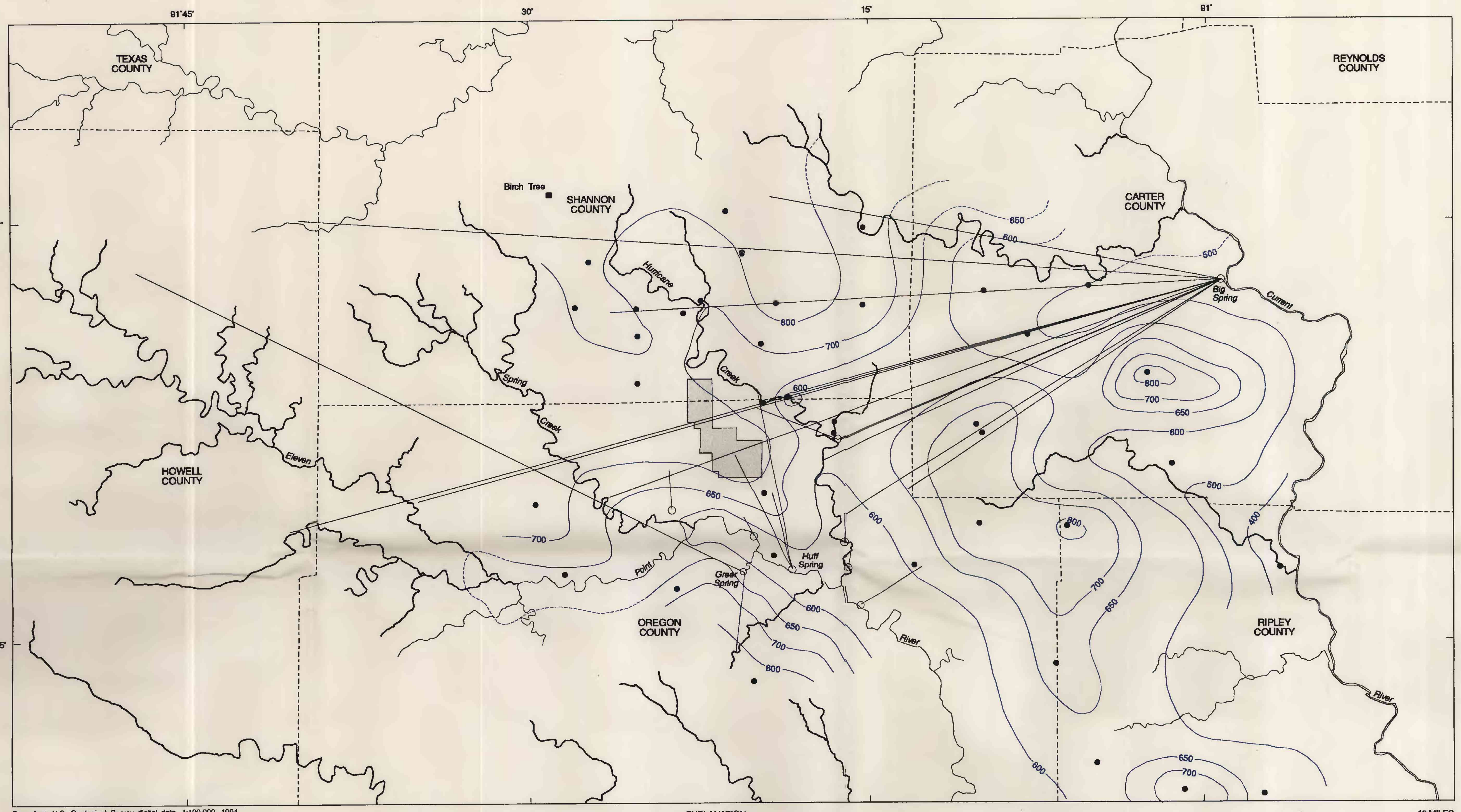
PREPARED IN COOPERATION WITH THE
MISSOURI DEPARTMENT OF CONSERVATION

WATER-RESOURCES INVESTIGATIONS REPORT 95-4096
Ground-water level changes and flow patterns SHEET 1 OF 1
Imes, J.L., and Kleeschulte, M.J., 1995, Seasonal ground-water level changes (1990-93) and flow patterns in the Fristoe Unit of the Mark Twain National Forest, southern Missouri



EXPLANATION

PREFERENCE RIGHT LEASE APPLICATION AREA

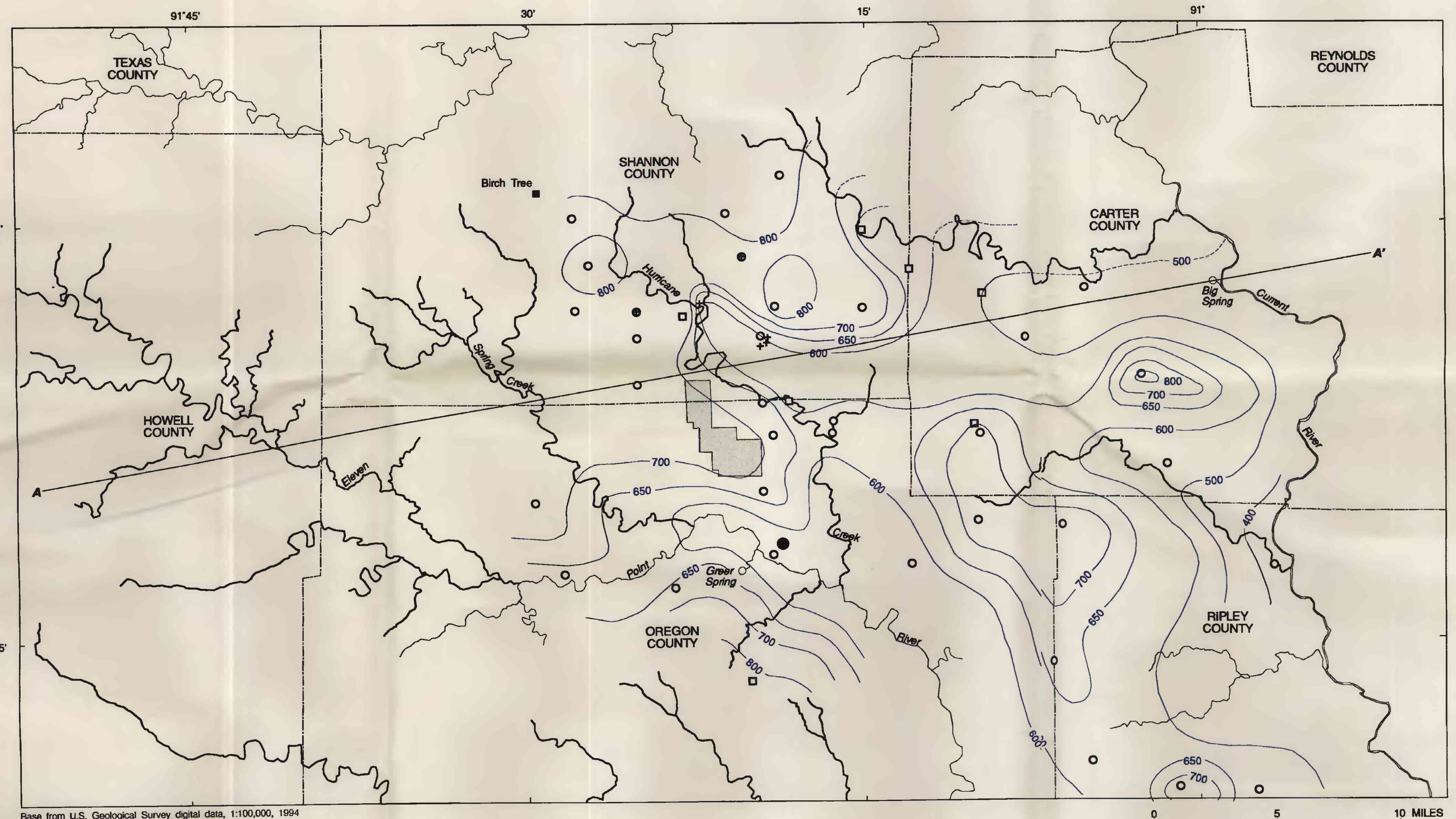
STREAM–Darker line signifies a stream known to lose part or all of its flow during certain hydrologic conditions (Harvey, 1980)

800 POTENTIOMETRIC CONTOUR–Shows altitude at which water would have stood in tightly cased wells in June 1993. Dashed line indicates interpretation beyond control points. Intervals are 50 and 100 feet. Datum is sea level

DYE-TRACE–Shows straight-line path between injection point and recovery point (open circle at end of path) Dye-trace data are from Aley (1975) and Gann and others (1976).

WATER-LEVEL DATA POINT

Figure 2. Potentiometric surface during seasonal high-flow conditions (June 1993) and dye-trace investigations.



EXPLANATION

PREFERENCE RIGHT LEASE APPLICATION AREA

STREAM–Darker line signifies a stream known to lose part or all of its flow under certain hydrologic conditions (Harvey, 1980)

600 POTENTIOMETRIC CONTOUR–Shows altitude at which water would have stood in tightly cased wells in October 1992. Dashed line indicates interpretation beyond control points. Intervals are 50 and 100 feet. Datum is sea level

A——A' LINE OF SECTION

RANGE OF MEASURED WATER LEVELS, IN FEET

- Less than or equal to 50
- Greater than 50 and less than or equal to 100
- Greater than 100

CONTINUOUSLY MONITORED WATER WELL–Water levels are shown in figure 4

Figure 3. Potentiometric surface during seasonal low-flow conditions (October 1992) and maximum measured seasonal ranges of water levels from May 1990 to September 1993. A generalized geologic section is shown in figure 5. Note the increased depth and extent of the ground-water trough between Big Spring and Hurricane Creek from high-flow conditions. The conduit system can more effectively drain ground water from the bedrock under low-flow conditions.

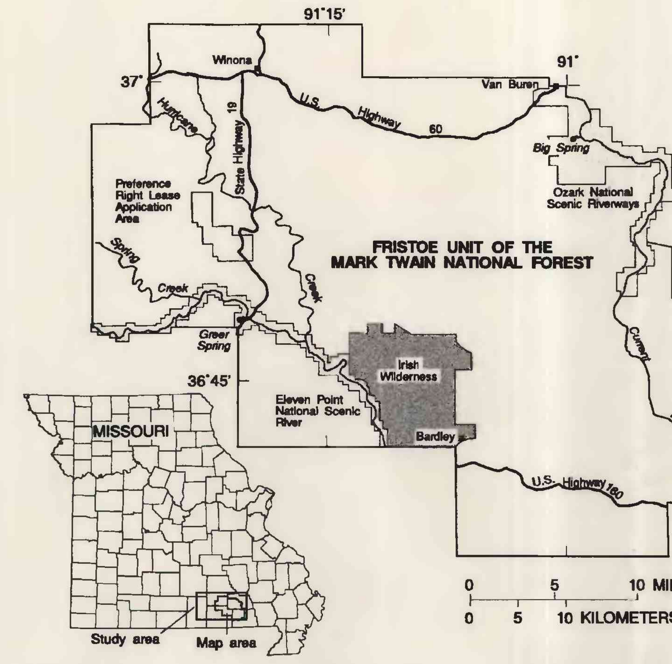


Figure 1. Location of study area and the Fristoe Unit of the Mark Twain National Forest.

INTRODUCTION

A comprehensive investigation of ground-water flow in the Fristoe Unit of the Mark Twain National Forest in southern Missouri was begun in October 1989 by the U.S. Geological Survey (USGS) in cooperation with the Missouri Department of Conservation, because of concerns about planned exploration for lead ore and associated minerals within the forest boundaries. Permission for exploration was granted by the U.S. Forest Service on a 5.9-square-mile Preference Right Lease Application Area (PRLAA; fig. 1) located near State Highway 19 between Spring Creek and Hurricane Creek. The exploration area is located within a larger area of well-developed karst terrane characterized by an extensive network of solution-enlarged fractures ranging from small channels to large conduits. Numerous small springs and several large springs (Vineyard and Feder, 1974) discharge from the carbonate bedrock to supply deeply incised streams. Ground-water flow through the predominately dolomitic bedrock is complex and not well understood. The primary purpose of the investigation is to collect background hydrological, hydrochemical, and biological data in the Fristoe Unit of the Mark Twain National Forest. These data will provide a baseline for comparison with similar data that could be collected during possible mine operations to assess the effect of mining on the natural system (Kleeschulte and Sutley, 1995). This report describes seasonal ground-water-level changes and flow patterns in the Fristoe Unit determined during the first part of the investigation.

ACKNOWLEDGMENTS

Support by the U.S. Department of Agriculture, Forest Service and the U.S. Department of the Interior, Bureau of Land Management is gratefully acknowledged. These agencies provided significant help in the design, coordination, and management of this study.

SEASONAL GROUND-WATER-LEVEL CHANGES (1990-93) AND FLOW PATTERNS

To develop a more complete understanding of the ground-water flow system near the PRLAA and the relation of the flow system to ground-water discharge at springs, recent ground-water-level measurements in domestic and exploration wells and historical dye-trace data were analyzed. Water-level measurements were made in the spring and fall from 1990 through 1993 to assess seasonal variations in ground-water levels and changing flow patterns. Potentiometric-surface maps based on two sets of these water-level measurements are shown in figures 2 and 3. The potentiometric surface for June 1993 (seasonal high-flow conditions) generally shows a pattern of higher water levels in the upland areas between streams and lower water levels in lowland areas along stream valleys, with potentiometric contours trending approximately parallel to the streams (fig. 2). The PRLAA is on an upland area that straddles a ground-water divide separating the Eleven Point River and Spring Creek Basins from the Hurricane Creek Basin. Typically, this pattern indicates ground-water recharge in the upland areas and ground-water discharge in adjacent stream valleys. However, a ground-water trough exists between Hurricane Creek and Big Spring on the Current River. The pattern of the 500- and 600-foot altitude potentiometric-surface contours west of Big Spring (altitude 460 feet) is typical of ground-water discharge to streams, except that no surface stream exists along the axis of the contours. A probable extension of the ground-water discharge pattern is evident at a well near Hurricane Creek east of the PRLAA that has a water-level altitude less than 600 feet. This pattern suggests the presence of a network of subsurface fractures and conduits that extend from Big Spring to Hurricane Creek and forms the primary pathway for movement of ground water to Big Spring. Ground-water flow through such a conduit system from Hurricane Creek to Big Spring is consistent with the fact that the altitude of Hurricane Creek near the upgradient end of the hypothesized conduit system is about 290 feet higher than the altitude of Big Spring.

A much more extensive conduit system than that defined by recent water-level measurements is indicated because dye injected 20 miles west of the mapped subsurface conduit system has been traced to Big Spring (Gann and others, 1976, sheet 2). Although the extent of the Big Spring catchment area has been partially mapped using dye-trace techniques, actual ground-water flow paths cannot be determined by this method. A more dense areal distribution of ground-water-level measurements in wells completed in different bedrock strata will be necessary to more accurately define the system. The successful recovery of dye injected within the catchment area of Big Spring at springs in the Eleven Point River Basin (fig. 2) and small springs in the Current River Basin indicates the presence of different flow systems. Of particular interest are dye injections in the vicinity of the PRLAA that were traced to Huff Spring south of the lease area, indicating the existence of ground-water flow at nearly right angles to the direction of flow to Big Spring.

Ground-water levels in upland areas generally were lower during seasonal low-flow conditions (fig, 3; October 1992) than water levels during seasonal high-flow conditions (fig. 2; June 1993), but the flow patterns are similar. The ground-water trough extending from Big Spring to Hurricane Creek is wider and extends farther upstream in the Hurricane Creek Basin during low-flow conditions than it extended during high-flow conditions. Wells that had the larger water-level variations generally are located in or near the ground-water trough associated with the subsurface conduit system. Water levels in these wells generally varied more than 100 feet, and in at least one case, more than 200 feet. Most wells that had the larger water-level variations are deep wells (more than 1,000-feet deep). The large water-level variations may be the result of the rapid filling of bedrock fractures during rainfall and subsequent rapid drainage of the fractures during periods of decreased or no rainfall. The rapid drainage implies that ground-water flow velocities are large near and in the conduit system that links bedrock fractures to the orifice of Big Spring. The effect of the conduit system is to capture ground water that normally would have discharged as streamflow in the lower reaches of Hurricane Creek.

An example of the typically strong correlation between rainfall, ground-water levels, and discharge from springs in the area from October 1, 1989, to September 30, 1993, is shown in figure 4. Ground-water levels shown are from a continuously monitored 1,650-foot deep well located approximately 2 miles from Greer Spring (fig. 3). Discharge at Greer Spring (altitude 590 feet) ranges from approximately 200 to 800 cubic feet per second, increasing abruptly at the onset of substantial rainfall, and declining at a fairly rapid rate during periods of little or no rainfall. Water-level changes in the well correlate closely with rainfall and discharge at Greer Spring. Thus, increased rainfall in the vicinity of the spring quickly fills fractures in the carbonate bedrock. Because the fractures are hydraulically well connected, a rise in ground-water levels almost immediately increases the pressure head at the spring orifice and consequently increases discharge. The strong correlation with little or no lag time between recharge, ground-water-level changes, and discharge is indicative of a large-permeability bedrock terrane through which ground water can flow with little hydraulic impedance.

The conceptual model of ground-water movement and discharge to springs can be refined by more detailed consideration of the subsurface geology of the Fristoe Unit of the Mark Twain National Forest. A generalized geologic cross section is shown in figure 5. The Eleven Point River, Spring Creek, and Hurricane Creek are incised into the Roubidoux Formation and upper part of the Gasconade Dolomite. Springs associated with these stream basins, such as Greer Spring, discharge from solution openings in the upper part of the Gasconade Dolomite. The Current River is incised into the Eminence Dolomite, and ground-water discharge at Big Spring comes from the lower Eminence Dolomite and probably the underlying, more permeable, Potosi Dolomite. The upper part of the Eminence Dolomite commonly is more massive and contains fewer solution channels than the Potosi Dolomite and may form a weak hydraulic barrier between the overlying Roubidoux Formation and Gasconade Dolomite and the underlying lower Eminence Dolomite and Potosi Dolomite. Measured ground-water levels in the area west of Hurricane Creek and the upland areas north and south of the conduit system for Big Spring primarily reflect water levels in the Roubidoux Formation and Gasconade Dolomite. This is because the Eminence and Potosi Dolomites are more deeply buried west of Hurricane Creek and in upland areas east of Hurricane Creek, and the depth of measured wells generally is shallower than the top of the Eminence Dolomite. Water levels measured in areas east of Hurricane Creek near the conduit system generally reflect levels in the Eminence and Potosi Dolomites because these formations are closer to land surface, and the measured wells generally are deeper. Ground-water recharge in the area west of Hurricane Creek has the potential to move laterally within the Roubidoux Formation and Gasconade Dolomite towards springs (for example, Huff Spring) or streams, or vertically downward into the Eminence and Potosi Dolomites, depending on the strength of the hydraulic barrier at any particular location. Dye-trace studies indicate ground water that recharges the underlying Eminence and Potosi Dolomites flows toward the conduit system that supplies Big Spring. The potentiometric surface that expresses this flow pattern west of Hurricane Creek cannot be mapped with the available data. This conceptual model can explain the measured ground-water levels and the widely divergent flow paths indicated by dye-trace results.

In summary, the PRLAA is located within a larger area of well-developed karst terrane containing numerous solution-enlarged fractures. A northwest-southeast trending ground-water divide directs shallow ground water from the PRLAA through the Roubidoux Formation and Gasconade Dolomite. Water flowing southwest from the ground-water divide moves to the Eleven Point River or smaller springs in the Eleven Point River Basin. Ground-water-level mapping and dye-trace studies indicate that the PRLAA is near the upgradient end of a substantial large-permeability conduit system that supplies water to Big Spring. Ground water that moves northeast from the ground-water divide through the Roubidoux Formation and Gasconade Dolomite or moves vertically downward to the Eminence and Potosi Dolomites may enter the conduit system and be transported to Big Spring. To verify this conceptual model, it would be necessary to measure ground-water levels in selected wells west of Hurricane Creek. These wells would need to be completed in only the Roubidoux Formation and Gasconade Dolomite or in the Eminence and Potosi Dolomites.

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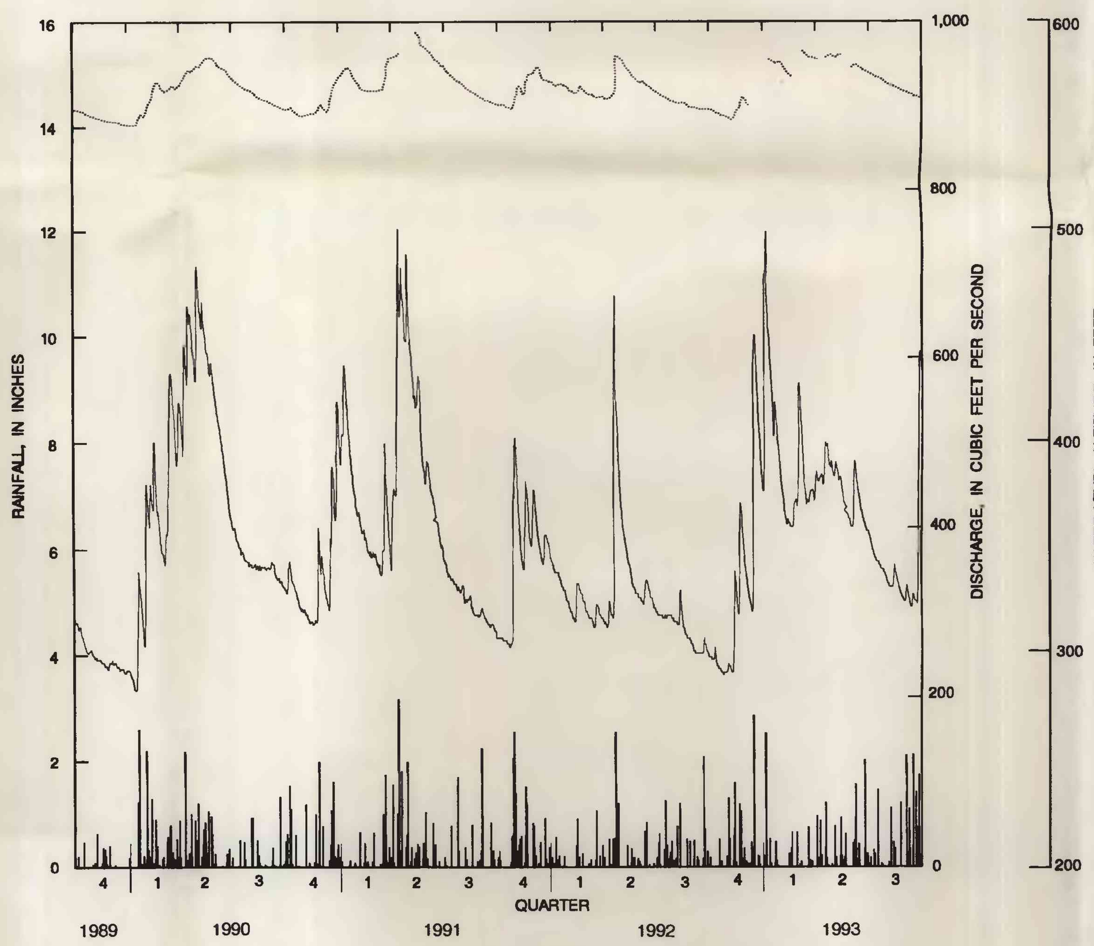

EXPLANATION

GROUND-WATER LEVELS

DISCHARGE FROM GREER SPRING

RAINFALL

Figure 4. Hydrographs of discharge from Greer Spring, ground-water levels in a 1,650-foot deep well near Greer Spring, and rainfall measured at the Chaney rain gage near Birch Tree, about 8 miles west of Winona. Rainfall data from October 1989 through December 1992 are from the U.S. Geological Survey Chaney rain gage near Birch Tree. Monitoring at this gage was discontinued during 1993. The rainfall data for 1993 are from the National Oceanic and Atmospheric Adminstration weather station at Willow Springs, about 50 miles west of Van Buren.

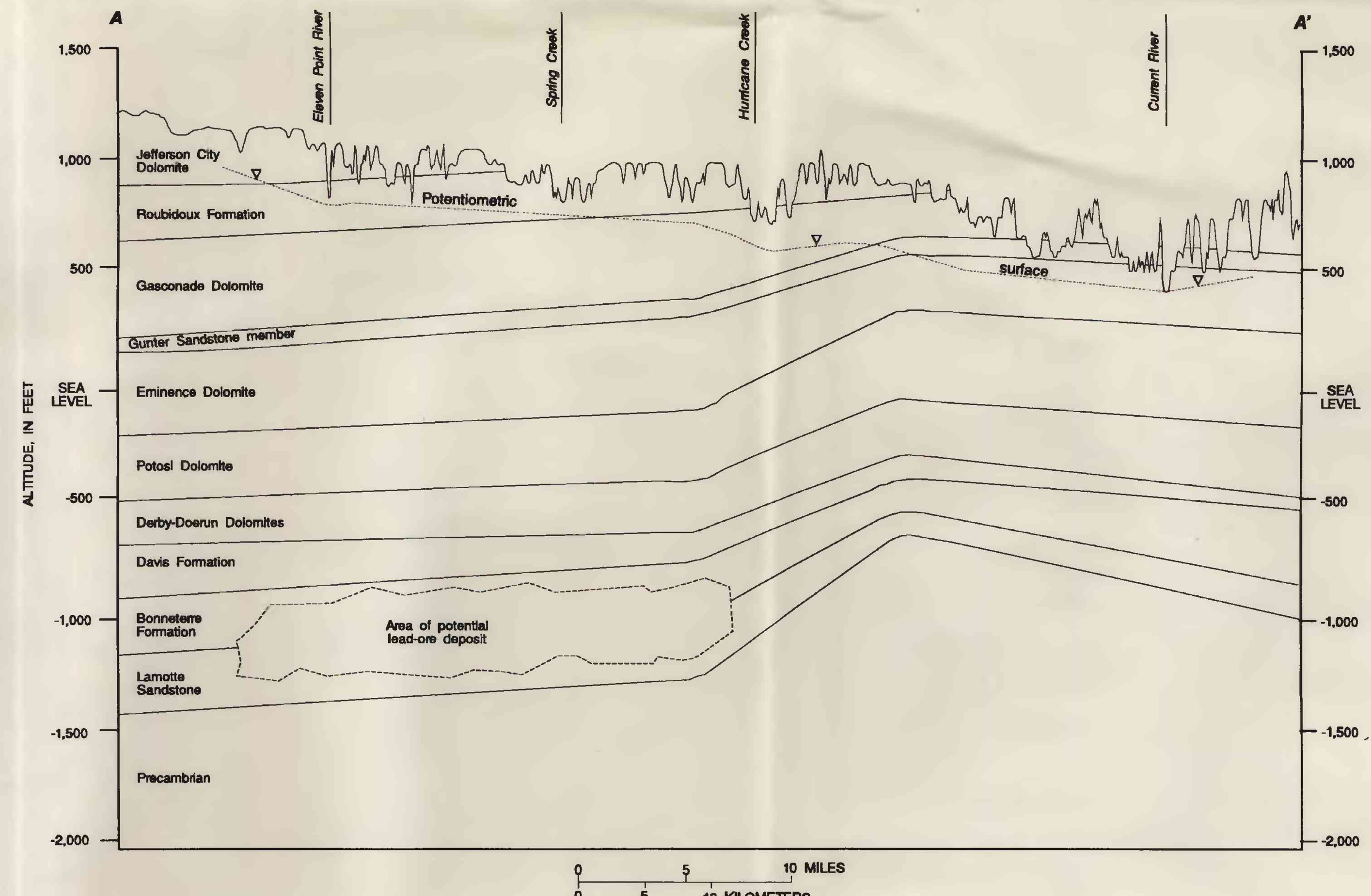

Figure 5. Generalized geologic section (line of section A-A' is shown on figure 3).

SEASONAL GROUND-WATER LEVEL CHANGES (1990-93) AND FLOW PATTERNS IN THE FRISTOE UNIT OF THE MARK TWAIN NATIONAL FOREST, SOUTHERN MISSOURI

By J.L. Imes and M.J. Kleeschulte

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