BURNING FORK DRAINAGE
BIOLOGICAL AND WATER QUALITY INVESTIGATION
FOR STREAM USE DESIGNATION

Kentucky Department for Environmental Protection
Division of Water
Biological Analysis Section

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ABSTRACT

A biological and water quality investigation of the Burning Fork subbasin (drainage area 18 mi^2) was conducted in September 1984. The primary purpose was to determine the effects of oil brine discharges on the stream's aquatic communities and water quality. The study also determined the existing water quality and assessed the impact to designate aquatic uses, based on the physicochemical and biological characteristics of the basin. According to the United States Geological Survey's hydrologic unit map the Burning Fork system has a total of 10 stream miles of which 6 miles are considered not to be supporting designated uses while 4 miles are partially supporting uses.

The Burning Fork System lies entirely in Magoffin County on the southern edge of the Unglaciated Alleghany Plateau. The rugged topography is a result of underlying Pennsylvanian aged rock strata of the Breathitt Formation.

Basin impacts include oil drilling operations (occurring throughout the drainage, but principally in the Birch and Arnet branches area), five permitted waste water dischargers (in the lower 2.5 miles) and some scattered coal mining operations. Additional impacts include urbanization in the lower-most portion of the drainage, silviculture and agriculture.

The oil well brine discharges have severely degraded the water quality of at least 10 miles of the Burning Fork system. Kentucky Surface Water Standards (KSWS) for dissolved oxygen, chloride, un-ionized ammonia, phenolic compounds, zinc and iron were exceeded. Of the 53 physicochemical parameters analyzed, 23 exceed the STORET (1979-1983) mean values at one or more sampled sites. Forty-nine sediment parameters were analyzed; nine of the parameters were considered moderately polluted, while five were considered heavily polluted at one or more of the sampling locations.

The biological communities were severely degraded by the oil well brine discharges. The algal community (53 taxa) was devoid of green algae and periphyton was scarce. The diatoms that exhibited the greatest relative abundance were either halophilic or tolerant to high conductivity. The macroinvertebrates (17 taxa) were severely stressed. Several major groups of aquatic insects, which are common to eastern Kentucky streams, were absent from the Burning Fork systems. The fish fauna was depauperate. Only nine taxa were taken from the system and the Index of Biotic Integrity was either poor or could not be calculated.

Bacteriological data was collected from nine locations in the Salyersville, Kentucky area. Six of the sites were located in the Burning Fork system. The fecal coliform counts at four locations exceeded KSWS for primary contact recreation.

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RECOMMENDATIONS

1) Based on the diversity of suitable aquatic habitat that exists throughout the Burning Fork system and the assumption that communities could recover with the elimination of the oil well brines, it is recommended that the entire segment be designated for Aquatic Life/Warmwater Aquatic habitat per 401 KAR 5:031, Section 4(1) and the criteria of that section be applied without modification.

2) Fecal coliform counts are expected to meet Kentucky Surface Water Standards (KSWS) provided that wastewater treatment plants are operated correctly, direct pipes from private sewage disposal systems to the creek are eliminated and proper land use practices are implemented. Therefore, it is recommended that the Burning Fork system be designated for Primary and Secondary Contact Recreation per 401 KAR 5:031, Section 6 and the criteria of that section be applied without modification. It is further recommended that additional bacteriological studies be conducted in the Burning Fork and Licking River systems to precisely identify fecal comtamination sources and recommend appropriate solutions.

3) Since no public water supply withdrawal occurs in the Burning Fork system, this portion of the segment <u>is</u> <u>not</u> recommended for Domestic Water Supply (401 KAR 5:031, Section 5).

4) Based upon observed and measured negative impacts to water quality and aquatic life, it is recommended that Division of Water district office personnel implement mitigation and corrective measures in the Burning Fork basin.

5) It is recommended that additional physicochemical and biological monitoring be repeated to document the success of enforcement action and to determine instream water quality improvement and recovery.

SUMMARY

1) The Burning Fork subbasin in Magoffin County constitutes a portion of the Licking River segment (05040) according to the Water Quality Management Plan for Kentucky. The stream system lies on the southern edge of the Unglaciated Alleghany Plateau of the Appalachian Plateaus Province, which is also known as the Eastern Coal Fields. Burning Fork is a fourth order stream which drains 46.6 km^2 (18 mi^2). It flows west for approximately 12.6 km (7.5 mi) before joining the Licking River. Though no flow data exist on Burning Fork, observations made during this study indicate that approximately the upper half of the drainage does not flow during dry periods of the year. Basin impacts, principally created by brine and sewage discharges, will need to be mitigated before the streams in the basin can achieve the recommend designated uses of Aquatic Life/Warmwater Aquatic Habitat and Recreational Use/Primary and Secondary Contact Recreation.

2) Ten miles of the Burning Fork system appear on the United State Geological Survey's hydrologic unit map. Biological and physicochemical data indicate that approximately 6 miles are not supporting designated uses with the remaining 4 miles considered partially impaired.

3) The major impact to the Burning Fork system is oil brine. Lesser impacts include permitted wastewater treatment discharges (occurring in the lower 2.5 miles of the drainage), coal mining operations (scattered throughout the drainage), urbanization (confined to the area around the mouth), silviculture and agriculture.

4) Potential and existing stream uses, such as recreation, water supply, etc., have been impaired or eliminated by brine pollution.

5) Kentucky Surface Water Standards (KSWS) for dissolved oxygen, chloride, un-ionized ammonia, phenolic compounds, zinc and iron were violated at one or

more sampled sites. In addition, the stream bottoms below Birch Branch were covered with a reddish iron deposit.

6) Of the 53 physicochemical parameters analyzed from five locations, 23 exceeded STORET (1978-1983) mean values at one or more sites. The parameters were as follows: conductivity, acidity, alkalinity, biochemical oxygen demand, chemical oxygen demand, chloride, total dissolved solids, fluorides, total hardness, suspended solids, ammonia-nitrogen, total Kjeldahl nitrogen, phosphorus, barium, calcium, chromium, iron, magnesium, manganese, nickel, potassium, sodium, and zinc.

7) A total of 49 sediment parameters were analyzed. Except for pentachlorophenol, all of the 31 organics were at or near detection levels. Of the 18 remaining parameters, nine were considered moderately polluted (ammonia, oil and grease, total Kjeldahl nitrogen, arsenic, iron, lead, manganese, nickel and zinc) and five were classified as heavily polluted (oil and grease, cyanide, iron, manganese and nickel) at one or more of the sampling locations.

8) Bacteriological criteria, collected from nine locations in the Salyersville area (i.e. Licking River and the Burning Fork System), violated KSWS at four locations. The fecal coliform/fecal streptococcus ratios were mixed, indicating the source of fecal contamination orginated from both human and animal sources. This data indicates that at least 10 miles of the Burning Fork system are not attaining the primary contact recreational use. An unknown number of miles in the Salyersville are not meeting Primary Contact Recreational Use criteria.

9) The Burning Fork system has well developed small stream aquatic habitats. It possess good pool riffle development throughout most of the system, as well as good bankside habitats. If the severe brine discharges were

eliminated this stream system would be expected recover and support a diverse aquatic flora and fauna.

10) A total of 53 algal taxa were observed from the Burning Fork System. The algal community was stressed at all three biological sampling locations. No green algae was observed and periphyton was scarce. The diatoms that exhibited the greatest relative abundance were either halophilic or tolerant to high conductivities, which is a reflection of the brine discharges. Diatom taxa richness and species diversity were relatively low at each station.

11) The macroinvertebrate communities were stressed as indicated by the low number of taxa encountered in the basin (17). The taxa richness, species diversity and equitability were low at two of the three sampling sites. These values could not be calculated at one location since no living organisms were observed. Several major groups of aquatic insects (Ephemeroptera, Plecoptera and Trichoptera) were not observed in the Burning Fork system. These organisms would be expected to be present because there is suitable aquatic habitat throughout the drainage.

12) The fish fauna of the Burning Fork system was depauperate. A total of only nine species were taken from the basin. No fish were collected at one site (40-3) because of an excessively high chloride level (37,200 mg/l). The Index of Biotic Integrity was calculated as poor at the two locations in which fish were present.

INTRODUCTION

The Burning Fork subbasin lies within Magoffin County, Kentucky. This drainage, including tributaries, from the headwaters to the confluence with Licking River (Licking River MP 269.9), constitutes a portion of one segment (Proctor, Davis, Ray, Inc. 1975) designated as 05 (Licking River Basin) 40 (Licking River segment).

A survey of Burning Fork was undertaken by the Kentucky Department for Environmental Protection (DEP) in September, 1984. Five sampling stations were established (Figure 1) and sampled once during a low flow period. The location of these stations, dates sampled and parametric coverage are given in Appendix A.

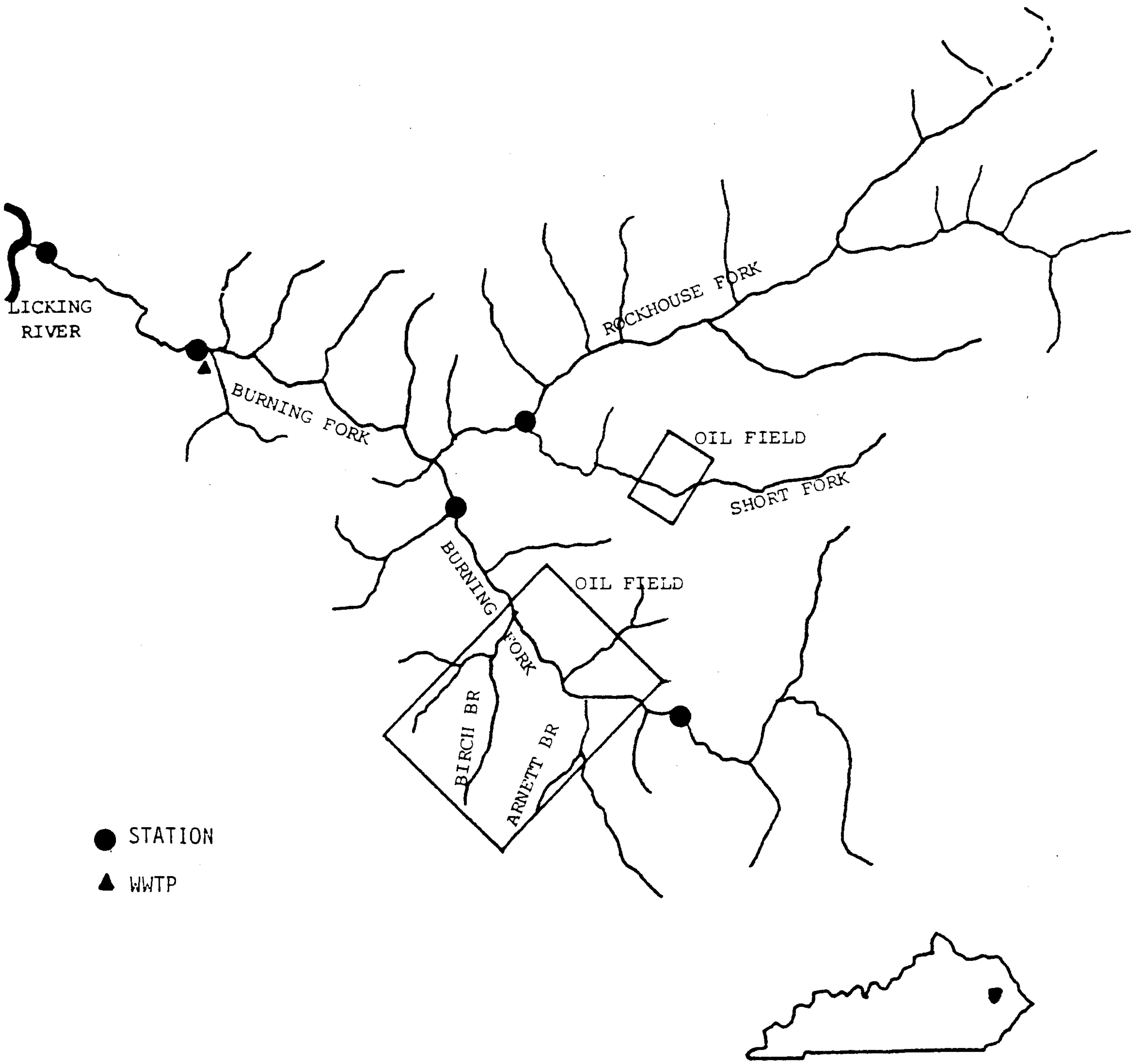
The purposes of this investigation were as follows:

1. To determine the existing water quality of the basin.
2. To determine the aquatic uses currently being achieved in the drainage.
3. To determine the causes of any impairments of the aquatic uses.
4. To determine what aquatic uses can be attained based on the physical, chemical and biological characteristics of the watershed.

However, because of the study design and time constraints, it was not always possible to address specific sources of constituents which may be impairing the aquatic uses or to recommend remedies for problems. A more detailed, multi-discipline approach would be required to study those aspects and determine an appropriate management plan.

A review of the United States Geological Survey's hydrologic unit map indicates that 10 miles of the Burning Fork system appear there. Data from this report show that 6 miles of the systems do not support designated uses while the remaining 4 miles only partially support usees.

Figure 1: Map of the Burning Fork Subbasin with Sampling Locations



Literature Review

There is apparently no published physicochemical or biological data on the Burning Fork System.

Basin Impacts

Five permitted dischargers discharge treated waste to Burning Fork or its small tributaries in the lower 2.5 miles of the stream (Table 1). The largest permitted discharger is the Prater Borders Elementary School with a design capacity of 5,000 gallons-per-day (GPD). Pipes draining household waste into the creek, were observed in the upper half of the drainage.

Oil drilling and coal mining operations have occurred or are occurring in the drainage. An oil field is located in the Birch and Arnet Branch portions of the drainage. Scattered oil wells also occur in the Rockhouse Branch section of the drainage. Small active and inactive surface mining operations may be found throughout the drainage. A deep mining operation and a coal preparation facility are located in the headwaters of Burning Fork near Ivyton, Kentucky.

Additional watershed activities include silviculture, agriculture and urban (primarily the city of Salyersville) uses.

Table 1: Permitted Dischargers to Segment 05040

Facility #	Facility Name	Design Flow (GPD)
05040001	Parkway Motel	1,000
05040002	Prater Borders Elementary School	5,000
05040004	Appalachia Motel	4,000
05014011	Parkway Standard Service Station	1,500
05040012	Druthers Resturant	3,000

Stream Uses

Because of the severe brine pollution that is presently occurring, Burning Fork's recreational potential has been eliminated. Some fishing may occur around the mouth of the stream. Because of the pollution problems, Burning Fork probably is rarely used for swimming; no primary contact recreation was observed during this study.

Domestic water supply withdrawal does not occur in the drainage.

Hunting for waterfowl, small mammals and deer may occur throughout the drainage in rural areas. Game animals, as well as non-game species, may utilize the various streams and adjacent buffer zones for breeding, rearing young, feeding and as a water supply. Trapping for small mammals such as muskrats, mink, etc., is also expected to occur in the drainage. Several dead muskrats were observed at station 05040003 along with numerous dead crayfish. The extremely poor water quality observed at this site was apparently responsible.

METHODS

Water and composite sediment samples were analyzed in accordance with the latest edition of Standard Methods for the Examination of Water and Wastewater (APHA 1981) and United States Environmental Protection Agency's (U. S. EPA) Methods for Chemical Analysis of Water and Waste (U.S. EPA 1979). Field turbidity measurements were taken with an HF Instruments Model DRT-15 turbidimeter. Field conductivity was determined with a Yellow Springs Instrument Company (YSI) Model 33 S-C-T meter. Field measurements for dissolved oxygen (DO) and water temperature were conducted with a YSI Model 54A oxygen meter. An Analytical Measurements Model 707B pH meter was used for field pH.

Biological samples were collected utilizing a variety of techniques. Qualitative algal samples were procurred by selectively scraping or suctioning material from all available habitats. Samples were preserved in the field with 5% buffered formalin and transported to the Division of Water (DOW) biological laboratory for analysis. Diatoms were treated with 30% hydrogen peroxide and potassium dichromate to remove organic material (van der Werff 1955), and several slides randomly scanned for the presence of rare taxa.

Macroinvertebrate qualitative samples were taken by selective picking various substrate types and by collecting in different habitats with a triangular kick net. Quantitative samples were collected using a modified Hornig and Pollard (1978) travel-kick method over a 3.05 m (10 ft) length for 60 seconds. All invertebrate samples were preserved in the field in 70% alcohol solution and transported to the DOW biological laboratory for enumeration and identification. The trophic relationships follow those outlined by Merritt and Cummins (1978) and Hawkins and Sedell (1982). Aquatic macroinvertebrates were placed into one of three pollution categories, (i.e. tolerant, facultative and intolerant), generally based on information presented by Weber (1973) and Hart and Fuller (1974). These categories are defined by Beck (1955) and Weber

(1973) as follows: tolerant organisms are associated with gross organic contamination and are generally capable of thriving under anaerobic circumstances; facultative organisms are capable of tolerating a wide range of environmental conditions, including moderate levels of organic enrichments, but cannot exist under anaerobic conditions; intolerant organisms are sensitive to even moderate levels of organic enrichment and are generally unable to withstand even moderate reductions of dissolved oxygen.

Diatom and macroinvertebrate species diversity ($\bar{d}$) and equitability (e) were calculated using the procedure described by Weber (1973). Diatom relative abundance, $\bar{d}$ and e were generated by counting a minimum of 500 valves. Macroinvertebrate relative abundance was calculated with the pooled quantitative data.

Fish were collected using a 3.4 m by 1.2 m, 0.3 cm mesh, common sense minnow seine. Both pool and riffle areas and all recognizable habitat types were sampled. The fish samples were preserved in 10% formalin solution and transported to the DOW biological laboratory for enumeration and identification. Fish community structure was analyzed using the methods of Karr (1981).

Bacteriological samples were collected from directly below the water's surface in 250 ml, wide mouth, sterile nalgene jars, placed on wet ice and returned for analysis to the DOW laboratory within six hours. Analyses for fecal coliform and fecal streptococcocus bacteria were performed using the membrane filter techniques outlined by Bordner et al. (1978).

PHYSICAL EVALUATION

Burning Fork, a fourth order stream, lies entirely in Magoffin County, Kentucky. It flows west for 12.1 km (7.5 mi) and joins the Licking River (MP 269.9) at Salyersville (population 1350). The largest tributary to Burning Fork is Rockhouse Fork. According to Bower and Jackson (1981), Burning Fork drains 46.6 km^2 (18 mi^2). Though no flow data exist for the Burning Fork system, because of the small size of the stream and the very low water levels observed during sampling, the stream flow during periods of drought is through to be zero. Waste treatment plant discharges in the lower portion of the drainage, may create some perminate flow.

The basin lies along the southern edge of the Unglaciated Allegheny Plateau, a region of the Appalachian Plateaus Province (Quarterman and Powell 1978). This area is also known as part of the Cumberland Plateau (Lobeck 1929) and/or part of the Eastern Kentucky Coal Field (Rice et al. 1980). Generally, it is a well-dissected upland with level or flat land occurring only along creek valleys (McGrain and Currens 1978). Burning Fork meanders through a narrow valley surrounded by steep, forested hillsides. Elevations range from 305m (1000 ft) above mean sea level (msl) in the headwaters down to 256 m (840 ft) above msl at the mouth. Average gradient for Burning Fork is 4m/km (21.3 ft/mi); however, sampling locations were selected in areas of moderate to low gradient.

The rugged topography is a result of underlying Pennsylvanian aged rock strata of the Breathitt Formation (McDowell et al. 1981). Minerals found in these strata include siltstone, shale, sandstone and coal. Alluvial deposits form the major strata underlying Burning Fork closer to its mouth. Three soil association occur in the drainage (Proctor, Davis, and Ray 1975); their characteristics are given in Table 2.

The following is a brief description of the sampling stations. More detailed information is given in Appendix A.

Table 2: Soils of the Burning Fork Subbasin

Soil Association	Slope [1,2] %	Drainage[2] Class	Potential [1] Sediment Runoff	Infiltration	Septic Tank[1] Absorbtion Rating
Stendal	0-3	Somewhat poorly-drained	Medium	Slow	Severe
Pope	0-4	Well drained	Low	Moderate	Severe
Cotaco	2-8	Moderately well to Somewhat poorly-drained	Medium	Slow	Moderate
Jefferson	5-20	Well-drained	High	Moderate	Severe
Wharton	3-10	Moderately well-drained	High	Slow	Severe
Dekalb	12-75	Somewhat excessively to well-drained	High	Moderate	Severe
Weikert	50-70	-----	High	Moderate	Severe
Shelocta	30-70	----	High	Moderate	Severe

(1) Proctor, Davis and Ray (1976)

(2) Bailey and Winsor (1964)

Burning Fork

05040001 (40-1)

Physicochemical samples were collected at the KY 7 bridge (MP 0.1) in Magoffin County. The stream is fourth order, with low gradient and consisted of a long pool. It receives runoff from the city of Salyersville (pop. 1,352) and adjacent row crops. Stream banks were covered with a diversity of vegetation and their stability was good. Stream width ranged from 3 to 5m and depth from 0.2 to 0.6 m. The water and substrate had a reddish color, as well as an oil sheen on the surface. Fines with scattered boulders were the primary substrate materials (also present were trash and debris, i.e. old tires, cans, bottles, etc.). Submerged roots and logs provided additional stream habitat.

Burning Fork

05040002 (40-2)

Physicochemical and biological samples were collected below Lick Branch (MP 1.35), just off the Mountain Parkway in Magoffin County. Burning Fork at this location is a fourth order, low gradient stream alternating between long pools and small riffles. Adjacent land has been converted into commercial development at the upper end of the site and old fields downstream. The riparian zone extended from both banks for approximately 15m. Bank stability was considered good. Stream width ranged from 1 to 5m and depth from 0.1 to 0.3m. The water had a slight reddish color. Gravel and fines were the primary substrate material throughout the site. Other stream habitats noted were old tires, submerged roots and logs.

Burning Fork

05040003 (40-3)

Physicochemical and biological samples were collected at a ford (MP 3.25) just off KY 1888 in Magoffin County. Burning Fork is a third order, low gradient stream at this point, alternating between long pools and small riffles. Land use in the area is primarily agriculture and scattered dwellings. Riparian zones had been altered to lawn grasses extending to the water's edge in some areas and seldom exceeded 10m. Bank stability was rated fair. Stream width ranged from 1 to 5m and depth from 0.01 to 0.5m. The substrate, primarily gravel and fines, was covered with a red flocculent. The water also had an obvious red cast. Dead crayfish and muskrats were observed in shallow water areas. No aquatic animal life was found. Local residents reported observing live minnows, frogs, snakes and crayfish before a recent slug of brine water entered the stream.

Burning Fork

05040004 (40-4)

Physicochemical samples were collected from a long pool area of Burning Fork just off KY 1888 between Ivyton and Bradley. Here, the stream is second order with low gradient and no riffles. Adjacent land use included agriculture and scattered dwellings. Riparian zones were narrow, typically 3 to 6m. Bank stability was good. Stream width ranged from 3 to 5m and depth from 0.15 to 0.6m. Stream habitats included undercut banks, submerged roots and logs and log piles.

Rockhouse Fork

05040005 (40-5)

Physicochemical and biological samples were collected below the mouth of Short Fork just off KY 1415 in Magoffin County. At this location, Rockhouse Fork is a third order, low gradient stream alternating between long pools and short, shallow riffles. Adjacent land use included row crops and pastures. Riparian zones in most areas were less than 10m wide. Stream banks were lined with shrubs and considered stable. Stream width ranged from 1 to 6m and depth from 0.1 to 0.6m. Pool substrate materials were primarily fines and detritus, while pebbles, gravel and fines formed riffle substrates. Undercut banks, submerged roots and logs, log piles and man-made objects (tires and other assorted debris) provided additional instream habitats.

PHYSICOCHEMICAL DISCUSSION

A total of 53 physicochemical parameters were analyzed from surface grab samples taken from five sampling locations in the Burning Fork system (Table 3). Composite sediment samples were collected at all five sampling locations and a total of 49 parameters were analyzed. No additional published physicochemical or sediment data exist for the Burning Fork system.

Data from this report indicate that the entire drainage is impacted by brine discharges from oil well drilling operations. Those parameters typically associated with brine discharges (i.e. chloride (Cl), sodium (Na), conductivity, total dissolved solids, total hardness, etc.) were elevated at all sampling locations. Other basin activities, such as surface mining, apparently have little effect on the water quality in the drainage. The five WWTP's that discharge into the lower 2.5 miles of the drainage (Figure 1) may be responsible for degrading the water quality, however, these impacts would be difficult to separate from those caused by brine discharges.

Conductivity, total dissolved solids (TDS) and total hardness were considerably elevated above the STORET (1979-1983) mean values at all stations except at 40-4 (Table 4), while the alkalinity values were below or only slightly elevated above the STORET (1979-1983) mean (Tables 3 and 4). Conductivity values greatly exceed the 150-500 umhos/cm range noted by Ellis (1937) as supporting a well developed fish fauna. Ellis (1937) observed that when conductivity exceeded 500 umhos/cm the fish fauna was reduced. McCarraher and Thomas (1968) observed inhibited fish spawning when the TDS values exceeded 2000 mg/l. All stations except 40-4 greatly exceeded this TDS value (Tables 3 and 4). Hardness is caused by polyvalent metallic ions dissolved in water (U.S. EPA 1976) nine of which were recorded from the Burning Fork system at levels that exceed STORET (1979 - 1983) mean values (Table 4). Using the hardness classifications established by Sawyer (1960), stations 40-1, 40-2, 40-3, while 40-5 will be considered

Table 3: Physicochemical data for for the Burning Fork System

Parameter	Stations 40-1	40-2	40-3	40-4	40-5
Conductivity (umhos/cm @ 25°C)	3,996	6,300	90,000	428	14,790
Salinity (0/100)	2	5	54	0	8
pH (S.U.)	7.3	7.3	6.3	7.8	7.1
Air temperature (°C)	29	27	26	27	27
Water temperature (°C)	21	22.5	25	24	24
Turbidity (NTU)	6.0	1.8	360	64.0	5.6
DO (mg/l)	*2.3	5.5	*2.7	12.3	9.2
Acidity (mg/l)	16.4	11.4	148	7.0	8.0
Alkalinity (mg/l)	82.4	52.3	36.2	126	58.8
BOD_5 (mg/l)	8.6	9.2	42.3	20.3	4.7
Chloride (mg/l)	1,390	2,250	37,200	481	5,040
COD (mg/l)	68.9	83.9	310	51.7	55.9
CN (free) (mg/l)	<0.01	<0.01	<0.01	<0.01	<0.01
Total Dissolved Solids (mg/l)	3,070	4,930	66,800	308	11,100
Fluoride (mg/l)	0.12	0.11	0.14	0.16	<0.10
Total Hardness (mg/l)	652	1,000	14,800	165	2,280
Sulfide (mg/l)	<0.01	<0.1	<0.1	<0.1	<0.1
Phenols (mg/l)	<0.005	<0.005	0.015	0.008	0.010
Sulfate (mg/l)	17.0	27.3	<2.0	50.8	<2.0
Suspended Solids (mg/l)	16	20	57	60	30
Total Organic Carbon (mg/l)	4.7	2.6	ND	11.6	3.4
NH_3-N (mg/l)	0.645	0.200	*45.3	0.053	0.149
$NO_2 + NO_3$ - N (mg/l)	0.070	0.155	0.025	0.215	0.035
TKN (mg/l)	1.62	0.585	141	1.51	0.467
Phosphorous (total) (mg/l)	0.71	0.013	0.042	0.162	0.013
Phosphorous (dissolved) Ortho (mg/l)	0.017	0.001	0.015	0.004	0.004
Phthalate Esters (ug/l)	<0.150	<0.24	<0.150	<0.150	<0.150
Benzyl butyl phthalate (ug/l)	<0.025	<0.04	<0.025	<0.025	<0.025
Dis (2-ethylhexyl) phthalate (ug/l)	<0.025	<0.04	<0.025	<0.025	<0.025
Bi-n-butal phthalate (ug/l)	<0.025	<0.04	<0.025	<0.025	<0.025
Di-n-octyl phthalate (ug/l)	<0.025	<0.04	<0.025	<0.025	<0.025
Di-ethyl phthalate (ug/l)	<0.025	<0.0-4	<0.025	<0.025	<0.025
Di-methyl phthalate (ug/l)	<0.025	<0.04	<0.025	<0.025	<0.025
Al (total)) (ug/l)	<1	<1	1	34	10
As (total) (ug/l)	<1	<1	<1	<1	<1
Ba (total) (ug/l)	2,900	4,230	128,000	79	7,430
Be (total) (ug/l)	<1	<1	<1	<1	<1
Cd (total) (ug/l)	<1	<1	<1	<1	<1
Ca (total) (mg/l)	177	354	4,560	49.7	810
Cr (total) (ug/l)	<1	5	2	<1	<1
Cu (total) (ug/l)	4	2	1	1	2
Fe (total) (ug/l)	3,220	400	67,200	2,950	1,230
Pb (total) (ug/l)	<1	<1	<1	<1	<1
Mg (total) (mg/l)	45.9	70.1	8.99	12.8	17.2
Mn (total) (ug/l)	4,270	1,270	19,100	1,370	1,780
Hg (total) (ug/l)	<0.1	<0.1	0.1	<0.1	<0.1
Ni (total) (ug/l)	<1	<1	17	<1	<1
K (total) (mg/l)	9.86	13.5	142	4.48	19.9
Se (total) (ug/l)	<1	<1	<1	<1	<1
Ag (total) (ug/l)	<1	<1	<1	<1	<1
Na (total) (mg/l)	664	1,040	17,100	72.8	1,770
Zn (total) (ug/l)	31	13	108	24	36
Oil and Greese	<1.0	<1.0	<1.0	<1.0	<1.0

ND - not determined

Table 4: List of Parameter by Station that Exceeded STORET (1979-1983) mean values.

Parameter	Stations/Values	STORET Mean
Conductivity (umhos/cm)	40-1 (3,996), 40-2 (6,300) 40-3 (90,000) 40-4 (428), 40-5 (14,790)	318
Acidity (mg/l)	40-1 (16.4), 40-2 (11.4), 40-3 (148) 40-5 (8.0)	7.35
Alkalinity (mg/l)	40-4 (126)	85.8
BOD_5 (mg/l)	40-1 (8.6), 40-2 (9.2), 40-3 (42.3) 40-4 (20.3), 40-5 (4.7)	1.24
Chloride (mg/l)	40-1 (1,390), 40-2 (2,250), 40-3 (37,200) 40-4 (481), 40-5 (5,040)	21.30
Total Dissolved Solids (mg/l)	40-1 (3,070), 40-2 (4,930), 40-3 (66,800, 40-4 (308), 40-5 (11,100)	227
Florides (mg/l)	40-3 (0.14), 40-4 (0.16)	0.13
Total Hardness (mg/l)	40-1 (652), 40-2 (1,000), 40-3 (14,800), 40-4 (165), 40-5 (2,280)	136
Suspended Solids (mg/l)	40-3 (57), 40-4 (60)	54.5
NH_3-N (mg/l)	40-1 (0.645), 40-3 (45.3)	0.233
TKN (mg/l)	40-1 (1.62), 40-3 (141), 40-4 (1.51)	0.64
Phosphorous mg/l	40-1 (0.71), 40-4 (0.162)	0.147
Ba (total) (ug/l)	40-1 (2,900), 40-2 (4,230), 40-3 (128,000), 40-4 (79), 40-5 (7,430)	76.5
Ca (Total) (mg/l)	40-1 (177), 40-2 (354), 40-3 (4,560), 40-4 (49.7), 40-5 (810)	44.9
Cr (total) (ug/l)	40-2 (5)	3.1
Fe (total) (ug/l)	40-1 (3,220), 40-3 (67,200), 40-4 (2,950) 40-5 (1,230)	1,023
Mg (total) mg/l	40-1 (45.9), 40-2 (70.1), 40-5 (17.2)	14.4
Mn(Itotal (ug/l)	40-1 (4,270), 40-2 (1,270), 40-3 (19,100), 40-4 (1,370), 40-5 (1,780)	205
Ni (total) (ug/l)	40-3 (17)	15.9
K (total) (ug/l)	40-1 (9.86), 40-2 (13.5), 40-3 (142), 40-4 (4.48), 40-5 (19-9)	3.6
Na (total) (mg/l)	40-1 (664), 40-2 (1,040), 40-3 (17,100), 40-4 (72.8), 40-5 (1,770)	23.3
Zn (total) (mg/l)	40-3 (108)	37.9
COD (mg/l)	40-1 (68.9), 40-2 (83.9), 40-3 (310), 40-4 (51.7), 40-5 (55.9)	13.1

very hard, while station 40-4 falls in the hard category. The elevated values for conductivity, TDS and hardness observed in the Burning Fork system are the result of the brine discharges occurring in the drainage.

Dissolved oxygen (DO) values were below Kentucky Surface Water Standards (KSWS), 401 KAR5:031, Section 4(1)(e)1, at stations 40-1 and 40-3. In addition, the dissolved oxygen percent saturation was 26% and 31% at stations 40-1 and 40-3, the remaining two stations both exceed 100%. Unpolluted streams will normally be at 100% saturation or slightly above; however, sluggish waters may exhibit some greater variation, while the input of organic matter will cause oxygen concentrations to decrease (Whitton 1975). According to Ellis (1937), Thompson (1925) and Stroud (1967), 5 mg/l DO is the lower limit for a "well rounded fish fauna". Reduction in the level of available oxygen (i.e. reduced, DO and percent saturation levels) has an adverse effect on many physiological, biochemical and behavioral processes in fish (Davis 1975).

The biochemical oxygen demand (BOD_5) and chemical oxygen demand (COD) were elevated above the STORET (1979-1983) mean value at all sampling locations. The BOD_5 values at stations 40-3 an 40-4 were particularly high. Biochemical oxygen demands of this magnitude may result in dissolved oxygen depletion, particularly at night when algal respiration exceeds photosynthesis. This may eliminate those taxa requiring high levels of DO. The high COD values observed are the result of the oil well discharges.

Chloride greatly exceeded the STORET (1979-1983) mean of 22.0 mg/l at all sampling locations and KSWS at all sites except 40-4 (Table 4). In addition, sodium chloride is the major constituent of the brines. Studies by Birge et al. (1985) indicate that chronic toxicity to embryos and larvae of sensitive aquatic organisms will occur at 600 mg/l, while acute toxicity will occur at 1200 mg/l. All sites except 40-4 exceeded both the chronic and acute toxicity levels for embryos and larvae of sensitive aquatic species.

According to KSWS 401 KAR 5:031 Section 4(h) phenolic compounds should not exceed 5 ug/l. Stations 40-2, 40-4 and 40-5 exceeded this criterion. Phenolic compounds are known to impart objectionable orders in water supplies and undesirable tastes in fish tissue at levels as low as 2 to 5 ug/l (CWQC 1972).

Ammonia (NH_3-N) concentrations exceeded the STORET (1979 - 1983) mean at stations 40-1 and 40-3 (Table 4) and violated the KSWS for un-ionized ammonia, 401 KAR 5:031, Section 4(1) (g), at station 4-3. Ammonia concentrations in surface waters are normally 1.0 mg/l or less (CWQC 1972). The toxicity of NH_3-N is affected by pH (Ellis 1937, U.S. EPA 1976), temperature, ionic strength (U.S. EPA 1976) and DO concentrations (Downing and Merkens 1955, Merkens and Downing 1957). According to U.S. EPA (1976) many laboratory experiments have demonstrated that lethal concentrations for a variety of fish species range from 0.2 to 2.0 mg/l. Although concentrations of un-ionized NH_3-N below 0.2 mg/l may not be lethal to a significant portion of a fish population, such concentrations may still exert adverse physiological or histopathological effects (Flis 1968, Lloyd and Orr 1969, Smith and Piper 1975). Flis (1968) noted that carp exposed to sublethal NH_3-N concentrations developed extensive necrotic changes and tissue breakdown in various organs. Therefore, the un-ionized NH_3-N concentrations observed at station 40-3 may be acutely toxic to freshwater organisms.

Total Kjeldahl nitrogen (TKN) exceeded the STORET (1979-1983) mean value at stations 40-1, 40-3 and 40-4 (Table 4). The value observed at station 40-3 was exceptionally high, even greater than what would be expected for raw sewage. Total Kjeldahl nitrogen is a measure of NH_3-N plus certain forms of organic nitrogen concentrations and vary from a few hundred micrograms per liter in some lakes to more than 20 mg/l in raw sewage (APHA 1981).

The total phosphorus concentrations observed at stations 40-1 and 40-4 exceeded the STORET 1979-1983 mean value (Table 4). However phosphorus values of the magnitude observed at these stations is not sufficient to create a serious problem.

Total metal values for barium (Ba), calcium (Ca), chromium (Cr), iron (Fe), magnesium (Mg), manganese (Mn), nickel (Ni), potassium (K), sodium (Na) and zinc (Zn) exceeded STORET mean values (Table 4). In addition KSWS for iron 401 KAR 5:031 Section 4(1)(i)4 were exceeded at four of the five sampling stations during this study.

Barium exceeded the STORET (1979-1983) mean value of 76.5 µg/l at all stations. Barium, an alkaline earth metal, occurs in nature chiefly as barite ($BaSO_4$) and witherite ($BaCO_3$), both of which are highly insoluble (U.S. EPA 1976). Experimental data indicate that the soluble Ba concentration in fresh and marine water generally would have to exceed 50 mg/l before toxicity to aquatic life would be expected (U.S. EPA 1976). The U.S. EPA (1976) speculated that in most natural waters there is sufficient sulfate and carbonate to precipitate the Ba present as a virtually insoluble, nontoxic compound. Station 40-3 had a Ba value greatly in excess of 50 mg/, which may be toxic to the aquatic life there.

The iron (Fe) concentration observed at stations 40-1, 40-3, 40-4 an 40-5 exceeded KSWS for warmwater aquatic habitat, 401 KAR 5:031, Section 4(1)(i)4. Iron is an abundant and widespread constituent of rocks and soil, and concentrations of only a few tenths of a milligram per liter in water can render it unsuitable for some uses (Hem 1970). The U.S. EPA (1976) recommended a protective criterion of 1.0 mg/l (= 1000 ug/l), which is equivalent to KSWS, for the protection of aquatic life. However, concentrations of iron less than the 1.0 mg/l value may be toxic to aquatic life. Warnick and Bell (1969) derived a 96-hour LC_{50} of 320 ug/l of iron for selected aquatic insects, i.e. certain mayflies, stoneflies and caddisflies, all of which are important fish food organisms. However, acute and chronic embryo-larval toxicity tests conducted on both fish and aquatic invertebrates by Birge et al. (1985) indicate that long-term exposure to iron should not exceed 1.0 mg/l. Therefore, iron concentrations at the stations listed above have the potential to be toxic to aquatic life.

Zinc is a common trace element of natural waters and is required in the metabolism of most organisms. The toxicity of Zn is influenced by hardness, DO, pH (U.S. EPA 1976), and ionic strength (U.S. EPA 1980). However, the available toxicity data indicate that hardness effects are much less dramatic for chronic toxicity of Zn than for acute toxicity (U.S. EPA 1980). The U.S. EPA criteria for total recoverable Zn, for freshwater aquatic life, is 47 ug/l as a 24-hour average and a concentration (in ug/l) should not exceed the value given by the formula e(0.83[ln(hardness)]+1.95) at any time. Therefore, the Zn concentration observed at all stations may pose chronic toxicity problems for the aquatic life.

Sodium (Na) exceeded the STORET (1979-1983) mean value of 23.3 mg/l at all sampling sites. A review of the physicochemical data indicate that sodium chloride (NaCl) is the principal constituent of the brine discharges to Burning Fork. Brine studies by Wiebe et al. (1934) in Texas, Clemens and Jones (1954) in Oklahoma and Krieger and Hendrickson (1960) and DOW (1982) in Kentucky showed the principal constituent was NaCl. Sodium, the most abundant member of the alkali-metal group, tends to stay in solution once dissolved (Hem 1970). Therefore, excessive Na concentrations, such as the ones observed here, may have public health ramification for anyone that is on a low sodium diet using the brine impacted stream reaches as a drinking water source.

Sediment data were collected from the same five sampling locations in the Burning Fork system. A total of 49 parameters were analyzed. Of the 31 organics tested for, all were near or below detection levels (Table 5). Of the remaining 18 parameters, nine fell in U.S. EPA (1977) moderately polluted category at one or more stations, while five were considered in the heavily polluted range at one or more locations (Table 6).

Table 5: Sediment Data for the Burning Fork System Collected November 14, 1984

Parameters (mg/kg)	40-1	40-2	40-3	40-4	40-5
Chemical Oxygen Demand	23,100	22,300	24,500	15,700	19,900
NH_3-N	112	31.1	97.8	19.3	142
Oil & Grease	4340	984	822	266	1040
Total Kjeldahl Nitrogen	1870	1020	1130	381	1750
Total Organic Carbon, %	1.3	0.5	0.4	0.1	0.7
Volatile Solids, %	5.4	5.0	5.1	2.6	6.5
Cyanide	<1.4	<1.10	<0.88	<0.74	<1.09
PCB's	<0.1	<0.1	<0.1	<0.1	1.0
Aldrin	<0.01	<0.01	<0.01	<.01	<0.01
Dieldrin	<0.01	<0.01	<0.01	<0.01	<0.01
DDT, Total	0.01	<0.01	<0.01	<0.01	<0.01
O,P' - DDE	<0.01	<0.01	<0.01	<0.01	<0.01
P,P' - DDE	0.01	<0.01	<0.01	<0.01	<0.01
O,P' - DDK	<0.01	<0.01	<0.01	<0.01	<0.01
P,P' - DDK	<0.01	<0.01	<0.01	<0.01	<0.01
O,P' - DDT	<0.01	<0.01	<0.01	<0.01	<0.01
P,P' - DDT	<0.01	<0.01	<0.01	<0.01	<0.01
Cis Isomer (Chlordane)	0.02	<0.01	<0.01	<0.01	<0.01
Trans Isomer (Chlordane)	0.02	0.02	<0.01	<0.01	<0.01
Trans Isomer (Nonachlor)	<0.01	<0.01	<0.01	<0.01	<0.01
Endosulfan I	<0.01	<0.01	<0.01	<0.01	<0.01
Endosulfan II	<0.01	<0.01	<0.01	<0.01	<0.01
Endosulfan Sulfate	<0.01	<0.01	<0.01	<0.01	<0.01
Endrin	<0.01	<0.01	<0.01	<0.01	<0.01
Endrin Aldehyde	<0.01	<0.01	<0.01	<0.01	<0.01
Endrin Ketone	<0.01	<0.01	<0.01	<0.01	<0.01
Hexachlorobenzene	<0.01	<0.01	<0.01	<0.01	<0.01
Hexachlorocyclohexane	<0.01	<0.01	<0.01	<0.01	<0.01
Alpha BHC, dry solids	<0.01	<0.01	<0.01	<0.01	<0.01
Beta BHC	<0.01	<0.01	<0.01	<0.01	<0.01
Gamma BHC (Lindane)	<0.01	<0.01	<0.01	<0.01	<0.01
Delta BHC	<0.01	<0.01	<0.01	<0.01	<0.01
Methoxychlor	<0.01	<0.01	<0.01	<0.01	<0.01
Mirex	<0.01	<0.01	<0.01	<0.01	<0.01
Pentachlorophenol	<0.02	0.044	<0.02	<0.02	<0.02
Tetrachlorophenol 2,3,4,5	<0.02	<0.02	<0.02	<0.02	<0.02
Tetrachlorophenol 2,3,4,6	<0.02	<0.02	<0.02	<0.02	<0.02
Toxaphene	<0.1	<0.1	<0.1	<0.1	<0.1
Aluminum	5630	8650	7960	4580	11,500
Arsenic	2.14	3.55	3.81	2.25	4.92
Cadmium	0.139	0.080	<0.001	0.035	0.183
Chromium	11.8	12.0	13.8	10.3	16.3
Copper	11.5	12.3	13.6	8.72	14.8
Iron	34,000	32,700	25,300	18,300	26,700
Lead	43.8	16.1	14.8	10.0	15.0
Manganese	339	375	261	395	4050
Mercury	0.032	0.032	0.021	0.019	0.027
Nickel	43.7	56.8	43.2	11.5	25.9
Zinc	88.0	80.6	75.1	47.3	90.3

Table 6: List of Sediment Parameters and Stations that Exceed the United States Environmental Protection Agencies' (1977) Sediment Guidelines

Parameters (mg/kg)	Moderately Polluted	Heavily Polluted
Ammonia	40-1, 40-3, 40-5	
Oil and Grease	40-5	40-1
Total Kjeldahl Nitrogen	40-1, 40-2, 40-3, 40-5	
Cyanide		40-1, 40-2, 40-3, 40-4, 40-5
Arsenic	40-2, 40-3, 40-5	
Iron	40-4	40-1, 40-2, 40-3, 40-5
Lead	40-1	
Manganese	40-1, 40-2, 40-3	40-5
Nickel	40-1, 40-3, 40-5	40-2
Zinc	40-5	

BIOLOGICAL EVALUATION

The biological communities existing in the Burning Fork system were adversely impacted by the oil well brine discharges. At all three sites sampled biologically (40-2, 40-3 and 40-5) the flora and fauna were reduced from what would normally be expected from unimpacted streams of this size in eastern Kentucky.

Bacteriological analyses were conducted for fecal coliform (FC) and fecal streptococci (FS) bacteria at nine locations in the Salyersville, Kentucky area, six of which were located in the Burning Fork system. Four of the samples exceeded the KSWS fecal coliform bacteria criterion for primary contact recreation. Also, the FC/FS ratios were mixed, indicating the fecal pollution source originated from both human and animal sources.

The algal community (53 taxa) was stressed at all three sampling locations. The periphyton was scarce and no green algae was observed. The diatoms that exhibited the greatest relative abundance (RA) were either halophilic or tolerant of high conductivities. Diatom taxa richness and species diversity ($\bar{d}$) were relatively low at each station. (Appendix C).

The macroinvertebrate communities (17 taxa) observed in the Burning Fork system were severely stressed by oil well brine discharges. The total number of taxa, species diversity and equitability were low (Appendix D). No macroinvertebrates were collected at 40-3. Several major groups of aquatic insects (Ephemeroptera, Plecoptera and Trichoptera), which are common constituents of eastern Kentucky streams, were not observed in the Burning Fork system.

The fish fauna of the Burning Fork system was stressed by oil well brine discharges. Only nine taxa were collected from the Burning Fork drainage (Appendix E). This is considerably below what would normally be expected from a stream system of this size based on data presented by Harker et. al (1971) and Jones (1970). Furthermore, the Index of Biotic Integrity (IBI) was poor at stations 40-2 and 40-5 and could not be calculated at stations 40-3 because that site was devoid of fish.

Bacteria

Of the nine bacteriological samples collected in the Salyersville area, four exceeded the fecal coliform (FC) standard for primary contact recreation (i.e. swimming) 401 KAR 5:031, Section 6(1)a (Table 7). There were no violations of the FC standard for secondary contact recreation (i.e. fishing) or pH.

Table 7: Bacteriological Data for the Burning Fork System

Station No.	Source	FC per 100 ml	FS per 100m	FC/FS
40-1	Burning Fork	3000	160	18.75
40-5	Rockhouse Fork	2500	240	10.42
40-6	Burning Fork	980	220	4.45
40-7	Burning Fork	250	280	0.89
40-8	Burning Fork	20	500	0.04
40-9	Burning Fork	220	2400	0..09
40-10	Licking River	16,000	700	22.86
40-11	Salyersville WWTP	<50	<50	NA
40-12	Licking River	220	30	7.3
		< 50	< 50	NA

FC = Fecal Coliforms
FS = Fecal Streptococci
NA = Not Available

Fecal coliform/fecal streptococci ratios were mixed, indicating fecal pollution impacts by man and animal (Table 7). The human influence is probably from pipe discharges, which carried untreated household waste to the drainage, or improperly operating septic tanks. The discharge of the Salyersville WWTP was very turbid and odorous, but low in fecal coliforms, indicating sufficient chlorination was occurring to kill the bacteria present. The chlorination also reduced the amount of bacteria present in the Licking River below the WWTP. The highest FC level (16,000 per 100 ml) observed in the study was just above the WWTP which is influenced by urban runoff from the city of Salyersville.

Any impact from brine water discharges to bacteria was not clear. Further testing should be done in the Licking River and the Burning Fork system with regard to primary contact recreation, because the loading from the Salyersville WWTP and septic tanks may pose a threat to that use.

Algae

Attached algal samples were collected from stations on Burning Fork (40-2 and 40-3) and Rockhouse Branch (40-5) and yielded a total of 53 taxa. A periphyton species list appears appears in Appendix C. Periphyton was scarce at all three stations. The samples were dominated by diatoms, although filamentous blue green algae were present in collections from stations 40-2 and 40-5. No green algae were collected from Burning Fork or Rockhouse Branch. The dominant diatom species from each site were species associated with brackish water. Diatom taxa richness and diversity were relatively low at each station (Appendix C). This suggests that the algal community structure has been altered by the elevated chloride concentrations.

Burning Fork

40-2

The periphyton community collected from this station was limited to six species of blue green algae and 29 species of diatoms. The sampled diatom community was dominated by *Nitzschia reversa* (42.9% relative abundance). *Navicula heufleri* var. *leptocephala* (17.4%) and *Navicula cryptocephala* var. *exilis* (11.0%) were common. *Nitzschia reversa* is associated with streams of high conductivity (Harker, et al. 1981; DOW unpublished data). *Navicula cryptocephala* var. *exilis* and *N. heufleri* var. *leptocephala*, each of which comprised greater than 10% of the diatom community at all three stations, are species tolerant of high chloride concentrations (DOW unpublished data). Diatom species diversity, was relatively low (2.805); equitability was also low (0.463). Twenty-one species were encountered during qualitative counts. The unusually low diatom species richness and diversity combined with the presence of several halophilic species, is indicative of stress resulting from high chloride concentrations.

Burning Fork

40-3

Attached algae were scarce here; no green or bluegreen algae were found and iron hydroxide precipitate was abundant. The diatom community was dominated by *Nitzschia filiformis* (51.4%), a brackish water species (Hustedt 1930; Lowe 1974). *Navicula heufleri* var. *leptocephala* (26.7%) and *N. cryptocephala* var. *exilis* (16.5%) were common in the sample. With a conductivity of 90,000 umhos/cm and chloride concentration of 37,200 mg/l, it is not surprising that station 40-3 had the lowest diatom species diversity (1.872) and equitability (.397) of all three stations sampled. Only 12 taxa were encountered during the proportional count of 500 valves; one additional species was located during random scanning of the sample. Several diatom species collected from this station are considered brackish water species (Lowe 1974; Patrick and Reimer 1967; DOW unpublished data) including *Gyrosigma distortum*, previously unreported from Kentucky (Camburn 1982). Based on the low species richness, diversity and equitability and the dominance of brackish water species, it appears that the diatom community of station 40-3 was adversely affected by the brine discharges occurring in the drainage.

Rockhouse Branch

40-5

As was the case at stations 40-2 and 40-3, attached algae were not abundant here. Three species of filamentous blue green algae were collected, along with 36 species of diatoms, 22 of which were present in the proportional count of 500 valves. The dominant diatom species at this station, *Nitzschia sigma*, is classified by Lowe (1974) as mesohalobous (i.e. a brackish water form) or euryhalobous (occurring over broad ranges of salt concentration). *Navicula cryptocephala* var. *exilis* (23.9%) and *N. heufleri* var. *leptocephala* (23.3%) were again common in the sample. Diatom species diversity (2.754) and equitability (0.426) at this station were higher than station 40-3 and similar to station 40-2, corresponding to the conductivities and chloride concentrations of the 3 sampling sites. The diatom species collected from Rockhouse Branch were forms commonly found in brackish water or water with high conductivity values and elevated chloride concentrations, suggesting that this station is also affected by oil well brine discharges.

Macroinvertebrates

The macroinvertebrate communities were severely degraded by oil well discharges. Seventeen taxa were collected from the system during quantitative and qualitative sampling (Appendix D). With the exception of the midge *Chironomus decorus* gp. at 40-2 and the damselfly *Argia* sp. at 40-5, all populations were depauperate (Appendix D). In addition, several groups of aquatic insects (ephemeropterans, plecopterans, coleopterans and trichopterans) common to eastern Kentucky streams were not observed in the Burning Fork system. Charles (1964) observed either reduction or elimination of these groups in streams impacted by oil well brines. Woodward and Riley (1983) observed a reduction in Plecoptera and Trichoptera in areas impacted by oil field discharges. DOW (1982) also observed a reduction or elimination in Ephemeroptera and Trichoptera in areas receiving oil well brines.

Burning Fork

40-2

A total of 11 taxa were collected from this location. The ephemeropterans, plecopterans, coleopterans, megalopterans and trichopterans were not collected during qualitative and quantitative sampling. Seven of the 11 taxa were chironomids, the only organisms taken in the quantitative samples. Charles (1964), DOW (1982) and Woodward and Riley (1983) observed increases in dipterans in areas impacted by oil well discharges. A similar sized stream north of Burning Fork (Caney Creek) sampled by Harker et al. (1979) yielded 39 taxa of aquatic invertebrates and had all major taxonomic groups. Data presented by Harker et al (1979) indicated that streams in eastern Kentucky have most major groups of aquatic insects as well as crustaceans and mollusks. This site had ample habitat (refer to Physical Evaluation); therefore, a variety of aquatic organisms similar to that observed by Harker et al. (1979) in Caney Creek would have been expected.

Both $\bar{d}$ and e were extremely low (0.1270 and 0.0428, respectively) (Appendix D). Wilbur (1970) notes that polluted streams usually have $\bar{d}$ values below 1.0 and Weber (1983) states that e values of 0.0 to 0.3 are often recorded from degraded streams. The $\bar{d}$ and e values observed here indicate the stream is under severe stress.

<u>Burning Fork</u>

<u>40-3</u>

This stream was so degraded by oil well brines that no aquatic invertebrates were found during quantitative and qualitative sampling. (Appendix D) Since all major habitat types were present, Burning Fork at this location would be expected to have all major groups of aquatic insects present during any sampling period.

<u>Rockhouse Fork</u>

<u>40-5</u>

Seven species of macroinvertebrates were collected from Rockhouse Fork during this study (Appendix D). Though small, this stream had all major habitat types; therefore, it would be expected to support a diverse macroinvertebrate fauna, similar to that reported by Harker et al. (1979) from Caney Creek. The ephemeropterans, plecopterans, coleopterans, megalopterans and trichopterans were not encountered, a further indication of the severe impact caused by oil well brine discharges. Species diversity and e were not calculated because no organisms were taken during quantitative sampling. This is an additional indication that Rockhouse Fork is under severe stress.

Fish

There are no previous records of fish collections from Burning Fork. Jones (1970) sampled several other small streams in the area and Harker et al. (1979) reported fish data from streams in the upper Licking River System.

Eight species and 243 individuals were collected from Burning Fork at 40-2. None of these species are considered intolerant and the community was dominated by striped shiners *Notropis chrysocephalus*, an omnivore. No top carnivores were found. The Index of Biotic Integrity (IBI) was 34, which is in the poor range.

No fish were collected at station 40-3. Any fish that may have been present would have been killed or driven out by the high levels of chloride and ammonia present.

Rockhouse Fork (40-5) yielded only two species and had an IBI of 28 or Poor. However, it is interesting to note that the majority of the community was made up of the northern studfish *Fundulus catenatus*. This represents a considerable range extension for the species and is apparently the first reported collection from the Licking River drainage. Thirty-three specimens were taken, ranging in size from 2.6 cm to 6.5 cm in total length. Obviously, a breeding population is present, however, the origin of that population cannot be determined.

Harker et al. (1979) sampled a similar sized stream (Caney Creek, site No. KL01MOR) north of Burning Fork in Morgan County. They reported 25 species, which included an excellent compliment of minnows, darters, sunfishes, catfishes and suckers. The diversity reported by Harker et al. (1979) greatly exceeded anything observed in Burning Fork; the most diverse site in Burning Fork (40-2) only supported eight species. Since the station 40-2 on Burning Fork was similar in size, gradient and habitat type to the Harker et al. (1979) site on Caney Creek, the fish faunas would be expected to be similar. However, the oil well brines have severely impacted the fish fauna of Burning Fork reducing it to a mere fraction of what would be expected.

APPENDIX A

Site Information

Site No:	05040001
Stream:	Burning Fork
County:	Magoffin
Location:	KY 7 bridge
Latitude:	37^{o} 44' 55"
Longitude:	83^{o} 04' 00"
USGS Topo Quad:	Salyersville South, KY
DOW Map No.:	10-56
RMI:	0.1
Sampling Dates:	9-25-84
Type Sampling:	Physicochemical
Stream Gradient:	Low
Pool Width:	3 to 5 m
Pool Depth:	0.2 to 0.6 m
Pool Substrate:	Primarily boulders and fines
Riffle Width:	ND
Riffle Depth:	ND
Riffle Substrate:	ND
Bank Height:	Approximately 6 m
Bank Slope:	50 to 60%
<u>Riparian Vegetation - %</u>	
Trees:	60
Shrubs:	30

Site Information

Herbs:	10
Exposed:	0-5
Width:	ND
Canopy over Stream - %	25 to 50
Bank Stability:	Good
Erosion:	Slight
Sedimentation:	Moderate
Imbeddedness:	½
Periphyton Abundance:	Moderate
Stream Habitat:	Pool, submerged roots and logs, log piles, man-made objects
Hydraulic Structures:	Bridge abutment
Physical Impacts:	None
Nonpoint Sources:	Urban runoff (Salyersville), row crops, KY 7, US 460

ND - Not Determined

NA - Not Applicable

Site Information

Site No:	05040002
Stream:	Burning Fork
County:	Magoffin
Location:	Off Mt. Pkwy., below Lick Branch
Latitude:	37° 44' 50"
Longitude:	83° -03' 58"
USGS Topo Quad:	Salyersville South, KY
DOW Map No.:	10-56
RMI:	1.35
Sampling Dates:	9-25-26-84
Type Sampling:	Biological/Physicochemical
Stream Gradient:	Low
Pool Width:	3 to 5m
Pool Depth:	0.1 to 0.3m
Pool Substrate:	Primarily gravel and fines
Riffle Width:	Up to 3m
Riffle Depth:	0.1 to 0.15m
Riffle Substrate:	Primarily gravel and fines
Bank Height:	Approximately 5m
Bank Slope:	Varied from 30 to 60%
Riparian Vegetation - %	
Trees:	50
Shrubs:	30

Site Information

Herbs:	10
Exposed:	5
Width:	Approximately 15m
Canopy over Stream - %	50 to 75
Bank Stability:	Good
Erosion:	None
Sedimentation:	Moderate
Imbeddedness:	$\frac{1}{4}$
Periphyton Abundance:	Moderate
Stream Habitat:	Riffle, pool, submerged roots and logs, man-made objects
Hydraulic Structures:	None
Physical Impacts:	None
Nonpoint Sources:	Adjacent commercial development, Mountain Parkway

ND - Not Determined

NA - Not Applicable

Site Information

Site No:	05040003
Stream:	Burning Fork
County:	Magoffin
Location:	Ford, just off KY 1888
Latitude:	37° 43' 34"
Longitude:	83° 01' 15"
Stream Order:	III
USGS Topo Quad:	Salyersville South, KY
DOW Map No.:	10-56
RMI:	3.25
Sampling Dates:	9-25-26-84
Type Sampling:	Biological/Physicochemical
Stream Gradient:	Low
Pool Width:	3 to 5 m
Pool Depth:	0.3 to 0.5 m
Pool Substrate:	Fines
Riffle Width:	1 to 2m
Riffle Depth:	0.01 to 0.1m
Riffle Substrate:	Primarily gravel and fines
Bank Height:	Approximately 2m
Bank Slope:	40 to 60%
Riparian Vegetation - %	
Trees:	10
Shrubs:	30

Site Information

Herbs:	60
Exposed:	0-5
Width:	0 to 10m
Canopy over Stream - %	0 to 25
Bank Stability:	Fair
Erosion:	Slight
Sedimentation:	Moderate
Imbeddedness:	½
Periphyton Abundance:	Sparse
Stream Habitat:	Riffles, pools, undercut banks, man-made objects
Hydraulic Structures:	Bridge abutment, ford
Physical Impacts:	Riparian zone modified to lawn grasses
Nonpoint Sources:	Scattered dwellings, row crops, KY 1888

ND - Not Determined

NA - Not Applicable

Site Information

Site No:	*05040004
Stream:	Burning Fork
County:	Magoffin
Location:	Between Ivyton and Bradley, just off KY 1888
Latitude:	37° 42' 35"
Longitude:	83° 59' 53"
Stream Order:	II
USGS Topo Quad:	Ivyton, KY
DOW Map No.:	10-57
RMI:	5.1
Sampling Dates:	9-25-84
Type Sampling:	Physicochemical
Stream Gradient:	Low
Pool Width:	3 to 5m
Pool Depth:	Approximately 0.6m
Pool Substrate:	ND
Riffle Width:	NA
Riffle Depth:	NA
Riffle Substrate:	NA
Bank Height:	0.6 to 1.5m
Bank Slope:	30 to 60%
Riparian Vegetation - %	
Trees:	20
Shrubs:	30

Site Information

Herbs:	35
Root Mats:	5
Exposed:	10
Width:	3 to 6m
Canopy over Stream - %	25 to 50
Bank Stability:	Good
Erosion:	None
Sedimentation:	Moderate
Imbeddedness:	ND
Periphyton Abundance:	Moderate
Stream Habitat:	Pools, occasional undercut bank, submerged roots and logs, log piles
Hydraulic Structures:	log jam
Physical Impacts:	None
Nonpoint Sources:	Scattered dwelling, agriculture, KY 1888

ND - Not Determined

NA - Not Applicable

Site Information

Site No:	05040005
Stream:	Rockhouse Fork
County:	Magoffin
Location:	Off KY 1415
Latitude:	37° 44' 00"
Longitude:	83° 00' 50"
Stream Order:	III
USGS Topo Quad:	Salyersville, KY
DOW Map No.:	10-56
RMI:	0.6
Sampling Dates:	9-25-26-84
Type Sampling:	Biological/Physicochemical
Stream Gradient:	Low
Pool Width:	4 to 6m
Pool Depth:	0.3 to 0.6m
Pool Substrate:	Primarily fines and detritus
Riffle Width:	1 to 1.5m
Riffle Depth:	0.1 to 0.2m
Riffle Substrate:	Pebbles/Gravel/Fines
Bank Height:	0.6 to 3m
Bank Slope:	30 to 60%
Riparian Vegetation - %	
Trees:	20
Shrubs:	50

Site Information	
Herbs:	20
Root Mats:	5
Exposed:	5
Width:	3 to 6m
Canopy over Stream - %	25 to 50
Bank Stability:	Good
Erosion:	Slight
Sedimentation:	Slight
Imbeddedness:	$\frac{1}{4}$
Periphyton Abundance:	Moderate
Stream Habitat:	Riffles, pools, undercut banks, submerged roots and logs, log piles, man-made objects
Hydraulic Structures:	None
Physical Impacts:	None
Nonpoint Sources:	Pastures, row crops, KY 1415

ND - Not Determined

NA - Not Applicable

APPENDIX B

Algal Synoptic List for the
Burning Fork Drainage

Taxa	Station		
	40-2	40-3	40-5
Cyanochloronta			
Anabaena oscillariodes	X	-	-
Microcoleus vaginatus	X	-	-
Oscillatoria lutea	X	-	X
Schizothrix calcicola	X	-	X
Schizothrix friesii	X	-	-
Spirulina subsalsa	X	-	X
Chrysophycophyta			
Bacillariophyceae			
Achnanthes lanceolata var. *dubia*	X	-	-
Achnanthes spp.	X	-	X
Amphora spp.	X	-	X
Cocconeis placentula var. *euglypta*	-	-	X
Cyclotella meneghiniana	X	-	-
Cymbella minuta	X	-	-
Cymbella minuta var.*silesiaca*	-	-	X
Cymbella naviculiformis	-	-	-
Cymbella tumida	-	-	X
Entomoneis alata	X	-	X
Frustulia vulgaris	X	-	X
Gomphonema angustatum	X	-	X
Gomphonema parvulum	-	-	X
Gomphonema subclavatum var. *mexic.*	-	-	X
Gyrosigma distortum	-	X	X
Gyrosigma nodiferum	X	-	-
Gyrosigma scalproides	X	X	X
Melosira varians	-	-	X
Meridion circulare	-	-	X
Navicula cryptocephala	X	X	X
Navicula cryptocephala var.*exilis*	X	X	X
Navicula cryptocephala var. *veneta*	X	-	-
Navicula heufleri var. *leptocephala*	X	X	X
Navicula notha	-	-	X
Navicula pygmaea	X	-	-
Navicula radiosa var.*tenella*	-	-	X
Navicula radiosa	-	-	X
Navicula rhynchocephala	X	X	X
Navicula symmetrica	X	X	X
Navicula viridula var. *avenacea*	X	-	X
Navicula spp.	X	X	X
Nitzschia apiculata	X	-	X
Nitzschia clausii	-	X	-
Nitzschia dissipata	X	-	-
Nitzschia filiformis	X	X	X
Nitzschia hungarica	X	-	X

Algal Synoptic List for the
Burning Fork Drainage (cont'd.)

Taxa	Station 40-2	Station 40-3	Station 40-5
Nitzschia lacunarum	X	-	-
Nitzschia microcephala	-	-	X
Nitzschia reversa	X	-	X
Nitzschia romana	-	X	-
Nitzschia sigma	X	-	X
Nitzschia spp.	X	X	X
Pinnularia sp.	X	-	X
Plagiotropis lepidoptera var. *probo.*	X	-	-
Rhoicosphenia curvata	-	-	X
Surirella ovata	X	-	X
Thalassiosira weissflogii	-	-	X
Total Number of Taxa	36	12	38

Diatom Species Proportional Counts for the Burning Fork System at Station 40-2

Taxa	Relative Abundance
Nitzschia reversa	42.9%
Navicula heufleri var. *leptocephala*	17.4%
Navicula cryptocephala var. *exilis*	11.0%
Navicula rhynchocephala	8.1%
Navicula symmetrica	4.8%
Nitzschia filiformis	3.3%
Navicula cryptocephala var. *veneta*	2.1%
Navicula spp.	2.1%
Nitzschia spp.	1.5%
Nitzschia lacunarum	1.3%
Gyrosigma nodiferum	1.0
Nitzschia dissipata	0.8%
Amphora sp.	0.6%
Entomoneis alata	0.6%
Navicula cryptocephala	0.4%
Nitzschia apiculata	0.4%
Achnanthes sp.	0.2%
Frustulia vulgaris	0.2%
Navicula pygmaea	0.2%
Navicula viridula var. *avenacea*	0.2%

Total individuals:	517
Taxa richness:	21
Diversity ($\bar{d}$):	2.805
Equitability (e):	0.463

Diatom Species Proportional Counts for the Burning Fork System at Station 40-3

Taxa	Relative Abundance
Nitzschia filiformis	50.4%
Navicula heufleri var. *leptocephala*	26.7%
Navicula cryptocephala var.*exilis*	16.5%
Navicula symmetrica	2.0%
Navicula clausii	1.6%
Navicula spp.	0.0%
Achnanthes sp.	0.6%
Nitzschia spp.	0.8%
Nitzschia romana	0.4%
Gyrosigma distortum	0.2%
Gyrosigma scalproides	0.2%
Navicula rhynchocephala	0.2%

Total individuals:	502
Taxa richness:	12
Diversity ($\bar{d}$):	1.872
Equitability (e):	0.397

Diatom Species Proportional Counts
for the Burning Fork System at Station 40-5

Taxa	Relative Abundance
Nitzschia sigma	31.0%
Navicula cryptocephala var.*exilis*	23.9%
Navicula heufleri var. *leptocephala*	23.3%
Nitzschia hungarica	6.9%
Navicula apiculata	2.8%
Navicula rhynchocephala	2.4%
Navicula symmetrica	1.4%
Navicula cryptocephala	1.2%
Thalassiosira weissflogii	1.2%
Nitzschia spp.	1.2%
Navicula spp.	1.0%
Entomoneis alata	0.8%
Navicula radiosa var. *tenella*	0.8%
Gyrosigma distortum	0.4
Nitzschia reversa	0.4
Rhoicosphenia curvata	0.4%
Amphora sp.	0.2%
Navicula notha	0.2%
Navicula viridula var. *avenacea*	0.2%
Nitzschia microcephala	0.2%
Synedra ulna var. contracta	0.2%
Pinnularia sp.	0.2%

Total individuals:	507
Taxa richness:	22
Diversity ($\bar{d}$)	2.754
Equitability (e):	0.426

APPENDIX C

Macroinvertebrate Synoptic List
for the Burning Fork System

Taxa	Stations 40-2	40-3	40-5
Basommatophora			
Physidae			
Physella sp.	-	-	1
Decapoda			
Cambaridae			
Orconectes putnami	2	-	8
Odonata			
Aeschnidae			
Boyeria vinosa	3	-	-
Calopterygidae			
Calopteryx sp.	-	-	1
Coenagrionidae			
Argia sp.	-	-	22
Enallagma sp.	3	-	-
Hemiptera			
Nepidae			
Ranatra sp.	1	-	-
Diptera			
Chironomidae			
Chironomus decorus gp.	920	-	-
Chironomus sp.	-	-	2
Cricotopus tremulus sp.	2	-	-
Dicrotendipes neomodestus	-	-	5
Natarsia baltimoreus	1	-	-
Paratanytarsus sp.	9	-	-
Phaenopsectra sp.	3	-	-
Polypedilum illinoense	1	-	-
Culicidae	6	-	-
Ephydridae			
Ephydra sp.	-	-	3
Total Number of Organisms	951	0	42
Total Number of Taxa	11	0	7
Species Diversity (d)	0.1270	NA	NA
Equitability (e)	0.3333	NA	NA

NA - Not applicable

APPENDIX D

Fish Synoptic List

for Burning Fork Subbasin

Species

Burning Fork 05040002	
Campostoma anomalum	3
Ericymba buccata	17
Notropis chrysocephalus	145
Pimephales notatus	15
Semotilus atromaculatus	40
Catostomus commersoni	5
Etheostoma nigrum	17
Lamprey ammocoetes	1
IBI-34 (Poor)	
Burning Fork 05040003	
No Fish	
Rockhouse Fork 05040005	
Semotilus atromaculatus	2
Fundulus catenatus	33
IBI - 28 (Poor)	
Total Number of Taxa	9

Index of Biotic Integrity for Selected Stations In the Burning Fork System

Station	Stream Size	Number of Individuals: Total Species	Total Individ-uals	Darter Species	Sunfish Species	Sucker Species	Intol erant Species	Proprotion of Individuals (%): Omini-vores	Insecti-vorous Cyprinids	Green Sunfish	Top Carni--vores	Hybrids	Diseased etc.	Index	Class
40-2	Head	0/8	+ /243	0/1	-/0	0/1	-/0	-/89	-/0	+ /0	-/0	+ /0	+ /0	34	Poor
40-3	Head			NO FISH										No FISH	
40-5	Head	-/2	-/35	-/0	-/0	-/0	-/0	+ /6	-/0	+ /0	-/0	+ /0	+ /0	28	Poor

APPENDIX E

LITERATURE CITED

(APHA) American Public Health Association. 1981. Standard methods for the examination of water and wastewater, 15th Edition. Am. Publ. Heal. Assoc., Am. Water Works Assoc., Water Poll. Contr. Fed., Washington, D.C.

Beck, W.M., Jr. 1955. Suggested method for reporting biotic data. Sew. Ind. Wastes, 27:1193-1197.

Birge, W.J., J.E. Hudson, J.A. Black, and A.G. Westerman. 1978. Embryo-larval bioassays on inorganic coal elements and in situ biomonitoring of coal-waste effluent. In Surface Mining and Fish/Wildlife needs in the Eastern United States, Proceeding of a Symposium, D.E. Samel, J.R. Staufer, C.H. Hocutt, and W.T. Masons FWS/OBS - 78-81, Fish and Wildlife Service, U.S. Department of the Interior, pp 97-104.

Birge, W.J., et al. 1985. Recommendations on numerical values for regulating iron and chloride concentrations for the purpose of protecting warmwater species of aquatic life in the Commonwealth of Kentucky. Memo of Agreement No. 5429. KY. Nat. Res. and Environ. Prot. Cab. 1985.

Bordner, R., and P. Scarpino, J. Winter, editors. 1978. Microbiological methods for monitoring the environment, water and wastes. Environ. Monit. Supp. Lab., U.S. EPA., Cincinnati, OH. EPA-600/8-78-017.

Bower, D.E. and W.H. Jackson. 1981. Drainage areas of streams of selected locations in Kentucky. U.S. Dept. Int., Geol. Surv., Louisville, KY. Open File Rept. 81-61.

Camburn, K.E. 1982. The Diatoms (Bacillariophyceae) of Kentucky: A checklist of previously reported taxa. Trans. KY. Acad. Sci., 43:10-20.

Charles, J.R. 1964. Effects of oil well brines. In: Proceedings of the Eighteenth Annual Conference. Southeastern Assoc. Game Fish Comm.

Clemens, H.P. and W.H. Jones. 1954. Toxicity of brine water from oil wells. Trans. Am. Fish. Soc. 84:97-109.

(CWQC) Committee on Water Quality Criteria. 1972. Water quality criteria. Environ. Studies Board, Nat. Acad. Sci., Nat. Acad. Eng. Washington, D.C.

Davis, J.C. 1975. Minimal dissolved oxygen requirements of aquatic life with emphasis on canadian species: a review. J. Fish. Res. Bd. Can., 32:2295-2332.

(DOW) Division of Water. 1982. Ross Creek drainage biological and water quality investigation. KY Dept. Nat. Res., Div. of Water, Biol. Branch. Tech. Rept. No. 1.

Downing, K.M. and J.C. Merkens. 1955. The influence of dissolved oxygen concentration on the toxicity of un-ionized ammonia to rainbow trout (*Salmo gairdneri* Richardson). Ann. Appl. Biol. 43:243.

LITERATURE CITED

Ellis, M.M. 1937. Detection and measurement of stream pollution. Bull. Bur. Fish., 48:365-437.

Flis, J. 1968. Histopathological changes induced in carp (*Cyprinus carpio* L.) by ammonia water. Acta Hydrobiol. 10:205-238.

Harker, D.F., Jr., S.M. Call, M.L. Warren, Jr., K.E. Camburn, P. Wigley. 1979. Aquatic biota and water quality survey of the Appalachian Province, eastern Kentucky. KY. Nat. Pres. Comm., Frankfort, KY. Tech. Rept.

Harker, D.F., Jr., M.L. Warren, Jr., K.E. Camburn and R.R. Cicerello. 1981. Aquatic biota and water quality survey of the Western Kentucky Coal Field. KY. Nat. Pres. Comm. Tech. Rept., 896p.

Hart, C.W., Jr. and S.L. H. Fuller, Editors. 1974. Pollution ecology of freshwater invertebrates. Academic Press, New York, N.Y.

Hawkins, C.P. and J.R. Sedell. 1981. Longitudinal and seasonal changes in functional organization of macroinvertebrate communities in four Oregon streams. Ecology, 62(2).

Hem, J.D. 1970. Chemical behavior of metals in aqueous media. Geological Survey Professional Paper 713, U.S. Government Printing Office, Washington, D.C., pp. 19-24.

Hornig, C.E. and J.E. Pollard. 1978. Macroinvertebrate sampling techniques for streams in semi-arid regions. Comparison of Surber method and unit-effort traveling kick method. Off. Res. Devel., Environ. Monit. Sup. Lab., U.S. EPA, Las Vegas, NV. EPA 600/4-78-040.

Hustedt, F. 1930. Bacillariophyta (Diatomeae) In: Pascher, A., ed. Die Susswasser-flora Mitteleuropas. (The freshwater flora of middle Europe) Gustav Fischer Verlag, Jena. W. Germany.

Jones, A.R. 1970. Inventory and classification of streams in the Licking River drainage. KY. Dept. Fish and Wildl. Res., Bull. NO. 53.

Karr, J.R. 1981. Assessment of Biotic Integrity Using Fish Communities. Fisheries, 6:21-27.

Krieger, R.A. and G.E. Hendrickson. 1960. Effects of Greensburg oil field brines on the streams, wells and springs of the upper Green River basin, Kentucky. KY Geol. Surv., Series X.

Lloyd, R. and L.D. Orr. 1969. The diuretic response by rainbow trout to sublethal concentrations of ammonia. Water Res. 3:335-344.

Lobeck, A.K. 1929. The geology and physiography of the Mammoth Cave National Park: Kentucky Geol. Survey, ser. 6, University of Kentucky, Lexington, KY.

LITERATURE CITED

Lowe, R.L. 1974. Environmental requirements and pollution tolerance of freshwater diatoms. Nat. Environ. Res. Cent., Off. Res. Devel., U.S. EPA., Cincinnati, OH. EPA-670/4-74-005.

McCarraher, D.B. and R. Thomas. 1968. Some ecological observations on the fathead, Pimephales promelas in the alkaline water of Nebraska. Trans. Amer. Fish. Soc., 97:52-55.

McDowell, R.C., G.J. Grabowski, Jr., and S.L. Moore. 1981. Geologic map of Kentucky. U.S. Geol. Surv. and the Eleventh KY Geol. Surv. 4 Sheets, Univ. of KY, Lexington, KY.

McGrain, P. and J.C. Currens. 1978. Topography of Kentucky. KY Geol. Surv., Series x, Sp. Pub. 25, Univ. of KY., Lexington, KY.

McKee, L.E. and H.W. Wolf, editors. 1963. Water quality criteria, 2nd ed. Calif. State Water Qual. Contr. Brd., Sacramento, CA.

Merkins, J.C. and K.M. Downing. 1957. The effect of tension of dissolved oxygen on the toxicity of un-ionized ammonia to several species of fish. Ann. Appl. Biol. 45:521-527.

Merritt, R.W. and K.W. Cummins, Editors. 1978. An introduction to the aquatic insects of North America. Kendall/Hunt Publ. Co. Dubuque, IA.

Patrick, R. and C.W. Reimer. 1966. The diatoms of the United States exclusive of Alaska and Hawaii. Mongr. Acad. Nat. Sci. Phila., No. 13.

Phillips, G.R. and R.C. Russo. 1978. Metal bioaccumulation in fishes and aquatic invertebrates: A literature review. U.S. EPA., Environ. Res. Lab., Off. Res. and Devel., Cincinnati, OH. EPA-600/3-78-103.

Proctor-Davis-Ray. 1975. The river basin water quality management plan for Kentucky, Licking River. KY. Div. Water Qual., KY. Dept. Nat. Res. Environ. Prot.

Quarterman, E. and R.L. Powell. 1978. Potential ecological/geological natural landmarks of the Interior Low Plateaus. U.S. Dept. Int. Nat. Park Serv., Washington, D.C.

Rice, C.L., E.G. Sable, G.R. Dever, Jr. and T.M. Kehn. 1980. The Mississippian and Pennsylvanian (Carboniferous) systems in Kentucky. U.S.G.S. Geo. Sur. Prof. Pap., 1110-F, 32p.

Sawyer, C.H. 1960. Chemistry for sanitary engineers. McGraw-Hill Book Co., New York.

Smith, C.E. and R.G. Piper. 1975. Lesions associated with chronic exposure to ammonia. In: W.E. Ribelin and G. Migaki, editors. The Pathology of Fishes. Univ. Wisc. Press, Madison, WI.

STORET. 1979-1983. United States Environmental Protection Agency water quality file. U.S. EPA, Office of Reg. and Stds., Washington, D.C.

LITERATURE CITED

Stroud, R.H. 1967. Water quality criteria to protect aquatic life: A summary. Am. Fish. Soc., Spec. Pbl., 4:33-37.

Thompson, D.H. 1925. Some observations on the oxygen requirements of fishes in the Illinois River. Ill. Nat. Hist. Surv. Bull., 15:423-437.

(U.S. EPA) U.S. Environmental Protection Agency. 1976. Quality criteria for water. U.S. Environ. Prot. Agency, Washington, D.C. EPA-440/9-76-023.

________________. 1977. Guidelines for the pollution classification of Great Lakes harbor sediments. U.S. EPA., Region V, Chicago, IL.

________________. 1979. EPA methods for chemical analysis of water and wastes. Environmetnal Monitoring and Support Laboratory, Office of Research and Development. Cincinnati, OH. EPA-600-4-79-020.

________________. 1980. Ambient water quality criteria for zinc. U.S. EPA, Off. Water Reg. Stds., Washington, D.C. EPA 440/5-80-079.

Van der Werff, A. 1955. A new method of concentrating and cleaning diatoms and other organisms. Int. Ver. Theor. Angew. Limnol. Verh., 12:276-277.

Warnik, S.L. and H.L. Bell. 1969. The acute toxicity of some heavy metals to different species of aquatic insects. J. Water Poll. Contr. Fed., 41:280-284.

Weber, C.I., editor. 1983. Biological field and laboratory methods for measuring the quality of surface water and effluents. Environ. Res. Lab., Office. Res. and Devel., U.S. EPA, Cincinnati, OH. EPA-670/4-73-00.

Whitton, B.A., Editor. 1975. Studies in ecology-Volume 2. River ecology. Univ. California Press. Berkeley and Los Angeles, CA.

Wiebe, A.H., J.G. Burr and H.E. Faubion. 1934. The problem of stream pollution in Texas with special reference to salt water from the oil fields. Trans. Am. Fish. Soc. 64:81-85.

Wilhm, Jerry L. 1970. Range of diversity index in benthic macroinvertebrate populations. J. Water Pollut. Control Fed. 42, 221 (1970).

Woodward, D.F., and R.G. Riley. 1983. Petroleum hydrocarbon concentrations in a salmonid stream contaminated by oil field discharge water and effects on macrobenthos. Arch. Environ. Contam. Toxicol. 12,327-334 (1983).