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Atlas of Wetlands in the Principal Coal Surface Mining Region of Western Kentucky

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ATLAS OF WETLANDS IN THE PRINCIPAL COAL SURFACE MINING REGION OF WESTERN KENTUCKY

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DISCLAIMER

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PREFACE

This atlas is the major product of Phase I of a research project entitled "Wetland Identification and Management Criteria for the Kentucky Western Coal Field" sponsored jointly by the Fish and Wildlife Service (FWS) and the Office of Surface Mining Reclamation and Enforcement (OSM), the Office of Water Policy (OWP), U.S. Department of the Interior, and the Kentucky Water Resources Research Institute (KWRRI). The research was carried out by the Energy and Ecological Systems Group at the University of Louisville, Kentucky.

A series of maps derived from 1979 aerial photography (1:24,000), EPA land use overlays, USGS topographic maps, and ground reconnaissance, emphasizes the presence of wetlands and other bodies of water in the Western Kentucky Coal Field. Descriptions of significant wetlands, hydrology, fish and wildlife resources, and water quality accompany each map as further aids to resource managers. Wetland types correspond to the classification recently developed by the U.S. Fish and Wildlife Service[1]. Coal mining activity determined by aerial photography during 1979-80 is also indicated on the maps.

The atlas will aid both public agencies and private concerns in dealing with the management of wetland resources amid surface coal mining activities in Western Kentucky. The document will be particularly useful for reference purposes involving the Clean Water Act of 1977 (PL 95-217), which provides for protection of wetlands from dredge and fill activity, and the Surface Mining Control and Reclamation Act (PL 95-87), which establishes requirements to minimize adverse impacts of surface mining to fish and wildlife resources.

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[1] Cowardin, L.M. et al. 1979, Classification of Wetlands and Deepwater Habitats of the United States. U.S. Fish & Wildlife Service, FWS/OBS - 79/31, Washington, DC 20240.

ABSTRACT

This atlas contains maps of wetlands and surface mining activity in the Western Kentucky Coal Field, and focuses on a 3960 km^2 (1530 mi^2) region where approximately 90 percent of surface mining in the Coal Field occures. Some present and potential competition exists between surface coal mining and wetland protection. A wetland classification, based on the recent FWS classification, includes six types of palustrine systems and one each of riverine and laucstrine systems. Wetlands and surface mines are located on twenty-seven 7.5 minute USGS quadrangles that define the study region. A total of 460 km^2 (177 mi^2) of wetlands are identified. Approximately 84 percent are broad-leaved deciduous forested wetlands, mostly as periodically-flooded riparian hardwood forests along broad alluvial bottom-lands. Also, several significant persistent emergent wetlands, shrub-scrub wetlands, and needle-leaved deciduous forested wetlands (bald cypress swamps) are identified in the study region. Summaries of geology and coal mining, hydrology, water quality, wetland vegetation and unique fish and wildlife species are presented for each quadrangle. Effects of existing and potential future surface mining of coal on wetland structure, function, and value are discussed. Species lists for vegetation and fish and wildlife and recent water quality data for the study region are given in the Appendices.

Descriptors:

Wetlands*, Maps, Surface Water, Coal Mining,Hydrology, Water Quality, Geology, Vegetation, Environmental Effects* Fish Populations, Wildlife.

Identifiers:

Atlas of Wetlands, Western Kentucky Coal Field, Wetland Protection, FWS Classification of Wetlands.

ABBREVIATIONS

AGENCY

EPA	U.S. Environmental Protection Agency
FWS	Fish and Wildlife Service, U.S. Department of the Interior
KNREPC or KDNREP	Kentucky Natural Resources and Environmental Protection Cabinet
KNPC	Kentucky Nature Preserves Commission
KWRRI	Kentucky Water Resources Research Institute
OSM	Office of Surface Mining Reclamation and Enforcement, U.S. Department of the Interior
OWRT	Office of Water Research and Technology, U.S. Department of the Interior
USGS	Geological Survey, U.S. Department of the Interior

SCIENTIFIC NOTATION

cfs	cubic feet per second (measure of streamflow)
cm	centimeter
dbh	diameter at breast height
ha	hectares (2.47 acres)
km^2	square kilometer
m	meter
mg/l	milligrams per liter
mi^2	square miles
NTU	nephelometric turbidity units
umhos/cm	micromhos per centimeter (measure of electrical conductance of water)

ACKNOWLEDGMENTS

This atlas is the result of contributions from many individuals and several State and Federal agencies. The Kentucky Nature Preserves Commission (KNPC), with Don Harker and Richard Hannan as directors, was most generous in providing aerial photography, technical data, and reviews for this study. Their earlier reports on the study region were particularly helpful in providing data and synthesis on our study area. Brian Anderson of KNPC was especially helpful in identifying available information for this atlas.

Valuable assistance and suggestions were provided by the various members of an advisory group, particularly by John A. Holbrook, III, and Claude Downing, Office of Surface Mining Reclamation and Enforcement; John Brame and Gary Grisham, Kentucky Bureau of Surface Mining Reclamation and Enforcement; Bob Logan and Don Walker, Kentucky Natural Resources and Environmental Protection Cabinet; Jeff Krause, Peabody Coal Company; Jeffery Sole, Kentucky Department of Fish and Wildlife Resources; and Larry Vinzant, U. S. Fish and Wildlife Service, Atlanta, Georgia. Technical reviews was contributed by Mr. John Hefner, Wetlands Coordinator, and Dr. Ronnie J. Haynes, Coal Coordinator, U. S. Fish and Wildlife Service, Region 4, Atlanta, Georgia. Thoughtful reviews were also supplied by David Parsons and Lee Barclay from the Cookville, Tennessee, Field Office, FWS.

Funding for this project was provided by the U. S. Fish and Wildlife Service (FWS), the Office of Surface Mining Reclamation and Enforcement (OSM), and the Kentucky Water Resources Research Institute (KWRRI). Robert Grieves and Ralph Huffsey were generous with OWRT support from KWRRI. Henry J. Gerke, III represented and provided support from OSM. Douglas Gladwin, Eastern Energy and Land Use Team, served as project officer for a portion of the project.

Shawn Richardson, project cartographer, developed maps and artwork with the assistance of Bill Leftridge. Melanie Tackett, Karen Cozine, and Thelma Goldstein of the Systems Science Institute entered and edited the text on the word processor. Robert Bosserman of the University of Louisville contributed to early stages of the project. Ruthmarie Mitsch carefully proofread the manuscript.

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INTRODUCTION

Wetlands are increasingly being recognized as important natural resources. The value of wetlands as a habitat for fish and wildlife has long been known. As stated by Odum (1979), "Thousands of acres of fresh water marshes were preserved for their value as waterfowl habitat at a time in our history when drainage of marshes and swamps was considered the proper thing to do as people colonized the frontier." But swamps and marshes contribute more than wildlife protection. They serve as nature's system for regulating water flow and water quality in many regions. They have been shown to control floods, prevent droughts, recharge groundwater reservoirs, improve water quality, assimilate wastes, and aid in global cycling of certain elements. This recognized importance has led to the enactment of wetland protection measures in several states and to federal enforcement of wetland regulation through Section 404 of the Federal Clean Water Act of 1977 and Executive Order 11990, Protection of Wetlands, dated May 24, 1977.

Many wetlands are found in Western Kentucky, particularly in the Mississippi Embayment, along the Ohio River, and in the Western Kentucky Coal Field. This atlas is limited to a region in the last area where extensive surface mining of coal has taken place for over a century. Here, potential competition exists between the protection of wetlands and the surface extraction of coal, both of which are important for regional and national interests. This atlas will contribute to the understanding and resolution of this potential competition by defining the extent, types, and importance of wetlands in the region of major coal mining activity in Western Kentucky.

THE WESTERN KENTUCKY COAL FIELD

The Western Kentucky Coal Field (Figure 1) is the southeastern extension of the Eastern

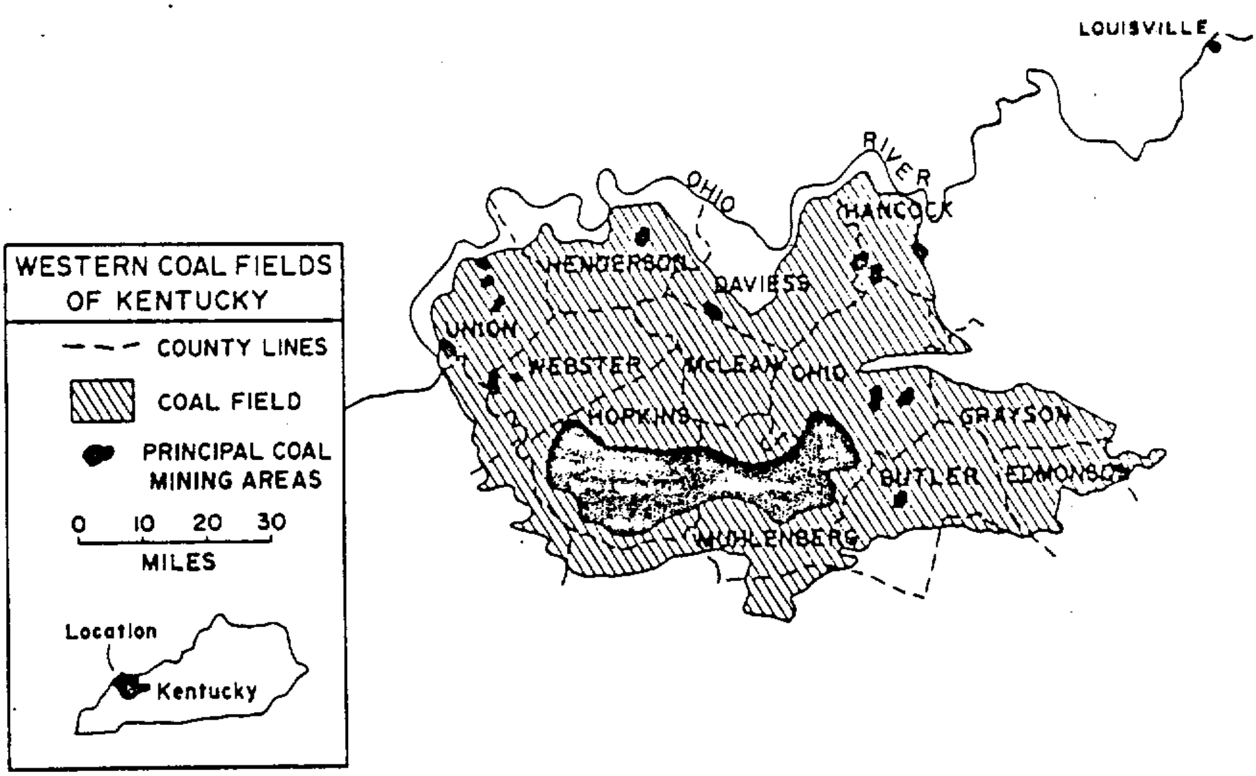


Figure 1. Western Kentucky Coal Field.

Interior Coal Region that includes much of Illinois and southwestern Indiana. The Field is about 12,000 square kilometers (4600 square miles) in size and has experienced significant surface mining since the technique was first introduced in Muhlenberg County in 1829. The Western Kentucky Coal Field was estimated to originally contain 41 billion short tons of coal, with about 38.6 billion short tons now remaining (Table 1). In 1980, the total amount of coal mined in the Field was 41 million tons, with about 21 million tons obtained through surface mining (Kentucky Department of Mines and Minerals, 1981). Since coal mining began in Western Kentucky, about 88% of the tonnage has been mined in Muhlenberg, Hopkins, and Ohio Counties (Table 1); the atlas focuses on this area of primary coal mining activity within the Western Kentucky Coal Field.

Physical Features

The Western Kentucky Coal Field has a generally undulating to slightly hilly terrain, in contrast to the mountainous Eastern Coal Field of Kentucky. The Coal Field is found in the Shawnee Hills Section of the Interior Low Plateaus Physiographic Province. This Shawnee Hills Section is, in turn, surrounded on the eastern and southern edges by the Dripping Springs Escarpment, a 30 to 90 m (100 to 300 foot) high sandstone ridge that has been dissected by several major streams (KNPC, 1980).

The slight relief and the wide, silt-filled valleys of several rivers and streams create ideal conditions for the development of wetlands, particularly riparian wetlands. The major streams that intersect the Western Kentucky Coal Field include the Green, Rough, Pond, Tradewater, and Barren Rivers (Figure 2). The Ohio River, forming the northern border of the Western Kentucky Coal Field, has many significant riparian wetlands along its shoreline; however, coal resources are generally absent adjacent to the river.

General Ecology

The climate of the Western Kentucky Coal Field is described by KNPC (1980) as humid and continental "with no water deficiency in any season." The annual precipitation of 115 cm (45 inches) and adequate to high humidity, combined

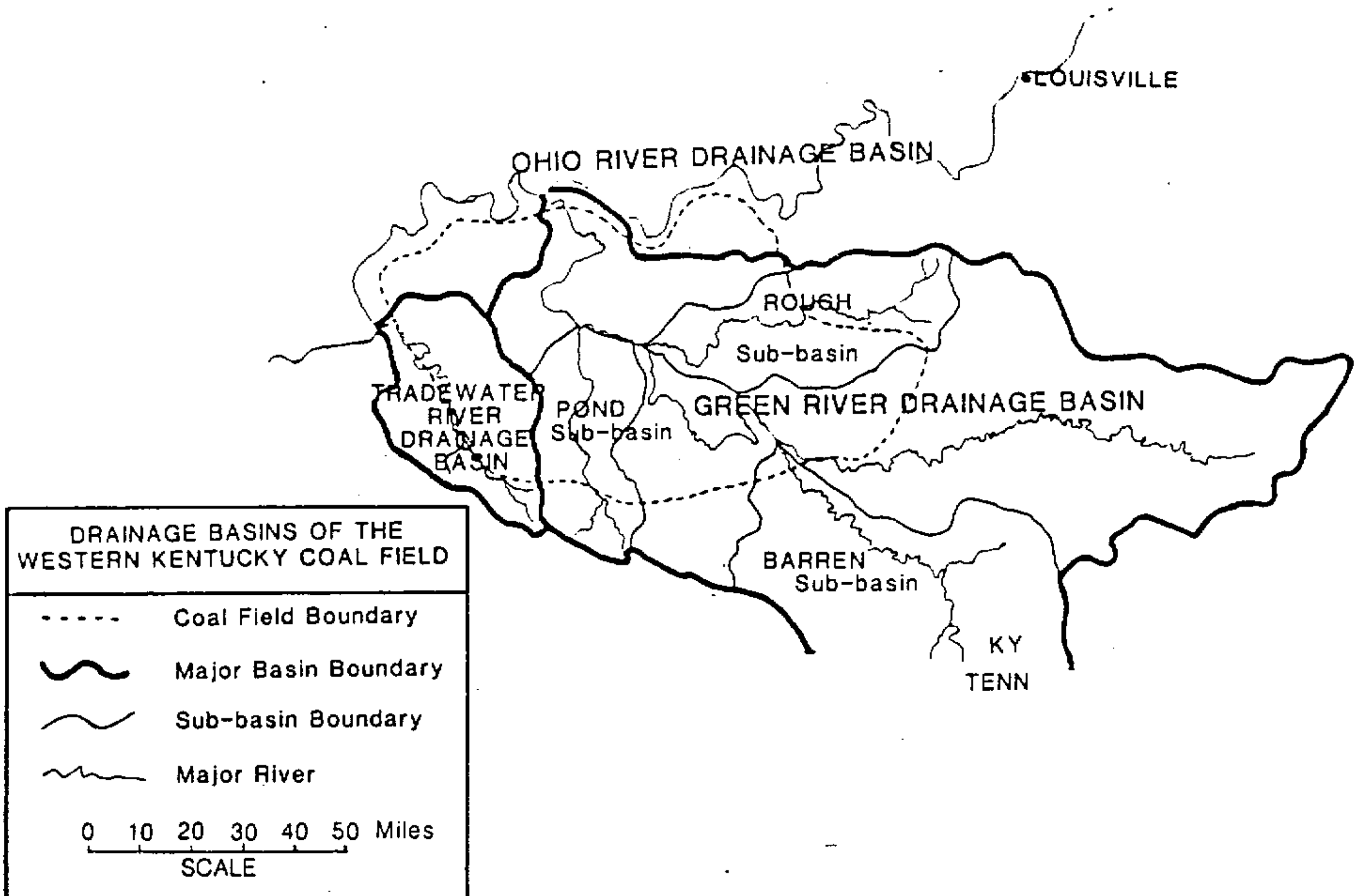


Figure 2. River drainage basins in Western Kentucky Coal Field.

Table 1. Coal resources of Western Kentucky by county in thousands of short tons.[a]

County	Totals	Mined or Now Unavailable	Remaining
Breckinridge	268	0	268
Butler	413,692	9,058	404,634
Caldwell	67,376	236	67,140
Christian	70,720	7,375	63,345
Crittenden	41,634	0	41,634
Daviess	1,330,323	22,500	1,307,823
Edmonson	159,607	1,214	158,393
Grayson	105,038	181	104,857
Hancock	170,276	2,702	167,574
Henderson	6,852,765	32,114	6,820,651
Hopkins	8,814,801	879,702	7,935,099
McLean	3,576,413	22,876	3,553,537
Muhlenberg	4,723,837	981,488	3,742,349
Ohio	1,824,572	220,545	1,604,027
Union	6,506,974	124,460	6,382,514
Warren	8,148	96	8,052
Webster	6,332,849	58,184	6,264,554
Western Kentucky Coal Field Total	40,989,293	2,362,731	38,626,562

[a]Smith and Brant (1978)

with alluvial and loess-derived soils of medium fertility, cause the coal field to be included in the Western Mesophytic Forest Region as defined by Braun (1950). The entire coal field region is included in the oak-hickory ecoregion of the eastern deciduous forest by Bailey (1976). However, no single climax type of terrestrial vegetation defines the entire area, although various upland regions may be classified as oak-hickory or beech-maple forests. The bottomland forests along some rivers in the coal field are often described as northern extensions of the Southern Floodplain Forest of the Lower Mississippi River.

Slow-flowing streams and rivers, some intermittent, are major aquatic ecosystems in the Western Kentucky Coal Field and several reservoirs have been built for water supply and mine reclamation. Aquatic flora and fauna are diverse overall but are severely stressed in many regions. Some streams have been channelized to drain bottomlands that are now in agricultural or residential use. Some of this channelization has isolated and flooded backwater swamps and old meander channels, in addition to creating a less diverse aquatic habitat in the streams. Acid mine drainage from coal mines, both active and abandoned, has affected several hundred miles of streams, particularly in the Green and Tradewater Basins. KDNREP (1981) found 310 miles of streams in the Tradewater River Basin and 584 miles of streams in the Green River Basin to be affected by coal mining activities. Of those totals, 244 miles in the Tradewater Basin and 271 miles in the Green Basin were affected by acid mine drainage. Streams with extremely poor water quality due to mine drainage and long-term sedimentation may be mostly devoid of aquatic life. Adjacent floodplains may have areas with stands of dead timber and other woody vegetation marked with ferric hydroxide precipitate (yellowboy).

Surface coal mining now disturbs an estimated 1600 hectares (4000 acres) per year in Western Kentucky (Jones and Enoch, 1981), with much of the pre-mining land use in agriculture. Reclamation of mined land proceeds at a similar rate, with the land often returned to pasture. Much of Kentucky's prime farmland is found in the western part of the state including the rich bottomland soils of former wetlands along the Tradewater, Green, and Ohio Rivers. Major cash crops include soybean, corn, tobacco, and winter wheat (Lebus, 1981). Only in Muhlenberg and Ohio Counties is less than 50% of the land in agriculture. It is thus possible to have three-way competition for use of bottomland areas in Western Kentucky--for natural values of wildlife habitat and water regulation, for agricultural values, and for coal-producing values.

METHODS

The study region, a 3960 km^2 portion of the Western Kentucky Coal Field, represents a belt of principal surface mining activity. The region encompasses 27 USGS 7.5 minute quadrangle maps. Wetland and surface mine maps were developed at a 1:24,000 (1 inch = 2000 feet) scale from the following data sources:

1) USGS 7.5 minute quadrangles,

2) color photography at 1:24,000 scale from high-altitude aircraft flown in 1979-80,

3) land-use overlays developed from aerial photography, and

4) ground truth and field reconnaissance.

Quadrangle maps were prepared as photographic composites of 1) wetland maps, 2) coal surface mining maps, and 3) USGS 7.5 minute quadrangles. USGS maps had original wetland indicators and topographic lines removed prior to composition. Topographic lines were retained on the first quadrangle map (Providence) to show general topographic features of the study area. A general map of wetlands at the 1:250,000 scale was prepared from the information on the original 1:24,000 quadrangles.

Wetlands were classified according to a modified FWS classification (Cowardin et al., 1979). Descriptions of the wetland classes are given in detail in the next section, pp. 5-8. Modifications included the use of two hydrologically-defined subclasses of broad-leaved deciduous forested wetlands and the omission of more than one class each for the Riverine and Lacustrine systems. Seasonally flooded and semi-permanently flooded broad-leaved deciduous forested wetlands, while different habitats, were combined for purposes of this atlas. The extent of each wetland type was determined by an area digitizer.

Previous studies by other organizations and field studies by the authors were used to describe and quantify the ecological features for each wetland map. Geologic information was obtained from pertinent maps and publications. Hydrologic data were taken primarily from USGS publications. Water chemistry data were obtained from previous studies (USGS, 1981; KNPC, 1981; KDNREP, 1981), from project field measurements, and from recent unpublished data of KDNREP. Seven stations were monitored seasonally during 1981-82, and ten additional stations were included during a synoptic survey in July 1982. Standard laboratory techniques, described by Mitsch et al. (1982), were used for data determined by this study. Summaries of water quality data for each quadrangle indicate the average and standard deviation (68% of the measurements if normally distributed) if more than two samples are available. Vegetation of specific sites was identified during field observations by the authors and by KNPC (1980, 1981). Fish and wildlife data were obtained primarily from field records of KNPC.

Status designations of flora and fauna were determined by the Endangered Species Committee of the Kentucky Academy of Science and the Kentucky Nature Preserves Commission (Branson et al., 1981). These designations do not imply protection under State of Kentucky statute but are meant as guidelines for planning activities. Four categories were emphasized: Endangered, Threatened, Special Concern, and Undetermined. Endangered species are in danger by extinction within or by exclusion from their normal range in Kentucky. Threatened species are subject to limitations within or future exclusion from their normal range in Kentucky and are likely to become endangered. The Special Concern category includes species which need to be observed closely because of limited distibution or because they are subject to environmental factors that may preclude their survival. A species assigned Undetermined status is one about which there is insufficient information concerning its distribution, nesting habits, or reaction to environmental stress. This category suggests need for additional investigation of the species in question to determine a definite status.

Locations of surface mines, determined from aerial photographs and land-use maps, were verified from Kentucky Bureau of Surface Mining Reclamation and Enforcement maps. Surface mine categories are described in the next section, p. 9. Wetland and surface mines were considered mutually exclusive in mapping so no overlap was designated. Coal mining tonnage for the Coal Field and the study region were calculated from Kentucky Department of Mines and Minerals (1981) data.

WETLAND AND SURFACE MINING CLASSIFICATION

WETLANDS

The classification of wetlands of the Western Coal Field of Kentucky was a necessary prerequisite to the development of a wetland atlas. The wetland types, listed with map symbols in Table 2 and on the page opposite each quadrangle map, are generally from the U.S. Fish and Wildlife Service's (FWS) Classification of Wetlands and Deepwater Habitats of the United States (Cowardin et al., 1979). That classification was designed to meet several long-range objectives, among which were "to furnish units for inventory and mapping" and "to provide uniformity in concept and terminology" (Cowardin et al., 1979). The wetlands are arranged in a hierarchical fashion with the most general level, the SYSTEM, referring to broad categories that share similar hydrologic, geomorphologic, chemical, or biological features. There are three wetland and deepwater habitat systems represented in the Western Kentucky Coal Field:

1) Palustrine - wetlands dominated by trees, shrubs, or persistent emergents;

2) Riverine - wetlands contained within a channel except those dominated by trees, shrubs, or persistent emergents; and

3) Lacustrine - deepwater habitats in topographic depressions (lakes) or dammed river channels (reservoirs).

Each system is further subdivided into classes.. Eight classes of wetlands and deepwater habitats within the Western Kentucky Coal Field are defined here, including six types of palustrine systems and one each for the riverine and lacustrine systems. Further classification of lacustrine and riverine systems was not attempted. Riverine systems are shown on the maps as streams and rivers, and the aquatic bed class is used to identify those slow-flowing stream channels where large expanses of rooted or floating vascular plants are found. Impounded reservoirs are the only limnetic systems generally seen in the study region. These man-made lakes are often part of the surface coal mine reclamation process. The classes of wetlands and deepwater habitats used in this atlas are discussed below.

Persistent Emergent Wetlands

This class includes wetlands dominated by erect, rooted aquatic plants with dead vegetation standing at least through winter until the beginning of the next growing season. Dominant vegetation in this type of wetland includes cattail (Typha spp.), sedges (e.g., Carex spp.), bulrushes (Scirpus spp.), three-way sedge (Dulichium arundinaceum), spike rush (Eleocharis spp.), and certain true grasses such as reed grass (Phragmites sp.). This type of wetland is often defined as a freshwater marsh and includes both shallow and deep marshes of the old FWS classification (Shaw and Fredine, 1956). A typical emergent wetland in the Western Kentucky Coal Field is shown in Figure 3. These wetlands are generally hydrologically defined as permanently flooded or intermittently exposed, which indicates that surface water is present continuously or continuously except for periods for extreme drought.

Figure 3. Persistent emergent wetland.

Broad-Leaved Deciduous Forested Wetlands

Two types of bottomland hardwood forests were identified in the Western Kentucky Coal Field, with the distinction made on the basis of water regime:

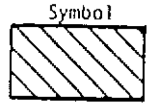
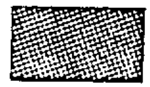
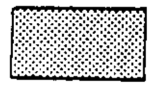
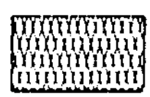
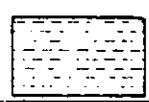
Seasonally or semi-permanently flooded - Surface water is present throughout the growing season or for extended periods, especially early in the growing season. Otherwise the water table is usually at or near land surface.

Temporarily flooded - Surface water is present for brief periods during the growing season but the water table is otherwise well below the soil surface.

The distinction between these two types of bottomland wetlands is often seen in the type of vegetation present. Seasonally and semi-permanently flooded bottomland forests found in Western Kentucky are dominated by a diverse array of hardwoods including green ash (Fraxinus pennsylvanica), red maple (Acer rubrum), silver maple (Acer saccharinum), sycamore (Platanus occidentalis), black willow (Salix nigra), river birch (Betula nigra), and sweet gum (Liquidambar styraciflua).

Temporarily flooded bottomlands represent the highest elevation of floodplain associations and are flooded for 2 to 12.5% of the growing

Table 2. Wetlands and surface mine classification of Western Kentucky study region. Symbols are used on map quadrangles on pages 19-87.

	Symbol
PALUSTRINE SYSTEMS	
PERSISTENT EMERGENT WETLAND	
BROAD-LEAVED DECIDUOUS FORESTED WETLAND	
Seasonally or Semi-Permanently Flooded	
Temporarily Flooded	
NEEDLE-LEAVED DECIDUOUS FORESTED WETLAND	
DEAD FORESTED WETLAND	
SHRUB-SCRUB WETLAND	
LACUSTRINE SYSTEM	
LIMNETIC IMPOUNDMENTS	
RIVERINE SYSTEM	
AQUATIC BED WETLAND	
SURFACE MINES	
ACTIVE OR ABANDONED SURFACE MINES	
REVEGETATED SURFACE MINES	

season (Wharton et al., 1982). This type of wetland is more common in Western Kentucky than is the seasonally or semi-permanently flooded type despite its frequent drainage for agricultural fields. Several species of oak including swamp chestnut oak (Quercus michauxii) and pin oak (Q. palustris) are characteristic of this infrequently flooded bottomland, although several species of hickory (Carya cordiformis and Carya glabra) are often present. Many trees found in the more frequently flooded bottomlands, including maples (Acer), ash (Fraxinus), and American elm (Ulmus americana), are codominants in the temporarily flooded bottomlands. Figure 4 shows a typical broad-leaved deciduous forested wetland in the Western Kentucky Coal Field.

Figure 4. Broad-leaved deciduous forested wetland.

Needle-Leaved Deciduous Forested Wetlands

There are several palustrine forested wetlands in the Western Kentucky region that are dominated by the deciduous conifer bald cypress (Taxodium distichum) and merit particular attention because of their unique features. Cypress is common to frequent along the Mississippi bottomlands from Louisiana to southern Illinois and on the Atlantic Coastal Plain from Florida to New Jersey. Some of the cypress in the Western Kentucky Coal Field are the northeastern-most extensions of the cypress found along the Mississippi embayment. Bald cypress swamps are found along Cypress Creek and in the Henderson Sloughs areas in the Western Kentucky Coal Field but are otherwise infrequent. The water regime is usually intermittently exposed. Less frequent flooding leads to dominance of broad-leaved bottomland trees over cypress; permanent flooding of deep (over 1 meter) water eventually eliminates cypress altogether because the seeds need a brief dry period for germination.

A typical cypress swamp (needle-leaved deciduous forested wetland) from the Western Kentucky Coal Field is shown in Figure 5. The canopy is generally very open, allowing for dense growth of various herbaceous and shrubby aquatic plants in and above the water.

Figure 5. Needle-leaved deciduous forested wetland (cypress swamp).

Dead Forested Wetlands

There are isolated areas in the Western Kentucky Coal Field where dead trees dominate the horizon of the wetland. These wetlands are often in transition to persistent emergent or aquatic bed wetlands, but they are identified by their most notable feature--dead standing trees. The trees could have been killed by altered hydrology (usually flooding) or by the toxic effects of coal mine drainage. The flooding often occurs due to the activities of man (e.g., highway construction) or due to beaver dams. Figure 6 is a photograph of a dead forested wetland in Western Kentucky.

Figure 6. Dead forested wetland.

Shrub-Scrub Wetlands

This type of wetland (Figure 7) is dominated by woody vegetation less than 6 m (20 feet) tall. The woody vegetation includes stunted or young trees and shrubs. Water regime in these types of wetlands in Western Kentucky is generally permanently flooded or intermittently exposed. Dominant vegetation types, all broad-leaved deciduous, include the shrub buttonbush (*Cephalanthus occidentalis*) and small trees in willow (*Salix* spp.) and red maple (*Acer rubrum*) thickets. No needle-leaved or evergreen shrub-scrub wetlands have been observed in Western Kentucky.

Figure 7. Shrub-scrub wetland.

Aquatic Bed Wetlands

This type of wetland, the only class in the Riverine system in this atlas, includes habitats dominated by plants that grow on or below the surface. In addition to the persistent emergent wetlands, these wetlands are the only other type classified here for non-woody vascular aquatic plants. The aquatic bed wetland (Figure 8) is found in great expanses in the Clear Creek water shed, where plants such as pondweed (*Potamogeton* spp.), coontail (*Ceratophyllum demersum*), water milfoil (*Myriophyllum* spp.), and bladderwort (*Utricularia* spp.) dominate certain areas. Lizard's tail (*Saururus cernuus*) and smartweed (*Polygonum* spp.) are non-persistent emergent aquatic plants that are also frequently found in this region. Because of their infrequent occurrence at other sites, a separate classification for non-persistent emergent wetlands was not used.

Figure 8. Aquatic bed wetland.

Limnetic Impoundments

The only Lacustrine systems mapped separately in the atlas are surface water reservoirs. Many have been established for reclamation purposes on surface-mined lands (Figure 9). No attempt was made to distinguish between the littoral and limnetic zones of these reservoirs, nor was any attempt made to subdivide the limnetic impoundment into classes based on bottom material. The locations of these reservoirs on the maps are useful in that they give gauges of expected downstream conditions during heavy rainfall. The presence of an upstream reservoir may lessen the suddenness and intensity of downstream flooding of riparian wetlands.

Figure 9. Limnetic impoundment.

SURFACE COAL MINING

Surface coal mining activity is divided into two major categories: 1) active or abandoned surface mines, and 2) revegetated surface mines. These classifications were made primarily from aerial photography with adequate vegetation cover indicating revegetated areas. The categories are not meant to imply any compliance or noncompliance with existing surface mining regulations.

The active and abandoned (orphaned) surface mines could not consistently be separated by inspection of aerial photography (1:24,000) despite the fact that some of the mined areas were abandoned without reclamation several years ago. This loss of information is balanced by the fact that both active and abandoned mines often cause the most significant effects to downstream wetlands. Reclaimed surface mines, on the other hand, are designed to lessen the impacts on downstream ecosystems. Because surface mining is a dynamic process with land continually being stripped and reclaimed, the placement of mines in this study must be thought of as a "snapshot," around 1979; their location and size are only an estimate of present conditions. Wetlands and maps were considered to be mutually exclusive in this atlas, so no overlap will be shown. This does not mean that surface mining does not occur in wetland environments.

Surface mining in the Western Kentucky Coal Field is generally done by area mining techniques. Several large draglines (Figure 10) are presently in the study region to remove overburden. Reclamation practices now primarily involve revegetation to pastureland with a combination of fescue grass, legumes such as Korean clover, and some cover crops including wheat, rye, and barley. Few tree species are now used in reclamation, although black locust (Robinia pseudoacacia) and several species of pine (Pinus spp.) were used in the past.

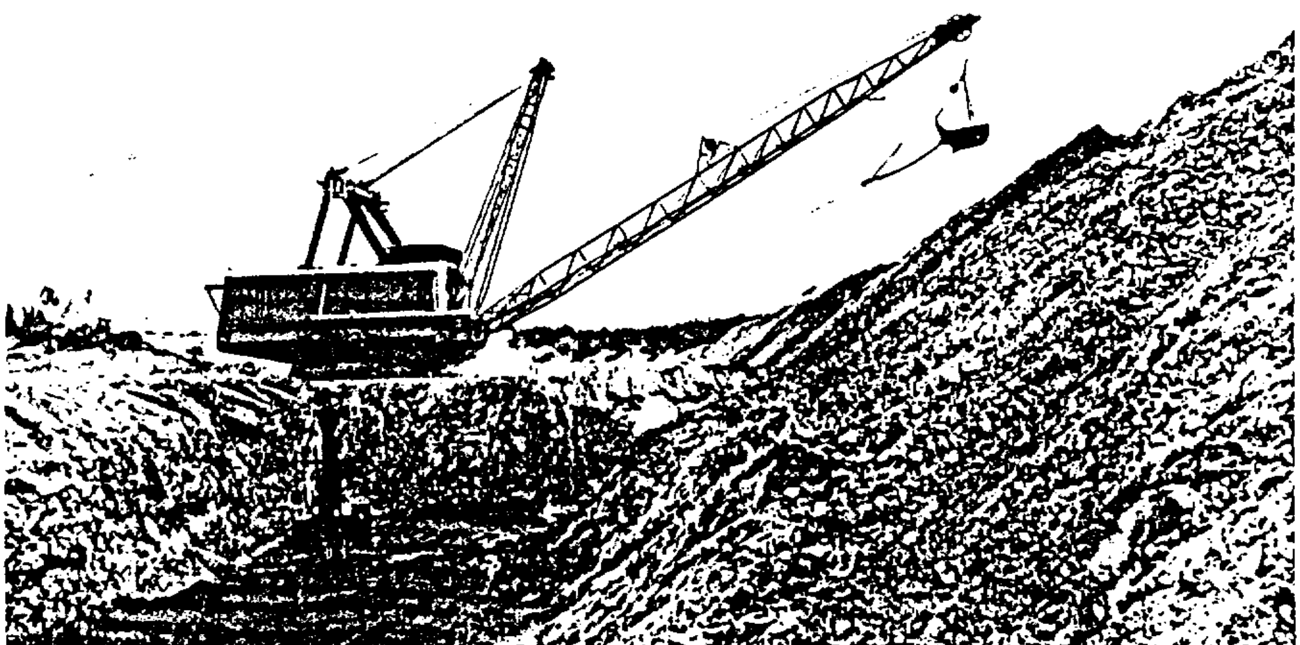


Figure 10. Coal surface mining in Western Kentucky.

REGIONAL SUMMARY

The study region for this atlas, shown in Figures 11 and 12, includes the section of the Western Kentucky Coal Field where most of the present surface mining is taking place. The study region encompasses 27 USGS 7.5 minute quadrangles for a total coverage of 3960 km^2 (1530 mi^2). This coverage represents approximately one-third of the Western Kentucky Coal Field. This section synthesizes the considerable amount of data obtained for the 27 quadrangle study region. Details of the geology, hydrology, water chemistry, wetland vegetation, and fish and wildlife resources for each quadrangle are discussed with each map in the next section. Complete lists of vegetation, fish and wildlife, and water quality data for the study region are given in the appendices.

Coal Mining

The coal mining activity of the study region and the Western Coal Field is shown in Figure 11. The map shows areas of surface mining prior to 1966 and since that time (until approximately 1974-75). In 1980, an estimated 28 million tons of coal, or approximately 68 percent of all the coal produced in the Coal Field, were mined from the study region. Approximately 19 million tons, or 90 percent of all the coal surface-mined in Western Kentucky, were obtained from the study region in 1980. This amount of surface mining results in a surface disturbance of approximately 1500 ha (3800 acres).

Wetland Resources

There are approximately 459 km^2 (177 mi^2) of lands in the study region that have been identified as wetlands (Figure 12 and Table 3). A breakdown of wetland areas for each 7.5 minute quadrangle is given in Appendix A. Small wetland areas appear in almost every topographic depression, while more extensive wetlands occur on the floodplains of several streams and rivers. The study region encompasses two major watersheds that drain to the Ohio River--the Green River and the Tradewater River Basins. The broad floodplains of these rivers and their tributaries have been cleared in many areas for agriculture, and drainage projects are common to produce more arable land. Coal mining throughout the region also has stressed many of the wetland systems. Acid mine drainage, increased sediment loads, and altered water regimes have had an effect on the number, size, and composition of these wetlands.

The major type of wetland found in the study region is the Broad-Leaved Deciduous Forested Wetland, also referred to as the Bottomland Hardwood Forest. Of the total of 386 km^2 (149 mi^2) of wetlands in this category, approximately 26% were determined to be seasonally or semi-permanently flooded, which means they are flooded for at least extended periods, especially early in the growing season. Seventy-four percent of the bottomland wetlands were classified as only temporarily flooded, which indicates that the sites are generally dry except for brief flooding during the growing season. The next most frequent wetland or deep water habitat in the study region was the limnetic impoundment which covers an estimated 40 km^2 (15 mi^2). Persistent emergent wetlands (marshes) were found in 16 km^2 (6.2 mi^2). Needle-leaved forested wetlands, which indicate the presence of bald cypress (*Taxodium distichum*) swamps, were found to cover 5.6 km^2 (2.2 mi^2). Dead forested wetlands and shrub-scrub wetlands, found in 8.1 km^2 (3.1 mi^2) of the study region, indicate severe stress in the past, usually from flooding, acid mine drainage, or a combination of both.

Table 3. Extent of wetlands and deepwater habitats in study region of Western Kentucky Coal Field. Study region is shown in Figure 12.

Wetland Type	Area km^2	Area mi^2
Palustrine Systems		
Persistent Emergent	16.2	6.2
Broad-leaved		
Deciduous Forested		
Seasonally or Semi-Permanently Flooded	102.1	39.4
Temporarily Flooded	283.6	109.5
Needle-Leaved		
Deciduous Forested	5.6	2.2
Dead Forested	1.7	0.6
Shrub-Scrub	6.4	2.5
Lacustrine System		
Limnetic		
Impoundments	40.0	15.4
Riverine System		
Aquatic Bed		
Wetland	3.2	1.2
TOTAL AREA	458.8	177.0

Tradewater River Basin. The Tradewater River Basin contains the largest wetland system in the Coal Field. The Clear Creek system (Site 1 on Figure 12), including Clear, Lick, Rose and Weirs Creeks, encompasses 48.5 km^2 (18.7 mi^2) and is the most severely mining-impacted wetland in Western Kentucky. In terms of area affected and original diversity of habitats, the wetland may be one of the most severely impacted ecosystems in the country. Five of the wetland types discussed in this atlas appear in the Clear Creek system. The seasonally or semi-permanently flooded, broad-leaved deciduous forest is the dominant wetland type. Stream channels are often poorly defined, and standing water extends across broad areas through much of the year. Temporarily flooded, broad-leaved deciduous forests predominate on the floodplains of streams with definite channels. Mining activities, highway obstructions, and beaver activity have increased the water level in many of the wetlands in the Clear Creek system. Death of bottomland hardwoods in these areas allowed the appearance of other wetland types including shrub-scrub, persistent emergent and aquatic bed wetlands. Two Kentucky Threatened plants (Table 4) are found in the Rose-Weirs Creeks wetland areas of the Coiltown quadrangle. The proximity of mining and the likely destruction or alteration of habitat contribute heavily to the listing of these plants as Threatened. These plants do occur outside of the study area.

Nearly all the wetlands in the Tradewater River Basin are affected by coal mining. Dawson Springs Seep Swamp (Site 2 on Figure 12), however, shows no indication of mining impact. This wetland was identified as a potential ecological/geological natural landmark of the Interior Low Plateaus Physiographic Province by Quarterman and Powell (1978). Although the primary source of water is a seep beneath a sandstone bluff, Montgomery Creek seasonally floods this broad-leaved deciduous forest. The understory is poorly developed, and the herbaceous layer contains a variety of sedges and ferns which are generally absent from mining-affected wetlands.

Green River Basin. The Green River Basin contains both mining-impacted and nearly natural wetland areas. The Pond Creek wetlands (Site 3 on Figure 12) have been severely impacted by mining. Actual surface mines within the wetland, as well as indirect mining effects, have destroyed large sections of bottomland hardwood forest. These areas are dead forested wetlands or are in transition toward persistent emergent and shrub-scrub wetlands. The remaining forested wetlands are restricted to a narrow band of riparian forest along the channelized, acidic stream.

The headwaters of Cypress and Little Cypress Creeks are located in the midst of surface mines and consequently receive large amounts of mine drainage. In the upper reaches of the Cypress Creek wetland system (Site 4 on Figure 12), however, large expanses of persistent emergent marshes serve to mitigate the effects of mine runoff. Both streams are channelized, and forested wetlands dominate the floodplain. Impoundments behind the dredge spoil support the most well-developed stands of bald cypress in the Coal Field. These needle-leaved deciduous forests are extensive along the middle reaches of Cypress Creek and are regionally significant as the northeastern-most extent of cypress in the Mississippi Embayment. Seasonally and temporarily flooded broad-leaved deciduous forests are present along the artificial levees and in areas where the floodplain is not impounded. Several rare and infrequent plants occur in this habitat. One Special Concern species and one Threatened plant from the Central City West quadrangle have been reported (Table 4).

Fish and Wildlife Resources

Fish and wildlife species that have been reported in the study region and have been assigned Endangered, Threatened, Special Concern, or Undetermined status determined by the Endangered Species Committee of the Kentucky Academy of Science and the Kentucky Nature Preserves Commission are listed in Table 5. The quadrangle and the major drainage basin in which the species were reported are also given. The majority of these species have been reported from Hartford, Central City West, Dawson Springs, and Coiltown quandrangles.

Three Endangered species, one mussel and two birds, have been reported in the study region. Five fish species, one bird species, and one mammal species are listed as Threatened and have been found in the study region. There are also eight Special Concern species and six species of Undetermined status identified from the study region.

Table 4. Plant species that are listed as Threatened and Special Concern status that have been reported in Western Kentucky study region.[a]

Status	Species name	Common name	Quadrangle	River Basin
Threatened	Chelone obliqua var. speciosa[b]	pink turtlehead	Hartford	Green
	Didiplis diandra	water purslane	Nebo Coiltown	Tradewater
	Limnobium spongia	frog's bit	Coiltown	Tradewater
	Zizaniopsis miliacea	southern wild rice	Central City West	Green
Special Concern	Decodon verticillatus	swamp loosestrife	Central City West	Green
	Utricularia gibba	humped bladderwort	Livermore	Green

[a]from KNPC (1981, 1982) and Branson et al. (1981).
[b]Federal Candidate for Listing; currently under review for federal listing.

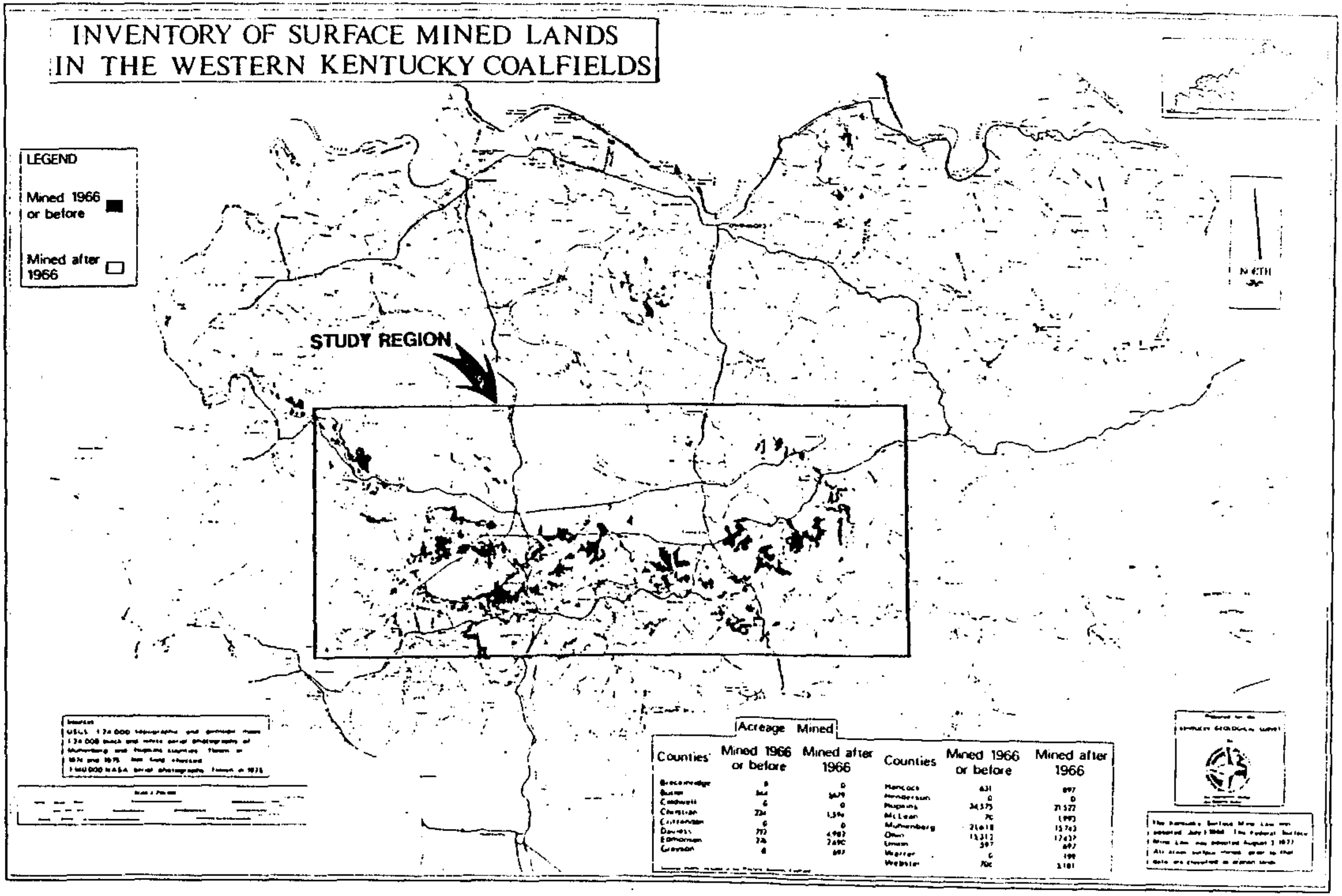


Figure 11. Study region of Western Kentucky Coal Field showing surface coal mining. Original map prepared by Geography Department, Eastern Kentucky University, for Kentucky Geological Survey.

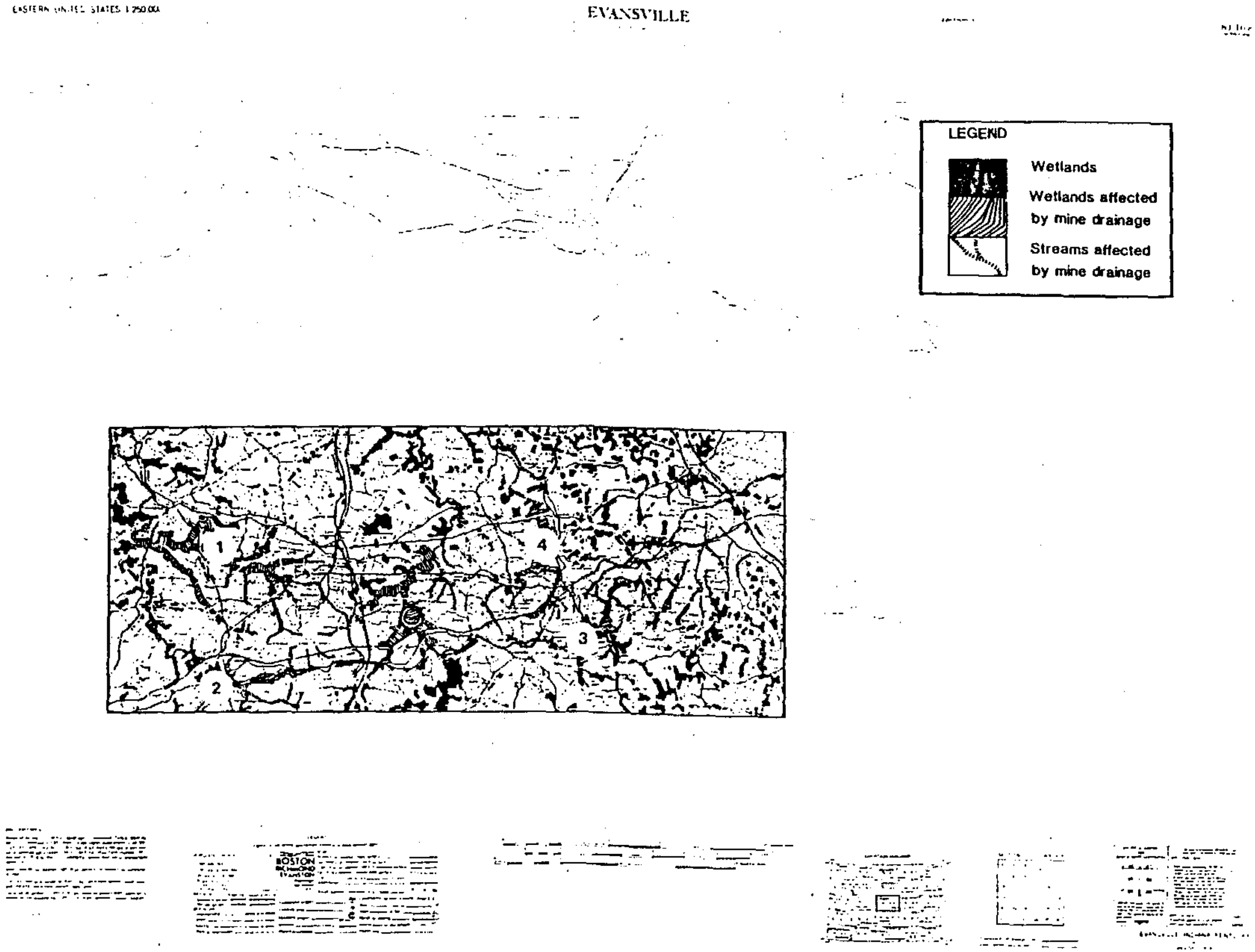


Figure 12. Wetlands in study region of Western Kentucky Coal Field.

Table 5. Fish and wildlife species listed as Endangered, Threatened, of Special Concern, or Undetermined Status that have been reported in the Western Kentucky study region.[a]

Status	Species name	Common name	Quadrangle	River Basin
Endangered	Botaurus lentiginosus	American bittern	Madisonville West	Tradewater
	Epioblasma sampsoni	Sampson's pearly mussel	Livermore	Green
	Ixobrychus exilis	least bittern	Madisonville West	Tradewater
Threatened	Ammocrypta pellucida	eastern sand darter	Central City East	Green
			South Hill	Green
			Paradise	Green
			Hartford	Rough (Green)
	Etheostoma histrio	harlequin darter	Equality	Rough (Green)
			Hartford	Rough (Green)
	Hybognathus hayi	cypress minnow	Graham	Green
	Lepisosteus oculatus	spotted gar	Coiltown	Tradewater
			Rochester	Green
	Percina shumardi	river darter	Hartford	Rough (Green)
	Podilymbus podiceps	pied-billed grebe	Madisonville West	Tradewater
	Sylvilagus aquaticus	swamp rabbit	Central City West	Cypress Creek (Green)
Special Concern	Ambystoma talpoideum	mole salamander	Dawson Springs	Tradewater
	Elassoma zonatum	banded pygmy sunfish	Coiltown	Tradewater
			Central City West	Cypress Creek (Green)
	Hyla avivoca	birdvoiced treefrog	Dawson Springs	Tradewater
	Ichthyomyzon unicuspis	silver lamprey	Rochester	Green
	Lepomis punctatus	spotted sunfish	Graham	Green
	Percina copelandi	channel darter	Hartford	Rough (Green)
	Percina phoxocephala	slenderhead darter	Dawson Springs	Tradewater
			Livermore	Green
			Equality	Rough (Green)
			Paradise	Green
			Hartford	Rough (Green)
			Central City West	Cypress Creek (Green)
	Polyodon spathula	paddlefish	Hartford	Rough (Green)
Undetermined	Ardea herodias	great blue heron	Central City West	Cypress Creek (Green)
	Buteo lineatus	red-shouldered hawk	Central City West	Cypress Creek (Green)
	Circus cyaneus	marsh hawk	Central City West	Cypress Creek (Green)
	Erimyzon sucetta	lake chubsucker	Dalton	Tradewater
			Coiltown	Tradewater
			Hartford	Rough (Green)
			Central City West	Cypress Creek (Green)
	Percina ouachitae	yellow darter	Hartford	Rough (Green)
	Zapus hudsonius	meadow jumping mouse	Dawson Springs	Tradewater
			Sacramento	Green
			Hartford	Rough (Green)

[a]from KNPC (1981, 1982) and Branson et al. (1981).

Coal surface mining has reduced the macroinvertebrate and fish diversity of several streams and wetland areas in the Western Kentucky Coal Field. Clear Creek, Cypress Creek, and Pond Creek wetlands have been mined and drained extensively, and the effects of acid drainage, stream channelization, and increased turbidity are reflected in the limited biota of these areas. The main channels of the Tradewater and Pond Rivers, in addition to many small tributaries, have significantly poorer diversity of fish due to mine drainage. However, game fish such as largemouth bass and sunfish are found in Mud River, and bluegill and black bass are caught in the Tradewater River (Sehlinger and Underwood, 1980). The Green River, with its greater assimilative capacity, supports several game fish species, including the striped bass (Morone saxatilus) which is classified by the FWS as a Species of Special Emphasis in their Regional Resource Priorities (RRP) program.

Future Management Issues

The wetlands and aquatic habitats of the Western Kentucky Coal Field, already subjected to considerable ecological stress from mining activity, face an uncertain future. Although the production of coal in the region has been slightly depressed for the last few years, the potential exists for a boom in coal production in the last part of this century. Four synthetic fuel plants have recently been proposed for locations along the Ohio river in Western Kentucky with a combined synthetic oil production of over 260,000 barrels per day. These plants, if built, would require an annual increase in coal production, mostly from the Western Kentucky Coal Field, of about 40 million tons per year (Holmes et al., 1981). This would double the Field's current coal production and some of this increased production would undoubtedly occur through surface mining in areas with wetlands and critical habitats.

Certain wetland areas that were once protected due to their inhospitable conditions may now be opened for surface mining due to advances in technology. New electric drag lines, lighter bulldozers with more traction, and trucks that can carry more weight allow for surface mining in wetlands where it might have been difficult before (Brame, personal communication). With depletion of much of the easy-to-reach coal and with the increased price of fossil fuels, mining companies are going into areas such as wetlands that might have been marginally profitable before. Seasonally to temporarily flooded riparian bottomlands are prime candidates for increased disturbance due to these technological and economic changes.

Proposed research for Phase 2 of this project will involve the identification of management techniques that can be used to lessen the impact of surface mining on adjacent and downstream wetlands. It will also identify where opportunities may exist for creating wetlands in the reclamation process and where wetlands can be used as "interface ecosystems" to lessen the effects of chemical and hydrologic modification of streams and rivers.

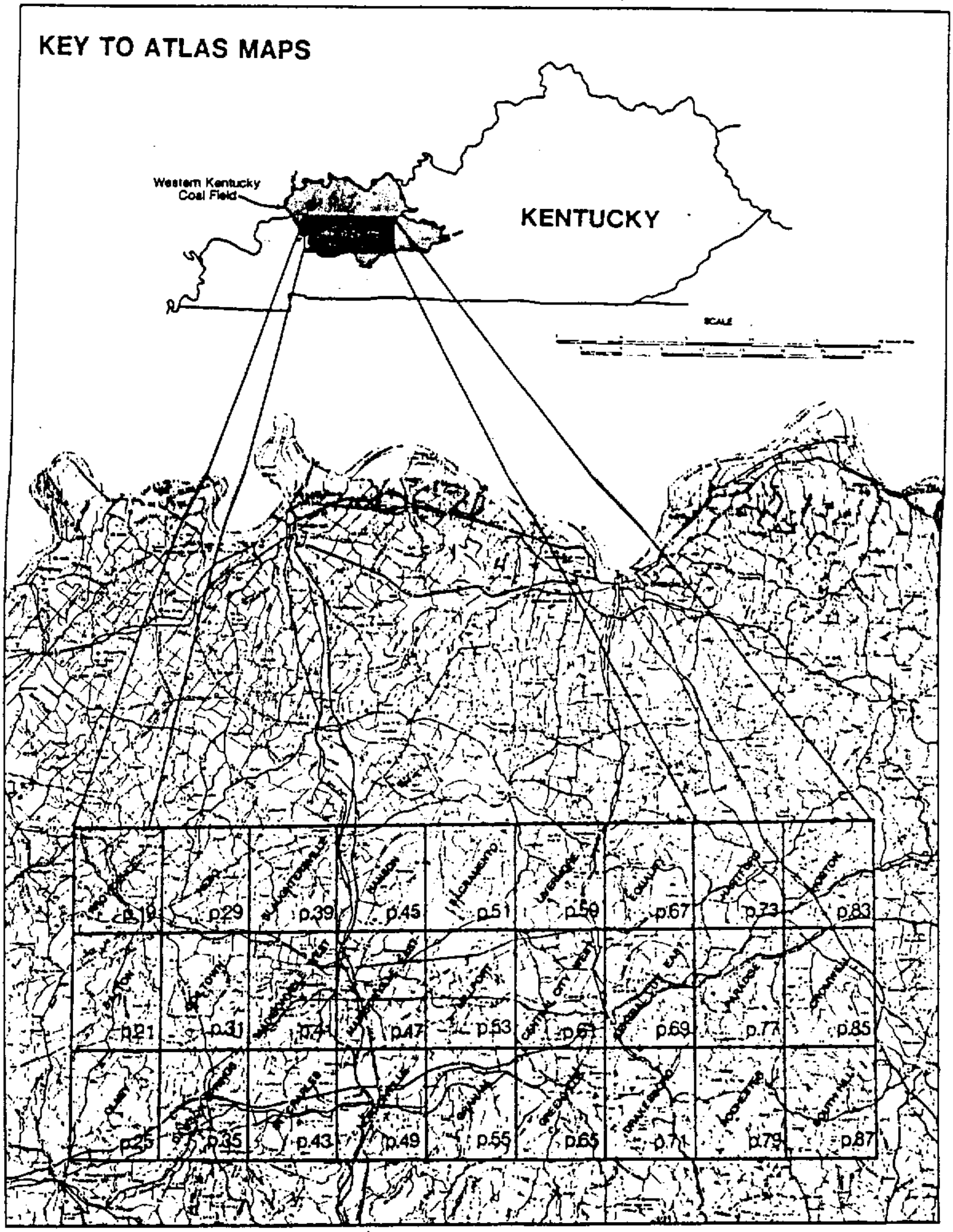


Figure 13. Key to 7.5 minute quadrangles.

Providence

Location. Webster, Crittenden, and Hopkins Counties
Tradewater River Drainage Basin

Geology and Coal Mining. The floodplain of the Tradewater River is underlain by clay, silt, sand, and gravel alluvium of the Quaternary System (Kehn, 1966b). The uplands are primarily Caseyville Formation of the Lower Pennsylvanian Series. The No. 4 coal bed found in the watershed has been mined using both deep and surface operations (Palmer, 1966).

Hydrology. Streamflow of the Tradewater River is currently measured upstream at Olney (see Olney quadrangle). Infrequent streamflow measurements are available for the Tradewater River at Montezuma Bridge (Site 1) for 1953-1978. Streamflow of Caney Fork near Clay (immediately north of Providence quadrangle, Site 4) ranged from 0 to 18 cfs in 1980 (USGS, 1980).

Water Quality. USGS stations located at Craborchard Creek (Site 2) and Caney Fork (Site 4) have only sparse information available (Table 6). Data from 1966 and 1981 indicate severe surface mining runoff in Craborchard Creek (Grubb and Ryder, 1972; KDNREP, unpublished data). KDNREP also found high concentrations of manganese, sulfates, aluminum, and conductivity in the Tradewater River in 1981 near Providence.

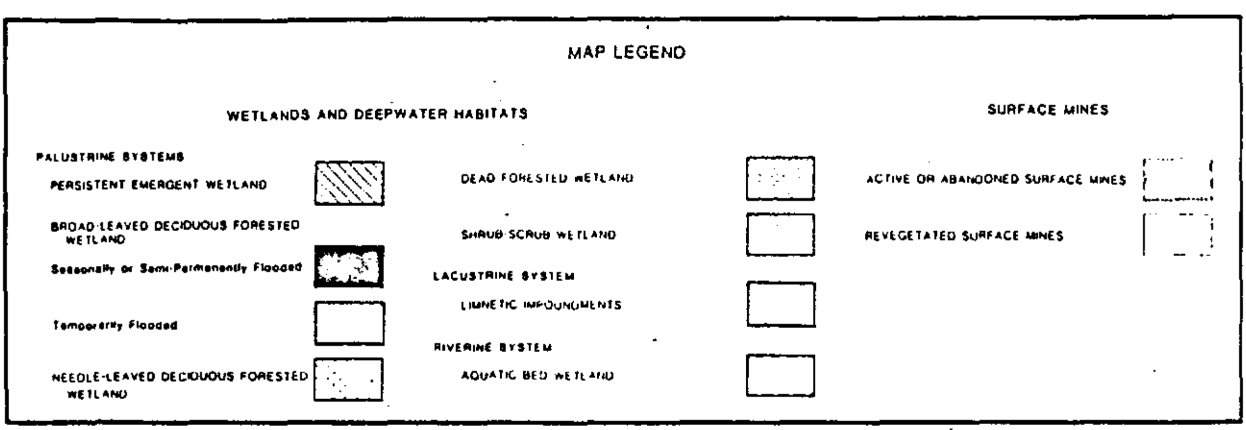
Wetland Vegetation. The floodplain at Site 1 consists of two sloughs and a bottomland hardwood forest. One slough contains a *Quercus palustris* (pin oak) - *Ulmus americana* (American elm) community with *Acer saccharinum* (silver maple), *Fraxinus pennsylvanica* (green ash), *Liquidambar styraciflua* (sweetgum), and *Quercus lyrata* (overcup oak). The other slough is an *Acer saccharinum* - *Fraxinus pennsylvanica* community associated with *Quercus lyrata* and *Ulmus rubra* (slippery elm). A *Quercus stellata* (post oak) - *Carya ovata* (shagbark hickory) - *Q. falcata* var. *pagodaefolia* (Spanish oak) community dominates the floodplain forest (KNPC, 1980). Site 3 is a *Salix nigra* (black willow) - *Fraxinus pennsylvanica* swamp (water depth about 1.5 m) adjacent to Caney Fork with an associated *Typha*-sedge - rush marsh.

Table 6. Water quality summary for Providence quadrangle. Values are given as average (# of samples) unless only one measurement was taken.

Parameter	Date	Site number 2	Site number 3 and 4	
pH	1966[a]	6.8	---	
	1980[b]	7.5	7.35	(2)
	1981[c]	7.0	---	
	1982[d]	---	7.2	
Conductivity, umhos/cm	1966	5480	---	
	1980	260	277	(2)
	1981	2120	---	
	1982	---	190	
Dissolved Oxygen, mg/l	1982	---	6.8	
Sulfate, mg/l	1966	3620	---	
	1980	58	62	(2)
	1981	1126	---	
	1982	---	26	
Turbidity, NTU	1982	---	61	
Suspended Solids, mg/l	1980	37	9.5	(2)
	1981	24	---	
Iron, mg/l (dissolved)	1980	0.01	0.11	(2)
	1981	2.98	---	
	1982	---	2.49	
Manganese, mg/l (dissolved)	1980	0.15	0.11	(2)
	1981	2.5	---	

[a]Grubb and Ryder (1972).
[b]USGS (1981).
[c]KDNREP (unpublished data).
[d]this study.

Fish and Wildlife. The wildlife of the Montezuma Bridge Area (Site 1), reported by KNPC (1980), includes the white-footed mouse (*Peromyscus leucopus*), the least shrew (*Cryptotis parva*), and several amphibians: *Acris crepitans* (northern cricket frog), *Bufo americanus* (American toad), and *Rana catesbeiana* (bullfrog). One common turtle, *Sternotherus odoratus* (stinkpot), also was observed in the area.



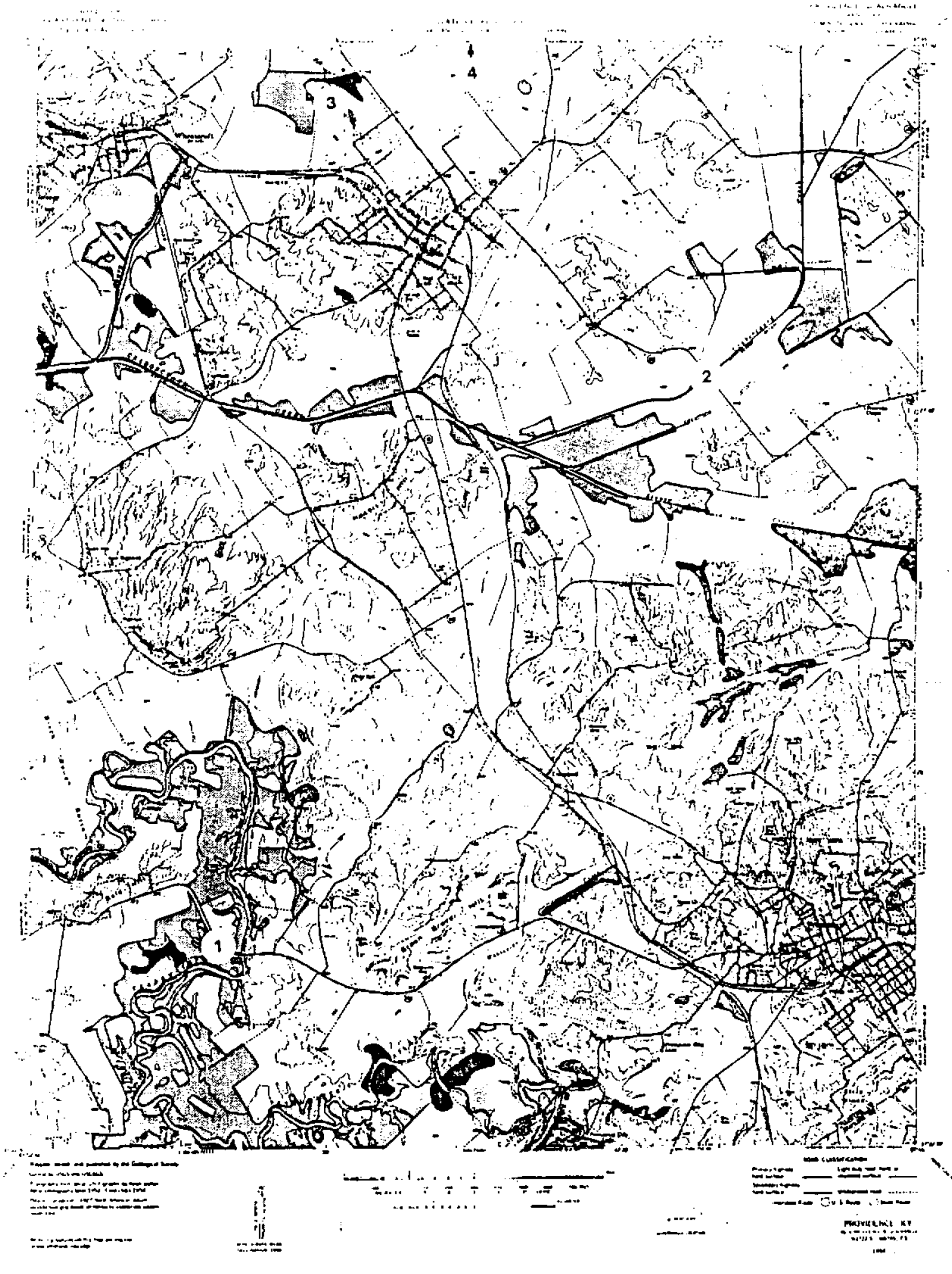


Figure 14. Wetlands and surface mines of Providence quadrangle.

Dalton

Location. Caldwell, Hopkins, Crittenden, and Webster Counties
Tradewater River Drainage Basin

Geology and Coal Mining. The bottomlands of the Tradewater Basin are primarily alluvium of clay, silt, sand, and gravel of the Quaternary System. The predominant soil association is Zanesville-DeKalb-Muskingum-Falaya (Humphrey et al., 1966). The No. 4 coal bed found within the watershed has been mined locally (Palmer, 1966).

Hydrology. A dead forested wetland that is permanently flooded (Site 1) is located adjacent to the Tradewater River and Brooks Creek near a reclaimed surface mine. For further hydrologic data of the Tradewater River, refer to the Olney quadrangle. The Land Branch Wetland (Site 2) near the Tradewater River has an intermittent to permanently flooded hydroperiod and has both altered and unaltered water areas (KNPC, 1980). Lick Creek Swamp (Site 4), 2 miles north of Dalton in Hopkins County, has a hydroperiod that ranges from intermittently flooded to permanently flooded. The water regime here has been altered by surface mining and logging (KNPC, 1980).

Water Quality. Brooks Creek Wetland (Site 1) was found to be turbid and murky in low flow conditions. Brooks Creek Wetland, however, is influenced by nearby surface mining which has changed the swamp. Water quality data (Table 7) show conductivity and sulfate readings well above normal, indicating the presence of mine drainage. KDNREP (1981) found extremely degraded water quality in 1980 in the upper reaches of Brooks Creek. Water quality data have been presented by KNPC (1980, 1981) for Land Branch Wetland (Site 2). The wetland has turbid, poorly oxygenated water typical of the late summer sampling time. The water quality, otherwise, is good (KNPC, 1981).

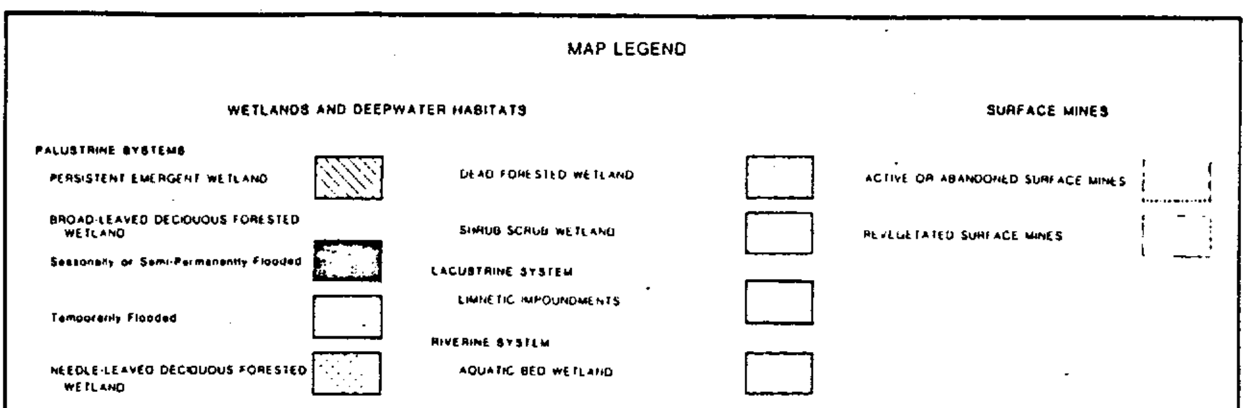
Recent water quality data for Lick Creek Wetland (Site 4) have been presented by USGS (1981), although Grubb and Ryder (1972) made some reference to it. Lick Creek is much like Clear Creek (see Coiltown quadrangle), an extremely acidic, mine drainage-impacted wetland. Lick Creek joins Clear Creek about 2 miles upstream of the confluence with the Tradewater River. For a discussion of Clear Creek water quality, which is partially in the Dalton quadrangle, see the Coiltown quadrangle. Extensive data on the water quality of the Tradewater River have been collected at Olney, south of the Dalton quadrangle (see Olney quadrangle).

Table 7. Water quality summary for Dalton quadrangle.

Parameter	Date	Site number		
		1	2	4
pH	1980[a]	---	---	4.1
	1981[b]	---	7.5	---
	1982[c]	6.8	---	---
Conductivity, umhos/cm	1980	---	---	420
	1981	---	308	---
	1982	900	---	---
Dissolved Oxygen, mg/l	1980	---	---	---
	1981	---	3.0	---
	1982	6.4	---	---
Sulfate, mg/l	1980	---	---	250
	1981	---	0	---
	1982	419	---	---
Turbidity, NTU	1980	---	---	---
	1981	---	100	---
	1982	26.5	---	---
Suspended Solids, mg/l	1980	---	---	10
	1981	---	200	---
	1982	---	---	---
Iron, mg/l	1980	---	---	0.43
	1981	---	---	---
	1982	0.13	---	---
Manganese, mg/l	1980	---	---	2.0

[a]USGS (1981).
[b]KNPC (1981).
[c]this study.

Wetland Vegetation. The wetland located near the confluence of Jennings and Brooks Creeks with the Tradewater River (Site 1) consists of a dead hardwood swamp surrounded by a band of hardwood forest. The standing dead timber in the swamp includes *Fraxinus pennsylvanica* (green ash), *Quercus* sp. (oak), and *Carya* sp. (hickory). No shrubs or aquatic macrophytes are apparent. The surrounding bottomland hardwoods contained the species above and also *Acer rubrum* (red maple) and *A. saccharinum* (silver maple) as important overstory trees.



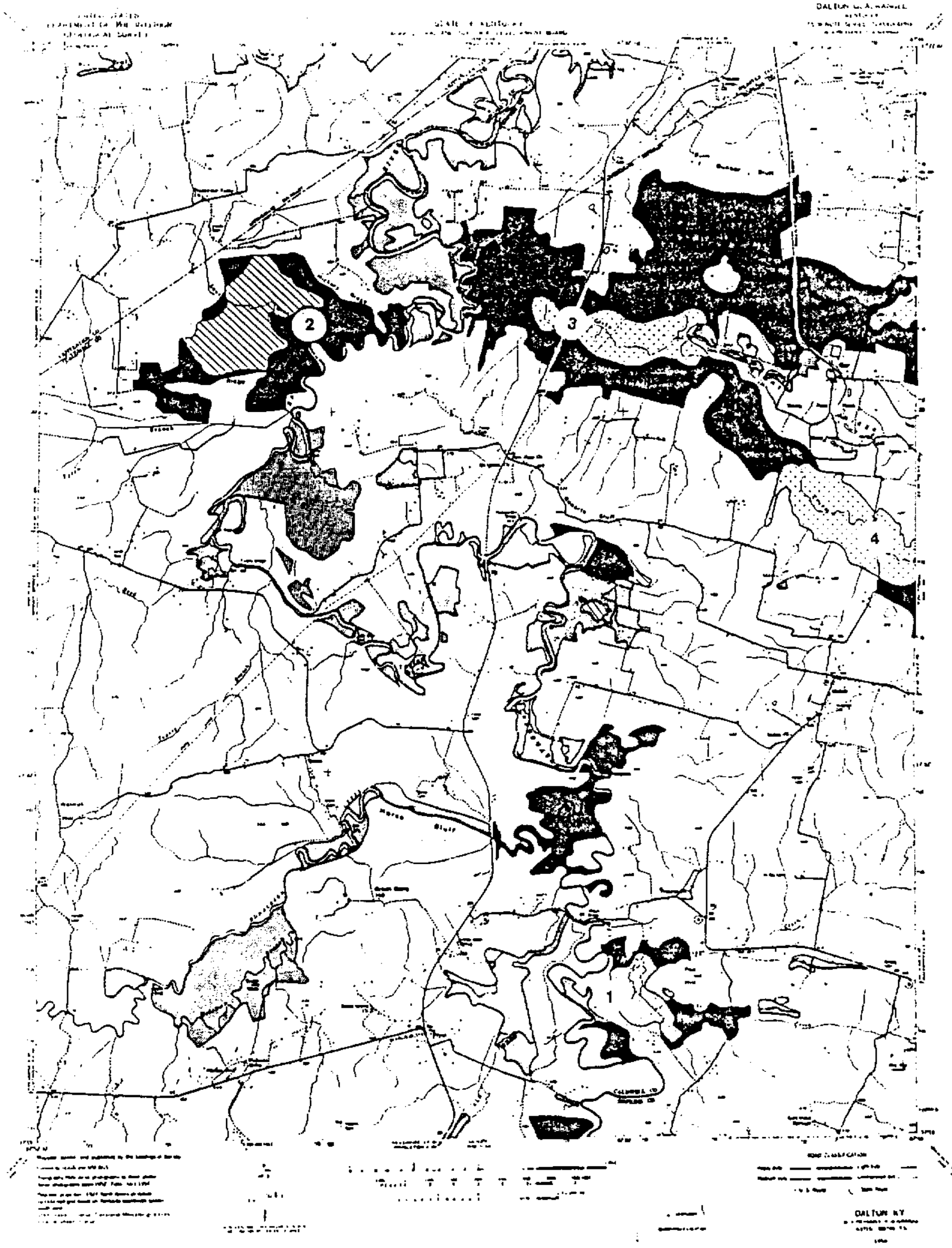


Figure 15. Wetlands and surface mines of Dalton quadrangle.

Land Branch Wetland (Site 2) is a bottomland hardwood forest with much standing dead timber. Beaver activity is apparent in the wetland. The central part of the wetland is forested with Acer spp. (maples), Betula nigra (river birch), and Platanus occidentalis (sycamore) with Cephalanthus occidentalis (buttonbush) and Hibiscus laevis (mallow) in the understory. The swamp is adjacent to a marshy area containing a large number of sedges, rushes, and grasses, as well as several hydrophytic dicots (KNPC, 1980).

Lower Clear Creek (Site 3) is a mosaic of shrub-scrub, aquatic bed, and forested wetlands. Quercus phellos (willow oak) and Q. palustris (pin oak) dominate the riparian swamp forest, while buttonbush dominates the shrub-scrub wetland. The Clear Creek system is discussed more fully with the Coiltown quadrangle.

Fish and Wildlife. Wildlife observed in July 1982 at the Brooks Creek Wetland (Site 1) includes bluegills (Lepomis macrochirus) and the green-backed heron (Butorides striatus).

KNPC (1981) reported Dytiscidae (predaceous diving beetles) and Hydrophilidae (water scavenger beetles) as the most diverse taxonomic components of the macroinvertebrates of Land Branch Wetland (Site 2); they also report Anodonta imbecillis (freshwater mussel) and Erimyzon sucetta (lake chubsucker). The lake chubsucker is a special interest species listed by Branson et al. (1981) as being of Undetermined status. This rating suggests the need for further investigation of this species within Kentucky wetland areas.

Additional fish found in the Dalton Quadrangle are listed in Appendix C.

Olney

Location. Caldwell and Hopkins Counties
Tradewater River Drainage Basin

Geology and Coal Mining. Extensive faulting in the Tradewater basin has resulted in numerous formations which are discussed in detail by Nelson (1964), Kehn (1977a), Palmer (1967), Hansen (1973), and Rogers and Trace (1976). Grubb and Ryder (1972) have summarized the geology of the Tradewater River watershed. Mineral resources in the basin consist of coal, oil, gas, limestone, and sandstone. Commercial deep mining and, more recently, surface mining have been operating in several beds including Nos. 4, 6, 7, 9, 11, 12, and 14 in the Tradewater Basin. Some have been depleted while others are present in sizable reserves (KNPC, 1981). No surface mines are evident in 1979 aerial photos of the Olney quadrangle.

Hydrology. The stream discharge for the Tradewater River at Olney (Site 1) ranged from 0.8 to 4,720 cfs for water year 1980 (USGS, 1981). The Tradewater River drainage area at this point is 660 km^2 (255 mi^2) and average discharge is 334 cfs. KNPC (1981) reports that this stream has been channelized, while the Flynn Fork channel (Site 2) is relatively undisturbed. Grubb and Ryder (1972) reported stream discharge at Creekmur Bridge (Site 2) to range from 0.004 to 34 cfs for the period of June 1966 to June 1967. Near its mouth, Flynn Fork has a discharge range of 0.1 to 34 cfs, averaging 8.3 cfs (Grubb and Ryder, 1972).

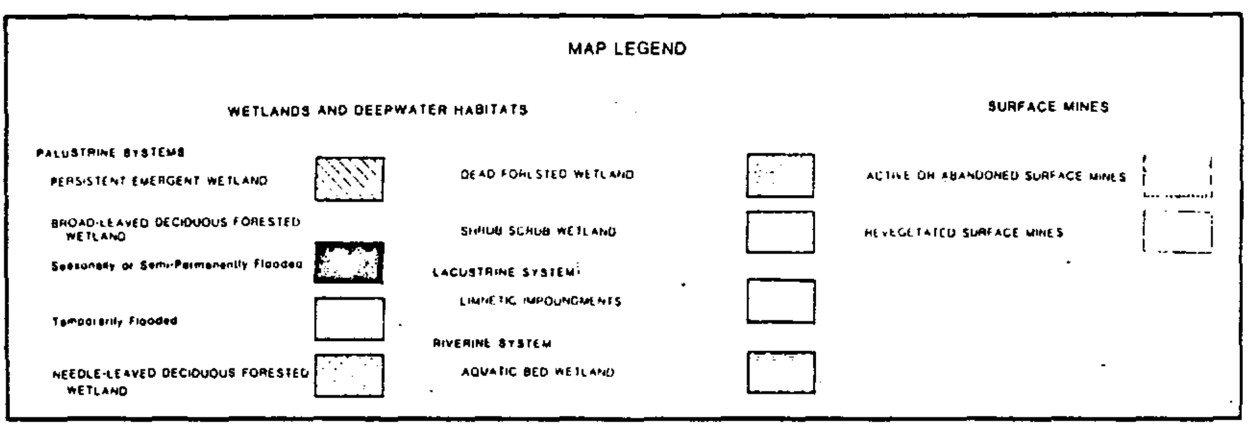
Water Quality. The Tradewater River cuts across the northeastern corner of the Olney quadrangle and has been analyzed in detail at Olney (Site 1 on Table 8). This site has one of the best records of water quality data in the Western Kentucky Coal Fields. Grubb and Ryder (1972) presented an extensive analysis of the relationship between upstream mining activities and the water quality observed over a period of years at Olney. An analysis of trends of sediment loads was found to follow closely the trend of strip mine coal production upstream from Olney (Grubb and Ryder, 1972). USGS analyses before 1980 indicate that the water quality at Olney is degraded by periodic but persistent problems of sediment, low pH (less than 4.0), and high concentrations of metals such as aluminum (greater than 29 mg/l) and manganese (greater than 17 mg/l). Recent data presented by USGS (1981), KNPC (1981), and KDNREP (unpublished data) (Table 8) do not reflect these adverse conditions. Domestic and municipal waste is also known to enter the Tradewater at four points upstream (Metcalf and Eddy, Inc., 1975).

Water quality data from Flynn Fork (Site 2) at Creekmur Bridge have been reported by Grubb and Ryder (1972), Metcalf and Eddy, Inc. (1975), KNPC (1981), and KDNREP (unpublished data). The last two studies demonstrated that water quality is relatively good, although dissolved oxygen is low (Table 8).

Table 8. Water quality summary for Olney quadrangle. Values are given as average ± standard deviation (# of samples) unless only one measurement was taken.

Parameter	Date	Site number 1		Site number 2
pH	1980[a]	6.86 ± .32	(8)	---
	1981[b]	7.0		7.0
	1981[c]	6.8		7.2
Conductivity, umhos/cm	1980	320 ± 101	(8)	---
	1981	253		197
	1981	449		285
Dissolved Oxygen, mg/l	1980	---		---
	1981[b]	4.7		2.5
Sulfate, mg/l	1980	114 ± 43	(8)	---
	1981	35		10
	1981	165		41.4
Turbidity, NTU	1980	---		---
	1981	7.0		16
	1981	2.9		4.7
Suspended Solids, mg/l	1980	46 ± 60	(7)	---
	1981	100		0
	1981	3.0		6
Iron, mg/l (dissolved)	1980	0.065 ±0.044	(8)	---
	1981	---		---
	1981	.034		0.09
Manganese, mg/l (dissolved)	1980	1.3 ±0.75	(8)	---
	1981	---		---
	1981	0.81		0.09

[a]USGS (1981).
[b]KNPC (1981).
[c]KDNREP (unpublished data).



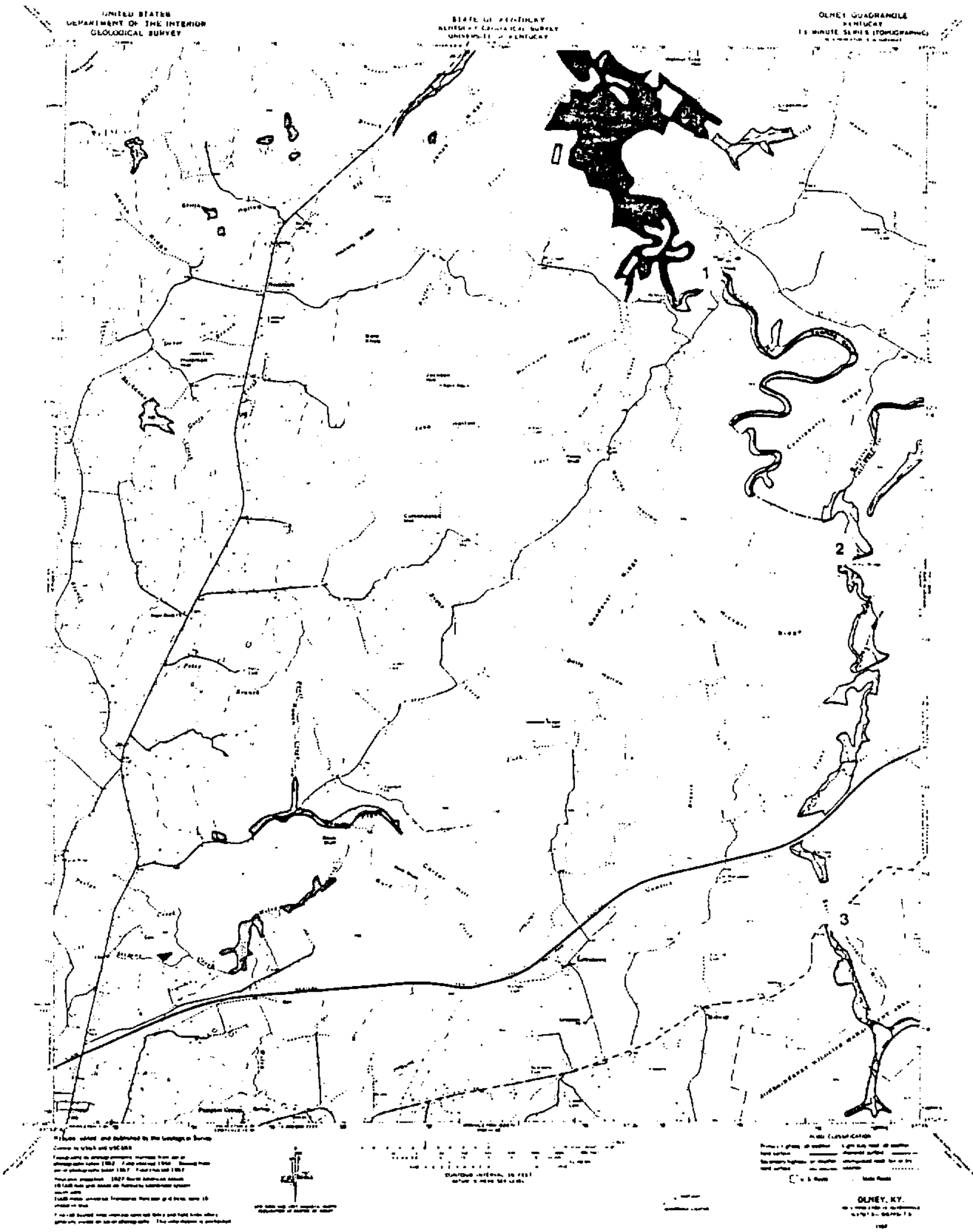


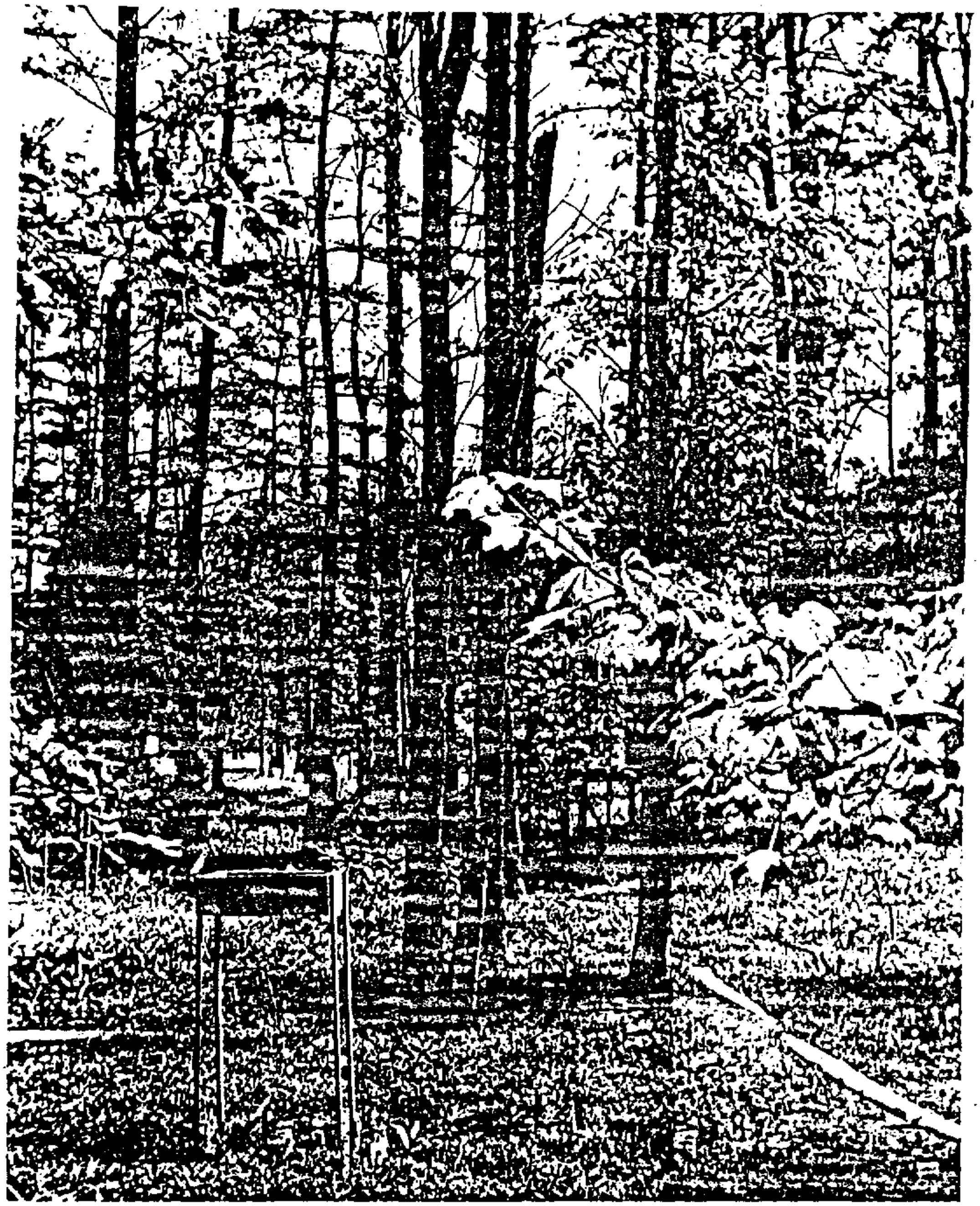
Figure 16. Wetlands and surface mines of Olney quadrangle.

Wetland vegetation. The watershed is typically hilly with floodplains best developed along the Tradewater River and Flynn Fork. Agriculture is practiced in much of the floodplain of the watershed. The once prevalent forested wetlands have been drained and cleared of vegetation. The remaining riparian forests (e.g., Sites 1 and 2), though small, are generally well developed and contain a mixture of hydrophytic and mesophytic trees. Typical forest species are Acer negundo (box elder), A. rubrum (red maple), A. saccharinum (silver maple), Betula nigra (river birch), Carpinus caroliniana (American hornbeam), Cephalanthus occidentalis (buttonbush), Fraxinus pennsylvanica (green ash), Liriodendron tulipifera (tulip tree), Nyssa sylvatica (black gum), Platanus occidentalis (sycamore), Quercus alba (white oak), Sassafras albidum (sassafras), and Ulmus americana (American elm). There are also isolated small tracts of floodplain forest of similar composition located along the entire Tradewater River (KNPC, 1981).

Fish and Wildlife. Macroinvertebrate collections made by KNPC from the Tradewater River at Olney (Site 1) were dominated by Chironomidae (midges) and Cheumatopsyche sp. larvae (caddisflies). The fishes reported as most abundant in this area were Notropis fumeus (ribbon shiner) and Fundulus olivaceus (blackspotted topminnow). Macrobenthos reported for Flynn Fork (Site 2) included Cheumatopsyche sp. (caddisflies), Chironomidae (midges), and Stenacron sp. (mayflies) (KNPC, 1981).

The East Fork of Flynn Fork near Hunter Bluff (Site 3) also is dominated by midges and caddisflies as the macrobenthic components. Wildlife recorded for this area include Peromyscus leucopus (white-footed mouse), Blarina brevicauda (short-tailed shrew), Mus musculus (house mouse), and Bufo americanus (american toad) (KNPC, 1980).

Appendix C includes additional fish and wildlife reported from the Olney quadrangle.



Nebo

Location. Webster and Hopkins Counties
Tradewater River Drainage Basin

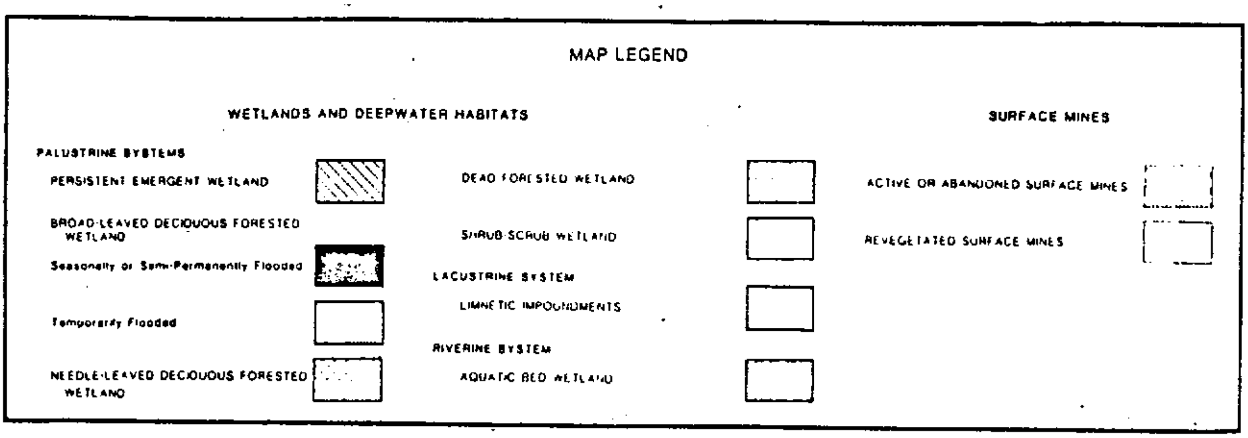
Geology and Coal Mining. The uplands of the Nebo quadrangle are underlain primarily by Pennsylvanian Age shale, siltstone, and coal of the Lisman and Henshaw Formations. The wetlands and floodplains are composed of Quaternary Age alluvium of clay, silt, sand, and gravel (Grubb and Ryder, 1972). Agriculture is the dominant land use, with little coal mining evident in the area.

Hydrology. Little stream flow data have been measured in this quadrangle. See Coiltown quadrangle for discussion of hydrology applicable to Rose Creek and Weirs Creek Wetlands (Site 1).

Water Quality. No water quality data are available for the major portion of the Nebo quadrangle, although some information may be extrapolated from surrounding areas. Large amounts of information on water quality characteristics are available for Rose and Weirs Creeks downstream of Nebo. These streams flow directly into the Coiltown topographic area and are discussed with that quadrangle. Likewise, information on Slover Creek may be obtained from the Craborchard Creek station within the Providence quadrangle.

Wetland Vegetation. Rose and Weirs Creek Wetlands (Site 1) extend from the Nebo quadrangle into the Coiltown quadrangle. Most of the Rose Creek floodplain has been cleared for agriculture. The wetland is an open shrubby area containing Betula nigra (river birch), Cephalanthus occidentalis (buttonbush), and Salix nigra (black willow) as dominant species. Didiplis diandra (water purslane), a Threatened plant in Kentucky, was reported as abundant by KNPC (1980). The wetland area along Weirs Creek contains standing dead timber in a Hibiscus laevis (mallow)-Cephalanthus occidentalis community. The surrounding area of bottomland forest is composed of Fraxinus pennsylvanica (green ash), Acer rubrum (red maple), Liquidambar styraciflua (sweetgum), Quercus bicolor (swamp white oak), Q. lyrata (overcup oak), Q. palustris (pin oak), and Q. phellos (willow oak) as reported by KNPC (1980).

Fish and Wildlife. No fish and wildlife data are available for the Nebo quadrangle wetlands. See Coiltown quadrangle for fish and wildlife in Weirs Creek and Rose Creek Wetlands.



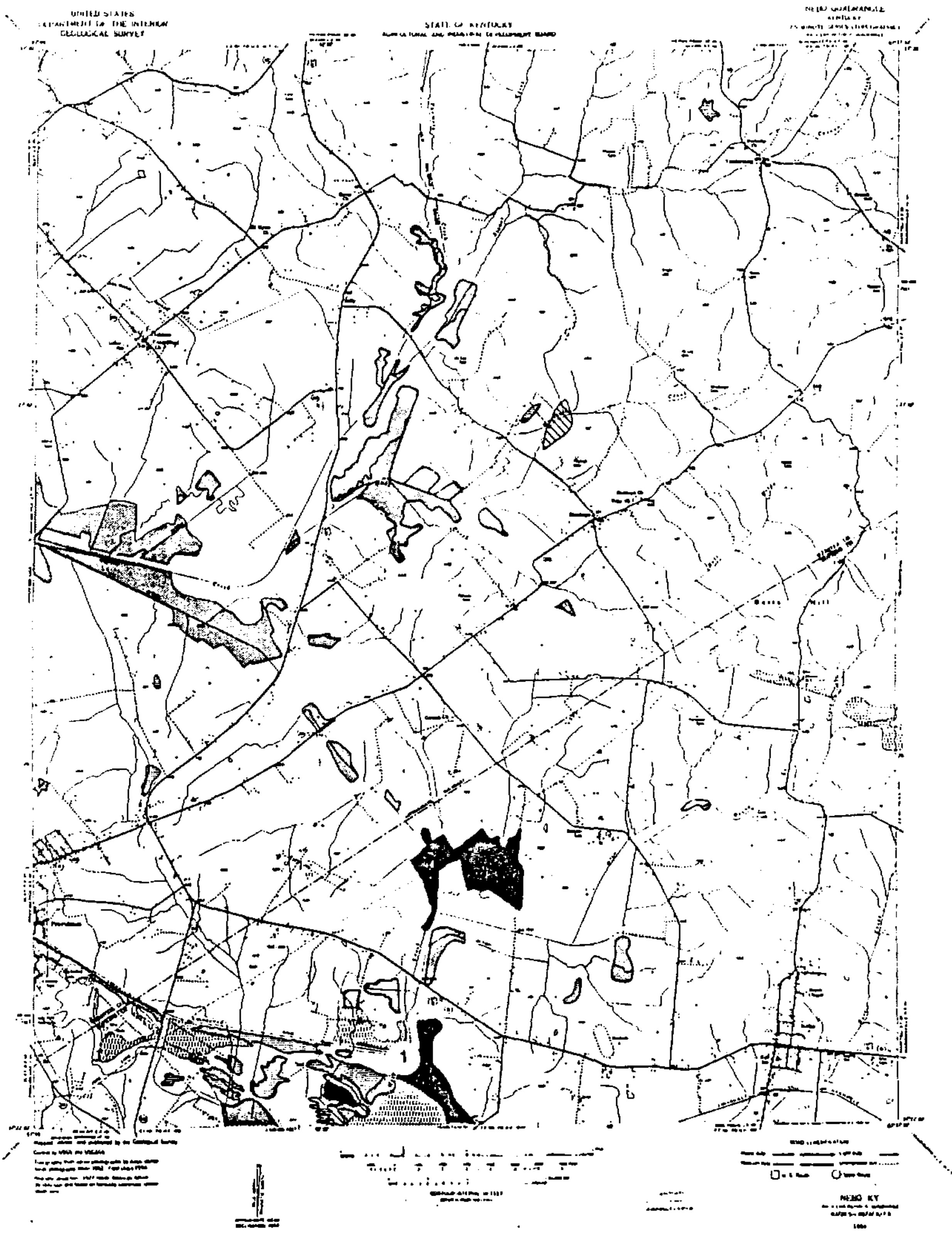


Figure 17. Wetlands and surface mines of Nebo quadrangle.

Coiltown

Location. Hopkins County
Tradewater River Drainage Basin

Geology and Coal Mining. The Clear, Rose, and Weirs Creek watersheds are underlain by four broad categories of geologic strata. Extensive faulting, however, has created a disjunct distribution of the materials (Franklin, 1967; Palmer, 1967). Uplands north and west in the quadrangle are underlain primarily by Pennsylvanian shale, sandstone, limestone, clay, siltstone, and coal of the Lisman and Henshaw formations. Southeastern portions generally contain Middle Pennsylvanian shale, sandstone, coal, siltstone, limestone, and underclay of the Carbondale Formation. Sandstone, siltstone, shale, limestone, underclay, and coal of the Tradewater Formation of Pennsylvanian origin dominate the southern sections. Stream channels and wetlands are underlain by Quaternary Age gravel, sand, silt, and clay.

Extensive areas are being surface mined or are in various stages of revegetation throughout the central and southern portions of the quadrangle. Coal mines vary in size from small mines on hillsides to area mines covering several hundred hectares. Most mines occur in hillsides adjacent to wetlands. Some coal, however, has been surface mined from the wetlands themselves (KNPC, 1981).

Hydrology. Most of the main channel and tributaries of Clear Creek Wetland have been altered by coal mining, channelization, and beaver dams. The hydroperiod of this extensive wetland is intermittently exposed to permanently flooded. Streamflow at Site 1 is continuous and is impounded there by a beaver dam.

The Rose Creek Wetland (Site 4) is characterized by intermittent flooding and has a drainage area of 5.4 km^2 (2.1 mi^2). KNPC (1981) reports that 86% of Rose Creek was channelized 5 to 20 years ago.

The Weirs Creek Wetland (Site 3) is characterized by a permanently flooded hydroperiod that has been significantly altered by stream channelization (KNPC, 1980, 1981). Weirs Creek is joined by Rose Creek, both of which then flow into Clear Creek.

Lick Creek Swamp is also partially within the Coiltown Quadrangle. For further hydrologic data on this wetland, refer to the Dalton Quadrangle.

Water Quality. Some recent water quality data are available for this topographic area (Table 9). Coiltown quadrangle is of great interest since it contains a major portion of the largest wetland complex in the Western Kentucky Coal Field including Clear Creek, Lick Creek, and Rose-Weirs Creeks Wetlands. The area is also heavily surface mined, and the water quality is poor. Rose and Weirs Creeks converge at the northern periphery of the topographic map and lie partially within the Nebo quadrangle. Water quality data for Rose Creek (Site 4 on Table 9) indicate low dissolved oxygen values but otherwise better water conditions than other sites in the quadrangle, especially in comparison with Clear Creek (KNPC, 1980, 1981). Recent water quality analyses of Rose Creek have been presented by KNPC (1981) and KDNREP (1981). Data collected from Weirs Creek (Site 3) show high conductivity and sulfates, indicating mine drainage and/or surface disturbance (KNPC, 1980, 1981). Other data (Neichter, 1972; Leuthart, 1975) exist for this area, with most of it quite variable. Surface mining has increased in the basin in recent years and may be the reason for the variability seen in Weirs Creek.

By far the largest wetland in the Western Kentucky Coal Field is Clear Creek Swamp. This system stretches from the eastern edge of the Madisonville West quadrangle west across Coiltown quadrangle and well into the Dalton quadrangle where it flows into the Tradewater River. The general water quality of the Clear Creek watershed is perhaps better known than any other wetland within the Western Kentucky Coal Field. Interest in the area has stemmed primarily from the severe acid mine drainage problems which date back to the early 1900s (Leuthart, 1975). Grubb and Ryder (1972) identified Clear Creek as a major contributor of acid to the Tradewater River system. They characterized the water as a calcium-magnesium-sulfate type and noted that the creek flowed year-round as a result of inflow from mining activities. Shawler (1974) reported

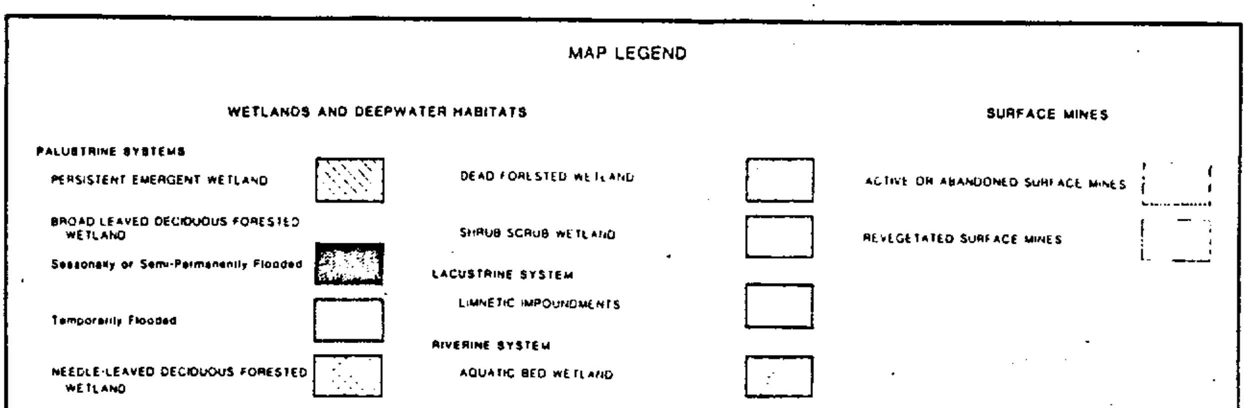


Figure 18. Wetlands and surface mines of Coltown quadrangle.

Table 9. Water quality summary for Coiltown quadrangle. Values are given as average $\pm$ standard was deviation (# of samples) unless only one measurement taken.

Parameter	Date	Site number 1	2	3	4
pH	1980[a]	---	---	---	6.6
	1981[b]	7.0	---	8.0	7.5
	1981[c]	3.8	---	---	---
	1982[d]	5.16 $\pm$ 1.1 (11)	5.83 $\pm$ .68 (9)	---	---
Conductivity, umhos/cm	1980	---	---	---	355
	1981	929	---	942	389
	1981	1930	---	---	---
	1982	1235 $\pm$ 408 (11)	2600 $\pm$ 677 (11)	---	---
Dissolved Oxygen, mg/l	1980	---	---	---	2.5
	1981[b]	4.1	---	5.7	4.9
	1982	5.8 $\pm$ 2.1 (8)	7.98 $\pm$ 1.64 (8)	---	---
Sulfate, mg/l	1980	---	---	---	43
	1981	200	---	200	60
	1981	1049	---	---	---
	1982	645 $\pm$ 113 (9)	647 $\pm$ 44 (9)	---	---
Turbidity, NTU	1980	---	---	---	4.9
	1981	8.4	---	41	62
	1981	1049	---	---	---
	1982	2.86 $\pm$ 1.25 (11)	2.37 $\pm$ 1.26 (11)	---	---
Suspended Solids, mg/l	1981	0	---	100	100
	1981	1.0	---	---	---
Iron, mg/l (dissolved)	1980	---	---	---	0.95*
	1981[c]	1.49	---	---	---
	1982	3.32 $\pm$ 1.19 (11)	4.40 $\pm$ 4.03 (11)	---	---
Manganese, mg/l (dissolved)	1980	---	---	---	1.47*
	1981[c]	4.05	---	---	---
	1982	4.0 $\pm$ 2.27 (9)	6.21 $\pm$ 1.56 (9)	---	---

*total

[a]KDNREP (1981).
[b]KNPC (1981).
[c]KDNREP (unpublished data).
[d]this study.

better water quality near the mouth of Clear Creek than in upstream reaches and concluded that the wetland is serving to store, deposit, or dilute the chemical consituents of mine drainage. Examination of water quality analyses by others (Neitcher, 1972; Leuthart, 1975; USGS, 1980, 1981; KDNREP, 1981) indicates acid water as the primary water quality problem although, as noted by Leuthart (1975), varying degrees of impact in Clear Creek have been recorded over the years. This is partially attributed to the large area inundated, to the seasonal/diurnal fluxes, and to the different degree of impact suffered by some areas relative to others. According to Metcalf and Eddy, Inc. (1975), four point source discharges are located in the watershed. Three of these are domestic (school or city treatment plants), and the fourth emanates from a coal company (KNPC, 1981).

Mitsch et al. (1982) presented water quality data as part of a preliminary classification and management scheme for the Western Kentucky Coal Field. A continuation of that effort has yielded detailed information on the chemical characteristics of Clear Creek (Table 9). Three intensive study sites were chosen: 1) at KY 630 Bridge (see Madisonville West quadrangle), 2) at Watson Bridge (Site 2), and 3) and at the KY 109 Bridge (Site 1). Site 1 was also sampled by KNPC (1981). The results indicate very poor water quality of the Clear Creek system with extremely high levels of dissolved materials, particularly sulfates, iron, and manganese. This poor water quality can be generally attributed to drainage from active and abandoned coal mines. The final tributary of the Clear Creek system is Lick Creek. This area is much like Clear Creek, which it joins to the west in the Dalton quadrangle. For a discussion of Lick Creek water quality, see the Dalton quadrangle narrative.

Wetland Vegetation. Numerous wetland vegetation types occur in Clear Creek Wetland. The poorly defined stream channel supports aquatic bed communities of *Eleocharis* sp. and *Sphagnum* sp. as well as emergent stands of *Eleocharis quadrangulata* (spike rush), *Dulichium arundinaceum* (three-way sedge), *Rhynchospora corniculata* (horned-rush), *Saururus cernuus* (lizard tail), and *Typha latifolia* (common cattail). In many of the open sloughs along the channel, shrub-scrub communities of *Cephalanthus occidentalis* (buttonbush) and *Hibiscus laevis* (mallow), and thickets of *Acer rubrum* (red maple), *Betula nigra* (river birch), *Fraxinus pennsylvanica* (green ash), and *Liquidambar styraciflua* (sweetgum) occur. Bottomland forests adjacent to the stream are dominated primarily by *L. styraciflua* with *A. rubrum*, *Quercus lyrata* (overcup oak), *Q. michauxii* (swamp chestnut oak), *Q. palustris* (pin oak), and *Q. phellos* (willow oak) as associates. *Betula nigra* is important near the water channels.

Rose Creek Wetland (Site 4) is a young forested wetland formed by pooled creek drainage. Submerged beds of Didiplis diandra (water purslane), a Kentucky Threatened plant, and stands of Cephalanthus occidentalis and Saururus cernuus are present. Thickets of Betula nigra occur to the outside of these areas with Salix nigra and Acer rubrum (KNPC, 1981).

Weirs Creek Wetland (Site 3) is a shallow swamp contiguous with a strip mine lake. Due to water level changes caused by surface mining, the original swamp forest trees have been killed. Weirs Creek Wetland now primarily supports extensive beds of Typha, Cephalanthus occidentalis, and Hibiscus laevis with Ceratophyllum demersum (hornwort) and Nuphar advena (spatterdock) in open water areas. A Kentucky Threatened plant, Limnobium spongia (frog's bit), also occurs in Weirs Creek (KNPC, 1982).

Fish and Wildlife. The most common fishes of the Clear Creek Wetland include the grass pickerel (Esox americanus vermiculatus), golden shiner (Notemigonus crysoleucas), and the pirate perch (Aphredoderus sayanus) (KNPC, 1981). A special interest fish, Erimyzon sucetta (lake chubsucker), is also found in this area. Diversity among macroinvertebrate species is generally low, probably caused by poor water quality.

The macroinvertebrate fauna from the Rose Creek Wetland is more diverse and is dominated by the Hemiptera (true bugs) and the Coleoptera (beetles) (KNPC, 1981). The most abundant fish species include Esox americanus vermiculatus (grass pickerel), Notemigonus crysoleucas (golden shiner), and Fundulus olivaceus (blackspotted topminnow). Also recorded from this area is the banded pygmy sunfish, Elassoma zonatum, listed by Branson et al. (1981) as being of Special Concern, having a peripheral range in Kentucky. This is the only location in the Tradewater Basin from which this species has been taken (Warren and Cicerello, 1982). Since suitable habitat exists throughout the drainage basin, this suggests that the species may have been eliminated elsewhere due to poor water quality.

Macroinvertebrates from the Weirs Creek Wetland include three species of freshwater mussel: Anodonta grandis, A. imbecillis, and Ligumia subrostrata. Fish species reported by KNPC (1981) include Gambusia affinis (mosquito fish), Fundulus olivaceus (blackspotted topminnow), Lepomis macrochirus (bluegill), and Etheostoma gracile (slough darter). One special interest fish, Etheostoma chlorosomum (bluntnose darter), and one Threatened species, Lepisosteus oculatus (spotted gar), are reported in this area (Branson et al., 1981; KNPC, 1981).

Other fish species reported from this quadrangle are listed in Appendix C.

Dawson Springs

Location. Hopkins, Caldwell, and Christian Counties
Tradewater River Drainage Basin

Geology and Coal Mining. Dawson Springs Seep Swamp (Site 2) is approximately 40 hectares (100 acres) of bottomland hardwood forest, old field, wet meadows, and forested uplands. The bottomlands are underlain by alluvium of the Quaternary System composed of clay, silt, sand, and gravel (Kehn, 1966a). The soils are Collins, Falaya, and Waverly silt loams. These soils are deep, poorly drained, and seasonally flooded (Humphrey et al., 1966). The uplands are underlain by the Caseyville formation of the Lower Pennsylvanian series, Pennsylvanian system. KNPC (1980) reported the area free of coal drainage pollutants but could not determine whether a recent mine would have any effect on the wetland. The primary source of water is a seep from beneath a sandstone bluff.

Hydrology. KNPC (1981) reports that Montgomery Creek (Site 1) is a relatively undisturbed fourth-order stream. Dawson Springs Seep Swamp (Site 2), a seasonally-flooded bottomland hardwood forest, is located along Montgomery Creek. Grubb and Ryder (1972) report a range in streamflow at this site from 0.24 to 95 cfs from February 1966 to June 1967.

Stream discharge of the Tradewater River at Pooles Mill Bridge, upstream of this quadrangle, ranged from 0.0 to 257 cfs over the period March through September, 1980 (USGS, 1981). Grubb and Ryder (1972) reported an average discharge of 107 cfs at this point.

Water Quality. Since the Tradewater River has numerous acid tributaries flowing into it, small, non-acid tributaries contribute greatly to modification of acid extremes. This was noted by Grubb and Ryder (1972) while presenting water quality data for Montgomery Creek (Site 1 on Table 10). The KNPC has also collected water quality data (Table 10) on Montgomery Creek and noted that, as with other non-mined streams, there is a tendency to cease flow during summer months. The stream was noted as flowing and very turbid; it often meanders through areas of poorly defined channels. Discharges of sewage are apparently limited to those from domestic septic tanks. Aerial photographs indicate recent surface mining activities 6 km (3.7 miles) upstream of the sampling site; their effect on water quality has been undetected (Table 10). Dawson Springs Seep Swamp (Site 2) is located along Montgomery Creek near its confluence with the Tradewater River. To date this wetland has remained uncontaminated by surface mine drainage. Maple Swamp (Site 4) is a large area of bottomland hardwoods and dead wooded swamp. No water quality parameters have been measured for the wetland area itself, although surface mines are located just upstream of the dead swamp. Cany Creek (Site 3), which drains Maple Swamp, was studied by Grubb and Ryder (1972) and found to be extremely affected by coal mine drainage (Table 10). The stream is affected for several miles upstream as well (see St. Charles quadrangle).

A large unnamed wetland associated with Hurricane Creek (Site 5) shows definite surface mine impact (Table 10). The bright orange ferric hydroxide precipitate, extremely low pH and dissolved oxygen values, and high conductivity, sulfate, and iron values are unmistakably due to coal mining runoff. One source of pollution is a large coal storage area located adjacent to the upper west fork of Hurricane Creek. This area may be observed from the KY 62 Bridge east of Dawson Springs. The poor quality waters of Hurricane and Cany Creeks flow into the Tradewater River, adding to the overall degradation of this major drainage system.

An analysis of Lick Creek near KY 109 in the northern part of the quadrangle by KDNREP (1981) indicated that this stream was "severely impacted by mine drainage".

Wetland Vegetation. Dawson Springs Seep Swamp (Site 2) is a second growth bottomland hardwood forest. The major canopy species are *Acer rubrum* (red maple), *Fraxinus pennsylvanica* (green ash), *Liquidambar styraciflua* (sweetgum), *Quercus palustris* (pin oak), and *Q. michauxii* (swamp chestnut oak). The understory is poorly developed except in areas of deeper water where the open canopy has allowed *Cephalanthus occidentalis* (buttonbush) and *Itea virginica* (Virginia willow) to flourish (KNPC, 1980). An adjacent persistent emergent marsh contains numerous sedges and rushes.

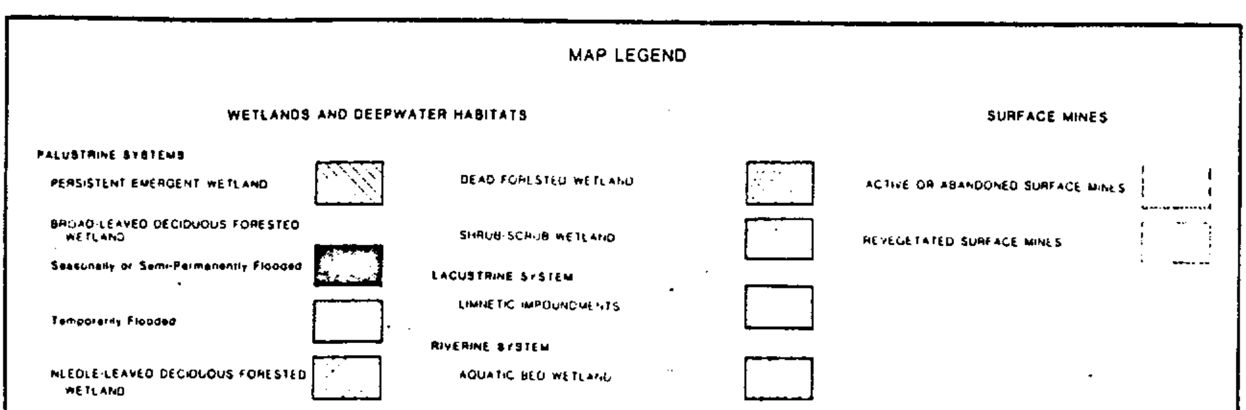


Figure 19. Wetlands and surface mines of Dawson Springs quadrangle.

Table 10. Water quality summary for Dawson Springs quadrangle. Values are given as average ± standard deviation (# of samples) unless only one measurement was taken.

Parameter	Date	Site number 1	3	5
pH	1966[a]	7.3	3.1 ± 0.3 (12)	
	1980[b]	7.0	---	---
	1981[c]	7.0	---	---
	1982[d]	---	---	2.7
Conductivity, umhos/cm	1966	258	2106 ± 743 (13)	---
	1980	115	---	---
	1981	218	---	---
	1982	---	---	2900
Dissolved Oxygen, mg/l	1966	---	---	---
	1980	3.4	---	---
	1982	---	---	2.0
Sulfate, mg/l	1966	28	1175 ± 422 (12)	---
	1980	0	---	---
	1981	38.1	---	---
	1982	---	---	656
Turbidity, NTU	1966	---	---	---
	1980	100+	---	---
	1981	12	---	---
	1982	---	---	12.0
Suspended Solids, mg/l	1966	---	---	---
	1980	200	---	---
	1981	26	---	---
	1982	---	---	---
Iron, mg/l (dissolved)	1966	0.03	15.4 ± 13.5 (6)	---
	1980	---	---	---
	1981	0.15	---	---
	1982	---	---	4.89
Manganese, mg/l (dissolved)	1966	---	14.9 ± 7.7 (6)	---
	1980	---	---	---
	1981	0.17	---	---
	1982	---	---	---

[a]Grubb and Ryder (1972).
[b]KNPC (1980).
[c]KDNREP (unpublished data).
[d]this study.

Maple Swamp (Site 4) is a seasonally-flooded bottomland hardwood forest. To the south of Maple Swamp Road, the forest is dominated by Acer rubrum, Liquidambar styraciflua, and Betula nigra (river birch). To the north of the road is a dead semi-permanently flooded forest containing standing dead A. rubrum, F. pennsylvanica, and C. occidentalis. The wetland receives mine drainage.

The riparian community (Site 5) along Hurricane Creek is sparse with very few canopy sized trees. The dominant species is B. nigra, with a few A. rubrum interspersed. Most of the trees are less than 6" dbh (15 cm) and the herbaceous layer is absent or sparse.

Platanthera flava (tubercled orchid), a plant species of some interest, was reported from the Montgomery Creek wetland near Site 2.

Fish and Wildlife. Macroinvertebrates reported from Montgomery Creek Wetland (near Site 2) by KNPC (1981) include the mayfly (Stenacron sp.), the alderfly (Sialis sp.), and the caddisfly (Cheumatopsyche sp.). Several other wildlife species are reported from this wetland (KNPC, 1980) including the white-footed mouse (Peromyscus leucopus), the short-tailed shrew (Blarina brevicauda), the green-backed heron (Butorides striatus), the small-mouth salamander (Ambystoma texanum), the gray treefrog (Hyla chrysoscelis complex), the American toad (Bufo americanus), and the copper-belly water snake (Nerodia erythrogaster neglecta).

The macroinvertebrate fauna of the Dawson Springs Seep Swamp (Site 2) is dominated by two species of mayflies (Stenacron sp. and Hexagenia munda), the alderfly (Sialis sp.), and the caddisfly (Cheumatopsyche sp.). Two wildlife species from this area, Ambystoma talpoideum (mole salamander) and Hyla avivoca (bird-voiced treefrog), are listed as Special Concern species by Branson et al. (1981). A mammal of special interest, the meadow jumping mouse (Zapus hudsonius), is also found in this wetland. Listed as a Special Concern species is the slenderhead darter (Percina phoxocephala), taken from the Tradewater River near Dawson Springs.

Additional fish and wildlife from this area are listed in Appendix C.

Slaughtersville

Location. Hopkins and Webster Counties
East Fork Deer Creek, Green River Basin; also drained by Tradewater River Basin

Geology and Coal Mining. The uplands of the Slaughtersville quadrangle are underlain by Pennsylvanian Age sandstone, siltstone, shale, limestone, coal, and underclay of the Henshaw and Lisman formations. Coal has been surface mined intermittently from three locales and deep mined in the southern part of the quadrangle. The coal in this area is generally of little commercial value (Kehn, 1964). Alluvial deposits of Quaternary Age underlie the floodplains and stream channels.

Hydrology. Streamflow of East Fork Deer Creek near Sebree (Site 1) ranged from 0.01 to 133 cfs from March to September 1980 (USGS, 1981). This quadrangle also includes tributaries of the Tradewater River.

Water Quality. Although the Slaughtersville topographic area has few wetland areas and little water quality data, some information is available for the larger streams (Table 11). A major stream in the Green River Basin, East Fork Deer Creek (Site 1), has been monitored by the USGS. This site is outside the Slaughtersville quadrangle but contains cumulative information for East Fork Deer Creek surface waters before they flow into the Green River. Iron, manganese, magnesium, and specific conductance are slightly elevated but well below water quality standards (Table 11). Overall, the surface water quality of the Slaughtersville quadrangle is good.

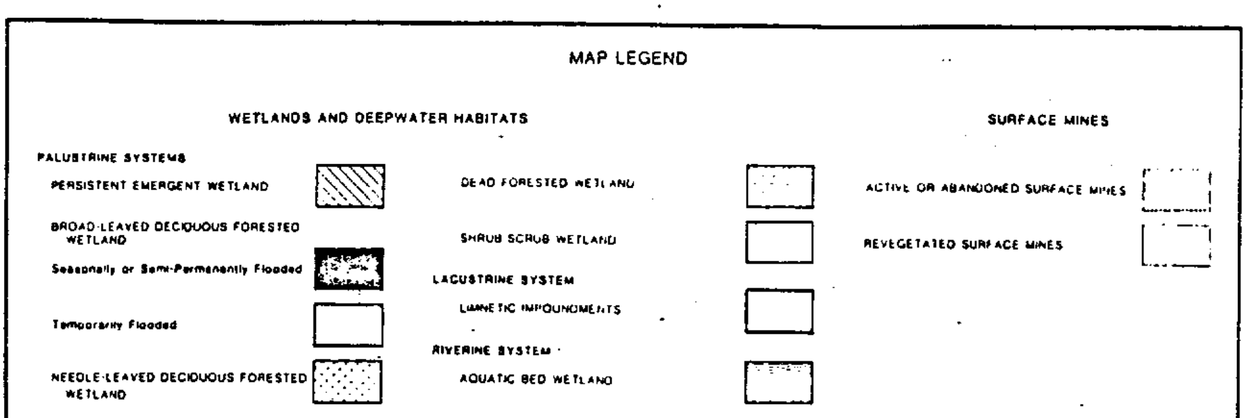
Table 11. Water quality summary for Slaughtersville quadrangle. Values are given as average ± standard deviation (# of samples).

Parameter	Date	Site number 1
pH	1980[a]	7.15 ± 0.2 (4)
Conductivity, umhos/cm	1980	389 ± 181 (4)
Dissolved Oxygen, mg/l	1980	---
Sulfate, mg/l	1980	89.5 ± 44.2 (4)
Turbidity, NTU	1980	---
Suspended Solids, mg/l	1980	62.5 ± 43.8 (4)
Iron, mg/l (dissolved)	1980	0.21 ± 0.05 (4)
Manganese, mg/l (dissolved)	1980	0.95 ± 1.3 (4)

[a]USGS (1981).

Wetland Vegetation. The Slaughtersville quadrangle is almost entirely upland with wetlands occurring only as disjunct patches of floodplain forest. The major area of bottomland hardwood forest lies along the East Fork Deer Creek. The forest is composed of species typically found in floodplains of the area, such as *Acer rubrum* (red maple), *A. saccharinum* (silver maple), *Betula nigra* (river birch), *Liquidambar styraciflua* (sweetgum), *Platanus occidentalis* (sycamore), *Quercus palustris* (pin oak), and *Salix nigra* (black willow).

Fish and Wildlife. No fish and wildlife data are available for wetlands in the Slaughtersville quadrangle.



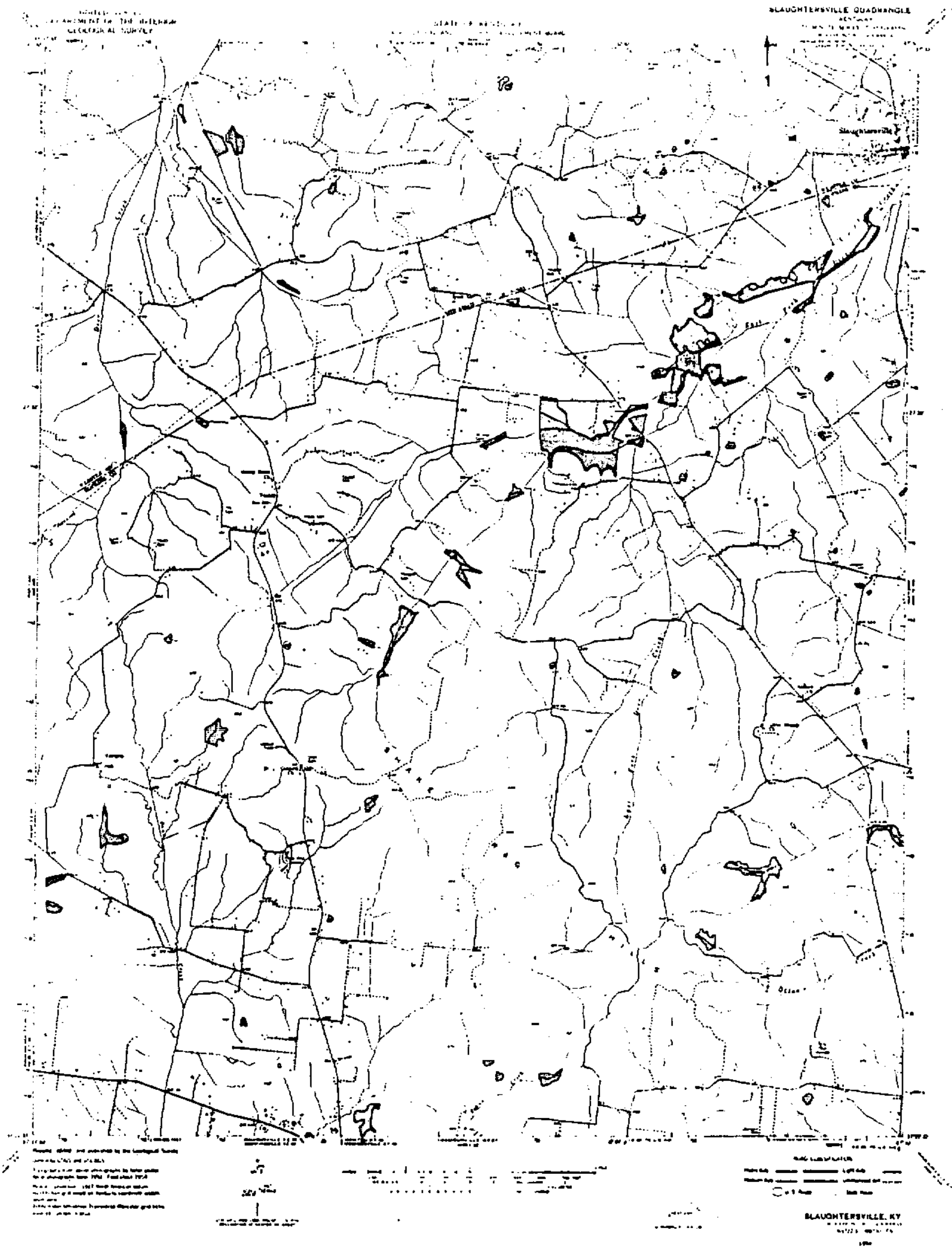


Figure 20. Wetlands and surface mines of Slaughtersville quadrangle.

Location. Hopkins County
Tradewater River Drainage Basin

Geology and Coal Mining. The uplands of the Madisonville West quadrangle are underlain by Pennsylvania Age shale, limestone, sandstone, coal, and clay of the Lisman and Carbondale Formations. The wetlands and stream floodplains are underlain by alluvial silt, clay, sand, and gravel of Quaternary Age. Coal and limestone have been extensively exploited in the quadrangle. Coal has been mined since about 1870 from both deep and surface mines. In recent years, much of the coal has come from surface mines on the No. 9, 11, and 14 beds (Kehn, 1964).

Hydrology. This quadrangle includes the upstream reaches of Clear Creek Wetland which is discussed with Coiltown Quadrangle. Clear Creek is infrequently monitored by the USGS at KY 70 Bridge (Site 2). Streamflow from March to September 1980 ranged from 0.0 cfs to 1.1 cfs for 3 measurements. Greasy Creek, a tributary to Clear Creek, has been channelized for over 20 years. Several reservoirs have been constructed for water supply and mine reclamation on the upstream reaches of Clear and Greasy Creeks.

Water Quality. Since Clear Creek drains this entire topographic area, reference should be made to the Coiltown quadrangle for discussion of water quality. Two sites lie within the Madisonville West quadrangle (Table 12), but are discussed in detail in the Coiltown narrative. The sparse data collected by USGS (1981) and KDNREP (unpublished data) at the KY 70 bridge (Site 2) and by this study from KY 630 (Site 1) on Clear Creek (Table 12) indicate severe acid mine drainage. The most persistent low pH readings noted in this study have been recorded at Site 1.

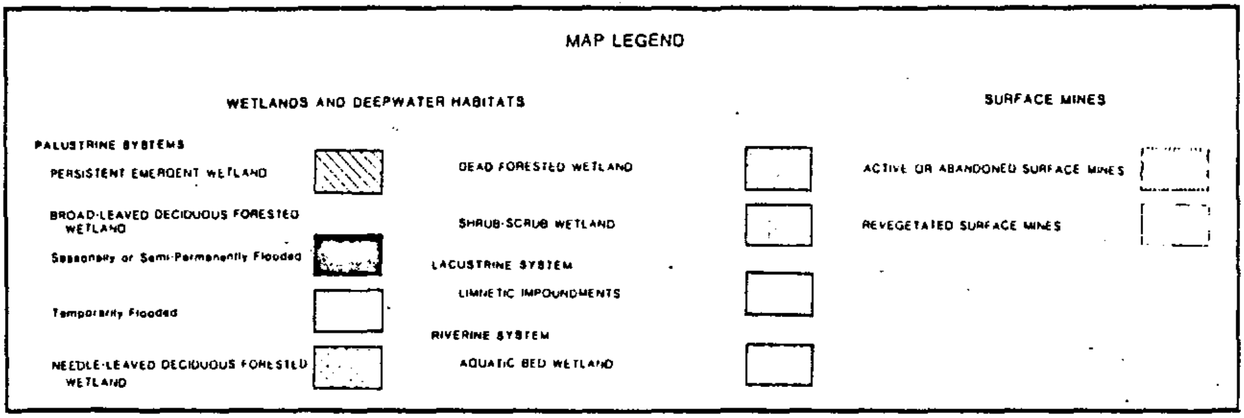
Wetland Vegetation. Clear Creek flows through extensive bottomland hardwood forests in the Madisonville West quadrangle. These forests may be well developed with *Liquidambar styraciflua* (sweetgum), *Acer rubrum* (red maple), *Quercus lyrata* (overcup oak), *Q. michauxii* (swamp chestnut oak), *Q. palustris* (pin oak), and *Q. phellos* (willow oak) as canopy species (KNPC, 1980). Young forests with thicket-like areas are also present. Some of the community types noted are *Betula nigra* (river birch) - *A. rubrum*, *Fraxinus pennsylvanica* (green ash) - *A. rubrum*, and *L. styraciflua* - *A. rubrum* (Site 1).

Fish and Wildlife. Refer to the Coiltown quadrangle for wildlife information about Clear Creek Wetland. Three bird species, the pied-billed grebe (*Podilymbus podiceps*), the American bittern (*Botaurus lentiginosus*), and the least bittern (*Ixobrychus exilis*) are reported from this quadrangle (KNPC, 1982). The American bittern and the least bittern are reported by Branson et al. (1981) as Endangered as nesting species in Kentucky. The pied-billed grebe is reported as a Threatened species. All three species require a wetland area for successful nesting.

Table 12. Water quality summary for Madisonville West quadrangle. Values are given as average ± standard deviation (# of samples) unless only one measurement was taken.

Parameter	Date	Site number 1	Site number 2
pH	1980[a]	---	3.35
	1981[b]	---	3.9
	1982[c]	3.79 ± 0.17 (11)	---
Conductivity, umhos/cm	1980	---	2825
	1981	---	2466
	1982	2227 ± 685 (11)	---
Dissolved Oxygen, mg/l	1980	---	---
	1982	6.65 ± 1.16 (8)	---
Sulfate, mg/l	1980	---	1600
	1981	---	159
	1982	685 ± 130 (9)	---
Turbidity, NTU	1980	---	---
	1981	---	46
	1982	3.5 ± 4.0 (11)	---
Suspended Solids, mg/l	1980	---	24
	1981	---	43
	1982	---	---
Iron, mg/l (dissolved)	1980	---	8.3
	1981	---	6.18
	1982	5.9 ± 3.0 (11)	---
Manganese, mg/l (dissolved)	1980	---	9.3
	1981	---	3.64
	1982	14.5 ± 7.5 (9)	---

[a]USGS (1981).
[b]KDNREP (unpublished data).
[c]this study.



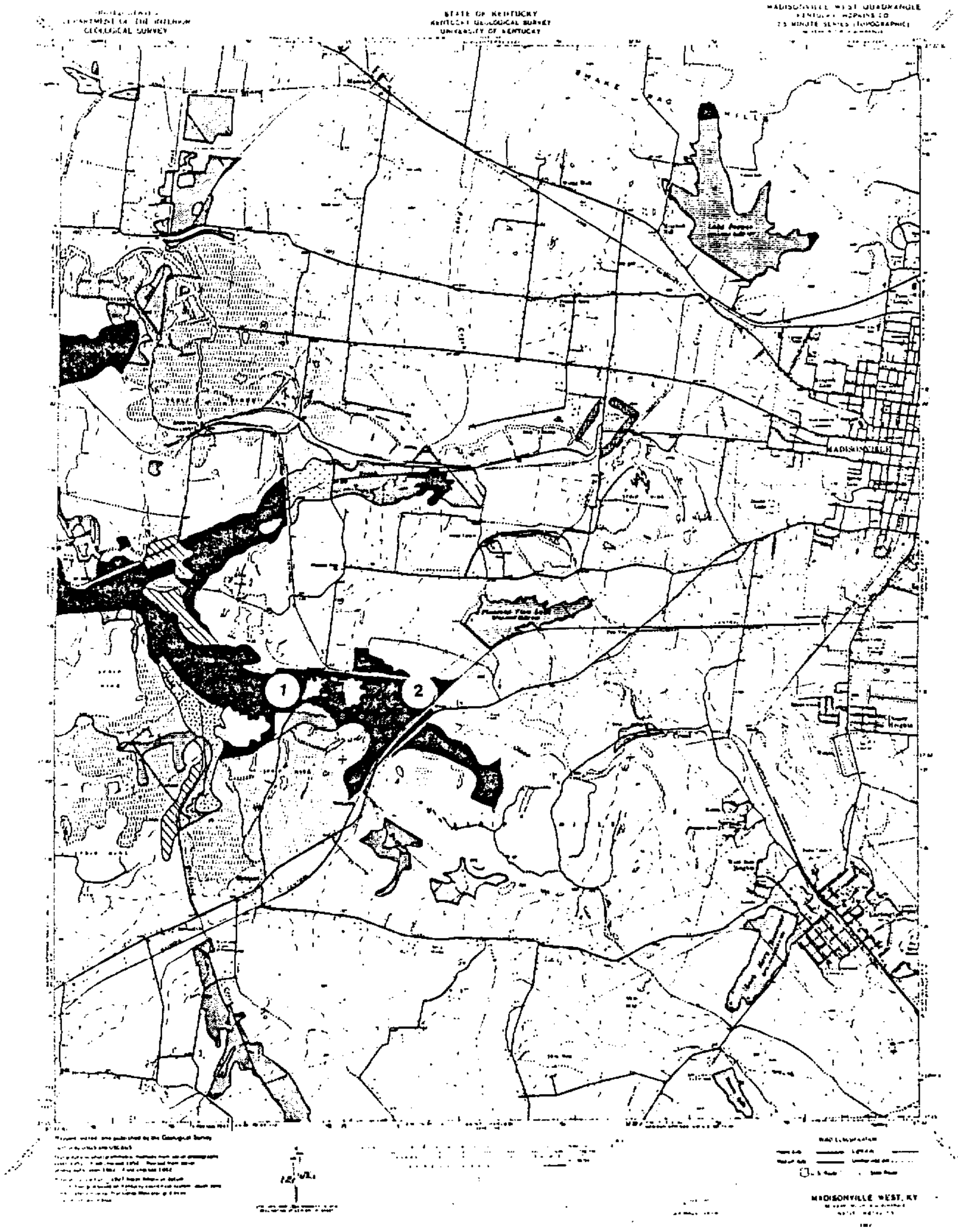


Figure 21. Wetlands and surface mines of Madisonville West quadrangle.

St. Charles

Location. Hopkins County
Tradewater and Green River
Drainage Basins

Geology and Coal Mining. The bottomlands of Cany Creek are underlain by Quaternary System alluvium of clay, silt, sand, and gravel. Surface mining is present throughout the hills of the St. Charles quadrangle and adjacent to Cany Creek along much of its length. There is a large region of reclaimed and active surface mines in the headwaters of several tributaries of the Green and Tradewater Basins northeast of St. Charles. Abandoned surface mines are also found in the south-central portion of the quadrangle in the headwaters of Buffalo Creek.

Hydrology. Open water areas were observed in July 1982 along Cany Creek (Site 1), a tributary to the Tradewater River. This wetland is probably intermittently to permanently flooded. Grubb and Ryder (1972) reported a streamflow range of 0.9 to 44 cfs from February 1966 to October 1967 for Cany Creek. They reported that 0.8 mi^2 of the 25.6 mi^2 in the Cany Creek drainage basin was strip mined. No USGS streamflow data are available for Cany Creek.

Water Quality. Records of chemical analyses of waters from the St. Charles topographic area are scarce. Grubb and Ryder (1972) and the present study in 1982 found evidence of severe mining impact in Cany Creek (Sites 1 and 2 on Table 13). This is true for both the stream channel and the associated wetlands. Orange sediments indicate high iron content of these waters. High acidity has yielded clear pools with low turbidity, although dissolved substances are high. Sulfates are very high, implicating runoff from surface mines which are located throughout the drainage basin of this tributary of the Tradewater River system.

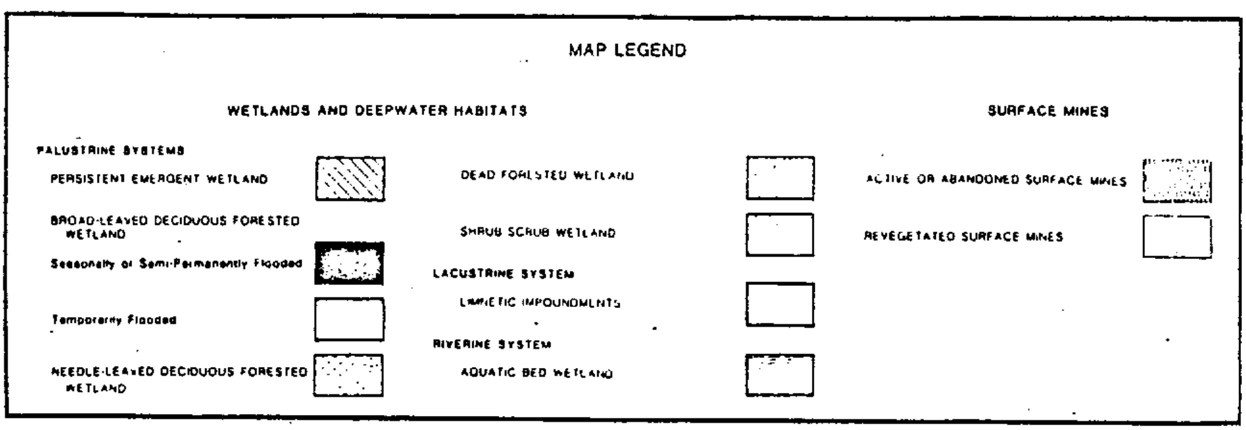
Table 13. Water quality summary for St. Charles quadrangle. Values are given for single measurements.

Parameter	Date	Site number 1	2
pH	1965[a]	---	2.9
	1982[b]	3.2	---
Conductivity, umhos/cm	1965	---	3340
	1982	2100	---
Dissolved Oxygen, mg/l	1965	---	---
	1982	5.5	---
Sulfate, mg/l	1965	---	2080
	1982	726	---
Turbidity, NTU	1965	---	4
	1982	0.52	---
Iron, mg/l (dissolved)	1965	---	54
	1982	6.10	---
Manganese, mg/l (dissolved)	1965	---	22
	1982	---	---

[a]Grubb and Ryder (1972).
[b]this study.

Wetland Vegetation. Cany Creek at Site 1 opens into a dead swamp containing some small standing dead timber (mostly *Acer rubrum*). The open water is edged by stands of *Juncus* sp. (rush) and some small willows. A narrow riparian forest lines the stream, which is dominated by *Salix* sp. (willow), *Liquidambar styraciflua* (sweetgum), *Betula nigra* (river birch), and *Acer rubrum* (red maple).

Fish and Wildlife. No data are available for fish and wildlife of the St. Charles quadrangle.



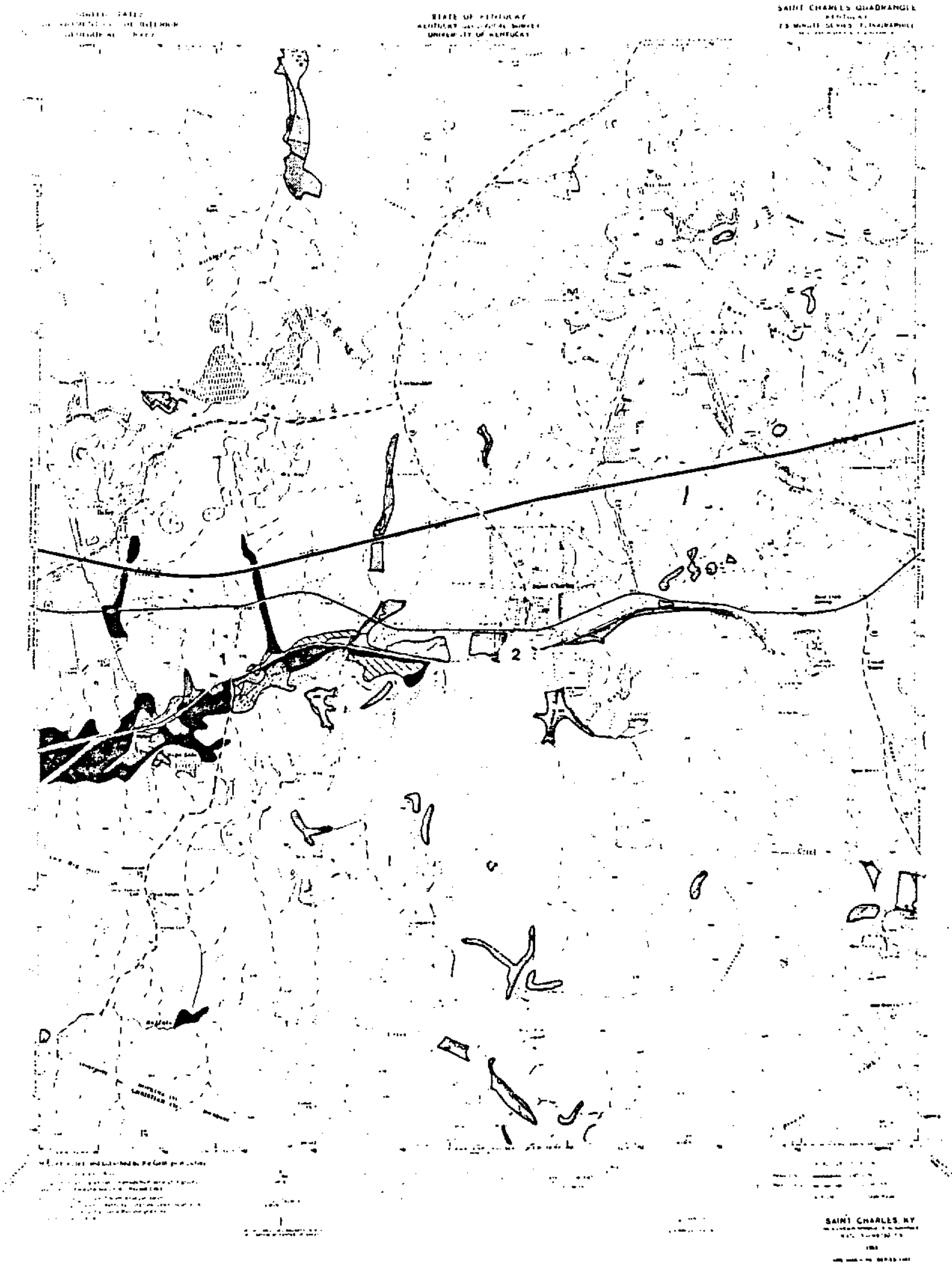


Figure 22. Wetlands and surface mines of St. Charles quadrangle.

Hanson

Location. Hopkins County
Pond River Sub-Basin of Green
River Drainage Basin

Geology and Coal Mining. The broad flood-plains of Otter and Elk Creeks are underlain by Quaternary Age alluvium of clay, silt, sand, and gravel. No coal mining activity is evident in the quadrangle, but several gas and oil wells are scattered throughout. Some surface mine activity has begun since 1979 near Otter Creek in the center of the quadrangle. Upland areas generally contain Pennsylvanian Age shale (Kehn, 1963).

Hydrology. The streamflow of Otter Creek, from a USGS station about 15 km (9.3 miles) downstream of Hanson (Site 1), was 0.0 to 1.7 cfs for three readings from May to September 1980. Otter Creek and its adjacent wetlands then drain into the Pond River. Otter Creek and Elk Creek have been channelized along much of their lengths.

Water Quality. The existing water quality data for this topographic area are from the USGS monitoring station on Otter Creek (Site 1). This large tributary of the Pond River drains the major portion of the Hanson topographic area. The data (Table 14) characterize Otter Creek as a stream with relatively good water quality. KDNREP (1981) analyzed Otter Creek in 1980 upstream of Site 1 near the Pennyrile Parkway and found slightly high values of iron and manganese but low sulfate concentrations, indicating little mining impact.

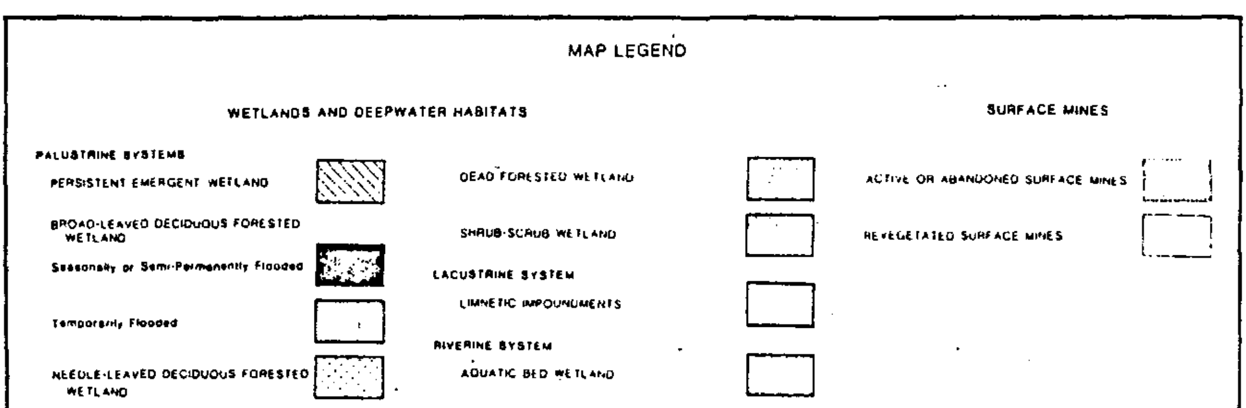
Wetland Vegetation. By far the most important land use in the Hanson quadrangle is agriculture. Much of the once extensive bottomland forests have been cleared. Riparian vegetation is limited to narrow bands along the channelized streams. *Acer rubrum* (red maple), *Betula nigra* (river birch), and *Salix nigra* (black willow) are common constituents of these communities. The isolated tracts of floodplain forest are composed of the typical mixed hardwoods of this region.

Table 14. Water quality summary for Hanson quadrangle. Values are given as average of two samples.

Parameter	Date	Site number 1
pH	1980[a]	6.8
Conductivity, umhos/cm	1980	314.
Dissolved Oxygen, mg/l	1980	---
Sulfate, mg/l	1980	50.5
Turbidity, NTU	1980	---
Suspended Solids, mg/l	1980	102
Iron, mg/l (dissolved)	1980	0.35
Manganese, mg/l (dissolved)	1980	0.63

[a]USGS (1981).

Fish and Wildlife. No data are reported for fish and wildlife in the wetlands of Hanson quadrangle.



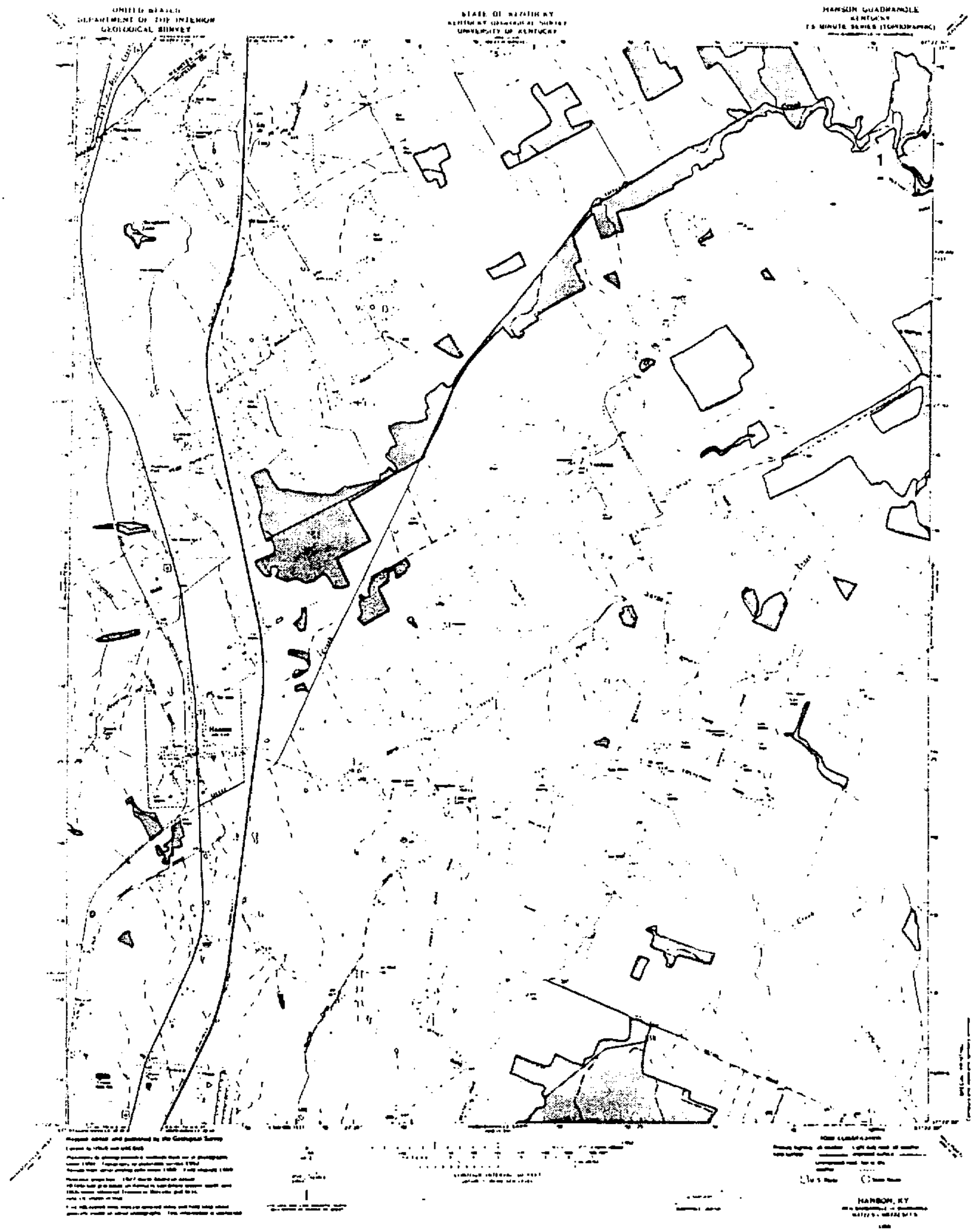


Figure 23. Wetlands and surface mines of Hanson quadrangle.

Madisonville East

Location. Hopkins County
Pond River Sub-Basin of Green River Drainage Basin

Geology and Coal Mining. Flat Creek Wetland (Site 2) is located in the Flat Creek floodplain in eastern Hopkins County. These lowland areas are underlain with Quaternary Age alluvial clay, silt, sand, and gravel. Soil associations in the bottomlands are: Belknap-Waverly, Karnak-McGary-Belknap, Stripmine-Frondorf, and Zanesville-Frondorf-Belknap (KNPC, 1980).

Much of the area has been drastically changed by surface mining. KNPC (1981) reported that most of the easily exploited coal resources of Flat Creek have been mined, and that coal mining will likely decline in this area. However, past surface mining activities have altered drainage characteristics and left many water-filled pits (KNPC, 1981).

Hydrology. KNPC (1980) reported that Flat Creek Wetland (Site 2) in the Pond River Basin has a permanently flooded water regime and is affected by surface mining. The drainage of Flat Creek has been altered by water reservoirs that were created by surface mining activity. Streamflow of Flat Creek near Madisonville (Site 1) ranged from 0.0 to 15 cfs for four readings from March to September 1980 (USGS 1981). Flat Creek and its tributaries have been channelized for over 20 years.

Water Quality. Several water quality surveys have been conducted on the main stem of Flat Creek (McLemore and Young, 1976; KDNREP, 1981; USGS, 1981). According to KNPC (1981), these studies reported extremely low pH values (less than 4.0) and, as in the West Fork Pond River (see Graham quadrangle), there was a tendency for sulfates and conductivity to increase at low flow. Water quality data (Table 15) characterize Flat Creek (Site 1) as extremely acidic and high in dissolved metals, such as iron and managanese. The data presented by KNPC (1980, 1981) indicate that the wetland adjacent to Flat Creek (Site 2) is greatly influenced by mine drainage. This is demonstrated by elevated sulfate, conductivity, and hardness values, although the pH reading was well above neutral. Orange ochre precipitate was also reported to occur on the substrate of Flat Creek wetlands.

Wetland Vegetation. The open, shrubby wetland (Site 2) is surrounded by a bottomland forest composed of *Acer rubrum* (red maple), *Betula nigra* (river birch), *Liquidambar styraciflua* (sweetgum), *Quercus macrocarpa* (bur oak), and *Ulmus rubra* (slippery elm). Understory dominants and wetland shrubs are *Cephalanthus occidentalis* (buttonbush), *Betula nigra*, and *Salix nigra* (black willow). *Saururus cernuus* (lizard tail) is the dominant herbaceous plant and is associated with various sedges, pondweeds, and pond lilies (KNPC, 1980). The swamp contains standing dead timber in water about 1 meter (3.3 ft.) deep.

Table 15. Water quality summary for Madisonville East quadrangle. Values are given as average ± standard deviation (# of Samples) unless only one measurement was taken.

Parameter	Date	Site number 1	Site number 2
pH	1980[a]	3.4 ± 0.16 (3)	---
	1981[b]	---	8.5
Conductivity, umhos/cm	1980	2123 ± 531 (3)	---
	1981	---	2256
Dissolved Oxygen, mg/l	1980	---	---
	1981	---	9.1
Sulfate, mg/l	1980	1180 ± 322 (3)	---
	1981	---	650
Turbidity, NTU	1980	---	---
	1981	---	4.8
Suspended Solids, mg/l	1980	25 ± 7 (2)	---
	1981	---	0
Iron, mg/l (dissolved)	1980	5.5 ± 0.5 (3)	---
	1981	---	---
Manganese, mg/l (dissolved)	1980	13.97 ± 4.37 (3)	---
	1981	---	---

[a]USGS (1981).
[b]KNPC (1981).

A large tract of bottomland hardwood forest is contained in the White City Wildlife Management area (Site 3). However, mining is now taking place in the area.

Fish and Wildlife. The macroinvertebrates from the Flat Creek Wetland are represented most abundantly by the Odonata (dragonflies) as reported by KNPC (1981). They also noted that Retzer (1980) reported only the flier (*Centrarchus macropterus*) as a fish species from Flat Creek.

Other fishes reported in the Madisonville East quadrangle are listed in Appendix C.

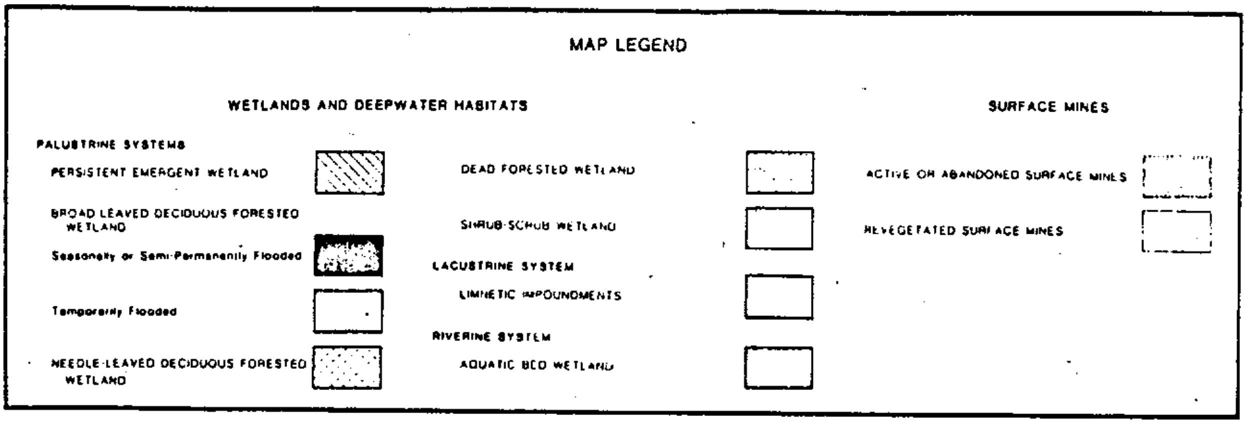


Figure 24. Wetlands and surface mines of Madisonville East quadrangle.

Nortonville

Location. Hopkins and Christian Counties
Pond River Sub-Basin of Green
River Drainage Basin

Geology and Coal Mining. The uplands are underlain by sandstone, siltstone, shale, limestone, coal, and underclay of Middle Pennsylvanian Age. Extensive faulting has divided the quadrangle into predominantly Carbondale Formation to the north and Tradewater Formation in the south. The stream channels and broad floodplains are alluvial deposits of the Quaternary Age, composed of clay, silt, sand, and gravel. Coal has been both deep and surface mined throughout the quadrangle for about 100 years. Three large mines are currently active, and significant coal reserves remain (Palmer, 1968).

Hydrology. Low-flow of Drakes Creek near White Plains (Site 1) ranged from 0.0 to 1.9 cfs for 3 measurements from June through August 1980 (USGS, 1981). Streamflow ranged from 0.0 to 150 for 4 measurements during the period March to September 1980. These data indicate severe low flow in the summer and relatively dramatic spring flooding. Drakes Creek Wetland (Site 2) and Pleasant Run Wetland (Site 3) were estimated to be intermittently flooded, although standing water (0.5 to 1.0 ft.) was observed at the Drakes Creek Site in July 1982.

Water Quality. Surface waters of the Nortonville topographic area are degraded by surface mining. This is especially true in the northeastern half and southeastern portion of the quadrangle. Samples taken from Pleasant Run (Site 3) near its confluence with Drakes Creek indicate the impact of surface mining. Water quality (Table 16) has low pH and high dissolved iron and sulfates, all characteristic of mine drainage.

Water quality data (Table 16) from Drakes Creek (Site 1) are much like those of Pleasant Run. All parameters indicate severe effects of coal mine runoff. Additional wetland areas associated with Drakes Creek are located in the northeastern corner of the quadrangle and along the Western Kentucky Parkway. These, too, are likely affected by surface mining. Those along the Parkway contain dead trees, and some iron precipitate is evident. Long Pond, a large wetland in the extreme northeastern corner of the quadrangle, is discussed in conjunction with the Graham quadrangle. Significant mine drainage was seen in 1980 on Grays Branch of McFarland Creek in the southeastern corner of the quadrangle (KDNREP, 1981).

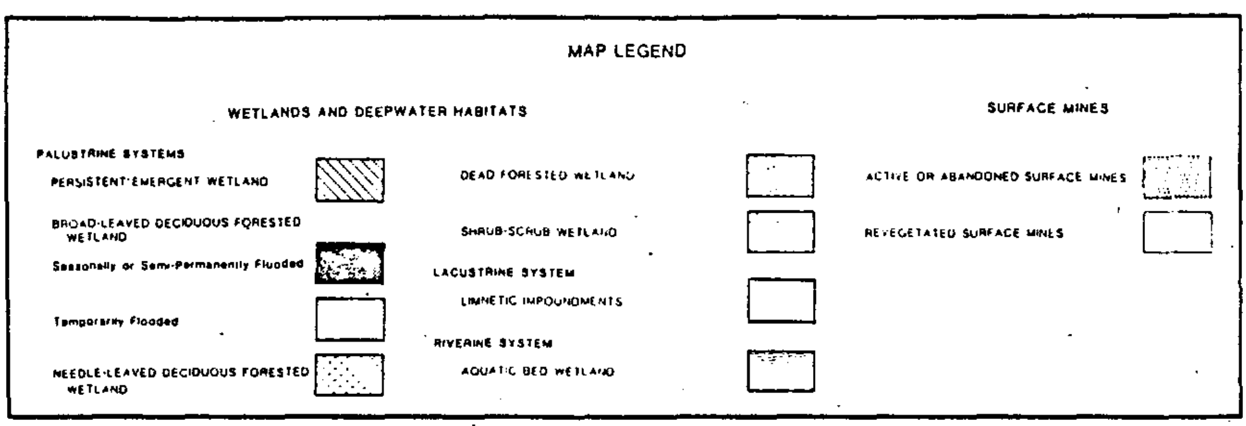
Table 16. Water quality summary for Nortonville quadrangle. Values are given as average ± standard deviation (# of samples) unless only one measurement was taken.

Parameter	Date	Site number 1	Site number 3
pH	1980[a]	3.97 ± .67 (3)	---
	1982[b]	---	2.9
Conductivity, umhos/cm	1980	1253 ± 798.6(3)	---
	1982	---	5400
Dissolved Oxygen, mg/l	1980	---	---
	1982	---	6.5
Sulfate, mg/l	1980	600 ± 386 (3)	---
	1982	---	822
Turbidity, NTU	1980	---	---
	1982	---	0.25
Suspended Solids, mg/l	1980	23 ± 2.16 (3)	---
	1982	---	---
Iron, mg/l (dissolved)	1980	6.17 ± 5.6 (3)	---
	1982	---	4.5
Manganese, mg/l (dissolved)	1980	7.47 ± 5.5 (3)	---
	1982	---	---

[a] USGS (1981).
[b] this study.

Wetland Vegetation. Pleasant Run and its tributaries flow through bottomland hardwood forests in the Nortonville quadrangle. Two community types were noted. A temporarily flooded bottomland forest along an intermittent stream (Site 3) is dominated by a young *Acer rubrum* (red maple)-*Betula nigra* (river birch) community. *Acer rubrum*, *Liquidambar styraciflua* (sweetgum), *Quercus phellos* (willow oak), and *Salix nigra* (black willow) are the canopy species of a semi-permanently flooded forest (Site 2). *Cephalanthus occidentalis* (buttonbush) dominates the understory, while *Nuphar advena* (spatterdock) and *Saururus cernuus* (lizard tail) dominate the herbaceous layer. A small portion of the bottomland hardwood forest along Drakes Creek is included in the White City Wildlife Management Area (Site 4).

Fish and Wildlife. No fish and wildlife data are available for the Nortonville quadrangle.



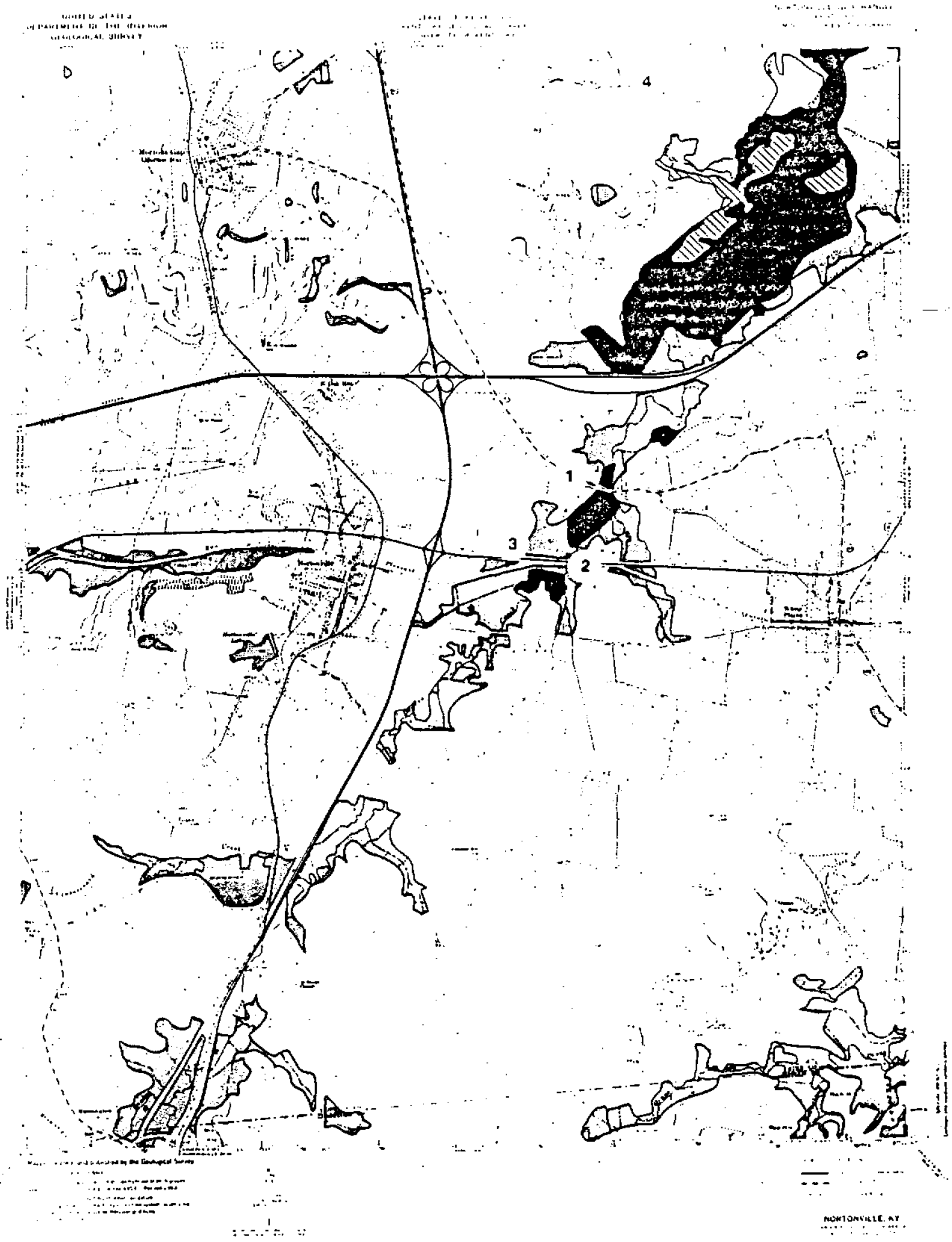


Figure 25. Wetlands and surface mines of Nortonville quadrangle.

Sacramento

Location. McLean, Hopkins, and Muhlenberg Counties
Pond River Sub-Basin of Green River Drainage Basin

Geology and Coal Mining. The floodplain of the Pond River is underlain by alluvial and lacustrine deposits of clay, silt, sand, and gravel from the Pleistocene and Holocene Series of the Quaternary System. The dominant soil association is Melvin-Karnak-McGary (Cox, 1980). No surface coal mining is seen in this quadrangle.

Hydrology. The floodplain bottomlands of the Pond River are characterized by an intermittent hydroperiod and a relatively unaltered flooding regime (KNPC, 1980). Streamflow of the Pond River near Vandetta (Site 1) ranged from 188 to 5150 cfs for seven readings from October 1979 to July 1980 (USGS, 1981).

Water Quality. The Sacramento topographic area is bisected by one of the major drainage channels of the Western Kentucky Coal Field, the Pond River. Data from the USGS monitoring station on the Pond River (Site 1) characterize it as having relatively good water quality with a tendency to dilute acidic runoff (Table 17). Poor water quality episodes occur in the Pond River from time to time. Specific conductance and iron values; however, range above average throughout the year, demonstrating the constant influence of surface mines upstream.

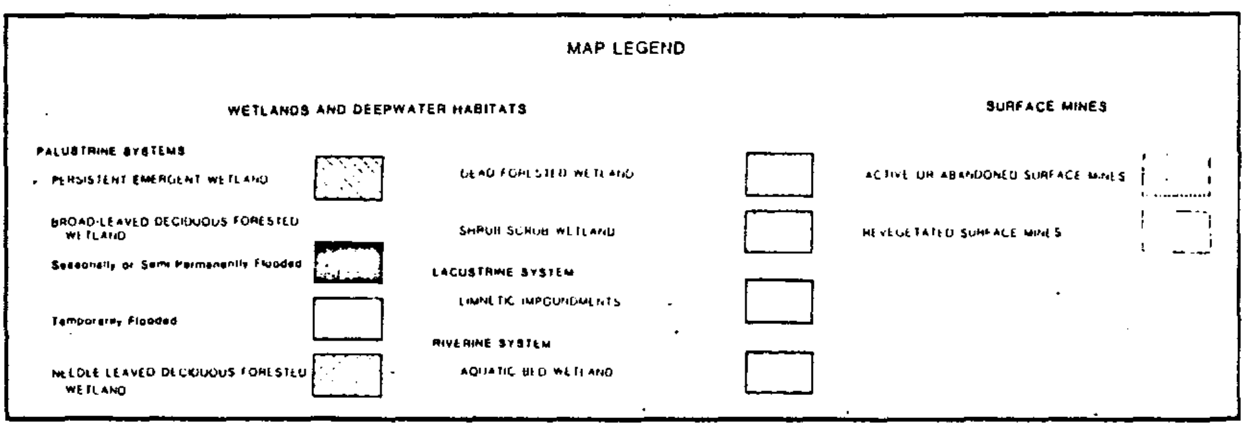
Wetland Vegetation. The Pond River floodplain represented an excellent example of bottomland hardwood forest. An Acer saccharinum (silver maple) community dominated the lower terrace with Platanus occidentalis (sycamore) as an associate species. The upper terrace of the floodplain was composed of a Liquidambar styraciflua (sweetgum) community with Carya cordiformis (bitternut hickory), Carya spp. (other hickories), and Quercus spp. (oaks) as associate species. Laportea canadensis (wood nettle) was the dominant herbaceous plant in both communities. Most of the bottomland forests near Site 2, though evident on the 1979 aerial photos, have since been destroyed by logging (KNPC, 1980).

Table 17. Water quality summary for Sacramento quadrangle. Values are given as average ± standard deviation (# of samples).

Parameter	Date	Site number 1
pH	1980[a]	6.9 ± 0.02 (7)
Conductivity, umhos/cm	1980	618 ± 276 (7)
Dissolved Oxygen, mg/l	1980	---
Sulfate, mg/l	1980	254 ± 148 (7)
Turbidity, NTU	1980	---
Suspended Solids, mg/l	1980	40.6 ± 32.3 (7)
Iron, mg/l (dissolved)	1980	0.20 ± 0.36 (7)
Manganese, mg/l (dissolved)	1980	1.44 ± 1.13 (7)

[a]USGS (1981).

Fish and Wildlife. One mammal, the meadow jumping mouse (Zapus hudsonius), is reported from the floodplain of the Pond River near Site 2 (KNPC, 1980). This species is given Undetermined status by Branson et al. (1981), indicating the need for more information about its occurrence in Kentucky.



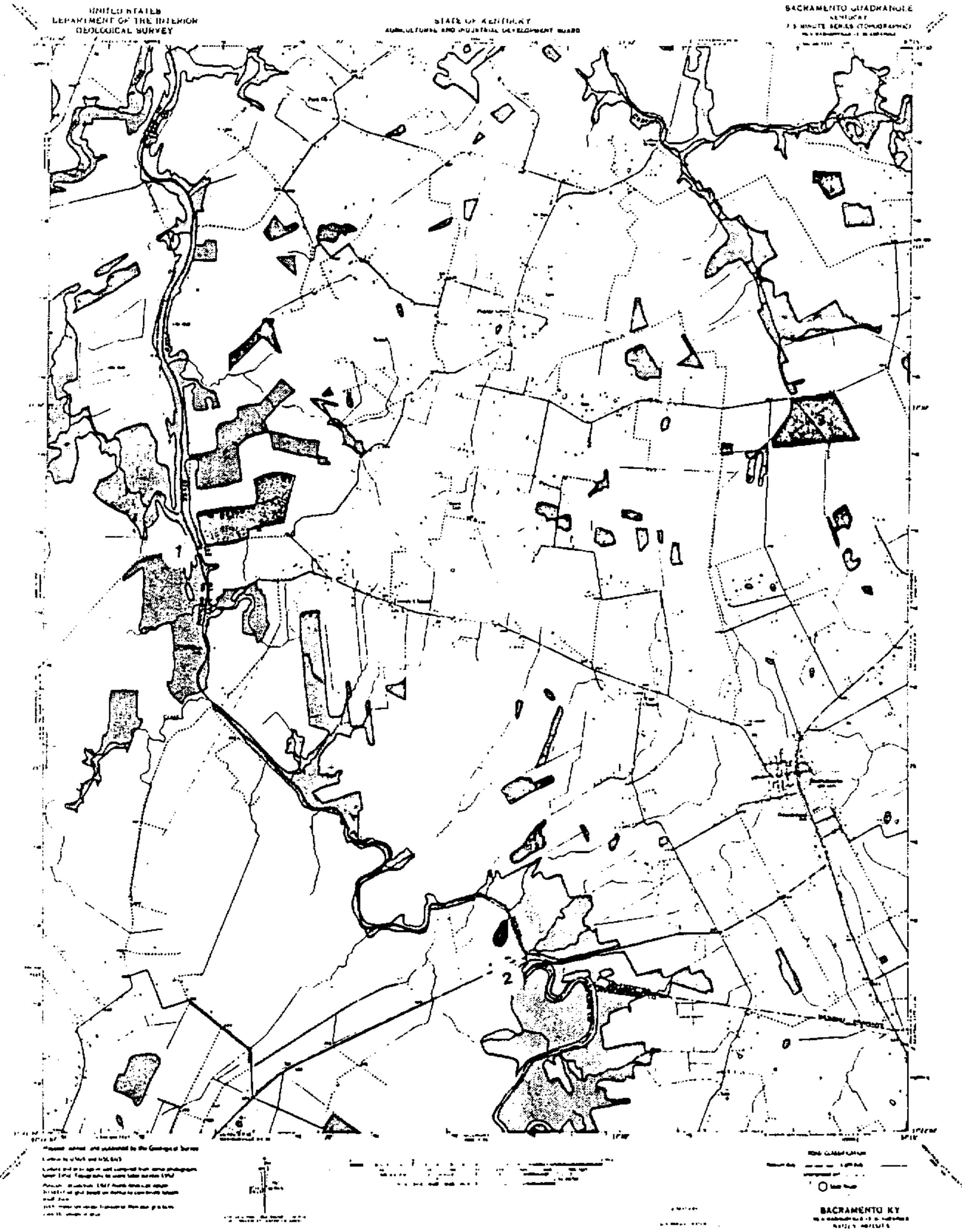


Figure 26. Wetlands and surface mines of Sacramento quadrangle.

Millport

Location. Muhlenberg and Hopkins Counties
Pond River Sub-Basin of Green River Drainage Basin

Geology and Coal Mining. To the southeast of the Pond River, the topography is hilly; while to the northwest, the floodplain gently slopes upward. The floodplain of the Pond River is extremely broad with land uses of agriculture, mining, and bottomland forest; and it is underlain by Quaternary Age alluvial and lacustrine deposits of clay, silt, sand, and gravel. Extensive deep and surface coal mining has occurred for many years throughout the Millport quadrangle, and large reserves still remain (Franklin, 1973).

Hydrology. This quadrangle includes part of the Pond River, which is discussed with the Sacramento quadrangle, and the Flat Creek Wetland, which is discussed in the Madisonville East quadrangle. Cardwell Wetland (Site 1) is an intermittently flooded wetland that is affected by deep mining.

Water Quality. No water quality monitoring stations on the Pond River are located within the confines of the Millport topographic area. Mining is prevalent in the western sections, and mine drainage is suspected to enter the Pond River and its various tributaries. Proximal water quality data on the Pond River may be obtained from the Sacramento quadrangle discussion. A small portion of Long Pond Wetland occurs in the extreme southwestern corner of the Millport quadrangle. Water quality of this area is discussed in the narrative of the Graham quadrangle. The Flat Creek wetlands lie along the western border of the Millport quadrangle and into the Madisonville East quadrangle; they are discussed in the Madisonville East narrative.

KDNREP (1981) reported slightly elevated values of iron and manganese in Log Creek, a tributary of the Pond River in the northern part of the quadrangle, but no mining impact was indicated.

Wetland Vegetation. Extensive tracts of bottomland hardwood forest have been cleared for agriculture or surface mined in the Pond River basin. Some mesophytic forests have been inundated in the last 10 years due to the collapse of deep mine shafts in the northwest section of the quadrangle. Site 1 is a bottomland forest in the midst of marshes created by the collapsed shafts. The marshes are characterized by monotypic stands of *Typha latifolia* (common cattail) and *Phragmites communis* (giant reed). The bottomland forest is dominated by *Liquidambar styraciflua* (sweetgum) with *Acer rubrum* (red maple) and *Fraxinus pennsylvanica* (green ash) as associates. The canopy is closed and trees range from 8-46 cm (3-18 inches) in diameter. The understory is dominated by *Celtis occidentalis* (hackberry). The marshes contain standing dead timber of the forest canopy species.

Fish and Wildlife. No data are available for fish and wildlife in wetlands in Millport quadrangle. See narrative with Sacramento quadrangle for Pond River biota.

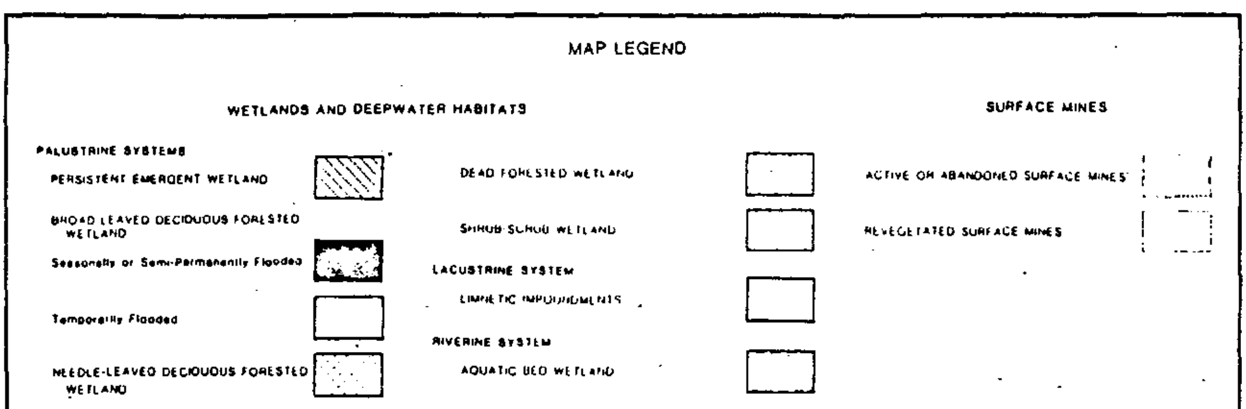


Figure 27. Wetlands and surface mines of Millport quadrangle.

Graham

Location. Muhlenberg, Hopkins and Christian Counties
Pond River Sub-Basin of Green River Drainage Basin

Geology and Coal Mining. All bottomlands in the Pond River watershed are underlain by Quaternary System alluvium of clay, silt, sand, and gravel. The soil association at Site 6 is Zanesville-Frondorf-Weikert, at Sites 1 and 3 Melvin-Karnak-McGary, and at Site 2 Belknap-Waverly (Froedge, 1980; Cox, 1980; Kehn, 1968). Coal is deep mined near the upper reaches of the West Fork Pond River and surface mining is apparent near Long Pond (Site 2) and the Pond River (Site 3).

Hydrology. Long Pond (Site 2), a wetland adjacent to the Pond River, is permanently flooded (KNPC, 1980). Thompson Creek Wetland (Site 4) was observed to have 0.5 to 1.0 feet of standing water in July 1982. The Graham quadrangle also includes part of the floodplain wetlands of the Pond River at Jarrels Creek (Site 5). Both Jarrels Creek and Thompson Creek have been extensively channelized for at least 20 years.

The West Fork of Pond River has several adjacent wetlands (Site 6) that are intermittently flooded. Approximately 3% of the stream channel near these wetlands has been impounded (KNPC, 1980, 1981). Streamflow for the West Fork measured near Apex (Site 9) ranged from 0.0 to 454 cfs for four readings from March to September 1980 (USGS, 1981). This indicates both major flooding and low-flow conditions on this stream during the year. Streamflow on the East Fork of Pond River (Site 8) averages 269 cfs (USGS, 1981).

Water Quality. Water quality of Long Pond (Site 2), located along the northwestern corner of the Graham quadrangle, has not been investigated until recently. The data (Table 18) suggest some mining influence on both Pond River and Long Pond (KNPC, 1980, 1981).

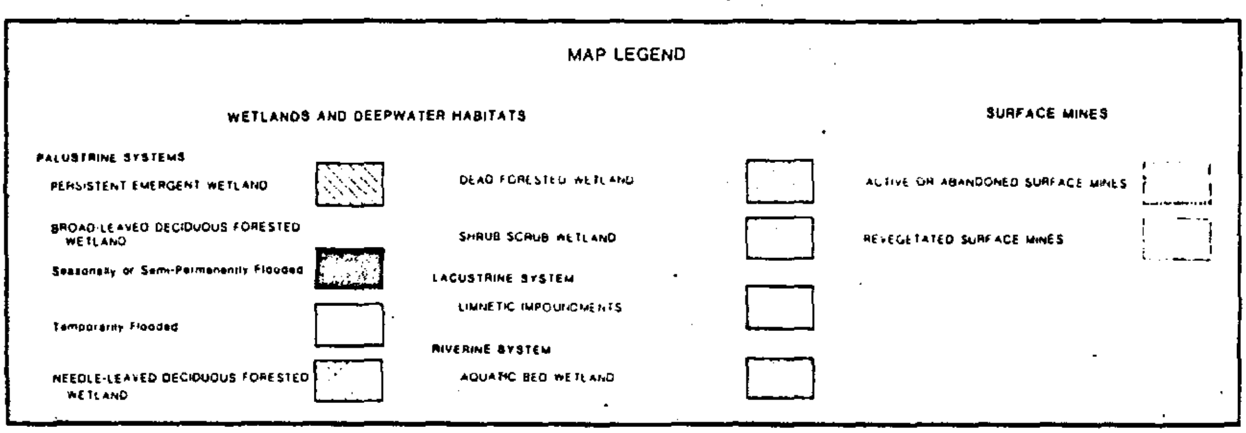
Data from Thompson Creek (Site 4), located in the north central section of the Graham topographic area (Table 18), indicate a surface water highly degraded by surface mine runoff. The substrate of this area was brightly colored with iron floc. The West Fork of Pond River (Site 9) has been analyzed by McLemore and Young (1976), USGS (1980, 1981), and KNPC (1981). The data indicate decreasing flow in the summer months with a concomitant rise in conductivity, sulfates, hardness, and alkalinity. Surface mining seems to have influence, although not too severe, on the West Fork Pond River.

Water quality data for Halls Creek, a tributary of Jarrels Creek in the southeastern corner of the quadrangle, indicate no mining impact (KDNREP, 1981).

Table 18. Water quality summary for Graham quadrangle. Values are given as average ± standard deviation (# of samples) unless only one measurement was taken.

Parameter	Date	Site number 2	Site number 4	Site number 9
pH	1980[a]	---	---	7.1 ±0.29 (3)
	1981[b]	7.0	---	7.5
	1982[c]	---	3.2	---
Conductivity, umhos/cm	1980	---	---	302 ±8 (3)
	1981	700	---	516
	1982	---	1300	---
Dissolved Oxygen, mg/l	1980	---	---	---
	1981	3.4	---	3.0
	1982	---	4.7	---
Sulfate, mg/l	1980	---	---	48.3 ±15.7 (3)
	1981	160	---	120
	1982	---	459	---
Turbidity, NTU	1980	---	---	---
	1981	46	---	37
	1982	---	1.5	---
Suspended Solids, mg/l	1980	---	---	88.5 ±13.5 (2)
	1981	100	---	100
	1982	---	---	---
Iron, mg/l (dissolved)	1980	---	---	0.086 ±0.073 (3)
	1981	---	---	---
	1982	---	2.0	---
Manganese, mg/l (dissolved)	1980	---	---	0.53 ±0.16 (3)
	1981	---	---	---
	1982	---	---	---

[a]USGS (1981).
[b]KNPC (1981).
[c]this study.



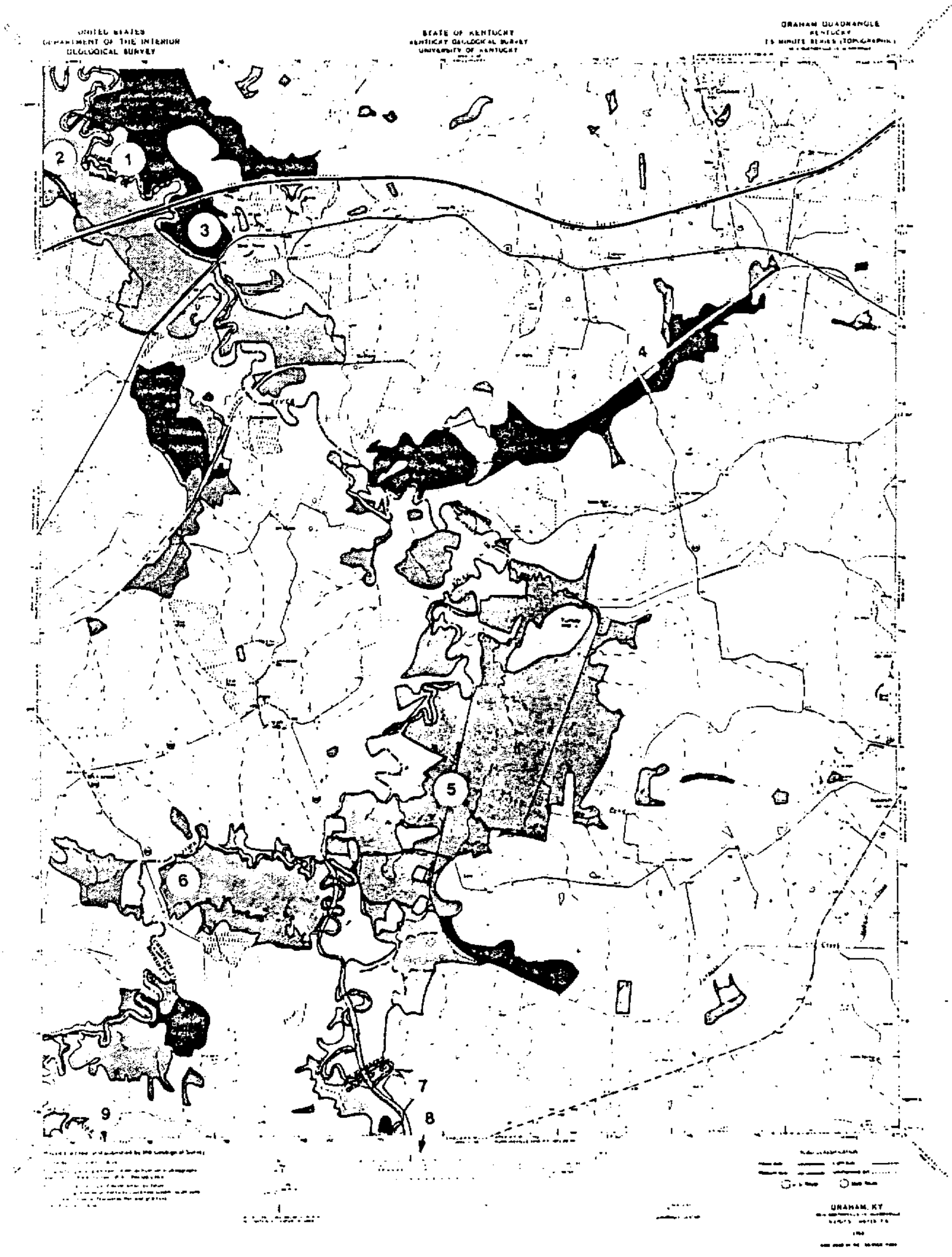


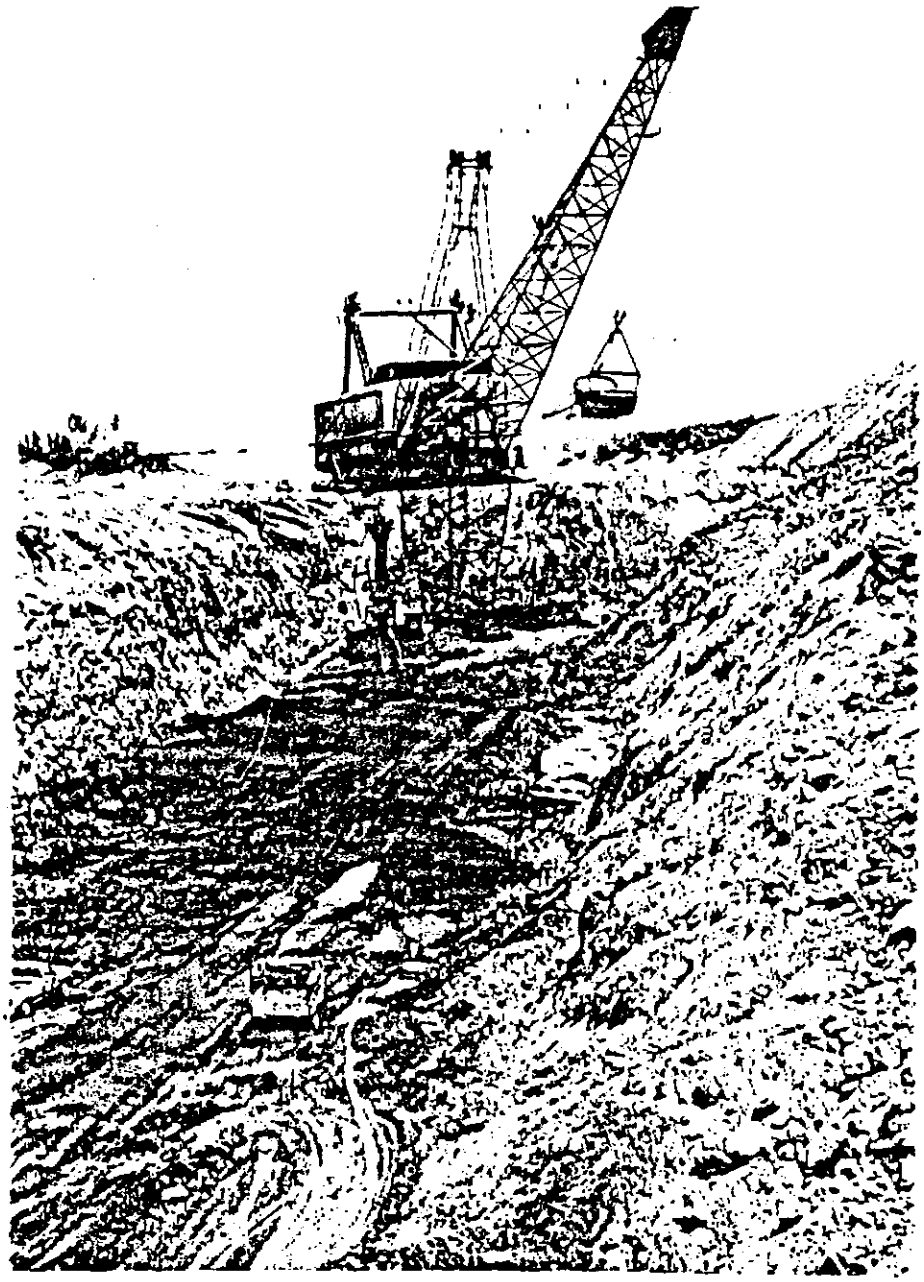
Figure 28. Wetlands and surface mines of Graham quadrangle.

Wetland Vegetation. The broad floodplain of the Pond River system supports many bottomland hardwood communities. Site 7 is a second-growth floodplain forest including an Acer negundo (box elder)-A. saccharinum (silver maple)-Platanus occidentalis (sycamore)-Liquidambar styraciflua (sweetgum) community and a Liquidambar styraciflua -Quercus spp. (oaks) community. Site 6 is a narrow riparian forest containing typical floodplain species. The bottomlands beyond the banks have been cleared for agriculture. Site 3 is an extensive second-growth forest with a semi-permanently flooded slough. The slough contains only Populus heterophylla (swamp cottonwood) as a canopy species with a dense understory of Cephalanthus occidentalis (buttonbush). The floodplain forest of Pond River (Site 1) has been heavily logged in recent years and is now choked with Rubus sp., Smilax sp. (greenbrier), and Toxicodendron radicans (poison ivy). Before clearing, typical floodplain species were present. Long Pond (Site 2), an oxbow and surrounding second-growth forest, includes Acer rubrum (red maple), Betula nigra (river birch), Fraxinus pennsylvanica (green ash), Liquidambar styraciflua, Platanus occidentalis, Populus heterophylla, Quercus lyrata, (overcup oak), Q. palustris, (pin oak), and Q. phellos (willow oak) in the overstory. The open areas of water support a variety of shrubs, emergents, and floating vegetation (KNPC, 1980, 1981). Site 4 is a dead tree swamp with dead Acer rubrum and Betula nigra saplings, Cephalanthus occidentalis, and Leersia oryzoides (rice cut grass) in water from 0.5 to 1.5 feet deep. An open coal pit just upstream has probably contributed to the condition of this wetland.

Fish and Wildlife. Major macroinvertebrate taxa from the West Fork of the Pond River (Site 9) include a mayfly (Stenacron interpunctatum), and a stonefly (Acroneuria evoluta). The steelcolor shiner (Notropis whipplei), bluntnose minnow (Pimephales notatus), and stripe-tail darter (Etheostoma kennicotti) comprise the most abundant fish species from this area (KNPC, 1981).

The Long Pond Wetland (Site 2) macroinvertebrate fauna is dominated by true bugs (Hemiptera), dragonflies (Odonata), and beetles (Coleoptera) (KNPC, 1981). Common fish species reported by KNPC (1981) include two species of shiner (Notropis emiliae and N. fumeus), the blackstripe topminnow (Fundulus notatus), and the brook silversides (Labidesthes sicculus). Several fish of interest are found in this area including the spotted sunfish (Lepomis punctatus), the bluntnose darter (Etheostoma chlorosomum), and the orangethroat darter (Etheostoma spectabile) (KNPC, 1982). The cypress minnow (Hybognathus hayi), listed as a Threatened species by Branson et al. (1981), is also found in Long Pond. The river otter (Lutra canadensis) has also been reported in this area (KNPC, 1982).

Other fish species reported from the Graham quadrangle are listed in Appendix C.



Livermore

Location. McLean and Muhlenberg Counties
Pond River Sub-Basin of Green
River Drainage Basin

Geology and Coal Mining. Floodplain wetlands, stream channels, and the lower slopes of stream valleys are underlain with Quaternary Age alluvial and lacustrine deposits of clay, silt, sand, and gravel. Uplands through much of the watershed contain sandstone, shale, siltstone, coal, and underclay of the Pennsylvanian Age Lisman and Sturgis Formations. Only a few surface mines occur in this quadrangle, and, except for those near Buttonsberry, are small in size. The Melvin-Karnak-McGary soil association dominates the lowlands. The soil is primarily Karnak silty clay which has a high water holding capacity, deep root zone, low organic matter content, and high natural fertility (KNPC, 1981).

Hydrology. The Livermore topographic area contains a small portion of the Green River, a major drainage channel of the Western Kentucky Coal Field. A complete monitoring station is maintained by the USGS at Calhoun, which lies less than five miles (8.5 km) downstream from Livermore, Kentucky. This quadrangle includes part of the Cypress Creek Wetland which is discussed with the Central City West quadrangle.

Water Quality. Water quality data (Table 19) of the Green River at Calhoun (Site 1) indicate a rather silt-laden river with good capability to dilute surface mine runoff received from upstream. The other major stream area in the Livermore quadrangle is Cypress Creek. This tributary of the Pond River has been monitored extensively for water quality characteristics due to the large number of wetlands which are associated with it. Since the Central City West quadrangle contains the most heavily studied part of Cypress Creek wetlands, reference should be made to that quadrangle narrative. One sample, taken by KDNREP (unpublished data) in 1982 from Cypress Creek at Vicker Bridge (KY 81) in the northwestern corner of the quadrangle, indicates mine drainage even in the lower reaches of Cypress Creek.

Wetland Vegetation. Agriculture is the predominant land use in the Cypress Creek watershed north of KY 70. The once extensive wetlands near Black Lake (Site 2) have been mostly converted to

Table 19. Water quality summary for Livermore quadrangle. Values are given as average ± standard deviation (# of samples).

Parameter	Date	Site number 1
pH	1980[a]	7.7 ± 0.03 (8)
Conductivity, umhos/cm	1980	289.25 ± 47.79 (8)
Dissolved Oxygen, mg/l	1980	---
Sulfate, mg/l	1980	39.38 ± 3.34 (8)
Turbidity, NTU	1980	---
Suspended Solids, mg/l	1980	68.7 ± 34.19 (10)
Iron, mg/l (dissolved)	1980	0.025 ± 0.0004 (8)
Manganese, mg/l (dissolved)	1980	0.117 ± 0.05 (7)

[a]USGS (1981).

farm land. The wetland forest along Cypress Creek (Site 3) is contiguous only north to the Muhlenberg-McLean County line. Dredge spoils on both sides of the channelized stream support *Acer rubrum* (red maple), *Betula nigra* (river birch), *Fraxinus* spp. (ashes), *Liquidambar styraciflua* (sweetgum), *Platanus occidentalis* (sycamore), *Quercus* spp. (oaks), *Salix nigra* (black willow), and *Ulmus rubra* (slippery elm). Mixed swamp forests behind the levees are composed of *A. rubrum*, *B. nigra*, *Fraxinus* sp., *Populus heterophylla* (swamp cottonwood), *Quercus palustris* (pin oak), and *Taxodium distichum* (bald cypress). Impounded areas with water about 1 m (3 feet) deep are usually composed entirely of *T. distichum* with dead broad-leaved deciduous trees scattered. *Limnobium spongia* (frog's bit), a Kentucky Threatened plant, and *Utricularia gibba* (humped bladderwort), a plant of Special Concern, are found in a shallow swamp (Site 4) in Black Lake Bottoms (KNPC, 1982).

Fish and Wildlife. Few fish and wildlife data are available for this quadrangle. The slenderhead darter (*Percina phoxocephala*), a Special Concern fish, and Sampson's pearly mussel (*Epioblasma sampsoni*), an Endangered species, are reported in the Green River near Livermore (KNPC, 1982).

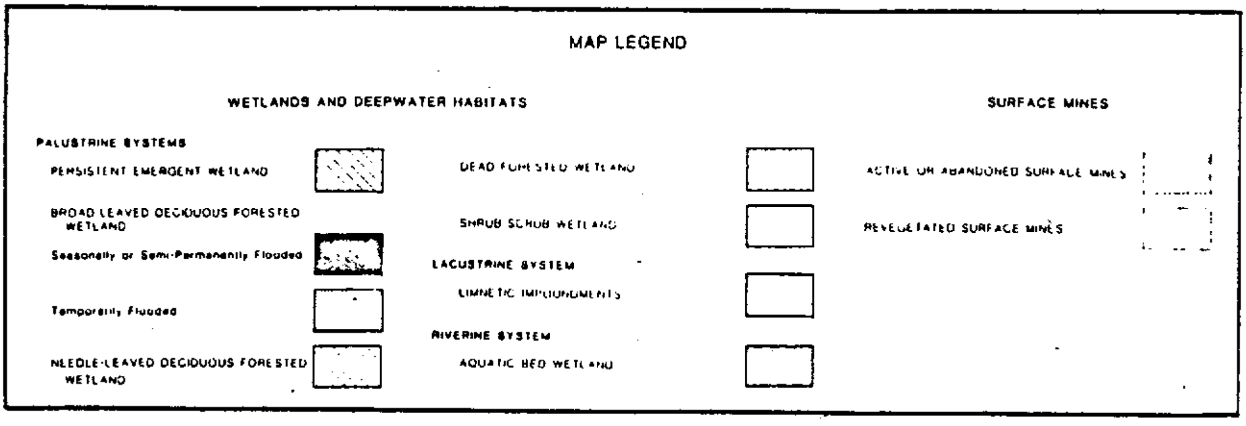


Figure 29. Wetlands and surface mines of Livermore quadrangle.

Central City West

Location. Muhlenberg and Ohio Counties
Pond River Sub-Basin of Green River Drainage Basin

Geology and Coal Mining. Floodplains, wetlands, and stream channels in this quadrangle are underlain by alluvial and lacustrine deposits of clay, silt, sand, and gravel from the Quaternary System. Uplands in most of the Cypress Creek watershed contain sandstone, shale, siltstone, coal, and underclay of the Pennsylvanian Age Lisman Formation. The south and southwest portions of the watershed are underlain by the Carbondale Formation. South of KY 70, the landscape is dominated by surface mining. Numerous coal beds have been deep and surface mined, notably, the Nos. 9, 11, and 12 beds. The largest recoverable reserves remain in the No. 9 bed (Palmer, 1969).

Hydrology. Cypress Creek and its associated wetlands comprise the major aquatic habitat within the Central City West quadrangle. Cypress Creek flows to the north through Livermore topographic area and into the Pond River near Calhoun. Ninety-seven per cent of the stream channels along Cypress Creek and Little Cypress Creek were altered by channelization (KNPC, 1981). Hydrologic data are available from several stations. Streamflow of Cypress Creek near Calhoun averages 247 cfs and ranged from 4.4 to 2070 cfs in 1980. Streamflow of Cypress Creek near Central City (Site 4) ranged from 14 to 34 cfs from March to September 1980. Little Cypress Creek near Central City (Site 3) ranged from 4 to 27 cfs for March to September 1980 (USGS, 1980).

Water Quality. Water quality data from Cypress Creek have been collected by USGS (1980, 1981), Axon (1980), KNPC (1981), KDNREP (1981), and Mitsch et al. (1982). This drainage basin has been degraded by surface mine runoff, and recent data indicate a continuation of this problem. Water quality data are presented for four sites along Cypress Creek (Table 20). Three sampling sites on Cypress Creek have been monitored in the present study: at the KY 70 bridge in the western main channel (Site 4); just west of Central City on Little Cypress Creek (Site 3); and at the KY 81 bridge (Site 2). A permanently flooded cypress wetland (Site 1) adjacent to Cypress Creek has also been monitored. USGS (1981) data from Sites 3 and 4 and KNPC (1981) data from Site 2 are also presented in Table 20. KDNREP (1981) found the "highest recorded values for specific conductance, sulfates, iron, and manganese in the Green River Basin" on Little Cypress Creek at the Western Kentucky Parkway.

Analyses indicate a definite and continued influence of surface mining on the Cypress Creek watershed. Although pH values are relatively neutral, elevated levels of conductivity, sulfate, and metals continue to occur. The wetland areas adjacent to Cypress Creek may be acting as sinks for mine wastes. Differences between the 1980 and 1981-82 data indicate a slight improvement in water quality. Major problems in Little Cypress Creek include siltation, sewage, and urban runoff from Central City (KNPC, 1980, 1981).

Wetland Vegetation. The Cypress Creek watershed includes extensive wetlands which lie adjacent to Cypress and Little Cypress Creeks. A number of community types are evident in the wetland system. Large *Typha* (cattail) marshes are evident in many areas (e.g., Site 4). A narrow band of riparian forest lines the streams. This riparian forest (Site 5) is dominated generally by *Acer rubrum* (red maple), *Betula nigra* (river birch), and/or *Fraxinus pennsylvanica* (green ash). Common associated species are *Liquidambar styraciflua* (sweetgum), *Populus heterophylla* (swamp cottonwood), *Salix nigra* (black willow), and *Ulmus americana* (American elm). Mixed swamp forests (Site 6) may also occur including *A. rubrum*, *B. nigra*, *Carya laciniosa* (shellbark hickory), *C. ovata* (shagbark hickory), *L. styraciflua*, *Platanus occidentalis* (sycamore), *Populus heterophylla*, *Quercus lyrata* (overcup oak), *Q. palustris* (pin oak), *Taxodium distichum* (bald cypress), and *Ulmus americana* (KNPC, 1980).

In deeper swamps behind the stream levees (e.g., Site 1), stands of *Taxodium distichum* often occur. Many of the swamps are too deep to support other trees, but some of the swamps include a sparse understory of *A. rubrum*, *B. nigra*, and *Fraxinus profunda* (pumpkin ash). *Cephalanthus occidentalis* (buttonbush), *Itea virginica* (Virginia-willow), *Nuphar advena* (spatterdock), and *Potamogeton* sp. (pondweed) are often present. KNPC (1980) reported the following wetland species found at Cypress Creek as rare or infrequent in Kentucky: *Mikania scandens*

MAP LEGEND

WETLANDS AND DEEPWATER HABITATS

PALUSTRINE SYSTEMS
- PERSISTENT EMERGENT WETLAND
- BROAD-LEAVED DECIDUOUS FORESTED WETLAND
  - Seasonally or Semi-Permanently Flooded
  - Temporarily Flooded
- NEEDLE-LEAVED DECIDUOUS FORESTED WETLAND
- DEAD FORESTED WETLAND
- SHRUB SCRUB WETLAND

LACUSTRINE SYSTEM
- LIMNETIC IMPOUNDMENTS

RIVERINE SYSTEM
- AQUATIC BED WETLAND

SURFACE MINES
- ACTIVE OR ABANDONED SURFACE MINES
- REVEGETATED SURFACE MINES

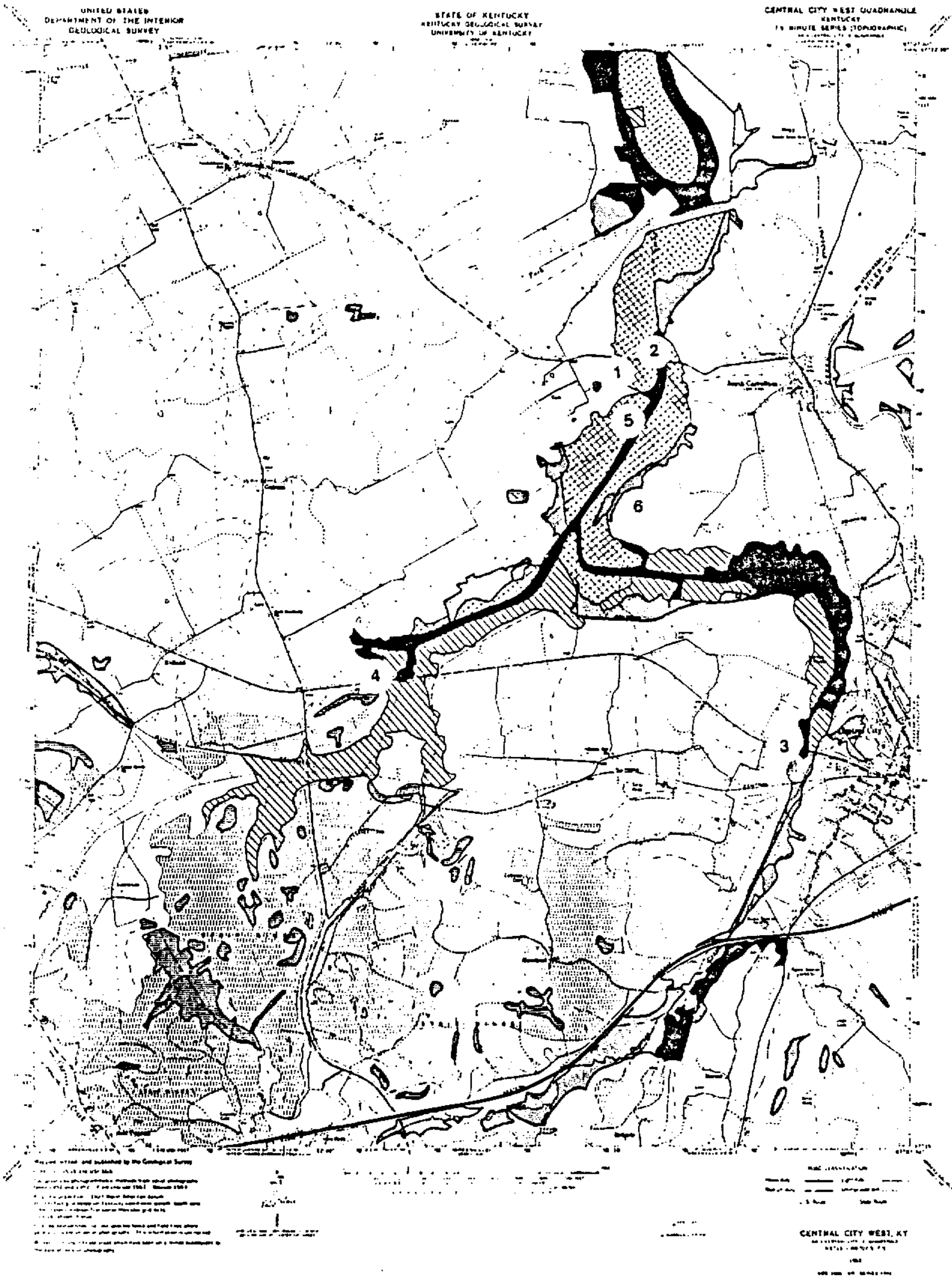


Figure 30. Wetlands and surface mines of Central City West quadrangle.

Table 20. Water quality summary for Central City West quadrangle. Values are given as average ± standard deviation (# of samples) unless only one measurement was taken.

Parameter	Date	Site number 1	2	3	4
pH	1980[a]	---	---	7.42 ± 0.17 (4)	7.45 ± 0.29 (4)
	1981[b]	---	7.5	---	---
	1982[c]	6.91 ± 0.37 (11)	6.97 ± .01 (11)	6.99 ± 0.02 (11)	6.95 ± 0.02 (11)
	1982[d]	---	---	---	7.0
Conductivity, umhos/cm	1980	---	---	3585 ± 1113 (4)	2458 ± 632 (4)
	1981	---	2958	---	---
	1982	1035 ± 633 (11)	1172 ± 614 (9)	2275 ± 1412 (11)	2290 ± 550 (11)
	1982	---	---	---	2284
Dissolved Oxygen, mg/l	1981	---	4.1	---	---
	1982	6.0 ± 3.5 (10)	8.0 ± 2.5 (10)	9.8 ± 1.7 (10)	9.7 ± 2.7 (10)
Sulfate, mg/l	1980	---	---	1975 ± 630 (4)	1542 ± 441 (4)
	1981	---	800	---	---
	1982	374 ± 226 (9)	616 ± 133 (9)	680 ± 121 (9)	704 ± 101 (9)
	1982	---	---	---	1425
Turbidity, NTU	1981	---	21	---	---
	1982	2.5 ± 1.7 (11)	1.6 ± 1.3 (11)	6.4 ± 3.6 (11)	1.6 ± 0.8 (11)
	1982	---	---	---	2.9
Suspended Solids, mg/l	1980	---	---	29 ± 7 (4)	13 ± 8 (4)
	1982	---	---	---	5
Iron, mg/l	1980	---	---	0.80 ± 0.13 (4)	0.27 ± 0.34 (4)
(dissolved)	1982	0.64 ± 0.32 (11)	0.80 ± 0.13 (4)	0.70 ± 0.02 (11)	0.61 ± 0.15 (11)
	1982	---	---	---	0.52
Manganese, mg/l	1980	---	---	2.9 ± 1.3 (4)	2.5 ± 2.0 (4)
(dissolved)	1982	1.1 ± 0.9 (9)	1.1 ± 1.3 (9)	3.8 ± 0.5 (9)	4.0 ± 2.1 (9)
	1982	---	---	---	0.32

[a]USGS (1981).
[b]KNPC (1981).
[c]this study.
[d]KDNREP (unpublished data).

(climbing hempweed), *Paspalum fluitans* (lens grass), *Sparganium androcladum* (bur-reed), *Triadenium tubulosum* (marsh-St. John's-wort), *Woodwardia areolata* (netted chain-fern), *Zizaniopsis miliacea* (southern wild rice), and *Decodon verticillatus* (swamp loosestrife).

Fish and Wildlife. The abundant macroinvertebrates reported by KNPC (1980, 1981) from the Cypress Creek Wetland include Coleoptera (beetles), Diptera (true flies), and Hemiptera (true bugs). Fish of Special Concern recorded from this area include the banded pygmy sunfish (*Elassoma zonatum*) and the slenderhead darter (*Percina phoxocephala*). One species of Undetermined status, the lake chubsucker (*Erimyzon sucetta*), is also found here (KNPC, 1980, 1982).

One Threatened mammal, the swamp rabbit (*Sylvilagus aquaticus*), is reported from this area. Three bird species of Undetermined status, the great blue heron (*Ardea herodias*), red-shouldered hawk (*Buteo lineatus*), and marsh hawk (*Circus cyaneus*), occur here as well (Branson et al., 1980; KNPC, 1982).

Additional wildlife from this wetland are listed in Appendix C.

Greenville

Location. Muhlenberg County
Pond River Sub-Basin and the
Green River Drainage Basin

Geology and Coal Mining. The uplands of the Greenville quadrangle are underlain primarily by Middle Pennsylvanian Age sandstone, siltstone, shale, limestone, coal, and underclay of the Carbondale and Tradewater Formations. Stream channels and floodplains are composed of Quaternary System alluvium of clay, silt, sand, and gravel. Coal, gas, and oil are important mineral resources. Coal has been mined mostly from the northern section of the quadrangle since the late 1800s. However, most of those large mines have been abandoned or are inactive as reported by Kehn (1971). Recent mines, not shown here, have started west of KY 171 in the central and southern part of the quadrangle.

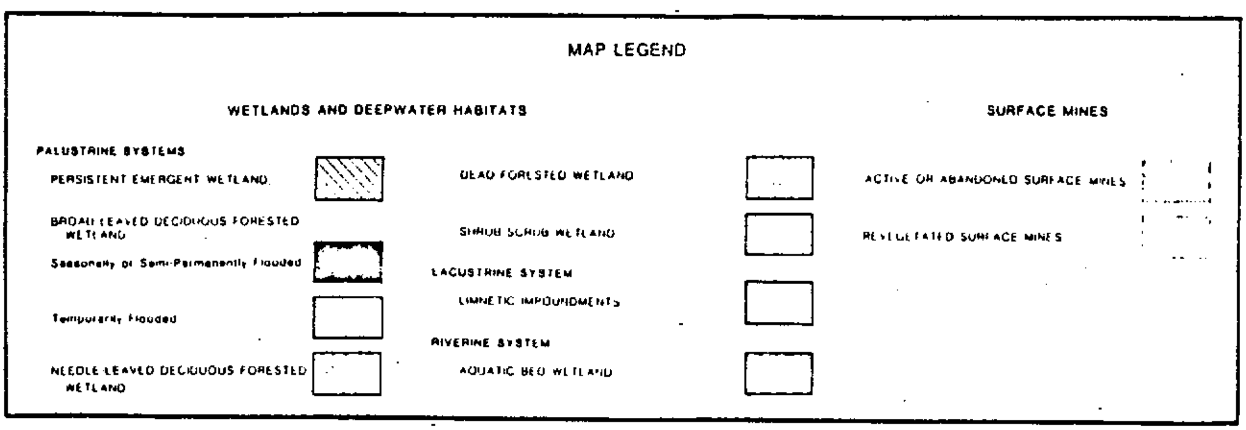
Hydrology. This quadrangle includes the head waters of Cypress Creek and Little Cypress Creek which are discussed with the Central City West Quadrangle. Caney Creek, Sandlick Creek, and Pond Creek, tributaries of the Green River which appear in this quadrangle, are extensively channelized.

Water Quality. Little water quality information is available for streams and wetlands within the Greenville quadrangle. The northern portions of this area, north of Greenville township, are drained by the headwaters of Cypress and Little Cypress Creeks and are heavily mined. Discussion of water quality of the Cypress Creek basin is contained in the Central City West quadrangle narrative.

Unpublished data by KDNREP from 1982 for Caney Creek (near Site 1) indicate mine drainage with high sulfates (331 mg/l) and dissolved manganese (2.2 mg/l).

Wetland Vegetation. Very few wetland areas occur in the largely upland Greenville quadrangle. Small patches of riparian forest are found along Caney Creek (Site 1) and Pond Creek (Site 2). These forests contain typical floodplain species including *Acer rubrum* (red maple), *A. saccharinum* (silver maple), *Betula nigra* (river birch), *Liquidambar styraciflua* (sweetgum), *Platanus occidentalis* (sycamore), and *Salix nigra* (black willow).

Fish and Wildlife. No fish and wildlife data are available for this quadrangle. Refer to Central City West quadrangle for species in Cypress Creek watershed.



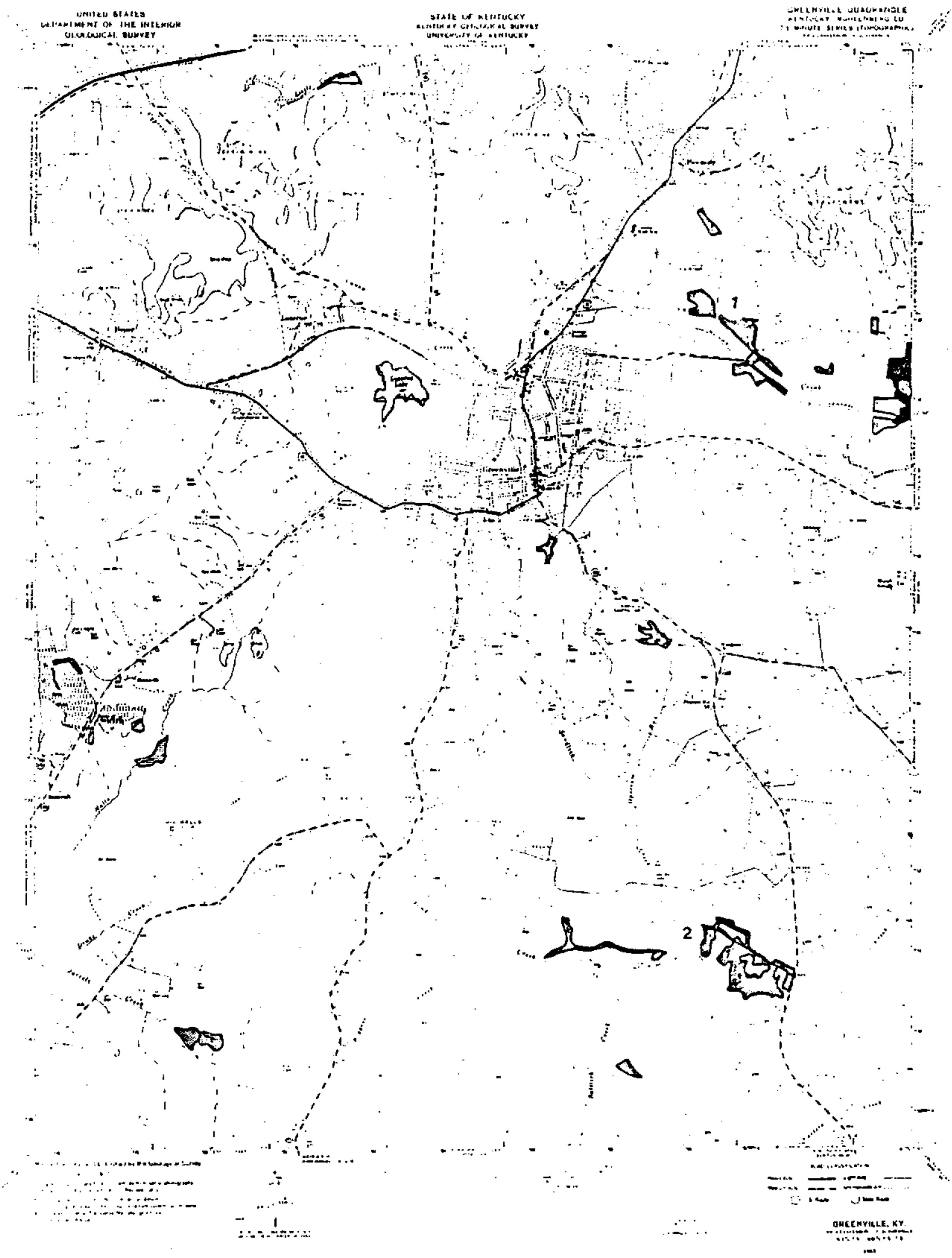


Figure 31. Wetlands and surface mines of Greenville quadrangle.

Equality

Location. Ohio, McLean, and Muhlenberg Counties
Green River Drainage Basin

Geology and Coal Mining. The broad floodplains of the Rough River are underlain by Quaternary Age alluvial and lacustrine deposits of clay, silt, sand, and gravel. The low hills behind the floodplains are of Middle and Lower Pennsylvanian Age and contain extensive coal deposits (Goudarzi, 1969).

Hydrology. This quadrangle includes several miles of the Green River and one of its major tributaries, the Rough River. KNPC (1981) reports that 71% of the Rough River was channelized more than 20 years ago. A wetland area (Site 2) along the Rough River is characterized by an intermittently-flooded hydroperiod. For additional hydrologic data, refer to the Hartford Quadrangle.

Water Quality. Although the Equality topographic area contains several river miles of the Green River, no recent water quality analyses have been conducted within this area. Adequate proximal data may be obtained downstream at the Calhoun monitoring station (see Livermore quadrangle discussion). The other major river, the Rough River, runs along the northern border of this area. KNPC (1981) analyzed the Rough River at U.S. Lock #1 (Site 1), 12 km (7.5 miles) above its mouth. The data (Table 21) indicate a turbid stream with high sediment loads.

Wetland Vegetation. Much of the floodplain forest along the Rough River (Site 2) has been logged or cleared for agriculture since the aerial photos used here were taken. Site 2 is choked with shrubby vegetation, with no canopy and no discernible community development (KNPC, 1980). The remaining areas of bottomland forest are typical of the region, with a variety of maples, oaks, and ashes dominating the communities.

Table 21. Water quality summary for Equality quadrangle. Values are given for only one sample.

Parameter	Date	Site number
		1
pH	1981[a]	7.5
Conductivity, umhos/cm	1981	209
Dissolved Oxygen, mg/l	1981	5.2
Sulfate, mg/l	1981	20
Turbidity, NTU	1981	67
Suspended Solids, mg/l	1981	100
Iron, mg/l (dissolved)	1981	---
Manganese, mg/l (dissolved)	1981	---

[a]KNPC (1981)

Fish and Wildlife. One Threatened fish species, the harlequin darter (*Etheostoma histrio*), has been reported from the Rough River (Site 1), as has one species of Special Concern, the slenderhead darter (*Percina phoxocephala*) (KNPC, 1981).

Other fish reported from the Equality quadrangle are listed in Appendix C.

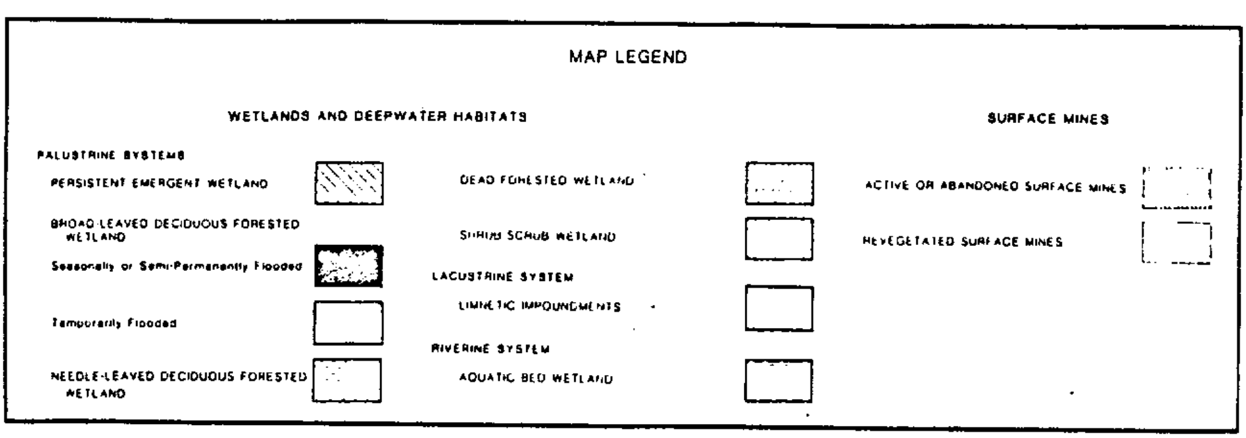


Figure 32. Wetlands and surface mines of Equality quadrangle.

Central City East

Location. Muhlenberg and Ohio Counties
Green River Drainage Basin

Geology and Coal Mining. Surface geology of the uplands is composed of sandstone, shale, coal, siltstone, underclay, and limestone of the Pennsylvanian Age Lisman Formation (Palmer, 1972). The Nos. 11 and 12 coal beds have been extensively mined in the Pond Creek watershed. The surface mining has yielded much unconsolidated material on hills surrounding the floodplain. The lowlands are underlain by alluvial silt, clay, sand, and gravel of Quaternary origin.

Hydrology. The hydroperiod for the old channel of Pond Creek has been altered by coal surface mining and by channelization. Streamflow for Pond Creek near Martwick (Site 1) ranged from 6.9 to 626 cfs from March to September 1980, for four measurements (USGS, 1981). Wetlands along Pond Creek (Sites 2 and 3) also have intermittently to permanently flooded conditions and have been altered by surface mining (KNPC, 1980). Pond Creek has been channelized for at least twenty years.

Water Quality. Sparse data on the Green River have been collected at Paradise and are included with the Paradise quadrangle. Water quality data for Pond Creek (Site 1) and its tributaries have been reported recently by the USGS (1981) and KDNREP (1981). The USGS (1981) data (Table 22) indicate a highly polluted stream with high specific conductance, sulfate, and several metals. Roy F. Weston, Inc. (1975) reported that most of the creek is continually affected by acid mine drainage. Data reported by KNPC (1981) from a cut-off meander of Pond Creek (Site 2) showed a neutral pH but indicated influence of mine drainage. While sampling, the present researchers were told by a local resident that this particular meander had been a favorite "fishing hole" until approximately 1 1/2 years ago. At that time, mine drainage began to flow into the area (Site 3).

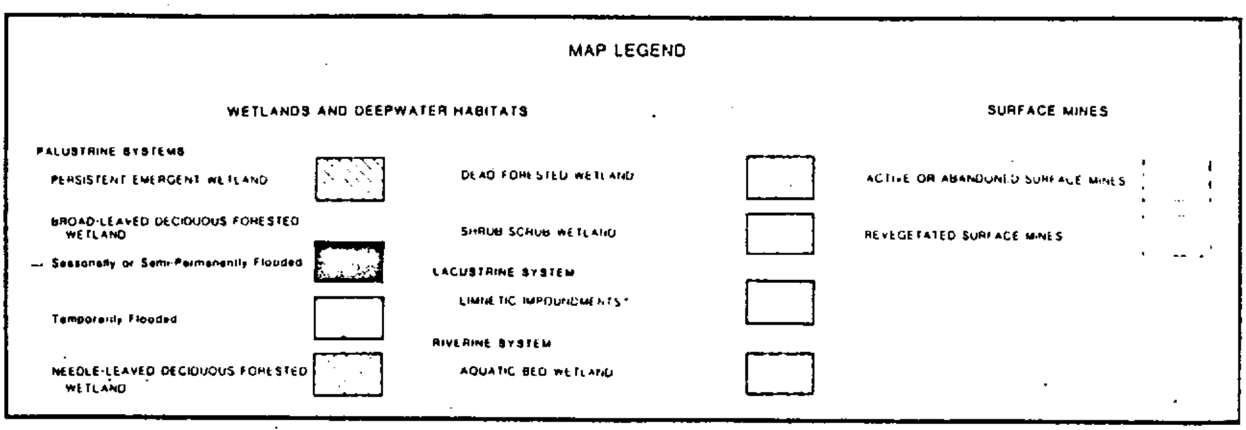
Wetland Vegetation. Much of the floodplain of Pond Creek has been impacted by logging, stripping, or mining-caused water level changes. Standing dead timber occurs in much of the wetland with second-growth forest in the remaining naturally vegetated areas. The forest (Site 3) is characterized by *Acer saccharum* (sugar maple), *Betula nigra* (river birch), *Carpinus caroliniana* (American hornbeam), *Carya ovata* (shagbark hickory), *Fraxinus pennsylvanica* (green ash), *Liquidambar styraciflua* (sweetgum), *Quercus* spp. (oaks), *Salix nigra* (black willow), *Sassafras albidum*, and *Ulmus* sp. (elm).

Table 22. Water quality summary for Central City East quadrangle. Values are given as average ± standard deviation (# of samples) unless only one measurement was taken.

Parameter	Date	Site number 1	2	3
pH	1980[a]	6.85 ± .5 (4)	---	---
	1981[b]	---	7.5	---
	1982[c]	---	---	7.4
Conductivity, umhos/cm	1980	2411 ±1314 (4)	---	---
	1981	---	3248	---
	1982	---	---	4900
Dissolved Oxygen, mg/l	1980	---	---	---
	1981	---	7.1	---
	1982	---	---	8.0
Sulfate, mg/l	1980	1233 ± 607 (4)	---	---
	1981	---	1200	---
	1982	---	---	851
Turbidity, NTU	1980	---	---	---
	1981	---	---	---
	1982	---	---	5.85
Suspended Solids, mg/l	1980	163[d]	---	---
	1981	---	0	---
	1982	---	---	---
Iron, mg/l (dissolved)	1980	2.89 ± 2.81(3)	---	---
	1981	---	---	---
	1982	---	---	0.27
Manganese, mg/l (dissolved)	1980	4.13 ± 1.16(3)	---	---
	1981	---	---	---
	1982	---	---	---

[a]USGS (1981).
[b]KNPC (1981).
[c]this study.
[d]average of two samples.

Fish and Wildlife. The fish population of this area has been reduced as a result of surface mining impacts, but the eastern sand darter (*Ammocrypta pellucida*), a Threatened species in Kentucky, has been reported from the Green River near river mile 85 (KNPC, 1982). A list of fishes from this wetland is included in Appendix C. Wading birds such as the green-backed heron (*Butorides striatus*) have been observed at the Pond Creek Wetland (Site 3).



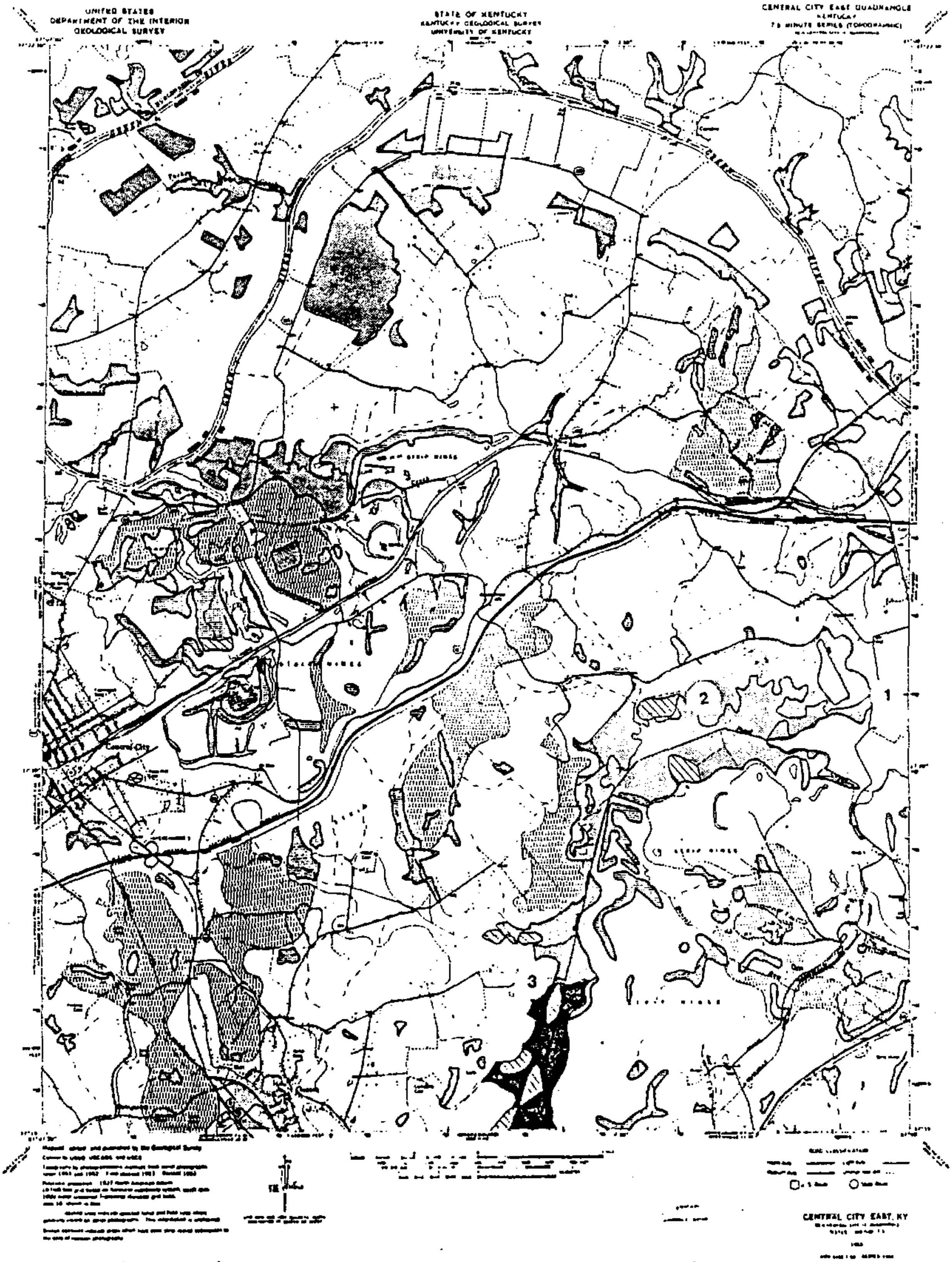


Figure 33. Wetlands and surface mines of Central City East quadrangle.

Drakesboro

Location. Muhlenberg County
Green River Drainage Basin

Geology and Coal Mining. The bottomlands of the streams are Quaternary System alluvium of clay, silt, sand, and gravel. The principal soil association is Belknap-Waverly (Cox, 1980). Approximately 80% of the Pond Creek watershed has been or is being surface mined for coal (KNPC, 1981).

Hydrology. This quadrangle includes a portion of Pond Creek which is discussed with the Central City East Quadrangle. Several impoundments are located in the Pond Creek Basin in the Drakesboro quadrangle.

Water Quality. The major portion of the Drakesboro topographic area is drained by Pond Creek, a large tributary of the Green River. The main channel of Pond Creek (Site 1) and adjacent spatterdock marsh (Site 2) were sampled at the KY 176 Bridge and southwest of the bridge, respectively. The water quality data for Pond Creek (Site 1) contrast sharply with that of the marsh (Site 2) (Table 23). The clear stream has extremely low pH and high sulfate, iron, and conductivity levels. Unpublished data from KDNREP from this site in 1982 show similar conditions. The marsh, on the other hand, seems to be receiving only periodic influxes of acid mine drainage as is evidenced by the reduced values for most parameters. The lower reaches of Pond Creek are discussed with the Central City East narrative.

Wetland Vegetation. The Pond Creek wetlands have been severely impacted by the surface mining surrounding the area and by haul roads crossing the swamp. The wetlands are a composite of marshes, scrub-shrub wetlands, and forested wetlands. A narrow riparian forest lines the channelized Pond Creek at Site 1. This bottomland includes *Acer rubrum* (red maple), *Betula nigra* (river birch), and *Liquidambar styraciflua* (sweetgum). Adjacent to the hardwoods on the east is a shrub-scrub area of *Salix nigra* (black willow) and *A. rubrum* which opens to a marsh and pond area. The marsh (Site 2) contains *Typha* sp. (cattail) and *Nuphar advena* (spatterdock).

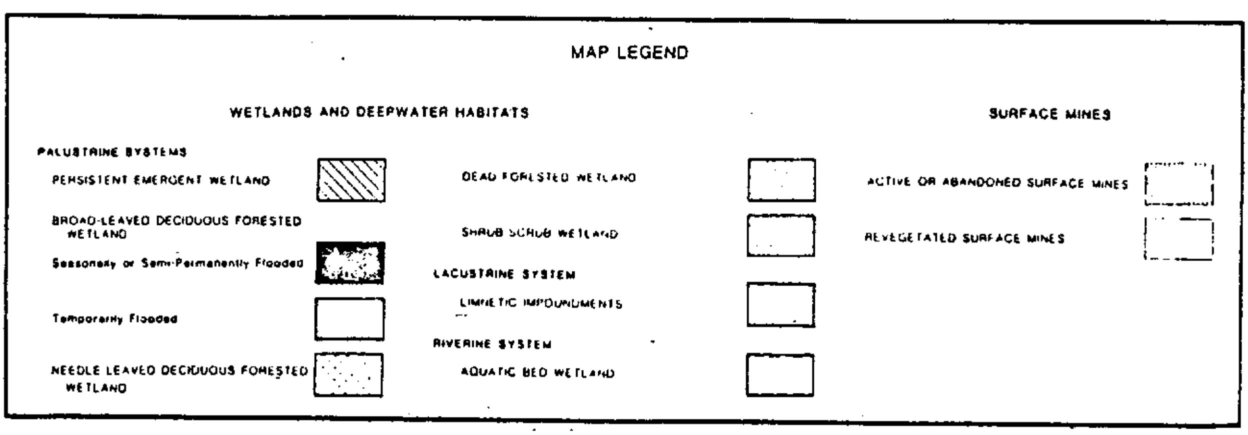
Table 23. Water quality summary for Drakesboro quadrangle. Values are given for one measurement.

Parameter	Date	Site number 1	Site number 2
pH	1982[a]	2.8	6.9
	1982[b]	3.6	---
Conductivity, umhos/cm	1982	5800	1350
	1982	936	---
Dissolved Oxygen, mg/l	1982[a]	6.4	8.5
Sulfate, mg/l	1982	523	405
	1982	654	---
Turbidity, NTU	1982	0.9	2.9
	1982	17	---
Suspended Solids, mg/l	1982	---	---
	1982	16	---
Iron, mg/l (dissolved)	1982	13.1	0.4
	1982	6.3	---
Manganese, mg/l (dissolved)	1982	---	---
	1982	5.67	---

[a]this study.
[b]KDNREP (unpublished data).

The remainder of the Pond Creek wetlands have similar composition. At Site 3, however, and farther downstream, much of the swamp is dead, with standing dead timber and very few shrubs or aquatic macrophytes.

Fish and Wildlife. No data on fish and wildlife are available for the Drakesboro quadrangle. Refer to Central City East quadrangle for biota of Pond Creek.



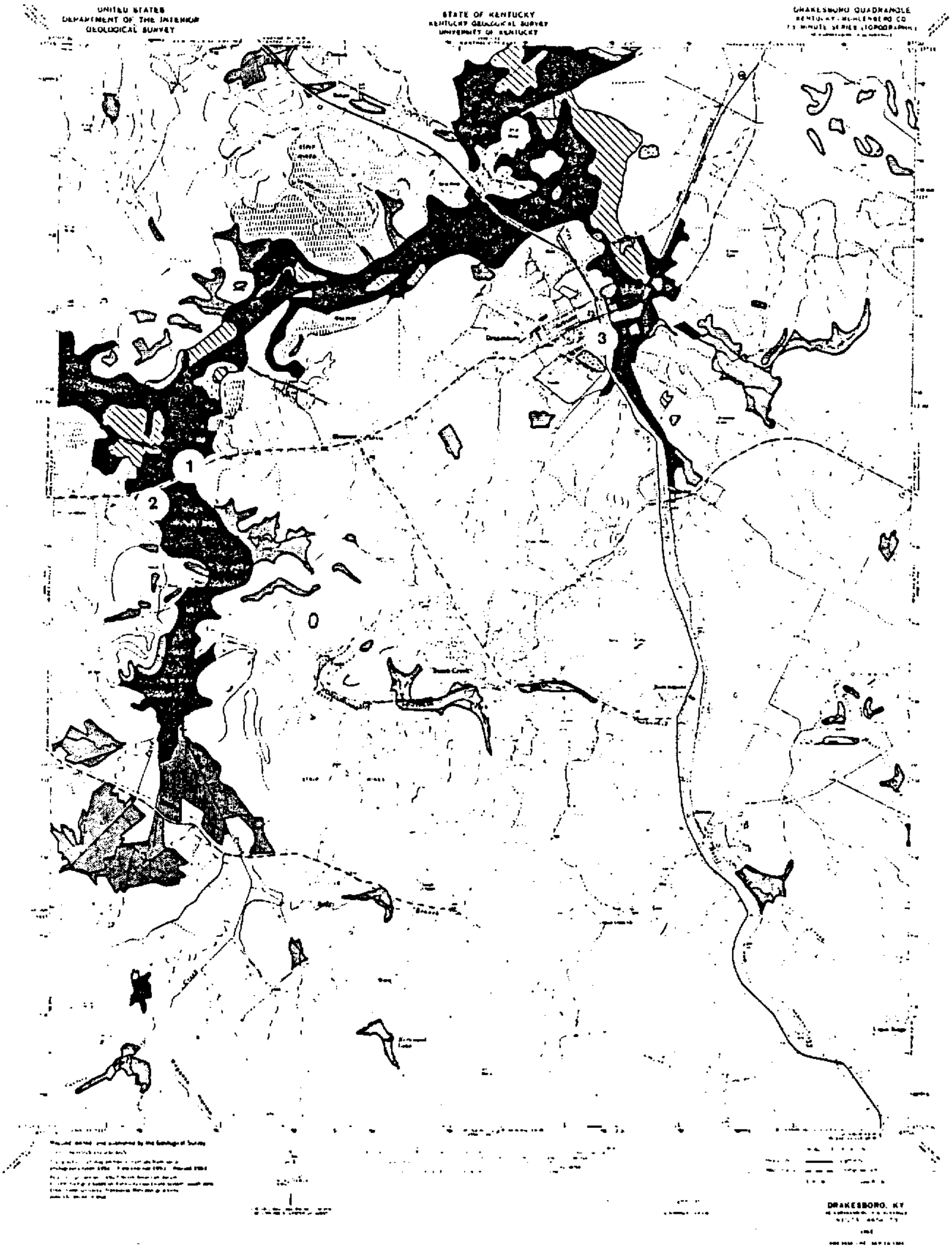


Figure 34. Wetlands and surface mines of Drakesboro quadrangle.

Hartford

Location. Ohio County
Rough River Sub-Basin of Green River Drainage Basin

Geology and Coal Mining. Broad alluvial floodplains dominate the topography of the area north of Rough River and near the mouth of Muddy Creek. South of the river, low hills predominate with extensive coal deposits and mining. These uplands are underlain by Lower and Middle Pennsylvanian Age deposits of Tradewater, Caseyville, and Carbondale Formation sandstone, shale, siltstone, coal, limestone, underclay, and conglomerate (Goudarzi, 1968). Bottomlands are underlain by clay, silt, sand, and gravel of the Quaternary System.

Hydrology. The stream channel of the Rough River at Rock House Slough (Site 3) is relatively unaltered. Streamflow of the Rough River at Dundee (Site 4), northeast of this quadrangle, averages 1064 cfs. Discharge ranged from 111 to 8940 cfs from October 1979 to September 1980 (USGS, 1981). Wetlands along Muddy Creek (Site 2) have been altered by stream channelization along 77% of the stream channel (KNPC, 1981).

Water Quality. The Hartford topographic area contains several wetlands and a major river, the Rough River. Water quality for the area is varied. Muddy Creek (Site 2), just south of Hartford, has been examined by Roy F. Weston, Inc. (1975), Laflin (1980), and KDNREP (1981). Roy F. Weston, Inc. (1975) identified domestic sewage discharge, mine drainage, pesticide run-off, and oil residuals as the major sources of water pollution. They also noted that at low flow the entire discharge of Muddy Creek consisted of waste water. Data presented by Laflin (1980) indicated intermittent acid flow in the stream, with pH values ranging from 3.3 to 5.4 (KNPC, 1980). Data presented by KNPC (1980, 1981) indicate a highly turbid, eutrophic stream with high conductivity (Table 24). KDNREP (1981) found the North Fork Muddy Creek, east of KY 231, to be impacted by mine drainage. Water quality data for Rockhouse Slough (Site 3) are limited to a single sample (KNPC, 1981), and are therefore difficult to interpret. Water quality for the Rough River is presented with the Equality quadrangle.

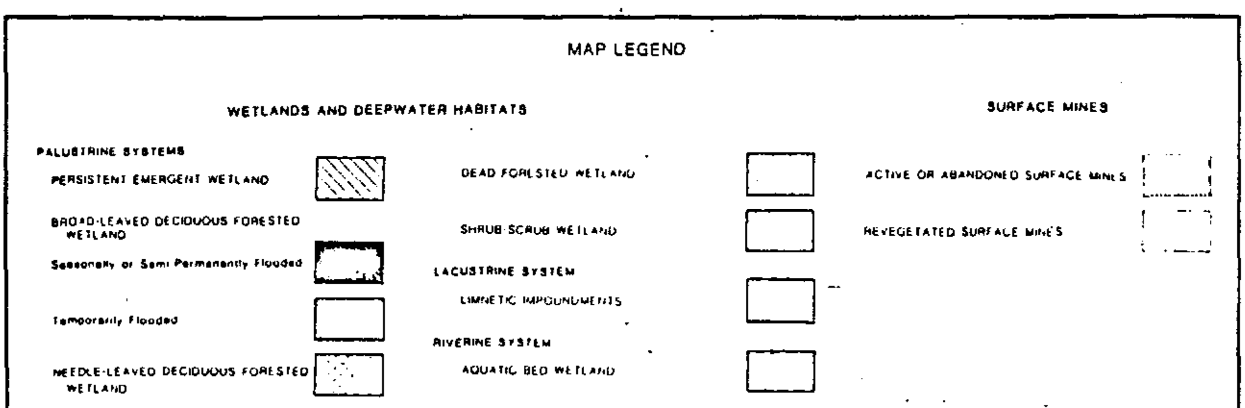
Table 24. Water quality summary for Hartford quadrangle. Values are given for one measurement.

Parameter	Date	Site number 2	Site number 3
pH	1981[a]	7.5	6.5
Conductivity, umho/cm	1981	544	210
Dissolved Oxygen, mg/l	1981	1.5	1.2
Sulfate, mg/l	1981	20	
Turbidity, NTU	1981	28	24
Suspended Solids, mg/l	1981	50	
Iron, mg/l (dissolved)	1981	---	---
Manganese, mg/l (dissolved)	1981	---	---

[a]KNPC (1981).

Wetland Vegetation. McCormick Slough (Site 1) is an old oxbow of the Rough River. The dominant woody species are Salix nigra (black willow) and Acer saccharinum (silver maple) with associates Fraxinus pennsylvanica (green ash) and Populus deltoides (eastern cottonwood). Although the floodplain has been extensively cleared for agriculture, several wetlands remain. Muddy Creek wetland (Site 2) encompasses about 200 ha (490 acres) of bottomland forest. The old creek channel contains a Quercus lyrata (overcup oak) - Q. palustris (pin oak) community with Acer rubrum (red maple), Fraxinus pennsylvanica (green ash), and Liquidambar styraciflua (sweet gum). A community of slightly higher elevation is dominated by Q. palustris, Q. falcata var. pagodaefolia (Spanish oak), and L. styraciflua, with associates of A. rubrum, Carya laciniosa (shellbark hickory), Nyssa sylvatica (black gum), Q. lyrata, and Ulmus americana (American elm), as reported by KNPC (1980).

Rock House Slough (Site 3) is composed of a partially-lumbered, wooded slough and a second-growth bottomland forest. The slough contains Acer rubrum, Betula nigra (river birch), Platanus occidentalis (sycamore), Populus heterophylla (swamp cottonwood), Quercus lyrata, Q. palustris, and Salix nigra. The forested tracts have two



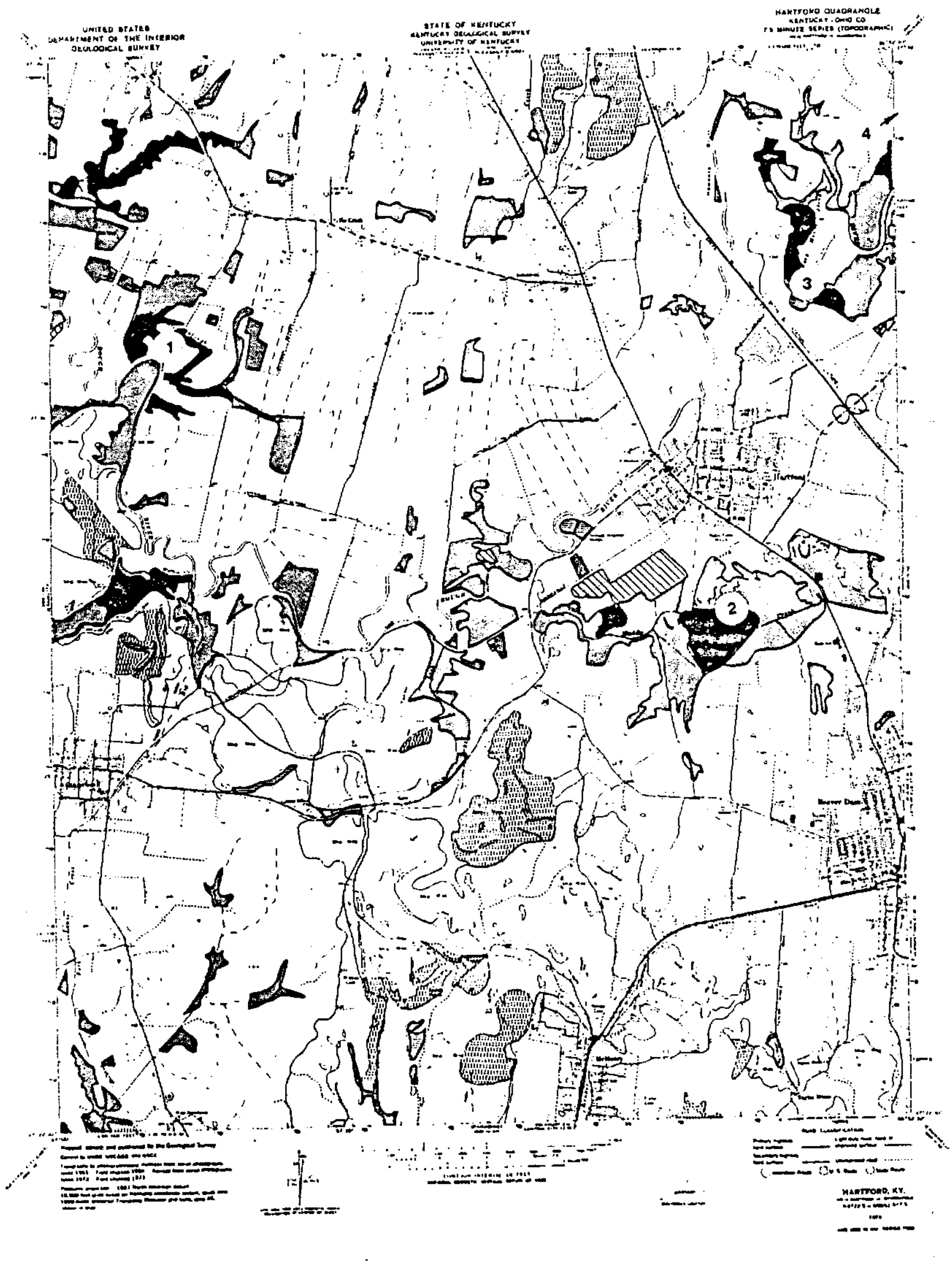


Figure 35. Wetlands and surface mines of Hartford quadrangle.

principal communities: a Q. palustris swamp with A. rubrum, F. pennsylvanica, and L. styraciflua; and a Q. palustris - A. rubrum forest with F. pennsylvania, L. styraciflua, and Ulmus americana. A Federal Candidate for Listing and a Kentucky Threatened plant, Chelone obliqua var. speciosa (pink turtlehead), was observed at both Sites 2 and 3 (KNPC, 1980).

Fish and Wildlife. Macroinvertebrates reported from Muddy Creek Wetland (Site 2) include dragonflies (Odonata), beetles (Coleoptera), true bugs (Hemiptera), midges (Chironomidae), mayflies (Stenacron sp.), and caddisflies, (Cheumatopsyche sp.) (KNPC, 1981). Laflin (1980) found that fishing in Muddy Creek is limited to backwater wetlands except in the spring during spawning runs from the Rough River (KDNREP, 1981). A species of Special Concern, the paddle fish (Polyodon spathula), is reported from this wetland area (KNPC, 1981 after Laflin, 1980). A mammal of Undetermined status, the meadow jumping mouse (Zapus hudsonius), is reported from Muddy Creek area (KNPC, 1982).

Rock House Slough (Site 3) has a fairly diverse macroinvertebrate fauna, including beetles (Coleoptera), leeches (Hirudinea), true bugs (Hemiptera), corixids (Hesperocorixa sp.), ancylids (Ferrissia sp.), and other snails (Gastropoda). Fish reported as being abundant at this site include sunfish (Lepomis spp.), largemouth bass (Micropterus salmoides), white crappie (Pomoxis annularis), mosquito fish (Gambusia affinis), golden shiner (Notemigonus crysoleucas), and the lake chubsucker (Erimyzon sucetta). The meadow jumping mouse (Z. hudsonius) is also recorded at this site (KNPC, 1981, 1982).

Three Threatened fish--the eastern sand darter (Ammocrypta pellucida), the harlequin darter (Etheostoma histrio), and the river darter (Percina shumardi)--are reported in the Rough River near Hartford. Two species of Special Concern from the same area include the channel darter (Percina copelandi) and the slenderhead darter (Percina phoxocephala). One species of Undetermined status, the yellow darter (Percina ouachitae), is also reported in the Rough River (KNPC, 1980).

Additional fish from this area are listed in Appendix C.

Paradise

Location. Ohio and Muhlenberg Counties
Green River Drainage Basin

Geology and Coal Mining. The uplands of the Paradise quadrangle are underlain by sandstone, siltstone, shale, limestone, coal, and clay of the Upper Pennsylvanian Sturgis Formation and the Middle Pennsylvanian Carbondale Formation. Bottomlands are alluvial silt, clay, sand, and gravel of the Quaternary System. Coal is the most important mineral resource and has been mined since the early 19th century. Both underground and surface mines are active in the area. Principal coal reserves are in the southern part of the quadrangle, with lesser amounts occurring in the north (Kehn, 1974).

Hydrology. The Green River at Paradise (Site 1) has an average discharge of 9522 cfs from a drainage area of 16,0014 km^2 (6183 mi^2). The discharge ranged from 560 to 39,700 cfs from October 1979 to September 1980. This quadrangle also includes Lewis Creek at Rockport (Site 2) which had a streamflow of 0.4 to 119 cfs from March to September 1980 (USGS, 1981).

Water Quality. Sparse water quality data are available for the Green River at Paradise, (Site 1). Mine drainage is diluted in a large river, such as the Green, resulting in the low conductivity measured there (Table 25). Pond Creek, a tributary of the Green River, enters the Paradise quadrangle from the west. Specific details on water quality of this stream are discussed with the Central City East quardrangle.

Water quality data (Table 25) for Lewis Creek (Site 2) have been reported by the USGS (1981). The data characterize this stream as impacted by surface mining. While pH values range from 4.8 to 7.0, values for conductivity, sulfate, suspended solids, and several metals are very high (see also Appendix D). These values are direct indicators of acid mine drainage.

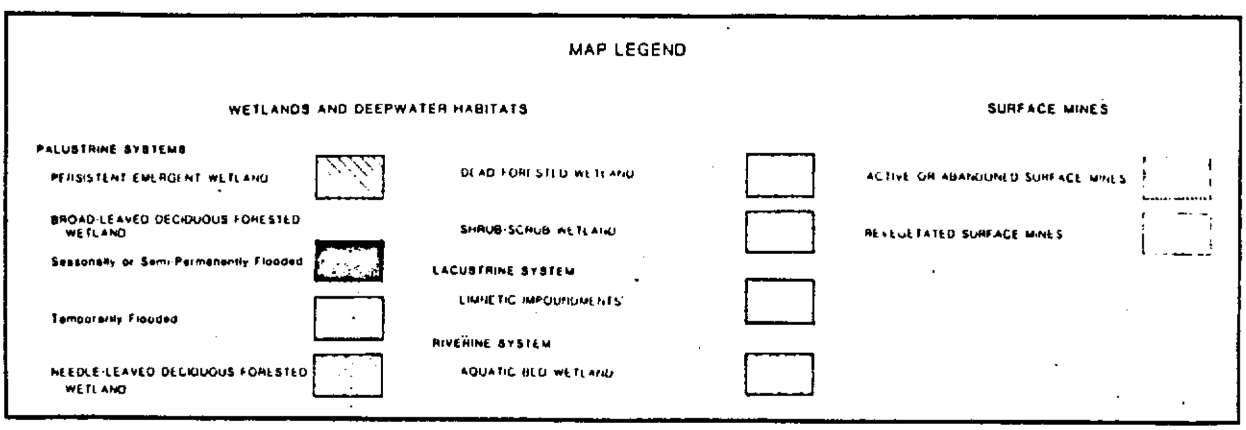
Wetland Vegetation. The wetlands of the Paradise quadrangle are composed of bottomland forests along the Green River and its tributaries and marshes, shrub-scrub wetlands, and swamp forests created or heavily impacted by surface mining. The floodplain forests contain *Acer rubrum* (red maple), *A. saccharinum* (silver maple), *Betula nigra* (river birch), *Cephalanthus occidentalis* (buttonbush), *Liquidambar styraciflua* (sweetgum), *Platanus occidentalis* (sycamore), and *Salix nigra* (black willow), as well as other typical bottomland species. Cleared areas of floodplain may support sedge-rush meadows. Marshes of the mining area (Site 3) generally are dominated by *Typha latifolia* (common cattail).

Table 25. Water quality summary for Paradise quadrangle. Values are given as average ± standard deviation (# of samples).

Parameter	Date	Site number 1	Site number 2
pH	1980[a]	---	5.95 ±0.89 (4)
Conductivity, umho/cm	1980	277 ± 72(9)	2234 ± 848 (4)
Dissolved Oxygen, mg/l	1980	---	---
Sulfate, mg/l	1980	---	1213 ± 454 (4)
Turbidity, NTU	1980	---	---
Suspended Solids, mg/l	1980	---	37 ± 42 (4)
Iron, mg/l (dissolved)	1980	---	0.39 ±0.24 (4)
Manganese, mg/l (dissolved)	1980	---	6.15 ± 1.7 (4)

[a]USGS (1981).

Fish and Wildlife. One Threatened species, the eastern sand darter (*Ammocrypta pellucida*), occurs in the Green River near Paradise (Site 1). The slenderhead darter (*Percina phoxocephala*) is found in Pond Creek (Site 3) and is listed as a Special Concern species (KNPC, 1982; Branson et al., 1981). Two recently delisted fish, *Hybognathus nuchalis* (silvery minnow) and *Aphredoderus sayanus* (pirate perch), were found in Pond Creek near its mouth (KNPC, 1981).



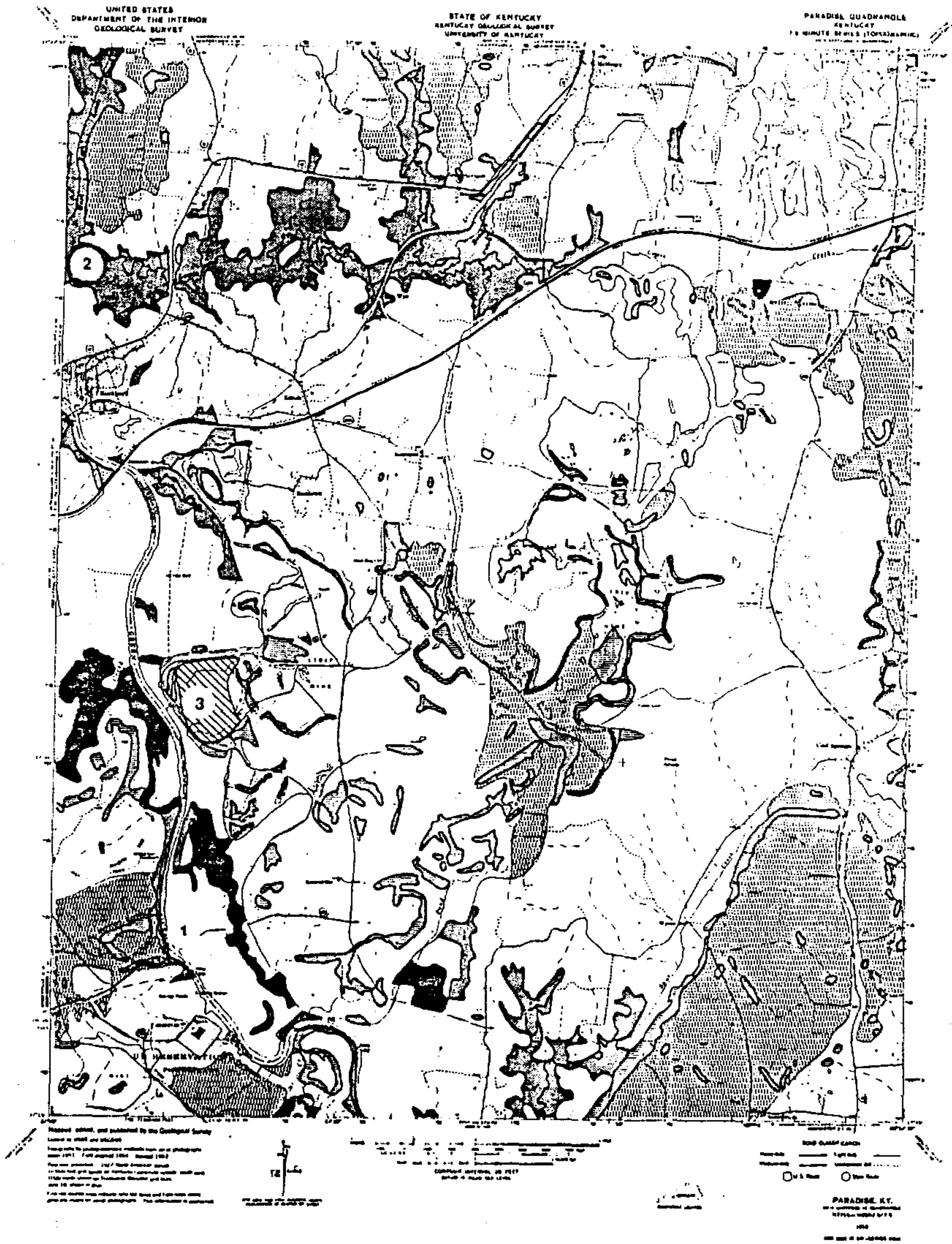


Figure 36. Wetlands and surface mines of Paradise quadrangle.

Rochester

Location. Muhlenberg, Butler, and Ohio Counties
Green River Drainage Basin, Mud River Sub-Basin of the Green River Drainage Basin

Geology and Coal Mining. The topography of Rocky Creek watershed (Site 2) is characterized by highly dissected hills with flat ridgetops and a broad floodplain. The geology of the watershed was investigated by Kehn (1977b, 1978) and includes two sections divided by the Twin Tunnels Fault System. South of the fault, uplands are underlain by Pennsylvanian Age Caseyville Formation sandstone and coal. North of the fault, sandstone, shale, limestone, coal, and underclay of Pennsylvanian Age Tradewater Formation predominate. Streams and floodplains are underlain with Quarternary Age alluvium of clay, silt, sand, and gravel. Mining near Rocky Creek is limited to four small surface mines (34 ha), located just upstream of Site 2. Extensive surface mining has taken place near the Green River.

Hydrology. This quadrangle includes Mud River and Rocky Creek. Mud River stretches across the Rochester topographic area, north-to-south, and meets the Green River at Rochester. Streamflow for the Mud River near Huntsville (Site 1), from October 1979 to August 1980, ranged from 5.6 to 368 cfs for 8 readings (USGS, 1981). Streamflow for Rocky Creek near Penrod (Site 2) for March to September 1980 ranged from 0.0 to 157 cfs for 4 readings. KNPC (1981) reports that 31% of the stream channel of Rocky Creek has been impounded.

Water Quality. Water quality data have been recorded for the Mud River (USGS, 1980, 1981; Charles, 1979; KNPC, 1981) for several years (Site 1). The data indicate good water quality, although Charles (1979) and KNPC (1981) recorded low dissolved oxygen values in upstream segments. Low mining influence in the watershed is reflected in the low sulfate and conductivity readings (Table 26). A high chloride reading (see Appendix D), recorded by KNPC (1981), may be due to oil drilling activities in the watershed.

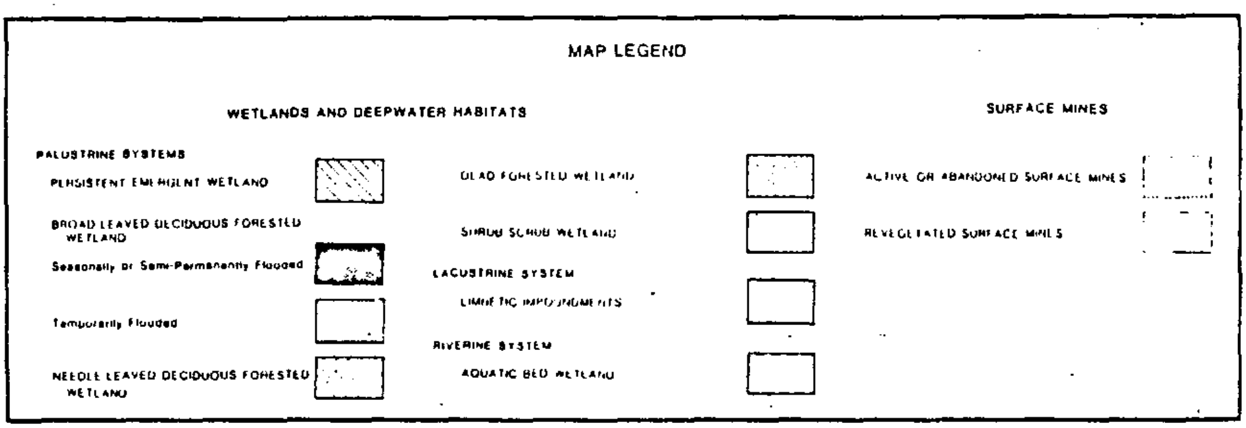
Rocky Creek (Site 2), a large tributary of the Mud River, has been the subject of investigations by several researchers (USGS, 1980, 1981; Axon, 1981; KNPC, 1981; KDNREP, 1981). Due to the discharge of Lake Malone, both flow and water quality have been altered (Axon, 1981). KNPC (1981) data (Table 26) indicate some mining influence. These readings, however, were recorded nearer to the confluence of Rocky Creek with the Mud River than were those of other studies. Tributaries of Rocky Creek have recorded pH values as low as 4.0 and conductivity readings as high as 1550 umhos/cm (KNPC, 1981). KDNREP (1981) found Hazel Creek, a tributary to Rocky Creek, to be impacted by mine drainage with high values of conductivity, sulfate, iron, and manganese. The Rocky Creek watershed has good water quality upstream, near Lake Malone.

Several small tributaries to the Green River (in the northern part of the quadrangle) drain former surface mines. KDNREP (1981) found high conductivity and sulfate for two such streams, Spur Creek (4 km NW of Rochester) and Jacobs Creek near Paradise.

Table 26. Water quality summary for Rochester quadrangle. Values are given as average ± standard deviation (# of samples) unless one measurement was taken.

Parameter	Date	Site number 1	Site number 2
pH	1980[a]	7.5 ± 0.3 (8)	6.7 ± 0.3 (3)
	1981[b]	7.0	6.0
Conductivity, umhos/cm	1980	317 ± 58 (8)	109 ± 15 (3)
	1981	336	487
Dissolved Oxygen, mg/l	1980	---	---
	1981	3.9	4.2
Sulfate, mg/l	1980	26.3 ± 7.6 (8)	17.7 ± 4.0 (3)
	1981	<10	100
Turbidity, NTU	1980	---	---
	1981	18	8
Suspended Solids, mg/l	1980	---	---
	1981	0	0
Iron, mg/l (dissolved)	1980	0.10 ± 0.11(8)	0.07 ± .05 (3)
Manganese, mg/l (dissolved)	1980	0.14 ± 0.15(8)	0.85 ± 1.1 (3)

[a]USGS (1981).
[b]KNPC (1981).



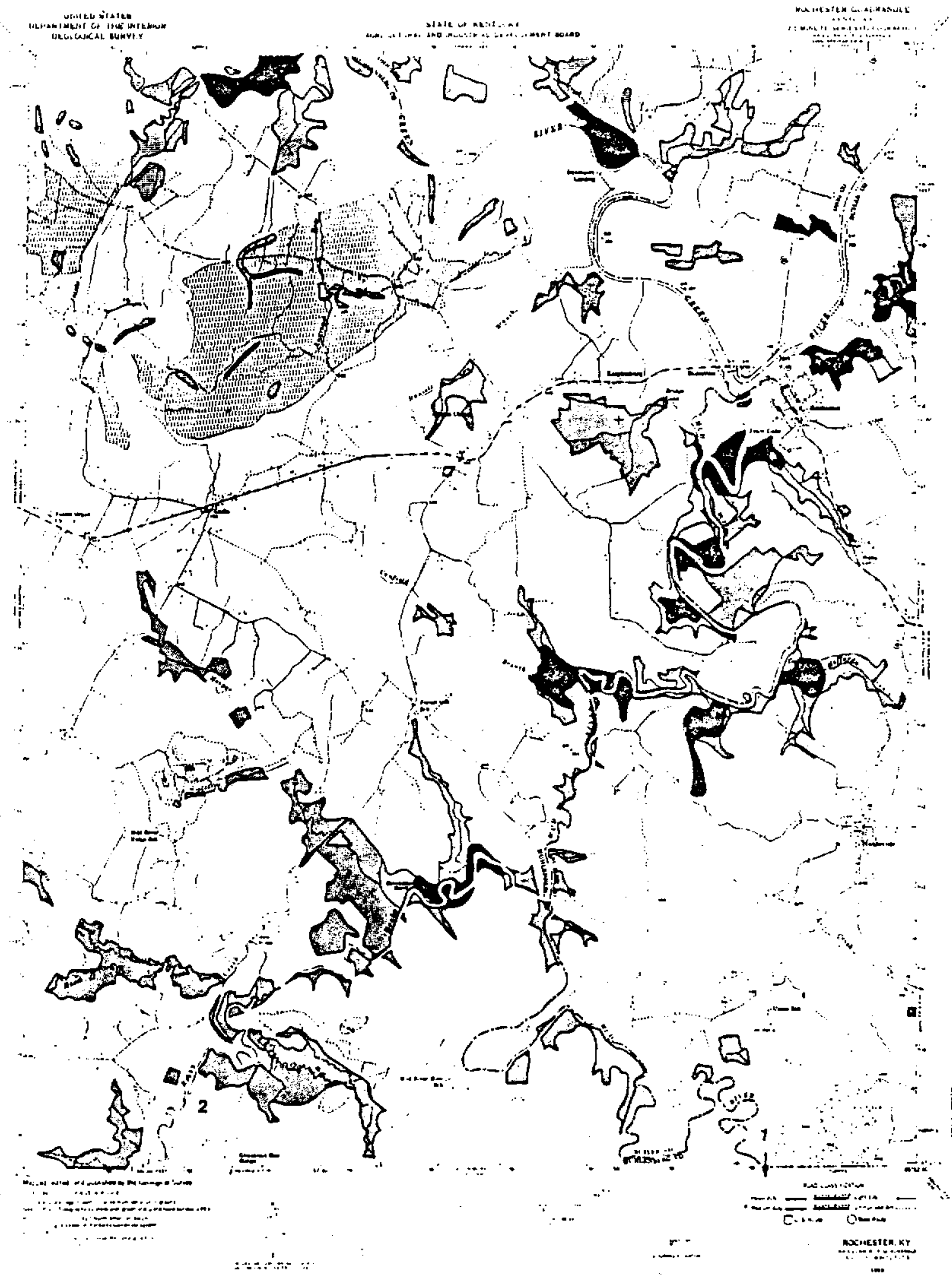
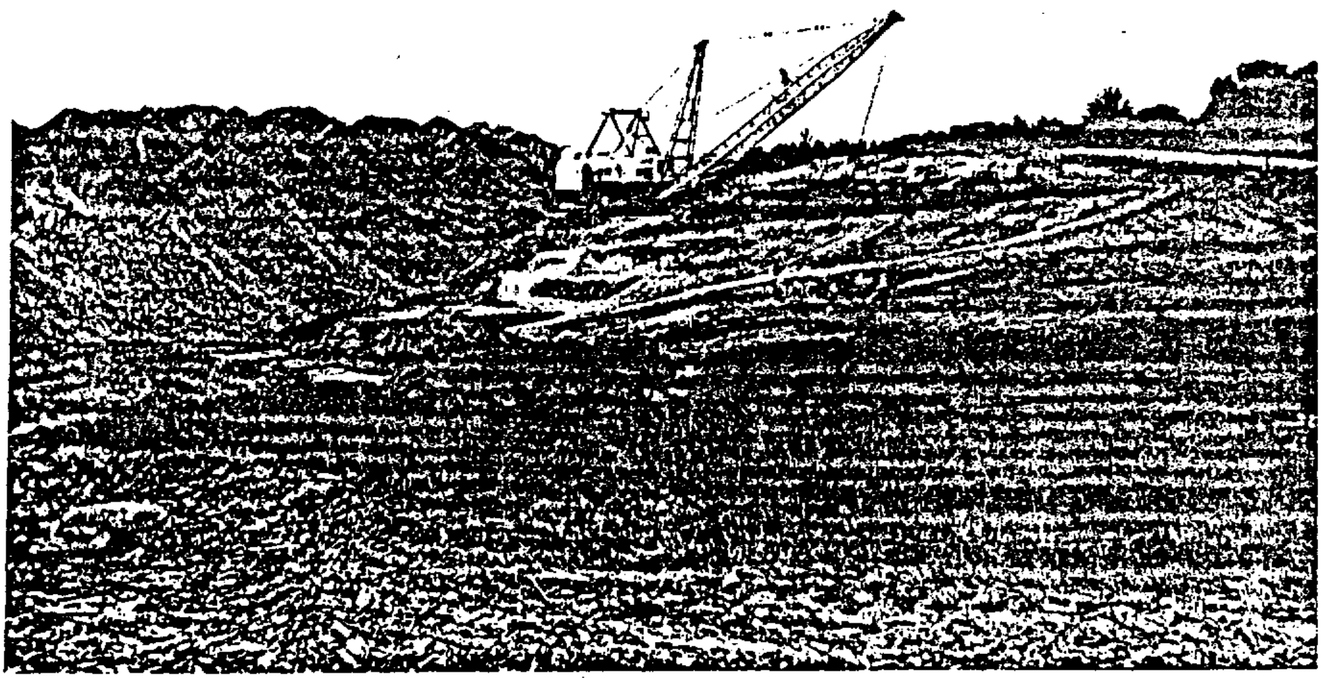


Figure 37. Wetlands and surface mines of Rochester quadrangle.

Wetland Vegetation. Stream banks and the forested parts of the floodplain are occupied by bottomland hardwoods. Much of the floodplain has been cleared for agriculture. Riparian trees include Acer rubrum (red maple), A. saccharinum (silver maple), Betula nigra (river birch), Carpinus caroliniana (American hornbeam), Carya sp. (hickory), Fagus grandifolia (beech), Fraxinus sp. (ash), Liquidambar styraciflua (sweetgum), Quercus sp. (oak), and Sassafras albidum (sassafras). The canopy of the bottomland forests is generally closed, with only an occasional opening (KNPC, 1981).

Fish and Wildlife. Macroinvertebrates reported by KNPC (1981) from Rocky Creek (Site 2) include dragonflies (Odonata) and the freshwater spongilla fly (Climacia sp.). The most abundant fish species include three shiners (Notropis emiliae, N. fumeus, and N. umbratilis), the mosquito fish (Gambusia affinis), and the blackstripe topminnow (Fundulus notatus). The silver lamprey (Ichthyomyzon unicuspis) is reported in the Green River near Rochester and is listed by Branson et al. (1981) as a Special Concern species. One Threatened fish species, the spotted gar (Lepisosteus oculatus), is also reported from that location.

Additional fish species are listed in Appendix C.



Horton

Location. Ohio County
Rough River Sub-Basin of the
Green River Drainage Basin

Geology and Coal Mining. Most of the Muddy Creek watershed is comprised of low hills, while the western portion is dominated by broad alluvial floodplains of the Quaternary System. Coal from the Nos. 9, 11, and Elm Lick beds has been deep and surface mined from several sites. The Nos. 4, 11, and Elm Lick beds persist throughout the watershed (Gildersleeve, 1975).

Hydrology. Muddy Creek near Beaver Dam (Site 1) has streamflow which ranged from 0.0 to 256 cfs for 4 readings from March to September, 1980 (USGS, 1981).

Water Quality. Water quality data (Table 27) for Muddy Creek (Site 1) have been recorded for several years (Roy F. Weston, Inc., 1975; USGS, 1980, 1981; and Laflin, 1980). Both mining and domestic wastes affect Muddy Creek. For downstream water quality, refer to the Hartford quadrangle. The Muddy Creek headwaters at Site 2 have good water quality, suggesting that most other headwater streams in the area have similar conditions. The water quality of Threelick Fork has been monitored by USGS (1981) and is similar to Muddy Creek headwaters.

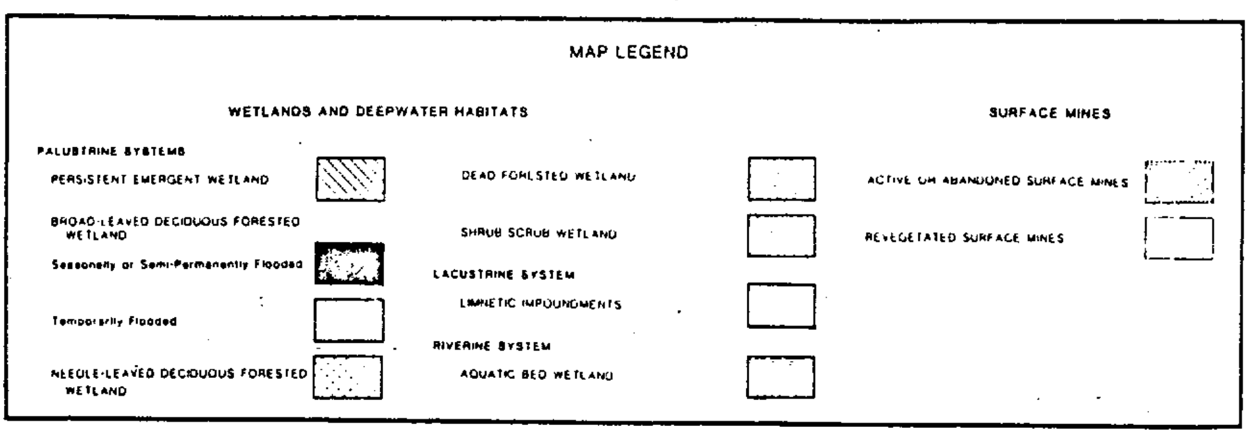
Wetland Vegetation. The lowland areas of the watershed are devoted to agriculture with little of the original forested wetland habitat remaining. Forests are generally restricted to a narrow band of riparian vegetation and an occasional young forest on the second or third terrace (KNPC, 1981). These forests consist of trees including *Acer negundo* (box elder), *A. rubrum* (red maple), *A. saccharum* (sugar maple), *A. saccharinum* (silver maple), *Betula nigra* (river birch), *Fraxinus pennsylvanica* (green ash), *Liquidambar styraciflua* (sweetgum), *Platanus occidentalis* (sycamore), and *Salix nigra* (black willow).

Table 27. Water quality summary for Horton quadrangle. Values are given as average ± standard deviation (# of samples) unless only one measurement was taken.

Parameter	Date	Site number 1	Site number 2
pH	1980[a]	6.77 ± .18 (3)	---
	1982[b]	---	7.4
Conductivity, umhos/cm	1980	324 ± 156 (3)	---
	1982	---	300
Dissolved Oxygen, mg/l	1980	---	---
	1982	---	7.8
Sulfate, mg/l	1980	23.7 ± 1.7 (3)	---
	1982	---	58.5
Turbidity, NTU	1980	---	---
	1982	---	2.05
Suspended Solids, mg/l	1980	32 ± 45 (4)	---
	1982	---	---
Iron, mg/l (dissolved)	1980	0.057 ± 0.034(3)	---
	1982	---	0.11
Manganese, mg/l (dissolved)	1980	1.41 ± 0.70 (3)	---
	1982	---	---

[a]USGS (1981).
[b]this study.

Fish and Wildlife. No fish and wildlife data are reported from the Horton quadrangle.



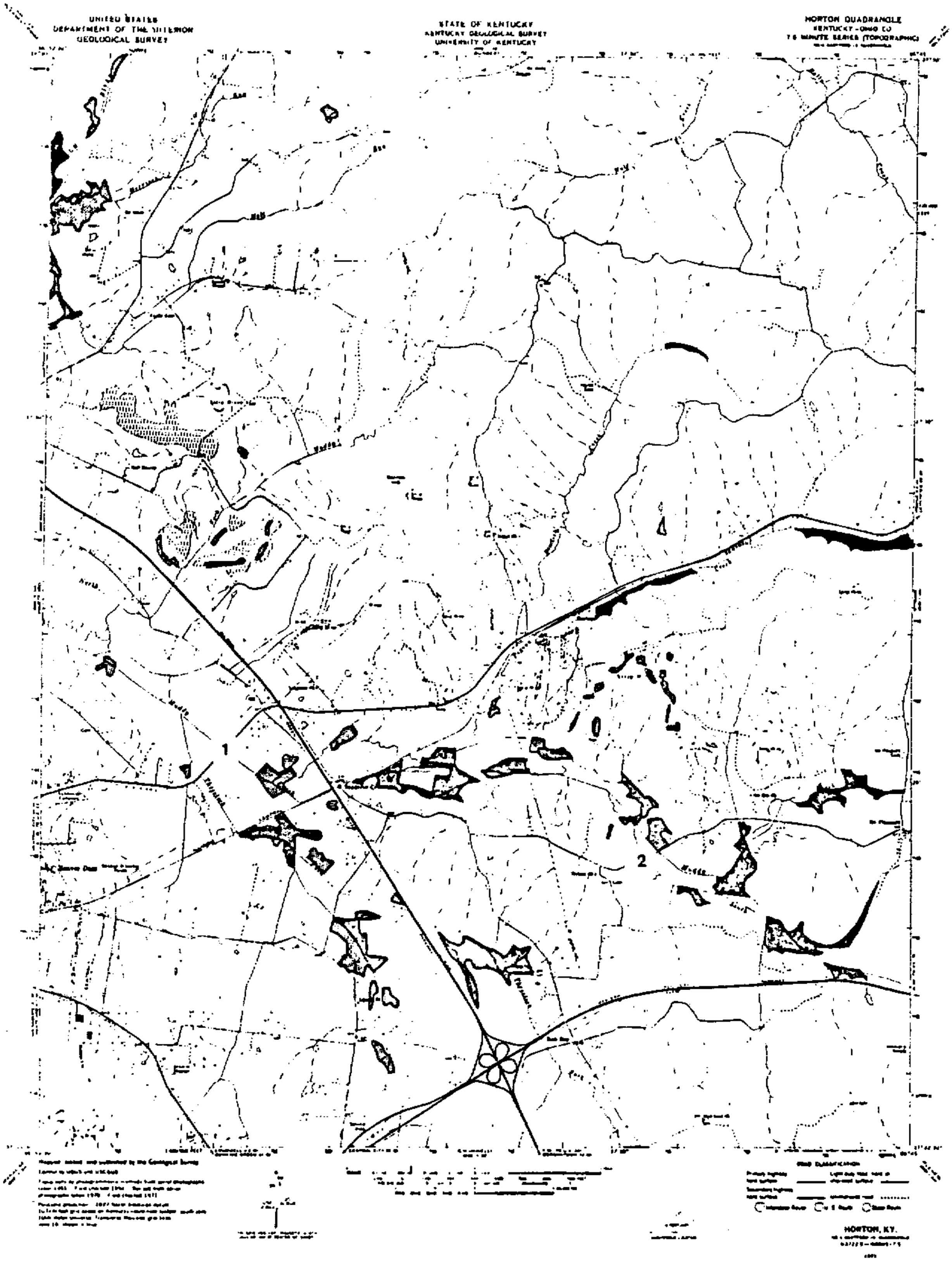


Figure 38. Wetlands and surface mines of Horton quadrangle.

Cromwell

Location. Butler and Ohio Counties
Green River Drainage Basin

Geology and Coal Mining. Uplands north and west of the Green River are underlain almost entirely by Middle Pennsylvanian Age shale, siltstone, sandstone, coal, underclay, and limestone of the lower Carbondale and Upper Tradewater Formations. The Big Bend uplands contain gravel deposits which overlie the Carbondale and Tradewater Formations. The gravel is concealed by a loess mantle. Coal and gravel are the only exploited mineral resources. The Nos. 9 and 11 coal beds have been extensively surface mined in the western part of the quadrangle. All mines were inactive in 1971 (Gildersleeve 1975). Quaternary alluvium of clay, silt, sand, and gravel underlies the stream channels and bottomlands.

Hydrology. This quadrangle includes part of the Lewis Creek Wetlands discussed with the Paradise Quadrangle. Taylor Lake (Site 1), a permanently flooded oxbow with a relatively unaltered water regime, is also included in this quadrangle (KNPC, 1980).

Water Quality. Little water quality information is available for surface waters within the Cromwell topographic area. Some interesting wet areas occur along Thoroughfare Creek but these have not been analyzed. The Green River makes a large loop through this quadrangle but has no monitoring stations in this quadrangle. The nearest data recording station is located at Woodbury, 13 miles upstream of the Cromwell quadrangle. This station falls far outside the study area. A mean conductivity of 258 $\pm$ 33 for eight readings was recorded for 1980.

Wetland Vegetation. Taylor Lake (Site 1) is composed of communities of different successional stages from open water to forested. Some of the communities are: open water, Lemna-Wolffia (duckweeds), Nuphar advena (spatterdock), Cephalanthus occidentalis (buttonbush) - N. advena - Populus heterophylla (swamp cottonwood) - Salix sp. (willow) and Acer saccharinum (silver maple) - Fraxinus pennsylvanica (green ash), as reported by KNPC (1980). On the floodplain of Lewis Creek along the Western Kentucky Parkway (Site 2), two wetland communities were observed. A young Acer rubrum forest dominated much of the bottomland. In open areas, sedge meadows composed of Carex sp. (sedge), Scirpus sp. (bulrush), and Juncus sp. (rush) may occur in small patches.

Fish and Wildlife. No data are available for this quadrangle.

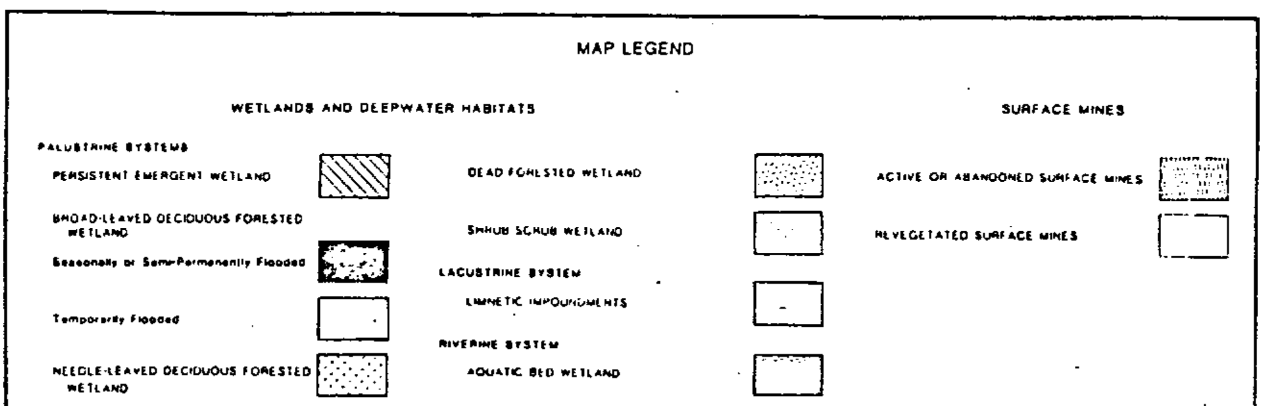


Figure 39. Wetlands and surface mines in Cromwell quadrangle.

South Hill

Location. Butler County
Green River Drainage Basin

Geology and Coal Mining. The geology of the Muddy Creek watershed has been described by Gildersleeve (1972) and Moore (1974). Stream channels and floodplains are underlain primarily by unconsolidated alluvial clay, silt, sand, and gravel of Quaternary Age. No soil survey is available. Coal resources are found in the northeast portion of the watershed where reserves were estimated at 54 million tons in 1963. Mining has occurred east and west of Muddy Creek between KY 70 and the Green River, in the Sandy Creek drainage and in Persimmon Creek (KNPC, 1981).

Hydrology. Wetlands along Muddy Creek (Sites 1 and 2) are intermittently flooded; approximately 55% of the stream channel near these wetlands was channelized 30 years ago. Streamflow of Muddy Creek at Dunbar (Site 1) ranged from 0.7 to 325 cfs from March to September 1980 for 4 readings. Also included in this quadrangle is part of Doolin Lake Swamp (Site 3), an intermittently flooded wetland with a relatively unaltered water regime (KNPC, 1980).

Water Quality. Water quality data for Muddy Creek (Site 1) have been presented by (USGS 1980, 1981), KDNREP (1981), and KNPC (1981). The most extensive analysis was performed by Golden and Twilley (1976) who concluded that the overall water quality was good upstream of the KY 70 bridge. They did note a decrease in dissolved oxygen and an increase in nutrients (ammonia and phosphorus) at a station near the mouth. The data reported in Table 28 are similar to those from other sources (KNPC, 1981).

No water quality data are available for the section of the Green River which runs east-west across the northern edge of the South Hill quadrangle.

Wetland Vegetation. The Muddy Creek watershed is mostly hilly, but the floodplain of the stream is broad and well-developed. Agriculture is the primary land use in the watershed. Extensive channelization of Muddy Creek and its tributaries has promoted agriculture in the once extensive wetlands. Remnants of riparian wetlands still occur along the stream.

Table 28. Water quality summary for South Hill quadrangle. Values are given as average ± standard deviation (# of samples) unless only one measurement was taken.

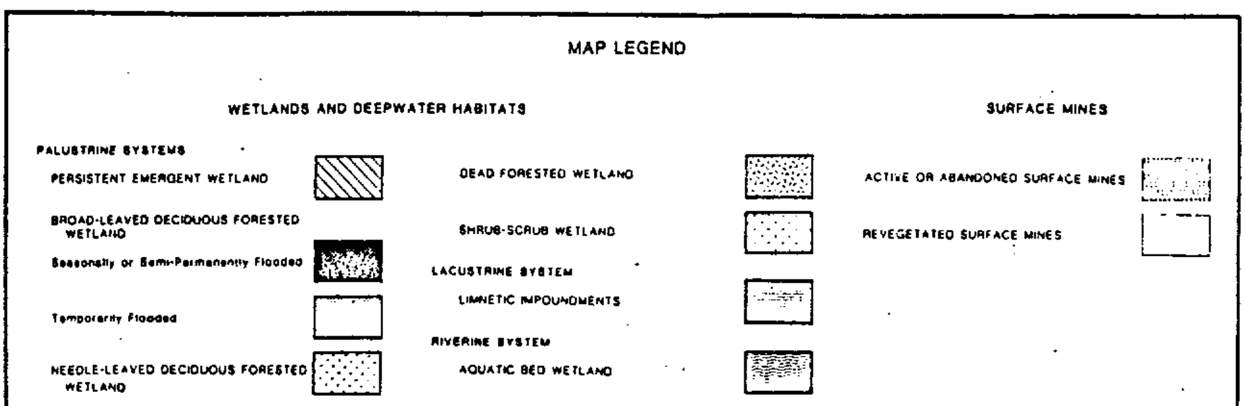
Parameter	Date	Site number 1
pH	1980[a]	7.55 ±0.03 (4)
	1981[b]	7.5
Conductivity, umhos/cm	1980	263 ± 56 (4)
	1981	234
Dissolved Oxygen, mg/l	1980	---
	1981	6.5
Sulfate, mg/l	1980	32.5 ± 14.2 (4)
	1981	---
Turbidity, NTU	1980	---
	1981	16
Suspended Solids, mg/l	1980	49 ± 36 (4)
	1981	0
Iron, mg/l (dissolved)	1980	0.038 ± 0.019 (4)
	1981	---
Manganese, mg/l (dissolved)	1980	0.088 ± 0.024 (4)
	1981	---

[a]USGS (1981)
[b]KNPC (1981)

The bottomland hardwood forest along Muddy Creek (Site 2) is temporarily flooded and is characterized by second-growth Quercus palustris (pin oak), Quercus lyrata (overcup oak), and Fraxinus pennsylvanica (green ash). The trees are 15-51 cm (6-20 inches) in diameter (KNPC, 1980). The understory community is composed primarily of Cephalanthus occidentalis (buttonbush), Cornus sp. (dogwood), Crataegus sp. (hawthorn), and Ilex decidua (swamp holly).

Along Muddy Creek at the KY 70 bridge (Site 1), a second-growth riparian community is present. Woody species are Acer negundo (box elder), A. rubrum (red maple), Cephalanthus occidentalis, Liquidambar styraciflua (sweetgum), Platanus occidentalis (sycamore), Salix sp. (willow), and Ulmus sp. (elm).

Doolin Lake Swamp (site 3) falls only partly in the South Hill quadrangle, with the larger portion appearing on the Morgantown quadrangle. The young swamp forest has been logged occasionally. The overstory community is composed of small trees (≤ 10 cm dbh), including Acer



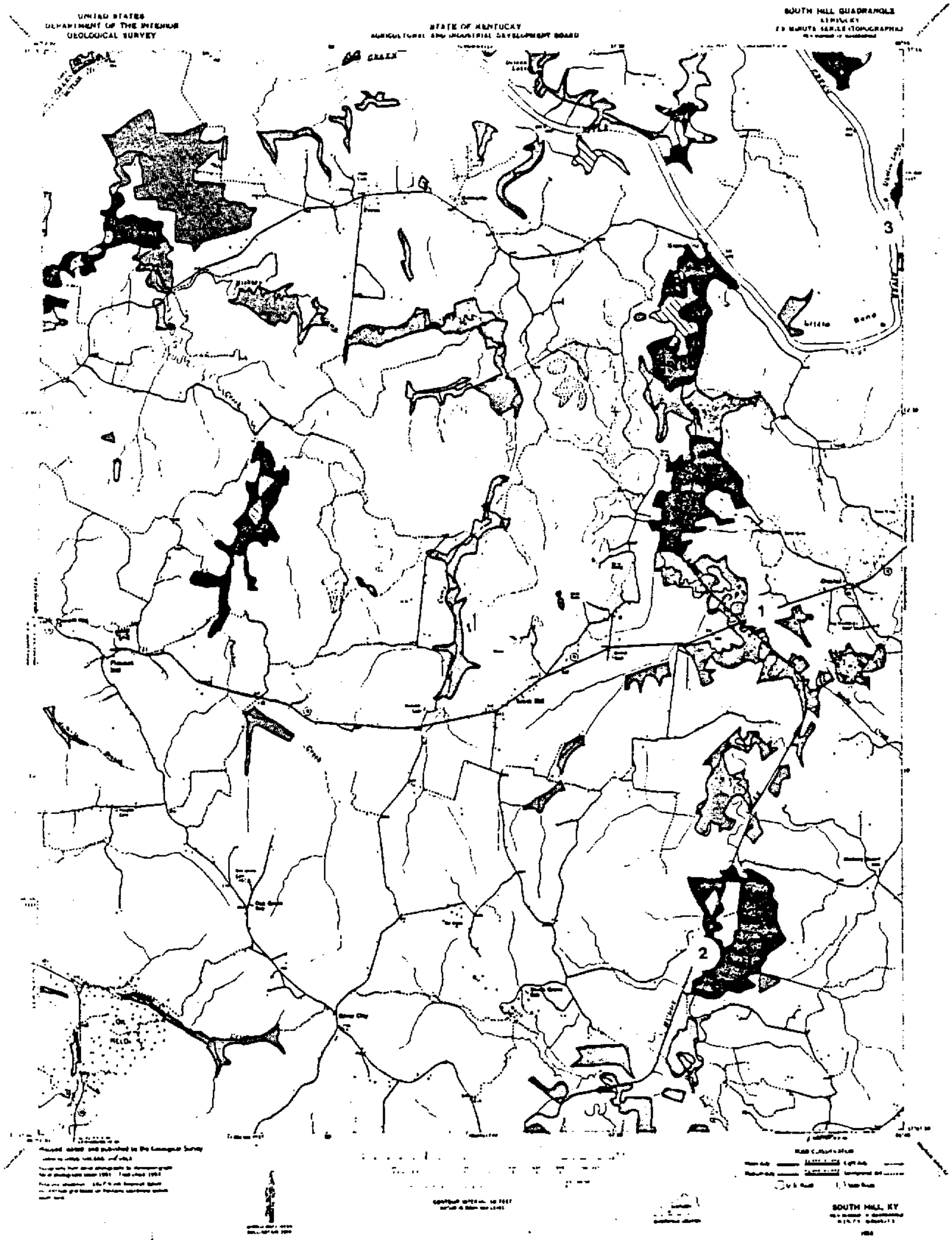


Figure 40. Wetlands and surface mines of South Hill quadrangle.

negundo, Acer saccharinum (silver maple), Betula nigra (river birch), and Populus deltoides (cottonwood). The herbaceous layer is well developed with a mix of hydrophytic and mesophytic species (KNPC, 1980).

Fish and Wildlife. The freshwater mussel, Corbicula leana, is reported as a major component of the macroinvertebrate fauna of Muddy Creek (KNPC, 1981). An elmid (Stenelmis sp.) and the caddisfly (Cheumatopsyche sp.) are also found in this area. One Threatened fish species, the eastern sand darter (Ammocrypta pellucida), is reported near the mouth of Muddy Creek (KNPC, 1982).

Additional fish species are listed in Appendix C.

Axon, J.R. 1980. Annual performance report for statewide fisheries management project. Part III of IV. Subsection III: Streams Research and Management. D-J Project No. F-50, Segment 2. Kentucky Department of Fish and Wildlife Resources, Fisheries Division, Frankfort, KY.

Axon, J.R. 1981. Annual performance resport for statewide fisneries management project. Part III of IV. Subsection III: Streams Research 2. Kentucky Department of Fish and Wildlife Resources, Fisheries Division, Frankfort, KY.

Bailey, R.G. 1976. Ecoregions of the United States. U.S. Forest Service, Ogden, UT (1:7,500,000 map).

Branson, B.A., D.F. Harker, J.M. Baskin, M.E. Medley, D.L. Batch, B. Monroe, L.R. Phillippe, and P. Cupp. 1981. Endangered, threatened, and rare animals and plants of Kentucky. Trans. Ky. Acad. Sci. 42(3-4):77-89.

Braun, E.L. 1950. Deciduous forests of eastern North America. Hafner Publishing Co., New York. 596 p.

Charles, J.R. 1979. Annual performance report for statewide fisheries management project. Part III of IV. Subsection III. Streams research and management. D-J Project No. 50, Segment 1. Kentucky Department of Fish and Wildlife Resources, Frankfort, KY.

Cowardin, L.M., V.G. Carter, F.C. Golet, and E.T. LaRoe. 1979. Classification of wetlands and deepwater habitats of the United States. U.S. Fish and Wildlife Service 79/31, Washington D.C. 103 p.

Cox, F.R., Jr. 1980. Soil survey of McLean and Muhlenberg counties, Kentucky. Soil Conservation Service, United States Department of Agriculture, Washington, D.C.

Franklin, G.J. 1967. Geologic quadrangle maps of the United States. Geologic map of the Coiltown quadrangle, Hopkins County, Kentucky. Map GQ-629. United States Geological Survey, Washington, D.C.

Franklin, G.J. 1973. Geologic map of the Millport quadrangle, Muhlenberg and Hopkins counties, Kentucky. Map GQ-1050. United States Geological Survey, Washington, D.C.

Froedge, R.D. 1980. Soil survey of Christian County, Kentucky. Soil Conservation Service, United States Department of Agriculture, Washington, D.C.

Gildersleeve, B. 1972. Geologic map of the Morgantown quadrangle Butler and Warren counties, Kentucky. Map GQ-1040. United States Geological Survey, Washington, D.C.

Gildersleeve, B. 1975. Geologic quadrangle maps of the United States. Geologic map of the Cromwell quadrangle, Butler and Ohio counties, Kentucky. Map GQ-1250. United States Geological Survey, Reston, VA.

Golden, M.F. and C.E. Twilley. 1976. Fisheries investigations of a channelized stream, Big Muddy Creek watershed, Kentucky. Trans. KY Acad. Sci. 37(3-4):85-90.

Goudarzi, G.H. 1968. Geologic quadrangle maps of the United States. Geologic map of the Hartford quadrangle, Ohio County, Kentucky. Map GQ-741. United States Geological Survey, Washington, D.C.

Goudarzi, G.H. 1969. Geologic quadrangle maps of the United States. Geologic map of the Equality quadrangle, western Kentucky. Map GQ-815. United States Geological Survey, Washington, D.C.

Grubb, H.F. and P.D. Ryder. 1972. Effects of coal mining on the water resources of the Tradewater River Basin, Kentucky. Geological Survey Water-Supply Paper 1940. Kentucky Geological Survey, Lexington, KY.

Hansen, D.E. 1973. Geologic map of the Dawson Springs SW quadrangle, western Kentucky. Map GQ-1061. United States Geological Survey, Washington, D.C.

Holmes, D.F., Jr., J.E. Jones, Jr. and E. VanHouse. 1981. An assessment of alternative fossil energy resources in Kentucky. Kentucky Department of Energy, Division of Technology Assessment, Frankfort, KY. 41 p.

Humphrey, M.E., R.A. Hayes, and P.M. Love. 1966. Soil survey of Caldwell County, Kentucky. Soil Conservation Service, United States Department of Agriculture, Washington, D.C.

Jones, J.E., Jr. and H.G. Enoch. 1981. The Kentucky synfuel industry: a basis for assessment and planning. Kentucky Department of Energy, Frankfort, KY. 89 p.

KDNREP. 1981. The effects of coal mining activities on the water quality of streams in the western and eastern coalfields of Kentucky. Kentucky Dept. for Natural Resources and Environmental Protection, Division of Water, Frankfort, KY. 484p.

Kehn, T.M. 1963. Geology of the Madisonville East quadrangle, Kentucky. Map GQ-252. United States Geological Survey, Washington, D.C.

Kehn, T.M. 1964. Geology of the Madisonville West quadrangle, Kentucky. Map GQ-346. United States Geological Survey, Washington, D.C.

Kehn, T.M. 1966a. Geologic quadrangle maps of the United States. Geologic map of the Dawson Springs quadrangle, western Kentucky. Map GQ-573. United States Geological Survey, Washington, D.C.

Kehn, T.M. 1966b. Geologic quadrangle maps of the United States. Geologic map of the Providence quadrangle, western Kentucky. Map GQ-491. United States Geological Survey, Washington, D.C.

Kehn, T.M. 1968. Geologic quadrangle maps of the United States. Geologic map of the Graham quadrangle, western Kentucky. Map GQ-765. United States Geological Survey, Washington, D.C.

Kehn, T.M. 1971. Geologic map of the Greenville quadrangle, Muhlenberg County, Kentucky. Map GQ-907. United States Geological Survey, Washington, D.C.

Kehn, T.M. 1974. Geologic map of Paradise quadrangle, Muhlenberg and Ohio counties, Kentucky. Map GQ-1173, United States Geological Survey, Reston, VA.

Kehn, T.M. 1977a. Geologic map of the Crofton quadrangle, Christian and Hopkins counties, Kentucky. Map GQ-1361. United States Geological Survey, Reston, VA.

Kehn, T.M. 1977b. Geologic map of the Kirksmansville quadrangle, Muhlenberg and Todd counties, Kentucky. Map GQ-1421. United States Geological Survey, Reston, VA.

Kehn, T.M. 1978. Geologic map of the Rosewood quadrangle, western Kentucky. Map GQ-1445. United States Geological Survey, Reston, VA.

Kentucky Department of Mines and Minerals. 1981. Annual report. Lexington, KY.

KNPC. 1980. Western Kentucky coal field: preliminary investigations of natural features and cultural resources. D.F. Harker, R.R. Hannan, M.L. Warren, L.R. Phillippe, K.E. Camburn, R.S. Caldwell, S.M. Call, G.J. Fallo and D. Van Norman (authors), Kentucky Nature Preserves Commission. Frankfort, KY. 584p.

KNPC. 1981. Aquatic biota and water quality survey of the Western Kentucky Coal Field. D.F. Harker, M.L. Warren, K.E. Camburn and R.R. Cicerello (authors) Kentucky Nature Preserves Commission, Frankfort, KY. 896p.

KNPC. 1982. Natural heritage program (computer printout). Kentucky Nature Preserves Commission, Frankfort, KY.

Laflin, B.D. 1980. Inventory and classification of streams in the Rough River and Nolin River drainages. Fisheries Bulletin No. 65, Kentucky Department of Fish and Wildlife Resources, Frankfort, KY.

Lebus, M.M. 1981. The synthetic fuels industry in Kentucky: an assessment of socioeconomic issues. Kentucky Dept. of Energy, Frankfort, KY. 55 p.

Leuthart, C.A. 1975. Reclamation of orphan strip mined land in southern Illinois and western Kentucky. Doctoral Dissertation, University of Louisville, Louisville, KY.

McLemore, W.N. and J. Young. 1976. Annual performance report for western fishery district investigation. D-J Project Report No. F-41-3. Kentucky Dept. of Fish and Wildlife Resources, Fisheries Division, Frankfort, KY.

Metcalf and Eddy, Inc. 1975. The river basin water quality management plan for Kentucky, Vol. 8, Ohio River. Metcalf and Eddy, Inc., Boston, MA.

Mitsch, W.J., R.W. Bosserman, P.L. Hill and J.R. Taylor. 1982. Classification and management of wetlands in the Western Kentucky Coal Field. Research Report No. 131. Water Resources Research Institute, Lexington, KY. 78 p.

Moore, S.L. 1974. Geologic map of the South Hill quadrangle, Butler and Ohio counties, Kentucky. Map GQ-1180. United States Geological Survey, Reston, VA.

Neichter, P.L. 1972. Water quality survey of the Weirs Creek levee system, Kentucky. Master's Thesis. University of Louisville, Louisville, KY. 66 p.

Nelson, W.H. 1964. Geology of the Pleasant Green Hill quadrangle, Kentucky. Map GQ-321. United States Geological Survey, Washington, D.C.

Odum, E.P. 1979. The value of wetlands: a hierarchical approach. Pages 16-25 in P.E. Greeson, J.R. Clark, and J.E. Clark, eds. Wetland functions and values: the state of our understanding. American Water Resources Association, Minneapolis, MN.

Palmer, J.E. 1966. Geologic quadrangle maps of the United States. Geologic map of the Dalton quadrangle, western Kentucky. Map GQ-490. United States Geological Survey, Washington, D.C.

Palmer, J.E. 1967. Geologic map of the Saint Charles quadrangle, Hopkins and Christian counties, Kentucky. Map GQ-674. United States Geological Survey, Washington, D.C.

Palmer, J.E. 1968. Geologic map of the Nortonville quadrangle, Hopkins and Christian counties, Kentucky. Map GQ-762. United States Geological Survey, Washington D.C.

Palmer, J.E. 1969. Geologic quadrangle maps of the United States. Geologic map of the Central City West quadrangle, Muhlenberg and Ohio counties, Kentucky. Map GQ-831. United States Geological Survey, Washington, D.C.

Palmer, J.E. 1972. Geologic quadrangle maps of the United States. Geologic map of the Central City East quadrangle, Muhlenberg and Ohio counties, Kentucky. Map GQ-1031. United States Geological Survey, Washington, D.C.

Quarterman, E., and R.L. Powell. 1978. Potential ecological/geological natural landmarks on the Interior Low Plateaus. United States Department of the Interior, Washington, D.C.

Retzer, M.E. 1980. Fishes of the lower Green River drainage, Kentucky. Thesis. Southern Illinois University at Carbondale, Carbondale, IL.

Rogers, W.B., and R.D. Trace. 1976. Geologic quadrangle maps of the United States. Geologic map of the Crider quadrangle, Caldwell County, Kentucky. Map GQ-1283. United States Geological Survey, Reston, VA.

Roy F. Weston, Incorporated. 1975. Kentucky River Basin Water Quality Management Plan. Volume III. Green River Basin. KY Dept. for Natural Resources and Environmental Protection, Division of Water, Frankfort, KY.

Sehlinger, B. and W.C. Underwood. 1980. A fishing guide to the streams of Kentucky. Thomas Press, Ann Arbor, MI. 378 p.

Shaw, S.P. and C.G. Fredine. 1956. Wetlands of the United States: their extent and their value to waterfowl and other wildlife. U.S. Fish and Wildlife Service. Circular 39. Washington, D.C. 67 p.

Shawler, M.E. 1974. Neutralization of acidic run-off from surface mines in western Kentucky. Master's Thesis. University of Louisville, Louisville, KY.

Smith, G.E. and R.A. Brant. 1978. Western Kentucky coal resources. Institute for Mining and Minerals Research, Lexington, KY.

USGS. 1980. Water resources data for Kentucky, 1979. Water-data report KY-79-1. United States Geological Survey. Louisville, KY.

USGS. 1981. Water resources data for Kentucky, 1980. Water-data report KY-80-1. United States Geological Survey. Louisville, KY.

Warren, M.L., Jr. and R.R. Cicerello. 1982. New records, distribution, and status of ten rare fishes in the Tradewater and Lower Green Rivers, Kentucky. Proceedings of the Southeastern Fishes Council, Vol. 3, No. 4.

Wharton, C.H., W.M. Kitchens, E.C. Pendleton, and T.W. Sipe. 1982. The ecology of bottomland hardwood swamps of the Southeast: a community profile. U.S. Fish and Wildlife Service, FWS/OBS-81/37, Washington, D.C. 133 p.

APPENDIX A

Table A-1. Area of wetlands in study region quadrangles.

Quadrangle	Area of Wetland, km²								
	Persistent Emergent	Broad-leaved Deciduous Forested[a] SSPF	Broad-leaved Deciduous Forested[a] TF	Needle-leaved Deciduous Forested	Dead Forested	Shrub-Scrub	Limnetic Impoundment	Aquatic Bed	Total
Providence	--	0.65	19.08	--	--	--	0.54	--	20.27
Dalton	1.40	13.86	10.09	--	0.48	2.40	0.43	0.17	28.83
Olney	--	2.80	3.63	--	--	--	0.24	--	6.67
Nebo	0.13	1.46	5.14	--	--	--	1.36	--	8.09
Coiltown	1.78	14.93	3.51	--	--	3.35	1.32	3.01	27.90
Dawson Springs	0.54	4.38	7.81	--	--	0.10	2.15	--	14.98
Slaughtersville	--	--	2.31	--	--	--	0.53	--	2.84
Madisonville West	0.65	5.64	3.88	--	0.47	0.29	4.08	--	15.01
St. Charles	0.33	1.86	1.87	--	0.43	--	1.13	--	5.62
Hanson	--	--	13.41	--	--	--	--	--	13.41
Madisonville East	2.27	10.00	12.47	--	0.29	0.04	2.39	--	27.46
Nortonville	0.70	5.40	13.89	--	--	--	0.96	--	20.95
Sacramento	0.03	0.05	20.49	--	--	--	0.11	--	20.68
Millport	0.21	2.03	14.05	--	--	--	4.43	--	20.72
Graham	0.01	6.56	22.64	--	0.03	--	0.43	--	29.67
Livermore	0.32	1.82	15.21	1.05	--	--	0.53	--	18.93
Central City West	3.76	4.14	5.35	4.58	--	--	2.22	--	20.05
Greenville	0.03	0.19	1.41	--	--	--	0.45	--	2.08
Equality	0.43	0.13	22.08	--	--	0.04	1.30	--	23.98
Central City East	0.56	0.98	17.71	--	--	--	5.30	--	24.55
Drakesboro	1.99	11.20	5.47	--	--	0.13	1.73	0.02	20.54
Hartford	0.55	2.89	12.37	--	--	--	0.54	--	16.35
Paradise	--	2.25	10.41	--	--	--	5.43	--	18.09
Rochester	--	3.15	13.58	--	--	--	1.34	--	18.07
Horton	--	0.11	3.93	--	--	--	0.36	--	4.40
Cromwell	0.04	0.74	11.28	--	--	--	0.41	--	12.47
South Hill	0.45	4.86	10.52	--	--	0.02	0.29	--	16.14
Total	16.18	102.08	283.59	5.63	1.70	6.37	40.00	3.20	458.75

[a]Explanation of subheadings:

SSPF = Seasonally or Semi-Permanently Flooded
TF = Temporarily Flooded

APPENDIX B

Table B-1. A list of vegetation of the study region and wetland types from which they were reported.[a]

Species	Wetland Type[b]	Status[c]
Acalypha rhomboidea (three-seeded mercury)	3,5	
Acer negundo (box elder)	3	
A. rubrum (red maple)	2,3,4,5	
A. saccharinum (silver maple)	2,3	
A. saccharum (sugar maple)	3	
Alisma plantago-aquatica (water-plantain)	2,5,6	
Ammania coccinea (long-leaved ammania)	3	
Arisaema dracontium (green dragon)	2	
Arundinaria gigantea (giant cane)	2,3	
Asclepias incarnata (swamp-milkweed)	2	
A. perennis (milkweed)	5	
Asimina triloba (pawpaw)	3	
Athyrium filix-femina (lady fern)	2,3	
Betula nigra (river birch)	2,3,4,5	
Boehmeria cylindrica (bog-hemp)	2,3,5	
Boltonia asteroides (boltonia)	5	
Botrychium dissectum (grape fern)	2,3	
Campsis radicans (trumpet creeper)	2,3	
Carex glausescens (sedge)	5	
C. grayii (sedge)	5	
Carpinus caroliniana (American hornbeam)	2,3	
Carya cordiformis (bitternut hickory)	3	
C. laciniosa (shellbark hickory)	2,3	
C. ovata (shagbark hickory)	2,3	
C. tomentosa (mockernut hickory)	3	
Cassia fasciculata (partridge-pea)	2,3	
Catalpa speciosa (catalpa tree)	2,3	
Celtis occidentalis (hackberry)	2,3	
Cephalanthus occidentalis (buttonbush)	2,3,4,5	
Ceratophyllum demersum (hornwort)	5,6	
Chasmanthium latifolium (sea oats)	2,5	
Chelone obliqua var. speciosa (pink turtlehead)	2,3	T(CL)
Cicuta maculata (spotted cowbane)	5	
Cinna arundinacea (wood reedgrass)	2,5	
Commelina diffusa (dayflower)	2,3,5	
C. virginica (dayflower)	2,3,5	
Cornus florida (flowering dogwood)	3	
Crataegus viridis (hawthorn)	2,3	
Cynanchum laeve (blue vine)	5	
Cyperus erythrorhizos (sedge)	2,3,5	
C. esculentus (yellow nut-grass)	3,5	
C. flavescens (sedge)	3,5	
C. strigosus (sedge)	3,5	
Decodon verticillatus (swamp loosestrife)	2,4	S
Deparia acrostichoides (silvery spleenwort)	2,3	
Didiplis diandra (water purslane)	2,5,6	T
Diodia virginiana (buttonweed)	3,5	
Diospyros virginiana (common persimmon)	3	
Dulichium arundinaceum (three-way sedge)	6	
Echinochloa crusgallii (barnyard grass)	1,3	

[a]Reported from this study, KNPC (1980), and KNPC (1981).
[b]Wetland types are:
1 Persistent emergent
2 Broad-leaved deciduous, seasonally or semi-permanently flooded
3 Broad-leaved deciduous, temporarily flooded
4 Needle-leaved deciduous
5 Shrub-scrub
6 Aquatic bed or non-persistent emergent
[c]from Branson et al. (1981).

Table B-1 Cont. A list of vegetation of the study region and wetland types from which they were reported.[a]

Species	Wetland Type[b]	Status[c]	Species	Wetland Type[b]	Status[c]
Echinochloa muricata (barnyard grass)	3		Juglans cinerea (butternut)	3	
Eclipta prostrata (yerba-de-tajo)	3		J. nigra (black walnut)	3	
Eleocharis acicularis (spike rush)	2,5,6		Juncus brachycarpus (rush)	1,5	
E. obtusa (spike rush)	2,5,6		J. effusus (rush)	1,5	
E. quadrangulata (spike rush)	5,6		J. validus (rush)	1,5	
Eupatorium coelestinum (mistflower)	2,3		Laportea canadensis (wood nettle)	3	
E. serotinum (boneset)	3		Leersia oryzoides (rice-cutgrass)	2,3	
Fagus grandifolia (beech)	3		L. virginica (cutgrass)	5	
Forestiera acuminata (swamp privet)	2,3,5		Limnobium spongia (frog's bit)	2,5,6	T
Fraxinus pennsylvanica (green ash)	2,3,5		Lindera benzoin (spicebush)	2,3	
F. profunda (pumpkin ash)	2,4		Lindernia dubia (false pimpernel)	3	
Galium tinctorium (bedstraw)	3,5		Linum medium (wild flax)	5	
Geum virginianum (avens)	3,5		Liquidambar styraciflua (sweetgum)	2,3,5	
Gleditsia triacanthos (honey locust)	3		Liriodendron tulipifera (tulip tree)	3	
Glyceria striata (fowl-meadow grass)	5		Lobelia cardinalis (cardinal flower)	3,5	
Helianthus microcephalus (small wood-sunflower)	5		L. inflata (Indian tobacco)	3,5	
Heliotropium indicum (turn-sole)	3,5		Ludwigia palustris (marsh purslane)	5,6	
Hibiscus laevis (mallow)	2,5		Lycopus virginicus (bugle weed)	3,5	
Hydrangea arborescens (wild hydrangea)	3		Mikania scandens (climbing hempweed)	3,5	
Hymenocallus caroliniana (spider-lily)	5		Mimulus alatus (winged monkey-flower)	3,5	
Hypericum hypericoides (St. John's-wort)	5		Morus rubra (mulberry)	3	
H. mutilum (St. John's-wort)	5		Nuphar advena (spatterdock)	1,2,4,5,6	
Ilex decidua (swamp holly)	3,5		Nyssa sylvatica (black gum)	3	
Impatiens capensis (spotted touch-me-not)	3,5		Onoclea sensibilis (sensitive fern)	2,3,5	
Itea virginica (Virginia-willow)	2,4		Ophioglossum vulgatum (adder's tongue)	2,3	

[a]Reported from this study, KNPC (1980), and KNPC (1981).
[b]Wetland types are:
1 Persistent emergent
2 Broad-leaved deciduous, seasonally or semi-permanently flooded
3 Broad-leaved deciduous, temporarily flooded
4 Needle-leaved deciduous
5 Shrub-scrub
6 Aquatic bed or non-persistent emergent

[c]from Branson et al. (1981)

Table B-1 Cont. A list of vegetation of the study region and wetland types from which they were reported.[a]

Species	Wetland Type[b]	Status[c]	Species	Wetland Type[b]	Status[c]
Osmunda cinnamomea (cinnamon fern)	2,3		Q. michauxii (swamp chestnut oak)	2,3	
Oxalis stricta (yellow wood sorrel)	3		Q. palustris (pin oak)	2,3	
Panicum rigidulum (munro grass)	5		Q. phellos (willow oak)	2,3	
Parthenocissus quinquefolia (Virginia creeper)	2,3		Q. shumardii (Shumard's red oak)	2	
Paspalum fluitans (swamp bead grass)	2,3		Q. stellata (post oak)	3	
P. laeve (bead grass)	3,5		Rhexia mariana (meadow beauty)	5	
Passiflora lutea (small passion-flower)	5		R. virginica (meadow beauty)	5	
Penthorum sedoides (ditch stonecrop)	3,5		Rhus copallina (dwarf sumac)	3	
Phragmites communis (giant reed)	1		Rhynchospora corniculata (beaked rush)	1,6	
Phyla lanceolata (fog-fruit)	3,5		Rotala ramosior (tooth-cup)	3	
Phytolacca americana (pokeweed)	5		Salix nigra (black willow)	2,3,5	
Platanthera flava (tubercled orchid)	2		Sassafras albidum (sassafras)	3	
Platanus occidentalis (sycamore)	2,3		Saururus cernuus (lizard tail)	2,6	
Pluchea camphorata (camphorweed)	2,3		Scirpus cyperinus (bulrush)	5	
Polygonum amphibium (water smartweed)	2,3,4		S. tabenaemontanii (bulrush)	5	
P. pennsylvanicum (common smartweed)	2,3,4		Sida spinosa (prickly sida)	5	
Populus deltoides (eastern cottonwood)	2,3		Sparganium androcladum (bur-reed)	1,2,4,5	
P. heterophylla (swamp cottonwood)	2		Spermacoce glabra (smooth buttonweed)	5	
Portulaca oleracea (purslane)	5		Styrax americana (American snowbell)	2,3	
Prunella vulgaris (self-heal)	3		Symphoricarpos orbiculatus (coralberry)	3	
Quercus alba (white oak)	3		Taxodium distichum (bald cypress)	2,4	
Q. bicolor (swamp white oak)	2,3		Thelypteris noveboracensis (New York fern)	2,3	
Q. falcata var. pagodaefolia (spanish oak)	3		Toxicodendron radicans (poison ivy)	3	
Q. lyrata (overcup oak)	2,3		Trachelospermum difforme (climbing dogbane)	2	
Q. macrocarpa (bur oak)	2,3		Triadenium tubulosum (marsh-St. John's-wort)	2	

[a]Reported from this study, KNPC (1980), and KNPC (1981).
[b]Wetland types are: 1 Persistent emergent
2 Broad-leaved deciduous, seasonally or semi-permanently flooded
3 Broad-leaved deciduous, temporarily flooded
4 Needle-leaved deciduous
5 Shrub-scrub
6 Aquatic bed or non-persistent emergent
[c]from Branson et al. (1981)

Table B-1 Cont. A list of vegetation of the study region and wetland types from which they were reported.[a]

Species	Wetland Type[b]	Status[c]	Species	Wetland Type[b]	Status[c]
Typha latifolia (common cattail)	1,5		*Vernonia gigantea* (tall ironweed)	2,3	
Ulmus alata (winged elm)	3		*Vitis palmata* (catbird grape)	2,3	
U. americana (American elm)	2,3		*Woodwardia areolata* (netted chain-fern)	2,3,5	
U. rubra (slippery elm)	2,3		*Xanthium strumarium* (common cocklebur)	5	
Utricularia gibba (humped bladderwort)	2,4	S	*Zizaniopsis miliacea* (southern wild rice)	2,3,4	T

[a]Reported from this study, KNPC (1980), and KNPC (1981).
[b]Wetland types are:
1 Persistent emergent
2 Broad-leaved deciduous, seasonally or semi-permanently flooded
3 Broad-leaved deciduous, temporarily flooded
4 Needle-leaved deciduous
5 Shrub-scrub
6 Aquatic bed or non-persistent emergent
[c]from Branson et al. (1981)

Table C-1. List of fish and wildlife reported in wetlands and deepwater habitats in study region at Western Kentucky Coal Field[a]

	Status[b]	Providence	Dalton	Olney	Nebo	Coiltown	Dawson Springs	Slaughtersville	Madisonville West	St. Charles	Hanson	Madisonville East	Nortonville	Sacramento	Hillport	Graham	Livermore	Central City West	Greenville	Equality	Central City East	Drakesboro	Hartford	Paradise	Rochester	Horton	Cromwell	South Hill
AMPHIBIANS																												
Acris crepitans (northern cricket frog)		X																X										
Ambystoma talpoideum (mole salamander)	S						X																					
A. texanum (small-mouth salamander)							X																					
Bufo americanus (american toad)		X		X			X																					
B. woodhousei fowleri (Fowler's toad)																		X										
Hyla avivoca (bird-voiced frog)	S						X																					
Hyla chrysocelis complex (gray treefrog)							X											X										
Pseudacris triseriata (striped chorus frog)																		X										
Rana catesbeiana (bullfrog)		X																										
Rana clamitans (green frog)							X																					
R. sphenocephalus (southern leopard frog)																		X										
BIRDS																												
Aix sponsa (wood duck)																		X										
Anas carolinensis (green-winged teal)																		X										
A. platyrhynchos (mallard)																		X										
A. rubripes (black duck)																		X										
Ardea herodias (great blue heron)	U																	X										
Botaurus lentiginosus (American bittern)	E								X																			
Buteo lineatus (red-shouldered hawk)	U																	X										
Butorides striatus (green-backed heron)			X				X														X							

[a]From KNPC (1980, 1981, 1982) and Branson et al. (1981).
[b]Status according to Branson et al. (1981)
E - Endangered
T - Threatened
S - Special Concern
U - Undetermined

Table C-1 Cont. List of fish and wildlife reported in wetlands and deepwater habitats in study region at Western Kentucky Coal Field[a]

	Status[b]	Providence	Dalton	Olney	Nebo	Coiltown	Dawson Springs	Slaughtersville	Madisonville West	St. Charles	Hanson	Madisonville East	Nortonville	Sacramento	Millport	Graham	Livermore	Central City West	Greenville	Equality	Central City East	Drakesboro	Hartford	Paradise	Rochester	Horton	Cromwell	South Hill
BIRDS (Cont.)																												
Circus cyaneus (marsh hawk)	U																	X										
Ixobrychus exilis (least bittern)	E								X																			
Podilymbus podiceps (pied-billed grebe)	T								X																			
FISH																												
Amia calva (bowfin)						X												X										
Ammocrypta pellucida (eastern sand darter)	T																				X		X	X				X
Aphredoderus sayanus (pirate perch)			X	X		X	X									X		X					X	X	X			X
Aplodinotus grunniens (freshwater drum)																		X		X			X					
Campostoma anomalum (central stoneroller)																				X			X		X			
Catostomus commersoni (white sucker)				X			X																X					
Centrarchus macropterus (flier)			X	X		X	X					X						X			X		X		X			
Cottus carolinae (banded sculpin)																												X
Cyprinus carpio (common carp)						X												X		X								
Dorosoma cepedianum (gizzard shad)			X			X	X													X			X					X
Elassoma zonatum (banded pygmy sunfish)	S					X										X		X										
Erimyzon oblongus (creek chubsucker)			X	X			X									X							X					
E. sucetta (lake chubsucker)	U		X			X												X					X					
Esox americanus (redfin pickerel)				X		X	X											X										
E. americanus vermiculatus (grass pickerel)			X	X		X	X									X		X			X		X		X			

[a]from KNPC (1980, 1981, 1982) and Branson et al. (1981).
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Table C-1 Cont. List of fish and wildlife reported in wetlands and deepwater habitats in study region at Western Kentucky Coal Field[a]

	Status[b]	Providence	Dalton	Olney	Nebo	Wiltown	Dawson Springs	Slaughtersville	Madisonville West	St. Charles	Hanson	Madisonville E	Nortonville	Sacramento	Millport	Graham	Livermore	Central City West	Greenville	Equality	Central City East	Drakesboro	Hartford	Paradise	Rochester	Rockport	Cromwell	South Hill
FISH (Cont.)																												
Etheostoma asprigene (mud darter)				X														X					X		X			X
E. chlorosomum (bluntnose darter)						X	X									X												
E. flabellare (fantail darter)																X									X			
E. gracile (slough darter)				X		X										X		X			X		X					X
E. histrio (harlequin darter)	T																			X			X					
E. kennicotti (stripetail darter)				X			X									X												X
E. nigrum (johnny darter)				X												X									X			X
E. spectabile (orangethroat darter)																X												
E. squamiceps (spottail darter)				X												X							X		X			X
Fundulus notatus (blackstripe topminnow)																X		X					X		X			X
F. olivaceus (blackspotted topminnow)			X	X		X	X													X								
Gambusia affinis (mosquitofish)			X	X		X										X		X		X	X		X		X			X
Hiodon tergisus (mooneye)																				X								
Hybognathus hayi (cypress minnow)	T															X												
H. nuchalis (silvery minnow)																								X				
Ichthyomyzon unicuspis (silver lamprey)	S																								X			
Ictalurus melas (black bullhead)			X			X	X									X		X			X							
I. natalis (yellow bullhead)			X	X		X	X									X		X					X					
I. punctatus (channel catfish)				X																X								X
Labidesthes sicculus (brook silversides)																X		X		X			X					X

[a]from KNPC (1980, 1981, 1982) and Branson et al. (1981).

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Table C-1 Cont. List of fish and wildlife reported in wetlands and deepwater habitats in study region at Western Kentucky Coal Field[a]

	Status[b]	Providence	Dalton	Olney	Nebo	Coiltown	Dawson Springs	Slaughtersville	Madisonville West	St. Charles	Hanson	Madisonville East	Nortonville	Sacramento	Millport	Graham	Livermore	Central City West	Greenville	Equality	Central City East	Drakesboro	Hartford	Paradise	Rochester	Horton	Cromwell	South Hill
FISH (Cont.)																												
Lepisosteus oculatus (spotted gar)						X																			X			
Lepomis cyanellus (green sunfish)			X	X		X	X									X		X			X		X		X			X
L. gulosus (warmouth)			X	X		X	X									X		X			X		X		X			X
L. macrochirus (bluegill)			X	X		X	X					X				X		X		X	X		X		X			X
L. megalotis (longear sunfish)				X			X									X		X		X	X		X		X			X
L. microlophus (redear sunfish)			X									X				X				X								
L. punctatus (spotted sunfish)	S															X												
Micropterus punctulatus (spotted bass)																X				X					X			X
M. salmoides (largemouth bass)			X	X		X	X					X				X		X		X	X		X		X			X
Minytrema melanops (spotted sucker)							X																X		X			X
Moxostoma erythrurum (golden redhorse)				X																			X		X			X
Notemigonus crysoleucas (golden shiner)			X	X		X	X									X							X		X			
Notropis atherinoides (emerald shiner)																				X								X
N. buchanani (ghost shiner)																				X								
N. chrysocephalus (striped shiner)				X																X			X		X			X
N. emiliae (pugnose minnow)							X									X				X					X			X
N. fumeus (ribbon shiner)				X			X									X		X					X		X			X
N. spilopterus (spotfin shiner)																				X			X					X
N. umbratilis (redfin shiner)				X												X							X		X			X
N. whipplei (steelcolor shiner)																X				X					X			X

[a]from KNPC (1980, 1981, 1982) and Branson et al. (1981).
[b]Status according to Branson et al. (1981)
E - Endangered
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Table C-1 Cont. List of fish and wildlife reported in wetlands and deepwater habitats in study region at Western Kentucky Coal Field[a]

	Status[b]	Providence	Dalton	Olney	Nebo	Coiltown	Dawson Springs	Slaughtersville	Madisonville West	St. Charles	Hanson	Madisonville East	Nortonville	Sacramento	Millport	Graham	Livermore	Central City West	Greenville	Equality	Central City East	Drakesboro	Hartford	Paradise	Rochester	Horton	Cromwell	South Hill
FISH (Cont.)																												
Noturus gyrinus (tadpole madtom)				X			X									X									X			X
N. nocturnus (freckled madtom)																				X								X
Percina caprodes (longperch)																				X								X
Percina copelandi (channel darter)	S																						X					
P. maculata (blackside darter)				X			X									X		X		X			X		X			X
P. ouachitae (yellow darter)	U																						X					
P. phoxocephala (slenderhead darter)	S						X										X	X		X			X	X				
P. sciera (dusky darter)				X												X				X					X			X
P. shumardi (river darter)	T																			X			X					
Phenacobius mirabilis (suckermouth minnow)																							X					
Pimephales notatus (bluntnose minnow)				X			X									X		X		X			X		X			X
P. vigilax (bullhead minnow)																X				X								X
Polyodon spathula (paddlefish)	S																						X					
Pomoxis annularis (white crappie)						X	X									X				X			X		X			
P. nigromaculatus (black crappie)			X			X												X										
Pylodictis olivaris (flathead catfish)																												
Semotilus atromaculatus (creek chub)				X			X																					
MAMMALS																												
Blarina brevicauda (short-tailed shrew)				X			X																					
Castor canadensis (beaver)																		X										

[a]From KNPC (1980, 1981, 1982) and Branson et al. (1981).
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Table C-1 Cont. List of fish and wildlife reported in wetlands and deepwater habitats in study region at Western Kentucky Coal Field[a]

	Status[b]	Providence	Dalton	Olney	Nebo	Coiltown	Dawson Springs	Slaughtersville	Madisonville West	St. Charles	Hanson	Madisonville East	Mortonville	Sacramento	Millport	Graham	Livermore	Central City West	Greenville	Equality	Central City East	Drakesboro	Hartford	Paradise	Rochester	Horton	Cromwell	South Hill
MAMMALS (Cont.)																												
Cryptotis parva (least shrew)		X																										
Lutra canadensis (river otter)																X												
Microtus ochrogaster (prairie vole)																		X										
Mus musculus (house mouse)				X														X										
Odocoileus virginianus (white-tailed deer)																		X										
Ondatra zibethicus (muskrat)																		X										
Peromyscus leucopus (white-footed mouse)		X		X			X											X										
P. maniculatus bairdii (deer mouse)																		X										
Procyon lotor (raccoon)																		X										
Reithrodontomys humulis (harvest mouse)																		X										
Sylvilagus aquaticus (swamp rabbit)	T																	X										
Zapus hudsonius (meadow jumping mouse)	U						X							X									X					
MUSSELS (CLAMS)																												
Anodonta grandis (floater)						X																						
Anodonta imbecillis (paper pond shell)			X			X																						
Corbicula leana (Asiatic clam)																												X
Epioblasma sampsoni (Sampson's pearly mussel)	E																X											
Ligumia subrostrata (pond mussel)						X																						
REPTILES																												
Nerodia erythrogaster neglecta (copper-belly water snake)							X																					
Sternotherus odoratus (stinkpot)		X																										

[a]From KNPC (1980, 1981, 1982) and Branson et al. (1981).
[b]Status according to Branson et al. (1981)
E - Endangered
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APPENDIX D

Table D-1. Water quality data from study region.

Parameter	Providence				Dalton		
	Site 2 Craborchard Creek		Site 4 Caney Fork near Clay		Site 1 Brooks Creek	Site 2 Land Branch	Site 4 Lick Creek
Date	03/27/80	12/08/81	03/27/80	05/08/80	06/18/80	08/22/80	03/26/80
Time	0955	---	1130	0935	---	---	1535
Streamflow, Instantaneous, cfs	28	---	18	0.8	---	---	51
Specific Conductance, micromhos/cm	260	2120	193	360	3747	308	420
pH	7.5	7.0	7.2	7.5	3.0	7.5	4.1
Temperature, °C	9.0	---	12.0	16.0	24.5	23	9.0
Hardness, mg/l as $CaCO_3$	---	1060	---	---	---	100	---
Hardness, Noncarbonate, mg/l $CaCO_3$	---	---	---	---	---	---	---
Acidity, Total, mg/l	---	45	---	---	199	---	0.3
Calcium, Dissolved, mg/l as Ca	---	238	---	---	---	---	---
Magnesium, Dissolved, mg/l as Mg	---	91	---	---	---	---	---
Sodium, Dissolved, mg/l as Na	---	115	---	---	---	---	---
Potassium, Dissolved, mg/l as K	---	7.25	---	---	---	---	---
Alkalinity, mg/l as $CaCO_3$	44	94	26	78	0	172	---
Sulfate, Dissolved, mg/l as SO_4	58	1126	39	85	2045	0	250
Chloride, Dissolved, mg/l as Cl	---	22.4	---	---	---	0	---
Fluoride, Dissolved, mg/l as F	---	0.33	---	---	---	---	---
Solids, Residue at 180° C, Dissolved, mg/l	202	1786	129	232	---	---	324
Nitrogen, NO_2+NO_3, mg/l as N	---	.415	---	---	---	---	---
Phosphorus, Total, mg/l as P	---	.027	---	---	---	---	---
Arsenic, Total, ug/l as As	---	2.0	---	---	---	---	---
Barium, Total Recoverable, ug/l as Ba	---	58.0	---	---	---	---	---
Cadmium, Total Recoverable, ug/l as Cd	---	2	---	---	---	---	---
Chromium, Total Recoverable, ug/l as Cr	---	4	---	---	---	---	---
Copper, Total Recoverable, ug/l as Cu	---	7	---	---	---	---	---
Cyanide, Total, mg/l as Cn	---	---	---	---	---	---	---
Iron, Total Recoverable, mg/l as Fe	1.50	3.78	0.90	0.28	14.6	---	0.54
Iron, Dissolved, mg/l as Fe	0.01	2.98	0.13	0.10	---	---	0.43
Lead, Total Recoverable, ug/l as Pb	---	34	---	---	---	---	---
Manganese, Total Recoverable, mg/l as Mn	0.15	2.46	0.13	0.09	24.5	---	2.0
Manganese, Dissolved, mg/l as Mn	0.13	2.50	0.11	---	---	---	2.0
Mercury, Total Recoverable, ug/l as Hg	---	0.4	---	---	---	---	---
Silver, Total Recoverable, ug/l as Ag	---	3	---	---	---	---	---
Zinc, Total Recoverable, ug/l as Zn	---	26	---	---	---	---	---
Silica, Dissolved, mg/l as SiO_2	---	---	---	---	---	1	---
Selenium, Total, ug/l as Se	---	1.0	---	---	---	---	---
Selenium, Dissolved, ug/l as Se	---	1.0	---	---	---	---	---
Sediment, Suspended, mg/l	37	24	14	5	---	200	10
Dissolved Oxygen, mg/l	---	---	---	---	5.6	3.0	---
CO_2, mg/l	---	---	---	---	---	17.5	---
Turbidity, NTU	---	22	---	---	---	100	---
Aluminum, mg/l as Al	---	0.77	---	---	---	---	---
Nickel, mg/l as Ni	---	0.37	---	---	---	---	---
Data Source[a]	1	5	1	1	4	2	1

[a] 1 - USGS (1981)
2 - KNPC (1980, 1981)
3 - Present Study
4 - KDNREP (1981)
5 - KDNREP (unpublished data)

Table B-1 Cont. Water quality data from study region.

Parameter	Olney						
	Site 2 Flynn Fork		Site 1 Tradewater River at Olney				
Date	08/08/80	12/09/81	10/03/79	11/15/79	12/28/79	03/05/80	03/19/80
Time	---	---	1500	1310	1205	1205	1215
Streamflow, Instantaneous, cfs	---	---	101	115	1540	235	1170
Specific Conductance, micromhos/cm	197	285	420	450	168	335	170
pH	7.0	7.2	6.7	6.8	7.6	6.8	6.7
Temperature, °C	26	---	18.5	8.5	6.5	4.0	10.0
Hardness, mg/l as $CaCO_3$	120	131.8	---	---	---	---	---
Hardness, Noncarbonate, mg/l $CaCO_3$	---	---	---	---	---	---	---
Acidity, Total, mg/l	---	10	---	---	---	---	---
Calcium, Dissolved, mg/l as Ca	---	41	---	---	---	---	---
Magnesium, Dissolved, mg/l as Mg	---	6.3	---	---	---	---	---
Sodium, Dissolved, mg/l as Na	---	6.3	---	---	---	---	---
Potassium, Dissolved, mg/l as K	---	3.5	---	---	---	---	---
Alkalinity, mg/l as $CaCO_3$	140	102	18	22	30	30	28
Sulfate, Dissolved, mg/l as SO_4	10	41.4	150	170	57	120	44
Chloride, Dissolved, mg/l as Cl	0	8.9	---	---	---	---	---
Fluoride, Dissolved, mg/l as F	---	0.12	---	---	---	---	---
Solids, Residue at 180° C, Dissolved, mg/l	---	182	257	272	126	226	115
Nitrogen, NO_2+NO_3, mg/l as N	---	0.66	---	---	---	---	---
Phosphorus, Total, mg/l as P	---	.027	---	---	---	---	---
Arsenic, Total, ug/l as As	---	1.0	---	---	---	---	---
Barium, Total Recoverable, ug/l as Ba	---	40.0	---	---	---	---	---
Cadmium, Total Recoverable, ug/l as Cd	---	<1	---	---	---	---	---
Chromium, Total Recoverable, ug/l as Cr	---	<1	---	---	---	---	---
Copper, Total Recoverable, ug/l as Cu	---	2	---	---	---	---	---
Cyanide, Total, mg/l as Cn	---	<0.01	---	---	---	---	---
Iron, Total Recoverable, mg/l as Fe	---	0.66	0.8	0.4	2.4	1.1	10.0
Iron, Dissolved, mg/l as Fe	---	0.92	0.05	0.08	0.16	0.08	0.07
Lead, Total Recoverable, ug/l as Pb	---	11	---	---	---	---	---
Manganese, Total Recoverable, mg/l as Mn	---	.090	2.2	2.2	0.4	1.4	0.63
Manganese, Dissolved, mg/l as Mn	---	.092	2.2	2.2	0.36	1.4	0.38
Mercury, Total Recoverable, ug/l as Hg	---	0.3	---	---	---	---	---
Silver, Total Recoverable, ug/l as Ag	---	<1	---	---	---	---	---
Zinc, Total Recoverable, ug/l as Zn	---	8	---	---	---	---	---
Silica, Dissolved, mg/l as SiO_2	---	---	---	---	---	---	---
Selenium, Total, ug/l as Se	---	1.0	---	---	---	---	---
Selenium, Dissolved, ug/l as Se	---	1.1	---	---	---	---	---
Sediment, Suspended, mg/l	0	6	14	5	37	36	190
Dissolved Oxygen, mg/l	2.5	---	---	---	---	---	---
CO_2, mg/l	17.5	---	---	---	---	---	---
Turbidity, NTU	16	4.7	---	---	---	---	---
Aluminum, mg/l as Al	---	0.66	---	---	---	---	---
Nickel, mg/l as Ni		0.011	---	---	---	---	---
Data Source[a]	2	5	1	1	1	1	1

[a] 1 - USGS (1981)
2 - KNPC (1980, 1981)
3 - Present Study
4 - KDNREP (1981)
5 - KDNREP (unpublished data)

Table D-1 Cont. Water quality data from study region.

Parameter	Olney Site 1 Cont. Tradewater River					Coiltown Site 1 Clear Creek	
Date	05/14/80	07/09/80	08/20/80	12/08/80	12/09/81	06/19/81	06/19/81
Time	0915	1100	1200	---	---	1620	1620
Streamflow, Instantaneous, cfs	21	72	4.4	---	---	---	---
Specific Conductance, micromhos/cm	410	295	310	253	449	440	440
pH	6.9	6.4	7.0	7.0	6.8	6.2	6.2
Temperature, °C	19.0	29.0	28.0	28.0	---	---	---
Hardness, mg/l as $CaCO_3$	---	120	---	140	200	---	---
Hardness, Noncarbonate, mg/l $CaCO_3$	---	110	---	---	---	---	---
Acidity, Total, mg/l	---	0.1	---	---	11	---	---
Calcium, Dissolved, mg/l as Ca	---	27	---	---	48	---	---
Magnesium, Dissolved, mg/l as Mg	---	12	---	---	18.4	15	17
Sodium, Dissolved, mg/l as Na	---	4.7	---	---	7	12.8	13.0
Potassium, Dissolved, mg/l as K	---	2.6	---	---	5.2	4.3	4.1
Alkalinity, mg/l as $CaCO_3$	30	11	48	72	40.6	---	---
Sulfate, Dissolved, mg/l as SO_4	160	112	98	35	165	---	---
Chloride, Dissolved, mg/l as Cl	---	3.1	---	0	6.7	---	---
Fluoride, Dissolved, mg/l as F	---	0.2	---	---	0.15	---	---
Solids, Residue at 180° C, Dissolved, mg/l	309	200	229	---	294	---	---
Nitrogen, NO_2+NO_3, mg/l as N	---	0.47	---	---	.315	---	---
Phosphorus, Total, mg/l as P	---	0.04	---	---	.024	---	---
Arsenic, Total, ug/l as As	---	1	---	---	2.0	---	---
Barium, Total Recoverable, ug/l as Ba	---	<50	---	---	51.0	---	---
Cadmium, Total Recoverable, ug/l as Cd	---	2	---	---	2	---	---
Chromium, Total Recoverable, ug/l as Cr	---	<10	---	---	2	<100	<100
Copper, Total Recoverable, ug/l as Cu	---	5	---	---	2	<100	<100
Cyanide, Total, mg/l as Cn	---	0	---	---	<0.01	---	---
Iron, Total Recoverable, mg/l as Fe	0.55	1.3	0.41	---	0.306	---	---
Iron, Dissolved, mg/l as Fe	0.04	0.02	0.01	---	0.034	1.5	1.9
Lead, Total Recoverable, ug/l as Pb	---	6	---	---	8	---	---
Manganese, Total Recoverable, mg/l as Mn	1.4	2.0	0.74	---	0.804	---	---
Manganese, Dissolved, mg/l as Mn	1.4	2.0	0.47	---	0.805	0.9	1.0
Mercury, Total Recoverable, ug/l as Hg	---	0.9	---	---	0.8	---	---
Silver, Total Recoverable, ug/l as Ag	---	0	---	---	<1	---	---
Zinc, Total Recoverable, ug/l as Zn	---	60	---	---	26	0	0
Silica, Dissolved, mg/l as SiO_2	---	7.5	---	---	---	---	---
Selenium, Total, ug/l as Se	---	0	---	---	1.0	---	---
Selenium, Dissolved, ug/l as Se	---	---	---	---	1.0	---	---
Sediment, Suspended, mg/l	---	32	7	100	3	---	---
Dissolved Oxygen, mg/l	---	---	---	4.7	---	3.4	3.4
CO_2, mg/l	---	---	---	10	---	---	---
Turbidity, NTU	---	---	---	7.0	2.9	4.7	4.8
Aluminum, mg/l as Al	---	---	---	---	0.280	0.9	0.9
Nickel, mg/l as Ni	---	---	---	---	0.022	<0.1	<0.1
Data Source[a]	1	1	1	2	5	3	3

[a] 1 - USGS (1981)
2 - KNPC (1980, 1981)
3 - Present Study
4 - KDNREP (1981)
5 - KDNREP (unpublished data)

Table D-1 Cont. Water quality data from study region.

Parameter	Colltown Site I Cont. Clear Creek						
Date	07/24/81	07/24/81	09/19/81	09/19/81	10/10/81	10/10/81	12/09/81
Time	1300	1300	1750	1750	1200	1200	---
Streamflow, Instantaneous, cfs	---	---	---	---	---	---	---
Specific Conductance, micromhos/cm	1100	1100	1400	1400	1600	1600	1930
pH	4.5	4.5	6.2	6.2	6.1	5.9	3.8
Temperature, °C	---	---	---	---	---	---	---
Hardness, mg/l as $CaCO_3$	---	---	---	---	---	---	874
Hardness, Noncarbonate, mg/l $CaCO_3$	---	---	---	---	---	---	---
Acidity, Total, mg/l	---	---	---	---	---	---	84
Calcium, Dissolved, mg/l as Ca	---	---	---	---	---	---	215
Magnesium, Dissolved, mg/l as Mg	72	77	129	130	118	119	19
Sodium, Dissolved, mg/l as Na	35.5	36.3	41.4	42.6	65.6	66.7	49
Potassium, Dissolved, mg/l as K	2.8	3.4	5.2	5.1	5.8	5.9	6.0
Alkalinity, mg/l as $CaCO_3$	---	---	---	---	---	---	0
Sulfate, Dissolved, mg/l as SO_4	569	569	612	612	818	880	1049
Chloride, Dissolved, mg/l as Cl	---	---	---	---	---	---	15
Fluoride, Dissolved, mg/l as F	---	---	---	---	---	---	0.37
Solids, Residue at 180° C, Dissolved, mg/l	---	---	---	---	---	---	1568
Nitrogen, NO_2+NO_3, mg/l as N	---	---	---	---	---	---	0.25
Phosphorus, Total, mg/l as P	---	---	---	---	---	---	.01
Arsenic, Total, ug/l as As	---	---	---	---	---	---	5.0
Barium, Total Recoverable, ug/l as Ba	---	---	---	---	---	---	19.0
Cadmium, Total Recoverable, ug/l as Cd	---	---	---	---	---	---	2
Chromium, Total Recoverable, ug/l as Cr	<100	<100	<100	<100	<100	<100	4
Copper, Total Recoverable, ug/l as Cu	<100	<100	<100	<100	<100	<100	8
Cyanide, Total, mg/l as Cn	---	---	---	---	---	---	---
Iron, Total Recoverable, mg/l as Fe	---	---	---	---	---	---	1.626
Iron, Dissolved, mg/l as Fe	2.3	2.3	5.8	5.8	5.9	5.8	1.488
Lead, Total Recoverable, ug/l as Pb	---	---	---	---	---	---	36
Manganese, Total Recoverable, mg/l as Mn	---	---	---	---	---	---	4.06
Manganese, Dissolved, mg/l as Mn	3.9	4.0	3.6	3.6	7.6	7.8	4.05
Mercury, Total Recoverable, ug/l as Hg	---	---	---	---	---	---	0.3
Silver, Total Recoverable, ug/l as Ag	---	---	---	---	---	---	<1
Zinc, Total Recoverable, ug/l as Zn	0	0	0	0	0	0	103
Silica, Dissolved, mg/l as SiO_2	---	---	---	---	---	---	---
Selenium, Total, ug/l as Se	---	---	---	---	---	---	1.0
Selenium, Dissolved, ug/l as Se	---	---	---	---	---	---	1.4
Sediment, Suspended, mg/l	---	---	---	---	---	---	1
Dissolved Oxygen, mg/l	4.1	4.1	7.9	7.9	---	---	---
CO_2, mg/l	---	---	---	---	---	---	---
Turbidity, NTU	1.0	1.0	3.3	3.4	3.0	3.0	2.0
Aluminum, mg/l as Al	1.4	1.7	1.2	1.1	1.3	1.1	0.45
Nickel, mg/l as Ni	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	.066
Data Source[a]	3	3	3	3	3	3	5

[a] 1 - USGS (1981)
2 - KNPC (1980, 1981)
3 - Present Study
4 - KDNREP (1981)
5 - KDNREP (unpublished data)

Table D-1 Cont. Water quality data from study region.

Parameter	Coiltown						
	Site 1 Cont. Clear Creek			Site 2 Clear Creek			
Date	03/26/82	06/04/82	06/04/82	06/19/81	06/19/81	07/24/81	07/24/81
Time	1115	1115	1115	1515	1515	1030	1030
Streamflow, Instantaneous, cfs	---	---	---	---	---	---	---
Specific Conductance, micromhos/cm	1500	1500	1500	2600	2600	2800	2800
pH	3.6	3.7	3.7	6.4	6.4	5.3	5.3
Temperature, °C	---	---	---	---	---	---	---
Hardness, mg/l as $CaCO_3$	---	---	---	---	---	---	---
Hardness, Noncarbonate, mg/l $CaCO_3$	---	---	---	---	---	---	---
Acidity, Total, mg/l	---	---	---	---	---	---	---
Calcium, Dissolved, mg/l as Ca	---	---	---	---	---	---	---
Magnesium, Dissolved, mg/l as Mg	61	---	---	137	142	144	144
Sodium, Dissolved, mg/l as Na	23.5	---	---	64.5	66.0	62.8	60.7
Potassium, Dissolved, mg/l as K	4.7	---	---	6.9	7.4	7.9	8.0
Alkalinity, mg/l as $CaCO_3$	---	---	---	---	---	---	---
Sulfate, Dissolved, mg/l as SO_4	523	600	622	---	---	578	578
Chloride, Dissolved, mg/l as Cl	---	---	---	---	---	---	---
Fluoride, Dissolved, mg/l as F	---	---	---	---	---	---	---
Solids, Residue at 180° C, Dissolved, mg/l	---	---	---	---	---	---	---
Nitrogen, NO_2+NO_3, mg/l as N	---	---	---	---	---	---	---
Phosphorus, Total, mg/l as P	---	---	---	---	---	---	---
Arsenic, Total, ug/l as As	---	---	---	---	---	---	---
Barium, Total Recoverable, ug/l as Ba	---	---	---	---	---	---	---
Cadmium, Total Recoverable, ug/l as Cd	---	---	---	---	---	---	---
Chromium, Total Recoverable, ug/l as Cr	<100	---	---	<100	<100	<100	<100
Copper, Total Recoverable, ug/l as Cu	<100	---	---	<100	<100	<100	<100
Cyanide, Total, mg/l as Cn	---	---	---	---	---	---	---
Iron, Total Recoverable, mg/l as Fe	---	---	---	---	---	---	---
Iron, Dissolved, mg/l as Fe	2.1	1.8	1.9	2.6	2.6	2.9	2.9
Lead, Total Recoverable, ug/l as Pb	---	---	---	---	---	---	---
Manganese, Total Recoverable, mg/l as Mn	---	---	---	---	---	---	---
Manganese, Dissolved, mg/l as Mn	3.6	---	---	3.8	3.8	7.0	6.7
Mercury, Total Recoverable, ug/l as Hg	---	---	---	---	---	---	---
Silver, Total Recoverable, ug/l as Ag	---	---	---	---	---	---	---
Zinc, Total Recoverable, ug/l as Zn	100	---	---	100	100	100	100
Silica, Dissolved, mg/l as SiO_2	---	---	---	---	---	---	---
Selenium, Total, ug/l as Se	---	---	---	---	---	---	---
Selenium, Dissolved, ug/l as Se	---	---	---	---	---	---	---
Sediment, Suspended, mg/l	---	---	---	---	---	---	---
Dissolved Oxygen, mg/l	---	7.8	7.8	6.5	6.5	6.2	6.2
CO_2, mg/l	---	---	---	---	---	---	---
Turbidity, NTU	1.3	2.9	3.0	0.6	0.6	2.2	2.2
Aluminum, mg/l as Al	2.6	---	---	0.5	0.6	2.9	3.3
Nickel, mg/l as Ni	<0.1	---	---	0.11	0.10	0.11	0.11
Data Source[a]	3	3	3	3	3	3	3

[a] 1 - USGS (1981)
2 - KNPC (1980, 1981)
3 - Present Study
4 - KDNREP (1981)
5 - KDNREP (unpublished data)

Table D-1 Cont. Water quality data from study region.

Parameter	Colltown Site 2 Cont. Clear Creek						
Date	09/19/81	09/19/81	10/10/81	10/10/81	03/26/82	06/04/82	06/04/82
Time	1715	1715	1415	1415	1010	1330	1330
Streamflow, Instantaneous, cfs	---	---	---	---	---	---	---
Specific Conductance, micromhos/cm	3500	3500	3000	3000	1500	1650	1650
pH	6.5	6.5	5.8	5.9	4.4	3.7	3.7
Temperature, °C	---	---	---	---	---	---	---
Hardness, mg/l as $CaCO_3$	---	---	---	---	---	---	---
Hardness, Noncarbonate, mg/l $CaCO_3$	---	---	---	---	---	---	---
Acidity, Total, mg/l	---	---	---	---	---	---	---
Calcium, Dissolved, mg/l as Ca	---	---	---	---	---	---	---
Magnesium, Dissolved, mg/l as Mg	169	166	264	254	85	---	---
Sodium, Dissolved, mg/l as Na	122.4	121.9	142.4	141.2	27.3	---	---
Potassium, Dissolved, mg/l as K	11.4	11.4	13.4	13.2	26.9	---	---
Alkalinity, mg/l as $CaCO_3$	---	---	---	---	---	---	---
Sulfate, Dissolved, mg/l as SO_4	666	666	652	685	717	620	660
Chloride, Dissolved, mg/l as Cl	---	---	---	---	---	---	---
Fluoride, Dissolved, mg/l as F	---	---	---	---	---	---	---
Solids, Residue at 180° C, Dissolved, mg/l	---	---	---	---	---	---	---
Nitrogen, NO_2+NO_3, mg/l as N	---	---	---	---	---	---	---
Phosphorus, Total, mg/l as P	---	---	---	---	---	---	---
Arsenic, Total, ug/l as As	---	---	---	---	---	---	---
Barium, Total Recoverable, ug/l as Ba	---	---	---	---	---	---	---
Cadmium, Total Recoverable, ug/l as Cd	---	---	---	---	---	---	---
Chromium, Total Recoverable, ug/l as Cr	<100	<100	<100	<100	<100	---	---
Copper, Total Recoverable, ug/l as Cu	<100	<100	<100	<100	<100	---	---
Cyanide, Total, mg/l as Cn	---	---	---	---	---	---	---
Iron, Total Recoverable, mg/l as Fe	---	---	---	---	---	---	---
Iron, Dissolved, mg/l as Fe	6.8	6.7	7.1	7.1	5.4	2.1	2.1
Lead, Total Recoverable, ug/l as Pb	---	---	---	---	---	---	---
Manganese, Total Recoverable, mg/l as Mn	---	---	---	---	---	---	---
Manganese, Dissolved, mg/l as Mn	7.8	7.7	7.4	7.1	4.6	---	---
Mercury, Total Recoverable, ug/l as Hg	---	---	---	---	---	---	---
Silver, Total Recoverable, ug/l as Ag	---	---	---	---	---	---	---
Zinc, Total Recoverable, ug/l as Zn	0	0	0	0	100	---	---
Silica, Dissolved, mg/l as SiO_2	---	---	---	---	---	---	---
Selenium, Total, ug/l as Se	---	---	---	---	---	---	---
Selenium, Dissolved, ug/l as Se	---	---	---	---	---	---	---
Sediment, Suspended, mg/l	---	---	---	---	---	---	---
Dissolved Oxygen, mg/l	9.3	9.3	---	---	---	9.9	9.9
CO_2, mg/l	---	---	---	---	---	---	---
Turbidity, NTU	2.1	2.0	3.2	3.5	1.1	4.4	4.2
Aluminum, mg/l as Al	0.5	1.0	0.7	0.7	2.8	---	---
Nickel, mg/l as Ni	<0.10	<0.10	0.12	0.12	0.11	---	---
Data Source[a]	3	3	3	3	3	3	3

[a] 1 - USGS (1981)
2 - KNPC (1980, 1981)
3 - Present Study
4 - KDNREP (1981)
5 - KDNREP (unpublished data)

Table D-1 Cont. Water quality data from study region.

Parameter	Coiltown Site 3 Weirs Creek	Coiltown Site 4 Rose Creek		Dawson Springs Site 1 Montgomery Creek		Slaughtersville Site 1 East Fork Deer Creek near Sebree	
Date	08/13/80	06/19/80	08/13/80	08/07/80	12/07/81	03/25/80	05/06/80
Time	----	---	----	----	---	1230	1025
Streamflow, Instantaneous, cfs	---	---	---	---	---	133.0	6.4
Specific Conductance, micromhos/cm	942	355	389	115	218	215	260
pH	8.0	6.6	7.5	7.0	7.0	6.9	7.5
Temperature, °C	32	20.5	31	27	---	6.5	19.0
Hardness, mg/l as $CaCO_3$	680	---	160	70	94.4	---	---
Hardness, Noncarbonate, mg/l $CaCO_3$	---	---	---	---	---	---	---
Acidity, Total, mg/l	---	8.0	---	---	11.0	---	---
Calcium, Dissolved, mg/l as Ca	---	---	---	---	29	---	---
Magnesium, Dissolved, mg/l as Mg	---	---	---	---	4.8	---	---
Sodium, Dissolved, mg/l as Na	---	---	---	---	3.75	---	---
Potassium, Dissolved, mg/l as K	---	---	---	---	4.05	---	---
Alkalinity, mg/l as $CaCO_3$	116	99	92	68	61	38	58
Sulfate, Dissolved, mg/l as SO_4	200	43	60	0	38.1	41	67
Chloride, Dissolved, mg/l as Cl	0	---	0	0	1.2	---	---
Fluoride, Dissolved, mg/l as F	---	---	---	---	0.06	---	---
Solids, Residue at 180° C, Dissolved, mg/l	---	---	---	---	126	139	168
Nitrogen, NO_2+NO_3, mg/l as N	---	---	---	---	0.315	---	---
Phosphorus, Total, mg/l as P	---	---	---	---	0.062	---	---
Arsenic, Total, ug/l as As	---	---	---	---	2.0	---	---
Barium, Total Recoverable, ug/l as Ba	---	---	---	---	59.0	---	---
Cadmium, Total Recoverable, ug/l as Cd	---	---	---	---	<1	---	---
Chromium, Total Recoverable, ug/l as Cr	---	---	---	---	1	---	---
Copper, Total Recoverable, ug/l as Cu	---	---	---	---	5	---	---
Cyanide, Total, mg/l as Cn	---	---	---	---	<0.01	---	---
Iron, Total Recoverable, mg/l as Fe	---	0.95	---	---	1.578	3.40	0.81
Iron, Dissolved, mg/l as Fe	---	---	---	---	0.148	0.23	0.02
Lead, Total Recoverable, ug/l as Pb	---	---	---	---	10	---	---
Manganese, Total Recoverable, mg/l as Mn	---	1.47	---	---	0.198	0.22	0.15
Manganese, Dissolved, mg/l as Mn	---	---	---	---	0.170	0.15	0.13
Mercury, Total Recoverable, ug/l as Hg	---	---	---	---	0.8	---	---
Silver, Total Recoverable, ug/l as Ag	---	---	---	---	<1	---	---
Zinc, Total Recoverable, ug/l as Zn	---	---	---	---	16	---	---
Silica, Dissolved, mg/l as SiO_2	---	---	---	---	---	---	---
Selenium, Total, ug/l as Se	---	---	---	---	1.0	---	---
Selenium, Dissolved, ug/l as Se	---	---	---	---	1.0	---	---
Sediment, Suspended, mg/l	100	---	100	200	22	59	25
Dissolved Oxygen, mg/l	5.7	2.5	4.9	3.4	---	---	---
CO_2, mg/l	12.5	---	7.5	12.5	---	---	---
Turbidity, NTU	41	4.9	62	100+	12	---	---
Aluminum, mg/l as Al	---	---	---	---	0.83	---	---
Nickel, mg/l as Ni	---	---	---	---	.008	---	---
Data Source[a]	2	4	2	2	5	1	1

[a] 1 - USGS (1981)
2 - KNPC (1980, 1981)
3 - Present Study
4 - KDNREP (1981)
5 - KDNREP (unpublished data)

Table D-1 Cont. Water quality data from study region.

Parameter	Slaughtersville Site 1 East Fork Deer Creek near Sebree		Madisonville West Site 1 Clear Creek				
Date	07/14/80	09/10/80	06/19/81	06/19/81	07/23/81	07/23/81	09/19/81
Time	1045	1040	1445	1445	1300	1300	1715
Streamflow, Instantaneous, cfs	0.16	0.01	---	---	---	---	---
Specific Conductance, micromhos/cm	402	680	2100	2100	2500	2500	3000
pH	7.0	7.2	3.9	3.9	3.8	3.8	3.6
Temperature, °C	28.5	21.5	---	---	---	---	---
Hardness, mg/l as $CaCO_3$	150	---	---	---	---	---	---
Hardness, Noncarbonate, mg/l $CaCO_3$	52	---	---	---	---	---	---
Acidity, Total, mg/l	---	---	---	---	---	---	---
Calcium, Dissolved, mg/l as Ca	37	---	---	---	---	---	---
Magnesium, Dissolved, mg/l as Mg	13	---	114	110	132	124	188
Sodium, Dissolved, mg/l as Na	19	---	51.9	52.1	26.8	26.4	43.6
Potassium, Dissolved, mg/l as K	4.4	---	6.3	6.2	5.9	5.9	8.6
Alkalinity, mg/l as $CaCO_3$	94	150	---	---	---	---	---
Sulfate, Dissolved, mg/l as SO_4	90	160	---	---	635	635	926
Chloride, Dissolved, mg/l as Cl	19	---	---	---	---	---	---
Fluoride, Dissolved, mg/l as F	0.3	---	---	---	---	---	---
Solids, Residue at 180° C, Dissolved, mg/l	281	492	---	---	---	---	---
Nitrogen, NO_2+NO_3, mg/l as N	0.63	---	---	---	---	---	---
Phosphorus, Total, mg/l as P	0.07	---	---	---	---	---	---
Arsenic, Total, ug/l as As	2	---	---	---	---	---	---
Barium, Total Recoverable, ug/l as Ba	100	---	---	---	---	---	---
Cadmium, Total Recoverable, ug/l as Cd	0	---	---	---	---	---	---
Chromium, Total Recoverable, ug/l as Cr	20	---	<100	<100	<100	<100	<100
Copper, Total Recoverable, ug/l as Cu	3	---	<100	<100	<100	<100	<100
Cyanide, Total, mg/l as Cn	0	---	---	---	---	---	---
Iron, Total Recoverable, mg/l as Fe	1.20	3.50	---	---	---	---	---
Iron, Dissolved, mg/l as Fe	0.03	0.56	2.10	1.93	5.50	5.60	7.79
Lead, Total Recoverable, ug/l as Pb	1	---	---	---	---	---	---
Manganese, Total Recoverable, mg/l as Mn	0.73	3.00	---	---	---	---	---
Manganese, Dissolved, mg/l as Mn	0.64	2.90	5.5	5.4	14.9	14.3	23.8
Mercury, Total Recoverable, ug/l as Hg	0.3	---	---	---	---	---	---
Silver, Total Recoverable, ug/l as Ag	0	---	---	---	---	---	---
Zinc, Total Recoverable, ug/l as Zn	10	---	300	300	200	200	100
Silica, Dissolved, mg/l as SiO_2	9.3	---	---	---	---	---	---
Selenium, Total, ug/l as Se	0	---	---	---	---	---	---
Selenium, Dissolved, ug/l as Se	---	---	---	---	---	---	---
Sediment, Suspended, mg/l	31	135	---	---	---	---	---
Dissolved Oxygen, mg/l	---	---	7.5	7.5	5.1	5.1	6.0
CO_2, mg/l	---	---	---	---	---	---	---
Turbidity, NTU	---	---	3.5	3.5	0.4	0.4	0.3
Aluminum, mg/l as Al	---	---	8.3	8.9	4.6	5.0	7.0
Nickel, mg/l as Ni	---	---	0.15	0.15	0.19	0.19	0.17
Data Source[a]	1	1	3	3	3	3	3

[a] 1 - USGS (1981)
2 - KNPC (1980, 1981)
3 - Present Study
4 - KDNREP (1981)
5 - KDNREP (unpublished data)

Table II-1 Cont. Water quality data from study region.

Parameter	Madisonville West						
	Site 1 Cont. Clear Creek						Site 2 Clear Creek
Date	09/19/81	10/10/81	10/10/81	03/25/82	06/04/82	06/04/82	12/09/81
Time	1715	1200	1200	1815	1420	1420	---
Streamflow, Instantaneous, cfs	---	---	---	---	---	---	---
Specific Conductance, micromhos/cm	3000	2800	2800	900	1400	1400	2466
pH	3.6	3.5	3.7	4.1	3.9	3.9	3.9
Temperature, °C	---	---	---	---	---	---	---
Hardness, mg/l as $CaCO_3$	---	---	---	---	---	---	1250
Hardness, Noncarbonate, mg/l $CaCO_3$	---	---	---	---	---	---	---
Acidity, Total, mg/l	---	---	---	---	---	---	164
Calcium, Dissolved, mg/l as Ca	---	---	---	---	---	---	44
Magnesium, Dissolved, mg/l as Mg	198	197	195	77	---	---	18
Sodium, Dissolved, mg/l as Na	45.3	62.2	63.8	35.7	---	---	7.9
Potassium, Dissolved, mg/l as K	8.8	10.2	10.6	4.6	---	---	5.2
Alkalinity, mg/l as $CaCO_3$	---	---	---	---	---	---	0
Sulfate, Dissolved, mg/l as SO_4	926	562	630	633	610	612	159
Chloride, Dissolved, mg/l as Cl	---	---	---	---	---	---	12.9
Fluoride, Dissolved, mg/l as F	---	---	---	---	---	---	0.8
Solids, Residue at 180° C, Dissolved, mg/l	---	---	---	---	---	---	204
Nitrogen, NO_2+NO_3, mg/l as N	---	---	---	---	---	---	0.14
Phosphorus, Total, mg/l as P	---	---	---	---	---	---	0.009
Arsenic, Total, ug/l as As	---	---	---	---	---	---	10
Barium, Total Recoverable, ug/l as Ba	---	---	---	---	---	---	33
Cadmium, Total Recoverable, ug/l as Cd	---	---	---	---	---	---	3
Chromium, Total Recoverable, ug/l as Cr	<100	<100	<100	<100	---	---	6
Copper, Total Recoverable, ug/l as Cu	<100	<100	<100	<100	---	---	12
Cyanide, Total, mg/l as Cn	---	---	---	---	---	---	<0.01
Iron, Total Recoverable, mg/l as Fe	---	---	---	---	---	---	6.52
Iron, Dissolved, mg/l as Fe	8.0	9.1	9.1	8.6	1.5	1.62	6.18
Lead, Total Recoverable, ug/l as Pb	---	---	---	---	---	---	38
Manganese, Total Recoverable, mg/l as Mn	---	---	---	---	---	---	3.70
Manganese, Dissolved, mg/l as Mn	25.3	18.3	18.9	4.4	---	---	3.64
Mercury, Total Recoverable, ug/l as Hg	---	---	---	---	---	---	0.5
Silver, Total Recoverable, ug/l as Ag	---	---	---	---	---	---	5
Zinc, Total Recoverable, ug/l as Zn	100	200	200	200	---	---	295
Silica, Dissolved, mg/l as SiO_2	---	---	---	---	---	---	---
Selenium, Total, ug/l as Se	---	---	---	---	---	---	1.0
Selenium, Dissolved, ug/l as Se	---	---	---	---	---	---	1.0
Sediment, Suspended, mg/l	---	---	---	---	---	---	43
Dissolved Oxygen, mg/l	6.0	---	---	---	8.0	8.0	---
CO_2, mg/l	---	---	---	---	---	---	---
Turbidity, NTU	0.3	0.5	0.6	9.3	10.1	10.1	46
Aluminum, mg/l as Al	6.2	7.4	7.3	3.7	---	---	1.13
Nickel, mg/l as Ni	0.18	0.19	0.18	0.13	---	---	.105
Data Source[a]	3	3	3	3	3	3	5

[a] 1 - USGS (1981)
2 - KNPC (1980, 1981)
3 - Present Study
4 - KDNREP (1981)
5 - KDNREP (unpublished data)

Table D-1 Cont. Water quality data from study region.

Parameter	Hanson Site 1 Otter Creek near Hanson				Madisonville East Site 1 Flat Creek Near Madisonville			
Date	05/06/80	06/19/80	07/14/80	09/10/80	03/26/80	05/07/80	07/16/80	09/09/80
Time	1230	---	1400	1300	1035	1050	0820	1100
Streamflow, Instantaneous, cfs	1.7	---	0.39	0.0	15.0	3.8	0.45	0.0
Specific Conductance, micromhos/cm	306	380	323	---	1400	2310	2660	---
pH	7.0		6.6	---	3.6	3.4	3.2	---
Temperature, °C	21.5	18	30.5	---	7.0	15.5	26.5	---
Hardness, mg/l as $CaCO_3$	---	---	120	---	---	---	1100	---
Hardness, Noncarbonate, mg/l $CaCO_3$	---	---	32	---	---	---	1100	---
Acidity, Total, mg/l	---	6.4	0.3	---	2.3	4.3	6.5	---
Calcium, Dissolved, mg/l as Ca	---	---	33	---	---	---	210	---
Magnesium, Dissolved, mg/l as Mg	---	---	10	---	---	---	50	---
Sodium, Dissolved, mg/l as Na	---	---	15	---	---	---	26	---
Potassium, Dissolved, mg/l as K	---	---	4.7	---	---	---	5.7	---
Alkalinity, mg/l as $CaCO_3$	82	154	92	---	---	---	0	---
Sulfate, Dissolved, mg/l as SO_4	64	37.8	37	---	740	1300	1500	---
Chloride, Dissolved, mg/l as Cl	---	---	21	---	---	---	9.2	---
Fluoride, Dissolved, mg/l as F	---	---	0.3	---	---	---	2.0	---
Solids, Residue at 180° C, Dissolved, mg/l	237	---	202	---	---	2080	2500	---
Nitrogen, NO_2+NO_3, mg/l as N	---	---	0.60	---	---	---	0.41	---
Phosphorus, Total, mg/l as P	---	---	0.02	---	---	---	0.05	---
Arsenic, Total, ug/l as As	---	---	2	---	---	---	0	---
Barium, Total Recoverable, ug/l as Ba	---	---	200	---	---	---	100	---
Cadmium, Total Recoverable, ug/l as Cd	---	---	0	---	---	---	22	---
Chromium, Total Recoverable, ug/l as Cr	---	---	10	---	---	---	20	---
Copper, Total Recoverable, ug/l as Cu	---	---	2	---	---	---	18	---
Cyanide, Total, mg/l as Cn	---	---	0	---	---	---	0	---
Iron, Total Recoverable, mg/l as Fe	---	0.81	2.5	---	6.8	5.9	7.0	---
Iron, Dissolved, mg/l as Fe	0.62	---	0.08	---	4.8	5.9	5.8	---
Lead, Total Recoverable, ug/l as Pb	---	---	3	---	---	---	16	---
Manganese, Total Recoverable, mg/l as Mn	---	3.52	0.69	---	8.6	16.0	20.0	---
Manganese, Dissolved, mg/l as Mn	---	---	0.63	---	7.9	16.0	18.0	---
Mercury, Total Recoverable, ug/l as Hg	---	---	0.5	---	---	---	0.7	---
Silver, Total Recoverable, ug/l as Ag	---	---	0	---	---	---	0	---
Zinc, Total Recoverable, ug/l as Zn	---	---	50	---	---	---	2100	---
Silica, Dissolved, mg/l as SiO_2	---	---	9.9	---	---	---	58	---
Selenium, Total, ug/l as Se	---	---	0	---	---	---	0	---
Selenium, Dissolved, ug/l as Se	---	---	---	---	---	---	---	---
Sediment, Suspended, mg/l	88	---	116	---	18	32	---	---
Dissolved Oxygen, mg/l	---	2.6	---	---	---	---	---	---
CO_2, mg/l	---	---	---	---	---	---	---	---
Turbidity, NTU	---	4.5	---	---	---	---	---	---
Aluminum, mg/l as Al	---	---	---	---	---	---	---	---
Nickel, mg/l as Ni	---	---	---	---	---	---	---	---
Data Source[a]	1	4	1	1	1	1	1	1

[a] 1 - USGS (1981)
2 - KNPC (1980, 1981)
3 - Present Study
4 - KDNREP (1981)
5 - KDNREP (unpublished data)

Table D-1 Cont. Water quality data from study region.

Parameter	Madisonville East Site 1 Flat Creek near Madisonville	Nortonville Site 1 Drakes Creek near White Plains			
Date	08/06/80	03/26/80	05/07/80	07/15080	09/09/80
Time	----	0910	0930	1405	1000
Streamflow, Instantaneous, cfs	---	150	---	1.2	0
Specific Conductance, micromhos/cm	2256	400	1110	2250	---
pH	8.5	4.9	3.6	3.4	---
Temperature, °C	35.0	8.0	18.0	29.0	---
Hardness, mg/l as $CaCO_3$	1700	---	---	840	---
Hardness, Noncarbonate, mg/l $CaCO_3$	---	---	---	840	---
Acidity, Total, mg/l	---	---	2.0	6.8	---
Calcium, Dissolved, mg/l as Ca	---	---	---	170	---
Magnesium, Dissolved, mg/l as Mg	---	---	---	100	---
Sodium, Dissolved, mg/l as Na	---	---	---	24	---
Potassium, Dissolved, mg/l as K	---	---	---	4.2	---
Alkalinity, mg/l as $CaCO_3$	320	---	0	0	---
Sulfate, Dissolved, mg/l as SO_4	650	160	540	1100	---
Chloride, Dissolved, mg/l as Cl	0	---	---	19	---
Fluoride, Dissolved, mg/l as F	---	---	---	1.7	---
Solids, Residue at 180° C, Dissolved, mg/l	---	266	858	1820	---
Nitrogen, NO_2+NO_3, mg/l as N	---	---	---	0.05	---
Phosphorus, Total, mg/l as P	---	---	---	0	---
Arsenic, Total, ug/l as As	---	---	---	0	---
Barium, Total Recoverable, ug/l as Ba	---	---	---	100	---
Cadmium, Total Recoverable, ug/l as Cd	---	---	---	10	---
Chromium, Total Recoverable, ug/l as Cr	---	---	---	20	---
Copper, Total Recoverable, ug/l as Cu	---	---	---	13	---
Cyanide, Total, mg/l as Cn	---	---	---	0	---
Iron, Total Recoverable, mg/l as Fe	---	2.9	5.0	18.0	---
Iron, Dissolved, mg/l as Fe	---	1.2	3.3	14.0	---
Lead, Total Recoverable, ug/l as Pb	---	---	---	13	---
Manganese, Total Recoverable, mg/l as Mn	---	2.0	5.8	17.0	---
Manganese, Dissolved, mg/l as Mn	---	2.0	5.4	15.0	---
Mercury, Total Recoverable, ug/l as Hg	---	---	---	0.5	---
Silver, Total Recoverable, ug/l as Ag	---	---	---	0	---
Zinc, Total Recoverable, ug/l as Zn	---	---	---	1700	---
Silica, Dissolved, mg/l as SiO_2	---	---	---	39	---
Selenium, Total, ug/l as Se	---	---	---	0	---
Selenium, Dissolved, ug/l as Se	---	---	---	---	---
Sediment, Suspended, mg/l	0	20	24	25	---
Dissolved Oxygen, mg/l	9.1	---	---	---	---
CO_2, mg/l	7.5	---	---	---	---
Turbidity, NTU	4.8	---	---	---	---
Aluminum, mg/l as Al	---	---	---	---	---
Nickel, mg/l as Ni	---	---	---	---	---
Data Source[a]	2	1	1	1	1

[a] 1 - USGS (1981)
2 - KNPC (1980, 1981)
3 - Present Study
4 - KDNREP (1981)
5 - KDNREP (unpublished data)

Table D-1 Cont. Water quality data from study region.

Parameter	Sacramento Site 1 Pond River near Vandetta						
Date	10/04/79	11/14/79	01/04/80	02/14/80	03/20/80	05/21/80	07/10/80
Time	1145	1230	1500	1035	0920	1015	0830
Streamflow, Instantaneous, cfs	5150	729	928	188	590	570	900
Specific Conductance, micromhos/cm	280	500	427	1100	470	955	595
pH	6.7	7.1	7.2	6.7	7.2	7.1	6.6
Temperature, °C	17.0	9.0	3.5	2.5	9.5	22.5	30.0
Hardness, mg/l as $CaCO_3$	---	---	---	---	---	---	230
Hardness, Noncarbonate, mg/l $CaCO_3$	---	---	---	---	---	---	210
Acidity, Total, mg/l	---	---	---	---	---	---	0.2
Calcium, Dissolved, mg/l as Ca	---	---	---	---	---	---	56
Magnesium, Dissolved, mg/l as Mg	---	---	---	---	---	---	23
Sodium, Dissolved, mg/l as Na	---	---	---	---	---	---	20
Potassium, Dissolved, mg/l as K	---	---	---	---	---	---	3.7
Alkalinity, mg/l as $CaCO_3$	34	54	48	10	46	50	21
Sulfate, Dissolved, mg/l as SO_4	79	200	160	540	160	400	240
Chloride, Dissolved, mg/l as Cl	---	---	---	---	---	---	8.6
Fluoride, Dissolved, mg/l as F	---	---	---	---	---	---	0.3
Solids, Residue at 180° C, Dissolved, mg/l	174	369	302	880	302	756	455
Nitrogen, NO_2+NO_3, mg/l as N	---	---	---	---	---	---	0.59
Phosphorus, Total, mg/l as P	---	---	---	---	---	---	0.06
Arsenic, Total, ug/l as As	---	---	---	---	---	---	1
Barium, Total Recoverable, ug/l as Ba	---	---	---	---	---	---	100
Cadmium, Total Recoverable, ug/l as Cd	---	---	---	---	---	---	1
Chromium, Total Recoverable, ug/l as Cr	---	---	---	---	---	---	10
Copper, Total Recoverable, ug/l as Cu	---	---	---	---	---	---	11
Cyanide, Total, mg/l as Cn	---	---	---	---	---	---	0.01
Iron, Total Recoverable, mg/l as Fe	1.0	1.6	1.6	---	5.5	1.1	2.3
Iron, Dissolved, mg/l as Fe	1.0	0.04	0.09	---	0.02	0.01	0.02
Lead, Total Recoverable, ug/l as Pb	---	---	---	---	---	---	0
Manganese, Total Recoverable, mg/l as Mn	0.42	1.8	0.75	3.7	1.3	2.5	2.1
Manganese, Dissolved, mg/l as Mn	0.4	1.8	0.75	3.7	1.1	0.25	2.1
Mercury, Total Recoverable, ug/l as Hg	---	---	---	---	---	---	0.7
Silver, Total Recoverable, ug/l as Ag	---	---	---	---	---	---	0
Zinc, Total Recoverable, ug/l as Zn	---	---	---	---	---	---	60
Silica, Dissolved, mg/l as SiO_2	---	---	---	---	---	---	6.3
Selenium, Total, ug/l as Se	---	---	---	---	---	---	0
Selenium, Dissolved, ug/l as Se	---	---	---	---	---	---	---
Sediment, Suspended, mg/l	19	23	26	10	102	26	78
Dissolved Oxygen, mg/l	---	---	---	---	---	---	---
CO_2, mg/l	---	---	---	---	---	---	---
Turbidity, NTU	---	---	---	---	---	---	---
Aluminum, mg/l as Al	---	---	---	---	---	---	---
Nickel, mg/l as Ni	---	---	---	---	---	---	---
Data Source[a]	1	1	1	1	1	1	1

[a] 1 - USGS (1981)
2 - KNPC (1980, 1981)
3 - Present Study
4 - KDNREP (1981)
5 - KDNREP (unpublished data)

Table D-1 Cont. Water quality data from study region.

Parameter	Graham					
	Site 2 Long Pond	Site 9 West Fork Pond River near Apex				
Date	08/15/80	03/25/80	05/06/80	07/15/80	09/08/80	08/05/80
Time	----	1415	1330	1045	1425	----
Streamflow, Instantaneous, cfs	---	425	21	1.7	0	---
Specific Conductance, micromhos/cm	700	185	355	365	---	516
pH	7.0	6.7	7.4	7.2	---	7.5
Temperature, °C	28	9.0	19.0	29.0	---	26
Hardness, mg/l as $CaCO_3$	330	---	---	150	---	215
Hardness, Noncarbonate, mg/l $CaCO_3$	---	---	---	54	---	---
Acidity, Total, mg/l	---	---	---	---	---	---
Calcium, Dissolved, mg/l as Ca	---	---	---	47	---	---
Magnesium, Dissolved, mg/l as Mg	---	---	---	9.0	---	---
Sodium, Dissolved, mg/l as Na	---	---	---	14	---	---
Potassium, Dissolved, mg/l as K	---	---	---	2.9	---	---
Alkalinity, mg/l as $CaCO_3$	112	42	100	100	---	72
Sulfate, Dissolved, mg/l as SO_4	160	27	64	54	---	120
Chloride, Dissolved, mg/l as Cl	0	---	---	18	---	0
Fluoride, Dissolved, mg/l as F	---	---	---	0.2	---	---
Solids, Residue at 180° C, Dissolved, mg/l	---	131	239	239	---	---
Nitrogen, NO_2+NO_3, mg/l as N	---	---	---	0.7	---	---
Phosphorus, Total, mg/l as P	---	---	---	0.36	---	---
Arsenic, Total, ug/l as As	---	---	---	---	---	---
Barium, Total Recoverable, ug/l as Ba	---	---	---	100	---	---
Cadmium, Total Recoverable, ug/l as Cd	---	---	---	0	---	---
Chromium, Total Recoverable, ug/l as Cr	---	---	---	10	---	---
Copper, Total Recoverable, ug/l as Cu	---	---	---	5	---	---
Cyanide, Total, mg/l as Cn	---	---	---	0	---	---
Iron, Total Recoverable, mg/l as Fe	---	3.1	0.64	2.1	---	---
Iron, Dissolved, mg/l as Fe	---	0.19	0.03	0.04	---	---
Lead, Total Recoverable, ug/l as Pb	---	---	---	4	---	---
Manganese, Total Recoverable, mg/l as Mn	---	0.22	0.31	1.3	---	---
Manganese, Dissolved, mg/l as Mn	---	0.07	0.24	1.2	---	---
Mercury, Total Recoverable, ug/l as Hg	---	---	---	1.0	---	---
Silver, Total Recoverable, ug/l as Ag	---	---	---	0	---	---
Zinc, Total Recoverable, ug/l as Zn	---	---	---	30	---	---
Silica, Dissolved, mg/l as SiO_2	---	---	---	8.0	---	---
Selenium, Total, ug/l as Se	---	---	---	0	---	---
Selenium, Dissolved, ug/l as Se	---	---	---	---	---	---
Sediment, Suspended, mg/l	100	102	---	75	---	100
Dissolved Oxygen, mg/l	3.4	---	---	---	---	3.0
CO_2, mg/l	15	---	---	---	---	12.5
Turbidity, NTU	46	---	---	---	---	37
Aluminum, mg/l as Al	---	---	---	---	---	---
Nickel, mg/l as Ni	---	---	---	---	---	---
Data Source[a]	2	1	1	1	1	2

[a] 1 - USGS (1981)
2 - KNPC (1980, 1981)
3 - Present Study
4 - KDNREP (1981)
5 - KDNREP (unpublished data)

Table D-1 Cont. Water quality data from study region.

Parameter	Livermore Site I Green River at Lock 2 at Calhoun						
Date	10/23/79	12/07/79	01/16/80	02/29/80	04/04/80	04/10/80	04/16/80
Time	1400	1210	1130	1200	0820	0945	1545
Streamflow, Instantaneous, cfs	19300	31300	20600	8900	23600	10800	24100
Specific Conductance, micromhos/cm	200	260	260	310	---	290	---
pH	7.6	7.4	7.4	7.7	---	7.6	---
Temperature, °C	17.0	8.5	7.0	8.0	---	14.5	---
Hardness, mg/l as $CaCO_3$	---	---	---	---	---	---	---
Hardness, Noncarbonate, mg/l $CaCO_3$	---	---	---	---	---	---	---
Acidity, Total, mg/l	---	---	---	---	---	---	---
Calcium, Dissolved, mg/l as Ca	---	---	---	---	---	---	---
Magnesium, Dissolved, mg/l as Mg	---	---	---	---	---	---	---
Sodium, Dissolved, mg/l as Na	---	---	---	---	---	---	---
Potassium, Dissolved, mg/l as K	---	---	---	---	---	---	---
Alkalinity, mg/l as $CaCO_3$	80	96	84	106	---	92	---
Sulfate, Dissolved, mg/l as SO_4	21	37	36	43	---	41	---
Chloride, Dissolved, mg/l as Cl	---	---	---	---	---	---	---
Fluoride, Dissolved, mg/l as F	---	---	---	---	---	---	---
Solids, Residue at 180° C, Dissolved, mg/l	129	159	150	187	---	195	---
Nitrogen, NO_2+NO_3, mg/l as N	---	---	---	---	---	---	---
Phosphorus, Total, mg/l as P	---	---	---	---	---	---	---
Arsenic, Total, ug/l as As	---	---	---	---	---	---	---
Barium, Total Recoverable, ug/l as Ba	---	---	---	---	---	---	---
Cadmium, Total Recoverable, ug/l as Cd	---	---	---	---	---	---	---
Chromium, Total Recoverable, ug/l as Cr	---	---	---	---	---	---	---
Copper, Total Recoverable, ug/l as Cu	---	---	---	---	---	---	---
Cyanide, Total, mg/l as Cn	---	---	---	---	---	---	---
Iron, Total Recoverable, mg/l as Fe	1.50	1.40	1.10	0.61	---	1.3	---
Iron, Dissolved, mg/l as Fe	0.06	0.01	0.04	0.05	---	0.01	---
Lead, Total Recoverable, ug/l as Pb	---	---	---	---	---	---	---
Manganese, Total Recoverable, mg/l as Mn	0.19	0.24	0.19	0.20	---	0.25	---
Manganese, Dissolved, mg/l as Mn	---	0.14	0.11	0.19	---	0.16	---
Mercury, Total Recoverable, ug/l as Hg	---	---	---	---	---	---	---
Silver, Total Recoverable, ug/l as Ag	---	---	---	---	---	---	---
Zinc, Total Recoverable, ug/l as Zn	---	---	---	---	---	---	---
Silica, Dissolved, mg/l as SiO_2	---	---	---	---	---	---	---
Selenium, Total, ug/l as Se	---	---	---	---	---	---	---
Selenium, Dissolved, ug/l as Se	---	---	---	---	---	---	---
Sediment, Suspended, mg/l	94	57	69	34	115	44	140
Dissolved Oxygen, mg/l	---	---	---	---	---	---	---
CO_2, mg/l	---	---	---	---	---	---	---
Turbidity, NTU	---	---	---	---	---	---	---
Aluminum, mg/l as Al	---	---	---	---	---	---	---
Nickel, mg/l as Ni	---	---	---	---	---	---	---
Data Source[a]	1	1	1	1	1	1	1

[a] 1 - USGS (1981)
2 - KNPC (1980, 1981)
3 - Present Study
4 - KDNREP (1981)
5 - KDNREP (unpublished data)

Table D-1 Cont. Water quality data from study region.

Parameter	Livermore Site 1 Cont. Green River at Lock 2 at Calhoun			Central City West Site 1 Cypress Wetland near Cypress Creek		
Date	06/05/80	07/31/80	09/28/80	06/20/81	06/20/81	07/23/81
Time	0930	1015	0950	1300	1300	1215
Streamflow, Instantaneous, cfs	5960	3640	1070	---	---	---
Specific Conductance, micromhos/cm	290	340	364	880	880	480
pH	7.8	7.8	8.0	6.3	6.3	7.3
Temperature, °C	23.0	28.5	28.8	24	23	24
Hardness, mg/l as $CaCO_3$	---	140	---	---	---	---
Hardness, Noncarbonate, mg/l $CaCO_3$	---	86	---	---	---	---
Acidity, Total, mg/l	---	---	---	---	---	---
Calcium, Dissolved, mg/l as Ca	---	42	---	---	---	---
Magnesium, Dissolved, mg/l as Mg	---	8.9	---	39	40	19
Sodium, Dissolved, mg/l as Na	---	11	---	17	17	15
Potassium, Dissolved, mg/l as K	---	2.3	---	4	4.7	2
Alkalinity, mg/l as $CaCO_3$	90	56	102	---	---	---
Sulfate, Dissolved, mg/l as SO_4	41	44	52	13	13.2	675
Chloride, Dissolved, mg/l as Cl	---	12	---	---	---	---
Fluoride, Dissolved, mg/l as F	---	0.2	---	---	---	---
Solids, Residue at 180° C, Dissolved, mg/l	173	221	226	---	---	---
Nitrogen, NO_2+NO_3, mg/l as N	---	0.91	---	---	---	---
Phosphorus, Total, mg/l as P	---	0.06	---	---	---	---
Arsenic, Total, ug/l as As	---	2	---	---	---	---
Barium, Total Recoverable, ug/l as Ba	---	100	---	---	---	---
Cadmium, Total Recoverable, ug/l as Cd	---	1	---	---	---	---
Chromium, Total Recoverable, ug/l as Cr	---	40	---	<0.1	<0.1	<0.1
Copper, Total Recoverable, ug/l as Cu	---	3	---	<0.1	<0.1	<0.1
Cyanide, Total, mg/l as Cn	---	0.01	---	---	---	---
Iron, Total Recoverable, mg/l as Fe	1.4	1.0	1.9	---	---	---
Iron, Dissolved, mg/l as Fe	0.01	0.01	0.01	0.6	0.6	0.09
Lead, Total Recoverable, ug/l as Pb	---	3	---	---	---	---
Manganese, Total Recoverable, mg/l as Mn	0.17	0.14	0.26	---	---	---
Manganese, Dissolved, mg/l as Mn	0.07	0.03	0.12	0.8	0.7	1.7
Mercury, Total Recoverable, ug/l as Hg	---	<0.1	---	---	---	---
Silver, Total Recoverable, ug/l as Ag	---	0	---	---	---	---
Zinc, Total Recoverable, ug/l as Zn	---	10	---	0	0	0
Silica, Dissolved, mg/l as SiO_2	---	4.7	---	---	---	---
Selenium, Total, ug/l as Se	---	0	---	---	---	---
Selenium, Dissolved, ug/l as Se	---	---	---	---	---	---
Sediment, Suspended, mg/l	38	42	54	---	---	---
Dissolved Oxygen, mg/l	---	---	---	3.1	3.1	2.1
CO_2, mg/l	---	---	---	---	---	---
Turbidity, NTU	---	---	---	0.5	0.5	2.6
Aluminum, mg/l as Al	---	---	---	0	0	0
Nickel, mg/l as Ni	---	---	---	<0.1	<0.1	<0.1
Data Source[a]	1	1	1	3	3	3

[a] 1 - USGS (1981)
2 - KNPC (1980, 1981)
3 - Present Study
4 - KDNREP (1981)
5 - KDNREP (unpublished data)

Table D-1 Cont. Water quality data from study region.

Parameter	Central City West Site 1 Cont. Cypress Wetland near Cypress Creek							
Date	07/23/81	09/18/81	09/18/81	02/27/82	02/27/82	03/25/82	06/03/82	06/03/82
Time	1215	1600	1600	1715	1715	1200	1215	1215
Streamflow, Instantaneous, cfs	---	---	---	---	---	---	---	---
Specific Conductance, micromhos/cm	500	2300	2300	900	900	550	850	850
pH	7.5	6.6	7.0	7.2	7.2	6.8	6.9	6.9
Temperature, °C	25	17	18	10	10	---	22	22
Hardness, mg/l as $CaCO_3$	---	---	---	---	---	---	---	---
Hardness, Noncarbonate, mg/l $CaCO_3$	---	---	---	---	---	---	---	---
Acidity, Total, mg/l	---	---	---	---	---	---	---	---
Calcium, Dissolved, mg/l as Ca	---	---	---	---	---	---	---	---
Magnesium, Dissolved, mg/l as Mg	15	161	119	44	47	9	---	---
Sodium, Dissolved, mg/l as Na	16	106	109	24	21	19	---	---
Potassium, Dissolved, mg/l as K	2.3	10.8	11.5	6.9	6.6	5.2	---	---
Alkalinity, mg/l as $CaCO_3$	---	---	---	---	---	---	---	---
Sulfate, Dissolved, mg/l as SO_4	675	459	386	466	341	341	---	---
Chloride, Dissolved, mg/l as Cl	---	---	---	---	---	---	---	---
Fluoride, Dissolved, mg/l as F	---	---	---	---	---	---	---	---
Solids, Residue at 180° C, Dissolved, mg/l	---	---	---	---	---	---	---	---
Nitrogen, NO_2+NO_3, mg/l as N	---	---	---	---	---	---	---	---
Phosphorus, Total, mg/l as P	---	---	---	---	---	---	---	---
Arsenic, Total, ug/l as As	---	---	---	---	---	---	---	---
Barium, Total Recoverable, ug/l as Ba	---	---	---	---	---	---	---	---
Cadmium, Total Recoverable, ug/l as Cd	---	---	---	---	---	---	---	---
Chromium, Total Recoverable, ug/l as Cr	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	---	---
Copper, Total Recoverable, ug/l as Cu	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	---	---
Cyanide, Total, mg/l as Cn	---	---	---	---	---	---	---	---
Iron, Total Recoverable, mg/l as Fe	---	---	---	---	---	---	---	---
Iron, Dissolved, mg/l as Fe	0.1	1.1	1.2	0.69	0.69	0.68	0.66	0.68
Lead, Total Recoverable, ug/l as Pb	---	---	---	---	---	---	---	---
Manganese, Total Recoverable, mg/l as Mn	---	---	---	---	---	---	---	---
Manganese, Dissolved, mg/l as Mn	1.9	2.1	2.1	0	0	0.2	---	---
Mercury, Total Recoverable, ug/l as Hg	---	---	---	---	---	---	---	---
Silver, Total Recoverable, ug/l as Ag	---	---	---	---	---	---	---	---
Zinc, Total Recoverable, ug/l as Zn	0	0	0	0	0	0	---	---
Silica, Dissolved, mg/l as SiO_2	---	---	---	---	---	---	---	---
Selenium, Total, ug/l as Se	---	---	---	---	---	---	---	---
Selenium, Dissolved, ug/l as Se	---	---	---	---	---	---	---	---
Sediment, Suspended, mg/l	---	---	---	---	---	---	---	---
Dissolved Oxygen, mg/l	2.3	7	7.1	12.1	12.1	---	5.5	5.5
CO_2, mg/l	---	---	---	---	---	---	---	---
Turbidity, NTU	2.8	1.0	0.8	2.0	2.9	2.7	5.6	5.2
Aluminum, mg/l as Al	0	0	0	0	0	0	---	---
Nickel, mg/l as Ni	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	---	---
Data Source[a]	3	3	3	3	3	3	3	3

[a] 1 - USGS (1981)
2 - KNPC (1980, 1981)
3 - Present Study
4 - KDNREP (1981)
5 - KDNREP (unpublished data)

Table D-1 Cont. Water quality data from study region.

Parameter	Central City West Site 2 Cypress Creek at KY 81							
Date	06/20/81	06/20/81	07/23/81	07/23/81	09/18/81	09/18/81	02/27/82	02/27/82
Time	1215	1215	1045	1045	1500	1500	1640	1640
Streamflow, Instantaneous, cfs	---	---	---	---	---	---	---	---
Specific Conductance, micromhos/cm	---	---	2600	2600	2100	2300	1500	1500
pH	6.8	6.8	6.9	6.9	7.0	7.2	6.9	6.9
Temperature, °C	22	23	27	28	17	17	9	9
Hardness, mg/l as $CaCO_3$	---	---	---	---	---	---	---	---
Hardness, Noncarbonate, mg/l $CaCO_3$	---	---	---	---	---	---	---	---
Acidity, Total, mg/l	---	---	---	---	---	---	---	---
Calcium, Dissolved, mg/l as Ca	---	---	---	---	---	---	---	---
Magnesium, Dissolved, mg/l as Mg	85	84	114	133	106	120	82	78
Sodium, Dissolved, mg/l as Na	58.5	57.2	92.1	94	99.6	102	55.2	50
Potassium, Dissolved, mg/l as K	5.5	6.7	9.9	8.7	11.4	11.2	6	6.3
Alkalinity, mg/l as $CaCO_3$	---	---	---	---	---	---	---	---
Sulfate, Dissolved, mg/l as SO_4	---	---	685	695	809	809	574	543
Chloride, Dissolved, mg/l as Cl	---	---	---	---	---	---	---	---
Fluoride, Dissolved, mg/l as F	---	---	---	---	---	---	---	---
Solids, Residue at 180° C, Dissolved, mg/l	---	---	---	---	---	---	---	---
Nitrogen, NO_2+NO_3, mg/l as N	---	---	---	---	---	---	---	---
Phosphorus, Total, mg/l as P	---	---	---	---	---	---	---	---
Arsenic, Total, ug/l as As	---	---	---	---	---	---	---	---
Barium, Total Recoverable, ug/l as Ba	---	---	---	---	---	---	---	---
Cadmium, Total Recoverable, ug/l as Cd	---	---	---	---	---	---	---	---
Chromium, Total Recoverable, ug/l as Cr	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Copper, Total Recoverable, ug/l as Cu	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Cyanide, Total, mg/l as Cn	---	---	---	---	---	---	---	---
Iron, Total Recoverable, mg/l as Fe	---	---	---	---	---	---	---	---
Iron, Dissolved, mg/l as Fe	0.9	0.9	1.9	1.9	1.7	1.7	0.9	0.9
Lead, Total Recoverable, ug/l as Pb	---	---	---	---	---	---	---	---
Manganese, Total Recoverable, mg/l as Mn	---	---	---	---	---	---	---	---
Manganese, Dissolved, mg/l as Mn	4.0	4.0	1.2	2.3	0.7	0.8	0.9	0.9
Mercury, Total Recoverable, ug/l as Hg	---	---	---	---	---	---	---	---
Silver, Total Recoverable, ug/l as Ag	---	---	---	---	---	---	---	---
Zinc, Total Recoverable, ug/l as Zn	0	0	0	0	0	0	0	0
Silica, Dissolved, mg/l as SiO_2	---	---	---	---	---	---	---	---
Selenium, Total, ug/l as Se	---	---	---	---	---	---	---	---
Selenium, Dissolved, ug/l as Se	---	---	---	---	---	---	---	---
Sediment, Suspended, mg/l	---	---	---	---	---	---	---	---
Dissolved Oxygen, mg/l	6.7	6.7	5.2	5.0	8.0	8.0	12.5	12.5
CO_2, mg/l	---	---	---	---	---	---	---	---
Turbidity, NTU	1.3	1.3	0.8	0.9	0.4	0.5	0.6	0.9
Aluminum, mg/l as Al	0	0.1	0	0	0	0	0	0
Nickel, mg/l as Ni	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Data Source[a]	3	3	3	3	3	3	3	3

[a] 1 - USGS (1981)
2 - KNPC (1980, 1981)
3 - Present Study
4 - KDNREP (1981)
5 - KDNREP (unpublished data)

Table D-1 Cont. Water quality data from study region.

Parameter	Central City West: Site 2 Cont. Cypress Creek at KY 81			Central City West: Site 3 Little Cypress Creek at KY 70				
Date	03/25/82	06/03/82	06/03/82	03/27/80	05/08/80	06/12/80	08/17/80	09/12/80
Time	1145	1150	1150	1235	0910	---	1305	1140
Streamflow, Instantaneous, cfs	---	---	---	27	12	---	8.0	3.9
Specific Conductance, micromhos/cm	750	1300	1300	1900	3280	3343	4400	4750
pH	7.1	7.1	7.1	7.4	7.3	4.8	7.3	7.7
Temperature, °C	---	23	23	6.5	17.0	19	32.0	24.5
Hardness, mg/l as $CaCO_3$	---	---	---	---	---	---	1200	---
Hardness, Noncarbonate, mg/l $CaCO_3$	---	---	---	---	---	---	1100	---
Acidity, Total, mg/l	---	---	---	---	---	52	---	---
Calcium, Dissolved, mg/l as Ca	---	---	---	---	---	---	180	---
Magnesium, Dissolved, mg/l as Mg	56	---	---	---	---	---	170	---
Sodium, Dissolved, mg/l as Na	30.3	---	---	---	---	---	570	---
Potassium, Dissolved, mg/l as K	4.8	---	---	---	---	---	13	---
Alkalinity, mg/l as $CaCO_3$	---	---	---	22	210	0	94	326
Sulfate, Dissolved, mg/l as SO_4	553	439	439	1000	1900	1905	2300	2700
Chloride, Dissolved, mg/l as Cl	---	---	---	---	---	---	20	---
Fluoride, Dissolved, mg/l as F	---	---	---	---	---	---	0.5	---
Solids, Residue at 180° C, Dissolved, mg/l	---	---	---	1750	3030	---	4130	H930
Nitrogen, NO_2+NO_3, mg/l as N	---	---	---	---	---	---	4.1	---
Phosphorus, Total, mg/l as P	---	---	---	---	---	---	0.01	---
Arsenic, Total, ug/l as As	---	---	---	---	---	---	0	---
Barium, Total Recoverable, ug/l as Ba	---	---	---	---	---	---	100	---
Cadmium, Total Recoverable, ug/l as Cd	---	---	---	---	---	---	1	---
Chromium, Total Recoverable, ug/l as Cr	<0.1	---	---	---	---	---	20	---
Copper, Total Recoverable, ug/l as Cu	<0.1	---	---	---	---	---	2	---
Cyanide, Total, mg/l as Cn	---	---	---	---	---	---	0	---
Iron, Total Recoverable, mg/l as Fe	---	---	---	4.1	0.51	13.3	0.97	0.59
Iron, Dissolved, mg/l as Fe	0.21	0.39	0.42	3.0	0.09	---	0.07	0.06
Lead, Total Recoverable, ug/l as Pb	---	---	---	---	---	---	4	---
Manganese, Total Recoverable, mg/l as Mn	---	---	---	4.8	5.8	6.87	2.2	1.4
Manganese, Dissolved, mg/l as Mn	0.8	---	---	4.1	4.3	---	1.9	1.4
Mercury, Total Recoverable, ug/l as Hg	---	---	---	---	---	---	0.1	---
Silver, Total Recoverable, ug/l as Ag	---	---	---	---	---	---	0	---
Zinc, Total Recoverable, ug/l as Zn	0	0	0	---	---	---	40	---
Silica, Dissolved, mg/l as SiO_2	---	---	---	---	---	---	12	---
Selenium, Total, ug/l as Se	---	---	---	---	---	---	1	---
Selenium, Dissolved, ug/l as Se	---	---	---	---	---	---	---	---
Sediment, Suspended, mg/l	---	---	---	30	25	---	23	40
Dissolved Oxygen, mg/l	---	7.5	7.5	---	---	8.2	---	---
CO_2, mg/l	---	---	---	---	---	---	---	---
Turbidity, NTU	4.2	3.4	3.5	---	---	9.3	---	---
Aluminum, mg/l as Al	0	0	0	---	---	---	---	---
Nickel, mg/l as Ni	<0.1	<0.1	<0.1	---	---	---	---	---
Data Source[a]	3	3	3	1	1	4	1	1

[a] 1 - USGS (1981)
2 - KNPC (1980, 1981)
3 - Present Study
4 - KDNREP (1981)
5 - KDNREP (unpublished data)

Table D-1 Cont. Water quality data from study region.

Parameter	Central City West Site 3 Cont. Little Cypress Creek at KY 70						
Date	06/20/81	06/20/81	07/23/81	07/23/81	09/18/81	09/18/81	02/27/82
Time	1130	1130	----	----	----	----	----
Streamflow, Instantaneous, cfs	---	---	---	---	---	---	---
Specific Conductance, micromhos/cm	2400	2400	4500	4500	330	330	2800
pH	6.5	6.5	6.8	7.0	7.4	7.4	6.9
Temperature, °C	22	22	27	28	18	19	8.5
Hardness, mg/l as $CaCO_3$	---	---	---	---	---	---	---
Hardness, Noncarbonate, mg/l $CaCO_3$	---	---	---	---	---	---	---
Acidity, Total, mg/l	---	---	---	---	---	---	---
Calcium, Dissolved, mg/l as Ca	---	---	---	---	---	---	---
Magnesium, Dissolved, mg/l as Mg	102.0	99	141	155	118	117	128
Sodium, Dissolved, mg/l as Na	125.0	125.8	325.3	330.6	188.8	188.7	167.3
Potassium, Dissolved, mg/l as K	8.9	8.9	14.2	13.4	10.7	10.6	9.4
Alkalinity, mg/l as $CaCO_3$	---	---	---	---	---	---	---
Sulfate, Dissolved, mg/l as SO_4	---	---	482	482	789	790	726
Chloride, Dissolved, mg/l as Cl	---	---	---	---	---	---	---
Fluoride, Dissolved, mg/l as F	---	---	---	---	---	---	---
Solids, Residue at 180° C, Dissolved, mg/l	---	---	---	---	---	---	---
Nitrogen, NO_2+NO_3, mg/l as N	---	---	---	---	---	---	---
Phosphorus, Total, mg/l as P	---	---	---	---	---	---	---
Arsenic, Total, ug/l as As	---	---	---	---	---	---	---
Barium, Total Recoverable, ug/l as Ba	---	---	---	---	---	---	---
Cadmium, Total Recoverable, ug/l as Cd	---	---	---	---	---	---	---
Chromium, Total Recoverable, ug/l as Cr	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Copper, Total Recoverable, ug/l as Cu	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Cyanide, Total, mg/l as Cn	---	---	---	---	---	---	---
Iron, Total Recoverable, mg/l as Fe	---	---	---	---	---	---	---
Iron, Dissolved, mg/l as Fe	0.81	0.87	1.12	1.11	0.31	0.33	0.79
Lead, Total Recoverable, ug/l as Pb	---	---	---	---	---	---	---
Manganese, Total Recoverable, mg/l as Mn	---	---	---	---	---	---	---
Manganese, Dissolved, mg/l as Mn	4.3	4.3	3.0	3.1	3.5	3.5	4.3
Mercury, Total Recoverable, ug/l as Hg	---	---	---	---	---	---	---
Silver, Total Recoverable, ug/l as Ag	---	---	---	---	---	---	---
Zinc, Total Recoverable, ug/l as Zn	0.1	0	0	0	0.1	0.1	0.1
Silica, Dissolved, mg/l as SiO_2	---	---	---	---	---	---	---
Selenium, Total, ug/l as Se	---	---	---	---	---	---	---
Selenium, Dissolved, ug/l as Se	---	---	---	---	---	---	---
Sediment, Suspended, mg/l	---	---	---	---	---	---	---
Dissolved Oxygen, mg/l	7.5	7.5	8.3	8.3	10.0	10.0	11.5
CO_2, mg/l	---	---	---	---	---	---	---
Turbidity, NTU	10.0	10.0	0.4	0.5	4.4	4.5	10.0
Aluminum, mg/l as Al	2.8	2.7	0.7	0.8	0.8	1.1	1.9
Nickel, mg/l as Ni	0.11	0.13	<0.1	<0.1	<0.1	<0.1	0.11
Data Source[a]	3	3	3	3	3	3	3

[a] 1 - USGS (1981)
2 - KNPC (1980, 1981)
3 - Present Study
4 - KDNREP (1981)
5 - KDNREP (unpublished data)

Table D-1 Cont. Water quality data from study region.

Parameter	Central City West						
	Site 3 Cont. Little Cypress Creek at KY 70				Site 4 Cypress Creek near Central City at KY 70		
Date	02/27/82	03/25/82	06/03/82	06/03/82	03/27/80	05/08/80	07/17/80
Time	----	----	1300	1300	1100	1140	1050
Streamflow, Instantaneous, cfs	---	---	---	---	25	21	14
Specific Conductance, micromhos/cm	2800	1100	2230	2230	1600	2500	2350
pH	6.9	7.3	7.1	7.1	7.1	7.9	7.4
Temperature, °C	8.5	---	22.5	22.5	6.0	21.0	29.0
Hardness, mg/l as $CaCO_3$	---	---	---	---	---	---	1300
Hardness, Noncarbonate, mg/l $CaCO_3$	---	---	---	---	---	---	1300
Acidity, Total, mg/l	---	---	---	---	---	---	---
Calcium, Dissolved, mg/l as Ca	---	---	---	---	---	---	270
Magnesium, Dissolved, mg/l as Mg	119	97	---	---	---	---	160
Sodium, Dissolved, mg/l as Na	163.3	104.1	---	---	---	---	97
Potassium, Dissolved, mg/l as K	9.0	7.4	---	---	---	---	6.9
Alkalinity, mg/l as $CaCO_3$	---	---	---	---	114	88	76
Sulfate, Dissolved, mg/l as SO_4	748	822	640	640	930	1700	1400
Chloride, Dissolved, mg/l as Cl	---	---	---	---	---	---	15
Fluoride, Dissolved, mg/l as F	---	---	---	---	---	---	0.9
Solids, Residue at 180° C, Dissolved, mg/l	---	---	---	---	1400	2610	2310
Nitrogen, NO_2+NO_3, mg/l as N	---	---	---	---	---	---	0.07
Phosphorus, Total, mg/l as P	---	---	---	---	---	---	0.01
Arsenic, Total, ug/l as As	---	---	---	---	---	---	0
Barium, Total Recoverable, ug/l as Ba	---	---	---	---	---	---	100
Cadmium, Total Recoverable, ug/l as Cd	---	---	---	---	---	---	2
Chromium, Total Recoverable, ug/l as Cr	<0.1	<0.1	---	---	---	---	20
Copper, Total Recoverable, ug/l as Cu	<0.1	<0.1	---	---	---	---	2
Cyanide, Total, mg/l as Cn	---	---	---	---	---	---	0
Iron, Total Recoverable, mg/l as Fe	---	---	---	---	1.1	0.48	1.9
Iron, Dissolved, mg/l as Fe	0.79	0.59	0.7	0.7	0.85	0.08	0.05
Lead, Total Recoverable, ug/l as Pb	---	---	---	---	---	---	1
Manganese, Total Recoverable, mg/l as Mn	---	---	---	---	6.0	3.4	1.2
Manganese, Dissolved, mg/l as Mn	4.4	3.8	---	---	5.3	3.4	1.2
Mercury, Total Recoverable, ug/l as Hg	---	---	---	---	---	---	<0.1
Silver, Total Recoverable, ug/l as Ag	---	---	---	---	---	---	0
Zinc, Total Recoverable, ug/l as Zn	0.1	0	---	---	---	---	30
Silica, Dissolved, mg/l as SiO_2	---	---	---	---	---	---	1.3
Selenium, Total, ug/l as Se	---	---	---	---	---	---	0
Selenium, Dissolved, ug/l as Se	---	---	---	---	---	---	---
Sediment, Suspended, mg/l	---	---	---	---	5	5	23
Dissolved Oxygen, mg/l	11.5	---	11.8	11.8	---	---	---
CO_2, mg/l	---	---	---	---	---	---	---
Turbidity, NTU	10.0	9.9	5.2	5.8	---	---	---
Aluminum, mg/l as Al	2.0	1.5	---	---	---	---	---
Nickel, mg/l as Ni	0.11	<0.1	---	---	---	---	---
Data Source[a]	3	3	3	3	1	1	1

[a] 1 - USGS (1981)
2 - KNPC (1980, 1981)
3 - Present Study
4 - KDNREP (1981)
5 - KDNREP (unpublished data)

Table D-1 Cont. Water quality data from study region.

Parameter	Central City West Site 4 Cypress Creek near Central City at KY 70						
Date	09/12/80	06/20/81	06/20/81	07/23/81	07/23/81	09/18/81	09/18/81
Time	0930	1045	1045	----	----	----	----
Streamflow, Instantaneous, cfs	34	---	---	---	---	---	---
Specific Conductance, micromhos/cm	3380	2700	2800	2500	2500	2900	2900
pH	7.4	6.5	6.5	6.5	6.7	7.1	7.3
Temperature, °C	24.0	22	22	26	27	19	19
Hardness, mg/l as $CaCO_3$	---	---	---	---	---	---	---
Hardness, Noncarbonate, mg/l $CaCO_3$	---	---	---	---	---	---	---
Acidity, Total, mg/l	---	---	---	---	---	---	---
Calcium, Dissolved, mg/l as Ca	---	---	---	---	---	---	---
Magnesium, Dissolved, mg/l as Mg	---	145	135	133	131	154	132
Sodium, Dissolved, mg/l as Na	---	47.1	45.1	62.2	60.9	56.5	54.3
Potassium, Dissolved, mg/l as K	---	7.3	6.8	8.7	9.1	31.4	23.3
Alkalinity, mg/l as $CaCO_3$	82	---	---	---	---	---	---
Sulfate, Dissolved, mg/l as SO_4	2140	---	---	610	631	856	850
Chloride, Dissolved, mg/l as Cl	---	---	---	---	---	---	---
Fluoride, Dissolved, mg/l as F	---	---	---	---	---	---	---
Solids, Residue at 180° C, Dissolved, mg/l	3540	---	---	---	---	---	---
Nitrogen, NO_2+NO_3, mg/l as N	---	---	---	---	---	---	---
Phosphorus, Total, mg/l as P	---	---	---	---	---	---	---
Arsenic, Total, ug/l as As	---	---	---	---	---	---	---
Barium, Total Recoverable, ug/l as Ba	---	---	---	---	---	---	---
Cadmium, Total Recoverable, ug/l as Cd	---	---	---	---	---	---	---
Chromium, Total Recoverable, ug/l as Cr	---	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Copper, Total Recoverable, ug/l as Cu	---	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Cyanide, Total, mg/l as Cn	---	---	---	---	---	---	---
Iron, Total Recoverable, mg/l as Fe	0.51	---	---	---	---	---	---
Iron, Dissolved, mg/l as Fe	0.08	0.9	0.89	0.59	0.59	0.60	0.62
Lead, Total Recoverable, ug/l as Pb	---	---	---	---	---	---	---
Manganese, Total Recoverable, mg/l as Mn	0.18	---	---	---	---	---	---
Manganese, Dissolved, mg/l as Mn	0.17	5.4	4.9	1.2	1.2	2.5	2.3
Mercury, Total Recoverable, ug/l as Hg	---	---	---	---	---	---	---
Silver, Total Recoverable, ug/l as Ag	---	---	---	---	---	---	---
Zinc, Total Recoverable, ug/l as Zn	---	0	0	0	0	0	0
Silica, Dissolved, mg/l as SiO_2	---	---	---	---	---	---	---
Selenium, Total, ug/l as Se	---	---	---	---	---	---	---
Selenium, Dissolved, ug/l as Se	---	---	---	---	---	---	---
Sediment, Suspended, mg/l	18	---	---	---	---	---	---
Dissolved Oxygen, mg/l	---	6.7	6.7	6.2	6.2	11.5	11.3
CO_2, mg/l	---	---	---	---	---	---	---
Turbidity, NTU	---	1.0	1.0	1.3	1.3	1.2	1.2
Aluminum, mg/l as Al	---	0.2	0.2	0.6	0.7	0.7	0
Nickel, mg/l as Ni	---	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Data Source[a]	1	3	3	3	3	3	3

[a] 1 - USGS (1981)
2 - KNPC (1980, 1981)
3 - Present Study
4 - KDNREP (1981)
5 - KDNREP (unpublished data)

Table D-1 Cont. Water quality data from study region.

Parameter	Central City West Site 4 Cont. Cypress Creek near Central City at KY 70					
Date	02/27/82	02/27/82	03/25/82	06/03/82	06/03/82	07/14/82
Time	----	----	----	1325	1325	1000
Streamflow, Instantaneous, cfs	---	---	---	---	---	---
Specific Conductance, micromhos/cm	2000	2000	1000	1950	1950	2284
pH	7.2	7.2	7.3	7.1	7.1	7.0
Temperature, °C	8	8	---	26	26	---
Hardness, mg/l as $CaCO_3$	---	---	---	---	---	1386
Hardness, Noncarbonate, mg/l $CaCO_3$	---	---	---	---	---	---
Acidity, Total, mg/l	---	---	---	---	---	16
Calcium, Dissolved, mg/l as Ca	---	---	---	---	---	270
Magnesium, Dissolved, mg/l as Mg	112	103	79	---	---	139
Sodium, Dissolved, mg/l as Na	43.6	41.1	31.3	---	---	57.5
Potassium, Dissolved, mg/l as K	9.7	5.7	4.7	---	---	6.80
Alkalinity, mg/l as $CaCO_3$	---	---	---	---	---	43.4
Sulfate, Dissolved, mg/l as SO_4	770	748	699	580	590	1425
Chloride, Dissolved, mg/l as Cl	---	---	---	---	---	18.5
Fluoride, Dissolved, mg/l as F	---	---	---	---	---	0.6
Solids, Residue at 180° C, Dissolved, mg/l	---	---	---	---	---	2086
Nitrogen, NO_2+NO_3, mg/l as N	---	---	---	---	---	0.27
Phosphorus, Total, mg/l as P	---	---	---	---	---	0.034
Arsenic, Total, ug/l as As	---	---	---	---	---	---
Barium, Total Recoverable, ug/l as Ba	---	---	---	---	---	37
Cadmium, Total Recoverable, ug/l as Cd	---	---	---	---	---	3
Chromium, Total Recoverable, ug/l as Cr	<0.1	<0.1	<0.1	---	---	4
Copper, Total Recoverable, ug/l as Cu	<0.1	<0.1	<0.1	---	---	22
Cyanide, Total, mg/l as Cn	---	---	---	---	---	0.032
Iron, Total Recoverable, mg/l as Fe	---	---	---	---	---	0.784
Iron, Dissolved, mg/l as Fe	0.57	0.56	0.41	0.5	0.5	0.520
Lead, Total Recoverable, ug/l as Pb	---	---	---	---	---	42
Manganese, Total Recoverable, mg/l as Mn	---	---	---	---	---	1.470
Manganese, Dissolved, mg/l as Mn	6.9	6.4	5.3	---	---	0.318
Mercury, Total Recoverable, ug/l as Hg	---	---	---	---	---	0.2
Silver, Total Recoverable, ug/l as Ag	---	---	---	---	---	5
Zinc, Total Recoverable, ug/l as Zn	0.1	0.1	0.1	---	---	21
Silica, Dissolved, mg/l as SiO_2	---	---	---	---	---	---
Selenium, Total, ug/l as Se	---	---	---	---	---	13
Selenium, Dissolved, ug/l as Se	---	---	---	---	---	12
Sediment, Suspended, mg/l	---	---	---	---	---	5
Dissolved Oxygen, mg/l	11.5	11.5	---	12.8	12.8	---
CO_2, mg/l	---	---	---	---	---	---
Turbidity, NTU	1.0	1.2	1.8	3.1	3.1	2.9
Aluminum, mg/l as Al	0.1	0	0	---	---	0.152
Nickel, mg/l as Ni	0.13	0.13	<0.1	---	---	0.034
Data Source[a]	3	3	3	3	3	5

[a] 1 - USGS (1981)
2 - KNPC (1980, 1981)
3 - Present Study
4 - KDNREP (1981)
5 - KDNREP (unpublished data)

Table D-1 Cont. Water quality data from study region.

Parameter	Greenville Site I Caney Creek	Equality Site I Rough River	Central City East Site I Pond Creek near Mortwick			
Date	07/14/82	08/26/80	03/24/80	05/05/80	07/14/80	09/15/80
Time	1100	----	1320	1155	1130	0830
Streamflow, Instantaneous, cfs	---	---	626	47	18	6.9
Specific Conductance, micromhos/cm	788	209	815	2020	2350	4460
pH	7.0	7.5	6.1	6.7	7.3	7.3
Temperature, °C	---	28	10	19.5	28.5	21.0
Hardness, mg/l as $CaCO_3$	280	105	---	---	1100	---
Hardness, Noncarbonate, mg/l $CaCO_3$	---	---	---	---	1100	---
Acidity, Total, mg/l	33	---	---	---	---	---
Calcium, Dissolved, mg/l as Ca	85	---	---	---	210	---
Magnesium, Dissolved, mg/l as Mg	17.8	---	---	---	150	---
Sodium, Dissolved, mg/l as Na	35	---	---	---	150	---
Potassium, Dissolved, mg/l as K	10.1	---	---	---	7.5	---
Alkalinity, mg/l as $CaCO_3$	89	108	11	44	82	141
Sulfate, Dissolved, mg/l as SO_4	331	20	370	1100	1400	2060
Chloride, Dissolved, mg/l as Cl	43.5	0	---	---	9.8	---
Fluoride, Dissolved, mg/l as F	.65	---	---	---	0.5	---
Solids, Residue at 180° C, Dissolved, mg/l	540	---	581	1770	2370	4520
Nitrogen, NO_2+NO_3, mg/l as N	0.09	---	---	---	0.43	---
Phosphorus, Total, mg/l as P	1.27	---	---	---	0.02	---
Arsenic, Total, ug/l as As	---	---	---	---	1	---
Barium, Total Recoverable, ug/l as Ba	94	---	---	---	<50	---
Cadmium, Total Recoverable, ug/l as Cd	1	---	---	---	1	---
Chromium, Total Recoverable, ug/l as Cr	2	---	---	---	20	---
Copper, Total Recoverable, ug/l as Cu	10	---	---	---	3	---
Cyanide, Total, mg/l as Cn	<0.01	---	---	---	0	---
Iron, Total Recoverable, mg/l as Fe	3.32	---	6.1	7.5	3.8	0.92
Iron, Dissolved, mg/l as Fe	.095	---	5.6	5.8	0.06	0.1
Lead, Total Recoverable, ug/l as Pb	17	---	---	---	4	---
Manganese, Total Recoverable, mg/l as Mn	17.8	---	2.6	4.8	4.9	5.1
Manganese, Dissolved, mg/l as Mn	2.2	---	2.5	4.8	---	5.1
Mercury, Total Recoverable, ug/l as Hg	0.2	---	---	---	0.7	---
Silver, Total Recoverable, ug/l as Ag	1	---	---	---	0	---
Zinc, Total Recoverable, ug/l as Zn	48	---	---	---	100	---
Silica, Dissolved, mg/l as SiO_2	---	---	---	---	13	---
Selenium, Total, ug/l as Se	3	---	---	---	0	---
Selenium, Dissolved, ug/l as Se	---	---	---	---	---	---
Sediment, Suspended, mg/l	22	100	55	32	561	6
Dissolved Oxygen, mg/l	---	5.2	---	---	---	---
CO_2, mg/l	---	7.5	---	---	---	---
Turbidity, NTU	6.2	67	---	---	---	---
Aluminum, mg/l as Al	1.055	---	---	---	---	---
Nickel, mg/l as Ni	0.047	---	---	---	---	---
Data Source[a]	5	2	1	1	1	1

[a] 1 - USGS (1981)
2 - KNPC (1980, 1981)
3 - Present Study
4 - KDNREP (1981)
5 - KDNREP (unpublished data)

Table D-1 Cont. Water quality data from study region.

Parameter	Central City East Site 2 Old Channel Pond Creek	Drakesboro Site 1 Pond Creek	Hartford Site 2 Muddy Creek	Hartford Site 3 Rock House Slough	Paradise Site 1 Green River	
Date	09/24/80	07/14/82	09/25/80	09/25/80	10/23/79	12/06/79
Time	----	1200	----	----	1230	1430
Streamflow, Instantaneous, cfs	---	---	---	---	17800	20200
Specific Conductance, micromhos/cm	3248	936	544	210	230	230
pH	7.5	3.6	7.5	6.5	---	---
Temperature, °C	20	---	20	19	17.5	8.5
Hardness, mg/l as $CaCO_3$	1500	471	---	---	---	---
Hardness, Noncarbonate, mg/l $CaCO_3$	---	---	---	---	---	---
Acidity, Total, mg/l	---	72.4	---	---	---	---
Calcium, Dissolved, mg/l as Ca	---	95	---	---	---	---
Magnesium, Dissolved, mg/l as Mg	---	56	---	---	---	---
Sodium, Dissolved, mg/l as Na	---	15	---	---	---	---
Potassium, Dissolved, mg/l as K	---	4.3	---	---	---	---
Alkalinity, mg/l as $CaCO_3$	136	0	164	84	---	---
Sulfate, Dissolved, mg/l as SO_4	1200	654	20	0	---	---
Chloride, Dissolved, mg/l as Cl	0	8.4	50	0	---	---
Fluoride, Dissolved, mg/l as F	---	0.4	---	---	---	---
Solids, Residue at 180° C, Dissolved, mg/l	---	904	---	---	---	---
Nitrogen, NO_2+NO_3, mg/l as N	---	0.665	---	---	---	---
Phosphorus, Total, mg/l as P	---	0.046	---	---	---	---
Arsenic, Total, ug/l as As	---	---	---	---	---	---
Barium, Total Recoverable, ug/l as Ba	---	125	---	---	---	---
Cadmium, Total Recoverable, ug/l as Cd	---	4	---	---	---	---
Chromium, Total Recoverable, ug/l as Cr	---	2	---	---	---	---
Copper, Total Recoverable, ug/l as Cu	---	4	---	---	---	---
Cyanide, Total, mg/l as Cn	---	<0.01	---	---	---	---
Iron, Total Recoverable, mg/l as Fe	---	7.96	---	---	---	---
Iron, Dissolved, mg/l as Fe	---	6.30	---	---	---	---
Lead, Total Recoverable, ug/l as Pb	---	33	---	---	---	---
Manganese, Total Recoverable, mg/l as Mn	---	5.68	---	---	---	---
Manganese, Dissolved, mg/l as Mn	---	5.67	---	---	---	---
Mercury, Total Recoverable, ug/l as Hg	---	0.2	---	---	---	---
Silver, Total Recoverable, ug/l as Ag	---	3	---	---	---	---
Zinc, Total Recoverable, ug/l as Zn	---	276	---	---	---	---
Silica, Dissolved, mg/l as SiO_2	---	---	---	---	---	---
Selenium, Total, ug/l as Se	---	---	---	---	---	---
Selenium, Dissolved, ug/l as Se	---	30	---	---	---	---
Sediment, Suspended, mg/l	0	16	18	0	---	---
Dissolved Oxygen, mg/l	1.2	---	1.5	1.2	---	---
CO_2, mg/l	17.5	---	15.0	17.5	---	---
Turbidity, NTU	24	17	28	24	---	---
Aluminum, mg/l as Al	---	4.685	---	---	---	---
Nickel, mg/l as Ni	---	0.129	---	---	---	---
Data Source[a]	2	5	2	2	1	1

[a] 1 - USGS (1981)
2 - KNPC (1980, 1981)
3 - Present Study
4 - KDNREP (1981)
5 - KDNREP (unpublished data)

Table D-1 Cont. Water quality data from study region.

Parameter	Paradise Site 1 Cont. Green River at Paradise						
Date	12/12/79	01/17/80	02/26/80	04/09/80	06/04/80	07/30/80	09/27/80
Time	1610	1305	1330	1000	1100	1030	0945
Streamflow, Instantaneous, cfs	78100	14100	11100	9520	5390	3640	906
Specific Conductance, micromhos/cm	150	280	280	280	290	330	430
pH	---	---	---	---	---	---	---
Temperature, °C	8.0	7.0	8.5	14.0	23.5	31.0	28.5
Hardness, mg/l as $CaCO_3$	---	---	---	---	---	---	---
Hardness, Noncarbonate, mg/l $CaCO_3$	---	---	---	---	---	---	---
Acidity, Total, mg/l	---	---	---	---	---	---	---
Calcium, Dissolved, mg/l as Ca	---	---	---	---	---	---	---
Magnesium, Dissolved, mg/l as Mg	---	---	---	---	---	---	---
Sodium, Dissolved, mg/l as Na	---	---	---	---	---	---	---
Potassium, Dissolved, mg/l as K	---	---	---	---	---	---	---
Alkalinity, mg/l as $CaCO_3$	---	---	---	---	---	---	---
Sulfate, Dissolved, mg/l as SO_4	---	---	---	---	---	---	---
Chloride, Dissolved, mg/l as Cl	---	---	---	---	---	---	---
Fluoride, Dissolved, mg/l as F	---	---	---	---	---	---	---
Solids, Residue at 180° C, Dissolved, mg/l	---	---	---	---	---	---	---
Nitrogen, NO_2+NO_3, mg/l as N	---	---	---	---	---	---	---
Phosphorus, Total, mg/l as P	---	---	---	---	---	---	---
Arsenic, Total, ug/l as As	---	---	---	---	---	---	---
Barium, Total Recoverable, ug/l as Ba	---	---	---	---	---	---	---
Cadmium, Total Recoverable, ug/l as Cd	---	---	---	---	---	---	---
Chromium, Total Recoverable, ug/l as Cr	---	---	---	---	---	---	---
Copper, Total Recoverable, ug/l as Cu	---	---	---	---	---	---	---
Cyanide, Total, mg/l as Cn	---	---	---	---	---	---	---
Iron, Total Recoverable, mg/l as Fe	---	---	---	---	---	---	---
Iron, Dissolved, mg/l as Fe	---	---	---	---	---	---	---
Lead, Total Recoverable, ug/l as Pb	---	---	---	---	---	---	---
Manganese, Total Recoverable, mg/l as Mn	---	---	---	---	---	---	---
Manganese, Dissolved, mg/l as Mn	---	---	---	---	---	---	---
Mercury, Total Recoverable, ug/l as Hg	---	---	---	---	---	---	---
Silver, Total Recoverable, ug/l as Ag	---	---	---	---	---	---	---
Zinc, Total Recoverable, ug/l as Zn	---	---	---	---	---	---	---
Silica, Dissolved, mg/l as SiO_2	---	---	---	---	---	---	---
Selenium, Total, ug/l as Se	---	---	---	---	---	---	---
Selenium, Dissolved, ug/l as Se	---	---	---	---	---	---	---
Sediment, Suspended, mg/l	---	---	---	---	---	---	---
Dissolved Oxygen, mg/l	---	---	---	---	---	---	---
CO_2, mg/l	---	---	---	---	---	---	---
Turbidity, NTU	---	---	---	---	---	---	---
Aluminum, mg/l as Al	---	---	---	---	---	---	---
Nickel, mg/l as Ni	---	---	---	---	---	---	---
Data Source[a]	1	1	1	1	1	1	1

[a] 1 - USGS (1981)
2 - KNPC (1980, 1981)
3 - Present Study
4 - KDNREP (1981)
5 - KDNREP (unpublished data)

Table D-1 Cont. Water quality data from study region.

Parameter	Paradise				Rochester			
	Site 2				Site 1			
	Lewis Creek at Rockport				Mud River near Huntsville			
Date	03/24/80	05/05/80	07/14/80	09/15/80	10/25/79	12/06/79	01/17/80	02/29/80
Time	1655	1440	1505	1015	1415	1210	1430	1110
Streamflow, Instantaneous, cfs	119	18	5.8	0.37	160	307	364	183
Specific Conductance, micromhos/cm	865	2250	2700	3120	420	296	307	310
pH	5.4	6.6	4.8	7.0	7.5	7.0	7.6	7.6
Temperature, °C	10.0	20.0	27.5	21.5	15.0	5.5	9.5	5.0
Hardness, mg/l as $CaCO_3$	---	---	1300	---	---	---	---	---
Hardness, Noncarbonate, mg/l $CaCO_3$	---	---	1300	---	---	---	---	---
Acidity, Total, mg/l	---	---	0.3	---	---	---	---	---
Calcium, Dissolved, mg/l as Ca	---	---	270	---	---	---	---	---
Magnesium, Dissolved, mg/l as Mg	---	---	140	---	---	---	---	---
Sodium, Dissolved, mg/l as Na	---	---	120	---	---	---	---	---
Potassium, Dissolved, mg/l as K	---	---	8.8	---	---	---	---	---
Alkalinity, mg/l as $CaCO_3$	3	20	0	---	154	102	94	---
Sulfate, Dissolved, mg/l as SO_4	450	1300	1600	1500	24	21	27	32
Chloride, Dissolved, mg/l as Cl	---	---	4.1	---	---	---	---	---
Fluoride, Dissolved, mg/l as F	---	---	0.4	---	---	---	---	---
Solids, Residue at 180° C, Dissolved, mg/l	710	2040	2540	3240	249	185	201	194
Nitrogen, NO_2+NO_3, mg/l as N	---	---	0.21	---	---	---	---	---
Phosphorus, Total, mg/l as P	---	---	0.01	---	---	---	---	---
Arsenic, Total, ug/l as As	---	---	0	---	---	---	---	---
Barium, Total Recoverable, ug/l as Ba	---	---	<50	---	---	---	---	---
Cadmium, Total Recoverable, ug/l as Cd	---	---	1	---	---	---	---	---
Chromium, Total Recoverable, ug/l as Cr	---	---	10	---	---	---	---	---
Copper, Total Recoverable, ug/l as Cu	---	---	4	---	---	---	---	---
Cyanide, Total, mg/l as Cn	---	---	0	---	---	---	---	---
Iron, Total Recoverable, mg/l as Fe	1.4	1.2	1.1	2.3	1.0	0.75	1.3	0.63
Iron, Dissolved, mg/l as Fe	0.47	0.72	0.3	0.05	0.19	0.03	0.14	0.02
Lead, Total Recoverable, ug/l as Pb	---	---	1	---	---	---	---	---
Manganese, Total Recoverable, mg/l as Mn	4.6	6.8	---	4.8	0.32	0.1	0.12	0.09
Manganese, Dissolved, mg/l as Mn	4.4	6.8	8.6	4.8	0.27	0.08	0.04	0.07
Mercury, Total Recoverable, ug/l as Hg	---	---	0.5	---	---	---	---	---
Silver, Total Recoverable, ug/l as Ag	---	---	0	---	---	---	---	---
Zinc, Total Recoverable, ug/l as Zn	---	---	190	---	---	---	---	---
Silica, Dissolved, mg/l as SiO_2	---	---	20	---	---	---	---	---
Selenium, Total, ug/l as Se	---	---	0	---	---	---	---	---
Selenium, Dissolved, ug/l as Se	---	---	---	---	---	---	---	---
Sediment, Suspended, mg/l	108	26	5	9	35	12	51	22
Dissolved Oxygen, mg/l	---	---	---	---	---	---	---	---
CO_2, mg/l	---	---	---	---	---	---	---	---
Turbidity, NTU	---	---	---	---	---	---	---	---
Aluminum, mg/l as Al	---	---	---	---	---	---	---	---
Nickel, mg/l as Ni	---	---	---	---	---	---	---	---
Data Source[a]	1	1	1	1	1	1	1	1

[a] 1 - USGS (1981)
2 - KNPC (1980, 1981)
3 - Present Study
4 - KDNREP (1981)
5 - KDNREP (unpublished data)

Table D-1 Cont. Water quality data from study region.

Parameter	Rochester							
	Site 1 Cont. Mud River near Huntsville					Site 2 Rocky Creek near Penrod		
Date	04/11/80	06/04/80	07/30/80	08/27/80	09/22/80	03/25/80	05/09/80	07/15/80
Time	0805	1340	1045	1310	----	1520	1030	1400
Streamflow, Instantaneous, cfs	368	334	46	5.6	---	157	12	2.8
Specific Conductance, micromhos/cm	230	295	300	380	336	95	107	125
pH	7.7	7.9	7.2	7.3	7.0	6.4	6.8	6.9
Temperature, °C	14	19.5	25.5	25	24	8.0	14.0	27.5
Hardness, mg/l as $CaCO_3$	---	---	130	---	120	---	---	46
Hardness, Noncarbonate, mg/l $CaCO_3$	---	---	24	---	---	---	---	5
Acidity, Total, mg/l	---	---	---	---	---	---	---	0.2
Calcium, Dissolved, mg/l as Ca	---	---	43	---	---	---	---	12
Magnesium, Dissolved, mg/l as Mg	---	---	4.6	---	---	---	---	3.9
Sodium, Dissolved, mg/l as Na	---	---	11	---	---	---	---	3
Potassium, Dissolved, mg/l as K	---	---	4	---	---	---	---	2
Alkalinity, mg/l as $CaCO_3$	86	100	102	106	132	13	20	41
Sulfate, Dissolved, mg/l as SO_4	27	22	16	41	<10	20	20	13
Chloride, Dissolved, mg/l as Cl	---	---	17	---	50	---	---	3.9
Fluoride, Dissolved, mg/l as F	---	---	0.2	---	---	---	---	0.1
Solids, Residue at 180° C, Dissolved, mg/l	174	187	176	300	---	60	72	85
Nitrogen, NO_2+NO_3, mg/l as N	---	---	0.98	---	---	---	---	0.53
Phosphorus, Total, mg/l as P	---	---	0.16	---	---	---	---	0.05
Arsenic, Total, ug/l as As	---	---	1	---	---	---	---	2
Barium, Total Recoverable, ug/l as Ba	---	---	100	---	---	---	---	100
Cadmium, Total Recoverable, ug/l as Cd	---	---	3	---	---	---	---	0
Chromium, Total Recoverable, ug/l as Cr	---	---	30	---	---	---	---	10
Copper, Total Recoverable, ug/l as Cu	---	---	4	---	---	---	---	1
Cyanide, Total, mg/l as Cn	---	---	0	---	---	---	---	0
Iron, Total Recoverable, mg/l as Fe	0.65	3.9	2.4	1.3	---	0.84	0.98	0.99
Iron, Dissolved, mg/l as Fe	0.03	0.03	0.32	0.04	---	0.12	0.06	0.02
Lead, Total Recoverable, ug/l as Pb	---	---	14	---	---	---	---	1
Manganese, Total Recoverable, mg/l as Mn	0.11	0.3	0.36	0.5	---	0.14	0.37	2.10
Manganese, Dissolved, mg/l as Mn	0.03	0.01	0.23	0.42	---	0.11	0.35	2.10
Mercury, Total Recoverable, ug/l as Hg	---	---	0.6	---	---	---	---	0.2
Silver, Total Recoverable, ug/l as Ag	---	---	0	---	---	---	---	0
Zinc, Total Recoverable, ug/l as Zn	---	---	20	---	---	---	---	10
Silica, Dissolved, mg/l as SiO_2	---	---	6.5	---	---	---	---	3.3
Selenium, Total, ug/l as Se	---	---	0	---	---	---	---	0
Selenium, Dissolved, ug/l as Se	---	---	---	---	---	---	---	---
Sediment, Suspended, mg/l	---	133	95	44	0	41	15	12
Dissolved Oxygen, mg/l	---	---	---	---	3.9	---	---	---
CO_2, mg/l	---	---	---	---	10	---	---	---
Turbidity, NTU	---	---	---	---	18	---	---	---
Aluminum, mg/l as Al	---	---	---	---	---	---	---	---
Nickel, mg/l as Ni	---	---	---	---	---	---	---	---
Data Source[a]	1	1	1	1	2	1	1	1

[a] 1 - USGS (1981)
2 - KNPC (1980, 1981)
3 - Present Study
4 - KDNREP (1981)
5 - KDNREP (unpublished data)

Table D-1 Cont. Water quality data from study region.

Parameter	Rochester Site 2 Cont. Rocky Creek	Horton Site 1 Muddy Creek near Beaver Dam				Horton Site 3 Threelick Creek	
Date	09/24/80	03/24/80	05/05/80	07/14/80	09/09/80	03/24/80	05/05/80
Time	----	1235	1315	1315	----	1350	1120
Streamflow, Instantaneous, cfs	---	256	15	2.4	0	54	3.4
Specific Conductance, micromhos/cm	487	160	280	533	---	140	150
pH	6.0	6.2	6.9	7.2	---	6.5	8.0
Temperature, °C	20	10	17	26	---	6.0	18
Hardness, mg/l as $CaCO_3$	8	---	---	230	---	---	---
Hardness, Noncarbonate, mg/l $CaCO_3$	---	---	---	190	---	---	---
Acidity, Total, mg/l	---	---	---	---	---	---	---
Calcium, Dissolved, mg/l as Ca	---	---	---	56	---	---	---
Magnesium, Dissolved, mg/l as Mg	---	---	---	21	---	---	---
Sodium, Dissolved, mg/l as Na	---	---	---	13	---	---	---
Potassium, Dissolved, mg/l as K	---	---	---	4.8	---	---	---
Alkalinity, mg/l as $CaCO_3$	36	10	14	34	---	22	43
Sulfate, Dissolved, mg/l as SO_4	100	53	110	190	---	26	24
Chloride, Dissolved, mg/l as Cl	0	---	---	2.6	---	---	---
Fluoride, Dissolved, mg/l as F	---	---	---	0.2	---	---	---
Solids, Residue at 180° C, Dissolved, mg/l	---	105	177	373	---	94	83
Nitrogen, NO_2+NO_3, mg/l as N	---	---	---	9.0	---	---	---
Phosphorus, Total, mg/l as P	---	---	---	0.01	---	---	---
Arsenic, Total, ug/l as As	---	---	---	0	---	---	---
Barium, Total Recoverable, ug/l as Ba	---	---	---	100	---	---	---
Cadmium, Total Recoverable, ug/l as Cd	---	---	---	0	---	---	---
Chromium, Total Recoverable, ug/l as Cr	---	---	---	10	---	---	---
Copper, Total Recoverable, ug/l as Cu	---	---	---	62	---	---	---
Cyanide, Total, mg/l as Cn	---	---	---	0	---	---	---
Iron, Total Recoverable, mg/l as Fe	---	2.8	0.45	0.48	---	2.3	0.59
Iron, Dissolved, mg/l as Fe	---	0.09	0.07	0.01	---	0.15	0.05
Lead, Total Recoverable, ug/l as Pb	---	---	---	1	---	---	---
Manganese, Total Recoverable, mg/l as Mn	---	1.1	2.4	0.87	---	0.19	0.08
Manganese, Dissolved, mg/l as Mn	---	0.95	2.4	0.87	---	0.14	0.08
Mercury, Total Recoverable, ug/l as Hg	---	---	---	0.2	---	---	---
Silver, Total Recoverable, ug/l as Ag	---	---	---	0	---	---	---
Zinc, Total Recoverable, ug/l as Zn	---	---	---	30	---	---	---
Silica, Dissolved, mg/l as SiO_2	---	---	---	9.3	---	---	---
Selenium, Total, ug/l as Se	---	---	---	4	---	---	---
Selenium, Dissolved, ug/l as Se	---	---	---	---	---	---	---
Sediment, Suspended, mg/l	0	110	6	9	3	102	7
Dissolved Oxygen, mg/l	4.2	---	---	---	---	---	---
CO_2, mg/l	22.5	---	---	---	---	---	---
Turbidity, NTU	8	---	---	---	---	---	---
Aluminum, mg/l as Al	---	---	---	---	---	---	---
Nickel, mg/l as Ni	---	---	---	---	---	---	---
Data Source[a]	2	1	1	1	1	1	1

[a] 1 - USGS (1981)
2 - KNPC (1980, 1981)
3 - Present Study
4 - KDNREP (1981)
5 - KDNREP (unpublished data)

Table D-1 Cont. Water quality data from study region.

Parameter	Horton Site 3 Cont. Threelick Creek		Cromwell Site 1 Green River at Lock 4 at Woodbury					
Date	07/14/80	09/09/80	10/25/79	12/06/79	01/14/80	02/28/80	04/17/80	06/02/80
Time	1200	1115	1100	1015	1400	1030	1330	1515
Streamflow, Instantaneous, cfs	0.32	0.09	13300	19800	14800	7220	9310	6340
Specific Conductance, micromhos/cm	210	195	220	200	260	270	280	230
pH	7.7	7.5	---	---	---	---	---	---
Temperature, °C	27	24	16.0	8.0	7.5	6.0	12.5	19.5
Hardness, mg/l as $CaCO_3$	68	---	---	---	---	---	---	---
Hardness, Noncarbonate, mg/l $CaCO_3$	18	---	---	---	---	---	---	---
Acidity, Total, mg/l	---	---	---	---	---	---	---	---
Calcium, Dissolved, mg/l as Ca	19	---	---	---	---	---	---	---
Magnesium, Dissolved, mg/l as Mg	4.9	---	---	---	---	---	---	---
Sodium, Dissolved, mg/l as Na	8.7	---	---	---	---	---	---	---
Potassium, Dissolved, mg/l as K	3.0	---	---	---	---	---	---	---
Alkalinity, mg/l as $CaCO_3$	50	60	---	---	---	---	---	---
Sulfate, Dissolved, mg/l as SO_4	24	15	---	---	---	---	---	---
Chloride, Dissolved, mg/l as Cl	7.5	---	---	---	---	---	---	---
Fluoride, Dissolved, mg/l as F	0.2	---	---	---	---	---	---	---
Solids, Residue at 180° C, Dissolved, mg/l	123	114	---	---	---	---	---	---
Nitrogen, NO_2+NO_3, mg/l as N	0.34	---	---	---	---	---	---	---
Phosphorus, Total, mg/l as P	0.03	---	---	---	---	---	---	---
Arsenic, Total, ug/l as As	1	---	---	---	---	---	---	---
Barium, Total Recoverable, ug/l as Ba	100	---	---	---	---	---	---	---
Cadmium, Total Recoverable, ug/l as Cd	0	---	---	---	---	---	---	---
Chromium, Total Recoverable, ug/l as Cr	10	---	---	---	---	---	---	---
Copper, Total Recoverable, ug/l as Cu	2	---	---	---	---	---	---	---
Cyanide, Total, mg/l as Cn	0	---	---	---	---	---	---	---
Iron, Total Recoverable, mg/l as Fe	0.33	0.22	---	---	---	---	---	---
Iron, Dissolved, mg/l as Fe	0.11	0.06	---	---	---	---	---	---
Lead, Total Recoverable, ug/l as Pb	1	---	---	---	---	---	---	---
Manganese, Total Recoverable, mg/l as Mn	0.17	0.16	---	---	---	---	---	---
Manganese, Dissolved, mg/l as Mn	0.17	0.13	---	---	---	---	---	---
Mercury, Total Recoverable, ug/l as Hg	0.3	---	---	---	---	---	---	---
Silver, Total Recoverable, ug/l as Ag	0	---	---	---	---	---	---	---
Zinc, Total Recoverable, ug/l as Zn	10	---	---	---	---	---	---	---
Silica, Dissolved, mg/l as SiO_2	8.6	---	---	---	---	---	---	---
Selenium, Total, ug/l as Se	0	---	---	---	---	---	---	---
Selenium, Dissolved, ug/l as Se	---	---	---	---	---	---	---	---
Sediment, Suspended, mg/l	6	3	---	---	---	---	---	---
Dissolved Oxygen, mg/l	---	---	---	---	---	---	---	---
CO_2, mg/l	---	---	---	---	---	---	---	---
Turbidity, NTU	---	---	---	---	---	---	---	---
Aluminum, mg/l as Al	---	---	---	---	---	---	---	---
Nickel, mg/l as Ni	---	---	---	---	---	---	---	---
Data Source[a]	1	1	1	1	1	1	1	1

[a] 1 - USGS (1981)
2 - KNPC (1980, 1981)
3 - Present Study
4 - KDNREP (1981)
5 - KDNREP (unpublished data)

Table II-1 Cont. Water quality data from study region.

Parameter	Cromwell Site I Cont. Green River		South Hill Site I Muddy Creek at Dunbar				
Date	07/28/80	08/25/80	03/25/80	05/08/80	07/15/80	09/16/80	10/01/80
Time	1200	1300	----	----	----	----	----
Streamflow, Instantaneous, cfs	5390	809	275	19	13	0.73	---
Specific Conductance, micromhos/cm	260	310	215	310	200	327	234
pH	---	---	7.2	8.0	7.6	7.4	7.5
Temperature, °C	21.0	26.0	8.5	17.0	26.5	22.0	17.0
Hardness, mg/l as $CaCO_3$	---	---	---	---	83	---	110
Hardness, Noncarbonate, mg/l $CaCO_3$	---	---	---	---	9	---	---
Acidity, Total, mg/l	---	---	---	---	---	---	---
Calcium, Dissolved, mg/l as Ca	---	---	---	---	28	---	---
Magnesium, Dissolved, mg/l as Mg	---	---	---	---	3.2	---	---
Sodium, Dissolved, mg/l as Na	---	---	---	---	3.1	---	---
Potassium, Dissolved, mg/l as K	---	---	---	---	2.3	---	---
Alkalinity, mg/l as $CaCO_3$	---	---	71	120	74	104	108
Sulfate, Dissolved, mg/l as SO_4	---	---	25	33	17	55	10
Chloride, Dissolved, mg/l as Cl	---	---	---	---	4.8	---	0
Fluoride, Dissolved, mg/l as F	---	---	---	---	0.2	---	---
Solids, Residue at 180° C, Dissolved, mg/l	---	---	140	190	113	106	---
Nitrogen, NO_2+NO_3, mg/l as N	---	---	---	---	0.52	---	---
Phosphorus, Total, mg/l as P	---	---	---	---	0.07	---	---
Arsenic, Total, ug/l as As	---	---	---	---	0	---	---
Barium, Total Recoverable, ug/l as Ba	---	---	---	---	<50	---	---
Cadmium, Total Recoverable, ug/l as Cd	---	---	---	---	0	---	---
Chromium, Total Recoverable, ug/l as Cr	---	---	---	---	10	---	---
Copper, Total Recoverable, ug/l as Cu	---	---	---	---	4	---	---
Cyanide, Total, mg/l as Cn	---	---	---	---	0	---	---
Iron, Total Recoverable, mg/l as Fe	---	---	2.6	0.75	2.4	0.53	---
Iron, Dissolved, mg/l as Fe	---	---	0.05	0.06	0.01	0.03	---
Lead, Total Recoverable, ug/l as Pb	---	---	---	---	4	---	---
Manganese, Total Recoverable, mg/l as Mn	---	---	0.18	0.15	0.21	0.13	---
Manganese, Dissolved, mg/l as Mn	---	---	0.07	0.1	0.06	0.12	---
Mercury, Total Recoverable, ug/l as Hg	---	---	---	---	0.5	---	---
Silver, Total Recoverable, ug/l as Ag	---	---	---	---	0	---	---
Zinc, Total Recoverable, ug/l as Zn	---	---	---	---	50	---	---
Silica, Dissolved, mg/l as SiO_2	---	---	---	---	4.2	---	---
Selenium, Total, ug/l as Se	---	---	---	---	0	---	---
Selenium, Dissolved, ug/l as Se	---	---	---	---	---	---	---
Sediment, Suspended, mg/l	---	---	70	15	98	13	0
Dissolved Oxygen, mg/l	---	---	---	---	---	---	6.5
CO_2, mg/l	---	---	---	---	---	---	7.5
Turbidity, NTU	---	---	---	---	---	---	16
Aluminum, mg/l as Al	---	---	---	---	---	---	---
Nickel, mg/l as Ni	---	---	---	---	---	---	---
Data Source[a]	1	1	1	1	1	1	1

[a] 1 - USGS (1981)
2 - KNPC (1980, 1981)
3 - Present Study
4 - KDNREP (1981)
5 - KDNREP (unpublished data)

INDICES

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