GROUND-WATER RESOURCES

Ground water in the Great Smoky Mountains National Park comes from rain and snow. A part of the precipitation, even on the steepest mountain slopes, seeps into the ground. Water absorbed by the ground moves down to the water table and then moves downslope through a complex system of openings in the rocks underlying the park and eventually discharges to streams through springs and seeps. The movement of ground water toward the discharge points is continuous, but slow. Therefore, there is always a reservoir of ground water available for man's use, even during prolonged droughts. This reservoir can be tapped by either dug or drilled wells.

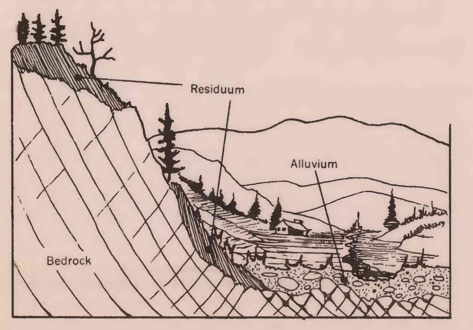
The rate and amount of water that wells will yield depend on the number, size, and interconnection of the openings in the rocks. These factors differ tremendously from place to place in the park. The result is that yields of wells located only a few hundred feet apart may differ considerably. Two wells at Little Greenbrier (site no. 18) are a good example. One well has an estimated yield of 2 gpm (gallons per minute). The second well, only 600 feet away, has a yield of 125 gpm.

The abundance of water-filled openings in the rock depends partly on the type and nature of the rock. In general, the highly favorable areas for developing ground-water supplies (see ground-water availability map) are where large, water-filled fractures in the bedrock are connected with thick, water-saturated weathered material. The least favorable areas for developing ground-water supplies are where a few, small, widely spaced fractures in the bedrock are connected to thin, relatively dry weathered material. The moderately favorable areas for developing ground-water supplies have conditions that are between these two extremes.

GROUND-WATER BEARING MATERIALS

For the purposes of this report, the rock materials of the park can be divided into two broad types, weathered material and bedrock. Each type has its particular influence on ground water in the area. The weathered material forms a nearly continuous cover over the bedrock, and is derived from the bedrock during the process of weathering. Weathering gradually reduces the bedrock to smaller and smaller particles and alters some of the minerals to clays.

The particles comprising the weathered materials range in size from clay to sand, but these materials also contain scattered blocks of unweathered rock, some of boulder size. These deposits are usually ungraded; that is, the particle sizes are intermixed rather than being in layers composed of different size particles such as gravel, sand, or clay. Figure 1 illustrates the kind and location of weathered materials.



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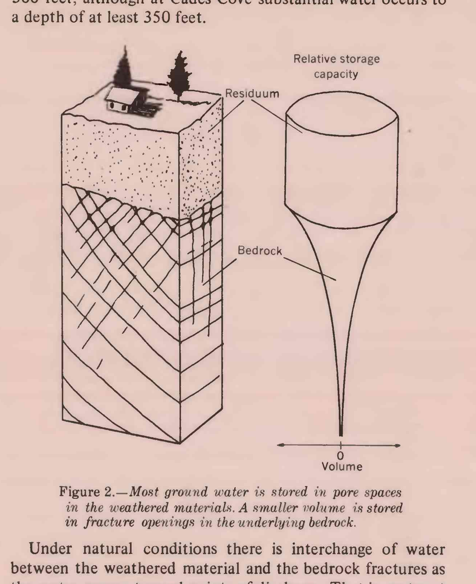

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... facilities are located in narrow valleys and some are in high areas near ridgetops. The potential for developing large yields is greater in broad valley floors or on gentle valley slopes; it is least in the areas along and near ridgetops. If a water supply must be obtained for a high area, selecting a well location in a nearby draw should improve chances for obtaining a useable yield. In any location, it may be necessary to drill more than one well before a useable yield can be obtained.

There is no direct way to determine thickness of the weathered material other than by drilling; yet, where no bedrock outcrops are present in the general area of the site the saturated thickness of these materials generally is sufficient. Weathered materials generally are thick along gentle valley slopes, on valley floors, and on some ridgetop locations, but the water-yielding potential of thick deposits of weathered materials on ridgetops is counteracted by the greater depth to water and the fact that the saturated zone in the weathered material is generally only a few feet thick. Steeper, hillside locations are least likely to be covered by thick, extensive deposits of weathered material.

PERFORMANCE OF WELLS

Ground-water supplies in the Great Smoky Mountains may be developed either from large-diameter wells excavated in the weathered material or from wells drilled into the bedrock. Bedrock wells generally are more trouble-free and less subject to pollution, and for these reasons, the remainder of this discussion will be devoted to wells drilled into bedrock. The wells in the park are 6 to 8 inches in diameter, and cased to bedrock. The space around between the drill hole and the casing is grouted with cement to a depth sufficient to prevent inflow of surface runoff, generally 10 feet from the surface, and the wells are finished as open holes, most of which are less than 200 feet deep.

When a well is pumped, the water level in the well drops, and water enters the well from the fractures penetrated by the well. The water discharging from the fractures is replaced by water percolating or flowing to them from the weathered material. Thus, pumping a well changes the natural gradient of the water table near the well and establishes a new, steeper gradient toward the well from all directions.

The rate at which water can be pumped from a well depends on (1) the number and size of the fractures penetrated by the well, (2) the extent of interconnection between fractures near the well, (3) the extent of connection between the fractures and the weathered material, and (4) the depth below the water table of the fractures penetrated by the well. On the other hand, the total amount of water that can be pumped from a well between periods of recharge depends only on the water-storage capacity of the fractures and weathered material near the well. Most of the capacity for water storage is in the weathered material, so that the capacity for pumpage from a well depends mostly on the saturated thickness of the weathered material near the well.

The combination of maximum well yield (in gallons per minute) and capacity for pumpage between periods of recharge (in gallons) determines well performance. The manner in which the various factors described above affect the performance of two wells is shown in figure 3. Well *A* penetrates a thick layer of saturated weathered material, then penetrates several fractures that are highly interconnected with each other and with the overlying weathered material.

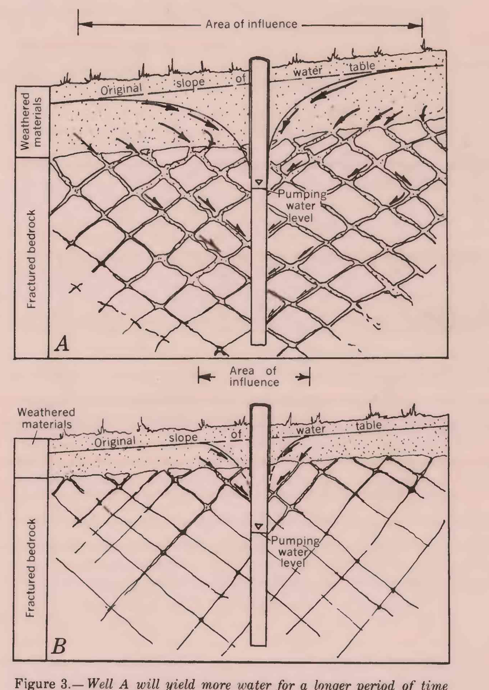

Figure 3.—*Well A will yield more water for a longer period of time than well B, because well A penetrates a more extensively developed fracture system overlain by thick, saturated weathered material.*

Some of these fractures are deep and have been enlarged by weathering. The performance of this well is good; well yield is relatively high and pumping can remove water from storage in the thick weathered material over a broad area. Well *B* penetrates a thin layer of saturated weathered material and a few, poorly developed, shallow fractures. The performance of this well is poor; well yield is substantially less than well *A* and the smaller area influenced by pumping contains considerably less water in storage.

Twenty six pumping tests of three types were made on wells in the Great Smokies National Park. A few tests were made at constant discharge for the duration of the test, but most tests were of the "step-drawdown" type in which the well was pumped at two or more discharge rates. The third type of test was a variation of the step-drawdown type in which the well was pumped at several levels of discharge, except that the water level was allowed to recover to the pre-pumping, or static, water level after each interval of pumping. The Smokemont well no. 3 (site no. 26) and Deep Creek well (site no. 13) were tested in this manner. Partial results of the pumping tests are listed in table 1. Examples of the three types of tests (fig. 4) show that the water level in the pumped well declines until the quantity of water moving toward the well balances the quantity being pumped. After this, the pumping water level is stable, unless the pumping rate is changed. After pumping stops, water levels recover to near the static (original) position. Water levels in most wells in the park are stable within 2 hours after pumping starts and they recover to within a few feet of the original water level within a few minutes after pumping stops.

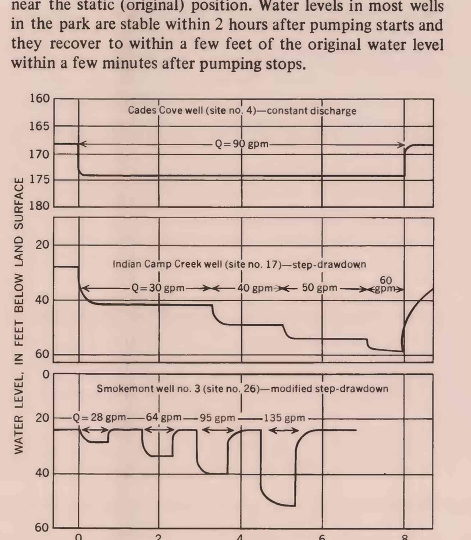

Figure 4.—*Three types of pumping tests were run on wells.*

Specific capacity (pumping rate of a well divided by the drawdown of water level) is a basis for comparing the productivity of the fractures penetrated by different wells. Use of step-drawdown pumping tests allows calculation of changes in specific capacity with different pumping rates. Specific capacities at maximum discharge of wells in the park range between 0.04 gpm per ft (gallons per minute per foot of drawdown) at Green Mountain (site no. 16, well no. 1) and 13.8 at Cades Cove (site no. 4), as shown in figure 5.

Figure 5.—*A frequency plot indicates that half the wells have specific capacities of 0.6 gpm per ft or greater at maximum pumping rates.*

Maximum discharge as used here refers to maximum pumping rate; in many cases, this represents maximum capacity of the pump, not of the well. The median specific capacity for the tested wells is 0.6 gpm per ft. Changes in specific capacity with pumping rate are shown in figure 6.

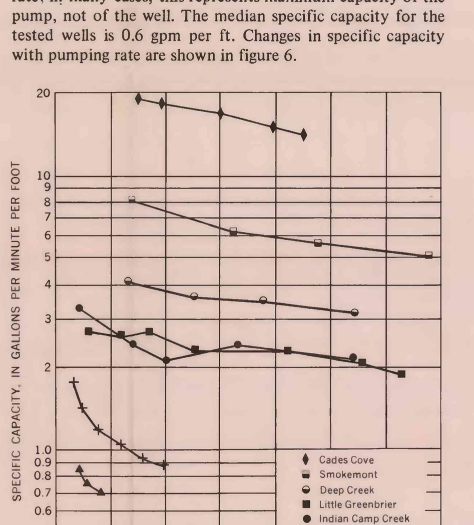

Figure 6.—*Change in specific capacity with discharge is variable from well to well.*

Yields of wells drilled in Great Smokies National Park range from less than 1 gpm to as much as 135 gpm (fig. 7). The median yield is about 35 gpm, and about 1 well of 6 yields 100 gpm or more (fig. 7).

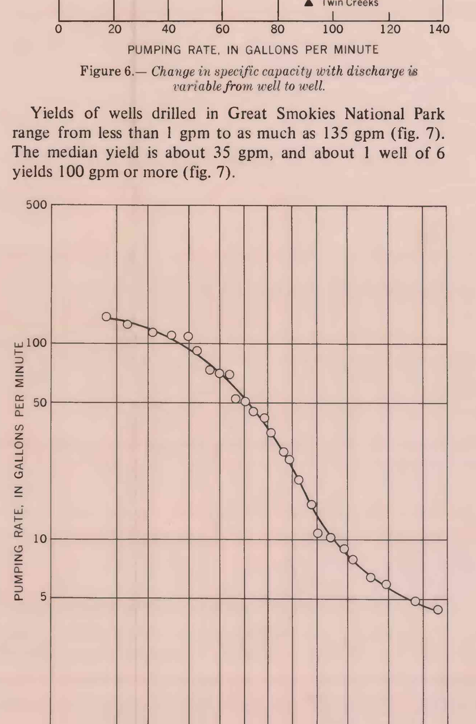

Figure 7.—*A frequency plot of maximum pumping rates for the 26 pumped wells indicates that half the wells yield 35 gpm or more.*

WATER QUALITY

CHEMICAL QUALITY

The dissolved-solids content of both ground water and surface water is low because the rocks of the Great Smoky Mountains are made up almost entirely of minerals of low solubility, except the carbonate rocks that underlie isolated areas such as Cades Cove. However, ground water is generally somewhat higher in dissolved solids than surface water. On the average, total dissolved solids in ground water is about 50 mg/l (milligrams per liter) and in surface water during periods of low flow, about 20 mg/l. Water in the Park is acidic nearly everywhere; the pH of ground water averages 6.4, and pH of the surface water averages 5.9 for the samples analyzed. A comparison of average ground-water and surface-water quality is shown on figure 8. Complete results of analyses of 23 ground-water samples and 18 surface-water samples are listed in tables 2 and 3.

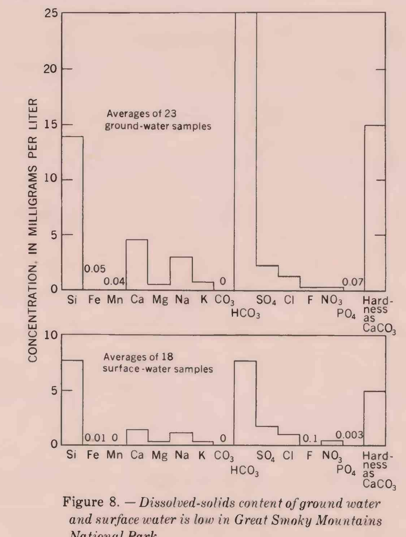

Figure 8.—*Dissolved-solids content of ground water and surface water is low in Great Smoky Mountains National Park.*

BIOLOGICAL QUALITY

Water samples were collected from several streams for analysis of coliform bacteria content in July 1968. Results of analyses of 52 samples show that coliform bacteria were present at nearly all sampling sites but generally in low concentrations (table 4); there was little or no relation as to whether or not park facilities were upstream from the sampling site.

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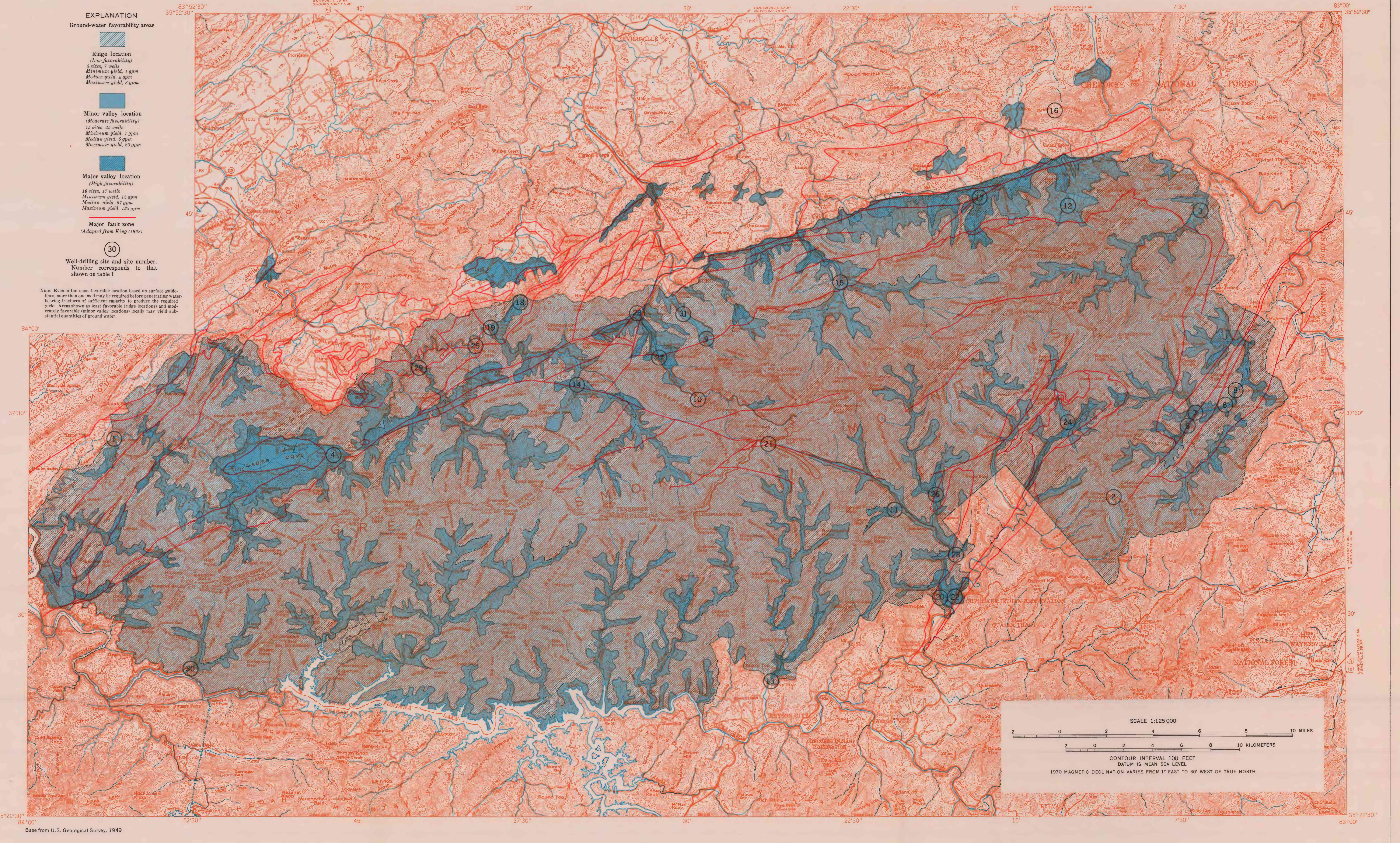

GROUND-WATER AVAILABILITY MAP

Table 1.—*Results of test drilling and pumping*

(Location of each site is shown on ground-water availability map.)

Site No.	Site name and well number[a]	Depth of well (ft)	Thickness of weathered material (ft)	Maximum pumping rate (gpm)	Draw-down (ft)	Specific capacity at maximum pumping rate (gpm per ft)	Water level before pumping, (ft below land surface)	Type of rock penetrated by well
1	Abrams Creek	185	10	6	34	0.18	5	Phyllite.
2	Balsam Mountain No. 1	150	1	8	17	.47	3	Sandstone.
	No. 2	200		b<1				Do.
3	Big Creek	151	19	b2				Sandstone.
4	Cades Cove	350	110	90	6.5	13.8	168	Phyllite, weathered.
5	Cataloochee	165	27	35	60	.58	9	Phyllite, schist.
6	Cataloochee Maintenance	188	10	25	60	.41	4	Sandstone, phyllite.
7	Cataloochee New Area	184	73	67	67	1.00	6	Do.
8	Cataloochee Residential Area	152	20	40	110	.36	7	Do.
9	Cherokee Orchard	87	65	10	7.5	1.33	52	Do.
10	Chimneys Campground No. 1	45	6	b<1				Sandstone.
	No. 2	105	44	b5				Do.
	No. 3	212	24	6.5	110+	.06	45	Do.
11	Collins Creek Picnic Area	148	60	70	56	1.25	21	Gneiss.
12	Cosby Creek Campground No. 1	188	30	15		.30	15	Sandstone, phyllite.
	No. 2	196	80	b13				Do.
13	Deep Creek Campground	125	23	108	34	3.18	7	Quartzite.
14	Elkmont Campground No. 1	220	27	b8				Sandstone, phyllite.
	No. 2	160	54	b12				Do.
	No. 3	215	30	50	55	.91	27	Do.
15	Greenbrier Campground No. 1	98	30	b8				Siltstone, phyllite.
	No. 2	97	35	b6				Do.
16	Green Mountain No. 1	202	18	5	115	.04	40	Sandstone.
	No. 2	140	14	b<1				Do.
	No. 3	125	24	4	43	.09	49	Do.
	No. 4	130	20	b<1				Do.
17	Indian Camp Creek	194	38	108	50	2.16	30	Phyllite, weathered.
18	Little Greenbrier No. 1	100	24	b2				Do.
	No. 2	125	22	125	60	2.08	14	Do.
19	Metcalf Bottoms No. 1	150	30	10	20	.50	13	Phyllite.
	No. 2	242	20	b5				Do.
	No. 3	200	12	b4				Do.
20	Main Oconoluftee Area	150	46	45	45	1.00	4	Sandstone, phyllite.
21	Newfound Gap	225	24	4.5	45	.10	37	Phyllite, sandstone.
22	Old Oconoluftee Area No. 1	120	?	b<1				Clay, sand.
	No. 2	100	?	b<1				Do.
23	Park Headquarters	125	15	72	31	2.32	9	Phyllite, weathered.
24	Round Bottom	99	18	110	27	4.07	10	Gneiss, granite.
25	Sinks	125	18	b5				Phyllite, sandstone.
26	Smokemont Campground No. 1	85	22	b13				Quartzite.
	No. 2	100	25	b<5				Do.
	No. 3	150	23	135	26	5.19	14	Do.
27	Sugarlands	120	20	50	50	1.00	7	Phyllite.
28	Towstring	148	30	28	123	.23	+2	Gneiss.
29	Tremont	130	14	10	40	.25	12	Phyllite.
30	Twentymile	186	15	b4				Sandstone.
31	Twin Creeks No. 1	165	60	b<5				Siltstone, weathered.
	No. 2	120	55	b2				Do.
	No. 3	150	44	20	35	.57	27	Do.

[a]Wells numbered if more than one well was drilled at site.
[b]Estimated yield. No pumping test data available.

Table 2.—*Results of chemical analyses of ground-water samples*

(Concentrations in milligrams per liter; specific conductance in micromhos at 25°C. Fe and Mn in solution when analyzed. Analyses by U.S. Geological Survey.)

Site No.	Site name	Date of collection	SiO_2	Al	Fe	Mn	Ca	Mg	Na	K	CO_3	HCO_3	SO_4	Cl	F	NO_3	PO_4	Dissolved solids-residue	Ca–Mg hardness Total	Non-carbonate	Specific conductance	pH	Temperature °C	°F
2	Balsam Mountain	8–9–68	7	1.3	0.09	0.01	2.4	0.3	1.0	0.4	0	10	0.2	0.6	0.1	0.2	0.10	28	7	0	21	5.5	9	49
5	Cataloochee (No. 1)	6–28–67	13	.1	.16	.02	4.6	.3	7.9	1.0	0	26	1.6	6.5	.6	.1	.00	49	14	0	65	6.1		
6	Cataloochee Maintenance (No. 2)	12–13–68	16	.2	.10	.01	8.0	.6	6.2	.8	0	43	2.6	.6	.2	.2	.09	58	22	0	66	6.6		
7	Cataloochee New Area (No. 3)	12–11–68	18	.0	.04	.01	10	.5	2.6	.8	0	42	1.2	.5	.2	.2	.29	59	27	0	65	6.8	12	54
8	Cataloochee Residential Area (No. 4)	12–17–68	17	.0	.08	.01	7.2	.8	4.4	.6	0	38	1.2	.8	.1	.3	.10	54	22	0	60	6.6	12	54
9	Cherokee Orchard	12–18–68	7	.1	.04	.02	1.0	.3	.9	.3	0	6	.4	.5	.1	.6	.01	14	4	0	14	5.5	12	54
11	Collins Creek Picnic Area	6–15–67	12	.1	.08	.01	1.8	.5	1.9	.9	0	13	1.6	.7	.1	.1	.06	25	8	0	25	6.0	13	56
13	Deep Creek Campground	6–15–66	21	.0	.01	.01	4.8	1.7	3.0	1.2	0	30	1.0	1.1	.2	.1	.15	46	19	0	51	6.5	13	56
14	Elkmont Campground	10–16–67	15	.1	.00	.01	6.9	.5	3.9	1.0	0	31	2.2	1.9	.2	.1	.02	44	20	0	56	6.3	13	56
16	Green Mountain	8–8–67	13	.0	.02	.01	1.1	.1	.1	2.6		8	1.0	1.2	.0	.1	.01	23	3	0	16	5.8	15	59
17	Indian Camp Creek	10–13–67	13	.1	.02	.00	3.0	.8	2.0	.4	0	17	.4	.6	.1	.1	.00	27	11	0	29	5.8	13	56
18	Little Greenbrier	5–24–68	20	.1	.10	.01	3.0	1.6	4.6	.3	0	29	1.8	.3	.1	.1	.26	46	14	0	45	6.4	14	58
19	Metcalf Bottoms	3–3–67	10		.02	.00	4.6	1.1	3.3	.4	0	26	2.6	1.9	.0	.0		32	16	0	59	6.9	14	58
20	Main Oconoluftee Area	8–8–68	22	.0	.09	.01	3.7	.5	4.0	1.0	0	22	2.0	.6	.1	.1	.31	48	11	0	40	6.5	13	56
21	Newfound Gap	2–14–69	12	.1	.52	.18	16	4.3	2.2	1.2	0	60	13	1.6	.1	.4	.01	75	57	8	119	7.8	11	52
23	Park Headquarters	1–3–66	20		.03	.00	6.1	.2	4.8	.0	0	32	2.2	.4	.2	.0		45	16	0	53	6.7	13	56
24	Round Bottom	6–29–67	14	.0	.02	.02	4.2	.1	2.9	.6		19	2.8	.9	.1	.1	.00	34	11	0	38	6.2	11	52
26	Smokemont Campground	8–7–68	13	.1	.10	.01	2.9	.3	2.4	.8	0	14	1.6	.5	.1	.1	.15	33	8	0	27	6.0	12	54
27	Sugarlands	2–12–69	19	.0	.01	.01	4.5	1.6	4.1	.6	0	30	1.2	1.0	.0	.2	.02	49	18	0	50	7.4	13	56
28	Towstring	6–27–67	17	.0	.05	.01	14	.3	4.4	1.3	0	47	7.2	1.0	.4	.1	.00	70	37	0	97	7.9	11	52
29	Tremont	10–17–67	17	.1	.00	.00	18	1.8	3.4	1.0	0	60	10	1.6	.2	.1	.00	77	54	4	113	7.1	14	58
30	Twenty mile	4–24–69	16	2.1	1.9	.06	13	1.1	3.2	2.8		52	8.0	1.8	.1	.4	.01	76	39	0	97	7.7		
31	Twin Creeks	5–21–68	16	.1	.17	.00	2.5	.6	3.8	.4	0	21	.2	1.5	.1	.1	.06	38	8	0	35	6.2	13	56

Table 3.—*Results of chemical analyses of surface-water samples collected September 24–25, 1968*

(Concentrations in milligrams per liter; specific conductance in micromhos at 25°C. Fe and Mn in solution when analyzed. Analyses by U.S. Geological Survey.)

Station No.	Station name	SiO_2	Fe	Ca	Mg	Na	K	CO_3	HCO_3	SO_4	Cl	F	NO_3	PO_4	Dissolved solids-residue	Ca-Mg hardness Total	Non-carbonate	Specific conductance	pH	Temperature °C	°F
4611.8	Cosby Creek	7.3	0.01	1.3	0.5	1.3	0.2	0	5	1.8	0.8	0.0	0.3	0.00	22	5	1	18	5.6	14	58
4691	Little Pigeon River	7.9	.01	1.2	.5	.9	.3	0	6	2.2	.7	.1	.3	.00	24	5	0	17	5.5	19	66
4692.3	West Prong Little Pigeon River	4.0	.00	1.6	.7	.6	.2	0	3	3.2	1.0	.1	1.4	.00	21	7	4	20	5.8	14	58
4692.9	Dudley Creek	13	.02	2.0	.6	2.2	.4	0	15	.2	.7	.2	.3	.00	27	8	0	26	6.1		
4971.8	Little River at Elkmont	6.0	.01	1.3	.4	.8	.5	0	8	2.4	.1	.0	.3	.00	21	4	0	15	6.9	16	61
4972.4	Lynn Camp Prong	6.9	.03	1.0	.3	1.0	.4	0	6	2.2	.7	.0	.4	.00	18	4	0	15	5.5	16	61
4972.7	Middle Prong Little River	6.6	.00	1.6	.6	1.0	.4	0	8	.8	.6	.1	1.3	.00	22	6	0	20	5.9		
5181	Abrams Creek	8.1	.01	19	8.3	1.2	.6		95	2.8	1.3	.1	.9	.00	92	81	2	161	6.8	14	58
5106.8	Oconaluftee River	7.1	.01	1.2	.4	.8	.3		6	2.6	.8	.2	.3	.01	23	4	0	17	5.9	15	59
5109.35	Raven Fork	7.7	.01	1.0	.3	1.2	.4		7	1.6	.7	.1	.4	.00	24	4	0	15	5.9		
5120	Oconaluftee River	8.6	.01	1.1	.4	1.6	.5		8	1.2	1.0	.2	.2	.02	19	4	0	19	5.8		
5127.4	Deep Creek	7.3	.01	.8	.3	.9	.3		6	1.6	1.0	.1	.3	.00	18	3	0	13	5.6	17	63
5135	Noland Creek	6.3	.01	.7	.2	.8	.3		4	.6	.7	.1	.4	.00	20	4	0	10	5.6		
5136.45	Forney Creek	6.9	.01	.8	.2	.9	.4		5	1.0	.8	.1	.4	.01	14	3	0	12	5.6		
5140	Hazel Creek	7.5	.00	.9	.3	1.1	.3		7	1.2	1.0	.1	.4	.00	23	3	0	14	6.0		
5142.3	Eagle Creek	7.3	.03	.8	.3	1.1	.3		6	.8	.7	.1	.4	.01	23	3	0	13	6.0		
5151.2	Twenty Mile Creek	8.5	.00	.8	.3	1.2	.4		6	1.0	.6	.1	.4	.00	19	3	0	14	6.9	15	59
5178	Parson Branch near Calderwood	10	.03	4.0	.8	1.6	.7	0	21	.8	1.3	.0	.3	.00	38	14	0	37	6.2	16	61
5181.1	Forge Creek near Cades Cove	7.1	.06	1.0	.3	1.0	.4	0	8	1.2	1.1	.1	.3	.00	28	4	0	15	5.6	17	63

Table 4.—*Results of coliform bacteria counts, July 1968*[a]

[illegible]

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