Geohydrologic and Water-Quality Assessment of the Fort Leonard Wood Military Reservation, Missouri, 1994–95

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U.S. GEOLOGICAL SURVEY
Water-Resources Investigations Report 96–4270

Prepared in cooperation with the
DIRECTORATE OF PUBLIC WORKS,
ENVIRONMENTAL DIVISION,
FORT LEONARD WOOD MILITARY RESERVATION

Rolla, Missouri
1996

U.S. DEPARTMENT OF THE INTERIOR

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ACRONYMS AND INITIALISMS

BTEX	Benzene-Toluene-Ethylbenzene-Xylene
CCD	Capitina-Clarksville-Doniphan
CFR	Code of Federal Regulations
DOD	U.S. Department of Defense
DPWED	Directorate of Public Works, Environmental Division
DRMO	Defense Reutilization Maintenance Office
FLW	Fort Leonard Wood
FLWMR	Fort Leonard Wood Military Reservation, also Base
FSP	Field Sampling Plan
GC-FID	Gas Chromatograph with Flame Ionization Detection
HACN	Hartville-Ashton-Cedargap-Nolin
IRP	Installation Restoration Program
MCL	Maximum Contaminant Level
MDGLS	Missouri Department of Natural Resources, Division of Geology and Land Survey
NCO	Non-Commissioned Officers
NVW	Needleye-Viraton-Wilderness
OB/OD	Open-Burn/Open-Detonation
OSHA	Occupational Safety and Health Act
PCB	Polychlorinated biphenyls
QA	Quality Assurance
QAPP	Quality-Assurance Project Plan
QC	Quality Control
RCRA	Resource Conservation and Recovery Act
SARA	Superfund Amendments and Reauthorization Act
STP	Sewage Treatment Plant
SWMU	Solid-waste management unit
USAEHA	U.S. Army Environmental Hygiene Agency
USAF	U.S. Air Force
USEPA	U.S. Environmental Protection Agency
USGS	U.S. Geological Survey
USMC	U.S. Marine Corps
VOC	Volatile organic compound
XAC	Explosives associated compound

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ABSTRACT

A coordinated regional geohydrologic and water-quality assessment of the Fort Leonard Wood Military Reservation (FLWMR) in south-central Missouri, has described geologic controls on ground-water flow at the FLWMR and provided a reliable data base of background ground- and surface-water quality. Ground-water levels and flow directions beneath the FLWMR are similar under conditions of high-base and low-base flow and have been modified from pre-karst conditions in the central and northeastern parts of the FLWMR by substantial karst development. Fractures commonly do not extend through the full thickness of bedrock formations and display little evidence of solution activity. Substantial dissolution of interbedded dolomitic material in the Roubidoux Formation has caused collapse of overlying sandstone-rich strata and provided large permeability pathways for ground-water flow. The catchment areas for Shanghai Spring and Miller Spring, discharge points for large volumes of water infiltrating upland areas at the FLWMR, are better delineated by dye-trace investigations conducted during the study. Stream-discharge measurements indicate that water in the Big Piney River and lower Roubidoux Creek near the FLWMR is almost entirely derived from tributary and spring inflow. The upstream-most reach of Roubidoux Creek on the FLWMR receives substantial ground-water recharge through its streambed.

Results of ground-water sampling indicate that the shallow ground water is vulnerable to contamination from surficial sources. Samples from several wells indicated human or animal wastes effects or nitrogen-containing fertilizers and contained detectable concentrations of pesticides. Volatile organic compounds detected in small concentrations in ground water include probable by-products of well chlorination (chloromethane, trichloromethane, bromomethane, bromodichloromethane, dibromochloromethane, and bromoform), total xylenes, methyltertiarybutylether, and non-target volatile organic compounds tentatively identified as dibromomethylbenzene, 1-bromo-3,5-dimethylbenzene, 4-bromo-1,2-dimethylbenzene, cyanogen chloride, 2-methylpropanal, pentanal, and 2,4-dimethyl heptane. No semivolatile organic compounds or explosives associated compounds were detected, but the pesticides diazinon, *p,p'*-DDE, and tebuthiuron were detected.

Two springs, Shanghai Spring and the pumping station spring, show probable septic contamination. Ballard Hollow Spring shows fecal coliform and fecal streptococcus bacteria contamination that may originate at a nearby horse stable. Shanghai Spring contains detectable concentrations of the volatile organic compound trichloromethane (possibly a preservative contaminant) and the pesticides prometon and simazine. Substantial concentrations of the volatile organic compound tetrachloroethene (PCE) also were detected. No surface-water samples

from streams exiting or bordering the FLWMR contained volatile or semivolatile organic compounds or explosives associated compounds. The pesticides tebuthiuron, atrazine, deethylatrazine, and *p,p'*-DDE were detected in the Big Piney River and a tributary. Small concentrations of octachlorodibenzoparadioxin (OCDD), a natural combustion product, were detected in streambed sediment.

INTRODUCTION

During 1980, the U.S. Department of Defense (DOD) devised a comprehensive Installation Restoration Program (IRP) to assess and to control the migration of environmental contamination that may have resulted from past operations or disposal practices at DOD facilities. The IRP underwent changes after the Superfund Amendments and Reauthorization Act (SARA) was passed during 1986. This Act requires federal facilities to adhere to guidelines and procedures set forth by the U.S. Environmental Protection Agency (USEPA) for the investigation and restoration of former disposal and spill sites. The long-range objectives of the IRP at the FLWMR are to assess the extent and magnitude of contamination at selected closed solid-waste management units (SWMUs).

During 1994, the Directorate of Public Works, Environmental Division (DPWED), FLWMR requested support from the U.S. Geological Survey (USGS) in a regional basewide geohydrologic and water-quality assessment and investigation of the quality of water at selected SWMUs at the FLWMR (fig. 1). The regional geohydrologic assessment was designed to characterize the geohydrologic framework of the FLWMR and provide the background hydrochemical data necessary to conduct and interpret more detailed investigations of contaminant distribution and movement near individual SWMUs. Specific objectives for the regional assessment were:

1) to determine regional ground-water flow directions and discharge locations in and bordering the FLWMR, and
2) to assess the current and background ground- and surface-water quality in and bordering the FLWMR.

The study area for the reconnaissance appraisal of the 17 selected SWMUs includes the immediate vicinity of each site and areas to which ground or surface water can readily migrate from the site. Preliminary site-specific investigations at 11 SWMUs (fig. 1) currently (1996) are completed on the FLWMR. Many leachate, ground- and surface-water, soil, and sediment samples have been collected from areas in and near these selected SWMUs. Investigations at six sites (FLW-006, FLW-012, FLW-013, FLW-014, FLW-015, and FLW-016) have been temporarily suspended and little data have been collected at these sites. The 17 sites selected for detailed study are:

FLW-002	Closed sanitary landfill 2
FLW-003	Closed sanitary landfill 3A
FLW-004	Closed sanitary landfill 3B
FLW-005	Closed sanitary landfill 3C
FLW-006	Closed sanitary landfill at ballfield
FLW-012	Closed sanitary landfill 10A
FLW-013	Closed sanitary landfill 10B
FLW-014	Closed sanitary landfill 11A
FLW-015	Closed sanitary landfill 11B
FLW-016	Closed sanitary landfill 11C
FLW-028	Directorate of Public Works old fire training area
FLW-030	Open-burn/open-detonation (OB/OD) area in range 24
FLW-032	Air National Guard cannon range open-burning, explosives associated compounds (XACs) burial area
FLW-037	Directorate of Public Works old pesticide storage building 2206
FLW-040	Ammunition container storage area
FLW-059	Closed sanitary landfill
FLW-060	Closed sanitary landfill

Purpose and Scope

This report presents the results of a coordinated geological, hydrological, and hydrochemical data-collection and data-analysis effort designed to characterize regional ground- and surface-water flow and quality at the FLWMR. The study was conducted from October 1994 to October 1995. The study area for geohydrologic assessment included the 64,000-acre FLWMR and bordering areas. The bordering areas of interest were areas east of the FLWMR between the military reservation and the Big Piney River, including the river (fig. 2); areas west of the FLWMR between the reservation and Roubidoux Creek, including the creek (fig. 2); and the small area north of the FLWMR between the Big Piney River and Roubidoux Creek, and south of Interstate 44 (figs. 1, 2).

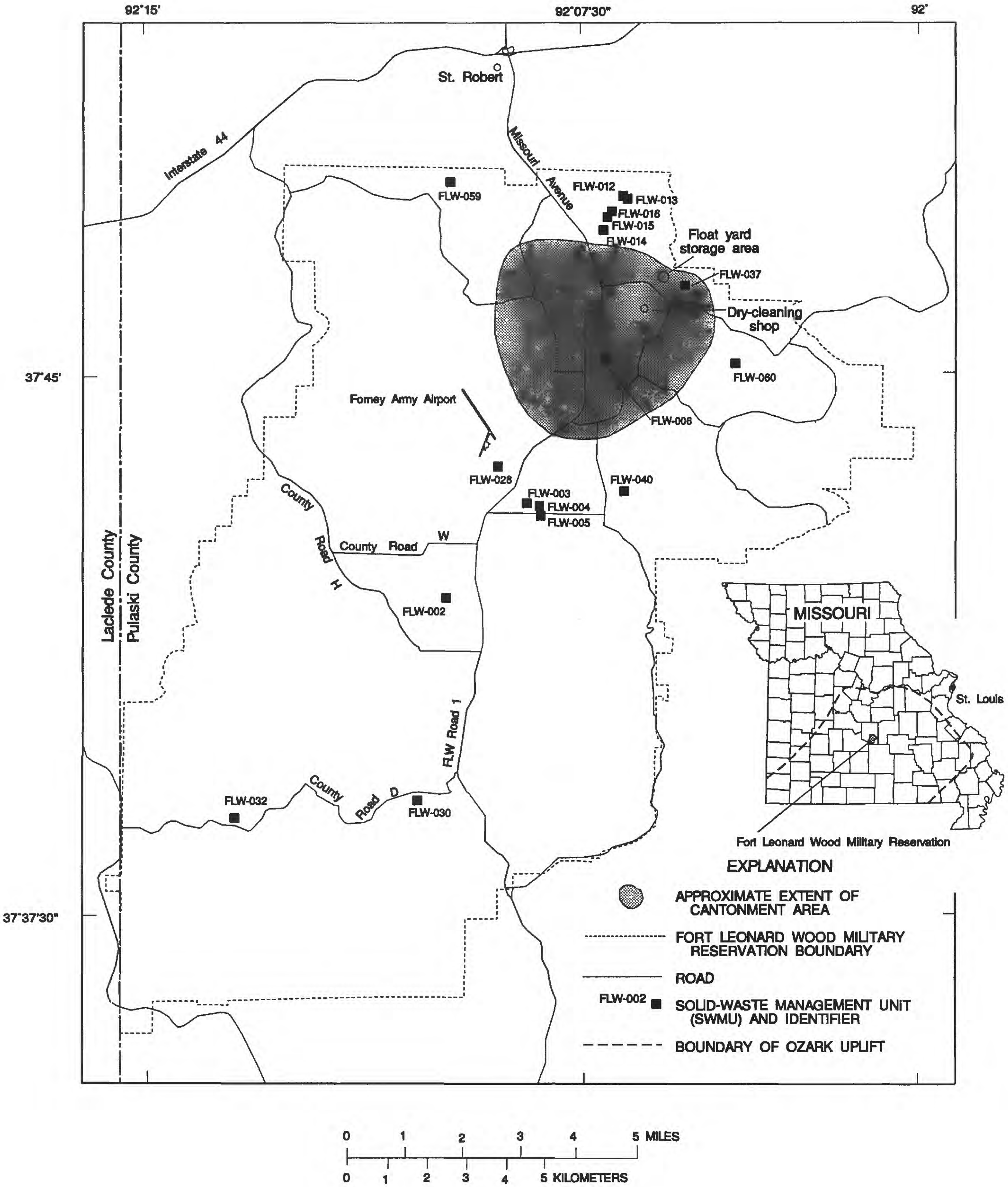
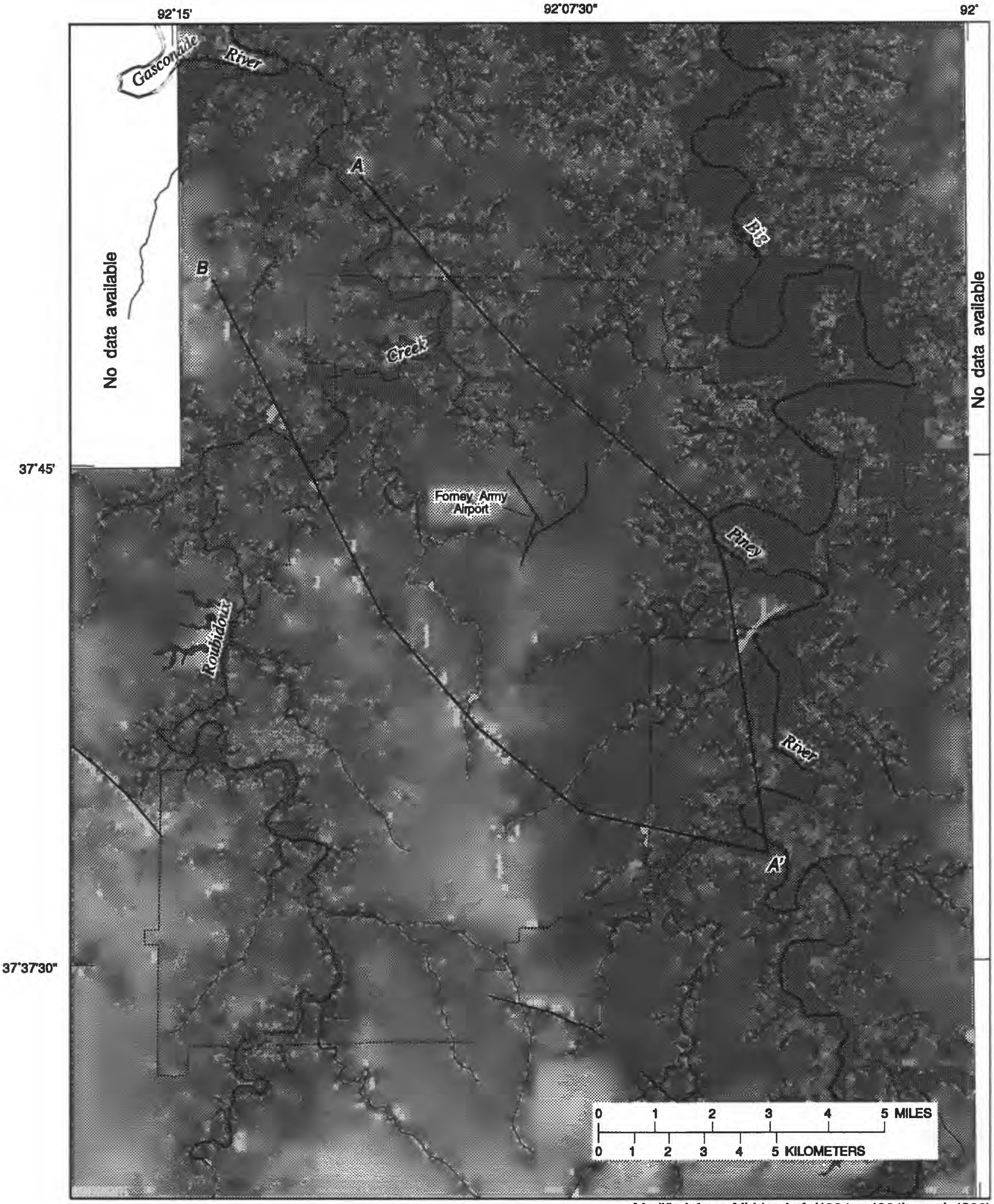


Figure 1. Location of the Fort Leonard Wood Military Reservation and 17 solid-waste management units identified as potential sources of ground- or surface-water contamination.



Modified from Middendorf (1984a, 1984b, and 1986) and Sumner and Easson (1986)

EXPLANATION

- JEFFERSON CITY DOLOMITE
- ROUBIDOUX FORMATION
- GASCONADE DOLOMITE
- FORT LEONARD WOOD MILITARY RESERVATION BOUNDARY
- FAULT
- *A-A'* TRACE OF GEOLOGIC SECTION

Figure 2. Bedrock geologic formations at the Fort Leonard Wood Military Reservation.

Regional ground-water flow directions were determined by developing potentiometric surface maps based on ground-water-level measurements in domestic and public-water-supply wells. Ground-water discharge was measured directly at the many springs that flow from karstic limestone and dolostone bedrock at the FLWMR and indirectly by measuring changes in surface-water flow rates for the Big Piney River, Roubidoux Creek, and their tributaries that drain the FLWMR. Ground-water, surface-water, and streambed material samples were collected from various locations at the FLWMR to define the water quality and the relation to the water quality of the immediate surrounding area. Sampling locations generally were chosen to represent the regional water quality at the FLWMR, rather than chosen to be representative of any specific area. Most of the sample sites characterize native or natural water quality. Site specific data for the SWMUs are not included in this regional geohydrologic report.

Fort Leonard Wood Military Reservation History and Facilities

The FLWMR is located in south-central Missouri (fig. 1), approximately 130 mi (miles) southwest of the city of St. Louis. The mission of the FLWMR primarily is combat troop training. It consists of approximately 64,000 acres of land, including a small aircraft landing strip, Forney Army Airport. The history of the FLWMR began during 1941 when it was opened for the training of combat troops in World War II. The FLWMR was closed during 1946 at the end of the war, but was re-opened in 1956 as a combat troop training center and engineering school.

Many facilities are concentrated in the cantonment area (fig. 1) that occupies the north-central part of the FLWMR. This area contains classrooms, barracks, recreation and shopping facilities, and support units. The remainder of the FLWMR contains large tracts of land set aside for small arms firing ranges, training areas for armored vehicles night maneuvers, an Air National Guard cannon and strafing range, and heavy equipment training areas. Currently (1996), the FLWMR is home to the 1st Engineer Brigade (Center), the 3rd Basic Training Brigade, the 43rd Adjutant General Battalion, and a Military Police Command.

The 1st Engineer Brigade (Center) provides support for Engineer Officer Basic and Engineer Officer Advanced Training Courses and includes an engineer combat battalion composed of two fire-fighting detachments, an evacuation hospital, a transportation company, an engineer pipeline company, an engineer company, and a quarry company. The 3rd Basic Training Brigade annually trains 20,000 initial-entry recruits and 4,000 combat engineers and provides support services for several Army Reserve Units. The 43rd Adjutant General Battalion supplies inprocessing services, training of Non-Commissioned Officers (NCO) through the Libby Non-Commissioned Officer Academy, basic NCO courses, advanced NCO courses, Drill Sergeant School, and Initial Entry Cadre Training.

Several tenant organizations operate on the FLWMR, including the Medical Department, which operates the General Leonard Wood Army Hospital, Dental Activity, Defense Printing Service, Testing and Evaluation Coordination Office, Defense Investment Service, Ordnance Disposal Detachment, Army Trial Defense Service, Resident Agency, U.S. Marine Corps (USMC) Administration Detachment, U.S. Air Force (USAF) Technical Training Group, U.S. Army Defense Reutilization Maintenance Office (DRMO), Commissary, Army Reserve Training Center, Army Readiness Group, Tactical Fighter Wing Detachment 1 of the Air National Guard, Engineer Housing Support Center, and Army Information Center.

Previous Investigations

Previous hydrologic investigations at the FLWMR have focused almost exclusively on chemical analyses of ground-water samples collected from monitoring wells installed near selected SWMUs. None of these studies have attempted to understand the regional ground-water and surface-water hydrology of the FLWMR or the geohydrologic settings of the SWMUs in relation to the regional hydrology.

During 1987 and 1988, the U.S. Army Environmental Hygiene Agency (USAEHA, 1988a) conducted an investigation of the effect of SWMUs FLW-002, FLW-003, FLW-004, and FLW-005 on ground water in nearby unconsolidated deposits. Seventeen shallow wells were drilled into the unconsolidated deposits to collect ground-water samples. Depth to the water table in the upland area commonly exceeds 100 ft (feet), which accounts for the observation that all 17 wells were dry in the fall and only 3 contained sufficient water to sample in the spring. The sampled water probably was water temporarily perched above less permeable sediments. One landfill leachate sample was collected. The report concludes that there was no adverse effects on ground-water in the unconsolidated deposits; however, two of four samples had concentrations of sodium [28 to 102 mg/L (milligrams per liter)] and chloride (37 and 97 mg/L) larger than expected background concentrations, indicating effects from landfill leachate.

A later study conducted by the USAEHA (1988b) documented and characterized 40 SWMU sites and concluded that sites FLW-002, FLW-003, FLW-004, FLW-005, FLW-022, FLW-028, FLW-030, FLW-032, and FLW-037 warranted additional environmental investigations. No monitoring-well drilling or water sampling was conducted during this study.

Three additional deeper monitoring wells ranging from 83 to 100 ft deep were installed around the perimeter of FLW-002 in 1990. Water levels in these wells ranged from 33 to 69 ft below land surface. No organic compounds were detected in water samples from these wells. Four additional deeper monitoring wells also were installed during 1990 around landfill FLW-003 and adjacent landfills FLW-004 and FLW-005 at depths of 57 to 103 ft. Only one well contained water and was sampled for trace elements, priority pollutant volatile organic compounds (VOCs), semivolatile organic compounds, pesticides, and polychlorinated biphenyls (PCBs). Organic compounds were not detected, but barium was detected at a concentration of 210 μg/L (micrograms per liter; U.S. Army Environmental Hygiene Agency, 1990).

During 1993, the USAEHA (1993) collected soil samples to characterize old fire training areas FLW-050, FLW-051, and FLW-052. Total petroleum hydrocarbon concentrations in 7 of 35 samples from FLW-050, 1 of 28 samples from FLW-051, and 1 of 15 samples from FLW-052 equaled or exceeded minimum detection limits of 4 μg/L. No sample contained benzene, toluene, ethylbenzene, or xylene (BTEX) in concentrations greater than 1 μg/L.

During 1993, the Radian Corporation (1993) completed a study of the float yard storage area, furniture repair shop satellite storage area, building 2563 battery acid storage area, and an open-burn/open-detonation (OB/OD) area in Cannon Range 36. Small concentrations of lead (Pb) were detected in soils, and odors from soil sample boreholes indicated the presence of VOCs at the float yard storage area. Surface soil samples at the furniture repair shop area contained Pb concentrations of 156 mg/kg (milligrams per kilogram), but it was unclear whether this concentration was significant as compared to natural background Pb concentrations in the residuum (Connor and Shacklette, 1975), which can be as large as 120 mg/kg. Volatile organic compounds also were detected in soils near the repair shop. Several XACs were detected in soil samples from the OB/OD area at Cannon Range 36. No evidence existed that the XACs were migrating offsite by overland runoff or had entered the ground-water system.

ENVIRONMENTAL SETTING

Climatology

The FLWMR area is characterized by a humid, temperate climate with warm, humid summers and cool, wet winters. The average annual temperature is 57 °F (degrees Fahrenheit). The recorded temperature extremes at the Forney Army Airport from 1963 to 1994 are a maximum of 109 °F (August 1980) and a minimum of -13 °F (December 1985). The average annual precipitation recorded at the airport is about 42 in. (inches; National Oceanic and Atmospheric Administration, 1951–80, 1994).

Physiography and Topography

The FLWMR occupies a large part of southern Pulaski County and a small part of eastern Laclede County in south-central Missouri. It is located within the Salem Plateau of the Ozark Plateaus Physiographic Province (Fenneman, 1938), an area characterized by a rugged terrain of thin soils and narrow steep-walled valleys. Most of the FLWMR is located on a broad ridge between the northerly flowing Big Piney River to the east and the northerly flowing Roubidoux Creek to the west (fig. 2). Tributary streams to the Big Piney River and Roubidoux Creek drain the upland areas and are deeply incised into the sides of the ridge.

Area relief generally is the result of gradual uplift of the Ozark Dome in southern Missouri and erosion of the uplifted rocks by precipitation runoff and streamflow. The regional land surface altitude ranges from about 1,150 ft above sea level along parts of the central ridge to about 750 ft above sea level at the Big Piney River near the northeastern boundary of the FLWMR. Roubidoux Creek is not as deeply incised, nor does it have as large a flow, as the Big Piney River. The altitude of Roubidoux Creek near the northwestern boundary of the FLWMR is about 780 ft above sea level.

Soil Types and Distribution

The U.S. Department of Agriculture, Soil Conservation Service (1979) has surveyed and mapped soils at the FLWMR. Surface soils at the FLWMR generally were formed over consolidated sandstone and cherty limestone bedrock deposits. Three general types of soils cover the FLWMR: the Needleye-Viraton-Wilderness (NVW), the Capitina-Clarksville-Doniphan (CCD), and the Hartville-Ashton-Cedargap-Nolin (HACN). The fragipan clay subsoils and soils, which are common to the area, contain a large clay content and can inhibit the downward movement of ground water in the unsaturated zone. Fragipan subsoils can locally alter the normal vertical movement of recharging ground water, causing the water to perch on top of the fragipan and flow laterally to more permeable vertical pathways or emerge at land surface as ground-water seeps.

The NVW soils, loamy upland soils with fragipans, commonly are along the nearly level to moderately steep central ridge of the FLWMR. These soils form in cherty limestone residuum and are characterized by a cherty silt loam surface soil overlying a moderately permeable cherty silty clay loam subsoil that is supported by an underlying massive compact brittle fragipan. The CCD soils are loamy upland soils that contain fragipan or are chert throughout. They commonly are on nearly level to extremely steep slopes between the central ridge of the FLWMR and the Big Piney River and Roubidoux Creek valleys. These soils form in cherty limestone and dolostone residuum and are characterized by a cherty silt loam surface soil overlying a massive compact brittle fragipan or moderately permeable clay subsoil. The HACN soils are poorly to excessively drained loamy bottom land soils commonly in the narrow Big Piney River and Roubidoux Creek valleys. These soils form in cherty limestone residuum and are characterized by a silt loam or cherty silt loam surface soil overlying a slowly to moderately permeable silt, silty clay, or cherty silt loam subsoil.

Most natural soils on the FLWMR have been altered extensively by construction and development on the FLWMR and ongoing training activities. In some large areas along the western flank of the central ridge, the surface soils and subsoils have been completely stripped or altered by years of heavy equipment training activities.

GEOHYDROLOGIC FRAMEWORK

The geohydrologic assessment of the FLWMR included a comprehensive geologic mapping program to identify fractures and faults and a less intensive effort to verify and refine existing bedrock geology maps. Onsite mapping was conducted by the USGS between November 1994 and May 1995. All onsite observations, data interpretations, and geologic mapping (compiled at 1:24,000 scale) are published separately from this report in Harrison and others (1996). The total mapped area was the approximate equivalent of three 7.5-minute quadrangle maps and generally extended from Interstate 44 to the southern boundary of the FLWMR and from Roubidoux Creek to the Big Piney River, including all parts of the FLWMR that are located outside of this general boundary. However, the geologic mapping program was centered on the FLWMR property and extended beyond the FLWMR property only to the extent necessary to support the mapping effort on the FLWMR property. Geologic descriptions in this report generally are condensed from the geologic mapping program and selected previous investigations. The reader is referred to Harrison and others (1996) for a more complete assessment of the geology of the FLWMR and a comprehensive set of observations made during the geologic mapping program.

Bedrock geologic formation maps (fig. 2) at the FLWMR were completed by the Missouri Department of Natural Resources, Division of Geology and Land Survey (MDGLS) in the mid 1980's. Bedrock geology maps of the southern two-thirds of the FLWMR were compiled at 1:62,500 scale (Middendorf, 1986; Sumner and Easson, 1986), and maps of the northern one-third were compiled at 1:24,000 scale (Middendorf, 1984a, 1984b). Because the focus of this study was on hydrology, not geology, no earnest attempt was made to refine these bedrock geology maps. However, as surficial expressions of bedrock contacts were observed onsite during fracture and fault mapping, the contacts were noted, and a revised bedrock geology map (Harrison and others, 1996) at 1:24,000 scale was produced that incorporated corrections and additions to the existing maps.

Mapping of fractures included identification and characterization of fracture sets and characterization of fractures by persistence, aperture, and solution activity (hydrologically active or inactive). At the beginning of the study a substantial component of ground-water flow at the FLWMR was assumed to be controlled by permeable zones associated with solution-enlarged fractures and bedding planes. Thus, a large part of the geologic assessment was directed toward developing a better understanding of these geologic features.

Structural Setting

A preliminary assessment of the geologic structural setting of the FLWMR was conducted before onsite observations were initiated to determine the general relation between structural features beneath the FLWMR and the regional structure of the Ozark Uplift of southern Missouri (fig. 1). This assessment was accomplished by review of previously published maps and articles on the geology of southern Missouri and by preparation of structure maps of the base of the Roubidoux Formation and base of the Gasconade Dolomite near the FLWMR. The data base of the altitudes for geologic formation contacts used to construct these maps was compiled from data on file at the MDGLS.

The Ozark Uplift of southern Missouri is part of a large rhyolite-granite basement complex that probably formed a continental divide in Late Precambrian time (Lidiak and others, 1966; Muehlberger and others, 1966, 1967). Through a series of depositional and erosional cycles extending from Cambrian to Pennsylvanian time, the oldest geologic formations in southern Missouri crop out in southeastern Missouri, and younger formations crop out in approximately concentric rings around the older core. Rocks of early Ordovician age are exposed at the FLWMR, which is located on the northern flank of a structural high extending from southeast Missouri to the southwestern corner of the State (McCracken, 1971). The most prominent regional structural feature at the FLWMR is an unnamed anticline expressed as a north-trending ridge in contoured altitudes of the top of the Roubidoux Formation (McCracken, 1971, plate 1).

Maps of regional structure features and contours on the base of the Gasconade Dolomite and base of the Roubidoux Formation were prepared during the geologic assessment of the FLWMR. The base of the Gasconade Dolomite (Harrison and others, 1996) is characterized by a low-altitude area in the central FLWMR area and an anticlinal ridge (maximum altitude about 750 ft above sea level) extending northward through the northeastern and eastern part of the FLWMR. The low-altitude area is mapped based on only a single measurement and may be anomalous. The southern FLWMR area contains a prominent northwest-southeast trending normal fault, interpreted to be a segment of a single regional fault, previously mapped as the Countyline Fault to the northwest and the Palace Fault to the southeast (fig. 3). The fault has a displacement in excess of 100 ft in some places. The Gasconade Dolomite is about 300 ft thick at the FLWMR.

The structure of the base of the Roubidoux Formation (Harrison and others, 1996) is quite similar to that of the underlying Gasconade Dolomite. With the addition of more available data for the shallower Roubidoux Formation, the isolated low-altitude area in central FLWMR appears as part of a narrow elongated basin extending northeast from the Countyline Fault. The southwestern boundary of the basin is the downthrown side of Countyline Fault. The prominent north-trending anticlinal ridge is evident at the base of the Roubidoux Formation and attains a maximum altitude of about 1,050 ft above sea level in the northern part of FLWMR. The thickness of the Roubidoux Formation is about 150 ft at the FLWMR.

One of several interesting observations noted during the onsite mapping was structural evidence for substantial dissolution of the more dolomitic parts of the Roubidoux Formation (Harrison and others, 1996). Bedding plane attitudes in the underlying Gasconade Dolomite are nearly horizontal throughout the FLWMR. Bedding plane attitudes in sandstone beds of the upper part of the Roubidoux Formation consistently reflect a pattern of narrow steep-sided folds. The large difference in attitudes as measured in the two formations is regarded as a result of the dissolution of dolomitic material in the lower part of the Roubidoux Formation and subsequent collapse of the overlying sandstone-rich beds. The nature of the collapse indicates that solution activity in the Roubidoux Formation is concentrated in interbedded dolostone in the lower part of the formation.

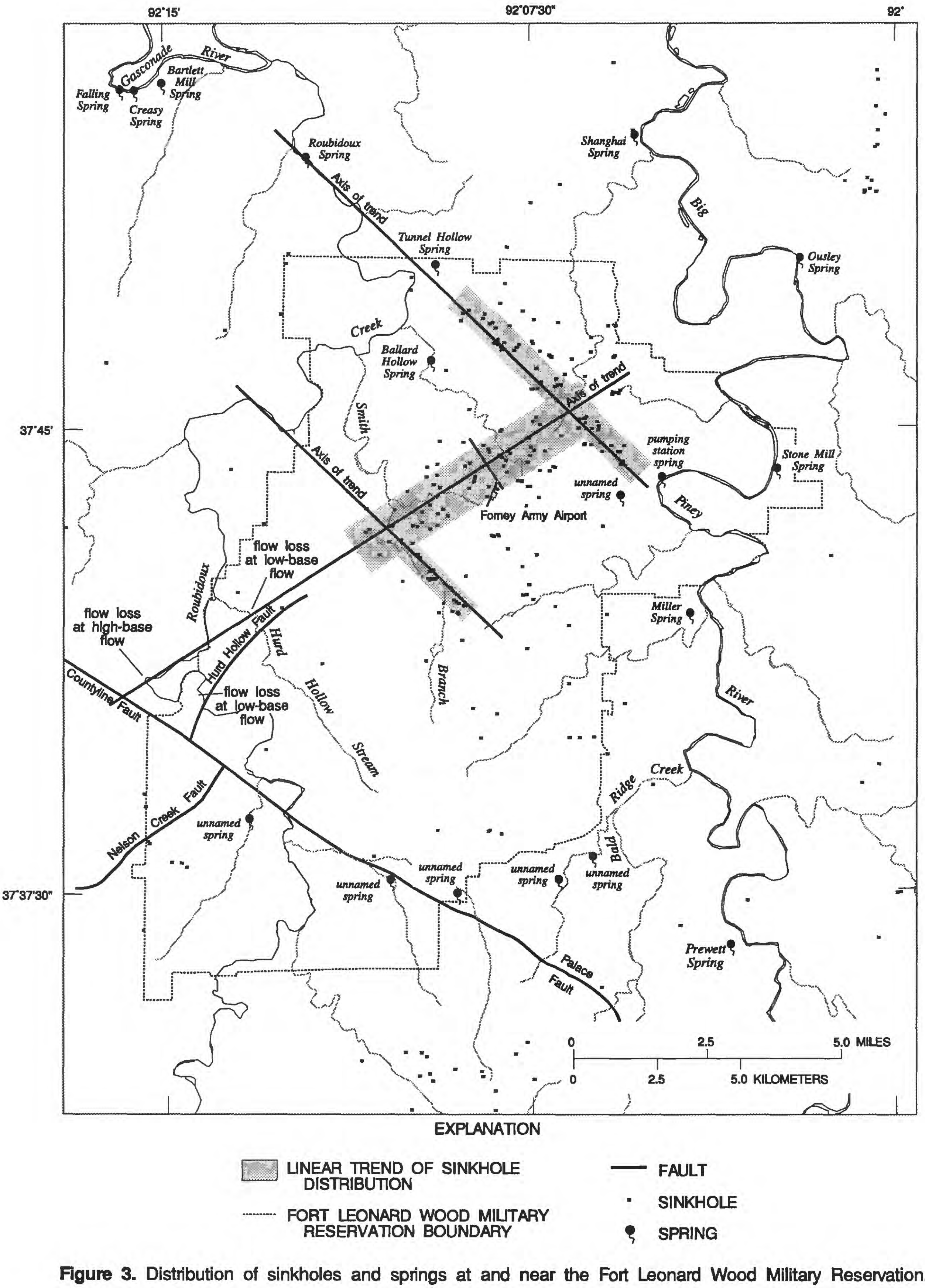


Figure 3. Distribution of sinkholes and springs at and near the Fort Leonard Wood Military Reservation.

Bedrock Geology and Stratigraphy

Bedrock geology of the FLWMR area consists of a sequence of three lower formations of Ordovician age of the Canadian Series. The Gasconade Dolomite, predominantly a cherty dolostone, is the oldest bedrock formation that crops out at the FLWMR. Exposures of Gasconade Dolomite (fig. 2) primarily are seen as bedrock bluffs along the Big Piney River and Roubidoux Creek valleys. The approximately 250-ft-thick lower part of the Gasconade Dolomite contains a sandstone unit, the Gunter Sandstone Member, that is persistent throughout most of southern Missouri, but is not exposed in the study area. The approximately 50-ft-thick upper dolomitic section of the formation grades from a coarsely crystalline dolostone with a large chert content to an overlying more finely crystalline dolostone with a small chert content. The upper part of the Gasconade Dolomite was observed to contain intraformational breccia horizons as much as 4 ft thick that probably are indicative of larger permeability zones and may be capable of rapidly transmitting large quantities of ground water. Most caves and larger springs in the study area are contained in the upper part of the Gasconade Dolomite.

The lithology of the overlying Roubidoux Formation ranges from sandstone to dolomitic sandstone and cherty dolostone. The Roubidoux Formation crops out (fig. 2) in upland areas and hillsides in the western, northern, and eastern parts of the FLWMR. Most of the observed sinkholes in the upland areas of FLWMR are formed in the Roubidoux Formation.

The youngest bedrock formation, the Jefferson City Dolomite, has a maximum thickness in the study area of about 200 ft and is exposed in the southern part of the FLWMR along the central upland ridge that trends north-south through the FLWMR midway between the Big Piney River and Roubidoux Creek (fig. 2). This finely crystalline argillaceous dolostone commonly contains shale partings and brecciated chert. Solution activity was not observed in any Jefferson City Dolomite outcrop. Small ground-water seeps are common near the base of the dolostone and probably are caused by the resistant basal Quarry Ledge[1]. The beginning of flow in the headwaters of some small streams may be associated with the contact between the Roubidoux Formation and Jefferson City Dolomite.

Two geologic sections that trend northwest-southeast across the central and northern parts of the FLWMR (fig. 4) show substantial stream entrenchment resulting from erosion of the Gasconade Dolomite and younger rocks by the Big Piney River and Roubidoux Creek. Beneath the Gasconade Dolomite, but not exposed in the FLWMR area, are the Eminence and Potosi Dolomites, Derby-Doe Run Dolomite, Davis Formation, Bonneterre Formation, and Lamotte Sandstone, all overlying Precambrian basement rocks. Most recharge at FLWMR probably does not flow into these deeper formations. The Potosi Dolomite is a massive thick-bedded dolostone that is vuggy and contains quartz druse. This formation is a source of ground water for municipalities throughout southern Missouri, and several public-supply wells in the FLWMR area are completed in the formation. The Potosi Dolomite is separated from the Gasconade Dolomite by the Eminence Dolomite, which commonly is less karstic and, therefore, less permeable than either the Potosi Dolomite or Gasconade Dolomite.

Modern stream valleys at and near the FLWMR, primarily the Big Piney River and Roubidoux Creek, contain thin alluvial deposits. This alluvium consists of both sorted and unsorted accumulations of sand, silt, gravel, and clay.

Fracture Patterns and Karst Features

The permeability of limestone and dolostone bedrock geologic formations that underlie the FLWMR has been greatly increased by dissolution. Evidence of the magnitude of dissolution is shown by the numerous, irregular, small folds with steep attitudes and the numerous sinkholes that have been created in the Roubidoux Formation by collapse of overburden into solution-enlarged cavities. Preliminary concepts of ground-water flow at the FLWMR assumed that solution-enlarged fracture systems were responsible for the observed patterns of sinkhole development and that conduit systems created from solution-enlarged intersecting fractures directed ground water to major springs. Therefore, the main emphasis of the geologic mapping program was to determine the density and properties of fractures in the FLWMR area. Specific physical properties measured during onsite observations included fracture orienta-

[1]Terminology is that of the Missouri Division of Geology and Land Survey.

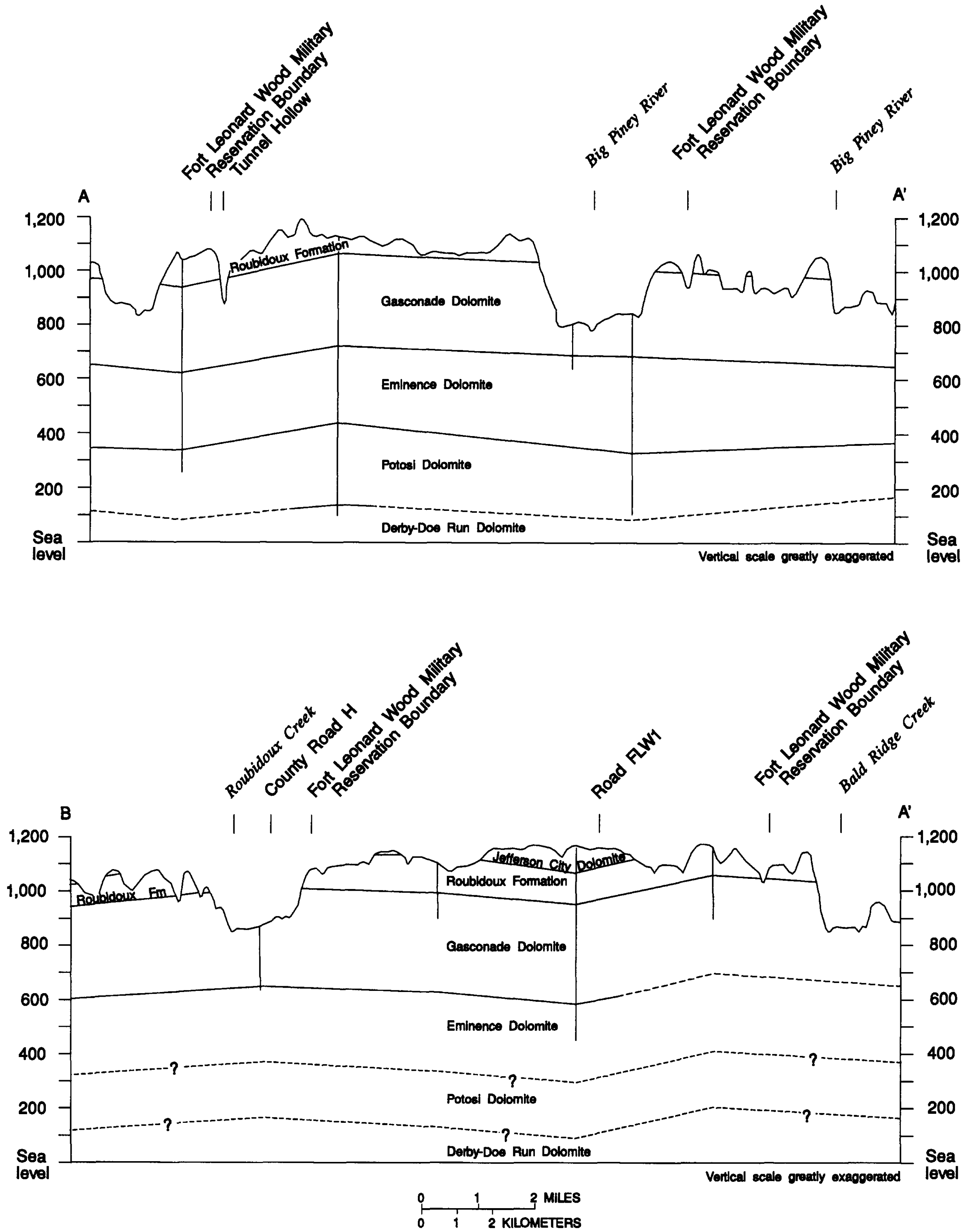


Figure 4. Generalized geologic sections trending northwest to southeast across the Fort Leonard Wood Military Reservation (the traces of sections A-A' and B-A' are shown in figure 2).

tion and persistence and a characterization of fractures as hydraulically active or inactive based on evidence of solution activity in the fracture.

Before this study, fracture flow was thought to be the method by which recharge in upland areas of the FLWMR was transported rapidly through the Jefferson City Dolomite and Roubidoux Formation to the larger springs that flow from openings in the upper part of the Gasconade Dolomite. Onsite observations of hundreds of fractures at the FLWMR (Harrison and others, 1996) revealed that less than 10 percent of fractures in the Jefferson City Dolomite and less than 5 percent of fractures in the Roubidoux Formation extend through the entire thickness of the formations (through-going). About 10 percent of fractures in the Gasconade Dolomite are through-going. A larger density of through-going fractures are located near Roubidoux Creek and Smith Branch in the northwestern part of FLWMR where stream channels seem to be strongly controlled by fractures. Bedrock-formation fracture patterns display preferred orientations locally (fracture domains), but apparently neither through-going nor non-through-going fractures in the FLWMR area display a strong preferred regional orientation.

Of all observed fractures, only about 4.5 percent in the Jefferson City Dolomite, about 1.5 percent in the Roubidoux Formation, and about 20 percent in the Gasconade Dolomite show evidence of solution activity (Harrison and others, 1996). Fracture sets exhibiting solution activity have a pronounced northeast orientation. Conduit flow may have developed in some of these fractures. However, about 98 percent of all observed fractures have narrow (less than 0.5 in.) apertures and show no evidence of secondary mineralization. These observations, combined with evidence of extensive dissolution of interbedded dolostone in the lower part of the Roubidoux Formation and the fact that nearly 45 percent of all observed Gasconade Dolomite outcrops showed evidence of bedding-plane-controlled caves, solution cavities, or vugs, lead to the conclusion that much of the water discharged at large springs is transported along high-permeability pathways within solution-enlarged bedding planes rather than fractures.

An inventory of typical karst features such as springs, seeps, losing streams, sinkholes, and caves was conducted during the regional geohydrologic assessment to help develop a more complete concept of ground-water flow. One observation, resulting from the compilation of sinkhole location data from USGS 7.5-minute topographic maps, high-resolution digital contour data for the FLWMR, and onsite observations, is that many of the sinkholes located in the north-central part of the FLWMR are distributed along a 1-mi-wide linear trend oriented northeast to southwest (fig. 3). The major axis of this band of sinkholes is parallel to and in line with a 1.5-mi-long linear segment of Roubidoux Creek within a reach of the creek characterized by a sequence of near right-angle shifts in flow direction and complete flow loss. The axis also intersects Hurd Hollow Stream at the point of flow loss. The occurrence of abrupt changes in stream channel directions, a linear stream segment, flow loss in two streams, and a linear band of sinkholes oriented along a common line strongly indicates an area of substantial hydrologic control by fractures.

The mapping of fractures resulted in the identification of previously unmapped faults that presumably are the cause of the lost surface-water flow in Roubidoux Creek and Hurd Hollow Stream. The faults are the previously mentioned extension of Countyline Fault into the southern FLWMR and Hurd Hollow Fault, which intersects the Countyline Fault at a steep angle in the vicinity of flow loss at low-base flow in Roubidoux Creek. The Hurd Hollow Fault extends northeast from the Countyline Fault into the interior of the FLWMR and crosses Hurd Hollow near the point of flow loss in Hurd Hollow Stream (Harrison and others, 1996; fig. 3). The mapping also identified the intersection of two smaller faults, a probable extension of Nelson Creek Fault and Hurd Hollow Fault, with the larger Countyline Fault.

Two narrower bands of sinkholes with major axes oriented northwest to southeast also are evident in figure 3. Extensions of the major axes of these bands also intersect near-linear segments of Roubidoux Creek northwest of the FLWMR. One of the bands also extends along a near-linear 1-mi-long reach of Smith Branch. These features also are indicative of fracture or fault control, but no direct evidence has been found that links these features to a common structure.

GROUND-WATER HYDROLOGY

Ground-water resources of the region primarily are associated with the Ozark Plateaus aquifer system, consisting of consolidated sediments of Cambrian through Ordovician age (Imes and Emmett, 1994). Ground-water supplies near the FLWMR are from wells that are completed in the Ozark aquifer, the middle aquifer of the Ozark Plateaus aquifer system. Although the lower few tens of feet of the Jefferson City Dolomite can be saturated locally at the FLWMR, the formation normally is unsaturated. The underlying Roubidoux Formation, Gasconade Dolomite, and Potosi Dolomite commonly are productive water-bearing formations. The upper part of the Eminence Dolomite commonly is a massive dolostone containing few vugs or solution features and probably forms a weak hydraulic barrier to vertical ground-water flow between the Gasconade Dolomite and Potosi Dolomite.

Recharge to the aquifer primarily is by percolation of precipitation through permeable residuum and bedrock. Ground-water flow in the aquifer mainly is controlled by regional topography, but local anomalies on the regional flow system are produced by flow through solution-enlarged openings in the karst bedrock. Karst features commonly are well developed in the Gasconade Dolomite and Potosi Dolomite. The presence of karst features can substantially alter the movement of ground water from flow patterns commonly associated with rocks of more uniform permeability. Because of the areal extent and the permeability of the aquifer, water-supply wells are numerous and productive. Wells completed in the Roubidoux Formation-Gasconade Dolomite rock sequence commonly yield from several tens of gallons per minute to several hundreds of gallons per minute (Melton, 1976). Wells completed in the Potosi Dolomite are capable of yielding from several hundred gallons per minute to as much as 1,000 gal/min (gallons per minute; Fuller and others, 1967).

General directions of ground-water movement beneath the FLWMR were determined by mapping the water table or potentiometric surface associated with underlying geohydrologic units using measured water levels in wells. Domestic and public-supply wells were inventoried before and during the time ground-water-level measurements were made, and well construction data were collected where possible. Water levels were measured in existing production wells, previously drilled SWMU monitoring wells, and domestic wells. Many water levels were measured in areas bordering the FLWMR to supplement the few water-level measurements available from wells located within the FLWMR. The measurements were made twice, once during seasonal high-base flow conditions and once during seasonal low-base flow conditions. Most measured water levels were from wells completed in the Roubidoux Formation-Gasconade Dolomite rock sequence. Only a few wells are completed in the Potosi Dolomite; consequently, there are insufficient data to map the potentiometric surface of ground water in the Potosi Dolomite.

Ground-Water Levels—High-Base Flow

Water-level measurements were made in domestic and public-water-supply wells located in the general FLWMR area from November 2 to December 2, 1994, to provide a set of measurements representing ground-water levels during high-base flow conditions. Water levels in six additional wells were measured in the winter and spring of 1995 to complete the data base. Approximately 120 homes and businesses were visited during the survey; however, water levels were measured in only 60 wells because of the inability to gain access to some wells. These measured values of depth to water and the computed water-level altitudes are listed in table 1.

The high-base flow regional ground-water levels between the Big Piney River and Gasconade River (fig. 5) primarily represent hydraulic conditions in the Roubidoux Formation-Gasconade Dolomite rock sequence. A few measurements that represent water levels in the underlying Eminence Dolomite and Potosi Dolomite or a weighted average of water levels in the Roubidoux Formation, Gasconade Dolomite, and underlying Eminence and Potosi Dolomites also are incorporated into the map (for example, measurements from dw 015 and dw 065, table 1).

Water levels exhibit a distinct transition in character between the southern and the northern part of the mapped area. In the southern one-half of the mapped area, water levels generally are higher along the major recharge areas on topographic ridges and are lower toward discharge areas in the major river valleys. The higher levels in the upland areas are supported by the percolation of rainwater through the soil and unsaturated zone of the upland areas. The rate of ground-water flow away from the upland recharge areas is determined by the bedrock permeability. Ground-water flow is perpendicular to the contour lines of equal hydraulic head, or water-level altitude, and is directed to regional streams where the ground water discharges. The slight offset of the regional ground-water divide between the Big Piney River and Roubidoux Creek west of the regional topographic divide

Table 1. Water-level measurements made in selected domestic and public-supply wells during high-base and low-base flow conditions at and near the Fort Leonard Wood Military Reservation

[ddmmss, degrees, minutes, seconds; x-coord, x coordinate; y-coord, y coordinate; --, no data; all depths in feet below land surface]

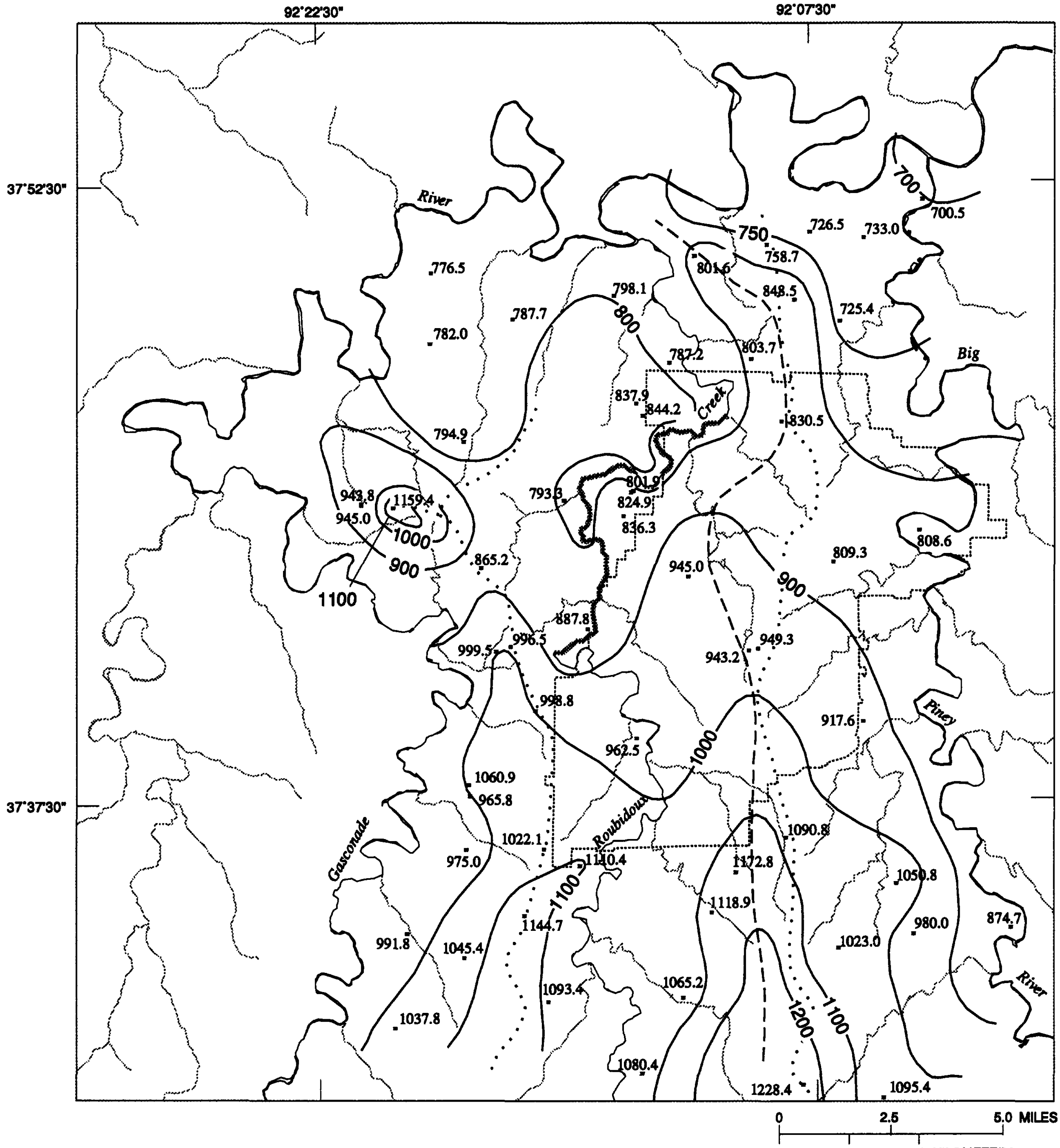
			State plane zone 4426				High-base flow			Low-base flow		
Well number	Latitude (ddmmss)	Longitude (ddmmss)	x-coord	y-coord	Land-surface altitude (feet above sea level)	Well depth (feet)	Date (month-day-year)	Depth to water (feet)	Water-level altitude (feet above sea level)	Date	Depth to water (feet)	Water-level altitude (feet above sea level)
dw 001	375203	0920402	624929	740842	830	230	11–02–94	129.5	700.5	08–29–95	124.6	705.4
dw 002	375114	0920729	608351	735814	795	240	11–02–94	68.5	726.5	10–12–95	68.3	726.7
dw 003	375105	0920549	616375	734937	1,010	395	11–02–94	277.0	733.0	08–30–95	273.4	736.6
dw 004	375056	0920848	602022	733969	1,065	--	11–03–94	306.3	758.7	08–30–95	304.3	760.7
dw 005	375040	0921102	591280	732312	992	350	11–03–94	190.4	801.6	08–30–95	189.6	802.4
dw 006	375018	0921909	552221	729983	1,031	360	11–04–94	254.5	776.5	08–31–95	252.7	778.3
dw 007	374943	0921331	579345	726509	1,010	320	11–04–94	211.9	798.1	08–30–95	210.5	799.5
dw 008	374935	0920758	606064	725792	1,075	341	11–03–94	226.5	848.5	08–30–95	217.5	857.5
dw 009	374910	0921638	564350	723131	1,031	--	11–04–94	243.3	787.7	08–31–95	241.7	789.3
dw 010	374904	0920634	612817	722683	1,035	--	11–22–94	309.6	725.4	08–30–95	309.8	725.2
dw 011	374835	0921911	552081	719565	1,105	496	11–04–94	323.0	782.0	08–31–95	321.0	784.0
dw 012	374809	0920918	599678	717069	1,075	390	11–10–94	271.3	803.7	08–30–95	274.0	801.0
dw 013	374805	0921149	587561	716622	795	110	11–10–94	7.8	787.2	08–31–95	8.2	786.8
dw 014	374706	0921251	582603	710639	1,025	400	11–10–94	187.1	837.9	08–31–95	191.5	833.5
dw 015	374638	0920823	604128	707881	1,122	--	12–02–94	291.5	830.5	08–31–95	327.3	794.7
dw 016	374612	0921810	557006	705111	1,050	--	11–09–94	255.1	794.9	08–31–95	260.7	789.3
dw 017	374458	0921258	582080	697691	873	260	01–27–95	71.1	801.9	08–30–95	83.3	789.7
dw 018	374456	0921302	581760	697488	880	175	01–27–95	55.1	824.9	08–30–95	61.2	818.8
dw 019	374445	0921506	571803	696347	905	--	11–09–94	111.7	793.3	08–28–95	117.4	787.6
dw 020	374442	0922120	541765	695980	1,095	--	11–22–94	151.2	943.8	08–28–95	151.5	943.5

Table 1. Water-level measurements made in selected domestic and public-supply wells during high-base and low-base flow conditions at and near the Fort Leonard Wood Military Reservation—Continued

			State plane zone 4426				High-base flow			Low-base flow		
Well number	Latitude (ddmmss)	Longitude (ddmmss)	x-coord	y-coord	Land-surface altitude (feet above sea level)	Well depth (feet)	Date (month-day-year)	Depth to water (feet)	Water-level altitude (feet above sea level)	Date	Depth to water (feet)	Water-level altitude (feet above sea level)
dw 021	374440	0922120	541765	695778	1,100	--	11–22–94	155.0	945.0	08–28–95	155.0	945.0
dw 022	374436	0922021	546505	695381	1,235	--	11–22–94	75.6	1,159.4	10–12–95	75.6	1,159.4
dw 023	374422	0921316	580645	694045	1,052	490	02–09–95	215.7	836.3	08–30–95	195.0	857.0
dw 024	374358	0920412	624353	691783	870	--	12–01–94	61.4	808.6	08–29–95	65.9	804.1
dw 025	374313	0920651	611502	687193	1,100	--	12–01–94	290.7	809.3	08–31–95	280.0	820.0
dw 026	374308	0921739	559536	686506	1,200	500	11–09–94	334.8	865.2	08–28–95	327.0	873.0
dw 027	374253	0921117	590234	685074	1,090	--	03–31–95	145.0	945.0	--	--	--
dw 028	374138	0921423	575310	677443	910	55	11–22–94	22.2	887.8	08–31–95	32.2	877.8
dw 029	374113	0921646	563822	674885	1,230	--	11–28–94	233.5	996.5	08–28–95	226.0	1,004.0
dw 030	374107	0920910	600478	674389	1,120	290	12–01–94	170.7	949.3	08–30–95	168.2	951.8
dw 031	374106	0921713	561654	674172	1,100	220	11–28–94	100.5	999.5	08–28–95	94.8	1,005.2
dw 032	373939	0921601	567463	665386	1,195	--	11–28–94	196.2	998.8	08–28–95	192.0	1,003.0
dw 033	373919	0920558	615959	663527	1,078	--	11–22–94	160.4	917.6	08–31–95	158.1	919.9
dw 034	373857	0921255	582432	661179	1,125	--	12–01–94	162.5	962.5	08–30–95	164.2	960.8
dw 035	373750	0921805	557516	654339	1,112	100	11–28–94	51.1	1,060.9	08–31–95	49.9	1,062.1
dw 036	373734	0921803	557680	652721	1,035	154	11–28–94	69.2	965.8	10–11–95	70.0	965.0
dw 037	373630	0920822	604444	646387	1,190	--	11–22–94	99.3	1,090.8	10–11–95	87.3	1,102.7
dw 038	373616	0921547	568641	644857	1,273	--	11–28–94	250.9	1,022.1	08–30–95	250.5	1,022.5
dw 039	373616	0921810	557133	644831	1,075	--	11–29–94	100.0	975.0	08–29–95	100.8	974.2
dw 040	373551	0921441	573958	642343	1,173	--	11–29–94	62.6	1,110.4	08–30–95	61.0	1,112.0
dw 041	373540	0920954	597060	641303	1,326	--	11–22–94	153.2	1,172.8	--	--	--

Table 1. Water-level measurements made in selected domestic and public-supply wells during high-base and low-base flow conditions at and near the Fort Leonard Wood Military Reservation—Continued

Well number	Latitude (ddmmss)	Longitude (ddmmss)	State plane zone 4426		Land-surface altitude (feet above sea level)	Well depth (feet)	High-base flow			Low-base flow		
			x-coord	y-coord			Date (month-day-year)	Depth to water (feet)	Water-level altitude (feet above sea level)	Date	Depth to water (feet)	Water-level altitude (feet above sea level)
dw 042	373522	0920500	620729	639577	1,182	--	11–09–94	131.2	1,050.8	08–29–95	133.2	1,048.8
dw 043	373442	0921039	593458	635424	1,185	--	11–22–94	66.1	1,118.9	08–30–95	64.0	1,121.0
dw 044	373439	0921624	565687	635039	1,312	--	11–28–94	167.3	1,144.7	08–29–95	160.0	1,152.0
dw 045	373416	0920131	637585	632981	939	--	11–09–94	64.3	874.7	08–30–95	62.9	876.1
dw 046	373414	0922000	548303	632474	1,000	--	11–29–94	8.2	991.8	08–29–95	8.2	991.8
dw 047	373409	0920429	623258	632205	1,195	--	11–08–94	215.0	980.0	08–29–95	211.8	983.3
dw 048	373349	0920647	612156	630134	1,222	--	11–10–94	199.0	1,023.0	08–29–95	197.0	1,025.0
dw 049	373338	0921815	556764	628850	1,085	--	11–28–94	39.6	1,045.4	08–29–95	38.4	1,046.6
dw 050	373238	0921133	589152	622868	1,172	--	11–22–94	106.8	1,065.2	08–30–95	111.7	1,060.3
dw 051	373233	0921541	569181	622304	1,191	--	11–29–94	97.6	1,093.4	08–30–95	96.3	1,094.7
dw 052	373156	0922023	546476	618514	1,115	--	11–29–94	77.2	1,037.8	08–29–95	75.7	1,039.3
dw 054	373048	0921249	583065	611723	1,142	--	11–09–94	61.6	1,080.4	10–11–95	71.2	1,070.8
dw 055	373030	0920753	606921	609986	1,370	--	11–08–94	141.6	1,228.4	08–30–95	142.0	1,228.0
dw 056	373012	0920546	617161	608207	1,145	--	11–08–94	49.6	1,095.4	08–29–95	36.2	1,108.8
dw 057	372947	0920545	617253	605679	1,225	--	11–10–94	137.7	1,087.3	--	--	--
dw 058	372938	0920316	629265	604823	1,250	300	11–08–94	151.2	1,098.8	08–29–95	182.7	1,067.3
dw 059	372737	0920606	615616	592524	1,410	--	11–10–94	181.2	1,228.8	08–30–95	175.5	1,234.5
dw 060	374303	0921402	576973	686044	898	126	--	--	--	08–31–95	93.2	804.8
dw 064	374312	0920648	611862	687100	1,092	630	--	--	--	08–31–95	263.8	828.2
dw 065	374104	0920926	599193	674081	1,144	692	01–24–95	200.8	943.2	10–11–95	208.3	935.7
dw 066	374648	0921239	583572	708821	900	340	01–31–95	55.8	844.2	08–30–95	53.8	846.2



EXPLANATION

FORT LEONARD WOOD MILITARY RESERVATION BOUNDARY

WATER-LEVEL CONTOUR--Shows altitude of water table, Fall 1994 and winter and spring 1995. Dashed where approximately located. Contour interval is variable. Datum is sea level

STREAM--Shaded reach is dry except during substantial runoff events

GROUND-WATER DIVIDE

TOPOGRAPHIC DIVIDE

1037.8 MEASURED GROUND-WATER LEVEL--Number is altitude in feet

Figure 5. Altitude of shallow ground-water levels at and near the Fort Leonard Wood Military Reservation during high-base flow conditions.

indicates that bedrock permeability generally may be larger in the Big Piney River Basin. Ground-water levels south of the FLWMR are greater than 1,100 ft above sea level between the Big Piney River and Roubidoux Creek valleys and between the Gasconade River and Roubidoux Creek valleys. Apparently, all three streams receive ground-water discharge in this part of the mapped area.

In the central part of the FLWMR, the regional ground-water divide is as much as 2 mi west of the regional topographic divide. The large lateral separation between the ground-water and topographic divides indicates a substantially larger bedrock permeability in the east-central part of the FLWMR than in the west-central part. Evidence for this increased permeability is the unusually low water level (809.3 ft above sea level) measured in the old ammunition dump well (dw 025) and the large concentration of sinkholes (fig. 3) that indicate the presence of a well-developed karst terrane throughout the central and northeastern parts of the FLWMR. The major effects of the secondary permeability zone are to redirect ground water that normally would have flowed westward to Roubidoux Creek eastward to the Big Piney River and to redirect ground water that would have flowed eastward to the Big Piney River more northward toward Shanghai Spring. More evidence of this flow pattern will be presented during the discussion of dye-trace investigations and streamflow measurements. Water-level contours in the extreme north-central part of the FLWMR are more typical of an area where flow is not dominated by karst; that is, flow is east and west from a ground-water divide that is beneath the regional topographic divide. However, karst features are not absent from this area.

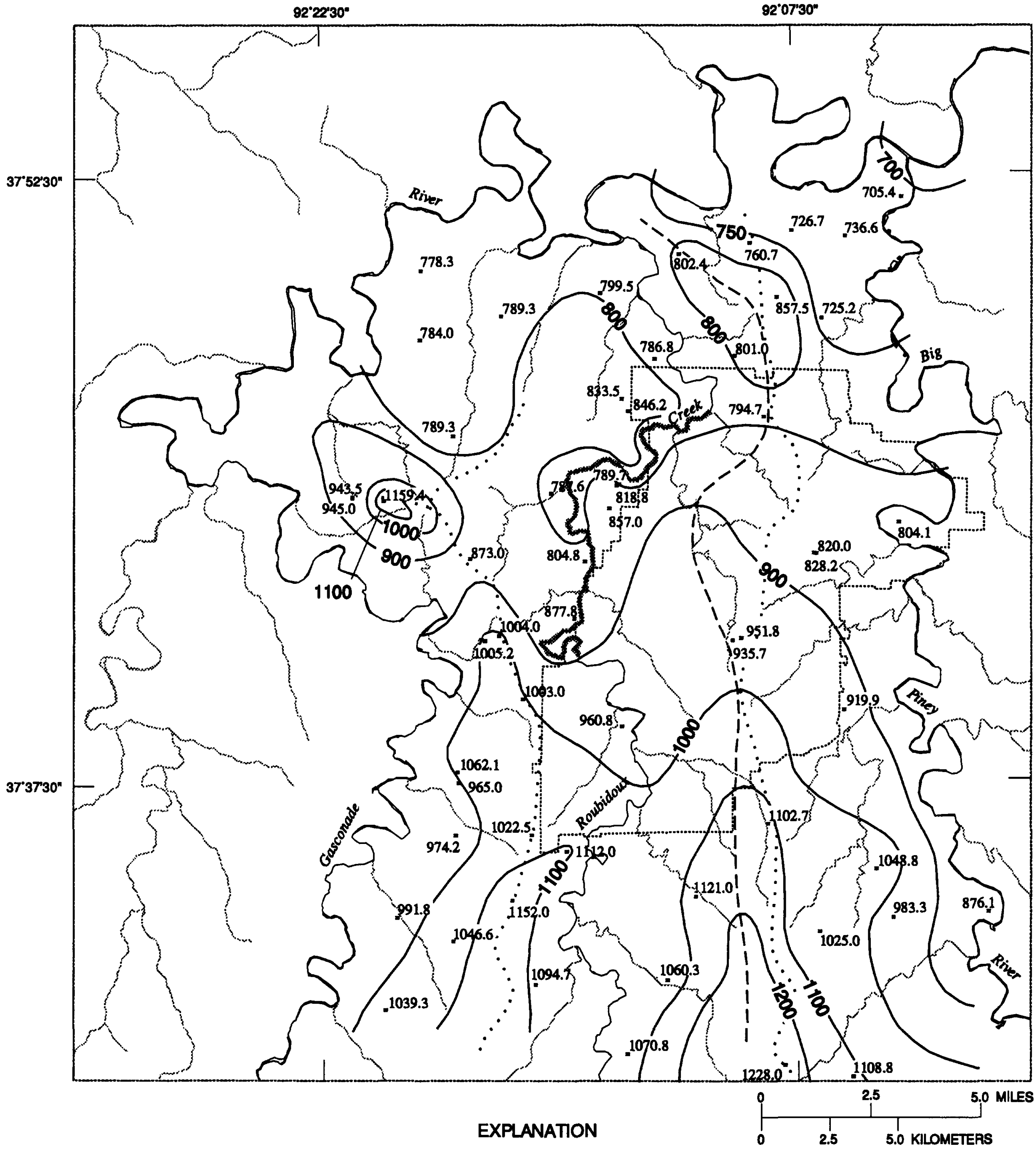
The small oval-shaped mound of ground water about 5 mi west of the FLWMR probably is caused by the presence of low permeability material in the topographically high area centered on the mound. The single measured water level (1,159.4 ft above sea level) on which the contoured mound primarily is based is more than 200 ft above water levels measured in nearby wells. Although the depth of this well is not known, it is likely that the well is shallow (perhaps less than 100 ft deep) and the water-level measurement is not representative of hydraulic heads in the lower part of the Roubidoux Formation and Gasconade Dolomite. Water levels north of the mound are low (less than 800 ft above sea level) and quite uniform throughout an area that includes a major topographic ridge and the Gasconade River valley. The water levels exhibit a small northward gradient toward the Gasconade River. The presence of such a uniform water-level surface within an area of large relief (about 400 ft) indicates a substantial increase in bedrock permeability consistent with greatly enhanced bedding-plane permeability by widespread dissolution of one or more carbonate beds. The enhanced permeability alters surface-water flow in the Gasconade River and is observable using dye-trace investigations. Evidence of the effect of the increased permeability on flow patterns will be presented during the discussion of dye-trace investigations and streamflow measurements.

Ground-Water Levels—Low-Base Flow

Water-level measurements were made during low-base flow conditions in selected domestic and public-water-supply wells from August 28 to August 31, 1995. Water levels in six additional wells were measured October 11 and 12, 1995, to complete the data base. Depth-to-water measurements and the computed water-level altitudes during low-base flow conditions are listed in table 1.

The mapped low-base flow regional ground-water levels (fig. 6) primarily represent hydraulic conditions in the Roubidoux Formation-Gasconade Dolomite rock sequence and differs little from the mapped ground-water-level measurements during high-base flow conditions (fig. 5). The most notable difference between these two sets of measurements is that the water levels during low-base flow conditions within and near the northern FLWMR boundary are about 35 ft lower than water levels during high-base flow conditions. The character of the water-level surface in this area is almost solely based on measurements in the main supply well for the FLWMR (Indiana Avenue well, dw 015). Water-level measurements typically are taken only after the pump has been turned off for about one-half hour or more. The much lower water level measured in well dw 015 during low-base flow conditions possibly represents the regional effect of the operating well during a period of increased water use, not the direct effect of dryer climatic conditions.

Lower water levels (about 10 ft) also were measured during low-base flow conditions in two wells in the Roubidoux Creek valley. The lower level may be caused by decreased ground-water flow into the extremely permeable rock beneath the dry stream channel in this part of the valley and continued north-



EXPLANATION

FORT LEONARD WOOD MILITARY RESERVATION BOUNDARY

WATER-LEVEL CONTOUR--Shows altitude of water table, August and October 1995. Dashed where aproximately located. Contour interval is variable. Datum is sea level

STREAM--Shaded reach is dry except during substantial runoff events

GROUND-WATER DIVIDE

TOPOGRAPHIC DIVIDE

1094.7 MEASURED GROUND-WATER LEVEL--Number is altitude in feet

Figure 6. Altitude of shallow ground-water levels at and near the Fort Leonard Wood Military Reservation during low-base flow conditions.

ward drainage of the water through large fractures and conduits. However, in general, most measured ground-water-level changes from high- to low-base flow conditions were small, especially in upland areas. A possible explanation is that ground-water storage in the karst terrane is large and the system has the capacity to supply substantial quantities of water to discharge points, such as springs, for sustained periods of decreased rainfall.

Vertical Ground-Water Flow

Three well pairs included in the regional ground-water-level survey provide an opportunity to estimate vertical hydraulic-head differences at these locations. The wells comprising each well pair are located within a few hundred feet of one another and are completed in different geologic formations. Wells dw 017 and dw 018 (table 1) are located at the west-central border of the FLWMR and were drilled about 200 ft apart; well dw 018 is completed in the middle part of the Gasconade Dolomite and well dw 017 in the lower part of the Gasconade Dolomite. During high-base flow conditions, the water level in the shallower well was about 20 ft higher than levels in the deeper well (824.9 and 801.9 ft above sea level). During low-base flow conditions, the water level in the shallower well was about 30 ft higher than the level in the deeper well (818.8 and 789.7 ft). The vertical hydraulic gradient in this area was downward to the base of the Gasconade Dolomite.

Another well pair is located at an ammunition dump in the east central part of the FLWMR (table 1, wells dw 025 and dw 064). These wells are about 100 ft apart. The exact depth of the shallower well is not known; however, the well is reported to have been drilled a short distance into the Eminence Dolomite (about 400 ft deep). The deeper well was completed at 630 ft in the Potosi Dolomite and was cased to 488 ft (middle part of the Eminence Dolomite). Because the deeper well was drilled after the water-level measurements were completed during high-base flow conditions, only water levels during low-base flow conditions were obtained at the well. Under low-base flow conditions, water levels in the shallower well were about 8 ft lower than levels in the deeper well (820.0 and 828.2 ft). The vertical hydraulic gradient in this area was upward from the Potosi Dolomite to the Gasconade Dolomite. However, in this part of the FLWMR, water levels in the Roubidoux Formation and Gasconade Dolomite are relatively low because the large permeability caused by dissolution of the carbonate rock in this area effectively drains ground water rapidly to nearby springs. In the absence of such a well-developed karst terrane, the vertical gradient possibly would be downward.

The third well pair is located in the south-central FLWMR (table 1, wells dw 030 and dw 065). These wells are located about 1,300 ft apart. The depth of the shallower well is 290 ft and is cased to 82 ft deep. This well is completed in the middle part of the Gasconade Dolomite. The deeper well was completed to a depth of 692 ft in the Potosi Dolomite and was cased to 295 ft (also in the middle part of the Gasconade Dolomite). Unfortunately for this analysis, the deeper well is open to both the Gasconade Dolomite and Potosi Dolomite, and a clear distinction between water levels in the two formations cannot be made. During high-base flow conditions, water levels in the shallower well were about 6 ft higher than levels in the deeper well (949.3 and 943.2 ft). During low-base flow conditions, water levels in the shallower well were about 16 ft higher than levels in the deeper well (951.8 and 935.7 ft). The vertical hydraulic gradient in this broad upland apparently was downward from the Gasconade Dolomite to the Potosi Dolomite.

Based on the scant data available and by comparison with regional ground-water flow patterns and flow patterns in nearby areas of similar geologic conditions, vertical hydraulic gradients generally are thought to be downward from the Gasconade Dolomite to the Potosi Dolomite in the FLWMR area. These gradients probably are small. Where the highly permeable karst terrane in the Roubidoux Formation and Gasconade Dolomite rapidly transports ground water through conduits to local points of discharge (springs), hydraulic heads in these formations are lowered and can locally be lower than heads in the Potosi Dolomite. In these local areas, vertical hydraulic gradients can be upward into the Gasconade Dolomite.

Dye-Trace Investigations of Fracture and Conduit Flow

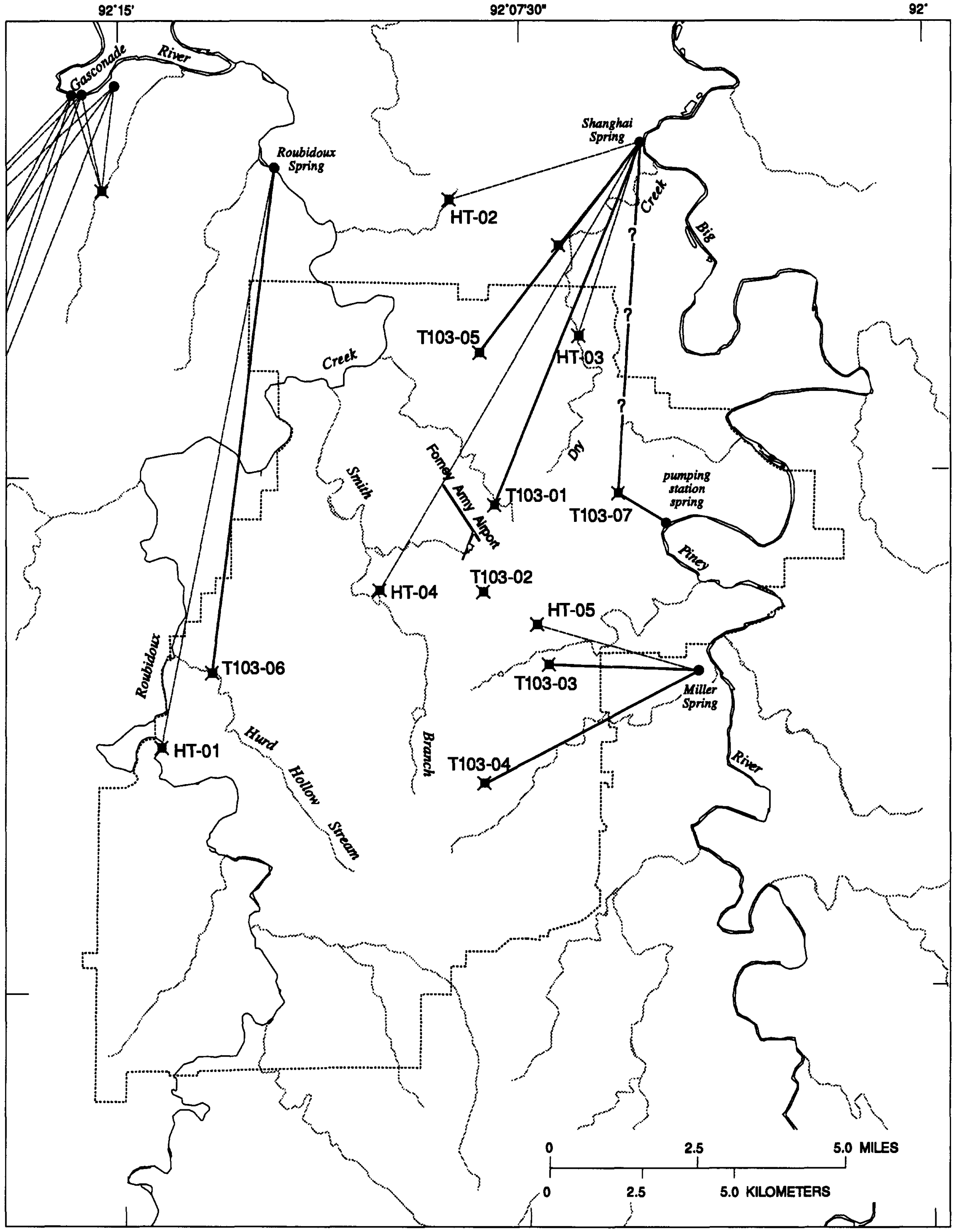
Ground-water flow at the FLWMR is a complex combination of flow through porous residual material and bedrock and flow through hydraulically active fractures and along solution-enlarged openings between bedding planes. Ground-water flow in a hydrologic system of this complexity often is difficult to fully understand based solely on potentiometric data. The small number of water wells on the FLWMR and low density of accessible water wells around the FLWMR relative to the large size of the study area make the construction of detailed and accurate potentiometric maps difficult. Dye-tracing techniques were, therefore, used to supplement water-level measurements and provide direct evidence of hydraulic connectivity between specific ground-water recharge areas, such as sinkholes, and major ground-water discharge points, such as springs. Dye-trace investigations are a valuable method of determining ground-water flow directions and rates in a karst terrane and for delineating spring catchment areas.

At least five dye-trace tests are known to have been conducted in or near the FLWMR before this study began. These tests are labeled HT-01 to HT-05 on figure 7. The injection point for dye-trace test HT-01 (Harvey, 1980, p. 34–35) was the point at which Roubidoux Creek loses flow under low-base flow conditions. The injected dye was recovered at Roubidoux Spring, about 10.5 mi north of the injection site, about 5 days after injection. Dye for dye-trace test HT-02 (Harvey, 1980, p. 34–35) was injected into a tributary of Dry Creek near St. Robert (fig. 1) and was recovered at Shanghai Spring 2.8 mi to the northeast. Dye-trace test HT-03 (Harvey, 1980, p. 34–35 and p. 36–37) was made to determine if wastewater from the FLWMR sewage treatment plant (STP) was being transported to Shanghai Spring. Dye injected into the sewage outflow, which is discharged into Dry Creek, was recovered at Shanghai Spring 2.5 mi to the north-northeast. Dye-trace test HT-04 (Rory McCarthy, FLWMR, written commun., 1995) was conducted by MDGLS after a sinkhole in the northeast part of a small lake collapsed and drained part of the lake. Dye injected into the sinkhole was recovered at Shanghai Spring 9.0 mi northwest of the lake, indicating an interbasin transfer of water across the central surface-water divide of the FLWMR. Dye for tracer test HT-05 (unpublished data on file at the MDGLS) was injected into a sinkhole near the upper edge of Range 19 Lake and was recovered at Miller Spring 3.0 mi east of the injection site.

Seven tests using fluorescent dyes were conducted during this study between February and September 1995. Dye injection locations at the FLWMR generally were chosen based on the availability of a substantial opening through the unsaturated zone to the water table. Visual evidence of such openings include the presence of water-formed conduits in the bottom of sinkholes and substantial loss of streamflow over short distances. Although many sinkholes are present throughout the northern one-half of the FLWMR, most of these sinkholes are not suitable as injection sites because the sinkhole bottom is sealed by residuum and clay soils. Sinkholes north of Forney Army Airport, beyond the northern extent of Jefferson City Dolomite bedrock (fig. 2), are more likely to be open or to be filled by more-permeable friable soils and plant root mats. Dye recovery detection was attempted at downgradient perennial streams, springs, and seeps associated with ground-water discharge to the Big Piney River, Roubidoux Creek, Gasconade River, and their tributaries.

Background fluorescent spectra checks and attempted dye recoveries were made by placing approximately 10 g (grams) of activated coconut charcoal encased in a fiberglass mesh into flowing surface water. The charcoal packets were kept immersed from a few days to about 2 weeks. After retrieval from the water, each charcoal packet was washed with clean water, dried, and split into two samples of approximately equal weight. One-half of the sample was archived in case the analysis needed to be repeated. The other one-half was eluted in a solution of 95 percent isopropyl alcohol and 5 percent ammonium hydroxide by volume. The elutant solution was analyzed for the presence of fluorescent materials using a scanning spectrofluorophotometer adjusted to illuminate the solution using a range of excitation wavelengths from 300 to 650 nm (nanometers) and monitor the fluorescence (emission) spectra from 320 to 670 nm using a 3-nm window at a +20-nm shift from the excitation wavelength. All analyses were qualitative. The reader is referred to Mull and others (1988) for a review of standard dye-tracing techniques.

Before dye was injected into the ground-water flow system, a series of preliminary background checks for fluorescent materials were made at several potential dye-recovery sites north and east of the FLWMR. The background check sites (fig. 8) included 11 sites in the Big Piney River Basin (Shanghai Spring, Dry Creek at the STP outflow, the “Boy Scout Camp” tributary, the pumping station spring, the “Asphalt Plant” stream, Miller Spring, and 5 locations on the Big Piney River) and 8 sites in the Roubidoux Creek Basin (Roubidoux Spring, Ballard Hollow stream, and six locations on Roubidoux Creek). Background checks were conducted on a few additional



EXPLANATION

FORT LEONARD WOOD MILITARY RESERVATION BOUNDARY

T103-01 DYE-TRACE TEST AND NUMBER—Conducted during this study. Questioned where uncertain

HT-04 DYE-TRACE TEST AND NUMBER—Historical data

INJECTION POINT

RECOVERY POINT

Figure 7. Injection and recovery points for dye-trace tests T103-01 to T103-07 and historical dye-trace tests at and near the Fort Leonard Wood Military Reservation.

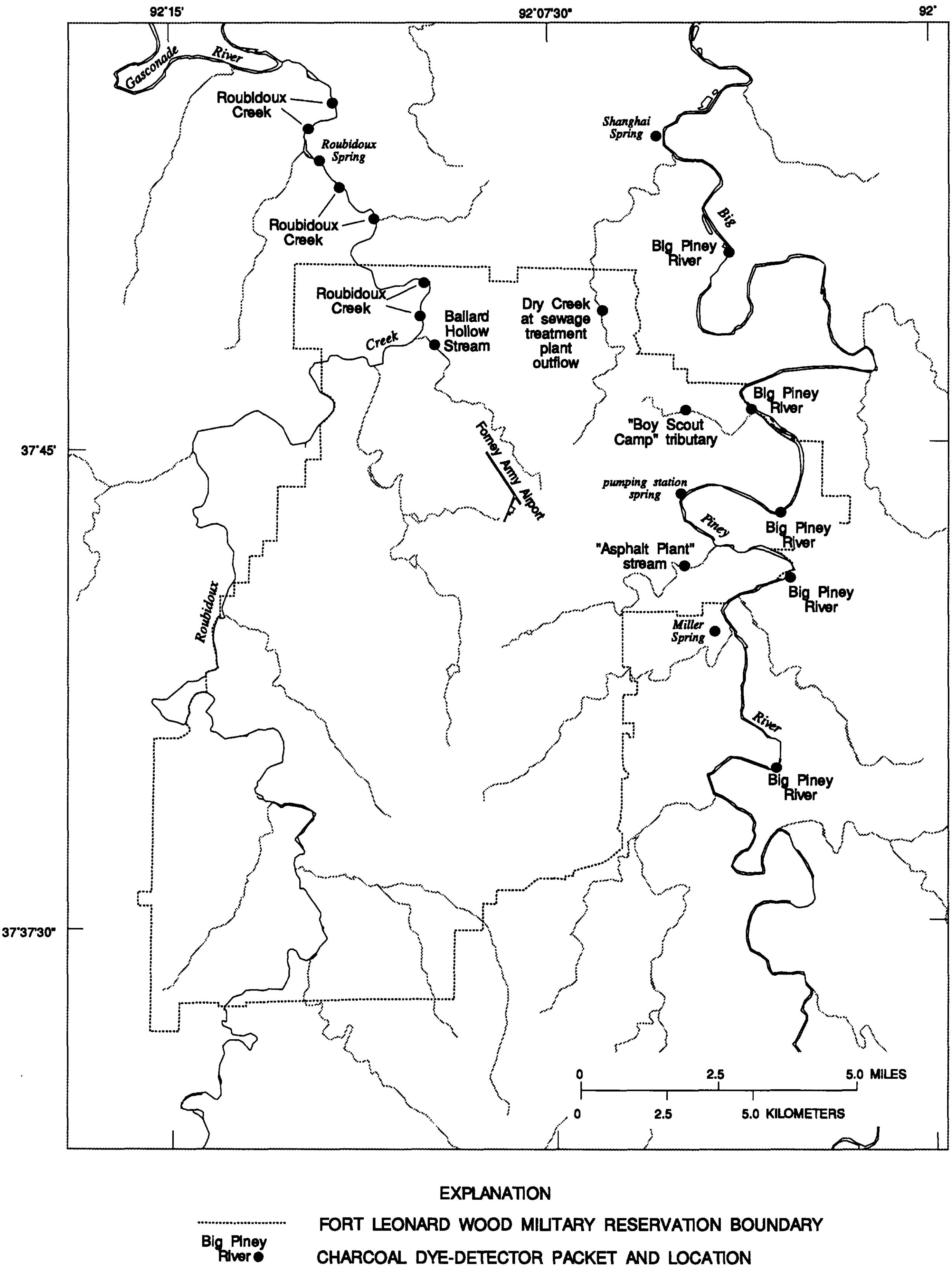


Figure 8. Distribution of charcoal packets placed in surface water and springs for monitoring of background dye concentrations at and near the Fort Leonard Wood Military Reservation.

sites (Creasy Spring, Stone Mill Spring, Bartlett Mill Spring, Ousley Spring, and Road FLW 32 unnamed spring, fig. 3) during the investigation because it became necessary to incorporate new potential dye-recovery sites into the network. Background checks also were repeated at each potential recovery site incorporated into a dye-trace test to determine whether residual dye concentrations from a previous dye-trace test had sufficiently decreased before the injection of more dye into the flow system. The typical background fluorescence spectra for preliminary background check samples were a broad low-intensity peak centering on an emission wavelength of about 440 nm. However, three of the sites (Shanghai Spring, Dry Creek at the STP outflow, and the pumping station spring) had well-defined fluorescence peaks at about 520 nm. This wavelength is consistent with the presence of fluorescein dye and may be derived from household cleaning products or automotive antifreeze. The background fluorescence spectra at Shanghai Spring were nearly identical to that at the STP outflow, indicating that outflow from the STP enters the ground-water flow system through the Dry Creek streambed and resurges at Shanghai Spring (fig. 7, trace HT-03).

Dye injection for the first dye-trace test (T103-01, fig. 7) was on February 14, 1995. Preparation for the dye-trace test included an additional background check at nine potential recovery sites a few days before the dye injection. The test was performed by injecting 3 L (liters) of Rhodamine WT dye in a large sinkhole located about 0.75 mi north of Forney Army Airport control tower. Rhodamine WT dye was used because its fluorescence peak wavelength (567 nm) is higher than the wavelength of detected background fluorescent materials at Shanghai Spring, a site at which dye recovery was anticipated. A pre-injection flush of 100 gal (gallons) of water and post-injection flush of 400 gal of water were used to quickly move the dye through the unsaturated zone. The maximum concentration of Rhodamine WT dye was detected at Shanghai Spring from February 24 to 27, 1995. Travel time from the injection site and Shanghai Spring, a lateral distance of 6.55 mi and altitude difference of about 360 ft, was 10 to 13 days. Dye was not detected at eight other recovery sites. The relatively short time for the dye pulse to pass through Shanghai Spring (3 days) indicates that water primarily is transported from the injection site to the spring through a single well-defined fracture or bedding-plane opening. Dye concentrations before and after these 3 days were small relative to the maximum dye concentration. The estimated ground-water flow rate is about 0.5 mi per day. A summary of the dye-trace injection and recovery data for T103-01 is presented in tables 2 and 3, at the back of this report. The relative fluorescence intensity of dye eluted from charcoal packets placed in Shanghai Spring during the dye-trace test is shown in figure 9.

A second dye-trace test (T103-02, fig. 7) was conducted by injecting Rhodamine WT dye into a small (about 6-ft diameter) sinkhole in a wooded area at the south edge of SWMU FLW-003 on March 16, 1995. This site was chosen in an attempt to conduct a dye-trace test from the immediate vicinity of FLW-003, FLW-004, and FLW-005, landfills under investigation during the same time as the regional geohydrologic assessment was being conducted. It was understood that this was not an ideal site for dye injection. Although the large rocks and gravel that filled the bottom of the sinkhole did not completely restrict flow into the subsurface, the infiltration rate was small, and there was no certainty that flow to the water table was unimpeded. Background dye concentrations at potential recovery sites were checked before the dye-trace test was conducted. Dye concentrations at Shanghai Spring had receded to background concentrations. Approximately 4 L of Rhodamine WT dye were used in the injection, which included a 600-gal post-injection flush. Potential recovery sites (table 4, at the back of this report) were monitored for Rhodamine WT dye for about 4 months after the injection date. No dye was recovered from this injection. The only indication that dye recovery might be successful was during analysis of charcoal packets collected from Shanghai Spring on May 12, 1995. Fluorescence spectra from this analysis showed a previously undetected peak at 572 nm; however, the peak intensity was extremely small and may have been caused by residual dye from dye-trace test T103-01. Packets collected from Shanghai Spring on May 15 and 19, 1995, also indicated the peak at the same small intensity. The peak was not present in analyses of packets recovered after May 19, 1995. The movement of the dye to the water table was assumed to have been impeded by clayey residuum and bound into the clay matrix.

A third dye-trace test (T103-03, fig. 7) was initiated on April 17, 1995, with the injection of 2 lbs (pounds) of fluorescein dye into an opening at the northeastern side of a large sinkhole located about 300

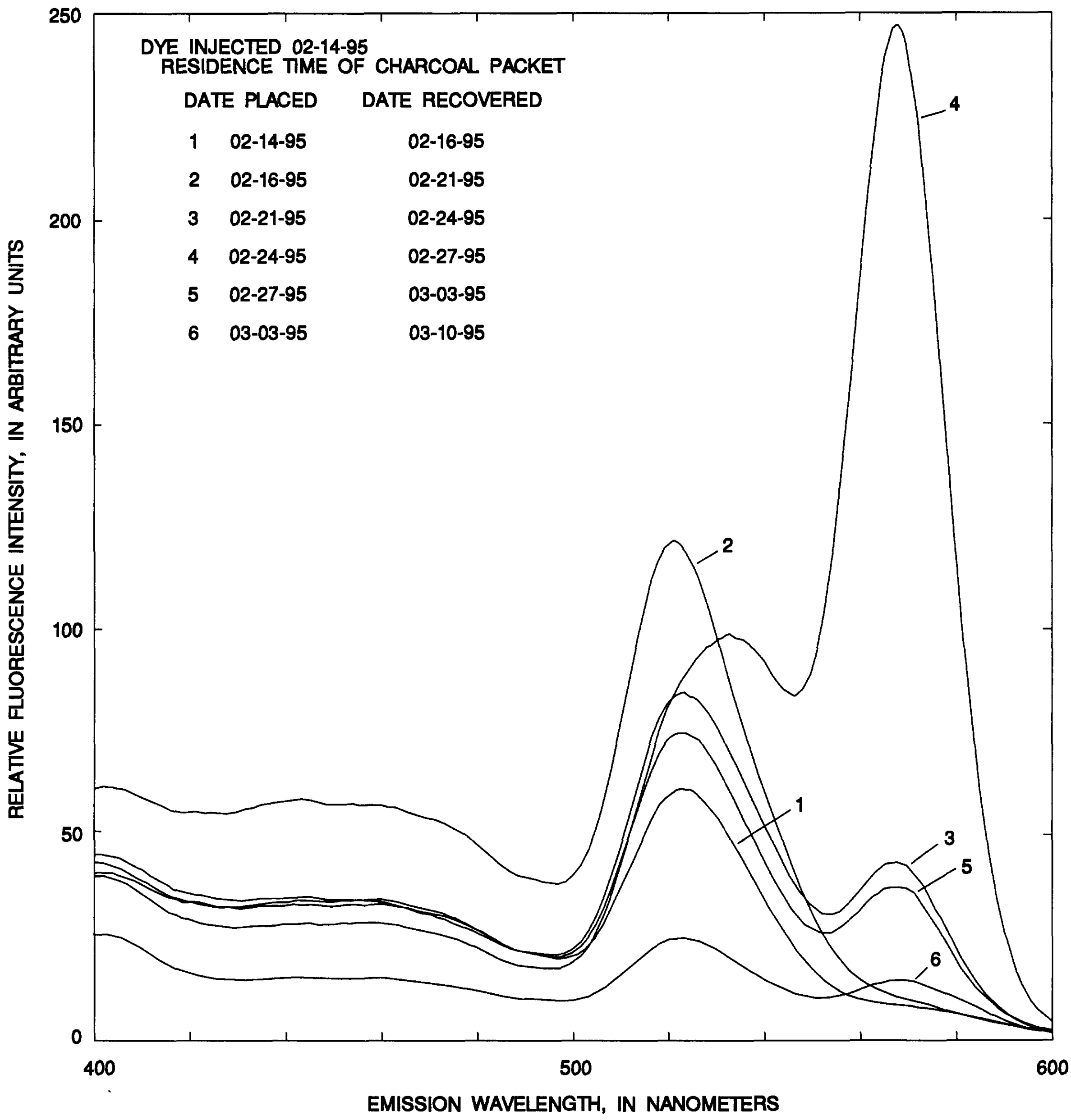


Figure 9. Spectral analysis of fluorescent material extracted from activated charcoal packets placed in Shanghai Spring during dye-trace test T103-01.

ft south of Bradford Cemetery. The injection process included a 100-gal pre-injection flush and 500-gal post-injection flush. Fluorescein dye was used in this test to maintain distinction from the ongoing dye-trace test T103-02, which used Rhodamine WT dye. The injected dye was recovered at Miller Spring, located 3.93 mi east of the sinkhole at an altitude of about 240 ft lower than the sinkhole, about 4 days after injection. The estimated ground-water flow rate is about 1 mi per day. Dye-trace injection and recovery data for T103-03 are presented in tables 5 and 6, at the back of this report. Relative fluorescence intensity of dye eluted from charcoal packets collected at Miller Spring during a 3-week period after injection is shown in figure 10.

A fourth dye-trace test (T103-04, fig. 7) was conducted on May 9, 1995, with the injection of 2.5 lbs of fluorescein dye into a small sinkhole that is the easternmost of a series of four sinkholes extending nearly parallel to a dirt and gravel road along the northern boundary of a small arms firing range. Fluorescein dye again was used in this test to maintain distinction from on-going dye-trace test T103-02. A small opening in the bottom of the sinkhole provided

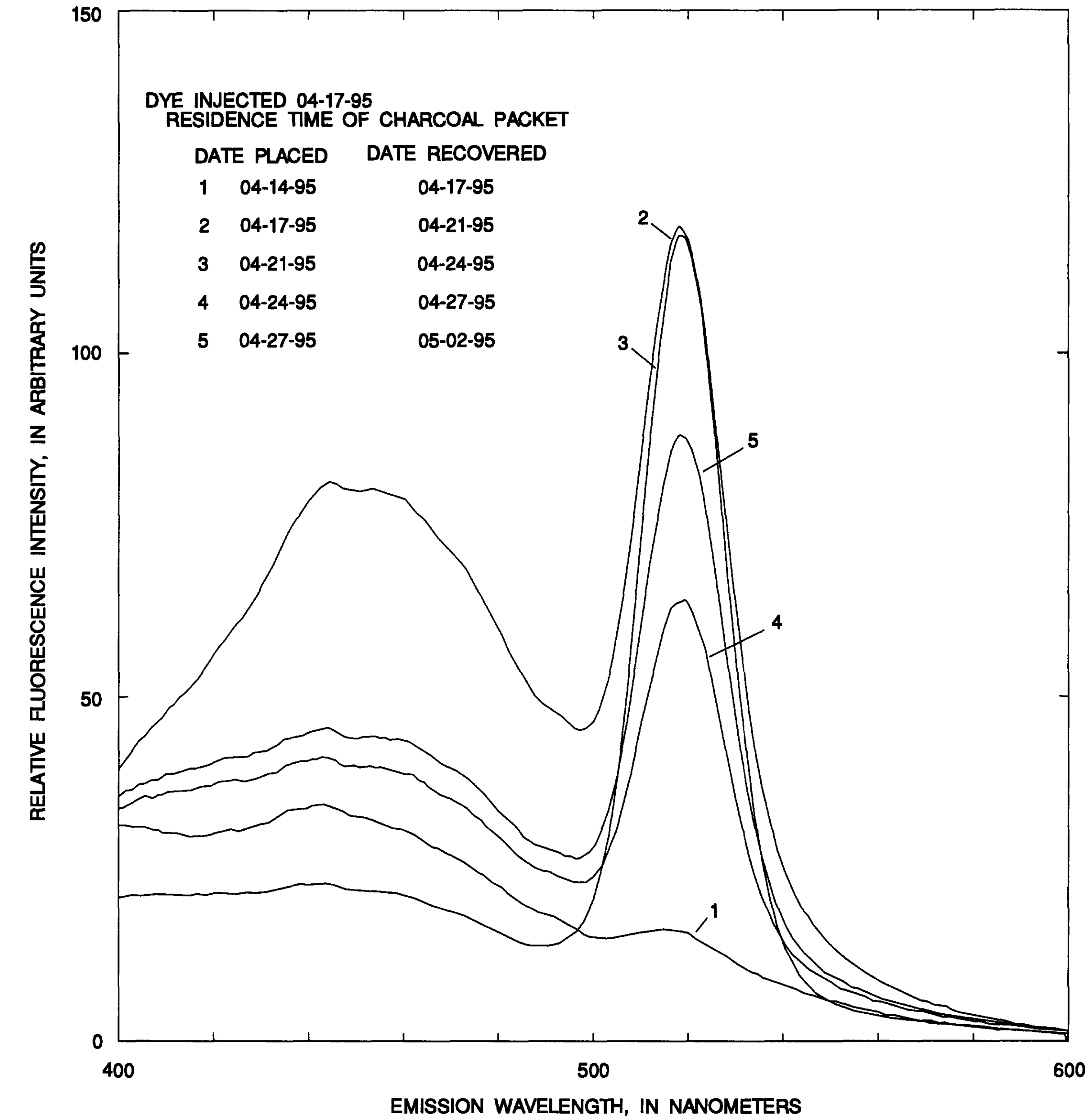


Figure 10. Spectral analysis of fluorescent material extracted from activated charcoal packets placed in Miller Spring during dye-trace test T103-03.

access to a 10- to 15-ft deep cavity beneath the sinkhole. Dye injection was followed by a flush of 500 gal of water to rapidly move the dye into the saturated zone. The injected dye was recovered at Miller Spring. Maximum dye concentrations at Miller Spring as indicated by the intensity of fluorescence spectra occurred about 13 days after injection; however, substantial concentrations of dye were detected at the spring from about 3 days after injection until about 25 days after injection. Miller Spring is located 4.08 mi northeast of the sinkhole. The ground-water flow rate along the path carrying the greatest dye load is about 0.3 mi per day. Dye-trace injection and recovery data for T103-04 are presented in tables 7 and 8, at the back of this report. The relative fluorescence intensity of dye eluted from charcoal packets collected at Miller Spring during the dye-trace test is shown in figure 11.

A fifth dye-trace test (T103-05, fig. 7) was conducted on May 26, 1995, with the injection of 1.25 to 1.50 lbs of fluorescein dye into a sinkhole located about 100 ft north of the west end of Pulaski Avenue in the northwestern corner of the cantonment area. The dye was placed in an opening beneath a large tree growing from the southern bank of the sinkhole. Fluo-

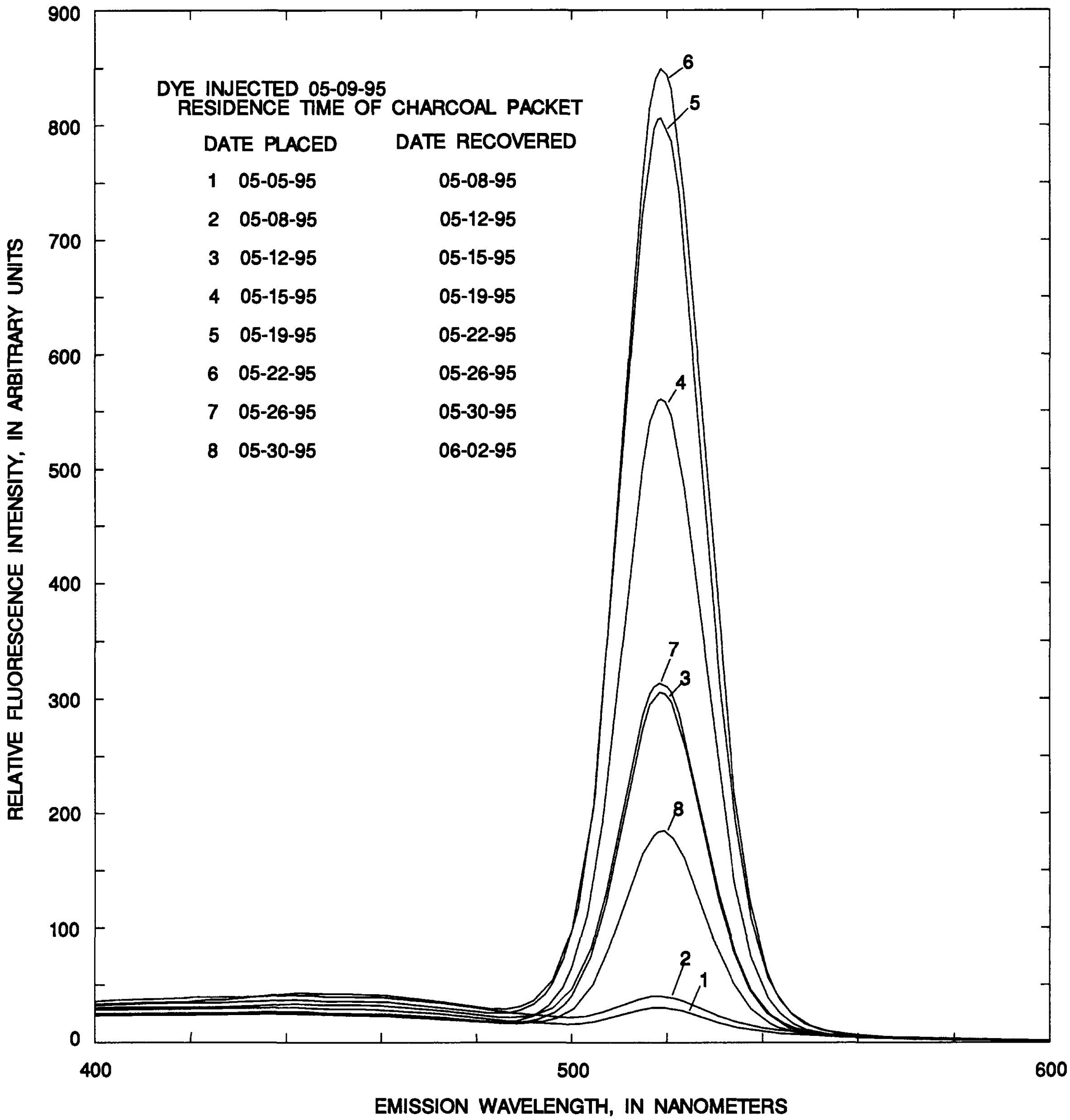


Figure 11. Spectral analysis of fluorescent material extracted from activated charcoal packets placed in Miller Spring during dye-trace test T103-04.

rescein dye was used in this test to maintain distinction from dye-trace test T103-02. The injection site was flushed with 50 gal of water before injection and 450 gal after injection. The injected dye was recovered at Shanghai Spring from about 4 to 29 days after injection, with peak concentrations occurring about 10 to 14 days after injection. The altitude of Shanghai Spring is 295 ft lower than the injection sinkhole. The slower rise and fall of peak dye concentrations at the spring as compared to dye-trace test T103-01 indicates a more complex multi-channel flow path from the Pulaski Avenue sinkhole to Shanghai Spring than from the Forney Army Airport sinkhole to Shanghai Spring. The ground-water flow rate along the path carrying the greatest dye load is about 0.4 mi per day. Shangai Spring is located 4.49 mi northeast of the sinkhole. Dye-trace injection and recovery data for T103-05 are presented in tables 9 and 10, at the back of this report. Relative fluorescence intensity of dye eluted from charcoal packets collected at Shanghai Spring for 6 weeks after injection is shown in figure 12.

Dye-trace test T103-06 (fig. 7) was begun July 6, 1995, and completed in August 1995. The dye, 1 gal of Rhodamine WT, was injected into a losing stream in

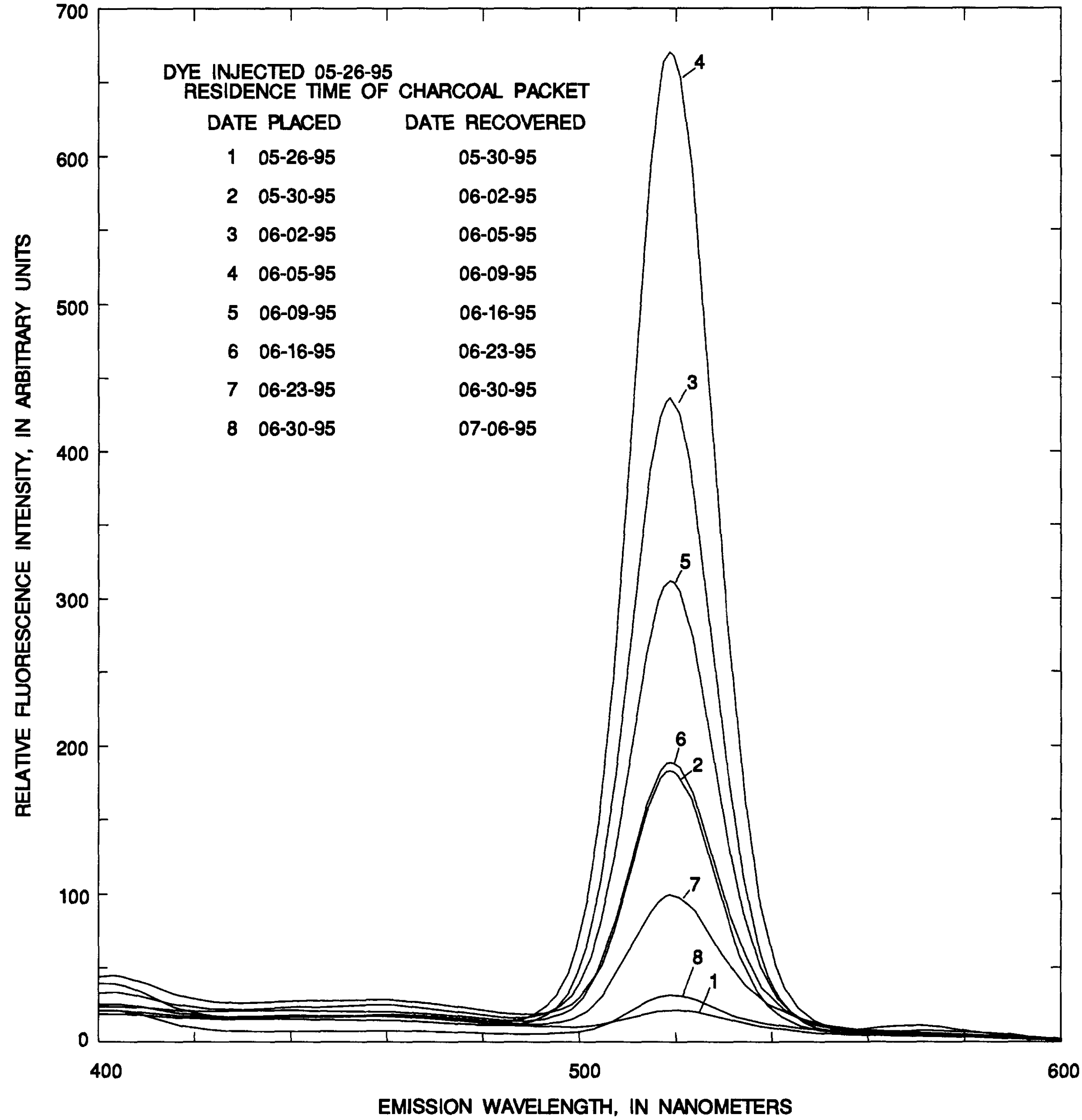


Figure 12. Spectral analysis of fluorescent material extracted from activated charcoal packets placed in Shanghai Spring during dye-trace test T103-05.

Hurd Hollow near the location of complete flow loss. Dye was recovered at Roubidoux Spring at an altitude 132 ft lower that the Hurd Hollow injection site about 8 to 15 days after injection. Dye concentrations before and after the 8- to 15-day travel time were small as compared to the peak concentrations. The ground-water flow rate along the path carrying the greatest dye load is estimated at 0.5 to 1 mi per day. No dye was recovered from Roubidoux Creek between Roubidoux Spring and the point at which flow returns near Ballard Hollow, which indicates that the source of water in Roubidoux Creek downstream from the long dry reach (fig. 6) is discharge of shallow ground water from nearby upland areas. Surface water that flows into the karst terrane beneath Roubidoux Creek near the point of total streamflow loss apparently flows beneath the lower gaining reach of Roubidoux Creek and discharges at Roubidoux Spring. Dye-trace injection and recovery data for T103-06 are presented in tables 11 and 12, at the back of this report. Relative fluorescence intensity of dye eluted from charcoal packets collected at Roubidoux Spring for 6 weeks after injection is shown in figure 13.

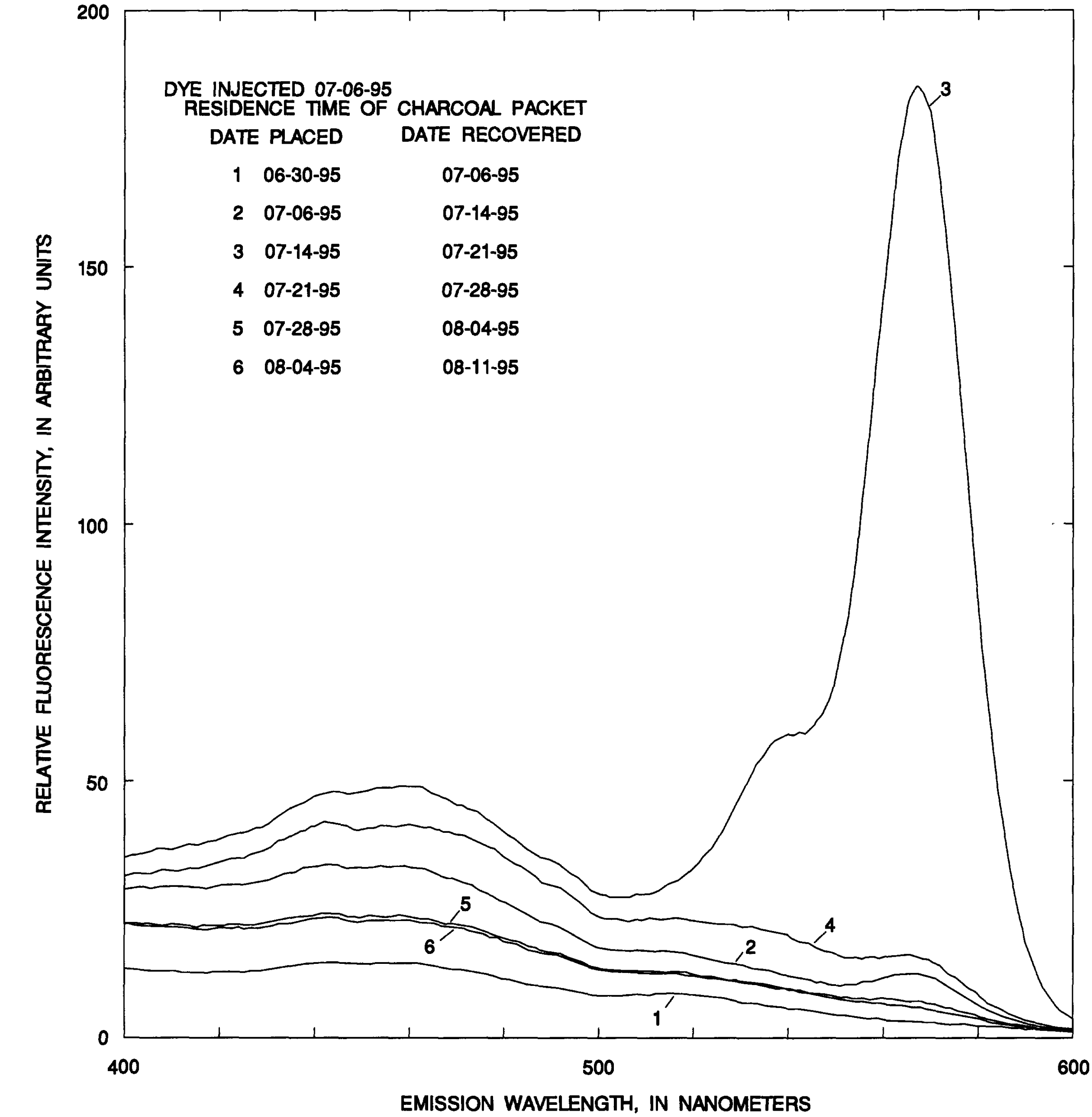


Figure 13. Spectral analysis of fluorescent material extracted from activated charcoal packets placed in Roubidoux Spring during dye-trace test T103-06.

Dye-trace test T103-07 (fig. 7) began July 13, 1995, and was completed in September 1995. Fluorescein dye was used in this dye-trace test to maintain distinction from dye-trace test T103-06, which was in progress simultaneously. The dye was injected into a large sinkhole at the junction of roads FLW 24 and FLW 22 near the eastern edge of the cantonment area. A substantial pulse of dye was detected at the pumping station spring, located about 0.5 mi north of the Big Piney River pumping station, between 1 and 8 days after injection. Background concentrations of fluorescein dye were consistently detected at this recovery site during the course of the dye-trace test. The background fluorescein could be derived from residential areas 1 mi west of the spring. However, the magnitude of the dye pulse detected after dye injection far exceeded the measured background concentrations. Substantial dye concentrations also were detected after the peak concentration, indicating that some water is flowing through alternate paths or temporarily is retained in storage. The ground-water flow rate along the path carrying the greatest dye load is less than 1 mi per day. Also, about 1 to 8 days after injection, analyses of charcoal packets collected from Shanghai Spring indicated the presence of fluorescein dye. The dye concentration at Shanghai Spring (fig. 7) was substantial, but was not considered large enough to be clearly distinguished from fluctuating concentrations of background fluorescent material at the spring. This dye-trace test could be repeated with more dye injected or a different dye to confirm or deny a direct hydraulic connection between the injection point and Shanghai Spring. Dye-trace injection and recovery data for T103-07 are presented in tables 13, 14, and 15, at the back of this report. Relative fluorescence intensity of dye eluted from charcoal packets collected at the pumping station spring is shown in figure 14; relative fluorescence intensity of dye eluted from charcoal packets collected at Shanghai Spring is shown in figure 15.

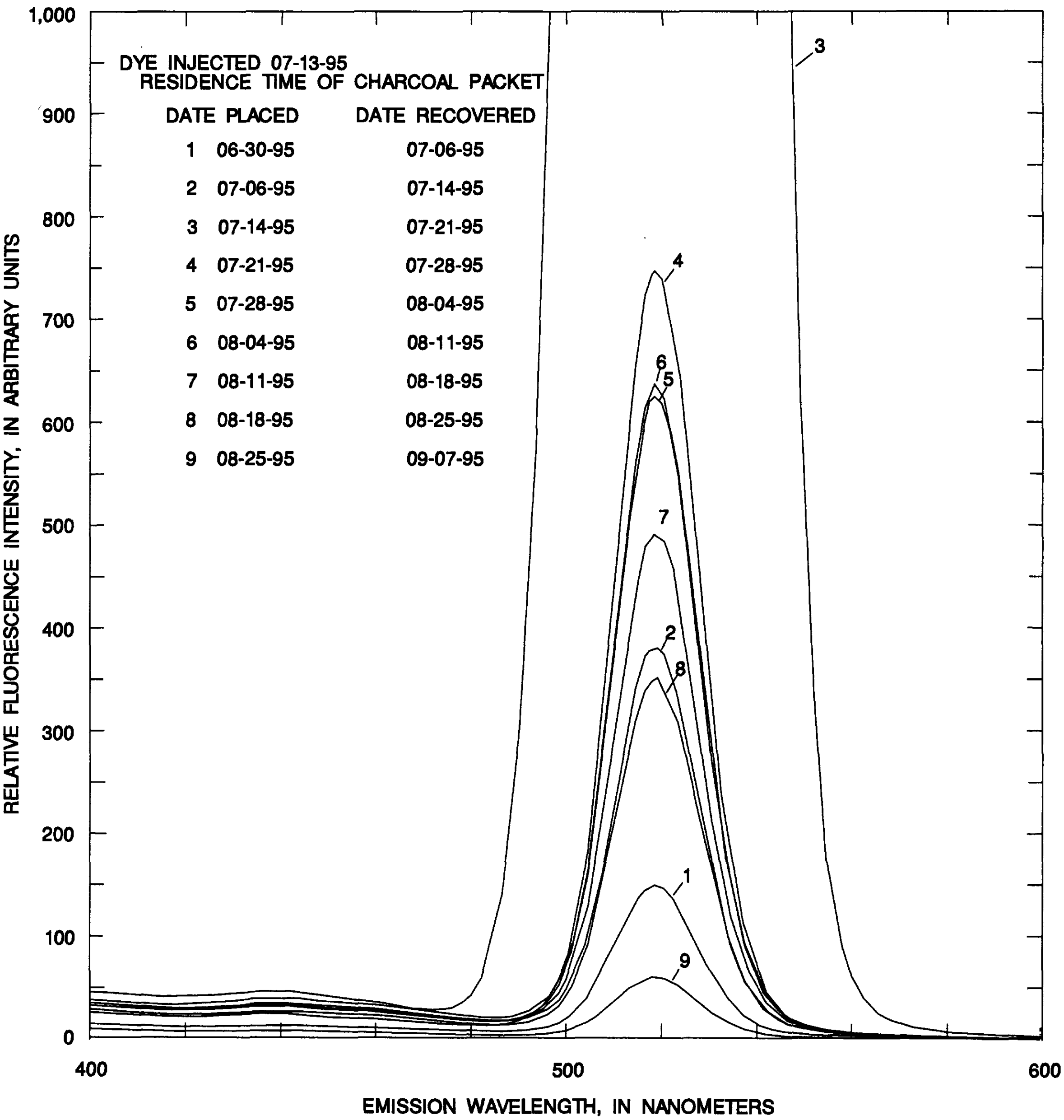


Figure 14. Spectral analysis of fluorescent material extrated from activated charcoal packets placed in the pumping station spring during dye-trace test T103-07.

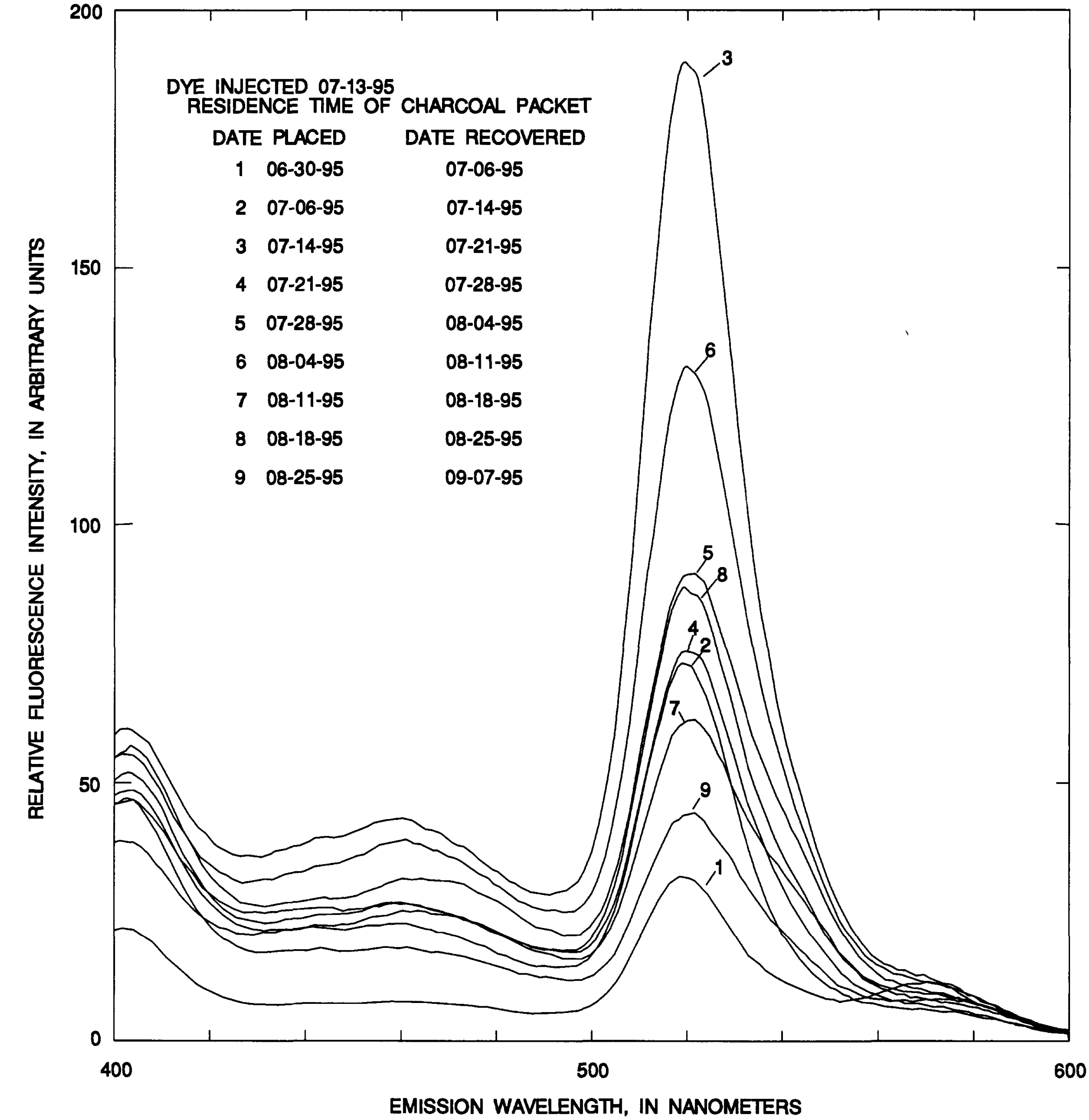
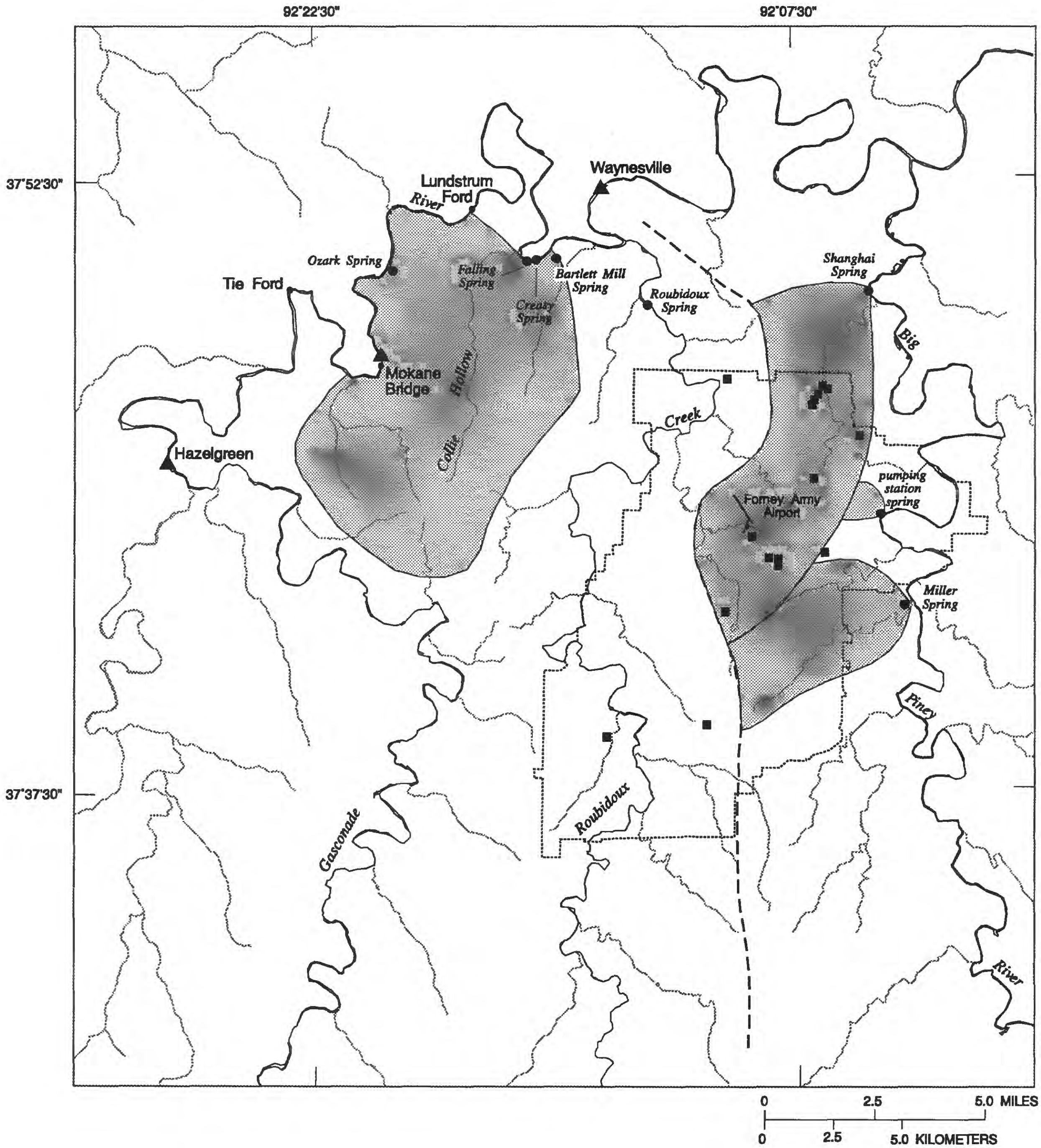


Figure 15. Spectral analysis of fluorescent material extracted from activated charcoal packets placed in Shanghai Spring during dye-trace test T103-07.

Based on historical dye-trace investigations near the FLWMR, dye-trace tests conducted as part of this study, and ground-water-level measurements made during high- and low-base flow conditions, a map (fig. 16) was constructed showing the probable catchment areas of selected springs. The catchment area of the combined Falling Spring, Creasy Spring, and Bartlett Mill Spring drainage system is based entirely on historical dye traces, primarily conducted by the MDGLS near the Gasconade River (fig. 7). The eastern and southern boundaries of that area were drawn mostly based on ground-water divides as determined from mapped ground-water levels in figure 6, except that part of the southern boundary is drawn south of the divide to incorporate results of a dye-trace test in that area. The northwestern boundary is drawn coincident with a losing reach of the Gasconade River.

The probable catchment area of Shanghai Spring lies southwest of the spring. The western boundary of that catchment area was drawn to coincide with the regional ground-water divide that extends through the FLWMR (fig. 6). Other bound-



EXPLANATION

(shaded pattern)	PROBABLE CATCHMENT AREA
....	FORT LEONARD WOOD MILITARY RESERVATION BOUNDARY
– – – – –	GROUND-WATER DIVIDE
●	SPRING
■	SOLID-WASTE MANAGEMENT UNIT (SWMU)
Hazelgreen ▲	STREAM DISCHARGE MEASUREMENT SITE OR GAGING STATION AND IDENTIFIER (FROM BOLON, 1953)

Figure 16. Probable catchment areas of selected major springs at and near the Fort Leonard Wood Military Reservation.

aries were drawn to enclose dye-injection points known to transmit water to Shanghai Spring. The probable catchment area of the pumping station spring is based solely on the single dye-trace test to that spring and is assumed to share a common boundary with the catchment area of Shanghai Spring. The probable catchment area of Miller Spring extends west of the spring to the regional ground-water divide and is assumed to have a common boundary with the catchment area of Shanghai Spring. The remainder of that area is drawn to encompass dye-injection points known to transmit water to Miller Spring.

SURFACE-WATER HYDROLOGY

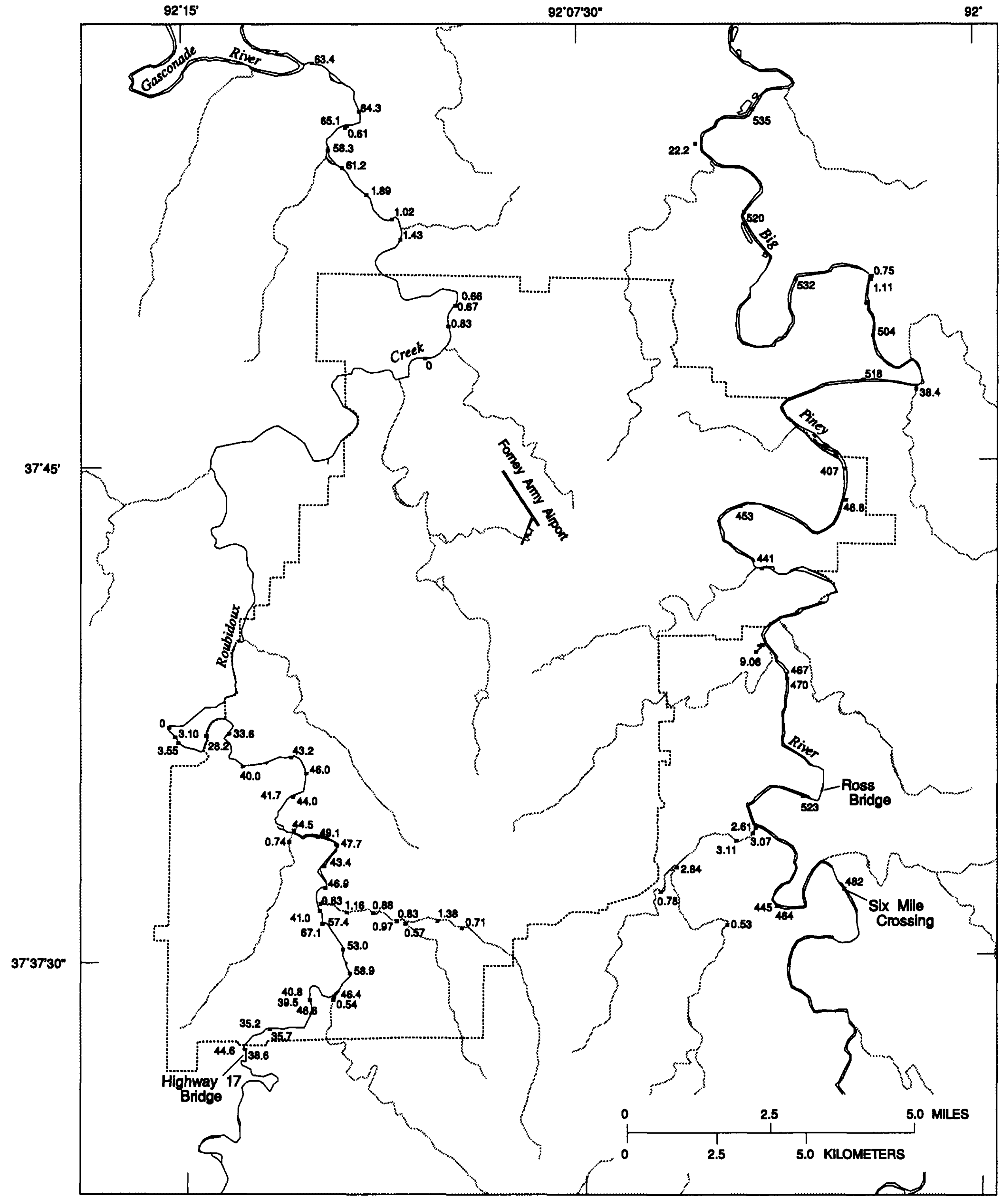
Surface-water drainage within the FLWMR is by small tributary streams and dry washes that direct water from a central topographic ridge that divides the eastern and western parts of the FLWMR. Drainage systems in the eastern one-half of the FLWMR discharge water into the Big Piney River, which flows northward near the eastern boundary of the FLWMR and discharges into the Gasconade River. Drainage systems in the western one-half of the FLWMR discharge water into Roubidoux Creek, which flows northward near the western boundary of the FLWMR and discharges water into the Gasconade River. Several large manmade ponds and lakes that have been built on the FLWMR are located in a 3-mi wide band that extends east-west across the FLWMR immediately south of Forney Army Airport. Most of these impoundments were constructed near the central dividing ridge in the headwater areas of small ephemeral streams. At least one lake was built over an active sinkhole that subsequently collapsed.

The Big Piney River and Roubidoux Creek are the two primary discharge areas for precipitation that percolates through the unsaturated zone and recharges the water table in the FLWMR. Previous seepage-run measurements, a series of stream discharge measurements made along a stream reach during a short time to identify where gains and losses in flow occur, were conducted on these streams and the Gasconade River northwest of the FLWMR. The measurements provided data on changes in the volumetric rate of streamflow along each stream channel. These flow-rate changes were used to estimate the magnitude and distribution of ground-water discharge to each stream and, thus, identify gaining and losing stream reaches to quantify the degree of ground- and surface-water interaction.

The USGS conducted a low-flow seepage run on the Big Piney River, September 17 and 18, 1953, and determined the recurrence interval of the measured streamflow. The recurrence interval is the average interval (in years) between occurrences of discharge less than that measured. The discharge was determined at six sites on the mainstem of the Big Piney River from where flow began in Texas County (about 10 mi south of the FLWMR) to its mouth in Pulaski County. The discharge of two tributary streams also was measured. The following streamflow discharge and recurrence intervals were determined upstream from Houston (25 mi southeast of the FLWMR), 12 ft^3/s (cubic feet per second) discharge, 25-year recurrence interval; middle reaches (from Houston to Ross Bridge; fig. 17), 106 ft^3/s, 5 years; and lower reaches (from Ross Bridge to mouth), 161 ft^3/s, 2 years (Skelton, 1976). The results of this seepage run indicate that the discharge generally increased downstream.

A seepage run also was conducted on the Roubidoux Creek by the USGS on July 13, 1971 (Skelton, 1976, fig. 7). The discharge was determined at 10 sites along the mainstem of Roubidoux Creek from its headwaters in Texas County to its mouth in Pulaski County. The three measurements made on Roubidoux Creek mainstem in Texas County show the discharge increases downstream, the entire flow of the creek is lost in Pulaski County, and flow begins again in the lower reach of the creek in the northern part of the FLWMR (fig. 6). The recurrence interval for the 10 ft^3/s discharge measured near the mouth of Roubidoux Creek was determined to be 2 years.

During September 17 and 18, 1953, a low-flow seepage run was conducted by the USGS on the Gasconade River between the USGS gaging stations at Hazelgreen and Waynesville (fig. 16; Bolon, 1953). The most downstream part of this reach receives water from springs that collect water from a catchment area northwest of the FLWMR (fig. 16). The seepage-run data indicated that flow diminished from 32.2 to 3.9 ft^3/s between Tie Ford and Lundstrum Ford, with most of the flow being lost between Mokane Bridge and Ozark Spring (Bolon, 1953). Substantial flow was observed entering a sinkhole at the west side of the Gasconade River immediately north of the bridge approach at Ozark Spring. Additional measurements made at a later date indicate the river consistently



EXPLANATION

FORT LEONARD WOOD MILITARY RESERVATION BOUNDARY

.36.6 STREAM DISCHARGE MEASUREMENT--Number is flow rate, in cubic feet per second. Selected tributary discharge measurements larger than 0.05 cubic foot per second are shown

Figure 17. Stream discharge measurements for the high-base flow seepage run made on the Big Piney River, Roubidoux Creek, and selected small tributary streams in December 1994 at and near the Fort Leonard Wood Military Reservation.

loses flow (from 18 to 30 ft^3/s) in this reach, regardless of river stage. Other measurements made during the 1953 seepage run indicated that within the reach of the Gasconade River between the mouth of Collie Hollow to and including Bartlett Mill Spring (0.75 river mi reach) the flow increased in the Gasconade River from 4.3 to 69.8 ft^3/s. Most of this increase in flow was observed boiling up through the gravel in the streambed and adjacent to the channel. Flow also was contributed by Creasy, Falling, and Bartlett Mill Springs and from other unnamed springs. The temperature of the water from the gravel boils was about 5 °F warmer than the water from the other springs, indicating that the water from the gravel boils had not traveled sufficiently underground to assume low ground-water temperatures (Bolon, 1953).

Three sets of seepage-run measurements were conducted on the Big Piney River, and two sets of seepage-run measurements were conducted on Roubidoux Creek during this investigation. The first two seepage runs on the Big Piney River were made during high-base flow conditions and the third during low-base flow conditions. The first Roubidoux Creek seepage run was made during high-base flow conditions; the second was during low-base flow conditions. Measurements made during high-base and low-base flow conditions are necessary to assess seasonal variations in the magnitude of ground-water discharge to streams. Continual stream-stage data were also collected at a gaging station on the Big Piney River at Ross Bridge (fig. 17).

Springs are present along the Big Piney River near the eastern border of the FLWMR (fig. 3) and, to a much lesser extent, along Roubidoux Creek near the western border of the FLWMR. Some of the larger springs are Shanghai Spring, Ousley Spring, Stone Mill Spring, and Miller Spring in the Big Piney River Basin and Roubidoux Spring in the Roubidoux Creek Basin. Several smaller perennial and wet-weather springs discharge from solution-enlarged bedrock contacts and fractures throughout the FLWMR. Discharge rates of many of these springs were measured as part of the seepage-run measurements.

Methodology

Generally, seepage runs are designed to be made during periods of minimum streamflow and minimal daily streamflow fluctuations (base flow periods). During these periods, streams are sustained by ground water and spring discharge, not by surface runoff. These base flow periods typically occur in late summer or fall. However, a seepage run made in the winter or spring when base flows are larger (high-base flow) can supply valuable information in stream reaches of extreme water loss, such as Roubidoux Creek. The series of discharge measurements in the seepage run normally is designed to be made in consecutive downstream order. During both seepage runs on Roubidoux Creek, this procedure could not be used because of accessibility restrictions. Where a firing range overlapped a part of Roubidoux Creek, access to that part of Roubidoux Creek was denied when that range was being used on a particular day. This interruption in the normal procedure caused data gaps along selected stream reaches that were filled as the stream reach could be accessed.

During the seepage-run measurements, access to measuring sections on the Big Piney River was primarily gained by boat; access to sections on Roubidoux Creek was by wading. Wading measurements were made at selected locations along both streams and at the mouths of inflowing tributaries. Seepage-run measurements were made at locations where stream channel morphology and velocity were conducive to accurate discharge measurements. Discharge was measured using either a standard AA or pygmy current meter, depending on stream velocity and depth. The methods used to make discharge measurements and the criteria used to determine the type of current meter applicable to the measuring section are described by Rantz and others (1982). The accuracy of the measurements were rated according to stream channel conditions and uniformity of flow. The rated measurement accuracy is subjective and defined as follows: "good" means that the actual discharge is thought to be within 5 percent of the measured discharge, "fair" is 5 to 8 percent; and "poor" is more than 8 percent. Where channel conditions were not adequate for making discharge measurements, either because of insufficient depths or small flow velocities, discharge was estimated. However, all measurements were not given a rating. The error at the sites where flow is estimated may exceed 8 percent.

Generally, check measurements were made each day at one or more of the measuring sections. This check measurement consisted of a streamflow measurement made by two different people at the same measuring section and was used as a quality-control procedure. The two measurements were expected to be within the degree of accuracy defined by the rated measuring conditions.

Specific conductance and temperature of the water were typically measured at the discharge measurement site. Specific conductance values were measured using a portable conductivity meter with temperature compensation designed to read in microsiemens per centimeter at 25 °C (degrees Celsius). Water temperature was measured with a thermistor to the nearest 0.1 °C.

During the winter and spring when high-base flow conditions occur, sustained periods of no precipitation rarely occur. For this reason, the seepage runs were started after precipitation had occurred and sufficient time had elapsed for small tributary streams to stop flowing. However, the Big Piney River and Roubidoux Creek still had substantial variations in daily streamflow during the December 1994 and February 1995 high-base flow seepage runs. These conditions probably showed more variability than a normal base flow period; however, the series of discharge measurements were made, and collectively they will be referred to as high-base flow seepage runs.

To establish the daily flow rate variation, a policy was established that the last section measured each day would be the first section measured at the beginning of the following day. This procedure was not followed during the December 1994 seepage run on the Big Piney River. Because of this fact and quality-control concerns, a second high-base flow seepage run was conducted on the river in February 1995.

During the data analysis of these seepage runs, adjustments were made to the measured discharge along the mainstem of both the Big Piney River and Roubidoux Creek. The first adjustment removed the quantity of flow contributed to the mainstem of the stream by tributaries and springs. This "inflow adjustment" was made to each discharge measurement on the mainstem by first calculating the cumulative discharge of all tributaries and springs that entered the mainstem upstream of the site where the discharge measurement was made. The cumulative total from tributary and spring inflow was then subtracted from the discharge measurement. This adjustment was made to remove the increase in flow along the mainstem from sources that were visibly contributing water. Therefore, any net increase in discharge along the stream reach after this adjustment was applied would be a result of the diffuse ground-water inflow along the streambed and not surface water or spring inflow.

A second adjustment, hereafter referred to as the "common-base adjustment," was made to the measured discharges along the mainstem of both the Big Piney River and Roubidoux Creek during the three high-base flow seepage runs. The common-base adjustment was applied primarily to remove some of the substantial daily flow rate variation that was occurring in these streams during the high-base flow conditions. This adjustment involved applying a shift to each set of daily discharge measurements, so that discharge measurements made on consecutive days could be brought to a common base. Each set of discharge measurements consists of all the mainstem discharge measurements made on a specific day. The applied shift was determined by the difference in the consecutive discharge measurements that were made at the same measuring section at the end of the day and at the start of the following day. For example, rainfall on February 14 and 15 caused the discharge measured at river mile 23.68 to change from 408 ft^3/s on February 14 to 501 ft^3/s when the interrupted seepage run was restarted on February 17. Because flow in the stream increased 93 ft^3/s from propagation of water from areas upstream of the FLWMR, this amount was subtracted from all the measurements made on February 17 to bring those measurements to the same base as measurements made previously.

The procedure of measuring the discharge at the same section at the end of the day and again at the start of the following day was not followed during the December 1994 seepage run on the Big Piney River. Therefore, the applied common-base adjustment was determined using the difference in daily mean discharge as recorded at the gaging station at Ross Bridge. The decrease in daily mean flow in the Big Piney River was determined to be 88 ft^3/s at the gaging station for the period during the seepage run. This variation was prorated and then subtracted from the discharge measurements made on each corresponding day. This correction considerably reduced the fluctuation of the measurements; however, the data scatter was still large compared to the small variations expected from ground-water inflow.

High-Base Flow Stream and Spring Discharge

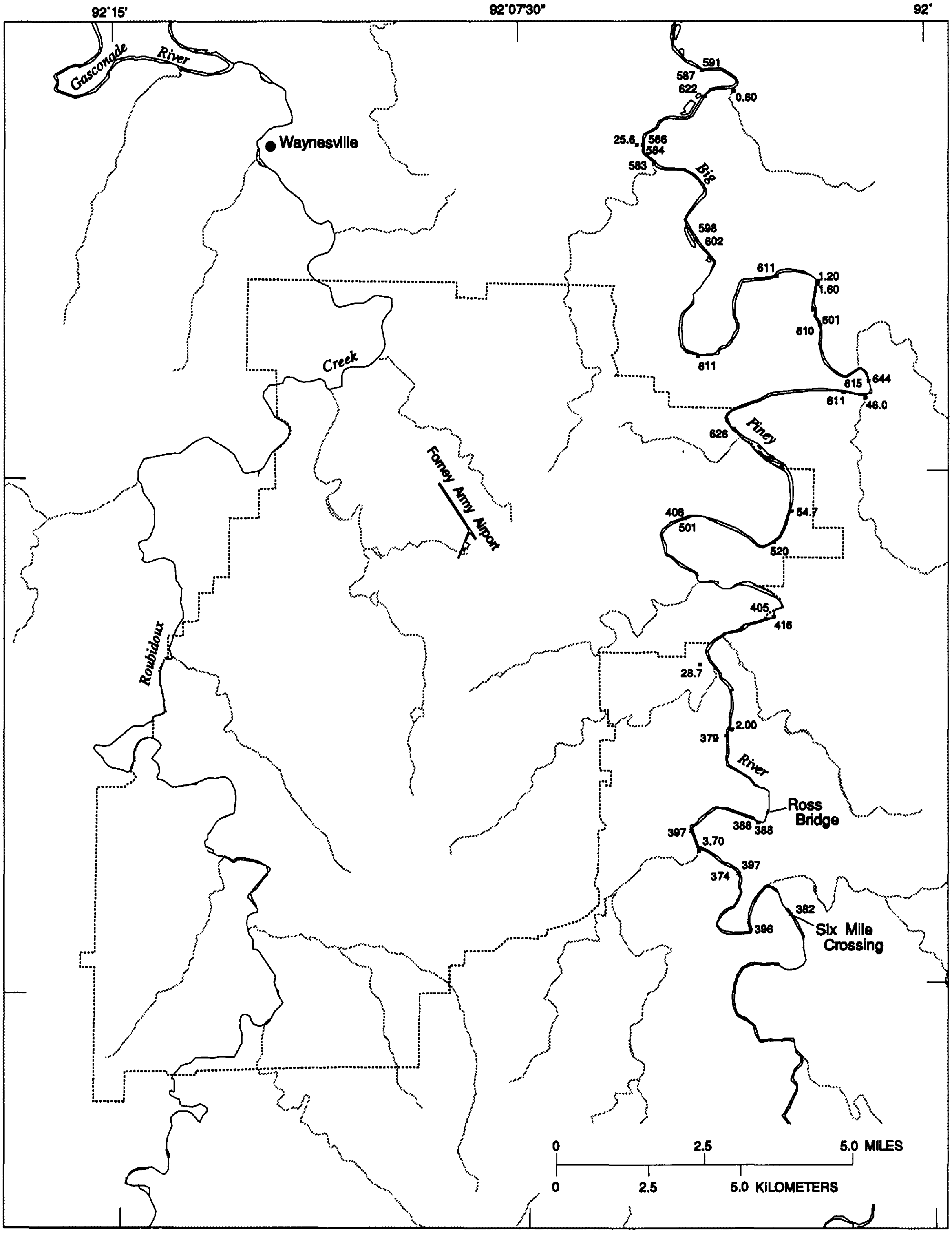
The first high-base flow seepage run (table 16, at the back of this report; fig. 17) on the mainstem of the Big Piney River was made during December 12 to 14, 1994. Between November 21 and December 8, 1994, 0.23 in. of rainfall was recorded at Waynesville (fig. 18); on December 9, 1994, 0.21 in. of rainfall was recorded (National Oceanic and Atmospheric Administration, 1994). Runoff and increased ground-water inflow to streams and springs caused river conditions to change 2 days before the scheduled start of the seepage run; however, measurements were continued as scheduled. Discharge was measured at 16 locations in the mainstem of the Big Piney River along a 38-river mi reach from an access locally known as Six Mile Crossing to the mouth of the river. A substantial part of this river reach borders or is interior to the FLWMR. Discharge also was measured or estimated at the mouths of 81 stream and spring tributaries of Big Piney River (58 of which had no flow). Four springs (Shanghai Spring, Ousley Spring, Stone Mill Spring, and Miller Spring) with substantial flow were identified, and their discharge was measured. Four tributary streams that drain the FLWMR were investigated in more detail. Discharge measurements were made in these four streams from the stream mouths at Big Piney River to the point where flow began in the headwater areas.

Because of substantial daily streamflow fluctuations and procedural and quality-control concerns during the first seepage run, a second high-base flow seepage run was conducted on the Big Piney River between February 13 to 22, 1995 (table 17, at the back of this report; fig. 18). During the interval from the planning stage to the start of this second seepage run, streamflow and climatological conditions were favorable. However, between February 14 and 15, 1995, a total of 0.30 in. of rainfall was recorded at the FLWMR. The remainder of the seepage run was postponed on February 15, 1995, and began again on February 17, 1995. Because daily streamflow fluctuations were still considered to be extreme, further work was postponed until February 20. During this seepage run the same 38-river mi reach of Big Piney River was measured as in the first seepage run. During this seepage run, 31 discharge measurements were made at 22 locations on the mainstem of Big Piney River. Discharge also was determined at the mouths of 41 stream and spring tributaries (15 of which had no flow).

A high-base flow seepage run (table 16; fig. 17) also was made on Roubidoux Creek from December 12 to 14, 1994. Discharge was determined at 58 locations (16 of which had no flow) along a 34 river mi reach of Roubidoux Creek from the Missouri Highway 17 bridge to the mouth. Flow also was determined at the mouth of 40 stream and spring tributaries of Roubidoux Creek (27 of which had no flow). A reach of Roubidoux Creek from the Missouri Highway 17 bridge to 2 river mi downstream was remeasured on December 15, 1994, because the percentage of difference between check measurements made along this reach during the seepage run were outside acceptable limits. These seepage-run data also were analyzed to determine the diffuse ground-water inflow component by applying the inflow adjustment, and the common-base adjustment was applied to adjust the measurements of each succeeding day. The common-base adjustment primarily corrected the data for small flow changes caused by propagation of water from areas upstream of the FLWMR and the small differences caused by different individuals measuring separate reaches of the same stream.

Low-Base Flow Stream and Spring Discharge

Stream discharge measurements (table 18, at the back of this report; fig. 19) also were made on the same 38-river mi reach of the Big Piney River during low-base flow conditions from September 18 to 25, 1995. Although rainfall occurred before the start of and during the seepage run, antecedent conditions were excessively dry and there was little runoff. Streamflow fluctuations were minimal during this seepage run even though 0.66 in. of rainfall was recorded at the FLWMR on September 19, 1995. The river reach measured on September 19 was reexamined the next day to verify that effects of the rainfall on streamflow were minimal. Twenty-five low-flow discharge measurements were made on the Big Piney River mainstem at 19 locations. Discharge also was determined at the mouth of 57 stream and spring tributaries (35 of which had no flow). Because of the sustained dry weather before the measurements and the minimal effect of the September 19th rainfall, the only adjustments made to this streamflow data were the subtraction of tributary inflows from mainstem measurements (inflow adjustment).

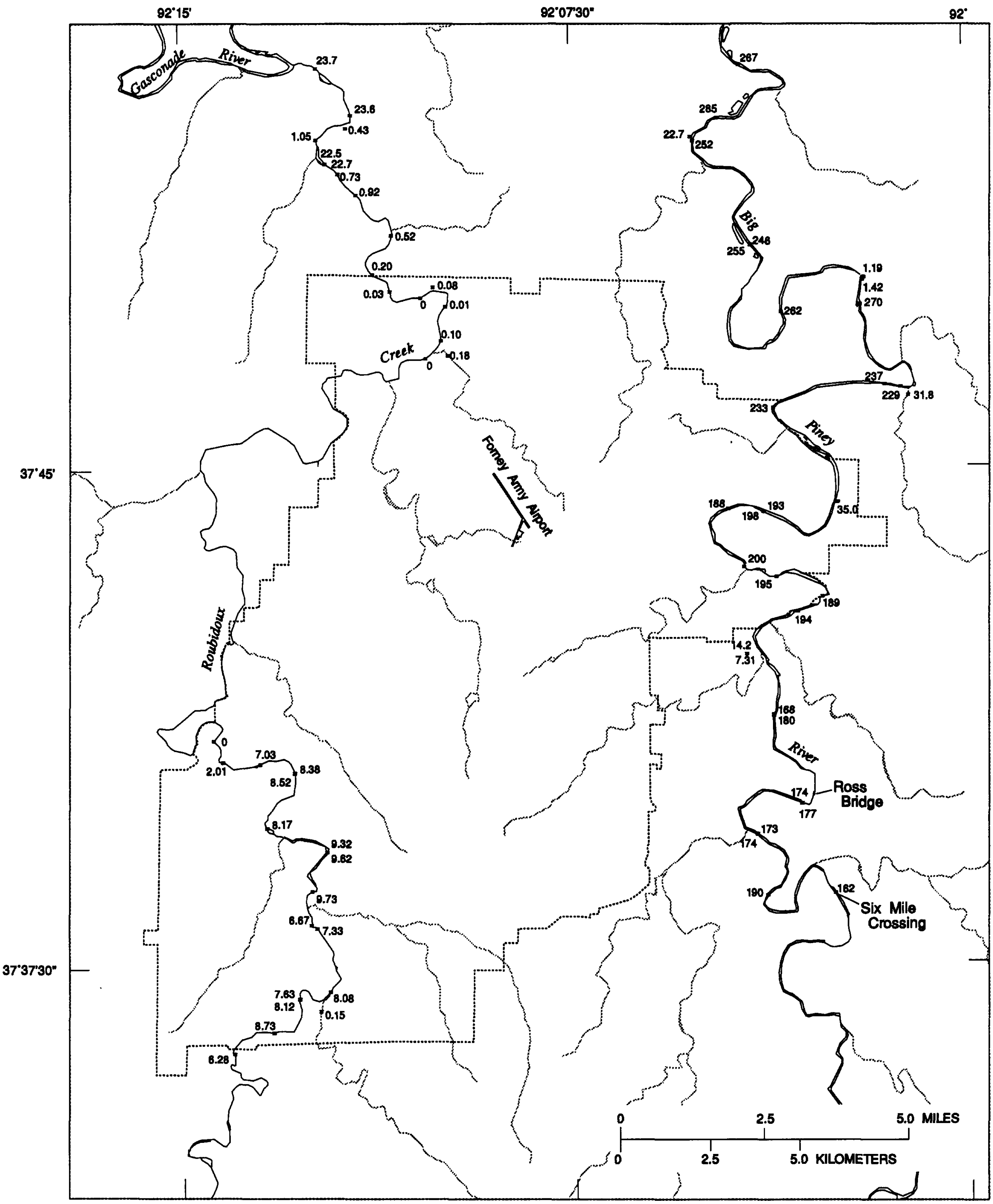


EXPLANATION

FORT LEONARD WOOD MILITARY RESERVATION BOUNDARY

. 382 STREAM DISCHARGE MEASUREMENT--Number is flow rate, in cubic feet per second. Selected tributary discharge measurements larger than 0.05 cubic foot per second are shown

Figure 18. Stream discharge measurements for the high-base flow seepage run made on the Big Piney River in February 1995 at and near the Fort Leonard Wood Military Reservation.



EXPLANATION

FORT LEONARD WOOD MILITARY RESERVATION BOUNDARY

23.6 STREAM DISCHARGE MEASUREMENT--Number is flow rate, in cubic feet per second. Selected tributary discharge measurements larger than 0.05 cubic foot per second are shown

Figure 19. Stream discharge measurements for the low-base flow seepage run made on the Big Piney River, Roubidoux Creek, and selected small tributary streams in September 1995 at and near the Fort Leonard Wood Military Reservation.

A low-flow seepage run was conducted on Roubidoux Creek from September 5 to 13, 1995, along the same 34 river mi reach that was investigated during the high-base flow seepage run (table 18; fig. 19). Twenty-nine discharge measurements were made (3 with no flow) at 25 different locations. Discharge also was determined at the mouth of 24 stream and spring tributaries (15 of which had no flow). Only the inflow adjustment was required to analyze this seepage-run data, considering the lack of rainfall before and during the measurements.

Ground-Water Discharge to Streams

The result of the seepage runs indicates a substantial increase in stream discharge in the mainstem of the Big Piney River from Six Mile Crossing to the mouth of the river. Much of this increased flow was caused by the inflow of tributaries and springs. To differentiate between the amount of flow contributed by inflow from tributaries and springs and that contributed by diffuse ground-water inflow, the inflow adjustment was applied. The result represents the effects of surface- and ground-water interaction. The adjusted discharge data were plotted as a function of the location of the measurement from the mouth of the stream (fig. 20).

Analyses of the general trend of stream discharge data collected on the Big Piney River during February 1995 at high-base flow and September 1995 at low-base flow (fig. 20) indicate that the river, with respect to the ground-water system, loses water from about 30 to 38 river mi upstream from the mouth, gains water from about 18 to 30 river mi upstream from the mouth, and loses water from about 18 river mi upstream from the mouth to near the mouth. All data was adjusted for tributary and spring inflow and the high-base flow data collected in December 1994 and February 1995 was adjusted for daily flow rate variation. However, the large uncertainty in the streamflow measurements (estimated at 5 to about 10 percent) and the relatively small magnitude of flow changes caused by surface- and ground-water interaction makes it difficult to state any conclusion with certainty. The December 1994 adjusted data contain too much scatter to provide even a qualitative estimate of the location of losing or gaining stream reaches.

An analysis of stream discharge data collected on Roubidoux Creek during high- and low-base flow conditions as adjusted for tributary and spring inflow and adjusted to a common base during high-base flow conditions (fig. 20) indicates Roubidoux Creek to be a markedly different type of stream from the Big Piney River. Stream discharge measurements indicate that Roubidoux Creek gains water through its streambed from 28 to about 34 river mi upstream from the mouth. During high-base flow conditions, the entire flow of Roubidoux Creek is lost from about 22 to about 28 river mi upstream from the mouth, with most of the loss occurring within about a 1-mi reach. During low-base flow conditions, the entire flow is lost 24 river mi upstream from the mouth, or about 2 river mi upstream from the point of flow loss during high-base flow conditions. This flow loss occurs at and is associated with the intersection of Roubidoux Creek, the Countyline Fault, and Hurd Hollow Fault (Harrison and others, 1996; fig. 3). Hurd Hollow Fault also crosses Hurd Hollow near where Hurd Hollow Stream loses its entire flow. Measurements made on the lower reach of Roubidoux Creek (from 1 to 8 river mi upstream from the mouth) indicate that essentially all flow in this reach of the creek is derived from tributary or spring inflow.

During all but the highest flow conditions caused by large amounts of runoff, Roubidoux Creek is dry throughout the nearly 7 to 8 river mi reach identified by shading on figures 5 and 6. Ground-water levels along this reach of Roubidoux Creek typically are 20 to 30 ft below the streambed, and the creek is a subterranean trough-shaped feature in the water-table surface. Part of the explanation for this situation is that, in this reach, the Roubidoux Creek stream channel contains thick gravel deposits and may be controlled by large hydraulically connected fractures. Although some ground water does flow toward Roubidoux Creek from the central part of the FLWMR along this reach (fig. 5), the diversion of large quantities of ground water from the Roubidoux Creek Basin to the Big Piney River by karst features substantially decreases available ground-water discharge and, therefore, streamflow in Roubidoux Creek. Flow in Roubidoux Creek resumes about 2 river mi before the stream channel crosses the northern boundary of the FLWMR.

WATER QUALITY

Water-quality samples were collected from selected domestic and public-supply wells, springs, the Big Piney River, Roubidoux Creek, and selected

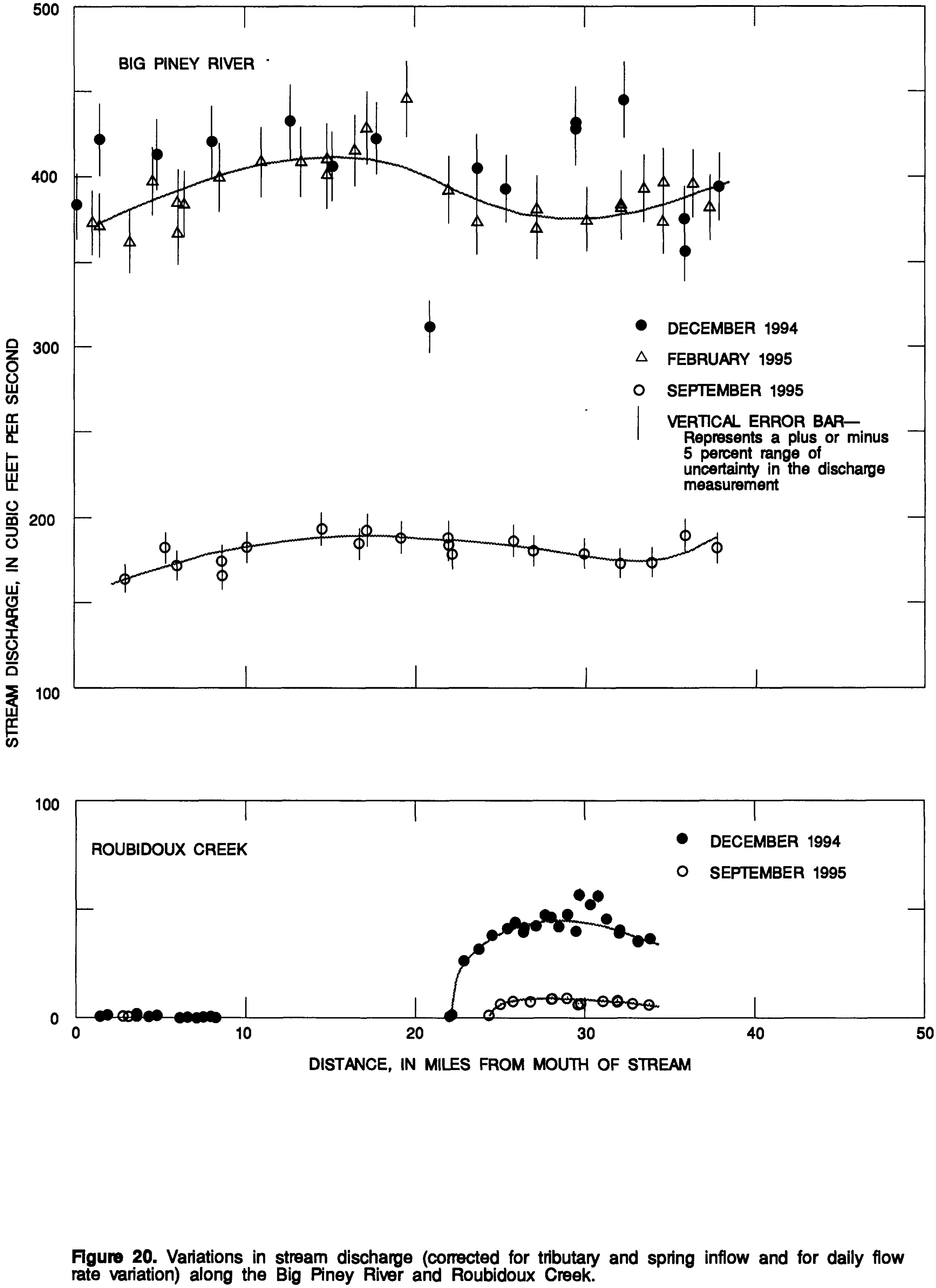


Figure 20. Variations in stream discharge (corrected for tributary and spring inflow and for daily flow rate variation) along the Big Piney River and Roubidoux Creek.

tributaries draining the FLWMR to determine baseline water-quality conditions. Sample locations generally were chosen to represent regional water sources and not effects from any specific source area or site. Depending on the location, water samples were analyzed for a comprehensive suite of inorganic and organic constituents, including dissolved and total major cations, anions, and trace elements, total cyanide (CN_t), nutrients, total organic carbon (TOC), a suite of 73 VOCs, semivolatile organic compounds or semivolatile organic compound scan by gas chromatography with flame ionization detection (GC-FID), selected pesticides, chlorophenoxy-acid herbicides, and XACs. Streambed sediment samples were analyzed for grain size, concentrations of major and trace inorganic constituents, chlorophenoxy-acid herbicides, chlorinated organic compounds, XACs, and dioxins and furans. Concentrations of major and trace inorganic constituents generally refer to the dissolved phase unless noted otherwise.

Methodology

Water-quality samples were collected using modifications of standard USGS methods (Guy and Norman, 1970; Wood, 1976; Shelton, 1994). Water samples from domestic and public-supply wells were collected from the tap nearest the wellhead. Interviews with domestic well owners were conducted to determine the location of water softeners or pressure tanks and recent water use. All wells were purged to remove stagnant water in the well bore, pump, and pipes before sampling. Domestic wells were purged by allowing water to flow freely for a minimum of 30 minutes. Public-supply wells were sampled by allowing the pump to run for a minimum of 20 minutes. During purging, specific conductance, pH, and water temperature were monitored in a closed beaker; water-quality samples were not collected until these measurements had stabilized. Stabilization criteria generally were as follows: specific conductance (successive measurements within 2 percent), pH (successive measurements within 0.02 pH unit), and temperature (successive measurements within 0.5 °C). Samples for analyses of total inorganic and organic constituents were collected in plastic or baked-glass bottles directly from the tap. Samples for the determination of VOCs were collected in 40 mL (milliliter) amber glass vials fitted with a Teflon-lined septum cap.

All sample preservation and filtering was done at the site immediately after sample collection. Samples for dissolved inorganic constituent analyses were filtered through a 0.45 μm (micrometer) nominal pore-size disposable capsule filter using a peristaltic pump as the pressure source. Samples for the determination of dissolved organic constituents were filtered using a 142-mm (millimeter) diameter 1.0 μm pore-size baked glass fiber filter placed in an aluminum filter holder. A fluid metering pump was used as the pressure source. Corrugated Teflon tubing was used to attach the pump to the filter assembly.

Depth-integrated water samples were collected from the Big Piney River, Roubidoux Creek, Miller Spring, Shanghai Spring, and Roubidoux Spring using a hand-held USGS DH-81 isokinetic Teflon sampler according to the methods described in Edwards and Glysson (1988) and Ward and Hair (1990). A minimum of 10 individual subsamples were collected at equal widths across the stream. Subsamples were composited in 3-L Teflon containers. Samples for analyses of VOCs were collected directly from the spring or stream by filling and capping the bottles beneath the water surface near the center of flow.

Determinations of specific conductance, pH, temperature, dissolved oxygen concentration, and total alkalinity were made at the sampling site. Specific conductance, temperature, and concentrations of dissolved oxygen were determined using portable meters and placing probes near the center of flow. The pH was measured by immersing the pH probe in a closed beaker containing water collected from the subsample nearest the center of flow. Samples from smaller springs and tributaries were collected by filling sample bottles or compositing containers directly from the center of flow.

All water-quality, sediment-sampling, and support equipment (for example, compositing containers, churn splitter, cone splitter, peristaltic pump hose, and pump hoses) were thoroughly cleaned before initial use and between each onsite use. The general cleaning protocol included an initial rinse with a non-phosphate detergent, followed by successive rinses in tap water, dilute acid, deionized water, methanol (organic-compound sampling only), and organic-free deionized water (organic-compound sampling only). In addition, samplers, pumps, and hoses were pre-rinsed with ambient water before sample collection and processing. The effectiveness of the cleaning procedures was monitored by the use of routine equipment blanks. In addition to equipment blanks, a number of VOC trip blanks (containing organic-free deionized water) were carried to the sampling sites, preserved, and shipped in sample coolers to verify contaminants were not introduced into VOC samples during sample handling or storage.

The specific conductance of water samples was measured using a portable conductance meter with temperature compensation designed to express values in microsiemens per centimeter at 25 °C. The meter was calibrated before each measurement using standards prepared by the USGS water-quality laboratory in Ocala, Florida. Temperature was measured to the nearest 0.1 °C using a thermistor attached to the conductance meter. The pH was measured using a portable pH meter calibrated with standard buffers bracketing the expected sample pH before each measurement. Dissolved oxygen concentrations were determined using a portable dissolved oxygen meter. Alkalinity was determined by using incremental titration of 0.16 normal (N) standardized sulfuric acid to 25 mL of sample past the carbonate-bicarbonate inflection point (approximately pH 8.3) and the bicarbonate-carbonic acid inflection point (approximately pH 4.5). Concentrations of carbonate (CO_3), bicarbonate (HCO_3), and CO_3 alkalinity were later computed using a computer program to integrate the rate of pH change to the equivalence of acid added.

To reduce or prevent the loss of ions or organic compounds from water samples, a variety of sample preservation treatments were used. When possible, filtering and adding chemical treatments to environmental samples was done inside a water-quality van to reduce the potential for contamination by airborne particulates. Samples to be analyzed for dissolved or total major cations and trace elements were acidified to a pH less than 2 using concentrated trace-metal-grade nitric acid (HNO_3). Samples for the determination of CN_t were preserved using 10 M (molar) sodium hydroxide to a pH greater than 10 and chilled to 4 °C. A HNO_3-potassium dichromate solution was used to preserve samples for the analyses of total mercury (Hg_t). Samples for nutrient analysis were acidified to a pH less than 2 using concentrated sulfuric acid (H_2SO_4) and chilled to 4 °C. A total of four vials were filled for each VOC sample; two vials were preserved with organic-free hydrochloric acid (HCl) and two vials were unacidified. All VOC vials were placed in a dedicated cooler and chilled to 4 °C. Samples for laboratory analysis or scan by GC-FID of semivolatile organic compounds were chilled to 4 °C. Pesticide samples were filtered onsite and chilled to 4 °C for transport to the USGS laboratory in Rolla, Missouri, where they were extracted using a C-18 extraction cartridge. The cartridges were chilled and shipped to the USGS water-quality laboratory in Arvada, Colorado, where they were reextracted and analyzed. Samples for the determination of XACs were placed in baked-glass bottles and chilled to 4 °C for transport to the laboratory. Between 30 and 50 subsamples were collected from the top 2 cm (centimeters) of the streambed sediment in a stainless steel container for compositing. Subsamples for grain size and analysis of inorganic constituents were placed in sealed zip-lock bags. Subsamples for the determination of organic compounds were placed in baked wide-mouth glass jars and chilled to 4 °C. All samples were shipped overnight and analyzed within guidelines established in the Sampling and Analysis Plan on file at the USGS in Rolla, Missouri.

Concentrations of most dissolved major cations and trace elements, except sodium (Na), total sodium (Na_t), potassium (K), total antimony (Sb_t), total arsenic (As_t), Hg_t, total selenium (Se_t), and total thallium (Tl_t), in water samples were determined by using inductively coupled liquid plasma (ICP). Concentrations of Na, Na_t, and K were measured using atomic adsorption (AA). Concentrations of Sb_t, As_t, and Se_t were determined using AA with graphite furnace or hydride generation. Total mercury was determined by cold vapor. Concentrations of the common ions chloride (Cl), sulfate (SO_4), and nutrients, such as total nitrite plus nitrate (NO_2+NO_3), total nitrite (NO_2), and total ammonia (NH_3), were determined by colorimetry, and concentrations of fluoride (F) were determined by ion-specific electrode. A modification of Method 524.2 (Eichelberger and others, 1992) was used to determine concentrations of VOCs in water. Semivolatile organic compounds were analyzed by Method 625 (Code of Federal Regulations, 1994). Concentrations of 47 selected pesticides in water were determined using a USGS method described in Zaugg and others (1995). The minimum reporting levels for this method ranged from 0.001 to 0.018 µg/L. Concentrations of XACs in water were determined by gas chromatography using a electron capture detector described in Schumacher and others (1996).

Concentrations of semivolatile organic compounds in sediment were determined using modifications to methods described in SW 846 (U. S. Environmental Protection Agency, 1986d). Concentrations of XACs in sediment were determined using Method 8330 (U.S. Environmental Protection Agency, 1990). A list of constituents and method reporting levels for inorganic and organic constituents in water and sediment samples and USEPA drinking water maximum contaminant levels (MCL) are given in table 19, at the back of this report.

Quality Assurance

An extensive quality assurance (QA) program has been implemented by the USGS to ensure the production of scientifically accurate data of known and documented quality. The effectiveness of a QA program is measured by the quality of data generated. Data quality is judged in terms of its accuracy, precision, completeness, representativeness, and comparability. A field sampling plan (FSP) and quality-assurance project plan (QAPP) were developed to describe, in detail, the methods and procedures used by the USGS for the collection, preservation, shipping, and analysis of project environmental samples to ensure that appropriate levels of QA and quality control (QC) were achieved (Sampling and Analysis Plan on file at the USGS in Rolla, Missouri). The QA program was developed to ensure and validate that inconsistencies in field protocols, the field protocols themselves, or analytical protocols do not introduce error into the data-collection process. Onsite QC checks were introduced into the sample collection procedures to minimize (and identify if it occurred) the potential for interference or introduction of contaminants during sample collection, storage, transport, and equipment decontamination. Laboratory QC checks were implemented to ensure the accuracy of the analytical data and minimize, or document the occurrence of, laboratory contamination and variability in analytical results.

Onsite quality checks included the proper calibration of all instruments using standard solutions, the collection of blank and duplicate samples, and adherence to standard sample collection protocols or documentation of variations. The most common error attributable to onsite procedures is contamination of the sample matrix. Two general forms of contamination occur: systematic and erratic. The goal of the field QA program is to decrease the systematic component and provide evidence of the erratic component by:

- Calibrating instruments daily
- Performing duplicate onsite measurements
- Collecting and analyzing equipment blanks
- Collecting and analyzing duplicate samples
- Collecting trip blanks for VOC

Of the 80 water-quality samples collected during the regional assessment of the FLWMR, 8 (10 percent) were duplicate samples. Eight (10 percent) equipment blanks and seven additional VOC trip blanks were collected. Duplicate samples were analyzed for all constituents determined in the original sample. Equipment blanks were analyzed for physical properties and dissolved and total inorganic constituents, VOCs, semivolatile organic compounds, selected pesticides, and XACs. The additional VOC trip blanks were analyzed only for VOCs. A summary of the relative percent difference (RPD) for the various physical properties and inorganic constituents between duplicate and the original samples is given in table 20, at the back of this report. The median and maximum values detected in the equipment blank samples also are listed in table 20.

Values of physical properties and concentrations of constituents in duplicate samples were similar to those in the original samples. To assess the general comparability of duplicate samples to original samples, a median RPD was calculated for each physical property or inorganic chemical constituent. The median RPD was derived by calculating the percent difference between each pair of sample and duplicate values and computing a median of those eight values. Generally, the RPD between the duplicate and original sample values was less than 5 percent (table 20). The largest median RPD between duplicate and original samples was for total phosphorus (P_t), boron (B), and iron (Fe) with median RPD values of 28, 33, and 13 percent (table 20). The concentrations of these constituents in the samples and duplicates were at or near the reporting levels, where large variations can be expected to occur.

Values of physical properties and concentrations of inorganic constituents in the equipment blank samples generally were small as compared to concentrations detected in water samples. Maximum concentrations of major constituents were less than 1 mg/L, and maximum concentrations of trace elements were near the reporting levels except for B (20 μg/L), Fe (7 μg/L), total iron (Fe_t, 10 μg/L), Pb (50 μg/L), zinc (Zn, 8 μg/L), and total zinc (Zn_t, 4 μg/L). Although the maximum concentrations of these constituents approached concentrations detected in some of the environmental samples, the median concentrations in the blanks were near or less than the reporting levels.

A review of the analytical data for inorganic constituents in ground-water (table 21, at the back of this report), spring (table 22, at the back of this report), and surface-water (table 23, at the back of this report) samples indicated that concentrations of calcium (Ca), barium (Ba), and Pb were commonly larger than concentrations of total calcium (Ca_t), total barium (Ba_t), and total lead (Pb_t). Dissolved inorganic constituents were analyzed at the USGS laboratory in Arvada, Colorado, using a simultaneous scanning vertical torch ICP, whereas total inorganic constituents were analyzed at the USGS laboratory in Ocala, Florida, using a total digestion (U.S. Environmental Protection Agency Method 200.7) and a sequential scanning inclined torch ICP. Except for Pb, the differences are small as compared to the actual concentrations of Ca, Ba, Ca_t, and Ba_t in the water samples and are not significant. The most probable explanation is a slight (about 5 percent) analytical bias between the methods used at the two laboratories.

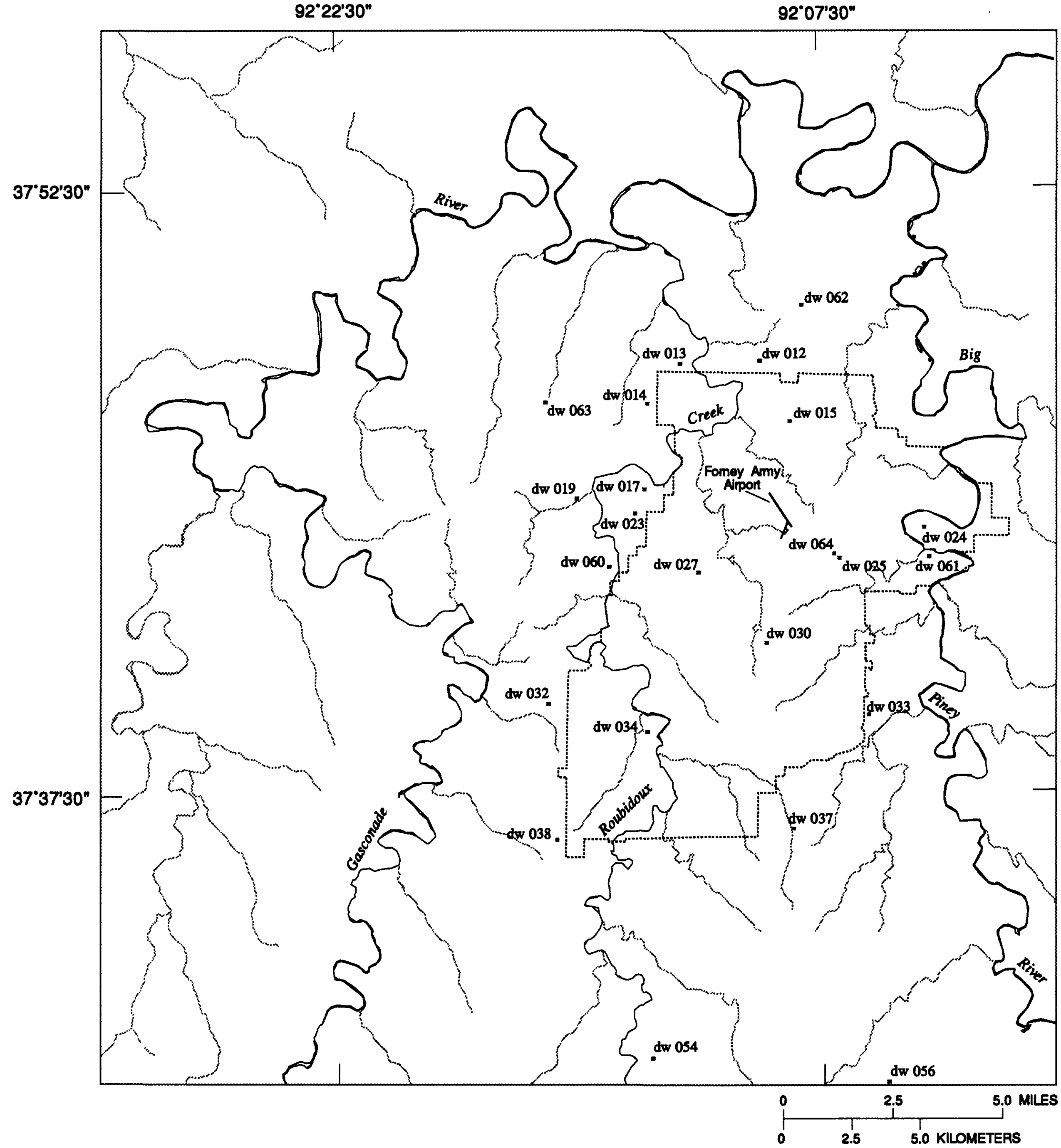
Because the solubility of Pb in water at near-neutral pH values is less than 1 μg/L, reported values of Pb in the tens of micrograms per liter are suspect. The maximum Pb concentration (50 μg/L) detected in the blank samples (table 20) indicates the determination of Pb in water samples in this study may be unreliable. A possible source of the anomalous Pb concentrations is contamination during sample collection and preservation. Samples for Pb and Pb_t are treated identically except samples for Pb determination are pumped through a disposable capsule filter. Filter contamination is possible; however, all filter lots are quality checked for metal contamination by the USGS laboratory in Ocala, Florida, prior to use. Several water samples from the FLWMR also had reported Pb concentrations substantially larger than the reporting level of 10 μg/L and significantly larger than reported concentrations for Pb_t. Contamination during sampling is possible; however, contamination also would be expected to affect Pb_t concentration. The small Pb_t concentration indicates contamination is unlikely. The QA data and comparison of Pb and Pb_t in water samples indicates that concentrations of Pb determined by vertical torch ICP probably are less reliable than those determined by inclined torch ICP.

None of the blank samples contained detectable concentrations of semivolatile organic compounds, selected pesticides, or XACs; however, one VOC blank contained a chloromethane concentration of 1.8 μg/L (table 24, at the back of this report). In addition, a comparison of acidified and unacidified VOC water samples indicated the trihalomethane (THM) compounds, chloromethane, and trichloromethane were present only in the acidified samples. A thorough review of the QA samples and blanks indicates that chloromethane and trichloromethane were present as contaminants in the HCl used to preserve VOC samples collected between January and July 1995. Water samples that contained only chloromethane or trichloromethane without other VOCs are suspect and probably indicate contamination from the preservative. Interferences from the contaminated acid resulted in the reporting levels for several THM in several samples being raised from 0.02 to 0.4 μg/L. These samples are identified in table 24. After the contamination was discovered, fresh HCl was used to preserve samples collected after August 1, 1995.

Regional Ground-Water Quality

The USGS collected 34 (includes 2 duplicates) samples from 23 wells at the FLWMR during 1995 (fig. 21). Analytical data for these samples are given in table 21. All wells except wells dw 027, dw 061, and dw 064 were sampled during high-base flow conditions between February and May 1995. Samples were collected for the determination of dissolved and total inorganic constituents, total nutrients, VOCs, semivolatile organic compounds, selected pesticides, and XACs. To determine if ground-water quality varied with season, nine of the wells were sampled again during low-base flow conditions in August 1995. Wells were not sampled for pesticides or XACs during the low-base flow sampling. No obvious difference in water quality was detected between the high- and low-base flow samples; however, samples from a number of wells indicate the effects of human or animal wastes or nitrogen-containing fertilizers. Several well samples also contained detectable pesticide concentrations.

Concentrations of major cations and anions and trace elements in well samples were used to establish background concentrations for ground water at the FLWMR. The range and 95th percentile of physical properties, major cations and anions, and trace elements in ground-water samples are included in table 25. The 95th percentile represents the value for which



EXPLANATION

FORT LEONARD WOOD MILITARY RESERVATION BOUNDARY

dw 038 GROUND-WATER SAMPLING SITE AND WELL IDENTIFIER

Figure 21. Location of domestic and public-supply wells sampled at and near the Fort Leonard Wood Military Reservation.

Table 25. Background concentrations of selected physical properties and major and trace inorganic constituents in ground-water, spring, and surface-water samples at and near the Fort Leonard Wood Military Reservation

[µS/cm, microsiemens per centimeter at 25 degrees Celsius; °C, degrees Celsius; mg/L, milligrams per liter; <, less than; col/100 mL; colonies per 100 milliliters; --, no data available; µg/L, micrograms per liter; ≤, less than or equal to]

Physical property or chemical constituent	Ground water (wells)		Spring		Surface water	
	Range	95th percentile	Range	95th percentile	Range	95th percentile
Specific conductance (µS/cm)	315-680	510	203-434	390	211-548	359
Temperature (°C)	11.5-21	18.0	2.5-23.5	18.8	4.5-31	29
pH (standard units)	7.3-7.9	7.9	6.8-8.2	7.8	7.3-8.2	8.2
Calcium (mg/L)	.2-75	68	21-45	44	24-55	38
Calcium, total (mg/L)	.1-72	65	19-44	42	23-53	36
Magnesium (mg/L)	.1-42	38	11-25	24	13-32	22
Magnesium, total (mg/L)	.1-43	38	12-27	26	14-31	24
Sodium (mg/L)	1.3-150	4.4	.9-7	2.9	.9-39	3.5
Sodium, total (mg/L)	1.4-150	5.0	1-7.2	3	.9-38	3.7
Potassium (mg/L)	.2-2.2	1.7	.9-2.3	2	.8-7.4	2.7
Bicarbonate (mg/L)	192-438	344	108-264	257	113-294	220
Chloride (mg/L)	1.0-37	6.2	1.1-9.6	4.7	.7-38	4.7
Sulfate (mg/L)	1.8-26	15	4.3-17	9.4	2.9-44	6.8
Fluoride (mg/L)	<.1-0.6	.1	<.1-.2	<.1	<.1-.7	<.3
Nitrate plus nitrite, total (mg/L)	<.02-7.2	1	<.02-2.0	0.7	<.02-2.7	.5
Nitrite, total (mg/L)	<.001-.02	<.01	<.001-.01	<.01	<.001-.26	<.01
Ammonia, total (mg/L)	<.01-.03	.03	<.01-.05	.04	<.01-8.4	.04
Phosphorus, total (mg/L)	<.02-.03	<.03	<.02-.38	<.04	<.02-1.5	<.03
Alkalinity, it, total (mg/L)	157-359	282	89-216	212	92-241	206
Total organic carbon (mg/L)	<.1-88	2.8	.7-36	15.4	.8-7.7	3.8
Dissolved solids, sum of constituents (mg/L)	170-382	290	108-252	226	130-286	222
Hardness, total (mg/L)	1-360	286	98-220	207	110-270	198
Fecal Coliform (col/100 mL)	--	--	0-810	180	<2-1,000	428
Fecal Strep (col/100 mL)	--	--	0-360	280	<2-540	430
Antimony, total (µg/L)	<1-2	<1	≤1	1	≤1	1
Arsenic, total (µg/L)	≤1	<1	≤1	1	≤1	1
Barium (µg/L)	25-210	144	35-58	54	23-88	64
Barium, total (µg/L)	20-200	140	40-50	50	30-80	66
Beryllium (µg/L)	<.5	<.5	<.5	<.5	<.5-19	<1
Beryllium, total (µg/L)	<.5-2.5	<.5	<.5-1.3	.5	<.5-1.4	1.3
Boron (µg/L)	<10-20	<20	<10-110	21	<10-140	30
Boron, total (µg/L)	220	<20	<20-120	20	<20-150	20
Cadmium (µg/L)	<1-2	<1	<1-3	<3	<1-3	<2
Cadmium, total (µg/L)	21	<1	21	1	≤1	1
Chromium (µg/L)	<5	<5	<5	<5	<5	<5
Chromium, total (µg/L)	25	<5	25	5	≤5	5
Cobalt (µg/L)	<3	<3	<3	<3	<3	<3

Table 25. Background concentrations of selected physical properties and major and trace inorganic constituents in ground-water, spring, and surface-water samples at and near the Fort Leonard Wood Military Reservation—Continued

Physical property or chemical constituent	Ground water (wells)		Spring		Surface water	
	Range	95th percentile	Range	95th percentile	Range	95th percentile
Cobalt, total (µg/L)	<3-4	<3	23	3	≤3	3
Copper (µg/L)	<10-40	17	<10	<10	<10	<10
Copper, total (µg/L)	<10-40	<20	210	10	≤10	10
Iron (µg/L)	<3-75	<64	<3-110	43	<3-80	51
Iron, total (µg/L)	4-750	225	10-230	200	7-470	<285
Lead (µg/L)	<10-40	<10	<10-60	<10	<1-40	<10
Lead, total (µg/L)	≤10	10	≤10	10	<10-18	10
Lithium (µg/L)	<4-9	<7	<4	<4	<4-5	5
Manganese (µg/L)	<1-5	2	<1-290	<75	<1-160	<58
Manganese, total (µg/L)	<1-33	1	1-330	136	1-240	<58
Mercury, total (µg/L)	≤.1	<.1	<.1-.3	<.2	<.1-.2	<.2
Molybdenum (µg/L)	<10-20	<10	<10-30	<10	≤10	<10
Nickel (µg/L)	<10	<10	<10	<10	≤10	<10
Nickel, total (µg/L)	≤10	<10	≤10	10	≤10	10
Selenium, total (µg/L)	<1	<1	≤1	1	≤1	<1
Silver (µg/L)	<1-3	1	≤1	<1	<1-2	<2
Silver, total (µg/L)	≤1	<1	≤1	1	≤1	1
Strontium (µg/L)	<1-62	59	28-51	49	24-58	<48
Thallium, total (µg/L)	≤1	<1	≤1	1	≤1	1
Vanadium (µg/L)	≤6	<6	<6	<6	<6	<6
Vanadium, total (µg/L)	≤1	<1	≤1	1	<1-2	1
Zinc (µg/L)	<3-750	<445	<3-6	<6	<3-10	<8
Zinc, total (µg/L)	<4-760	<410	<4-20	<10	<4-20	<9

95 percent of the samples are equal to or less than. The 95th percentile was assumed to represent a conservative approximation of the upper limit of background values. A subjective iterative procedure was followed. If a constituent value for a particular sample exceeded the 95th percentile, the sample was examined closely to determine if other physical properties or constituents exceeded their respective 95th percentiles. For example, physical properties and constituents commonly related to similar sources, such as increased specific conductance values and Na, Cl, and nutrient concentrations associated with effects from septic tanks or feed lots, were considered to represent non-background conditions. The values for these constituents were listed in table 21 and, although listed in the range, were not used to calculate the 95th percentiles for the particular constituents (table 25). A sample from well dw 023 (table 21) was not used to calculate the 95th percentiles. This sample contained concentrations of Ca, Ca_t, Mg, and Mg_t less than 1 mg/L and concentrations of Na, and Na_t of 150 mg/L. This sample was inadvertently collected from a tap down line of a water softener, and concentrations of major cations and anions and trace elements are not representative of background conditions.

Ground-water quality at the FLWMR is similar to the regional water quality of the Ozark aquifer described by Imes and Davis (1991). Imes and Davis

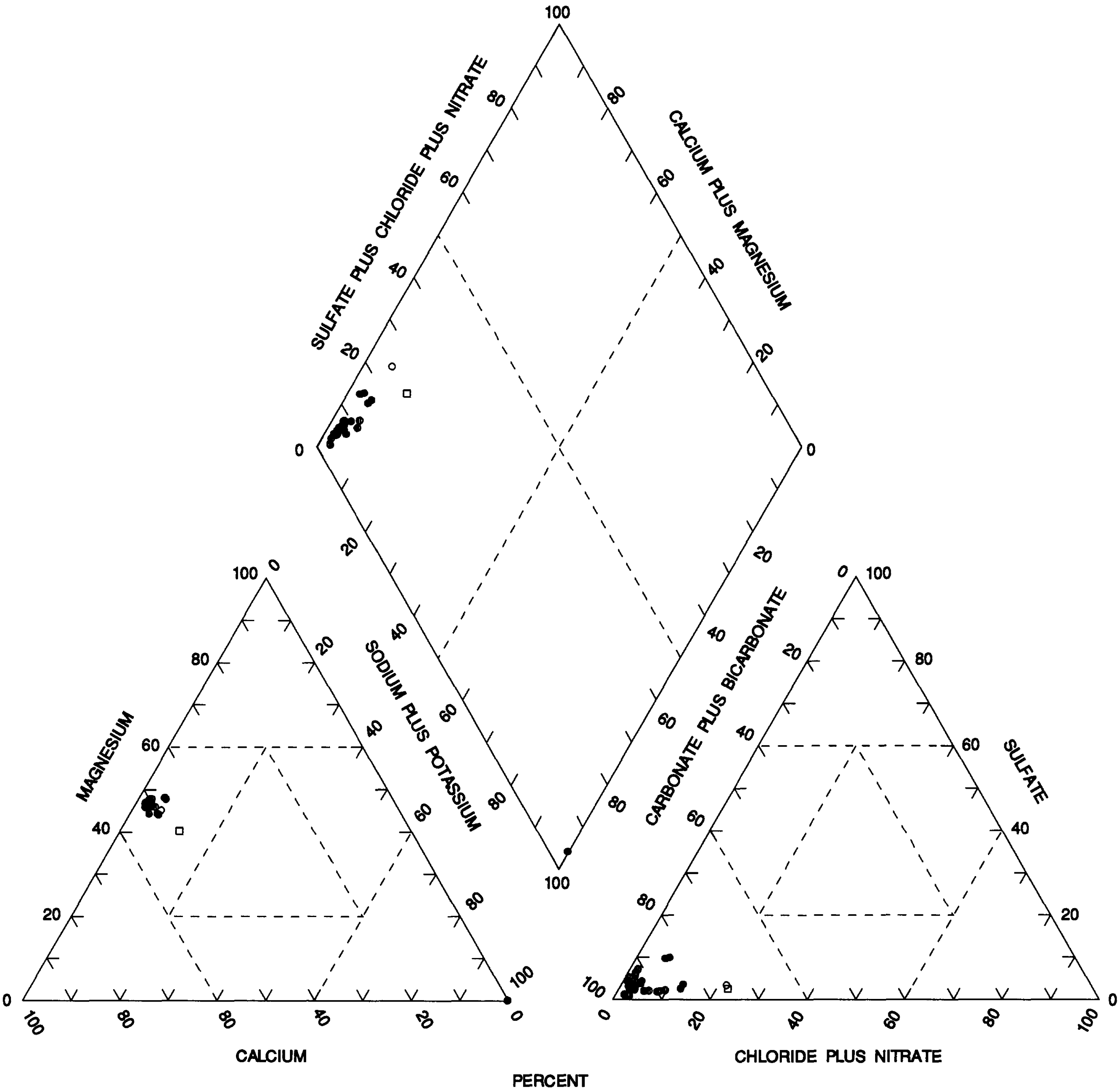
(1991) indicated that ground water in the Ozark aquifer in south-central Missouri generally is a Ca-Mg-HCO_3 type with Cl and SO_4 concentrations less than 10 mg/L and dissolved solids less than 300 mg/L. Ground water at the FLWMR has specific conductance values ranging from 315 to 680 μS/cm (background 95th percentile of 510 μS/cm), pH values about 7.5, and Ca, Mg, and HCO_3 as the predominant ions. Concentrations of dissolved solids generally were less than 300 mg/L (table 21). Samples from most wells plot within a narrow field on a trilinear diagram near the Ca plus Mg-CO_3 plus HCO_3 vertex (fig. 22), reflecting the predominately carbonate lithology of the Roubidoux Formation, Gasconade Dolomite, Eminence Dolomite, and Potosi Dolomite. Samples from wells dw 038 and dw 056 have large concentrations of Cl (37 and 22 mg/L) and plot outside the background range for ground water. Molar ratios of Ca to Mg in ground-water samples range from 0.97 to 1.18 with a median of 1.1. Ground water in equilibrium with limestone (predominately comprised of the mineral calcite) would be expected to have ratios much larger than one (Hem, 1992). Molar ratios of Ca to Mg of one generally indicate that dissolution of the mineral dolomite is the primary source of Ca and Mg in solution. Equilibrium speciation calculations using the geochemical code WATEQ4F (Ball and others, 1987) indicate that all ground-water samples (except the sample from well dw 023) were at equilibrium with the minerals calcite ($CaCO_3$) and dolomite [$(Ca, Mg)(CO_3)_2$], indicating that equilibrium with these minerals controls the pH and concentrations of Ca, Mg, and HCO_3. Ground-water samples plot along the line for weathering of carbonate material by carbonic acid (fig. 23), according to the equation:

$$CO_2 + H_2O + (Ca, Mg, Sr)CO_3 = (Ca, Mg, Sr)^{2+} + 2HCO_3^{1-}, \qquad (1)$$

rather than mineral acid dissolution or hydrolysis. The slopes of the regression lines for well (0.57) and spring (0.58) samples are similar to the theoretical slope of 0.5 from equation 1.

Samples from wells dw 017, dw 019, dw 024, dw 030, dw 033, dw 037, dw 038, dw 054, and dw 056 indicate effects of human or animal wastes or fertilizers on ground-water quality. Larger than background concentrations of Na, Na_t, Cl, and NO_2+NO_{3t} were detected in samples from wells dw 024, dw 030, dw 037, dw 038, and dw 056. Well dw 024 is located at the FLWMR golf course and also may be affected by fertilizers applied on the golf course. The larger than background concentration of Cl (6.3 mg/L) in the sample from well dw 033 also may indicate the effects of septic or animal waste, considering that the NO_2+NO_{3t} concentration was at the background concentration of 1 mg/L. The larger than background concentrations of NO_2+NO_{3t} in samples from wells dw 017 (6.9 mg/L), dw 019 (7.2 mg/L), and dw 054 (3.8 mg/L) were somewhat anomalous because they were not associated with larger than background concentrations of Na, Na_t, or Cl (table 21). Samples from wells dw 019, dw 033, dw 037, dw 054, and dw 056 also have larger than background concentrations of TOC, possibly related to human or animal wastes.

Concentrations of most trace elements in ground-water samples generally were less than detection or less than a few tens of micrograms per liter except for Ba, Ba_t, Fe_t, strontium (Sr), Zn, and Zn_t. Carbonate rock forming minerals such as calcite and dolomite contain trace quantities of Ba and Sr, and concentrations of these constituents in ground water are largely derived from dissolution of these minerals by percolating water. Concentrations of Ba, however, commonly are limited by the solubility of the mineral barite ($BaSO_4$). Indeed, samples from wells dw 017, dw 030, dw 032, dw 034, and dw 062 are at equilibrium with barite. Barite is present in the weathered residuum overlying bedrock throughout much of the Ozarks and dissolution of this mineral also could contribute to the large Ba and Ba_t concentrations detected in samples from well dw 034 (210 and 200 μg/L). Oxidation and dissolution of the mineral pyrite (FeS_2) within the bedrock is a potential source of Fe in the ground water. The solubility of Fe (Fe^{3+}) oxy-hydroxides is small, however, and Fe commonly is present as colloidal or small particles in ground water. Generally, concentrations of Fe_t were substantially larger than Fe, indicating most Fe is present in the particulate phase. In addition, corrosion of common well construction materials such as steel casings, pumps, pump riser pipes, and steel and galvanized water pipes can contribute to Fe detected in ground-water samples. Thirteen ground-water samples contained large (68 to 760 μg/L) concentrations of dissolved Zn or Zn_t. Generally, increased Zn concentrations are associated with Zn-bearing minerals such as sphalerite (ZnS) or cerussite [$Zn(CO_3)$]; however, Zn mineralization is not known to occur in the vicinity of the FLWMR, and the most likely source for the increased Zn and Zn_t con-



EXPLANATION

• WELL SAMPLE

○ WELL dw 038

□ WELL dw 056

Figure 22. Trilinear diagram depicting relative concentrations of major cations and anions in ground-water samples.

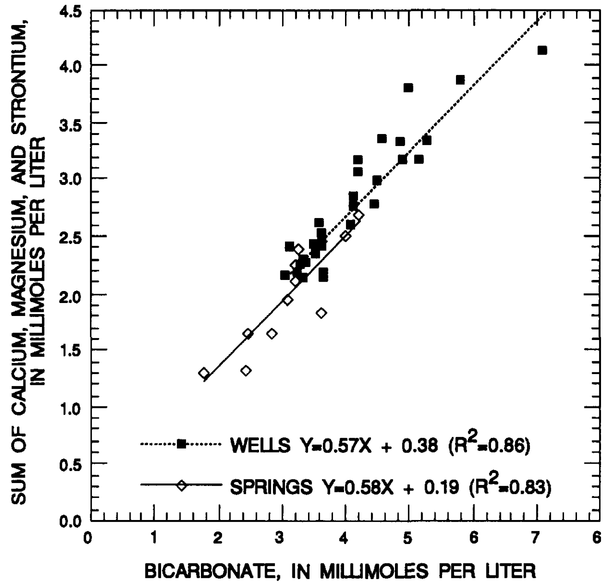


Figure 23. Sum of calcium, magnesium, and strontium as related to bicarbonate in water samples from wells and springs at the Fort Leonard Wood Military Reservation.

centrations is the corrosion of galvanized pipes used in many domestic and public-supply wells.

Samples from wells dw 015, dw 024, dw 025, dw 030, dw 061, and dw 064 contained small (less than 1.6 μg/L) concentrations of THM, such as chloromethane, trichloromethane, bromomethane, bromodichloromethane, dibromochloromethane, and bromoform, that probably are the result of chlorination of the wells or a contaminant from the HCl used to preserve some samples (as previously discussed in the "Quality Assurance Section," table 24). Chlorine in the form of household bleach commonly is used to disinfect domestic and public-supply wells after installation or servicing or is poured down wells with known bacterial contamination. Bromine is present in trace quantities in bleach and is the probable source of the bromine-containing THM. Well dw 064 is a new supply well for an ammunition storage area. This well was sampled shortly after it was completed, and the concentrations of trichloromethane (0.9 μg/L), bromodichloromethane (0.7 μg/L), and dibromochloromethane (0.5 μg/L) detected probably are related to bleach used to disinfect this well after it was completed. Only three ground-water samples contained detectable concentrations of VOCs other than THM. A sample from well dw 015 (August 29, 1995) contained total xylene concentrations of 0.3 μg/L, and a sample from well dw 024 (August 29, 1995) and a duplicate sample from well dw 030 (August 30, 1995) contained methyltert-butylether (MTBE) concentrations of 0.3 and 0.6 μg/L. Xylene and MTBE commonly are present in fuels such as gasoline. A sample collected from well dw 033 (February 23, 1995) contained acetone (1.4 μg/L) and 2-butanone (0.2 μg/L), which are contaminants traced to a permanent marker used to label VOC vials from this well.

Several non-target VOCs were tentatively identified in samples from wells dw 015, dw 024, and dw 060. Samples from well dw 015 contained dibromomethylbenzene (estimated at 0.1 μg/L), 1-bromo-3,5-dimethylbenzene (estimated at 0.3 μg/L), and 4-bromo-1,2-dimethylbenzene (estimated at 0.2 μg/L). Brominated benzene derivatives are somewhat unusual and probably are formed during the chlorination of wells. The parent compound of the brominated benzene derivatives, however, is most likely a substituted benzene such as xylene, indicating small xylene concentrations may be present in ground water near this well. A sample collected from well dw 024 (April 6, 1995) contained the non-target VOCs cyanogen chloride, 2-methylpropanal, and pentanal (0.1 μg/L). Cyanogen chloride is a highly toxic compound (Budavari and others, 1989). This compound probably is formed during chlorination similar to many of the THM. The sample from well dw 060 contained the tentatively identified non-target VOC 2,4-dimethyl heptane (estimated at 0.1 μg/L).

No semivolatile organic compounds or XACs were detected in any ground-water samples; however, dissolved pesticides were detected in samples from wells dw 014, dw 032, dw 033, and dw 060. Diazinon was the most commonly detected pesticide, detected at 5 ng/L (nanograms per liter) in samples from wells dw 014 and dw 032 and at 7 ng/L in the sample from well dw 060. The sample from well dw 033 contained a trace quantity (2 ng/L) of *p,p'*-DDE, a degradation product of DDT. Tebuthiuron was detected at 14 ng/L in the sample from well dw 060. Tebuthiuron is a non-selective herbicide used in rangelands, rights-of-way, and industrial areas (Meister Publishing Company, 1994). The effects of pesticides, human or animal wastes, and fertilizer on the water quality in several sampled wells indicates much of the shallow ground water at the FLWMR and vicinity is susceptible to contamination from surficial sources.

Spring-Water Quality

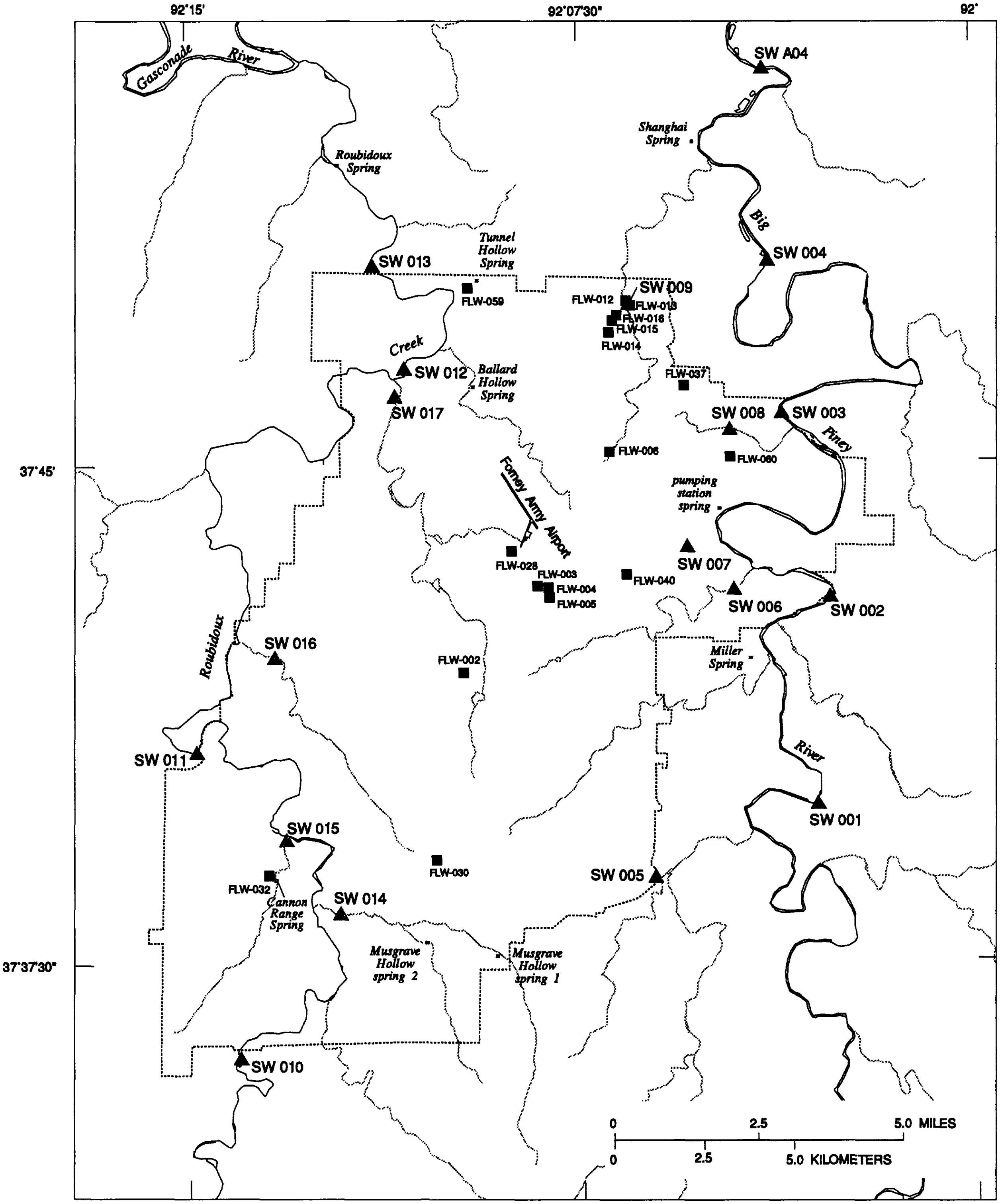
The USGS collected 19 water samples (including 3 duplicates) from 9 springs at and near the FLWMR between March 1 and September 1, 1995 (fig. 24). Springs were to be sampled during high-base flow (spring) and low-base flow (July–August) conditions; however, Ballard Hollow Spring, Musgrave Hollow spring 1, and Tunnel Hollow Spring were dry during the low-base flow sampling and Cannon Range Spring was not sampled during high-base flow conditions. Springs were sampled for dissolved and total inorganic constituents, total nutrients, VOCs, semivolatile organics scan by GC-FID, selected pesticides, and XACs at high-base flow, and for all the above except for pesticides at low-base flow. Analytical data for these samples and 11 additional water samples collected from Roubidoux Spring as part of the USGS ambient water-quality program are listed in table 22. Background concentrations of physical properties and chemical constituents were calculated in a similar manner as those for ground-water samples and are listed in table 25. Except for Shanghai Spring, spring discharges were substantially smaller during the low-base flow sampling in August 1995 than during high-base flow conditions. A review of 17 discharge measurements made by the USGS at Shanghai Spring between 1992 and 1996 indicates that discharge is similar during high- and low-base flow conditions (data on file at the USGS, Rolla, Missouri).

Water samples from springs had specific conductance values ranging from 203 to 434 µS/cm and plot near the Ca, Mg-HCO_3 vertex on a trilinear diagram (fig. 25). Similar to ground-water samples from wells, water samples from springs had pH values of about 7.5 and Ca, Mg, and HCO_3 as the principal ions (table 22).

Spring samples also plot along the weathering line of carbonate material by carbonic acid (fig. 23) and have molar ratios of Ca to Mg of about 1.1, indicating dissolution of dolomite is the principle source of major ions in spring samples. The annual loads of Ca and Mg discharged from springs such as Miller Spring represent dissolution of a substantial mass of bedrock, indicating a dynamic karst system that is continually developing. For example, assuming (1) all Ca in water samples from Shanghai Spring is derived from dissolution of dolomite, (2) a daily mean discharge of 18 ft^3/s, and (3) an average Ca concentration of 38 mg/L, the yearly mass of Ca discharged by Shanghai Spring represents the dissolution of about 35,000 ft^3 (cubic feet) of bedrock equivalent to a cubic cavern with dimensions of 33 ft per side. This constant dissolution of material over many thousands of years has manifested itself in the extensive dissolution and collapse features observed within the lower part of the Roubidoux Formation.

Boxplots showing the distribution of selected physical properties, chemical constituents, and ion ratios in samples from ground water, springs, and major streams and tributaries at the FLWMR are shown in figure 26. Background concentrations of major and trace inorganic constituents in spring samples generally were smaller than concentrations detected in ground-water samples from wells (table 25; fig. 26). Specific conductance values and concentrations of inorganic constituents in spring water samples generally were larger in low-base flow samples than in high-base flow samples (table 22), reflecting dilution by increased local recharge during high-base flow conditions.

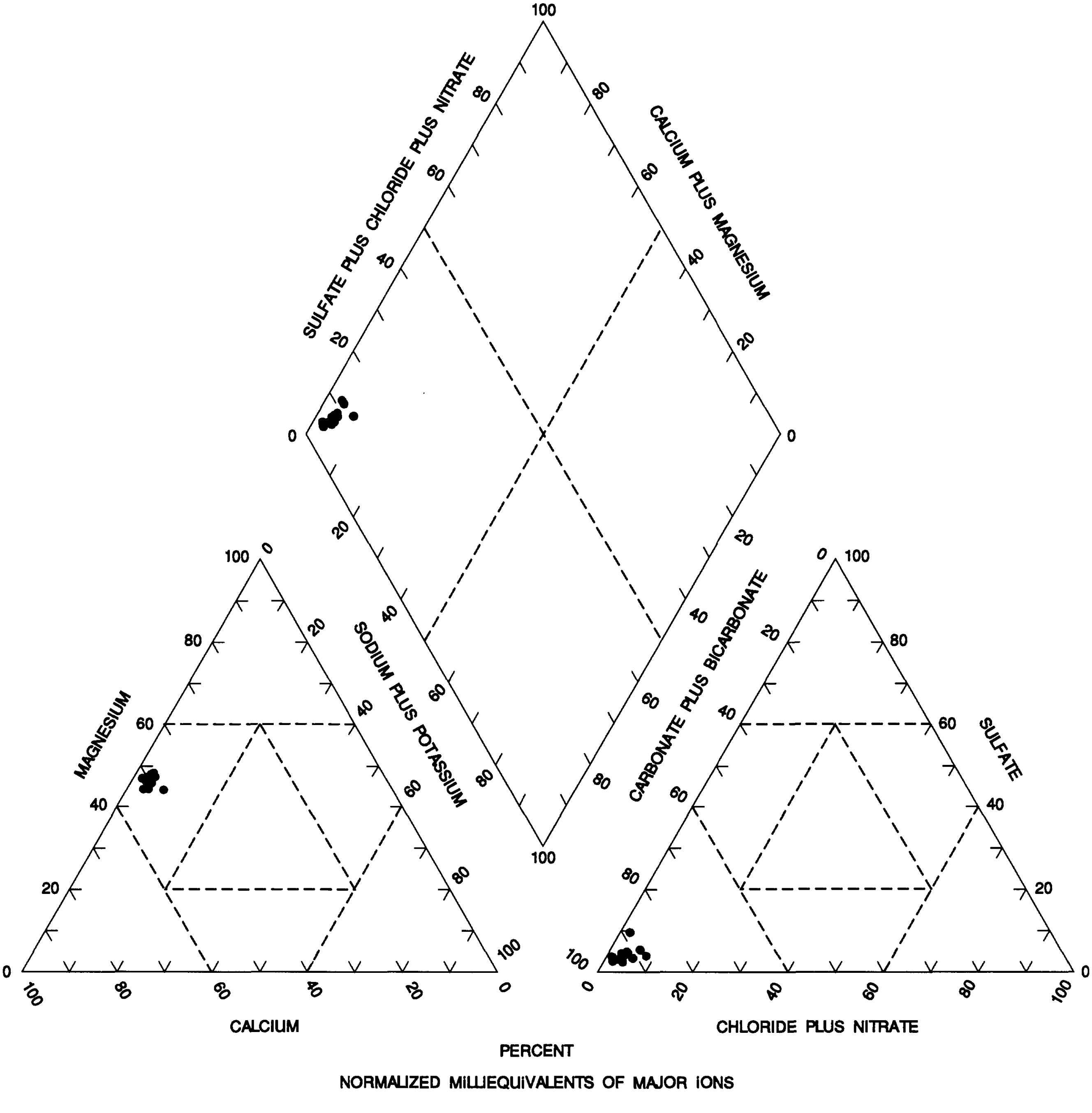
Water samples from Shanghai Spring and the pumping station spring had probable effects of septic contamination. The high- and low-base flow samples from Shanghai Spring contained larger than background concentrations of Na (7.0 mg/L), Na_t (7.1 and 7.2 mg/L), Cl (9.6 and 8.5 mg/L), NO_2+NO_{3t} (1.4 and 2.0 mg/L), P_t (0.07 and 0.38 mg/L), B (32 and 30 µg/L), and B_t (30 and 40 µg/L). The high-base flow sample also contained larger than background concentrations of SO_4 (10 mg/L) and NH_3 (0.05 mg/L). The low-base flow sample also contained larger than background specific conductance values (434 µS/cm) and concentrations of K (2.3 mg/L). The low-base flow sample from the pumping station spring contained larger than background Na (3.1 mg/L), Na_t (3.2 mg/L), Cl (6.4 mg/L), and NO_2+NO_{3t} (0.88 mg/L) concentrations. The high-base flow sample from the pumping station spring contained only TOC (36 mg/L) concentrations larger than background. A historical dye-trace test (fig. 7, trace HT-03; Harvey, 1980) verified a subsurface connection between Shanghai Spring and Dry Creek, which contains the sewage treatment plant. Effluent from the plant is a likely source of the larger than background constituent concentrations in Shanghai Spring. The pumping station spring is downgradient of a residential area, and runoff through storm sewers or leakage from sanitary or combined storm and sanitary sewers is a likely source of the larger than background constituent concentrations.



EXPLANATION

....	FORT LEONARD WOOD MILITARY RESERVATION
▲ SW 014	SPRING, SURFACE-WATER, OR STREAMBED SEDIMENT SAMPLE SITE AND IDENTIFIER
■ FLW-002	SOLID-WASTE MANAGEMENT UNIT AND IDENTIFIER

Figure 24. Location of spring, surface-water, or streambed sediment sample sites at the Big Piney River, Roubidoux Creek, and tributaries and contributing springs at and near the Fort Leonard Wood Military Reservation.



EXPLANATION

• SPRING SAMPLING SITES INCLUDE:

Ballard Hollow Spring
Miller Spring
Musgrave Hollow spring 1
Musgrave Hollow spring 2
Pumping station spring
Roubidoux Spring
Shanghai Spring
Tunnel Hollow Spring
Cannon Range Spring

Figure 25. Trilinear diagram depicting relative concentrations of major cations and anions in spring samples.

Geochemical modeling indicates the water quality of Shanghai Spring can be simulated by mixing uncontaminated spring water with the flow lost from Dry Creek. A simple mixing model was developed using the geochemical code PHREEQE (Parkhurst and others, 1980). Because Miller Spring and Shanghai Spring are located in similar geologic settings and had identical low-base flow discharges (26 ft^3/s), water-quality data from Miller Spring were used to represent the uncontaminated component of flow in the model. Measured discharges and constituent concentrations in the high-base flow sample from Dry Creek (table 23, site SW 009) and the low-base flow sample from Miller Spring (table 22) were used in the model. A constant volume mixing scenario was used, and equilibrium with calcite and a partial pressure of carbon dioxide (CO_2) of $1 \times 10^{-2.3}$ atmospheres were assumed. Results of the modeling indicate that all of the flow lost in Dry Creek probably emerges at Shanghai Spring (table 26).

Spring samples contained various densities of fecal coliform [0 to 810 col/100 mL (colonies per 100 mL)] and fecal streptococcus bacteria (0 to 360 col/100 mL; table 22). Most of the results involved non-ideal colony counts. The sample from Ballard Hollow Spring contained among the largest densities of fecal coliform (150 col/100 mL) and fecal streptococcus (360 col/100 mL) bacteria within the ideal count range (table 22). The ratio of fecal coliform to fecal streptococcus bacteria in this sample is 2.4. A fecal coliform to fecal streptococcus bacteria ratio greater than 4.1 generally is indicative of human waste and ratios less than 0.7 are indicative of animal waste (American Public Health Association and others, 1985). Ratios between 0.7 and 4.4 generally are interpreted as mixed human-animal wastes; however, ratios from sampling points more than 24 hours downstream from the source may be unreliable because fecal streptococcus bacteria have a relatively short life span outside their animal host. A possible source of the bacterial contamination to Ballard Hollow Spring is the FLWMR horse stable located about 1 mi east of Ballard Hollow Spring. The mixed human-animal waste signature (ratio of 2.4) could indicate that the travel time from the source to Ballard Hollow Spring is greater than 24 hours.

Water samples from Shanghai Spring contained detectable concentrations of VOCs (table 24). Tetrachloroethene (PCE; 1.5 and 0.8 µg/L) and trichloromethane (less than or equal to 0.2 µg/L) were detected in the high- and low-base flow samples from Shanghai Spring. The trace concentration (0.2 µg/L) of trichloromethane detected in the high-base flow sample, however, may be related to contamination from the HCl preservative because chloromethane, a known preservative contaminant, also was detected in this sample. The concentrations of PCE may be biased low. Water discharged from Shanghai Spring flows through a cave system at least several hundred feet before reaching the spring orifice (Vineyard and Feder, 1974). Because of its large Henry's law constant of 1.46×10^{-2} atmospheres-cubic meter per mole (Montgomery, 1991), PCE would quickly volatilize once water enters the cave system. Concentrations in water samples collected downgradient from the spring orifice probably are smaller than those in water entering the cave system. Assuming an average PCE concentration of 1.2 µg/L and a daily mean discharge of 18 ft^3/s (Vineyard and Feder, 1974), about 19 kg (kilograms), or 3 gal, of PCE is discharged per year from Shanghai Spring.

At least one known and two potential sources of PCE contamination are known at the FLWMR: SWMU FLW-002 located about 2.5 mi southwest of Forney Army Airport and a dry-cleaning shop and float yard storage area (fig. 1). Samples collected by the USGS from monitoring wells at SWMU FLW-002 contained PCE concentrations (less than 0.2 to 4.7 µg/L) close to the MDNR MCL of 5 µg/L. The SWMU FLW-002 is about 1.5 mi south of a dye-injection point where dye concentrations were detected at Shanghai Spring and about 1.2 mi southeast of a dye-injection point where dye concentrations were detected at Miller Spring. Because no dye-trace tests have been conducted in the immediate vicinity of SWMU FLW-002, conduit ground-water flow from that site to Shanghai Spring cannot be eliminated from consideration. Wastes containing PCE from the dry-cleaning shop temporarily were stored in the float yard located within the cantonment area about 3.5 mi southwest of Shanghai Spring (fig. 24). This area is within the probable catchment area of Shanghai Spring as defined by dye-trace tests (fig. 16). Two shallow (less than 2 ft deep) soil samples collected in 1992 during an investigation of the float yard (Radian Corporation, 1993) contained PCE; however, concentrations were less than the method reporting level of 2 µg/kg (micrograms per kilogram). No subsurface samples were collected, and only four surficial samples were analyzed for PCE. An outside storage pad and

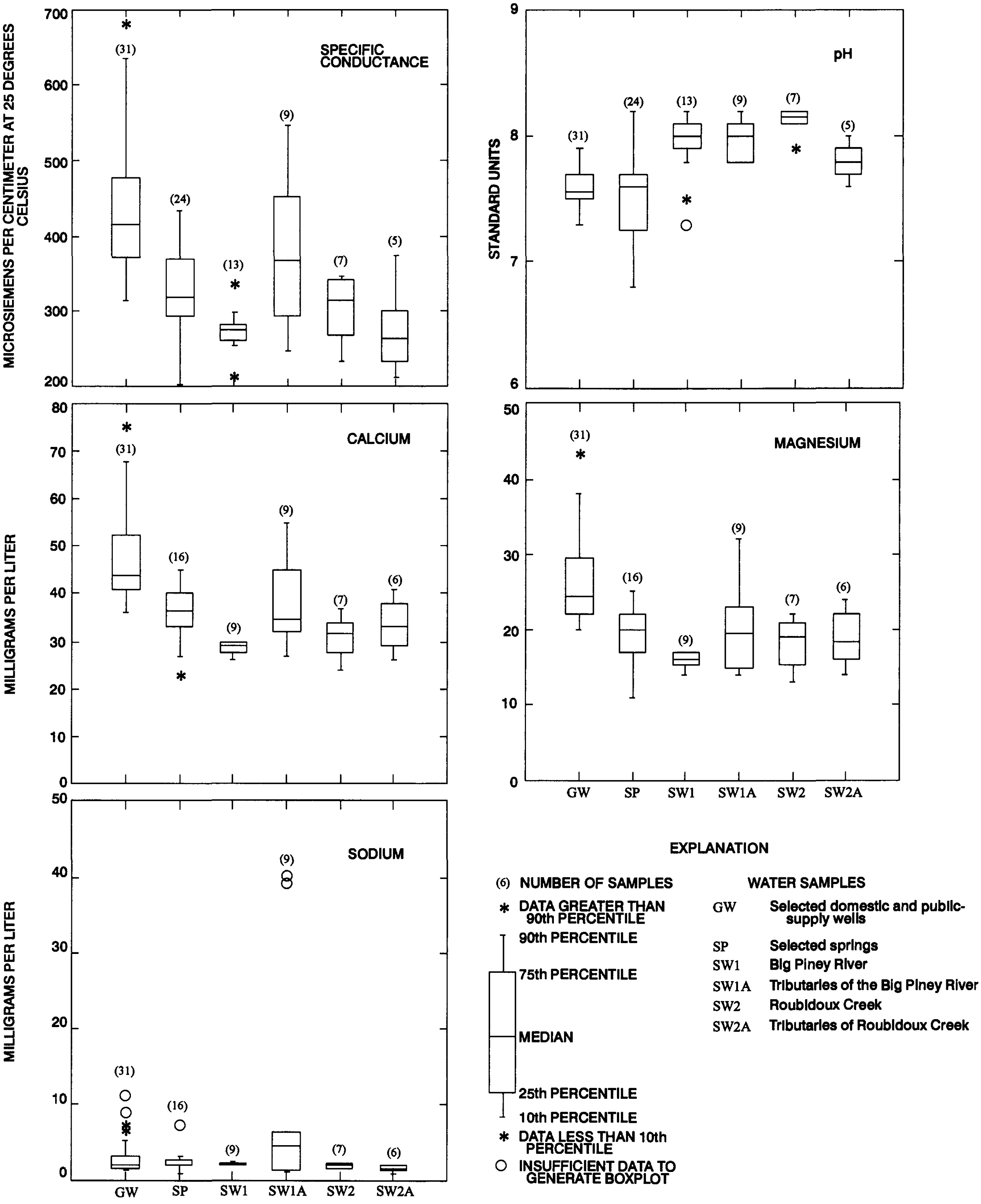


Figure 26. Boxplots of selected physical properties and chemical constituents in water samples from wells, springs, and major streams and tributaries at the Fort Leonard Wood Military Reservation.

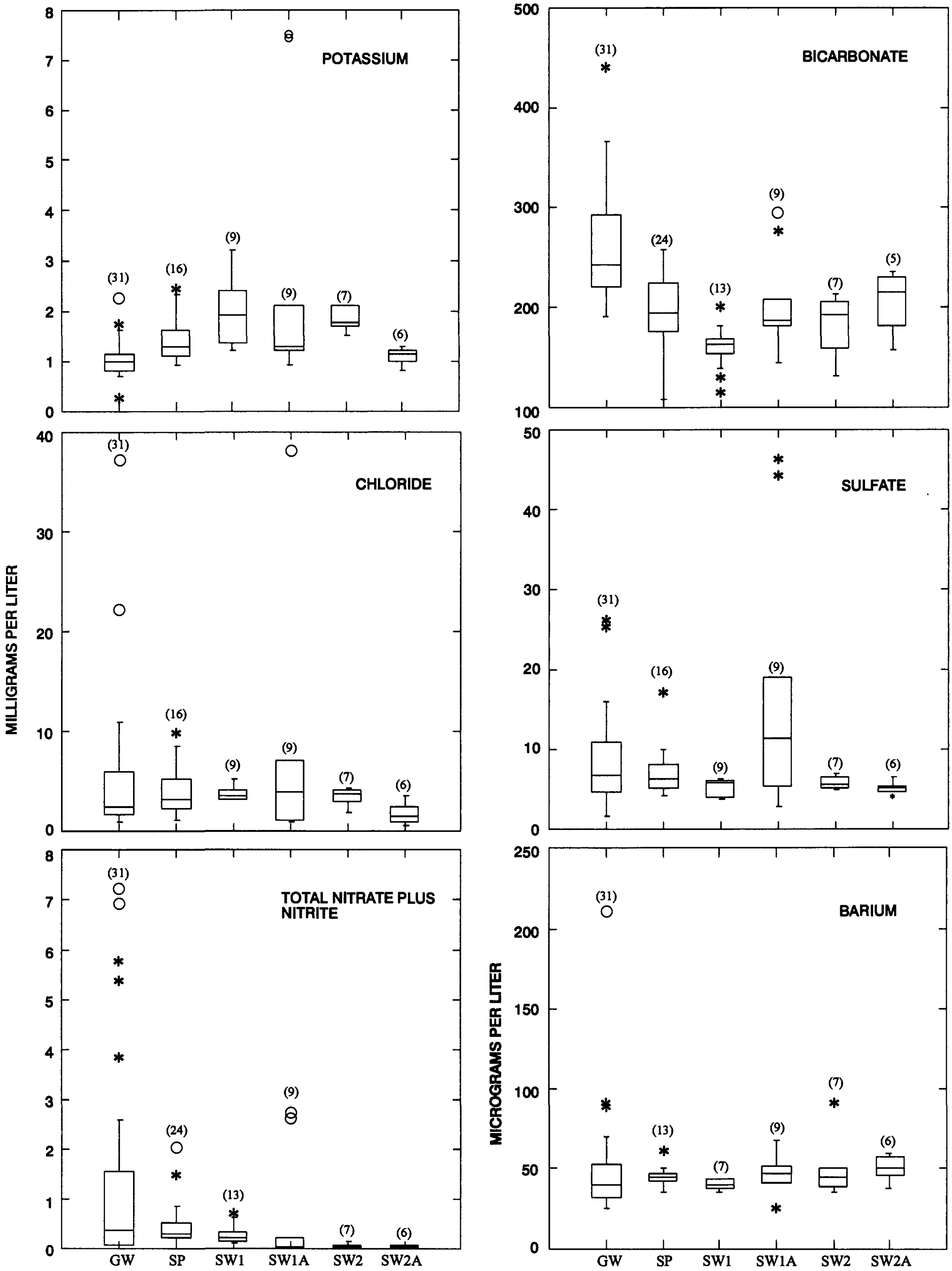


Figure 26. Boxplots of selected physical properties and chemical constituents in water samples from wells, springs, and major streams and tributaries at the Fort Leonard Wood Military Reservation—Continued.

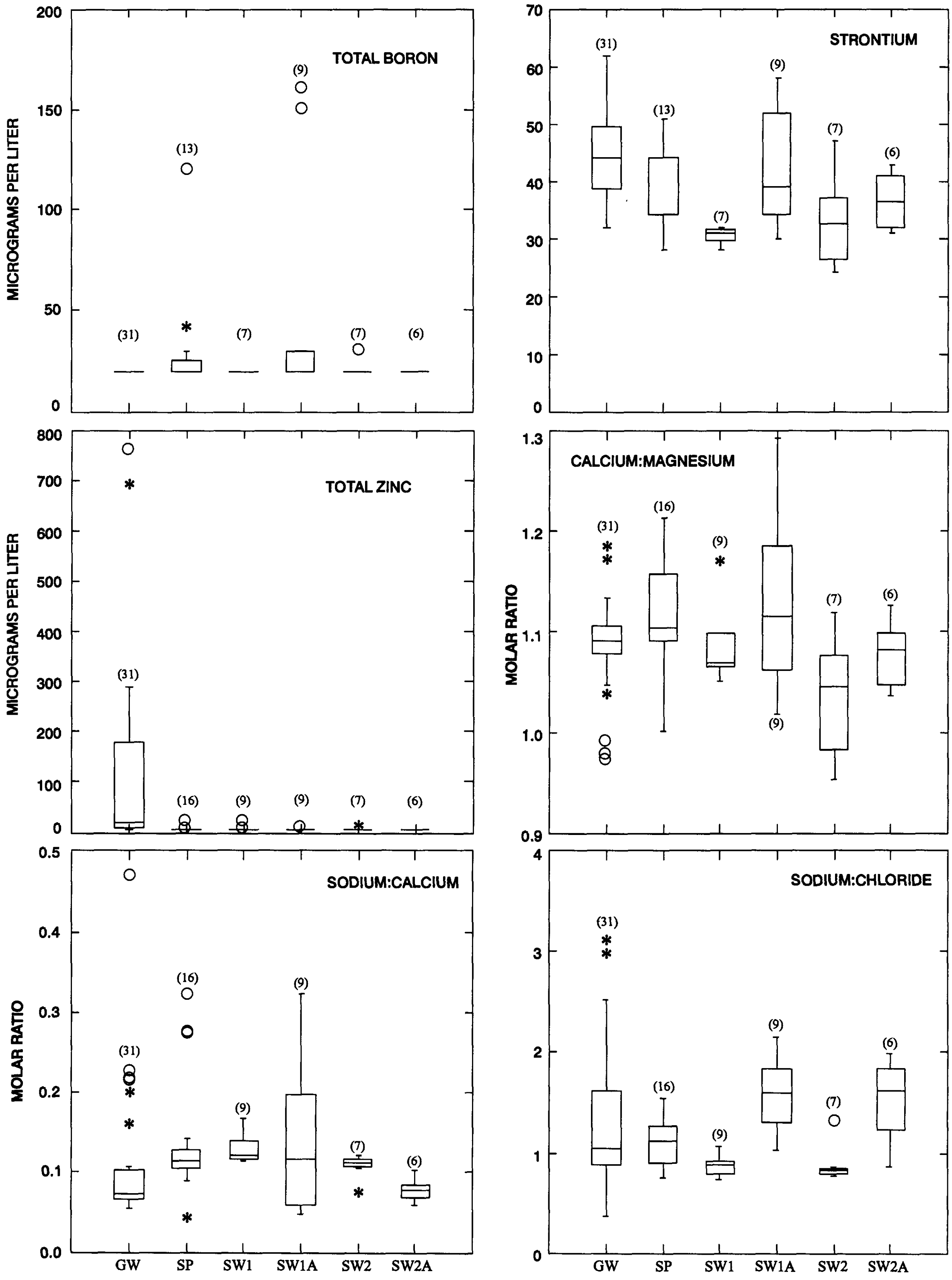


Figure 26. Boxplots of selected physical properties and chemical constituents in water samples from wells, springs, and major streams and tributaries at the Fort Leonard Wood Military Reservation—Continued.

Table 26. Simulation of water quality at Shanghai Spring

[na, not applicable; mg/L, milligrams per liter; µg/L, micrograms per liter]

Descriptor	Miller Spring 08-14-95	Dry Creek 06-13-95	Shanghai Spring 08-15-95	Simulated Shanghai Spring[a]
Flow component (percent)	83	17	na	na
pH	7.6	7.8	7.7	7.6
Temperature (degrees Celsius)	13.5	21.5	15.5	14.9
Calcium, dissolved (mg/L)	38	32	45	46
Magnesium, dissolved (mg/L)	21	15	25	20
Sodium, dissolved (mg/L)	2.0	39	7.0	8.3
Potassium (mg/L)	1.2	7.4	2.4	2.3
Bicarbonate (mg/L)	195	182	257	235
Sulfate (mg/L)	5.1	46	9.1	12.1
Chloride (mg/L)	2.3	38	8.5	8.5
Nitrate plus nitrate as nitrogen, total (mg/L)	.36	2.7	2.0	2.2
Strontium (µg/L)	38	52	47	40

[a]Dissolution of 2.4×10^{-4} moles of calcite per liter and partial pressure of carbon dioxide of $1 \times 10^{-2.3}$ atmospheres.

drain lines leading from the building containing the dry-cleaning shop and the float yard are possible PCE sources. Other potential sources include several other closed SWMUs (FLW-006, FLW-012, FLW-013, FLW-014, FLW-015, and FLW-016) within the Shanghai Spring probable catchment area that have not yet been investigated.

High-base flow samples from the pumping station spring and Shanghai Spring contained detectable concentrations of the pesticides prometon (7 and 8 ng/L) and simazine (8 and 6 µg/L). Prometon is a nonselective herbicide used for the control of many weeds and grasses (Meister Publishing Company, 1994). Simazine is a selective herbicide commonly used on crops such as corn and alfalfa, and on turf grasses. The absence of these pesticides from other springs at and near the FLWMR indicates they probably are, or were, used in the residential and industrial areas within the catchment areas of these springs. None of the spring samples contained detectable quantities of semivolatile organic compounds or XACs.

Surface-Water Quality

During this investigation, the USGS collected 32 water-quality samples (including 4 duplicate samples) from 17 surface-water sites at and near the FLWMR between April 1 and October 10, 1995 (fig. 24). Water samples were collected from the Big Piney River and Roubidoux Creek upstream (sites SW 001 and SW 010) and downstream (sites SW 004 and SW 013) from the FLWMR (fig. 24). In addition, water samples were collected from sites on the Big Piney River (sites SW 002 and SW 003) and Roubidoux Creek (sites SW 011 and SW 012) and near the mouth of tributaries draining the FLWMR. Data from seven water-quality samples (including one duplicate sample) collected from the Big Piney River near Devils Elbow (site SW A04, fig. 24) downstream from the FLWMR as part of the USGS ambient water-quality monitoring program also were included. Surface-water samples also were collected during high- and low-base flow conditions. High-base flow samples were collected during April and June 1995 and low-base flow samples were collected during August and October 1995 (table 23). Samples from the Big Piney River and Roubidoux Creek were analyzed for dissolved and total major and trace inorganic constituents, VOCs, semivolatile organic compounds, pesticides (high-base flow only), and XACs (high-base flow only). Samples from tributary sites were analyzed for dissolved and total major and trace inorganic constituents, VOCs, semivolatile organic compound scan by GC-FID, pesticides (high-base flow only), and XACs (high-base flow only).

Despite large differences in discharge and drainage basin size, samples from surface-water sites (excluding samples from site SW 009) generally had similar values of physical properties and inorganic constituents. Because of the similar water quality at most of the surface-water sites, generally data from all sites except site SW 009 were used to calculate background values for surface water. Background values of physical properties and concentrations of inorganic chemical constituents were calculated using an interpretative process similar to that used for ground-water and spring samples and are listed in table 25.

Surface-water samples generally had specific conductance values less than about 350 µS/cm and Ca, Mg, and HCO_3 as the major ions. Samples from surface-water sites, except those from sites SW 007, SW 008, and SW 009, plot in a group near the Ca, Mg-HCO_3 vertex on a trilinear diagram (fig. 27). Samples from site SW 007 contained larger than background concentrations of Na (4.2 and 6.3 mg/L), Na_t (4.3 and 6.1 mg/L), and SO_4 (13 and 19 mg/L). This site is on a tributary stream that flows into the Big Piney River about 0.25 river mi downstream from the FLWMR water-treatment plant. The plant uses aluminum sulfate [$Al_2(SO_4)_3$] and sodium hydroxide (NaOH) during the treatment process, and overflow from the plant is a possible source of the increased Na and SO_4 concentrations in these samples. Samples from site SW 008 contained larger than background values of specific conductance (399 and 452 µS/cm) and concentrations of Ca (45 and 55 mg/L), Ca_t (42 and 53 mg/L), Mg (23 and 32 mg/L), Mg_t (31 mg/L in one sample), Na (4.7 and 4.9 mg/L), Na_t (4.7 mg/L), HCO_3 (275 mg/L in one sample), SO_4 (17 and 9.8 mg/L), Cl (7.0 and 5.8 mg/L), B (37 µg/L in one sample), B_t (30 µg/L), and Sr (54 and 58 µg/L). The source of the larger than background concentrations is uncertain; however, the lack of increased concentrations of nutrients indicates the source is not sewage or septic effluent. This tributary drains a large part of the cantonment area and may be affected by runoff from a number of industrial facilities, a closed landfill 0.5-mi upstream, or runoff from residential areas within the basin. The discharge at site SW 009 during the high-base flow sampling was composed almost entirely of effluent from the sewage treatment plant (about 1,500 ft upstream) and, consequently, the water quality is substantially degraded. The high-base flow sample had larger than background values of specific conductance (548 µS/cm) and concentrations of Na (39 mg/L), Na_t (38 mg/L), K (7.4 mg/L), SO_4 (44 mg/L), Cl (38 mg/L), F (0.7 mg/L), dissolved solids (286 mg/L), TOC (7.7 mg/L), NO_2+NO_{3t} (2.7 mg/L), NO_{2t} (0.26 mg/L), NH_3 (8.4 mg/L), P_t (1.5 mg/L), B (140 µg/L), B_t (150 µg/L), and Sr (52 µg/L). During the low-base flow sampling, effluent from the sewage treatment plant was lost to the subsurface before it reached site SW 009.

Generally, concentrations of major inorganic constituents and nutrients had an inverse relation with discharge; the smallest discharges and the largest constituent concentrations generally occurred during the low-base flow sampling. This inverse relation is caused by the decreased proportion of low ionic-strength precipitation/runoff during low-base flow conditions. Samples from the Big Piney River at site SW 001, however, did not follow this trend, and concentrations of most major inorganic constituents and nutrients, except for K, silica (SiO_2), and NO_2+NO_{3t}, were smaller in the low-base flow sampling. Although the low-base flow discharge (292 ft^3/s) was smaller than the high-base flow discharge (441 ft^3/s), the low-base flow sample was collected on the receding limb of a small rise caused by rainfall several days before sample collection. Specific conductance values and most constituent concentrations were, therefore, diluted by rainfall runoff. The larger K, SiO_2, and NO_2+NO_{3t} concentrations in the low-base flow sample from site SW 001 may be caused by leaching of K and NO_2+NO_{3t} from soils or plant matter. Hem (1992) noted that during periods of relatively high discharge, K concentrations in streams from the central United States were nearly as large or larger during times of high discharge as during low discharge and attributed this to leaching of K from soil and organic material by runoff.

None of the surface-water samples contained detectable concentrations of VOCs, semivolatile organic compounds, or XACs; however, high-base flow samples from the Big Piney River (sites SW 001, SW 002, SW 003, and SW 004) and tributary site SW 008 contained several pesticides (table 24). Tebuthiuron was detected in samples from site SW 001 (9 ng/L), site SW 002 (8 ng/L), and site SW 003 (9 ng/L). The detection of this herbicide in the upstream sample (site SW 001) and similar concentrations in the samples from sites SW 002 and SW 003 indicate sources

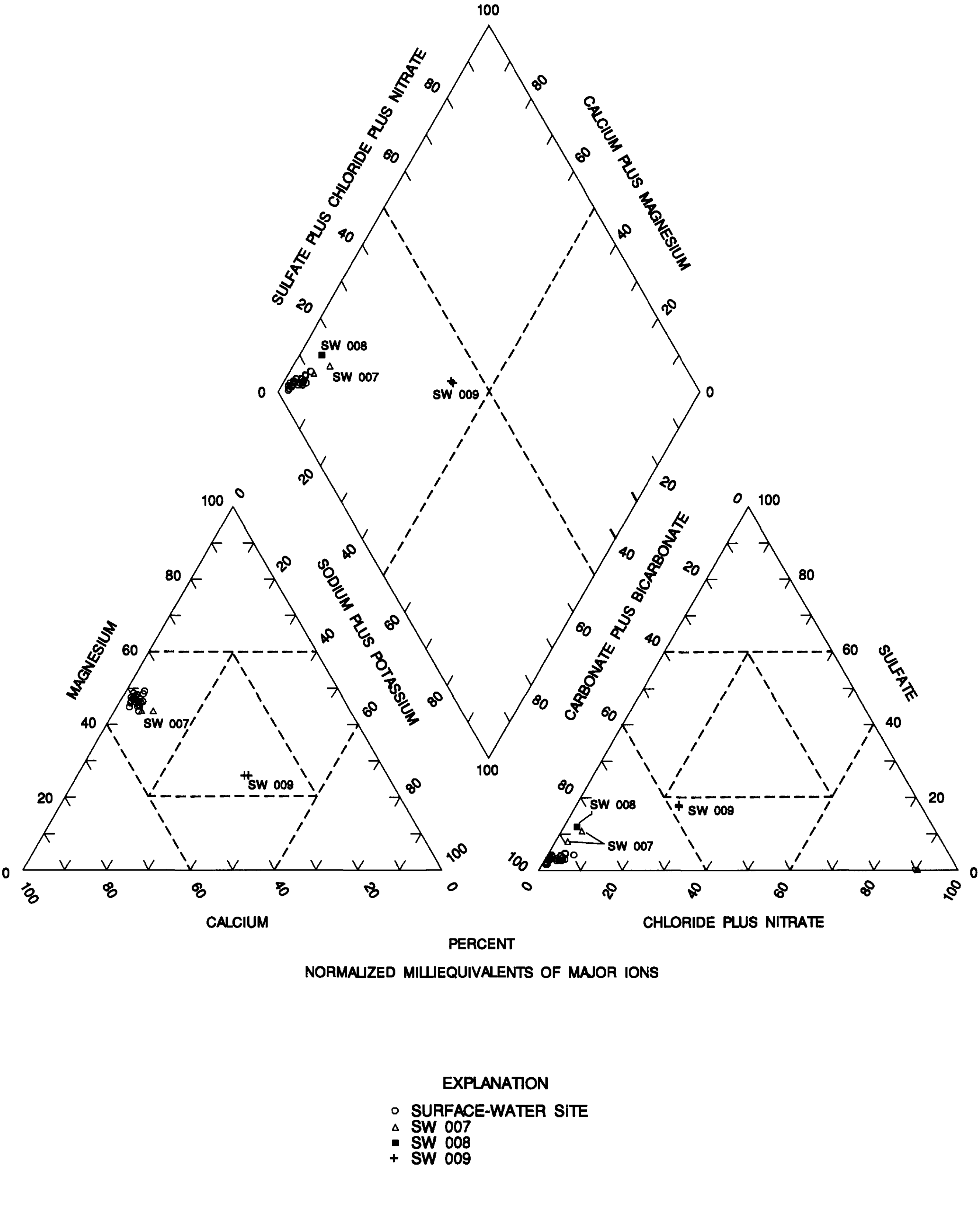


Figure 27. Trilinear diagram depicting relative concentrations of major cations and anions in surface-water samples.

other than the FLWMR. Atrazine was detected in the sample from site SW 002 (2 ng/L) and an atrazine metabolite, deethylatrazine, was detected in samples from sites SW 002 and SW 004 (4 ng/L). Atrazine is a widely used selective herbicide commonly applied in the spring on row crops such as corn, and widespread occurrence of atrazine in streams in the central United States has been attributed to runoff from agricultural areas (Goolsby and others, 1991). Several corn fields along the Big Piney River in the vicinity of site SW 002 are a possible source of the atrazine detected. The sample from tributary site SW 008 contained *p,p'*-DDE at the reporting level of 1 ng/L. The SWMU FLW-037, the old pesticide building where pesticides were mixed and stored at the FLWMR, is located about 0.5 mi upstream from site SW 008. Large concentrations of DDT and other organochlorine pesticides have been detected in soils adjacent to the SWMU FLW-037 (U.S. Army Environmental Hygiene Agency, 1992). In 1995, the USGS detected *p,p'*-DDE, DDT, chlordane, and dieldrin in streambed sediment samples between the SWMU FLW-037 and site SW 008 (data on file at the USGS, Rolla, Missouri).

Streambed Sediment Quality

Streambed sediment samples were collected from Big Piney River and Roubidoux Creek upstream (sites SW 001 and SW 010) and downstream (SW 004 and SW 013) from the FLWMR (fig. 24). Initially, these samples were analyzed for grain size, concentrations of major and trace inorganic constituents, chlorophenoxy-acid herbicides, chlorinated organic compounds, XACs, dioxin, and furans. Analytical results of subsamples submitted for grain size, trace element, and chlorinated organic compounds had not been received at the time of this report. None of the samples contained detectable concentrations of chlorophenoxy-acid herbicides or XACs. Small concentrations of octachlorodibenzoparadioxin (OCDD) were detected in streambed sediment samples from sites SW 001 (0.21 μg/kg) and SW 004 (0.01 μg/kg). Small concentrations of OCDD are common because this compound can be produced as a natural combustion product.

SUMMARY AND CONCLUSIONS

A geohydrologic and water-quality assessment of the Fort Leonard Wood Military Reservation has increased the knowledge of geologic controls on regional ground-water flow in the karst terrane at the Fort Leonard Wood Military Reservation, has provided background water-quality data for ground- and surface-water resources at the Fort Leonard Wood Military Reservation, and has identified the presence of organic compound contamination in Shanghai Spring, a major discharge point for ground water flowing from the Fort Leonard Wood Military Reservation and adjacent areas to the north. Geologic mapping of the southern Fort Leonard Wood Military Reservation area resulted in identification of an extension of the Countyline Fault through the southern Fort Leonard Wood Military Reservation and the presence of two intersecting smaller faults, a probable extension of Nelson Creek Fault and a new fault named Hurd Hollow Fault. One geologic observation of hydrologic interest was structural evidence for substantial dissolution of interbedded dolostone in the lower part of the Roubidoux Formation and collapse of overlying sandstone-rich strata. The zones of dissolution along bedding planes offer large permeability pathways for ground-water flow. A conclusion derived from observations of hundreds of fractures at the Fort Leonard Wood Military Reservation is that fractures commonly do not extend through the full thickness of formations, and most fractures do not show evidence of solution activity.

Ground-water levels and general directions of ground-water flow beneath the Fort Leonard Wood Military Reservation are similar under conditions of high-base and low-base flow. Ground-water levels in the central part of the Fort Leonard Wood Military Reservation show characteristics associated with substantial karst development. Ground water that normally would have flowed westward to Roubidoux Creek is redirected eastward to the Big Piney River by zones of large secondary permeability, and ground water that would have flowed eastward to the Big Piney River is redirected more northward toward Shanghai Spring. The regional ground-water divide in this area is as much as 2 miles west of the regional topographic divide. Water levels in the southern Fort Leonard Wood Military Reservation area generally are higher along the major recharge areas on topographic ridges and lower at discharge areas in the major river valleys. Ground-water flow is nearly perpendicular to the regional streams. Vertical ground-water flow generally is downward from the Gasconade Dolomite to the Potosi Dolomite, but may be upward in areas of highly permeable karst terrane where ground-water levels in the Roubidoux Formation and Gasconade Dolomite are lowered because of rapid flow of ground water through conduits to nearby springs.

Dye-trace tests, used to investigate ground-water flow from distinct recharge points (such as sinkholes) to discharge points (such as springs), were used to determine ground-water flow directions and rates in the karst terrane at the Fort Leonard Wood Military Reservation and to determine catchment areas for several springs. The catchment area of Shanghai Spring includes a substantial part of the north-central and northeastern Fort Leonard Wood Military Reservation. Miller Spring receives water from much of the east-central part of the Fort Leonard Wood Military Reservation. The boundary location between Shanghai Spring and Miller Spring catchment areas has been narrowed, but further investigations would be necessary to delineate this boundary.

A series of stream-discharge measurements, or seepage-run measurements, made on the Big Piney River and Roubidoux Creek during high-base and low-base flow conditions were analyzed to determine ground-water discharge through their streambeds. Stream-discharge data for the Big Piney River indicate that the river loses water from about 30 to 38 river miles above its mouth, gains water from about 18 to 30 river miles above its mouth, and loses water from about 18 river miles above its mouth to near its mouth. However, the uncertainty in these measurements and the small magnitude of apparent ground-water inflow make a definitive conclusion impossible. Data from streamflow measurements indicate that Roubidoux Creek gains water from 28 to about 34 river miles above its mouth. During high-base flow conditions, the entire flow of Roubidoux Creek is lost 22 miles above its mouth. During low-base flow conditions, the entire flow is lost 24 miles above the mouth. This flow loss is associated with the intersection of Roubidoux Creek, the Countyline Fault, and Hurd Hollow Fault. Measurements made on about the lower 8 river miles of Roubidoux Creek indicate that essentially all flow in this reach of the creek is derived from tributary stream or spring inflow. During all but the highest flow conditions, Roubidoux Creek is dry throughout a 7- to 8-river mile reach along the western boundary of the Fort Leonard Wood Military Reservation.

Water-quality samples collected from regional ground-water and surface-water sources during high-base and low-base flow conditions were used to establish baseline water-quality conditions at the Fort Leonard Wood Military Reservation. No obvious difference was detected in water quality between samples collected during high- and low-base flow conditions. Ground-water quality at the Fort Leonard Wood Military Reservation is similar to the regional water quality of the Ozark aquifer, a calcium magnesium bicarbonate type water with concentrations of chloride and sulfate less than 10 milligrams per liter; dissolved solids concentrations generally were less than 300 milligrams per liter. Ground-water specific conductance values ranged from 315 to 680 microsiemens per centimeter, pH was about 7.5, and calcium, magnesium, and bicarbonate were the predominant ions. Major and trace elements concentrations in well samples were used to establish background concentrations for ground water at the Fort Leonard Wood Military Reservation. Concentrations of most trace elements in ground-water samples generally were less than detection limits or less than a few tens of micrograms per liter except for barium, total barium, total iron, strontium, zinc, and total zinc. Thirteen ground-water samples contained large (68 to 760 micrograms per liter) concentrations of dissolved zinc or total zinc. The most likely source for the increased zinc and total zinc concentrations is the corrosion of galvanized pipes used in many domestic and public-water-supply wells.

Samples from six wells contained small (less than 1.6 micrograms per liter) concentrations of trihalomethane compounds, such as chloromethane, trichloromethane, bromomethane, bromodichloromethane, dibromochloromethane, and bromoform, that probably are the result of chlorination of the wells or contaminated hydrochloric acid used to preserve some samples. Only three ground-water samples contained detectable concentrations of volatile organic compounds other than trihalomethane compounds; one sample contained total xylenes concentrations of 0.3 microgram per liter, and two samples contained methyltertiarybutylether concentrations of 0.3 and 0.6 microgram per liter. One or more of the non-target volatile organic compounds dibromomethylbenzene, 1-bromo-3,5-dimethylbenzene, 4-bromo-1,2-dimethylbenzene, cyanogen chloride, 2-methylpropanal, pentanal, and 2,4-dimethyl heptane were tentatively identified in samples from three wells. No semivolatile organic compounds or explosives associated compounds were detected in any ground-water samples. The pesticides diazinon, *p,p'*-DDE (a degradation product of DDT), or tebuthiuron was detected in samples from four wells. The results of ground-water sampling indicate that much of the shallow ground water in the Fort Leonard Wood Military Reservation is susceptible to contamination from surficial sources.

Water-quality samples were collected from eight springs during high-base flow and six springs during low-base flow at the Fort Leonard Wood Military Reservation. Spring water had specific conductance values ranging from 203 to 434 microsiemens per centimeter, pH values of about 7.5, and calcium, magnesium, and bicarbonate as the principal ions. Dissolution of dolomite is the principal source of major ions in spring samples; annual calcium and magnesium loads at major springs represent dissolution of a substantial rock mass. Background concentrations of major and trace inorganic constituents in spring samples generally were smaller than concentrations detected in ground-water samples from wells. Specific conductance values and concentrations of inorganic constituents generally were larger in spring-water samples collected during low-base flow, reflecting dilution by increased local recharge during high-base flow conditions. Samples from two springs, Shanghai Spring and the pumping station spring, exhibit probable effects of septic contamination. Results of geochemical modeling indicate that all of the flow lost in Dry Creek probably emerges at Shanghai Spring. Fecal coliform and fecal streptococcus bacteria densities varied in spring water; among the largest densities were detected in the sample from Ballard Hollow Spring, the source of which may possibly be the Fort Leonard Wood Military Reservation horse stable located about 1 mile east of Ballard Hollow Spring. Water samples from Shanghai Spring contained detectable concentrations of trichloromethane (possibly a preservative contaminant) and concentrations of tetrachloroethene equivalent to a discharge of 3 gallons of tetrachloroethene per year. High-base flow samples from the pumping station spring and Shanghai Spring contained detectable concentrations of the pesticides prometon and simazine.

Water samples collected from 17 surface-water sites at the Fort Leonard Wood Military Reservation during high- and low-base flow conditions generally (excluding samples from site SW 009) had similar values of physical properties and concentrations of inorganic constituents. Surface-water samples generally had specific conductance values less than about 350 microsiemens per centimeter and calcium, magnesium, and bicarbonate as the major ions. Concentrations of major inorganic constituents and nutrients typically had an inverse relation with discharge, except for one sample collected from the Big Piney River, where the concentrations probably were diluted by runoff. No surface-water samples contained detectable concentrations of volatile, semivolatile organic compounds, or explosives associated compounds; however, samples from the Big Piney River and a tributary contained the pesticides tebuthiuron, atrazine, deethylatrazine, and *p,p'*-DDE.

Analytical results of streambed sediment samples collected from Big Piney River and Roubidoux Creek for grain size, trace element and chlorinated organics analysis are not yet available. No samples contained detectable concentrations of chlorophenoxy-acid herbicides or explosives associated compounds. Small concentrations of octachlorodibenzoparadioxin, a natural combustion product, were detected in bed sediment samples from two sites.

SELECTED REFERENCES

American Public Health Association and others, 1985, Standard methods for the examination of water and wastewater (16th ed.): Washington, D.C., American Public Health Association, 1,268 p.

American Society for Testing Materials, 1984, 1984 annual book of ASTM standards—Volume 4.08, Soil and Rock, Building Stones: Philadelphia, Pa., American Society for Testing Materials, p. 345, 371.

Ball, J.W., Nordstrom, K.D., and Zachmann, D.W., 1987, WATEQ4F—A personal computer Fortran translation of the geochemical code WATEQ2 with revised data base: U.S. Geological Survey Open-File Report 87–50, 108 p.

Bates, R.L., and Jackson, J.A., 1980, Glossary of geology (2d ed.): Falls Church, VA., American Geological Institute, 788 p.

Bolon, H.C., 1953, Low-water study of the Gasconade River Basin: U.S. Geological Survey Open-File Report 53–24, 10 p.

Budavari, Susan, O'Neil, M.J., Smith, Ann, and Heckelman, P.E., eds., 1989, The Merck index: Rahway, N.J., Merck and Co., Inc., 1,606 p.

Code of Federal Regulations, 1994, Title 40, part 136 Appendix A, Method 635, p. 574–601.

Connor, J.J., and Shacklette, H.T., 1975, Background geochemistry of some rocks, soils, plants, and vegetables in the conterminous United States: U.S. Geological Society Professional Paper 574–F, 168 p.

Edwards, T.K., and Glysson, G.D., 1988, Field methods for measurement of fluvial sediment: U.S. Geological Survey Open-File Report 86–531, 118 p.

Eichelberger, J.W., Munch, J.W., and Beller, T.A., 1992, Measurement of purgeable organic compounds in water by capillary column gas chromatography/mass spectrometry: U.S. Environmental Protection Agency Environmental Systems Monitoring Laboratory, rev. 4.0, p. 5–51.

Fenneman, N.M., 1938, Physiography of the Eastern United States: New York, McGraw-Hill Book Co., p. 419–518.

Fuller, D.L., Knight, R.D., and Harvey, E.J., 1967, Ground water, *in* Mineral and Water Resources of Missouri: Rolla, Missouri Division of Geology and Land Survey, v. 43, 2d ser., 399 p.

Goolsby, D.A., Coupe, R.C., and Markovchick, D.J., 1991, Distribution of selected herbicides and nitrate in the Mississippi River and its major tributaries: U.S. Geological Survey Water-Resources Investigations Report 91–4163, 36 p.

Guy, H.P., and Norman, V.W., 1970, Field methods for measurement of fluvial sediments: U.S. Geological Survey Techniques of Water-Resources Investigations, book 3, chap. C-2, 59 p.

Harrison, R.W., Orndorff, R.C., and Weems, Robert, 1996, Geology of the Fort Leonard Wood Military Reservation and adjacent areas of south-eastern Missouri, with contributions on Quaternary terraces by Paul E. Anderson, Dennis Mienert, and Grant Butler: U.S. Geological Survey Open-File Report 96–60, 255 p., 10 plates.

Harvey, E.J., 1980, Ground water in the Springfield-Salem Plateaus of southern Missouri and northern Arkansas: U.S. Geological Survey Water-Resources Investigations Report 80–101, 66 p.

Hem, J.D., 1992, Study and interpretation of the chemical characteristics of natural water (3d ed.): U.S Geological Survey Water-Supply Paper 2254, 263 p.

Horowitz, A.J., 1985, A primer on trace metal-sediment chemistry: U.S. Geological Survey Water-Supply Paper 2277, 67 p.

Imes, J.L., and Emmett, L.F., 1994, Geohydrology of the Ozark Plateaus aquifer system in parts of Missouri, Arkansas, Oklahoma, and Kansas: U.S. Geological Survey Professional Paper 1414–D, 127 p.

Imes, J.L., and Davis, J.V., 1991, Water type and concentration of dissolved solids, chloride, and sulfate in ground water from the Ozark aquifer in Missouri, Arkansas, Kansas, and Oklahoma: U.S. Geological Survey Hydrologic Investigations Atlas HA–711–K, 4 sheets.

Koenig, John W., ed., 1961, The stratigraphic succession in Missouri: Rolla, Missouri Division of Geology and Land Survey, v. 40, 2d series, 185 p.

Lidiak, E.G., Marvin, R.F., Thomas, H.H., Bass, M.N., 1966, Eastern area, part 4, *in* Geochronology of the Midcontinent Region, United States: Journal of Geophysical Research, v. 71, p. 5,427–5,438.

Meister Publishing Company, 1994, Farm chemicals handbook: Willoughby, Ohio, Section C, p. C1–C410.

Melton, R.W., 1976, The regional geohydrology of the Roubidoux and Gasconade Formations, Arkansas and Missouri: Fayetteville, University of Arkansas, unpublished M.S. thesis, 160 p.

McCracken, M.H., 1971, Structural features of Missouri: Rolla, Missouri Division of Geology and Land Survey Report of Investigations 49, 99 p.

Middendorf, M.A., 1984a, Geology of the Devils Elbow quadrangle, Missouri: Rolla, Missouri Division of Geology and Land Survey Open-File Map OFM–84–192d–GI, 1:24,000 scale, 1 sheet.

———1984b, Geology of the Waynesville quadrangle, Missouri: Rolla, Missouri Division of Geology and Land Survey Open-File Map OFM–84–192c–GI, 1:24,000 scale, 1 sheet.

———1986, Geology of the Dryknob, Brownfield, Drew, and Winnipeg quadrangles, Missouri: Rolla, Missouri Division of Geology and Land Survey Open-File Map OFM–84–190–GI, 1:52,500 scale, 1 sheet.

Montgomery, J.H., 1991, Ground water chemicals field guide: Chelsea, Mich., Lewis Publishing Inc., 271 p.

Muehlberger, W.R., Denison, R.E., and Lidiak, E.G., 1967, Basement rocks in continental interior of the United States: Bulletin of the American Association of Petroleum Geologists, v. 51, p. 2,351–2,380.

Muehlberger, W.R., Hedge, C.E., Denison, R.E., and Marvin, R.F., 1966, Southern area, part 3, *in* Geochronology of the Midcontinent Region, United States: Journal of Geophysical Research, v. 71, p. 5,409–5,426.

Mull, D.S., Liebermann, T.D., Smoot, J.L., Woosley, L.H., and Mikulak, R.J., 1988, Application of dye-tracing techniques for determining solute-transport characteristics of ground water in karst terranes: U.S. Environmental Protection Agency EPA 904/6–88–001, 103 p.

National Institute for Occupational Safety and Health, 1985, NIOSH/OSHA Pocket guide to chemical hazards: U.S. Department of Health and Human Services, DHHS No. 85–114, 249 p.

National Oceanic and Atmospheric Administration, 1951–80, Climatological data-National Summary: Asheville, N.C., National Climatic Data Center.

———1994, Climatological data monthly summary, Missouri: Asheville, N.C., National Climatic Data Center, v. 98, no. 11 and 12.

Occupational Safety and Health Administration, 1989, Hazardous waste operations and emergency response: CFR 1910.120, p. 330–330.34.

Oesch, R.D., and Oesch, D.W., 1986, Cave resources of Ft. Leonard Wood—An inventory and evaluation: Missouri Department of Conservation, 157 p.

Office of the Federal Register, 1962 (July 16), Part 300, National oil and hazardous substances pollution contingency plan, Subpart H: Washington, D.C., Federal Register, National Archives and Records Service.

Parkhurst, D.L., Thorstenson, D.C., and Plummer, L.N., 1980, PHREEQE—A computer program for geochemical calculations: U.S. Geological Survey Water-Resources Investigations 80–96, 193 p.

Radian Corporation, 1993, Final report, multi-site RCRA Investigation, Fort Leonard Wood, Missouri: Kansas City, Mo., U.S. Army Corps of Engineers.

Rantz, S.E., and others, 1982, Measurements and computation of streamflow—Volume 1. Measurement of stage and discharge: U.S. Geological Survey Water-Supply Paper 2175, 284 p.

Sawyer, C.N., and McCarty, P.L., 1978, Chemistry for environmental engineering (3rd ed.): New York, McGraw-Hill Inc., p. 120, 514–519.

Sax, N.I., 1984, Dangerous properties of industrial materials (6th ed.): New York, Van Nostrand Reinhold, Co.

Schumacher, J.G., Merten, L.M., Hockanson, E.A., and DeRusseau, S.N., 1996, Hydrologic and water-quality data for the Weldon Spring ordnance works, St. Charles County, Missouri, 1992–95: U.S. Geological Survey Open-File Report 96–218, 101 p.

Shelton, L.R., 1994, Field guide for the collection and processing of stream-water samples for the National Water-Quality Assessment Program: U.S. Geological Survey Open-File Report 94–455, 42 p.

Skelton, John, 1976, Missouri stream and springflow characteristics, low-flow frequency and flow duration: Rolla, Missouri Division of Geology and Land Survey Water Resources Report 32, 71 p.

Smith, J.A., Witkowski, P.J., and Fusillo, T.V., 1987, Manmade organic compounds in the surface waters of the United States—A review of current understanding: U.S. Geological Survey Open-File Report 87–209, 182 p.

Sumner, H.S., and Easson, Greg, 1986, Geology of the Bloodland, Big Piney, Roby, and Slabtown Springs quadrangles, Missouri: Rolla, Missouri Division of Geology and Land Survey Open-File Map OFM–84–189–GI, 1:24,000 scale, 1 sheet.

U.S. Army Environmental Hygiene Agency, 1988a, Interim final report, Hazardous waste consultation No. 37–26–1646–88, evaluation of solid waste management units, Fort Leonard Wood, Missouri, 1–4 June 1987 and 27 June–1 July 1988: Aberdeen Proving Ground, Md.

———1988b, Geohydrologic study no. 38–26–0919–88, investigation of closed landfills, Fort Leonard Wood, Missouri, 29 October–6 November and 14–18 March 1988: Aberdeen Proving Ground, Md.

U.S. Army Environmental Hygiene Agency, 1990, Geohydrologic study no. 38–26–k865–91, Sampling Visit, Fort Leonard Wood, Missouri, 13–24 August—15–18 September 1990: Aberdeen Proving Ground, Md.

———1992, RCRA facility assessment report: Fort Leonard Wood, Fort Leonard Wood, Missouri.

———1993, Ground-water quality consultation no. 38–26–KV44–93, RCRA facility assessment-Sampling Visit, Fort Leonard Wood, Missouri, 29 March–2 April 1993: Aberdeen Proving Ground, Md.

U.S. Army Toxic and Hazardous Materials Agency, 1983, Explosives in soil by HPLC, Method No. 8H: Aberdeen Proving Ground, Md.

U.S. Department of Agriculture, Soil Conservation Service, 1979, Missouri general soil map and soil association descriptions: 74 p.

———1989, Soil survey of Pulaski County, Missouri: 120 p., 12 sheets.

U.S. Department of Defense, 1981, Defense environmental quality program policy memorandum (DEQPPM81–5).

U.S. Environmental Protection Agency, 1983, Methods for chemical analysis of water and wastes: USEPA/600/4–79–020.

———1985, Remedial action at waste disposal sites: Washington, D.C., Office of Emergency and Remedial Response, USEPA/625/6–85/006.

———1986a, Superfund exposure assessment manual: Washington, D.C., Office of Emergency and Remedial Response.

———1986b, Quality criteria for water: Office of Water Regulations and Standards, USEPA/440/5–86–001.

———1986c, Methods for organic chemical analysis of municipal and industrial wastewater: Federal Register, 40 CFR 136, App. A, July 1, 1986.

———1986d, Test methods for evaluating solid waste: Office of Solid Waste and Emergency Response, Washington, D.C., SW 846, v. 1A, 3rd ed.

———1990, Method 8330 (Nitroaromatics and nitroamines by high performance liquid chromatography), *in* Test methods for evaluating solid waste, physical/chemical methods, SW 846: Washington, D.C., Office of Solid Waste and Emergency Response, rev. 0.

Vineyard, J.D., and Feder, G.L., 1974, Springs of Missouri: Rolla, Missouri Division of Geology and Land Survey, Water Resources Report 29, 266 p.

Ward, J.R., and Hair, C.A., 1990, Methods for the collection and processing of surface-water and bed-material samples for physical and chemical analyses: U.S. Geological Survey Open-File Report 90–140, 71 p.

Wood, W.W., 1976, Guidelines for the collection and field analysis of ground-water samples for selected unstable constituents: U.S. Geological Survey Techniques of Water-Resources Investigations, book 1, chap. D–1, 25 p.

Zaugg, S.D., Sandstrom, M.W., Smith, S.G., and Fehlberg, K.M., 1995, Methods of analysis by the U.S. Geological Survey national water quality laboratory—Determination of pesticides in water by C-18 solid-phase extraction and capillary-column gas chromatography/mass spectrometry with selection-ion monitoring: U.S. Geological Survey Open-File Report 95–181, 49 p.

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TABLES

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Table 2. Summary for injection site and attempted recovery sites during dye-trace test T103-01

Tracer Injection date:	**02-14-95**	**Tracer Test No:**	**T103-01**
		Project No:	**MO-10300**

Injection Site

Site name:	Forney Army Airport	Latitude:	374433
County:	Pulaski	Longitude:	0920802
Quadrangle:	Bloodland	Land net:	sec. 22, T. 35 N, R. 11 W
Altitude:	1,075 ± 10 feet	Quarter section:	SE1/4 NW1/4 SW1/4; CBD

Site description: Large sinkhole, about 100 feet in diameter; domed interior; probable cave collapse.
Field conditions: Overcast sky; intermittent sleet, temperature about 30 degrees Fahrenheit.
Hydrologic conditions: ___ low flow; ___ high flow; _x_ high-base flow; ___ low-base flow; ___ flood flow

Tracing agent:	Rhodamine WT	Pre-injection flush:	100 gallons
Agent quantity:	3 liters	Post-injection flush:	400 gallons
Time:	1:05 p.m.	Investigator(s):	Imes/Brenden/Hockanson

Remarks: Water for pre- and post-injection flushes was provided by the Fort Leonard Wood fire department. Rory McCarthy (Fort Leonard Wood, Directorate of Public Works, Environmental Officer) and Diana Travis (Missouri Division of Geology and Land Survey) observed the dye injection. Onsite survey of the area south of the injection site yielded six sinkholes of varying sizes. One sinkhole contained a distinct conduit to the subsurface. Dye was detected at Shanghai Spring 10 to 13 days after injection.

Attempted Recovery Sites

No.	Site name	Latitude-longitude (degrees minutes seconds)	Sample method	Distance (miles)	Test results[a]
1	Miller Spring	374204 - 0920414	Charcoal	4.49	n
2	Pumping station spring	374416 - 0920451	Charcoal	2.92	n
3	**Shanghai Spring**	**374951 - 0920515**	**Charcoal**	**6.55**	**p**
4	Ballard Hollow Stream near Laughlin Cemetery	374636 - 0920948	Charcoal	2.85	n
5	Small spring in Tunnel Hollow	374745 - 0920926	Charcoal	3.89	n
6	Roubidoux Spring	374931 - 0921205	Charcoal	6.80	n
7	Creasy Spring	375037 - 0921538	Charcoal	9.83	n
8	Stone Mill Spring	374424 - 0920229	Charcoal	5.07	n
9	Bartlett Mill Spring	375043 - 0921503	Charcoal	9.55	n

[a]p, positive dye detection; n, no dye detected.

Table 3. Summary for successful dye recovery at Shanghai Spring during dye-trace test T103-01

Tracer injection date:	**02-14-95**	**Tracer Test No:**	**T103-01**
		Project No:	**MO-10300**

Injection Site

Site name:	Forney Army Airport	Latitude:	374433
County:	Pulaski	Longitude:	0920802
Quadrangle:	Bloodland	Land net:	sec. 22, T. 35 N, R. 11 W
Altitude:	1,075 ± 10 feet	Quarter section:	SE1/4 NW1/4 SW1/4; CBD

Site description: Large sinkhole, about 100 feet in diameter; domed interior; probable cave collapse.
Field conditions: Overcast sky; intermittent sleet, temperature about 30 degrees Fahrenheit.
Hydrologic conditions: ___ low flow; ___ high flow; _x_ high-base flow; ___ low-base flow; ___ flood flow

Tracing agent:	Rhodamine WT	Pre-injection flush:	100 gallons
Agent quantity:	3 liters	Post-injection flush:	400 gallons
Time:	1:05 p.m.	Investigator(s):	Imes/Brenden/Hockanson

Recovery Site

Site name:	Shanghai Spring	Latitude:	374951
County:	Pulaski	Longitude:	0920515
Quadrangle:	Devils Elbow	Land net:	sec. 24, T. 36 N, R. 11 W
Altitude:	715 feet	Quarter section:	NE1/4 NE1/4 SW1/4; CAA
Sampling method:	Activated coconut charcoal	Trace length:	6.55 miles
Analytical method:	Scanning spectrofluorophotometer	Travel time:	10 to 13 days

File names of the sequence of traces indicating a positive dye recovery

19950213.06	19950216.09	19950221.09
19950224.09	19950227.09	19950303.09

Remarks: The relatively short period (10 to 13 days) that dye passed through Shanghai Spring indicates that water primarily is transported from the injection site to the spring through a single well-defined fracture or bedding-plane opening. Dye concentrations before and after this 3-day period were small relative to the maximum dye concentration. Flow rate along path carrying greatest dye load is about 0.5 mile per day.

Table 4. Summary for injection site and attempted recovery sites during dye-trace test T103-02

Tracer injection date:	**03-16-95**	**Tracer Test No:** **Project No:**	**T103-02** **MO-10300**

Injection Site

Site name:	SWMU FLW-003	Latitude:	374318
County:	Pulaski	Longitude:	0920816
Quadrangle:	Bloodland	Land net:	sec. 33, T. 35 N, R. 11 W
Altitude:	1,098 ± 5 feet	Quarter section:	SE1/4 NE1/4 NE1/4; AAC

Site description: About 200 feet into wooded area at south edge of solid-waste management unit FLW-003.
Field conditions: Partly cloudy; about 75 degrees Fahrenheit; previous rainfall about 1 week before injection.
Hydrologic conditions: ___ low flow; ___ high flow; _x_ high-base flow; ___ low-base flow; ___ flood flow

Tracing agent:	Rhodamine WT	Pre-injection flush:	60 gallons
Agent quantity:	4 liters	Post-injection flush:	600 gallons
Time:	2:40 p.m.	Investigator(s):	Imes/Brenden

Remarks: Injection in small sinkhole at south edge of solid-waste management unit FLW-003. Sinkhole is about 6 feet in diameter and 5 feet deep and located between two old manmade trenches. Preliminary to the injection, an 8- to 10-inch thick mass of rootlets and organic material was dug from the hole, exposing rock rubble. Rocks were removed to a depth of about 1.5 feet during the pre-injection flush. The sinkhole contained no clay fill and accepted flush water at a rate of about 2.5 gallons per minute. Two other small sinkholes in the area contained substantial clay fill and were unsuitable as injection sites. The post-injection flush was conducted in two stages; a 200-gallon flush at the time of dye injection and a 400-gallon flush 4 days after injection. The dye apparently remained trapped in clay deposits beneath the "sinkhole."

Attempted Recovery Sites

No.	Site name	Latitude-longitude (degrees minutes seconds)	Sample method	Distance (miles)	Test results[a]
1	Miller Spring	374204 - 0920414	Charcoal	3.93	n
2	Pumping station spring	374416 - 0920451	Charcoal	3.30	n
3	Shanghai Spring	374951 - 0920515	Charcoal	8.02	n
4	Ballard Hollow Stream near Laughlin Cemetery	374636 - 0920948	Charcoal	4.03	n
5	Small spring in Tunnel Hollow	374745 - 0920926	Charcoal	5.23	n
6	Roubidoux Spring	374931 - 0921205	Charcoal	7.94	n
7	Stone Mill Spring	374424 - 0920229	Charcoal	5.44	n
8	Unnamed stream 0.3 mile south of pumping station	374347 - 0920517	Charcoal	2.78	n
9	"Asphalt Plant" stream	374303 - 0920456	Charcoal	3.11	n
10	Ousley Spring	374747 - 0920156	Charcoal	7.73	n

[a]n, no dye detected.

Table 5. Summary for injection site and attempted recovery sites during dye-trace test T103-03

Tracer injection date:	**04-17-95**	**Tracer Test No:**	**T103-03**
		Project No:	**MO-10300**

Injection Site

Site name:	Bradford Cemetery Sinkhole	Latitude:	374210
County:	Pulaski	Longitude:	0920702
Quadrangle:	Big Piney	Land net:	sec. 2, T. 34 N, R. 11 W
Altitude:	1,040 ± 5 feet	Quarter section:	SE1/4 NW1/4 NW1/4; BBD

Site description: About 300 feet from Bradford Cemetery Road in large (300 by 150 feet) sinkhole.
Field conditions: Cloudy; about 70 degrees Fahrenheit; intermittent light rainfall, storm approaching.
Hydrologic conditions: ___ low flow; _x_ high flow; ___ high-base flow; ___ low-base flow; ___ flood flow

Tracing agent:	Fluorescein	Pre-injection flush:	100 gallons
Agent quantity:	2 lbs	Post-injection flush:	500 gallons
Time:	1:30 p.m.	Investigator(s):	Imes/Kleeschulte

Remarks: Injection in hole in northeast side of base of large sinkhole located about 300 feet southwest of bend in Bradford Cemetery Road. Sinkhole is elliptical, about 300 by 150 feet, and about 60 feet deep. The injection was in a pit having a surface opening about 12 by 18 inches and expanding into a cavity about 6 feet long by 4 feet wide by 5 feet deep. The injected dye and water entered the ground through a small hole beneath a large boulder in the bottom of the cavity.

Attempted Recovery Sites

No.	Site name	Latitude-longitude (degrees minutes seconds)	Sample method	Distance (miles)	Test results[a]
1	**Miller Spring**	**374204 - 0920414**	**Charcoal**	**3.93**	**p**
2	Pumping station spring	374416 - 0920451	Charcoal	3.30	n
3	Shanghai Spring	374951 - 0920515	Charcoal	8.02	n
4	Ballard Hollow Stream near Laughlin Cemetery	374636 - 0920948	Charcoal	4.03	n
5	Small spring in Tunnel Hollow	374745 - 0920926	Charcoal	5.23	n
6	Roubidoux Spring	374931 - 0921205	Charcoal	7.94	n
7	Stone Mill Spring	374424 - 0920229	Charcoal	5.44	n
8	Unnamed stream 0.3 mile south of pumping station	374347 - 0920517	Charcoal	2.78	n
9	"Asphalt Plant" stream	374303 - 0920456	Charcoal	3.11	n
10	Ousley Spring	374747 - 0920156	Charcoal	7.73	n

[a]p, positive dye detection; n, no dye detected.

Table 6. Summary for successful dye recovery at Miller Spring during dye-trace test T103-03

Tracer injection date:	**04-17-95**	**Tracer Test No:**	**T103-03**
		Project No:	**MO-10300**
	Injection Site		
Site name:	Bradford Cemetery Sinkhole	Latitude:	374210
County:	Pulaski	Longitude:	0920702
Quadrangle:	Big Piney	Land net:	sec. 2, T. 34 N, R. 11 W
Altitude:	1,040 ± 5 feet	Quarter section:	SE1/4 NW1/4 NW1/4; BBC
Site description:	About 300 feet from Bradford Cemetery Road in large (300 by 150 feet) sinkhole.		
Field conditions:	Cloudy; about 70 degrees Fahrenheit; intermittent light rainfall, storm approaching.		
Hydrologic conditions:	___ low flow; _x_ high flow; ___ high-base flow; ___ low-base flow; ___ flood flow		
Tracing agent:	Fluorescein	Pre-injection flush:	100 gallons
Agent quantity:	2 lbs	Post-injection flush:	500 gallons
Time:	1:30 p.m.	Investigator(s):	Imes/Kleeschulte
	Recovery Site		
Site name:	Miller Spring	Latitude:	374204
County:	Pulaski	Longitude:	0920414
Quadrangle:	Big Piney	Land net:	sec. 6, T. 34 N, R. 10 W
Altitude:	798 feet	Quarter section:	SE1/4 NW1/4 NE1/4; ABD
Sampling method:	Activated coconut charcoal	Trace length:	3.93 miles
Analytical method:	Scanning spectrofluorophotometer	Travel time:	about 4 days

File names of the sequence of traces indicating a positive dye recovery

19950414.04	19950417.04	19950421.04
19950424.04	19950427.04	

Remarks: The first dye detection at Miller Spring occurred within 4 days of injection. Concentrations of dye at the spring remained at maximum levels 4 to 7 days after injection, then began decreasing from peak values. Flow rate along path carrying greatest dye load is about 1 mile per day.

Table 7. Summary for injection site and attempted recovery sites during dye-trace test T103-04

Tracer injection date:	**05-09-95**	**Tracer Test No:**	**T103-04**
		Project No:	**MO-10300**

Injection Site

Site name:	Range 18 sinkhole series	Latitude:	374026
County:	Pulaski	Longitude:	0920815
Quadrangle:	Bloodland	Land net:	sec. 10, T. 34 N, R. 11 W
Altitude:	1,100 feet	Quarter section:	NW 1/4 SW 1/4 NW 1/4; BCB

Site description: 0.97 mile from solid-waste management unit FLW-001 and dirt road at north edge of Range 18.
Field conditions: Cloudy; about 60 degrees Fahrenheit.
Hydrologic conditions: ____ low flow; ___ high flow; _x_ high-base flow; ___ low-base flow; ___ flood flow

Tracing agent:	Fluorescein	Pre-injection flush:	None
Agent quantity:	2.5 lbs	Post-injection flush:	500 gallons
Time:	11:30 a.m.	Investigator(s):	Imes/Brenden

Remarks: Injection in eastern-most sinkhole of a series of four sinkholes approximately parallel to the dirt road along the northern edge of Range 18. The sinkhole is about 20 by 12 feet with a small pit beneath a large rock in the north side of the sinkhole. During the flushing operation, the base of the pit collapsed, revealing a 10 to 15 feet deep cavity beneath the pit and overhanging rock.

Attempted Recovery Sites

No.	Site name	Latitude-longitude (degrees minutes seconds)	Sample method	Distance (miles)	Test results[a]
1	**Miller Spring**	**374204 - 0920414**	**Charcoal**	**4.08**	**p**
2	Pumping station spring	374416 - 0920451	Charcoal	5.38	n
3	Shanghai Spring	374951 - 0920515	Charcoal	11.12	n
4	Ballard Hollow spring	374830 - 0921056	Charcoal	6.72	n
5	Small spring in Tunnel Hollow	374745 - 0920926	Charcoal	8.49	n
6	Roubidoux Spring	374931 - 0921205	Charcoal	11.00	n
7	Stone Mill Spring	374424 - 0920229	Charcoal	6.97	n
8	Unnamed stream 0.3 mile south of pumping station	374347 - 0920517	Charcoal	4.72	n
9	"Asphalt Plant" stream	374303 - 0920456	Charcoal	4.28	n
10	Ousley Spring	374747 - 0920156	Charcoal	10.23	n

[a]p, positive dye detection; n, no dye detected.

Table 8. Summary for successful dye recovery at Miller Spring during dye-trace test T103-04

Tracer injection date:	**05-09-95**	**Tracer Test No:**	**T103-04**
		Project No:	**MO-10300**

Injection Site

Site name:	Range 18 sinkhole series	Latitude:	374026
County:	Pulaski	Longitude:	0920815
Quadrangle:	Bloodland	Land net:	sec. 10, T. 34 N, R. 11 W
Altitude:	1,100 feet	Quarter section:	NW1/4 SW1/4 NW 1/4; BCB

Site description: 0.97 mile from solid-waste management unit FLW-001 and dirt road at north edge of Range 18.
Field conditions: Cloudy; about 60 degrees Fahrenheit.
Hydrologic conditions: ___ low flow; ___ high flow; _x_ high-base flow; ___ low-base flow; ___ flood flow

Tracing agent:	Fluorescein	Pre-injection flush:	None
Agent quantity:	2.5 lbs	Post-injection flush:	500 gallons
Time:	11:30 a.m.	Investigator(s):	Imes/Brenden

Recovery Site

Site name:	Miller Spring	Latitude:	374204
County:	Pulaski	Longitude:	0920414
Quadrangle:	Big Piney	Land net:	sec. 6, T. 34 N, R. 10 W
Altitude:	798 feet	Quarter section:	SE1/4 NW1/4 NE1/4; ABD
Sampling method:	Activated coconut charcoal	Trace length:	4.08 miles
Analytical method:	Scanning spectrofluorophotometer	Travel time:	about 13 days

File names of the sequence of traces indicating a positive dye recovery

19950505.04	19950508.04	19950512.04
19950515.04	19950519.04	19950522.04
19950526.04	19950530.04	

Remarks: Dye concentrations from elutriated charcoal packets placed in Miller Spring were largest about 13 days after injection. The slow rate of increase and decrease of dye concentrations as dye passed through the spring suggests a complex multi-path flow system. Flow rate along path carrying greatest dye load is about 0.3 mile per day.

Table 9. Summary for injection site and attempted recovery sites during dye-trace test T103-05

Tracer Injection date:	**05-26-95**	**Tracer Test No:**	**T103-05**
		Project No:	**MO-10300**

Injection Site

Site name:	Pulaski Avenue	Latitude:	374647
County:	Pulaski	Longitude:	0920817
Quadrangle:	Waynesville	Land net:	sec. 9, T. 35.N, R. 11 W
Altitude:	1,045 feet	Quarter section:	SE1/4 NE1/4 NE1/4; AAD

Site description: 700 feet east of intersection of Pulaski and Indiana Avenues; north side of road.
Field conditions: Overcast with showers; considerable rainfall in past week.
Hydrologic conditions: ___ low flow; _x_ high flow; ___ high-base flow; ___ low-base flow; ___ flood flow

Tracing agent:	Fluorescein	Pre-injection flush:	50 gallons
Agent quantity:	1.25 to 1.50 lbs	Post-injection flush:	450 gallons
Time:	2:15 p.m.	Investigator(s):	Brenden

Remarks: Injection in hole beneath large elm tree at southern edge of eastern-most sinkhole of two sinkholes located along Pulaski Avenue. Road passes through western-most sinkhole, which has a flat vegetated bottom and no drainage hole. Intense rainfall occurred within 2 hours of the dye injection.

Attempted Recovery Sites

No.	Site name	Latitude-longitude (degrees minutes seconds)	Sample method	Distance (miles)	Test results[a]
1	Miller Spring	374204 - 0920414	Charcoal	6.55	n
2	Pumping station spring	374416 - 0920451	Charcoal	4.26	n
3	**Shanghai Spring**	**374951 - 0920515**	**Charcoal**	**4.49**	**p**
4	Ballard Hollow spring	374830 - 0921056	Charcoal	1.30	n
5	Small spring in Tunnel Hollow	374745 - 0920926	Charcoal	1.52	n
6	Roubidoux Spring	374931 - 0921205	Charcoal	4.69	n
7	Stone Mill Spring	374424 - 0920229	Charcoal	5.97	n
8	Unnamed stream 0.3 mile south of pumping station	374347 - 0920517	Charcoal	4.25	n
9	"Asphalt Plant" stream	374303 - 0920456	Charcoal	4.40	n
10	Ousley Spring	374747 - 0920156	Charcoal	5.91	n
11	Roubidoux Creek near Burchard Hollow	374611 - 0920929	Charcoal	3.15	n

[a]p, positive dye detection; n, no dye detected.

Table 10. Summary for successful dye recovery at Shanghai Spring during dye-trace test T103-05

Tracer injection date:	**05-26-95**	**Tracer Test No:** **Project No:**	**T103-05** **MO-10300**

Injection Site

Site name:	Pulaski Avenue	Latitude:	374647
County:	Pulaski	Longitude:	0920817
Quadrangle:	Waynesville	Land net:	sec. 9, T. 35 N, R. 11 W
Altitude:	1,045 feet	Quarter section:	SE1/4 NE1/4 NE1/4; AAD

Site description:	700 feet east of intersection of Pulaski and Indiana Avenues; north side of road.
Field conditions:	Overcast with showers; considerable rainfall in past week.
Hydrologic conditions:	___ low flow; _x_ high flow; ___ high-base flow; ___ low-base flow; ___ flood flow

Tracing agent:	Fluorescien	Pre-injection flush:	50 gallons
Agent quantity:	1.25 to 1.50 lbs	Post-injection flush:	450 gallons
Time:	2:15 p.m.	Investigator(s):	Brenden

Recovery Site

Site name:	Shanghai Spring	Latitude:	374951
County:	Pulaski	Longitude:	0920515
Quadrangle:	Devils Elbow	Land net:	sec. 24, T. 36 N, R. 11 W
Altitude:	715 feet	Quarter section:	NE1/4 NE1/4 SW1/4; CAA

Sampling method:	Activated coconut charcoal	Trace length:	4.49 miles
Analytical method:	Scanning spectrofluorophotometer	Travel time:	10 to 14 days

File names of the sequence of traces indicating a positive dye recovery

19950526.11	19950530.11	19950602.11
19950605.11	19950609.11	19950616.11
19950623.11	19950630.11	

Remarks: Peak dye concentrations at the spring occurred 10 to 14 days after dye injection. The slower rate of increase and decrease of dye concentrations about the peak value as compared to dye-trace test T103-01 indicates a more complex multichannel flow path from the Pulaski Avenue sinkhole to Shanghai Spring than from the Forney Army Airport sinkhole to Shanghai Spring. Flow rate along path carrying greatest dye load is about 0.4 mile per day.

Table 11. Summary for injection site and attempted recovery sites during dye-tract test T103-06

Tracer injection date:	**07-06-95**	**Tracer Test No:** **Project No:**	**T103-06** **MO-10300**

Injection Site

Site name:	Hurd Hollow Stream	Latitude:	374205
County:	Pulaski	Longitude:	0921319
Quadrangle:	Bloodland	Land net:	sec. 2, T. 34 N, R. 12 W
Altitude:	902 ± 5 feet	Quarter section:	NE1/4 SE1/4 NW1/4; BDA

Site description: In streambed of Hurd Hollow near point of flow loss in pool of water with small inflow.
Field conditions: Partly sunny—scattered rainfall during the week.
Hydrologic conditions: _x_ low flow; ___ high flow; ___ high-base flow; ___ low-base flow; ___ flood flow

Tracing agent:	Rhodamine WT	Pre-injection flush:	None
Agent quantity:	1 gallon	Post-injection flush:	None
Time:	3:30 p.m.	Investigator(s):	Brenden/Collier

Remarks: Injection in pool of water near the point where Hurd Hollow Stream loses flow. Some rainfall occurred the night before the injection.

Attempted Recovery Sites

No.	Site name	Latitude-longitude (degrees minutes seconds)	Sample method	Distance (miles)	Test results[a]
1	Creasy Spring	375037 - 0921538	Charcoal	10.02	n
2	**Roubidoux Spring**	**374931 - 0921205**	**Charcoal**	**8.63**	**p**
3	Roubidoux Creek near Burchard Hollow	374611 - 0920929	Charcoal	7.70	n
4	Tunnel Hollow spring	374745 - 0920926	Charcoal	7.42	n
5	Ballard Hollow spring	374830 - 0921056	Charcoal	5.87	n
6	Miller Spring	374204 - 0920414	Charcoal	8.29	n
7	Road FLW 32 tributary	374347 - 0920517	Charcoal	7.63	n
8	Pumping station spring	374416 - 0920451	Charcoal	8.16	n
9	Stone Mill Spring	374424 - 0920229	Charcoal	10.27	n
10	Shanghai Spring	374951 - 0920515	Charcoal	11.57	n

[a]p, positive dye detection; n, no dye detected.

Table 12. Summary for successful dye recovery at Roubidoux Spring during dye-trace test T103-06

Tracer injection date:	**07-06-95**	**Tracer Test No:**	**T103-06**
		Project No:	**MO-10300**

Injection Site

Site name:	Hurd Hollow Stream	Latitude:	374205
County:	Pulaski	Longitude:	0921319
Quadrangle:	Bloodland	Land net:	sec. 2, T. 34 N, R. 12 W
Altitude:	902 ± 5 feet	Quarter section:	NE1/4 SE1/4 NW1/4; BDA

Site description: In streambed of Hurd Hollow near point of flow loss in pool of water with small inflow.
Field conditions: Partly sunny—scattered rainfall during the week.
Hydrologic conditions: _x_ low flow; ___ high flow; ___ high-base flow; ___ low-base flow; ___ flood flow

Tracing agent:	Rhodamine WT	Pre-injection flush:	None
Agent quantity:	1 gallon	Post-injection flush:	None
Time:	3:30 p.m.	Investigator(s):	Brenden/Collier

Recovery Site

Site name:	Roubidoux Spring	Latitude:	374931
County:	Pulaski	Longitude:	0921205
Quadrangle:	Waynesville	Land net:	sec. 25, T. 36 N, R. 12 W
Altitude:	770 feet	Quarter section:	SE1/4 NE1/4 NW1/4; BAD

Sampling method:	Activated coconut charcoal	Trace length:	8.63 miles
Analytical method:	Scanning spectrofluorophotometer	Travel time:	8 to 15 days

File names of the sequence of traces indicating a positive dye recovery

19950630.10	19950706.02	19950714.02
19950721.02	19950728.02	19950804.02

Remarks: Dye recovery at Roubidoux Spring was confined to a relatively small time range compared to the total period during which recovery was attempted. Dye concentrations before and after the 8- to 15-day travel time were small as compared with peak concentrations. Flow rate along path carrying greatest dye load is about 0.5 to 1 mile per day.

Dye was not recovered in a charcoal packet placed in Roubidoux Creek between the point at which flow returns to Roubidoux Creek near Ballard Hollow and Roubidoux Spring. This indicates that the source of water in Roubidoux Creek downstream from the long dry reach is discharge of shallow ground water from nearby upland areas. Surface water lost to karst terrane beneath Roubidoux Creek near the Cannon Range apparently flows beneath the lower reach of Roubidoux Creek and discharges at Roubidoux Spring.

Table 13. Summary for injection site and attempted recovery sites during dye-trace test T103-07

Tracer Injection date:	**07-13-95**	**Tracer Test No:**	**T103-07**
		Project No:	**MO-10300**

Injection Site

Site name:	Sinkhole at junction of FLW 24 and FLW 22	Latitude:	374442
County:	Pulaski	Longitude:	0920544
Quadrangle:	Big Piney	Land net:	sec. 24, T. 35 N, R. 11 W
Altitude:	1,010 feet	Quarter section:	SE1/4 SW1/4 NW1/4; BCD

Site description: Large sinkhole at south side of junction of roads FLW 24 (pumping station) and FLW 22.
Field conditions: Hot, humid, and sunny. No rainfall in the past week.
Hydrologic conditions: _x_ low flow; ___ high flow; ___ high-base flow; ___ low-base flow; ___ flood flow

Tracing agent:	Fluorescein	Pre-injection flush:	300 gallons
Agent quantity:	0.50 lb	Post-injection flush:	700 gallons
Time:	10:20 p.m.	Investigator(s):	Brenden

Remarks: Sinkhole had two visible openings in the southeast corner. A large amount of organic matter was removed from around both openings in the event one would not take flush water. Largest opening was used and was opened to 1.5 feet diameter by 1.5 feet deep before flushing. Opening took flush water quickly with minimum amount of pooling. Water never overflowed the opening at any time, which indicates a good connection to underground fractures.

Attempted Recovery Sites

No.	Site name	Latitude-longitude (degrees minutes seconds)	Sample method	Distance (miles)	Test results[a]
1	Creasy Spring	375037 - 0921538	Charcoal	11.32	n
2	Roubidoux Spring	374931 - 0921205	Charcoal	7.99	n
3	Roubidoux Creek near Burchard Hollow	374611 - 0920929	Charcoal	6.46	n
4	Tunnel Hollow spring	374745 - 0920926	Charcoal	4.86	n
5	Ballard Hollow spring	374830 - 0921056	Charcoal	3.78	n
6	Miller Spring	374204 - 0920414	Charcoal	3.33	n
7	Road FLW 32 tributary	374347 - 0920517	Charcoal	1.14	n
8	**Pumping station spring**	**374416 - 0920451**	**Charcoal**	**.95**	**p**
9	Stone Mill Spring	374424 - 0920229	Charcoal	2.99	n
10	**Shanghai Spring**	**374951 - 0920515**	**Charcoal**	**5.93**	**u**
11	"Asphalt Plant" stream	374303 - 0920456	Charcoal	2.15	n

[a]p, positive dye detection; n, no dye detected; u, uncertain (inconclusive results).

Table 14. Summary for successful dye recovery at the pumping station spring during dye-trace test T103-07

Tracer injection date:	**07-13-95**	**Tracer Test No:**	**T103-07**
		Project No:	**MO-10300**

Injection Site

Site name:	Sinkhole at junction of FLW 24 and FLW 22	Latitude:	374442
County:	Pulaski	Longitude:	0920544
Quadrangle:	Big Piney	Land net:	sec. 24, T. 35 N, R. 11 W
Altitude:	1,010 feet	Quarter section:	SE1/4 SW1/4 NW1/4; BCD

Site description: Large sinkhole at south side of junction of roads FLW 24 (pumping station) and FLW 22.
Field conditions: Hot, humid, and sunny. No rainfall in the past week.
Hydrologic conditions: _x_ low flow; ___ high flow; ___ high-base flow; ___ low-base flow; ___ flood flow

Tracing agent:	Fluorescein	Pre-injection flush:	300 gallons
Agent quantity:	0.50 lb	Post-injection flush:	700 gallons
Time:	10:20 p.m.	Investigator(s):	Brenden

Recovery Site

Site name:	Pumping station spring	Latitude:	374416
County:	Pulaski	Longitude:	0920451
Quadrangle:	Big Piney	Land net:	sec. 24, T. 35 N, R. 11 W
Altitude:	825 feet	Quarter section:	SE1/4 SE1/4 SE1/4; CCC

Sampling method:	Activated coconut charcoal	Trace length:	0.95 mile
Analytical method:	Scanning spectrofluorophotometer	Travel time:	1 to 8 days

File names of the sequence of traces indicating a positive dye recovery

19950630.07	19950706.08	19950714.08
19950721.08	19950728.08	19950804.08
19950811.08	19950818.08	19950825.08

Remarks: Fluorescein has always been present in the background at this recovery site. The background fluorescein may be derived from residential areas 1 mile west of the spring. Dye recovery was within 1 to 8 days after injection. Initial recovery concentrations were large, indicating a well-defined flow path. Substantial dye concentrations were also detected after the peak concentration, indicating some water is flowing through alternate paths or is temporarily retained in storage. Flow rate along path carrying greatest dye load is less than 1 mile per day.

Table 15. Summary for uncertain dye recovery at Shanghai Spring during dye-trace test T103-07

Tracer injection date:	**07-13-95**	**Tracer Test No:** **Project No:**	**T103-07** **MO-10300**

Injection Site

Site name:	Sinkhole at junction of FLW 24 and FLW 22	Latitude:	374442
County:	Pulaski	Longitude:	0920544
Quadrangle:	Big Piney	Land net:	sec. 24, T. 35 N, R. 11 W
Altitude:	1,010 feet	Quarter section:	SE1/4 SW1/4 NW1/4; BCD

Site description: Large sinkhole at south side of junction of roads FLW 24 (pumping station) and FLW 22.
Field conditions: Hot, humid, and sunny. No rainfall in the past week.
Hydrologic conditions: _x_ low flow; ___ high flow; ___ high-base flow; ___ low-base flow; ___ flood flow

Tracing agent:	Fluorescein	Pre-injection flush:	300 gallons
Agent quantity:	0.50 lb	Post-injection flush:	700 gallons
Time:	10:20 p.m.	Investigator(s):	Brenden

Recovery Site

Site name:	Shanghai Spring	Latitude:	374951
County:	Pulaski	Longitude:	0920515
Quadrangle:	Devils Elbow	Land net:	sec. 24, T. 36 N, R. 11 W
Altitude:	715 feet	Quarter section:	NE1/4 NE1/4 SW1/4; CAA

Sampling method:	Activated coconut charcoal	Trace length:	5.93 miles
Analytical method:	Scanning spectrofluorophotometer	Travel time:	--

File names of the sequence of traces indicating a positive dye recovery

19950630	19950706	19950714
19950721	19950728	19950804
19950811	19950818	19950825

Remarks: A small fluorescein peak was observed at Shanghai Spring several days after the successful recovery at the pumping station spring. Because dye concentrations at Shanghai Spring were substantial immediately before injection, it is not certain that the peak dye concentration detected 1 to 8 days after injection of dye into the sinkhole at roads FLW 24 and 22 was caused by the injected dye. This dye-trace test could be repeated using a different injected dye or larger quantity of fluorescein dye to confirm recovery at Shanghai Spring.

Table 16. Discharge measurements and selected physical properties for the Big Piney River, Roubidoux Creek, and tributaries, December 1994

[mi, mile; ft^3/s, cubic feet per second; µS/cm, microsiemens per centimeter at 25 degrees Celsius; temp., temperature; °C, degrees Celsius; N/A, not applicable; lb, left bank; --, no data; rb, right bank; see 1a, see measurement no. 1a; e, estimated; <, less than]

Measurement number	Stream name	Tributary name	Bank	Distance from mouth (mi)	Date (month-day-year)	Flow rate (ft^3/s)	Specific conductance (µS/cm)	Temp. (°C)	Remark or measurement rating
1	Big Piney River	N/A		0.081	12–14–94	506	333	6.0	--
2	Big Piney tributary	unnamed	lb	.381	12–14–94	0	--	--	--
3	Big Piney tributary	unnamed	lb	.895	12–14–94	0	--	--	--
4	Big Piney tributary	unnamed	rb	1.414	12–14–94	.27	448	9.7	--
5	Big Piney River	N/A		1.495	12–14–94	544	334	5.8	--
6	Big Piney tributary	unnamed	rb	1.578	12–14–94	0	--	--	--
7	Big Piney tributary	unnamed	lb	1.619	12–14–94	0	--	--	--
8	Big Piney tributary	unnamed	rb	1.757	12–14–94	0	--	--	--
9	Big Piney tributary	unnamed	lb	2.646	12–14–94	.09	539	4.9	--
10	Big Piney tributary	unnamed	lb	2.994	12–14–94	0	--	--	--
11	Big Piney tributary	unnamed	rb	3.007	12–14–94	0	--	--	--
12	Big Piney tributary	unnamed	rb	3.083	12–14–94	0	--	--	--
13	Big Piney tributary	unnamed	lb	3.272	12–14–94	0	--	--	--
14	Big Piney tributary	unnamed	rb	3.513	12–14–94	0	--	--	--
15	Big Piney tributary	unnamed	rb	3.961	12–14–94	0	--	--	--
16	Big Piney tributary	unnamed	rb	4.055	12–14–94	.15	343	7.9	--
17	Big Piney tributary	unnamed	lb	4.469	12–14–94	0	--	--	--
18	Big Piney River	N/A		4.853	12–14–94	535	324	5.8	--
19	Big Piney tributary	unnamed	rb	4.970	12–14–94	.02	364	6.0	--
20	Big Piney tributary	unnamed	rb	5.081	12–14–94	0	--	--	--
21	Big Piney tributary	unnamed	lb	5.594	12–14–94	0	--	--	--
22	Big Piney tributary	Shanghai Spring	lb	5.925	12–14–94	22.2	424	14.0	--
23	Big Piney tributary	Dry Creek	lb	6.464	12–14–94	0	--	--	--
24	Big Piney tributary	unnamed	rb	6.483	12–14–94	0	--	--	--
25	Big Piney tributary	unnamed	lb	6.698	12–14–94	0	--	--	--
26	Big Piney tributary	unnamed	rb	7.022	12–14–94	0	--	--	--
27	Big Piney tributary	unnamed	rb	7.627	12–14–94	0	--	--	--
28	Big Piney River	N/A		8.060	12–14–94	520	334	5.3	--
29	Big Piney tributary	unnamed	lb	8.161	12–14–94	0	--	--	--
30	Big Piney tributary	unnamed	rb	8.485	12–14–94	.04	491	6.8	--
31	Big Piney tributary	unnamed	rb	9.058	12–14–94	0	--	--	--
32	Big Piney tributary	unnamed	lb	10.132	12–14–94	0	--	--	--
33	Big Piney tributary	unnamed	lb	10.766	12–14–94	0	--	--	--
34	Big Piney tributary	unnamed	lb	11.116	12–14–94	0	--	--	--
35	Big Piney tributary	unnamed	lb	11.592	12–14–94	0	--	--	--
36	Big Piney tributary	unnamed	lb	11.872	12–14–94	0	--	--	--
37	Big Piney tributary	unnamed	lb	12.603	12–14–94	0	--	--	--
38	Big Piney River	N/A		12.676	12–14–94	532	324	6.3	--
39	Big Piney tributary	unnamed	lb	13.015	12–14–94	0	--	--	--
40	Big Piney tributary	unnamed	rb	13.557	12–14–94	0	--	--	--
41	Big Piney tributary	unnamed	lb	13.896	12–14–94	0	--	--	--
42	Big Piney tributary	Ousley Spring	rb	14.062	12–14–94	.75	465	12.9	--
43	Big Piney tributary	unnamed spring	rb	14.139	12–14–94	1.11	441	11.2	--
44	Big Piney tributary	unnamed	rb	15.112	12–14–94	0	--	--	--
45	Big Piney River	N/A		15.165	12–14–94	504	334	5.1	--
46	Big Piney tributary	unnamed	lb	15.481	12–13–94	0	--	--	--

Table 16. Discharge measurements and selected physical properties for the Big Piney River, Roubidoux Creek, and tributaries, December 1994—Continued

Measurement number	Stream name	Tributary name	Bank	Distance from mouth (mi)	Date (month-day-year)	Flow rate (ft^3/s)	Specific conductance (µS/cm)	Temp. (°C)	Remark or measurement rating
47	Big Piney tributary	Smokey Hollow	rb	16.217	12–13–94	0	--	--	--
48	Big Piney tributary	unnamed	rb	16.381	12–13–94	0	--	--	--
49	Big Piney tributary	spring branch	rb	16.702	12–14–94	.04	501	5.2	--
50	Big Piney tributary	Spring Creek	rb	16.829	12–13–94	38.4	308	10.0	--
51	Big Piney tributary	unnamed	rb	17.276	12–13–94	0	--	--	--
52	Big Piney tributary	unnamed	rb	17.588	12–13–94	0	--	--	--
53	Big Piney River	N/A		17.763	12–13–94	518	228	6.1	--
54	Big Piney tributary	unnamed	lb	19.740		see 1a	--	--	--
55	Big Piney tributary	unnamed	rb	19.850	12–13–94	0	--	--	--
56	Big Piney River	N/A		20.886	12–13–94	407	321	10.0	--
57	Big Piney tributary	Stone Mill spring	rb	21.393	12–13–94	46.8	270	13.7	--
58	Big Piney tributary	unnamed	rb	21.852	12–13–94	0	--	--	--
59	Big Piney tributary	unnamed	rb	22.179	12–13–94	0	--	--	--
60	Big Piney tributary	unnamed	rb	22.428	12–13–94	0	--	--	--
61	Big Piney tributary	unnamed	rb	22.849	12–13–94	0	--	--	--
62	Big Piney tributary	unnamed	rb	23.213	12–13–94	0	--	--	--
63	Big Piney River	N/A		23.679	12–13–94	453	318	5.4	--
64	Big Piney tributary	pump station culvert	lb	23.985	12–13–94	.12	385	12.0	--
65	Big Piney tributary	unnamed	lb	24.120		see 6a	--	--	--
66	Big Piney tributary	unnamed	lb	24.402		see 9a	--	--	--
67	Big Piney tributary	unnamed	lb	24.545	12–13–94	.06	419	2.5	--
68	Big Piney tributary	unnamed	lb	25.319	12–13–94	0	--	--	--
69	Big Piney River	N/A		25.424	12–13–94	441	336	5.0	--
70	Big Piney tributary	unnamed	lb	25.709	12–13–94	0	--	--	--
71	Big Piney tributary	unnamed	rb	26.992	12–13–94	0	--	--	--
72	Big Piney tributary	unnamed	rb	28.203	12–13–94	0	--	--	--
73	Big Piney tributary	Miller Spring	lb	28.605	12–12–94	9.06	308	13.0	--
74	Big Piney tributary	McCourtney Hollow	lb	28.930	12–13–94	0	--	--	--
75	Big Piney tributary	unnamed	rb	29.403	12–13–94	0	--	--	--
76	Big Piney River	N/A		29.495	12–13–94	470	--	--	--
77	Big Piney River	N/A		29.495	12–13–94	467	335	4.5	--
78	Big Piney tributary	unnamed	rb	29.557	12–12–94	0	--	--	--
79	Big Piney tributary	unnamed	lb	29.587	12–12–94	0	--	--	--
80	Big Piney tributary	unnamed	lb	29.971	12–12–94	0	--	--	--
81	Big Piney tributary	unnamed	rb	30.831	12–12–94	0	--	--	--
82	Big Piney tributary	unnamed	lb	31.259	12–12–94	0	--	--	--
83	Big Piney tributary	unnamed	rb	31.588	12–12–94	0	--	--	--
84	Big Piney tributary	unnamed	rb	31.895	12–12–94	.02	478	4.5	--
85	Big Piney River	N/A		32.367	12–12–94	523	341	6.0	--
86	Big Piney tributary	unnamed	rb	32.730	12–12–94	0	--	--	--
87	Big Piney tributary	unnamed	lb	33.462	12–12–94	.03	331	2.4	--
88	Big Piney tributary	unnamed	rb	33.615	12–12–94	0	--	--	--
89	Big Piney tributary	unnamed	lb	33.907		see 13a	--	--	--
90	Big Piney tributary	unnamed	lb	35.872	12–12–94	.02	413	3.5	--
91	Big Piney River	N/A		35.900	12–12–94	445	342	5.2	--
92	Big Piney River	N/A		35.900	12–12–94	464	342	5.2	--
93	Big Piney tributary	unnamed	lb	35.934	12–12–94	.10	431	2.5	--
94	Big Piney tributary	unnamed	lb	36.435	12–12–94	0	--	--	--

Table 16. Discharge measurements and selected physical properties for the Big Piney River, Roubidoux Creek, and tributaries, December 1994—Continued

Measurement number	Stream name	Tributary name	Bank	Distance from mouth (mi)	Date (month-day-year)	Flow rate (ft^3/s)	Specific conductance ($\mu S/cm$)	Temp. (°C)	Remark or measurement rating
95	Big Piney tributary	Crossing Hollow	rb	37.311	12–12–94	0.24	426	4.5	--
96	Big Piney tributary	unnamed	rb	37.588	12–12–94	0	--	--	--
97	Big Piney River	N/A		37.942	12–12–94	482	324	5.1	--
1a	unnamed stream	N/A		.066	12–21–94	.29	400	8.6	--
2a	unnamed stream	N/A		.332	12–21–94	.46	--	--	--
3a	unnamed stream tributary	unnamed south fork	rb	.862		see 1b	--	--	--
4a	unnamed stream	N/A		1.045	12–21–94	.29	500	9.1	--
5a	unnamed stream	N/A		1.320	12–21–94	0	--	--	--
6a	"Pumping station" stream	N/A		.021	12–13–94	.12	444	5.7	--
7a	"Pumping station" stream	N/A		.364	12–21–94	.26	440	11.2	--
8a	"Pumping station" stream	N/A		.526	12–21–94	0	--	--	--
9a	unnamed stream	N/A		.035	12–13–94	.11	356	6.4	--
10a	unnamed stream	N/A		.282	12–21–94	.30	--	--	--
11a	unnamed stream tributary	unnamed tributary	lb	.662		see 2b	--	--	--
12a	unnamed stream	N/A		.787	12–21–94	0	--	--	--
13a	Bald Ridge Creek	N/A		.043	12–12–94	2.61	335	7.5	--
14a	Bald Ridge Creek	N/A		.141	12–21–94	3.07	--	--	--
15a	Bald Ridge Creek	N/A		.502	12–21–94	3.11	--	--	--
16a	Bald Ridge Creek	N/A		1.821	12–22–94	2.84	--	--	--
17a	Bald Ridge Creek tributary	Little Bald Ridge Creek	lb	1.832		see 3b	--	--	--
18a	Bald Ridge Creek tributary	unnamed	lb	2.945	12–22–94	0	--	--	--
19a	Bald Ridge Creek tributary	unnamed	lb	3.173	12–22–94	0	--	--	--
20a	Bald Ridge Creek	N/A		3.786	12–22–94	.53	--	--	--
21a	Bald Ridge Creek	N/A		4.712	12–22–94	0	--	--	flow begins
22a	Bald Ridge Creek tributary	unnamed	rb	5.221	12–22–94	0	--	--	--
23a	Bald Ridge Creek tributary	unnamed	lb	5.662	12–22–94	0	--	--	--
24a	Bald Ridge Creek	N/A		6.405	12–22–94	0	--	--	--
1b	unnamed south fork	N/A	rb	.153	12–21–94	0	--	--	--
2b	unnamed tributary	N/A		.145	12–21–94	0	--	--	--
3b	Little Bald Ridge Creek tributary	Falls Hollow	lb	.277		see 1c	--	--	--
4b	Little Bald Ridge Creek	N/A		.606	12–21–94	.78	--	--	--
5b	Little Bald Ridge Creek tributary	unnamed spring	rb	1.332	12–22–94	0	--	--	--
6b	Little Bald Ridge Creek tributary	N/A	lb	1.916	12–22–94	0	--	--	--
7b	Little Bald Ridge Creek tributary	Wildcat Hollow spring	rb	2.197	12–22–94	0	--	--	--

Table 16. Discharge measurements and selected physical properties for the Big Piney River, Roubidoux Creek, and tributaries, December 1994—Continued

Measurement number	Stream name	Tributary name	Bank	Distance from mouth (mi)	Date (month-day-year)	Flow rate (ft^3/s)	Specific conductance (µS/cm)	Temp. (°C)	Remark or measurement rating
1c	Falls Hollow tributary	unnamed	lb	0.023	12–22–94	0	--	--	--
2c	Falls Hollow	N/A		.138	12–22–94	0	--	--	--
1	Roubidoux Creek	N/A		.136	12–13–94	63.4	241	10.9	--
2	Roubidoux Creek	N/A		1.417	12–13–94	64.3	365	11.7	good
3	Roubidoux Creek	N/A		1.861	12–13–94	65.1	400	11.3	--
4	Roubidoux Creek tributary	sewage plant outflow	rb	1.889	12–13–94	.61	825	8.3	poor
5	Roubidoux Creek	N/A		2.493	12–13–94	58.3	365	12.0	good
6	Roubidoux Creek tributary	Roubidoux Spring	rb	2.928	12–13–94	61.2	351	12.8	--
7	Roubidoux Creek	N/A		3.565	12–13–94	1.89	385	5.7	fair
8	Roubidoux Creek tributary	unnamed	rb	3.768	12–13–94	0	--	--	--
9	Roubidoux Creek	N/A		4.277	12–13–94	1.02	375	4.8	fair
10	Roubidoux Creek tributary	Burchard Hollow	rb	4.586	12–13–94	0	--	--	pumping at creek
11	Roubidoux Creek	N/A		4.767	12–13–94	1.43	333	6.2	good
12	Roubidoux Creek tributary	unnamed	lb	5.447	12–13–94	0	--	--	--
13	Roubidoux Creek	N/A		6.116	12–13–94	.28	350	6.2	--
14	Roubidoux Creek	N/A		6.546	12–13–94	.36	332	4.4	fair/poor
15	Roubidoux Creek	N/A		7.086	12–13–94	.29	356	4.7	good
16	Roubidoux Creek	N/A		7.514	12–13–94	.67	357	6.0	fair
17	Roubidoux Creek	N/A		7.514	12–13–94	.66	295	5.5	poor
18	Roubidoux Creek	N/A		7.929	12–13–94	.83	372	5.5	poor
19	Roubidoux Creek	N/A		8.250	12–13–94	.31	357	7.4	fair/poor
20	Roubidoux Creek tributary	Ballard Hollow	rb	8.350		see 1a	--	--	--
21	Roubidoux Creek tributary	unnamed	rb	8.654	12–13–94	0	--	--	--
22	Roubidoux Creek	N/A		8.769	12–13–94	0	--	--	--
23	Roubidoux Creek	N/A		8.893	12–13–94	0	--	--	--
24	Roubidoux Creek	N/A		9.338	12–13–94	.03e	--	--	--
25	Roubidoux Creek	N/A		9.565	12–13–94	0	--	--	--
26	Roubidoux Creek	N/A		9.830	12–13–94	0	--	--	--
27	Roubidoux Creek tributary	unnamed	lb	10.882	12–13–94	0	--	--	--
28	Roubidoux Creek	N/A		11.244	12–13–94	0	--	--	--
29	Roubidoux Creek tributary	unnamed	rb	11.862	12–13–94	0	--	--	--
30	Roubidoux Creek	N/A		11.943	12–13–94	0	--	--	--
31	Roubidoux Creek	N/A		12.184	12–13–94	0	--	--	--
32	Roubidoux Creek (Highway H)	N/A		12.921	12–13–94	0	--	--	--
33	Roubidoux Creek tributary	unnamed	lb	13.447	12–13–94	0	--	--	--
34	Roubidoux Creek tributary	Town Hollow	lb	13.832	12–13–94	0	--	--	--
35	Roubidoux Creek	N/A		14.088	12–13–94	0	--	--	--

Table 16. Discharge measurements and selected physical properties for the Big Piney River, Roubidoux Creek, and tributaries, December 1994—Continued

Measurement number	Stream name	Tributary name	Bank	Distance from mouth (mi)	Date (month-day-year)	Flow rate (ft³/s)	Specific conductance (µS/cm)	Temp. (°C)	Remark or measurement rating
36	Roubidoux Creek	N/A		14.287	12–13–94	0	--	--	--
37	Roubidoux Creek	N/A		14.498	12–13–94	0	--	--	--
38	Roubidoux Creek tributary	York Hollow	lb	14.574	12–13–94	0	--	--	--
39	Roubidoux Creek tributary	unnamed	lb	14.928	12–13–94	0	--	--	--
40	Roubidoux Creek tributary	Elliot Branch	lb	15.322	12–13–94	0	--	--	--
41	Roubidoux Creek	N/A		15.551	12–13–94	0	--	--	--
42	Roubidoux Creek	N/A		16.973	12–13–94	0	--	--	--
43	Roubidoux Creek	N/A		17.433	12–13–94	0	--	--	--
44	Roubidoux Creek tributary	unnamed	rb	17.641	12–13–94	0	--	--	--
45	Roubidoux Creek tributary	Hurd Hollow	rb	19.251	12–13–94	0	--	--	--
46	Roubidoux Creek	N/A		21.729	12–13–94	0	--	--	--
47	Roubidoux Creek	N/A		21.733	12–13–94	.46	361	1.8	--
48	Roubidoux Creek	N/A		21.776	12–13–94	0	--	--	--
49	Roubidoux Creek tributary	unnamed	lb	22.013	12–13–94	0	--	--	--
50	Roubidoux Creek	N/A		22.039	12–13–94	3.10	361	2.3	--
51	Roubidoux Creek	N/A		22.158	12–14–94	3.55	363	4.3	good/fair
52	Roubidoux Creek tributary	unnamed	lb	22.196	12–14–94	0	--	--	--
53	Roubidoux Creek tributary	unnamed	lb	22.639	12–14–94	0	--	--	--
54	Roubidoux Creek	N/A		22.924	12–14–94	28.2	363	4.1	good
55	Roubidoux Creek	N/A		23.765	12–14–94	33.6	361	4.7	good
56	Roubidoux Creek tributary	unnamed	lb	23.908	12–14–94	.01e	--	--	--
57	Roubidoux Creek tributary	unnamed	lb	24.267	12–14–94	0	--	--	--
58	Roubidoux Creek tributary	unnamed	lb	24.541	12–14–94	0	--	--	--
59	Roubidoux Creek	N/A		24.582	12–14–94	40.0	364	4.3	good
60	Roubidoux Creek tributary	unnamed	lb	24.606	12–14–94	0	--	--	--
61	Roubidoux Creek tributary	unnamed	rb	25.257	12–14–94	0	--	--	--
62	Roubidoux Creek	N/A		25.459	12–14–94	43.2	366	4.2	good
63	Roubidoux Creek	N/A		25.886	12–14–94	46.0	355	4.3	good/fair
64	Roubidoux Creek tributary	unnamed	rb	25.893	12–14–94	.01e	--	--	--
65	Roubidoux Creek tributary	unnamed	rb	26.230	12–14–94	0	--	--	--
66	Roubidoux Creek	N/A		26.418	12–14–94	41.7	308	3.9	good
67	Roubidoux Creek	N/A		26.418	12–12–94	44.0	360	5.5	good
68	Roubidoux Creek tributary	unnamed	rb	26.887	12–12–94	0	--	--	--

Table 16. Discharge measurements and selected physical properties for the Big Piney River, Roubidoux Creek, and tributaries, December 1994—Continued

Measurement number	Stream name	Tributary name	Bank	Distance from mouth (mi)	Date (month-day-year)	Flow rate (ft^3/s)	Specific conductance (µS/cm)	Temp. (°C)	Remark or measurement rating
69	Roubidoux Creek tributary	unnamed	lb	26.920	12–12–94	0	--	--	--
70	Roubidoux Creek	N/A		27.148	12–12–94	44.5	358	5.0	good/fair
71	Roubidoux Creek tributary	unnamed	lb	27.195		see 3a	--	--	--
72	Roubidoux Creek tributary	unnamed	lb	27.377	12–12–94	0	--	--	--
73	Roubidoux Creek tributary	unnamed	rb	27.546	12–12–94	.03e	--	--	--
74	Roubidoux Creek	N/A		27.657	12–12–94	49.1	365	4.4	good
75	Roubidoux Creek	N/A		27.980	12–12–94	47.7	360	6.0	poor
76	Roubidoux Creek tributary	unnamed	rb	28.000	12–12–94	.15e	--	--	--
77	Roubidoux Creek	N/A		28.458	12–12–94	43.4	265	6.0	--
78	Roubidoux Creek	N/A		28.963	12–12–94	48.9	140	5.0	--
79	Roubidoux Creek tributary	Musgrave Hollow	rb	29.355		see 12a	--	--	--
80	Roubidoux Creek	N/A		29.478	12–12–94	41.0	318	4.8	fair
81	Roubidoux Creek	N/A		29.724	12–12–94	57.4	338	5.0	poor
82	Roubidoux Creek	N/A		29.724	12–12–94	67.1	338	5.0	good
83	Roubidoux Creek	N/A		30.320	12–12–94	53.0	330	5.1	good
84	Roubidoux Creek	N/A		30.775	12–12–94	56.9	248	5.7	--
85	Roubidoux Creek	N/A		31.284	12–12–94	46.4	358	5.9	--
86	Roubidoux Creek tributary	unnamed	rb	31.296	12–12–94	.54	316	6.0	fair
87	Roubidoux Creek	N/A		32.043	12–15–94	39.5	--	--	good
88	Roubidoux Creek	N/A		32.043	12–12–94	48.6	358	7.4	--
89	Roubidoux Creek	N/A		32.043	12–12–94	40.8	--	--	--
90	Roubidoux Creek tributary	unnamed	lb	32.056	12–12–94	0	--	--	--
91	Roubidoux Creek tributary	unnamed	rb	32.432	12–12–94	0	--	--	--
92	Roubidoux Creek tributary	Little Piney Creek	rb	32.823	12–12–94	.02e	361	6.2	--
93	Roubidoux Creek tributary	unnamed	lb	32.969	12–12–94	<.01e	475	6.1	--
94	Roubidoux Creek	N/A		33.175	12–15–94	35.7	--	--	good
95	Roubidoux Creek	N/A		33.175	12–12–94	35.2	369	4.3	poor
96	Roubidoux Creek tributary	unnamed	lb	33.315		see 25a	--	--	--
97	Roubidoux Creek tributary	unnamed	lb	33.548	12–12–94	0	--	--	--
98	Roubidoux Creek	N/A		33.849	12–15–94	36.6	--	--	good
99	Roubidoux Creek	N/A		33.849	12–12–94	44.8	363	4.1	good
100	Highway 17 bridge	N/A		33.939		--	--	--	--
1a	Ballard Hollow	N/A		.117	12–13–94	.05e	444	4.1	--
2a	Ballard Hollow	N/A		.907	12–13–94	.02e	--	--	--
3a	unnamed stream	N/A		.069	12–12–94	.37	333	4.6	good/fair
4a	unnamed stream	N/A		.180	12–15–94	.74	--	--	--

Table 16. Discharge measurements and selected physical properties for the Big Piney River, Roubidoux Creek, and tributaries, December 1994—Continued

Measurement number	Stream name	Tributary name	Bank	Distance from mouth (mi)	Date (month-day-year)	Flow rate (ft^3/s)	Specific conductance (μS/cm)	Temp. (°C)	Remark or measurement rating
5a	unnamed stream tributary	unnamed	lb	0.210	12–15–94	0	--	--	--
6a	unnamed stream tributary	unnamed	lb	.911	12–15–94	0	--	--	--
7a	unnamed stream	N/A		1.121	12–15–94	.19	258	9.6	--
8a	unnamed stream tributary	Mush Paddle Hollow	lb	1.634	12–15–94	0	--	--	--
9a	unnamed stream	N/A		1.663	12–15–94	.24	244	10.4	--
10a	unnamed stream	N/A		2.286	12–15–94	.12e	--	--	flow begins
11a	unnamed stream	N/A		2.472	12–15–94	0	--	--	--
12a	Musgrave Hollow	N/A		.066	12–14–94	.63	336	5.3	fair/poor
13a	Musgrave Hollow	N/A		.605	12–14–94	1.16	215	4.6	poor
14a	Musgrave Hollow	N/A		1.098	12–14–94	.88	363	5.5	poor
15a	Musgrave Hollow tributary	unnamed	rb	1.396	12–14–94	0	--	--	--
16a	Musgrave Hollow	N/A		1.642	12–14–94	.83	198	4.1	--
17a	Musgrave Hollow	N/A		1.642	12–14–94	.97	233	4.0	fair
18a	Musgrave Hollow tributary	unnamed	lb	1.796		see 1b	--	--	--
19a	Musgrave Hollow tributary	unnamed	rb	2.218	12–14–94	0	--	--	--
20a	Musgrave Hollow tributary	unnamed	rb	2.320	12–14–94	0	--	--	--
21a	Musgrave Hollow	N/A		2.398	12–14–94	1.36	234	4.1	fair
22a	Musgrave Hollow	N/A		2.878	12–14–94	.71	269	5.1	fair
23a	Musgrave Hollow	N/A		3.416	12–14–94	.50	252	6.1	fair
24a	Musgrave Hollow	N/A		4.058	12–14–94	.01	--	--	flow begins
25a	unnamed stream	N/A		.003	12–12–94	0	--	--	--
26a	unnamed stream spring	N/A		.085	12–12–94	<.01e	530	10.2	--
27a	unnamed stream	N/A		.152	12–12–94	0	--	--	--
1b	unnamed stream	N/A		.036	12–14–94	.57	134	4.2	fair
2b	unnamed stream	N/A		.482	12–14–94	.25	96	5.6	poor
3b	unnamed stream spring	N/A		.581	12–14–94	.12e	--	--	--
4b	unnamed stream	N/A		1.080	12–14–94	.35	343	5.7	fair
5b	unnamed stream	N/A		1.378	12–14–94	0	--	--	--
6b	unnamed stream	N/A		1.920	12–14–94	0	--	--	--

Table 17. Discharge measurements and selected physical properties for the Big Piney River and tributaries, February 1995

[mi, mile; ft^3/s, cubic feet per second; µS/cm, microsiemens per centimeter at 25 degrees Celsius; temp., temperature; °C, degrees Celsius; N/A, not applicable; rb, right bank; --, no data; lb, left bank]

Measurement number	Stream name	Tributary name	Bank	Distance from mouth (mi)	Date (month-day-year)	Flow rate (ft^3/s)	Specific conductance (µS/cm)	Temp. (°C)	Remark or measurement rating
1	Big Piney River	N/A		0.462	02–22–95	603	303	9.5	good
2	Big Piney tributary	unnamed	rb	1.074	02–21–95	.05	--	--	--
3	Big Piney tributary	unnamed	rb	1.424	02–21–95	.4	--	--	--
4	Big Piney River	N/A		1.475	02–22–95	601	308	8.9	fair/poor
5	Big Piney tributary	unnamed	lb	2.652	02–21–95	.2	--	--	--
6	Big Piney River	N/A		3.261	02–22–95	591	306	8.4	good
7	Big Piney River	N/A		3.261	02–21–95	587	307	8.7	good
8	Big Piney tributary	unnamed	rb	4.049	02–21–95	.6	--	--	--
9	Big Piney River	N/A		4.590	02–21–95	622	308	8.6	good
10	Big Piney tributary	unnamed	rb	5.085	02–21–95	.03	--	--	--
11	Big Piney tributary	unnamed	lb	5.589	02–21–95	0	--	--	--
12	Big Piney tributary	Shanghai Spring	lb	5.948	02–21–95	25.6	389	13.3	good/fair
13	Big Piney River	N/A		6.083	02–21–95	566	306	7.8	fair
14	Big Piney River	N/A		6.083	02–21–95	584	306	7.8	fair
15	Big Piney tributary	unnamed	lb	6.235	02–21–95	.2	--	--	--
16	Big Piney River	N/A		6.453	02–21–95	583	307	7.4	fair/poor
17	Big Piney tributary	unnamed	lb	6.470	02–21–95	0	--	--	--
18	Big Piney tributary	unnamed	lb	6.690	02–21–95	0	--	--	--
19	Big Piney tributary	unnamed	rb	7.021	02–21–95	0	--	--	--
20	Big Piney tributary	unnamed	lb	8.155	02–21–95	0	--	--	--
21	Big Piney tributary	unnamed	rb	8.478	02–21–95	.2	--	--	--
22	Big Piney River	N/A		8.523	02–21–95	598	308	7.1	good
23	Big Piney River	N/A		8.523	02–20–95	602	299	9.6	good/fair
24	Big Piney tributary	unnamed	rb	9.472	02–20–95	.1	--	--	--
25	Big Piney tributary	unnamed	lb	10.127	02–20–95	.02	--	--	--
26	Big Piney tributary	unnamed	lb	10.764	02–20–95	0	--	--	--
27	Big Piney tributary	unnamed	rb	10.924	02–20–95	0	--	--	--
28	Big Piney River	N/A		10.979	02–20–95	611	299	9.6	good/fair
29	Big Piney tributary	unnamed	lb	11.104	02–20–95	0	--	--	--
30	Big Piney River	N/A		13.319	02–20–95	611	302	9.0	good
31	Big Piney tributary	Ousley Spring	rb	14.052	02–20–95	1.2	440	13.1	fair/poor
32	Big Piney tributary	unnamed	rb	14.124	02–20–95	1.6	385	3.8	good/fair
33	Big Piney River	N/A		14.847	02–20–95	601	303	8.3	good
34	Big Piney River	N/A		14.847	02–20–95	610	303	8.3	good
35	Big Piney tributary	unnamed	rb	16.208	02–20–95	0	--	--	--
36	Big Piney tributary	unnamed	rb	16.368	02–20–95	0	--	--	--
37	Big Piney River	N/A		16.491	02–20–95	615	306	6.9	good/fair
38	Big Piney River	N/A		16.491	02–17–95	644	285	7.1	good
39	Big Piney tributary	unnamed	rb	16.703	02–17–95	.02	--	--	--
40	Big Piney tributary	Spring Creek	rb	16.817	02–17–95	46.0	275	10.4	good/fair
41	Big Piney River	N/A		17.194	02–17–95	611	288	6.5	good
42	Big Piney tributary	unnamed	lb	17.844	02–17–95	.1	--	--	--
43	Big Piney tributary	unnamed	lb	18.798	02–17–95	.1	--	--	--
44	Big Piney River	N/A		19.541	02–17–95	628	285	6.5	good/fair
45	Big Piney tributary	Stone Mill Spring	rb	21.378	02–17–95	54.7	250	12.2	good
46	Big Piney tributary	unnamed	lb	21.528	02–17–95	.05	--	--	--

Table 17. Discharge measurements and selected physical properties for the Big Piney River and tributaries, February 1995—Continued

Measurement number	Stream name	Tributary name	Bank	Distance from mouth (mi)	Date (month-day-year)	Flow rate (ft^3/s)	Specific conductance (μS/cm)	Temp. (°C)	Remark or measurement rating
47	Big Piney River	N/A		21.999	02–17–95	520	296	4.5	good
48	Big Piney River	N/A		23.680	02–17–95	501	295	4.7	fair
49	Big Piney River	N/A		23.680	02–14–95	408	296	4.4	fair
50	Big Piney tributary	unnamed	lb	24.412	02–14–95	.05	--	--	--
51	Big Piney River	N/A		27.219	02–14–95	405	295	4.7	good
52	Big Piney River	N/A		27.219	02–14–95	416	295	4.7	good
53	Big Piney tributary	Miller Spring	lb	28.598	02–14–95	28.7	240	12.3	fair
54	Big Piney tributary	unnamed	rb	29.389	02–14–95	.1	--	--	--
55	Big Piney tributary	unnamed	rb	29.874	02–14–95	0	--	--	--
56	Big Piney tributary	unnamed	rb	30.013	02–14–95	2.0	--	--	--
57	Big Piney tributary	unnamed	rb	30.064	02–14–95	0	--	--	--
58	Big Piney River	N/A		30.156	02–14–95	379	294	4.6	good
59	Big Piney tributary	unnamed	rb	31.138	02–14–95	0	--	--	--
60	Big Piney tributary	unnamed	lb	31.228	02–14–95	0	--	--	--
61	Big Piney River	N/A		32.166	02–14–95	388	298	4.2	good
62	Big Piney River	N/A		32.166	02–13–95	386	289	5.4	good
63	Big Piney River	N/A		33.524	02–13–95	397	290	5.4	good
64	Big Piney tributary	Bald Ridge Creek	lb	33.876	02–13–95	3.7	275	4.4	fair
65	Big Piney tributary	unnamed	rb	34.373	02–13–95	0	--	--	--
66	Big Piney River	N/A		34.658	02–13–95	374	292	5.2	good
67	Big Piney River	N/A		34.658	02–13–95	397	292	5.2	good
68	Big Piney tributary	unnamed	lb	34.812	02–13–95	.2	--	--	--
69	Big Piney tributary	unnamed	lb	35.822	02–13–95	.2	--	--	--
70	Big Piney Tributary	unnamed	lb	35.870	02–13–95	.2	--	--	--
71	Big Piney River	N/A		36.403	02–13–95	396	292	4.8	good
72	Big Piney River	N/A		37.897	02–13–95	382	292	4.0	good

Table 18. Discharge measurements and selected physical properties for the Big Piney River, Roubidoux Creek, and tributaries, September 1995

[mi, mile; ft^3/s, cubic feet per second; spec. cond., specific conductance; µS/cm, microsiemens per centimeter at 25 degrees Celsius; temp., temperature; °C, degrees Celsius; N/A, not applicable; rb, right bank; --, no data; lb, left bank; e, estimated; see 1a, see measurement no. 1a]

Measurement number	Stream name	Tributary name	Bank	Distance from mouth (mi)	Date (month-day-year)	Flow rate (ft^3/s)	Spec. Cond. (µS/cm)	Temp. (°C)	Remark or measurement rating
1	Big Piney River	N/A		3.013	09–25–95	267	342	15.9	fair
2	Big Piney River tributary	unnamed	rb	3.533	09–22–95	0	--	--	--
3	Big Piney River tributary	unnamed	rb	3.954	09–22–95	0	--	--	--
4	Big Piney River tributary	unnamed	rb	4.043	09–22–95	0	--	--	--
5	Big Piney River tributary	unnamed	lb	4.436	09–22–95	0	--	--	--
6	Big Piney River	N/A		5.388	09–25–95	285	345	15.3	good-fair
7	Big Piney River tributary	unnamed	lb	5.565	09–22–95	0	--	--	--
8	Big Piney River tributary	Shanghai Spring	lb	5.963	09–25–95	22.7	469	15.2	fair-poor
9	Big Piney River	N/A		6.037	09–25–95	252	335	14.8	fair-poor
10	Big Piney River tributary	unnamed	lb	6.469	09–22–95	0	--	--	--
11	Big Piney River tributary	unnamed	lb	6.680	09–22–95	0	--	--	--
12	Big Piney River tributary	unnamed	rb	7.002	09–22–95	.10e	520	12.0	--
13	Big Piney River tributary	unnamed	rb	7.610	09–22–95	0	--	--	--
14	Big Piney River tributary	unnamed	lb	8.141	09–22–95	0	--	--	--
15	Big Piney River tributary	unnamed	rb	8.472	09–22–95	.05e	--	--	--
16	Big Piney River	N/A		8.711	09–25–95	246	336	14.5	good-fair
17	Big Piney River	N/A		8.711	09–22–95	255	328	16.5	good-fair
18	Big Piney River tributary	unnamed	rb	9.067	09–22–95	.10e	--	--	--
19	Big Piney River tributary	unnamed	lb	9.368	09–22–95	0	--	--	--
20	Big Piney River tributary	unnamed	lb	9.400	09–22–95	0	--	--	--
21	Big Piney River tributary	unnamed	lb	9.946	09–22–95	.30e	521	11.1	--
22	Big Piney River	N/A		10.154	09–22–95	262	329	15.9	good
23	Big Piney River tributary	unnamed	lb	10.217	09–22–95	0	--	--	--
24	Big Piney River tributary	unnamed	rb	10.593	09–22–95	0	--	--	--
25	Big Piney River tributary	unnamed	lb	10.650	09–22–95	0	--	--	--
26	Big Piney River tributary	unnamed	rb	11.702	09–22–95	0	--	--	--
27	Big Piney River tributary	Ousley Spring	rb	12.574	09–22–95	1.19	470	13.7	poor
28	Big Piney River tributary	unnamed	rb	13.214	09–22–95	1.42	447	14.0	poor
29	Big Piney River tributary	unnamed	lb	14.203	09–22–95	.20e	--	--	--
30	Big Piney River	N/A		14.547	09–22–95	270	328	15.4	good-fair
31	Big Piney River tributary	unnamed	lb	15.426	09–22–95	0	--	--	--
32	Big Piney River tributary	unnamed	rb	15.629	09–22–95	0	--	--	--
33	Big Piney River tributary	unnamed	rb	16.408	09–22–95	0	--	--	--
34	Big Piney River tributary	Spring Creek	rb	16.694	09–22–95	31.8	324	13.0	good
35	Big Piney River tributary	unnamed	rb	16.744	09–22–95	.50e	413	10.5	--
36	Big Piney River	N/A		16.787	09–22–95	229	332	14.1	good
37	Big Piney River	N/A		17.230	09–21–95	237	330	16.6	good-fair
38	Big Piney River	N/A		19.244	09–21–95	233	330	16.6	good-fair
39	Big Piney River tributary	Stone Mill Spring	rb	21.367	09–21–95	35.0	340	14.8	poor
40	Big Piney River	N/A		22.006	09–21–95	193	329	17.2	good
41	Big Piney River	N/A		22.010	09–21–95	198	329	17.2	fair
42	Big Piney River	N/A		22.254	09–20–95	188	325	18.2	fair
43	Big Piney River tributary	unnamed spring	lb	22.660	09–20–95	.50e	404	13.9	--
44	Big Piney River tributary	unnamed	lb	24.381	09–20–95	.30e	--	--	runoff?
45	Big Piney River tributary	unnamed	lb	24.511	09–20–95	.05e	--	--	runoff?
46	Big Piney River	N/A		25.207	09–19–95	200	325	19.3	fair
47	Big Piney River tributary	unnamed	lb	25.289	09–19–95	.07e	--	--	--

Table 18. Discharge measurements and selected physical properties for the Big Piney River, Roubidoux Creek, and tributaries, September 1995—Continued

Measurement number	Stream name	Tributary name	Bank	Distance from mouth (mi)	Date (month-day-year)	Flow rate (ft^3/s)	Spec. Cond. (μS/cm)	Temp. (°C)	Remark or measurement rating
48	Big Piney River	N/A		25.855	09–20–95	195	325	18.1	good-fair
49	Big Piney River tributary	unnamed	rb	26.940	09–19–95	0	--	--	--
50	Big Piney River	N/A		27.051	09–20–95	189	329	17.6	good-fair
51	Big Piney River	N/A		27.583	09–19–95	194	328	19.1	fair
52	Big Piney River tributary	unnamed	rb	28.135	09–20–95	0	--	--	--
53	Big Piney River tributary	Miller Spring	lb	28.581	09–20–95	7.31	370	13.8	fair
54	Big Piney River tributary	Miller Spring	lb	28.581	09–19–95	14.2	369	13.8	poor
55	Big Piney River tributary	unnamed	lb	28.715	09–19–95	0	--	--	--
56	Big Piney River tributary	unnamed	rb	29.344	09–19–95	0	--	--	--
57	Big Piney River tributary	unnamed	lb	29.508	09–19–95	0	--	--	--
58	Big Piney River tributary	unnamed	lb	29.876	09–19–95	0	--	--	--
59	Big Piney River tributary	unnamed spring	rb	29.947	09–19–95	.15e	478	14.4	--
60	Big Piney River tributary	unnamed slough	rb	29.986	09–19–95	.05e	--	--	--
61	Big Piney River	N/A		30.024	09–20–95	180	328	17.9	good
62	Big Piney River	N/A		30.024	09–19–95	168	327	19.3	good
63	Big Piney River tributary	unnamed	rb	30.729	09–19–95	0	--	--	--
64	Big Piney River tributary	unnamed spring	lb	30.967	09–19–95	.20e	380	13.9	--
65	Big Piney River tributary	unnamed	rb	31.113	09–19–95	0	--	--	--
66	Big Piney River tributary	unnamed	lb	31.154	09–18–95	0	--	--	--
67	Big Piney River tributary	unnamed	rb	31.527	09–19–95	0	--	--	--
68	Big Piney River tributary	unnamed	rb	31.835	09–19–95	0	--	--	--
69	Big Piney River	N/A		32.120	09–19–95	177	329	19.1	good
70	Big Piney River	N/A		32.120	09–18–95	174	--	--	good-fair
71	Big Piney River tributary	unnamed	rb	32.384	09–18–95	0	--	--	--
72	Big Piney River tributary	unnamed	rb	32.714	09–18–95	0	--	--	--
73	Big Piney River tributary	unnamed	lb	33.393	09–18–95	0	--	--	--
74	Big Piney River tributary	unnamed	lb	33.784	09–18–95	.15e	--	--	--
75	Big Piney River tributary	Bald Ridge Creek	lb	33.826	09–18–95	.50e	--	--	--
76	Big Piney River	N/A		34.024	09–18–95	173	--	--	good-fair
77	Big Piney River	N/A		34.024	09–18–95	174	--	--	good
78	Big Piney River tributary	unnamed	rb	34.321	09–18–95	0	--	--	--
79	Big Piney River tributary	unnamed	lb	34.759	09–18–95	0	--	--	--
80	Big Piney River tributary	unnamed	lb	35.342	09–18–95	0	--	--	--
81	Big Piney River	N/A		35.965	09–18–95	190	328	19.0	good-fair
82	Big Piney River tributary	unnamed	lb	36.129	09–18–95	.05	413	14.6	--
83	Big Piney River tributary	unnamed	lb	36.408	09–18–95	.10	419	14.7	--
84	Big Piney River tributary	Crossing Hollow	rb	36.453	09–18–95	.07	462	14.4	--
85	Big Piney River	N/A		37.841	09–18–95	182	324	18.4	good-fair
1	Roubidoux Creek	N/A		.403	09–06–95	23.7	400	21.1	good
2	Roubidoux Creek	N/A		1.490	09–06–95	23.6	405	19.3	fair-poor
3	Roubidoux Creek tributary	unnamed	rb	1.621	09–05–95	0	--	--	--
4	Roubidoux Creek tributary	STP outflow		1.725	09–06–95	.43	392	17.6	poor
5	Roubidoux Creek tributary	unnamed spring	lb	2.312	09–05–95	1.05	393	17.5	good-fair
6	Roubidoux Creek tributary	unnamed	lb	2.568	09–05–95	0	--	--	--
7	Roubidoux Creek tributary	unnamed	lb	2.626	09–05–95	0	--	--	--
8	Roubidoux Creek	N/A		2.787	09–06–95	22.7	352	17.7	good
9	Roubidoux Creek	N/A		2.787	09–05–95	22.5	388	17.9	fair
10	Roubidoux Creek	N/A		3.072	09–05–95	.73	380	29.2	fair-poor
11	Roubidoux Creek	N/A		3.567	09–05–95	.92	--	--	fair

Table 18. Discharge measurements and selected physical properties for the Big Piney River, Roubidoux Creek, and tributaries, September 1995—Continued

Measurement number	Stream name	Tributary name	Bank	Distance from mouth (mi)	Date (month-day-year)	Flow rate (ft^3/s)	Spec. Cond. ($\mu S/cm$)	Temp. (°C)	Remark or measurement rating
12	Roubidoux Creek tributary	unnamed	rb	4.585	09–05–95	0	--	--	--
13	Roubidoux Creek	N/A		4.716	09-05-95	.52			
14	Roubidoux Creek tributary	unnamed	rb	4.848	09–05–95	0	--	--	--
15	Roubidoux Creek	N/A		5.555	09–05–95	.20	--	--	--
16	Roubidoux Creek	N/A		6.059	09–05–95	.03	--	--	--
17	Roubidoux Creek	N/A		6.991	09–05–95	0	--	--	--
18	Roubidoux Creek tributary	unnamed spring	rb	7.148	09–05–95	.08	--	--	--
19	Roubidoux Creek tributary	Tunnel Hollow stream	rb	7.287	09–05–95	0	--	--	--
20	Roubidoux Creek	N/A		7.473	09–05–95	.01e	--	--	--
21	Roubidoux Creek	N/A		8.234	09–05–95	.10	401	26.9	good
22	Roubidoux Creek tributary	Ballard Hollow stream	rb	8.295	09–05–95	.18	463	22.2	fair
23	Roubidoux Creek	N/A		8.340	09–05–95	0	--	--	flow begins
24	Roubidoux Creek tributary	unnamed	lb	24.034	09–12–95	0	--	--	--
25	Roubidoux Creek	N/A		24.062	09–13–95	0	--	--	end of flow
26	Roubidoux Creek	N/A		24.343	09–13–95	2.01	349	22.5	good-fair
27	Roubidoux Creek	N/A		25.039	09–13–95	7.03	354	22.2	good-fair
28	Roubidoux Creek	N/A		25.801	09–13–95	8.38	351	22.8	good
29	Roubidoux Creek	N/A		25.801	09–12–95	8.52	328	22.7	good
30	Roubidoux Creek tributary	unnamed	rb	26.192	09–12–95	0	--	--	--
31	Roubidoux Creek	N/A		26.823	09–12–95	8.17	353	22.4	fair
32	Roubidoux Creek tributary	unnamed	rb	26.902	09–12–95	0	--	--	--
33	Roubidoux Creek tributary	unnamed	lb	27.155	09–12–95	0	--	--	--
34	Roubidoux Creek tributary	unnamed	lb	27.347	09–12–95	0	--	--	--
35	Roubidoux Creek tributary	unnamed	rb	27.504	09–12–95	.03e	--	--	--
36	Roubidoux Creek tributary	unnamed	rb	28.005	09–12–95	.05e	--	--	--
37	Roubidoux Creek	N/A		28.054	09–12–95	9.32	358	21.3	good-fair
38	Roubidoux Creek	N/A		28.064	09–11–95	9.62	354	20.4	good-fair
39	Roubidoux Creek	N/A		28.963	09–11–95	9.73	355	21.5	good
40	Roubidoux Creek tributary	unnamed	lb	29.155	09–12–95	0	--	--	--
41	Roubidoux Creek tributary	Musgrave Hollow		29.303		see 1a	--	--	--
42	Roubidoux Creek	N/A		29.638	09–11–95	6.67	356	21.8	poor
43	Roubidoux Creek	N/A		29.763	09–11–95	7.33	356	21.7	good-fair
44	Roubidoux Creek tributary	unnamed	rb	30.753	09–11–95	0	--	--	--
45	Roubidoux Creek	N/A		31.062	09–11–95	8.06	350	22.2	fair
46	Roubidoux Creek tributary	unnamed	rb	31.247	09–11–95	.15e	343	19.7	--
47	Roubidoux Creek	N/A		31.909	09–11–95	8.12	353	22.2	poor
48	Roubidoux Creek	N/A		31.909	09–12–95	7.63	354	20.6	good
49	Roubidoux Creek tributary	Little Piney Creeek	rb	32.767	09–12–95	.01e	396	18.8	--
50	Roubidoux Creek tributary	unnamed	rb	32.818	09–12–95	.01e	302	21.2	--
51	Roubidoux Creek	N/A		32.853	09–12–95	6.73	358	21.5	fair
52	Roubidoux Creek tributary	unnamed	lb	33.229	09–11–95	0	--	--	--
53	Roubidoux Creek tributary	unnamed	lb	33.433	09–11–95	0	--	--	--
54	Roubidoux Creek	N/A		33.796	09–05–95	6.28	358	22.2	--
1a	Musgrave Hollow	N/A		.000	09–12–95	0	--	--	--
2a	Musgrave Hollow tributary	unnamed	rb	1.376		see 1b	--	--	--
3a	Musgrave Hollow	N/A		1.541	09–12–95	.45e	--	--	--
1b	unnamed tributary	N/A		.457	09–12–95	.05e	--	--	--

Table 19. Constituents and detection limits of inorganic and organic analyses for water and sediment samples and Missouri Department of Natural Resources drinking-water maximum contaminant levels (MCL)

[MRL, method reporting level; µS/cm, microsiemens per centimeter at 25 degrees Celsius; --, no data available; mg/L, milligrams per liter; µg/L, micrograms per liter; L, listed; µg/kg, micrograms per kilogram; ng/g, nanograms per gram; PCN, Polychlorinated nepthalene; EPTC, s-Ethyl dipropylthiocarbamate; BHC, 1,2,3,4,5,6,-Hexachlorocyclohexane; DCPA, N-(3,4-dichlorophenyl)propionamide; ***, not determined]

Group or family	Constituent	MRL	MCL
	Physical properties and inorganic compounds, in water		
	Specific conductance	1.0 µS/cm	--
	pH	.01 units	6.5-9.0
	Oxygen, dissolved	.1 mg/L	--
	Calcium, dissolved	.02 mg/L	--
	Calcium, total	.02 mg/L	--
	Magnesium, dissolved	.02 mg/L	--
	Magnesium, total	.002 mg/L	--
	Sodium, dissolved	.2 mg/L	--
	Sodium, total	.5 mg/L	--
	Potassium, dissolved	.1 mg/L	--
	Alkalinity, total, by incremental titration	1.0 mg/L	--
	Bicarbonate, by incremental titration	1.0 mg/L	--
	Carbonate, by incremental titration	1.0 mg/L	--
	Alkalinity, total, pH 4.5 end point	1.0 mg/L	--
	Sulfate, dissolved	.2 mg/L	250 mg/L
	Chloride, dissolved	.1 mg/L	250 mg/L
	Fluoride, dissolved	.01 mg/L	4 mg/L
	Silica, dissolved	.1 mg/L	--
	Cyanide, total	.01 mg/L	.2 mg/L
	Dissolved solids, residue at 180 degrees Celsius	1.0 mg/L	--
	Dissolved solids, sum of constituents	1.0 mg/L	--
	Hardness, total	1.0 mg/L	--
	Organic carbon, total	.1 mg/L	--
	Nitrite plus nitrate, total as nitrogen	.01 mg/L	--
	Nitrite, total as nitrogen	.001 mg/L	--
	Ammonia, total as nitrogen	.01 mg/L	--
	Phosphorus, total	.010 mg/L	--
	Fecal coliform, in colonies per 100 milliliters	1	--
	Fecal streptococci, in colonies per 100 milliliters	1	--
	Antimony, total	1.0 µg/L	6 µg/L
	Arsenic, total	1.0 µg/L	50 µg/L
	Barium, dissolved	1.0 µg/L	--
	Barium, total	5.0 µg/L	2,000 µg/L
	Beryllium, dissolved	.5 µg/L	--
	Beryllium, total	1.0 µg/L	4 µg/L
	Boron, dissolved	10.0 µg/L	--
	Boron, total	20.0 µg/L	L
	Cadmium, dissolved	1.0 µg/L	--
	Cadmium, total	5.0 µg/L	5 µg/L
	Chromium, dissolved	5.0 µg/L	--
	Chromium, total	10.0 µg/L	100 µg/L
	Cobalt, dissolved	3.0 µg/L	--
	Cobalt, total	10.0 µg/L	--
	Copper, dissolved	10.0 µg/L	--
	Copper, total	10.0 µg/L	1,000 µg/L
	Iron, dissolved	3.0 µg/L	--
	Iron, total	5.0 µg/L	300 µg/L
	Lead, dissolved	10.0 µg/L	--

Table 19. Constituents and detection limits of inorganic and organic analyses for water and sediment samples and Missouri Department of Natural Resources drinking-water maximum contaminant levels (MCL)—Continued

Group or family	Constituent	MRL	MCL
	Physical properties and inorganic compounds, in water—Continued		
	Lead, total	1.0 μg/L	15 μg/L
	Lithium, dissolved	4.0 μg/L	--
	Manganese, dissolved	1.0 μg/L	--
	Manganese, total	5.0 μg/L	50 μg/L
	Mercury, total	.10 μg/L	2 μg/L
	Molybdenum, dissolved	10.0 μg/L	--
	Nickel, dissolved	10.0 μg/L	--
	Nickel, total	10.0 μg/L	100 μg/L
	Selenium, total	1.0 μg/L	50 μg/L
	Silver, dissolved	1.0 μg/L	--
	Silver, total	5.0 μg/L	100 μg/L
	Strontium, dissolved	10.0 μg/L	--
	Thallium, total	1.0 μg/L	2 μg/L
	Vanadium, dissolved	6.0 μg/L	--
	Vanadium, total	10.0 μg/L	L
	Zinc, dissolved	3.0 μg/L	--
	Zinc total	5.0 μg/L	5,000 μg/L
	Volatile organic compounds (total), in water		
Substituted ethane	Chloroethane	0.2 μg/L	--
	1,2-Dibromoethane (EDB)	.2 μg/L	0.05μg/L
	1,1-Dichloroethane	.2 μg/L	--
	1,2-Dichloroethane	.2 μg/L	5 μg/L
	1,1,1-Trichloroethane	.2 μg/L	200 μg/L
	1,1,2-Trichloroethane	.2 μg/L	5 μg/L
	1,1,1,2-Tetrachloroethane	.2 μg/L	--
	1,1,2,2-Tetrachloroethane	.2 μg/L	--
	Trichlorotrifluoroethane	.2 μg/L	--
Substituted ethene	Vinyl chloride	.2 μg/L	2 μg/L
	1,1-Dichloroethene	.2 μg/L	7 μg/L
	cis-1,2-Dichloroethene	.2 μg/L	70 μg/L
	trans-1,2-Dichloroethene	.2 μg/L	100 μg/L
	1,1,2-Trichloroethene	.2 μg/L	5 μg/L
	Tetrachloroethene (PCE)	.2 μg/L	5 μg/L
Substituted methane	Bromomethane	.2 μg/L	--
	Dibromomethane	.2 μg/L	--
	Bromoform	.2 μg/L	100 μg/L
	Bromochloromethane	.2 μg/L	--
	Dibromochloromethane	.2 μg/L	100 μg/L
	Chloromethane	.2 μg/L	--
	Dichloromethane	.2 μg/L	5 μg/L
	Chloroform	.2 μg/L	100 μg/L
	Chlorofluoromethane	.2 μg/L	--
	Carbon tetrachloride	.2 μg/L	5 μg/L
	Dichlorobromomethane	.2 μg/L	100 μg/L
	Dichlorofluoromethane	.2 μg/L	--
	Dichlorodifluoromethane	.2 μg/L	--
	Trichlorofluoromethane	.2 μg/L	--
	Methyl iodide	.5 μg/L	--
	Carbon disulfide	.2 μg/L	--

Table 19. Constituents and detection limits of inorganic and organic analyses for water and sediment samples and Missouri Department of Natural Resources drinking-water maximum contaminant levels (MCL)—Continued

Group or family	Constituent	MRL	MCL
	Volatile organic compounds (total), in water—Continued		
Substituted propane	1,2-Dichloropropane	0.2 µg/L	5 µg/L
	1,3-Dichloropropane	.2 µg/L	5 µg/L
	2,2-Dichloropropane	.2 µg/L	--
	1,2,3-Trichloropropane	.2 µg/L	--
	1,2-Dibromo-3-chloropropane (DBCP)	.2 µg/L	.2 µg/L
Substituted propene	1,1-Dichloropropene	.2 µg/L	--
	cis-1,3-Dichloropropene	.2 µg/L	--
	trans-1,3-Dichloropropene	.2 µg/L	--
Substituted butene	Hexachlorobutadiene	.2 µg/L	--
Benzene derivatives	Benzene	.2 µg/L	5 µg/L
	Chlorobenzene	.2 µg/L	100 µg/L
	1,2-Dichlorobenzene	.2 µg/L	600 µg/L
	1,3-Dichlorobenzene	.2 µg/L	600 µg/L
	1,4-Dichlorobenzene	.2 µg/L	75 µg/L
	1,2,3-Trichlorobenzene	.2 µg/L	--
	1,2,4-Trichlorobenzene	.2 µg/L	70 µg/L
	Bromobenzene	.2 µg/L	--
	Ethylbenzene	.2 µg/L	70 µg/L
	Isopropylbenzene	.2 µg/L	--
	n-Propylbenzene	.2 µg/L	--
	Sec-butylbenzene	.2 µg/L	--
	Tert-butylbenzene	.2 µg/L	--
	n-Butylbenzene	.2 µg/L	--
	1,2,4-Trimethylbenzene	.2 µg/L	--
	1,3,5-Trimethylbenzene	.2 µg/L	--
	Xylenes, total	.2 µg/L	10 µg/L
	Styrene	.2 µg/L	100 µg/L
	Toluene	.2 µg/L	1 µg/L
	1,2-Chlorotoluene	.2 µg/L	--
	1,4-Chlorotoluene	.2 µg/L	--
	p-Isopropyltoluene	.2 µg/L	--
	Naphthalene	.2 µg/L	--
Ether	2-Chloroethylvinyl ether	.2 µg/L	--
	Ethyl ether	.2 µg/L	--
	Methyltertiarybutyl ether (MTBE)	.2 µg/L	--
Aldehyde	Acrolein	20 µg/L	--
Ketone	Acetone	5 µg/L	--
	2-Butanone (Methyl ethyl ketone)	<20	--
	2-Hexanone (Methyl butyl ketone)	<20	--
	4-Methyl-2-pentanone (MIBK)	<20	--
Ester	Vinyl acetate	.2 µg/L	--
Nitrile	Acrylonitrile	20 µg/L	--
	Semivolatile organic compounds (total), in water		
Acidic	2-Chlorophenol	5 µg/L	--
	2,4-Dichlorophenol	30 µg/L	--
	2,4-Dimethylphenol	5 µg/L	--
	4,6-Dinitro-ortho-cresol	30 µg/L	--
	2,4-Dinitrophenol	20 µg/L	--
	2-Nitrophenol	5 µg/L	--
	4-Nitrophenol	30 µg/L	--

Table 19. Constituents and detection limits of inorganic and organic analyses for water and sediment samples and Missouri Department of Natural Resources drinking-water maximum contaminant levels (MCL)—Continued

Group or family	Constituent	MRL	MCL
	Semivolatile organic compounds (total), in water—Continued		
Acidic—Continued	Para-chloro-meta cresol	30 µg/L	--
	Pentachlorophenol	30 µg/L	1 µg/L
	Phenol	5 µg/L	--
	2,4,6-Trichlorophenol	20 µg/L	--
Basic and neutral	Acenaphthene	5 µg/L	--
	Acenaphthylene	5 µg/L	--
	Anthracene	5 µg/L	--
	Benzidine	40 µg/L	--
	Benzo[*a*]anthracene	10 µg/L	.1 µg/L
	Benzo[*a*]pyrene	10 µg/L	.2 µg/L
	Benzo[*b*]fluoranthene	10 µg/L	.2 µg/L
	Benzo[*g,h,i*]perylene	10 µg/L	--
	Benzo[*k*]fluoranthene	10 µg/L	.2 µg/L
	bis(2-Chloroethoxy)methane	5 µg/L	--
	bis(2-Chloroethyl) ether	5 µg/L	--
	bis(2-Chloroisopropyl) ether	5 µg/L	--
	bis(2-Ethylhexyl)phthalate	5 µg/L	--
	4-Bromophenyl phenyl ether	5 µg/L	--
	n-Butylbenzyl phthalate	5 µg/L	100 µg/L
	2-Chloronaphthalene	5 µg/L	--
	4-Chlorophenly phenyl ether	5 µg/L	--
	Chrysene	10 µg/L	.2 µg/L
	1,2,5,6-Dibenzanthracene	10 µg/L	.3 µg/L
	1,2-Dichlorobenzene	5 µg/L	600 µg/L
	1,3-Dichlorobenzene	5 µg/L	600 µg/L
	1,4-Dichlorobenzene	5 µg/L	75 µg/L
	3,3'-Dichlorobenzidine	20 µg/L	--
	Diethylphthalate	5 µg/L	--
	Dimethylphthalate	5 µg/L	--
	Di-*n*-butyl phthalate	5 µg/L	--
	2,4-Dinitrotoluene	5 µg/L	--
	2,6-Dinitrotoluene	5 µg/L	--
	Di-*n*-octyl phthalate	10 µg/L	--
	1,2-Diphenylhydrazine	5 µg/L	--
	Fluoranthene	5 µg/L	--
	Fluorene	5 µg/L	--
	Hexachlorobenzene	5 µg/L	1 µg/L
	Hexachlorobutadiene	5 µg/L	--
	Hexachlorocyclopentadiene	5 µg/L	50 µg/L
	Indeno[*1,2,3-cd*]pyrene	10 µg/L	.4 µg/L
	Isophorone	5 µg/L	--
	Naphthalene	5 µg/L	--
	Nitrobenzene	5 µg/L	--
	n-Nitrosodimethylamine	5 µg/L	--
	n-Nitrosodi-n-propylamine	5 µg/L	--
	n-Nitrosodiphenylamine	5 µg/L	--
	Phenanthrene	5 µg/L	--
	Pyrene	5 µg/L	--
	1,2,4-Trichlorobenzene	5 µg/L	70 µg/L

Table 19. Constituents and detection limits of inorganic and organic analyses for water and sediment samples and Missouri Department of Natural Resources drinking-water maximum contaminant levels (MCL)—Continued

Group or family	Constituent	MRL	MCL
	Pesticides (dissolved), in water		
Acetanilide	Alachlor	0.009 μg/L	2 μg/L
Amide	Napropamide	.01 μg/L	--
	Propanil	.016 μg/L	--
Benzamide	Pronamide	.009 μg/L	--
Benzenamine	Ethalfluralin	.013 μg/L	--
Carbamate	Butylate	.008 μg/L	--
	Carbaryl	.046 μg/L	--
	Carbofuran	.013 μg/L	40 μg/L
	EPTC (Eptam)	.005 μg/L	--
	Pebulate	.009 μg/L	--
	Thiobencarb	.008 μg/L	--
Carbothioate	Molinate	.007 μg/L	--
Chloractetanilide	Metolachlor	.009 μg/L	L
	Propachlor	.015 μg/L	--
Cyclohexane	Alpha BHC	.007 μg/L	--
	Lindane	.011 μg/L	.2 μg/L
Dichloroethylene	2,6-Diethylaniline	.006 μg/L	--
	p,p'-DDE	.01 μg/L	--
Dinitroaniline	Pendimethalin	.018 μg/L	--
	Trifluralin	.012 μg/L	L
Methyluracil	Terbacil	.03 μg/L	--
Napthalene	Dieldrin	.008 μg/L	--
Organophosphate	Ethoprop	.012 μg/L	--
	Malathion	.01 μg/L	--
	Methyl Parathion	.035 μg/L	--
	Parathion	.022 μg/L	--
	Phorate	.011 μg/L	--
	Terbufos	.012 μg/L	--
Organophosphorus	Disulfoton	.008 μg/L	--
	Methyl azinphos	.038 μg/L	--
Phosphonodithioate	Fonofos	.008 μg/L	--
	Dimethoate	.024 μg/L	--
Phosphorothioate	Chlorpyrifos	.005 μg/L	--
	Diazinon	.008 μg/L	--
Pyrethroid	Permethrin	.016 μg/L	--
Substituted urea	Linuron	.039 μg/L	--
	Tebuthiuron	.015 μg/L	--
Sulfite ester	Propargite	.006 μg/L	--
Terepthalate/dimethyl	DCPA (Dacthal)	.004 μg/L	L
Thiocaramate	Triallate	.008 μg/L	--
Toluidine	Benfluralin	.013 μg/L	--
Triazine	Atrazine	.017 μg/L	3 μg/L
	Cyanazine	.013 μg/L	--
	Deethylatrazine	.007 μg/L	--
	Prometon	.008 μg/L	L
	Simazine	.008 μg/L	4 μg/L
Triazinone	Metribuzin	.012 μg/L	L

Table 19. Constituents and detection limits of inorganic and organic analyses for water and sediment samples and Missouri Department of Natural Resources drinking-water maximum contaminant levels (MCL)—Continued

Group or family	Constituent	MRL	MCL
	Explosives (total), in water		
	Nitrobenzine	0.1 µg/L	--
	2-Nitrotoluene	.4 µg/L	--
	3-Nitrotoluene	.4 µg/L	--
	4-Nitrotoluene	.3 µg/L	--
	1,3-Dinitrobenzene	.05 µg/L	--
	2,6-Dinitrotoluene	.005 µg/L	L
	2,3-Dinitrotoluene	.01 µg/L	--
	2,4-Dinitrotoluene	.006 µg/L	L
	3,4-Dinitrotoluene	.003 µg/L	--
	1,3,5-Trinitrobenzene	.1 µg/L	--
	2,4,6-Trinitrotoluene	.009 µg/L	--
	Tertyl	.1 µg/L	--
	RDX	.3 µg/L	--
	4-Amino 2,6-DNT	.2 µg/L	--
	3,5-Dinitroanaline	.2 µg/L	--
	2-Amino 4,6-DNT	.2 µg/L	--
	HMX	.05 µg/L	--
	Semivolatile organic compounds (total), in sediment		
Acidic	2-Chlorophenol	200 µg/kg	
	2,4-Dichlorophenol	200 µg/kg	
	2,4-Dimethylphenol	200 µg/kg	
	4,6-Dinitro-ortho-cresol	600 µg/kg	
	2,4-Dinitrophenol	600 µg/kg	
	2-Nitrophenol	200 µg/kg	
	4-Nitrophenol	600 µg/kg	
	Para-chloro-meta cresol	600 µg/kg	
	Pentachlorophenol	600 µg/kg	
	Phenol	200 µg/kg	
	2,4,6-Trichlorophenol	600 µg/kg	
Basic and neutral	Acenaphthene	200 µg/kg	
	Acenaphthylene	200 µg/kg	
	Anthracene	200 µg/kg	
	Benzidine	*** µg/kg	
	Benzo[*a*]anthracene	400 µg/kg	
	Benzo[*a*]pyrene	400 µg/kg	
	Benzo[*b*]fluoranthene	400 µg/kg	
	Benzo[*g,h,i*]perylene	400 µg/kg	
	Benzo[*k*]fluoranthene	400 µg/kg	
	bis(2-Chloroethoxy)methane	200 µg/kg	
	bis(2-Chloroethyl) ether	200 µg/kg	
	bis(2-Chloroisopropyl) ether	200 µg/kg	
	bis(2-Ethylhexyl)phthalate	200 µg/kg	
	4-Bromophenyl phenyl ether	200 µg/kg	
	n-Butylbenzyl phthalate	200 µg/kg	
	2-Chloronaphthalene	200 µg/kg	
	4-Chlorophenly phenyl ether	200 µg/kg	
	Chrysene	400 µg/kg	
	1,2,5,6-Dibenzanthracene	400 µg/kg	
	1,2-Dichlorobenzene	200 µg/kg	
	1,3-Dichlorobenzene	200 µg/kg	

Table 19. Constituents and detection limits of inorganic and organic analyses for water and sediment samples and Missouri Department of Natural Resources drinking-water maximum contaminant levels (MCL)—Continued

Group or family	Constituent	MRL	MCL
	Semivolatile organic compounds (total), in sediment—Continued		
Basic and neutral—Continued	1,4-Dichlorobenzene	200 μg/kg	
	3,3'-Dichlorobenzidine	*** μg/kg	
	Diethylphthalate	200 μg/kg	
	Dimethylphthalate	200 μg/kg	
	Di-*n*-butyl phthalate	200 μg/kg	
	2,4-Dinitrotoluene	200 μg/kg	
	2,6-Dinitrotoluene	200 μg/kg	
	Di-*n*-octyl phthalate	400 μg/kg	
	1,2-Diphenylhydrazine	*** μg/kg	
	Fluoranthene	200 μg/kg	
	Fluorene	200 μg/kg	
	Hexachlorobenzene	200 μg/kg	
	Hexachlorobutadiene	200 μg/kg	
	Hexachlorocyclopentadiene	200 μg/kg	
	Indeno[*1,2,3-cd*]pyrene	400 μg/kg	
	Isophorone	200 μg/kg	
	Naphthalene	200 μg/kg	
	Nitrobenzene	200 μg/kg	
	n-Nitrosodimethylamine	200 μg/kg	
	n-Nitrosodi-n-propylamine	200 μg/kg	
	n-Nitrosodiphenylamine	200 μg/kg	
	Phenanthrene	200 μg/kg	
	Pyrene	200 μg/kg	
	1,2,4-Trichlorobenzene	200 μg/kg	
	Chlorophenoxy-acid herbicides, in sediment		
	2,4,5-T	0.1 μg/kg	
	2,4-D	.1 μg/kg	
	2,4-DP	.1 μg/kg	
	Dicamba	.1 μg/kg	
	Picloram	.1 μg/kg	
	Silvex	.1 μg/kg	
	Explosives, in sediment		
	1,3-Dinitrobenzene	0.25 mg/kg	
	2,6-Dinitrotoluene	.26 mg/kg	
	2,4-Dinitrotoluene	.25 mg/kg	
	1,3,5-Trinitrobenzene	.25 mg/kg	
	2,4,6-Trinitrotoluene	.25 mg/kg	
	Tertyl	.65 mg/kg	
	RDX	1.00 mg/kg	
	4-Amino 2,6-DNT	.26 mg/kg	
	2-Amino 4,6-DNT	.26 mg/kg	
	HMX	2.20 mg/kg	
	Dioxin, in sediment		
	TCDD, total	0.013 ng/g	--
	2,3,7,8-TCDD	.013 ng/g	0.00003 ng/g
	PeCDD, total	.036 ng/g	--
	1,2,3,7,8-PeCDD	.036 ng/g	--
	HxCDD, total	.026 ng/g	--

Table 19. Constituents and detection limits of inorganic and organic analyses for water and sediment samples and Missouri Department of Natural Resources drinking-water maximum contaminant levels (MCL)—Continued

Group or family	Constituent	MRL	MCL
	Dioxin, in sediment—Continued		
	1,2,3,4,7,8-HxCDD	0.026 ng/g	--
	1,2,3,6,7,8-HxCDD	.026 ng/g	--
	1,2,3,7,8,9-HxCDD	.026 ng/g	--
	HpCDD, total	.015 ng/g	--
	1,2,3,4,6,7,8-HpCDD	.0073 ng/g	--
	OCDD	.25 ng/g	--
	Furan, in sediment		
	TCDF, total	0.067 ng/g	--
	2,3,7,8-TCDF	.067 ng/g	--
	PeCDF, total	.019 ng/g	--
	1,2,3,7,8-PeCDF	.019 ng/g	--
	2,3,4,7,8-PeCDF	.019 ng/g	--
	HxCDF, total	.014 ng/g	--
	1,2,3,4,7,8-HxCDF	.014 ng/g	--
	1,2,3,6,7,8-HxCDF	.014 ng/g	--
	2,3,4,6,7,8-HxCDF	.014 ng/g	--
	1,2,3,7,8,9-HxCDF	.014 ng/g	--
	H-CDF, total	.011 ng/g	--
	1,2,3,4,6,7,8-HpCDF	.011 ng/g	--
	1,2,3,4,7,8,9-HpCDF	.011 ng/g	--
	OCDF	.032 ng/g	--

Table 20. Quality-assurance data for physical properties and inorganic constituents in duplicate and blank water samples

[RPD, relative percent difference; <, less than; --, no data available]

Physical property or constituent	Median RPD of duplicates	Median blank value	Maximum blank value
Specific conductance, in microsiemens per centimeter	<1	2	6
pH, in standard units	1.4	7.8	8.0
Calcium, in milligrams per liter	<1	<.04	.05
Calcium, total, in milligrams per liter	3	.04	.1
Magnesium, in milligrams per liter	<1	<.02	.02
Magnesium, total, in milligrams per liter	<1	<.03	.04
Sodium, in milligrams per liter	<1	<.2	<.2
Sodium, total, in milligrams per liter	<1	.2	.2
Potassium, in milligrams per liter	1.4	<.1	.1
Alkalinity, incremental titration, total as $CaCO_3$, in milligrams per liter	<1	--	--
Bicarbonate, in milligrams per liter	--	--	--
Alkalinity, pH 4.5 endpoint, in milligrams per liter	<1	--	--
Chloride, in milligrams per liter	<1	.2	.7
Sulfate, in milligrams per liter	<1		
Fluoride, in milligrams per liter	<1	<.1	<.1
Silica, in milligrams per liter	1	.3	.4
Cyanide, in milligrams per liter	<1	<.02	<.02
Residue, loss upon ignition at 105 degrees Celsius, in milligrams per liter	2.1	9	16
Total dissolved solids, in milligrams per liter	<1	--	--
Hardness, as $CaCO_3$, in milligrams per liter	<1	<1	<1
Total organic carbon, in milligrams per liter	3.9	1.4	6.2
Nitrite plus nitrate, total as nitrogen, in milligrams per liter	<1	<.02	.02
Nitrite, total as nitrogen, in milligrams per liter	<1	<.006	.01
Ammonia, total as nitrogen, in milligrams per liter	<1	.01	.04
Phosphorus, total, in milligrams per liter	28	<.02	.02
Fecal coliform, in colonies per 100 milliliters	<1	<10	<10
Fecal streptococcus, in colonies per 100 milliliters	<1	<5	<5
Antimony, total, in micrograms per liter	<1	<1	1
Arsenic, in micrograms per liter	<1	<1	1
Barium, in micrograms per liter	<1	<2	<2
Barium, total, in micrograms per liter	<1	<2	2
Beryllium, in micrograms per liter	<1	<.5	<.5
Beryllium, total, in micrograms per liter	<1	<.5	.5
Boron, in micrograms per liter	33	<15	20
Boron, total, in micrograms per liter	<1	<20	20
Cadmium, in micrograms per liter	<1	<1	<1
Cadmium, total, in micrograms per liter	<1	<1	1
Chromium, in micrograms per liter	<1	<5	<5
Chromium, total, in micrograms per liter	<1	<5	5
Cobalt, in micrograms per liter	<1	<3	<3
Cobalt, total, in micrograms per liter	<1	<3	3

Table 20. Quality-assurance data for physical properties and inorganic constituents in duplicate and blank water samples—Continued

Physical property or constituent	Median RPD of duplicates	Median blank value	Maximum blank value
Copper, in micrograms per liter	<1	<10	<10
Copper, total, in micrograms per liter	<1	<10	10
Iron, in micrograms per liter	13	<3	7
Iron, total, in micrograms per liter	<1	<3	10
Lithium, in micrograms per liter	<1	<4	<4
Lead, in micrograms per liter	<1	<11	50
Lead, total, in micrograms per liter	<1	<10	10
Mercury, in micrograms per liter	<1	<.1	<.1
Manganese, in micrograms per liter	<1	<1	<1
Manganese, total, in micrograms per liter	<1	<1	1
Molybdenum, in micrograms per liter	<1	<10	<10
Nickel, in micrograms per liter	<1	<10	<10
Nickel, total, in micrograms per liter	<1	<10	10
Selenium, total, in micrograms per liter	<1	<1	<1
Silver, in micrograms per liter	<1	<1	3
Silver, total, in micrograms per liter	<1	<1	1
Strontium, in micrograms per liter	<1	<1	<1
Thallium, total, in micrograms per liter	<1	<1	<1
Vanadium, in micrograms per liter	<1	<6	<6
Vanadium, total, in micrograms per liter	<1	<1	1
Zinc, in micrograms per liter	<1	<8	8
Zinc, total, in micrograms per liter	<1	<4	4

ABBREVIATIONS AND REPORTING UNITS FOR CHEMICAL CONSTITUENTS AND NOTATIONS USED IN TABLES 21, 22, and 23

SC	Specific conductance, in microsiemens per centimeter at 25 degrees Celsius
pH	In standard units
lab	Laboratory
Temp	Water temperature, in degrees Celsius
DO	Dissolved oxygen, in milligrams per liter
Ca	Calcium, dissolved, in milligrams per liter
Ca_t	Calcium, total, in milligrams per liter
Mg	Magnesium, dissolved, in milligrams per liter
Mg_t	Magnesium, total, in milligrams per liter
Na	Sodium, dissolved, in milligrams per liter
Na_t	Sodium, total, in milligrams per liter
K	Potassium, dissolved, in milligrams per liter
$Alk_{(IT)}$	Alkalinity, total, in milligrams per liter as $CaCO_3$, by incremental titration
$HCO_{3(IT)}$	Bicarbonate, in milligrams per liter, by incremental titration
$CO_{3(IT)}$	Carbonate, in milligrams per liter, by incremental titration
$Alk_{(EP)}$	Alkalinity, total, in milligrams per liter as $CaCO_3$, pH 4.5 end point
SO_4	Sulfate, dissolved, in milligrams per liter
Cl	Chloride, dissolved, in milligrams per liter
F	Fluoride, dissolved, in milligrams per liter
SiO_2	Silica, dissolved, in milligrams per liter
CN_t	Cyanide, total, in milligrams per liter
ROE	Dissolved solids, residue at 180 degrees Celsius, in milligrams per liter
TDS	Dissolved solids, sum of constituents, in milligrams per liter
Hard	Hardness, total, in milligrams per liter as $CaCO_3$
TOC	Organic carbon, total, in milligrams per liter
NO_2+NO_{3t}	Nitrite plus nitrate, total as nitrogen, in milligrams per liter
NO_{2t}	Nitrite, total as nitrogen, in milligrams per liter
NO_{3t}	Nitrate, total, in milligrams per liter
NH_{3t}	Ammonia, total as nitrogen, in milligrams per liter
P_t	Phosphorus, total, in milligrams per liter
Sb_t	Antimony, total, in micrograms per liter
As_t	Arsenic, total, in micrograms per liter
Ba	Barium, dissolved, in micrograms per liter
Ba_t	Barium, total, in micrograms per liter
Be	Beryllium, dissolved, in micrograms per liter
Be_t	Beryllium, total, in micrograms per liter
B	Boron, dissolved, in micrograms per liter
B_t	Boron, total, in micrograms per liter
Cd	Cadmium, dissolved, in micrograms per liter
Cd_t	Cadmium, total, in micrograms per liter
Cr	Chromium, dissolved, in micrograms per liter
Cr_t	Chromium, total, in micrograms per liter
Co	Cobalt, dissolved, in micrograms per liter
Co_t	Cobalt, total, in micrograms per liter
Cu	Copper, dissolved, in micrograms per liter
Cu_t	Copper, total, in micrograms per liter
Fe	Iron, dissolved, in micrograms per liter
Fe_t	Iron, total, in micrograms per liter
Pb	Lead, dissolved, in micrograms per liter
Pb_t	Lead, total, in micrograms per liter
Li	Lithium, dissolved, in micrograms per liter
Mn	Manganese, dissolved, in micrograms per liter
Mn_t	Manganese, total, in micrograms per liter
Hg_t	Mercury, total, in micrograms per liter
Mo	Molybdenum, dissolved, in micrograms per liter
Ni	Nickel, dissolved, in micrograms per liter
Ni_t	Nickel, total, in micrograms per liter
Se_t	Selenium, total, in micrograms per liter
Ag	Silver, dissolved, in micrograms per liter
Ag_t	Silver, total, in micrograms per liter
Sr	Strontium, dissolved, in micrograms per liter
Tl_t	Thallium, total, in micrograms per liter
V	Vanadium, dissolved, in micrograms per liter
V_t	Vanadium, total, in micrograms per liter
Zn	Zinc, dissolved, in micrograms per liter
Zn_t	Zinc, total, in micrograms per liter
--	No data
<	Less than
>	Greater than
Q	Discharge, in cubic feet per second
e	Estimated
Colif	Fecal coliform, in colonies per 100 milliliters
Strep	Fecal streptococci, in colonies per 100 milliliters

Table 21. Physical properties and inorganic constituents in ground-water samples from wells at and near the Fort Leonard Wood Military Reservation

Well (fig. 21)	Date	Time	SC	SC, lab	pH	pH, lab	Temp	DO	Ca	Ca_t	Mg	Mg_t	Na	Na_t
dw 012	04/06/95	1305	508	515	7.6	7.6	16.0	--	60	52	33	31	2.1	2.1
dw 013	03/28/95	1430	370	347	7.8	7.6	13.5	--	38	36	22	22	1.5	1.6
	08/31/95	1325	317	340	7.9	7.7	16.5	--	36	38	20	21	1.5	2.0
dw 014	03/28/95	1050	397	370	7.8	7.4	14.0	--	41	38	23	22	1.3	1.4
	08/31/95	1220	350	371	7.9	7.7	16.0	--	39	42	21	24	1.3	1.6
dw 015	06/01/95	1100	428	430	7.6	7.6	16.0	--	48	43	27	26	1.8	1.8
	08/29/95	1120	405	432	7.8	7.5	21.0	--	45	48	25	27	1.4	1.8
dw 017	03/28/95	1320	469	470	7.6	7.5	13.5	--	51	46	28	27	2.8	2.8
dw 019	03/27/95	1355	509	486	7.5	7.4	14.5	--	52	50	29	29	2.1	2.2
dw 023	[a]03/29/95	0900	634	621	7.3	7.3	14.0	--	.18	.1	.11	.08	150	150
dw 024	04/06/95	0935	405	401	7.7	7.5	14.5	--	43	39	23	22	5.3	5.5
	08/29/95	1315	367	391	7.5	7.5	15.0	--	41	43	22	23	4.7	5.7
dw 025	03/30/95	1350	391	380	7.8	7.7	11.5	--	41	39	24	23	1.9	2.0
dw 027	07/18/95	1100	341	338	7.7	7.7	15.0	>1	36	32	20	18	1.4	1.4
	[b]07/18/95	1101	341	340	7.7	7.6	15.0	>1	37	31	20	18	1.4	1.5
	08/31/95	0955	315	341	7.7	7.6	15.0	--	36	37	20	20	1.6	2.1
dw 030	03/29/95	1335	540	524	7.5	7.5	13.5	--	53	50	33	33	6.1	6.3
	08/30/95	1045	482	513	7.5	7.6	18.0	--	50	54	31	34	6.2	6.6
	[b]08/30/95	1050	482	513	7.5	7.6	18.0	--	51	54	31	34	6.2	6.6
dw 032	03/27/95	1030	458	524	7.4	7.2	14.5	--	68	65	38	38	2.3	2.4
dw 033	02/23/95	1000	385	392	7.9	7.7	13.0	--	42	40	24	23	1.7	1.7
dw 034	03/31/95	1010	475	510	7.7	7.4	14.0	--	58	54	32	32	2.1	2.2
	08/30/95	1240	473	507	7.5	7.4	15.5	--	56	60	30	33	2.2	2.8
dw 037	02/23/95	1300	678	693	7.3	7.2	14.0	--	75	72	42	43	6.9	6.8
dw 038	03/27/95	1215	680	663	7.3	7.3	15.0	--	68	64	38	38	8.8	8.8
dw 054	02/24/95	0940	511	509	7.5	7.5	13.5	--	56	53	29	30	3.5	3.5
dw 056	02/24/95	1140	441	432	7.5	7.4	13.0	--	41	39	21	22	11	11
dw 060	04/05/95	1010	515	505	7.4	7.6	13.5	--	57	51	32	30	2.0	2.2
dw 061	06/01/95	1400	383	385	7.6	7.6	15.5	--	42	38	23	23	1.9	2.0
	08/29/95	1420	364	384	7.6	7.6	16.5	--	41	43	23	24	1.8	2.4
dw 062	03/29/95	1115	445	421	7.6	7.4	15.5	--	47	44	26	26	1.6	1.7
	08/30/95	1420	394	422	7.7	7.6	16.0	--	45	49	25	27	1.7	2.2
dw 063	03/27/95	1515	465	446	7.5	7.1	13.0	--	49	46	27	27	2.6	2.6
dw 064	08/23/95	1315	372	400	7.6	7.6	18.0	--	42	38	24	24	2.0	2.0

Table 21. Physical properties and inorganic constituents in ground-water samples from wells at and near the Fort Leonard Wood Military Reservation—Continued

Well (fig. 21)	Date	Time	K	Alk $_{(IT)}$	$HCO_{3(IT)}$	$CO_{3(IT)}$	$Alk_{(EP)}$	SO_4	Cl	F	SiO_2	CN_t	ROE
dw 012	04/06/95	1305	0.7	269	328	0	266	2.6	3.4	<0.10	9.1	<0.02	280
dw 013	03/28/95	1430	.7	172	210	0	172	2.1	1.0	<.10	8.6	<.02	182
	08/31/95	1325	.8	171	209	0	171	1.8	1.2	<.10	8.0	<.02	182
dw 014	03/28/95	1050	1.1	182	223	0	182	6.7	1.9	<.10	8.9	<.02	202
	08/31/95	1220	1.0	167	204	0	167	7.0	2.8	<.10	8.3	<.02	208
dw 015	06/01/95	1100	.8	227	277	0	226	7.2	2.3	<.10	8.8	<.02	234
	08/29/95	1120	.7	209	255	0	212	6.7	2.3	<.10	8.2	<.02	234
dw 017	03/28/95	1320	1.7	214	261	0	211	8.7	5.1	<.10	10	<.02	268
dw 019	03/27/95	1355	1.6	230	280	0	229	6.7	5.7	<.10	9.3	<.02	282
dw 023	[a]03/29/95	0900	.2	310	378	0	311	4.3	4.7	<.10	9.6	<.02	378
dw 024	04/06/95	0935	1.0	185	226	0	186	4.1	5.7	<.10	12	<.02	200
	08/29/95	1315	.9	174	212	0	173	4.2	7.2	.1	11	<.02	224
dw 025	03/30/95	1350	1.0	185	226	0	186	7.7	1.5	<.10	9.0	<.02	204
dw 027	07/18/95	1100	1.2	188	230	0	188	4.5	2.5	<.10	8.7	<.02	248
	[b]07/18/95	1101	1.2	188	230	0	188	5.0	2.5	<.10	8.9	<.02	188
	08/31/95	0955	1.2	157	192	0	157	7.2	2.5	<.10	8.2	<.02	170
dw 030	03/29/95	1335	1.1	234	285	0	230	26	7.5	<.10	10	<.02	290
	08/30/95	1045	1.1	214	261	0	215	25	7.8	<.10	9.6	<.02	288
	[b]08/30/95	1050	1.1	214	261	0	215	25	7.6	<.10	9.6	<.02	296
dw 032	03/27/95	1030	1.5	295	360	0	294	16	1.4	<.10	9.2	<.02	328
dw 033	02/23/95	1000	.9	186	226	0	192	4.1	6.3	<.10	9.3	<.02	198
dw 034	03/31/95	1010	1.1	246	301	0	246	11	1.1	<.10	9.4	<.02	282
	08/30/95	1240	1.1	262	319	0	259	11	1.7	<.10	8.7	<.02	278
dw 037	02/23/95	1300	1.1	359	438	0	359	7.7	11	<.10	10	<.02	374
dw 038	03/27/95	1215	1.0	253	309	0	252	11	37	<.10	13	<.02	382
dw 054	02/24/95	0940	2.2	249	304	0	249	5	6.1	<.10	10	<.02	272
dw 056	02/24/95	1140	1.7	171	206	0	169	5.4	22	<.10	12	<.02	234
dw 060	04/05/95	1010	4.2	230	280	1.6	229	8.9	1.6	<.02	11	<.02	266
dw 061	06/01/95	1400	.8	179	219	0	179	12	1.8	<.10	8.2	<.02	204
	08/29/95	1420	.8	161	196	0	161	12	1.7	<.10	8.1	<.02	212
dw 062	03/29/95	1115	.8	211	258	0	211	5.9	1.9	<.10	9	<.02	228
	08/30/95	1420	.8	183	224	0	189	6.2	2.6	<.10	8.4	<.02	224
dw 063	03/27/95	1515	.9	210	256	0	212	16	1.3	.6	8.7	<.02	244
dw 064	08/23/95	1315	1.1	186	227	0	185	11	2.2	<.10	7.9	<.02	212

Table 21. Physical properties and inorganic constituents in ground-water samples from wells at and near the Fort Leonard Wood Military Reservation—Continued

Well (fig. 21)	Date	Time	TDS	Hard	TOC	$NO_2 + NO_{3t}$	NO_{2t}	NO_{3t}	NH_{3t}	P_t	Sb_t	As_t	Ba
dw 012	04/06/95	1305	273	290	<0.1	0.83	<0.001	0.83	0.01	<0.02	<1	<1	40
dw 013	03/28/95	1430	177	190	1.7	.40	<.001	.40	.01	<.02	<1	<1	32
	08/31/95	1325	172	170	.6	.36	<.001	.36	<.01	<.02	<1	<1	30
dw 014	03/28/95	1050	194	200	1.6	.20	<.001	.20	.01	<.02	<1	<1	32
	08/31/95	1220	181	180	1.0	.19	<.001	.19	.01	<.02	<1	<1	31
dw 015	06/01/95	1100	232	230	1.3	.13	<.001	.13	.03	<.02	1	<1	32
	08/29/95	1120	215	220	.9	.11	<.001	.11	<.01	<.02	<1	<1	29
dw 017	03/28/95	1320	236	240	1.8	6.9	<.001	6.9	.01	.02	<1	<1	70
dw 019	03/27/95	1355	244	250	3.1	7.2	<.001	7.2	.01	<.02	<1	<1	51
dw 023	[a]03/29/95	0900	355	1	2.4	.34	<.001	.34	.01	<.02	<1	<1	<2
dw 024	04/06/95	0935	205	200	<.1	2.6	<.001	2.6	.01	.02	<1	<1	39
	08/29/95	1315	196	190	.9	2.4	<.001	2.4	.01	<.02	<1	<1	35
dw 025	03/30/95	1350	198	200	2.3	.06	<.001	.06	.01	<.02	<1	<1	34
dw 027	07/18/95	1100	187	170	.6	.74	<.001	.74	.02	<.02	2	1	40
	[b]07/18/95	1101	189	170	.7	.74	<.001	.74	.02	.02	1	1	40
	08/31/95	0955	171	170	.7	.72	<.001	.72	.01	<.02	<1	<1	40
dw 030	03/29/95	1335	277	270	2.6	1.5	<.001	1.5	.01	<.02	<1	<1	57
	08/30/95	1045	259	250	.9	1.6	<.001	1.6	.01	<.02	<1	<1	53
	[b]08/30/95	1050	--	260	.8	1.5	<.001	1.5	.01	<.02	<1	<1	53
dw 032	03/27/95	1030	314	330	2.2	<.02	<.001	--	.01	<.02	<1	<1	88
dw 033	02/23/95	1000	200	200	44	1.0	<.010	1.0	<.01	<.02	<1	<1	38
dw 034	03/31/95	1010	263	280	2.1	<.02	<.001	--	.01	<.02	<1	<1	210
	08/30/95	1240	268	260	1	<.02	<.001	--	.01	<.02	<1	<1	210
dw 037	02/23/95	1300	369	360	88	1.4	<.010	1.4	<.01	.02	<1	<1	44
dw 038	03/27/95	1215	329	330	2.8	5.7	<.001	5.7	.01	.03	<1	<1	53
dw 054	02/24/95	0940	262	260	58	3.8	<.010	3.8	<.01	<.02	<1	<1	56
dw 056	02/24/95	1140	216	190	38	5.3	<.010	5.3	<.01	.03	<1	<1	41
dw 060	04/05/95	1010	255	--	<.1	.43	<.001	.43	.01	<.02	<1	<1	72
dw 061	06/01/95	1400	198	200	1.3	.02	.02	--	.03	<.02	1	<1	26
	08/29/95	1420	185	200	.8	<.02	<.001	--	.01	<.02	<1	<1	25
dw 062	03/29/95	1115	219	220	1.6	.40	<.001	.40	.01	<.02	<1	<1	30
	08/30/95	1420	200	220	.7	.38	<.001	.38	.01	<.02	<1	<1	28
dw 063	03/27/95	1515	232	230	1.9	.04	<.001	.04	.01	<.02	<1	<1	86
dw 064	08/23/95	1315	202	200	.8	.02	<.001	.02	<.01	<.02	<1	<1	32

Table 21. Physical properties and inorganic constituents in ground-water samples from wells at and near the Fort Leonard Wood Military Reservation—Continued

Well (fig. 21)	Date	Time	Ba_t	Be	Be_t	B	B_t	Cd	Cd_t	Cr	Cr_t	Co	Co_t
dw 012	04/06/95	1305	40	<0.5	<0.5	10	<20	<1.0	<1	<5	<5	<3	<3
dw 013	03/28/95	1430	30	<.5	<.5	10	<20	<1.0	<1	<5	<5	<3	<3
	08/31/95	1325	30	<.5	<.5	<10	<20	<1.0	<1	<5	<5	<3	<3
dw 014	03/28/95	1050	30	<.5	<.5	10	<20	<1.0	<1	<5	<5	<3	<3
	08/31/95	1220	30	<.5	<.5	<10	<20	<1.0	<1	<5	<5	<3	<3
dw 015	06/01/95	1100	30	<.5	.5	20	20	<1.0	1	<5	<5	<3	3
	08/29/95	1120	30	<.5	<.5	20	<20	<1.0	<1	<5	<5	<3	<3
dw 017	03/28/95	1320	70	<.5	<.5	10	20	<1.0	<1	<5	<5	<3	<3
dw 019	03/27/95	1355	50	<.5	<.5	<10	<20	<1.0	<1	<5	<5	<3	<3
dw 023	[a]03/29/95	0900	<2	<.5	<.5	20	<20	<1.0	<1	<5	<5	<3	<3
dw 024	04/06/95	0935	40	<.5	<.5	10	<20	<1.0	<1	<5	<5	<3	<3
	08/29/95	1315	30	<.5	<.5	20	<20	<1.0	<1	<5	<5	<3	<3
dw 025	03/30/95	1350	30	<.5	<.5	20	<20	2	<1	<5	<5	<3	<3
dw 027	07/18/95	1100	40	<.5	.5	<10	20	<1.0	1	<5	5	<3	4
	[b]07/18/95	1101	40	<.5	.5	20	20	<1.0	1	<5	5	<3	3
	08/31/95	0955	40	<.5	<.5	10	<20	<1.0	<1	<5	<5	<3	<3
dw 030	03/29/95	1335	50	<.5	<.5	10	<20	<1.0	<1	<5	<5	<3	<3
	08/30/95	1045	50	<.5	<.5	10	<20	<1.0	<1	<5	<5	<3	<3
	[b]08/30/95	1050	50	<.5	<.5	20	<20	<1.0	<1	<5	<5	<3	<3
dw 032	03/27/95	1030	80	<.5	<.5	10	<20	<1.0	<1	<5	<5	<3	<3
dw 033	02/23/95	1000	40	<.5	<.5	10	<20	<1.0	<1	<5	<5	<3	<3
dw 034	03/31/95	1010	200	<.5	<.5	20	<20	<1.0	<1	<5	<5	<3	<3
	08/30/95	1240	200	<.5	<.5	20	<20	<1.0	<1	<5	<5	<3	<3
dw 037	02/23/95	1300	40	<.5	<.5	10	<20	<1.0	<1	<5	<5	<3	<3
dw 038	03/27/95	1215	50	<.5	<.5	20	<20	<1.0	<1	<5	<5	<3	<3
dw 054	02/24/95	0940	50	<.5	<.5	10	<20	<1.0	<1	<5	<5	<3	<3
dw 056	02/24/95	1140	40	<.5	<.5	20	<20	<1.0	<1	<5	<5	<3	<3
dw 060	04/05/95	1010	70	<.5	<.5	10	20	<1.0	<1	<5	<5	<3	<3
dw 061	06/01/95	1400	20	<.5	[c]2.5	20	20	<1.0	1	<5	<5	<3	3
	08/29/95	1420	20	<.5	<.5	20	<20	1	<1	<5	<5	<3	<3
dw 062	03/29/95	1115	30	<.5	<.5	<10	<20	1	<1	<5	<5	<3	<3
	08/30/95	1420	30	<.5	<.5	20	<20	<1.0	<1	<5	<5	<3	<3
dw 063	03/27/95	1515	80	<.5	<.5	20	<20	<1.0	<1	<5	<5	<3	<3
dw 064	08/23/95	1315	30	<.5	<.5	10	<20	<1.0	<1	<5	<5	<3	<3

Table 21. Physical properties and inorganic constituents in ground-water samples from wells at and near the Fort Leonard Wood Military Reservation—Continued

Well (fig. 21)	Date	Time	Cu	Cu_t	Fe	Fe_t	Pb	Pb_t	Li	Mn	Mn_t	Hg_t	Mo
dw 012	04/06/95	1305	<10	<10	<3	40	<10	<10	<4	<1	<1	0.1	<10
dw 013	03/28/95	1430	10	10	5	20	<10	<10	6	<1	<1	<.10	<10
	08/31/95	1325	<10	<10	75	50	<10	<10	<4	<1	<1	<.10	<10
dw 014	03/28/95	1050	<10	10	5	40	<10	<10	4	<1	1	<.10	<10
	08/31/95	1220	<10	10	<3	80	<10	<10	<4	<1	1	<.10	<10
dw 015	06/01/95	1100	<10	<10	<3	9	<10	10	<4	2	<1	.1	<10
	08/29/95	1120	20	20	<3	7	10	<10	<4	1	<1	<.10	10
dw 017	03/28/95	1320	<10	<10	4	4	<10	<10	5	<1	<1	.1	<10
dw 019	03/27/95	1355	<10	<10	4	30	<10	<10	7	<1	<1	--	<10
dw 023	[a]03/29/95	0900	<10	<10	4	20	<10	<10	<4	<1	<1	<.10	<10
dw 024	04/06/95	0935	<10	<10	<3	190	<10	<10	4	2	3	<.10	<10
	08/29/95	1315	<10	<10	<3	110	<10	<10	<4	<1	2	<.10	10
dw 025	03/30/95	1350	20	20	3	20	<10	<10	4	<1	<1	--	<10
dw 027	07/18/95	1100	<10	10	4	50	<10	10	<4	<1	3	.1	<10
	[b]07/18/95	1101	<10	10	9	100	<10	10	<4	<1	5	.1	<10
	08/31/95	0955	<10	<10	<3	6	<10	<10	<4	<1	<1	<.10	<10
dw 030	03/29/95	1335	40	40	<3	10	10	<10	7	<1	<1	<.10	<10
	08/30/95	1045	30	40	<3	9	<10	<10	<4	1	<1	<.10	20
	[b]08/30/95	1050	30	40	<3	9	20	<10	<4	<1	<1	<.10	<10
dw 032	03/27/95	1030	<10	<10	4	20	<10	<10	7	1	1	<.10	<10
dw 033	02/23/95	1000	<10	<10	<3	20	[c]20	<10	<4	<1	<1	.1	<10
dw 034	03/31/95	1010	<10	<10	63	110	<10	<10	9	2	1	.1	<10
	08/30/95	1240	<10	<10	64	100	[c]30	<10	<4	2	2	<.10	<10
dw 037	02/23/95	1300	20	30	<3	10	<10	<10	<4	<1	2	<.10	<10
dw 038	03/27/95	1215	<10	<10	3	60	<10	<10	6	<1	1	<.10	<10
dw 054	02/24/95	0940	<10	<10	<3	30	[c]30	<10	<4	<1	<1	<.10	<10
dw 056	02/24/95	1140	<10	<10	3	30	[c]20	<10	<4	<1	<1	.1	<10
dw 060	04/05/95	1010	<10	<10	<3	40	<10	<10	6	1	<1	<.10	<10
dw 061	06/01/95	1400	<10	<10	7	180	[c]40	10	<4	1	1	<.10	<10
	08/29/95	1420	<10	<10	<3	260	<10	<10	<4	<1	1	<.10	<10
dw 062	03/29/95	1115	<10	<10	<3	8	<10	<10	<4	<1	<1	<.10	<10
	08/30/95	1420	<10	20	<3	6	<10	<10	<4	<1	<1	<.10	10
dw 063	03/27/95	1515	<10	<10	7	10	<10	<10	6	<1	<1	.1	<10
dw 064	08/23/95	1315	<10	<10	12	750	[c]20	<10	<4	5	33	<.10	<10

Table 21. Physical properties and inorganic constituents in ground-water samples from wells at and near the Fort Leonard Wood Military Reservation—Continued

Well (fig. 21)	Date	Time	Ni	Ni_t	Se_t	Ag	Ag_t	Sr	Tl_t	V	V_t	Zn	Zn_t
dw 012	04/06/95	1305	<10	<10	<1	<1.0	<1	45	<1	<6	<1	240	160
dw 013	03/28/95	1430	<10	<10	<1	<1.0	<1	42	<1	<6	<1	16	20
	08/31/95	1325	<10	<10	<1	<1.0	<1	38	<1	<6	<1	99	100
dw 014	03/28/95	1050	<10	<10	<1	1	<1	34	<1	<6	<1	160	170
	08/31/95	1220	<10	<10	<1	<1.0	<1	32	<1	<6	<1	180	200
dw 015	06/01/95	1100	<10	<10	<1	2	<1	44	<1	<6	<1	<3	<4
	08/29/95	1120	<10	<10	<1	<1.0	<1	42	<1	<6	<1	11	9
dw 017	03/28/95	1320	<10	<10	<1	<1.0	<1	58	<1	<6	<1	12	10
dw 019	03/27/95	1355	<10	<10	<1	<1.0	<1	47	<1	<6	<1	190	190
dw 023	[a]03/29/95	0900	<10	<10	<1	2	<1	<1	<1	<6	<1	<3	8
dw 024	04/06/95	0935	<10	<10	<1	<1.0	<1	36	<1	<6	<1	81	80
	08/29/95	1315	<10	<10	<1	<1.0	<1	33	<1	<6	<1	68	90
dw 025	03/30/95	1350	<10	<10	<1	3	<1	48	<1	<6	<1	660	690
dw 027	07/18/95	1100	<10	10	<1	<1.0	1	39	1	<6	1	<3	7
	[b]07/18/95	1101	<10	10	<1	<1.0	1	41	1	<6	1	<3	6
	08/31/95	0955	<10	<10	<1	<1.0	<1	40	<1	<6	<1	<3	<4
dw 030	03/29/95	1335	<10	<10	<1	3	1	62	<1	<6	<1	3	10
	08/30/95	1045	<10	<10	<1	<1.0	<1	60	<1	<6	<1	5	7
	[b]08/30/95	1050	<10	<10	<1	<1.0	<1	59	<1	<6	<1	<3	6
dw 032	03/27/95	1030	<10	<10	<1	<1.0	<1	55	<1	<6	<1	16	20
dw 033	02/23/95	1000	<10	<10	<1	<1.0	<1	37	<1	<6	<1	230	220
dw 034	03/31/95	1010	<10	<10	<1	<1.0	<1	53	<1	<6	<1	250	290
	08/30/95	1240	<10	<10	<1	<1.0	<1	50	<1	<6	<1	270	270
dw 037	02/23/95	1300	<10	<10	<1	<1.0	<1	49	<1	<6	<1	260	260
dw 038	03/27/95	1215	<10	<10	<1	1	<1	50	<1	<6	<1	16	30
dw 054	02/24/95	0940	<10	<10	<1	<1.0	<1	54	<1	<6	<1	750	760
dw 056	02/24/95	1140	<10	<10	<1	<1.0	<1	35	<1	<6	<1	15	10
dw 060	04/05/95	1010	<10	<10	<1	<1	<1	52	<1	<6	<1	42	40
dw 061	06/01/95	1400	<10	<10	<1	<1.0	<1	41	<1	<6	<1	16	20
	08/29/95	1420	<10	<10	<1	2	<1	41	<1	<6	<1	22	30
dw 062	03/29/95	1115	<10	<10	<1	2	<1	47	<1	<6	<1	<3	6
	08/30/95	1420	<10	<10	<1	<1.0	<1	44	<1	<6	<1	<3	10
dw 063	03/27/95	1515	<10	<10	<1	3	<1	48	<1	<6	<1	10	10
dw 064	08/23/95	1315	<10	<10	<1	2	<1	46	<1	<6	<1	5	5

[a]Water sample collected after altered by water softener. Data not used in boxplots (fig. 26).
[b]Duplicate.
[c]Value is suspect.

Table 22. Physical properties and inorganic constituents in water samples from springs at and near the Fort Leonard Wood Military Reservation

Spring (fig. 24)	Date	Time	Q	SC	SC, lab	pH	pH, lab	Temp	DO	Ca	Ca_t	Mg
Ballard Hollow Spring	06/16/95	0915	1.7	353	355	7.3	7.2	13.0	7.3	39	34	20
Cannon Range Spring	07/12/95	1200	<.01	393	392	6.9	7.3	13.5	--	42	41	24
Miller Spring	06/16/95	1315	50	203	207	7.7	7.3	13.0	8.9	21	19	11
	[a]06/16/95	1320	50	203	206	7.7	7.4	13.0	8.9	21	19	11
	08/14/95	1420	26	328	355	7.6	7.6	13.5	8.5	38	36	21
Musgrave Hollow spring 1	06/16/95	1100	.13	242	264	7.1	7.0	14.0	3.5	27	24	15
Musgrave Hollow spring 2	06/22/95	1020	.1	296	309	7.4	7.2	19.0	1.0	34	34	17
	08/21/95	1430	.05e	371	390	8.2	7.4	23.5	.8	42	40	22
Pumping station spring	04/06/95	1500	.97	368	364	6.8	7.7	13.0	11	40	35	21
	08/15/95	1245	.42	389	410	7.6	7.6	13.5	11.5	43	41	23
Roubidoux Spring	11/10/93	1230	69	364	--	7.2	--	14.0	7.6	--	--	--
	01/19/94	0730	68	247	352	7.3	7.7	2.5	12.2	37	--	22
	03/17/94	0900	205	292	--	7.2	--	9.5	10	--	--	--
	04/05/94	1530	29	302	--	7.0	--	10.5	9.2	--	--	--
	06/02/94	1250	104	306	312	7.7	7.6	15.0	7.5	33	--	20
	08/25/94	1650	29	346	--	7.8	--	16.0	5.2	--	--	--
	11/16/94	1600	101	318	--	7.7	--	13.0	7.0	--	--	--
	01/23/95	1530	500	262	267	7.3	7.7	8.5	10.0	27	--	16
	03/28/95	1500	670	319	--	7.6	--	12.0	8.6	--	--	--
	04/24/95	1100	750	238	--	7.3	--	13.0	8.3	--	--	--
	06/23/95	1040	113	310	313	7.8	7.2	16.0	6.1	33	32	18
	[a]06/23/95	1045	113	310	313	7.8	7.4	16.0	6.1	33	32	18
	08/29/95	0800	23	390	--	7.1	--	17.5	5.5	--	--	--
Shanghai Spring	04/05/95	1245	26	382	378	7.1	7.5	13.5	10.1	38	30	21
	08/15/95	1445	26	434	455	7.7	7.4	15.5	6.9	45	44	25
	[a]08/15/95	1450	26	434	455	7.7	7.5	15.5	6.9	45	44	25
Tunnel Hollow Spring	06/14/95	1145	.23	317	322	7.3	7.2	13.0	7.3	36	30	20

Table 22. Physical properties and inorganic constituents in water samples from springs at and near the Fort Leonard Wood Military Reservation—Continued

Spring (fig. 24)	Date	Time	Mg_t	Na	Na_t	K	$Alk_{(IT)}$	$HCO_{3(IT)}$	$CO_{3(IT)}$	$Alk_{(EP)}$	SO_4	Cl
Ballard Hollow Spring	06/16/95	0915	20	2.0	2.0	1.6	163	199	0	162	17	2.0
Cannon Range Spring	07/12/95	1200	24	1.9	1.9	1.2	216	264	0	218	5.9	2.2
Miller Spring	06/16/95	1315	12	1.4	1.6	1.1	89	108	0	89	4.6	1.7
	[a]06/16/95	1320	11	1.4	1.4	1.2	89	108	0	89	4.5	1.8
	08/14/95	1420	21	2.0	2.0	1.2	160	195	0	167	5.1	2.3
Musgrave Hollow spring 1	06/16/95	1100	16	2.2	2.2	.9	124	151	0	123	5.8	2.3
Musgrave Hollow spring 2	06/22/95	1020	18	2.2	2.3	1.3	154	187	0	153	4.3	3.0
	08/21/95	1430	22	2.7	2.7	1.9	181	221	0	185	4.6	5.2
Pumping station spring	04/06/95	1500	20	2.8	2.8	1.1	182	222	0	171	8.1	4.3
	08/15/95	1245	26	3.1	3.2	1.3	199	243	0	198	7.1	6.4
Roubidoux Spring	11/10/93	1230	--	--	--	--	--	227	0	186	--	--
	01/19/94	0730	--	2.2	--	1.1	--	220	0	179	7.3	3.9
	03/17/94	0900	--	--	--	--	--	182	0	148	--	--
	04/05/94	1530	--	--	--	--	--	178	0	145	--	--
	06/02/94	1250	--	2.0	--	1.4	142	173	0	140	6.5	3.4
	08/25/94	1650	--	--	--	--	206	252	0	204	--	--
	11/16/94	1600	--	--	--	--	148	180	0	148	--	--
	01/23/95	1530	--	2.0	--	1.3	120	147	0	120	7.1	4.1
	03/28/95	1500	--	--	--	--	156	190	0	156	--	--
	04/24/95	1100	--	--	--	--	120	146	0	121	--	--
	06/23/95	1040	19	2.0	2.1	1.5	155	189	0	154	6.2	3.1
	[a]06/23/95	1045	18	2.0	2.1	1.5	155	189	0	154	6.2	3.1
	08/29/95	0800	--	--	--	--	196	239	0	193	--	--
Shanghai Spring	04/05/95	1245	17	7.0	7.1	1.7	174	212	0	172	10	9.6
	08/15/95	1445	27	7.0	7.2	2.3	211	257	0	211	9.1	8.5
	[a]08/15/95	1450	27	7.1	6.7	2.4	211	257	0	211	9.1	8.6
Tunnel Hollow Spring	06/14/95	1145	19	.9	1.0	1.1	160	195	0	160	6.0	1.1

Table 22. Physical properties and inorganic constituents in water samples from springs at and near the Fort Leonard Wood Military Reservation—Continued

Spring (fig. 24)	Date	Time	F	SiO_2	CN_t	ROE	TDS	Hard	TOC	$NO_2 + NO_{3t}$	NO_{2t}	NO_{3t}
Ballard Hollow Spring	06/16/95	0915	<0.10	8.9	<0.02	196	189	180	1.4	0.21	<0.001	0.21
Cannon Range Spring	07/12/95	1200	<.01	9.7	<.02	202	217	200	1.1	.21	<.001	.21
Miller Spring	06/16/95	1315	<.10	9.4	<.02	108	103	98	1.4	.26	<.001	.26
	[a]06/16/95	1320	<.10	9.3	<.02	122	103	98	1.4	.26	<.001	.26
	08/14/95	1420	.1	8.5	<.02	212	174	180	.7	.36	.001	.36
Musgrave Hollow spring 1	06/16/95	1100	<.10	8.9	<.02	146	136	130	1.2	.06	<.001	.06
Musgrave Hollow spring 2	06/22/95	1020	<.10	9.0	<.02	164	--	160	1.7	.03	<.001	.03
	08/21/95	1430	<.10	11	<.02	216	198	200	1.2	<.02	<.001	--
Pumping station spring	04/06/95	1500	<.10	8.9	<.02	202	--	--	36	.62	<.001	.62
	08/15/95	1245	.1	9.0	<.02	218	213	200	.9	.88	.001	.88
Roubidoux Spring	11/10/93	1230	--	--	--	--	--	--	--	.24	<.010	.24
	01/19/94	0730	<.10	--	--	194	182	180	--	.28	<.010	.28
	03/17/94	0900	--	--	--	--	--	--	--	.35	<.010	.35
	04/05/94	1530	--	--	--	--	--	--	--	.31	<.010	.31
	06/02/94	1250	<.10	--	--	168	151	160	--	.23	<.010	.23
	08/25/94	1650	--	--	--	--	--	--	--	.42	<.010	.42
	11/16/94	1600	--	--	--	--	--	--	--	.54	<.010	.54
	01/23/95	1530	<.10	--	--	150	130	130	--	.69	<.010	.69
	03/28/95	1500	--	--	--	--	--	--	--	.21	<.010	.21
	04/24/95	1100	--	--	--	--	--	--	--	.31	<.010	.31
	06/23/95	1040	<.10	7.9	<.02	166	--	160	1.5	.27	<.001	.27
	[a]06/23/95	1045	<.10	8.0	<.02	166	165	160	1.5	.26	<.001	.26
	08/29/95	0800	--	--	--	--	--	--	--	.41	.01	.40
Shanghai Spring	04/05/95	1245	.1	8.4	<.02	208	--	--	<.1	1.4	<.001	1.4
	08/15/95	1445	.2	9.1	<.02	252	233	220	1.2	2.0	.001	2.0
	[a]08/15/95	1450	.2	9.1	<.02	260	--	220	1.2	2.0	.001	2.0
Tunnel Hollow Spring	06/14/95	1145	<.10	9.3	<.02	172	170	170	1.5	.02	<.001	.02

Table 22. Physical properties and inorganic constituents in water samples from springs at and near the Fort Leonard Wood Military Reservation—Continued

Spring (fig. 24)	Date	Time	NH_{3t}	P_t	Colif	Strep	Sb_t	As_t	Ba	Ba_t	Be	Be_t
Ballard Hollow Spring	06/16/95	0915	0.01	<0.020	150	360	1	1	46	50	<0.5	0.5
Cannon Range Spring	07/12/95	1200	.01	<.020	--	--	1	1	45	40	<.5	1.3
Miller Spring	06/16/95	1315	.01	<.020	53	120	1	1	35	40	<.5	.5
	[a]06/16/95	1320	.01	<.020	53	120	1	1	35	40	<.5	.5
	08/14/95	1420	.01	.02	9	21	1	1	41	40	<.5	.5
Musgrave Hollow spring 1	06/16/95	1100	.01	<.020	46	29	1	1	41	40	<.5	.5
Musgrave Hollow spring 2	06/22/95	1020	.01	<.020	[b]4	[b]2	1	1	51	50	<.5	.5
	08/21/95	1430	<.010	<.020	0	0	<1	<1	[c]58	50	<.5	<.5
Pumping station spring	04/06/95	1500	.02	<.020	1	6	<1	<1	48	50	<.5	<.5
	08/15/95	1245	.01	.02	[b]13	47	1	1	47	50	<.5	.5
Roubidoux Spring	11/10/93	1230	.01	.03	[b]3	[b]8	--	--	--	--	--	--
	01/19/94	0730	.02	<.020	[b]0	[b]2	--	--	--	--	--	--
	03/17/94	0900	.03	.04	[b]8	[b]1	--	--	--	--	--	--
	04/05/94	1530	.02	<.020	[b]12	[b]8	--	--	--	--	--	--
	06/02/94	1250	.04	<.020	[b]6	[b]6	--	--	--	--	--	--
	08/25/94	1650	.02	.04	[b]4	[b]4	--	--	--	--	--	--
	11/16/94	1600	<.010	<.020	[b]1	93	--	--	--	--	--	--
	01/23/95	1530	.01	<.020	40	58	--	--	--	--	--	--
	03/28/95	1500	.01	.02	53	190	--	--	--	--	--	--
	04/24/95	1100	.02	<.020	180	280	--	--	--	--	--	--
	06/23/95	1040	.01	.02	[b]6	36	1	1	43	40	<.5	.5
	[a]06/23/95	1045	.01	<.020	--	--	1	1	43	40	<.5	.5
	08/29/95	0800	.01	.02	[b]810	[b]5	--	--	--	--	--	--
Shanghai Spring	04/05/95	1245	.05	.07	28	76	<1	<1	45	40	<.5	<.5
	08/15/95	1445	.01	.38	26	35	1	1	47	50	<.5	.5
	[a]08/15/95	1450	.01	.17	--	--	1	1	47	50	<.5	.5
Tunnel Hollow Spring	06/14/95	1145	<.010	<.020	80	53	1	1	43	50	<.5	<.5

Table 22. Physical properties and inorganic constituents in water samples from springs at and near the Fort Leonard Wood Military Reservation—Continued

Spring (fig. 24)	Date	Time	B	B_t	Cd	Cd_t	Cr	Cr_t	Co	Co_t	Cu	Cu_t
Ballard Hollow Spring	06/16/95	0915	110	120	2	1	<5	5	<3	3	<10	10
Cannon Range Spring	07/12/95	1200	20	20	<1	1	<5	5	<3	3	<10	10
Miller Spring	06/16/95	1315	<10	20	<1	1	<5	5	<3	3	<10	10
	[a]06/16/95	1320	10	20	<1	1	<5	5	<3	3	<10	10
	08/14/95	1420	10	20	<1	1	<5	5	<3	3	<10	10
Musgrave Hollow spring 1	06/16/95	1100	<10	20	2	1	<5	5	<3	3	<10	10
Musgrave Hollow spring 2	06/22/95	1020	20	20	<1	1	<5	5	<3	3	<10	10
	08/21/95	1430	20	<20	1	<1	<5	<5	<3	<3	<10	<10
Pumping station spring	04/06/95	1500	22	20	3	<1	<5	<5	<3	<3	<10	<10
	08/15/95	1245	20	20	<1	1	<5	5	<3	3	<10	10
Roubidoux Spring	11/10/93	1230	--	--	--	--	--	--	--	--	--	--
	01/19/94	0730	--	--	<1	<1	--	--	--	--	<1	--
	03/17/94	0900	--	--	--	--	--	--	--	--	--	--
	04/05/94	1530	--	--	--	--	--	--	--	--	--	--
	06/02/94	1250	--	--	<1	<1	--	--	--	--	<1	--
	08/25/94	1650	--	--	--	--	--	--	--	--	--	--
	11/16/94	1600	--	--	--	--	--	--	--	--	--	--
	01/23/95	1530	--	--	<1	<1	--	--	--	--	<1	--
	03/28/95	1500	--	--	--	--	--	--	--	--	--	--
	04/24/95	1100	--	--	--	--	--	--	--	--	--	--
	06/23/95	1040	[c]30	20	2	1	<5	5	<3	3	<10	10
	[a]06/23/95	1045	20	20	3	1	<5	5	<3	3	<10	10
	08/29/95	0800	--	--	--	--	--	--	--	--	--	--
Shanghai Spring	04/05/95	1245	32	30	2	<1	<5	<5	<3	<3	<10	<10
	08/15/95	1445	30	40	<1	1	<5	5	<3	3	<10	10
	[a]08/15/95	1450	30	40	<1	1	<5	5	<3	3	<10	10
Tunnel Hollow Spring	06/14/95	1145	20	<20	<1	1	<5	5	<3	3	<10	10

Table 22. Physical properties and inorganic constituents in water samples from springs at and near the Fort Leonard Wood Military Reservation—Continued

Spring (fig. 24)	Date	Time	Fe	Fe_t	Pb	Pb_t	Li	Mn	Mn_t	Hg_t	Mo	Ni
Ballard Hollow Spring	06/16/95	0915	10	100	<10	10	<4	<1	4	0.1	<10	<10
Cannon Range Spring	07/12/95	1200	4	70	<10	10	<4	2	5	.1	<10	<10
Miller Spring	06/16/95	1315	110	230	10	10	<4	2	5	.1	10	<10
	[a]06/16/95	1320	96	200	<10	10	<4	1	5	.1	<10	<10
	08/14/95	1420	4	20	[c]20	10	<4	<1	1	.1	<10	<10
Musgrave Hollow spring 1	06/16/95	1100	13	70	<10	10	<4	<1	3	.1	[c]30	<10
Musgrave Hollow spring 2	06/22/95	1020	12	30	[c]60	10	<4	2	7	<.10	<10	<10
	08/21/95	1430	<3	20	<10	<10	<4	290	330	<.10	<10	<10
Pumping station spring	04/06/95	1500	<3	50	<10	<10	<4	<1	1	<.10	[c]19	<10
	08/15/95	1245	3	10	<10	10	<4	1	1	.1	<10	<10
Roubidoux Spring	11/10/93	1230	--	--	--	--	--	--	--	--	--	--
	01/19/94	0730	<3	--	<1	3	--	<1	--	.3	--	--
	03/17/94	0900	--	--	--	--	--	--	--	--	--	--
	04/05/94	1530	--	--	--	--	--	--	--	--	--	--
	06/02/94	1250	<3	--	<1	1	--	3	--	.1	--	--
	08/25/94	1650	--	--	--	--	--	--	--	--	--	--
	11/16/94	1600	--	--	--	--	--	--	--	--	--	--
	01/23/95	1530	16	--	<1	1	--	2	--	.1	--	--
	03/28/95	1500	--	--	--	--	--	--	--	--	--	--
	04/24/95	1100	--	--	--	--	--	--	--	--	--	--
	06/23/95	1040	6	40	[c]50	10	<4	<1	2	.1	10	<10
	[a]06/23/95	1045	22	40	[c]50	10	<4	2	2	<.10	[c]20	<10
	08/29/95	0800	--	--	--	--	--	--	--	--	--	--
Shanghai Spring	04/05/95	1245	8	110	<10	<10	<4	1	3	.2	<10	<10
	08/15/95	1445	5	20	10	10	<4	<1	1	.1	<10	<10
	[a]08/15/95	1450	<3	20	<10	10	<4	<1	1	.1	<10	<10
Tunnel Hollow Spring	06/14/95	1145	20	180	<10	10	<4	1	3	<.10	<10	<10

Table 22. Physical properties and inorganic constituents in water samples from springs at and near the Fort Leonard Wood Military Reservation—Continued

Spring (fig. 24)	Date	Time	Ni_t	Se_t	Ag	Ag_t	Sr	Tl_t	V	V_t	Zn	Zn_t
Ballard Hollow Spring	06/16/95	0915	10	<1	<1	1	51	<1	<6	<1	<3	<4
Cannon Range Spring	07/12/95	1200	10	<1	<1	1	44	1	<6	1	<3	4
Miller Spring	06/16/95	1315	10	<1	<1	1	28	<1	<6	<1	<3	<4
	[a]06/16/95	1320	10	<1	1	1	28	<1	<6	<1	<3	<4
	08/14/95	1420	10	1	<1	1	38	1	<6	1	3	4
Musgrave Hollow spring 1	06/16/95	1100	10	<1	<1	1	32	<1	<6	<1	<3	<4
Musgrave Hollow spring 2	06/22/95	1020	10	<1	<1	1	34	1	<6	1	6	20
	08/21/95	1430	<10	<1	<1	<1	44	<1	<6	<1	<3	<4
Pumping station spring	04/06/95	1500	<10	<1	<1	<1	43	<1	<6	<1	3	<4
	08/15/95	1245	10	1	1	1	43	1	<6	1	<3	4
Roubidoux Spring	11/10/93	1230	--	--	--	--	--	--	--	--	--	--
	01/19/94	0730	--	--	--	--	--	--	--	--	6	6
	03/17/94	0900	--	--	--	--	--	--	--	--	--	--
	04/05/94	1530	--	--	--	--	--	--	--	--	--	--
	06/02/94	1250	--	--	--	--	--	--	--	--	<4	<4
	08/25/94	1650	--	--	--	--	--	--	--	--	--	--
	11/16/94	1600	--	--	--	--	--	--	--	--	--	--
	01/23/95	1530	--	--	--	--	--	--	--	--	<4	4
	03/28/95	1500	--	--	--	--	--	--	--	--	--	--
	04/24/95	1100	--	--	--	--	--	--	--	--	--	--
	06/23/95	1040	10	<1	<1	1	34	1	<6	1	<3	4
	[a]06/23/95	1045	10	<1	<1	1	34	1	<6	1	<3	4
	08/29/95	0800	--	--	--	--	--	--	--	--	--	--
Shanghai Spring	04/05/95	1245	<10	<1	<1	<1	45	<1	<6	1	3	<4
	08/15/95	1445	10	1	1	1	47	1	<6	1	5	4
	[a]08/15/95	1450	10	1	<1	1	47	1	<6	1	4	4
Tunnel Hollow Spring	06/14/95	1145	10	<1	<1	1	34	<1	<6	<1	<3	<4

[a]Duplicate.
[b]Non-ideal colony count.
[c]Value is suspect.

Table 23. Physical properties and inorganic constituents in surface-water samples collected at and near the Fort Leonard Wood Military Reservation

Identifier (fig. 24)	Date	Time	Q	SC	SC, lab	pH	pH, lab	Temp	DO	Ca	Ca_t	Mg
SW 001	04/03/95	1230	441	293	290	8.0	7.9	12.5	11.3	30	28	17
	08/14/95	1100	[b]292	253	266	8.1	7.7	27.5	8.4	27	26	14
SW 002	04/04/95	1400	443	279	286	7.9	8.0	13.5	12.5	30	28	17
SW 003	04/04/95	0930	516	279	284	7.8	7.8	11.5	10.2	28	28	16
	08/16/95	0950	282	274	287	8.1	7.8	26	8.3	29	30	16
	[a]08/16/95	0955	282	274	287	8.1	7.7	26	8.3	29	29	16
SW 004	04/05/95	1015	581	283	286	8.2	7.9	11.5	11.8	30	25	17
	08/16/95	1250	313	272	285	8.2	8.0	27	8.6	29	29	16
[b]SW A04	11/17/94	0800	790	297	--	8.1	--	9.5	10.6	--	--	--
	01/23/95	1045	1,180	259	260	7.9	8.1	4.5	13.6	26	--	15
	[a]01/23/95	1046	1,180	259	260	7.9	8.1	4.5	13.6	26	--	15
	03/29/95	0930	960	263	--	7.9	--	12.5	10.4	--	--	--
	04/21/95	1500	3,730	211	--	7.3	--	16.0	9.9	--	--	--
	06/30/95	1230	622	273	283	7.5	7.3	22.0	9.1	30	--	17
	08/28/95	1315	360	333	--	8.1	--	25.0	9	--	--	--
SW 005	06/19/95	1445	.9	246	248	8.2	7.5	22.0	8.6	27	26	14
	08/15/95	0900	.10	285	332	8.0	7.8	23.0	8.1	35	35	20
SW 006	06/13/95	1115	.36	293	339	8.0	7.7	22.5	9.5	37	32	21
	08/15/95	1145	.01	438	446	8.0	8.0	31.0	8.4	47	46	28
SW 007	06/13/95	1000	.85	318	322	8.1	7.8	14.0	10.0	34	30	18
	08/15/95	1020	.40	335	348	8.2	8.0	21.5	8.2	34	33	19
SW 008	04/04/95	1130	.44	399	408	7.8	7.8	10.5	11.5	45	42	23
	10/10/95	1115	.01	452	510	8.0	8.0	14.5	8.4	55	53	32
SW 009	06/13/95	1345	4.5	548	499	7.8	6.7	21.5	5.5	32	28	15
	[a]06/13/95	1350	4.5	548	499	7.8	6.8	21.5	5.5	32	27	15
SW 010	06/27/95	1245	19	296	301	8.2	7.4	22.5	8.2	30	29	17
	08/17/95	1215	14	341	350	8.1	7.7	29.5	7.8	34	33	21
	[a]08/17/95	1220	14	341	351	8.1	7.9	29.5	7.8	34	34	21
SW 011	06/29/95	1000	140	298	305	8.2	7.1	22.5	8.2	30	29	17
	08/22/95	1210	1	329	342	8.1	8.0	28.5	8	33	33	21
SW 012	06/28/95	1100	42	239	241	8.2	7.2	26.0	8.5	24	24	13
SW 013	06/28/95	1345	41	234	246	8.2	7.1	26.5	8.1	25	25	14
	08/23/95	1010	[e].10	347	364	7.9	7.4	25.0	7.2	37	36	22
SW 014	07/12/95	1130	--	--	326	--	7.8	--	--	34	34	19
	08/18/95	0945	.33	373	393	8.0	7.8	27.0	9.1	41	40	24
SW 015	07/12/95	1415	.90	300	302	7.9	7.9	27.5	--	32	31	18
	08/22/95	1020	[e].05	212	369	7.7	7.6	24.0	4.9	38	36	22
SW 016	06/22/95	1330	.27	264	270	7.6	7.5	19.0	8.9	29	28	16
SW 017	07/03/95	1030	--	232	240	7.8	7.4	17.5	--	26	23	14

Table 23. Physical properties and inorganic constituents in surface-water samples collected at and near the Fort Leonard Wood Military Reservation—Continued

Identifier (fig. 24)	Date	Time	Mg_t	Na	Na_t	K	$Alk_{(IT)}$	$HCO_{3(IT)}$	$CO_{3(IT)}$	$Alk_{(EP)}$	SO_4	Cl
SW 001	04/03/95	1230	17	2	2.2	1.2	140	170	0	139	6.1	4.2
	08/14/95	1100	16	1.9	2	2.8	114	139	0	118	3.8	3.2
SW 002	04/04/95	1400	17	2.1	2.1	1.3	106	129	0	106	5.9	3.8
SW 003	04/04/95	0930	17	2.3	2.1	3.2	138	168	0	134	6.0	4.0
	08/16/95	0950	17	1.9	2	2.3	131	160	0	129	3.9	3.2
	[a]08/16/95	0955	17	2.0	2	2.5	131	160	0	129	3.9	3.3
SW 004	04/05/95	1015	15	2.0	2	1.2	149	182	0	148	5.8	3.6
	08/16/95	1250	18	1.9	2	2.3	122	149	0	123	3.9	3.2
[b]SW A04	11/17/94	0800	--	--	--	--	149	182	0	149	--	--
	01/23/95	1045	--	2.5	--	1.4	136	166	0	--	6.4	5.2
	[a]01/23/95	1046	--	2.4	--	1.4	136	166	0	136	6.4	5.1
	03/29/95	0930	--	--	--	--	130	158	0	130	--	--
	04/21/95	1500	--	--	--	--	92	113	0	92	--	--
	06/30/95	1230	--	2.4	--	1.9	134	164	0	134	5.3	3.5
	08/28/95	1315	--	--	--	--	162	198	0	161	--	--
SW 005	06/19/95	1445	15	1.2	1.3	.9	119	145	0	120	4.0	1.0
	08/15/95	0900	20	1.3	1.4	1.3	162	197	0	167	2.9	1.1
SW 006	06/13/95	1115	21	1.1	1.0	1.0	170	207	0	170	5.4	1.1
	08/15/95	1145	31	1.3	1.4	1.4	241	294	0	240	5.8	1.6
SW 007	06/13/95	1000	18	4.2	4.3	1.3	149	182	0	148	13	3.0
	08/15/95	1020	20	6.3	6.1	2.1	152	185	0	161	19	5.0
SW 008	04/04/95	1130	22	4.7	4.7	1.2	156	190	0	152	17	7.0
	10/10/95	1115	31	4.9	4.7	1.3	226	275	0	219	9.8	5.8
SW 009	06/13/95	1345	15	39	38	7.4	149	182	0	149	44	38
	[a]06/13/95	1350	15	40	38	7.5	149	182	0	149	46	38
SW 010	06/27/95	1245	18	2.1	2.2	1.7	137	167	0	137	6.9	3.9
	08/17/95	1215	22	2.3	2.2	2.1	164	200	0	165	5.0	4.3
	[a]08/17/95	1220	23	2.3	2.2	2.1	164	200	0	165	5.0	4.3
SW 011	06/29/95	1000	18	1.9	2.1	1.5	152	185	0	150	6.5	3.5
	08/22/95	1210	21	2.2	2.2	2.1	175	213	0	175	5.1	3.9
SW 012	06/28/95	1100	14	1.5	1.6	1.8	108	132	0	109	5.6	3.0
SW 013	06/28/95	1345	14	1.5	1.6	1.7	126	154	0	125	5.7	3.0
	08/23/95	1010	23	1.6	1.7	1.7	175	213	0	176	6.6	1.9
SW 014	07/12/95	1130	20	2.0	2.0	1.3	--	--	--	--	5.5	2.5
	08/18/95	0945	26	2.0	2.0	1.2	185	226	0	191	6.5	3.6
SW 015	07/12/95	1415	19	1.5	1.4	1.0	168	205	0	164	4.8	1.3
	08/22/95	1020	24	1.5	1.6	1.2	192	235	0	193	3.7	1.6
SW 016	06/22/95	1330	16	1.2	1.2	.8	129	158	0	127	5.4	1.0
SW 017	07/03/95	1030	14	.9	.9	1.1	112	137	0	115	5.0	.7

Table 23. Physical properties and inorganic constituents in surface-water samples collected at and near the Fort Leonard Wood Military Reservation—Continued

Identifier (fig. 24)	Date	Time	F	SiO_2	CN_t	ROE	TDS	Hard	TOC	$NO_2 + NO_{3t}$	NO_{2t}	NO_{3t}
SW 001	04/03/95	1230	<0.10	3.2	<0.02	156	--	--	<0.1	0.16	<0.001	0.16
	08/14/95	1100	.1	8.8	<.02	164	130	130	3.0	.38	.001	.38
SW 002	04/04/95	1400	<.10	3.4	<.02	154	--	--	<.1	.16	<.001	.16
SW 003	04/04/95	0930	<.10	3.2	<.02	148	--	--	<.1	.16	<.001	.16
	08/16/95	0950	.1	8.7	.02	160	144	140	2.3	.32	.001	.32
	[a]08/16/95	0955	.1	8.8	<.02	162	144	140	2.4	.23	.001	.23
SW 004	04/05/95	1015	<.10	3.4	<.02	156	--	--	<.1	.13	<.001	.13
	08/16/95	1250	.1	8.5	<.02	170	138	140	2.1	.31	.001	.31
[b]SW A04	11/17/94	0800	--	--	--	--	--	--	--	.65	.001	.65
	01/23/95	1045	<.10	--	--	158	138	130	--	.63	.01	.62
	[a]01/23/95	1046	<.10	--	--	156	138	130	--	.65	.01	.64
	03/29/95	0930	--	--	--	--	--	--	--	.15	<.010	.15
	04/21/95	1500	--	--	--	--	--	--	--	.20	<.010	.20
	06/30/95	1230	<.10	--	--	150	141	140	--	.23	.01	.22
	08/28/95	1315	--	--	--	--	--	--	--	.15	.01	.14
SW 005	06/19/95	1445	<.10	9.1	<.02	134	129	130	1.6	.03	<.001	.03
	08/15/95	0900	.1	9.8	<.02	176	168	170	1.2	.02	.001	.02
SW 006	06/13/95	1115	<.10	8.3	<.02	184	177	180	.8	<.02	<.001	--
	08/15/95	1145	.1	9.9	<.02	240	240	230	1.7	.02	.001	.02
SW 007	06/13/95	1000	.3	7.7	<.02	176	171	160	1.3	.10	<.001	.10
	08/15/95	1020	.5	7.1	<.02	188	184	160	1.5	.22	.001	.22
SW 008	04/04/95	1130	<.10	7.4	<.02	230	--	--	<.1	.14	<.001	.14
	10/10/95	1115	.1	10	<.02	284	254	270	<.1	<.02	<.001	--
SW 009	06/13/95	1345	.7	9.5	<.02	286	275	140	7.7	2.7	.26	2.44
	[a]06/13/95	1350	.7	9.6	<.02	286	279	140	8.0	2.6	.47	2.13
SW 010	06/27/95	1245	<.10	8.3	<.02	154	152	150	3.1	.17	<.001	.17
	08/17/95	1215	.1	10	<.02	194	177	170	1.9	.02	.001	.02
	[a]08/17/95	1220	.1	10	<.02	190	177	170	1.8	.02	.001	.02
SW 011	06/29/95	1000	<.10	7.7	<.02	148	159	150	2.1	.11	<.001	.11
	08/22/95	1210	<.10	11	<.02	180	183	170	1.6	<.02	<.001	--
SW 012	06/28/95	1100	<.10	7.2	<.02	130	121	110	4.8	.09	<.001	.09
SW 013	06/28/95	1345	<.10	7.1	<.02	132	134	120	4.3	.03	<.001	.03
	08/23/95	1010	<.10	9.8	<.02	192	186	180	1.6	.05	<.001	.05
SW 014	07/12/95	1130	<.10	9.3	<.02	162	--	160	1.2	.08	<.001	.08
	08/18/95	0945	.1	11	<.02	212	201	200	1.4	.09	.001	.09
SW 015	07/12/95	1415	<.10	10	<.02	152	170	150	1.2	.04	<.001	.04
	08/22/95	1020	<.10	11	<.02	192	195	190	1.2	.08	<.001	.08
SW 016	06/22/95	1330	<.10	9.3	<.02	150	141	140	1.2	<.02	<.001	--
SW 017	07/03/95	1030	<.10	7.5	<.02	132	--	120	.8	.03	<.001	.03

Table 23. Physical properties and inorganic constituents in surface-water samples collected at and near the Fort Leonard Wood Military Reservation—Continued

Identifier (fig. 24)	Date	Time	NH_{3t}	P_t	Colif	Strep	Sb_t	As_t	Ba	Ba_t	Be	Be_t
SW 001	04/03/95	1230	0.01	<0.02	18	8	<1	<1	37	40	<0.5	<0.5
	08/14/95	1100	.01	.03	[d]10	[d]83	1	1	42	40	<.5	.5
SW 002	04/04/95	1400	.01	<.02	41	7	<1	<1	36	40	[e]19	<.5
SW 003	04/04/95	0930	<.010	<.02	57	12	<1	<1	38	40	<.5	<.5
	08/16/95	0950	.02	.02	--	--	1	1	44	50	<.5	.5
	[a]08/16/95	0955	.01	.02	[d]6	[d]13	1	1	44	50	<.5	.5
SW 004	04/05/95	1015	.01	<.02	42	7	<1	<1	39	40	<.5	<.5
	08/16/95	1250	.02	.02	[d]20	[d]22	1	1	44	50	<.5	.5
[b]SW A04	11/17/94	0800	<.070	.02	[d]1	[d]26	--	--	--	--	--	--
	01/23/95	1045	.01	<.02	[d]14	[d]25	--	--	--	--	--	--
	[a]01/23/95	1046	.01	.04	[d]14	[d]25	--	--	--	--	--	--
	03/29/95	0930	.02	<.02	350	69	--	--	--	--	--	--
	04/21/95	1500	.09	.02	1,000	540	--	--	--	--	--	--
	06/30/95	1230	.01	<.02	28	20	--	--	--	--	--	--
	08/28/95	1315	.02	.03	58	32	--	--	--	--	--	--
SW 005	06/19/95	1445	.02	<.02	57	130	1	1	41	40	<.5	.5
	08/15/95	0900	.01	.02	[d]13	360	1	1	52	50	<.5	.5
SW 006	06/13/95	1115	<.010	<.02	37	19	1	1	51	60	<.5	<.5
	08/15/95	1145	.01	.02	[d]8	39	1	1	68	70	<.5	.5
SW 007	06/13/95	1000	.01	<.02	46	150	1	1	43	50	<.5	<.5
	08/15/95	1020	.01	.02	250	460	1	1	47	50	<.5	.5
SW 008	04/04/95	1130	.01	<.02	3	6	<1	<1	47	50	<.5	<.5
	10/10/95	1115	<.01	.02	22	160	<1	<1	55	49	<.5	1.4
SW 009	06/13/95	1345	8.4	1.5	<2	<2	1	1	23	30	<.5	<.5
	[a]06/13/95	1350	8.6	1.4	<2	<2	1	1	23	30	<.5	<.5
SW 010	06/27/95	1245	.03	<.02	480	130	1	1	39	40	<.5	.5
	08/17/95	1215	.01	.02	60	42	1	1	51	40	<.5	.5
	[a]08/17/95	1220	.01	.02	--	--	1	1	51	40	<.5	.5
SW 011	06/29/95	1000	.03	<.02	--	--	1	1	41	40	<.5	.5
	08/22/95	1210	.01	<.02	[c]13	32	<1	<1	49	40	<.5	<.5
SW 012	06/28/95	1100	.02	<.02	110		1	1	35	30	<.5	.5
SW 013	06/28/95	1345	.02	.02	56		1	1	38	40	<.5	.5
	08/23/95	1010	.03	<.02	[d]13	49	<1	<1	88	80	<.5	<.5
SW 014	07/12/95	1130	.02	<.02	--	--	1	1	54	50	<.5	1.3
	08/18/95	0945	.01	.02	--	--	1	1	60	50	<.5	.5
SW 015	07/12/95	1415	.01	<.02	--	--	1	1	48	40	<.5	1.3
	08/22/95	1020	<.010	<.02	29	33	<1	<1	57	50	<.5	<.5
SW 016	06/22/95	1330	.01	.02	25	150	1	1	38	40	<.5	.5
SW 017	07/03/95	1030	.01	<.02	--	--	1	1	46	40	1	1.3

Table 23. Physical properties and inorganic constituents in surface-water samples collected at and near the Fort Leonard Wood Military Reservation—Continued

Identifier (fig. 24)	Date	Time	B	B_t	Cd	Cd_t	Cr	Cr_t	Co	Co_t	Cu	Cu_t
SW 001	04/03/95	1230	12	<20	<1	<1	<5	<5	<3	<3	<10	<10
	08/14/95	1100	10	20	<1	1	<5	5	<3	3	<10	10
SW 002	04/04/95	1400	19	<20	<1	<1	<5	<5	<3	<3	<10	<10
SW 003	04/04/95	0930	20	<20	3	<1	<5	<5	<3	<3	<10	<10
	08/16/95	0950	10	20	<1	1	<5	5	<3	3	<10	10
	[a]08/16/95	0955	<10	20	<1	1	<5	5	<3	3	<10	10
SW 004	04/05/95	1015	13	<20	1	<1	<5	<5	<3	<3	<10	<10
	08/16/95	1250	20	20	<1	1	<5	5	<3	3	<10	10
[b]SW A04	11/17/94	0800	--	--	--	--	--	--	--	--	--	--
	01/23/95	1045	--	--	<1	<1	--	--	--	--	<1	--
	[a]01/23/95	1046	--	--	<1	<1	--	--	--	--	<1	--
	03/29/95	0930	--	--	--	--	--	--	--	--	--	--
	04/21/95	1500	--	--	--	--	--	--	--	--	--	--
	06/30/95	1230	--	--	1.1	1	--	--	--	--	4	--
	08/28/95	1315	--	--	--	--	--	--	--	--	--	--
SW 005	06/19/95	1445	20	20	1	1	<5	5	<3	3	<10	10
	08/15/95	0900	<10	20	<1	1	<5	5	<3	3	<10	10
SW 006	06/13/95	1115	10	<20	<1	1	<5	5	<3	3	<10	10
	08/15/95	1145	10	20	<1	1	<5	5	<3	3	<10	10
SW 007	06/13/95	1000	20	20	<1	1	<5	5	<3	3	<10	10
	08/15/95	1020	20	20	<1	1	<5	5	<3	3	<10	10
SW 008	04/04/95	1130	37	30	<1	<1	<5	<5	<3	<3	<10	<10
	10/10/95	1115	--	30	2	<1	<5	<5	<3	<3	<10	<10
SW 009	06/13/95	1345	140	150	2	1	<5	5	<3	3	<10	10
	[a]06/13/95	1350	130	160	<1	1	<5	5	<3	3	<10	10
SW 010	06/27/95	1245	--	20	<1	1	<5	5	<3	3	<10	10
	08/17/95	1215	20	20	<1	1	<5	5	<3	3	<10	10
	[a]08/17/95	1220	10	20	<1	1	<5	5	<3	3	<10	10
SW 011	06/29/95	1000	--	20	<1	1	<5	5	<3	3	<10	10
	08/22/95	1210	30	<20	<1	<1	<5	<5	<3	<3	<10	<10
SW 012	06/28/95	1100	--	20	<1	1	<5	5	<3	3	<10	10
SW 013	06/28/95	1345	--	20	<1	1	<5	5	<3	3	<10	10
	08/23/95	1010	30	30	<1	<1	<5	<5	<3	<3	<10	<10
SW 014	07/12/95	1130	20	20	<1	1	<5	5	<3	3	<10	10
	08/18/95	0945	<10	20	<1	1	<5	5	<3	3	<10	10
SW 015	07/12/95	1415	20	20	2	1	<5	5	<3	3	<10	10
	08/22/95	1020	10	<20	<1	<1	<5	<5	<3	<3	<10	<10
SW 016	06/22/95	1330	20	20	1	1	<5	5	<3	3	<10	10
SW 017	07/03/95	1030	10	20	<1	1	<5	5	<3	3	<10	10

Table 23. Physical properties and inorganic constituents in surface-water samples collected at and near the Fort Leonard Wood Military Reservation—Continued

Identifier (fig. 24)	Date	Time	Fe	Fe_t	Pb	Pb_t	Li	Mn	Mn_t	Hg_t	Mo	Ni
SW 001	04/03/95	1230	4	60	<10	<10	<4	7	12	<0.10	<10	<10
	08/14/95	1100	37	180	<10	10	<4	9	32	.1	<10	<10
SW 002	04/04/95	1400	17	70	<10	<10	<4	10	14	.2	<10	<10
SW 003	04/04/95	0930	30	100	<10	<10	<4	12	19	.1	<10	<10
	08/16/95	0950	22	120	<10	10	<4	8	26	.1	<10	<10
	[a]08/16/95	0955	22	120	<10	10	<4	8	26	.1	<10	<10
SW 004	04/05/95	1015	25	100	[e]14	<10	<4	11	21	.1	<10	<10
	08/16/95	1250	26	120	<10	10	<4	9	28	.1	<10	<10
[b]SW A04	11/17/94	0800	--	--	--	--	--	--	--	--	--	--
	01/23/95	1045	35	--	<1	18	--	7	--	.2	--	--
	[a]01/23/95	1046	40	--	<1	13	--	7	--	.2	--	--
	03/29/95	0930	--	--	--	--	--	--	--	--	--	--
	04/21/95	1500	--	--	--	--	--	--	--	--	--	--
	06/30/95	1230	17	--	1	6	--	11	--	.2	--	--
	08/28/95	1315	--	--	--	--	--	--	--	--	--	--
SW 005	06/19/95	1445	14	20	[e]40	10	<4	1	2	<.10	<10	<10
	08/15/95	0900	<3	20	<10	10	<4	3	5	.1	<10	<10
SW 006	06/13/95	1115	80	130	[e]30	10	<4	73	71	.1	<10	10
	08/15/95	1145	10	70	<10	10	<4	11	16	.1	<10	<10
SW 007	06/13/95	1000	7	50	[e]20	10	<4	3	3	.1	<10	10
	08/15/95	1020	4	40	<10	10	<4	<1	5	.1	<10	<10
SW 008	04/04/95	1130	<3	10	<10	<10	<4	2	3	<.10	<10	<10
	10/10/95	1115	<3	7	[e]20	<10	<4	1	1	<.01	<10	<10
SW 009	06/13/95	1345	45	110	10	10	5	45	43	.1	<10	<10
	[a]06/13/95	1350	50	100	[e]30	10	5	45	42	.1	<10	<10
SW 010	06/27/95	1245	30	100	<10	10	5	10	19	.1	<10	<10
	08/17/95	1215	9	50	<10	10	<4	14	24	.1	<10	<10
	[a]08/17/95	1220	9	50	<10	10	<4	14	25	.1	<10	<10
SW 011	06/29/95	1000	16	80	<10	10	5	7	13	.1	<10	<10
	08/22/95	1210	3	80	<10	<10	<4	4	22	<.10	<10	<10
SW 012	06/28/95	1100	57	90	[e]20	10	5	3	9	.1	<10	<10
SW 013	06/28/95	1345	46	120	<10	10	5	4	21	.1	<10	<10
	08/23/95	1010	6	370	<10	<10	<4	160	240	<.10	<10	<10
SW 014	07/12/95	1130	6	20	<10	10	<4	5	5	.1	<10	<10
	08/18/95	0945	4	7	<10	10	<4	9	9	.1	<10	<10
SW 015	07/12/95	1415	<3	10	[e]20	10	<4	4	4	.1	10	<10
	08/22/95	1020	<3	7	[e]20	<10	<4	1	<1	<.10	<10	<10
SW 016	06/22/95	1330	11	40	[e]30	10	<4	2	4	<.10	<10	<10
SW 017	07/03/95	1030	25	470	<10	10	4	10	22	.1	<10	<10

Table 23. Physical properties and inorganic constituents in surface-water samples collected at and near the Fort Leonard Wood Military Reservation—Continued

Identifier (fig. 24)	Date	Time	Ni_t	Se_t	Ag	Ag_t	Sr	Tl_t	V	V_t	Zn	Zn_t
SW 001	04/03/95	1230	<10	<1	<1	<1	30	<1	<6	<1	<3	<4
	08/14/95	1100	10	1	<1.0	1	28	1	<6	1	<3	4
SW 002	04/04/95	1400	<10	<1	<1	<1	29	<1	<6	<1	<3	<4
SW 003	04/04/95	0930	<10	<1	<1	<1	29	<1	<6	<1	7	<4
	08/16/95	0950	10	1	1	1	31	1	<6	1	<3	4
	[a]08/16/95	0955	10	1	<1.0	1	31	1	<6	1	<3	4
SW 004	04/05/95	1015	<10	<1	<1	<1	31	<1	<6	<1	5	<4
	08/16/95	1250	10	1	<1.0	1	32	1	<6	1	3	4
[b]SW A04	11/17/94	0800	--	--	--	--	--	--	--	--	--	--
	01/23/95	1045	--	--	--	--	--	--	--	--	<4	5
	[a]01/23/95	1046	--	--	--	--	--	--	--	--	<4	4
	03/29/95	0930	--	--	--	--	--	--	--	--	--	--
	04/21/95	1500	--	--	--	--	--	--	--	--	--	--
	06/30/95	1230	--	--	--	--	--	--	--	--	10	20
	08/28/95	1315	--	--	--	--	--	--	--	--	--	--
SW 005	06/19/95	1445	10	<1	<1	1	30	1	<6	1	<3	4
	08/15/95	0900	10	1	<1	1	39	1	<6	1	<3	4
SW 006	06/13/95	1115	10	<1	<1	1	39	<1	<6	<1	<3	4
	08/15/95	1145	10	1	<1	1	49	1	<6	1	<3	4
SW 007	06/13/95	1000	10	<1	2	1	33	<1	<6	<1	<3	4
	08/15/95	1020	10	1	1	1	34	1	<6	1	4	4
SW 008	04/04/95	1130	<10	<1	<1	<1	54	<1	<6	<1	<3	<4
	10/10/95	1115	<10	<1	<1	<1	58	<1	<6	<1	<3	<4
SW 009	06/13/95	1345	10	<1	<1	1	52	<1	<6	<1	6	10
	[a]06/13/95	1350	10	<1	<1	1	53	<1	<6	<1	9	10
SW 010	06/27/95	1245	10	<1	<1	1	28	1	<6	1	7	5
	08/17/95	1215	10	1	<1	1	37	1	<6	1	<3	4
	[a]08/17/95	1220	10	1	<1	1	37	1	<6	1	<3	4
SW 011	06/29/95	1000	10	<1	1	1	29	1	<6	1	<3	5
	08/22/95	1210	<10	<1	<1	<1	36	<1	<6	<1	<3	<4
SW 012	06/28/95	1100	10	<1	<1	1	24	1	<6	1	5	4
SW 013	06/28/95	1345	10	<1	<1	1	25	1	<6	1	4	8
	08/23/95	1010	<10	<1	2	<1	47	1	<6	<1	<3	<4
SW 014	07/12/95	1130	10	<1	1	1	37	1	<6	1	5	4
	08/18/95	0945	10	1	1	1	41	1	<6	1	6	4
SW 015	07/12/95	1415	10	<1	<1	1	36	1	<6	1	<3	4
	08/22/95	1020	<10	<1	2	<1	43	<1	<6	<1	9	<4
SW 016	06/22/95	1330	10	<1	1	1	31	1	<6	1	4	4
SW 017	07/03/95	1030	10	<1	<1	1	32	1	<6	2	<3	4

[a]Duplicate. [b]Collected as part of the U.S. Geological Survey ambient water-quality monitoring program. [c]Daily mean discharge. [d]Non-ideal colony count. [e]Value is suspect.

Table 24. Concentrations of volatile organic compounds and pesticides detected in water samples at and near the Fort Leonard Wood Military Reservation

[VOC, volatile organic compound; µg/L, microgram per liter; ng/L, nanogram per liter; PCE, tetrachloroethene; MTBE, methyl-tertiary-butyl ether; --, no data available; <, less than; GC/MS, gas chromatography/mass spectrometry]

Site name	Date	Time	Total VOC (µg/L)	Total pesticides (ng/L)	Carbon disulfide	Chloro-methane	Trichloro-methane	Bromo-methane	Bromodichloro-methane	Dibromochloro-methane
dw 012	04/06/95	1305	--	--	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
dw 013	03/28/95	1430	0.1	--	.1	<.2	<.2	<.2	<.2	<.2
	08/31/95	1220	--	--	<.2	<.2	<.2	<.2	<.2	<.2
dw 014	03/28/95	1050	--	--	<.2	<.2	<.2	<.2	<.2	<.2
	08/31/95	1325	--	--	<.2	<.2	<.2	<.2	<.2	<.2
dw 015	[a]06/01/95	--	2.2	--	<.2	[b]1.1	.9	<.2	.5	.5
	08/29/95	1120	1.0	--	<.2	<.2	.2	<.2	.1	.2
dw 017	03/28/95	1320	--	--	<.2	[b].2	<.2	<.2	<.2	<.2
dw 019	03/27/95	1355	--	--	<.2	<.2	<.2	<.2	<.2	<.2
dw 023	03/29/95	0900	--	--	<.2	<.2	<.2	<.2	<.2	<.2
dw 024	[c]04/06/95	0935	1.5	--	<.2	[b].3	.3	<.2	.1	.6
	08/29/95	1315	1.1	--	<.2	<.2	.5	<.2	<.2	.1
dw 025	03/29/95	1335	2.1	--	<.2	[b].4	.3	<.2	<.2	.2
dw 027	07/18/95	1100	--	--	<.2	<.2	<.2	<.2	<.2	<.2
	[d]07/18/95	1101	--	--	<.2	[b]1.6	<.2	<.2	<.2	<.2
	08/31/95	0955	--	--	<.2	<.2	<.2	<.2	<.2	<.2
dw 030	03/29/95	1335	2.0	--	<.2	<.2	.4	<.2	<.2	.1
	08/30/95	1045	.2	--	<.2	<.2	.2	<.2	<.2	<.2
	[d]08/30/95	1050	1.3	--	<.2	<.2	.2	<.2	<.2	.2
dw 032	03/27/95	1030	--	--	<.2	[b].2	<.2	<.2	<.2	<.2
dw 033	02/23/95	1000	--	--	<.2	<.2	<.2	<.2	<.2	<.2
	03/31/95	1115	--	--	<.2	[b].2	<.2	<.2	<.2	<.2
dw 034	03/31/95	1010	--	--	<.2	[b].2	<.2	<.2	<.2	<.2
	08/30/95	1240	--	--	<.2	<.2	<.2	<.2	<.2	<.2
dw 037	02/23/95	1300	--	--	<.2	<.2	<.2	<.2	<.2	<.2
dw 038	03/27/95	1215	--	--	<.2	[b].1	<.2	<.2	<.2	<.2
dw 054	02/24/95	0940	--	--	<.2	<.2	<.2	<.2	<.2	<.2
dw 056	02/24/95	1140	--	--	<.2	<.2	<.2	<.2	<.2	<.2
dw 060	[e]04/05/95	1010	--	--	<.2	<.2	<.2	<.2	<.2	<.2
dw 061	04/05/95	1015	--	--	<.2	[b].2	<.2	<.2	<.2	<.2
	06/01/95	1400	--	--	<.2	[b].1	[b].2	<.2	<.2	<.2
	08/29/95	1420	.2	--	<.2	<.2	.2	<.2	<.2	<.2
dw 062	03/29/95	1115	--	--	<.2	[b].2	<.2	<.2	<.2	<.2
	08/30/95	1420	--	--	<.2	<.2	<.2	<.2	<.2	<.2
dw 063	03/27/95	1515	--	--	<.2	<.2	<.2	<.2	<.2	<.2
dw 064	08/23/95	1315	2.1	--	<.2	<.2	.9	<.2	.7	.5
Ballard Hollow Spring	06/16/95	0915	--	--	<.2	<.2	<.2	<.2	<.2	<.2
Cannon Range Spring	07/12/95	1200	--	--	<.2	<.2	<.2	<.2	<.2	<.2
Miller Spring	06/16/95	1315	--	--	<.2	[b]1.5	<.2	<.2	<.2	<.2
	[d]06/16/95	1320	--	--	<.2	[b]1.6	<.2	<.2	<.2	<.2
	08/14/95	1420	--	--	<.2	<.2	<.2	<.2	<.2	<.2
Musgrave Hollow spring 1	06/16/95	1100	--	--	<.2	[b]1.7	<.2	<.2	<.2	<.2
Musgrave Hollow spring 2	06/22/95	1020	--	--	<.2	[b]1.6	<.2	[b].1	<.2	<.2
	08/21/95	1430	--	--	<.2	<.2	<.2	<.2	<.2	<.2

Table 24. Concentrations of volatile organic compounds and pesticides detected in water samples at and near the Fort Leonard Wood Military Reservation—Continued

Site name	Date	Time	Bromoform	PCE	Chloro-benzene	Bromo-benzene	Xylenes (total)	Toluene	MTBE	Acetone	2-Butanone
dw 012	04/06/95	1305	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<1	<0.2
dw 013	03/28/95	1430	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<1	<.2
	08/31/95	1220	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<1	<.2
dw 014	03/28/95	1050	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<1	<.2
	08/31/95	1325	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<1	<.2
dw 015	[a]06/01/95	--	.3	<.2	<.2	<.2	<.2	<.2	<.2	<1	<.2
	08/29/95	1120	.2	<.2	<.2	<.2	.3	<.2	<.2	<1	<.2
dw 017	03/28/95	1320	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<1	<.2
dw 019	03/27/95	1355	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<1	<.2
dw 023	03/29/95	0900	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<1	<.2
dw 024	[c]04/06/95	0935	.5	<.2	<.2	<.2	<.2	<.2	<.2	<1	<.2
	08/29/95	1315	.2	<.2	<.2	<.2	<.2	<.2	.3	<1	<.2
dw 025	03/29/95	1335	.1	<.2	.2	1.3	<.2	<.2	<.2	<1	<.2
dw 027	07/18/95	1100	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<1	<.2
	[d]07/18/95	1101	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<1	<.2
	08/31/95	0955	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<1	<.2
dw 030	03/29/95	1335	<.2	<.2	.2	1.3	<.2	<.2	<.2	<1	<.2
	08/30/95	1045	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<1	<.2
	[d]08/30/95	1050	.3	<.2	<.2	<.2	<.2	<.2	.6	<1	<.2
dw 032	03/27/95	1030	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<1	<.2
dw 033	02/23/95	1000	<.2	<.2	<.2	<.2	<.2	<.2	<.2	[f]1.4	[f].2
	03/31/95	1115	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<1	<.2
dw 034	03/31/95	1010	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<1	<.2
	08/30/95	1240	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<1	<.2
dw 037	02/23/95	1300	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<1	<.2
dw 038	03/27/95	1215	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<1	<.2
dw 054	02/24/95	0940	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<1	<.2
dw 056	02/24/95	1140	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<1	<.2
dw 060	[e]04/05/95	1010	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<1	<.2
dw 061	04/05/95	1015	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<1	<.2
	06/01/95	1400	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<1	<.2
	08/29/95	1420	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<1	<.2
dw 062	03/29/95	1115	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<1	<.2
	08/30/95	1420	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<1	<.2
dw 063	03/27/95	1515	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<1	<.2
dw 064	08/23/95	1315	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<1	<.2
Ballard Hollow Spring	06/16/95	0915	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<1	<.2
Cannon Range Spring	07/12/95	1200	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<1	<.2
Miller Spring	06/16/95	1315	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<1	<.2
	[d]06/16/95	1320	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<1	<.2
	08/14/95	1420	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<1	<.2
Musgrave Hollow spring 1	06/16/95	1100	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<1	<.2
Musgrave Hollow spring 2	06/22/95	1020	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<1	<.2
	08/21/95	1430	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<1	<.2

Table 24. Concentrations of volatile organic compounds and pesticides detected in water samples at and near the Fort Leonard Wood Military Reservation—Continued

Site name	Date	Time	Dissolved pesticides (ng/L)							VOC Surrogate recoveries (percent)		
			Atrazine	Deethyl-atrazine	*p,p'*-DDE	Diazinon	Prometon	Simazine	Tebuthiuron	1,2-DCA	Toluene, D8	p-Bromo-fluoro benzene
dw 012	04/06/95	1305	<1	<1	<1	<1	<1	<1	<1	104	96	105
dw 013	03/28/95	1430	<1	<1	<1	<1	<1	<1	<1	94	92	106
	08/31/95	1220	<1	<1	<1	<1	<1	<1	<1	105	102	102
dw 014	03/28/95	1050	<1	<1	<1	5	<1	<1	<1	95	94	108
	08/31/95	1325	<1	<1	<1	<1	<1	<1	<1	106	102	101
dw 015	[a]06/01/95	--	<1	<1	<1	<1	<1	<1	<1	107	96	101
	08/29/95	1120	<1	<1	<1	<1	<1	<1	<1	102	101	98
dw 017	03/28/95	1320	<1	<1	<1	<1	<1	<1	<1	96	95	107
dw 019	03/27/95	1355	<1	<1	<1	<1	<1	<1	<1	94	96	105
dw 023	03/29/95	0900	<1	<1	<1	<1	<1	<1	<1	97	95	110
dw 024	[c]04/06/95	0935	<1	<1	<1	<1	<1	<1	<1	104	95	103
	08/29/95	1315	<1	<1	<1	<1	<1	<1	<1	101	101	98
dw 025	03/29/95	1335	<1	<1	<1	<1	<1	<1	<1	95	94	107
dw 027	07/18/95	1100	<1	<1	<1	<1	<1	<1	<1	111	101	95
	[d]07/18/95	1101	<1	<1	<1	<1	<1	<1	<1	102	97	99
	08/31/95	0955	<1	<1	<1	<1	<1	<1	<1	109	101	105
dw 030	03/29/95	1335	<1	<1	<1	<1	<1	<1	<1	98	95	110
	08/30/95	1045	<1	<1	<1	<1	<1	<1	<1	101	102	100
	[d]08/30/95	1050	<1	<1	<1	<1	<1	<1	<1	102	100	101
dw 032	03/27/95	1030	<1	<1	<1	5	<1	<1	<1	95	93	105
dw 033	02/23/95	1000	<1	<1	2	<1	<1	<1	<1	98	101	102
	03/31/95	1115	<1	<1	<1	<1	<1	<1	<1	100	94	99
dw 034	03/31/95	1010	<1	<1	<1	<1	<1	<1	<1	99	94	109
	08/30/95	1240	<1	<1	<1	<1	<1	<1	<1	102	100	99
dw 037	02/23/95	1300	<1	<1	<1	<1	<1	<1	<1	98	101	101
dw 038	03/27/95	1215	<1	<1	<1	<1	<1	<1	<1	97	95	106
dw 054	02/24/95	0940	<1	<1	<1	<1	<1	<1	<1	101	101	101
dw 056	02/24/95	1140	<1	<1	<1	<1	<1	<1	<1	100	101	102
dw 060	[e]04/05/95	1010	<1	<1	<1	7	<1	<1	14	103	97	104
dw 061	04/05/95	1015	<1	<1	<1	<1	<1	<1	<1	--	--	--
	06/01/95	1400	<1	<1	<1	<1	<1	<1	<1	104	90	100
	08/29/95	1420	<1	<1	<1	<1	<1	<1	<1	106	97	98
dw 062	03/29/95	1115	<1	<1	<1	<1	<1	<1	<1	96	92	109
	08/30/95	1420	<1	<1	<1	<1	<1	<1	<1	105	100	98
dw 063	03/27/95	1515	<1	<1	<1	<1	<1	<1	<1	--	--	--
dw 064	08/23/95	1315	<1	<1	<1	<1	<1	<1	<1	109	102	102
Ballard Hollow Spring	06/16/95	0915	<1	<1	<1	<1	<1	<1	<1	104	96	101
Cannon Range Spring	07/12/95	1200	<1	<1	<1	<1	<1	<1	<1	101	98	101
Miller Spring	06/16/95	1315	<1	<1	<1	<1	<1	<1	<1	98	95	96
	[d]06/16/95	1320	<1	<1	<1	<1	<1	<1	<1	106	97	104
	08/14/95	1420	<1	<1	<1	<1	<1	<1	<1	116	94	108
Musgrave Hollow spring 1	06/16/95	1100	<1	<1	<1	<1	<1	<1	<1	105	97	95
Musgrave Hollow spring 2	06/22/95	1020	<1	<1	<1	<1	<1	<1	<1	95	101	97
	08/21/95	1430	<1	<1	<1	<1	<1	<1	<1	110	104	96

Table 24. Concentrations of volatile organic compounds and pesticides detected in water samples at and near the Fort Leonard Wood Military Reservation—Continued

Site name	Date	Time	Total VOC (µg/L)	Total pesticides (ng/L)	Carbon disulfide	Chloro-methane	Trichloro-methane	Bromo-methane	Bromodichloro-methane	Dibromochloro-methane
Pumping station spring	04/06/95	1500	--	--	<0.2	[b]0.2	<0.2	<0.2	<0.2	<0.2
	08/15/95	1245	--	--	<.2	<.2	<.2	<.2	<.2	<.2
Roubidoux Spring	06/23/95	1040	--	--	<.2	[b]1.0	<.2	[b].1	<.2	<.2
	[d]06/23/95	1045	--	--	<.2	[b]1.8	<.2	[b].1	<.2	<.2
Shanghai Spring	04/05/95	1245	1.5	--	<.2	[b].2	[b].20	<.2	<.2	<.2
	08/15/95	1445	1.0	--	<.2	<.2	.18	<.2	<.2	<.2
	[d]08/15/95	1450	1.0	--	<.2	<.2	.16	<.2	<.2	<.2
Tunnel Hollow Spring	06/14/95	1145	--	--	<.2	[b]1.2	<.2	<.2	<.2	<.2
SW 001	04/03/95	1230	--	--	<.2	[b].2	<.2	<.2	<.2	<.2
	08/14/95	1100	--	--	<.2	<.2	<.2	<.2	<.2	<.2
SW 002	04/04/95	1400	--	--	<.2	<.2	<.2	<.2	<.2	<.2
SW 003	04/04/95	0930	--	--	<.2	<.2	<.2	<.2	<.2	<.2
	08/16/95	0950	--	--	<.2	<.2	<.2	<.2	<.2	<.2
	[d]08/16/95	0955	--	--	<.2	<.2	<.2	<.2	<.2	<.2
SW 004	04/05/95	1015	--	--	<.2	[b].2	<.2	<.2	<.2	<.2
	08/16/95	1250	--	--	<.2	<.2	<.2	<.2	<.2	<.2
SW 005	06/19/95	1445	--	--	<.2	[b]1.8	<.2	<.2	<.2	<.2
	08/15/95	0900	--	--	<.2	<.2	<.2	<.2	<.2	<.2
SW 006	06/13/95	1115	--	--	<.2	[b]1.1	<.2	<.2	<.2	<.2
SW 007	06/13/95	1000	--	--	<.2	[b]1.3	[b].10	<.2	<.2	<.2
	08/15/95	1020	--	--	<.2	<.2	[b].30	<.2	<.2	<.2
SW 008	04/04/95	1130	--	--	<.2	<.2	<.2	<.2	<.2	<.2
	10/10/95	1115	--	--	<.2	<.2	<.2	<.2	<.2	<.2
SW 009	06/13/95	1345	--	--	<.8	[b]1.0	[b]1.0	<.8	<.8	<.8
	[d]06/13/95	1350	--	--	<.4	[b]1.0	[b]1.0	<.4	<.4	<.4
	[d]06/13/95	1350	--	--	<.8	[b]1.0	[b]1.0	<.8	<.8	<.8
SW 010	06/27/95	1245	--	--	<.2	[b]1.5	<.2	<.2	<.2	<.2
	08/17/95	1215	--	--	<.2	<.2	<.2	<.2	<.2	<.2
	08/17/95	1220	--	--	<.2	<.2	<.2	<.2	<.2	<.2
SW 011	06/29/95	1000	--	--	<.2	[b]1.9	<.2	<.2	<.2	<.2
	08/22/95	1210	--	--	<.2	<.2	<.2	<.2	<.2	<.2
SW 012	06/28/95	1100	--	--	<.2	[b]1.7	<.2	<.2	<.2	<.2
SW 013	06/28/95	1345	--	--	<.2	[b]1.6	<.2	<.2	<.2	<.2
	08/23/95	1010	--	--	<.2	<.2	<.2	<.2	<.2	<.2
SW 014	07/12/95	1130	--	--	<.2	[b]1.1	<.2	<.2	<.2	<.2
	08/18/95	0945	--	--	<.2	<.2	<.2	<.2	<.2	<.2
SW 015	07/12/95	1415	--	--	<.2	<.2	<.2	<.2	<.2	<.2
	08/22/95	1020	--	--	<.2	<.2	<.2	<.2	<.2	<.2
SW 016	06/22/95	1330	.4	--	<.2	[b]1.4	<.2	[b].1	<.2	<.2
SW 017	07/03/95	1030	--	--	<.2	[b]1.7	<.2	<.2	<.2	<.2
Trip blank	05/09/95	1600	--	--	<.2	<.2	<.2	<.2	<.2	<.2
	06/01/95	1400	--	--	<.2	<.2	<.2	<.2	<.2	<.2
	06/13/95	1400	--	--	<.2	<.2	<.2	<.2	<.2	<.2
	06/13/95	1440	--	--	<.2	<.2	<.2	<.2	<.2	<.2
	06/19/95	1415	--	--	<.2	[b]1.8	<.2	<.2	<.2	<.2
	08/23/95	1100	--	--	<.2	<.2	<.2	<.2	<.2	<.2
	08/29/95	1020	--	--	<.2	<.2	<.2	<.2	<.2	<.2

Table 24. Concentrations of volatile organic compounds and pesticides detected in water samples at and near the Fort Leonard Wood Military Reservation—Continued

Site name	Date	Time	Bromoform	PCE	Chloro-benzene	Bromo-benzene	Xylenes (total)	Toluene	MTBE	Acetone	2-Butanone
Pumping station spring	04/06/95	1500	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<1	<0.2
	08/15/95	1245	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<1	<.2
Roubidoux Spring	06/23/95	1040	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<1	<.2
	[d]06/23/95	1045	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<1	<.2
Shanghai Spring	04/05/95	1245	<.2	1.5	<.2	<.2	<.2	<.2	<.2	<1	<.2
	08/15/95	1445	<.2	.8	<.2	<.2	<.2	<.2	<.2	<1	<.2
	[d]08/15/95	1450	<.2	.8	<.2	<.2	<.2	<.2	<.2	<1	<.2
Tunnel Hollow Spring	06/14/95	1145	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<1	<.2
SW 001	04/03/95	1230	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<1	<.2
	08/14/95	1100	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<1	<.2
SW 002	04/04/95	1400	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<1	<.2
SW 003	04/04/95	0930	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<1	<.2
	08/16/95	0950	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<1	<.2
	[d]08/16/95	0955	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<1	<.2
SW 004	04/05/95	1015	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<1	<.2
	08/16/95	1250	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<1	<.2
SW 005	06/19/95	1445	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<1	<.2
	08/15/95	0900	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<1	<.2
SW 006	06/13/95	1115	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<1	<.2
SW 007	06/13/95	1000	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<1	<.2
	08/15/95	1020	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<1	<.2
SW 008	04/04/95	1130	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<1	<.2
	10/10/95	1115	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<1	<.2
SW 009	06/13/95	1345	<.8	<.8	<.8	<.8	<.8	<.8	<.8	<.8	<.8
	[d]06/13/95	1350	<.4	<.4	<.4	<.4	<.4	<.4	<.4	<.4	<.4
	[d]06/13/95	1350	<.8	<.8	<.8	<.8	<.8	<.8	<.8	<.8	<.8
SW 010	06/27/95	1245	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<1	<.2
	08/17/95	1215	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<1	<.2
	08/17/95	1220	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<1	<.2
SW 011	06/29/95	1000	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<1	<.2
	08/22/95	1210	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<1	<.2
SW 012	06/28/95	1100	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<1	<.2
SW 013	06/28/95	1345	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<1	<.2
	08/23/95	1010	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<1	<.2
SW 014	07/12/95	1130	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<1	<.2
	08/18/95	0945	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<1	<.2
SW 015	07/12/95	1415	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<1	<.2
	08/22/95	1020	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<1	<.2
SW 016	06/22/95	1330	<.2	<.2	<.2	<.2	.13	.14	.15	<1	<.2
SW 017	07/03/95	1030	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<1	<.2
Trip blank	05/09/95	1600	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<1	<.2
	06/01/95	1400	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<1	<.2
	06/13/95	1400	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<1	<.2
	06/13/95	1440	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<1	<.2
	06/19/95	1415	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<1	<.2
	08/23/95	1100	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<1	<.2
	08/29/95	1020	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<1	<.2

Table 24. Concentrations of volatile organic compounds and pesticides detected in water samples at and near the Fort Leonard Wood Military Reservation—Continued

			Dissolved pesticides (ng/L)							VOC Surrogate recoveries (percent)		
Site name	Date	Time	Atrazine	Deethyl-atrazine	*p,p'*-DDE	Diazinon	Prometon	Simazine	Tebuthiuron	1,2-DCA	Toluene, D8	p-Bromo-fluoro benzene
Pumping station spring	04/06/95	1500	<1	<1	<1	<1	7	8	<1	103	96	103
	08/15/95	1245	<1	<1	<1	<1	<1	<1	<1	105	102	98
Roubidoux Spring	06/23/95	1040	<1	<1	<1	<1	<1	<1	<1	102	99	102
	[d]06/23/95	1045	<1	<1	<1	<1	<1	<1	<1	100	102	103
Shanghai Spring	04/05/95	1245	<1	<1	<1	<1	8	6	<1	94	97	98
	08/15/95	1445	<1	<1	<1	<1	<1	<1	<1	112	94	111
	[d]08/15/95	1450	<1	<1	<1	<1	<1	<1	<1	107	96	104
Tunnel Hollow Spring	06/14/95	1145	<1	<1	<1	<1	<1	<1	<1	103	97	98
SW 001	04/03/95	1230	<1	<1	<1	<1	<1	<1	9	100	98	97
	08/14/95	1100	<1	<1	<1	<1	<1	<1	<1	127	97	107
SW 002	04/04/95	1400	2	4	<1	<1	<1	<1	8	100	99	104
SW 003	04/04/95	0930	<1	<1	<1	<1	<1	<1	9	--	--	--
	08/16/95	0950	--	--	--	--	--	--	--	--	--	--
	[d]08/16/95	0955	--	--	--	--	--	--	--	--	--	--
SW 004	04/05/95	1015	<1	4	<1	<1	<1	<1	<1	99	96	100
	08/16/95	1250	<1	<1	<1	<1	<1	<1	<1	104	102	103
SW 005	06/19/95	1445	<1	<1	<1	<1	<1	<1	<1	103	98	103
	08/15/95	0900	<1	<1	<1	<1	<1	<1	<1	128	93	105
SW 006	06/13/95	1115	<1	<1	<1	<1	<1	<1	<1	109	93	103
SW 007	06/13/95	1000	<1	<1	<1	<1	<1	<1	<1	102	97	101
	08/15/95	1020	<1	<1	<1	<1	<1	<1	<1	123	95	104
SW 008	04/04/95	1130	<1	<1	1	<1	<1	<1	<1	99	99	100
	10/10/95	1115	<1	<1	<1	<1	<1	<1	<1	94	100	100
SW 009	06/13/95	1345	<1	<1	<1	<1	<1	<1	<1	106	100	98
	[d]06/13/95	1350	--	--	--	--	--	--	--	--	--	--
	[d]06/13/95	1350	<1	<1	<1	<1	<1	<1	<1	103	99	96
SW 010	06/27/95	1245	<1	<1	<1	<1	<1	<1	<1	99	99	101
	08/17/95	1215	<1	<1	<1	<1	<1	<1	<1	112	105	97
	08/17/95	1220	<1	<1	<1	<1	<1	<1	<1	107	104	100
SW 011	06/29/95	1000	<1	<1	<1	<1	<1	<1	<1	102	99	98
	08/22/95	1210	--	--	--	--	--	--	--	--	--	--
SW 012	06/28/95	1100	<1	<1	<1	<1	<1	<1	<1	98	98	103
SW 013	06/28/95	1345	<1	<1	<1	<1	<1	<1	<1	102	99	100
	08/23/95	1010	<1	<1	<1	<1	<1	<1	<1	105	101	104
SW 014	07/12/95	1130	<1	<1	<1	<1	<1	<1	<1	101	97	104
	08/18/95	0945	<1	<1	<1	<1	<1	<1	<1	107	104	100
SW 015	07/12/95	1415	<1	<1	<1	<1	<1	<1	<1	99	96	100
	08/22/95	1020	<1	<1	<1	<1	<1	<1	<1	110	104	96
SW 016	06/22/95	1330	<1	<1	<1	<1	<1	<1	<1	102	100	95
SW 017	07/03/95	1030	<1	<1	<1	<1	<1	<1	<1	104	92	105
Trip blank	05/09/95	1600	--	--	--	--	--	--	--	101	98	99
	06/01/95	1400	--	--	--	--	--	--	--	103	97	99
	06/13/95	1400	--	--	--	--	--	--	--	103	97	99
	06/13/95	1440	--	--	--	--	--	--	--	101	97	101
	06/19/95	1415	--	--	--	--	--	--	--	99	91	106
	08/23/95	1100	--	--	--	--	--	--	--	108	103	100
	08/29/95	1020	--	--	--	--	--	--	--	98	98	96

[a]Sample contained (tentatively identified by GC/MS) dibromomethylbenzene (0.1 µg/L); 1-bromo-3,5-dimethylbenzene (0.3 µg/L); and 4-bromo-1,2-dimethylbenzene (0.2 µg/L). All concentrations estimated.

[b]Compound present in the hydrochloric acid preservative.

[c]This sample also contained (tentatively identified by GC/MS) Cyanogen chloride (0.1 µg/L), 2-methylpropanal (0.1 µg/L), and pentanal (0.1 µg/L). All concentrations estimated.

[d]Duplicate.

[e]This sample also contained (tentatively identified by GC/MS) 2,4-dimethyl heptane (0.1 µg/L). Concentration estimated.

[f]Compound probably is the result of contamination from permanent felt-tip marking pen used to label this sample.