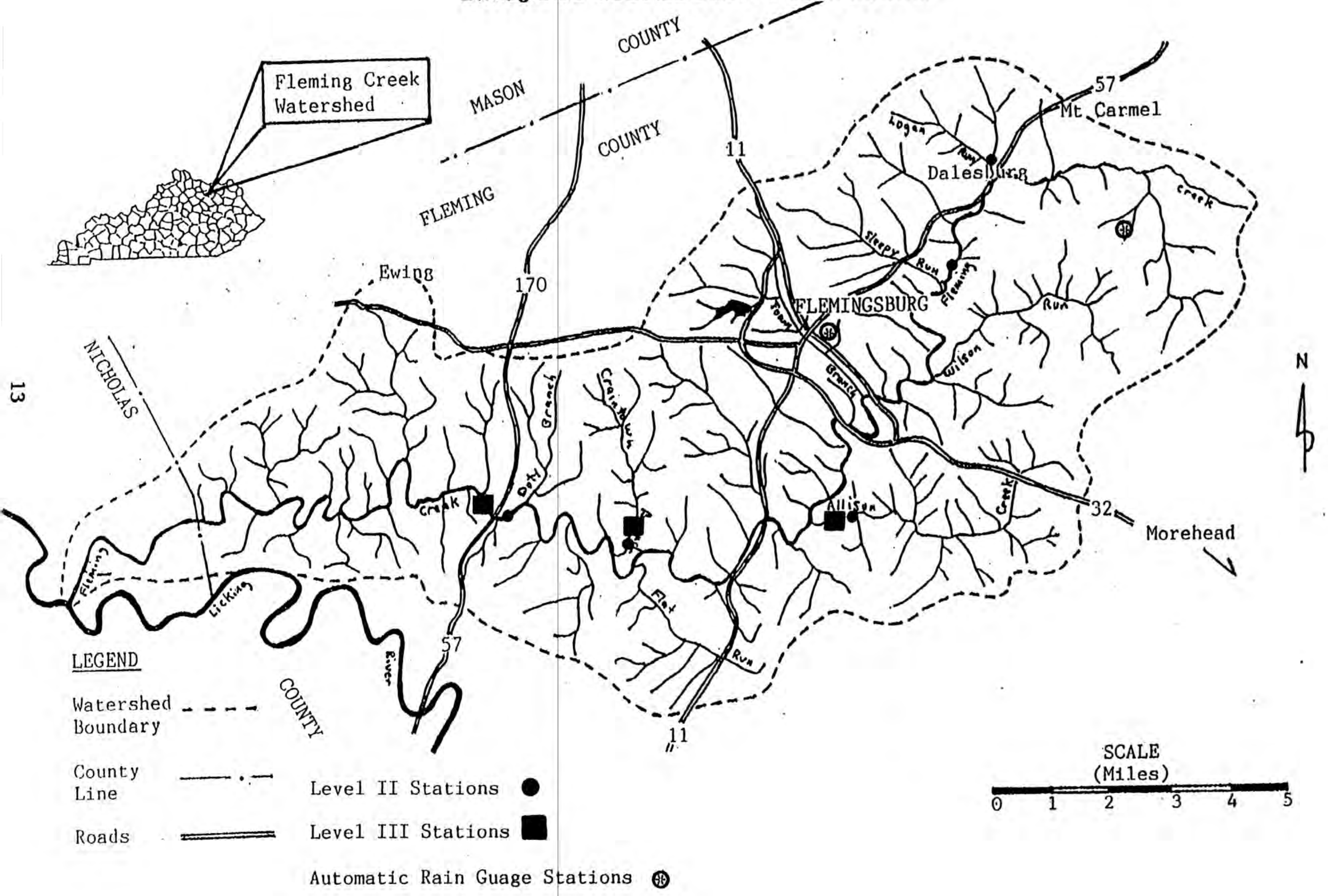
Water quality data is also being collected for the constructed wetland by the University of Kentucky. This monitoring is funded by U.S. EPA 319 monies FFY 1992 and FFY 1993. For more details concerning this activity, refer to reports specific to that project.

DOW water quality monitoring efforts commenced in the Spring of 1992, and will continue through several seasons. This monitoring is being executed in three phases.

Phase I: V (**Bacteriological Survey**) 27/28 stations were established throughout the project area and to the mouth of Fleming Creek for bacteriological/chemical sampling Appendix 1, Figure 5). Many of these stations were located in Fleming Creek mainstream upstream and downstream of confluences with major tributaries and at the mouths of those tributaries. Additional stations were established as needed at 3 to 5 mile intervals within the mainstream down to the mouth. This stations arrangement was incorporated so that

FIGURE 6

STATION LOCATIONS FOR LEVELS II AND III OF THE FLEMING CREEK PROJECT MONITORING PROGRAM



various portions of the watershed could be evaluated separately. Bacteriological/chemical data for Phase I included both high-flow (May 18, 1992) and low-flow (August 18, 1992) events. Phase I sampling was conducted prior to BMP installation and will be repeated after BMP installation to help document improvements in water quality as a result of BMP implementation.

Analysis for fecal coliform bacteria was accomplished using the membrane filter procedure as outlined in the Division of Water's "Methods for Assessing Biological Integrity of Surface Waters". All samples were processed and incubated within six hours from time of collection. Beginning and ending quality assurance checks were negative for contaminiation or carry-over of bacteria on both occasions. Approximately ten percent of the samples were duplicated for quality assurance.

The focus of Phase I is on fecal coliform counts; however, nutrient samples (TKN-N, NH_3-NH_4-N, NO_2-NO_3-N and Total P) are also being collected. The initial purpose of Phase I was 1) to document existing conditions within the watershed with respect to point and nonpoint pollution sources, and 2) to target portions of the watershed most impacted from animal wastes. Information obtained from pre-BMP Phase I data has been made available to NRCS to assistin BMP placement. This information will also be used to help demonstrate improvements in water quality by comparing pre-BMP versus post-BMP results. Refer to Appendix 4 for results of the pre-BMP bacteriological survey.

Phase II (Long-term Physicochemical Monitoring: From the initial (Phase I) stations, five long-term water quality monitoring sites were selected (Appendix 1, Figure 6). The selection of these five stations was based upon 1) areas with a high concentration of feedlots, 2) apparent impact from feedlot operations within subwaters (from Phase I pre-BMP data), and 3) proposed placement of BMPs (from initial USDA BMP sign-ups). The purpose of Phase II is to document a trend in water quality improvements over time, resulting from BMP implementation, in a holistic fashion.

More specifically, Phase II stations were established at Allison Creek, Logan Run, and Craintown Branch because these tributaries were found to be impacted from animal waste based upon preliminary water quality data and because animal waste management systems were proposed for these subwatersheds. Another station was established on Fleming Creek at the Flemingsburg-Beechburg road (Highway 3301) bridge intended to isolate the headwater portion of the project area for evaluation. The fifth Phase II station was established on Fleming Creek at Highway 170. This station was located downstream of all proposed animal waste systems for the purpose of evaluating the entire project area holistically.

Phase II monitoring centers around storm-event sampling, however some low-flow data has been collected. Water samples for this phase have been collected by depth integrated sampling. Field parameters measured for Phase II include water temperature, pH, dissolved oxygen, conductivity, and turbidity using portable meters. Laboratory analyses include total Kjeldahl nitrogen, ammonia-ammonium nitrogen, nitrate-nitrite nitrogen, total phosphorus, total suspended solids, total organic carbon, and 5-day biochemical oxygen demand. BOD_5 analysis was discontinued because initial measurements were consistently low.

Precipitation data is being gathered by two automatic rain gauges located within the watershed being monitored by Kentucky Department of Military Affairs. This information is also being obtained from Western Kentucky University. As water levels allow, stream flow is being measured at each station using a Marsh-McBirney analog flow meter. The flow data is being used to estimate loading of various constituents within the watershed. Refer to Appendix 4 for physicochemical data.

Phase III (Biological Monitoring): Physicochemical and biological data is being collected at three of the more impacted sites, based on Phase II data (Figure ___). Two of these stations are located near the mouth of impacted tributaries whose watershed will receive BMPs (Allison Creek and Craintown Branch. The third station is located in Fleming Creek proper (at Highway 170) downstream of all BMPs.

Three sets of biological data were collected prior to BMP implementation, with the exception of algal data which was collected only once. Physicochemical data collected for biological monitoring has been compiled with Phase II data. The same field and lab P-chem parameters have been analyzed for the biological monitoring.

Biological monitoring has been conducted annually in the Spring for fish and macroinvertebrate communities. Spring sampling was preferred because many Fleming Creek tributaries go dry during summer and fall. Sampling methods and levels-of-effort have been identical from station to station, and will remain so throughout the life of the project.

Fish have been collected by seine for one hour at each Phase III station from all habitats present. Three unit effort travelling-kick net (TKN) repetitions have also been performed at each station for collecting macroinvertebrates (Hornig and Pollard 1978). Approximately two square meters have been sampled for each TKN repetition. Additionally, the macroinvertebrate data has been supplemented through "selective sampling" to ensure that all aquatic habitats present are represented. Macroinvertebrates were "picked" in the field. Fish samples were preserved in a 10 percent formalin solution and macroinvertebrates were preserved in 70 percent ethanol.

The index of biotic integrity (Karr 1981) will be used to evaluate fish populations. The EPT index (Ephemeroptera, Plecoptera, Trichoptera), Macroinvertebrate Biotic Index (MBI) Hilsenhoff Biotic Index (Hilsenhoff 1977, 1982, 1987, 1988) and coefficient of community loss (Courtemanch and Davis 1987) and/or similarity index will be used for macroinvertebrates. The biological data will be used with the physicochemical and bacteriological data in an effort to document improvements in water quality over time. Fish data compiled to date is provided at Appendix 5, and the macroinvertebrate data is compiled at Appendix 6.

Because algae is an excellent indicator of nutrient enrichment, periphyton (attached algae) samples were collected from Fleming Creek, Allison Branch and Craintown Branch for chlorophyll <u>a</u> analysis on May 12, 1993. These samples were collected to estimate the amount of algal biomass that was present in the stream prior to installation of BMPs. Nuisance levels of periphyton, primarily cladophora (a filmaentous green alga), were present in both Allison Branch and Craintown Branch. Filaments longer than one meter were observed in those streams, and the substrate of Craintown Branch was 100% covered with Cladophora. Fleming Creek did not have such extensive growths, however periphyton was abundant.

At each site, three replicate samples were scraped and suctioned from 52.8 cm^2 circular areas of bedrock using a section of PVC pipe and an aspirator. The algae plus water collected in this manner was iced and returned to the laboratory, where it was homogenized in a 1 liter waring stainless steel industrial blender. A 1.0 ml subsample was used for chlorophyll a analysis. Each replicate was analyzed separately using a Turner Model 10 flurometer using methods outlined in Standard Methods (APHA 1992).

Quality Assurance/Quality Control:

Sampling locations, water quality parameters, and project objectives are provided in the project study plan. Sampling techniques and handling procedures being employed follow the criteria outlined in the Ecological Support Sections' Quality Assurance/Quality Control Guidelines and Standard Operating Procedures Manuals (DOW 1987, 1993). U.S. EPA approved field and laboratory methods and procedures will also be followed, where appropriate.

All pertinent field equipment has been calibrated according to manufacturer's recommendations prior to sampling. Duplicates or splits have been collected and analyzed for at least ten percent of the water samples. Moreover, proper chain-of-custody procedures have been followed for all samples. Taxonomic verifications have been performed for at least ten percent of the fish and macroinvertebrate samples by DOW Ecological Support Section biologist's with an in-depth knowledge of the subject groups. A log has been maintained for all water and biological samples.

Discussion of pre-BMP Findings (Water Quality):

Phase I (Bacteriological Survey): According to the results of the storm-event bacteriological sampling, every major tributary within the Fleming Creek project area yielded high fecal coliform levels. Colony counts from tributary stations ranged from a low of 500 (Flat Run) to over 16,000 colonies/100 ml (Allison Creek, Town Branch, and Logan Run), with an overall average of more than 9,000 colonies/100 ml for tributary stations. With the exception of Town Branch and Allison Creek, bacteria counts for the tributary samples were much lower for the low-flow event. Refer to Appendix 4 for results of the bacteriological survey.

The elevated colony counts observed for the storm-event samples is an indication that runoff containing animal waste is the principal source of bacteria contamination within Fleming Creek. If straight pipes, failing septic systems, or animal access were major contributors, then bacteria levels should have been much higher for the low-flow event. Although, animal access is a serious problem at certain locations (e.g., Wilson Run and Sleepy Run). Furthermore, the high bacteria counts for Town Branch can largely be attributed to the Flemingsburg Wastewater Treatment Plant and a stockyard located adjacent to the creek.

Phase II Long-term Physicochemical Monitoring): Six sets of pre-BMP, storm-event, physicochemical data and four sets of low-flow/mormal-flow physicochemical data have been collected for this project. Nutrient levels have not been detected at significantly high concentrations on a consistent basis. On a few occasions, nitrate and total Kjeldhal nitrogen have been observed in excess of 3.5 mg/l, and phosphorus values have been detected as high as 2.0 to 3.0 mg/l. Only a few storm-event folw measurements were obtained because water levels were often too high.

Algal blooms are frequent accurrence within the Fleming Creek watershed. This is a strong indication of a nutrient-rich system. The reason that observed nutrient valves, for the most part, have been relatively low con largely be attributed to problems associated with long-distance, storm-event, grab sampling. In many cases, periods of peak nutrient loads and even storm-events themselves have simply been missed. Because of the small volume of water quality data collected and the questionable usefulness of theis data for depicting worse case conditions, more credence will be given to biological parameters for ascertaining water quality changes.

Refer to Appendix 5 for results of the water quality data.

Phase III (Biological Monitoring): Karr's (1981) Index of Biotic Intergrity (IBI) was derived for each fleming Creek fish sample (Appendix 6). The IBI is conprised of twelve equally weighted metrics that con be grouped into three gerneral categories: species richness and composition; trophic compsition; and fish abundance and condition. Each metric is assigned a 5, 3, or 1 value depending upon whether the obtained value strongly approximates the expected value (5), somewhat approximates the expected value (3), or does not approximate the expected value (1).

The twelve individual metric values are summed to provide an IBI score, which will range between 12 to 60 (or no fish). A classification based on IBI scores is then assigned to describe the quality of the fish community at a given location. Pre-BMP IBI scores for Allison Creek ranged from 24 to 34, which is an indication of poor to very poor water quality conditions. Craintown Branch pre-BMP IBI scores ranged from 30 to 36, which is an indication of poor to poor-fair water quality conditions. Pre-BMP IBI scores were somewhat better for the Fleming Creek mainstem station ranging from 38 to 47, which is an indication of ppor-fair to good-fair water quality conditions. The higher IBI values from the Fleming Creek mainstem station can be primarily attributed to the larger stream size and superior habitat present at that location (as compared to the Allison Creek and Craintown Branch stations). Contaminant dilution probably also played a role. Despite the improvement in IBI scores at the mainstem station, fish diversity is not what it should be for a stream of this size and habitat suitability.

Several metrics were used to evaluate the pre-BMP macroinvertebrate community (Appendix 7). These metrics included taxa richness, the Ephemeroptera-Plecoptera-Trichoptera (EPT) Index, and the Hilsenhoff Biotic Index (HBI). Taxa richness refers to the total number of distinct taxa present in a sample (Karr 1981). In general, the greater the taxa richness the better the water quality, habitat diversity and/or habitat suitability. Pre-BMP counts for Fleming Creek macroinvertebrate data ranged from 28 to 49. This would be considered relatively high for the Interior Plateau physiographic region (KDOW unpublished data).

The EPT Index is derived by enumerating the total number of taxa within the generally pollution-sensitive insect orders of Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddisflies). A high EPT Index value will usually indicate good water quality, habitat diversity, and/or habitat suitability.

Pre-BMP values for Allison Creek and Craintown Branch ranged from 8 to 13 (fair to good), as compared to the mainstem station which yielded values of 14 to 17 (good to excellent). (KDOW unpublished data). The higher EPT values for the Fleming Creek station can primarily be attributed to better riffle habitat at that station as opposed to the two tributary stations.

The Hilsenhoff Biotic Index (HBI) is intended to characterize the overall pollution tolerance of a benthic macroinvertebrate community (Lenat 1988 and 1993). A pollution tolerance value (a_i) is assigned to each taxon within a sample. The total number of individuals within each taxon, up to 25, is multiplied by the tolerance value for that taxon (Lenat 1993). All products are then summed and divided by the total number of individuals to derive the HBI value.

HBI values can range from 0 to 10.0, and HBI interpretations are adjusted by ecoregion. Higher HBI values indicate poor water quality and lower values indicate good water quality. Pre-BMP HBI values for Allison Creek and Craintown Branch were significantly higher than those of the Fleming Creek mainstem station, indicating a higher prevalence of tolerant species at the two tributary stations. Even still, HBI values for Allison Creek and Craintown Branch (5.17 to 6.29) are considered fair to good-fair for the mountain ecoregion (Lenat ibid.). HBI values for the mainstem station (4.60 to 4.91) would be considered good for the mountain ecoregion. The improved IBI values at the Fleming Creek mainstem station can likely be explained by pollutant dilution.

Once post-BMP data has been collected, pre- and post- BMP macroinvertebrate data will be compared for each station individually by a coefficient of community loss (courtemanch and Davies, 1986) and/or similarity index. The coefficienct of community loss (I) is derived by the following equation...

where: a = number of taxa from post-BMP data;
b = number of taxa from pre-BMP data;
c = number of taxa common to both pre- and post-BMP data.

The coefficient of community loss is designed to measure the effects of wastewater on aquatic communities. Values derived by this calculation range from 0, indicating no harmful effects, to infinity, where there is a complete loss of a community. Macroinvertebrate data suggests that values exceeding .8 are reflective of excessively harmful change in biological community structure (Ibid.).

Fleming Creek, Allison Branch, and Craintown Branch had chlorophyll a mean values of 304, 462, and 500, mg/m^2, respectively (Appendix B). Nuisance biomass filamentous algae is represented by levels greater than 100-150 (Welch et al., 1988) and growth of Cladophora is controlled by a number of factors, including temperatures, nutrients and light (Dodds, 1990). It appears that a combination of these factors is contributing to the nuisance algal growth at all three sites. While reduction of nutrient levels instream would hypothetically reduce nuisance algal biomass, the critical nutrient concentrations necessary to avoid algal blooms in streams are presently insufficient to guide water managers (Biggs 1985), and would be dependent upon related abiotic factors including flow, current velocity, temperature, and light.

Summary of Pre-BMP Findings

Bacteriological data, algal (chlorophyall a) data, macroinvertebrate data, fish data, and land-use data are being employed in order to evaluate pre- vs. post- BMP water quality conditions for the Fleming Creek project. Water chemistry data collected thus far is insufficient to provide much insight as to water quality conditions. The bacteriological, chlorophyll a, and fish results all indicate that pre-BMP water quality is somewhat degraded within the study area. This is supported by a high quality density of animal feedlots within the Allison Creek subwatershed as well as other portions of the study area. The relatively favorable values derived from the macroinvertebrate data may appear to contradict those results, especially for the Allison Creek and Craintown Branch stations. Keep in mind however, that high nutrient loads can increase overall bioproductivity up to a point. Hence, the apparent fertility of the Fleming Creek watershed may be enhancing the macroinvertebrate community. Furthermore, macroinvertebrate diversity could actually decrease as water qulaity improves, since tolerant organisms should become less numerous.

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APPENDIX 1
FLEMING CREEK PROJECT STATIONS

Station #	Location	Data to be Collected	Station RMI-RMI of Confluence of Tribs with mainstem in Parenthesis
05029003	Fleming Creek mainstem at Hwy 32 bridge, in Nicholas County.	Bacteria (Phase I)	1.3
05029004	Fleming Creek mainstem adjacent to Yin Road, in Fleming County.	Bacteria (Phase I)	4.8
05029005	Unnamed trib to Fleming Creek adjacent to Hammonds Road, in Fleming County.	Bacteria (Phase I)	0.3(4.28)
05029006	Fleming Creek mainstem adjacent to Pike Bluff Road, in Fleming County.	Bacteria (Phase I)	8.75
05029007	Poplar Creek at mouth, in Fleming County.	Bacteria (Phase I)	0.1(9.4)
05029008	Fleming Creek mainstem just downstream of Doty Creek confluence, in Fleming County.	Bacteria (Phase I)	12.6
05029009	Doty Creek at mouth, in Fleming County.	Bacteria (Phase I)	0.1(12.65)
05029010	Fleming Creek mainstem just upstream of Doty Creek confluence, in Fleming County.	Bacteria (Phase I)	12.7
0502911	Fleming Creek mainstem just downstream of Craintown Branch confluence adjacent to Hwy 57, in Fleming County.	Bacteria (Phase I)	15.9
05029012	Fleming Creek mainstem just upstream of Craintown Branch confluence at Hwy 57 bridge, in Fleming County.	Bacteria (Phase I)	15.85

APPENDIX 1 (Continued)

05029013	Fleming Creek mainstem just upstream of Flat Run confluence, in Fleming County.	Bacteria (Phase I)	17.8
05029014	Flat Run near mouth, in Fleming County.	Bacteria (Phase I)	1.0(16.55)
05029015	Craintown Branch at mouth, in Fleming County.	Bacteria (Phase I), Long-term water monitoring (Phase II)	0.1(15.9)
05029016	Fleming Creek mainstem just downstream of Cassidy Creek confluence, in Fleming County.	Bacteria (Phase I)	20.05
05029017	Cassidy Creek at Hwy 11 bridge, in Fleming County.	Bacteria (Phase I)	0.4(20.06)
05029018	Fleming Creek mainstem just upstream of Cassidy Creek confluence, near Hwy 11, in Fleming County.	Bacteria (Phase I)	20.65
05029019	Fleming Creek mainstem just upstream of Allison Creek confluence, adjacent to Kendall North Road, in Fleming County.	Bacteria (Phase I)	22.7
05029020	Allison Creek just downstream of Smith's dairy near Hwy 697, in Fleming County.	Bacteria (Phase I), Long-term water quality monitoring (Phase II), and biological monitoring (Phase III)	0.8(22.65)
05029021	Flemingsburg Treatment Plant effluent on Town Branch, in Fleming County.	Bacteria (Phase I)	0.6(25.95)

APPENDIX 1 (Continued

05029022	Fleming Creek mainstem just downstream of Town Branch confluence, in Fleming County.	Bacteria (Phase I)	25.9
05029023	Town Branch at mouth, in Fleming County.	Bacteria (Phase I)	0.1(25.95)
05029024	Fleming Creek mainstem just upstream of Town Branch confluence at Hwy 32 bridge, in Fleming County.	Bacteria (Phase I)	26.0
05029025	Wilson Run near mouth, just downstream of Hwy 559 bridge, in Fleming County.	Bacteria (Phase I), may be sampled for Phase II depending on BMP placement	0.2(28.0)
05029026	Fleming Creek mainstem at Hwy 559 bridge, just upstream of Wilson Run confluence.	Bacteria (Phase I)	28.2
05029027	Sleepy Run downstream of Hwy 57 bridge, in Fleming County.	Bacteria (Phase I)	0.9(30.05)
05029028	Fleming Creek mainstem at Hwy 3301 bridge, in Fleming County.	Bacteria (Phase I), Long-term water quality monitoring (Phase II)	31.0
05029029	Logan Run at mouth adjacent to Hwy 57, in Fleming County.	Bacteria (Phase I), Long-term water quality monitoring (Phase II)	0.1(32.75)
05029030	Fleming Creek mainstem just above Logan Run confluence near Hwy 57, in Fleming County.	Bacteria (Phase I)	32.8
05029031	Fleming Creek mainstem just downstream of Hwy 170, in Fleming County.	Long-term water quality monitoring (Phase II), Biological monitoring (Phase III)	12.3
05029032	Allison Creek just upstream of Smith's dairy near Hwy 697, in Fleming County.	Long-term water quality monitoring (Phase II)	0.9(22.65)

APPENDIX 2

LIVESTOCK PRODUCTION LAND USE DATA (DOC 1995)

Parameter	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6	Zone 7	Zone 8	Totals
No. of beef operations	25	18	15	28	9	34	11	19	159
lbs. manure/day produced by beef operations	85,250	61,380	51,150	95,480	30,690	115,940	37,510	64,790	542,190
lbs. manure/yr produced by beef operations	31,116,250	22,403,700	18,669,750	34,850,200	11,201,850	42,318,100	13,691,150	23,648,350	197,899,350
Beef operations with waste systems installed*	-	-	-	-	-	-	-	-	-
Beef operations with waste systems planned*	-	-	-	-	-	-	-	-	-
No. of dairy operations	8	5	5	11	9	15	8	2	63
lbs. manure/day produced by dairy operations	40,700	25,438	25,438	55,963	45,788	76,313	40,700	10,175	320,515
lbs. manure/yr produced by dairy operations	14,855,500	9,284,870	9,284,870	20,426,495	16,712,620	27,854,245	14,855,500	3,713,875	116,987,975
Dairy operations with waste systems installed*	-	-	-	-	-	-	-	-	-
Dairy operations with waste systems planned*	-	-	-	-	-	-	-	-	-
Average herd size	50	50	50	50	50	50	50	50	-

APPENDIX 3

AGRONOMIC LAND USE DATA (DOC 1995)

Parameter	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6	Zone 7	Zone 8	Totals
Number of farms	44	35	24	63	31	65	24	21	307
Total acres	8,275	4,923	3,540	7,661	3,588	11,758	2,239	4,147	46,131
Cropland acres	4,589	3,741	2,801	5,878	2,519	7,837	1,615	3,087	32,067
Acres corn	796	652	391	873	408	1,231	119	398	4,868
Acres soybeans	104	90	63	163	66	177	41	82	786
Acres tobacco	158	120	79	190	80	252	60	112	1,051
Acres rotational hayland	947	744	517	1,259	430	2,897	567	794	8,155
Acres other cropland	0	0	0	0	0	0	0	0	0
Acres permanent pasture/ hayland	5,412	2,874	2,073	4,480	2,095	6,143	1,251	2,333	26,661
Acres woodland	858	443	417	697	509	1,058	201	428	4,611

APPENDIX 4

FLEMING CREEK BACTERIOLOGICAL SURVEY

LICKING RIVER BASIN				1992	
Station No.	**Source/Receiving Stream**	**Milepoint**	**Bacteria per 100ml**	**May 18 Storm Event***	**Aug 18 Low-flow**
05029003	Fleming Creek	1.3	Fecal Coliform:	400	20 / 30
05029004	Fleming Creek	4.8	Fecal Coliform:	560	60
05029005	Unnamed Trib. to Fleming Creek	0.3(4.28)	Fecal Coliform:	9,200	100
05029006	Fleming Creek	8.75	Fecal Coliform:	4,600	100
05029007	Poplar Creek	0.1(9.4)	Fecal Coliform:	9,200	260
05029008	Fleming Creek	12.6	Fecal Coliform:	750	60
05029009	Doty Creek	0.1(12.65)	Fecal Coliform:	5,000	80
05029010	Fleming Creek	12.7	Fecal Coliform:	740 / 650	140
05029011	Fleming Creek	15.85	Fecal Coliform:	250	120
05029012	Fleming Creek	15.9	Fecal Coliform:	460	30 / 60
05029013	Craintown Branch	0.1(15.9)	Fecal Coliform:	520	90
05029014	Flat Run	1.0(16.55)	Fecal Coliform:	500	10
05029015	Fleming Creek	17.8	Fecal Coliform:	500	130
05029016	Fleming Creek	20.05	Fecal Coliform:	210	210
05029017	Cassidy Creek	0.4(20.6)	Fecal Coliform:	2,400 / 1,800	10
05029018	Fleming Creek	20.65	Fecal Coliform:	500	270
05029019	Allison Creek	0.8(22.65)	Fecal Coliform:	>16,000	>16,000
05029020	Fleming Creek	22.7	Fecal Coliform:	420	250
05029021	Flemingsburg WWTP	0.6(25.95)	Fecal Coliform:	ND	3,600
05029022	Fleming Creek	25.9	Fecal Coliform:	15,000	1,000
05029023	Town Branch	0.1(25.95)	Fecal Coliform:	>16,000	6,800
05029024	Fleming Creek	26.0	Fecal Coliform:	500	1,100
05029025	Wilson Run	0.2(28.0)	Fecal Coliform:	5,600	720
05029026	Fleming Creek	28.2	Fecal Coliform:	1,400	490 / 530

APPENDIX 4 (Continued)

05029027	Sleepy Run	0.9(30.05)	Fecal Coliform:	16,000	500
05029028	Fleming Creek	31.0	Fecal Coliform:	12,000	200
05029029	Logan Run	0.1(32.75)	Fecal Coliform:	>16,000	100
05029030	Fleming Creek	32.8	Fecal Coliform:	3,200	530

WWTP = Wastewater Treatment Plant

* .75 inches of rain over the previous 12 hours.

APPENDIX 5

PRE-BMP FLEMING CREEK PHYSICOCHEMICAL DATA

ALLISON CREEK

Parameter	Sampling Event									
	5/8/92	5/12/92	5/18/92	8/18/92	1/5/93	2/21/93	3/17/93	4/3/93	5/12/93	5/12/94
Water temperature (c°)	13.8	27.8	22.9	25.0	8.3	-	4.9	6.9	22.7	17.0
Dissolved oxygen (mg/l)	10.4	11.0	8.1	10.2	11.5	-	11.7	11.8	8.2	10.8
Turbidity (NTU)	46.0	11.2	9.0	1.3	67.0	>200	106.0	169.0	5.0	10.5
Conductance (umhos/cm)	524	522	447	-	480	146	293	210	389	432
pH	6.8	7.5	7.6	6.8	7.5	7.6	6.7	7.0	7.3	7.9
Total suspended solids (mg/l)	142.0	5.0	6.0	6.0	38.0	658.0	42.0	106.0	16.0	18.0
Organic carbon (mg/l)	16.6	5.3	5.3	11.6	8.2	13.0	5.4	10.0	14.9	-
BOD_5 (mg/l)	-	5.6	6.5	-	3.7	-	-	3.7	-	-
Ammonia-nitrogen (mg/l)	.919	.208	1.090	.512	ND	.222	.071	.084	1.600	1.130
Total Kjeldhal nitrogen (mg/l)	3.920	.819	1.290	.567	.846	3.920	.748	1.20	3.070	1.940
Nitrate (mg/l)	.048	.209	.070	.098	1.400	.869	.808	.827	.177	.637
Phosphorus, total (mg/l)	.603	.078	.237	1.430	.161	1.540	.171	.324	.446	.429
Flow	*	*	-	-	-	-	*	367cfs	*	*
Rain amount (inches during previous 24 hrs)	1.0	0.0	.7	0.0	1.0+	1.5-2.3	10-12" snow melt, light rain	.65	0.0	0.0

ND = Not detected
* Computer program malfunction, values not calculated yet.

APPENDIX 5

CRAINTOWN BRANCH

Parameter	Sampling Event									
	5/8/92	**5/12/92**	**5/18/92**	**8/18/92**	**1/5/93**	**2/21/93**	**3/17/93**	**4/3/93**	**5/12/93**	**5/12/94**
Water temperature (C_o)	13.0	Not sampled	24.4	24.6	8.3	-	4.4	6.7	22.9	
Dissolved oxygen (mg/l)	11.3	"	10.3	7.1	11.5	-	11.8	11.3	12.6	8.8
Turbidity (NTV)	34.2	"	-		67.0	>200	82.0	199.0	4.6	6.4
Conductance (umhos/cm)	452	"	300	281	480	148	228	232	243	466
ph	5.8	"	8.4	7.3	7.5	7.6	6.4	7.2	8.0	7.9
Total suspended solids (mg/l)	12.0	"	ND	4.0	34.0	597.0	44.0	126.0	6.0	9.0
Organic carbon (mg/l)	5.2	"	3.7	3.8	4.1	11.4	8.4	12.6	4.8	-
BOD_5 (mg/l)	-	"	1.3	-	2.9	-	-	5.6	-	-
Ammonia-nitrogen (mg/l)	.058	"	ND	ND	ND	.222	.152	.227	ND	.066
Total Kjeldhal nitrogen (mg/l)	.737	"	.333	.053	.661	4.050	1.480	2.090	.633	ND
Nitrate (mg/l)	.227	"	.109	.071	2.800	.937	1.410	1.050	.011	1.050
Phosphorus, total (mg/l)	.187	"	.030	.047	.343	2.920	.521	1.070	.099	.136
Flow	*	"	-	-	*	-	*	*	*	*
Rain amount (inches during previous 24 hrs.)	1.0	"	.7	0.0	1.0+	1.5-2.3	10-12" snowmelt, light rain	.65	0.0	0.0

APPENDIX 5 (Continued)

LOGAN RUN

Parameter	Sampling Event									
	5/8/92	5/12/92	5/18/92	8/18/92	1/5/93	2/21/93	3/17/93	4/3/93	5/12/93	5/12/94
Water temperature (C_o)	13.7	**	18.7	20.1	8.0	-	4.4	5.8	**	**
Dissolved oxygen (mg/l)	10.4	**	8.6	8.2	11.5	-	11.8	11.8	**	**
Turbidity (NTV)	66.0	**	310.0	15.0	91.5	>200	82.0	>132	**	**
Conductance (umhos/cm)	398	**	330	555	331	142	228	203	**	**
pH	6.6	**	7.6	6.9	7.0	7.4	6.4	7.1	**	**
Total suspended solids (mg/l)	30.0	**	116.0	7.0	40.0	618.0	46.0	99.0	**	**
Organic carbon (mg/l)	3.9	**	7.5	2.3	5.6	12.2	5.3	7.6	**	**
BOD_5 (mg/l)	-	**	4.9	-	2.4	-		3.2	**	**
Ammonia-nitrogen (mg/l)	ND	**	.068	ND	ND	.109	.060	ND	**	**
Total Kjeldhal nitrogen (mg/l)	.681	**	1.450	ND	.700	3.21	.786	1.300	**	**
Nitrate (mg/l)	.135	**	1.080	1.200	1.980	.880	1.300	1.270	**	**
Phosphorus, total (mg/l)	.061	**	.151	.019	.100	.628	.135	.176	**	**
Flow	*	**	-	-	*	-	*	-	**	**
Rain amount (inches during previous 24 hrs.)	1.0	**	.7	0.0	1.0+	1.5-2.3	10-12" snowmelt, light rain	65	**	**

* Not sampled on these dates because these sites are not biological sampling stations.

**Not sampled.

APPENDIX 5 (Continued)

FLEMING CREEK AT FLEMINGSBURG-BEECHBURG ROAD (HWY 3301) BRIDGE

Parameter	Sampling Event									
	5/8/92	5/12/92	5/18/92	8/18/92	1/5/93	2/21/93	3/17/93	4/3/93	5/12/93	5/12/94
Water temperature (C^c)	13.6	**	20.6	18.8	8.5	-	3.1	5.5	**	**
Dissolved oxygen (mg/l)	10.5	**	7.4	5.8	11.2	-	12.0	11.6	**	**
Turbidity (NTV)	32.0	**	71.0	18.0	188.5	>200	122	>200	**	**
Conductance (umhos/cm)	350	**	376	396	256	152	184	178	**	**
pH	7.1	**	7.6	6.9	7.0	7.5	6.5	7.1	**	**
Total suspended solids (mg/l)	10.0	**	40.0	7.0	88.0	930.0	106.0	138.0	**	**
Organic carbon (mg/l)	3.8	**	3.7	3.7	12.7	9.6	7.9	9.6	**	**
BOD_5 (mg/l)	-	**	2.9	-	4.2	-	-	3.8	**	**
Ammonia-nitrogen (mg/l)	ND	**	.056	ND	.050	.186	.127	.146	**	**
Total Kjeldhal nitrogen (mg/l)	.563	**	.700	.061	1.200	4.010	.962	1.780	**	**
Nitrate (mg/l)	.165	**	.659	.618	1.590	.889	1.060	1.290	**	**
Phosphorus, total (mg/l)	.029	**	.061	.041	.181	1.030	.201	.276	**	**
Flow	*	**	-	-	*	-	*	-	**	**
Rain amount (inches during previous 24 hrs.)	1.0	**	.7	0.00	1.0+	1.5-2.3	10-12" snowmelt, light rain	.65	**	**

* Not sampled on these dates because these sites are not biological sampling stations.
** Not sampled.

APPENDIX 5 (Continued)

FLEMING CREEK AT FLEMINGSBURG-BEECHBURG ROAD (HWY 3301) BRIDGE

Parameter	Sampling Event									
	5/8/92	5/12/92	5/15/92	8/18/92	1/5/93	2/21/93	3/17/93	4/3/93	5/12/93	5/12/94
Water temperature (C^c)	14.8	21.8	23.4	22.4	9.4	-	3.9	6.1	22.9	17.8
Dissolved oxygen (mg/l)	11.0	10.5	7.5	10.3	11.0	-	11.9	11.8	4.4?	7.9
Turbidity (NTV)	9.0	17.0	7.7	.8	>200	>200	197.0	>200	-	11.8
Conductance (umhos/cm)	463	499	439	456	321	200	244	228	351	460
pH	6.4	7.5	7.5	7.6	7.7	7.7	6.8	7.2	7.0	7.7
Total suspended solids (mg/l)	2.0	10.0	ND	3.0	208.0	777.0	146.0	225.0	13.0	13.0
Organic carbon (mg/l)	3.5	3.9	3.1	4.8	12.1	11.2	5.79	10.3	5.5	-
BOD_5 (mg/l)	-	1.8	-	-	5.6	-	-	5.0	-	-
Ammonia-nitrogen (mg/l)	.050	ND	ND	ND	ND	.332	.110	.153	ND	ND
Total Kjeldhal nitrogen (mg/l)	.310	.367	.392	.064	1.560	4.14	1.42	1.790	.717	ND
Nitrate (mg/l)	.089	1.190	.406	.560	1.820	1.08	1.09	1.250	.113	1.530
Phosphorus, total (mg/l)	.057	.078	.053	.093	.513	1.99	.376	.603	0.87	.123
Flow	*	*	-	-	*	-	-	-	*	*
Rain amount (inches during previous 24 hrs.)	1.0	0.0	.7	0.0	1.0+	1.5-2.3	10-12" snowmelt, light rain	.65	0.0	0.0
* Not sampled on these dates because these sites are not biological sampling stations.										

APPENDIX 6

PRE-BMP FLEMING CREEK FISH DATA (PRE-BMP)

Species	Number of Specimens								
	1992			1993			1994		
	Allison Creek	Craintown Branch	Fleming Creek	Allison Creek	Craintown Branch	Fleming Creek	Allison Creek	Craintown Branch	Fleming Creek
Striped shiner (Luxilus chrysocephalus)	22	**	34	-	8	19	19	61	41
Redfin shiner (Lythrurus umbratilis)	20	**	92	4	-	101	29	2	33
Sand shiner (Notropis stramineus)	-	**	5	-	-	18	-	-	-
Silver shiner (N. photogenis)	-	**	-	-	-	6	-	-	11
Bluntnose minnow (Pimephales notatus)	36	**	53	31	16	56	3	93	3
Fathead minnow (P. promelos)	36	**	1	16	11	-	34	3	-
Goldfish (Carassius auratus)	1	**	-	-	-	-	-	-	-
Central stoneroller (Campostoma anomalum)	2	**	10	-	2	6	7	25	2
Creek chub (Semotilus atramaculatus)	10	**	3	-	1	-	-	8	-
White sucker (Catostomus commersoni)	-	**	-	7	-	-	-	1	-
Golden redhorse (Moxostoma erythrurum)	-	**	-	-	-	-	-	1	-
Brook silverside (Labidesthes sicculus)	-	**	1	-	-	-	-	-	-
Yellow bullhead (amiurus natalis)	-	**	-	-	-	-	-	-	-
Green sunfish (Lepomis cyanellus)	13	**	5	3	82	9	4	10	-
Bluegill (L. macrochirus)	-	**	9	-	6	2	2	14	-
Longear sunfish (L. megalotis)	-	**	2	-	2	3	-	1	-
Hybrid sunfish (probably L. megalotis x cyannellus)*	-	**	1	-	-	-	-	-	-
Hybrid sunfish (probably L. megalotis x macrochirus)*	-	**	-	-	1	-	-	-	-

APPENDIX 6 (Continued)

Largemouth bass (*Micropterus salmoides*)	-	**	-	-	1	-	-	-	-
Small mouth bass (*M. dolomieui*)	-	**	-	-	-	1	-	-	-
Rock bass (*Amoloplites rupestris*)	-	**	1	-	-	5	-	-	2
Logperch (*Percina caprodes*)	-	**	-	-	-	1	-	-	-
Greenside darter (*Etheastoma blennioides*)	-	**	1	-	-	2	-	-	-
Johnny darter (*E. flabellare*)	-	**	-	-	-	-	-	-	-
Fan tail darter (*E. flabellare*)	-	**	5	-	5	1	-	7	3
Rainbow darter (*E. caeruleum*)	3	**	2	-	-	1	-	-	-
Orangethroat darter (*E. spectabile*)	17		-	17	7	1	18	22	2
Number of Specimens	160	-	225	71	145	233	116	248	97
Number of Species	10	-	15	5	12	17	8	13	8
IBI	32 (poor)	-	42 (Fair	24 (very poor)	30 (Poor)	47 (Good-fair)	34 (Poor)	36 (Poor-fair)	38 (Poor-Fair)

* Not included in species counts.
** Fish not sampled.

APPENDIX 7

PRE-BMP MACROINVERTEBRATE DATA

Species	HBI Value (a_i)	1992						1993						1994					
		Allison Creek		Craintown Branch		Fleming Creek		Allison Creek		Craintown Branch		Fleming Creek		Allison Creek		Craintown Branch		Fleming Creek	
		n_i	$n_i x n_i$	n_i	$n_i x n_i$	n_i	$n_i x n_i$	n_i	$n_i x n_i$	n_i	$n_i x n_i$	n_i	$n_i x n_i$	n_i	$n_i x n_i$	n_i	$n_i x n_i$	n_i	$n_i x n_i$
Gastropoda (snails) Lymnaeidae <u>Lymnaea</u> (<u>Goniobasis</u>) sp.	-	-	-	**	**	-	-	1	-	2	-	34	-	-	-	1	-	13	-
Pleuroceridae <u>Pleurocera</u> sp.	-	8	-	**	**	40	-	-	-	-	-	-	-	-	-	-	-	-	-
Ancylidae <u>Ferrisa</u> <u>rivularis</u>	6.9	-	-	**	**	6	41.4	-	-	-	-	-	-	-	-	-	-	-	-
Planorbidae <u>Gyraulus</u> sp.	-	1	-	**	**	2	-	6	-	-	-	-	-	-	-	1	-	-	-
<u>Heliosoma</u> sp.	6.5	-	-	**	**	-	-	-	-	-	-	-	-	-	-	1	6.5	-	-
Physidae <u>Physella</u> (<u>Physa</u>) sp.	9.1	35	227.5	**	**	2	18.2	27	227.5	5	45.5	-	-	4	36.4	34	227.5	-	-
Pelecypoda (Mussels) Sphaeriidae <u>Sphaerium</u> sp.	7.7	-	-	**	**	-	-	4	30.8	4	30.8	18	138.6	-	-	-	-	16	132.2
<u>Pisidium</u> sp.	6.8	-	-	**	**	3	20.4	-	-	-	-	-	-	-	-	-	-	-	-
Unionidae <u>Lampsilis</u> <u>radiata</u>	-	-		**	**	*		-		-		*		-		-		*	

* Several
** Not sampled

APPENDIX 7 (Continued)

Species	HBI Value (a_i)	1992						1993						1994					
		Allison Creek		Craintown Branch		Fleming Creek		Allison Creek		Craintown Branch		Fleming Creek		Allison Creek		Craintown Branch		Fleming Creek	
		n_i	$n_i x n_i$	n_i	$n_i x n_i$	n_i	$n_i x n_i$	n_i	$n_i x n_i$	n_i	$n_i x n_i$	n_i	$n_i x n_i$	n_i	$n_i x n_i$	n_i	$n_i x n_i$	n_i	$n_i x n_i$
Decapoda (crayfish) Cambaridae Cambarus robustus	8.1	2	16.2	*	*	-	-	-	-	2	16.2	-	-	14	113.4	1	8.1	-	-
Orconectes rusticus	2.7	-	-	*	*	26	67.5	12	32.4	17	45.9	25	67.5	1	2.7	8	21.6	15	40.5
Amphipoda (Suds or Sideswimmers) Gammaridae Crangonyx shoemakeri	8.0	10	80.0	*	*	2	16.0	34	200.0	73	200.0	10	80.0	48	200.0	57	200.0	15	120.0
Isopoda (Pillbugs) Asellidae Lirceus lineatus	7.7	298	192.5	*	*	249	192.5	23 3	192.5	318	192.5	105	192.5	155	192.5	138	192.5	110	192.5
Oligochaeta (worms) Enchytracidae Enchytracus sp.	10.0	-	-	*	*	-	-	-	-	1	10.0	-	-	-	-	-	-	-	-
Lumbriculidae Rhynchelmis rostrata	7.3	-	-	*	*	-	-	-	-	-	-	-	-	-	-	18	131.4	-	-
Lumbricidae Lumbriculus sp.	-	-	-	*	*	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Tubificidae Tubifex tubifex	10.0	-	-	*	*	-	-	3	30.0	-	-	-	-	8	80.0	1	10.0	-	-
Brachiura sowerbyi	8.4	-	-	*	*	-	-	-	-	-	-	-	-	-	-	-	-	2	16.8
Hirudinea (Leaches) Hirudidae Haemopsis grandis	-	1	-	*	*	-	-	-	-	-	-	-	-	-	-	-	-	-	-
H. marmorata	-	-	-	*	*	-	-	5	-	-	-	-	-	2	-	2	-	-	-

* Not sampled

APPENDIX 7 (Continued)

Species	HBI Value (a_i)	1992						1993						1994					
		Allison Creek		Craintown Branch		Fleming Creek		Allison Creek		Craintown Branch		Fleming Creek		Allison Creek		Craintown Branch		Fleming Creek	
		n_i	$n_i x n_i$	n_i	$n_i x n_i$	n_i	$n_i x n_i$	n_i	$n_i x n_i$	n_i	$n_i x n_i$	n_i	$n_i x\text{-}n_i$	n_i	$n_i x n_i$	n_i	$n_i x n_i$	n_i	$n_i x n_i$
Erpobdellidae <u>Mourevbdella</u> <u>fervida</u>	7.8	-	-	*	*	-	-	-	-	1	7.8	-	-	-	-	-	-	-	-
Hirudinea sp. (leech case)	-	-	-	*	*	-	-	-	-	-	-	-	-	-	-	-	-	1	-
Coleoptera (Beetles) Elmidae <u>Stenelmis</u> sp.	5.4	49	135.0	*	*	153	135.0	18	97.2	152	135.0	214	135.0	20	108.0	124	135.0	107	135.0
<u>Ancyronyx</u> sp.	6.9	-	-	*	*	11	75.9	-	-	-	-	1	6.9	-	-	-	-	-	-
<u>Microcylloepus</u> sp.	2.1	-	-	*	*	-	-	-	-	-	-	1	2.1	-	-	-	-	-	-
Haliplidae <u>Peltodytes</u> sp.	8.5	4	34.0	*	*	1	8.5	8	68.0	17	144.5	8	68.0	6	51.0	8	68.0	-	-
Hydrophilidae <u>Berosus</u> sp.	8.6	1	8.6	*	*	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<u>Tropisternus</u> sp.	9.8	5	49.0	*	*	1	9.8	11	107.8	6	58.8	-	-	1	9.8	1	9.8	-	-
<u>Enochrus</u> sp.	8.5	1	8.5	*	*	-	-	3	25.5	-	-	-	-	-	-	-	-	-	-
<u>Cymbiodyta</u> sp.	-	-	-	*	*	-	-	1	-	-	-	-	-	-	-	-	-	-	-
<u>Hydrobius</u> sp.	-	-	-	*	*	-	-	-	-	-	-	-	-	1	-	-	-	-	-
Psephenus <u>Psephenus</u> <u>herrick</u>	2.5	1	2.5	*	*	4	10.0	-	-	24	60.0	29	62.5	-	-	1	2.5	5	12.5
Gyrinidae <u>Dineutus</u> sp.	5.5	-	-	*	*	-	-	5	27.5	-	-	-	-	-	-	-	-	-	-
Dytiscidae <u>Laccophilus</u> sp.	10.0	-	-	*	*	-	-	1	10.5	2	20.0	-	-	6	60.0	-	-	-	-
<u>Hydroporus</u> sp.	8.9	-	-	*	*	-	-	5	44.5	1	8.9	-	-	-	-	5	44.5	-	-
Scirtidae <u>Elodes</u> sp.	-	-	-	*	*	-	-	24	-	-	-	-		1	-	-	-	-	-

* Not sampled.

APPENDIX 7 (Continued)

Species	HBI Value (a_i)	1992						1993						1994					
		Allison Creek		Craintown Branch		Fleming Creek		Allison Creek		Craintown Branch		Fleming Creek		Allison Creek		Craintown Branch		Fleming Creek	
		n_i	$n_i x n_i$	n_i	$n_i x n_i$	n_i	$n_i x n_i$	n_i	$n_i x n_i$	n_i	$n_i x n_i$	n_i	$n_i x\text{-}n_i$	n_i	$n_i x n_i$	n_i	$n_i x n_i$	n_i	$n_i x n_i$
Hydraenidae Limnebius sp.	-	-	-	*	*	-	-	-	-	-	7.8	-	-	2	-	-	-	1	-
Staphylinidae Bledius sp.	-	-	-	*	*	-	-	-	-	-	-	-	-	1	-	-	-	-	-
Dryopidae Helicus sp.	5.4	-	-	*	*	1	5.4	-	-	-	-	-	-	-	-	-	-	-	-
Hemiptera (True bugs) Belostomatidae Belostoma sp.	9.8	4	39.4	*	*	2	19.6	4	39.4	-	-	-	-	2	19.6	2	19.6	-	-
Corixidae Tricorixiz sp.	9.0	-	-	*	*	1	9.0	-	-	-	-	-	-	-	-	-	-	-	-
Hesperocorixia sp.	9.0	-	-	*	*	-	-	11	99.0	2	18.0	1	9.0	-	-	-	-	3	27.0
Veliidae Rhagovelia sp.	-	-	-	*	*	-	-	2	-	1	-	1	-	-	-	-	-	-	-
Microvelia sp.	-	-	-	*	*	-	-	-	-	-	-	-	-	2	-	-	-	-	-
Gerridae Trepobates sp.	-	-	-	*	*	-	-	-	-	1	-	-	-	-	-	-	-	-	-
Megaloptera (Dobsonflies) Corydalidae Corydalus cornutus	5.6	-	-	*	*	2	11.2	-	-	2	11.2	5	28.0	-	-	-	-	-	-

* Not sampled.

APPENDIX 7 (Continued)

Species	HBI Value (a_i)	1992						1993						1994					
		Allison Creek		Craintown Branch		Fleming Creek		Allison Creek		Craintown Branch		Fleming Creek		Allison Creek		Craintown Branch		Fleming Creek	
		n_i	$n_i x n_i$	n_i	$n_i x n_i$	n_i	$n_i x n_i$	n_i	$n_i x n_i$	n_i	$n_i x n_i$	n_i	$n_i x\text{-}n_i$	n_i	$n_i x n_i$	n_i	$n_i x n_i$	n_i	$n_i x n_i$
Odonata (Dragonflies, Damselflies Coenagrionidae <u>Ishnora</u> sp.	9.4	1	9.4	*	*	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<u>Coenagrion</u> sp.	-	-	-	*	*	10	-	-	-	-	-	-	-	-	-	-	-	5	-
<u>Argia</u> sp.	8.7	-	-	*	*	1	8.7	2	17.4	-	-	3	26.1	-	-	1	8.7	-	-
<u>Amphiagarion</u> sp.	-	-	-	*	*	4	-	-	-	-	-	-	-	-	-	-	-	-	-
<u>Enallagma</u> sp.	9.0	-	-	*	*	-	-	-	-	-	-	14	126.0	-	-	-	-	-	-
Calopterygidae <u>Hataerina</u> sp.	6.2	-	-	*	*	-	-	-	-	-	-	2	12.4	-	-	-	-	-	-
Libellulidae <u>Libellula</u> sp.	9.8	-	-	*	*	-	-	11		-	107.8	-	-	1	938	-	-	-	-
<u>Erythemis</u> sp.	7.7	1	7.7	*	*	-	-	-	-	-	-	-	-	-	-	1	7.7	-	-
Aeshnidae <u>Boyeria</u> sp.	6.3	-	-	*	*	1	6.3	-	-	-	-	1	6.3	-	-	-	-	-	-
<u>Aeshna</u> sp.	-	-	-	*	*	1	-	-	-	-	-	-	-	-	-	-	-	-	-
Corduliidae <u>Neurocordulia</u> sp.	5.8	1	5.8	*	*	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Gomphidae <u>Gomphus</u> sp.	6.2	-	-	*	*	-	-	-	-	-	-	-	-	*	-	-	-	1	6.2

* Not sampled.

Species	HBI Value (a_i)	1992						1993						1994					
		Allison Creek		Craintown Branch		Fleming Creek		Allison Creek		Craintown Branch		Fleming Creek		Allison Creek		Craintown Branch		Fleming Creek	
		n_i	$n_i x n_i$	n_i	$n_i x n_i$	n_i	$n_i x n_i$	n_i	$n_i x n_i$	n_i	$n_i x n_i$	n_i	$n_i x\text{-}n_i$	n_i	$n_i x n_i$	n_i	$n_i x n_i$	n_i	$n_i x n_i$
Plecoptera (Stoneflies)							0.0	38											
Perlidae Perlesta sp. A.	0.0	85	0.0	*	*	85	0.0	38	0.0	-	-	42	0.0	40	0.0	20	0.0	63	0.0
Perlesta sp. B	0.0	-	-	*	*	-	-	-	-	-	-	-	-	1	0.0	-	-	1	0.0
Agnetina sp.	0.0	-	-	*	*	-	-	-	-	-	-	-	-	-	-	-	-	1	0.0
Neoperla sp.	1.6	-	-	*	*	1	1.6	-	-	-	-	-	-	-	-	-	-	-	-
Perlodidae Isoperla bilineata	5.5	1	5.5	*	*	-	-	-	-	-	-	-	-	1	5.5	-	-	4	22.0
Nemouridae Amphinemura sp.	3.4	-	-	*	*	-	-	-	-	-	-	-	-	-	-	-	-	2	6.8
Leuctridae Leuctra sp.	.7	-	-	*	*	-	-	-	-	-	-	-	-	-	-	-	-	1	.7
Trichoptera (Caddisflies) Hydropsychidae Cheumatopsyche sp.	6.6	10	66.0	*	*	-	-	-	-	7	46.2	-	-	-	-	-	-	-	-
Hydropsyche sp.	4.0	-		*	*	27	.100.0	-	-	1	4.0	9	36.0	-	-	6	24.0	1	4.0
Rhyacophilidae Rhyacophila fenestra	.9	27	22.5	*	*	1	.9	11	9.9	5	4.5	-	-	9	8.1	5	4.5	5	4.5
Polycentropidae Polycentropus sp.	3.5	-	-	*	*	-	-	-	-	-	-	-	-	-	-	-	-	1	3.5
Philopotamidae Chimarra sp.	2.8	-	-	*	*	3	8.4	-	-	13	36.4	3	8.4	-	-	-	-	16	44.8
Hydroptilidae Orthotrichia sp.	7.2	-	-	*	*	-	-	1	7.2	2	14.4	1	7.2	32	180.0	6	43.2	1	7.2
Leucotrichia sp.	4.3	-	-	*	*	-	-	-	-	1	4.3	-	-	-	-	-	-	-	-

* Not sampled.

Species	HBI Value (a_i)	1992						1993						1994					
		Allison Creek		Craintown Branch		Fleming Creek		Allison Creek		Craintown Branch		Fleming Creek		Allison Creek		Craintown Branch		Fleming Creek	
		n_i	$n_i x n_i$	n_i	$n_i x n_i$	n_i	$n_i x n_i$	n_i	$n_i x n_i$	n_i	$n_i x n_i$	n_i	$n_i x$-n_i	n_i	$n_i x n_i$	n_i	$n_i x n_i$	n_i	$n_i x n_i$
Ephemeroptera (Mayflies) Caenidae Caenis sp.	7.6	35	190.0	*	*	20	152.0	35	190.0	12	91.2	9	68.4	2	15.2	3	22.8	4	
Heptageniidae Stenonema femoratum	7.5	-	-	*	*	-	-	8	60.0	-	-	11	75.0	-	-	-	-	5	30.4
Stenomema sp.	3.4	16	54.4	*	*	16	54.4	1	3.4	2	6.8	1	3.4	-	-	-	-	-	37.5
Leucrocuta (Hexagenia) sp.	0.0	-	-	*	*	-	-	11	0.0	-	-	-	-	-	-	1	0.0	-	-
Stenocron sp.	3.9	-	-	*	*	-	-	-	-	3	11.7	-	-	-	-	-	-	1	3.9
Nixe (Hexagenia) sp.	4.7	-	-	*	*	-	-	-	-	-	-	-	-	3	14.1	-	-	-	-
Heptigenid sp.	-	-		*	*	-	-	-	-	-	-	-	-	-	-	1	-	-	-
Leptophenbidae Paraleptophlebia sp.	1.2	4	4.8	*	*	1	1.2	7	8.4	-	-	-	-	12	14.4	1	1.2	-	-
Baetidae Acentrollo amphus	3.6	-	-	*	*	-	-	-	-	-	-	-	-	-	-	-	-	3	10.8
Baetis sp. A	5.4	1	5.4	*	*	25	135.0	2	10.8	6	32.4	21	113.4	1	5.4	1	5.4	12	64.8
Baetis sp. B	5.4	2	10.8	*	*	15	81.0	-	-	-	-	-	-	-	-	-	-	-	-
Baetis sp. C	5.4	1	5.4	*	*	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Ephemerellidae Serratella (Ephemerella) sp.	1.7	-	-	*	*	25	42.5	-	-	8	13.6	34	42.5	-	-	-	-	5	8.5
Oligoneuriidae Isonychia sp.	3.8	-	-	*	*	4	15.2	-	-	1	3.8	-	-	-	-	-	-	-	-
Ephemeridae Hexagenia sp.	4.7	-	-	*	*	1	4.7	-	-	1	4.7	-	-	-	-	-	-	-	-
Ephemoroptera sp. A	-	-	-	*	*	1	-	-	-	-	-	-	-	-	-	-	-	-	-

* Not sampled.

APPENDIX 8

Chlorophyll*a* values (mg/m^2) for Fleming Creek May 12, 1992)					
	$\bar{x}$	min	max	sd	%C.V.
Fleming Creek	304	282	337	29.1	9.6
Allison Branch	462	314	673	187.9	40.7
Craintown Branch	500	459	551	46.7	9.4

Species	HBI Value (a_i)	1992						1993						1994					
		Allison Creek		Craintown Branch		Fleming Creek		Allison Creek		Craintown Branch		Fleming Creek		Allison Creek		Craintown Branch		Fleming Creek	
		n_i	$n_i x n_i$	n_i	$n_i x n_i$	n_i	$n_i x n_i$	n_i	$n_i x n_i$	n_i	$n_i x n_i$	n_i	$n_i x\text{-}n_i$	n_i	$n_i x n_i$	n_i	$n_i x n_i$	n_i	$n_i x n_i$
Diptera (Flies, Midges, Mosquitoes) Certatopogonidae Bezzia sp.	-	-	-	*	*	-	-	2	-	1	-	-	-	-	-	-	-	-	-
Ephydridae Dictya (probably pictipes)	-	-	-	*	*	-	-	1	-	-	-	-	-	-	-	-	-	-	-
Tabanidae Limnophila sp.	-	-	-	*	*	-	-	-	-	-	-	1	-	-	-	-	-	-	-
Tabanus sp.	9.7	-	-	*	*	-	-	-	-	1	9.7	1	9.7	-	-	-	-	-	-
Tipulidae Psuedolimnophila sp.	7.3	-	-	*	*	-	-	-	-	-	-	-	-	1	7.3	-	-	-	-
Tipula abdominalis	7.7	-	-	*	*	1	7.7	-	-	-	-	-	-	-	-	-	-	1	7.7
Simulidae Simulium vittatum	8.7	-	-	*	*	-	-	20	174.0	5	43.5	-	-	3	26.1	-	-	-	-
Simulium sp.	4.4	8	35.2	*	*	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Prosimulium sp.	2.6	23	59.8	*	*	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Chironomidae Chironomus sp.	9.8	69	245.0	*	*		-	119	245.0	2	19.6	-	-	4	39.2	1	9.8	-	-
Dicrotendipes sp.	7.9	-	-	*	*	-	-	3	23.7	-	-	-	-	-	-	-	-	-	-
Stictochironomus sp.	6.7	-	-	*	*	-	-	54	167.5	4	26.8	-	-	1	6.7	3	20.1	-	-
Phanenosectra sp.	6.8	-	-	*	*	-	-	8	54.4	-	54.4	-	-	-	-	-	-	-	-
Microtendipes sp.	6.2	-	-	*	*	-	-	4	24.8	-	-	-	-	-	-	2	12.4	-	-

* Not sampled.

APPENDIX 7 (Continued)

Species	HBI Value (a_i)	1992						1993						1994					
		Allison Creek		**Craintown Branch**		**Fleming Creek**		**Allison Creek**		**Craintown Branch**		**Fleming Creek**		**Allison Creek**		**Craintown Branch**		**Fleming Creek**	
		n_i	n_ixn_i	n_i	n_ixn_i	n_i	n_ixn_i	n_i	n_ixn_i	n_i	n_ixn_i	n_i	n_ix-n_i	n_i	n_ixn_i	n_i	n_ixn_i	n_i	n_ixn_i
Polypedilum sp.	6.9	-	-	*	*	4	27.6	4	27.6	-	-	-	-	-	-	-	-	1	6.9
Paracladopelma (probably doris	6.4	-	-	*	*	-	-	1	6.4	-	-	-	-	-	-	-	-	-	-
Cryptochironomus sp.	7.4	-	-	*	*	-	-	1	7.4	-	-	-	-	-	-	-	-	-	-
Chironomini sp. A	-	90	-	*	*	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Chironomini sp. B	-	1	-	*	*	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Thienemannimyia sp.	-	-	-	*	*	-	-	6	-	13	-	-	-	-	-	-	-	3	-
Procladius sp.	9.3	-	-	*	*	-	-	1	9.3	-	-	-	-	-	-	-	-	-	-
Clinotanypos sp.	9.1	-	-	*	*	-	-	-	-	-	-	-	-	-	-	1	9.1	-	-
Psectrotanypus sp.	10.0	-	-	*	*	-	-	-	-	-	-	-	-	1	10.0	-	-	-	-
Tanypodinae sp. A	-	1	-	*	*	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Paratanytarsus sp.	7.7	-	-	*	*	-	-	2	15.4	-	-	-	-	-	-	-	-	-	-
Tanytarsus sp.	6.7	-	-	*	*	-	-	21	140.7	-	-	-	-	-	-	-	-	-	-
Tanytarsini sp. A	-	-	-	*	*	1	-	-	-	-	-	-	-	-	-	-	-	-	-
Orthocladius sp. A	-	-	-	*	*	-	-	1	-	-	-	-	-	17	-	-	-	-	-
Orthocladius sp. B	-	-	-	*	*	-	-	1	-	-	-	-	-	-	-	-	-	-	-
Parametriocnemus sp.	3.7	-	-	*	*	-	-	-	-	1	3.7	-	-	-	-	-	-	-	-
Cricotopus sp.	7.0	-	-	*	*	-	-	-	-	1	7.0	-	-	-	-	-	-	-	-

* Not sampled.

Species	HBI Value (a_i)	1992						1993						1994					
		Allison Creek		Craintown Branch		Fleming Creek		Allison Creek		Craintown Branch		Fleming Creek		Allison Creek		Craintown Branch		Fleming Creek	
		n_i	$n_i x n_i$	n_i	$n_i x n_i$	n_i	$n_i x n_i$	n_i	$n_i x n_i$	n_i	$n_i x n_i$	n_i	$n_i x\text{-}n_i$	n_i	$n_i x n_i$	n_i	$n_i x n_i$	n_i	$n_i x n_i$
Eukiefferiella potthasti	3.7	-	-	*	-	-	-	-	-	-	-	-	-	250	92.5	-	-	-	-
Symposiocladius sp.	5.4	-	-	*	*	-	-	-	-	-	-	-	-	1	5.4	-	-	-	-
Paraphaenocladius sp.	-	-	-	*	*	-	-	-	-	-	-	-	-	6	-	18	-	-	-
Parachaetocladius sp.	-	-	-	*	*	-	-	-	-	-	-	-	-	1	-	-	-	-	-
Paracladius sp.	-	-	-	*	*	-	-	-	-	-	-	-	-	2	-	-	-	1	-
Psectrocladius sp.	3.8	-	-	*	*	-	-	-	-	-	-	-	-	1	3.8	-	-	-	-
Orthocladiinae sp. A	-	1	-	*	*	3	-	2	-	2	-	-	-	-	-	-	-	-	-
Orthocladiinae sp. B	-	-	-	*	*	-	-	-	-	-	-	-	-	-	-	1	-	-	-
Orthocladiinae sp. C	-	-	-	*	*	-	-	-	-	-	-	-	-	-	-	1	-	-	-
Chironomidae sp. A	-	5	5	*	*	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Chironomidae sp. B	-	1	-	*	*	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Chironomidae sp. C	-	1	-	*	*	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Chironomidae sp. D	-	2	-	*	*	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Number of taxa		39				39		49		42		28		39		35		35	
EPT		10				14		9		13		9		8		99		17	
Number of specimens		811				751		796		723		612		664		491		426	
HBI		5.17				4.60		6.43		5.91		4.91		5.75		6.29		4.81	

* Not sampled.