INTRODUCTION

Purpose and Scope

Prince William Forest Park is in the southern part of Prince William County, Va. Its natural beauty and nearness to Washington, D.C. have made it one of the most popular recreation areas in northern Virginia. In addition to many miles of foot trails, the U.S. National Park Service has provided campgrounds, cabin camps, picnic areas, and a nature museum, all of which require potable water supplies.

To help the Park Service plan the development of new facilities and effectively manage the park's total resources, the U.S. Geological Survey made a hydrologic study of the park from October 1972 to November 1975. The overall objective of the Survey's study was to evaluate the quantity and quality of the water resources. Available information was compiled and analyzed, and new data on streamflow, ground-water levels, and the chemical and biological quality of water were collected. Test wells were drilled, and aquifer tests were made at well sites to evaluate the occurrence and availability of ground water in the park.

Acknowledgments

This study was made by the Geological Survey in cooperation with the National Park Service. The cooperation and help of Park Service personnel at Prince William Forest Park are deeply appreciated. E. H. Nuckels and E. M. Miller, the author's colleagues at the Geological Survey, contributed significantly to the surface-water section of the report.

DESCRIPTION OF THE AREA

Location and Extent of the Area

Prince William Forest Park is about 30 miles southwest of Washington, D.C., and 20 miles north of Fredericksburg, Va. (figs. 1 and 2). The park includes 17,348 acres. The main part, about 13,000 acres, is bounded on the east by Interstate 95, on the south and west by State Highway 619, and on the north by State Highway 234. The remainder is an isolated area south of State Highway 619 on the north side of Chopawamsic Creek and Breckenridge Reservoir.

Surface Features and Drainage

The land surface is generally a southeastward-sloping plain well dissected by streams. Quantico Creek and South Fork Quantico Creek are the major streams. The park lies entirely within the Quantico Creek basin except for two small areas, one of which drains to Little Creek and the other to Chopawamsic Creek. Narrow ridgetops are separated by relatively steep-walled valleys. Near Quantico and South Fork Quantico Creeks (fig. 2), the tributaries are in deep, steep-sided valleys, but near the headwaters, the valleys are wide, shallow, and have gentle slopes. Little of the land in the park is flat except along ridgetops and along the flood plains of the Quantico Creeks. Total relief is 364 feet, from the highest point northwest of Oak Ridge Campground, at an altitude of 394 feet, to the lowest points in the bed of Quantico Creek near Interstate 95, which are about 30 feet above sea level.

Climate

Precipitation is well distributed throughout the year (fig. 3); however, August is generally the wettest month and February the driest. Heavy rains that cause flooding sometimes accompany tropical storms. During 1941-70, average annual precipitation at the Marine Corps Air Station at Quantico (about 5 miles southeast of the park) was 36.49 inches and the average annual temperature was 56.5°F (13.6°C).

Geologic Setting

Prince William Forest Park straddles the Fall Line, which is the boundary between the Piedmont province to the west and the Coastal Plain province to the east. The cross-section A-A'(fig. 4) shows the relation between the various geologic units. The western three-fourths lies in the Piedmont and is underlain by nearly vertically standing gneiss, schist, and phyllite beds of late Precambrian to early Paleozoic age. To the east, the bedrock is younger and consists of schist and greenstone of early Paleozoic age. Along the eastern boundary, the Quantico Formation of Late Ordovician age, crops out along Quantico Creek. Much younger Coastal Plain sediments, consisting of clay, sand, and gravel, unconformably overlie these metamorphosed rocks in the eastern third of the park (fig. 2). These sediments are part of the Potomac Group of Early Cretaceous age. The sediments are present on the tops of ridges and hills, are thickest to the east, and pinch out westward. The Coastal Plain sediments are 125 feet thick at well 52S30.

According to Southwick, Reed, and Mixon (1971), the park lies on the northwest limb of the Quantico syncline. Bedding in the metamorphic rocks strikes N.25°-35°E; dips generally are vertical but range from 30°NW to 55°SE (Mixon, Southwick, and Reed, 1972). The rocks have a strong plane of schistosity or foliation that is parallel or nearly parallel to the bedding. A prominent joint set strikes northwest. The planes of schistosity and jointing have a strong influence on the topography and thus on the course of streams.

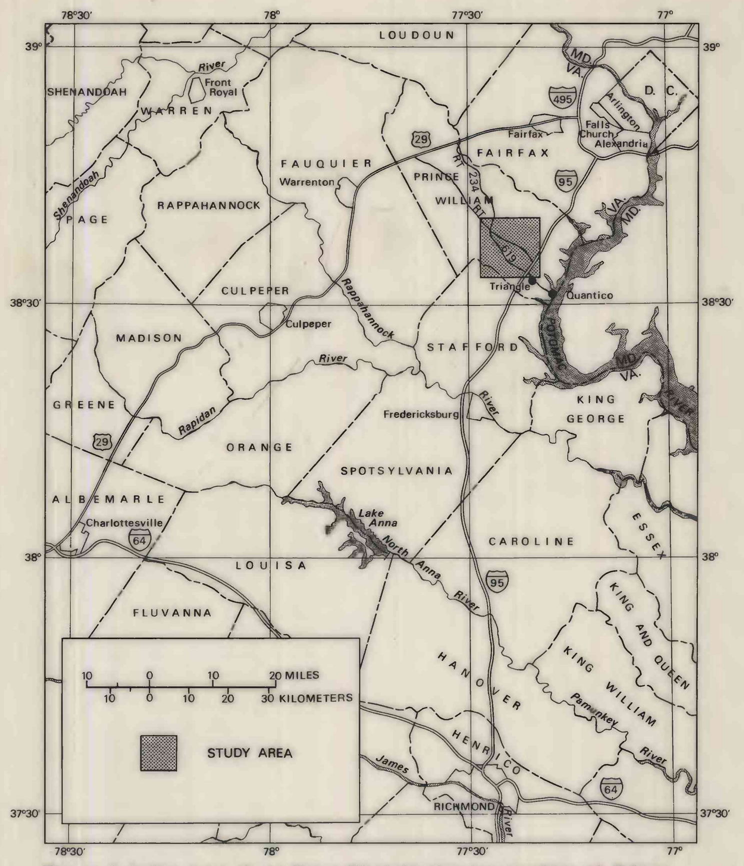

Figure 1. Index map of northern Virginia showing location of Prince William Forest Park.

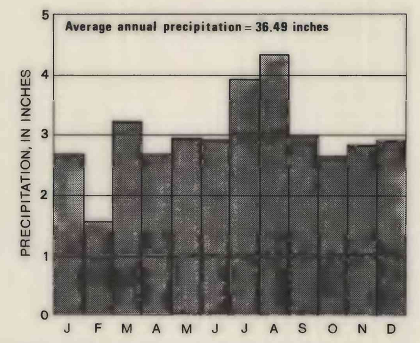

Figure 3. Average monthly precipitation at Quantico, 1941-70.

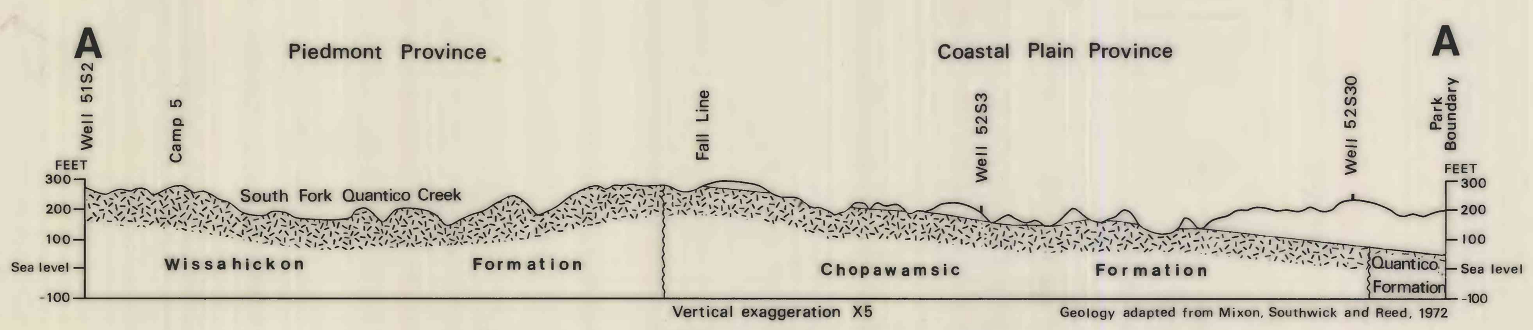

Figure 4. Cross-section A-A' of Prince William Forest Park.

PRESENT WATER SUPPLY

The recreational and service facilities are scattered throughout the park, and each area or cluster of buildings has a separate water supply. In 1976, 8 operating systems were supplied by 3 springs and 12 drilled wells; the wells range in depth from 102 to 343 feet. The locations of the wells, springs, and water storage tanks are shown in figure 2.

Water Use

The amount of water used is related to the number of visitors. The number of visitors increased from 24,000 in 1952 to 176,000 in 1961, 425,000 in 1971, and 503,000 in 1975. Because the water systems are not metered, estimates of water use were derived from detailed visitation figures kept since 1971. The graph in figure 5 shows monthly variations in both the number of park visitors and estimated water use. The graph for water use includes water used by residents and employees of the park.

A comparison was made between the yields of the wells and springs used for the respective water systems and anticipated future water needs. Assuming an amount for future need in each area that was 30 percent greater than the highest monthly water use for each area from 1971 to 1975, it was found that the present (1976) system of wells and springs should be able to accomodate such needs. Even if two-thirds of the total water demand occurred on weekend days, as it generally does, the water systems should be adequate. Larger storage facilities in high-use areas would reduce the short-term load on the supply wells and springs at time of peak demand.

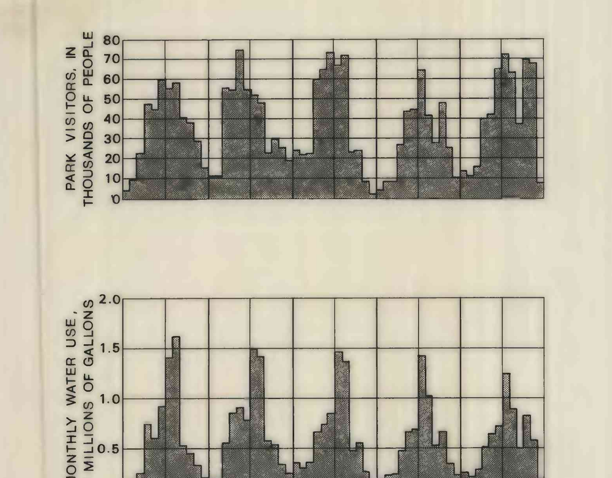

Figure 5. Graph showing monthly totals of visitors to the park and estimated monthly total water use in the park.

GROUND WATER RESOURCES

In general, the most favorable areas for developing ground-water supplies are where large water-filled fractures in the rock are overlain by a thick water-saturated weathered zone, Coastal Plain sediments, or both. A thick, well-developed soil zone at the surface helps to retard runoff and capture precipitation that eventually becomes part of the ground-water body. Soil and weathered bedrock zones are generally thickest on gentle slopes, valley floors, and broad, flat upland surfaces that have no rock outcrops. However, weathered zones overlying the bedrock are generally less than 50 feet thick and locally only a few feet thick. Rock outcrops are common. Coastal Plain sediments are thickest, as thick as 130 feet, in high areas in the easternmost part of the park.

Topography is an important factor to consider in locating ground-water supplies in the Piedmont part. Hilltops are generally poor sites because the weathered bedrock zone tends to be thin, the water table deep, and rock fractures few. Yet, for convenient access, most park facilities have been situated on hills or along ridgetops. Broad valleys underlain by thick sections of weathered material or alluvium are good locations; however, few such sites are present in Prince William Forest Park.

Well Yields

Reported yields of wells range from "dry" to 40 gal/min (gallons per minute), as shown in figure 2. Wells in the Coastal Plain generally have the highest yields, averaging 18 gal/min. Those in the Piedmont average 7 gal/min. Drilling records indicate that the wells in the Coastal Plain tap weathered or fractured zones in the underlying metamorphic rocks rather than the sediments themselves. Although the sediments contain appreciable amounts of sand and some gravel, the coarse layers are not extensive and contain much silt and clay. Such fine-grained material reduces permeability and transmissivity and, consequently, yields of wells. The sediments are, however, excellent aids to recharge; they store precipitation and release it slowly to the underlying weathered and fractured zones in the bedrock. Therefore, wells drilled in the Coastal Plain and cased through the sediments but left open in the weathered and fractured zones of the bedrock are much more likely to have high yields than wells in the Piedmont. The topographic location of a well in the Coastal Plain is not as critical as it is in the Piedmont.

Springs

Springs and seeps are common throughout the park. They form the headwaters of many small streams and commonly discharge at the contact between weathered and unweathered rock or between a sand layer and an underlying clay layer. Some of the larger springs and their flows are shown in figure 2. Three of the springs (51SS1, 51SS2, 52SS1) are used for water supplies.

Yields of the springs are generally 5 gal/min or less; however, the combined discharge of springs 51SS1 and 51SS2 at Camp 2 was 31 gal/min on June 8, 1973. Springs that are now unused could probably be developed individually or in combination to provide additional water supplies. The yield of springs varies seasonally--generally greatest from April to June, when ground-water levels are highest, and lowest in October. Some springs may be dry during part of the year, especially in late summer and fall.

Observation Wells

Water-level fluctuations in three of the seven wells utilized for observation during this study are shown along with monthly precipitation at Quantico in figure 6. A recorder was installed on well 52S16 to give a continuous record of the water level. Water-level measurements were made every 4 to 6 weeks in the other wells. Ground-water levels generally reach a maximum in April and a minimum in October. Changes observed in the seven wells seem to be primarily seasonal, reflecting changes in precipitation and evapotranspiration.

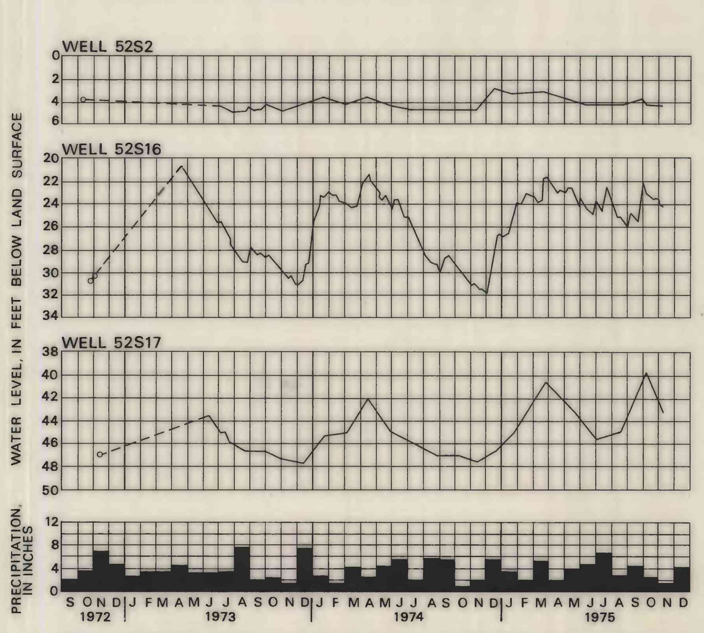

Figure 6. Graph showing water levels in observation wells in Prince William Forest Park and precipitation at Quantico.

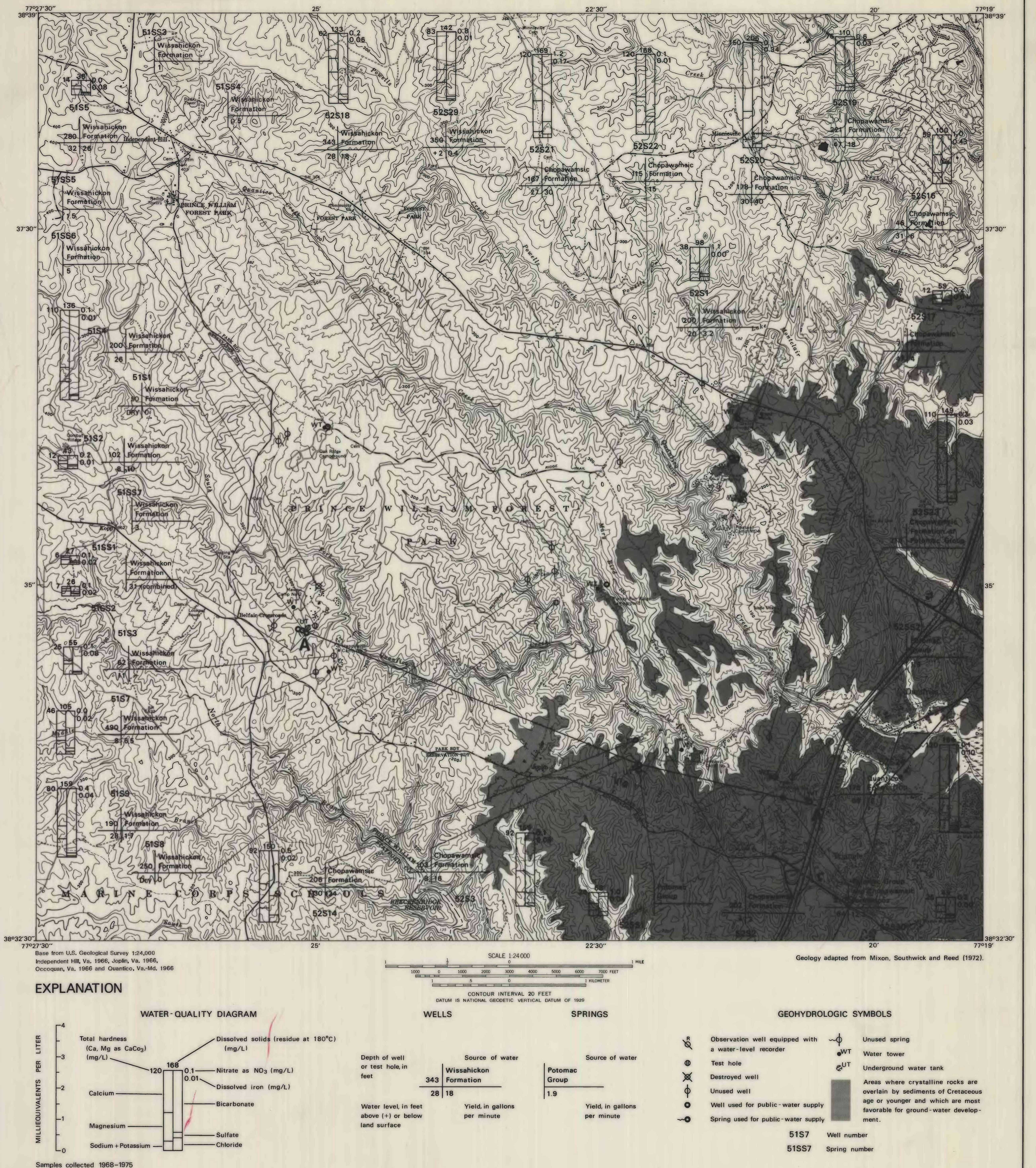

Figure 2. Map of Prince William Forest Park showing well and spring data, chemical analyses of ground-water, areas most favorable for ground-water development, and location of cross-section A-A'.

Test Drilling

Five test wells were drilled. Wells 51S7, 51S9, and 52S9, drilled in the Piedmont, were cased to the top of bedrock, left open in rock, and used as observation wells. Well 52S30 in the Coastal Plain was cased, screened, and eventually put into service as a public supply well. The fifth well (51S8) was backfilled because of poor yield. Wells 51S7 and 52S30 yielded enough water to permit the running of 24-hour constant-rate yield tests. Pertinent data for the test wells are included in figure 2.

Test drilling in the Piedmont part confirmed the hypothesis that water is found primarily in fractures in the rock, some of which are lined with calcite, and in fractured veins and lenses of quartz. Saprolite, the soft, clayey, weathered zone on top of hard bedrock did not yield appreciable amounts of water to the test wells.

Well 52S30 was drilled near the top of a hill south of Park Headquarters to determine the thickness and water-bearing potential of the Coastal Plain sediments that overlie bedrock in this part. Saprolite was reached at a depth of about 125 feet and schist at about 145 feet. Before further drilling, screens were installed opposite two water-bearing sandbeds. The yield of the well at this time was 1 to 2 gal/min. During further drilling in the rock to a depth of 310 feet, a calcite layer and a fracture zone were found, which increased the yield of the well to about 12 gal/min. Such data indicate that the sand layers in the Coastal Plain sediments may be too silty to have high permeabilities or to yield large amounts of water to wells. However, they are permeable enough to serve as good sources of recharge to the fracture systems in the underlying bedrock.

Quality of Ground Water

From 1968 to 1975, water samples were collected from wells and springs that furnish the park water supply, from unused wells, and from the test wells drilled as part of this study. Analyses of these samples are shown graphically in figure 2. The length of the bars on the graphs indicates concentration of major constituents in milliequivalents per liter. Relative percentages of the constituents can be seen by comparing lengths of the individual bars.

The ground water has a low concentration of dissolved solids and is of excellent quality. Hardness of water samples from Piedmont rocks ranged from 6 to 62 mg/L (milligrams per liter), whereas hardness in the Coastal Plain samples was 73 to 150 mg/L. The Piedmont wells and springs had dissolved-solids concentrations that ranged from 26 to 133 mg/L; specific conductance averaged 150 micromhos. In the Coastal Plain samples, dissolved-solids concentrations ranged from 110 to 206 mg/L, and specific conductance averaged 218 micromhos.

WATER RESOURCES OF PRINCE WILLIAM FOREST PARK, VIRGINIA

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