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Tennessee
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Water Management
Chattanooga, Tennessee

TVA/WM--93/11
MAY 1993

RESERVOIR VITAL SIGNS MONITORING - 1992

BACTERIOLOGICAL CONDITIONS IN THE TENNESSEE VALLEY

FOURTH ANNUAL REPORT

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TENNESSEE VALLEY AUTHORITY

Resource Group
Water Management

RESERVOIR MONITORING - 1992
BACTERIOLOGICAL CONDITIONS IN THE TENNESSEE VALLEY
FOURTH ANNUAL REPORT

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Chattanooga, Tennessee

May 1993

MASTER

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EXECUTIVE SUMMARY

Twenty-eight designated swimming beaches, four informal swimming areas, two canoe launching or landing sites, and two additional sites on a canoeing stream were sampled at least ten times each during 30-day sampling periods in the summer of 1992. One designated swimming beach, one informal swimming area, and two canoe launching or landing sites exceeded the recommended criterion of geometric mean concentrations of fecal coliform bacteria of 200/100 mL. In addition to these four sites, five designated swimming beaches and one informal swimming area exceeded the U.S. Environmental Protection Agency (EPA) recommended criterion by having more than 10 percent of the fecal coliform samples with concentrations greater than 400/100 mL. Rainfall was an important factor for these six sites and the four sites that did not meet the geometric mean criterion. Some sampling sites are affected by rainfall more than others. When bacteria concentrations increase after rainfall, it indicates that site is vulnerable to contamination from nonpoint sources of pollution. Recreational use of these sites following rainfall is discouraged. If samples collected within 24 hours of rainfall (one-half inch or more) are excluded, all but one of the ten sites have better bacteriological water quality, and two meet both the geometric mean and maximum concentration criteria.

Five canoe access locations on the Bear Creek floatway, plus one site upstream and another downstream of the floatway were sampled eight times each during 1992. All seven sites met recreation criteria.

Eighteen nonrecreation sites were also sampled to provide generic bacteriological water quality data on Tims Ford, Normandy, Guntersville, Nickajack, and Tellico Reservoirs, and two sites each were sampled on West Chickamauga and Roseberry Creeks. Seventeen of the reservoir sites met recreation criteria. Two of the stream sites met criteria during baseflow, but not when rainfall samples were included.

Field observations and the results of a special survey in July and August indicate that waterfowl, primarily geese, are impacting bacteriological water quality at some recreation sites. At least two of the five swimming areas not meeting all recreation criteria appear to be affected by waterfowl.

Fourteen reservoirs were sampled for fecal coliform bacteria at the forebay, and for 12 of these reservoirs, at a midreservoir station, once in the winter, and monthly from April through September as part of TVA's Reservoir Vital Signs Monitoring Program. Only five samples in this year's survey had concentrations greater than the normal detection limit of 10/100 mL, and none exceeded 200/100 mL.

The results of studies summarized above are consistent with previous surveys. Bacteriological water quality in most areas of TVA reservoirs is good. In streams it is much poorer, especially after rainfall.

BACTERIOLOGICAL CONDITIONS IN THE TENNESSEE VALLEY
FOURTH ANNUAL REPORT--1992

OVERVIEW

In 1989, TVA began a program of periodically monitoring swimming areas in TVA reservoirs to determine whether each site met bacteriological criteria for recreation. Many sites other than designated swimming areas are included in the program because other body contact recreation, such as skiing, occurs throughout most reservoirs. The sampling program is designed to provide information on all designated swimming areas about once every five years.

Each of the seven Tennessee Valley states has established bacteriological water quality criteria for various uses (3-9). For each state, a criterion for swimming and other body contact recreation is that the geometric mean of fecal coliform concentrations shall not exceed 200 colonies per 100 milliliters (200/100 mL). Tennessee and Virginia further require that no individual sample exceed 1000/100 mL. Kentucky and North Carolina require that no more than 20 percent of the samples exceed 400/100 mL, while Mississippi requires that no more than 10 percent exceed 400/100 mL. The number of required samples varies from two to ten, with Alabama not specifying a number. Generally the required samples are to be collected over a period of not more than 30 days with a minimum time period between sample collections. North Carolina specifies that all samples will be collected between May and September, and Georgia excludes samples collected during and immediately after a rain.

The U.S. EPA requires that each state provide an assessment of its water quality every two years in a document called the 305(b) report.

All of the states' 305(b) reports are then summarized by EPA into a national 305(a) report; an assessment of the nation's water quality. For consistency, EPA recommends the following criteria (11) be used for fecal coliform sampling during the primary contact recreation (swimming) season:

- 200 colonies per 100 mL should be used as a "not to be exceeded" geometric mean of seasonal samples, and
- Seasonal samples should be compared to the criterion of 400 colonies per 100 mL as a single sample maximum, using the following frequency specifications:

A. Fully Supporting: Criterion exceeded in 10 percent or less of measurements.

B. Partially Supporting: Criterion exceeded 11-25 percent of measurements.

C. Not Supporting: Criterion exceeded in more than 25 percent of measurements.

EPA's criteria will be used in this report. If any site meets EPA's criteria but fails to meet the state's criteria, or vice versa, it will be noted in the Recreation Site section.

The Recreation Site Summary (table 1) has the results of the 1989 through 1992 sampling at the recreation sites. This table is updated to include each year's survey results. Data from other surveys is included

Table 1. Recreation Site Summary

Reservoir or Site	Location	Date	Use Support
Kentucky Reservoir			
Kentucky Dam Village SP	TRM 22.4	May 1989	Fully Supports
Barge Island DUA	TRM 31.0	May 1989	Fully Supports
Kenlake State Park	TRM 42.1	May 1989	Fully Supports
Pacer Point Inf Rec	TRM 44.5	May 1989	Fully Supports
Thoroughbred RA	WCM 0.3	May 1989	Fully Supports
Paris Landing SP	TRM 66.3	May 1989	Fully Supports
Big Eagle DUA	ECM 1.0	May 1989	Fully Supports
Hillman Ferry	TRM 29.3	July/Aug 1989	Fully Supports
Piney Camp	TRM 62.0	July/Aug 1989	Fully Supports
Moor's Resort	Buckhorn CM 0.5	June 1992	Fully Supports
Big Bear Resort	Bear CM 2.5	June 1992	Fully Supports
Hester's Spot-In-The-Sun	TRM 32.85	June 1992	Partially Supports
Shawnee Bay Resort	W.F. Bee CM 0.6	June 1992	Fully Supports
Hickory Hill Resort	W.F. Bee CM 0.75	June 1992	Fully Supports
Cedar Knob Resort	Jonathan CM 3.15	June 1992	Partially Supports
Pirates Cove	Jonathan CM 4.4	June 1992	Partially Supports
Paradise Resort	Snipe CM 0.15	June 1992	Fully Supports
Irvin Cobb Resort	Blood RM 2.5	June 1992	Fully Supports
Missing Hills Camp	Cypress CM 1.0	June 1992	Fully Supports
Barkley Reservoir			
Brandon Springs Group			
Camp	CRM 82.0	July/Aug 1989	Fully Supports
Camp Energy	Energy Lake	July/Aug 1989	Fully Supports
Youth Station	CRM 54.0	July/Aug 1989	Fully Supports
Normandy Reservoir			
Barton Springs PUA	DRM 250.5	May/June 1992	Fully Supports
Cedar Point PUA	DRM 252.0	May/June 1992	Partially Supports
Beech River Projects			
Beech Reservoir swim area	Beech RM 35.3	May/June 1990	Fully Supports
Pine Reservoir swim area	Pine CM 5.2	May/June 1990	Fully Supports
Natchez Trace State Forest			
Cub Reservoir swim area	Cub CM 25.0	May/June 1990	Fully Supports
Pickwick Reservoir			
Pickwick Landing SP	TRM 207.0	May 1989	Fully Supports
Goat Island RA	TTWM 446.7	May 1989	Fully Supports
McFarland Bottoms Park	TRM 256.3	May 1989	Fully Supports
Bear Creek Reservoir			
Horseshoe Bend	Bear CM 77.4	May/June 1991	Fully Supports
Piney Point	Bear CM 75.4	May/June 1991	Fully Supports
Upper Bear Creek Reservoir			
Twin Forks	Bear CM 115.31	May/June 1991	Fully Supports
Quarter Creek	Bear CM 125.0	May/June 1991	Partially Supports
Mon Dye	L. Bear CM 5.7	May/June 1991	Fully Supports

Table 1 (Continued)

Reservoir or Site	Location	Date	Use Support
Little Bear Creek Reservoir			
Elliot Branch	L. Bear CM 13.3	May/June 1991	Partially Supports
Williams Hollow	L. Bear CM 17.4	May/June 1991	Partially Supports
Cedar Creek Reservoir			
Slickrock Ford	Cedar CM 30.4	May/June 1991	Partially Supports
Wheeler Reservoir			
Joe Wheeler SP	Page BrM 0.3	May/June 1990	Fully Supports
Mallard Creek PUA	Mallard CM 0.8	May/June 1990	Fully Supports
Round Is. PUA	TRM 297.2	May/June 1990	Fully Supports
Point Mallard Park	Flint CM 2.0	May/June 1990	Fully Supports
Tims Ford Reservoir			
Dry Creek RA	Dry CM 1.1	May/June 1992	Does Not Support
Estill Springs Park (Inf. Rec.)	ERM 163.7	May/June 1992	Fully Supports
Guntersville Reservoir			
Honeycomb Campground	Honeycomb CM 1.6	May/June 1992	Fully Supports
Carlisle Park	Browns CM 0.15	May/June 1992	Fully Supports
Jryceete Park	Browns CM 2.6	May/June 1992	Fully Supports
Marshall Co. Park 1	TRM 358.9	May/June 1992	Fully Supports
Lake Guntersville SP	Town CM 0.9	May/June 1992	Fully Supports
Siebold Creek PUA	TRM 364.7	May/June 1992	Fully Supports
Goose Pond Beach	UTM 1.6/TRM 378	May/June 1992	Fully Supports
Sequatchie River			
Canoe Take-Out	SqRM 37.95	July/Aug 1992	Fully Supports
Canoe Put-In	SqRM 41.65	July/Aug 1992	Fully Supports
Nickajack Reservoir			
Dam PUA (Shellmound)	TRM 425.4	May/June 1992	Fully Supports
Maple View PUA	TRM 425.3	May/June 1992	Fully Supports
Smith's Camp-On-The-Lake	TRM 429.6	May/June 1992	Does Not Support
Marion Co. Park	TRM 429.6	May/June 1992	Fully Supports
North Chickamauga Creek			
Hixson Greenway	NCCM 0.5	May/June 1992	Partially Supports
Bethel Bible Village	NCCM 3.45	May/June 1992	Partially Supports
South Chickamauga Creek			
At Graysville	SCCM 19.45	May/June 1992	Partially Supports
At Ringgold	SCCM 30.55	May/June 1992	Does Not Support
Chickamauga Reservoir			
Chickamauga Dam DUA	TRM 471.2	May/June 1989	Fully Supports
Lake Junior	Lake Junior	May/June 1989	Fully Supports
Skull Island RA	Norman BM 0.2	June 1990	Fully Supports
Grasshopper Creek RA	Mile 0.2	June 1990	Fully Supports

Table 1 (Continued)

Reservoir or Site	Location	Date	Use Support
Chickamauga Reservoir (Continued)			
Agency Creek RA	Agency CM 0.7	June 1990	Fully Supports
Armstrong Creek RA	TRM 505.6	June 1990	Fully Supports
Sale Creek RA	Sale CM 1.4	June 1990	Fully Supports
Possum Creek RA	Possum CM 1.5	June 1990	Fully Supports
Chester Frost Park	Dallas Bay 0.4	June 1990	Fully Supports
Watts Bar Reservoir			
Roane County Park	Caney CM 1.1	June 1990	Fully Supports
Caney Creek Inf Rec	Post Oak 0.15	June 1990	Partially Supports
Riley Creek RA	Riley CM 0.85	June 1990	Fully Supports
Fort Loudoun Reservoir			
Fort Loudoun Dam DUA	TRM 602.4	June 1989	Fully Supports
Yarberry Peninsula DUA	TRM 604.0	June 1989	Fully Supports
Louisville Point Pk	Lackey CM 0.2	June 1992	Fully Supports
Tellico Reservoir			
Notchy Creek RA	Notchy CM 2.2	June 1992	Fully Supports
Toqua RA	Harrison BrM 1.4	June 1992	Fully Supports
Vonore RA	Island CM 2.6	June 1992	Fully Supports
Lotterdale Cove	UTM 0.8/LTRM 9.4	June 1992	Fully Supports
Boone			
Boone Dam DUA	SHRM 18.8	May 1989	Fully Supports
Hiwassee River Basin			
Below Apalachia Dam			
Take-Out at Reliance	HiRM 47.88	June 1991	Fully Supports
US HW 411 Bridge	HiRM 42.6	June 1991	Fully Supports
Tributaries to Hiwassee River			
Grape Creek CAS	Song BrM 0.4	July/Aug 1990	Fully Supports
Mission Dam CAS	HiRM 106.1	July/Aug 1990	Fully Supports
Chatuge Reservoir			
Jackrabbit Campground	Phil. Ch. Cove	July/Aug 1990	Fully Supports
Hiawassee Swim Area	HiRM 126.6	July/Aug 1990	Fully Supports
Clay County Park	HiRM 121.8	July/Aug 1990	Fully Supports
Nottely Reservoir			
Poteet Creek	NRM 22.8	July/Aug 1990	Fully Supports
Parksville Reservoir			
(Ocoee Number 1)			
Mac Point RA	OcRM 16.0	June 1991	Fully Supports
Ocoee River			
Put-In	OcRM 24.25	June 1991	Fully Supports
Take-Out	OcRM 19.6	June 1991	Fully Supports

Table 1 (Continued)

Reservoir or Site	Location	Date	Use Support
Toccoa River			
Below Blue Ridge Dam	TocRM 52.7	July/Aug 1990	Fully Supports
Shallow Ford Bridge	TocRM 67.7	July/Aug 1990	Fully Supports
Blue Ridge Reservoir			
Morgantown Point	TocRM 54.3	July/Aug 1990	Fully Supports
Melton Hill Reservoir			
Melton Hill Dam DUA	CRM 23.5	June 1990	Partially Supports
Carbide Park	McCoy BrM 0.4	June 1990	Fully Supports
Solway Park Inf Rec	CRM 44.0	June 1990	Partially Supports
Clinch River below Norris Dam			
Launching Site	ClRM 77.1	June 1991	Partially Supports
Norris Reservoir			
Loyston Point RA	Mill CM 1.5	June 1991	Partially Supports
Big Ridge Lake SP	UT 1.9 to Mill Cr.	June 1991	Fully Supports

Abbreviations

BrM - Branch Mile
 ClRM - Clinch River Mile
 CM - Creek Mile
 Cr - Creek
 CRM - Cumberland River Mile
 DRM - Duck River Mile
 DUA - Day Use Area
 ERM - Elk River Mile
 FBRM - French Broad River Mile
 HiRM - Hiwassee River Mile
 HRM - Holston River Mile
 Inf. Rec. - Informal Recreation, Popular swimming
 area but not a designated swimming beach
 JnCM - Jonathan Creek Mile
 L - Little
 NChCM - North Chickamauga Creek Mile
 NRM - Nolichucky River Mile
 NtRM - Nottely River Mile
 OCRM - Ocoee River Mile
 RA - Recreation Area
 S & B - Surface and Bottom Samples
 SChCM - South Chickamauga Creek Mile
 SHRM - South Holston River Mile
 SP - State Park
 TocRM - Toccoa River Mile
 TTWM - Tennessee-Tombigbee Waterway Mile
 TRM - Tennessee River Mile
 UTM - Unnamed Tributary Mile
 WCM - Wildcat Creek Mile
 WRM - Watauga River Mile

in this table if at least ten samples were collected over a period of not more than 30 days, a minimum of 12 hours apart, and between May and September. If a location "does not support" recreation due to samples collected within 24 hours of rainfall of one-half inch or greater, but would be considered "fully supporting" or "partially supporting" without the rainfall samples, it is listed as "partially supporting" in table 1.

Physical, chemical, and bacteriological samples are collected at (usually) two locations on each of TVA's larger reservoirs once in the winter and then monthly from April through September as part of TVA's Reservoir Vital Signs Monitoring Program. The results of the bacteriological (fecal coliform) sampling are included in this report in the Vital Signs Monitoring Program section.

The results of the recreation site surveys for each reservoir are summarized in press releases during the summer. Survey results are provided to the state agencies with regulatory authority for posting and removing public advisories for water contact recreation.

RECREATION SITES

The 1992 sampling program consisted of ten swimming beaches on Kentucky Reservoir, six on Guntersville Reservoir, four each on Nickajack and Tellico Reservoirs, two on Normandy Reservoir, and one each on Tims Ford and Fort Loudoun Reservoirs. An informal swimming area on both Tims Ford and Guntersville Reservoirs and two on North Chickamauga Creek were also included. Four canoe access locations on the Sequatchie River and one on North Chickamauga Creek were sampled. Less than ten samples were analyzed for fecal coliform concentrations at three of the canoe access locations. Canoeing occurs through the two informal swimming areas on North Chickamauga Creek. Two sites were sampled in a reach of South Chickamauga Creek used for canoeing. One informal swimming area, five canoeing locations, and all but two of the swimming beaches met EPA's criteria (fully supports). Three of the other seven sites met all criteria when rainfall samples were excluded. Survey results are shown in table 3.

The results of the surveys are discussed individually below. In order to compare water quality among the various sites without constant reference to concentrations and numeric criteria, table 2 provides four relative water quality classifications for sites meeting EPA criteria (fully supports) and lists the criteria for sites that "partially supports" and "does not support" primary recreation. This table is modified slightly from the first two annual reports. For purposes of calculating geometric means, concentrations below the detection limit are considered to be at the detection limit; concentrations listed as greater than the stated values are considered to be the stated values.

Table 2. Comparative Water Quality Categories

Water Quality	Geometric Mean #/100 mL		Percent greater than 400/100 mL
Fully Supports			
Excellent	<= 20	and	0
Very Good	<= 50	and	0
Good	<=100	and	0
Acceptable	<=200	and	<= 10
Partially Supports	<=200	and	11 to 25
Does Not Support	> 200	and/or	> 25

<= less than or equal to

> greater than

The results are shown in table 3. The Tellico and Fort Loudoun samples were analyzed by the Tennessee Department of Environment and Conservation. Other samples were analyzed by TVA field engineering personnel.

The Wilcoxon ranking test for unpaired samples (1) was used to determine whether there was a significant difference between samples collected within 24 hours of rainfall (one-half inch or more) and samples collected during dry periods (baseflow). Concentrations below the detection limit were ranked lower than concentrations at the detection limit. The null hypothesis was that there was no difference in concentrations. The alternate hypothesis was that there was a difference. The two-tailed t-test was used with $\alpha = 0.05$.

Table 3. Fecal Coliform Concentrations at Recreation Sites in 1992 (colonies per 100 ml)

Date	Rain	Kentucky Reservoir									
		Moors Resort	Big Bear Resort	Hester's Spot-In-Sun	Shawnee Bay Resort	Hickory Hill	Cedar Knob	Pirates Cove	Paradise Cove	Irvin Cobb	Missing Hills
		BuCM 0.5	BCM 2.5	TRM 32.85	WFBCM 0.6	WFBCM 0.7	JCM 3.15	JCM 4.4	SnCM 0.15	BIRM 2.5	CYCM 1.0
June 1		< 10	10	< 10	27	< 10	73	64	82	10	10
June 2		< 10	18	18	< 10	< 10	6800	10	100	18	< 10
June 3	R	18	36	36	27	36	27	5900	100	73	10
June 4	R	82	220	127	836	27	991	5900	18	73	100
June 8		36	46	27	73	54	64	136	250	27	390
June 11		27	54	18	54	146	27	46	100	10	< 10
June 15		10	64	360	91	46	118	118	10	< 10	10
June 16		< 10	73	1600	127	36	154	137	36	27	18
June 17		146	18	136	390	27	10	200	10	82	< 10
June 18		210	10	27	54	54	10	46	220	18	< 10
June 23		54	10	420	73	< 10	64	< 10	220	36	46
June 25	R	54	260	109	210	64	154	100	64	200	54
Geometric Mean		32.3	37.5	75.1	81.8	32.1	92.9	128.7	63.3	30.9	22.6
Baseflow		29.3	25.0	73.8	64.3	29.9	77.4	56.6	47.0	20.7	19.0
After Rain (24-hrs)		43.0	127.2	79.3	168.0	39.6	160.3	1515.5	95.9	102.1	37.8

"After rainfall" samples are all samples collected within 24 hours of a rainfall of at least one-half inch.

"Baseflow" samples are all others.

Table 3 (Continued)

Date	Bear Creek Floatway							
	HW 5	HW 241	HW 172	Price's	Military	Bridge	Bridge	Bridge
	Bridge	Bridge	Bridge	Bridge	Bridge	Bridge	Bridge	Bridge
	Mile	Mile	Mile	Mile	Mile	Mile	Mile	Mile
	<u>113.9</u>	<u>111.8</u>	<u>104.8</u>	<u>99.4</u>	<u>95.7</u>			
July 11	92	82	390	26	33			
July 12	37	58	28	25	87			
July 18	113	74	220	48	280			
July 19	30	52	40	26	49			
July 25	103	73	210	20	56			
July 26	94	67	87	24	46			
August 1	91	94	260	46	27			
August 2	<u>14</u>	<u>128</u>	<u>95</u>	<u>46</u>	<u>55</u>			
Geometric Mean	59	76	120	31	59			

Table 3 (Continued)

<u>Date</u>	<u>Tims Ford Reservoir</u>			<u>Normandy Reservoir</u>		
	<u>Estill Spr</u>	<u>Dry</u>	<u>Creek RA</u>	<u>Barton Spr</u>	<u>Cedar</u>	
	<u>Park</u>	<u>Creek RA</u>		<u>PUA</u>	<u>Point PUA</u>	
	<u>ERM 163.7</u>	<u>DrCM 1.1</u>		<u>DRM 250.5</u>	<u>DRM 252.0</u>	
May 18	18	36		45	10	
May 21	220	18		27	1900	
May 22	45	18		36	64	
May 26	10	< 10		< 10	280	
May 28	10	< 10		18	< 10	
May 29	< 10	20		10	82	
June 3	10	10		70	40	
June 4	50	>2000		670	520	
June 5	260	1090		100	800	
June 10	70	600		140	20	
June 11	20	520		150	110	
June 12	70	450		50	30	
Geometric Mean	33.9	80.3		52.0	90.6	
Baseflow	29.6	49.0		43.7	59.2	
After Rainfall	50.7	352		87.5	324	

"After rainfall" samples are all samples collected within 24 hours of a rainfall of at least one-half inch.

"Baseflow" samples are all others.

Table 3 (Continued)

Date	Rain (Inches)	Guntersville Reservoir						
		Guntersville State Park TCM 0.9	Honeycomb Campground HCM 1.6	Jayceete Park BrCM 2.6	Carlisle Park BrCM 0.15	Marshall Co Park 1 TRM 358.9	Siebold Creek PUA TRM 364.7	Goosepond Island TRM 378
May 27		2	3	< 2	4	< 2	4	< 2
May 29		< 2	< 7	9	34	3	< 2	104
June 2		41	< 4	14	62	< 2	3	< 2
June 3		2	< 12	34	14	12	50	125
June 4	1.7	120	26	141	392	29	18	35
June 9	1.05	30	< 176	55	909	21	19	121
June 10	0.15	80	145	> 400	55	3	39	18
June 11		420	33	109	76	< 2	5	2
June 16		27	< 12	52	28	5	24	2
June 18		15	< 208	20	18	< 2	66	149
June 19	0.85	55	89	240	62	29	4	6
June 23		5	15	14	50	2	106	3
Geometric Mean		20.1	25.4	38.4	50.5	5.1	14.6	13.7
Baseflow		11.4	13.7	18.5	26.3	3	14.4	9.9
After Rainfall		63.1	87.7	165	187	15.2	15.2	26

"After rainfall" samples are all samples collected within 24 hours of a rainfall of at least one-half inch.

"Baseflow" samples are all others.

Table 3 (Continued)

Date	Rain	Nickajack Reservoir				North Chickamauga Cr.		South Chickamauga Cr.	
		Dam PUA Shellmound TRM 425.4	Marion Co Park TRM 429.6	Smith's Camp On The Lake TRM 429.13	Maple View PUA TRM 425.3	Hixson Greenway NCCM 0.5	Bethel Bible V. NCCM 3.45	At Graysville SCCM 19.45	At Ringgold SCCM 30.55
May 26		< 10	< 10	580	< 10	82	45	118	310
May 27		18	10	109	10	45	91	64	400
May 28		< 10	10	480	10	270	100	< 10	260
May 29	R	10	< 10	891	4	118	118	100	400
June 2		< 10	36	127	18	64	64	18	220
June 3	R	10	27	520	15	27	100	73	290
June 4	R	45	10	5200	48		FS 12900	FS 4100	FS 2900
June 5		200	164	1309	6	FS Interf	FS 700	FS 5200	FS Interf
June 7	R								
June 8		2500	400	420	< 10	1000	918	270	520
June 9	R	27	500	680	27	2300	3200	570	2600
June 10		64	82	1108	< 100	1236	Interf	FS 1982	FS 17100
June 11		64	45	1045	10	280	210	640	680
Geometric Mean		35.8	39	631	14	209.3	299.2	242.5	742.0
Baseflow		18.4	14.6	422	10	129	96.3	83.4	385
After Rainfall		50	63.4	772	17.4	289	572	414	1080

FS - Stream in floodstage when the sample was collected

"After rainfall" samples are all samples collected within 24 hours of a rainfall of at least one-half inch.
 "Baseflow" samples are all others.

Table 3 (Continued)

Date	Rain (Inches)	Tellico Reservoir				Fort Loudoun Reservoir	
		Notchy Creek RA NoCM 2.2	Toqua RA HrBrM 1.4	Vonore RA IsCM 2.6	Lotterdale Cove RA LIRM 9.4	Louisville Point Park LCM 0.2	
June 1		42	10	< 2	18		24
June 2		2	15	< 2	9		6
June 3		2	241	2	150		10
June 4		8	1700	2	210		14
June 8		8	70	< 2	12		10
June 10	0.47	20	126	14	190		28
June 11		162	40	3	43		40
June 15		5	25	4	33		114
June 18		6	32	8	680		69
June 22		2	62	2	3		35
June 23		3	76	< 2	20		75
June 24		2	32	< 2	< 2		9
Geometric Mean		6.5	60.9	2.9	32.4		24.3

Table 3 (Continued)

Nickajack Resurvey		North Chickamauga Cr.		Sequatchie River			
Date	Rain (Inches)	Hixson	Bethel	Lower	Upper	Lower	Upper
		Boat Ramp NCCM 0.35	Bible V. NCCM 3.45	Put-In SqRM 41.6	Take-Out SqRM 37.9	Take-Out SqRM 35.6	Put-In SqRM 51.3
July 27	0.57	9 nr	118 nr	191	250	600	
July 28	0.28	9 nr	145 nr	240	280	173	
July 29		64	127	145	136	127	
July 30		27	82	260	280	145	173
July 31		9		136	82	182	90
August 3		< 2		109	136	100	82
August 4			100	155	91		64
August 5		< 2	36	73	127	136	
August 6				109	82		
August 7		—	18	173	55	73	—
Geometric Mean		9	73	149	132	156	95.1
Notes:	BCM	- Bear Creek Mile			LCM	- Lackey Creek Mile	
	BrCM	- Brown Creek Mile			LTRM	- Little Tennessee River Mile	
	BuCM	- Buckhorn Creek Mile			NCCM	- North Chickamauga Creek Mile	
	CyCM	- Cypress Creek Mile			NoCM	- Notchy Creek Mile	
	DrCM	- Dry Creek Mile			nr	- No rain at this station	
	DRM	- Duck River Mile			R	- Rainfall ≥ 0.5 inches	
	DUA	- Day Use Area			RA	- Recreation Area	
	ERM	- Elk River Mile			SCCM	- South Chickamauga Creek Mile	
	HCM	- Honeycomb Creek Mile			SnCM	- Snipe Creek Mile	
	HrBrM	- Harrison Branch Mile			SqRM	- Sequatchie River Mile	
	Hw	- Highway			TCM	- Town Creek Mile	
	Interf	- Interference by other bacteria			TRM	- Tennessee River Mile	
	IsCM	- Island Creek Mile			WFBCM	- West Fork Bee Creek Mile	
	JCM	- Jonathan Creek Mile			UBC	- Upper Bear Creek	

Kentucky Reservoir

Ten swimming beaches were sampled on Kentucky Reservoir (figure 1) in June. Twelve samples were collected at each site, three within 24 hours of a rainfall of at least one-half inch. Bacteriological water quality was very good at Moor's Resort, Big Bear Resort, Hickory Hill, Irvin Cobb Resort, and Missing Hills Camp. If the rainfall samples are excluded, bacteriological water quality at Missing Hills improves to excellent.

Bacteriological water quality was good at Paradise Resort, and acceptable at Shawnee Bay Resort, improving to good if the rainfall samples are excluded. At Hester's Spot-In-The-Sun, Cedar Knob Resort, and Pirate's Cove, bacteriological water quality is partially supporting because two of the 12 samples at each site had fecal coliform concentrations greater than 400/100 mL. One of the high concentrations at Cedar Knob Resort and both at Pirate's Cove were rainfall samples. Excluding rainfall samples improves bacteriological water quality at Pirate's Cove to good.

The geometric mean of rainfall samples was higher than baseflow samples at each site except at Hester's Spot-In-The-Sun. Only at Irvin Cobb Resort was the difference significantly different.

Normandy and Tims Ford Reservoirs

Two swimming beaches on Normandy Reservoir (figure 2), and a swimming beach and an informal swimming area at Estill Springs Park on Tims Ford Reservoir (figure 3), were sampled 12 times each in late May and early June. Three of the 12 samples were collected within 24 hours of a rainfall of at least one-half inch. Bacteriological water quality

Figure 1. Kentucky Reservoir Recreation Sites

Figure 2. Normandy Reservoir Bacteriological Sampling Sites

Figure 3. Tims Ford Reservoir Bacteriological Sampling Sites

was very good at the informal swimming area at Estill Springs Park, acceptable at Barton Springs swimming beach on Normandy Reservoir, partially supporting at Cedar Point swimming beach on Normandy, and did not support recreation at the Dry Creek swimming beach on Tims Ford. The geometric mean criterion was met at all sites, but the fecal coliform concentrations exceeded 400/100 mL once at Barton Springs, three times at Cedar Point, and five times at Dry Creek. If rainfall samples are excluded, bacteriological water quality improves to very good at Barton Springs. Two of the high fecal coliform concentrations at Cedar Point and Dry Creek were rainfall samples, but excluding rainfall samples does not change the water quality categories for these two sites. At all four locations, fecal coliform concentrations were higher after rainfall, but at none of them was the difference significant.

The state of Tennessee criterion for the maximum fecal coliform concentration of 1000/100 mL was exceeded at both Dry Creek and Cedar Point.

Bear Creek Floatway

Eight fecal coliform samples were collected at each of five canoe access sites on the Bear Creek Floatway (figure 4) in July and early August. Bacteriological water quality was very good at the two most downstream sites, Price's Bridge and Military Bridge; good at the two most upstream sites, HW 5 Bridge and HW 241 Bridge; and acceptable at the HW 172 Bridge. See the nonrecreation section for a more complete discussion of the sampling results in Bear Creek.

Guntersville Reservoir

Six swimming beaches and an informal swimming area were sampled on Guntersville Reservoir (figure 5) in late May and June. Twelve samples

Figure 4. Bear Creek Floatway Bacteriological Sampling Sites

Figure 5. Guntersville Reservoir Bacteriological Sampling Sites

were collected at each site, including four within 24 hours of at least one-half inch of rainfall. Bacteriological water quality was excellent at the informal swimming area in Marshall County Park Number 1; very good at the swimming beaches at Jayceete Park, Honeycombe Creek, Siebold Creek, and Goose Pond Island; and acceptable at the swimming beaches at Guntersville State Park and Carlisle Park. Excluding rainfall samples improves the bacteriological water quality to excellent at Jayceete Park, Honeycombe Creek, Siebold Creek, and Goose Pond Island, and to very good at Carlisle Park. At each site, fecal coliform concentrations were higher after rainfall, but at no site was the difference significant.

Sequatchie River

Four canoe access sites on the Sequatchie River (figure 6) were sampled in late July and early August. Ten samples were collected at the lower put-in site and at the upper take-out site. Bacteriological water quality was acceptable at both locations. Eight samples were collected at the lower take-out site, and only four were taken at the upper put-in site. Both sites met the geometric mean criterion. The lower take-out site had one sample exceed the 400/100 mL criterion, making it partially supporting, improving to acceptable if the two rainfall samples are excluded. With only four samples, bacteriological water quality at the upper put-in site was not categorized.

Nickajack Reservoir

Four swimming beaches on Nickajack Reservoir (figure 7) were sampled in late May and early June. Twelve samples were collected at each site, including seven samples within 24 hours of rainfall of at least one-half inch. Bacteriological water quality was excellent at Maple View, acceptable at Nickajack Shellmound and Marion County Park,

Figure 6. Sequatchie River Canoe Access Locations

Figure 7. Nickajack Reservoir Bacteriological Sampling Sites

but did not support recreation at Smith's Camp On The Lake. Fecal coliform concentrations were higher after rainfall at all four sites, but the differences were not significant. Both Shellmound Recreation Area and Marion County Park had one rainfall sample greater than 400/100 mL, and if rainfall samples are excluded, bacteriological water quality at both sites improves to excellent.

Ten samples were collected over a two week period in late July and early August at Smith's Camp On The Lake to confirm the previous high concentrations and as part of a special study on the impacts of waterfowl (see separate section). The first week was, again, during a period of heavy rainfall, and all five fecal coliform samples were high. There was no local rainfall during the second week, and all five fecal coliform samples had concentrations less than 200/100 mL.

Although bacteriological water quality at Shellmound Recreation Area was acceptable by EPA criteria, one rainfall sample exceeded the state of Tennessee criterion of 1000/100 mL (for any one sample).

North and South Chickamauga Creeks

Two informal swimming areas in North Chickamauga Creek (figure 8) were sampled in late May and early June. Twelve samples were analyzed at the Bethel Bible Village and ten were analyzed at the Hixson Greenway swimming area. One sample at the Hixson Greenway swimming area was not analyzed for fecal coliforms due to interference by another bacteria. Seven of the twelve samples at Bethel Bible Village and five of ten at Hixson Greenway swimming area were collected within 24 hours of rainfall of at least one-half inch. Bacteriological water quality did not support recreation at either site. The geometric mean exceeded 200/100 mL, more than 25 percent of the samples exceeded 400/100 mL criteria, and each

Figure 8. North, South, and West Chickamauga Creeks
Bacteriological Sampling Sites

site had at least one sample that exceeded Tennessee's criterion of 1000/100 mL for any sample. If rainfall samples are excluded, bacteriological water quality improves to good at Bethel Bible Village and to acceptable at Hixson Greenway swimming area. Rainfall samples had significantly higher concentrations of fecal coliforms than baseflow samples at Bethel Bible Village. Concentrations were higher after rainfall at Hixson Greenway swimming area, but the difference was not statistically significant, probably due to having only ten, rather than 12, samples.

Both of these informal swimming areas on North Chickamauga Creek are in a stretch of stream used for canoeing. In late July and early August, ten fecal coliform samples were collected at the Bethel Bible Village and at the canoe take-out location at the Hixson Greenway. The latter location is downstream of both swimming sites. Due to interference by other bacteria, only seven samples were analyzed at each location. Bacteriological water quality was excellent at the Hixson Greenway canoe take-out site and good at Bethel Bible Village. One rainfall sample had been taken at the canoe take-out site during the May/June survey, and the fecal coliform concentration exceeded 1000/100 mL, which exceeds the state of Tennessee criterion for the maximum concentration of any sample.

Twelve samples were collected during late May and early June at two sites on a reach of South Chickamauga Creek (figure 8) used for canoeing. Seven of the samples were within 24 hours of rainfall of at least one-half inch. Bacteriological water quality did not support recreation at either site. If rainfall samples are excluded, bacteriological water quality at Graysville improves to acceptable. It also improves at Ringgold, but the geometric mean concentration of fecal

coliform bacteria remains greater than 200/100 mL. Although fecal coliform concentrations were higher at both sites after rainfall, the differences between rainfall and baseflow samples were not statistically significant. One sample at Ringgold was not analyzed due to interference by other bacteria.

Tellico and Fort Loudoun Reservoirs

Four swimming beaches on Tellico Reservoir (figure 9) and one on Fort Loudoun Reservoir (figure 10) were sampled in June. Twelve fecal coliform samples were collected, including two within 24 hours of a one-half inch rainfall. Bacteriological water quality was excellent at Notchy Creek Recreation Area; very good at Vonore Recreation Area, Lotterdale Cove Recreation Area, and at Louisville State Park on Fort Loudoun Reservoir. Excluding the rainfall samples, bacteriological water quality at Lotterdale Cove improves to excellent. Bacteriological water quality at Toqua Recreation Area was acceptable using the EPA criteria, but one non-rainfall sample exceeded the Tennessee criterion of 1000/100 mL for any sample. At each site, fecal coliform concentrations were higher after rainfall, but statistical analyses were not run to determine significant difference because there were only two rainfall samples.

Figure 9. Tellico Reservoir Bacteriological Sampling Sites

Figure 10. Fort Loudoun Reservoir Recreation Site

COMPARISON WITH PREVIOUS STUDY

In 1974, TVA conducted an extensive bacteriological survey of recreation sites throughout the Tennessee Valley (10). Nine sites on Kentucky Reservoir, two on Guntersville Reservoir, one on Tims Ford Reservoir, and five on Nickajack Reservoir were common to both the 1974 and 1992 surveys. All but one of the 17 sites were swimming areas. Table 4 compares the results of the two surveys.

Table 4. Comparison of 1974 and 1992 Bacteriological Surveys (geometric mean of fecal coliform concentrations [colonies/100 mL]).

<u>Location</u>	<u>1974</u>	<u>1992</u>
Kentucky Reservoir		
Moor's Resort	12	32
Big Bear Resort	19	38
Hester's Spot-In-The-Sun	10	75
Shawnee Bay Resort	14	82
Hickory Hill Resort	14	32
Cedar Knob Resort	17	93
Pirate's Cove	14	129
Paradise Resort	26	63
Irvin Cobb Resort	69	31
Guntersville Reservoir		
Honeycomb Creek PUA	24	25
Siebold Creek	21	15
Tims Ford Reservoir		
Dry Creek PUA	17	80
Nickajack Reservoir		
Shellmound PUA	53	36
Marion County Park	27	39
Smith's Camp On The Lake	95	390
Maple View PUA	39	14
Sullivan's Boat Ramp	300	48

On Nickajack Reservoir, the increase in fecal coliforms at Smith's Camp on the Lake can probably be attributed to an increase in waterfowl in the area. This may also account for the small increase at Marion County Park. The decrease in concentrations at the other three sites, especially at Sullivan's boat ramp, is probably due to the improvement in

sewage treatment at Chattanooga. A comparison of the results at the other three reservoirs seems to indicate that bacteriological water quality has deteriorated on Kentucky and Tims Ford Reservoirs and is unchanged in Guntersville Reservoir. However, a straight comparison of water quality data between two years should be done with caution. Factors such as differences in rainfall and runoff, sampling methods, and time of the year can make such comparisons meaningless. The sampling method was different in the two surveys. In 1974 samples were collected once a week, while four samples a week were collected in 1991. If concentrations vary over the course of the sampling season, the two methods could produce very different results, but because there was no variation in the 1974 samples, it is unlikely that the method or time of year accounts for the difference. The 1991 survey was conducted during a period of relatively frequent and heavy rainfall, which often results in higher fecal coliform concentrations. Figure 11 provides an overall comparison of bacteriological water quality at the 51 sites sampled in both 1974 and during the 1989 to 1992 period. Sampling procedures and rainfall conditions may account for some of the differences shown.

Figure 11. Comparison of Fecal Coliform Concentrations at 51 Sites Sampled in 1974 and Between 1989 and 1992

NONRECREATION SITES

Some incidental water contact occurs throughout the reservoir system: skiing occurs in all major reservoirs; water contact is common when launching or retrieving boats; fishermen and other boaters frequently wash their hands in the reservoir. Thus to provide guidance on appropriateness for use, this survey includes other areas in addition to swimming areas and canoeing streams. Inflow bacteriological water quality on Tims Ford and Normandy Reservoirs was measured by collecting fecal coliform samples on Boiling Fork Creek and the Elk River on Tims Ford Reservoir, and at three boat docks on the Normandy Reservoir. Fecal coliform samples were collected on two tributaries to Guntersville Reservoir and at one of the more popular camping areas. Guntersville Reservoir's tributaries are possible sources of bacteriological contamination and camping areas sometimes impact local water quality. In Nickajack Reservoir, samples were collected at two boat ramps and a fishing pier. The fishing pier is about two miles downstream of Chickamauga Dam and should provide a good indication of inflow bacteriological water quality; one boat ramp is located in downtown Chattanooga, and the other is about halfway between Chattanooga's sewage treatment plant and the swimming beaches at the downstream end of Nickajack Reservoir. Five nonrecreation sites were sampled on Tellico Reservoir, including two in embayments listed as contaminated in the state of Tennessee's 1990 305(b) report. Two other sites were at boat docks in recreation areas without designated swimming areas, and the other was at a fishing pier at the confluence of the Tellico and Little Tennessee Rivers. Sampling results are shown in table 5.

Table 5. Fecal Coliform Concentrations at Nonrecreation Sites in the Tennessee Valley in 1992
(colonies per 100 ml)

Date	Rain	Tims Ford Reservoir			Normandy Reservoir		
		Red Mill Bridge BoiFkM 3.4	Lee Ford Bridge ERM 154.6		Boyd Br. Boat Ramp ByBrM 0.7	Ward Chapel Boat Ramp DRM 255.2	Anthony Bridge Boat Ramp DRM 259.5
May 18		10	18		< 10	145	< 10
May 21		18	55		< 10	36	< 10
May 22		< 10	45		< 10	< 10	< 10
May 26		10	18		< 10	10	< 10
May 28		< 10	10		< 10	< 10	< 10
May 29	R	< 10	10		< 10	< 10	< 10
June 3		30	30		10	10	< 10
June 4	R	80	< 10		60	30	10
June 5		10	40		40	120	< 10
June 10		30	20		< 10	< 10	< 10
June 11		510	10		< 10	230	< 10
June 12		10	220		< 10	30	10
Geometric Mean		20.8	24.3		13.0	26.7	10.0
Baseflow		21.1	28.0		10.0	24.8	10.0
After Rainfall		20.0	15.9		28.8	33.0	10.0

"After rainfall" samples are all samples collected within 24 hours of a rainfall of at least one-half inch.
"Baseflow" samples are all others.

Table 5 (Continued)

Date	Rain (Inches)		Guntersville Reservoir		Roseberry Creek		Bear Creek Floatway	
	Short Cr.	Boat Ramp	Marshall Co Park 2	ShCM 1.6	At Hwy 72 Mile 5.2	Bridge near Hospital Mile 6.75	Up. Bear Tailrace Mile 114.6	Scott Bridge Mile 89.4
May 27	5		< 2		50	100	9	86
May 29	< 2		5		6600	45	15	58
June 2	< 2		11		510	9	12	197
June 3	< 2		5		1573	127	24	42
June 4	1.7		2		8700	>2000	55	240
June 9	1.05		7		2400	1264	48	199
June 10	0.15		4		420	370	9	99
June 11	5		5		430	182	8	68
June 16	< 2		5		270	240		
June 18	< 2		2		691	220	17	104
June 19	0.85		22		2300	3600		
June 23	2		2		470	100		
Geometric Mean	2.9		4.5		875.0	224.8		
Baseflow	3.7		5.9		2120	1350		
After Rainfall	2.5		3.9		562	91.6		

"After rainfall" samples are all samples collected within 24 hours of a rainfall of at least one-half inch.
 "Baseflow" samples are all others.

Table 5 (Continued)

Date	Rain	Nickajack Reservoir			West Chickamauga Creek	
		Sullivan Boat Ramp TRM 440.0	John Ross Landing TRM 464.0	Fishing Pier TRM 469.5	Alexander Bridge Mile 14.6	US 76 Bridge Mile 2.9
May 26		< 10	< 10	10	91	270
May 27		55	< 10	10	100	73
May 28		155	30	8	64	64
May 29	R	790	74	12	740	145
June 2		< 10	8	6	82	145
June 3	R	10	165	17	FS 127	109
June 4	R	18	Interf	Interf	FS 7100	13500
June 5		182	Interf	Interf	FS Interf	FS 5000
June 7	R					
June 8		55	700	27	420	320
June 9	R	36	350	27	240	290
June 10		91	91	10	FS Interf	380
June 11		36	91	< 10	282	310
Geometric Mean		47.8	59.9	12.2	249	337
Baseflow		41.9	22.9	9.5	113	141
After Rainfall		51.1	113.9	14.4	420	521

FS - Stream in floodstage when the sample was collected

"After rainfall" samples are all samples collected within 24 hours of a rainfall of at least one-half inch.
 "Baseflow" samples are all others.

Table 5 (Continued)

Date	Rain (inches)	Tellico Reservoir				
		Dam RA LIRM 0.6	Poplar Springs RA LTRM 3.9	Clear Cr. RA CLCM 0.5	Fishing Pier LTRM 19.2	Ninemile Creek Mile 2.3
June 1		< 2	< 2	< 2	38	38
June 2		< 2	< 2	< 2	2	16
June 3		6	2	2	2	63
June 4		5200	< 2	2	24	11
June 8		4	2	< 2	2	4
June 10	0.47	6	14	14	19	132
June 11		3	5	3	24	107
June 15		21	33	4	3	9
June 18		97	< 2	8	9	21
June 22		7	< 2	2	6	110
June 23		4	< 2	< 2	2	21
June 24		11	< 2	< 2	76	7
Geometric Mean		11.6	3.2	2.9	8.1	25.4

Notes: BoiFKM - Boiling Fork Mile

Br - Branch

ByBrM - Boyd Branch Mile

CLCM - Clear Creek Mile

Co - County

Cr - Creek

DRM - Duck River Mile

ERM - Elk River Mile

FS - Flood Stage

HWY - Highway

Interf - Interference by other bacteria

LTRM - Little Tennessee River Mile

R - Rainfall of at least one-half inch

ShCM - Short Creek Mile

TRM - Tennessee River Mile

The Wilcoxon ranking test (1) for unpaired samples was used to determine whether there was a significant difference in fecal coliform samples between rainfall and baseflow samples. This test was applied at each location with three or more rainfall samples. The null hypothesis was that there was no difference. The alternate hypothesis was that there was a difference. The two-tailed t-test was used with $\alpha = 0.05$.

Normandy and Tims Ford Reservoirs

Twelve fecal coliform samples, including four within 24 hours of rainfall of at least one-half inch, were collected at three boat ramps along the Duck River in Normandy Reservoir (figure 2). The city of Manchester is located upstream of Normandy Reservoir wastewater discharges and urban runoff from the Manchester area enters Normandy Reservoir above the Anthony Bridge sampling site. Bacteriological water quality at Anthony Bridge was excellent, with all fecal coliform samples at or below the detection limit of 10/100 mL. This indicates that the Manchester urban area was not impacting Normandy Reservoir during this sampling period. Four miles downstream at the Ward Chapel boat ramp, bacteriological water quality was very good. At the Boyd Branch boat ramp near Normandy Dam, bacteriological water quality was excellent. Fecal coliform concentrations at the latter two sites were higher after rainfall than during baseflow, but the differences were not statistically significant.

Samples were collected on the same 12 days on Tims Ford Reservoir off the Lee Ford Bridge over the Elk River and the Red Mill Bridge over Boiling Fork Creek (figure 3). These two sites are downstream of Tullahoma, Estill Springs, Cowan, Dechard, and about half of the urban area of Winchester. Winchester's sewage treatment plant discharges at the confluence of Boiling Fork Creek and Elk River. Bacteriological

water quality at Lee Ford Bridge was very good and acceptable at Red Mill Bridge. Excluding one baseflow sample which exceeded the criterion of 400/100 mL, bacteriological water quality at Red Mill Bridge was excellent. Although fecal coliform concentrations were lower after rainfall at Lee Ford Bridge than during baseflow, the difference was not statistically significant. Concentrations at Red Mill Bridge during baseflow and after rainfall were similar.

Bear Creek Floatway

Eight fecal coliform samples were collected at each of two non-access sites in July and early August (figure 4). Samples were collected in the tailrace of Upper Bear Creek Reservoir, upstream of the floatway, and at Scott Bridge, which was formerly an access site but is now downstream of the floatway. Bacteriological water quality was excellent in the tailrace and acceptable at Scott Bridge.

Figure 12 shows the geometric mean concentrations of the seven sites sampled in Bear Creek (five on the floatway, one upstream and one downstream). Concentrations rise steadily to reach a peak at the Highway 172 Bridge, drop off, and then increase over the last two sites. The signed rank test was used to determine if these increases, and decrease, were statistically significant. There was a statistically significant increase in fecal coliform concentrations between the tailrace and Highway 5, another between Highway 241 and Highway 172, another between Price's Bridge and the Military Bridge, and a statistically significant decrease between Highway 172 and Price's Bridge. The town of Bear Creek is in the drainage area between the tailrace and Highway 5, which may account for the increase in bacteria in this stream reach. There appears

to be no major source of contamination between Highway 172 and Price's Bridge, based on decrease in bacteria concentrations, even though most of the town of Phil Campbell and half of Hackelburg is in the drainage area. Nonpoint sources between Price's Bridge and the Military Bridge are still having an impact, as shown by the statistically significant increase in bacteria in this stretch, but the increase is not large enough to exceed recreation criteria. Bacteriological sampling of the Bear Creek floatway has occurred for several years in conjunction with the cleanup of several nonpoint sources. The sampling results in 1992 indicate that the cleanup efforts are continuing to be successful in reducing nonpoint sources of bacteria.

Guntersville Reservoir

Twelve fecal coliform samples, including four within 24 hours of rainfall of at least one-half inch, were collected at a boat ramp in the Short Creek Embayment, at a boat dock next to the camping area at Marshall County Park No. 2, and at two sites on Roseberry Creek (figure 5). The bacteriological water quality was excellent at the Short Creek boat ramp and Marshall County Park No. 2 boat dock. Rainfall and baseflow concentrations were similar.

The upstream sampling site on Roseberry Creek was located upstream of most of the runoff from Scottsboro. The Scottsboro sewage treatment plant is located between the upstream and downstream sites. The discharge pipe crosses Roseberry Creek and the discharge is into the

Figure 12. Bear Creek Floatway, Fecal Coliform Concentrations

Tennessee River. Most of the runoff from the Scottsboro urban area enters Roseberry Creek between the two sampling locations. During baseflow, bacteriological water quality at the upstream station was good, but three of the four rainfall samples had fecal coliform concentrations in excess of 1000/100 mL. These results are typical of streams impacted by runoff. Concentrations at the downstream site were statistically higher than at the upstream site. The increased concentrations after rainfall may be attributed to the runoff from the urban area, but of the high baseflow concentrations, seven of eight samples exceed 200/100 mL, which indicates impacts from a point source discharge. The discharge pipe from the sewage treatment plant may be leaking into Roseberry Creek.

Nickajack Reservoir

Twelve fecal coliform samples, including seven within 24 hours of rainfall of at least one-half inch, were collected at two boat ramps and a fishing pier on Nickajack Reservoir (figure 7), and at two bridges over West Chickamauga Creek in late May and early June. Two rainfall samples each at the fishing pier and at Ross's Landing boat ramp were not analyzed due to interference by other bacteria. Bacteriological water quality was excellent at the fishing pier at C. B. Robinson Bridge, located about one and one-half miles downstream of Chickamauga Dam, and acceptable at both boat ramps, improving to very good at both if rainfall samples are excluded. Much of the urban runoff from Chattanooga enters Nickajack Reservoir between the fishing pier and the Ross's Landing boat ramp. Using the Wilcoxon signed rank test, fecal coliform concentrations at Ross's Landing boat ramp were significantly higher than at the fishing pier at C. B. Robinson Bridge.

Sullivan's boat ramp is located about half way between Chattanooga's sewage treatment plant and the recreation areas at the downstream end of Nickajack Reservoir. The ramp is located at the outer side of a bend in the river and should be well located to measure the bacteriological water quality entering the downstream end of the reservoir. One rainfall but no baseflow sample concentration of fecal coliform bacteria exceeded 200/100 mL, indicating that runoff and sewage discharges from Chattanooga are not having a severe impact on the bacteriological water quality on the downstream end of the reservoir.

Fecal coliform concentrations were higher after rainfall than during baseflow. The differences were statistically significant at the fishing pier and at Ross's Landing.

West Chickamauga Creek

West Chickamauga Creek is a 175 square mile drainage area tributary to South Chickamauga Creek. Upstream of Alexander Bridge, West Chickamauga Creek forms one boundary of the Chickamauga National Battlefield. US 76 Bridge is 2.9 miles upstream of the confluence with South Chickamauga Creek. Two municipal sewage treatment plants, agricultural land, and urban areas lie between the two sampling sites. Bacteriological water quality at neither site supported recreational use, however, if rainfall samples are excluded, both sites support recreational use. Two rainfall samples at Alexander Bridge were not analyzed because of interference by other bacteria. Fecal coliform concentrations were higher at US 76 Bridge than at Alexander Bridge, but the difference was not statistically significant. Concentrations after rainfall were higher than baseflow at both sites. The difference was statistically significant at Alexander Bridge.

Tellico Reservoir

Twelve fecal coliform samples, including two collected within 24 hours of an one-half inch rainfall, were collected at five non-swimming areas on Tellico Reservoir (figure 9). Ninemile Creek and Clear Creek were listed in Tennessee's 305(b) report in 1990 as impacted by nonpoint sources. Bacteriological water quality was excellent at the Clear Creek boat dock, and very good at the bridge over the Ninemile Creek Embayment, improving to excellent at the latter site if the rainfall samples were excluded. Fecal coliform concentrations were higher at both sites after rainfall than during baseflow. Because the rainfall event was barely one-half inch, bacteriological water quality after rainfall cannot be adequately evaluated, and nonpoint sources could impact water quality after rainfall.

The other three sites include a fishing pier at the confluence of Tellico and Little Tennessee Rivers, a boat ramp at Poplar Springs Recreation Area four miles upstream of Tellico Dam, and another boat ramp near the navigation channel between Tellico and Fort Loudoun Reservoirs. Bacteriological water quality at the first two sites was excellent, and was acceptable near the navigation channel, improving to excellent if one high, non-rainfall sample was excluded. The one high concentration at the navigation channel exceeded Tennessee's criteria of 100\100 mL for any one sample.

SPECIAL STUDY ON IMPACT OF WATERFOWL

During the May/June survey of Nickajack Reservoir, one of the swimming beaches had high concentrations of fecal coliform bacteria. The suspected cause of these high concentrations was the large number of geese that were present during the survey. To follow up on this suspicion, the site was resampled in July and the first week in August. Ten samples were collected and analyzed for fecal coliform bacteria at the swimming beach and three other nearby sites (figure 13 and table 6). Fecal streptococcus bacteria were also analyzed at the swimming beach to evaluate the likely source of contamination. The swimming area is in a small, shallow cove with a narrow opening (mouth of the cove) to Nickajack Reservoir. A second sampling site was in the mouth of the cove. A third sampling site was at the head of the cove, the spot nearest the sewage holding tank used by the recreational vehicles at the campgrounds. The fourth sampling site was at a boat dock outside the small cove, but in the camping area. Field observations were that the waterfowl, predominantly geese, were generally concentrated at either the boat dock or the swimming beach.

The bacteriological water quality at the head of the cove and the mouth of the cove was good, improving to very good if the two rainfall samples at the start of the first week are excluded. The site at the head of the cove had the lowest fecal coliform concentrations of the four sites sampled, indicating the sewage holding tank is not the source of contamination. All five of the fecal coliform samples in the swimming area during the first week of the survey exceeded 200/100 mL (did not support recreation), while all five during the second week were less than 200/100 mL (good bacteriological water quality). It rained at the start of the first week, but not during the second week. However, the highest

Figure 13. Sampling Locations for Special Waterfowl Impacts Study on Nickajack Reservoir

Table 6. Fecal Coliform Concentrations During Special Waterfowl Impacts Survey Fecal Bacteria Concentrations (colonies per 100 mL)

Date	Rain (inches)	Swimming Beach		Head of Cove	Mouth of Cove	Boat Ramp	Approximate Number of Geese Present
		Coliform	Strep.				
July 27	0.57	290	310	91	27	1400	100
July 28	0.28	700	100	200	91	2600	100
July 29		682	330	118	390	5700	100
July 30		3655	>8000	220	360	11300	100
July 31		1100	900	36	27	4900	100
August 3		27	94	27	9	2400	100
August 4		64	120	45	45	2800	100
August 5		64	310	9	27	5400	12
August 6		27	49	27	9	10090	15
August 7		164	100	27	36	20000	100
Geometric Mean		221	255	52	55	4926	

Notes: Strep. - Streptococcus
FC/FS - Ratio of fecal coliform bacteria to fecal streptococcus bacteria

bacteria concentrations were on Thursday and Friday, which does not correspond with the rainfall. The signed rank test (see nonrecreation section) showed that fecal coliform concentrations were statistically higher at the swimming area than at either the head or mouth of the cove. This indicates that the source of high bacteria was at the swimming area, or at least closer to it than to either the head or mouth of the cove. High fecal streptococcus bacteria concentrations is an indicator of contamination by animals rather than humans. On six of the ten sampling days, fecal streptococcus concentrations were higher than fecal coliform concentrations, a further indication that the geese were the source of contamination.

Fecal coliform concentrations at the boat ramp exceeded 1000/100 mL in every sample. The two rainfall samples had two of the three lowest concentrations. This site had the highest fecal coliform concentrations of any site surveyed during the four years of this program. The consistently high concentration suggests that the geese are not the sole cause of fecal coliform bacteria at this location. A small stream draining an unsewered residential area enters the reservoir at the boat ramp. Failing septic tanks and straight pipes may contribute to the high fecal coliform concentrations. This site will be investigated in future surveys.

From physical observations and fecal coliform concentration patterns, waterfowl, especially geese, appear responsible for high bacteria concentrations at several locations. Geese tend to congregate around large open areas such as sandy beaches and boat ramps. Where this happens, concentrations of bacteria can greatly exceed criteria. Public

use is also apparently a factor. On Normandy Reservoir, two similar recreation areas are in close proximity, both with geese present. The bacteriological water quality at the more used site was far better than at the lesser used site indicating that people may scare the geese away from beaches.

VITAL SIGNS MONITORING

TVA began a Reservoir Monitoring Program in 1990 which included fecal coliform samples collected monthly from April through September and once during the winter at the forebay and a midreservoir station on selected reservoirs (figure 14). All nine Tennessee River reservoirs, plus Cherokee, Douglas, and Norris Reservoirs have been monitored since 1990. Sampling on Tellico and Melton Hill began in 1991. Norris Reservoir has two midreservoir stations, one each on the Clinch and Powell Rivers, while Wilson and Nickajack have no midreservoir sampling station. The sampling results are shown on table 7.

Using the recreation guidelines, all 27 sites had excellent bacteriological water quality. The only three sites with fecal coliform concentrations greater than the normal detection limit of 10/100 mL were Pickwick midreservoir, one winter sample; and Wilson forebay and Wheeler midreservoir, each with two summer samples. The highest single concentration was 109/100 mL at the Wheeler forebay in June. Because the concentrations were so low at all sampling sites, there was no statistically significant difference between concentrations at any location and the stations immediately upstream and downstream.

Figure 15 shows the summer (April through September) fecal coliform concentrations by year at the 17 sites where samples were collected all three years. All concentrations below 10/100 mL were assumed to be 10/100 mL for calculating geometric means. Concentrations were much lower in 1992 than in previous years, especially on Guntersville Reservoir.

Figure 14. Vital Signs Bacteriological Monitoring Sites

Table 7. Fecal Coliform Concentrations at Vital Signs Monitoring Stations in 1992 (colonies per 100 mL)

Month	Kentucky Reservoir		Pickwick Reservoir		Wilson Reservoir		Wheeler Reservoir	
	IRM 23.0	IRM 112/85	IRM 207.3	IRM 230.0	IRM 260.8	IRM 277.0	IRM 307.5	
Winter	< 10	< 10	< 10	27	10	10	< 10	
April	< 10	< 10	< 10	< 10	20	10	< 10	
May	< 10	< 10	< 10	< 10	< 10	< 10	< 10	
June	< 10	< 10	< 10	< 10	< 10	< 10	109	
July	< 10	< 10	< 10	< 10	< 10	< 10	< 10	
August	< 10	< 10	< 10	< 10	18	< 10	< 10	
September	< 10	< 10	< 10	< 10	10	< 10	55	
Geometric Means								
1990 to 1992	14.6	19.3	23.2	19.4	18.8	14.3	19.1	
Summer '92	<10.0	<10.0	10.0	10.0	12.4	10.0	19.8	

Table 7 (Continued)

Month	Guntersville Reservoir		Nickajack Reservoir	Chickamauga Reservoir		Watts Bar Reservoir	
	IRM 350.0	IRM 396.8		IRM 472.3	IRM 490.5	IRM 531.0	IRM 560.8
Winter	< 10	< 10	10	< 10	< 10	< 10	< 10
April	< 10	< 10	< 10	< 10	< 10	< 10	< 10
May	< 10	< 10					
June	< 10	10		10	10	< 10	< 10
July	< 10	< 10	< 10	< 10	< 10	< 10	10
August	< 10	< 10	< 10	< 10	< 10	< 10	< 10
September	< 10	< 10	10	< 10	< 10	< 10	< 10
Geometric Means							
1990 to 1992	85.6	28.4	14.1	13.4	13.4	10.6	11.8
Summer '92	10.0	10.0	10.0	10.0	10.0	10.0	10.0

Table 7 (Continued)

Month	Fort Loudoun Reservoir		Cherokee Reservoir		Douglas Reservoir		Norris Reservoir		
	TRM 603.2	TRM 624.6	HRM 53.0	HRM 76.0	FBR 33.0	FBR 60.7	CRM 80.0	CRM 125.0	PRM 30.0
Winter	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10
April	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10
May	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10
June	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10
July	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10
August	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10
September	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10
Geometric Means									
1990 to 1992	13.3	10.5	10.0	10.0	10.0	14.2	10.5	11.6	
Summer '92	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0

Table 7 (Continued)

Year	Month	Tellico Reservoir		Melton Hill Reservoir	
		LIRM 1.0	LIRM 21.0	CRM 24.0	CRM 45.0
1990	Winter	< 10	< 10	< 10	< 10
	April	65	< 10	< 10	< 10
	May	< 10	< 10	< 10	< 10
	June	< 10	< 10	< 10	< 10
	July	< 10	< 10	< 10	< 10
	August	24	33	< 10	13
	September	< 10	< 10	< 10	23

Geometric Means

1991 to 1992	13.2	10.9	10.0	13.6
Summer '92	15.8	12.2	10.0	12.0

Notes:

TRM - Tennessee River Mile
 HRM - Holston River Mile
 FBRM - French Broad River Mile
 LIRM - Little Tennessee River Mile
 CLRM - Clinch River Mile
 PRM - Powell River Mile

Figure 15. Comparison of Results of Vital Sign Bacteriological Monitoring for 1990, 1991, and 1992

QUALITY CONTROL

During most sampling dates, two samples were collected and analyzed for one station in each survey for quality control purposes. In tables 3 and 5, only the first samples collected are shown. Table 8 shows both of the duplicate samples taken each day of each survey. It is difficult to establish a criteria for comparing the data of duplicate fecal coliform analyses. A difference of one or two counts on the culture plate is well within the range of statistical probability. However, a difference of one on the plate can translate to concentration differences of anywhere between one and 1000 per 100 mL, depending on the dilution used. If one plate has only one or two colonies, then the second plate, with only one more, well within acceptability, may have twice the concentration of the first. Because neither ratios nor total differences appear to be an acceptable method of testing quality control, the following method is used for these surveys. The larger of each set of duplicate samples for each survey is treated as one set of samples, and the smaller samples are treated as a second set. The geometric mean of each set is calculated and compared for each survey and should give similar results. Triplicate samples were collected during the Vital Signs Monitoring Program instead of duplicate samples, and the largest and smallest values were used for comparison. Samples below detection were assumed to be one-half of the detection limit (to show a difference, the larger value of a duplicate was at the detection limit), and the sample shown as "greater than" was assumed to be 50 percent greater than the number shown. Table 8 shows a greater difference in duplicate sample analyses compared to previous years, although the differences in the Guntersville survey were primarily due to one sample on June 11.

Table 8. Quality Control--Duplicate Samples

<u>Reservoir/Stream</u>	<u>Station</u>	<u>Date</u>	<u>Larger</u>	<u>Smaller</u>	<u>Ratio</u>
Regular Bacteriological Sampling Program					
Kentucky	Moor's Resort	June 1	< 10	< 10	1.00
	Big Bear Resort	June 2	18	< 10	1.80
	Hester's Spot	June 3	173	36	4.81
	Shawnee Bay	June 4	1270	836	1.52
	Hickory Hill	June 8	55	27	2.04
	Cedar Knob	June 11	109	27	4.04
		June 23	64	55	1.16
	Pirate's Cove	June 15	118	10	11.80
		June 25	230	100	2.30
	Paradise Resort	June 16	36	< 10	3.60
	Irvin Cobb	June 17	82	64	1.28
	Missing Hills	June 18	< 10	< 10	1.00
Tims Ford	Lee Ford Bridge	May 18	18	< 10	1.80
	Red Mill Bridge	May 21	18	10	1.80
		June 10	30	20	1.50
	Dry Creek	May 22	18	10	1.80
		June 11	520	520	1.00
	Estill Springs	May 26	10	< 10	1.00
		June 12	100	70	1.43
Normandy	Barton Springs	May 28	18	10	1.80
	Cedar Point	May 29	82	10	8.20
	Boyd Branch	June 3	10	< 10	1.00
	Anthony Bridge	June 4	10	< 10	1.00
	Wards Chapel	June 5	120	110	1.09
Guntersville	Honeycomb Camp.	June 9	176	173	1.02
	Marshall Co. 2	June 2	11	< 10	1.10
	Carlisle Park	June 3	14	12	1.17
	Jayceette Park	May 29	< 10	< 10	1.00
	Marshall Co. 1	June 4	29	21	1.38
	Short Creek	May 27	< 10	< 10	1.00
	Gunt. St. Park	June 19	55	27	2.04
	Siebold PUA	June 10	39	27	1.44
	Goose Pond	June 11	430	< 10	43.00
		June 23	< 10	< 10	1.00
Roseberry Creek	Hwy 279 Bridge	June 16	290	270	1.07
	Near Hospital	June 18	300	220	1.36
Nickajack	Ross's Landing	May 26	18	< 10	1.80
	Marion Co. Park	May 28	64	10	6.40
	Smith's Camp	June 3	520	450	1.16
	Shellmound	June 5	200	100	2.00
	Fishing Pier	June 11	< 10	< 10	1.00
	Sullivan Ramp	May 27	55	55	1.00
	Ross's Landing	May 26	18	< 10	1.80
North Chickamauga Creek	Bethel Bible	June 4	13600	12900	1.05
	Greenway	June 10	1360	1240	1.10
South Chickamauga Creek	At Ringgold	May 29	400	330	1.21
	At Graysville	June 2	27	18	1.50
West Chickamauga Creek	US Hwy 76	June 9	330	290	1.14

Table 8 (Continued)

<u>Reservoir/Stream</u>	<u>Station</u>	<u>Date</u>	<u>Larger</u>	<u>Smaller</u>	<u>Ratio</u>
Vital Signs Monitoring Program					
Kentucky	Forebay	April 21	< 10	< 10	1.00
Pickwick	Forebay	May 18	< 10	< 10	1.00
Wilson	Forebay	June 15	< 10	< 10	1.00
Wheeler	Forebay	July 22	< 10	< 10	1.00
Fort Loudoun	Forebay	April 22	< 10	< 10	1.00
Tallico	Forebay	May 13	< 10	< 10	1.00
Melton Hill	Forebay	June 17	< 10	< 10	1.00
Cherokee	Forebay	July 20	< 10	< 10	1.00
Douglas	Forebay	August 17	< 10	< 10	1.00
Norris	Forebay	Sept. 21	< 10	< 10	1.00
Geometric Mean and Average Ratio					
	Kentucky		61.7	24.6	2.51
	Tims Ford/Normandy		32.9	16.8	1.96
	Guntersville/Roseberry Creek		37.6	20.6	1.83
	Excl. June 11 Sample		30.1	23.4	1.29
	Nickajack/Chickamauga Creeks		135.9	66.9	2.03

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