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Environmental Sciences Division
Publication No. 3189

OPERATED BY
MARTIN MARIETTA ENERGY SYSTEMS, INC.
FOR THE UNITED STATES
DEPARTMENT OF ENERGY

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ENVIRONMENTAL SCIENCES DIVISION

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Environmental Sciences Division
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CONTENTS

LIST OF FIGURES

LIST OF FIGURES (continued)

LIST OF TABLES

ACRONYMS AND INITIALISMS

ATDD	Atmospheric Turbulence and Diffusion Division
BMAP	Biological Monitoring and Assessment Program
BMP	Best Management Plan
CERCLA	Comprehensive Environmental Response, Compensation and Liability Act
cfs	cubic feet per second
DAS	Data Acquisition System
DOE	Department of Energy
EHPD	Environmental and Health Protection Division
EMC	Environmental Monitoring and Compliance
EPA	Environmental Protection Agency
ERFU	Environmental Restoration and Facilities Upgrade
ESD	Environmental Sciences Division
ETF	Engineering Test Facility
gpm	gallons per minute
HFIR	High Flux Isotope Reactor
HHMS	Hydrostatic Head Monitoring Station
HRE	Homogeneous Reactor Experiment
HRT	Homogeneous Reactor Test
ISV	In-Situ Verification
LLW	Low Level Waste
MB	Melton Branch
mgd	million gallons per day
MSL	mean sea level
NOAA	National Oceanic and Atmospheric Administration
NPDES	National Pollution Discharge Elimination System
NRWTF	Nonradiological Wastewater Treatment Facility
OHF	Old Hydrofracture Facility
ORNL	Oak Ridge National Laboratory
ORR	Oak Ridge Reactor
RAP	Remedial Action Program
SLB	Shallow Land Burial
SWSA	Solid Waste Storage Area
TARA	Test Area for Remedial Action
TOC	total organic carbon
TOX	total organic halides
TRU	Transuranium Processing Facility
USGS	U. S. Geological Survey
VOC	volatile organic compound
WAG	Waste Area Grouping
WOC	White Oak Creek
WOD	White Oak Dam
WOL	White Oak Lake

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ABSTRACT

BORDERS, D. M., C. B. SHERWOOD, J. A. WATTS, and R. H. KETELLE. 1989. Hydrologic data summary for the White Oak Creek Watershed: May 1987-April 1988. ORNL/TM-10959. Oak Ridge National Laboratory, Oak Ridge, Tennessee. 106 pp.

Hydrologic data collected on the White Oak Creek (WOC) watershed during the 1988 water year (May 1987-April 1988) are summarized. Many of these data have also been included in the Remedial Action Program Data Management and Information System data base. Dynamic hydrologic data collected on the surface and subsurface flow systems, which affect the quality or quantity of surface and groundwater, are described. Surface water data include discharge and runoff, surface water quality, radiological contamination of sediments, and descriptions of outfalls to the WOC flow system. Information on groundwater levels, aquifer characteristics, and groundwater quality are presented. Anomalies in the data that have been collected and problems with monitoring and accuracy are discussed. Appendices contain daily precipitation measurements and discharge rates at the WOC monitoring stations.

1. INTRODUCTION

This is the second in a series of annual reports prepared to summarize the hydrologic data collected on the White Oak Creek (WOC) watershed (Fig. 1). WOC drains the Oak Ridge National Laboratory (ORNL) and receives radioactive and nonradioactive effluents (treated and untreated) from Laboratory activities as well as leachates from subsurface waste storage areas in use since the early 1940s.

These annual reports are prepared as part of the ORNL Remedial Action Program (RAP), established in 1985 to provide comprehensive environmental management of areas where past research, development, and waste management activities have resulted in residual contamination of facilities or the environment. In 1986, Sherwood and Loar summarized the available information on hydro-geological and ecological characteristics of the WOC flow system and the nature and quantity of contaminants released into and from the system. Preparation of these annual summaries of hydrologic data is in response to their recommendation that characterization of the hydrology of the WOC watershed is needed to better understand the trends in both temporal and spatial patterns of the watershed.

1.1 PURPOSE AND SCOPE

This report documents the hydrologic data collected on the WOC watershed for the period May 1, 1987-April 30, 1988. The collection of hydrologic data is one component of the ongoing ORNL environmental studies and monitoring programs and is designed to aid in (1) characterizing the quantity and quality of the water in the flow system, (2) planning remedial action activities, and (3) providing long-term data availability and quality assurance. The report summarizes the available dynamic hydrologic data collected during the year along with information collected on the surface and subsurface flow systems, which affect the quantity or quality of surface and groundwater.

The ORNL RAP has divided all of the known active and inactive waste management areas, contaminated facilities, and potential sources

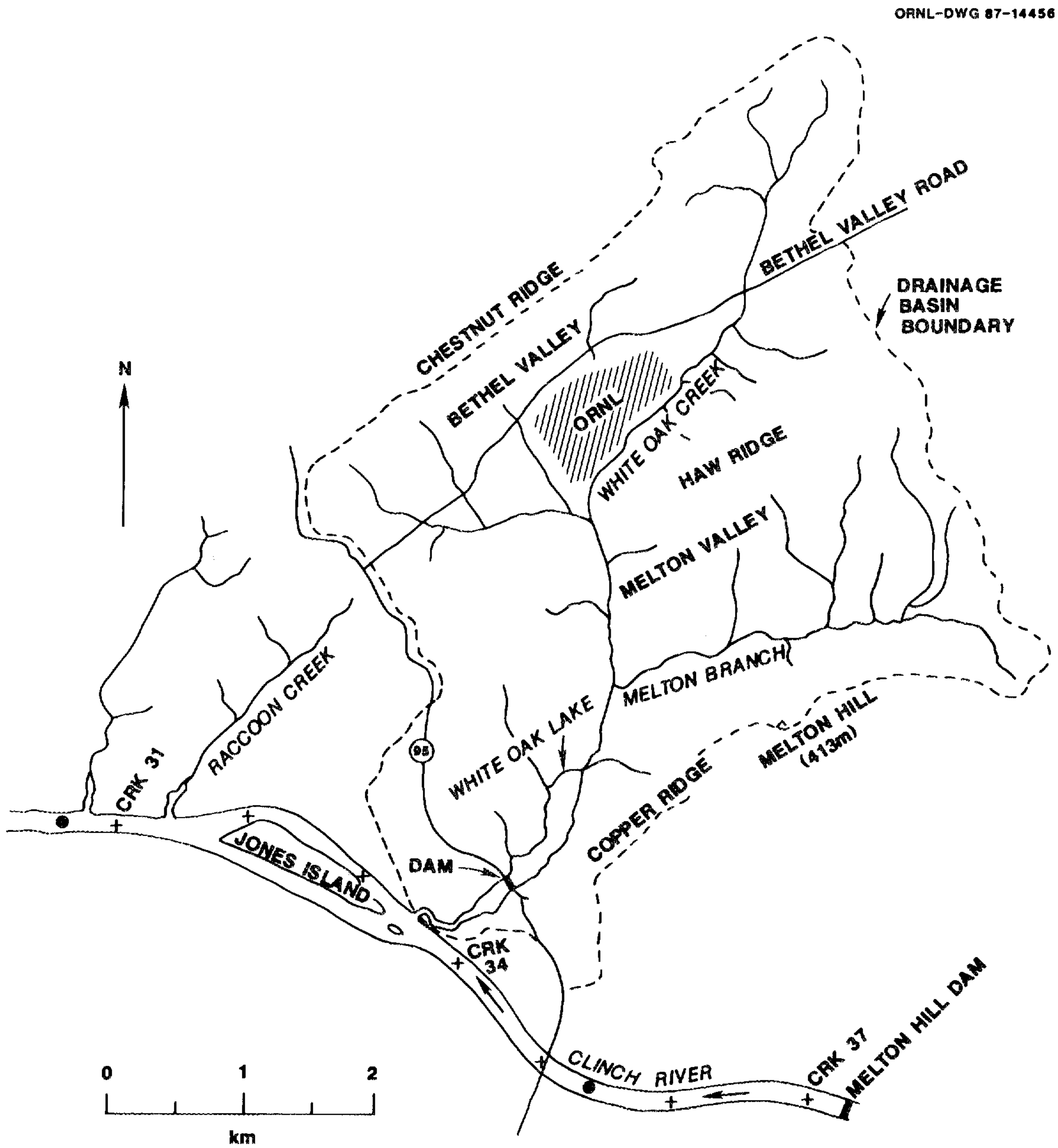

Fig. 1. WOC watershed boundaries. Revised from: Sherwood and Loar (1986).

of contaminants into 20 waste area groupings (WAGs), 11 of which are in the WOC watershed (Fig. 2). Most of the data included in this report have been compiled and formatted by the RAP Data and Information Management System, which was developed to provide a centralized repository for data pertinent to the RAP and to provide support for the investigations and assessments required for long-term remedial action of contaminated facilities and sites (Voorhees et al. 1986, 1988). Additional information can be obtained by contacting:

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ORNL-DWG 88-12924

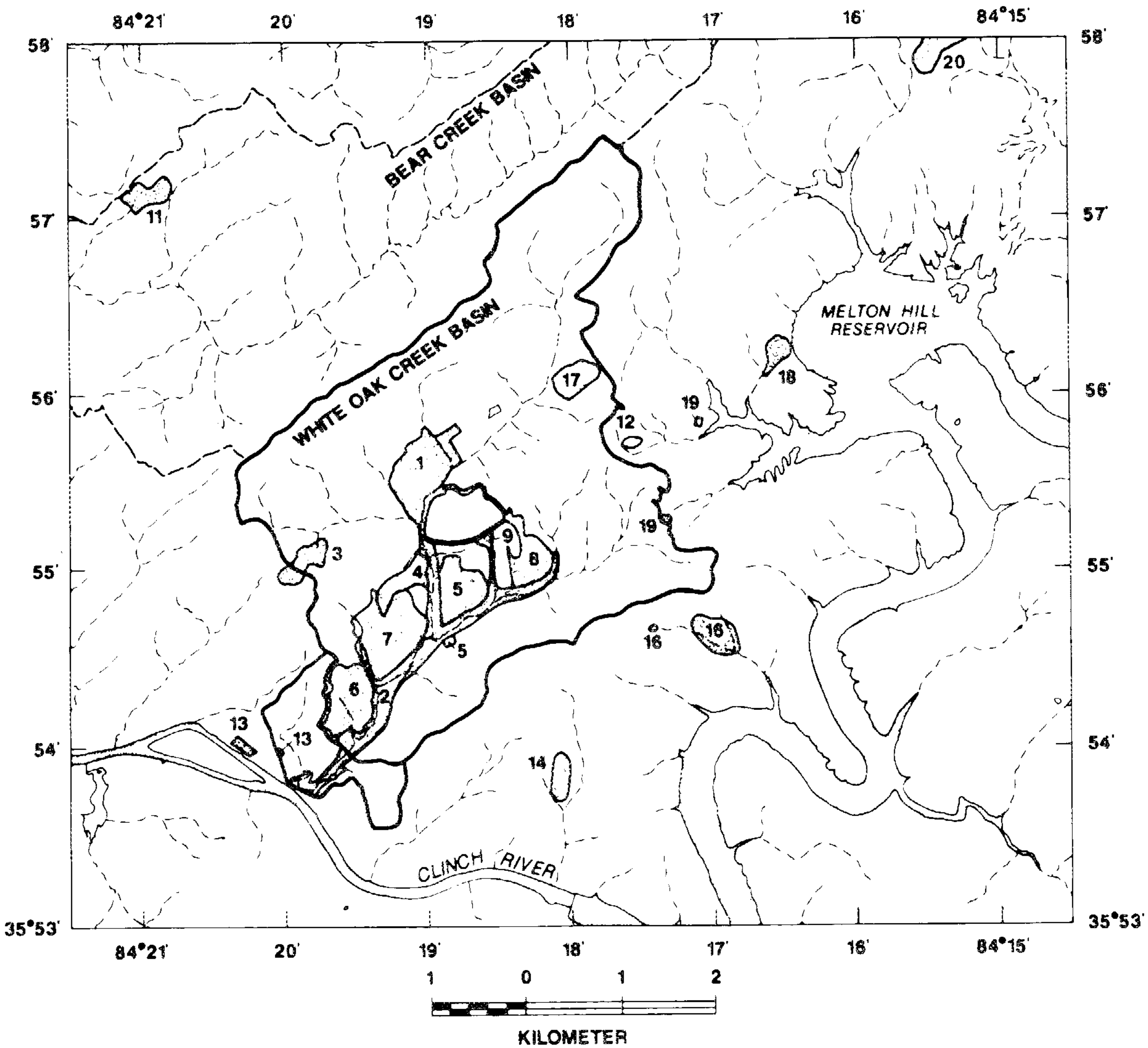


Fig. 2. Waste area groupings (WAGs) in the White Oak Creek watershed.

2. SITE DESCRIPTION

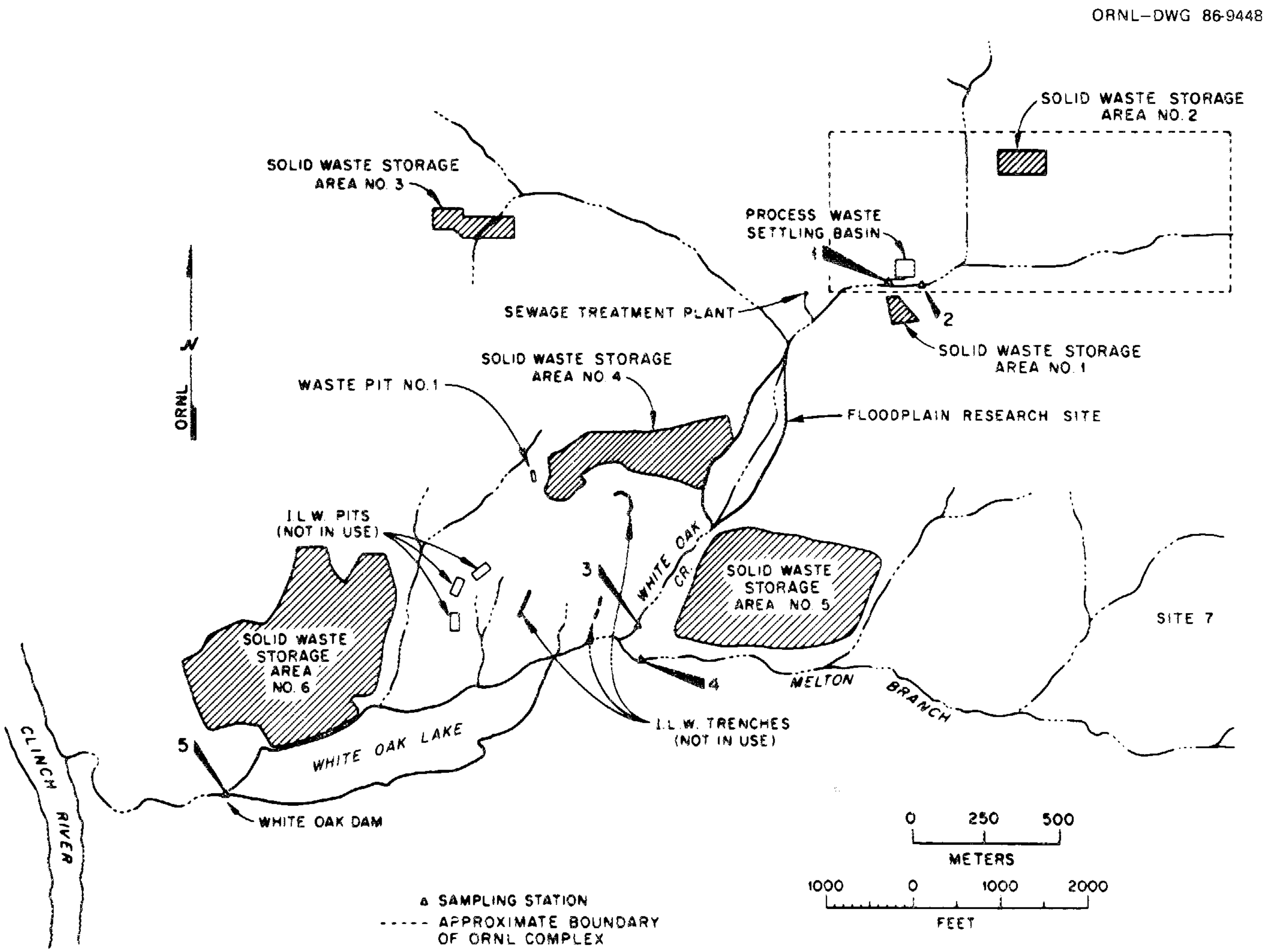
WOC rises from springs on the southeast slopes of Chestnut Ridge and, with its tributaries, drains much of Bethel and Melton Valleys (which include ORNL) to the Clinch River (Fig. 1). The waters of WOC are impounded by White Oak Dam (WOD), constructed 1.0 km (0.6 miles) upstream from the Clinch River in 1943 to form White Oak Lake (WOL), which serves as a holding pond for ORNL waste effluents. The drainage areas upstream from the confluence with the Clinch River and from WOD are ≈16.8 km^2 (6.5 $miles^2$) and 16.0 km^2 (6.15 $miles^2$), respectively (Martin Marietta Energy Systems, Inc. 1985). Elevations in the watershed range from 226 m above mean sea level (MSL) at the mouth of WOC to 413 m above MSL at the top of Melton Hill, the highest point on the Oak Ridge Reservation (McMaster 1963; McMaster and Waller 1965).

Four major geologic units underlie the WOC drainage basin. All formations strike northeast at about 56° and dip southeast at angles commonly between 30° and 40°.

The Rome Formation (Cambrian Age) is exposed along Haw Ridge. In general, the formation consists of soft argillaceous shale containing occasional thin siltstone layers <2.54 cm (1 in.) thick.

The Conasauga Group (Cambrian Age) underlies Melton Valley, including Solid Waste Storage Areas (SWSAs) 4, 5, and 6, and the pits and trenches area (Fig. 3). The pits and trenches area was formerly used for liquid waste disposal. The sequence through the Conasauga formation is gradational, from shale at the base to impure bedded limestone at the top. WOL and the lower part of WOC rest on limestone or shaley limestone of the Conasauga Group.

Proceeding in a northwest to southeast direction, the Knox Group (Cambrian and Ordovician Age) underlies much of Chestnut and Copper Ridges, which bound the WOC drainage basin to the north and south. The Knox Group, mostly composed of cherty dolomite in which sinkholes and caverns have developed, is the principal water-bearing formation in the watershed. The springs that occur along the southern slopes of Chestnut Ridge are the principal sources of the base flow of the upper portion of the WOC (McMaster and Waller 1965).



Approximate Location of Waste Disposal Areas and Sampling Stations at ORNL.

Fig. 3. Schematic of the WOC watershed showing potential area contamination sources.

The Chickamauga Group (Ordovician Age) underlies Bethel Valley, which includes the ORNL Main Plant area, and SWSAs 1, 2, and 3 (Fig. 3). This unit is composed predominantly of limestone, although shales, siltstones, and bedded chert comprise a significant minor part of the formation. Generally, the strata are thin to medium bedded. Cavities and fractures occur between the beds of the Chickamauga formation, but the cavities are less common than in the Knox Group formation.

WOD is a low-head structure with a normal lake elevation of 227.1 m (745 ft). The reservoir is only 0.9 m (3 ft) above full-pool elevation in the Clinch River, which is 226.6 m (742 ft). Recent work by Cox et al. (in press) indicates that the volume of WOL at normal pool level is ≈43,890 m^3 (1,546,330 ft^3). Flow from WOL discharges through a weir and a concrete-box culvert to the lower reach of WOC. In 1983, modifications were made to the flow system at the dam to increase the flood discharge capacity to 56.6 m^3/s (2000 ft^3/s). Tschantz (1987) estimated the 100-year flood peak to be ≈69.5 m^3/s (2453 ft^3/s).

Water levels and flow in WOC below the dam are largely controlled by the operation of the Melton Hill and Watts Bar Dams. Melton Hill Dam is located 3.7 km (2.3 miles) upstream on the Clinch River; Watts Bar Dam, which forms Watts Bar reservoir, is about 94 km (58.8 miles) downstream on the Tennessee River. When the Watts Bar reservoir is near full pool (generally April to October), backwater from the Clinch River creates an embayment in WOC below the dam.

Since WOL was created in 1943, studies have been undertaken to determine contaminant sources, quantities of contaminants released and retained in the lake, and the geology and hydro-geology of WOC and WOL. Table 1 presents a summary of some of the more important studies conducted since 1945. In some instances, the studies referenced in Table 1 represent summaries of the information developed; individual investigators have reported their efforts in greater detail in other reports and papers. An extensive listing of data and reports pertinent to the RAP may be retrieved from the RAP Data and Information Management System (Voorhees et al. 1988).

Table 1. Summary of significant studies conducted in WOC and WOL drainage area

Year	References	Areas of investigation
1945-46	Cheka and Morgan (1947)	First reported data on WOL sediments
1950	Setter and Kochitzky (1950)	Drainage areas and estimates of WOL capacity
1948-52	Abee (1953)	WOL sediments
1950-53	Krumholz (1954a,b,c)	Initial fish population and radioecological studies
1956-58	Auerbach et al. (1959)	68 shallow soil samples taken, soil mass estimated, total ^{90}Sr content estimated
		Agricultural plots established in former WOL bed
1958	Lee and Auerbach (1959)	Radiation field above the drained WOL
1961	Lomenick et al. (1961)	WOL sediments, vertical and lateral distribution studied, sediment volume estimates in drained WOL
1962	Lomenick et al. (1962)	^{106}Ru content and distribution in WOL sediments estimated
1962	Lomenick et al. (1963)	Variation in radionuclide and sediment content of water, 250 cores taken in lake bed, measured thickness of sediments and radionuclide content, Cs inventory
1964	McMaster and Richardson (1964)	Ten ranges of sediment concentrations, vertical distribution of ^{106}Ru, ^{137}Cs, and ^{60}Co measured
1965	Lomenick and Gardiner (1965)	Additional measurements of the vertical distribution of radionuclides in sediments
		Vertical distribution of ^{137}Cs studied
1969	Kolehmainen and Nelson (1969)	WOL radioecology studies
1970	Tamura et al. (1970)	Sediment sampling in embayment
1972	Blaylock et al. (1972)	Update of earlier assessment of radionuclides in WOL sediments

Table 1 (continued)

Year	References	Areas of investigation
1976	Webster (1976)	Hydrogeology of SWSAs 3, 4, 5, and 6
1977	Blaylock and Frank (1979)	Tritium in WOL sediments of WOL
1978	Edgar (1978)	Flood discharge estimates
1979	Cerling and Spalding (1981)	Analysis of streambed gravels for ^{60}Co, ^{90}Sr, and ^{137}Cs
1979-80	Loar et al. (1981a)	Comprehensive study of the aquatic ecology of WOC watershed and the WOC above and below the embayment
1982	Oakes et al. (1982a)	History of WOL, sediments, and water quality
1983 water	MMES (1984)[a]	Environmental monitoring report, WOL sediment and analyses
1984 water	MMES (1985)[a]	Environmental monitoring report, WOL sediment and analyses
1985	Cerling (personal	Update of 1979 streambed gravels survey communication)
1985	Synoptic ecological survey	Update results of the 1979-80 comprehensive survey (MMES 1986)[a]
1986	Blaylock et al. (In press)	Compilation of information on the radioecology of WOL
1986	Sherwood and Loar (1986)	Hydrologic data for the WOC watershed
1987	Loar et al. (1987)	First annual report on the ORNL Biological Monitoring and Abatement Program (BMAP)
1987	Tschantz (1987)	WOC hydrologic and spillway adequacy analysis
1988	Cox et al. (1988)	Mapping and volumetric determination of WOL

[a]Martin Marietta Energy Systems, Inc.
Source: Adapted from Sherwood and Loar 1986

Water in WOL contains measurable quantities of dissolved tritium (^{3}H) and ^{90}Sr, which are released through the monitoring station at WOD. Controlled releases of ORNL treated and untreated effluents to WOC include those from the Process Waste Treatment Plant, the Sewage Treatment Plant, and a variety of process waste holding ponds scattered throughout the ORNL complex (Fig. 4). WOC also receives effluent from SWSAs and low-level waste (LLW) pits and trenches, through both surface and groundwater flow (Fig. 3). Sediments within the WOC flow system have sorbed chemical and radioactive contaminants. Consequently, these contaminants have accumulated in the WOC floodplain and WOL sediments. Oakes et al. (1982) estimated that $\approx 5 \times 10^{6}$ ft^{3} of contaminated sediment have collected in the lake bed since 1943. The sediment in the lake bed contains an estimated 650 Ci (curies) of radioactive isotopes, primarily ^{60}Co, ^{90}Sr, and ^{137}Cs. During periods of heavy rainfall, both dissolved radionuclides and resuspended contaminated sediment are released from the lake into the Clinch River.

Groundwater occurs in all rocks that underlie the WOC basin. The dolomite of the Knox Group on Chestnut Ridge and the Chickamauga Group underlying Bethel Valley apparently discharge larger amounts of water, per unit drainage area, to the streams than the other geologic units. The Rome Formation on Haw Ridge and the Conasauga Group underlying Melton Valley discharge smaller quantities of water to the streams.

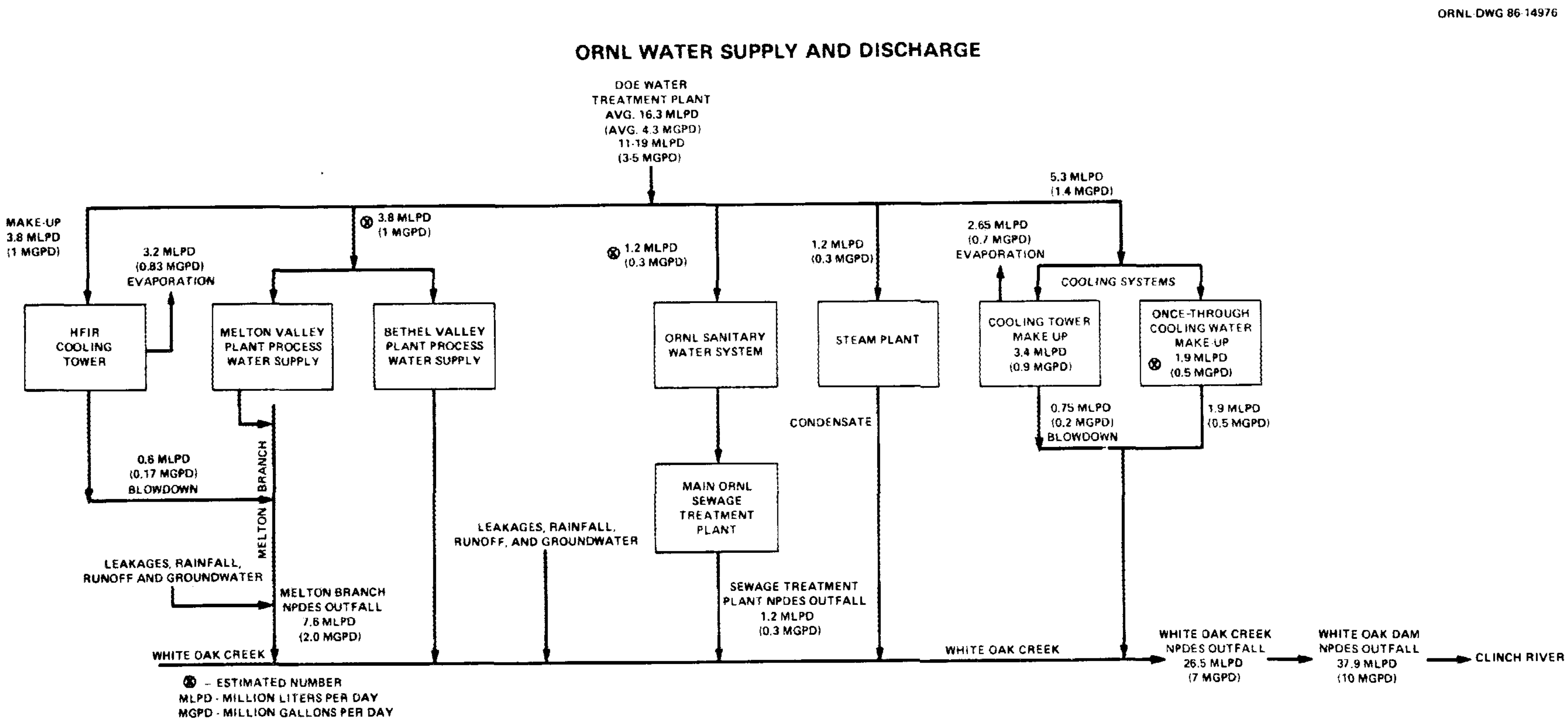


Fig. 4. ORNL water supply, process plants, and discharge. Source: Kasten 1986.

3. HYDROLOGIC DATA

The collection of hydrologic data in the WOC watershed began with facility planning studies in the early 1940s and has developed into a long-term program of environmental research studies and monitoring activities. Continual monitoring is required to cope with the Laboratory's waste management needs.

The hydrologic data available for the report period (May 1987-April 1988) were derived largely from ongoing studies of the ORNL RAP and from the continuing monitoring program conducted by the ORNL Environmental and Health Protection Division (EHPD). Much of the current monitoring is associated with the National Pollution Discharge Elimination System (NPDES) permit for ORNL operations (EPA 1986). Information on hydrologic data available in the RAP data and information system and data summaries for selected stations are given in the following sections.

3.1 CLIMATE

Precipitation, temperature, humidity, wind speed, and wind direction data are available for 15 stations located in the vicinity of the watershed (Table 2). The period of record varies from station to station. The National Oceanic and Atmospheric Administration Atmospheric Turbulence and Diffusion Division (NOAA/ATDD) monitoring station located in Oak Ridge about 15.4 km (9.6 miles) north of the center of the watershed is the closest long-term meteorological station with records dating from 1947 to the present.

Precipitation establishes the quantity and variations in runoff and streamflow. It is also the source for evapotranspiration and for replenishment to the groundwater system. Maximum, mean, and minimum annual precipitation amounts for stations near ORNL during the period 1954-1983 were 1890, 1326, and 897 mm (74.8, 52.2, and 35.3 in.), respectively (Webster and Bradley 1988). Monthly precipitation at the NOAA/ATDD station generally ranges from 135 to 158 mm (5.3 to 6.2 in.) during the wettest months (January-March) and from 74 to 97 mm (2.9 to 3.8 in.) during the driest months (August-October) (NOAA 1974).

Table 2. Meteorological stations in the vicinity of the WOC watershed[a]

Station description	Location	Period of record	Measurements
Knoxville (TYS)[b]	McGhee Tyson Airport	1942-present	Precipitation, wind, temperature temperature gradient, and humidity
Oak Ridge (ATDD)	City	1947-present	Precipitation, temperature, and temperature gradient
		1947-1979	Wind
ORNL Towers A & B	ORNL	1982-present	Precipitation, wind, temperature, and temperature gradient
ORNL Tower C (DEM99)	ORNL	1982-present	Precipitation, wind, temperature, temp., gradient, humidity, and solar radiation
Building 1505	ORNL	1984-present	Solar radiation
ORNL (DEM34)	WOD	1986-present	Precipitation
First Creek (1st)	ORNL	1987-present	Precipitation
USGS[c] 7500 Bridge	7500 Bridge	1987-present	Precipitation
USGS[c] (GS3)	SWSA 3	1984-present	Precipitation[d]
USGS[c] (GS5)	SWSA 5	1975-present	Precipitation[d]

Table 2 (continued)

Station description	Location	Period of record	Measurements
USGS[c] (GS6)	SWSA 6	1976-present	Precipitation[d]
ETF[e]	SWSA 6	1980-present	Precipitation[d]
EPICOR[f]	SWSA 6	1985-present	Precipitation, wind, temperature, and humidity
TR7	Trench 7	1985-1987	Precipitation
SW7	Center	1984-present	Precipitation

[a]At various times, meteorological measurements have been made at the Y-12 Plant, K-25 Plant, and early ORNL station, and the Tower Shielding Facility (ORO-99).

[b]Measurements also exist for the period 1871 until the station was moved to McGhee-Tyson.

[c]U.S. Geological Survey.

[d]Precipitation gages are not equipped to measure snowfall.

[e]Engineering Test Facility.

[f]Ion exchange resin leaching site.

Source: Adapted from Boegly et al. 1985.

The frequencies of occurrence for precipitation at various intensities over periods of 5 min to 24 h are shown in Table 3 (Huff and Frederick 1984). The mean annual runoff for streams in the ORNL area is 22.3 in. of water (McMaster 1967). The annual precipitation loss (precipitation minus runoff) is fairly constant from year to year at about 762 mm (30 in.). The loss is primarily caused by evapotranspiration. Meteorological stations for which data are available in the RAP data base management system are shown in Fig. 5. Site descriptions and information on data collection methodology are shown in Table 4.

Monthly precipitation for the period May 1987-April 1988 at sites in the watershed and the NOAA/ATDD station in Oak Ridge are shown in Table 5. The long-term mean, based on the 39-year period of record, for the NOAA/ATDD station is also given. Daily precipitation at these sites is presented in Appendix A.

The reporting period (May 1987-April 1988) is during a 3-year period of below normal precipitation. Annual precipitation measured at the NOAA/ATDD station was 1182 mm (47.3 in.) in 1985 (86% of normal for the 39-year period of record), 986 mm (39.4 in.) in 1986 (72% of normal), and 1024 mm (40.9 mm) in 1987 (75% of normal) (NOAA 1987a, b). As seen in Table 5, precipitation at the NOAA/ATDD station was below normal during each month of the reporting period except June and September 1987 and January 1988, causing a deficiency of > 254 mm (10 in.) for the 12-month period.

3.2 SURFACE WATER

Data on surface water flow and quality are collected at a number of sites in the WOC flow system as part of the environmental monitoring and compliance (EMC) program associated with the NPDES permit, evaluations by the Interim Waste Operations group, and in RAP studies. Some periodic water quality data are also collected as part of the Biological Monitoring and Assessment Program (BMAP), which is required by the NPDES permit (Loar et al. in press).

Table 3. Rainfall (mm) vs frequency for areas up to 25.9 km^2 (10 $miles^2$) in Anderson and Knox counties, Tennessee[a]

Duration frequency (years)	Minutes[b]					Hours[c]				
	5	10	15	30	60	2	3	6	12	24
2	10.92	16.51	20.32	28.96	38.10	45.72	50.80	60.96	71.12	83.82
5	12.70	19.81	24.89	35.32	47.26	60.96	53.50	76.20	91.44	106.68
10	14.22	22.61	28.45	41.91	55.88	68.58	73.66	88.90	104.14	121.92
25	16.26	26.16	33.02	48.01	53.50	76.20	86.36	99.06	119.38	139.70
50	18.03	29.21	36.83	53.59	71.12	86.36	93.98	119.38	134.62	154.94
100	19.56	32.00	40.64	59.94	78.74	96.52	101.60	124.46	144.78	167.64

Probable maximum, 6-h duration: 723.90

[a] 1 mm = 0.04 in.

[b] 2-, 100-year and 5-, 15-, and 60-min data from maps in NWS HYDRO-35 (Frederick et al. 1977). All other "minute" data calculated using appropriate equation from the same publication as indicated below.

10 min: (0.59)(15 min) + (0.41)(5 min)
30 min: (0.49) (60 min) + (0.51) (15 min)

5 year: (0.278)(100 year) + (0.674)(2 year)
10 year: (0.449)(100 year) + (0.496)(2 year)
25 year: (0.669)(100 year) + (0.293)(2 year)
50 year: (0.835)(100 year) + (0.146)(2 year).

[c] Interpolated from maps in USWB TP 40 (Hershfield 1961).

Source: Adapted from Huff and Frederick 1984

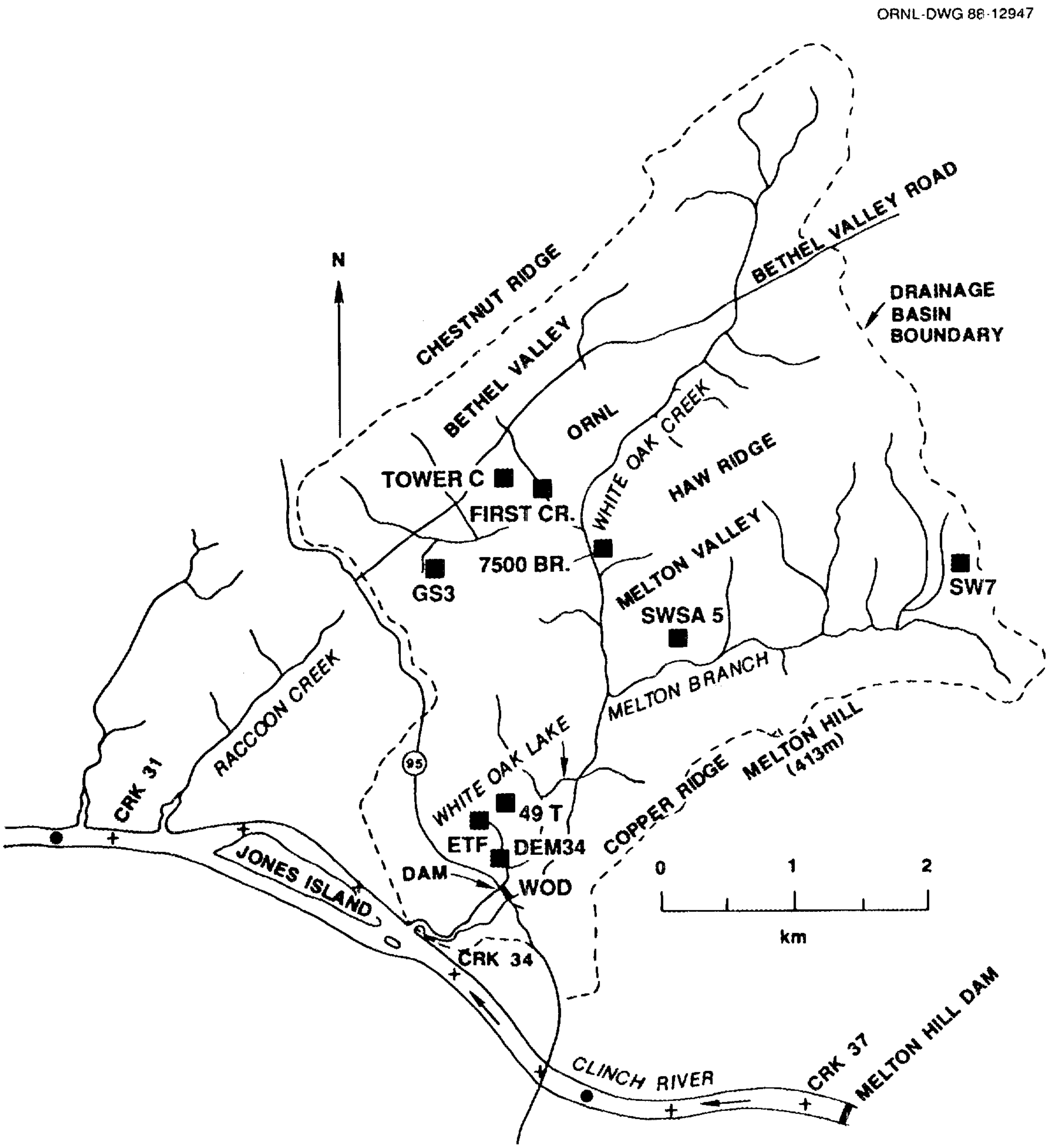


Fig. 5. Meteorological sites location in the WOC watershed for which data are included in RAP data management and information system.

Table 4. Selected site descriptions for precipitation stations in the WOC watershed and NOAA/ATDD Oak Ridge station

Site name[a] and identification[b]	Type of gage	Frequency of data collection	Smallest unit of measure for gage (in.)
NOAA/ATDD Oak Ridge (ATDD)	Belfort Weigh & Stick	Hourly	0.01
WOD (DEM34)	Belfort Heated Tip Bucket	10 min[c]	0.01
Met Tower[c] (DEM99)	MRI Tipping Bucket	10 min[c]	0.01
SWSA 6 (ETF)	Belfort Weighing	Daily	0.01
USGS/SWSA 3(GS3)	Belfort Weighing	Daily	0.01
USGS/SWSA 5(GS5)	Electric Tipping Bucket	Daily	0.01
USGS/7500BR.	Electric Tipping Bucket	Daily	0.01
49 Trench Site (SWSA 6) T49	Belfort Weighing	Daily	0.01
Center 7 Creek Watershed (SW7)	Belfort Weighing	Daily	0.01
First Creek (1st)	Belfort Weighing	Daily	0.01

[a]Site names used in the data descriptions: ATDD - Atmospheric Turbulence and Diffusion Division; NOAA - National Oceanic and Atmospheric Administration; SWSA - Solid Waste Storage Area; USGS - U.S. Geological Survey.

[b]Site IDs were assigned by the RAP.

[c]Data are stored in breakpoint format; level of resolution is 10 min.

Table 5. 1987-88 Monthly precipitation by station at the WOC watershed and NOAA/ATDD (mm)

Month	49 Trench	SWSA 6 (ETF)	GS5	GS3	First Creek[a]	SWSA 7	7500 Bridge[b]	ATDD Actual	ATDD Normal
May 1987	103.22	101.09	76.96	95.49		80.54		51.31	89.41
June 1987	83.81	83.69	72.14	88.64		69.49		108.20	100.08
July 1987	53.46	54.87	51.56	56.40	55.37	63.53		100.07	144.02
August 1987	46.98	51.82	41.14	38.09	44.41	33.41	56.37	48.76	97.79
September 1987	91.29	93.59	97.28	92.21	93.46	103.64		143.26	84.84
October 1987	14.74	15.25	17.53	17.78	18.42	17.77	26.41	17.52	69.09
November 1987	53.20	52.45	53.33	54.85	54.61	51.92	59.18	53.59	102.87
December 1987	81.75	82.52	82.56	84.58	83.02	86.96	95.00	87.11	136.14
January 1988	128.05	130.78	137.91	130.04	127.65	138.86	140.46	138.18	133.35
February 1988	68.32	72.77	69.09	69.09	71.38	71.49	83.06	87.12	133.10
March 1988	87.40	92.92	90.93	90.93	88.15	87.28	98.28	97.52	138.43
April 1988	69.60	73.03	71.89	79.75	77.87	69.74	88.11	86.88	106.93
Total (mm)	881.82	904.78	862.32	897.85	714.34	874.63	646.87	1019.52	1336.05
Total (in)	34.72	35.62	33.95	35.35	28.12	34.43	25.47	40.14	52.60

[a]Data collection began in July 1987.
[b]Data collection began in August 1987; data not available in September 1987.

3.2.1 Discharge and Runoff

Daily streamflow data collected at 12 sites (Fig. 6) in the WOC system are available in the RAP data base management system. Three sites, WOD, WOC above Melton Branch, and Melton Branch are operated by the EMC Department as part of the NPDES permit requirements, and nine sites are operated by the U.S. Geological Survey (USGS) as part of RAP studies to isolate individual contributions of upstream hydrologic units or for application in forecast modeling studies. An additional EMC site has been established on WOC upstream of Bethel Valley Road to monitor flow in the headwaters area. Data collection activities at this site will begin around September 1988. Stream discharge data have also been collected since April 1988 at two sites on tributaries that drain the pits and trenches area northeast of WOL as part of a RAP subtask to refine forecast modeling capabilities. This modeling study is being conducted by the ORNL Environmental Sciences Division (ESD).

Electronic signals transmitted from the EHPD stations are monitored by near real-time data systems of the EMC Data Acquisition System (DAS). Because of the complexity and importance of the EHPD sites, the following detailed station descriptions have been included.

1. WOD (X15). Station is located at the lower end of WOL where WOC flows under State Highway 95, 1 km (0.6 miles) above the confluence with the Clinch River. The station is housed in a metal building beside the channel. Water behind the dam flows through two gates [each 5.5 m (18 ft) wide], through a 12.2 m (40-ft)-wide channel, across a full-width V-shaped flume, then across a 0.9 m (3-ft)-wide Cipoletti weir [0.4 m (1.33 ft) high]. The notch elevations on the flume and weir are 227 m (744.0 ft) and 226.6 m (743.5 ft), respectively. Maximum lake elevation with the gates closed is 228.6 m (750 ft) above MSL. Crest elevation of the earthen dam is ≈ 230 m (755.05 ft) MSL at its lowest point near the longitudinal center (Tschantz 1987).

   The station contains three ultrasonic flow meters in stilling wells linked to the flow channel by piezometer tubes. Flow meters record high-flow range (max. 56,634 L/S (2000 cfs)) and medium-

ORNL-DWG 88-12946

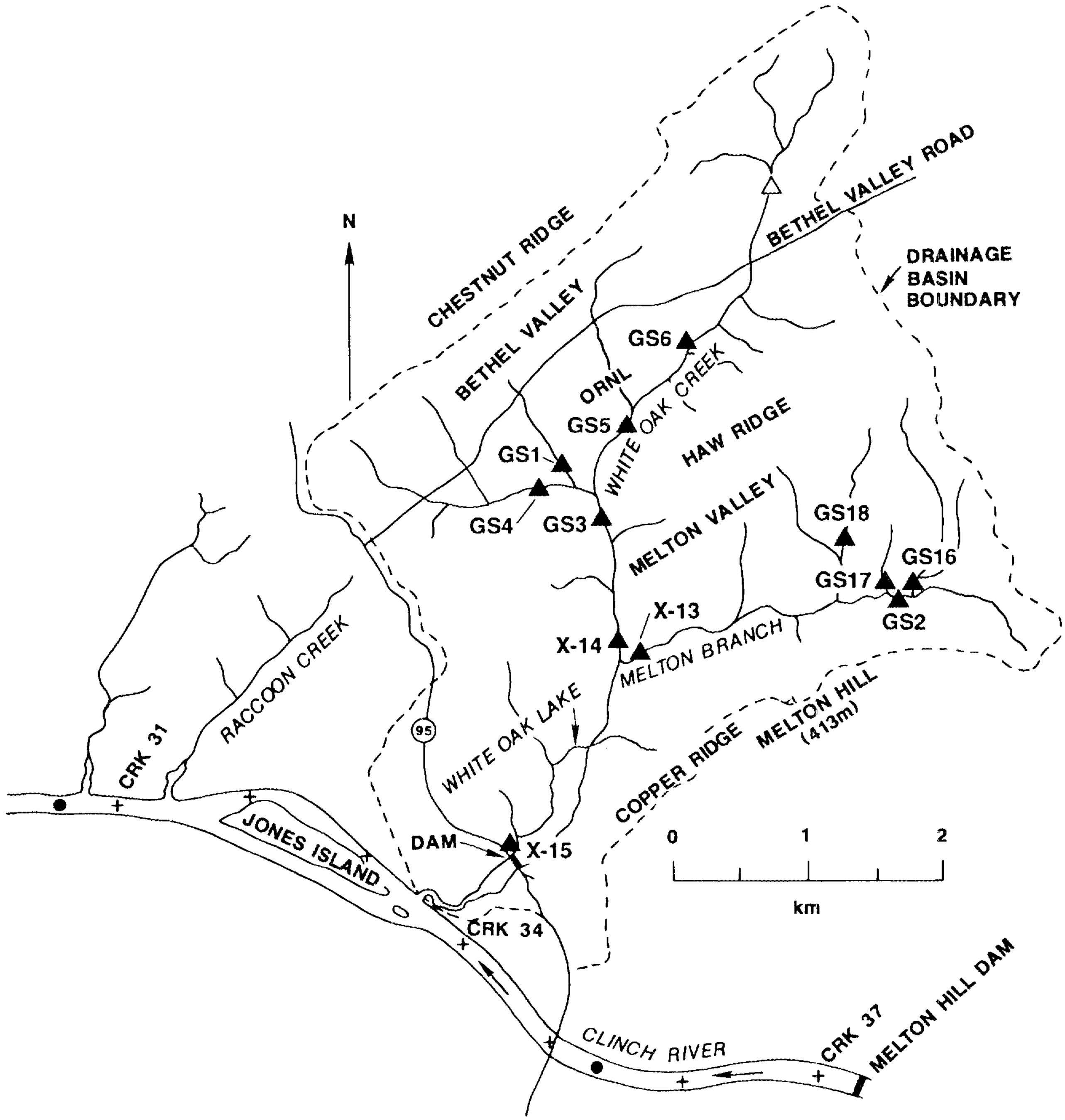


Fig. 6. Stream gaging stations in WOC and its tributaries. Open triangle symbol shows location of planned gaging station.

flow range (max. 5663 L/S (200 cfs)) by measuring hydraulic head behind the flume. These two units use the same stilling well. The low-flow range meter (max. 425 L/S (15 cfs)) measures hydraulic head in the pool upstream of the Cipoletti weir. A fourth ultrasonic unit measures tailwater below the low-flow weir and sounds an alarm if the Clinch River floods high enough to flow back into WOL.

2. WOC (X14). Station is located on WOC above the confluence with Melton Branch. The station is housed in a metal building beside the channel. Water flows into a pool upstream from the station, through twin 100° V-notch weirs [0.76 m (2.5 ft high)], and then through a 10.97 m (36-ft)-wide channel across a broad-crested flume. The elevations of the top of the weir, the weir notches, and the broad-crested flume are 230.2, 229.4, and 228.2 m (755.31, 752.81, and 748.75 ft), respectively.

   The station contains two ultrasonic flowmeters in stilling wells linked to the flow channel by piezometer tubes. The high-flow range meter records high-flow range [max. 3398 L/S (1200 cfs)] by measuring hydraulic head behind the flume. The low-flow range meter [max. 1699 L/S (60 cfs)] measures hydraulic head in the pool behind the V-notch weirs. The station also contains one ultrasonic unit to measure tailwater.

3. Melton Branch (X13). Station is located on Melton Branch above the confluence with WOC. The station is housed in a metal building beside the channel. Water flows into a pool upstream from the station retained by a sill, through a 120° V-notch weir [0.69 m ((2.25 ft) high], and then through a 7.3 m (24-ft)-wide channel across a broad-crested flume. The elevations of the top of the weir, the weir notch, and the broad-crested flume are 230.3 m (755.60), 229.6 m (753.35), and 229 m (751.43) feet, respectively.

The station contains two ultrasonic flow meters in stilling wells linked to the flow channel by piezometric tubes. The high-low range meter records high-flow range [max. 16990 L/S (600 cfs)] by measuring hydraulic head behind the flume. The low-flow range meter [max. 982.6 L/S (34.7 cfs)] measures hydraulic head in the pool behind the 120° V-notch weir. The station also contains one ultrasonic unit to measure tailwater.

The following is a station description summary for the nine USGS flow measurement sites:

1. Upper WOC (GS6 - USGS Sta. 03536320). Station is on WOC, just north of the point where WOC crosses White Oak Avenue, near Building 6000, ORNL. Instrumentation includes a float-type gage and stilling well in an instrument shelter on the right bank of the stream.

2. Parshall Flume on WOC (GS5 - USGS Sta. 03536380). Station is located at the existing MS-2 flume on WOC. Instrumentation includes digital recorder and small float system mounted at the upstream side of the concrete structure containing the flume, near the left bank.

3. First Creek (GS1 - USGS Sta. 03536450). Station is located at the new compound flume installed on First Creek, between Burial Ground Road and the confluence with the Northwest Tributary. Instrumentation includes a digital stage-height recorder mounted on the existing stilling well.

4. Northwest Tributary (GS4 - USGS Sta. 03536440). Station is located at the existing concrete and stainless steel weir that is used as the control. Instrumentation includes a bubbler unit for measuring stage height and a digital recorder.

5. WOC at the 7500 Bridge (GS3 - USGS Sta. 03536550). Station is located on WOC below the confluence with First Creek and Northwest Tributary. The instrumentation transmits data via the satellite telemetry system used by the USGS. The data are available in near real-time, but are also processed to produce printed summaries.

6. Melton Branch near Melton Hill (GS2 - USGS Sta. 03537100). Station is located in the upper reach of Melton Branch near the proposed SWSA 7. Instrumentation includes a float-type gage mounted on a stilling well and is equipped with a digital stage-height recorder.

7. East Seven Tributary (GS16 - USGS Sta. 03537050). Station is located on the east tributary to Melton Branch adjacent to the proposed SWSA 7. The control is a fiberglass H-flume. Instrumentation includes a float-type gage mounted on a stilling well and is equipped with a digital stage-height recorder.

8. Center Seven Tributary (GS17 - USGS Sta. 03537200). Station is located on the center of three tributaries to Melton Branch in the area designated as the proposed SWSA 7. The control is a fiberglass H-flume. Instrumentation includes a float-type gage mounted on a stilling well and is equipped with a digital stage-height recorder.

9. West Seven Tributary (GS18 - USGS Sta. 03537300). Station is located on the west tributary to Melton Branch adjacent to the proposed SWSA 7. The control is a combination rectangular/90° V-notch weir. Instrumentation includes a float-type gage mounted on a stilling well and is equipped with a digital stage-height recorder.

The following is a station description summary for ESD's two flow measurement sites on tributaries that drain the pits and trenches area northeast of WOL:

1. East Seep. Station is located on the east seep tributary to the headwaters of WOL. The control is a 90° V-notch weir. Instrumentation includes a Stevens model 7001 float-type punch tape water level recorder.

2. West Seep. Station is located on the west seep tributary to the headwaters of WOL. The control is a combination rectangular/120° V-notch weir. Instrumentation includes a Stevens model 7001 float-type punch tape water level recorder.

Monthly flow summaries for the three EHPD and nine USGS sites for which data are available in the RAP data management system are shown in Table 6. Daily flow data for these sites are presented in Appendix B.

To compare flows at selected gaging stations and to isolate contributions from different areas, monthly mean discharge for all stations and contributing areas in the WOC flow system (Fig. 7) has been summarized (Table 7). Drainage areas for each component in the flow system are shown in Fig. 8 and summarized in Table 8. For comparative purposes, the total contribution of flow (natural and imported) from each contributing area was divided by its drainage area to express monthly runoff volume in inches of water per area (Table 9).

Flow in WOC in the main ORNL plant area is augmented by the disposal of water imported for plant processes, potable supplies, and sanitary use. Also, the nature of the flow within the plant area is complex because of the effects of storm drainage, leakage into and out of an extensive system of underground pipes, and the increased permeability of disturbed subsurface materials along pipelines and within construction sites.

The discharge data from the six new USGS stations in the vicinity of the main plant permit the isolation of flow from some of the contributing areas. Figure 9(a) shows hydrographs of monthly mean

Table 6. Monthly flow summary for WOC watershed (flow rates in cfs)

Date	Statistic	Site ID[a]											
		GS1	GS2	GS3	GS4	GS5	GS6	GS16	GS17	GS18	X13	X14	X15
1987, May	Mean	0.47	0.08	7.60	0.69	3.47	0.17	b	b	b	0.61	6.76	7.83
	Minimum	0.27	0.01	6.30	0.54	2.80	0.07	b	b	b	0.29	5.51	5.97
	Maximum	1.10	0.59	12.00	1.30	6.80	1.20	b	b	b	1.18	11.36	14.31
June	Mean	0.34	0.02	6.81	0.69	3.14	0.13	b	b	b	0.38	6.83	7.28
	Minimum	0.21	0.00	5.90	0.54	2.60	0.05	b	b	b	0.11	5.83	6.02
	Maximum	1.10	0.16	11.00	2.40	4.40	0.51	b	b	b	2.15	13.24	15.67
July	Mean	0.33	0.01	6.75	0.68	2.89	0.13	b	b	b	0.61	6.28	6.65
	Minimum	0.21	0.00	5.80	0.54	2.20	0.04	b	b	b	0.23	4.60	4.83
	Maximum	0.64	0.23	11.00	0.89	5.90	1.10	b	b	b	1.41	8.32	10.23
August	Mean	0.44	0.00	6.29	0.64	2.46	0.05	0.00	0.00	b	0.34	6.03	6.71
	Minimum	0.27	0.00	5.30	0.52	2.20	0.02	0.00	0.00	b	0.22	5.30	5.30
	Maximum	0.88	0.00	8.80	0.83	4.30	0.28	0.00	0.00	b	0.71	9.69	14.08
September	Mean	0.32	0.00	6.20	0.66	3.02	0.15	0.00	0.00	0.00	0.48	6.33	6.62
	Minimum	0.17	0.00	5.30	0.54	2.40	0.02	0.00	0.00	0.00	0.23	4.64	5.06
	Maximum	1.70	0.00	16.00	1.20	11.00	2.30	0.02	0.05	0.01	1.27	10.57	10.79
October	Mean	0.20	0.00	5.23	0.62	2.57	0.06	0.00	0.00	0.00	0.76	4.97	5.86
	Minimum	0.17	0.00	4.30	0.41	1.70	0.04	0.00	0.00	0.00	0.25	4.22	4.98
	Maximum	0.26	0.00	6.20	0.74	3.80	0.17	0.01	0.00	0.00	1.87	6.13	8.87
November	Mean	0.23	0.00	5.94	0.62	3.04	0.13	0.00	0.01	0.00	0.45	6.02	6.70
	Minimum	0.18	0.00	5.00	0.53	2.30	0.04	0.00	0.00	0.00	0.19	4.87	5.31
	Maximum	0.65	0.00	9.90	0.90	6.00	0.84	0.02	0.03	0.00	1.16	10.04	11.20
December	Mean	0.28	0.04	6.39	0.70	3.33	0.22	0.02	0.03	0.02	0.75	6.45	7.25
	Minimum	0.14	0.00	4.80	0.52	2.40	0.05	0.00	0.01	0.00	0.39	4.22	4.60
	Maximum	0.96	0.45	12.00	1.30	7.00	1.20	0.15	0.14	0.19	1.62	10.72	12.13

Table 6. (continued)

Date	Statistic	GS1	GS2	GS3	GS4	GS5	GS6	GS16	GS17	GS18	X13	X14	X15
		Site ID[a]											
1988, January	Mean	0.83	1.03	10.54	1.34	5.87	1.34	0.42	0.19	0.24	3.32	10.07	14.31
	Minimum	0.28	0.05	5.80	0.58	3.00	0.09	0.05	0.02	0.01	0.56	4.98	6.31
	Maximum	5.90	14.00	58.00	8.70	34.00	17.00	4.50	2.10	3.00	62.87	67.00	129.90
February	Mean	0.77	0.45	8.93	0.99	4.77	0.57	0.27	0.09	0.17	1.70	8.83	11.64
	Minimum	0.34	0.07	6.50	0.63	3.00	0.09	0.05	0.02	0.02	0.56	5.85	7.50
	Maximum	2.90	4.80	28.00	4.30	18.00	5.90	3.00	0.92	1.80	9.08	30.42	39.50
March	Mean	0.97	0.83	10.35	1.26	5.59	1.26	0.42	0.14	0.25	1.81	10.26	13.53
	Minimum	0.35	0.07	6.30	0.61	2.80	0.09	0.04	0.02	0.02	0.54	4.77	6.84
	Maximum	5.50	14.00	56.00	9.30	36.00	18.00	6.80	2.30	4.10	11.08	54.60	70.06
April	Mean	0.72	0.30	8.07	0.96	3.94	0.35	0.19	0.06	0.12	1.48	7.60	9.66
	Minimum	0.42	0.07	6.10	0.67	2.80	0.09	0.03	0.01	0.01	0.50	5.85	6.16
	Maximum	1.40	1.20	14.00	1.90	7.00	1.30	0.73	0.21	0.41	4.72	11.81	16.52

[a]GS1 = First Creek
GS2 = Melton Branch near Melton Hill
GS3 = WOC below Melton Valley Drive
GS4 = Northwest Trib near Oak Ridge
GS5 = WOC near Wheat, TN
GS6 = WOC near Melton Hill
GS16 = Melton Branch Tributary (East Seven) near Oak Ridge
GS17 = MELTON Branch Tributary (Center Seven) near Oak Ridge
GS18 = MELTON Branch Tributary (West Seven) near Oak Ridge
X13 = WOC MS3 Station
X14 = Melton Branch MS4 Station
X15 = WOD MS5 Station

[b]Data collection began in August 1987 at stations GS16 and GS17 and began in September 1987 at Station GS18.

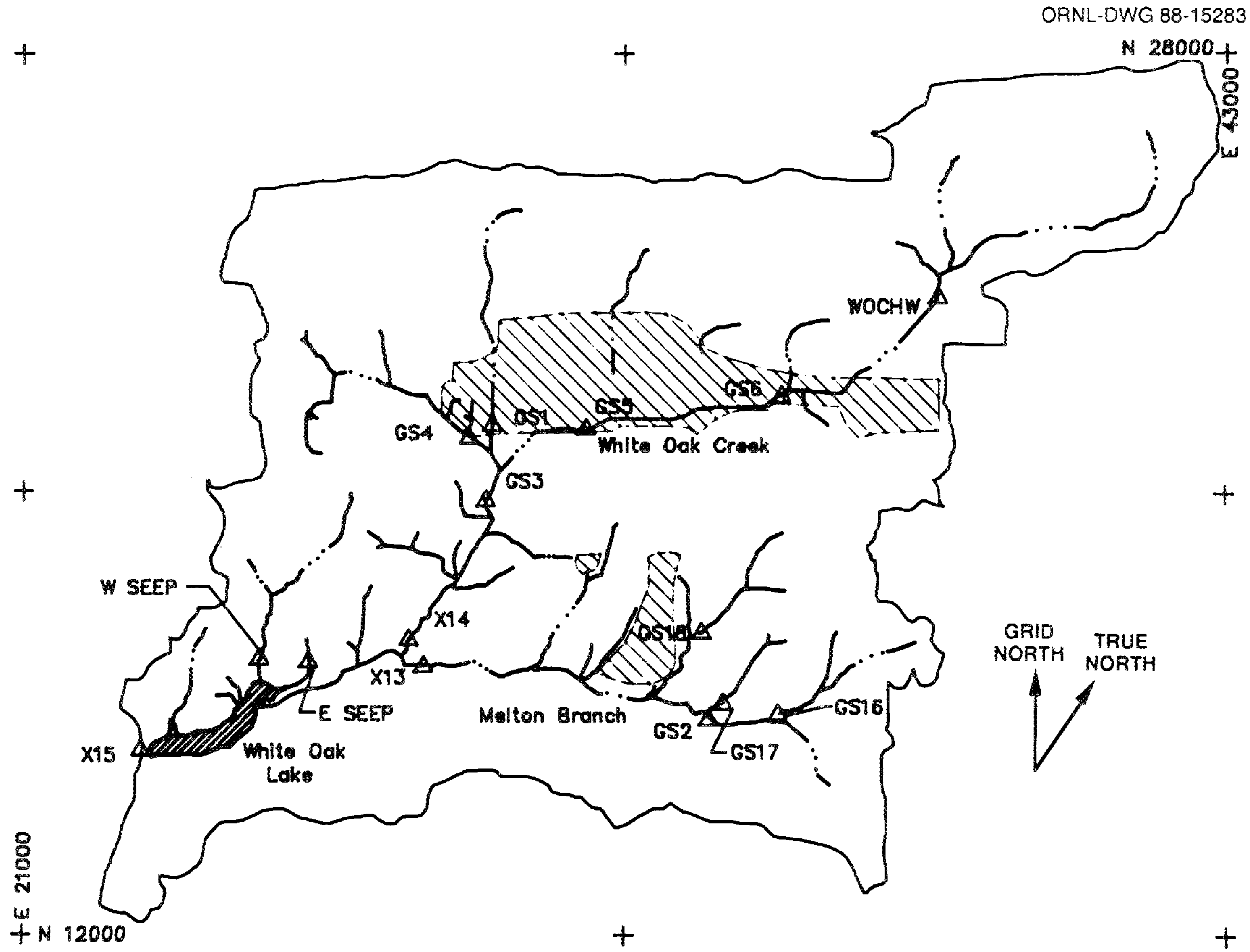


Fig. 7. WOC drainage basin with locations of monitoring stations. Physical facilities of ORNL are indicated by light shading. WOL is indicated by dark shading.

Table 7. WOC watershed mean flows or flow differences between gaged areas for May 1987-April 1988

Station name	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr
GS6	0.17	0.13	0.13	0.05	0.15	0.06	0.13	0.22	1.34	0.55	1.26	0.35
GS5	3.47	3.14	2.89	2.46	3.02	2.57	3.04	3.33	5.87	4.71	5.59	3.94
GS5-GS6	3.3	3.01	2.76	2.41	2.87	2.51	2.91	3.11	4.53	4.16	4.33	3.59
GS1	0.47	0.34	0.33	0.44	0.32	0.2	0.23	0.28	0.83	0.75	0.97	0.72
GS4	0.69	0.69	0.68	0.64	0.66	0.62	0.62	0.7	1.34	0.98	1.26	0.96
GS1+GS4+GS5	4.63	4.17	3.9	3.54	4	3.39	3.89	4.31	8.04	6.44	7.82	5.62
GS3	7.6	6.81	6.75	6.29	6.2	5.23	5.94	6.39	10.54	8.93	10.35	8.07
GS3-(GS1+4+5)	2.97	2.64	2.85	2.75	2.2	1.84	2.05	2.08	2.5	2.49	2.53	2.45
X14	6.76	6.83	6.28	6.03	6.33	4.97	6.02	6.45	10.07	8.83	10.26	7.6
X14-GS3	-0.84[a]	0.02	-0.47	-0.26	0.13	-0.26	0.08	0.06	-0.47	-0.1	-0.09	-0.47
GS16	NA	NA	NA	NA	0.001[b]	0.0003	0.002	0.02	0.42	0.27	0.42	0.19
GS2	0.08	0.02	0.01	0	0	0	0	0.04	1.03	0.44	0.83	0.3
GS2-GS16	0.08	0.02	0.01	0	-0.001	-0.0003	-0.002	0.02	0.61	0.17	0.41	0.11
GS17	NA	NA	NA	NA	0.002	0	0.01	0.03	0.19	0.08	0.14	0.06
GS18	NA	NA	NA	NA	0.003	0	0	0.02	0.24	0.16	0.25	0.12
GS2+GS17+GS18	0.08	0.02	0.01	0	0.007	0	0.01	0.09	1.46	0.68	1.22	0.48
X13	0.61	0.38	0.61	0.34	0.48	0.76	0.45	0.75	3.32	1.7	1.81	1.48
X13-(GS2+17+18)	0.53	0.36	0.6	0.34	0.48	0.76	0.44	0.66	1.86	1.02	0.59	1
X14+X13	7.37	7.21	6.89	6.37	6.81	5.73	6.47	7.2	13.39	10.53	12.07	9.08
X15	7.83	7.28	6.65	6.71	6.62	5.86	6.7	7.25	14.31	11.64	13.53	9.66
X15-(X14+X13)	0.46	0.07	-0.24	0.34	-0.19	0.13	0.23	0.05	0.92	1.11	1.46	0.58

[a]Negative flow values indicate the need to examine the design and operation of the gaging stations.
[b]Significant figures show that there the flow is non-zero.

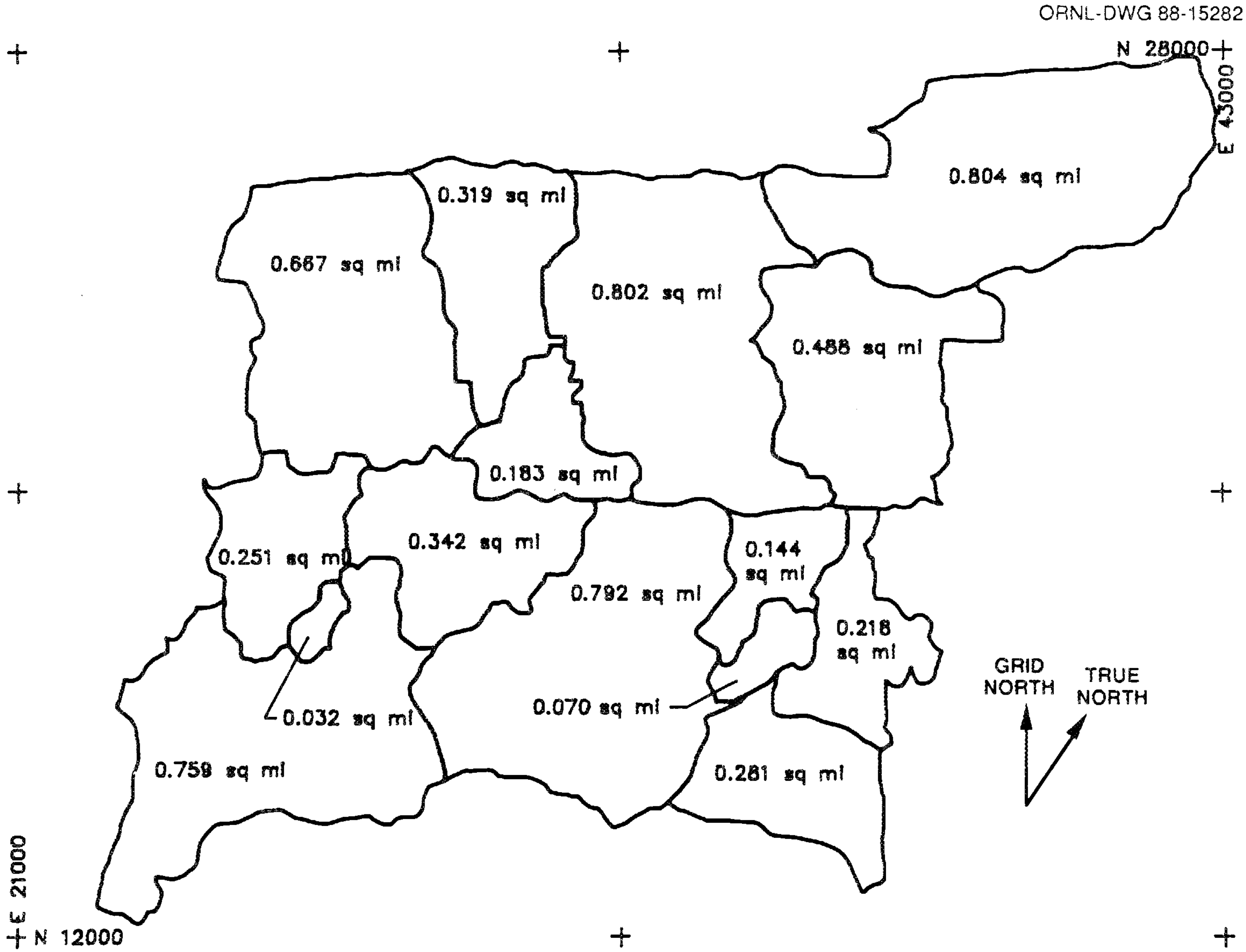


Fig. 8. Map of areal extent of WOC drainage basin subunits.

Table 8. Drainage area of discharge monitoring stations in WOC watershed

Monitoring station or contributing area	Common station name(s) or stream reach	Drainage area ($mile^2$)
GS1	First Creek	0.32
GS2	Upper Melton Branch (UMB)	0.50
GS3	7500 Bridge	3.26
GS4	Northwest Tributary (NWT)	0.67
GS5	Parshall Flume, MS2	2.09
GS6	Upper WOC	1.29
GS16	East Seven Creek (E7C)	0.22
GS17	Center Seven Creek (C7C)	0.07
GS18	West Seven Creek (W7C)	0.14
X13	Melton Branch (MBR), MS4	1.51
X14	WOC, MS3	3.61
X15	WOD, MS5	6.15
WOCHW	WOC Headwaters	0.80
E. Seep	East Seep Tributary	0.03
W. Seep	West Seep Tributary	0.25
X15-X14-X13	WOL Local Inflow	1.04
X13-(GS2+17+18)	MBR contributing area	0.79
GS2-GS16	MBR contributing area	0.28
X14-GS3	WOC contributing area	0.34
GS3-(GS1+4+5)	WOC contributing area	0.18
GS5-GS6	WOC contributing area	0.80

Table 9. WOC watershed flow summary runoff for May 1987 to April 1988 (in.)

Station name	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	Total
GS6	0.15	0.11	0.12	0.04	0.13	0.05	0.11	0.20	1.20	0.46	1.13	0.30	4.00
GS5	1.92	1.68	1.60	1.36	1.61	1.42	1.62	1.84	3.24	2.43	3.09	2.10	23.90
GS5-GS6	4.76	4.20	3.98	3.47	4.00	3.62	4.06	4.48	6.53	5.61	6.24	5.01	55.95
GS1	1.70	1.19	1.19	1.59	1.12	0.72	0.80	1.01	3.00	2.54	3.51	2.52	20.89
GS4	1.18	1.14	1.16	1.09	1.09	1.06	1.02	1.19	2.28	1.56	2.15	1.58	16.49
GS3	2.68	2.32	2.38	2.22	2.11	1.85	2.03	2.26	3.72	2.95	3.65	2.75	30.92
GS3-(GS1+4+5)	18.61	16.01	17.86	17.23	13.34	11.53	12.43	13.03	15.66	14.59	15.85	14.86	181.01
X14	2.16	2.11	2.00	1.92	1.96	1.59	1.86	2.06	3.21	2.64	3.27	2.35	27.13
X14-GS3	-2.85[a]	0.07	-1.59	-0.88	0.43	-0.88	0.26	0.20	-1.59	-0.32	-0.31	-1.54	-9.01
GS16	NA[b]	NA	NA	NA	0.01	0.00	0.01	0.11	2.21	1.33	2.21	0.97	NA
GS2	0.18	0.04	0.02	0.00	0.00	0.00	0.00	0.09	2.38	0.95	1.91	0.67	6.25
GS2-GS16	0.33	0.08	0.04	0.00	-0.01	-0.00	-0.01	0.08	2.50	0.65	1.68	0.44	5.79
GS17	NA	NA	NA	NA	0.04	0.00	0.16	0.49	3.13	1.23	2.31	0.96	NA
GS18	NA	NA	NA	NA	0.00	0.00	0.00	0.16	1.91	1.19	1.99	0.92	NA
X13	0.47	0.28	0.47	0.26	0.35	0.58	0.33	0.57	2.54	1.21	1.38	1.09	9.54
X13-(GS2+17+18)	0.77	0.51	0.87	0.49	0.67	1.10	0.62	0.96	2.70	1.38	0.86	1.40	12.32
X15	1.46	1.32	1.24	1.25	1.20	1.10	1.21	1.36	2.68	2.04	2.53	1.75	19.13
X15-(X14+X13)	0.51	0.08	-0.27	0.38	-0.20	0.14	0.25	0.06	1.02	1.15	1.62	0.62	5.35

[a]Negative flow values indicate the need to examine the design and operation of the gaging stations.
[b]NA - No data available.

ORNL-DWG 88-15280

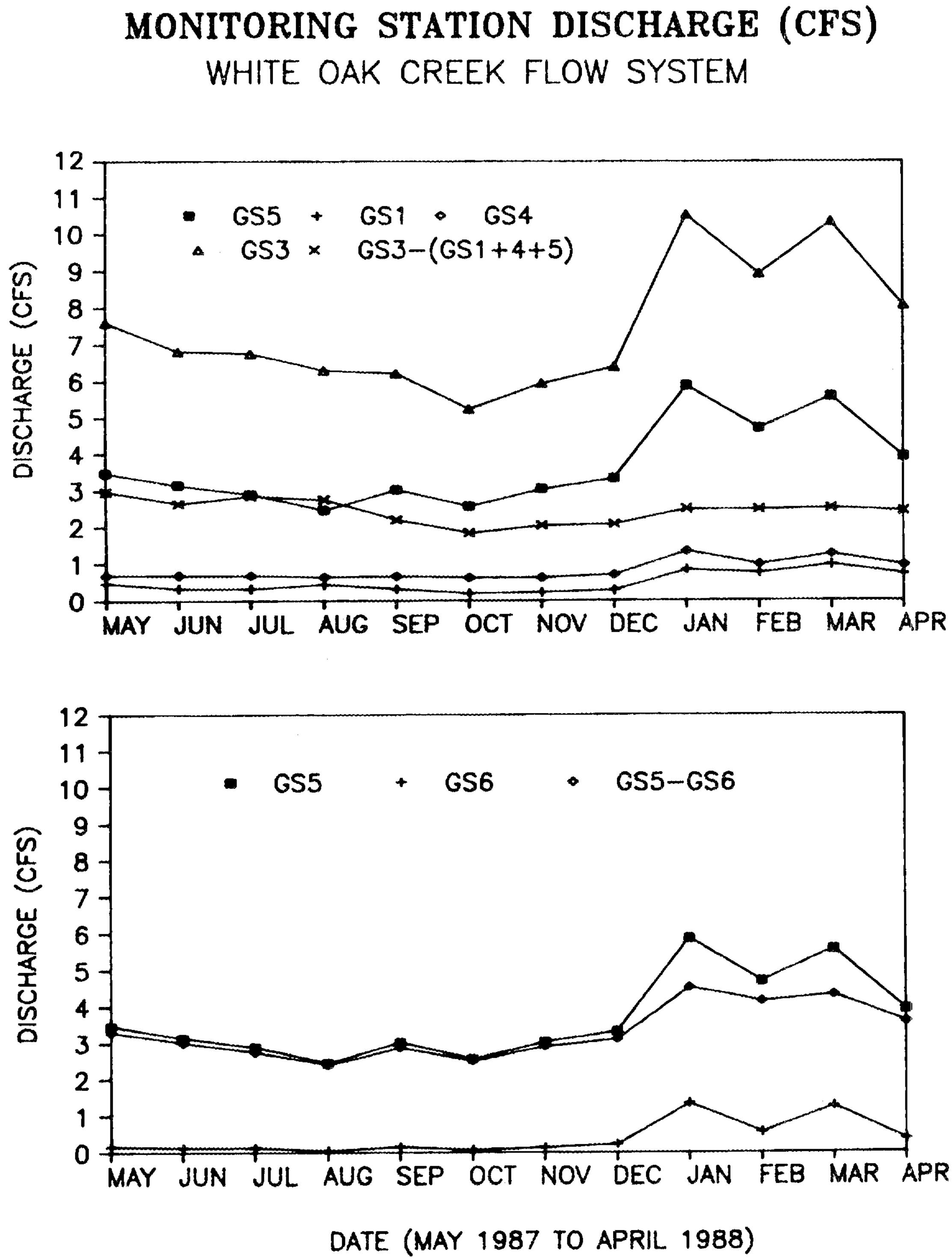


Fig. 9. Monthly mean discharge from USGS stations in vicinity of ORNL main plant area.

discharge at station GS3 on WOC downstream from the plant area, GS4 on the Northwest Tributary, GS1 on First Creek, GS5 on WOC below its junction with Fifth Creek, and the difference between flow at GS3 and the sum of the three upstream stations. This difference includes runoff from the contributing area, the upstream stations, and GS3 as well as 6 of the 10 major effluent discharges regulated under the ORNL NPDES permit (Table 9). Figure 9(b) shows monthly mean discharge at WOC station GS5 compared to discharge at station GS6, which is upstream of most plant activities. The differences in flow between these stations include the runoff from the contributing drainage area between the stations (including Fifth Creek) as well as the effluent discharge from the Oak Ridge Reactor (ORR) (Table 7) until November 1986 when the reactor was shut down and discharges ceased.

Flow in Melton Branch was augmented by effluent discharges of ≈ 7L/S (0.25 cfs) from the High Flux Isotope Reactor (HFIR) and ≈ 2.3 L/S (0.08 cfs) from the Transuranium Processing Facility (TRU) until November 1987. The HFIR was shut down at that time, and discharges were substantially reduced. Figure 10 shows monthly mean discharge in Melton Branch at station X13 near WOC, at station GS2 in upper Melton Branch, and at stations GS17 and GS18 in tributaries in the proposed SWSA 7 area that enters Melton Branch slightly downstream of GS2. The difference between flow at X13 and the sum of the upstream stations is shown beginning in November 1987 when data collection began at stations GS17 and GS18.

Figure 11(a) shows monthly mean discharge in WOC at GS3 to the south of Haw Ridge, at X14 upstream from the confluence with Melton Branch, and the difference between monthly discharge at the two stations. The fact that the comparison of discharge at the upstream and downstream stations shows negative flow for more than half of the year despite the 0.88 km^2 (0.34 $miles^2$) of contributing drainage area between the stations casts a strong suspicion about the accuracy of the flow measurements. Figure 11(b) shows monthly mean discharge at X14 on WOC, X13 on Melton Branch, X15 at WOD and the differences between the sum of flow at X14 and X13 and flow at the dam (X15). The occurrence of negative flows despite an appreciable contributing drainage area

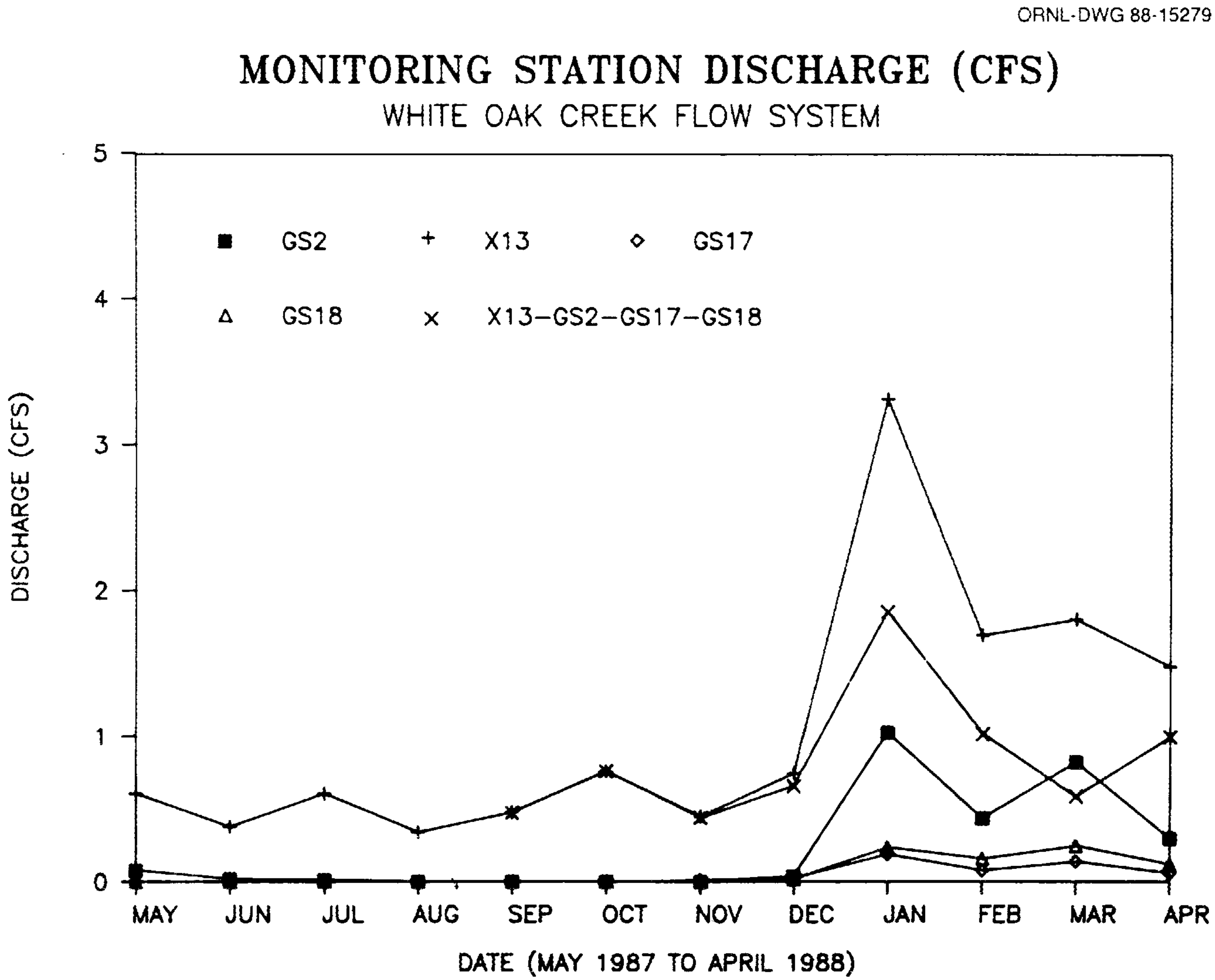


Fig. 10. Monthly mean discharge from monitoring stations in Melton Branch.

ORNL-DWG 88-15281

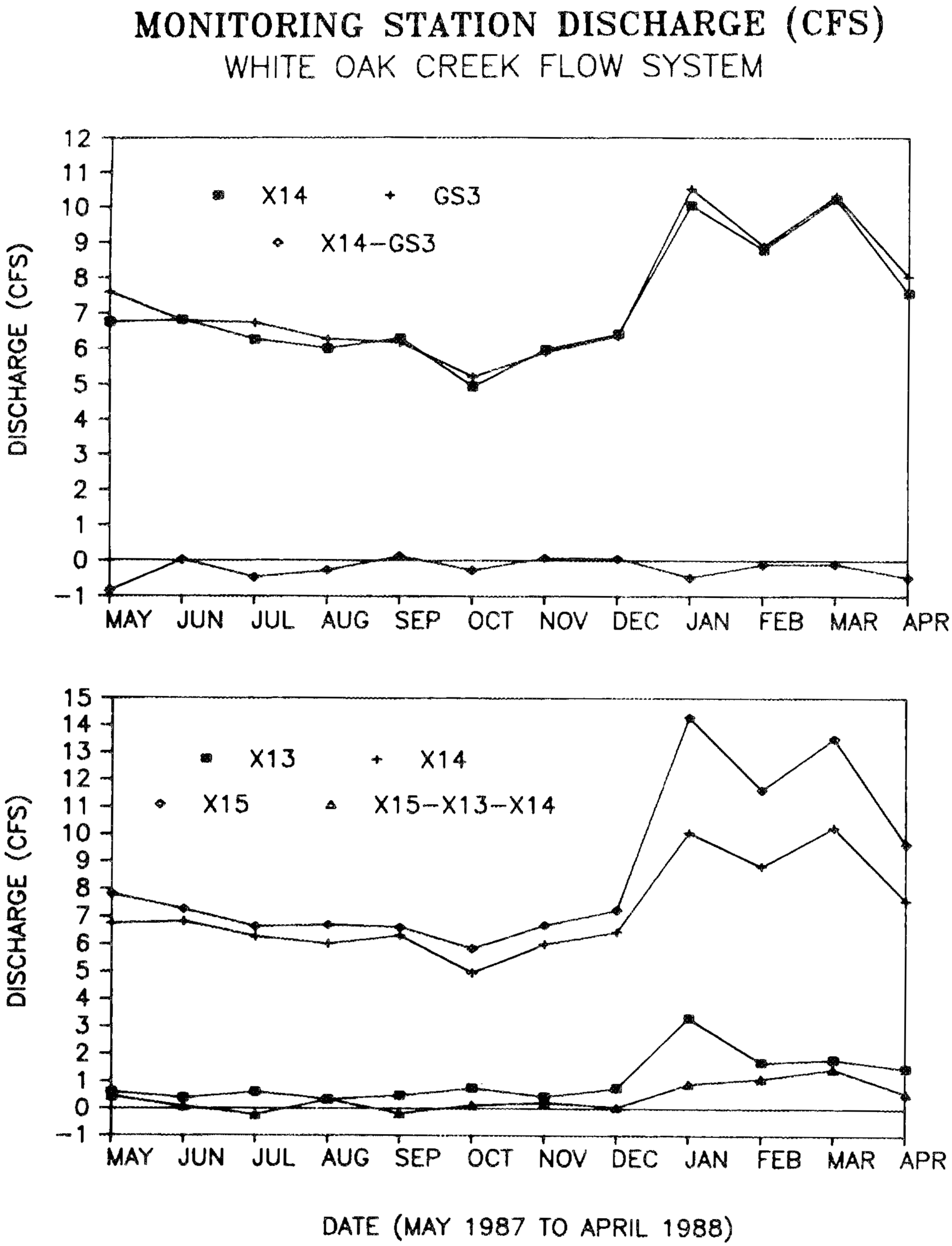


Fig. 11. Monthly mean discharge from monitoring stations located upstream and downstream of WOC station.

[2.69 km^2 (1.04 $miles^2$)] again indicates a need for examination of the design and operation of the gaging stations.

The negative differences at station X15 may be caused, in part, by high evaporation rates on WOL during hot, dry periods. Local inflows from ungaged areas around the lake are also negligible at these times. However, the major contributor to this error may be the result of streamflow monitoring problems that have been detected at upstream stations X13 and X14. Discharge at X13 on Melton Branch has been found to be substantially overestimated during high-flow events because of submergence of the flow structure. Overestimation of flows at X14 could also be a contributing factor. Silting problems at X14 and obstruction of the weir plates by aquatic plant life and debris at both stations can also cause errors in flow measurement.

The negative differences in discharge between station X14 and the upstream station GS3 partly result from conditions mentioned above. Obstruction of the stilling well intake line by silt causes a lag and attenuation in the rise of water levels inside the stilling well (where stage recording instruments are located) at X14. This results in lower flow rates and total volumes recorded for storm events. In addition, the flow structure at GS3 was inadequate to measure low flows with a high degree of accuracy until an upgrade that was completed in July 1988. This may have resulted in overestimation of flows at this site. These problems indicate the need for regular inspection and maintenance of the structures and equipment to ensure the quality of the data.

3.2.2 Surface Water Quality

Surface water quality is monitored by EHPD for both radiological and chemical constituents at several sites in the WOC flow system as part of the NPDES program. Additional water quality data have been collected at selected sites as part of the BMAP activities and other RAP studies. These in-stream sites are shown in Fig. 12.

Summaries of chemical and radiological data for the in-stream monitoring sites are reported in the EHPD environmental data reports (MMES 1987b-d, 1988a,b) issued quarterly. These data are also reported in the annual summary of environmental data for the Oak Ridge

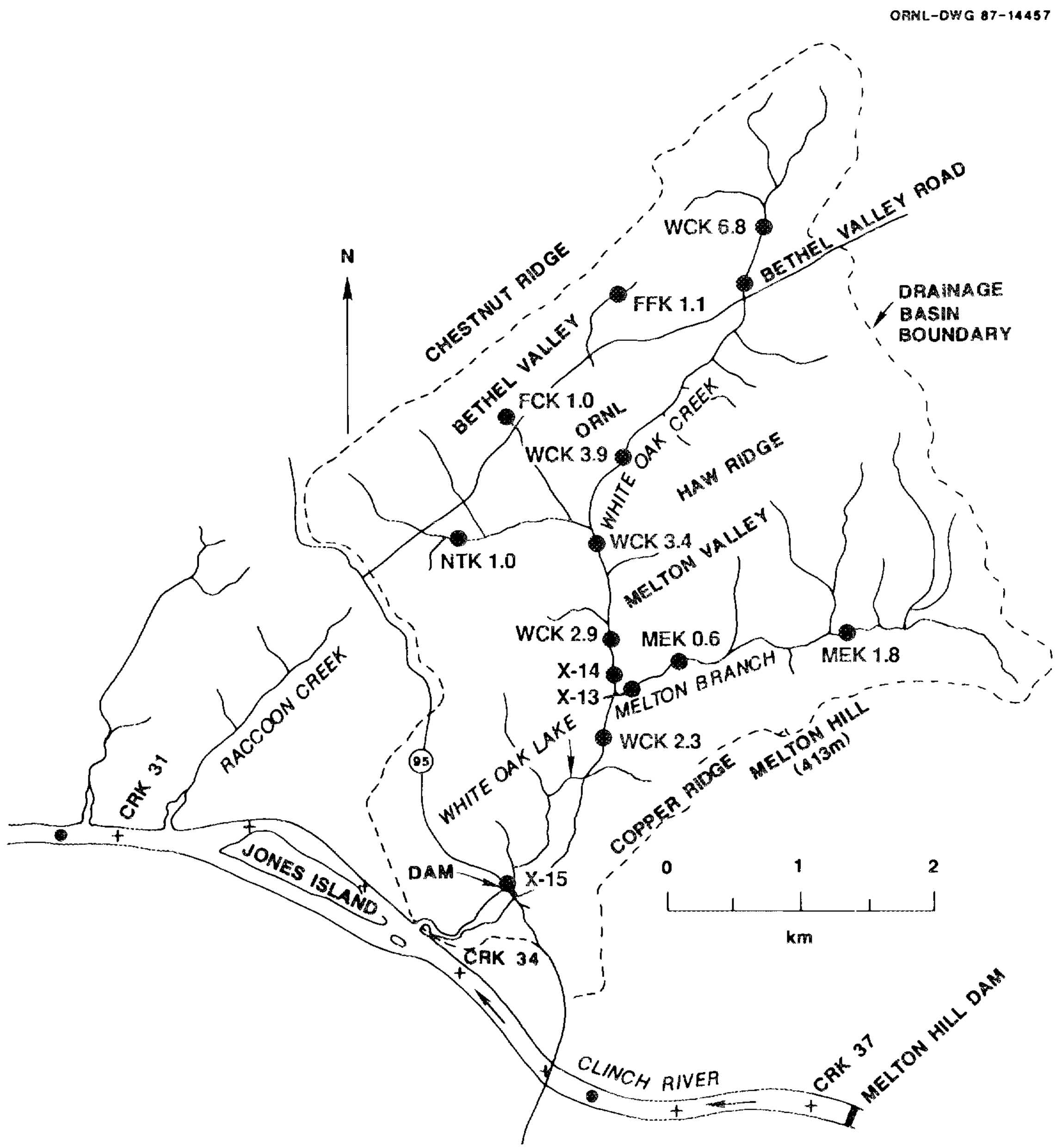


Fig. 12. Surface water quality monitoring or sampling sites in WOC and its tributaries.

Reservation (Environmental Safety and Health 1987). Additional analytical results for chemical and physical parameters at the EHPD sites and at a number of upstream reference sites are included in the BMAP annual report for 1987 (Loar et al. in press). Median concentrations of selected physical and chemical parameters in water samples from the three primary EHPD in-stream sites for the period May 1, 1987-April 30, 1988 are shown in Table 10. Tables 11 and 12 show the results of BMAP discrete water-quality sampling for chemical and physical parameters at ten sites in WOC and its tributaries during the same period.

Monthly discharge of selected radionuclides at the primary EHPD in-stream sites is calculated from flow and concentration values and presented in the quarterly environmental data reports. The discharge of ^{137}Cs, total radiological Sr, ^{60}Co, and ^{3}H at WOC (X14), Melton Branch (X13), and WOD (X15) for the period May 1987-April 1988 is shown in Figs. 13 and 14. The data in Fig. 14 show an apparent inconsistency during the winter months, where the discharge of tritium at the basin outlet is shown as only about one-half that of an upstream tributary (Melton Branch). These results suggest a problem with the procedure used for compositing flow-proportional samples from high, medium, and low ranges of flow rates. In addition, submerged flow conditions have been detected at the Melton Branch monitoring station during high-flow events (which occur primarily during the winter months). Channel constriction downstream of the flow structure causes a backwater effect resulting in higher water surface elevations for flows during these events. Because the instrumentation was designed and calibrated for assumed freeflow (unobstructed) conditions, flow rates are actually lower than recorded water surface elevations would indicate when submergence occurs. Because the volume of water is overestimated, the total mass of constituents (e.g., ^{137}CS, ^{90}Sr, ^{60}Co, and tritium) is also overestimated. Steps are being taken to resolve this matter at present.

Racoon Creek receives groundwater discharge from the western portion of SWSA 3. All other drainage from SWSA 3 is eastward into the WOC watershed. The monitoring station was established to complete the Stream Sampling Network necessary to determine the extent of

Table 10. Median concentrations (range in parentheses) of 34 water-quality parameters routinely monitored below ORNL at NPDES sites X13 (Melton Branch), X14 (WOC), and X15 (WOD), May 1987 - April 1988[a]

Parameter	Melton Branch		WOC		
	Above ORNL[b]	X13	Above ORNL[b]	X14	X15
Organics, µg/L					
Bromodichloromethane	ND	<5(all <5)	ND	<5(all <5)	<5(all <5)
Chloroform	ND	<5(all <5)	ND	<5(<5-62)	<5(all <5)
PCBs	<0.5(all <0.5)	<0.5(all <0.5)	<0.5(all <0.5)	<0.5(all <0.5)	<0.5(<0.5-0.5)
Phenols	ND	<1(<1-3)	ND	<1(<1-3)	<1[c]
Trichloroethene	ND	<5(all <5)	ND	<5(all <5)	<5(all <5)
Metals, µg/L					
Aluminum	39[c]	275(120-1300)	ND	<150(<120-1300)	485(210-4700)
Arsenic	ND	<60(<18-<60)	ND	<60(<18-<60)	<60(<18-<60)
Cadmium	0.05(0.01-0.59)	<2(all <2)	0.08(0.01-0.45)	<2(all <2)	<2(<2-3)
Chromium	0.41(0.17-1.5)	<24(<3.6-48)	0.39(0.05-1.5)	<24(<3.6-480)	<24(<3.6-93)
Copper	0.82(0.30-2.1)	<12(<6-17)	0.56(0.24-5.9)	<12(<6-15)	<12(<6-30)
Iron	97(47-578)	200(160-1100)	41(22-285)	185(61-1900)	690(290-4300)
Lead	0.70(0.2-5.7)	<4(all <4)	0.72(0.1-4.0)	<4(<4-12)	<4(<4-19)
Manganese	12[c]	98(43-200)	ND	33.5(15-120)	91.5(38-260)
Mercury	0.003(<0.001-1.19)	<0.05(all <0.05)	0.002(<0.001-0.36)	0.09(<0.05-0.11)	<0.05(<0.05-0.10)
Nickel	3.1(0.1-16)	<36(<3.6-3.9)	1.3(0.1-15)	<36(<3.6-170)	<36(<3.6-4.5)
Silver	ND	<5(all <5)	ND	<5(all <5)	<5(<2-<5)
Zinc	0.52(0.19-56)	16(<1.8-99)	1.1(0.25-36)	37.5(22-76)	23(12-100)

Table 10. (continued)

Parameter	Melton Branch		WOC		
	Above ORNL[b]	X13	Above ORNL[b]	X14	X15
<u>Other parameters, mg/L</u>					
Ammonia nitrogen	<0.2(all <0.2)	0.09(0.04-7.16)	<0.2(all <0.2)	0.09(0.05-2.91)	0.105(0.07-0.296)
BOD, 5-d	<5(all <5)	<5(<5-7)	<5(all <5)	<5(all <5)	<5(<5-9)
Chlorine, total residual[d]	0[e]	<0.01(<0.01-0.03)	0[e]	<0.01(<0.01-0.12)	<0.01(<0.01-0.10)
Conductivity (mS/cm)[f]	231(118-262)[g]	320(250-390)	ND	350(300-420)	335(0.7-400)
Dissolved oxygen[d]	ND	8.05(4.0-14.0)	ND	7.85(4.0-24.0)	7.95(0.0-12.0)
Dissolved solids[f]	158(118-266)	230(178-2074)	95(68-239)	239(190-545)	240(136-373)
Fluoride	0.1(0.0-0.2)[g]	1.0(<1.0-1.1)	ND	1.0(1.0-1.2)	1.0(1.0-1.1)
Nitrate	0.04(<0.005-1.10)	<5(all <5)	0.31(0.08-1.90)	<5(all <5)	<5(all <5)
Oil and grease[d]	<2(all <2)	<2(<2-15)	<2(all <2)	<2(<2-5)	<2(<2-26)
Organic carbon, total	ND	2.3(1.9-5.2)	ND	2.01(1.7-2.6)	3.1(2.2-6.3)
pH[f]	7.9(7.5-8.1)[g]	8.0(6.3-8.5)	ND	8.0(6.5-9.0)	8.0(6.4-8.5)
Phosphorus	0.012(0.003-0.152)	0.45(<0.1-1.7)	0.012(0.002-0.124)	0.3(0.1-0.42)	0.2(0.1-0.43)
Sulfate	12.1(6.8-16.4)	28.5(24-40)	2.93(0.26-4.76)	48.5(36-63)	43.5(28-49)
Suspended solids	8(<5-159)	5(<5-13)	<5(<5-30)	<5(<5-15)	26.5(5-94)
Temperature(°C)[f]	ND	11.65(1.6-24.0)	h	17.45(8.3-29.0)	11.9(1.6-28.0)
Turbidity (NTU)[f]	6.4(2.5-32)	15(0-35)	3.7(1.4-30)	69(0-165)	30(0-200)

[a]Analyses were based on 24-h composite samples collected monthly unless noted otherwise. ND = data not available.

[b]Values represent the median concentration (range in parentheses) of grab samples collected weekly between April 1979 and January 1980 in upper Melton Branch near MEK 1.8 and in upper WOC near WCK 6.3 (Boyle et al. 1982, Sect. 3.2.3.2 and Tables 4.15 and 4.16; ORNL Department of Environmental Monitoring and Compliance, unpublished data).

[c]N = 1; values for aluminum and manganese were obtained from McMaster (1967), Table 12.

[d]Grab sample collected weekly.

[e]Loar et al. (1987), Fig. 3-6.

[f]Grab sample collected monthly.

[g]Values represent the median concentration (range in parentheses) of six samples collected in 1961-1964 from upper WOC near WCK 6.8 (McMaster 1967, Table 11).

[h]See Loar et al. (in press), Table 2-6.

<u>Source</u>: RAP Data Managment and Information System (unpublished data). Data collected by ORNL Department of Environmental Monitoring and Compliance.

Table 11. Water quality parameters (means) determined from monthly water samples collected at 10 sampling stations in WOC watershed from May 1987-April 1988.

	Sampling station[a]									
Analysis	FCK1.0	FFK1.1	MEK0.6	MEK1.8	NTK1.0	WCK2.3	WCK2.9	WCK3.4	WCK3.9	WCK6.8
Alkalinity	2.94	2.80	2.55	2.23	3.67	2.30	2.27	2.25	2.23	2.57
Conductivity (μmhos/cm)	256.42	249.08	338.83	287.14	421.50	370.25	374.25	358.33	299.25	245.17
Hardness (mg/L as $CaCO_3$)	150.33	142.50	167.67	139.43	221.67	165.83	162.17	157.50	149.33	141.50
NH_4^+ (μg N/L)	7.84	4.88	10.80	10.85	11.03	65.73	14.40	16.83	23.48	9.10
NO_2 + NO_3 (mg N/L)	0.11	0.15	0.49	0.20	0.03	0.85	1.33	1.36	0.36	0.15
Total suspended solids (μg/L)	2.34	0.75	7.37	2.53	7.44	3.63	2.74	2.99	2.20	3.51
pH	8.01	7.81	8.07	7.93	8.00	8.03	8.04	8.03	8.07	8.05
Soluble reactive P (μg P/L)	6.72	6.10	546.31	276.77	2.07	204.74	195.80	183.20	66.19	2.47
TOC (mg/L)	1.03	0.81	2.47	2.24	1.91	2.02	1.92	1.99	2.26	1.21
Total P (μg P/L)	12.60	13.26	1160.83	918.37	23.37	459.56	450.94	482.37	339.88	10.17
Tot. soluble phosphorus (μg P/L)	11.32	10.34	1049.22	867.62	10.00	381.76	381.80	390.01	298.01	5.13
Temperature (°C)	13.38	13.62	12.08	10.00	11.88	15.37	16.56	17.38	18.67	11.27

[a]See Fig. 12 for location of sampling stations.

Table 12. Mean concentrations (mg/l) of dissolved elements at 10 sampling stations in WOC watershed based on ICP analyses of discrete water samples collected in July and October 1987 and February 1988[a]

	Sampling station[b]									
Analysis	FCK1.0	FFK1.1	MEK0.6	MEK1.8	NTK1.0	WCK2.3	WCK2.9	WCK3.4	WCK3.9	WCK6.8
Ca	33.3	31.3	50.5	44.25	70.67	52.6	54.0	49.2	53.0	32.0
Cu	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Cr	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Cd	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Fe	0.027	0.027	0.065	0.036	0.030	0.030	0.030	0.029	0.030	0.038
Mg	11.7	13.3	12.0	8.6	8.1	10.48	13.0	10.18	14.0	13.14
Mn	0.009	0.005	0.065	0.022	0.017	0.033	0.016	0.023	0.019	0.023
Na	0.59	0.89	6.81	4.5	7.73	15.8	22.0	14.72	17.0	0.812
Pb	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Si	3.27	2.93	3.53	3.13	2.53	2.4	3.3	2.14	3.2	3.58
Zn	0.016	0.015	0.057	0.043	0.034	0.028	<0.02	0.037	0.036	0.022

[a]Values below the limit of detection were used at detection limit concentration to calculate a mean.

[b]See Fig. 12 for locations of sampling stations.

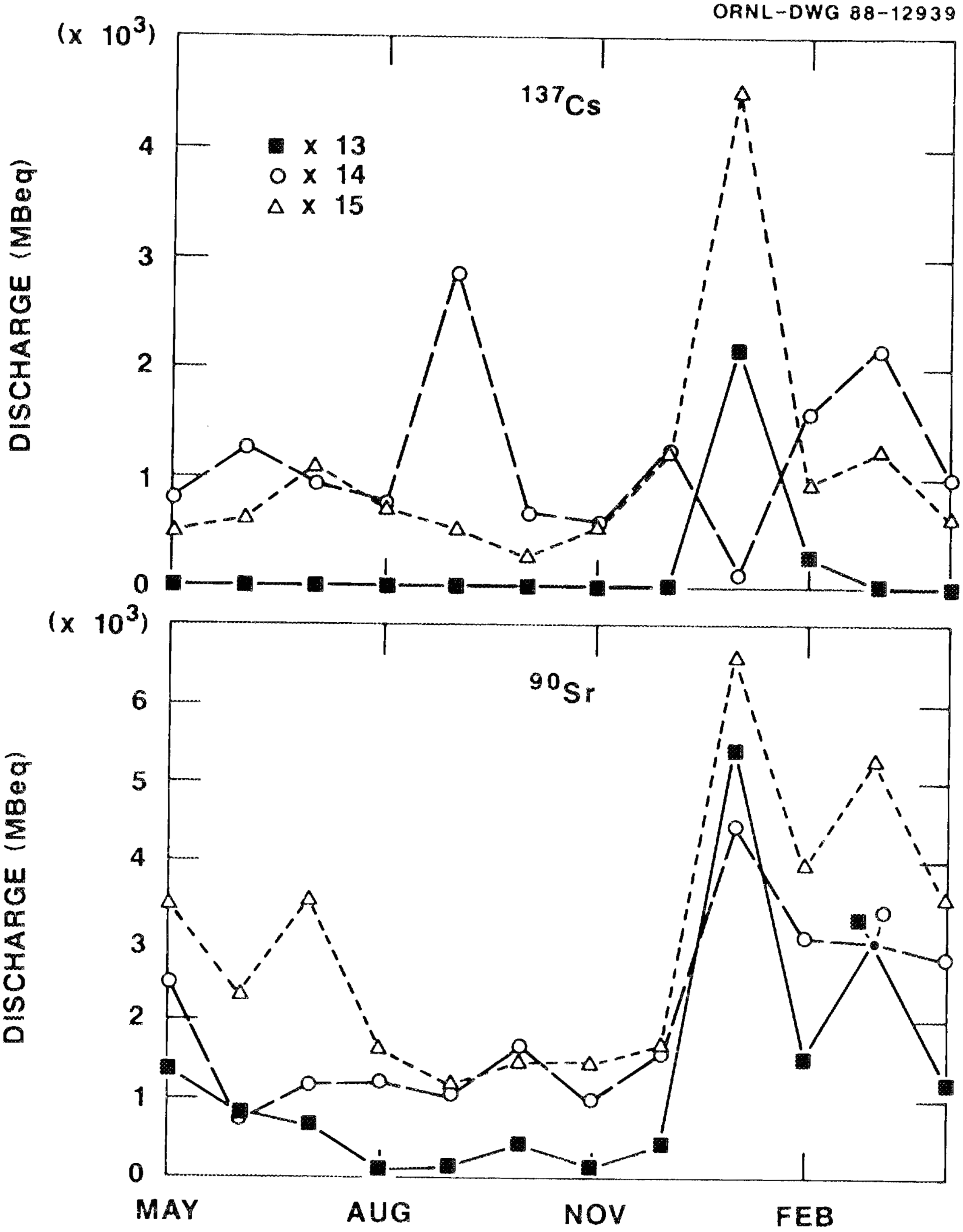


Fig. 13. Distribution of ^{137}Cs and ^{90}Sr at primary EMC in-stream sites for May 1987 to April 1988.

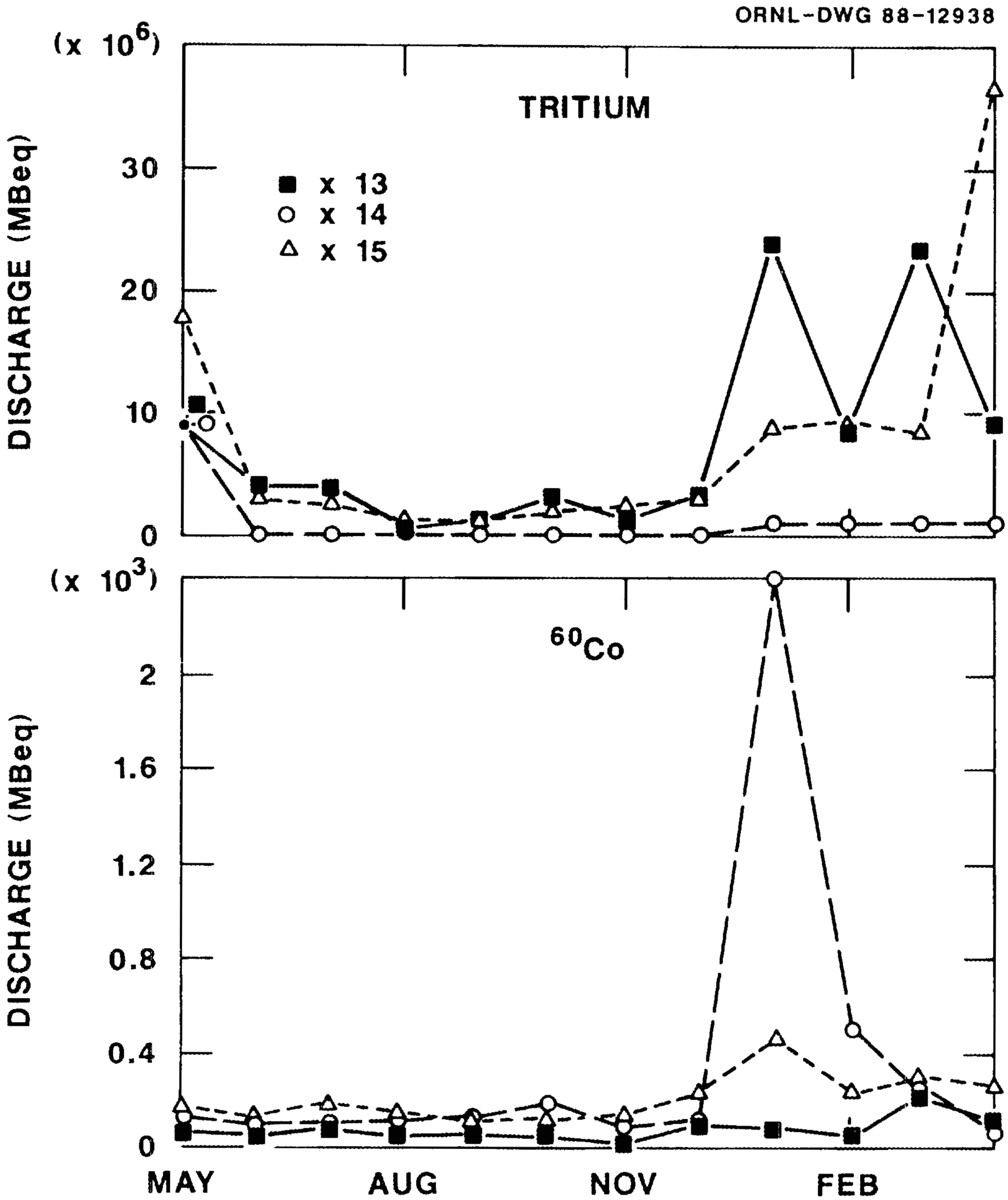


Fig. 14. Distribution of tritium and ^{60}Co at the primary EMC instream sites for May 1987 to April 1988.

radionuclide migration from ORNL's SWSAs; however, the station is not currently in operation. Some evidence of contaminants has been detected in EHPD's water-quality grab samples collected at this site.

3.2.3 Outfalls to the WOC Flow System

Water is supplied to the ORNL plant site from the DOE water treatment plant at an average rate of ≈ 4.0 million gallons per day (mgd) (6.19 cfs). This water is then distributed to ORNL facilities through two separate systems: potable and process (Fig. 3). Of the total amount of imported water, 38% [1.53 mgd (2.37 cfs)] is lost to the atmosphere as evaporation. The remaining 62% [2.47 mgd (3.82 cfs)] is subsequently discharged to the WOC surface water system (Kasten 1986). These discharges are categorized under the ORNL NPDES permit that was issued April 1, 1986.

NPDES Permit No. TN0002941 was issued to ORNL to monitor point sources at their point of discharge into receiving streams. Point source outfalls are discernible, confined, and discrete conveyances from which a process stream is discharged to receiving waters. The effluent must be monitored before it reaches the receiving water or mixes with any other wastewater stream. The permit identifies at least 176 stations; however, 10 major effluent discharges (Point Source Outfalls) regulated under the permit (Fig. 15) account for ≈ 83% of the water discharged to the WOC system. Table 13 identifies these outfalls and their average discharges into receiving streams. One additional point source outfall described under the NPDES permit is the planned Nonradiological Wastewater Treatment Facility (NRWTF), NPDES outfall No. X12. The expected average daily discharge from the facility is 500,000 mgd (0.77 cfs). Compliance level is expected to be attained by March 1990.

Additional outfalls to WOC are divided into categories according to effluent limitations and monitoring requirements. The following paragraphs describe each category and type of outfall.

ORNL-DWG 88-1516

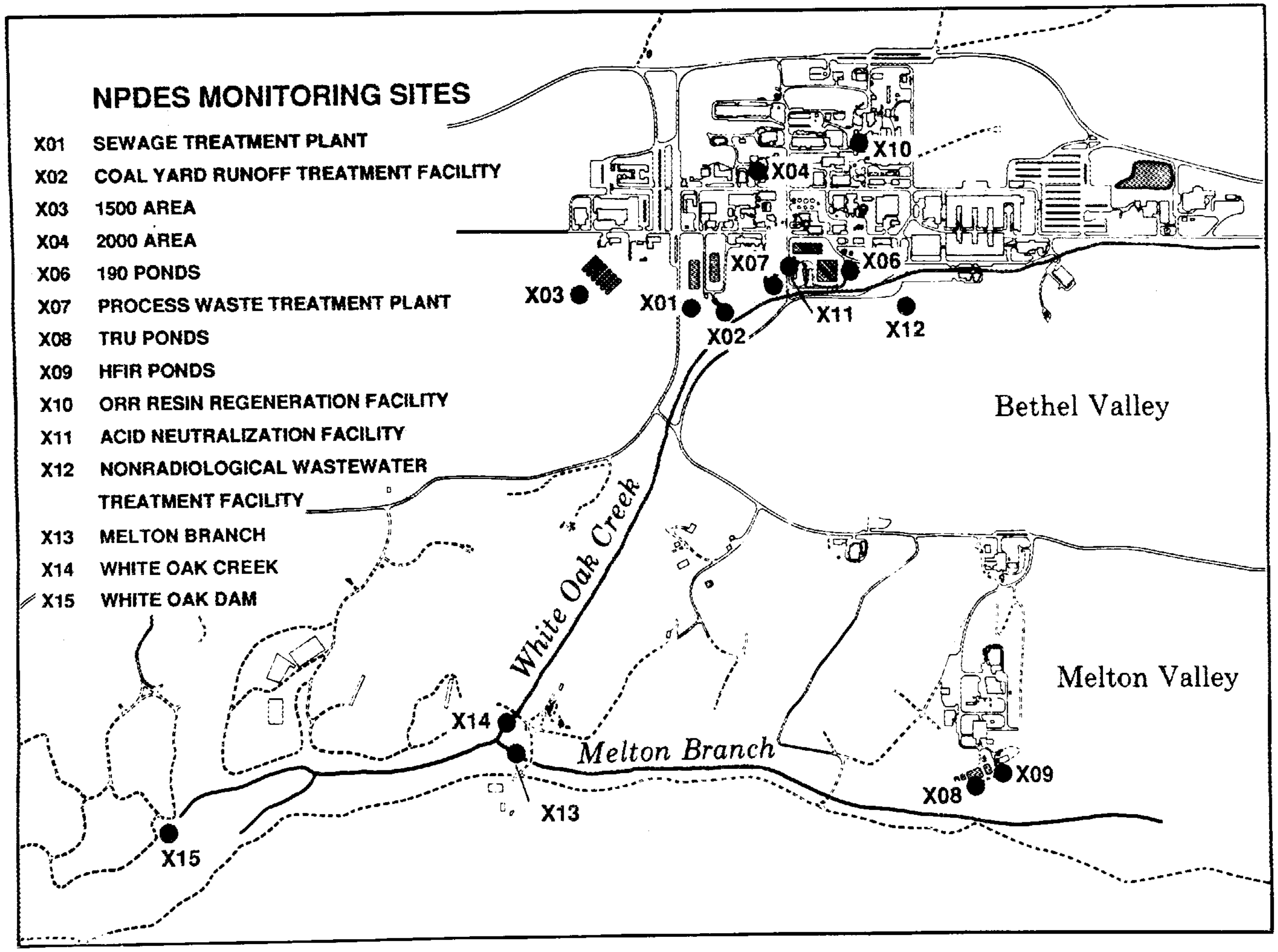


Fig. 15. Location of monitoring sites for the NDPES permit.

Table 13. Description of the ten major effluent discharges regulated under the ORNL NPDES permit issued April 1, 1986[a]

Receiving stream	Source of effluent discharge	NPDES outfall No.[a]	Average flow rate[b] [L/s (cfs)]
Fifth Creek	ORR[c] resin regeneration facility	X10	0.4(0.01)[d]
Melton Branch	TRU[c] process waste basins	X08	2.2(0.08)[d]
	HFIR[c] process waste basins	X09	7.0(0.25)[d]
Northwest Tributary	1500 area	X03	0.3(0.01)
WOC	Sewage Treatment Plant	X01	10.1(0.36)[e]
	Coal Year Runoff Treatment Facility	X02	1.0(0.04)[e]
	2000 area	X04	0.6(0.02)
	3539 and 3540 ponds	X06	5.9(0.21)[d]
	3544 Process Waste Treatment Plant	X07	7.9(0.28)[e]
	3518 Acid Neutralization Facility	X11	1.8(0.06)[d]

[a]No outfall X05 exists; outfall X12 is the planned discharge from the NRWTFscheduled for completion in 1989 with a March 1990 date for compliance and an estimated average flow rate of 22 L/s (0.8 cfs).

[b]For batch operations, average flow rate is based on days when waste is discharged.

[c]ORR = Oak Ridge Reactor; TRU = Transuranium Processing Facility; HFIR = High Flux Isotope Reactor.

[d]Batch discharge with frequencies of once every 5 d (X08), three times per month (X09), once every 5 to 8 d (X10), and 3 batches per d (X11); discharge X06 is batch if radioactivity is below predetermined levels.

[e]Maximum flow rates are 32.9 L/s (1.16 cfs) at X01, 9.6 L/s (0.34 cfs) at X02, and 18.8 L/s (0.67 cfs) at X07.

Source: EPA (1986).

<u>Category I Outfalls</u> - Storm Drains

These storm drains are uncontaminated by any industrial or commercial activity and do not discharge through any oil/water separator or other treatment facility. Each of the Category I outfalls (Table 14) are sampled annually to verify releases of pollutants to the environment. Limits have been placed on the following parameters: pH, temperature, oil and grease, and total suspended solids.

<u>Category II Outfalls</u> - Roof Drains, Parking Lot Drains, Storage Area Drains, Spill Area Drains, Once-Through Cooling Water, Cooling Tower Blowdown, and Condensate.

A Best Management Plan (BMP) is imposed on the discharges from Category II type outfalls (Table 15) contaminated by an industrial or commercial activity and not discharged through any oil/water separator or treatment equipment or facility. Category II outfalls are sampled quarterly to verify minimal releases of pollutants to the environment. Limits have been placed on the following parameters: pH, temperature, oil and grease, and total suspended solids.

<u>Category III Outfalls</u> - Process and/or Lab Drains

There can be no discharge of process wastewaters to the waters of WOC, Fifth Creek, Melton Branch, and Melton Hill Lake that may have an adverse impact on human health or to the environment according to guidelines in the NPDES permit. This condition applies to Category III outfalls (Table 16). Category III outfalls are sampled quarterly to verify minimal releases of pollutants to the environment. These outfalls are actually either Category I or Category II outfalls, but because of inflow and infiltration, cross-connects, or improper disposal of chemicals, have become contaminated with pollutants. The only limitation placed on these outfalls under the NPDES permit is pH levels.

<u>Miscellaneous Source Discharges</u>

These discharges have not been identified in the NPDES permit as a serial-numbered discharge. Each is specific to a special category identified by the EPA. Limitations have been placed on all

Table 14. Summary of Category I outfalls

Location	Total
WOC	16
First Creek	4
Fifth Creek	13
Melton Branch	1
	34

Table 15. Summary of Category II outfalls

Location	Subtotal	Total
WOC		34
Parking lot runoff	27	
Condensate	4	
Cooling tower blowdown	2	
Spill area drain	1	
First Creek		10
Parking lot runoff	8	
Storage area drain	2	
Melton Branch		4
Parking lot runoff	3	
Cooling tower blowdown	1	
Fifth Creek		13
Parking lot runoff	6	
Condensate	4	
Cooling tower blowdown	3	
		61

Table 16. Summary of Category III outfalls

Location/type	Total
WOC: process drains	14
First Creek: process drains	4
Melton Branch: settling ponds	6
Fifth Creek: process drains	8
	32

miscellaneous source outfalls. The following facilities have been placed in those categories:

1. 26 cooling towers;
2. 1 boiler (Bldg. 2519, Central Steam Plant);
3. 1 vehicle and equipment cleaning facility (Bldg. 7002);
4. 1 painting and corrosion control facility (Bldg. 7007);
5. 1 vehicle and equipment maintenance facility (Bldg. 7002);
6. 4 photographic laboratories (Bldg. 1500, 4500N, 7934, 7601); and
7. 1 firefighter training area (outside Bldg. 2500).

3.2.4 Contaminants in Sediments

Studies of WOC streambed gravels as indicators of the degree and location of sources of radiological contaminants (Cerling 1985; Cerling and Spalding 1981; Cerling and Spalding 1982) were continued during 1986-1987. A report by Cerling et al. (in press) documents the results of studies of new sources of ^{90}Sr and ^{137}Cs in First Creek and upper WOC behind the ORNL main plant. Reports have also been completed on current studies to quantify radionuclide flux at selected sites based on radionuclide and metal concentrations on gravels and the associated streamflows and to determine the mechanisms and rates of radionuclide and metal sorption and desorption on streambed gravels.

An aerial radiological survey was conducted during October 1986 to provide detailed information on the nature and location of radiological contaminants in floodplain sediments. The study report by EG&G Energy Measurements (Fritzsche 1987) describes the survey methodology and shows detailed contours on total radiological exposure, ^{137}Cs, ^{60}Co, and ^{208}Th on aerial photographs of the floodplain.

3.3 Groundwater

The characterization of groundwater occurrence, movement, and quality at ORNL has been the subject of many environmental studies in the past, and it is a major element in the RAP. Because of the complex nature of the ORNL operations, the subsurface materials, and the contaminants entering the groundwater flow system, large numbers of wells have been drilled during pre-RAP studies and in the RAP. Over

1300 wells have been drilled in the vicinity of ORNL during its 40-year history.

Information on most of these wells is included in the RAP data and information management system (Voorhees et al. 1988). However, because these wells were drilled at different times and for different purposes, there is considerable variation in the parameters recorded during construction and data collection activities. As seen in Fig. 16, which shows most of the wells, there is a fairly broad coverage of the ORNL area. As shown in Fig. 17 most of the remaining pre-RAP wells are located in the SWSAs and the pits and trenches areas.

The first comprehensive groundwater characterization study for the entire ORNL complex was initiated in FY 1986 as part of the Environmental Restoration and Facilities Upgrade (ERFU) Program. The focus of this study was to determine the potential for contaminant transport by groundwater within the WAG boundaries. The study included a major drilling program, monitoring and testing of observation wells, collection and analyses of water samples, implementation of a digital data management system, and interpretative reports on the massive amounts of data collected. By the end of FY 1987, more than 330 shallow piezometers, 31 hydrostatic head wells, 77 water-quality wells, 13 remedial action test area (TARA) wells, and 10 core holes had been completed. Water level data were being collected in more than 460 wells (continuous record in 82 wells) and periodic measurements in 380 wells. Slug tests for hydraulic conductivity had been conducted on more than 400 wells and water samples analyzed from more than 75 wells in the WAG areas.

The piezometer well sites (Fig. 18) were selected to provide a basic groundwater data collection network in all of the WAGs in conjunction with the existing pre-RAP wells. Most of the piezometers were drilled to the shallowest water-bearing zone. However, some wells were drilled to deeper zones to determine the potentiometric head and aquifer characteristics at those levels. At some sites, pairs of wells were installed for these purposes.

The hydrostatic head monitoring stations (HHMS) were drilled in SWSA 6 Pits and Trenches Area, and one cluster was drilled north of WOL

ORNL-DWG 88-1630

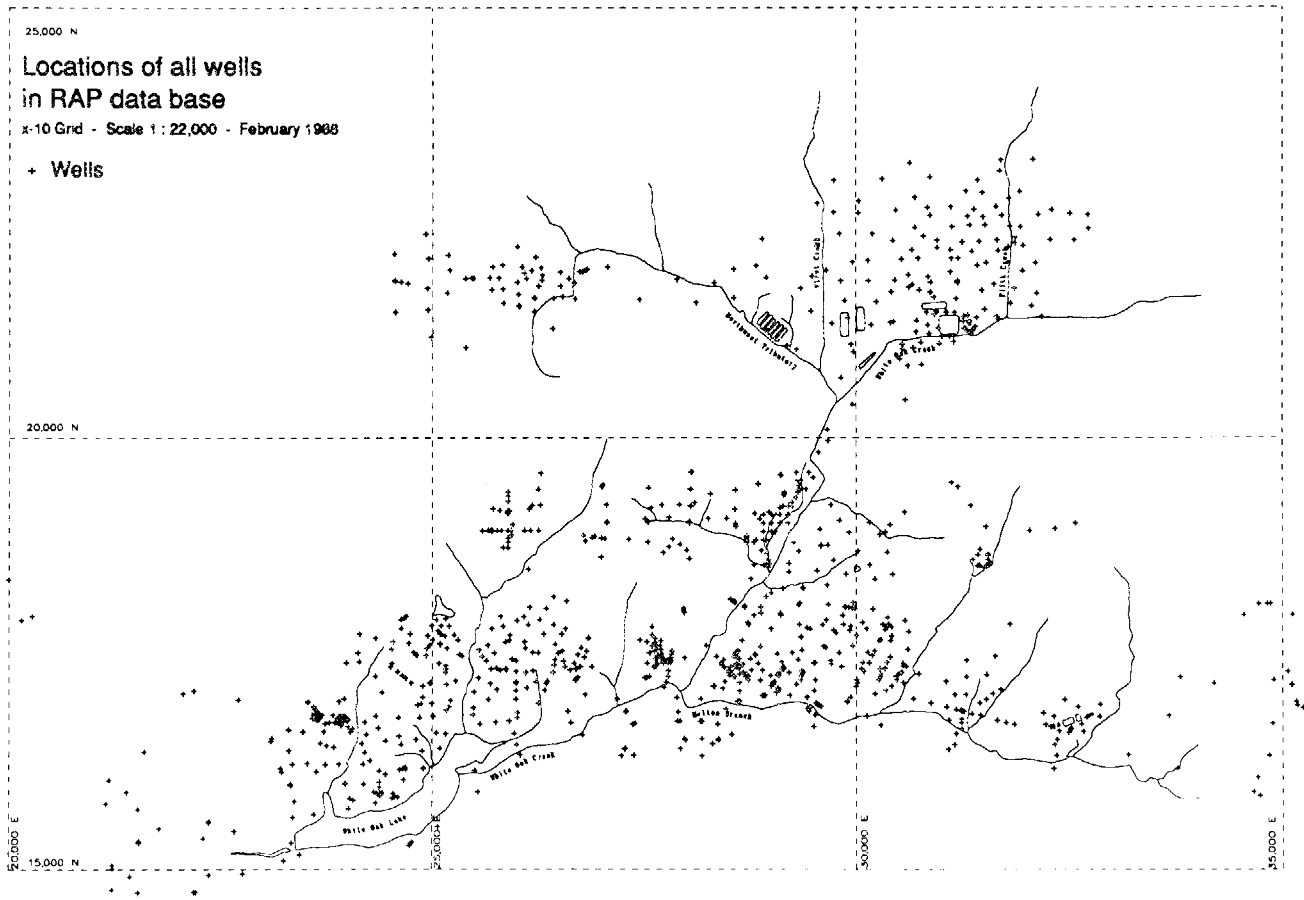


Fig. 16. Location of all wells installed as part of the Remedial Action Program.

ORNL-DWG 88-1631

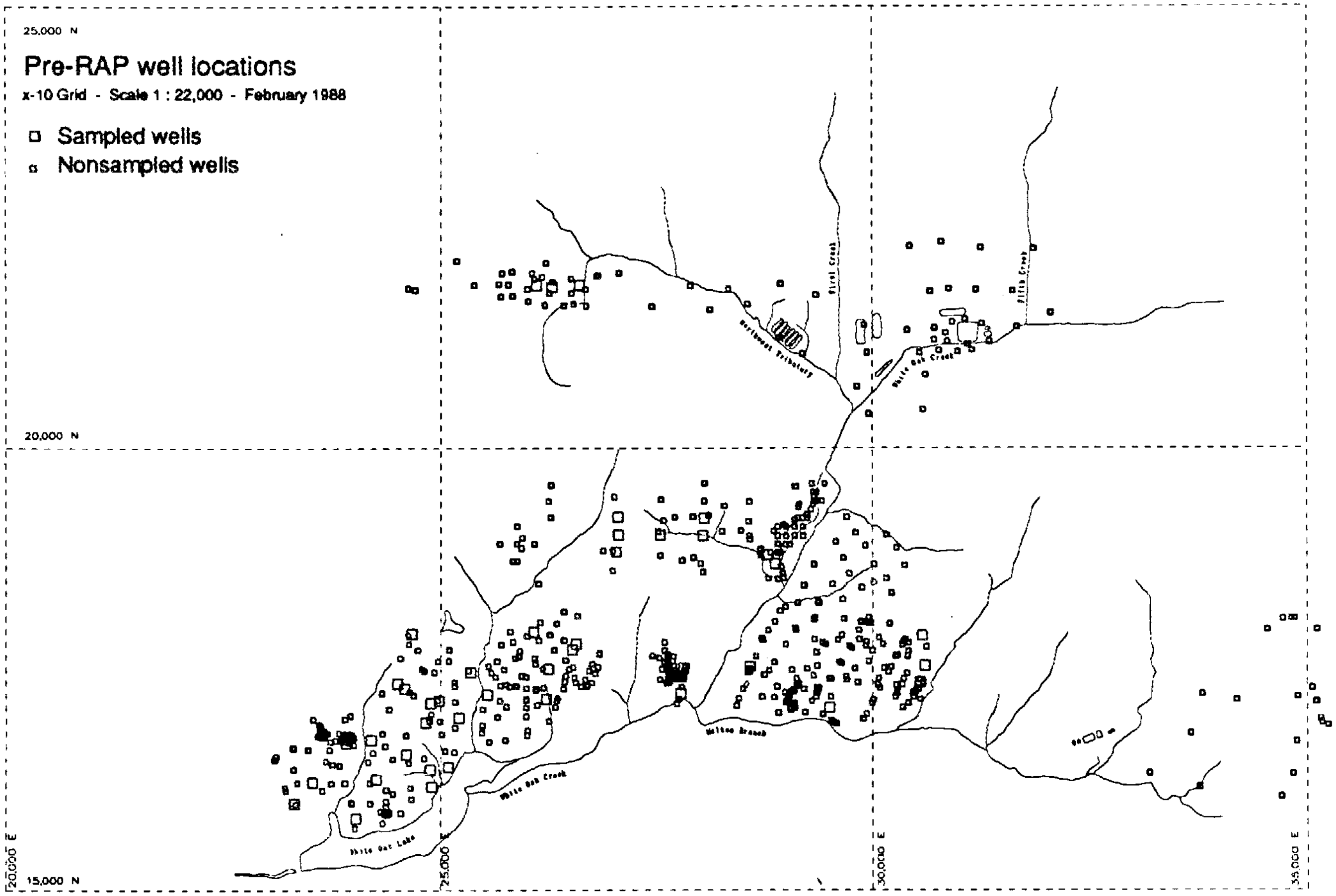


Fig. 17. Location of wells installed before the establishment of the Remedial Action Program.

ORNL-DWG 88-1632

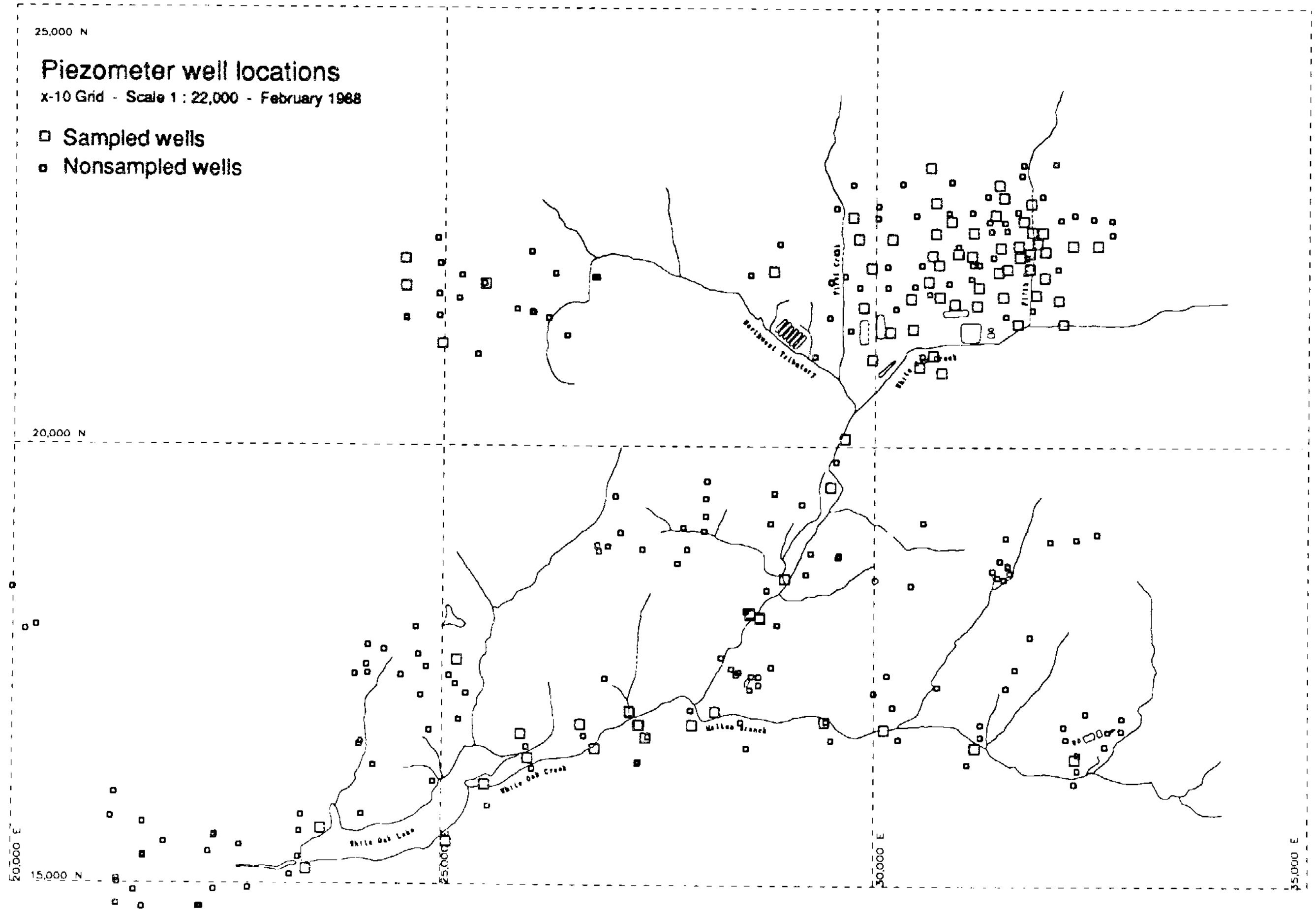


Fig. 18. Location of piezometer wells installed by the Remedial Action Program.

(Fig. 19) as part of a RAP study to characterize the vertical and lateral distribution of potentiometer head, geology, and water quality in the vicinity of the waste management areas. Each HHMS consists of a cluster of 3 wells drilled to depths of ≈ 24.4, 60.96, and 121.9 m (80, 200, and 400 ft), respectively. The data collected at these sites will aid in characterizing and modeling the deeper flow systems.

Eight-three water-quality wells have been installed in accordance with the Environmental Protection Agency (EPA) regulations and the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA). The EPA wells were installed at the perimeter of WAGs 1 and 6, within WAG 6, and around wastewater impoundments adjacent to three impoundment areas, the 3524, 3539-3540, and 7900 ponds (Fig. 20). New water-quality wells are sampled quarterly for water quality analysis by the EMC Department for 1 year. Sampling intervals are then determined based on analysis of the quarterly data. The older wells around wastewater impoundments are being sampled semiannually at the present time. A total of 72 water-quality wells are being developed as part of a network of > 250 wells to be installed in and around the WAGs, excluding 22 wells to be installed around the impoundments.

The CERCLA wells were installed during the pre-RAP study and are located adjacent to three impoundments - the 3513 pond, the Old Hydrofracture Facility (OHF) pond, and the Homogeneous Reactor Experiment (HRE) pond (Fig. 21) to characterize the quality of groundwater upgrade and downgrade from the ponds.

Figure 16 also shows the location of 13 wells installed in the TARA in SWSA 6 for use in demonstrations of trench closure alternatives such as the In-Situ Verification (ISV) and Shallow Land Burial (SLB) closures. ISV is a technique for immobilization and closure of waste trenches by the use of high temperatures to vitrify the buried material. A field demonstration conducted by Spalding and Jacobs produced a 20-ton mass of vitrified material in a 3/8-scale-model of a seepage trench containing stable strontium (Sr) and cesium (Cs). The trench was constructed to simulate a typical seepage trench used for liquid low-level radioactive waste disposal at ORNL from 1951 to 1966. Data were

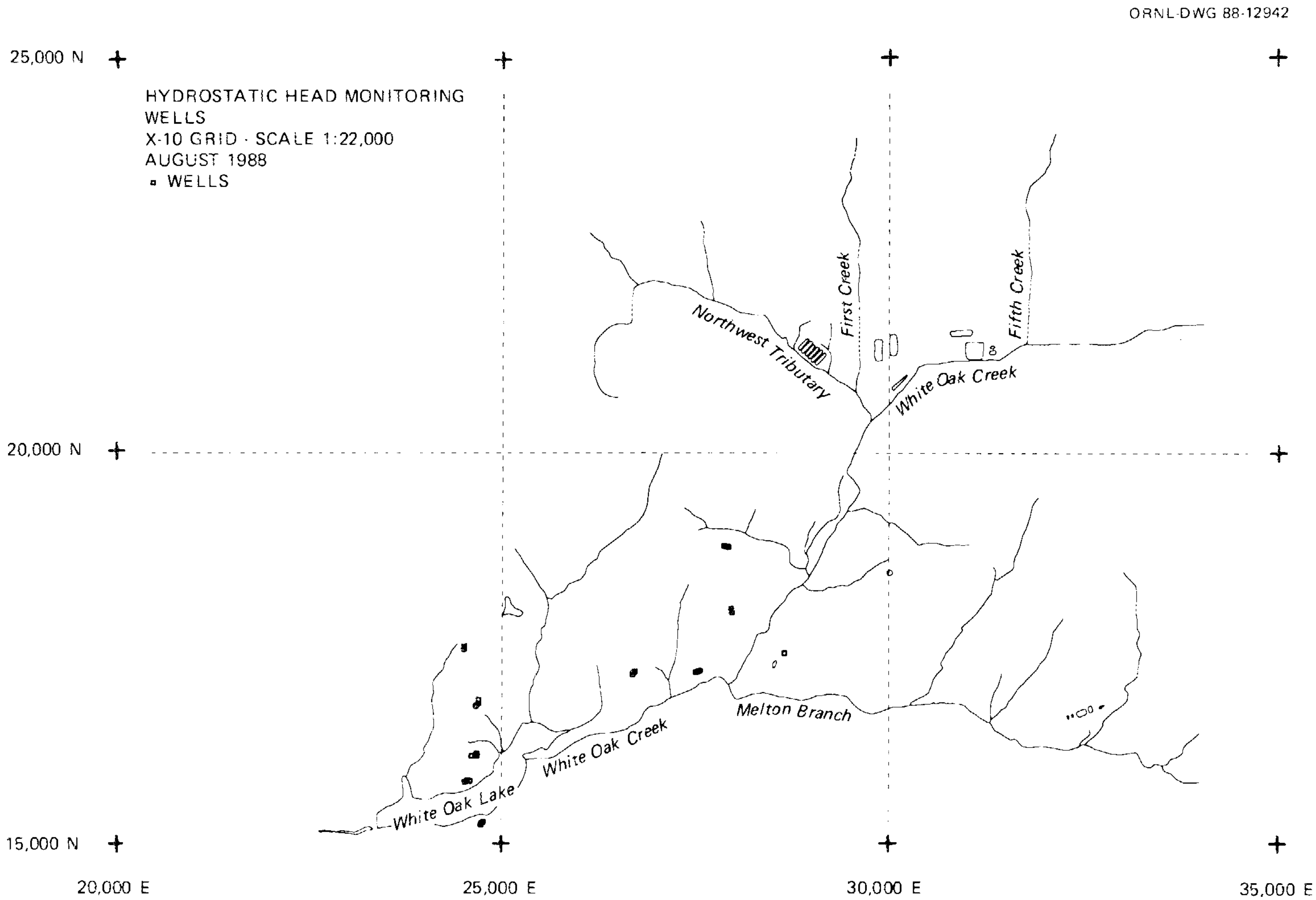


Fig. 19. Locations of hydrostatic head monitoring stations wells installed by the Remedial Action Program.

ORNL DWG 88-13651

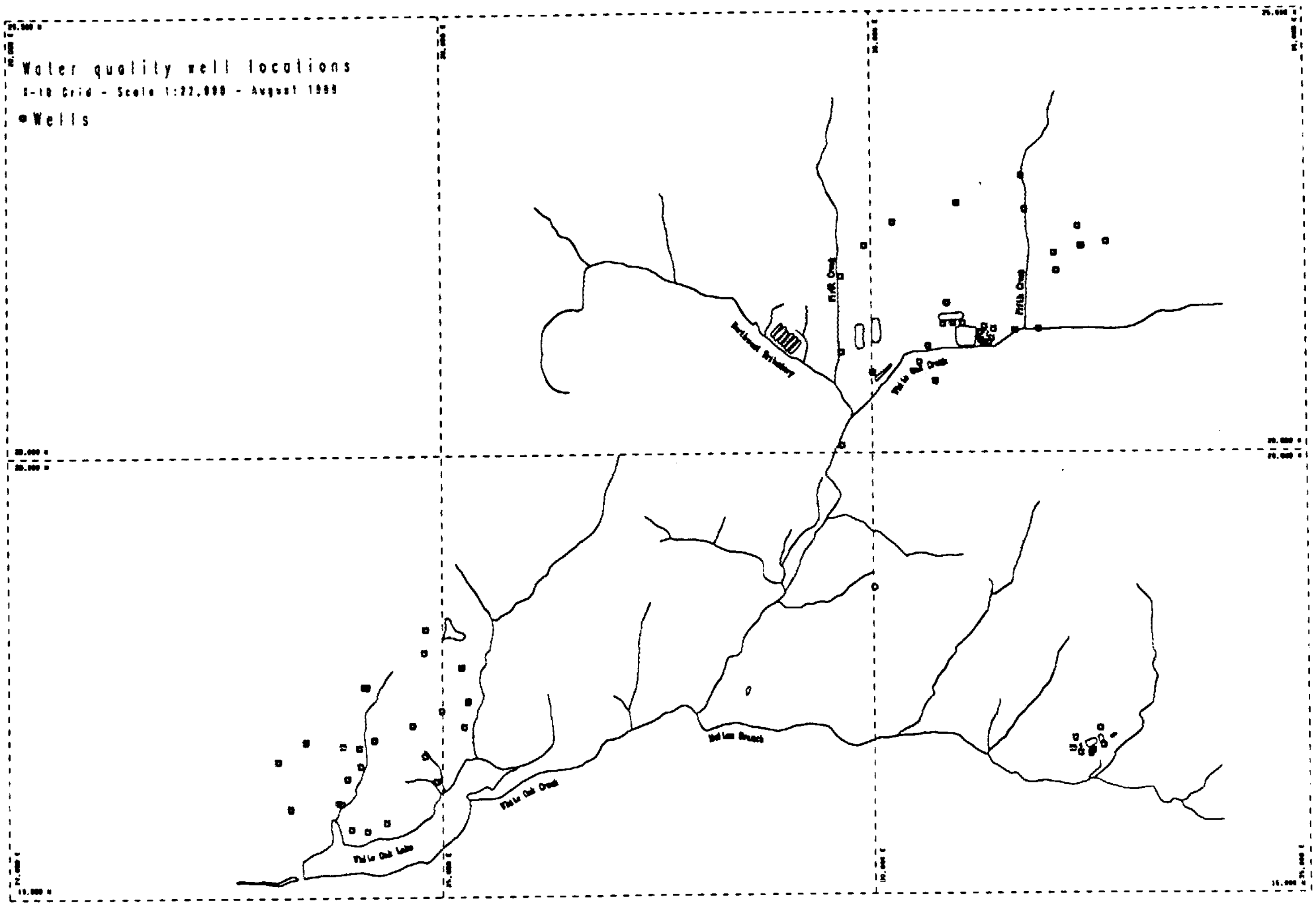


Fig. 20. Locations of water quality wells installed in 1985 by RAP for compliance with RCRA.

ORNL-DWG 88-1636

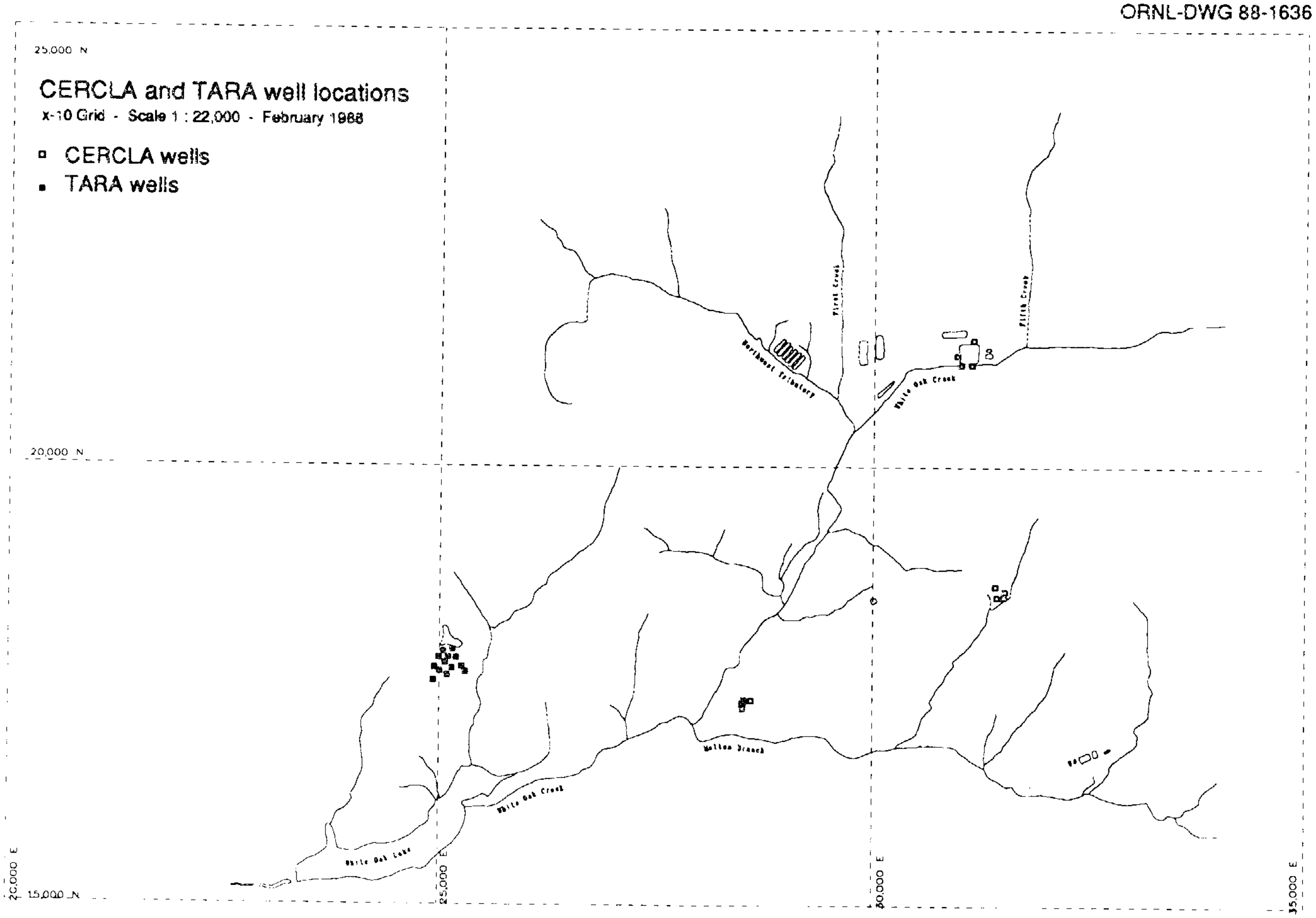


Fig. 21. Locations of wells installed for compliance with Comprehensive Enrivonmental Response, Compensation and Liability Act for the technology demonstration activities on Test Area for Remedial Action.

collected to aid in analyzing the test and to determine the leaching characteristics of the waste form produced.

The SLB closure demonstration included dynamic compaction, in situ grouting, and covering of a group of waste trenches in the TARA in SWSA 6. Groundwater data were collected to determine the effects of the closure activities on water levels and water quality in the trench area.

3.3.1 Groundwater Levels

Beginning in 1986, water level and hydraulic conductivity studies were made on the RAP piezometer wells. The objectives of the studies were to (1) determine the configuration of the water table, directions of groundwater flow, and lateral and vertical hydraulic gradients, (2) monitor short-term and seasonal water level changes resulting from variations in precipitation, (3) monitor long-term water level trends in representative wells to detect effects of climatic change and/or human activities, and (4) determine groundwater flow characteristics in the shallow subsurface materials by conducting hydraulic conductivity tests on a large number of piezometer wells.

The initial results of the study, including a graphical analysis of the data collected on geologic conditions, water level fluctuations, and aquifer characteristics, were summarized. All well and water level data for different locations in the ORNL area are available from the RAP data and information management system (Voorhees et al. 1988).

Hydrographs for two typical wells in the WOC Watershed are shown in Fig. 22. The hydrographs show similar response to changes in precipitation. However, the magnitude of the response to a given amount of precipitation varies because of the differences in aquifer storage capacity and permeability, hydraulic gradients, and the nature of the groundwater flow paths in the vicinity of the wells.

Flow nets (Fig. 23-25) showing the configuration of the water table and flow lines in the ORNL area were prepared from water level measurements made at the time of the seasonal low in October 1986. The equipotential lines on the flow nets show the configuration of the water table. However, the streamlines show only the general direction of groundwater flow because the local movement of groundwater is largely

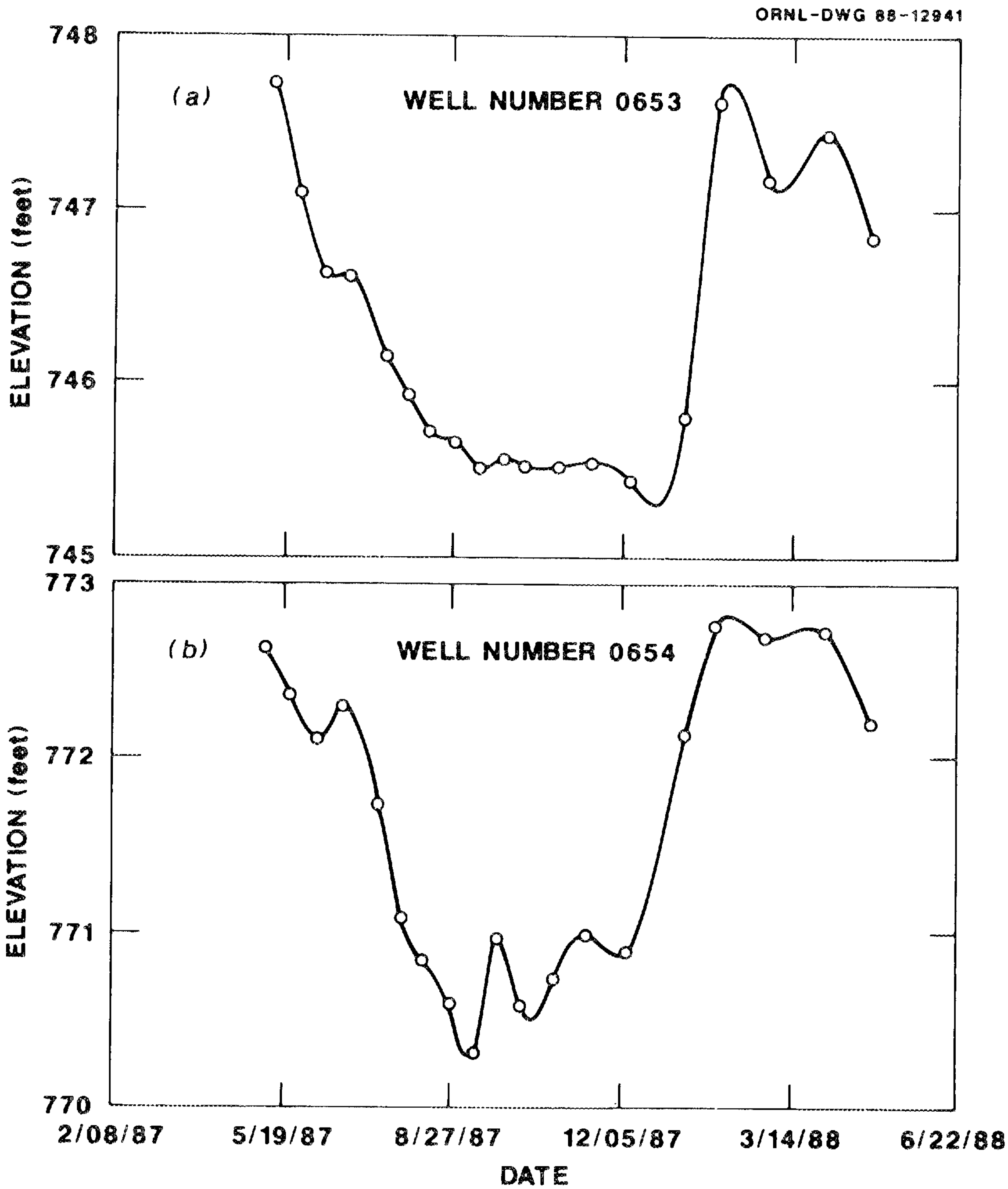


Fig. 22. Hydrographs plotted from measurements in selected piezometers in the WOC watershed.

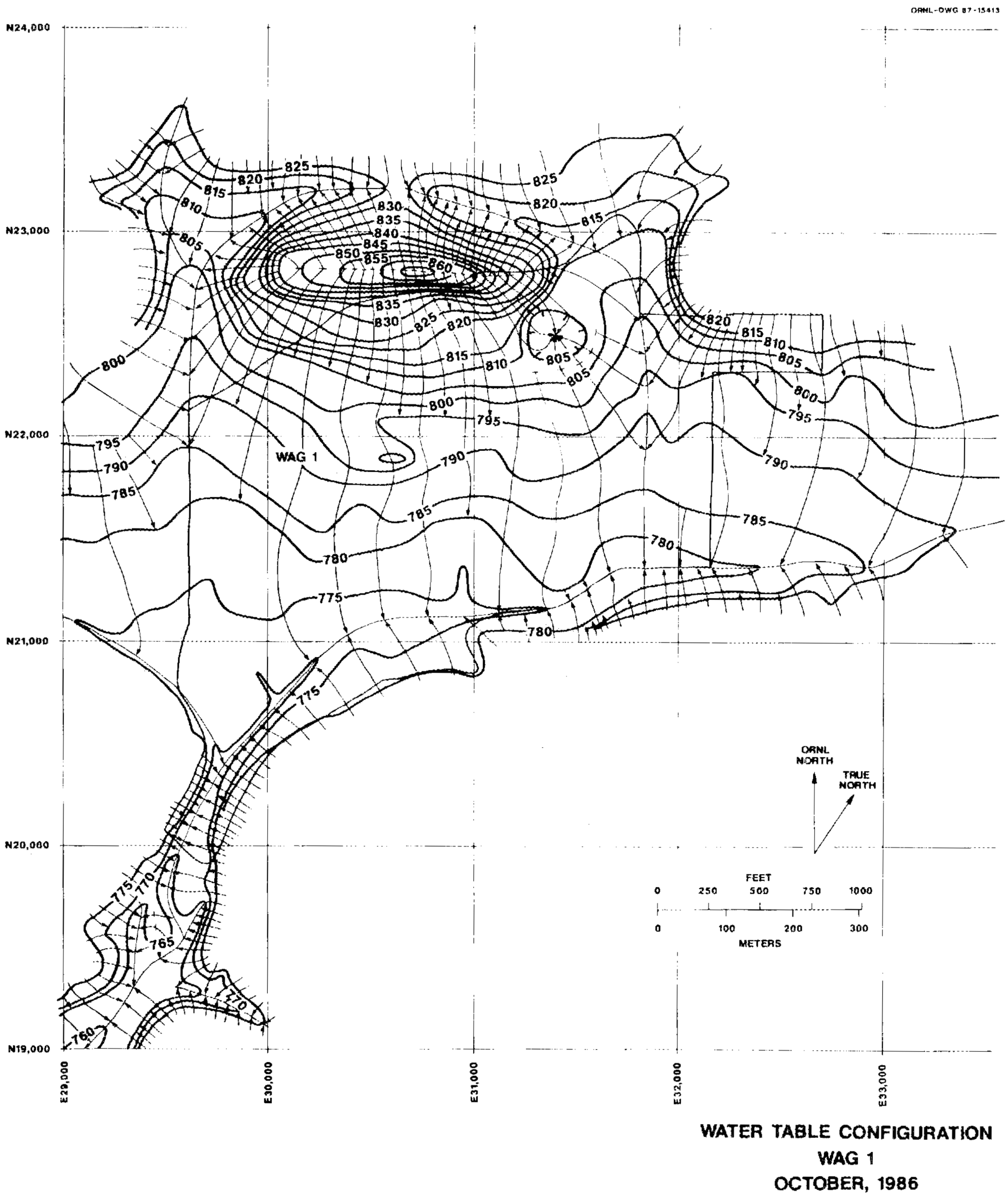


Fig. 23. Flow net showing configuration of water table and streamlines for WAG 6 and part of WAG 2 in October 1986.

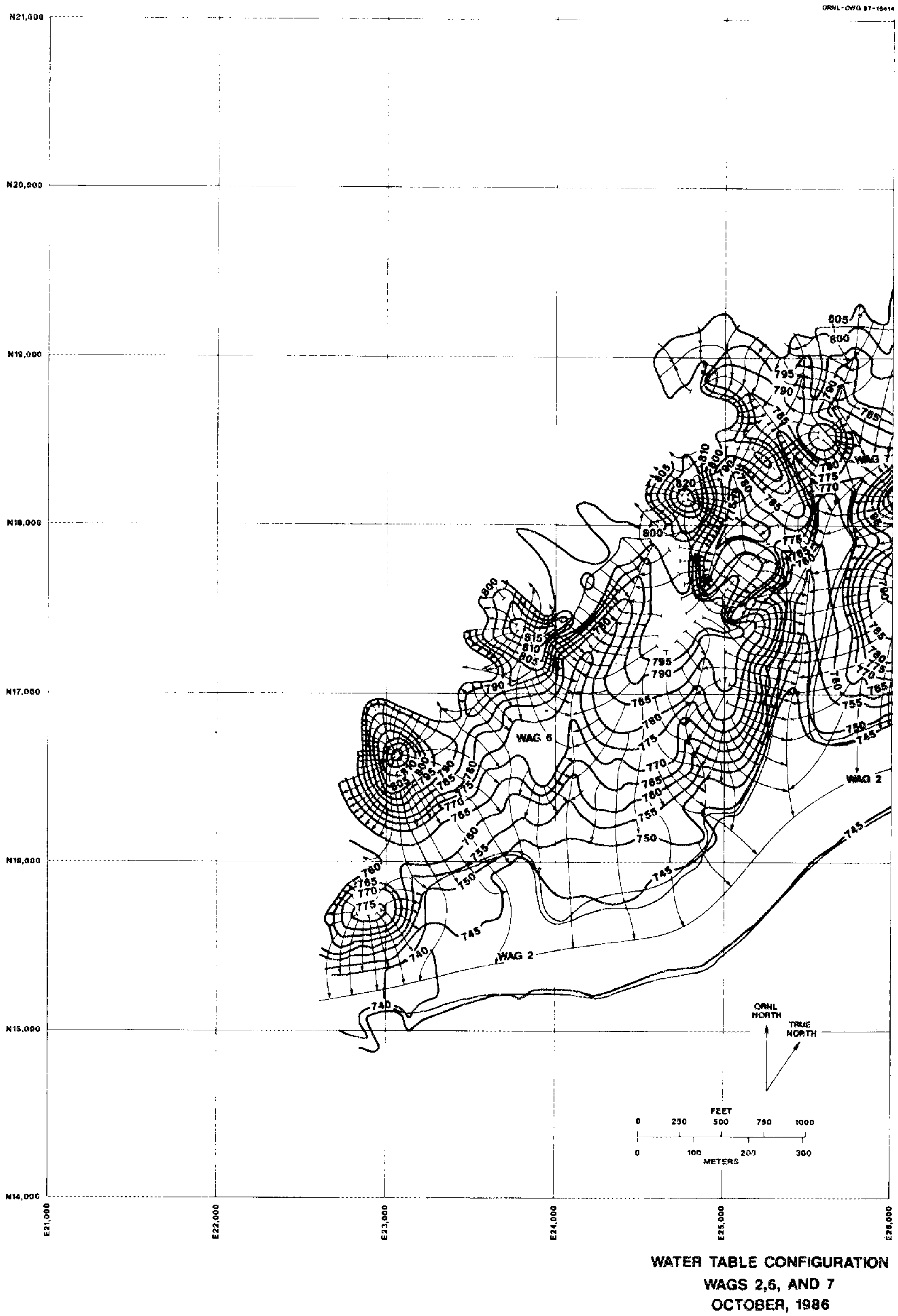


Fig. 24. Flow net showing the configuration of water table and streamlines for WAG 4, 5, 7, and part of WAG 2 in October 1986.

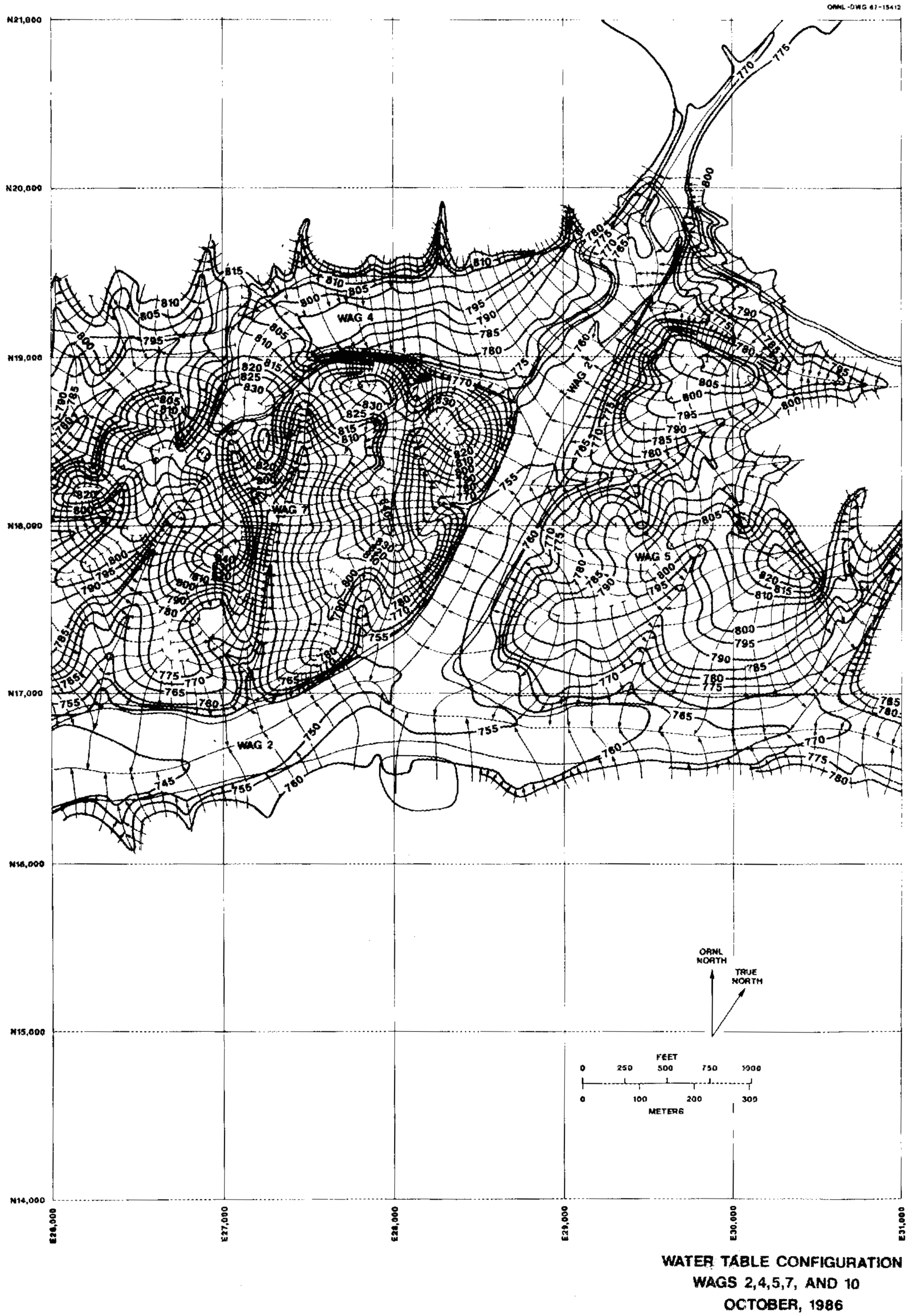


Fig. 25. Flow net showing the configuration of water table and streamlines for WAG 1 area in October 1986.

controlled by the size and orientations of fractures in the rock (Sledz and Huff 1981). Apparent hydraulic gradients calculated from the flow nets range from medians of 0.007, along-valley, and 0.016, cross-valley, in flat areas to 0.4 on steep hillsides.

A contour map of seasonal water level change in the ORNL plant area (WAG 1) from October 1986 to March 1987 (Fig. 26) shows changes of < 0.3 m (1 ft) in several areas. These anomalous areas may represent artificial control of water levels by the drainage effects of storm sewers, leakage into or out of underground pipe, or the increased permeability of trench materials.

3.3.2 Aquifer Characteristics

Hydraulic conductivity values were obtained from the results of slug tests conducted on about 407 piezometers and from about 90 tests conducted in previous studies. A cumulative probability plot of the values (Fig. 27) shows that the geometric mean value is 0.045 m/d and the one standard deviation range is 0.0058 to 0.29 m/d. As seen in Fig. 27, these data plot as a single lognormally distributed population for all aquifer and geologic units. The continuity of the plot indicates very few sharp changes in conductivity suggesting that large interconnecting cavities are relatively rare. In general, analysis of the slug test data indicates that although most shallow wells near ORNL are capable of yielding small amounts of water, only a few of the highest yielding wells could produce more than 1 gallon per minute (gpm).

3.3.3 Groundwater Quality

The long-term study of groundwater quality that began with early ORNL operations has been greatly intensified during the RAP. The RAP efforts include regulatory monitoring, scoping studies, and site investigations. Scoping surveys for which data are included in the data and information management system were conducted in the main plant area (WAG 1) and SWSA 3 (WAG 3), in the WOC floodplain, and in the pits and trenches area (WAG 7), SWSA 6 (WAG 6) and near WOL in WAG 2.

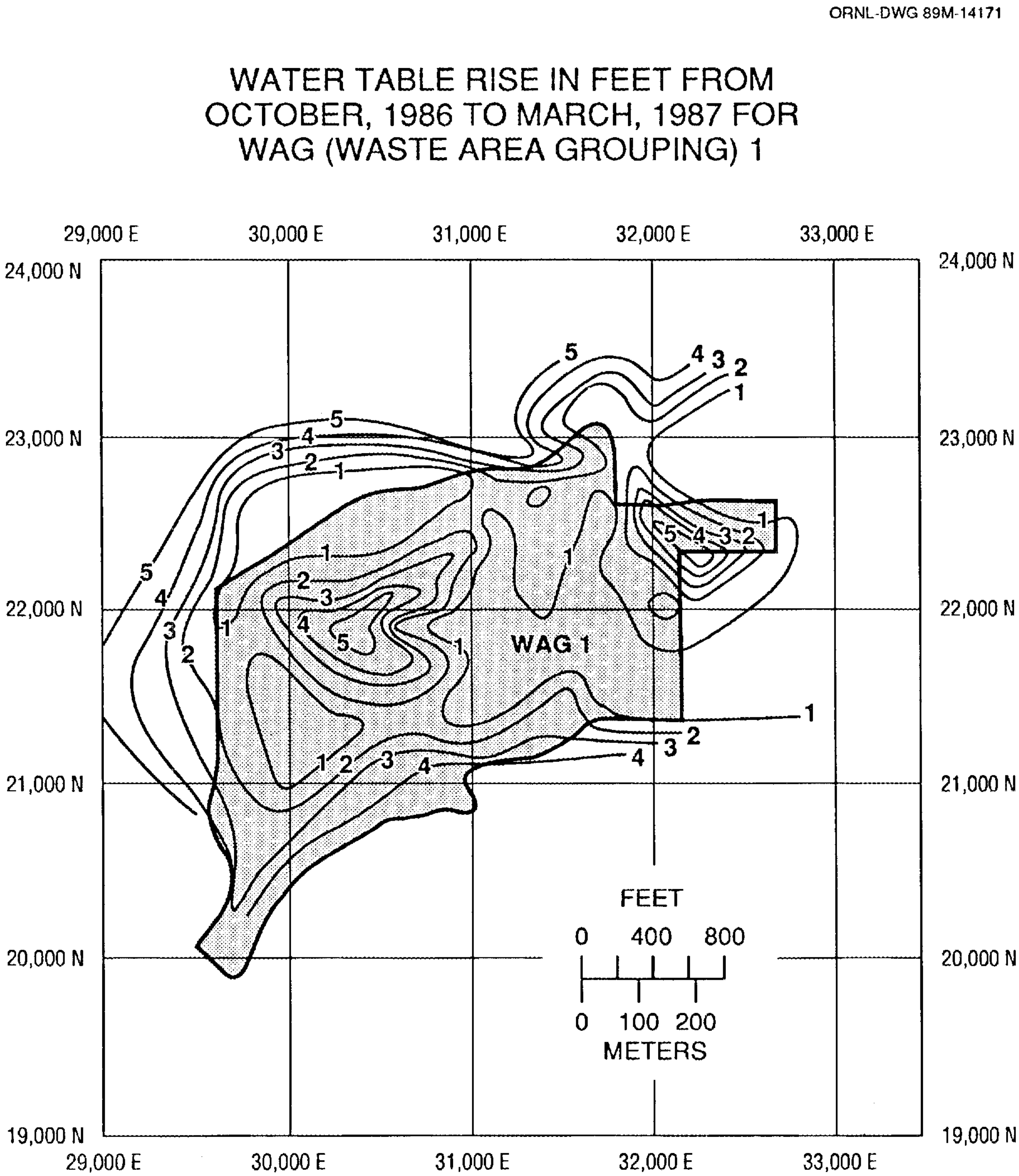


Fig. 26. Seasonal water table fluctuation in WAG 1 from October 1986 to April 1987.

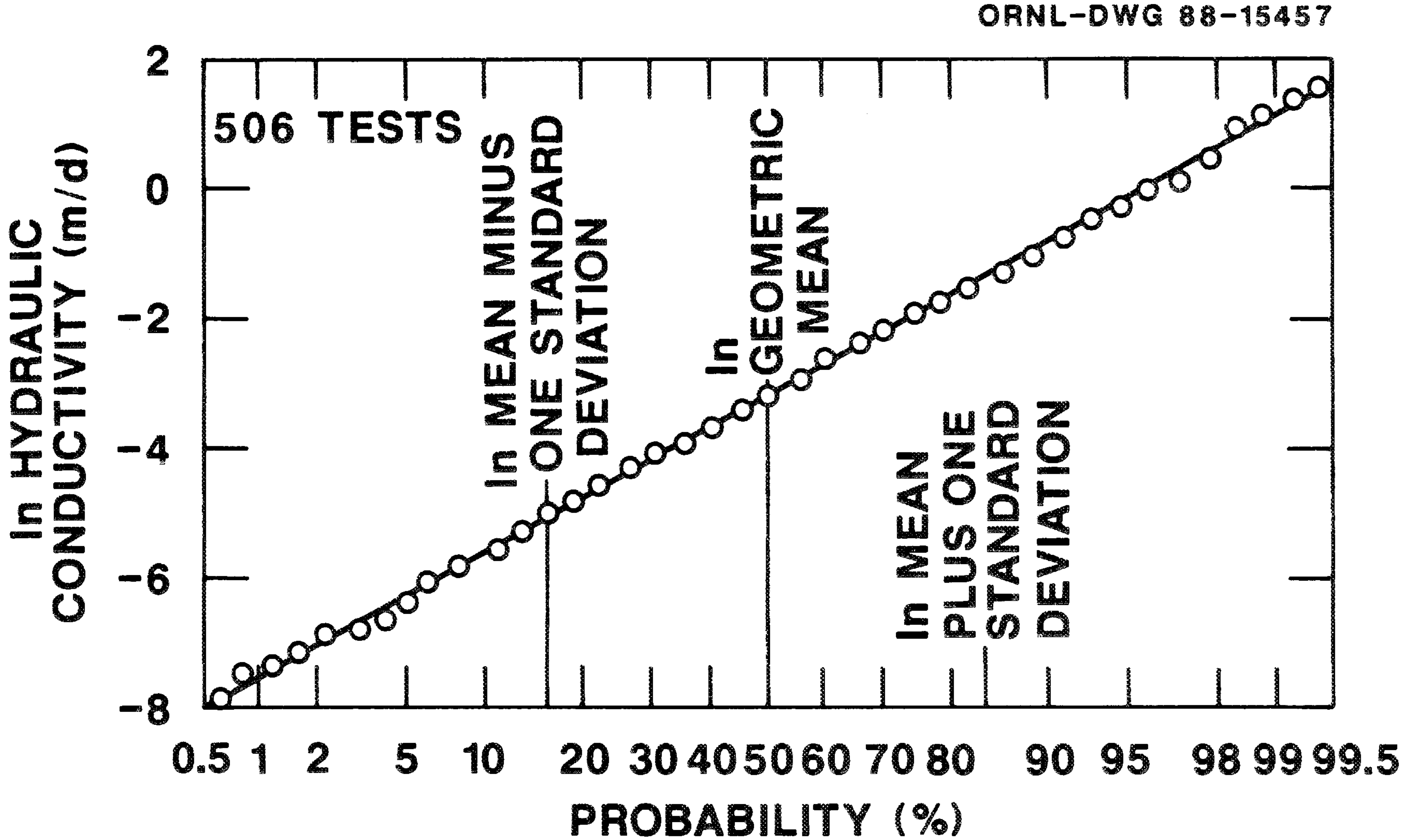


Fig. 27. Cumulative probability graph of hydraulic conductivity values from slug tests.

Unfiltered samples were collected from piezometers (locations shown in Fig. 18) for chemical and radiological analyses. The results of the scoping surveys provide only estimates of contaminant levels in the water because of the effects of suspended materials in the samples. However, the results are useful in planning the locations of water quality monitoring wells and additional groundwater studies. The distribution of gross beta, gross alpha, tritium activity, and volatile organic compounds (VOCs) in wells in the ORNL main plant area (WAG 1) is shown in Figs. 28-29. Gross beta activity in excess of 50 pCi/L, gross alpha in excess of 20 pCi/L, tritium in excess of 1000 pCi/L, and VOCs in excess of 50 μg/L indicate areas where groundwater may be contaminated.

The results of the scoping survey in the WOC floodplain indicate that the shallow groundwater has been affected by the radiological and chemical contaminants in the effluent from the long operation of the ORNL facilities as well as leachates from upgradient solid and liquid waste disposal areas. Radiological activity levels were above background in many piezometers. Tritium and ^{90}Sr levels were relatively high in water from a few piezometers. The highest levels of tritium ranged from 3.2 to 4.1 x 10^6 pCi/L in samples from three piezometers located along Melton Branch downgradient from SWSA 5. These data correlate with the results of recent groundwater studies that indicate appreciably higher levels of tritium in the SWSA 5 area (Amano et al. 1987). Strontium-90 levels ranging from 1485 to 2510 pCi/L were found in samples from three piezometers located in the vicinity of an old lake bed on WOC downgradient from SWSA 4. Elevated levels of ^{137}Cs were also found in water from wells in the two areas mentioned above as well as in water samples from two piezometers along Melton Branch downstream from the HF-2, HRT, and HFIR facilities and in an area of thick sediment deposits along WOC downgradient from the pits and trenches area. The highest ^{137}Cs and ^{60}Co levels, 324 and 62 pCi/L respectively, were found in water samples from well 378 located downgradient from the pits and trenches area. The distribution of gross beta and tritium activity in piezometers in the WOC floodplain is shown in Figs. 30-31.

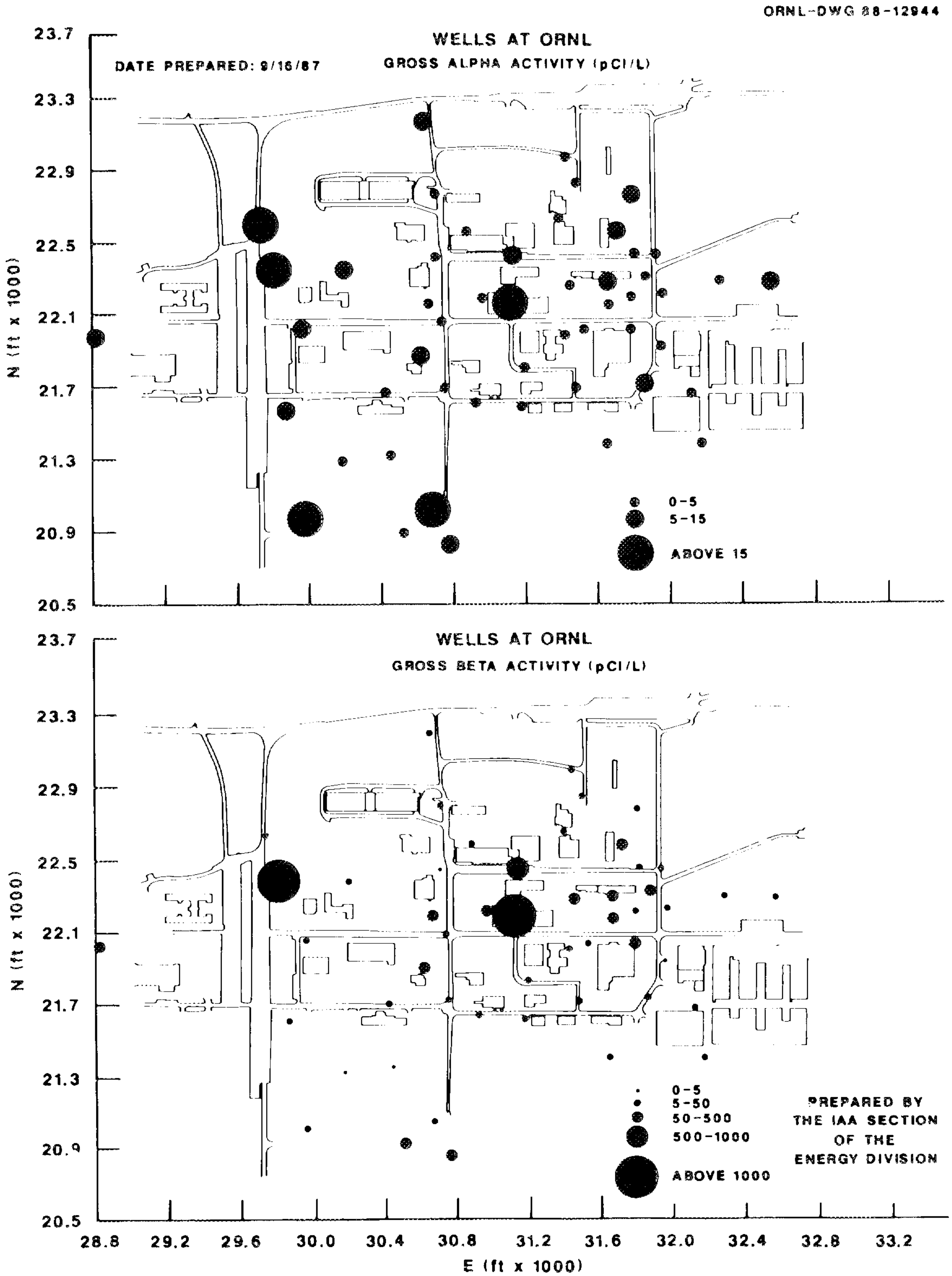


Fig. 28. Distribution of radionuclides in water samples from piezometer wells (a) gross alpha and (b) gross beta activity.

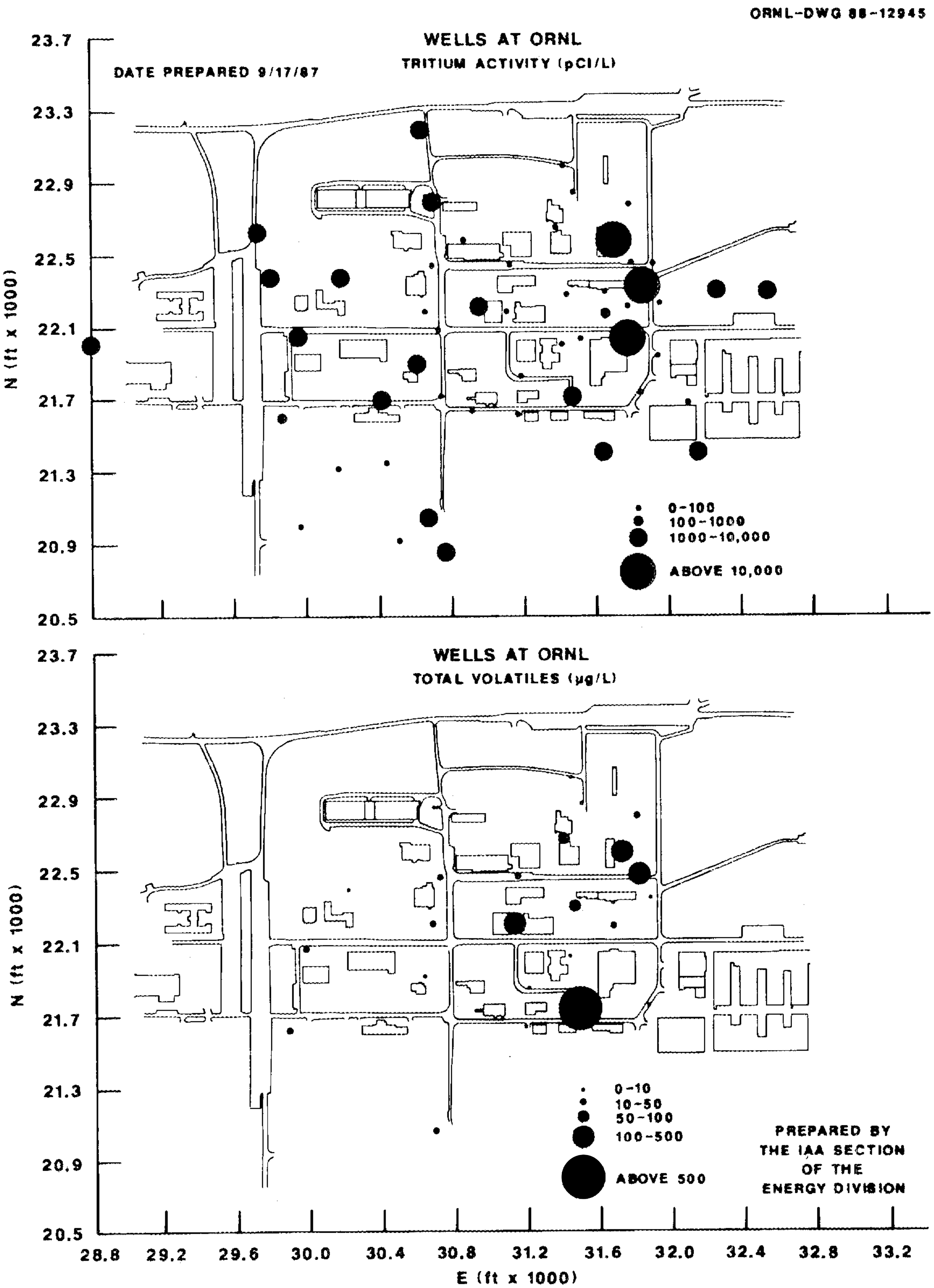


Fig. 29. Distribution of radionuclides in water samples from piezometer wells (a) tritium and (b) total volatiles activity.

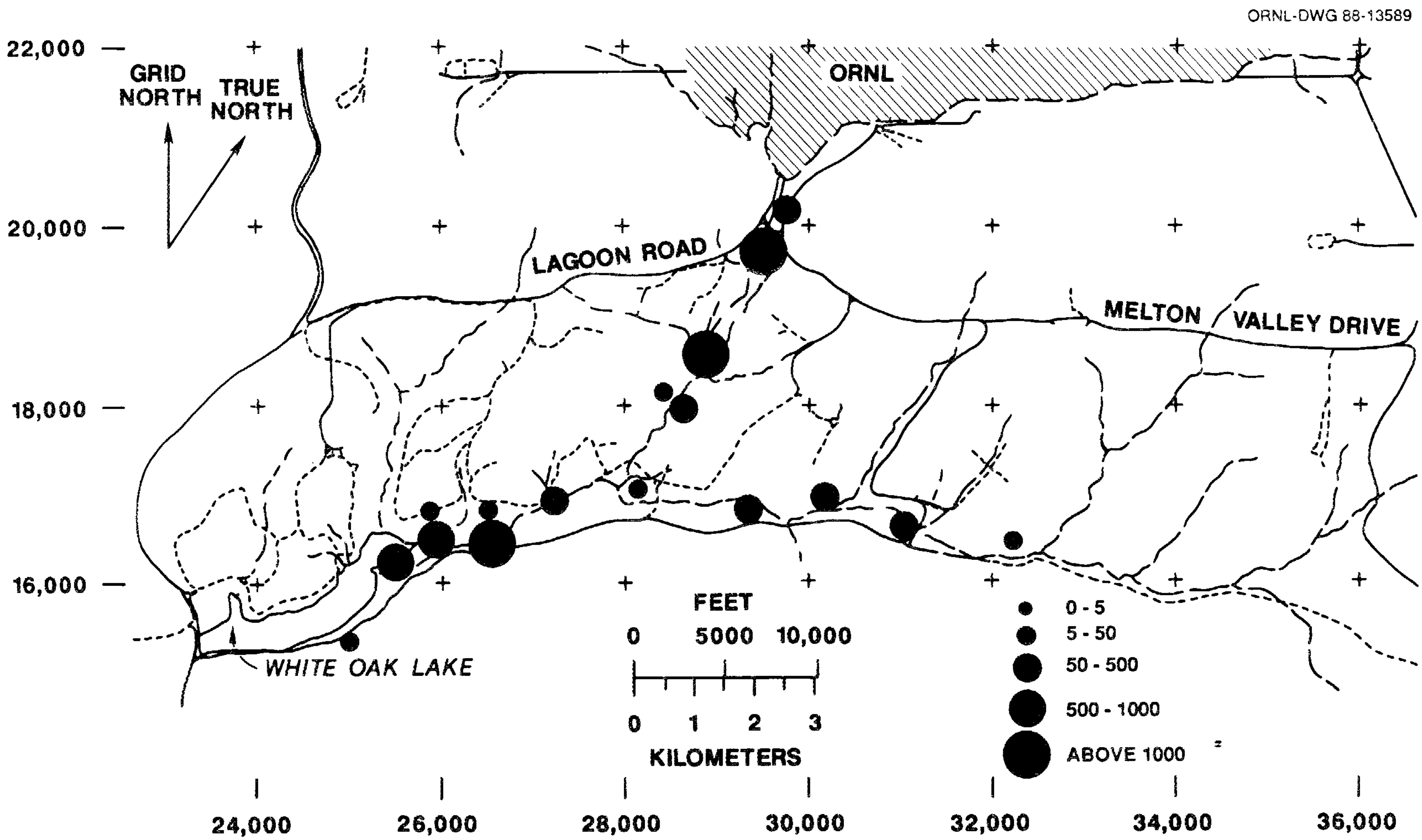


Fig. 30. Distribution of gross beta activity in piezometer wells located in the White Oak Creek floodplain. Units = pCi/L.

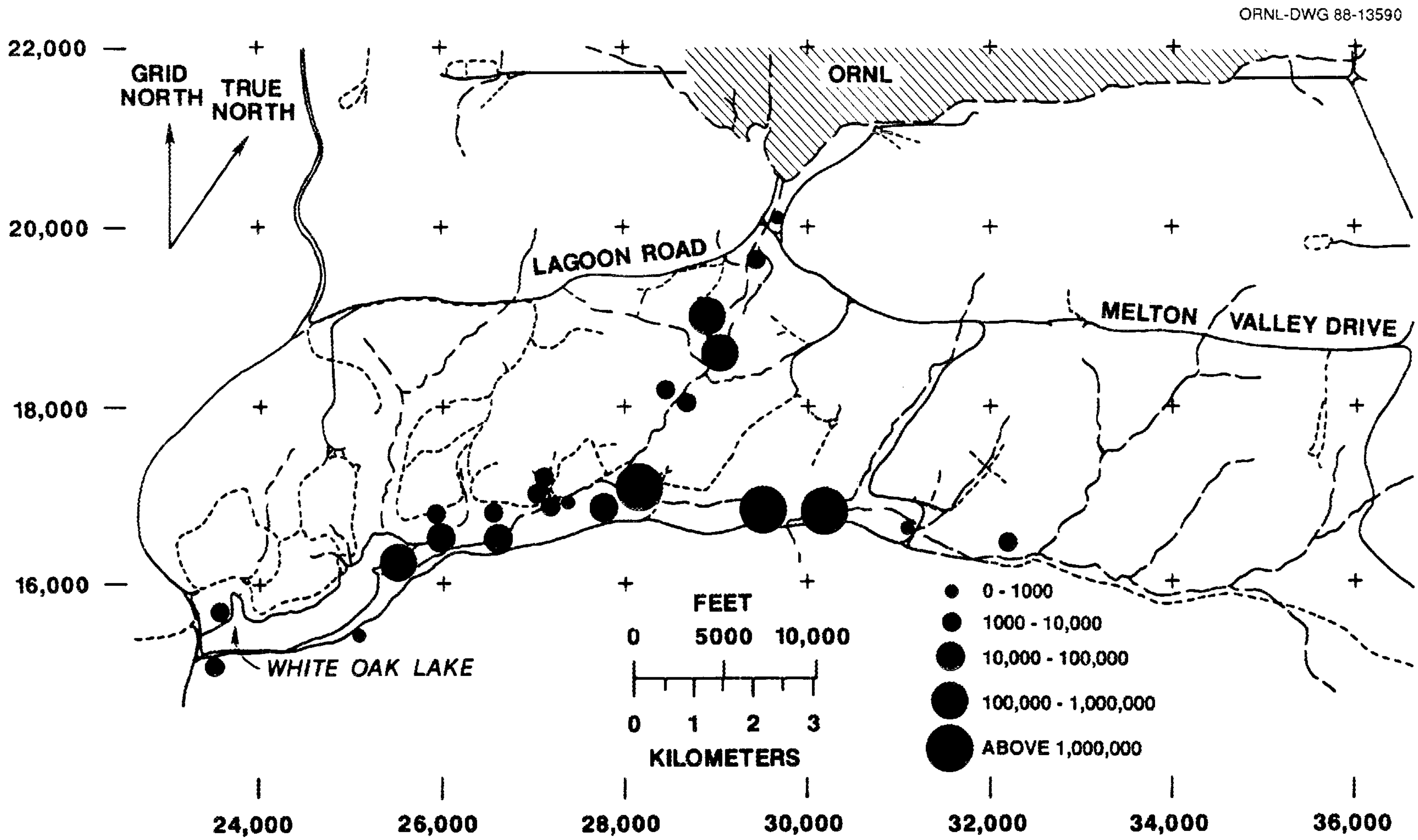


Fig. 31. Distribution of tritium in piezometer wells located in the White Oak Creek floodplain. Units = pCi/L.

A recent aerial radiological survey of the floodplain (Fritzsche 1987) shows elevated radiological activity in sediments in all the areas mentioned above.

The 31 wells in the HHMSs (Fig. 14) were sampled in July 1987. Filtered samples from depths of 30.5, 60.96, 121.9 m (100, 200, and 400 ft) at each well cluster site were analyzed for alkalinity, cations, anions, total organic carbon (TOC), fluorescence (drilling fluid traces), and radiological contaminants, as well as field pH, specific conductivity, redox potential, and temperature.

The 83 water-quality monitoring wells presently installed by the RAP (Fig. 20) are monitored by the ORNL EMC Department in accordance with EPA regulations. Initially, data were collected on a quarterly basis and analyzed for dissolved metals in filtered samples; total metals, organics, and anions in unfiltered samples; and pH, specific conductivity, and temperature in all samples.

Wells installed around pond 3513, OHF, and HRE (Fig. 21) as part of a CERCLA study conducted by Francis (1986) were monitored for a period of 1 year, beginning in February 1985. The samples were analyzed for cations, anions, fecal coliforms, mercury, PCBs, pesticides, phenols, and radiological contaminants. Multiple sample results for dissolved oxygen, pH, temperature, specific conductance, TOC, and total organic halides (TOX) were used to compare wells.

Rock core and geophysical logs from a 274 m (900 ft) core hole drilled at WOD indicate fractured rock throughout the length of the core hole, but suggest that little groundwater flow occurs below a depth of 121.9 m (400 ft). The analyses of samples of water collected at depths of 13.4 and 82.3 m (44 and 270 ft) showed no radiological contamination. Subsequent packer-pressure tests were conducted in the core hole to provide estimates of permeability values for different water-bearing zones. RAP reports on packer-pressure testing of the WOD core hole and five other core holes in the main ORNL plant area have been prepared (Golder Associates 1987).

3.4 Reports

Surface water and groundwater quality information has been collected as part of many RAP studies for characterization purposes or technology demonstrations. Many reports containing hydrologic data or information have been released by ORNL; published reports are included in the reference section. Information on reports in other ORNL report series included in the RAP bibliographic base may also be retrieved from the RAP data and information system (Voorhees et al. 1988).

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APPENDIX A

DAILY PRECIPITATION AT WOC STATIONS

Table A.1. Daily precipitation summary May 1987 - April 1988
Atmospheric Turbulence Diffusion Laboratory: Site ID = ATDD
(mm)

Day	May 87	Jun 87	Jul 87	Aug 87	Sep 87	Oct 87	Nov 87	Dec 87	Jan 88	Feb 88	Mar 88	Apr 88
1	0.00	1.52	4.32	2.79	0.00	0.00	0.00	0.51	12.70	0.76	0.00	13.21
2	5.08	0.25	0.51	0.00	0.00	0.00	0.00	0.00	0.00	13.72	0.00	1.02
3	9.40	3.56	10.16	1.02	0.00	0.00	0.00	1.52	8.13	23.11	1.27	4.83
4	2.54	0.00	29.21	0.00	0.00	0.00	0.00	0.25	0.00	15.24	8.89	0.00
5	0.00	0.00	20.57	0.51	4.57	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6	0.00	0.00	20.83	15.24	0.00	1.27	0.00	0.00	0.00	0.00	0.00	17.53
7	0.00	0.00	5.08	0.00	0.00	0.00	0.00	0.00	17.53	0.00	0.00	0.25
8	0.00	0.00	0.00	0.00	22.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00
9	0.00	0.00	0.00	8.89	0.00	0.00	5.59	0.00	0.00	0.00	2.54	0.00
10	0.00	3.56	0.00	4.06	0.00	0.00	18.29	0.00	0.00	0.00	52.83	0.00
11	0.00	0.00	7.87	0.00	1.27	0.00	0.00	1.27	0.00	5.08	0.00	0.00
12	0.00	6.35	0.00	8.38	64.01	0.00	0.00	0.00	0.51	0.00	12.19	11.43
13	0.00	0.00	1.52	0.00	0.00	0.00	0.00	0.00	1.78	0.00	0.00	0.00
14	0.76	0.25	0.00	0.00	0.00	0.00	0.00	4.57	0.00	0.00	0.00	0.00
15	0.00	0.00	0.00	0.00	0.00	0.00	0.00	13.21	0.00	16.76	0.00	4.57
16	0.00	20.07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
17	4.32	9.91	0.00	7.87	5.08	0.00	17.78	0.00	14.99	0.00	0.00	0.00
18	0.00	25.91	0.00	0.00	0.00	0.00	0.25	0.25	0.76	0.00	3.56	24.13
19	1.78	4.06	0.00	0.00	11.94	0.25	0.00	5.33	78.23	6.86	0.00	5.08
20	0.00	4.06	0.00	0.00	0.00	7.87	0.00	0.00	0.51	0.00	0.00	0.00
21	6.86	6.35	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
22	0.00	0.51	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
23	5.08	19.81	0.00	0.00	0.00	0.00	0.00	0.00	0.00	5.59	0.00	4.83
24	0.00	0.76	0.00	0.00	0.00	2.79	0.00	15.75	0.00	0.00	1.52	0.00
25	1.27	0.00	0.00	0.00	0.00	0.00	0.00	16.51	3.05	0.00	3.05	0.00
26	0.00	1.27	0.00	0.00	0.00	1.27	0.00	8.64	0.00	0.00	4.57	0.00
27	7.87	0.00	0.00	0.00	0.00	2.29	0.00	7.87	0.00	0.00	0.00	0.00
28	0.00	0.00	0.00	0.00	0.00	0.00	11.68	8.89	0.00	0.00	0.00	0.00
29	2.54	0.00	0.00	0.00	34.29	1.78	0.00	0.00	0.00	0.00	0.00	0.00
30	3.81	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		0.00	0.00
31	0.00		0.00	0.00		0.00		2.54	0.00		6.10	
	======	======	======	======	======	=====	======	======	======	======	======	======
Total (mm)	51.31	108.20	100.07	48.76	143.26	7.52	53.59	87.11	138.19	87.12	96.52	86.88
Total (in.)	2.02	4.26	3.94	1.92	5.64	0.69	2.11	3.43	5.44	3.43	3.80	3.42

Table A.2. Daily precipitation summary May 1987 - April 1988
USGS Rain Gage, Burial Ground 3: Site ID = GS3
(mm)

Day	May 87	Jun 87	Jul 87	Aug 87	Sep 87	Oct 87	Nov 87	Dec 87	Jan 88	Feb 88	Mar 88	Apr 88
1	0.00	0.00	6.86	0.00	0.00	0.00	0.00	0.76	12.95	0.25	0.00	10.92
2	0.00	0.00	3.05	0.00	0.00	0.00	0.00	0.00	0.00	11.94	0.00	0.00
3	11.18	1.52	11.18	0.25	0.00	0.00	0.00	0.51	7.11	13.46	0.76	6.35
4	8.89	0.00	7.37	0.00	0.00	0.00	0.00	0.00	1.27	14.99	5.59	0.00
5	0.00	0.00	8.38	1.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6	0.00	0.00	1.52	4.06	2.03	1.27	0.00	0.00	0.00	0.00	0.00	21.08
7	0.00	0.00	8.89	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8	0.00	0.00	0.00	0.00	3.56	0.00	0.00	0.00	0.00	0.00	0.00	0.00
9	0.00	0.00	0.00	0.00	0.00	0.00	8.89	0.00	0.00	0.00	3.56	0.00
10	0.00	0.00	0.00	4.32	0.00	0.00	19.56	0.00	0.00	0.51	55.63	0.00
11	0.00	0.00	7.37	0.00	0.51	0.00	0.00	0.51	0.00	3.56	0.00	2.03
12	0.00	11.68	0.00	18.54	54.10	0.00	0.00	0.00	4.06	0.00	14.22	6.10
13	0.00	1.02	1.78	0.25	0.00	0.00	0.00	0.00	5.08	0.00	0.00	0.00
14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.06	0.25	0.00	0.25	0.00
15	0.00	1.78	0.00	0.00	0.00	0.00	0.00	16.51	2.29	13.97	0.00	4.57
16	0.25	1.27	0.00	0.00	0.00	0.00	0.00	0.00	2.79	0.25	0.00	0.00
17	15.49	2.79	0.00	9.65	0.00	0.00	19.30	0.00	14.99	0.00	0.00	0.00
18	1.78	5.08	0.00	0.00	0.00	0.00	0.00	0.00	0.25	0.00	3.30	20.32
19	0.00	4.32	0.00	0.00	8.64	0.00	0.00	0.00	76.20	5.08	0.00	4.83
20	10.41	3.30	0.00	0.00	0.00	7.87	0.00	3.81	1.02	0.00	0.00	0.00
21	9.91	13.21	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
22	0.00	40.13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
23	0.00	0.25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	5.08	0.00	2.79
24	0.25	0.00	0.00	0.00	0.00	0.00	0.00	17.27	1.02	0.00	0.00	0.76
25	21.84	0.00	0.00	0.00	0.00	1.02	0.00	11.18	0.51	0.00	2.79	0.00
26	0.00	2.29	0.00	0.00	0.00	0.76	0.25	9.65	0.00	0.00	3.05	0.00
27	0.25	0.00	0.00	0.00	0.00	3.05	0.00	7.37	0.00	0.00	0.00	0.00
28	0.00	0.00	0.00	0.00	0.00	0.00	6.60	10.16	0.00	0.00	0.00	0.00
29	3.05	0.00	0.00	0.00	23.37	3.81	0.25	0.00	0.00	0.00	0.00	0.00
30	11.94	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		0.51	0.00
31	0.25		0.00	0.00		0.00		2.79	0.25		1.27	
	======	======	======	======	======	======	======	======	======	======	======	======
Total (mm)	95.49	88.64	56.40	38.09	92.21	17.78	54.85	84.58	130.04	69.09	90.93	79.75
Total (in.)	3.76	3.49	2.22	1.50	3.63	0.70	2.16	3.33	5.12	2.72	3.58	3.14

Table A.3. Daily precipitation data summary May 1987 - April 1988
USGS Rain Gage, Burial Ground 5: Site ID = GS5
(mm)

Day	May 87	Jun 87	Jul 87	Aug 87	Sep 87	Oct 87	Nov 87	Dec 87	Jan 88	Feb 88	Mar 88	Apr 88
1	0.00	0.00	4.83	0.00	0.00	0.00	0.00	1.02	12.95	0.25	0.00	10.41
2	0.00	0.00	0.25	0.00	0.00	0.00	0.00	0.00	0.00	11.94	0.00	0.00
3	8.89	0.51	14.22	2.54	0.00	0.00	0.00	0.51	7.87	13.46	0.76	4.83
4	11.18	0.00	6.86	0.00	0.00	0.00	0.00	0.00	0.51	14.99	5.59	0.00
5	0.00	0.00	9.40	1.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6	0.00	0.00	4.83	8.13	0.76	1.27	0.00	0.00	0.00	0.00	0.00	17.27
7	0.00	0.00	6.60	0.25	0.00	0.00	0.00	0.00	15.24	0.00	0.00	0.00
8	0.00	0.00	0.00	0.00	3.81	0.00	0.00	0.00	1.78	0.00	0.00	0.00
9	0.00	0.00	0.00	0.25	0.00	0.00	7.87	0.00	0.00	0.00	3.56	0.00
10	0.00	0.00	0.00	2.79	0.00	0.00	18.29	0.00	0.00	0.51	55.63	0.00
11	0.00	0.00	3.81	0.00	0.51	0.00	0.00	0.51	0.00	3.56	0.00	1.78
12	0.00	10.16	0.00	19.30	62.74	0.00	0.00	0.00	1.52	0.00	14.22	5.59
13	0.00	1.02	0.76	0.00	0.00	0.00	0.00	0.00	2.54	0.00	0.00	0.00
14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.32	0.00	0.00	0.25	0.00
15	0.00	0.51	0.00	0.00	0.00	0.00	0.00	16.51	0.00	13.97	0.00	5.08
16	1.02	0.51	0.00	0.00	0.00	0.00	0.00	0.00	2.29	0.25	0.00	0.00
17	23.11	4.57	0.00	5.59	0.00	0.00	17.78	0.00	16.00	0.00	0.00	0.00
18	0.51	2.29	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.30	19.05
19	0.00	5.59	0.00	0.00	9.14	0.25	0.00	0.00	74.42	5.08	0.00	4.83
20	0.25	1.52	0.00	0.00	0.00	7.37	0.00	3.30	1.27	0.00	0.00	0.00
21	8.64	12.70	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
22	0.00	31.24	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
23	0.00	0.51	0.00	0.00	0.00	0.00	0.00	0.00	0.00	5.08	0.00	2.29
24	0.25	0.25	0.00	0.00	0.00	0.00	0.00	18.29	0.76	0.00	0.00	0.76
25	2.03	0.00	0.00	0.00	0.00	1.02	0.00	8.64	0.76	0.00	2.79	0.00
26	1.52	0.76	0.00	0.00	0.00	0.51	0.00	8.89	0.00	0.00	3.05	0.00
27	0.00	0.00	0.00	0.00	0.00	3.30	0.25	7.87	0.00	0.00	0.00	0.00
28	0.00	0.00	0.00	1.27	0.00	0.00	9.14	10.16	0.00	0.00	0.00	0.00
29	5.59	0.00	0.00	0.00	20.32	3.81	0.00	0.00	0.00	0.00	0.00	0.00
30	13.97	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		0.51	0.00
31	0.00		0.00	0.00		0.00		2.54	0.00		1.27	
	======	======	======	======	======	======	======	======	======	======	======	======
Total (mm)	76.96	72.14	51.56	41.14	97.28	17.53	53.33	82.56	137.91	69.09	90.93	71.89
Total (in.)	3.03	2.84	2.03	1.62	3.83	0.69	2.10	3.25	5.43	2.72	3.58	2.83

Table A.4. Daily preciitation summary May 1987 - April 1988
Center 7 Creek Watershed: Site ID = SW7
mm)

	Day	May 87	Jun 87	Jul 87	Aug 87	Sep 87	Oct 87	Nov 87	Dec 87	Jan 88	Feb 88	Mar 88	Apr 88
	1	0.00	0.00	5.72	0.00	0.00	0.00	0.00	1.02	12.45	0.00	0.00	7.89
	2	0.00	0.00	1.02	0.00	0.00	0.00	0.00	0.00	0.00	12.58	0.00	0.00
	3	17.00	0.64	15.24	0.51	0.00	0.00	0.00	1.02	8.13	14.23	1.02	5.08
	4	6.88	0.00	7.88	0.00	0.00	0.00	0.00	0.10	0.00	13.96	7.11	0.00
	5	0.00	0.00	9.27	1.27	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	6	0.00	0.00	16.51	9.14	1.53	1.40	0.00	0.00	0.00	0.00	0.00	17.77
	7	0.00	0.00	4.32	0.00	0.00	0.00	0.00	0.00	17.28	0.00	0.00	0.00
	8	0.00	0.00	0.00	0.00	2.67	0.00	0.00	0.00	1.78	0.00	0.00	0.00
	9	0.00	0.00	0.00	3.56	0.00	0.00	9.73	0.00	0.00	0.00	3.56	0.00
	10	0.00	0.00	0.00	2.29	0.00	0.00	15.65	0.00	0.00	0.00	53.86	0.00
	11	0.00	0.00	2.54	0.00	0.51	0.00	0.00	0.64	0.00	4.32	0.00	1.79
	12	0.00	13.08	0.00	11.56	63.51	0.00	0.00	0.00	0.89	0.00	13.84	4.70
	13	0.00	1.78	1.03	0.00	0.00	0.00	0.00	0.00	1.27	0.00	0.00	0.00
	14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	5.09	0.00	0.00	0.00	0.00
	15	0.00	0.51	0.00	0.00	0.00	0.00	0.00	15.23	0.00	16.37	0.00	5.08
	16	1.78	1.65	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	17	25.15	12.08	0.00	4.83	1.14	0.00	17.15	0.00	17.82	0.00	0.00	0.00
	18	0.25	0.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.80	18.41
	19	0.00	7.24	0.00	0.00	10.16	0.25	0.00	0.00	76.97	5.07	0.00	4.96
	20	0.76	1.91	0.00	0.00	0.00	6.97	0.00	3.56	0.00	0.00	0.00	0.00
	21	10.15	13.84	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	22	0.00	13.97	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	23	0.00	1.52	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.96	0.00	3.17
	24	0.51	0.00	0.00	0.00	0.00	0.00	0.00	16.81	0.73	0.00	0.00	0.89
	25	2.82	0.00	0.00	0.00	0.00	1.52	0.00	11.38	0.91	0.00	1.52	0.00
	26	0.00	0.77	0.00	0.00	0.00	1.79	0.51	8.89	0.00	0.00	2.54	0.00
	27	0.00	0.00	0.00	0.00	0.00	2.03	0.00	10.52	0.00	0.00	0.00	0.00
	28	0.00	0.00	0.00	0.25	0.00	0.00	8.88	8.89	0.00	0.00	0.00	0.00
	29	2.29	0.00	0.00	0.00	24.12	3.81	0.00	0.00	0.00	0.00	0.00	0.00
	30	12.95	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		0.51	0.00
	31	0.00		0.00	0.00		0.00		3.81	0.63		0.52	
		=====	======	======	======	======	======	======	======	======	======	======	======
Total (mm)		80.54	69.49	63.53	33.41	103.64	17.77	51.92	86.96	138.86	71.49	87.28	69.74
Total (in.)		3.17	2.74	2.50	1.32	4.08	0.70	2.04	3.42	5.47	2.81	3.44	2.75

Table A.5. Daily precipitation data May 1987 - April 1988
Engineering Test Facility (SWSA 6): Site ID = ETF
(mm)

	Day	May 87	Jun 87	Jul 87	Aug 87	Sep 87	Oct 87	Nov 87	Dec 87	Jan 88	Feb 88	Mar 88	Apr 88
	1	0.00	0.00	6.86	0.00	0.00	0.00	0.00	0.63	12.57	0.00	0.00	9.53
	2	0.00	0.00	0.25	0.00	0.00	0.00	0.00	0.00	0.00	13.71	0.00	0.00
	3	18.39	1.02	14.47	0.38	0.00	0.00	0.00	0.76	8.38	14.73	1.40	5.96
	4	4.21	0.00	7.88	0.00	0.00	0.00	0.00	0.00	0.00	14.99	8.50	0.00
	5	0.00	0.00	8.26	2.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	6	0.00	0.00	0.25	9.65	1.26	0.76	0.00	0.00	0.00	0.00	0.00	17.02
	7	0.00	0.00	8.38	0.00	0.00	0.00	0.00	0.00	14.45	0.00	0.00	0.00
	8	0.00	0.00	0.00	0.00	5.08	0.00	0.00	0.00	0.76	0.00	0.00	0.00
	9	0.00	0.00	0.00	4.06	0.00	0.00	7.02	0.00	0.00	0.00	3.30	0.00
	10	0.00	0.00	0.00	2.79	0.00	0.00	20.55	0.00	0.00	0.00	54.09	0.00
	11	0.00	0.00	7.37	0.00	0.38	0.00	0.00	0.25	0.00	5.09	0.00	1.53
	12	0.76	8.89	0.00	24.77	62.24	0.00	0.00	0.00	0.51	0.00	14.21	4.70
	13	0.00	1.77	1.15	0.00	0.00	0.00	0.00	0.00	1.53	0.00	0.76	0.00
	14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	5.08	0.00	0.00	0.00	0.00
	15	0.00	0.63	0.00	0.00	0.00	0.00	0.00	17.03	0.00	14.98	0.00	6.35
	16	2.79	0.51	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	17	23.12	2.79	0.00	5.09	0.00	0.00	18.28	0.00	14.84	0.00	0.00	0.00
	18	0.00	5.59	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.30	18.30
	19	0.00	3.55	0.00	0.00	8.12	0.51	0.00	0.00	75.44	4.83	0.00	5.20
	20	3.31	2.42	0.00	0.00	0.00	7.12	0.00	3.80	0.00	0.00	0.00	0.00
	21	9.51	13.46	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	22	0.00	40.64	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	23	0.00	1.40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.44	0.00	3.17
	24	1.27	0.00	0.00	0.00	0.00	0.00	0.00	18.10	0.26	0.00	0.00	1.27
	25	3.31	0.00	0.00	0.00	0.00	0.76	0.00	7.28	1.28	0.00	2.54	0.00
	26	0.00	1.02	0.00	0.00	0.00	1.53	0.25	9.91	0.00	0.00	3.56	0.00
	27	0.00	0.00	0.00	0.00	0.00	2.03	0.00	7.12	0.00	0.00	0.00	0.00
	28	0.00	0.00	0.00	3.05	0.00	0.00	6.35	9.89	0.00	0.00	0.00	0.00
	29	19.69	0.00	0.00	0.00	16.51	2.54	0.00	0.00	0.00	0.00	0.00	0.00
	30	14.73	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		0.25	0.00
	31	0.00		0.00	0.00		0.00		2.67	0.76		1.01	
		======	======	======	======	======	======	======	======	======	======	======	======
TOTAL	L (mm)	101.09	83.69	54.87	51.82	93.59	15.25	52.45	82.52	130.78	72.77	92.92	73.03
	(in)	3.98	3.29	2.16	2.04	3.68	0.60	2.06	3.25	5.15	2.86	3.66	2.88

Table A.6. Daily precipitation summary May 1987 - April 1988
First Creek: Site ID = 1st
(mm)

Day	May 87	Jun 87	Jul 87	Aug 87	Sep 87	Oct 87	Nov 87	Dec 87	Jan 88	Feb 88	Mar 88	Apr 88
1			5.33	0.00	0.00	0.00	0.00	0.76	11.44	0.00	0.00	10.14
2			0.76	0.00	0.00	0.00	0.00	0.00	0.00	12.84	0.00	0.00
3			13.46	1.79	0.00	0.00	0.00	0.89	8.38	12.70	1.02	6.86
4			.13	0.00	0.00	0.00	0.00	0.00	0.00	13.97	5.33	0.00
5			9.15	1.27	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6			2.79	5.08	1.02	1.52	0.00	0.00	0.00	0.00	0.00	17.90
7			7.12	0.25	0.00	0.00	0.00	0.00	12.95	0.00	0.00	0.00
8			0.00	0.00	2.79	0.00	0.00	0.00	1.01	0.00	0.00	0.00
9			0.00	0.33	0.00	0.00	9.09	0.00	0.00	0.00	3.56	0.00
10			0.00	3.95	0.00	0.00	18.21	0.00	0.00	0.00	53.35	0.00
11			7.87	0.00	0.50	0.00	0.00	0.50	0.00	5.08	0.00	2.54
12			0.00	23.87	56.13	0.00	0.00	0.00	2.08	0.00	13.72	5.10
13			0.76	0.00	0.00	0.00	0.00	0.00	1.22	0.00	0.00	0.00
14			0.00	0.00	0.00	0.00	0.00	4.31	0.00	0.00	0.00	0.00
15			0.00	0.00	0.00	0.00	0.00	16.00	0.00	16.25	0.00	5.09
16			0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
17			0.00	7.87	0.76	0.00	19.69	0.25	14.74	0.00	0.00	0.00
18			0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.55	19.44
19			0.00	0.00	8.64	0.13	0.00	0.00	73.42	5.84	0.00	4.69
20			0.00	0.00	0.00	7.50	0.00	3.30	0.75	0.00	0.00	0.00
21			0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
22			0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
23			0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.70	0.00	5.34
24			0.00	0.00	0.00	0.00	0.00	16.77	1.02	0.00	0.38	0.77
25			0.00	0.00	0.00	1.15	0.00	10.41	0.00	0.00	2.79	0.00
26			0.00	0.00	0.00	1.54	0.63	9.03	0.00	0.00	3.31	0.00
27			0.00	0.00	0.00	2.77	0.00	8.91	0.00	0.00	0.00	0.00
28			0.00	0.00	0.00	0.00	6.99	8.85	0.00	0.00	0.00	0.00
29			0.00	0.00	23.62	3.81	0.00	0.00	0.00	0.00	0.00	0.00
30			0.00	0.00	0.00	0.00	0.00	0.00	0.00		0.25	0.00
31			0.00	0.00		0.00		3.04	0.64		0.89	
	======	======	======	======	======	======	======	======	======	======	======	======
Total (mm)			55.37	44.41	93.46	18.42	54.61	83.02	127.65	71.38	88.15	77.87
Total (in.)			2.18	1.75	3.68	0.73	2.15	3.27	5.03	2.81	3.47	3.07

Table A.7. Daily precipitation summary May 1987 - April 1988
49 Trench (SWSA 6): Site ID = T49
(mm)

Day	May 87	Jun 87	Jul 87	Aug 87	Sep 87	Oct 87	Nov 87	Dec 87	Jan 88	Feb 88	Mar 88	Apr 88
1	0.00	0.00	6.86	0.00	0.00	0.00	0.00	0.63	11.93	0.00	0.00	9.13
2	0.00	0.00	0.25	0.00	0.00	0.00	0.00	0.00	0.00	12.72	0.00	0.00
3	16.96	1.02	13.71	0.50	0.00	0.00	0.00	0.89	8.26	14.73	1.27	5.70
4	5.13	0.00	8.00	0.00	0.00	0.00	0.00	0.00	0.26	13.71	6.61	0.00
5	0.00	0.00	8.76	1.52	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6	0.00	0.00	0.51	9.40	1.27	1.02	0.00	0.00	0.00	0.00	0.00	16.52
7	0.00	0.00	7.87	0.00	0.00	0.00	0.00	0.00	14.23	0.00	0.00	0.00
8	0.00	0.00	0.00	0.00	3.55	0.00	0.00	0.00	0.90	0.00	0.00	0.00
9	0.00	0.00	0.00	3.30	0.00	0.00	8.70	0.00	0.00	0.00	2.04	0.00
10	0.00	0.00	0.00	3.31	0.00	0.00	19.50	0.00	0.00	0.00	54.75	0.00
11	0.00	0.00	6.73	0.00	0.38	0.00	0.00	0.63	0.00	4.32	0.00	1.53
12	0.38	9.14	0.00	21.46	60.95	0.00	0.00	0.00	0.63	0.00	13.08	4.83
13	0.00	1.52	0.77	0.00	0.00	0.00	0.00	0.00	1.01	0.00	0.76	0.00
14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.77	0.00	0.00	0.00	0.00
15	0.00	0.63	0.00	0.00	0.00	0.00	0.00	17.59	0.00	13.96	0.00	5.47
16	1.77	0.76	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
17	23.62	2.54	0.00	5.08	0.00	0.00	18.53	0.00	15.75	0.00	0.00	0.00
18	0.00	5.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.91	17.91
19	0.00	4.06	0.00	0.00	7.88	0.37	0.00	0.00	72.52	4.32	0.00	4.95
20	3.05	2.53	0.00	0.00	0.00	7.36	0.00	3.55	0.00	0.00	0.00	0.00
21	9.65	12.96	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
22	0.00	41.28	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
23	0.00	1.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.56	0.00	2.54
24	1.52	0.00	0.00	0.00	0.00	0.00	0.00	17.81	0.51	0.00	0.00	1.02
25	5.59	0.00	0.00	0.00	0.00	0.64	0.00	7.18	1.28	0.00	2.29	0.00
26	0.00	1.02	0.00	0.00	0.00	1.29	0.38	8.77	0.00	0.00	2.54	0.00
27	0.00	0.00	0.00	0.00	0.00	2.03	0.00	7.37	0.00	0.00	0.00	0.00
28	0.00	0.00	0.00	2.41	0.00	0.00	6.09	9.64	0.00	0.00	0.00	0.00
29	21.58	0.00	0.00	0.00	17.26	2.03	0.00	0.00	0.00	0.00	0.00	0.00
30	13.97	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		0.38	0.00
31	0.00		0.00	0.00		0.00		2.92	0.77		0.77	
	======	======	======	======	======	======	======	======	======	======	======	======
Total (mm)	103.22	83.81	53.46	46.98	91.29	14.74	53.20	81.75	128.05	68.32	87.40	69.60
Total (in.	4.06	3.30	2.10	1.85	3.59	0.58	2.09	3.22	5.04	2.69	3.44	2.74

APPENDIX B

DAILY DISCHARGE AT WOC STATIONS

Table B.1. Daily surface discharge summary May 1987 - April 1988
EMC Division: Site ID = X15
(cfs)

	Day	May 87	Jun 87	Jul 87	Aug 87	Sep 87	Oct 87	Nov 87	Dec 87	Jan 88	Feb 88	Mar 88	Apr 88
	1	7.52	7.54	6.07	5.88	6.05	8.87	5.83	8.12	9.81	7.50	7.21	8.47
	2	8.11	6.96	8.39	5.88	6.96	5.63	5.83	8.14	9.81	7.75	7.23	8.47
	3	8.11	6.58	8.52	5.88	5.38	5.25	6.08	7.12	9.81	10.69	7.86	8.47
	4	8.11	6.48	8.52	6.34	6.95	5.25	5.60	4.60	9.81	39.50	7.23	8.47
	5	11.33	6.62	8.52	7.27	5.85	5.25	5.88	5.64	10.68	29.06	7.77	8.59
	6	8.39	6.31	8.52	7.63	5.85	5.74	5.71	5.64	6.65	14.15	7.77	13.86
	7	6.71	6.31	8.52	7.13	5.85	6.02	5.34	5.64	8.14	14.15	7.77	12.87
	8	14.31	6.31	10.23	6.29	5.85	7.26	5.34	6.95	7.58	14.15	7.44	10.82
	9	6.99	7.21	9.38	6.29	6.84	5.91	5.34	6.39	7.03	11.16	6.90	10.69
	10	6.99	6.11	5.17	6.29	5.63	6.11	10.66	5.25	7.03	9.79	56.10	10.69
	11	6.99	6.53	6.48	14.08	5.46	6.11	9.92	5.32	7.03	9.50	70.06	10.69
	12	6.44	6.13	6.48	9.42	10.79	6.11	7.18	5.19	5.54	9.59	21.73	9.42
	13	6.45	6.56	6.48	10.27	10.79	6.56	6.58	5.19	8.65	9.77	21.73	11.57
	14	6.59	6.56	7.58	7.58	10.79	6.47	5.52	5.19	6.31	9.77	21.73	8.08
	15	5.97	6.56	4.83	5.78	7.06	6.50	5.52	12.13	7.64	9.77	15.44	8.54
	16	7.60	6.50	7.58	5.78	6.03	6.25	5.52	8.29	9.71	9.77	12.30	7.58
	17	7.60	7.57	5.21	5.78	6.05	5.04	11.20	6.82	9.71	12.35	12.86	7.58
	18	7.60	7.64	5.34	8.05	6.30	5.04	7.13	4.92	9.71	10.72	11.65	7.58
	19	9.36	6.82	5.34	6.00	6.45	5.04	7.29	6.14		10.18	10.36	16.52
	20	6.61	8.28	5.34	6.41	6.45	5.34	6.70	6.14	129.90	9.78	10.36	13.15
	21	12.04	8.28	7.07	6.71	6.45	6.59	5.86	6.14	46.85	9.78	10.36	12.33
	22	7.09	8.28	4.83	5.30	6.02	5.86	5.86	5.96	16.62	9.78	9.39	10.83
	23	7.37	15.67	6.14	5.30	5.89	5.77	5.86	6.02	11.79	8.54	8.28	9.35
	24	7.37	11.82	7.44	5.30	5.06	4.98	6.53	10.06	11.79	9.16	9.36	9.35
	25	7.37	7.01	5.12	5.30	5.38	4.98	5.31	10.06	11.79	8.97	6.99	9.35
	26	7.37	6.02	5.12	5.88	5.33	4.98	6.42	10.06	10.17	8.57	7.30	9.36
	27	7.72	6.42	5.12	6.24	5.33		7.26	10.06	8.51	7.90	7.30	6.16
	28	7.09	6.42	5.37	7.26	5.33	6.11	7.89	10.06	8.22	7.90	7.30	7.71
	29	6.31	6.42	6.10	5.59	6.59	5.45	7.89	9.25	7.97	7.90	7.26	6.78
	30	7.54	6.50	5.03	5.59	9.95	5.62	7.89	9.55	7.50		6.84	6.44
	31	7.54		6.25	5.59		5.83		8.57	7.50		7.67	.
		======	======	======	======	======	======	======	======	======	======	======	======
Miminum		5.97	6.02	4.83	5.30	5.06	4.98	5.31	4.60	6.31	7.50	6.84	6.16
Maximum		14.31	15.67	10.23	14.08	10.79	8.87	11.20	12.13	129.90	39.50	70.06	16.52
Mean		7.83	7.28	6.65	6.71	6.62	5.86	6.70	7.25	14.31	11.64	13.53	9.66

Table B.2. Daily surface discharge summary May 1987 - April 1988
EMC Division: Site ID = X14
(cfs)

Day	May 87	Jun 87	Jul 87	Aug 87	Sep 87	Oct 87	Nov 87	Dec 87	Jan 88	Feb 88	Mar 88	Apr 88
1	6.24	6.57	6.02	5.46	5.79	5.76	5.37	7.60	8.01	5.92	5.77	6.34
2	7.73	6.96	8.26	5.46	6.68	5.40	5.37	7.66	8.01	5.85	5.45	6.34
3	7.73	6.54	8.18	5.46	4.64	5.15	5.65	7.01	8.01	8.93	6.02	6.34
4	7.73	6.34	8.18	5.63	6.53	5.15	5.21	4.41	8.01	30.42	5.89	6.34
5	7.64	6.50	8.18	6.81	5.47	5.15	5.57	5.23	7.67	16.31	5.84	6.96
6	7.57	6.09	8.18	7.10	5.47	5.42	5.59	5.23	5.14	11.29	5.84	11.43
7	6.13	6.09	8.18	6.50	5.47	5.76	5.07	5.23	7.18	11.29	5.84	10.77
8	6.11	6.09	7.18	5.96	5.47	6.11	5.07	6.39	6.37	11.29	4.86	8.03
9	5.65	6.99	8.32	5.96	6.10	4.70	5.07	4.61	6.11	8.96	5.28	7.73
10	5.65	5.93	4.95	5.96	5.55	4.59	9.90	4.39	6.11	7.61	54.60	7.73
11	5.65	6.30	6.13	6.03	5.43	4.59	6.76	4.55	6.11	7.67	32.86	7.73
12	5.91	5.93	6.13	6.14	10.57	4.59	5.88	4.71	4.98	7.69	18.56	7.29
13	5.93	6.54	6.13	9.69	10.57	5.55	6.16	4.71	8.12	8.30	18.56	9.13
14	5.83	6.54	7.02	6.00	10.57	5.12	5.33	4.71	5.38	8.30	18.56	6.33
15	5.63	6.54	4.77	5.74	6.64	5.09	5.33	10.72	6.50	8.30	13.77	6.73
16	7.12	6.24	6.98	5.74	5.66	4.97	5.33	5.23	9.19	8.30	10.44	6.88
17	7.12	7.29	5.20	5.74	5.88	4.22	10.04	5.34	9.19	8.28	9.31	6.88
18	7.12	7.35	5.09	7.61	5.99	4.22	4.89	4.22	9.19	7.47	8.48	6.88
19	6.64	6.76	5.09	5.76	6.21	4.22	5.45	5.59		7.60	7.71	11.81
20	5.51	7.76	5.09	6.02	6.21	5.00	5.89	5.59	67.00	7.17	7.71	10.78
21	11.36	7.76	6.68	6.42	6.21	6.13	5.39	5.59	23.97	7.17	7.71	8.60
22	6.45	7.76	4.60	5.30	5.71	5.49	5.39	5.31	13.51	7.17	6.62	7.78
23	7.14	13.24	5.77	5.30	5.86	5.65	5.39	5.49	9.37	6.44	5.96	7.06
24	7.14	8.20	7.04	5.30	5.01	4.77	6.03	9.81	9.37	7.10	7.02	7.06
25	7.14	6.27	5.12	5.30	5.29	4.77	4.87	9.81	9.37	6.79	4.77	7.06
26	7.14	5.83	5.12	5.63	5.18	4.77	5.79	9.81	7.86	6.61	6.05	8.05
27	6.61	6.18	5.12	6.00	5.18		6.67	9.81	7.24	5.99	6.05	5.91
28	6.51	6.18	5.28	7.01	5.18	5.70	7.34	9.81	7.06	5.99	6.05	6.11
29	6.24	6.18	5.91	5.34	6.24	5.45	7.34	7.26	6.25	5.99	5.37	6.16
30	6.57	5.89	5.01	5.34	9.07	5.25	7.34	7.04	5.92		5.14	5.85
31	6.57		5.79	5.34		5.37		6.96	5.92		5.99	.
	======	======	======	======	======	======	======	======	======	======	======	======
Minimum	5.51	5.83	4.60	5.30	4.64	0.00	4.87	4.22	4.98	5.85	4.77	5.85
Maximum	11.36	13.24	8.32	9.69	10.57	6.13	10.04	10.72	67.00	30.42	54.60	11.81
Mean	6.76	6.83	6.28	6.03	6.33	4.97	6.02	6.45	10.07	8.83	10.26	7.60

Table B.3. Daily surface discharge summary May 1987 - April 1988
EMC Division: Site ID = X13
(cfs)

Day	May 87	Jun 87	Jul 87	Aug 87	Sep 87	Oct 87	Nov 87	Dec 87	Jan 88	Feb 88	Mar 88	Apr 88
1	0.62	0.49	0.51	0.43	0.26	0.46	0.36	0.53	1.47	0.59	0.67	1.06
2	1.06	0.28	1.05	0.43	0.28	0.31	0.36	0.48	1.47	0.56	0.59	1.06
3	1.06	0.17	1.41	0.43	0.23	0.30	0.34	0.57	1.47	1.66	0.65	1.06
4	1.06	0.11	1.41	0.71	0.42	0.30	0.36	0.42	1.47	9.08	0.63	1.06
5	1.18	0.12	1.41	0.46	0.38	0.30	0.29	0.40	1.36	6.07	0.91	1.01
6	0.82	0.22	1.41	0.53	0.38	0.32	0.28	0.40	0.73	2.18	0.91	2.43
7	0.59	0.22	1.41	0.63	0.38	1.38	0.27	0.40	0.76	2.18	0.91	3.61
8	0.50	0.22	0.88	0.33	0.38	1.87	0.27	0.56	0.70	2.18	0.56	2.06
9	0.39	0.22	0.57	0.33	0.74	1.53	0.27	0.45	0.64	1.27	0.63	1.45
10	0.39	0.19	0.57	0.33	0.26	1.65	0.76	0.45	0.64	1.07	1.50	1.45
11	0.39	0.23	0.53	0.34	0.32	1.65	0.62	0.39	0.64	0.93	11.08	1.45
12	0.42	0.20	0.53	0.31	1.27	1.65	0.50	0.47	0.56	1.01	5.61	1.21
13	0.37	0.36	0.53	0.59	1.27	1.83	0.36	0.47	0.80	1.42	5.61	1.61
14	0.36	0.36	0.56	0.26	1.27	1.58	0.19	0.47	0.59	1.42	5.61	0.99
15	0.34	0.36	0.36	0.22	0.42	1.59	0.19	1.41	0.70	1.42	3.50	0.93
16	1.04	0.26	0.60	0.22	0.65	1.58	0.19	0.67	2.16	1.42	2.03	1.12
17	1.04	0.28	0.50	0.22	0.40	0.45	1.16	0.54	2.16	1.78	1.61	1.12
18	1.04	0.46	0.25	0.43	0.54	0.45	0.57	0.42	2.16	1.41	1.41	1.12
19	0.77	0.32	0.25	0.29	0.42	0.45	0.60	0.48		1.28	1.25	4.72
20	0.50	0.52	0.25	0.28	0.42	0.34	0.59	0.48	62.87	1.30	1.25	3.84
21	0.68	0.52	0.39	0.29	0.42	0.46	0.46	0.48	7.95	1.30	1.25	2.15
22	0.63	0.52	0.23	0.29	0.31	0.29	0.46	0.46	2.89	1.30	0.94	1.53
23	0.43	2.15	0.37	0.29	0.32	0.28	0.46	0.70	1.45	0.94	0.79	1.06
24	0.43	0.63	0.40	0.29	0.28	0.25	0.50	1.62	1.45	1.22	0.99	1.06
25	0.43	0.32	0.30	0.29	0.29	0.25	0.37	1.62	1.45	1.07	0.71	1.06
26	0.43	0.29	0.30	0.25	0.29	0.25	0.63	1.62	1.04	0.90	0.85	0.97
27	0.34	0.26	0.30	0.23	0.29	0.41	0.40	1.62	0.80	0.81	0.85	0.56
28	0.34	0.26	0.32	0.25	0.29	0.41	0.54	1.62	0.79	0.81	0.85	0.65
29	0.29	0.26	0.37	0.24	0.36	0.39	0.54	1.56	0.65	0.81	0.62	0.56
30	0.49	0.60	0.40	0.24	0.88	0.37	0.54	0.90	0.59		0.62	0.50
31	0.49		0.46	0.24		0.36		0.74	0.59		0.87	
	======	======	======	======	======	======	======	======	======	======	======	======
Minimum	0.29	0.11	0.23	0.22	0.23	0.25	0.19	0.39	0.00	0.56	0.56	0.50
Maximum	1.18	2.15	1.41	0.71	1.27	1.87	1.16	1.62	62.87	9.08	11.08	4.72
Mean	0.61	0.38	0.61	0.34	0.48	0.76	0.45	0.75	3.32	1.70	1.81	1.48

Table B.4. Daily surface discharge summary May 1987 - April 1988
USGS Station: Site ID = GS1
(cfs)

Day	May 87	Jun 87	Jul 87	Aug 87	Sep 87	Oct 87	Nov 87	Dec 87	Jan 88	Feb 88	Mar 88	Apr 88
1	0.51	0.32	0.34	0.28	0.41	0.26	0.18	0.15	0.71	0.34	0.40	0.53
2	0.48	0.28	0.32	0.27	0.28	0.26	0.18	0.14	0.39	0.65	0.41	0.43
3	0.54	0.21	0.46	0.28	0.23	0.24	0.19	0.15	0.48	0.70	0.43	0.51
4	1.10	0.24	0.46	0.28	0.23	0.23	0.19	0.15	0.43	2.90	0.51	0.46
5	0.49	0.26	0.46	0.28	0.22	0.22	0.18	0.15	0.34	1.50	0.39	0.44
6	0.47	0.31	0.35	0.33	0.23	0.22	0.18	0.15	0.30	1.30	0.37	1.40
7	0.46	0.31	0.64	0.38	0.24	0.21	0.18	0.15	0.31	1.00	0.37	1.20
8	0.47	0.32	0.30	0.47	0.26	0.20	0.18	0.16	0.30	0.80	0.35	1.10
9	0.43	0.32	0.25	0.47	0.23	0.21	0.25	0.17	0.29	0.65	0.40	1.00
10	0.43	0.32	0.24	0.63	0.22	0.19	0.63	0.17	0.28	0.57	5.50	0.89
11	0.43	0.32	0.28	0.53	0.23	0.19	0.23	0.17	0.29	0.54	2.20	0.80
12	0.40	0.41	0.24	0.88	1.70	0.20	0.21	0.16	0.31	0.54	2.10	0.80
13	0.40	0.32	0.25	0.50	0.27	0.19	0.20	0.15	0.43	0.56	1.80	0.64
14	0.35	0.31	0.24	0.45	0.25	0.20	0.20	0.18	0.35	0.54	1.60	0.57
15	0.31	0.30	0.25	0.44	0.26	0.18	0.20	0.58	0.32	1.10	1.40	0.57
16	0.28	0.31	0.25	0.44	0.25	0.17	0.20	0.20	0.31	0.84	1.20	0.48
17	0.62	0.34	0.26	0.57	0.25	0.17	0.65	0.19	0.68	0.77	1.10	0.46
18	0.33	0.29	0.30	0.46	0.25	0.17	0.24	0.18	0.99	0.73	1.00	1.10
19	0.27	0.31	0.30	0.45	0.34	0.17	0.22	0.19	5.90	0.79	0.92	1.10
20	0.69	0.34	0.30	0.43	0.24	0.22	0.21	0.23	4.50	0.64	0.81	0.94
21	0.57	0.52	0.27	0.43	0.23	0.17	0.21	0.20	1.90	0.56	0.74	0.90
22	0.43	1.10	0.22	0.43	0.24	0.17	0.20	0.21	1.40	0.53	0.69	0.84
23	0.38	0.47	0.21	0.43	0.30	0.18	0.20	0.20	0.99	0.59	0.66	0.82
24	0.36	0.35	0.26	0.42	0.27	0.17	0.20	0.51	0.70	0.49	0.67	0.65
25	1.00	0.32	0.50	0.43	0.27	0.18	0.20	0.96	0.58	0.46	0.69	0.56
26	0.49	0.31	0.51	0.43	0.17	0.18	0.20	0.63	0.49	0.46	0.67	0.54
27	0.40	0.27	0.44	0.43	0.17	0.19	0.20	0.49	0.43	0.46	0.61	0.48
28	0.33	0.26	0.32	0.44	0.33	0.17	0.29	0.82	0.39	0.44	0.55	0.44
29	0.30	0.26	0.29	0.42	0.86	0.20	0.22	0.38	0.36		0.50	0.42
30	0.51	0.26	0.28	0.41	0.31	0.19	0.19	0.31	0.35		0.49	0.42
31	0.35		0.29	0.40		0.18		0.30	0.35		0.45	
	=====	=====	=====	=====	=====	=====	=====	=====	=====	=====	=====	=====
Minimum	0.27	0.21	0.21	0.27	0.17	0.17	0.18	0.14	0.28	0.34	0.35	0.42
Maximum	1.10	1.10	0.64	0.88	1.70	0.26	0.65	0.96	5.90	2.90	5.50	1.40
Mean	0.47	0.34	0.33	0.44	0.33	0.20	0.23	0.28	0.83	0.77	0.97	0.72

Table B.5. Daily surface discharge summary May 1987 - April 1988
USGS Station: Site ID = GS2
(cfs)

Day	May 87	Jun 87	Jul 87	Aug 87	Sep 87	Oct 87	Nov 87	Dec 87	Jan 88	Feb 88	Mar 88	Apr 88
1	0.12	0.02	0.00	0	0	0	0	0.00	0.33	0.07	0.10	0.12
2	0.10	0.02	0.00	0	0	0	0	0.00	0.22	0.20	0.10	0.16
3	0.12	0.01	0.01	0	0	0	0	0.00	0.11	0.48	0.10	0.16
4	0.59	0.01	0.01	0	0	0	0	0.00	0.22	4.80	0.17	0.18
5	0.14	0.02	0.01	0	0	0	0	0.00	0.11	1.40	0.12	0.12
6	0.10	0.01	0.03	0	0	0	0	0.00	0.07	0.62	0.10	0.84
7	0.09	0.01	0.23	0	0	0	0	0.00	0.07	0.41	0.08	0.62
8	0.07	0.01	0.03	0	0	0	0	0.00	0.06	0.28	0.07	0.35
9	0.06	0.00	0.01	0	0	0	0	0.00	0.06	0.21	0.09	0.24
10	0.05	0.00	0.01	0	0	0	0	0.00	0.05	0.17	14.00	0.19
11	0.04	0.00	0.01	0	0	0	0	0.00	0.05	0.14	2.10	0.17
12	0.04	0.00	0.01	0	0	0	0	0.00	0.05	0.15	1.60	0.21
13	0.03	0.00	0.00	0	0	0	0	0.00	0.05	0.10	2.10	0.16
14	0.03	0.00	0.00	0	0	0	0	0.00	0.05	0.10	1.20	0.13
15	0.03	0.00	0.00	0	0	0	0	0.02	0.05	0.62	0.70	0.14
16	0.02	0.00	0.00	0	0	0	0	0.01	0.05	0.52	0.46	0.15
17	0.31	0.01	0.00	0	0	0	0	0.01	0.08	0.33	0.35	0.12
18	0.15	0.01	0.00	0	0	0	0	0.00	1.30	0.26	0.32	0.99
19	0.06	0.01	0.00	0	0	0	0	0.00	12.00	0.31	0.29	1.20
20	0.05	0.01	0.00	0	0	0	0	0.01	14.00	0.28	0.23	0.71
21	0.07	0.02	0.00	0	0	0	0	0.01	1.30	0.19	0.19	0.45
22	0.08	0.16	0.00	0	0	0	0	0.00	0.57	0.17	0.17	0.31
23	0.04	0.08	0.00	0	0	0	0	0.00	0.32	0.20	0.13	0.28
24	0.03	0.03	0.00	0	0	0	0	0.01	0.22	0.18	0.13	0.21
25	0.02	0.02	0.00	0	0	0	0	0.15	0.18	0.14	0.13	0.16
26	0.03	0.01	0.00	0	0	0	0	0.14	0.11	0.13	0.13	0.13
27	0.03	0.01	0.00	0	0	0	0	0.16	0.10	0.13	0.11	0.11
28	0.03	0.00	0.00	0	0	0	0	0.45	0.09	0.11	0.10	0.10
29	0.01	0.00	0.00	0	0	0	0	0.14	0.07		0.10	0.09
30	0.03	0.00	0.00	0	0	0	0	0.06	0.07		0.10	0.07
31	0.04		0.00	0		0		0.05	0.07		0.09	
	======	=====	=====	=====	=====	=====	=====	=====	=====	=====	=====	=====
Minimum	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.07	0.07	0.07
Maximum	0.59	0.16	0.23	0.00	0.00	0.00	0.00	0.45	14.00	4.80	14.00	1.20
Mean	0.08	0.02	0.01	0.00	0.00	0.00	0.00	0.04	1.03	0.45	0.83	0.30

Table B.6. Daily surface discharge summary May 1987 - April 1988
USGS Station: Site ID = GS3
(cfs)

	Day	May 87	Jun 87	Jul 87	Aug 87	Sep 87	Oct 87	Nov 87	Dec 87	Jan 88	Feb 88	Mar 88	Apr 88
	1	7.2	6.8	7.1	6.4	5.6	5.6	5.5	5.8	9.8	6.8	6.8	7.5
	2	7.1	6.9	6.6	6.5	5.7	5.4	5.8	5.7	7.0	9.1	6.6	7.0
	3	7.3	6.8	7.6	6.6	5.8	5.2	5.5	5.4	7.5	9.5	6.6	7.3
	4	12.0	6.5	7.7	7.0	5.7	5.1	5.8	5.6	8.0	28.0	7.3	7.6
	5	8.1	6.4	8.3	7.0	5.6	5.4	5.5	5.3	6.5	14.0	6.3	7.0
	6	7.8	5.9	7.5	7.0	5.6	5.6	5.5	5.3	6.1	11.0	6.4	14.0
	7	7.7	6.0	11.0	6.9	5.6	5.6	5.0	5.7	6.2	9.6	6.4	9.9
	8	7.3	6.5	6.9	6.7	5.8	5.2	5.6	5.5	6.1	8.9	6.5	9.4
	9	7.0	6.5	6.7	6.2	5.6	5.3	5.9	5.4	5.8	8.2	6.8	8.6
	10	6.9	6.5	6.8	6.7	5.7	4.3	9.9	5.2	5.8	7.9	56.0	8.0
	11	7.1	6.6	6.5	6.0	5.7	4.9	6.0	5.1	5.8	7.7	22.0	7.6
	12	7.2	7.2	5.8	8.8	16.0	5.0	5.7	4.8	5.9	7.9	20.0	8.3
	13	7.0	6.5	5.9	6.7	6.3	5.1	5.8	4.8	7.5	6.9	18.0	7.3
	14	7.0	6.3	6.1	6.2	5.9	5.0	5.5	5.6	6.5	6.8	13.0	7.1
	15	7.0	6.3	5.9	5.7	5.9	5.0	5.5	9.5	6.3	11.0	11.0	7.2
	16	6.8	6.9	6.0	5.7	6.2	5.1	5.8	5.7	5.9	8.9	10.0	6.4
	17	10.0	8.0	6.2	6.6	6.2	4.3	9.7	5.1	8.7	8.2	9.3	6.2
	18	7.5	6.3	6.3	6.0	6.1	4.5	5.9	5.2	12.0	7.9	8.8	12.0
	19	7.5	6.5	6.0	6.0	6.8	4.9	5.5	5.4	49.0	8.6	8.3	10.0
	20	8.7	7.4	6.4	5.9	5.4	6.1	5.6	6.4	58.0	7.9	7.9	8.9
	21	9.1	8.2	6.7	6.0	5.3	5.2	5.3	5.8	15.0	6.7	7.8	9.0
	22	7.5	11.0	6.5	5.7	5.5	5.2	5.4	5.5	11.0	7.0	7.5	9.2
	23	6.4	7.7	6.9	5.7	5.5	5.2	5.4	5.2	9.5	7.8	7.3	9.4
	24	6.3	6.9	6.6	5.8	5.6	5.2	5.7	7.7	8.4	7.0	7.3	7.8
	25	9.3	6.5	6.6	5.8	5.5	5.0	5.9	12.0	8.1	7.0	7.3	6.8
	26	7.6	6.7	6.3	6.2	5.3	5.1	5.7	9.9	7.2	6.6	7.2	6.9
	27	6.9	6.3	6.5	6.4	5.4	5.5	5.4	8.5	7.0	6.7	6.4	6.9
	28	6.8	5.9	6.2	6.1	5.5	5.1	6.5	11.0	6.6	6.5	6.5	6.6
	29	6.8	6.1	6.3	5.8	8.7	5.6	6.0	7.3	6.5		6.5	6.2
	30	7.7	6.3	6.4	5.3	6.4	6.2	5.8	6.6	6.3		6.7	6.1
	31	6.9		6.8	5.6		6.1		6.2	6.7		6.5	
		=====	=====	=====	=====	=====	=====	=====	=====	=====	=====	=====	=====
MIN		6.3	5.9	5.8	5.3	5.3	4.3	5.0	4.8	5.8	6.5	6.3	6.1
Maximum		12.0	11.0	11.0	8.8	16.0	6.2	9.9	12.0	58.0	28.0	56.0	14.0
Mean		7.6	6.8	6.8	6.3	6.2	5.2	5.9	6.4	10.5	8.9	10.4	8.1

Table B.7. Daily surface discharge summary May 1987 - April 1988
USGS Station: Site ID = GS4
(cfs)

	Day	May 87	Jun 87	Jul 87	Aug 87	Sep 87	Oct 87	Nov 87	Dec 87	Jan 88	Feb 88	Mar 88	Apr 88
	1	0.64	0.69	0.74	0.77	0.56	0.64	0.75	0.71	1.10	0.64	0.68	0.78
	2	0.61	0.75	0.70	0.78	0.72	0.65	0.70	0.61	0.83	0.85	0.69	0.80
	3	0.65	0.81	0.72	0.81	0.76	0.61	0.53	0.63	0.81	1.00	0.66	0.79
	4	0.98	0.67	0.76	0.79	0.59	0.58	0.59	0.65	0.93	4.30	0.70	0.85
	5	0.65	0.66	0.76	0.81	0.58	0.60	0.61	0.59	0.72	1.80	0.62	0.80
	6	0.59	0.54	0.70	0.83	0.56	0.64	0.64	0.59	0.65	1.30	0.62	1.90
	7	0.57	0.54	0.89	0.73	0.57	0.66	0.58	0.61	0.67	1.00	0.61	1.40
	8	0.54	0.54	0.68	0.61	0.62	0.63	0.60	0.62	0.68	0.91	0.67	1.30
	9	0.54	0.54	0.71	0.61	0.58	0.67	0.67	0.68	0.61	0.81	0.71	1.00
	10	0.54	0.55	0.70	0.65	0.59	0.63	0.88	0.66	0.58	0.77	9.30	0.91
	11	0.55	0.59	0.72	0.61	0.64	0.63	0.64	0.65	0.64	0.75	3.00	0.88
	12	0.59	0.63	0.68	0.79	1.20	0.69	0.56	0.60	0.61	0.74	2.40	0.90
	13	0.58	0.62	0.66	0.63	0.58	0.54	0.56	0.59	0.67	0.71	2.60	0.84
	14	0.58	0.61	0.62	0.62	0.59	0.41	0.57	0.65	0.69	0.67	1.70	0.76
	15	0.64	0.57	0.64	0.57	0.60	0.58	0.58	0.89	0.68	1.20	1.40	0.79
	16	0.65	0.57	0.63	0.57	0.63	0.68	0.59	0.61	0.61	1.10	1.20	0.76
	17	0.78	0.62	0.64	0.66	0.60	0.65	0.90	0.60	0.90	0.94	1.00	0.77
	18	0.71	0.58	0.55	0.61	0.64	0.65	0.62	0.63	2.00	0.82	0.92	1.50
	19	0.73	0.58	0.54	0.59	0.63	0.65	0.59	0.56	8.50	0.92	0.84	1.50
	20	0.82	0.63	0.56	0.59	0.54	0.68	0.61	0.63	8.70	0.84	0.77	1.20
	21	0.70	0.66	0.71	0.61	0.55	0.62	0.54	0.57	2.00	0.73	0.74	1.10
	22	0.66	2.40	0.73	0.55	0.59	0.61	0.54	0.58	1.30	0.76	0.72	1.00
	23	0.65	0.94	0.71	0.54	0.62	0.63	0.56	0.52	1.10	0.76	0.72	0.98
	24	0.64	0.68	0.70	0.57	0.73	0.57	0.59	0.71	0.86	0.73	0.73	0.81
	25	1.30	0.69	0.58	0.57	0.80	0.59	0.61	1.30	0.80	0.70	0.73	0.77
	26	0.87	0.64	0.57	0.59	0.73	0.62	0.60	1.00	0.72	0.74	0.69	0.79
	27	0.69	0.61	0.58	0.59	0.65	0.62	0.58	0.90	0.70	0.66	0.65	0.77
	28	0.71	0.58	0.64	0.61	0.69	0.58	0.62	1.30	0.66	0.63	0.67	0.69
	29	0.78	0.61	0.72	0.55	0.90	0.61	0.58	0.81	0.66		0.71	0.70
	30	0.81	0.66	0.75	0.52	0.74	0.66	0.67	0.67	0.59		0.73	0.67
	31	0.77		0.80	0.57		0.74		0.69	0.62		0.75	
		=====	=====	=====	=====	=====	=====	=====	=====	=====	=====	=====	=====
MIN		0.54	0.54	0.54	0.52	0.54	0.41	0.53	0.52	0.58	0.63	0.61	0.67
Maximum		1.30	2.40	0.89	0.83	1.20	0.74	0.90	1.30	8.70	4.30	9.30	1.90
Mean		0.69	0.69	0.68	0.64	0.66	0.62	0.62	0.70	1.34	0.99	1.26	0.96

Table B.8. Daily surface discharge summary May 1987 - April 1988
USGS Station: Site ID = GS5
(cfs)

Day	May 87	Jun 87	Jul 87	Aug 87	Sep 87	Oct 87	Nov 87	Dec 87	Jan 88	Feb 88	Mar 88	Apr 88
1	3.4	3.0	3.3	2.2	2.4	2.5	3.3	2.8	5.6	3.0	3.1	3.6
2	3.4	3.0	3.1	2.2	2.4	2.3	3.2	2.8	3.8	4.7	3.1	3.1
3	3.7	2.9	3.8	2.3	2.4	2.2	2.9	2.8	4.2	5.1	3.1	3.4
4	6.8	2.9	3.8	2.4	2.4	2.2	3.0	2.7	4.1	18.0	3.7	3.3
5	3.6	2.8	4.3	2.5	2.4	2.3	3.0	2.7	3.6	8.4	3.1	3.0
6	3.5	2.7	3.7	2.6	2.5	2.4	2.9	2.7	3.4	6.4	3.0	7.0
7	3.5	2.6	5.9	2.4	2.6	2.4	2.6	2.7	3.3	5.3	2.9	5.0
8	3.2	2.8	3.3	2.2	2.8	2.3	2.8	2.7	3.2	4.7	2.9	4.6
9	3.1	2.8	3.0	2.2	2.7	2.2	3.2	2.7	3.1	4.3	3.2	4.1
10	3.0	3.0	2.9	2.5	2.6	1.7	6.0	2.7	3.0	4.0	36.0	3.9
11	3.0	3.0	2.9	2.2	2.7	2.0	3.2	2.7	3.0	4.0	14.0	3.8
12	3.0	3.8	2.7	4.3	11.0	2.2	3.0	2.4	3.0	4.0	11.0	4.3
13	3.1	3.1	2.7	2.8	3.2	2.3	2.9	2.4	3.9	3.5	11.0	3.7
14	3.0	2.9	2.6	2.4	2.9	2.3	2.9	2.7	3.4	3.3	8.4	3.4
15	2.9	3.0	2.5	2.2	2.8	2.3	2.8	5.2	3.2	5.8	6.8	3.7
16	2.8	3.6	2.6	2.3	2.8	2.2	2.8	2.9	3.1	4.4	5.7	3.2
17	5.3	4.2	2.6	2.9	2.8	1.7	5.1	2.7	5.0	4.0	4.9	3.0
18	3.2	3.1	2.4	2.5	2.8	1.7	2.6	2.7	6.7	3.8	4.6	6.1
19	3.0	3.1	2.4	2.4	3.6	2.6	2.3	2.7	29.0	4.5	4.1	5.5
20	3.8	3.6	2.6	2.3	2.8	3.8	2.6	3.0	34.0	3.9	3.8	4.6
21	4.8	4.4	2.7	2.4	2.7	3.0	2.7	2.8	9.4	3.7	3.6	4.5
22	3.4	4.3	2.6	2.3	2.5	3.0	2.7	2.8	6.6	3.7	3.5	4.3
23	2.9	3.3	2.6	2.3	2.5	2.8	2.8	2.8	5.2	4.1	3.4	4.3
24	2.8	3.1	2.5	2.3	2.4	2.7	2.7	4.4	4.5	3.7	3.2	3.7
25	4.3	3.0	2.2	2.4	2.4	2.7	2.7	7.0	4.2	3.6	3.3	3.5
26	3.2	3.0	2.2	2.5	2.4	2.8	2.7	5.3	3.9	3.4	3.3	3.4
27	3.0	2.8	2.4	2.6	2.5	3.2	2.7	4.6	3.7	3.2	3.0	3.3
28	2.9	2.7	2.4	2.6	2.5	3.1	3.4	6.2	3.5	3.1	3.0	3.1
29	3.0	2.8	2.3	2.4	4.9	3.7	2.9	3.9	3.3		2.9	2.9
30	3.8	2.9	2.3	2.3	3.1	3.7	2.7	3.4	3.1		2.8	2.8
31	3.1		2.3	2.4		3.4		3.2	3.0		2.8	
	=====	=====	=====	=====	=====	=====	=====	=====	=====	=====	=====	=====
Minimum	2.8	2.6	2.2	2.2	2.4	1.7	2.3	2.4	3.0	3.0	2.8	2.8
Maximum	6.8	4.4	5.9	4.3	11.0	3.8	6.0	7.0	34.0	18.0	36.0	7.0
Mean	3.5	3.1	2.9	2.5	3.0	2.6	3.0	3.3	5.9	4.8	5.6	3.9

Table B.9. Daily surface discharge summary May 1987 - April 1988
USGS Station: Site ID = GS6
(cfs)

Day	May 87	Jun 87	Jul 87	Aug 87	Sep 87	Oct 87	Nov 87	Dec 87	Jan 88	Feb 88	Mar 88	Apr 88
1	0.10	0.08	0.16	0.03	0.03	0.05	0.04	0.07	0.84	0.09	0.10	0.29
2	0.09	0.07	0.10	0.03	0.03	0.04	0.05	0.06	0.25	0.54	0.10	0.16
3	0.17	0.07	0.35	0.04	0.02	0.04	0.06	0.07	0.41	0.64	0.12	0.25
4	1.20	0.06	0.24	0.04	0.02	0.04	0.06	0.07	0.36	5.90	0.27	0.18
5	0.15	0.06	0.54	0.06	0.02	0.04	0.06	0.06	0.19	2.10	0.12	0.13
6	0.11	0.05	0.20	0.07	0.03	0.07	0.07	0.06	0.14	1.20	0.10	1.30
7	0.10	0.05	1.10	0.05	0.03	0.05	0.06	0.06	0.14	0.77	0.10	0.83
8	0.09	0.06	0.13	0.04	0.06	0.05	0.06	0.07	0.15	0.43	0.10	0.73
9	0.08	0.06	0.10	0.04	0.04	0.05	0.16	0.06	0.12	0.17	0.16	0.49
10	0.07	0.06	0.08	0.09	0.04	0.04	0.84	0.06	0.11	0.13	18.00	0.30
11	0.08	0.06	0.10	0.04	0.05	0.04	0.10	0.06	0.12	0.17	5.00	0.20
12	0.08	0.30	0.07	0.28	2.30	0.05	0.07	0.05	0.13	0.17	3.80	0.28
13	0.08	0.11	0.07	0.08	0.10	0.05	0.06	0.05	0.42	0.11	3.30	0.14
14	0.08	0.06	0.06	0.04	0.06	0.04	0.06	0.10	0.18	0.10	2.10	0.12
15	0.08	0.07	0.05	0.04	0.05	0.04	0.05	0.80	0.15	0.86	1.50	0.20
16	0.07	0.17	0.05	0.03	0.05	0.05	0.05	0.11	0.13	0.34	1.10	0.13
17	0.61	0.47	0.05	0.14	0.08	0.04	0.75	0.07	0.72	0.24	0.71	0.11
18	0.14	0.09	0.04	0.05	0.05	0.05	0.14	0.06	1.10	0.18	0.56	1.00
19	0.10	0.16	0.04	0.04	0.24	0.05	0.08	0.06	14.00	0.36	0.31	0.84
20	0.10	0.29	0.05	0.03	0.06	0.17	0.07	0.15	17.00	0.22	0.16	0.67
21	0.43	0.51	0.05	0.02	0.04	0.05	0.06	0.07	2.20	0.16	0.14	0.62
22	0.17	0.34	0.05	0.02	0.03	0.05	0.06	0.06	1.10	0.15	0.13	0.45
23	0.10	0.15	0.05	0.03	0.03	0.06	0.06	0.06	0.60	0.26	0.11	0.37
24	0.08	0.10	0.04	0.02	0.03	0.05	0.07	0.54	0.23	0.17	0.11	0.18
25	0.22	0.08	0.05	0.03	0.03	0.08	0.07	1.20	0.19	0.14	0.14	0.13
26	0.11	0.08	0.05	0.03	0.03	0.06	0.07	0.65	0.15	0.13	0.16	0.12
27	0.08	0.06	0.05	0.04	0.03	0.13	0.06	0.52	0.13	0.11	0.10	0.11
28	0.08	0.05	0.04	0.04	0.03	0.06	0.29	0.89	0.12	0.11	0.10	0.10
29	0.10	0.06	0.04	0.03	0.84	0.15	0.10	0.26	0.10		0.09	0.10
30	0.30	0.06	0.04	0.02	0.15	0.08	0.07	0.17	0.10		0.09	0.09
31	0.11		0.04	0.03		0.05		0.15	0.09		0.10	
	=====	=====	=====	=====	=====	=====	=====	=====	=====	=====	=====	=====
Minimum	0.07	0.05	0.04	0.02	0.02	0.04	0.04	0.05	0.09	0.09	0.09	0.09
Maximum	1.20	0.51	1.10	0.28	2.30	0.17	0.85	1.20	17.00	5.90	18.00	1.30
Mean	0.17	0.13	0.13	0.05	0.15	0.06	0.13	0.22	1.34	0.57	1.26	0.35

Table B.10. Daily surface discharge summary May 1987 - April 1988
Melton Branch tributary (east seven) near Oak Ridge: Site ID = GS16
USGS Site ID = 03537050
(cfs)

Day	May 87	Jun 87	Jul 87	Aug 87	Sep 87	Oct 87	Nov 87	Dec 87	Jan 88	Feb 88	Mar 88	Apr 88
1					0.00	0.01	0.00	0.00	0.19	0.06	0.05	0.07
2					0.00	0.00	0.00	0.00	0.13	0.13	0.05	0.11
3					0.00	0.00	0.00	0.00	0.06	0.31	0.05	0.10
4				0.00	0.00	0.00	0.00	0.00	0.15	3.00	0.10	0.12
5				0.00	0.00	0.00	0.00	0.00	0.07	0.67	0.09	0.09
6				0.00	0.00	0.00	0.00	0.00	0.05	0.33	0.07	0.60
7				0.00	0.00	0.00	0.00	0.00	0.05	0.26	0.06	0.45
8				0.00	0.00	0.00	0.00	0.00	0.05	0.15	0.05	0.26
9				0.00	0.00	0.00	0.00	0.00	0.05	0.12	0.07	0.18
10				0.00	0.00	0.00	0.02	0.00	0.05	0.09	6.80	0.14
11				0.00	0.00	0.00	0.00	0.00	0.05	0.08	1.00	0.12
12				0.00	0.01	0.00	0.00	0.00	0.05	0.09	0.83	0.15
13				0.00	0.00	0.00	0.00	0.00	0.05	0.07	1.20	0.12
14				0.00	0.00	0.00	0.00	0.01	0.05	0.05	0.54	0.09
15				0.00	0.00	0.00	0.00	0.02	0.05	0.36	0.32	0.10
16				0.00	0.00	0.00	0.00	0.02	0.05	0.32	0.23	0.11
17				0.00	0.00	0.00	0.01	0.01	0.05	0.21	0.17	0.09
18				0.00	0.00	0.00	0.00	0.01	1.00	0.17	0.16	0.67
19				0.00	0.00	0.00	0.00	0.01	4.40	0.20	0.16	0.73
20				0.00	0.00	0.00	0.00	0.01	4.50	0.19	0.12	0.41
21				0.00	0.00	0.00	0.00	0.01	0.62	0.13	0.10	0.27
22				0.00	0.00	0.00	0.00	0.00	0.30	0.10	0.09	0.18
23				0.00	0.00	0.00	0.00	0.00	0.20	0.13	0.08	0.17
24				0.00	0.00	0.00	0.00	0.01	0.15	0.13	0.07	0.12
25				0.00	0.00	0.00	0.00	0.13	0.14	0.10	0.07	0.08
26				0.00	0.00	0.00	0.00	0.09	0.13	0.09	0.08	0.07
27				0.00	0.00	0.00	0.00	0.09	0.12	0.08	0.07	0.05
28				0.00	0.00	0.00	0.01	0.15	0.11	0.07	0.06	0.04
29				0.00	0.01	0.00	0.01	0.07	0.10		0.05	0.04
30				0.00	0.02	0.00	0.00	0.03	0.09		0.04	0.03
31				0.00		0.00		0.02	0.09		0.04	
	======	======	======	======	======	======	======	======	======	======	======	======
Minimum	-	-	-	0.00	0.00	0.00	0.00	0.00	0.05	0.05	0.04	0.03
Maximum	-	-	-	0.00	0.02	0.01	0.02	0.15	4.50	3.00	6.80	0.73
Mean	-	-	-	0.00	0.00	0.00	0.00	0.02	0.42	0.27	0.42	0.19

Table B.11. Daily surface discharge summary May 1987 - April 1988
Melton Branch tributary(Center Seven) near Oak Ridge: Site ID = GS17
USGS SITE ID = 03537200
(cfs)

Day	May 87	Jun 87	Jul 87	Aug 87	Sep 87	Oct 87	Nov 87	Dec 87	Jan 88	Feb 88	Mar 88	Apr 88
1					0.96	1.00	1.00	1.00	0.11	0.02	0.02	0.03
2					0.95	0.99	1.00	1.00	0.07	0.05	0.02	0.03
3					0.95	0.99	1.00	1.00	0.05	0.08	0.02	0.03
4				1.00	0.94	0.98	1.00	1.10	0.07	0.92	0.04	0.03
5				1.00	0.94	0.98	1.00	1.00	0.04	0.22	0.03	0.03
6				1.00	0.94	0.98	1.00	1.00	0.04	0.09	0.02	0.17
7				1.00	0.95	0.99	1.00	1.00	0.04	0.06	0.02	0.16
8				1.00	0.96	0.98	1.00	1.00	0.04	0.05	0.02	0.09
9				0.99	0.98	0.98	1.00	1.00	0.04	0.04	0.03	0.06
10				1.00	0.98	0.98	1.10	1.00	0.04	0.03	2.30	0.04
11				0.99	0.98	0.97	1.00	1.00	0.04	0.03	0.31	0.04
12				0.99	1.10	0.97	1.00	1.00	0.03	0.04	0.23	0.05
13				1.00	1.00	0.97	1.00	1.00	0.03	0.03	0.34	0.04
14				0.99	0.99	0.97	1.00	1.00	0.03	0.03	0.17	0.03
15				0.99	0.99	0.96	1.00	1.10	0.03	0.10	0.10	0.04
16				0.99	0.99	0.96	1.00	1.10	0.02	0.09	0.06	0.04
17				0.99	0.99	0.96	1.10	1.10	0.08	0.07	0.05	0.03
18				1.00	0.99	0.96	1.10	1.10	0.40	0.06	0.04	0.15
19				0.99	1.00		1.00	1.00	2.00	0.07	0.04	0.21
20				0.99	1.00		1.00	1.10	2.10	0.05	0.04	0.14
21				0.98	0.99		1.00	1.10	0.20	0.04	0.03	0.09
22				0.98	0.99		1.00	1.00	0.09	0.04	0.03	0.05
23				0.98	0.98		1.00	1.00	0.06	0.04	0.03	0.04
24				0.97	0.98		1.00	1.10	0.04	0.04	0.03	0.04
25				0.97	0.97		1.00	1.20	0.04	0.03	0.03	0.03
26				0.96	0.97		1.00	1.20	0.03	0.03	0.03	0.03
27				0.96	0.97		1.00	1.20	0.03	0.03	0.03	0.02
28				0.96	0.96	1.00	1.10	1.20	0.03	0.03	0.02	0.02
29				0.97	0.99	1.00	1.10	1.20	0.02		0.02	0.02
30				0.96	1.00	1.00	1.10	1.10	0.02		0.02	0.01
31				0.96		1.00		1.10	0.02		0.02	
	======	======	======	======	======	======	======	======	======	======	======	======
Minimum	-	-	-	0.96	0.94	0.96	1.00	1.00	0.02	0.02	0.02	0.01
Maximum	-	-	-	1.00	1.10	1.00	1.10	1.20	2.10	0.92	2.30	0.21
Mean	-	-	-	0.98	0.98	0.98	1.02	1.06	0.19	0.09	0.14	0.06

Table B.12. Daily surface discharge summary May 1987 - April 1988
Melton Branch tributary (West Seven) near Oak Ridge: Site ID = GS18
USGS SITE ID = 03537300
(cfs)

Day	May 87	Jun 87	Jul 87	Aug 87	Sep 87	Oct 87	Nov 87	Dec 87	Jan 88	Feb 88	Mar 88	Apr 88
1					0.00	0.00	0.00	0.00	0.13	0.02	0.03	0.06
2					0.00	0.00	0.00	0.00	0.07	0.10	0.03	0.06
3					0.00	0.00	0.00	0.00	0.03	0.19	0.04	0.06
4					0.00	0.00	0.00	0.00	0.09	1.80	0.06	0.07
5					0.00	0.00	0.00	0.00	0.03	0.47	0.04	0.05
6					0.00	0.00	0.00	0.00	0.01	0.18	0.03	0.38
7					0.00	0.00	0.00	0.00	0.01	0.11	0.03	0.33
8					0.00	0.00	0.00	0.00	0.01	0.09	0.02	0.20
9					0.00	0.00	0.00	0.00	0.01	0.06	0.04	0.14
10					0.00	0.00	0.00	0.00	0.01	0.05	4.10	0.11
11					0.00	0.00	0.00	0.00	0.01	0.05	0.66	0.10
12					0.01	0.00	0.00	0.00	0.01	0.05	0.54	0.16
13					0.00	0.00	0.00	0.00	0.02	0.03	0.72	0.08
14					0.00	0.00	0.00	0.00	0.02	0.03	0.38	0.05
15					0.00	0.00	0.00	0.03	0.02	0.23	0.20	0.06
16					0.00	0.00	0.00	0.00	0.01	0.19	0.14	0.06
17					0.00	0.00	0.00	0.00	0.10	0.14	0.10	0.05
18					0.00	0.00	0.00	0.00	0.53	0.11	0.10	0.33
19					0.00	0.00	0.00	0.00	2.60	0.14	0.09	0.41
20					0.00	0.00	0.00	0.00	3.00	0.11	0.08	0.27
21					0.00	0.00	0.00	0.00	0.35	0.07	0.07	0.17
22					0.00	0.00	0.00	0.00	0.15	0.07	0.04	0.12
23					0.00	0.00	0.00	0.00	0.09	0.08	0.04	0.11
24					0.00	0.00	0.00	0.01	0.06	0.07	0.04	0.06
25					0.00	0.00	0.00	0.15	0.05	0.05	0.04	0.04
26				0.00	0.00	0.00	0.00	0.10	0.03	0.05	0.05	0.03
27				0.00	0.00	0.00	0.00	0.07	0.02	0.05	0.04	0.02
28				0.00	0.00	0.00	0.00	0.19	0.02	0.04	0.03	0.02
29				0.00	0.00	0.00	0.00	0.05	0.02		0.03	0.01
30				0.00	0.00	0.00	0.00	0.01	0.02		0.03	0.01
31				0.00		0.00		0.01	0.02		0.03	
	======	======	======	======	======	======	======	======	======	======	======	======
Minimum	-	-	-	0.00	0.00	0.00	0.00	0.00	0.01	0.02	0.02	0.01
Maximum	-	-	-	0.00	0.01	0.00	0.00	0.19	3.00	1.80	4.10	0.41
Mean	-	-	-	0.00	0.00	0.00	0.00	0.02	0.24	0.17	0.25	0.12

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