UNITED STATES

DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

RECONNAISSANCE OF STORMWATER-RUNOFF WATER QUALITY OF THE BIG PINEY CREEK SEGMENT OF THE CEDAR-PINEY CREEKS WATERSHED, YELL COUNTY, ARKANSAS

By James C. Petersen

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Prepared in cooperation with the

U.S. Soil Conservation Service

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JAMES G. WATT, Secretary

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Dallas L. Peck, Director

For additional information write to:

U.S. Geological Survey
Water Resources Division
2301 Federal Office Building
Little Rock, Arkansas 72201-3287

or

U.S. Department of Agriculture
Soil Conservation Service
Post Office Box 2323
Little Rock, Arkansas 72203

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Box 25425, Denver Federal Center
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CONVERSIONS

Multiply	By	To obtain
inch	2.54×10^{1}	millimeter
foot	0.3048	meter
mile	1.609	kilometer
foot per mile	0.1894	meter per kilometer
cubic foot per second	0.02832	cubic meter per second
acre	0.4047	hectare
pound	0.4536	kilogram
milligram	3.527×10^{-5}	ounce
ton (2000 pounds)	0.9072	metric ton (1000 kilograms)
liter	0.2642	gallon
micromho	1.000	microsiemens
Celsius	1.8, then add 32	Fahrenheit

National Geodetic Vertical Datum of 1929 (NGVD of 1929): A geodetic datum derived from a general adjustment of the first-order level nets of both the United States and Canada, formerly called mean sea level. NGVD of 1929 is referred to as sea level in this report.

RECONNAISSANCE OF STORMWATER-RUNOFF WATER QUALITY OF THE BIG PINEY CREEK SEGMENT OF THE CEDAR-PINEY CREEKS WATERSHED, YELL COUNTY, ARKANSAS

By James C. Petersen

ABSTRACT

A reconnaissance of the Big Piney Creek watershed was conducted between June 1981 and January 1982 to assess the water-quality of selected streams in the watershed. Streamflow was measured and water samples were collected three times at each of three sites during the study. All samples were collected during periods of stormwater runoff. The water was soft (7 to 20 milligrams per liter of hardness as calcium carbonate) and dissolved-solids concentrations ranged from 36 to 74 milligrams per liter. Suspended-sediment concentrations ranged from 7 to 144 milligrams per liter. The 5-day biochemical oxygen-demands, total-nitrogen concentrations and total-phosphorus concentrations ranged from 1.5 to 6.8 milligrams per liter, 0.54 to 5.8 milligrams per liter, and 0.03 to 0.56 milligram per liter, respectively. Fecal-coliform bacteria were present in large enough concentrations at two of the sites (340 to 490 colonies per 100 milliliters and 1,200 to 6,000 colonies per 100 milliliters) to indicate that the U.S. Environmental Protection Agency criterion for bathing waters and the Arkansas water-quality standard may be exceeded at times. Total-iron concentrations greater than 1,000 micrograms per liter (the U.S. Environmental Protection Agency criterion for protection of freshwater aquatic life) were detected at least once at all sites.

INTRODUCTION

Purpose and Scope

This report, prepared in cooperation with the U.S. Soil Conservation Service, documents the results of a water-quality reconnaissance of part (the Big Piney Creek watershed) of the Cedar-Piney Creeks watershed prior to construction of two dams proposed by the U.S. Soil Conservation Service. Both reservoirs are to be used primarily for flood control. Water samples were collected and discharge measurements were made at the proposed damsites and downstream near the mouth of Big Piney Creek (fig. 1). To assist the Soil Conservation Service with its planning activities, results were compared with pertinent water-quality criteria and Arkansas water-quality standards.

Description of Project Area

The Big Piney Creek watershed is in the Arkansas Valley region of the Interior Highlands. Creeks within the watershed flow southward into Big Piney Creek which empties into the Petit Jean River (fig. 1). Altitudes within the watershed range from approximately 2,200 feet above sea level at the northwestern edge to approximately 340 feet at the mouth of Big Piney Creek.

The northern part of the Big Piney Creek watershed is drained by Little Piney Creek and Truett Creek. Dams are proposed for both creeks (fig. 1). A dam has been constructed on Cedar Creek which drains the eastern part of the Cedar-Piney Creeks watershed. Water quality of Cedar Creek and of Big Piney Creek downstream from Cedar Creek was not considered in this report.

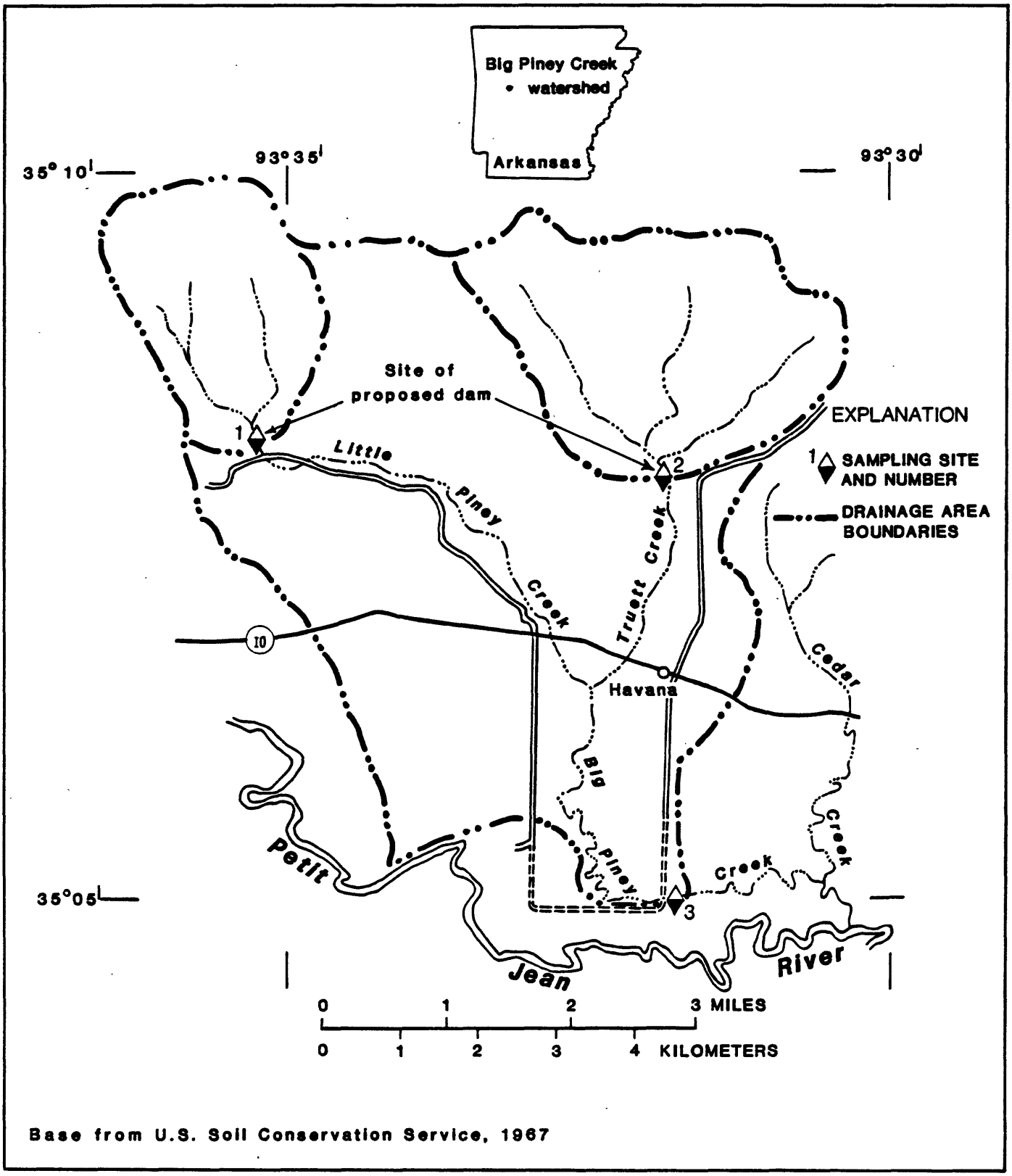

Figure 1.—Big Piney Creek study area.

Land-use maps and/or tabulations provided by the U.S. Soil Conservation Service reveal differences in the drainage areas upstream of the three sampling sites. The drainage area upstream from the Little Piney Creek damsite (site 1) is about 1,300 acres and is approximately 95 percent woodlands and 5 percent pasture. There are also two chicken houses within the drainage area. The drainage area upstream of the Truett Creek damsite (site 2) is about 2,200 acres and also is approximately 95 percent woodlands and 5 percent pasture. The total drainage area upstream of the Big Piney Creek sampling site (site 3) is about 11,000 acres and is approximately 60 percent woodlands, 30 percent pasture and 10 percent other crops and miscellaneous uses. There are also approximately 50 chicken houses within this drainage area. Chicken litter is commonly used on pastures throughout the entire watershed as fertilizer.

National Weather Service records (National Oceanic and Atmospheric Administration, 1979, pp. 2 and 4) indicate that the normal mean air temperature in the Big Piney Creek watershed area (Subiaco, Ark., about 15 miles northwest of Havana) is about 16.6° Celsius and that the normal annual precipitation in the area (Danville, Ark., about 10 miles southeast of Havana) is about 48.5 inches.

Four Middle Pennsylvanian formations crop out within the Big Piney Creek study area. These are, in descending order, the Savannah Formation, the McAlester Formation, the Hartshorne Sandstone, and the Atoka Formation (Haley and others, 1976). Chemical quality of groundwater within the Arkansas Valley region is related to the geology of the area (Cordova 1963, pp. 22-27). In the Arkansas Valley region sodium and bicarbonate were the dominant ions in water from three of the formations. In water from the Hartshorne Sandstone, bicarbonate, sulfate, calcium, sodium and

magnesium occurred but none were obviously the dominant anion or cation. Concentrations of total dissolved solids were less than 500 milligrams per liter (mg/L) in water from the Savannah Formation and the Hartshorne Sandstone but were more variable in water from the McAlester and Atoka Formations. Iron concentrations generally exceeded 2 mg/L in the Hartshorne Sandstone and the Atoka Formation. Groundwater hardness from the four formations in the Arkansas Valley region averaged 135 mg/L and ranged from 4 to 1,100 mg/L in 58 wells.

DATA COLLECTION

Sampling sites at the two proposed dam sites (sites 1 and 2) and another near the Cedar Creek-Big Piney Creek confluence (site 3) were selected (fig. 1). The U.S. Geological Survey station identification numbers are 350804093350600 for site 1 (Little Piney Creek near Marvinville), 350756093324800 for site 2 (Truett Creek near Havana) and 350504093310500 for site 3 (Big Piney Creek near Havana).

Water samples were collected during periods of stormwater runoff because it was anticipated that streamflows at sites 1 and 2 would be very low to nonexistent at other times. The samples were analyzed for common ions, selected forms of nitrogen and phosphorus, total organic carbon, biochemical oxygen-demand, turbidity, suspended-sediment concentration, and color. Water and air temperature, dissolved oxygen, specific conductance, pH, and instantaneous discharge also were measured during the collection of the samples. Samples also were collected for determination of fecal-coliform, total-coliform, and fecal-streptococcal bacteria concentrations. Results are shown in table 1.

Water samples were collected and analyzed according to methods described by Guy (1969), Guy and Norman (1970), Goerlitz and Brown (1972), Greeson and others (1977, pp. 21-62), and Skougstad and others (1979).

Table 1.--Physical, chemical, and bacteriological data, Big Piney Creek watershed

[CFS, cubic feet per second; E, estimated; umho, micromho; DEG C, degrees Celsius; MG/L, milligram per liter; UM, micrometer; MF, membrane filter; COLS., colonies; ML, milliliters; K, plate count outside ideal range; IMMED., immediate; NTU, nephelometric turbidity units; CACO3, calcium carbonate; AC-FT, acre-foot; T, ton (2000 pounds); SED SUSP., sediment suspended; DIAM., diameter; MM, millimeter;]

DATE	TIME	STREAM-FLOW, INSTAN-TANEOUS (CFS)	SPE-CIFIC CON-DUCT-ANCE (UMHO)	PH (UNITS)	TEMPER-ATURE (DEG C)	TEMPER-ATURE, AIR (DEG C)	OXYGEN, DIS-SOLVED (MG/L)
Site 1	350804093350600 - LITTLE PINEY CREEK NEAR MARVINVILLE, ARK (LAT 35 08 04 LONG 093 35 06)						
JUN 1981							
05...	1015	16	27	6.6	19.0	25.0	8.4
OCT							
19...	1225	.87	44	6.5	16.0	20.5	10.0
JAN 1982							
22...	1350	6.3	33	6.6	6.0	8.5	11.6
Site 2	350756093324800 - TRUETT CREEK NEAR HAVANA, ARK (LAT 35 07 56 LONG 093 32 48)						
JUN 1981							
05...	1100	21	32	6.8	19.0	25.0	8.4
OCT							
19...	1330	.59	44	6.6	13.0	20.0	10.6
JAN 1982							
22...	1440	13	39	6.8	4.5	9.5	12.2
Site 3	350504093310500 - BIG PINEY CREEK NEAR HAVANA, ARK (LAT 3 (LAT 35 05 04 LONG 093 31 05)						
JUN 1981							
05...	1245	86	68	7.1	22.0	24.5	7.1
OCT							
19...	1440	7.8	80	6.5	13.0	19.0	7.4
JAN 1982							
22...	1520	E82	90	6.7	2.0	10.5	11.6

Table 1.--Physical, chemical, and bacteriological data, Big Piney Creek watershed (continued)

DATE	TIME	OXYGEN, DIS-SOLVED (PER-CENT SATUR-ATION)	OXYGEN DEMAND, BIO-CHEM-ICAL, 5 DAY (MG/L)	COLI-FORM, FECAL, 0.7 UM-MF (COLS./ 100 ML)	STREP-TOCOCCI FECAL, KF AGAR (COLS. PER 100 ML)	COLI-FORM, TOTAL, IMMED. (COLS. PER 100 ML)	TUR-BID-ITY (NTU)	COLOR (PLAT-INUM-COBALT UNITS)
Site 1	350804093350600 - LITTLE PINEY CREEK NEAR MARVINVILLE, ARK (LAT 35 08 04 LONG 093 35 06)							
JUN 1981 05...		90	1.5	170	940	350	18	40
OCT 19...		102	3.0	82	410	640	26	60
JAN 1982 22...		94	1.8	200	1400	2400	64	150
Site 2	350756093324800 - TRUETT CREEK NEAR HAVANA, ARK (LAT 35 07 56 LONG 093 32 48)							
JUN 1981 05...		90	2.4	490	K2600	1700	23	50
OCT 19...		101	2.1	410	2000	--	50	110
JAN 1982 22...		94	1.9	340	5700	2800	59	150
Site 3	350504093310500 - BIG PINEY CREEK NEAR HAVANA, ARK (LAT 35 05 04 LONG 093 31 05)							
JUN 1981 05...		81	5.0	K1200	9800	3600	88	160
OCT 19...		70	3.0	K1200	3100	5500	50	100
JAN 1982 22...		84	6.8	6000	K94000	9400	130	150

Table 1.--Physical, chemical, and bacteriological data, Big Piney Creek watershed (continued)

DATE	HARDNESS MG/L AS CACO3)	HARDNESS NONCARBONATE (MG/L AS CACO3)	CALCIUM DISSOLVED (MG/L AS CA)	MAGNESIUM, DISSOLVED (MG/L AS MG)	POTASSIUM, DISSOLVED (MG/L AS K)	SODIUM, DISSOLVED (MG/L AS NA)	SODIUM ADSORPTION RATIO
Site 1 350804093350600 - LITTLE PINEY CREEK NEAR MARVINVILLE, ARK (LAT 35 08 04 LONG 093 35 06)							
JUN 1981							
05...	7	3.0	1.2	1.0	1.0	2.1	0.3
OCT							
19...	11	.00	1.7	1.7	1.1	1.2	.2
JAN 1982							
22...	8	.00	1.2	1.1	.8	2.4	.4
Site 2 350756093324800 - TRUETT CREEK NEAR HAVANA, ARK (LAT 35 07 56 LONG 093 32 48)							
JUN 1981							
05...	10	.00	1.8	1.3	1.0	2.4	0.3
OCT							
19...	13	.00	2.3	1.7	1.2	2.9	.4
JAN 1982							
22...	10	1.0	1.7	1.3	3.4	2.2	.4
Site 3 350504093310500 - BIG PINEY CREEK NEAR HAVANA, ARK (LAT 35 05 04 LONG 093 31 05)							
JUN 1981							
05...	19	8.0	3.9	2.3	3.2	4.0	0.4
OCT							
19...	20	.00	3.8	2.5	4.1	3.5	.4
JAN 1982							
22...	17	8.0	3.5	2.1	5.5	5.7	.7

Table 1.--Physical, chemical, and bacteriological data, Big Piney Creek watershed (continued)

DATE	PERCENT SODIUM	ALKALINITY LAB (MG/L AS CACO3)	CHLORIDE, DISSOLVED (MG/L AS CL)	FLUORIDE, DISSOLVED (MG/L AS F)	SILICA, DISSOLVED (MG/L AS SIO2)	SULFATE DISSOLVED (MG/L AS SO4)
Site 1 350804093350600 - LITTLE PINEY CREEK NEAR MARVINVILLE, ARK (LAT 35 08 04 LONG 093 35 06)						
JUN 1981						
05...	35	4.0	1.2	.1	11	5.1
OCT						
19...	17	16	2.9	<.1	13	3.8
JAN 1982						
22...	38	11	1.9	<.1	7.4	4.2
Site 2 350756093324800 - TRUETT CREEK NEAR HAVANA, ARK (LAT 35 07 56 LONG 093 32 48)						
JUN 1981						
05...	32	10	1.3	.1	9.9	2.6
OCT						
19...	31	17	2.3	<.1	10	4.7
JAN 1982						
22...	26	9.0	2.3	.1	6.3	5.1
Site 3 350504093310500 - BIG PINEY CREEK NEAR HAVANA, ARK (LAT 35 05 04 LONG 093 31 05)						
JUN 1981						
05...	27	11	4.1	.1	9.5	14
OCT						
19...	23	20	5.6	<.1	11	7.7
JAN 1982						
22...	34	9.0	7.6	<.1	4.2	11

Table 1.--Physical, chemical, and bacteriological data, Big Piney Creek watershed (continued)

DATE	SOLIDS, RESIDUE AT 180 DEG. C DISSOLVED (MG/L)	SOLIDS, SUM OF CONSTITUENTS, DISSOLVED (MG/L)	SOLIDS, DISSOLVED (TONS PER DAY)	SOLIDS, DISSOLVED (TONS PER AC-FT)	SOLIDS, RESIDUE AT 105 DEG. C, SUSPENDED (MG/L)	SEDIMENT, SUSPENDED (MG/L)	SEDIMENT, DISCHARGE, SUSPENDED (T/DAY)
Site 1 350804093350600 - LITTLE PINEY CREEK NEAR MARVINVILLE, ARK (LAT 35 08 04 LONG 093 35 06)							
JUN 1981							
05...	37	25	1.6	0.05	19	11	0.48
OCT							
19...	53	35	.12	.07	2	7	.02
JAN 1982							
22...	48	26	.82	.07	18	17	.29
Site 2 350756093324800 - TRUETT CREEK NEAR HAVANA, ARK (LAT 35 07 56 LONG 093 32 48)							
JUN 1981							
05...	36	26	2.0	0.05	11	14	0.79
OCT							
19...	46	35	.07	.06	12	21	.03
JAN 1982							
22...	48	28	1.7	.07	9	38	1.3
Site 3 350504093310500 - BIG PINEY CREEK NEAR HAVANA, ARK (LAT 35 05 04 LONG 093 31 05)							
JUN 1981							
05...	63	48	14.6	0.09	20	144	33
OCT							
19...	74	50	1.6	.10	30	40	.84
JAN 1982							
22...	70	45	--	.10	123	125	--

Table 1.--Physical, chemical, and bacteriological data, Big Piney Creek watershed (continued)

DATE	SED. SUSP. SIEVE DIAM. % FINER THAN .062 MM	SOLIDS, RESIDUE AT 105 DEG. C, TOTAL (MG/L)	CARBON, ORGANIC TOTAL (MG/L AS C)	NITRO-GEN, ORGANIC TOTAL (MG/L AS N)	NITRO-GEN, AMMONIA TOTAL (MG/L AS N)	NITRO-GEN, NITRITE TOTAL (MG/L AS N)
350804093350600 - LITTLE PINEY CREEK NEAR MARVINVILLE, ARK (LAT 35 08 04 LONG 093 35 06)						
JUN 1981						
05...	89	43	2.9	0.39	0.17	0.01
OCT						
19...	93	55	--	.64	.07	.01
JAN 1982						
22...	91	74	3.8	.38	.09	.03
350756093324800 - TRUETT CREEK NEAR HAVANA, ARK (LAT 35 07 56 LONG 093 32 48)						
JUN 1981						
05...	94	55	4.8	0.53	0.01	0.00
OCT						
19...	96	80	4.1	.25	.04	.02
JAN 1982						
22...	88	77	7.0	.57	.09	.03
350504093310500 - BIG PINEY CREEK NEAR HAVANA, ARK (LAT 35 05 04 LONG 093 31 05)						
JUN 1981						
05...	79	196	11	1.0	0.16	0.02
OCT						
19...	90	98	5.8	.63	.10	.03
JAN 1982						
22...	93	--	16	4.1	.61	.07

Table 1.--Physical, chemical, and bacteriological data, Big Piney Creek watershed (concluded)

DATE	NITROGEN, NITRATE TOTAL (MG/L AS N)	NITROGEN, TOTAL (MG/L AS N)	PHOSPHORUS, ORTHO, TOTAL (MG/L AS P)	PHOSPHORUS, TOTAL (MG/L AS P)	IRON, TOTAL RECOVERABLE (UG/L AS FE)	MANGANESE, TOTAL RECOVERABLE (UG/L AS MN)
350804093350600 - LITTLE PINEY CREEK NEAR MARVINVILLE, ARK (LAT 35 08 04 LONG 093 35 06)						
JUN 1981						
05...	0.09	0.66	0.03	0.04	430	10
OCT						
19...	.42	1.1	.01	.03	1200	30
JAN 1982						
22...	.17	.67	.04	.06	2100	30
350756093324800 - TRUETT CREEK NEAR HAVANA, ARK (LAT 35 07 56 LONG 093 32 48)						
JUN 1981						
05...	0.00	0.54	0.00	0.05	720	30
OCT						
19...	.29	.60	.03	.06	8500	6700
JAN 1982						
22...	.30	.99	.04	.07	1900	70
350504093310500 - BIG PINEY CREEK NEAR HAVANA, ARK (LAT 35 05 04 LONG 093 31 05)						
JUN 1981						
05...	0.38	1.6	0.11	0.23	5000	310
OCT						
19...	1.2	1.9	.10	.14	4000	510
JAN 1982						
22...	1.0	5.8	.44	.56	540	340

Discharge measurements were made according to methods described by Buchanan and Somers (1969).

RESULTS AND DISCUSSION

All water samples were collected during periods of stormwater runoff. Precipitation amounts for the 24 hours preceding 0600 on the date of collection were 0.95 inch for June 5, 1981; 0.00 inch for October 19, 1981 (4.05 inches for October 18, 1981); and 0.80 inch for January 22, 1982 (National Oceanic and Atmospheric Administration 1981, 1982). Estimated frequency of similar amounts of precipitation is shown in table 2. Instantaneous discharge ranged from 0.87 to 16 cubic feet per second at site 1, from 0.59 to 21 cubic feet per second at site 2, and from 7.8 to 86 cubic feet per second at site 3. Nutrient, bacteria, and suspended-sediment concentrations in streams are typically higher during stormwater-runoff periods and this should be considered before evaluating the data. Before evaluating the effect of the observed water-quality on the proposed reservoirs, it is also important to consider that although stormwater runoff is an unknown percentage of the annual discharge, it may be a very significant percentage.

Water collected at site 3, in the more agricultural part of the watershed, was generally different in quality from water collected at sites 1 and 2. Nutrient concentrations, biochemical oxygen-demand, fecal-bacteria concentrations, and suspended-sediment concentrations are typically higher in agricultural (including livestock and poultry) areas than in more undisturbed forested areas. This appears to be true for the Big Piney Creek watershed.

Table 2.--Estimated frequency of selected 24-hour precipitation amounts for the Yell County, Arkansas vicinity.

[Based on a frequency curve prepared by the U.S. Soil Conservation Service using U.S. Weather Bureau Technical Paper No. 40, Hershfield (1961).]

24-hour precipitation (inches)	Frequency per 100 years
$\geq$ 0.7	1000
$\geq$ 0.8	930
$\geq$ 0.9	860
$\geq$ 1.0	790
$\geq$ 2.0	340
$\geq$ 3.0	140
$\geq$ 4.0	60

At sites 1 and 2 specific conductivities were very similar and ranged from 27 to 44 micromhos per centimeter. Specific conductivity at site 3 was greater and ranged from 68 to 90 micromhos per centimeter. These relatively low values reflect the dilute nature of the stormwater runoff. This dilution was also reflected in the hardness and dissolved-solids concentrations. Water at all three sites was soft, ranging from 7 to 13 mg/L total hardness mg/L as calcium carbonate at sites 1 and 2 and from 17 to 20 mg/L total hardness as calcium carbonate at site 3. Dissolved-solids concentrations ranged from 36 to 53 mg/L at sites 1 and 2 and from 63 to 74 mg/L at site 3. No single cation was clearly predominant but bicarbonate (considering the total alkalinity concentrations) was generally the predominant anion. Low alkalinity concentrations (4.0 to 20 mg/L as calcium carbonate) indicate the poor buffering capacity of these streams during stormwater-runoff periods.

Color was similar at sites 1 and 2 and ranged from 40 to 150 platinum-cobalt units. Color was slightly higher at site 3 and ranged from 100 to 160 platinum-cobalt units. Turbidity at sites 1 and 2 generally was similar, ranging from 18 to 64 nephelometric turbidity units. Turbidity at site 3 was greater and ranged from 50 to 130 nephelometric turbidity units. Suspended-sediment concentrations ranged from 7 to 144 mg/L and were lowest at site 1 and greatest at site 3.

Dissolved-oxygen concentrations ranged from 8.4 to 11.6 mg/L at site 1 and from 8.4 to 12.2 mg/L at site 2. Dissolved-oxygen concentrations at site 3 were somewhat lower and ranged from 7.1 to 11.6 mg/L.

The 5-day biochemical oxygen-demands ranged from 1.5 to 3.0 mg/L at site 1 and from 1.9 to 2.4 mg/L at site 2. At site 3 the biochemical oygen-demands ranged from 3.0 to 6.8 mg/L.

Total-nitrogen concentrations ranged from 0.66 to 1.1 mg/L at site 1 and from 0.54 to 0.99 mg/L at site 2. Generally, organic nitrogen was the predominant form of nitrogen with concentrations ranging from 0.38 to 0.64 mg/L at site 1 and from 0.25 to 0.57 mg/L at site 2. Total-nitrogen concentrations at site 3 were greater and more variable. Concentrations ranged from 1.6 to 5.8 mg/L. Organic-nitrogen concentrations ranged from 0.63 to 4.1 mg/L.

Total-phosphorus concentrations at site 1 ranged from 0.03 to 0.06 mg/L. Concentrations at site 2 were slightly greater and ranged from 0.05 to 0.07 mg/L. A maximum total-phosphorus concentration of 0.05 mg/L has been recommended for streams entering reservoirs (National Technical Advisory Committee, 1968, p. 56). Total-phosphorus concentrations at site 3 were greater than at sites 1 or 2 and ranged from 0.14 to 0.56 mg/L.

Total organic-carbon concentrations ranged from 2.9 to 3.8 mg/L at site 1, from 4.1 to 7.0 mg/L at site 2, and from 5.8 to 16 mg/L at site 3.

Bacteriological samples contained 82 to 200 fecal-coliform bacteria colonies per 100 milliliters (mL) at site 1, 340 to 490 colonies per 100 mL at site 2, and 1,200 to 6,000 colonies per 100 mL at site 3. The State water-quality standard and the U.S. Environmental Protection Agency criterion for bathing waters is a log mean of 200 fecal-coliform bacteria colonies per 100 mL, based on a minimum of five samples throughout a period of not more than 30 days (Arkansas Department of Pollution Control and Ecology, 1975; U.S. Environmental Protection Agency, 1976, p. 42). Although collection frequency was inadequate for comparison with the State standard

or U.S. Environmental Protection Agency criterion, results indicate that the standard and criterion may be exceeded at times at sites 2 and 3.

Total-iron concentrations were highly variable at all sites and ranged from 430 to 8,500 micrograms per liter (µg/L). Concentrations greater than 1,000 µg/L were detected at all three sites and at these times exceeded the U.S. Environmental Protection Agency criterion for protection of freshwater aquatic life (U.S. Environmental Protection Agency, 1976, p. 78). Most of the iron is probably in the suspended phase.

Total-manganese concentrations ranged from 10 to 6,700 µg/L at sites 1 and 2 and from 310 to 510 µg/L at site 3. Manganese is not considered to be a problem for freshwater aquatic life but the U.S. Environmental Protection Agency criterion of 50 µg/L of manganese domestic water supplies (U.S. Environmental Protection Agency, 1976, p. 96) was exceeded at sites 2 and 3.

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