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CHEMICAL AND BACTERIOLOGICAL EVALUATION:

WATER QUALITY SURVEY

OF THE

OBED WILD AND SCENIC RIVER, TENNESSEE

United States Department of the Interior
National Park Service
Southeast Regional Office
Richard B. Russell Bldg.
75 Spring St., S.W.
Atlanta, GA 30303

Contract Number: CX500091148

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1982

ABSTRACT

A water quality study was conducted in the upper Emory River watershed during 1979 and 1980. The objectives of this study were (1) to characterize water quality of surface streams in the Obed Wild and Scenic River, and (2) identify potential "red flag" areas which existed in the Obed-Emory watershed. Eleven stations were sampled quarterly and 16 additional stations were sampled on a one-time basis.

Results of this study showed water quality problems existed in all major tributaries in the Obed-Emory watershed. The Obed River was degraded by municipal sewage discharges from Crossville. The sewage discharges had poor quality, e.g., high levels of nutrients and increased water turbidity. The "sewage fungi" bacterium associated with organic pollution, Sphaerotilis natans, was abundant between Crossville and Potters Ford in the Catoosa Wildlife Management area. The lower Obed River received seasonal high sediment levels from commercial forestry activities. Clear Creek and Daddys Creek generally had good water quality, however turbidity and nutrients were above background levels in several samples. In particular, Clear Creek was affected by sediments from exploration access roads and drilling sites. The Emory River was adversely affected by coal stripmining activities, both recent and relic sites . Numerous sources of acid mine drainage entered the Emory River during wet weather. Water chemistry data indicated that present water quality problems adversely affect habitats critical for feeding and reproduction of the spotfin chub, muskellunge, and other aquatic organisms in the Obed Wild and Scenic River environs.

ACKNOWLEDGEMENTS

Appreciation is given the Department of Biology and the U. S. Fish and Wildlife Service, Tennessee Cooperative Fishery Research Unit at Tennessee Technological University for equipment loans. Sincere thanks for assistance in sample collections or analyses are given L. Martino, J. Orr, S. Bakaletz, S. Mateja, C. McQuary, R. Puckett, J. Hughe, R. Fugill, D. Evans, and W. Pennington. Secretarial assistance was provided by Lisa Murray, Joanne Arway, Patsy Kemp, and Sharon Rader.

Cooperation from the U. S. Fish and Wildlife Service's Office of Endangered Species, National Park Service, and the Tennessee Wildlife Resources Agency greatly aided this study. We thank Gary Larson, Robert Smith, Walt Mayer, Doyle Kline and Jim Little for their contributions to the project.

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INTRODUCTION

Basis of Study

In September, 1979, The United States Department of Interior, National Park Service (NPS), contracted with Tennessee Technological University, Department of Biology, for a study on the physical-chemical water quality of parts of the upper Emory River watershed in Tennessee. Information generated in this study is to be used by the National Park Service for resource management planning purposes at the Obed Wild and Scenic River (OWSR). This report is one of two (physical-chemical and biological) first order evaluations of water quality in the watershed. The upper Emory watershed is critical habitat of two fish species with special status. The spotfin chub, Hybopsis monacha, is a federally listed threatened species, and muskellunge, Esox masquinongy ohioensis, is a Tennessee listed endangered species.

Background

The Obed Wild and Scenic River includes portions of four streams in the Emory River watershed on the Cumberland Plateau of Tennessee. These streams are Clear Creek, Daddys Creek, Obed River and the upper Emory River. Water quality within the Obed-Emory basin is degraded by land use activities. Land use activities that are known to contribute to the degradation of water quality include urban development in Crossville (siltation, municipal sewage discharges), coal, gas, and oil mining activities (acid mine water, toxic leachates, turbidity), and forestry activities (soil erosion). Previously, no comprehensive survey of the water quality in these streams was available. A brief

review of reports which contained physical-chemical water quality information on the Obed-Emory watershed follows.

The U. S. Geological Survey (USGS) has collected most of the historical hydrologic data in the upper Emory watershed. The longest continuous gage station record is 58 years at Oakdale, Tennessee. Data from USGS gage stations in the Obed-Emory basin was used to estimate the magnitude and frequency of floods on unregulated tributaries and the main streams (Randolph and Gamble 1976).

A recent report of the anomalous runoff regime of the Obed-Emory basin of the Cumberland Plateau examined stream flow characteristics (Mayfield 1980). Mayfield concluded that the highly permeable soils and impervious bedrock of the Obed-Emory basin force surplus water to move laterally through the soil and into stream channels, while precluding large amounts of subsurface storage which would stabilize streamflow.

Baseline conditions for surface water quality in major streams of the upper Emory basin is available from USGS and Tennessee Valley Authority (TVA) reports. For example, physical-chemical data for surface waters has been compiled by the TVA (TVA 1972) and Pennington (1980). The chemical quality of subsurface flow of the Upper Emory basin was compiled by DeBuchananue and Richardson (1956). Surface water quality stations, unfortunately, cannot discern the origin of pollutants or slugs of toxic wastes which may cause severe ecological damage in the receiving streams.

Several recent water quality surveys have been conducted to identify components of point source pollution in the Obed-Emory River. The impact of the Crossville Municipal Wastewater Treatment Plant on

Obed River mile 20.8 (km 33.3) to mile 38.6 (km 61.8) was assessed by Melgaard and McKinney (1979) in March 1979. The quality of water was degraded severely for approximately 3 km (2 mi.) below the plant outfall as indicated by high BODs (Biological Oxygen Demand) and nutrient enrichment (total phosphate 0.83 mg/1, total Kjeldahl nitrogen 4.11 mg/1. Moderately high streamflow usually experienced during the spring season probably improved water quality via dilution. A second major water quality problem in the Obed-Emory was coal stripmining activities.

The effects of coal mining activities on the lower Obed River, upper Emory River, and tributaries near Nemo Bridge were assessed by Abbott (1979). Poor water quality containing acid mine drainage affected the biological communities in portions of Camp Branch and Rock Creek. Camp Branch and Rock Creek had acid pH (3.6 and 3.9 respectively) which caused secondary water quality problems. The acid pH leached heavy metals and other mineral components from coal overburden material. Certain leachates (e.g., aluminum, copper, zinc, etc.) are very toxic to aquatic organisms in low concentrations (Biesinger and Christenson 1972; Shaw and Grushkin 1957; Warnick and Bell 1969; and others). The paucity of water quality data for the Obed-Emory River and the available funding from the National Park Service were important factors in the design of this project. Therefore, it was decided that a combination baseline survey and first order evaluation of water quality in the watershed was the most effective approach.

A first order stream survey of water quality was conducted to assess point source impacts. (Point source discharges can be defined as water and wastewaters entering a receiving body of surface water at more or less specific locations, e.g., municipal sewage treatment plant

effluents. Non-point source runoff, overland dispersal, on the other hand, usually enters surface water sources over widespread areas such as soil erosion, and the source-to-impact relationship may be more difficult to ascertain.) This method used control sites (reference stations) and below discharge sites to compare analytical results.

The objectives of this physical-chemical water quality survey were twofold: (1) to characterize the water quality of surface streams in the Obed Wild and Scenic River; and (2) to identify potential "red flag" areas which exist in the Obed-Emory watershed.

Report Design

Two reports on the aquatic environment of the OWSR have been produced. This part is the evaluation and analysis of physical-chemical water quality. The second report is an evaluation of the aquatic fauna (macroinvertebrate, fish, and amphibian populations) and biological assessment of water quality in the Obed-Emory drainage. Unpublished and other water quality information relevant to this study appear in Appendix I.

OBED-EMORY WATERSHED

Location

The upper Obed-Emory watershed, in the Tennessee River basin, is located in Cumberland and Morgan counties in east Tennessee (Figure 1). This water quality assessment was restricted to that part of the Obed-Emory basin lying above the gaging station at Oakdale, an area of 1979 km^2 (764 mi^2). The Obed and Emory rivers, Daddys Creek, Clear Creek, White Creek, Crab Orchard Creek and a number of smaller tributary streams were sampled.

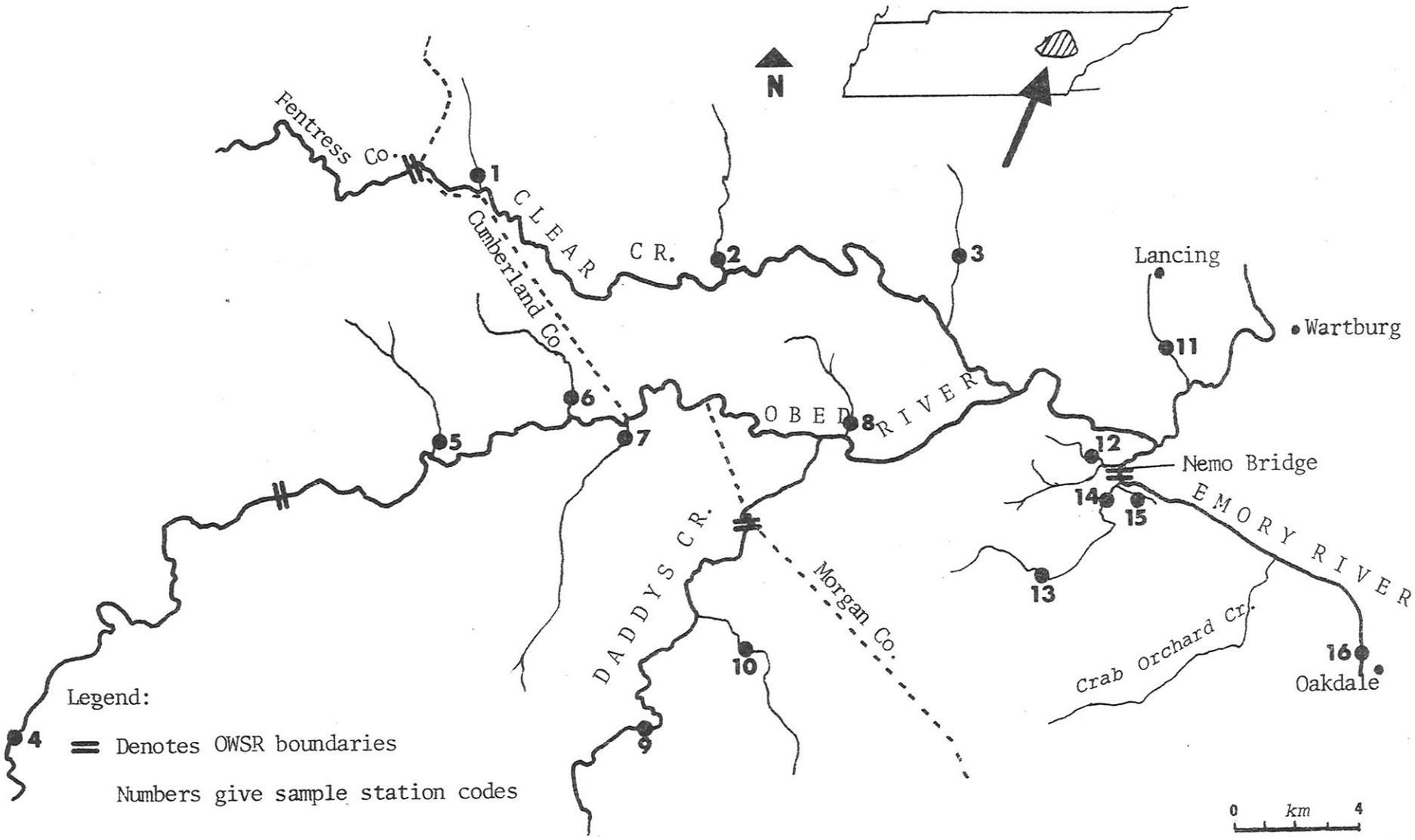


Figure 1. Map of the Obed-Emory Watershed.

Topography and Geology

The Obed-Emory basin primarily lies within Fenneman's Cumberland Plateau, which is less heavily dissected than the Cumberland Mountain section (Fenneman 1938). Typically, the undulating surface is submaturely dissected by young valleys whose steepness and depth increase towards the edges. The surface has developed by stripping of the overlying layers until the resistant sandstone strata were encountered.

The gradient of streams in the Cumberland Plateau reflects the type of rock they flow across and the geologic activity. Morisawa (1962) noted that streams have gentle gradients where they flow across resistant strata; steep gradients occur where streams cut through less resistant strata. The steepest segment of major streams is the section of Daddys Creek from the junction of Yellow Creek to Devil's Breakfast Table. This section of the stream is embedded in the less resistant shale. Figure 2 illustrates the longitudinal stream profiles of major streams in the Obed-drainage. Geologic activity which formed the Cumberland Plateau probably promoted the stream gradient profile. Rejuvenation by uplift would have affected the lower reaches first and progressed upstream. Since the elevation of the southern Cumberland Plateau is direct evidence of fairly recent uplift, then the stream profiles probably have resulted from a combination of lithologic control and rejuvenation by uplift (Mayfield 1980). The Cumberland Plateau characteristically is a relatively flat-topped, broad table which averages 300 m (1000 ft) above the adjacent lower land. The average surface elevation ranges from 515 m (1700 ft) to 606 m (2000 ft) above sea level.

Topographic provinces bear a direct relationship to the erosional history of the area and to physical properties of the underlying rocks.

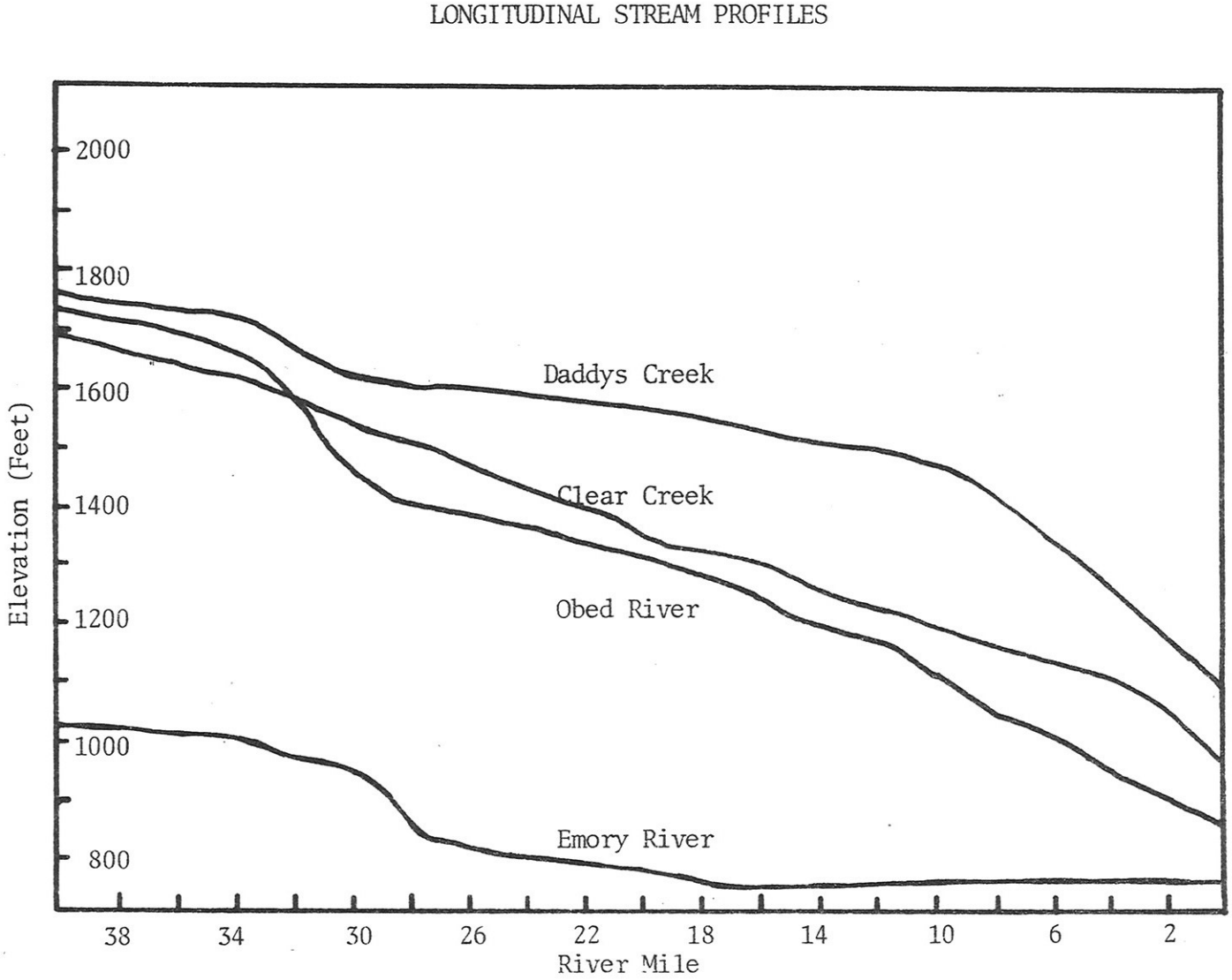


Figure 2. Stream profile of main streams of the Obed-Emory Watershed. (Source: Mayfield 1980)

Major rock formations are of sedimentary rocks. These strata, all of Carboniferous age, rest on an ancient surface of crystalline rocks. The strata are alternating beds of shale, siltstone, sandstone and coal. Coal seams within the shale units have been heavily exploited. This has resulted in significant local modifications of the landscape which may affect the hydrology.

Generally, water movement on the Cumberland Plateau is influenced by the Rockcastle Sandstone-Conglomerate which has a very low intergrandular permeability. Some secondary permeability results from fractures in the formation. The consolidated rock formations generally restrict lateral movement of groundwater to the upper zones and limit the quantity of groundwater storage in the watershed (TDOC 1972). For example, over 50% of the domestic supply wells yield less than 10 gallons per minute (GPM) and only 6% yield more than 25 GPM.

Soils

Soils information for the study area only is available from a Cumberland County, Tennessee, survey (Hubbard et al. 1950). Two soil series, the Hartsell fine sandy loam and the Muskingum fine sandy loam, account for about 95% of the soils in the basin. Both series are derived principally from sandstone interbedded with thin shale layers and average only about 30 inches to bedrock. Muskingum soils are usually stonier, lie on steeper slopes, and have faster internal drainage than the Hartsells series. Hartsells soils are rated as second or third class, which means that they are poor to good for cropland and fair to very good pastureland. On the other hand, Muskingum soils are mostly in the fifth class soil category because of their dominant stoniness and steeper slopes. Fifth class soils are defined as soils that are very

poor for cropland because of steep slopes, stoniness, or susceptibility to accelerated erosion.

The Hartsells soils are generally underlain by a relatively thin layer of yellowish-gray sand. The Muskingum series is similarly underlain by decomposed rock mixed with many small fragments of sandstone.

These soil series in combination with the underlying shale and sandstone bedrock contribute to extremes in streamflow. During heavy storm events rapid runoff occurs, and extreme floods occur. On the other hand, very low stream levels occur during low rainfall periods.

Hydrology

The water carried in streams is often considered to consist of a base-flow fraction made up of groundwater that infiltrates into the channel and a direct runoff fraction which enters the drainage system during and soon after precipitation periods (Linsley et al. 1975). The efficiency of the drainage system is dependent upon the natural arrangement of surface streams through which precipitation runoff is channeled. If the basin is well drained, the length of overland flow is short and surface runoff concentrates quickly and flood peaks are high. The length of tributaries, besides being an indicator of the slope of such terrain, is also an indicator of the quality of drainage. Steep, well drained areas generally have numerous short tributaries whereas flatter areas over deep and permeable soils have relatively long tributaries.

Drainage Areas

The Obed-Emory watershed technically is well drained. Three major streams feed into the Emory River above the Nemo Bridge near Wartburg.

Approximately 2240 km^2 are drained by the Emory watershed. The Emory River at Nemo Bridge, the downstream boundary for the OWSR, has a drainage area of 1585 km^2 (Table 1). Major tributary drainages of the OWSR include the Obed River (1347 km^2), Clear Creek (448 km^2, and Daddys Creek (453 km^2) (TVA 1970). A high ratio of rainfall to runoff occurs in major and minor streams of the Plateau because of poor water-storage capacity of the soil, also evidenced by the poorly-sustained base flow of even larger streams in the basin.

The U. S. Geological Survey and TVA cooperate with sample collections from stream gage stations at one permanent location, Oakdale, and several temporary stations located in the upper Emory watershed. The locations of these stations are given in Appendix II.

Water Supply Characteristics

Rainfall over Cumberland and Morgan counties averages 135 cm annually; March has the highest rainfall and October, on the average, is the driest month (Table 2). Typically, the area experiences nearly 30 drought-days in the average year (Table 3). General characteristics of the Obed-Emory watershed is given in Table 4. The left-hand portion of Table 4 shows the average year flows for all the streams and locations which have been gaged in the basin by the U. S. Geological Survey (USGS) and TVA.

Quality of Water

Generally, the water is of sufficient quality for domestic use and certain light industrial users. The water hardness is low to moderate (~20-50 mg/1) and acidity (pH) is nearly neutral. Some water on the plateau is affected by acid mine drainage; these waters typically have

Table 1. Drainage areas of the Obed/Emory Rivers system[a]

Name of Stream	River Mile	Location Reference	Drainage Area $mile^2$	Max discharge cfs	Date
Emory River	27.7	0.1 mile above Nemo Bridge (Nemo Bridge is downstream boundary for the Obed Wild and Scenic River)	612	185,000[c]	23 Mar 1929
Emory River	28.4	Above mouth of Obed River	91.5	31,200[b]	23 Mar 1929
Obed River	0	Mouth at Emory River Mile 28.4 near Nemo	520	105,000	27 May 1973
Obed River	4.4	Above mouth of Clear Creek	339		
Obed River	9.1	Above mouth of Daddys Creek	156		
Obed River	24.7	0.2 mile below Adams Bridge (upstream boundary for the Obed Wild and Scenic River)	92.4		
Clear Creek	0	Mouth at Obed River Mile 4.4	173		
Daddys Creek	0	Mouth at Obed River Mile 9.1 (includes 5.8 $mile^2$ sink area)	175		

[a]Source: Division of Water Control Planning, Hydraulic Data Branch, Tennessee Valley Authority, 1970.

[b]reading for 81 mi^2 drainage area.

[c]reading for 704 mi^2 drainage area.

Table 3. Emory River watershed -- average number of drought days.[a]

(Average for 1927-1956)

Month	Average Number of Drought-Days for 3-Inch Moisture Capacity in Root Zone Crossville, Tennessee
April	0
May	2
June	5
July	5
August	5
September	4
October	6
Total	27

[a]Source TVA 1968.

Table 4. Emory River watershed -- flows of gaged streams.[a]

Stream	Location	Drainage Area sq.mi.	Streamflow in Average Year: Average cfs	Streamflow in Average Year: Per Sq. Mi. cfs	Minimum 7-Day Flow: Amount cfs	Minimum 7-Day Flow: Per Day 1000 gallons	Minimum 30-Day Flow: Amount cfs
			Cumberland County,TN				
Daddys Creek	Near Grassy Cove	51.2	140	2.73	0	0	0.05
Daddys Creek	Near Crab Orchard	93.5	174	1.86	0	0	0.04
Daddys Creek	Near Hebbertsburg	139	285	2.05	0.3	190	0.5
			Morgan County,TN				
Emory River	Near Wartburg	83.2	146	1.75	0	0	0
Emory River	At Deermont	704	1,384	1.97	4.2	2,710	4.4
Emory River	At Oakdale	764	1,418	1.86	0	0	0
Obed River	Near Lancing	518	1,047	2.02	0.6	390	1.1
Clear Fork	Near Robbins	272	469	1.72	0.5	320	1.6

[a]Source TVA 1968.

a very low pH (4.0-5.5) which tends to be corrosive. Moreover, the low buffering capacity of the plateau surface waters can tolerate only low levels of pollutants; this is of particular concern for protection of fish and their food organisms.

Definition of Water Quality

The physical, chemical, and biological characteristics of water collectively determine its quality. Thus, any assessment of water quality in a watershed must consider these aspects. Likewise, factors influencing these characteristics must be identified as they exist in the watershed. In a water quality assessment to be used for the planning of a water resources development program, not only the present status of water quality must be determined, but future changes in water quality must be estimated by considering how land use in the watershed may exist in the future.

Land Use

The majority of land is forested (~92%) in the Obed-Emory basin. Farm land accounts for about 8% of the land. However, in 1974, both harvested land and pasture classifications accounted for less than 4% each. (TVA 1968).

The most economically important land use is for mineral production. Bituminous (soft) coal has been mined from as many as 63 mines in one year (1959). Presently, reserves are estimated at 43,797,233 tons for Cumberland County and 82,232,000 tons for Morgan County (TVA 1968). Most of the mining occurs in the upper Emory drainage area between Wartburg and Oliver Springs in the mountainous subsection of the Emory basin.

Urban development is centered in Crossville and Wartburg, having a combined 1970 population of 5922 (TVA 1968). Crossville is showing moderate population growth while Wartburg is considered stabilized. Other development has resulted from resort and retirement communities in the Crossville area. Development and alteration of the natural terrain in these areas is not intensive.

Development near the main stream corridors is restricted by the Wild and Scenic Rivers Act, PL 90-542. In the Obed River plan, a joint agreement treats the development of the river corridor and the Catoosa Wildlife Management Area as a whole. Management and visitor use facilities call for minimal development of the river system.

Point Source Discharges into the Upper Emory Watershed

Municipal

One town, Crossville, currently discharges the effluents from the water treatment plant (enters via branch below Holiday Lake, stream km 62.3) and municipal sewage treatment plant (stream km 61.4) into Obed River. Several resorts in the area also have sewage treatment unit discharges.

Industrial

Several industries directly or indirectly affect water quality. Daddys Creek occasionally receives process wastes from canneries located near Crossville; this is a seasonal discharge. The main source of water degradation results from mining activities in the watershed. High levels of suspended solids enter streams from unpaved haul roads for coal, gas, oil mining and forestry management activities. Moreover, toxic leachates are carried by acid mine drainage to the lower Obed

River, numerous locations on the upper Emory River and tributaries of the upper Emory River (Camp Branch, Rock Creek, Island Creek, Crab Orchard Creek, Crooked Fork Creek, and others). Many of the streams receiving acid mine drainage are void of fish and aquatic macroinvertebrates. The low buffering capacity of these softwater streams severely limits the amount of pollutants which can be discharged without disrupting the fragile aquatic ecosystem.

Location of Designated Critical Environmental Areas in the Watershed

Rare and Endangered Species

Two threatened fish species occur in the Obed Emory watershed. The muskellunge, Esox masquinongy ohioensis , (Tennessee listed) and the spotfin chub, Hybopsis monacha (federally listed). Habitat loss for these two species has resulted from municipal sewage discharges in Crossville, acid mine drainage from numerous sites, and sedimentation from forestry and mining activities (Abbott 1982).

Critical habitat areas for the spotfin chub and muskellunge exists throughout the Obed Wild and Scenic River boundaries.

The spotfin chub, an endemic species, inhabits large streams in upland areas of the Tennessee River system. They prefer swift to moderately swift current and are uncommon in areas with silt accumulation. The Ohio muskellunge inhabits large streams in upland and lowland areas of the upper Ohio River basin and originally extended as far south as northern Georgia and Alabama in the Cumberland Plateau region. The muskellunge prefers deep slow moving pools in the Obed-Emory River System.

Wild and Scenic River

The Obed-Emory River has 72.3 km of streams designated as a Wild and Scenic River Area. This includes portions of Clear Creek, Daddys Creek, Obed River, and Emory River above the Nemo bridge.

Location of Sampling Stations

Eleven sampling stations within the OWSR area were selected for a quarterly sampling program (Figure 3). Access to the streams was a major consideration in selecting sampling locations. Survey site locations are given in Table 5. Additional survey stations were established at 16 locations within the upper Emory drainage to establish baseline conditions (Table 6, Figure 1).

MATERIALS AND METHODS

Physical Chemical Measurements

Sample sites chosen were considered to be representative of the stream section. Measurements were taken in riffle and/or pool areas. As a result of the severe drought, the water samples during the summer months may not reflect upstream conditions since pools were isolated from each other with little discharge occurring in the streams. Samples were treated according to acceptable procedures for sample preparation and analysis (EPA 1974; APHA 1976). Table 7 gives the methodologies and precision of the tests. Chemical measurement accuracies were subjected to EPA Quality Assurance tests which consisted of running each batch of samples with blanks, known spike additions, and split samples in the laboratory. Samples of water for metal analyses were also analyzed by other laboratories. The results are for total concentration of compounds or elements, where applicable, which included

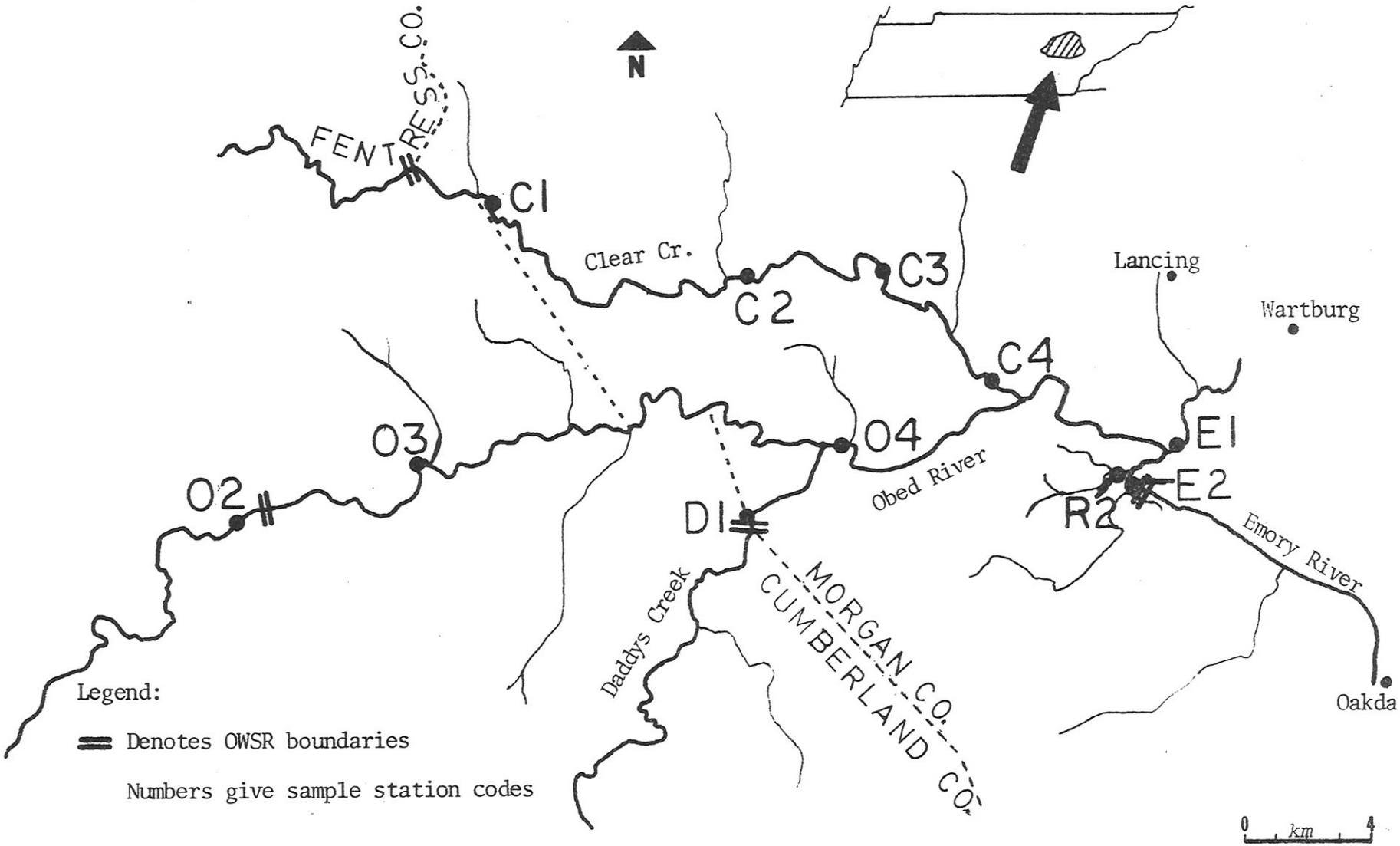


Figure 3. Stream survey sites - Obed Wild and Scenic River, Tennessee.

Table 5. Location of quarterly stream survey sites in the Obed-Emory River drainage.

Station Code	Stream	Stream km	Stream mile	Site	Latitude	Longitude
C1	Clear Cr.	23.7	14.8	Norris Ford	36° 07' 00"	84° 52' 00"
C2	Clear Cr.	13.8	8.6	Waltman Ford Bridge	36° 06' 50"	84° 47' 40"
C3	Clear Cr.	6.6	4.1	Jett Bridge	36° 07' 15"	84° 45' 00"
C4	Clear Cr.	2.4	1.5	Lilly Bridge	36° 06' 15"	84° 43' 15"
02	Obed River	39.9	24.9	Adams Bridge	36° 03' 45"	85° 58' 00"
03	Obed River	33.1	20.7	Potters Ford	36° 04' 30"	84° 54' 30"
04	Obed River	14.7	9.2	Obed Junction	36° 04' 45"	84° 46' 10"
D1	Daddys Cr.	3.7	2.3	Devils Bkfst.Table	36° 03' 30"	84° 47' 40"
E1	Emory River	46.0	28.8	Above Obed R.mouth	36° 04' 45"	84° 37' 00"
E2	Emory River	45.6	28.5	Nemo Bridge	36° 04' 12"	84° 40' 00"
R2	Rock Cr.	0.1	0.1	Nemo Bridge	36° 04' 12"	84° 40' 05"

Table 6. Water quality survey sites near the Obed Wild and Scenic River Area for tributary streams.

No.	Station	Stream km.	Stream mile	Location
1	Four Mile Creek	0.2	0.1	36° 08' 05" Lat. 84° 52' 25" Long. Above Norris Ford 0.3 km, entering Clear Cr. at stream km 24.1 in Morgan County, TN.
2	White Creek	0.5	0.3	36° 07' 25" Lat. 84° 47' 53" Long. Above Waltman Ford Bridge 0.2 km, entering Clear Cr. at stream km 14.0 in Morgan County, TN.
3	Little Clear Creek	4.0	2.5	36° 07' 45" Lat. 84° 43' 20" Long. Above Lilly Bridge 0.2 km, entering Clear Cr. at stream km 2.9 in Morgan County, TN.
4	Obed River	55.0	34.4	35° 59' 45" Lat. 85° 02' 40" Long. At route 127 bridge in Crossville, Cumberland County, TN
5	Elmore Creek	0.2	0.1	36° 04' 25" Lat. 84° 53' 53" Long. Entering Obed River at stream km 32.7 near Potters Ford, Morgan County, TN.
6	Tom Branch	0.1	0.1	36° 05' 15" Lat. 84° 45' 11" Long. Entering Obed River at stream km 30.4 in Morgan County, TN.
7	Otter Creek	0.1	0.1	36° 05' 00" Lat. 84° 49' 55" Long. Entering Obed River at stream km 25.2 in Morgan County, TN.
8	Ramsey Creek	0.2	0.1	36° 04' 48" Lat. 84° 45' 46" Long. At Obed Junction entering Obed River at stream km 14.3 in Morgan County,TN.
9	Daddys Creek	14.6	9.1	36° 59' 53" Lat. 84° 49' 25" Long. at Antioch Bridge on Daddys Creek stream km 14.6 in Cumberland County, TN. (USGS gage station No. 03539600).
10	Yellow Creek	2.6	1.6	36° 01' 07" Lat. 84° 47' 35" Long. Bridge crossing 0.2 km north of Hebbertsburg, Cumberland Co., TN.

Table 6. (Cont.)

No.	Station	Stream km.	Stream mile	Location
11	Campground Creek	1.8	1.1	36° 06' 28" Lat. 84° 38' 28" Long. Located 2.0 km SSE of Lancing, Morgan County, TN.
12	Camp Branch	0.1	0.1	36° 04' 15" Lat. 84° 40' 00" Long. Drains coal strip mine area as a tributary of Rock Creek (enters Emory River stream km 45.5) near Nemo Bridge, Morgan County, TN.
13	Island Creek	3.2	2.0	36° 03' 10" Lat. 84° 40" 25" Long. Tributary entering Emory River stream km. 43.6. Station located 0.2 km SW of Catoosa Game Check Station, Morgan County, TN.
14	Island Creek	0.7	0.4	36° 03' 52" Lat. 84° 39' 42" Long. Tributary entering Emory River stream km 43.6. Station located 1.1 km W of Nemo, Morgan County, TN.
15	White Horse Branch	0.1	0.1	36° 03' 53" Lat. 84° 39' 25" Long. Tributary 0.1 km above Island Creek mouth (enters Emory River stream km 43.6) Morgan County, TN.
16	Emory River	29.5	18.4	35° 59' 05" Lat. 84° 33' 20" Long. At bridge in Oakdale, Morgan County TN. (USGS gage station No. 03540500).

Table 7. Physical-chemical methodologies and precision.

Parameter	Methodology	Detection Limit
Stream discharge[a]	Current meter	
Turbidity[a]	Hach Portalab Turbidimeter	
Temperature[a]	Electronic probe	$\pm 0.2^{o}C$
Alkalinity	Potentiometric titration	± 5mg/1 $CaCO_3$
Acidity	Potentiometric titration	± 1.8 mg/1 $CaCO_3$
Dissolved oxygen[a]	Electronic meter	± 0.06 mg/1
pH[a]	Electronic meter	± 0.1 units
Conductivity[a]	Conductance cell	$\pm 1\%$
Total hardness	EDTA titrimetric method	$\pm 1\%$
Sulfate	Turbidimetric method	$\pm 9.1\%$
NO_3	NO_3 electrode method	± 0.1 mg/1
NH_3	NH_3 electrode method	0.1 mg/1
Kjeldahl Nitrogen	Kjeldahl digestion, NH_3 electrode method	0.1 mg/1
Total orthophosphate	Colorimetry, EPA SR Method	± 0.05 mg/1
Hydrolyzable phosphorus	Colorimetry, EPA SR Method	± 0.05 mg/1
Total phosphorus	Colorimetry	± 0.05 mg/1
Aluminum	Atomic Absorption Spectrophotometry	0.02 mg/1
Chromium	Atomic Absorption Spectrophotometry	0.002 mg/1
Copper	Atomic Absorption Spectrophotometry	0.005 mg/1
Iron	Atomic Absorption Spectrophotometry	0.003 mg/1
Lead	Atomic Absorption Spectrophotometry	0.01 mg/1
Manganese	Atomic Absorption Spectrophotometry	0.003 mg/1
Mercury	Atomic Absorption Spectrophotometry	0.33 µg/1
Zinc	Atomic Absorption Spectrophotometry	0.001 mg/1
Fecal coliforms	Membrane filter technic	
Fecal streptococci	Membrane filter technic	

Table 7 (Continued)

Parameter	Methodology	Detection Limit
Elemental scan	Jarrell-Ash Induced Plasma Spectrograph	(as mg/l)
Al		3.70
B		0.02
Ca		0.04
Cd		0.01
Co		0.01
Cr		0.03
Cu		0.07
Fe		0.03
K		1.60
Mg		0.01
Mn		0.01
Na		0.60
Ni		0.06
P		0.75
Pb		3.50
Zn		0.50
Herbicide phenoxyherbicide group	Gas Liquid Chromatography	(as µg/l)
2,4-D		5.2
2,4-DB		3.9
2,4,5-T		0.1
Dicamba		0.8
Silvex		0.1
Tordon		1.0
Pesticide		
Aldrin		0.008
Chlordane		0.20
DDD		0.04
DDE		0.02
DDT		0.09
Dieldrin		0.02
Endrin		0.03
Ethion		0.10
Heptachlor		0.008
Heptachlor Epoxide		0.01
Lindane		0.008
Malathion		1.40
Methoxychlor		0.30
Methyl Parathion		0.10
Mirex		0.07
Parathion		0.08
PCB 1242		0.60
PCB 1254		0.60
PCB 1260		0.60
Toxaphene		1.20

[a]Analysis made in the field.

suspended and dissolved portions. Bacteriological samples were immediately placed on ice and filtered within 8 hrs. after collection using 0.45 µm Millipore Filter discs.

Measurements of stream discharge were taken from riffle areas using a General Oceanic Model 2030 current meter at mid-depth. Stream profiles were obtained from stream channel width and depth readings at 25%, 50%, and 75% width. High stream discharges during several sample trips prevented actual measurements; the discharge was estimated for streams from fewer current and depth readings in those cases.

Stream substrate size was classified by Wentworth method (1922).

Class	Size (mm)
Boulder	> 256
Cobble	64-256
Pebble	16-64
Gravel	2-16
Sand	0.0625-2
Silt	0.0039-0.0625
Clay	< 0.0039

WATER QUALITY ASSESSMENT OF THE SUBWATERSHEDS IN THE UPPER EMORY BASIN

The water quality data are discussed by primary subwatersheds which includes Clear Creek, Obed River, Daddys Creek, and Emory Rivers, and their tributaries. The raw data from six major sampling trips is listed in Appendix III, Tables III-1 through III-9. Assessments of the subwatersheds follow the site evaluations, and are located at the end of this section. Interpretations of these data must consider the severe drought from June through December 1980 which tended to localize the effects of point source discharges.

Clear Creek Watershed

Station C-1 at Norris Ford

Stream substrate in riffle areas were 10% boulder, 50% large cobble, and 40% cobble sizes (Figure 4). Alder covered 95% of the streambank and overstory vegetation shaded 50% of the stream area in summer.

Water quality appeared to be excellent at C-1. Alkalinity ranged from 7 to 22 mg/1 and acidity 0 to 33 mg/1. Conductivity indicated low ion concentrations (16 to 37 µmhos/cm @ 25°C). An unidentified source of chromium was detected on 16 November 1979 (0.3 mg/1) and 3 May 1980 (0.01 mg/1), but not on other dates after "low flow" conditions isolated pools in the stream which indicated an upstream source.

Station C-2 at Waltman Ford (Barnett Bridge)

Stream substrate was 15% small boulder, 80% cobble and 5% large gravel sizes (Figure 5). Less than 10% of the stream was shaded by overstory. The streambanks showed signs of localized erosion. During a storm event on 16 November 1979 turbidity rose to 2800 NTU. The sources of suspended solids were the dirt road crossing Barnett Bridge and numerous unstabilized access roads leading to gas and oil drilling sites.

Water quality appeared good at C-2. However, the range of values for conductivity was higher (22 to 53 µmhos) than at C-1. Moreover, slightly higher levels of nitrogen and phosphorus were detected in several samples.

Station C-3 at Jett Bridge

Stream substrate was 40% small boulder and 60% cobble sizes (Figure 6). Alder grew along 95% of the streambank and overstory species

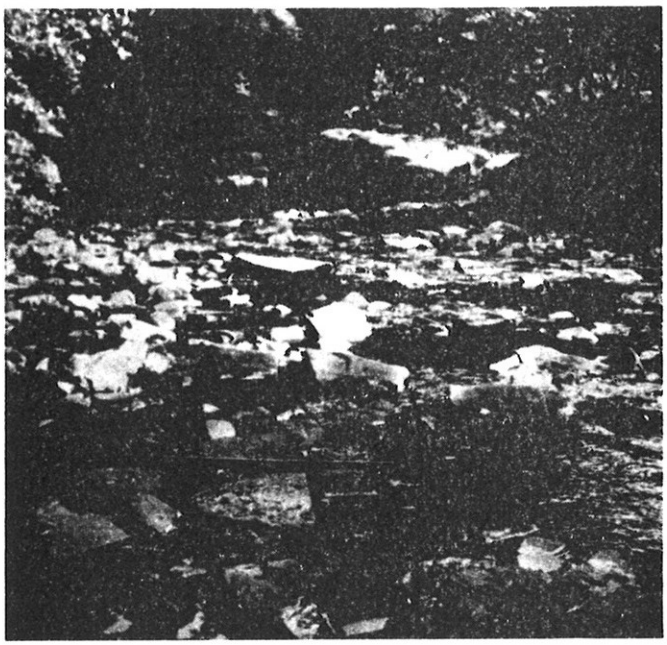


Figure 4. Station C-1 on Clear Creek.

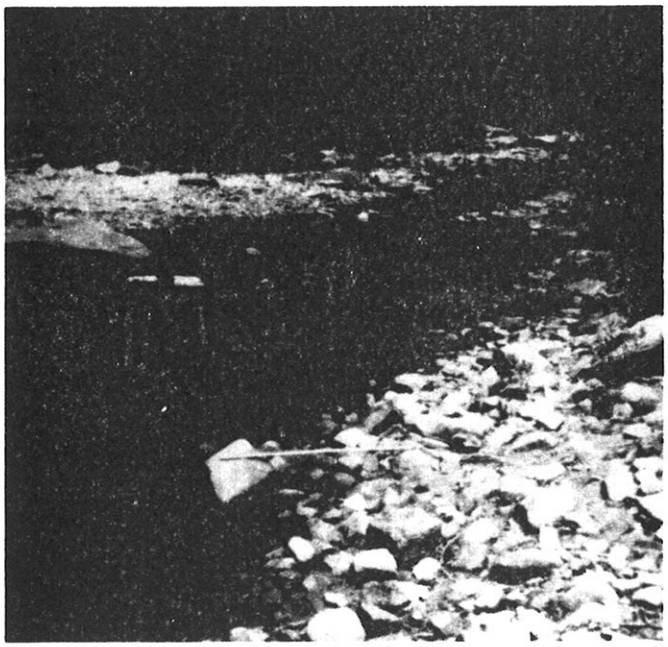


Figure 5. Station C-2 on Clear Creek.

(primarily cottonwood) allowed direct sunlight for only several hours daily in the summer. Several areas showed recent sediment deposits which were not as common at C-1 or C-2.

Water quality was considered good from chemical analyses at C-3. The range of values for specific conductivity continued to increase (22-92 µmhos/cm) downstream, indicating higher ion concentrations in Clear Creek. Other parameters measured remained at levels characteristic of Clear Creek.

Station C-4 at Lilly Bridge (Howard Mill)

Stream substrate was 15% large boulder, 40% small boulder, 40% cobble and 5% pebble sizes. The stream channel showed signs of recurrent scouring during floods which limited streambank plant growth. Overstory vegetation was not a factor in shading the stream channel, however, a high vertical bluff (170 m) on the west bank excluded direct evening sunlight.

Water quality showed no appreciable change although conductivity continued to rise (22-104 µmhos/cm) and turbidity averaged about 1 NTU higher than the C-3 level. Therefore, C-4 was considered to have good chemical water quality from the five samples analyzed. The U.S.G.S. has maintained a station at C-4 since 1965. A synopsis of their water data follows (median values): 2.8 mg/1 silica, 0.02 mg/1 filtered iron, 6 mg/1 HCO_3, 4.2 mg/1 SO_4, 1.4 mg/1 NO_3 (max), 20 mg/1 dissolved solids, 9 mg/1 hardness, and 27 µmhos/cm conductance (TVA 1972).

Station 1 Four Mile Creek--above C-1

Surface water was not available for analyses during extended drought.

Station 2 White Creek 0.2 km upstream of C-2

Stream substrate was 90% boulder and 10% cobble sizes (Figure 7). The dominant streambank species was alders and overstory cover was birch and maple.

White Creek was suspected of receiving domestic sewage (personal communication, Walter Mayer, NPS). Water data did not detect significant differences in chemical or bacteriological tests from concentrations found in Clear Creek (Table III-7). The severe drought prevented the transport of wastes downstream because of extensive dry areas in the channel which may have improved water quality near the stream mouth where samples were taken. A reconnaissance trip in the White Creek watershed detected several potential hazards. First, oil waste ponds were found that permitted surface discharges to the stream (Figure 8). Second, access roads to the areas were unstable and did not provide dewatering sluices to reduce the erosional force of runoff (Figure 9).

Station 3 Little Clear Creek

Little Clear Creek enters 0.3 km upstream of C-3. Stream substrate was 90% sandstone bedrock and 10% boulder size (Figure 10). The overstory canopy shaded 95% of the streambed in summer.

Water quality was characteristic of the Clear Creek watershed, that is, low alkalinity (10 mg/1), slightly acid pH (6.2) and a moderately low specific conductivity (48 µmhos/cm). The chemical quality probably was more representative of groundwater seeps than normal surface runoff.

Obed River Watershed

Station 4 Obed River at Route 127 bridge in Crossville

Stream substrate was sand deposited on large rubble and boulder sizes. The water filtration plant may be a source of these sand deposits

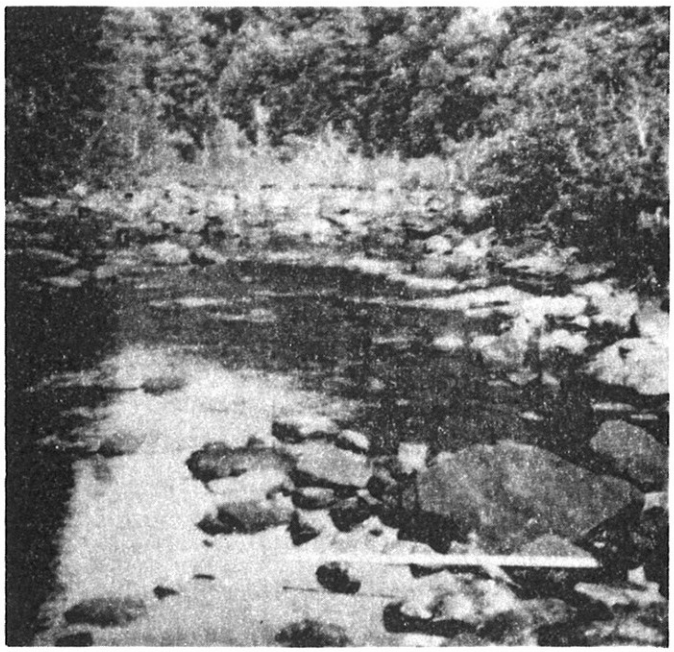


Figure 6. Station C-3 on Clear Creek.

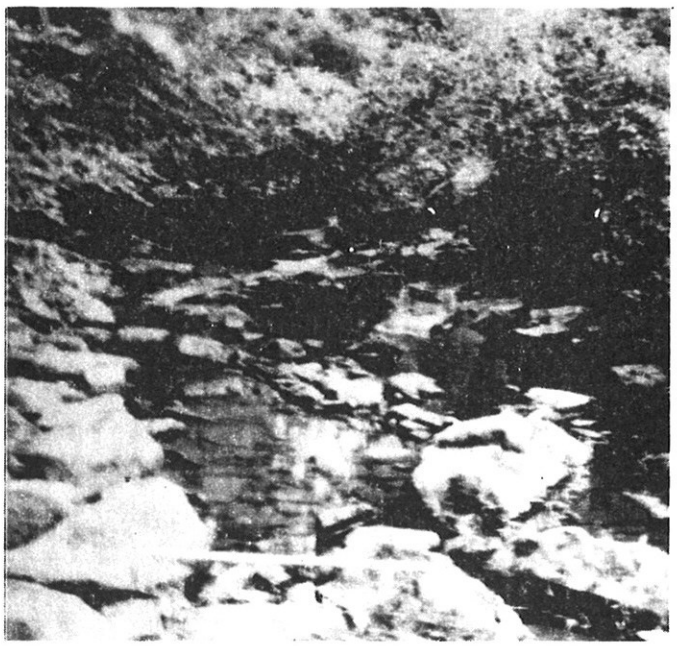


Figure 7. Station 2 — White Creek.



Figure 8. Oil catch basin in White Creek watershed.

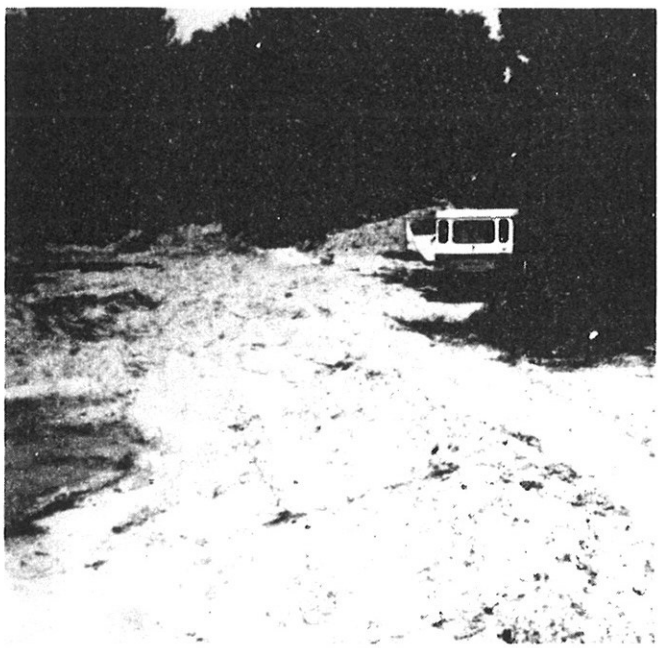


Figure 9. Typical denuded area resulting from gas and oil exploration activities.

since the sand filters are cleaned by backflushing. Backflushing releases large quantities of sand to the Obed River upstream of this station.

Water analyzed from Station 4 (1 October) was of poor quality. Conductivity was 220 µmhos, turbidity 8 NTU, moderate levels of NO_3 (1.1 mg/1), and very high phosphorus (total phosphorus 2.48 mg/1). Other indicators of organic pollution were high fecal coliform (2900 MPN/100 ml), fecal streptococci (11,400 MPN/100 ml), and abundant growth of "sewage fungi," Sphaerotilis natans (Table III-7).

Melgaard and McKinney (1979) reported Station 4 as having good water quality (29 March). In addition, their conclusion was based on high macroinvertebrate diversity. Therefore, conclusions based on the two studies indicate that the severe drought during 1980 did function to localize the effects of point source discharges. Since the large quantities of municipal sewage was not being transported appreciable distances downstream, then water quality would be expected to improve during the summer at downstream Stations 0-2 and 0-3.

Station 0-2 upstream of Adams bridge

Stream substrate in the sample area was 10% boulder, 85% cobble, and 5% sand sizes (Figure 11). Overstory canopy shaded 40% of the stream channel during the summer.

Water quality appeared to be fair at 0-2 between November 1979 and June 1980, corresponding to the period before low flow. Compared to downstream stations, conductivity, sulfate, nitrogen and phosphorus species, aluminum, iron and bacterial populations were higher. Following the onset of low flow, which prevented downstream transport of pollutants from Crossville, water quality was characteristic of the unpolluted tributaries water at 0-2. Similarly, the "sewage fungi" was present at

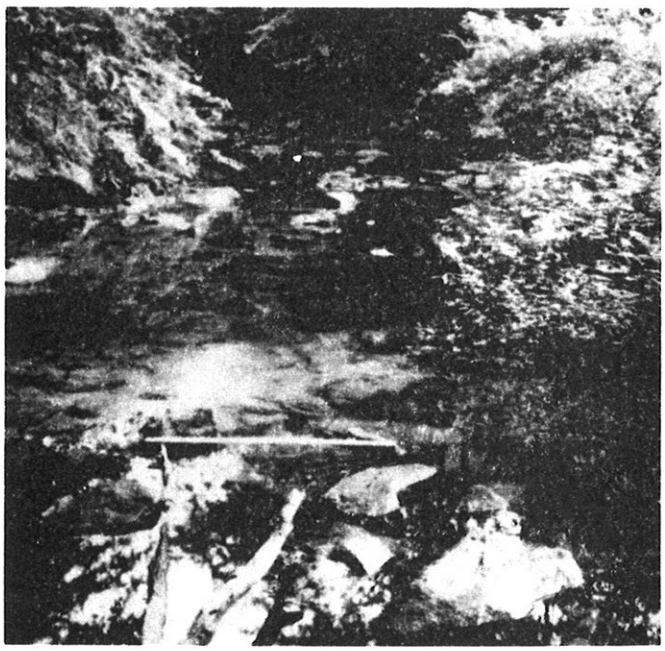


Figure 10. Station 3 — Little Clear Creek.



Figure 11. Station O-2 on Obed River.

this station until after water discharge was reduced by low flows. After low flow, very dense filamentous green algal growth was observed in the pools (Figure 11).

Station 0-3 upstream of Potters Ford

Stream substrate was 10% shale bedrock, 1% boulder, 60% cobble, and 29% large gravel sizes. The stream had a low gradient and only moderately well defined riffle areas. The entire 26 m wide stream channel remained covered with water because of the flat stream bottom. Only narrow margins on each stream bank provided shade to the stream.

Water quality was good although "sewage fungi" was observed on sticks in pools and runs. At 0-3 sulfates, several nutrients species, and bacterial densities (Tables III-2 through III-4) were found to be above background concentration for the Obed River. Again, the summer drought improved water quality at 0-3 by late summer (Table III-6). Dense algal mats, observed at 0-2, did not occur downstream at 0-3.

Station 0-4 at Obed Junction

Substrate was 90% boulder and 10% cobble size throughout the pool and riffle areas. The large substrate sizes reflected the scouring force of water on this station. Alder thickets were dense among boulders on the lateral edge of the stream channel.

Water quality at 0-4 appeared good. The nutrient loading problem noticed upstream was not evident at Obed Junction. This water can be characterized as being moderately soft, slightly acid, and low in nutrients. Although the enrichment problem has been corrected by stream assimilative processes, a new problem has developed at 0-4. Turbidity levels were consistently higher than normal for the Obed River. The February 1980 site visit records reported extensive areas cleared by one

of the forestry corporations between Jett bridge and Obed Junction. Ramsey Creek, a tributary entering at 0-4, contained a heavy sediment load. The sediment was moderately deep on the left channel of the Obed at 0-4.

Station 5 Elmore Creek downstream of 0-3

Substrate was 80% boulder, 15% cobble, and 5% sand sizes in the study area. Secondary growth hardwoods shaded almost 100% of the stream during the summer.

Water quality at station 5 was considered excellent (Table III-7). Conductivity, turbidity, and alkalinities were among the lowest in the watershed. As in several other tributaries, a trace of mercury (0.53 µg/1) was detected.

Station 6 Tom Branch at Obed stream km 30.4

Substrate was 50% cobbles, 40% gravel, and 10% sand size at the study site. The stream was shaded by a dense overstory canopy.

Water quality was excellent in this soft water stream. Station 6 had low alkalinity (7 mg/1) and conductivity (18 µmhos) typical of the undisturbed watershed on the Cumberland Plateau (Table III-7).

Station 7 Otter Creek at Obed stream km 25.2

Substrate was 90% cobbles and 10% large gravel in this stream once used by muskies for spawning. Alder thickets provided shade to 80% of the stream channel.

Water quality was excellent in Otter Creek, which drains a portion of the Catoosa Wildlife Management Area. Sulfates (2.9 mg/1) were about twofold higher than found in similar tributaries, and a trace of mercury was detected (0.73 µg/1).

Station 8 Ramsey Creek at 0-4

Substrate was 20% boulder, 70% cobble, 5% pebbles, and 5% sand sizes. The stream was well shaded throughout the year by hemlocks and the steep sides of the channel.

Water quality was good except for high sediment loads carried during storm events. No surface discharge occurred during the drought period so only basic water chemistry data were collected (Table III-7).

Daddys Creek Watershed

Station 9 Daddys Creek at Antioch bridge

Substrate was 20% boulder, 70% cobble, 10% large gravel size. The stream received little shade from trees adjacent to the stream channel.

Water quality was generally good with low conductivity (22 µmhos) and a slightly high pH (7.4). Nutrient concentrations were moderate for Plateau streams (Table III-7). The U.S.G.S. maintains a gage station at this site (TVA 1972).

Station D-1 at Devils Breakfast Table

Substrate was 40% boulder, 40% cobble, and 20% large gravel sizes (Figure 12). The stream channel had few trees near the riffle areas and lacked vegetative cover.

Water quality was good although conductivity significantly increased during the low-flow regime through the summer. Also, nutrient concentrations were slightly high on several occasions, but should not cause any problems to the aquatic ecosystem. Abbott (1979) reported a diverse assemblage of aquatic life at this site.

Station 10 Yellow Creek near Hebbertsburg bridge

Substrate was 80% shale bedrock and 20% boulder size at the sample site. Shading of the stream was moderate from secondary growth hardwoods.

Water quality analyses indicated the stream is without chemical pollution at present. It has low alkalinity and hardness which is typical of the Plateau soft water streams (Table III-7).

Emory River Watershed

Station E-1 upstream of Obed River mouth

Substrate was 35% boulder, 60% cobble, and 5% gravel size. The heaviest sediment loading of main tributaries in this study occurred at this site. The source was probably from extensive strip mining adjacent to the upstream river channel. The channel was shaded 20% by predominately alder and cottonwood.

Water quality was affected by higher than average levels of turbidity, sulfates, and conductivity. The water quality probably is poorest during storm events which may transport slugs of toxic strip-mine leachates downstream. Biological monitoring is better suited for detecting occasional toxic discharges.

Station E-2 upstream of Nemo bridge

Stream substrate was 20% shale bedrock, 60% boulder. and 20% cobble size (Figure 13). No streambank vegetation provided shading, however, extensive beds of water willow, Justicia americana, grew in the channel.

Water quality at E-2 was similar to lower Obed River water. Generally, conductivity, turbidity, and sulfates were higher in water samples at E-2 than at 0-4. The increases resulted from lower quality water in the Emory River sections affected by stripmining activities.

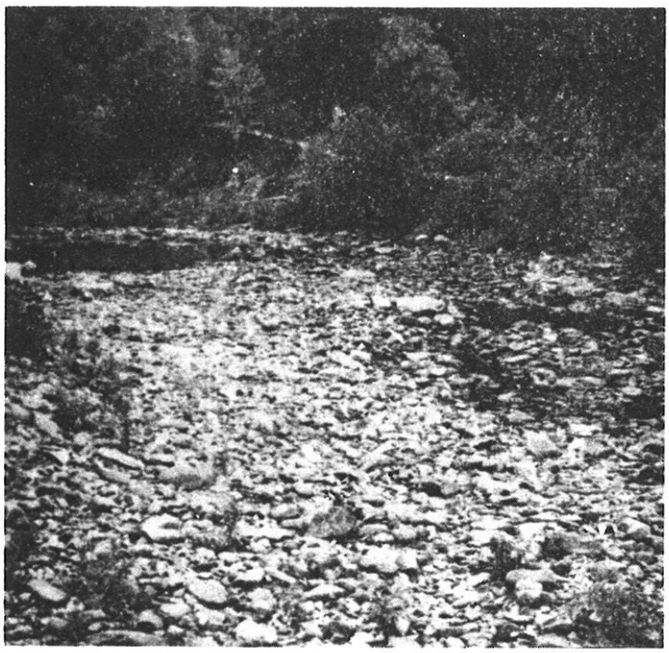


Figure 12. Station D-1 on Daddys Creek.

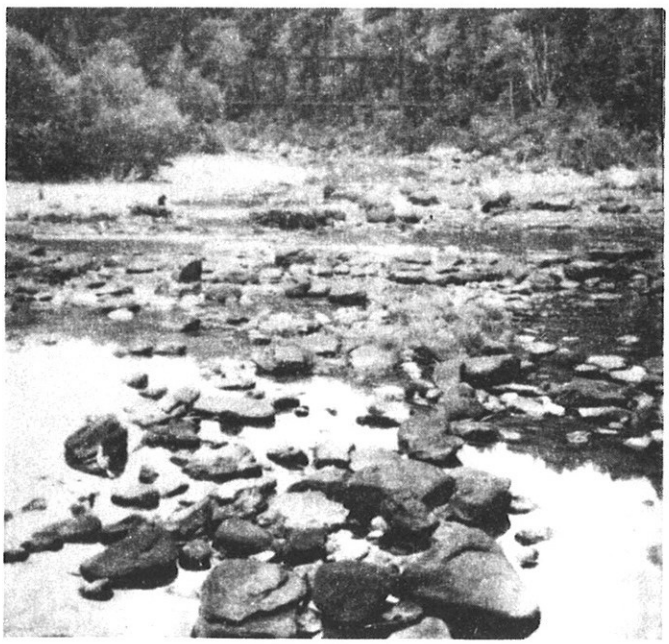


Figure 13. Station E-2 on Emory River.

Station R-2 at Nemo bridge

Stream substrate was 20% cobble, 60% large gravel, and 20% small gravel size. The substrate was covered by "yellowboy" deposits, characteristic of acid mine water.

Water quality is severely degraded by several abandoned and active mines in the Rock Creek watershed. The acid water leaches elements from rocks and soil which come in contact. Evidence of degraded water quality was high conductivity (e.g., 219 µmhos), very acid pH (e.g., 3.2) and toxic concentrations of elements (e.g., aluminum 3.82 mg/1).

Station 11 Campground Creek near Lancing

Stream substrate was 10% cobble and 90% silt. Recent agricultural activities in surrounding fields may have contributed to the sediment problem. Streambanks were stable and covered with dense growths of various vines and trees.

Water quality indicated high concentrations of ions (conductivity 230 µmhos), moderate turbidity (5 NTU), and the highest pH (7.8) recorded during this study. No surface discharge occurred during the drought period sample, therefore, only basic water chemistry data were collected (Table III-7).

Station 12 Camp Branch near Nemo bridge

Stream substrate was 80% cobble, 15% large gravel, and 5% silt size. All substrate was covered with "yellowboy." The stream flows through abandoned stripmine areas and spoils.

Water quality in Camp Branch was the poorest of all streams surveyed. The acid mine water (pH 3.2) had extremely high conductivity (450 µmhos), as well as high SO_4 (68 mg/1), nitrates (0.70 mg/1), and toxic aluminum (3.82 mg/1) (Table III-7).

Station 13 Island Creek near Catoosa

Stream substrate was 70% boulder, 20% cobble, 5% small gravel, and 5% pebble size. The stream channel appeared stabilized and had mature alder thickets providing shoreline cover.

No surface discharge occurred during the drought, therefore, basic water chemistry was taken from pools. The conductivity (72 µmhos), pH (6.8) and alkalinity are characteristic of clean Plateau streams (Table III-7).

Station 14 Island Creek at Emory River stream km 43.6

Stream substrate was 70% large boulder, 20% small boulder, 5% small pebble, and 5% gravel size. Substrate was covered with abundant green filamentous algal growth in the isolated pools. Overstory canopy shaded 40% of the stream channel. Dominant species were alder, hemlock, and black gum.

Water quality was recorded for basic parameters only due to no surface discharges. The water was of poor quality, indicated by acid pH (4.9), high conductivity (105 µmhos) and a moderate SO_4 concentration (26 mg/1) (Table III-7).

Station 15 White Horse Branch at Island Creek mouth

Stream was dry--no samples collected. Spotfin chubs were collected in 1979 in this branch.

Station 16 Emory River at Oakdale

Stream substrate was 80% small boulder and 20% cobble size. The stream channel area had no vegetative cover.

Water quality was good at the Oakdale station. The effects of coal stripmine discharges on water quality were less apparent at

station 16 than locations in the OWSR area near Nemo bridge. The water sample indicated low conductivity (34 μmhos), turbidity (3 NTU), SO_4 (6.2 mg/1) and nutrient levels (Table III-7).

The U.S.G.S. has maintained a gage station at this site for the past 58 years (TVA 1972).

Assessment of Water Quality

Clear Creek Watershed

Water quality was very good in the OWSR section of Clear Creek upstream of White Creek. Thereafter, turbidity and conductivity continually increased downstream which indicated perturbations in the watershed. During storm events sediment transport in streams was very high, with major sources of sediment from unpaved roads (county and petroleum exploration roads) and commercial forestry areas.

Tributary streams appeared, from physical-chemical analyses, to have good water quality during this survey. The severe drought, however, may have isolated contaminants near their point source discharge.

Obed River Watershed

Water quality was severely degraded between Holiday Lake in Crossville to below state route 127 bridge in Cumberland County. Organic pollution was found to cause many water quality problems up to 24 km (15 mi) downstream. Water quality problems such as sediment loading, increased oxygen demand, excessive algal growth from nutrients, and elevated bacterial levels may pose human health problems. During the severe drought in 1980, water quality improved in the OWSR between Adams bridge and Potters Ford because the Crossville sewage discharges were not transported downstream.

Water quality problems in the lower Obed River were caused by sediments from commercial forestry activities. Station 0-4 at Obed Junction had moderately deep sediment accumulations below its confluence with Ramsey Creek. Coal stripmining near the Obed River mouth may contribute additional sediments and acid mine drainage in wet weather.

Daddys Creek Watershed

Water quality was good in the Daddys Creek watershed, however, resorts and industries have the potential to produce an impact to the fragile aquatic environment. The most noticeable water quality problem was moderate nutrient levels on several occasions. Cannery wastewater from the Crossville area may contribute the nutrients.

Emory River Watershed

Water quality was marginal in several sections along the main river corridor. For example, the upper Emory River (above Obed River mouth) water quality indicated pollution from stripmining activities. Light sediment deposits covered the substrate which adversely affected these biological communities (Abbott 1979). Moreover, during rainstorms the moderately high levels of turbidity, sulfate, and conductivity may be accompanied by toxic leachates from surface runoff in stripmine areas.

Water quality in several tributaries to the Emory River in the OWSR was severely degraded by acid mine drainage. The streams had acid pH, very high conductivity, and toxic concentrations of metals. Several streams severely affected by acid mine drainage were Rock Creek, Island Creek, and Camp Branch.

ANALYSIS OF WATER QUALITY IN THE WATERSHED

Water quality characteristics are not uniform from place to place or from time to time at a fixed location in a given stream. Therefore, such variations or lack of variations in "grab" water samples may be difficult for a reader to comprehend unless one is familiar with the geohydrology of the watershed. Significant error and confusion about the data can result from not recognizing that such variations exist in water samples, especially when hydrologic events may transport the pollutional sources.

The purpose of collection of samples is the accumulation of data which can be used to interpret the quality of the water under investigation. Ideally, the sampling program should be so designed that a statistical confidence limit may be associated with each element of data. To do so, sampling should be sufficiently repetitive over a period of time (i.e. daily or weekly) to provide valid data about the condition or quality of the water. This first order water quality survey of the Obed-Emory River system was extensive in the range of analyses performed and it certainly provided a great deal of information on the sources and types of pollutants, the effects of seasonal variations in water discharge on water chemical composition (especially the prolonged "no-flow" period in summer), and stream sections having critical water pollution problems. However, a quarterly sampling program such as the one in this study, at best gives a one-time interpretation of water chemical composition sometime during a three month span. Some chemical problems of an acute nature could be missed; however, the sister report on the aquatic fauna (Abbott 1982) showed evidence of possible chemical pollution in several stream sections not found in the quarterly water sampling study, as

would be expected. Of course, the biological community perturbations detected don't identify what chemical problem existed. This data on water chemistry in the Obed-Emory River system was intended to provide the NPS with information necessary to start synthesizing management plans for the OWSR, and allow them to custom-fit future chemical studies in the area.

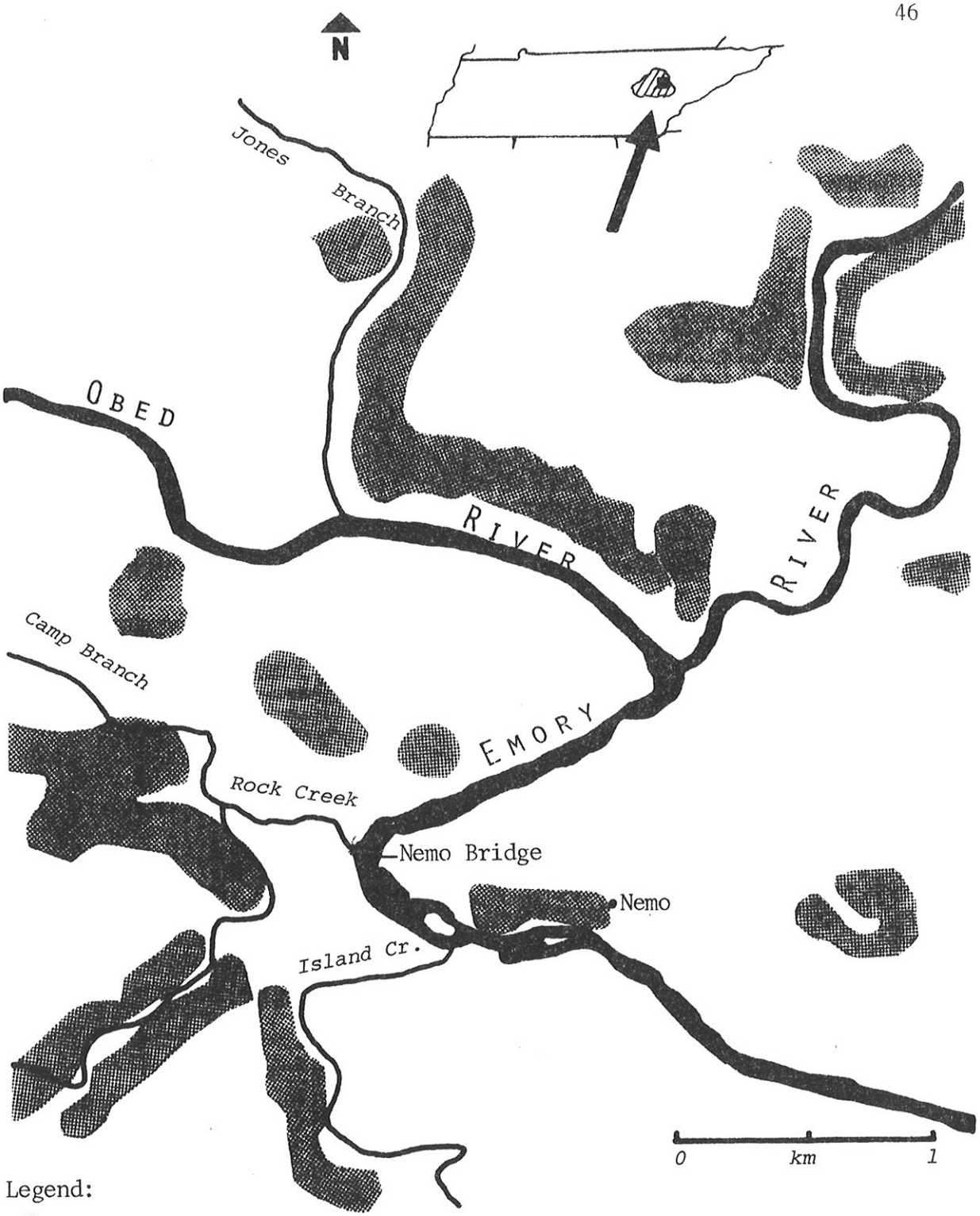
The hydrology of the Cumberland Plateau streams studied had a profound effect on the dispersal of wastes from human activities (sanitary wastewater, acid-mine leachates, agricultural and rural road erosion). Since one tends to scan water quality data for longitudinal differences, it is very misleading to assume that a decrease in waste quantities at downstream stations in the Plateau streams meant assimilation by the stream as normally occurs in most lotic systems. The point to bear in mind is that the sandstone has a very low permeability to water, therefore, extremely low discharge rates occur during the summer.

Qualifications on possible points of view for the data in this report resulting from (1) the single sample of tributary streams and quarterly sampling of the main streams of the Obed-Emory basin, and (2) the effect of the low ground water storage capacity, were to route some individuals away from foreseeable disagreements. Disagreements may have resulted if one overplayed the results in absence of preferable statistical confidence limits, or on the other hand, underplayed the results because of pollutants being temporarily retained upstream by low-flow conditions which existed from June through November, 1980.

The identified sources of pollution affecting main streams were siltation, acid mine leachates, and sanitary wastewater (Fig.15). Siltation resulted from a number of sources in the watershed and was a difficult

water quality parameter to assess in a quantitative sense. During the field surveys several intense storms were observed to transport heavy silt loads to the streams, especially from the rural dirt roads. More noticeable siltation was reported from the Crossville Municipal Sewage discharge (affected the upper Obed between Crossville and Adams Bridge), the commercial pine plantations near Obed Junction (via Ramsey Creek), and the stripmining in the Emory River gorge (above Obed River confluence). Acid-mine leachates which are toxic to aquatic organisms were detected in the lower Obed River, upper Emory River, and a number of tributary streams in the coal bearing areas (see Figure 14). Sanitary waste water produced organic pollution problems in the upper Obed River from Crossville downstream as far as Potters Ford in the Catoosa Wildlife Management area. Parasitic infestations on fish were very heavy in the organically polluted section, especially from Lernaea cyprinacea (parasitic copepod), and Uvulifer ambloplitis (trematode). The extent of "damage" to the recreational potential of the Obed-Emory River system from the detected water quality problems varied in severity depending on the stability of the stream environment and the frequency of the stresses.

Siltation problems usually had localized distribution in the Obed-Emory River except when human activities were either directly disturbing one of the tributaries or during the reduced flow period (which may last six months). High turbidity was also recorded after heavy rainfall which transported soil from rural roads, agricultural areas, and stripmining spoils. However, the effects of short term turbidity on the ecology of a stream is difficult to quantitatively assess. Generally, siltation reduced the diversity of stream habitats (which may exclude certain species of organisms) and covered benthic spawning



Legend:

Areas affected by coal stripmining in the Obed-Emory watershed

Figure 14. Areas affected by coal stripmining near the Obed and Emory Rivers confluence.

areas and food sources in streams. The final effect of increasing turbidity levels in the OWSR may be replacement of the native fish fauna with several species tolerant of higher turbidity levels.

Acid mine leachates were the gravest toxicity problem identified in the water quality samples. Streams sampled in the vicinity of the OWSR which were adversely affected by acid mine drainage (in decreasing order of severity) were Camp Branch, Rock Creek, Island Creek, and Emory River.

Acid mine drainage originates with the oxidation of sulfide minerals shown by the following equations:

$$2FeS_2 + 7O_2 + 2H_2O \rightarrow 2FeSO_4 + H_2SO_4 \quad (1)$$

$$4FeSO_4 + O_2 + H_2SO_4 \rightarrow 2Fe_2(SO_4)_3 + 2H_2O \quad (2)$$

$$Fe_2(SO_4)_3 + 6H_2O \rightarrow 2Fe(OH)_3 + 3H_2SO_4 \quad (3)$$

End products (Equation 3) of ferric sulfate oxidation reactions are ferric hydroxide ("yellowboy" precipitate) and more acid. Due to the low pH, the dissolved solids loading may contain significant quantities of iron, aluminum, copper, and other heavy metals, depending on mineralogical composition of the ore deposit and associated materials in contact with acid water. The toxicity of these heavy metal ions to aquatic macroinvertebrates and fishes has been well documented in many studies (Shaw and Grushkin 1957; Warnick and Bell 1969; Abbott 1979; Abbott 1982; and many others). On the other hand, the presence of rocks containing appreciable quantities of carbonates in some regions may help neutralize the acid formation from sulfide minerals in coal stripmining areas after many years; however, there are very low carbonate levels in the

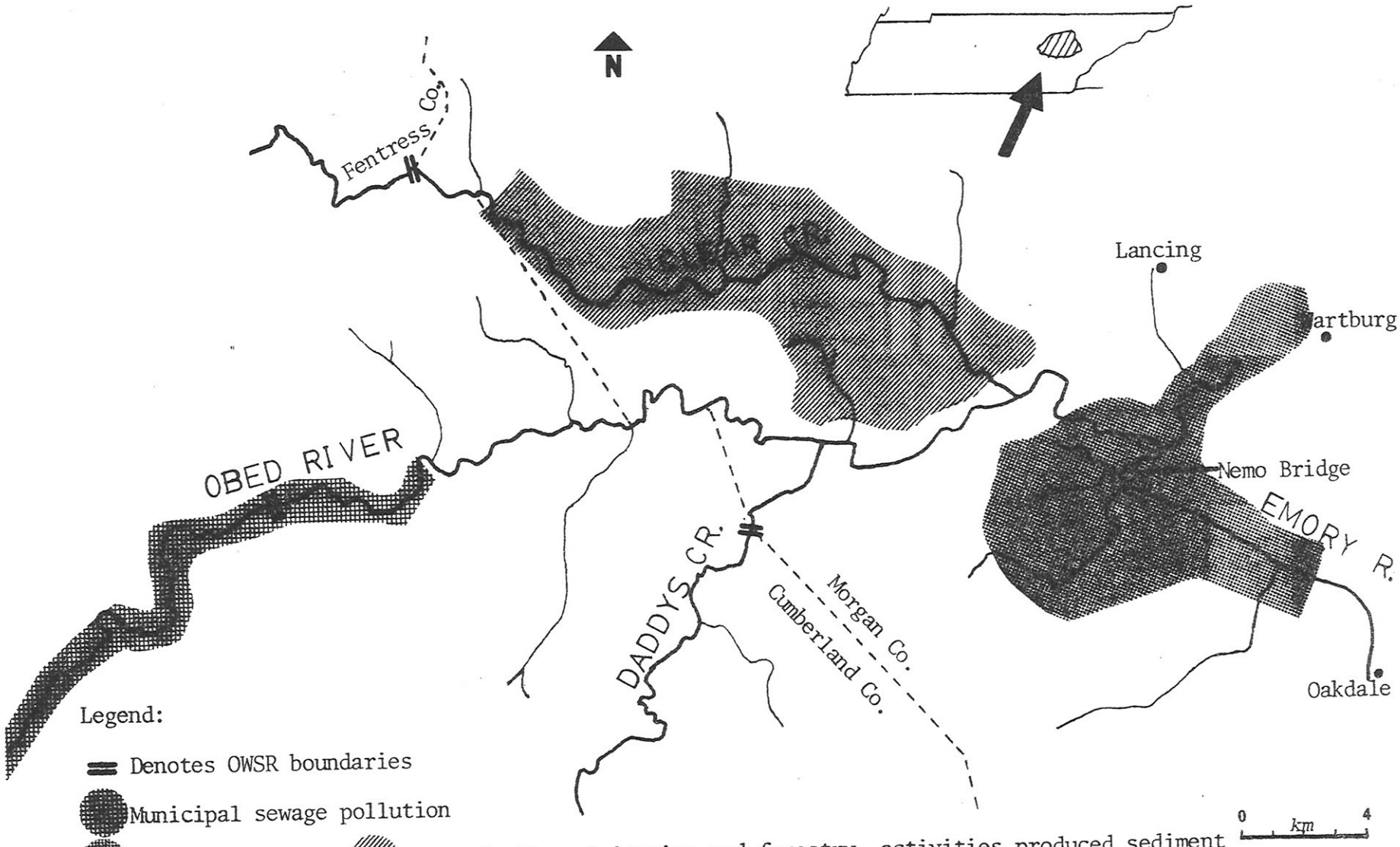


Figure 15. Map showing environmental problem areas in the Obed-Emory watershed.

rocks of the upper Emory River basin. Therefore, the acid mine leachate problems documented in this study affecting the OWSR are not expected to be self ameliorating. The total effect of acid mine leachates on the aquatic organisms is beyond the scope of this study. However, the potential adverse effects of slugs of leachate water entering the streams after localized heavy showers and the persistent discharges entering the streams would definitely produce serious impacts on the OWSR.

Sanitary wastewater discharges from Crossville were released approximately 19 km (12 mi.) above the OWSR boundary in the Obed River. The effects of increased nutrients, high organic content and the associated bacterial contamination caused excessive algal growth and increased the oxygen demand. The aquatic organisms native to this section of the Obed River, had been replaced by pollution tolerant organisms. Moreover, this study documented the effects of low stream flow restricting the transport of wastes downstream. Wastewater pollution was trapped in the upper Obed River during the extended "no streamflow" period from June through November 1980, causing more severe organic pollution problems near Crossville and allowing the assimilation of previously transported wastes in the OWSR area. Potential human health hazards from the wastewater should be evaluated in the future.

CONCLUSIONS

The results of this first order assessment of water quality in the OWSR documented the persistent water pollution problems. The statistical confidence limits possible on quarterly water "grab" samples and the extreme variations in streamflows during this study made sensitive conclusions difficult to support. However, much information on the

sources, types of pollutants, the effects of seasonal streamflow variations on water chemical composition, and the identification of stream sections having critical water pollution problems was collected.

The most widespread water quality problem was siltation. The sandy soils of the Cumberland Plateau were moderately to highly erodable. Steep terrains compound the problem when human activities disturb the ground cover. The most extensive sources of silt appeared to be (in decreasing order of magnitude) rural roadbeds, agricultural plots, coal, oil, and gas exploration access roads, and stripmining spoils.

Acid mine leachates were the gravest toxicity problem affecting the recreational potential and aquatic fauna. This pollution problem was very serious since the low buffering capacity of the stream water made assimilation of the acid wastes practically impossible other than by dilution.

Finally, the Crossville sanitary wastewater discharges into the Obed River caused the most widespread enrichment pollution. During sustained streamflow, the signs of organic pollution extended from Crossville downstream to Potters Ford, approximately 25 km (15 mi.). However, the intermittent streamflow which occurred from June through November, 1980, trapped the sanitary wastes near Crossville and the water quality in the upper OWSR section of the Obed River improved.

More detailed studies in the OWSR may find additional water quality problems missed by the quarterly sampling program in this research. In particular, the aquatic fauna study detected a recurrent chemical toxicity problem in Clear Creek at Lilly Bridge (Abbott 1982). This toxicant may be periodically dumped into the stream from the bridge.

RECOMMENDATIONS

This water quality evaluation of the Obed-Emory watershed has provided added insight into the chemical and physical characteristics of these systems. Moreover, several subject areas that need further investigation have been pointed out. Analysis of the water chemical data has led to the formulation of specific recommendations that should be considered in protecting and enhancing the ecological integrity of this watershed.

1. The effects of siltation should receive immediate attention since the sources are identifiable and the habitat for spotfin chub and muskellunge are being adversely affected.
2. Reclamation activities in the Emory River basin should address the problem of acid mine drainage and the amount of wastewater entering the river.
3. The discharge of wastewater from Crossville should be monitored and alternative plans evaluated.
4. Mining activities for coal, oil, and gas should be supervised and monitored to prevent heavy sediment loads to the streams from these activities.
5. Water chemical studies are not suited for detecting occasional waste releases; therefore, biological studies may be more useful to locate areas needing future chemical samples.

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LITERATURE CITED

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APPENDICES

Appendix I. Source listing of related environmental data for the Obed-Emory watershed.

Water quality
Chemical-physical

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Biological
Macroinvertebrates

Martino, L. E. 1979. Acute and chronic toxicity of characteristic acid stripmine wastes to aquatic macroinvertebrates: Selected heavy metals and hydrogen ion concentation. M.S. thesis, Tenn. Tech. Univ., Cookeville. 70 pp.

Orr, J. R. 1979. Acute and chronic toxicity of leachates from surface mine runoff to Stenonema spp. and Isonychia spp. mayfly nymphs. M.S. thesis, Tenn. Tech. Univ., Cookeville. 94 pp.

Wang, H. 1980. Toxicity of suspended solids and aluminum to representative species of Isonychia, Stenonema, and Goniobasis. M.S. thesis, Tenn. Tech. Univ., Cookeville. 65 pp.

Amphibians

DeLotelle, R. S. 1976. A herpetological survey of a mixed mesophytic forest on the Eastern Highland Rim, Tennessee. M.S. thesis, Tenn. Tech. Univ., Cookeville. 65 pp.

Snyder, D. H. 1972. Amphibians and reptiles of Land Between the Lakes Austin Peay State Univ., Clarksville, TN. 90pp.

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Fishes

Specimens and Collections

Etnier, David A. Univ. of Tennessee Ichthyology Collection, Knoxville, TN.

Jenkins, Robert E. Roanoke College, Dept. of Biology, Salem VA.

Forestry, Fisheries and Wildlife, TVA, Norris, TN.

Smith, Robert P. Fish and Wildlife Service, Great Smokey Mtn. National Park Hdqtrs., Gatlinburg, TN.

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General Resources

Minerals

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Soils

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Summary of Resources

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Appendix II. Water quality samples collected from gage stations in the upper Emory River Watershed[a]

U.S.G.S. Number	Stream	Stream km.	Stream mi.	Drainage Area (mi^2)	Location	Medium Chem. Charact. pH	Conduct.	SO_4	Biol. Sample[b]
3540500	Emory River @ Oakdale	29.3	18.3	764	Below Oakdale Bridge	6.8	49	9	1,2
3538500	Emory River near Wartburg	55.2	34.5	83.2	@ Wartburg--Lancing Rd.	6.8	57	11	
	Emory River near Gobey	72.3	45.3	11.0	0.2 mi. W of Macedonia Church	6.9	94	25	
3540100	Crab Orchard Cr. near Deermont	4.6	2.9	33.7	Bridge 1.9 mi. SW of Deermont	5.0	64	20	
3539860	Crooked Fork near Wartburg	10.0	6.2	50.3	@ U.S. highway 27	5.9	195	74	
	Bletchers Creek near Petros	1.1	0.69	4.7	Bridge 0.8 mi ESE of Petros	7.3	175	61	
3539800	Obed River near Lancing	2.4	1.5	518	@ Alley Ford	6.8	31	3.4	
	Obed River @ Obed Junction	14.4	9.0	331	0.1 mi below Daddys Cr. mouth	6.9	35	3.2	2
	Clear Creek near Lancing	2.4	1.5	170	@ Lilly Bridge (Howard Mill)	6.4	27	4.2	2
3539600	Daddys Creek near Hebbertsburg	14.6	9.1	139	@ Antioch Bridge	7.1	44	3.2	1,2

[a]Source TVA, 1972.

[b]Sources 1 = Pennington, 1980.
2 = Abbott, 1981.

Table III-1. Physical, chemical, and bacteriological water data, Obed-Emory Watershed, Tennessee, 16 November 1979.

Parameters[a]	C-1	C-2	C-3	C-4	0-2	0-3	0-4	D-1	E-1	E-2	R-2
Discharge (m^3/sec)	5.7	8.5	14.2	17.0	1.7	2.3	28.3	1.7	1.7	34.0	0.1
Temp. Ambient	13	18	12	12	-1	0	2	5	18	13	13
Wat. (°C)	7	8	7	7	8	8	8	8	8	8	9
Conductivity[c]	16	53	31	31	46	58	53	44	68	39	94
Turbidity (NTU)	0.5	1	1	1	1	1	1	1	3	1	1
St. sed.[e] (NTU)	2	2800	20	20	-	-	-	-	-	-	-
Alkalinity ($CaCO_3$)	9	10	6	6	2	0	1	0	4	0	3
Dissolved Oxygen	12.4	11.2	12.0	12.2	12.4	12.3	12.1	12.4	11.9	12.1	11.3
Hardness ($CaCO_3$)	16	12	18	12	22	6	16	18	16	16	24
SO_4	8	6	7	7	-	6	8	13	13	7	42
pH (units)	6.5	6.6	6.7	6.6	6.7	6.8	6.9	7.2	6.5	6.8	3.6
NO_2	0.01	0.01	0.01	ND	ND	ND	ND	0.01	0.01	0.02	ND
NO_3	0.2	0.3	0.2	0.1	0.1	0.1	0.1	0.1	0.2	0.2	0.2
NH_3	-	.38	.42	-	-	.45	-	.58	.28	.45	.46
Kjeldahl N	1.7	0.9	0.1	0.6	-	12.1	ND	10.7	0.1	ND	4.7
Orthophoshate	0.1	.01	.02	.02	.02	0.04	0.02	0.04	0.02	0.06	0.02
Phosphorus, total	0.1	1.2	1.1	0.6	-	0.4	0.1	1.6	0.1	1.2	0.1
hydrolyzable	-	-	-	-	-	-	-	-	-	-	-
Aluminum	0.7	0.9	0.7	0.8	-	0.6	0.8	0.8	0.8	0.8	1.7
Chromium	0.3	0.1	ND	0.1	-	ND	0.1	0.1	0.1	0.1	ND
Copper	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Iron	0.1	0.1	0.2	ND	-	0.3	0.2	0.2	0.3	0.2	0.5
Lead	-	-	-	-	-	-	-	-	-	-	-
Manganese	0.02	0.02	0.01	0.03	-	0.02	0.01	ND	0.04	0.01	0.65
Mercury[b]	-	-	-	-	-	-	-	-	-	-	-
Zinc	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.06
Fecal coliforms[d]	0	1	1	0	0	2	1	0	0	2	2
Total	0	1	1	0	0	3	2	1	0	4	3

[a]All parameters expressed as mg/l unless otherwise indicated.

[b]expressed as µg/l.

[c]µmhos/cm @ 25°C.

[d]MPN/100 ml.

[e]water samples taken immediately after rain storm, 28 October 1979.

ND--Not detected in sample.

Table III.2. Physical, chemical, and bacteriological water data, Obed-Emory Watershed, Tennessee, 29 February 1980.

Parameters[a]	C-1	C-2	C-3	C-4	O-2	O-3	O-4	D-1	E-1	E-2	R-2
Discharge (M^3/sec)	-	-	-	-	-	-	-	-	-	-	-
Temp., Wat. (°C)	5	5	5	3	0	0	5	0	2	4	-1
ambient (°C)	0	2	2	-4	-12	-2	0	0	-6	-6	-6
Conductivity[c]	28	28	32	26	45	37	32	33	51	50	84
Turbidity (NTU)	1	1	1	2	3	3	4	2	3	2	e
Alkalinity ($CaCO_3$	7	8	7	7	11	13	14	18	22	21	2
Dissolved Oxygen	14.4	13.2	12.8	13.0	13.6	13.1	13.2	13.3	12.8	13.0	e
Hardness (Total)	15	23	15	15	11	19	15	23	31	23	42
SO4	3.0	3.2	3.6	3.4	4.8	4.2	3.6	2.6	18	10.0	32.6
pH (units)	6.3	6.6	6.3	6.4	6.6	6.5	6.3	6.8	6.8	6.4	3.6
NO3	ND	0.10	ND	ND	0.36	0.28	0.10	0.18	0.10	0.05	0.46
NH3	ND	ND	ND	ND	0.1	0.05	ND	ND	ND	ND	ND
Kjeldahl N	ND	0.12	0.10	ND	0.36	0.12	0.05	ND	0.08	ND	0.30
Orthophosphate	ND	0.05	ND	ND	0.12	0.05	ND	0.05	ND	ND	0.03
Phosphorus total	ND	0.05	0.05	0.05	0.16	0.05	ND	0.10	ND	ND	0.18
hydrolyzable	ND	ND	ND	ND	0.05	ND	ND	ND	ND	ND	ND
Aluminum	0.07	0.16	0.03	0.90	1.09	0.03	0.32	0.81	0.53	0.28	4.37
Chromium	ND	ND	ND	0.02	ND	ND	ND	0.02	0.01	0.01	0.01
Copper	ND	ND	ND	0.01	ND	ND	ND	0.03	0.01	ND	ND
Iron	0.08	0.05	0.08	0.16	0.67	0.05	0.15	0.17	0.26	0.15	0.21
Lead	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Mercury	-	-	-	-	-	-	-	-	-	-	-
Zinc	0.02	0.06	0.02	0.16	0.05	ND	0.02	0.41	0.20	0.05	0.23
Fecal coliforms[d]	-	0	0	1	560	332	52	5	3	1	2
Fecal streptococci[d]	-	5	0	0	134	102	42	2	0	0	0

[a] expressed as mg/1 unless otherwise indicated.

[b] expressed as µg/1.

[c] µmhos/cm @ 25°C.

[d] MPN/100 ml

[e] interference from ice.

ND--Not detected in sample.

Table III.3. Physical, chemical, and bacteriological water data, Obed-Emory Watershed, Tennessee, 3 May 1980.

Parameters[a]	C-1	C-2	C-3	C-4	0-2	0-3	0-4	D-1	E-1	E-2	R-2
Discharge (M^3/sec)	4.2	7.1	8.5	9.1	5.7	8.5	11.3	5.0	4.0	28.3	0.1
Temp., Wat. (°C)	13	15	15	16	14	14	15	14	15	14	14
ambient (°C)	18	22	23	27	23	23	27	21	20	16	14
Conductivity[c]	22	22	22	22	29	28	25	35	47	25	70
Turbidity (NTU)	2	3	3	2	5	3	4	3	7	3	5
Alkalinity ($CaCO_3$	7	7	9	7	12	14	16	2	14	9	16
Acidity	0	11	29	11	29	13	5	19	25	21	39
Dissolved Oxygen[e]	-	-	-	-	8.7	-	-	-	-	-	-
Hardness (Total)	20	12	10	6	14	16	14	20	24	14	26
SO_4	2.2	2.2	1.6	2.0	3.2	3.6	2.6	1.2	40.2	26.0	66.0
pH (units)	5.8	5.8	5.7	5.9	5.7	5.2	6.5	6.3	5.2	6.1	3.4
NO_3	ND	0.01	0.02	ND	0.40	0.32	0.13	0.02	0.03	0.37	-
NH_3	ND	ND	ND	ND	0.08	0.05	ND	ND	ND	ND	-
Kjeldahl N	ND	0.10	ND	ND	0.32	0.28	0.10	0.05	0.12	0.08	0.56
Orthophosphate	0.01	0.03	0.06	0.01	0.04	0.01	0.03	0.01	0.01	0.03	0.03
Phosphorus, total	ND	0.5	0.6	0.4	0.3	0.4	0.6	0.3	0.5	0.07	0.2
hydrolyzable	-	-	-	-	-	-	-	-	-	-	-
Aluminum	0.19	ND	0.28	0.35	0.29	0.24	0.20	0.47	0.12	0.19	0.84
Chromium	0.01	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Copper	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Iron	0.10	0.08	0.09	0.08	0.20	0.22	0.11	0.16	0.19	0.14	0.46
Lead	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Mercury[b]	ND	-	-	-	-	-	-	-	-	-	-
Zinc	ND	0.001	0.001	ND	ND	ND	ND	0.004	0.004	0.005	0.033
Fecal coliforms[d]	2	6	3	0	54	40	3	5	3	2	3
Fecal streptococci[d]	5	2	10	2	117	68	6	3	8	10	9

[a] expressed as mg/l unless otherwise indicated.

[b] expressed as µg/1.

[c] µmhos/cm @ 25°C.

[d] MPN/100 ml

[e] instrument malfunctioned.

ND--Not detected in sample.

Table III-4. Physical, chemical, and bacteriological water data, Obed-Emory Watershed, Tennessee, 7 June 1980.

Parameters[2]	C-3	C-4	0-2	0-3	0-4 (5-28)	D-1	E-1	E-2	R-2
Discharge (M^3/sec)	0.7	0.7	1.1	1.1	-	0.5	0.3	2.8	0.04
Temp. Wat. (°C)	26	25	23	20	18	22	24	25	19
ambient (°C)	27	28	20	23	20	23	28	24	24
Conductivity[c]	38	35	70	58	32	50	73	45	131
Turbidity (NTU)	2	3	4	3	6	3	4	3	2
Alkalinity ($CaCO_3$	6	4	15	12	11	16	12	11	0
Acidity	3.5	-	0	0	9	0	0	0	15
Dissolved Oxygen	7.6	7.8	6.2	6.2	8.8	7.2	7.9	8.	9.1
Hardness (Total)	12	12	16	14	18	14	28	20	54
SO_4	5.3	5.0	8.5	4.3	3.8	3.3	20.6	20.3	62.0
pH (units)	5.9	5.6	8.5	6.2	6.6	6.3	6.0	5.5	3.5
NO_3	0.15	-	0.65	0.56	-	0.46	0.26	0.24	0.76
NH_3	ND	ND	0.02	0.02	ND	ND	ND	ND	ND
Kjeldahl N	ND	ND	ND	ND	-	ND	ND	ND	2.3
Orthophosphate	ND	ND	0.15	0.10	-	0.15	ND	ND	ND
Phosphorus total	ND	0.05	0.08	0.06	-	0.10	ND	ND	ND
hydrolyzable	ND	ND	0.05	-	-	0.03	ND	ND	ND
Aluminum	0.20	0.21	0.14	0.32	-	0.15	0.06	0.08	1.34
Chromium	ND	ND	ND	ND	-	ND	ND	ND	ND
Copper	ND	ND	ND	ND	-	ND	ND	ND	ND
Iron	0.07	0.16	0.12	0.12	-	0.08	0.16	0.12	0.18
Lead	ND	ND	ND	ND	-	ND	ND	ND	ND
Mercury[b]	0.47	ND	ND	ND	-	ND	ND	ND	ND
Fecal coliforms[d]	-	-	-	-	-	-	-	-	-
Fecal streptococci[d]	-	-	-	-	-	-	-	-	-

[a] expressed as mg/l unless otherwise indicated.

[b] expressed as µg/1.

[c] µmhos/cm @ 25°C.

[d] MPN/100 ml.

ND--Not detected in sample.

Table III-5. Physical, chemical, and bacteriological water data, Obed-Emory Watershed, Tennessee, 21 June 1980.

Parameters[a]	C-1	C-2	C-3
Discharge (M^3/sec)	0.1	0.1	0.2
Temp. Wat. (°C)	21	24	26
ambient (°C)	15	29	24
Conductivity[c]	37	32	42
Turbidity (NTU)	3	2	3
Alkalinity ($CaCO_3$)	22	20	3.2
Acidity	33	13	13
Dissolved Oxygen	8.6	8.8	8.8
Hardness (Total)	12	18	10
SO_4	8.3	6.4	6.3
pH (units)	5.8	6.5	6.5
NO_3	ND	ND	ND
NH_3	ND	ND	ND
Kjeldahl N	ND	ND	ND
Orthophosphate	0.04	0.05	0.05
Phosphorus total	0.04	0.05	0.02
hydrolyzable	ND	ND	ND
Aluminum	0.04	0.06	0.13
Chromium	ND	ND	ND
Copper	ND	ND	ND
Iron	0.14	0.19	0.17
Lead	ND	ND	ND
Mercury[b]	ND	0.40	-
Zinc	0.01	ND	0.008
Fecal coliforms[d]	0	1	0
Fecal streptococci[d]	5	3	0

[a] expressed as mg/l unless otherwise indicated.

[b] expressed as µg/l.

[c] µmhos/100 ml.

[d] MPN/100 ml.

ND Not detected in sample.