Hydraulic Characteristics of, and Ground-Water Flow in, Coal-Bearing Rocks of Southwestern Virginia

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Prepared in cooperation with the Virginia Department of Mines, Minerals, and Energy, Division of Mined Land Reclamation, and the Powell River Project that the potentiometric head for the test interval was lower than the pressure head exerted by the column of water in the open corehole. Equilibration at a transducer reading higher than the reading recorded prior to inflation indicated that the potentiometric head for the test interval was higher than the pressure head exerted by the column of water in the open corehole. The transducer reading prior to inflation was subtracted from the equilibrated reading after inflation, and this value was multiplied by the transducer calibration. The resulting value (with sign) was added to the altitude of the water level in the corehole to derive the potentiometric head of the test interval. Values for all the test intervals in a corehole provided a vertical profile of potentiometric heads that was referenced to the composite water level in the open corehole.

Potentiometric-head measurements were generally obtained for only permeable test intervals. In tight test intervals the transducer readings indicated the inflation surge and usually stayed high. Because of time constraints and the goal of acquiring data on as many test intervals as possible, the packers were deflated after a few minutes and moved to a new test interval. Thus, some permeable test intervals with high potentiometric heads may have been overlooked; however, most of these test intervals probably were tight.

A total of 52 coal-exploration coreholes were visited during this investigation. Hydraulic testing was conducted in 43 coreholes, and potentiometric-head measurements were made in 34. Representative plots of potentiometric head as a function of depth of the tested intervals for coreholes located on hilltops, on hillslopes, and in valleys are shown in figures 6, 7, and 8, respectively. The water level in each corehole is indicated along with the predominant lithology present in each interval tested in the corehole. The diagonal line in each graph represents the line of zero pressure head. All points that plot to the right of this line represent artesian test intervals, and all points that plot on this line represent test intervals with heads that are equal to their altitude.

Corehole water levels do not necessarily correspond to **water tables**. In an open corehole, a water level is a composite water level that represents the combined effect of the heads in each water-bearing interval intersected by the corehole. In coreholes where the potentiometric gradients are downward, the water table should be higher than the corehole water level; thus, water will drain into the corehole—cascading or dripping. In addition, if transmissivity is low, the water table could be nearly drained, and water leaking in could run down the corehole wall and not be audible. Cascading water was heard in coreholes 15 and 16, both of which were located on hillslopes.

The potentiometric heads of test intervals in hilltop coreholes generally were less than the corehole water levels (fig. 6). The depth to water for the eight coreholes on hilltops ranged from 100 to 376 ft below land surface, having a mean depth of 221 ft. In addition, two coreholes of 150- and 200-ft depth were dry. Potentiometric heads only were measured for a few test intervals in most hilltop coreholes because a large percentage of corehole depths were through unsaturated rock. The heads that were measured indicate a decrease in potentiometric head with increasing depth. A downward gradient also was indicated by the potentiometric-head data for coal seams in corehole 13; however, this hole was different from the other hilltop holes in that many of the test intervals indicate water-table conditions. The potentiometric heads of these coal seams coupled with the presence of lower transmissivity intervals between them indicate that some of the coal seams could be partially saturated, confined, or semiconfined and that water is probably perched in these coal seams. The steep **hydraulic gradient** probably indicates a partially unsaturated drain horizon at depth.

The potentiometric heads of test intervals in hillslope coreholes generally were less than the corehole water levels (fig. 7). The depth to water for the 30 coreholes on hillslopes ranged from 1 to 447 ft below land surface, having a mean depth of 109 ft. The potentiometric gradient generally was downward. Exceptions to the downward gradient were observed in coreholes 10, 28, and 36. Corehole 10 exhibited a split gradient—heads in a lithologic contact and a coal-seam test interval approximately 300 ft deep were higher than heads in adjacent test intervals. In addition, potentiometric head in a sandstone approximately 500 ft deep was 80–100 ft higher than heads in coal seams above and below it. Corehole 28 also exhibited a split gradient—head in a shale test interval approximately 200 ft deep was higher than that in the sandstone and coal-seam test intervals above and below it, respectively. Finally, in corehole 36, which intersected a coal seam at a depth of approximately 460 ft, head was substantially higher than those of the intervals tested above and below it. These split gradients were probably the result of a rapid drop in the corehole water level, the effects of drilling, or the effect of other nearby uncased coreholes that connected test intervals at depth with high head test intervals above. In either instance, some potentiometric heads in these test intervals probably had not equilibrated.

The potentiometric heads of test intervals in valley coreholes generally were similar to or less than the corehole water levels (fig. 8). The depth to water for the seven coreholes in valleys ranged from 10 to 76 ft below land surface with a mean depth of 39 ft. The potentiometric gradient generally was downward, but several test intervals at shallow depths usually exhibited equivalent heads that were often equal to the water level in the corehole.

GROUND-WATER FLOW

A conceptual ground-water-flow model of the coal fields of southwestern Virginia is presented in figure 9.

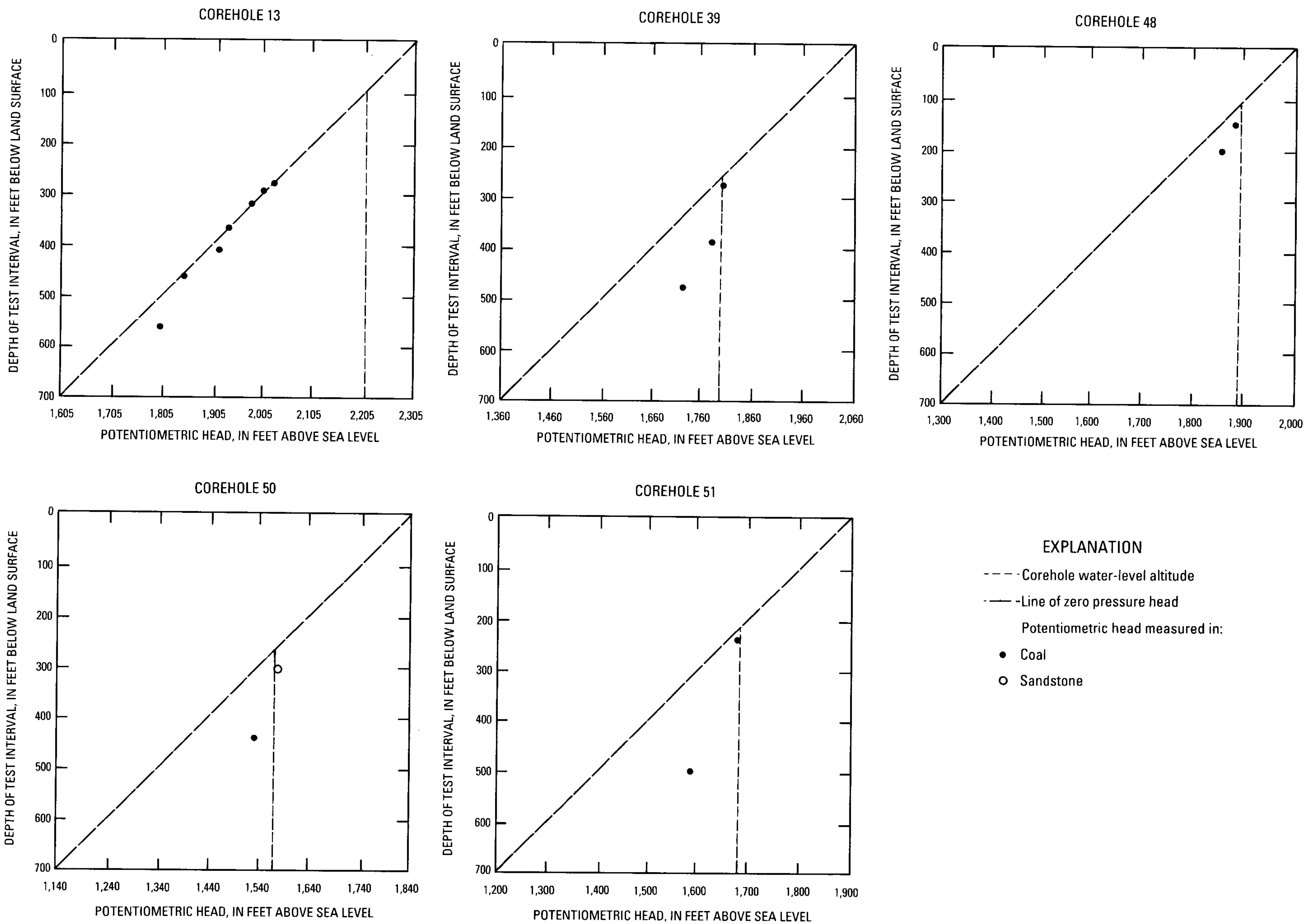

Figure 6. Potentiometric head as a function of depth below land surface for test intervals in hilltop coreholes 13, 39, 48, 50, and 51.

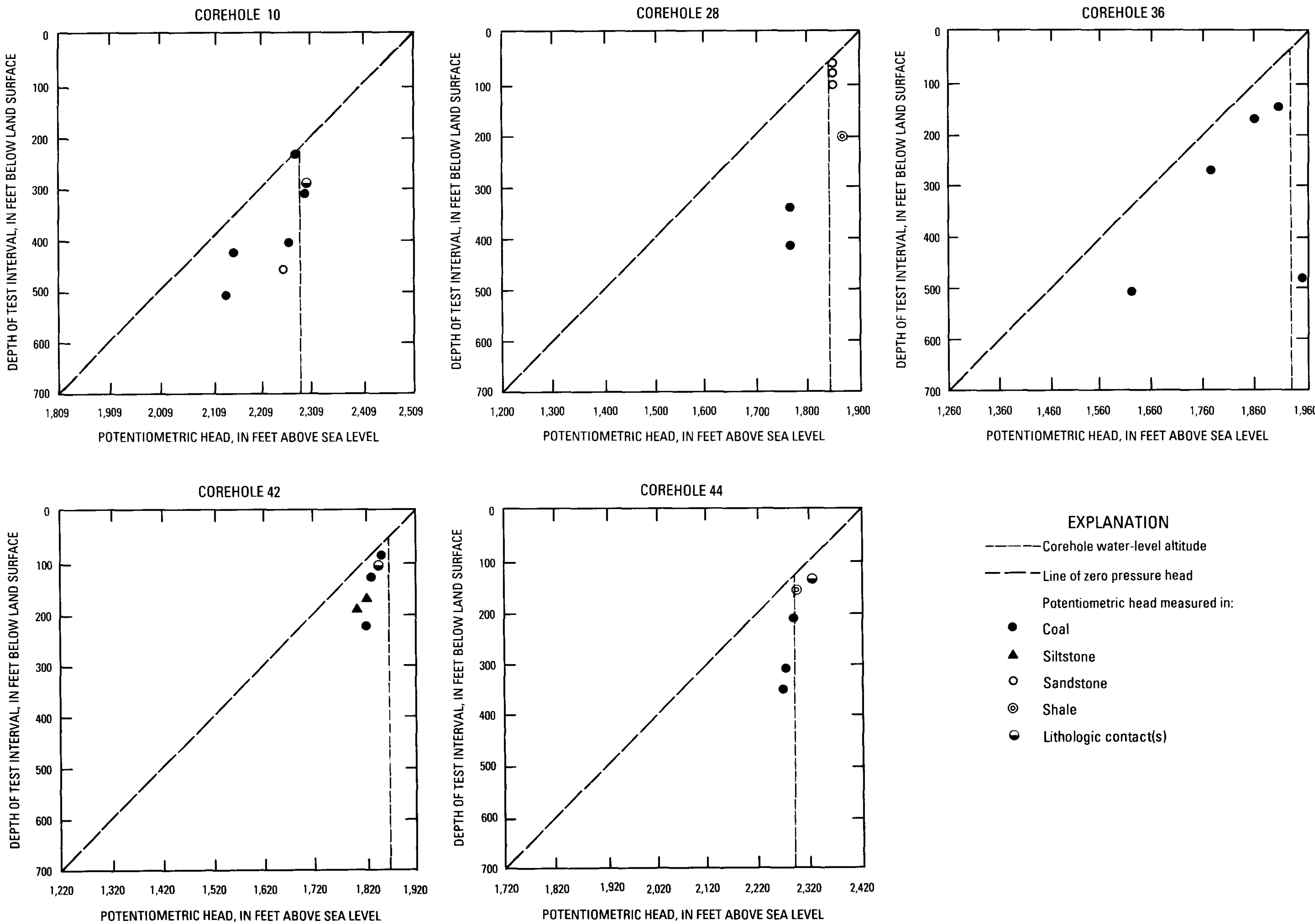

Figure 7. Potentiometric head as a function of depth below land surface for test intervals in hillslope coreholes 10, 28, 36, 42, and 44.

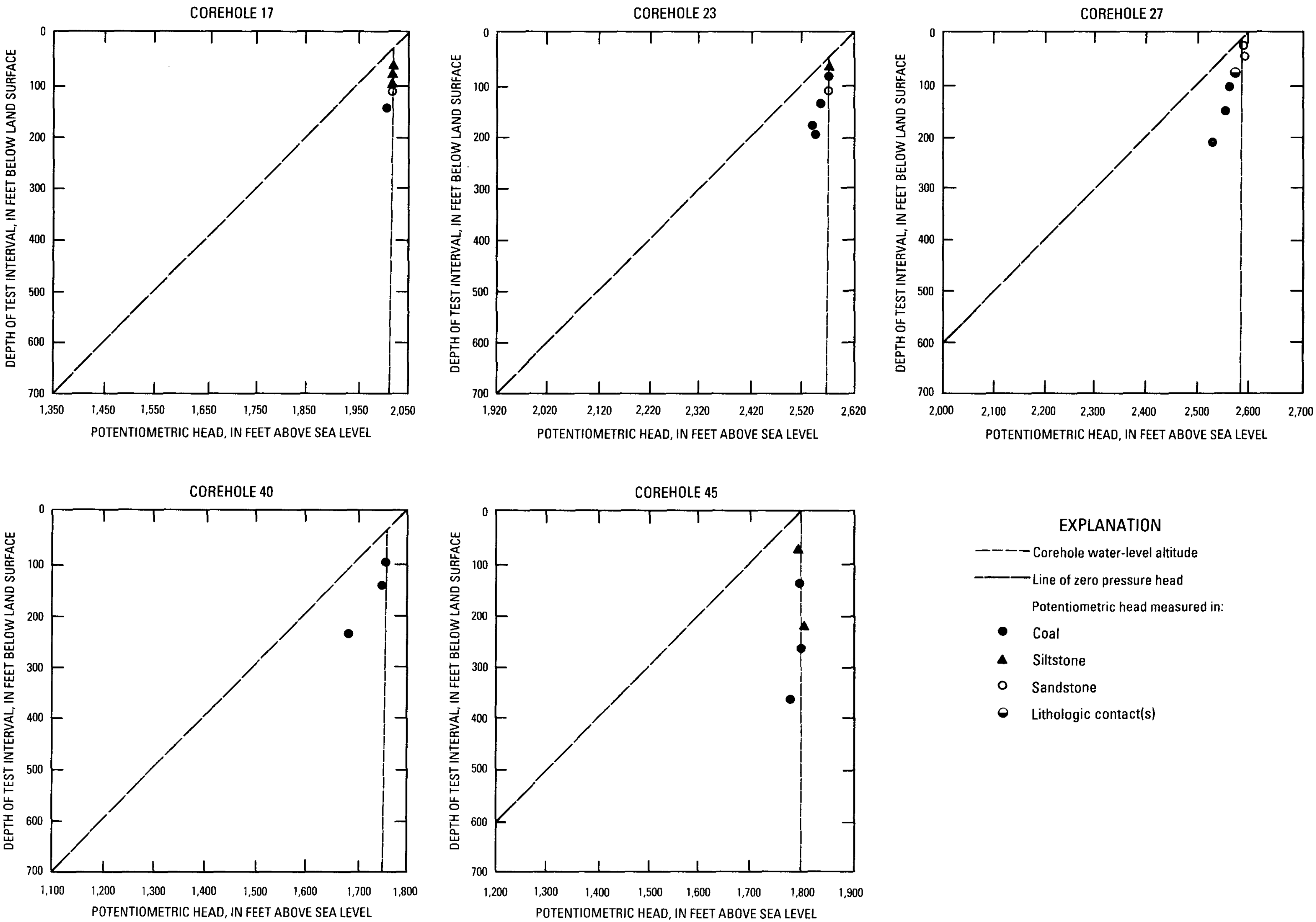

Figure 8. Potentiometric head as a function of depth below land surface for test intervals in valley coreholes 17, 23, 27, 40, and 45.

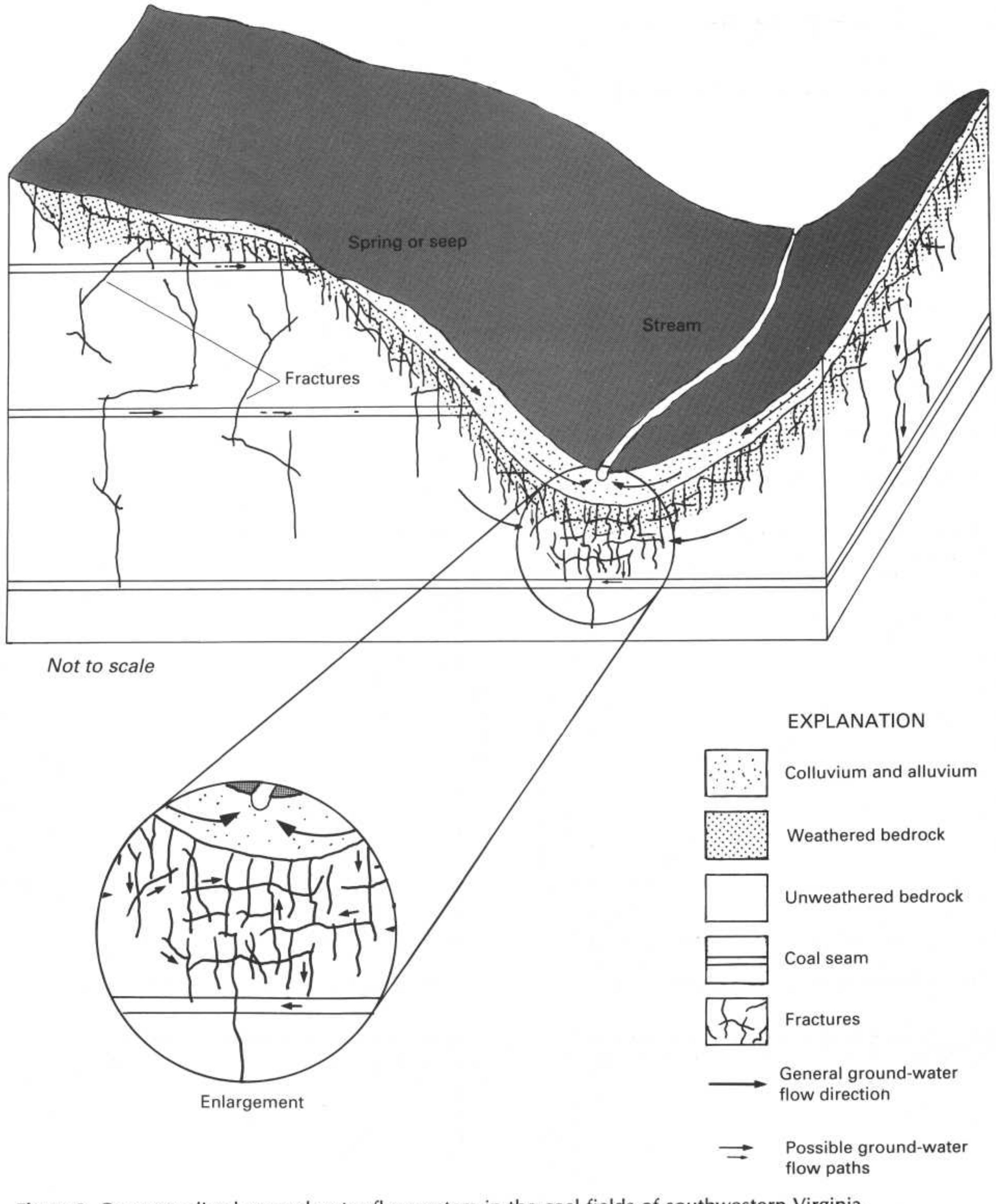

Figure 9. Conceptualized ground-water-flow system in the coal fields of southwestern Virginia.

Ground water generally flows through fractures, cleats, and bedding-plane partings. Permeability of coal seams is generally larger than that of other rock types or lithologic contacts. Fracturing is more intense in the shallow part of the system than in deeper parts, which supports the findings of Wyrick and Borchers (1981, fig. 5.1.5–2) and Trainer (1983, p. 112). However, even at shallow depths, fracture intensity is areally diverse as indicated by the low transmissivity intervals at shallow depths in some coreholes. This areal diversity in fracturing could be a reflection of structural features or other local conditions. The transmissivity of all rock types generally decreases with depth (fig. 5) as fracture size and number decrease. The transmissivities generally are similar for coal seams, sandstone, and lithologic contacts at depths less than 100 ft. However, siltstone and shale generally have the lowest transmissivities. Because of the high topographic relief in the area, ground-water-flow systems are limited in areal extent. Ground water beneath ridges and hills probably discharges to local springs and streams or flows downgradient as underflow in valleys.

The water level in the uncased coreholes (which may or may not be the water table) is influenced by topography. The average depth to water beneath hilltops was 221 ft; beneath hillslopes, 109 ft; and beneath valleys, 39 ft. Regardless of whether these water levels equate to the water table, the water-table aquifer generally is thin because of the interbedding of low-permeability and high-permeability rocks. Although a thick interval of strata at shallow depths can be saturated and have zones with similar heads, the interval does not necessarily represent one water-table aquifer. In many instances, the zones of high permeability that exhibit equal heads are separated by zones of much lower permeability. Thus, such a zone is a thin water-table aquifer, underlain by semiconfined and confined water-bearing zones.

Potentiometric-head measurements provide clues to the general ground-water-flow system in the area. A vertical profile of head measurements for a corehole situated on a hilltop usually indicated a sharp downward gradient (see fig. 6, corehole 39). A downward gradient is also observed in hillslope wells, although shallow zones commonly exhibited intervals of equal head (as previously discussed; see fig. 7, corehole 28). Finally, valley wells in the area usually exhibited shallow intervals of equal head below which head measurements indicated a downward gradient (see fig. 8, corehole 23). These head relations indicate that the high-relief areas function as recharge areas; water infiltrates the surface, percolates into the regolith, and flows downward and laterally through fractures in the shallow bedrock. Hydraulic conductivity decreases with increasing depth, and ground water flows primarily in the lateral direction along fractures or through coal seams. If vertical hydraulic conductivity is negligible, ground water continues to flow laterally, discharging as springs or seeps on hillslopes. Valleys function as discharge areas for the flow system, although upward gradients were usually not observed in wells located in this topographic setting. However, the few wells tested that indicated an upward gradient were adjacent to streams, possibly indicating that upward gradients are associated with the streams and will probably only be detected in close proximity to them. In general, water probably follows a stairstep flow path (Kipp and others, 1983), discharging to streams and (or) flowing downward into coal seams and old mine workings.

Permeable coal seams probably underlie valleys in the region; however, aquifer-test data indicate that the horizontal hydraulic conductivity of coal is a function of depth and probably decreases under ridges because of increased overburden pressures. Wahler and Associates (1979), in their studies of mine-dewatering problems, concluded that with increasing depth, soft rocks, such as shale, may seal deep fractures. Topographic relief in the area creates high heads for the ground-water-flow system. However, transmissivity data from the range of depths tested indicate that ground water primarily flows at moderate depths (<300 ft, see fig. 5), and deep regional ground-water flow is probably minimal. Trainer (1983, p. 112) stated that the depth and intensity of fracturing, lithology, and topographic relief influence the depth of active circulation of fresh ground water in horizontally bedded sedimentary rocks. He also concluded that, in this type of setting, ground-water circulation is typically restricted to modest depths.

SUMMARY AND CONCLUSIONS

Borehole geophysical logging, water-quality sampling, and hydraulic testing with a pneumatic straddle-packer assembly were used in coal-exploration coreholes to evaluate the aquifers in the coal fields of southwestern Virginia. Potentiometric-head relations in the coreholes were more complex than originally thought. Flow between test intervals in the coreholes made collection of samples representative of water quality in the tested intervals unfeasible. In addition, time constraints established to allow the retrieval of data on as many test intervals as possible made constant-head injection testing the predominant method of analysis used. Standard and modified slug-test methods are applicable to ground-water studies in terranes similar to the study area, particularly when resolution is needed for low values of transmissivity and (or) hydraulic conductivity. For such studies, the modified slug test, which is designed for tight formations, is a valid aquifer-test method.

Results from straddle-packer testing of 9-ft-long intervals in the predominantly clastic rocks of the coal fields indicate that transmissivity decreases with depth. Transmissivity values calculated from constant-head injection testing ranged from less than 0.001 to 60 ft^2/d in coal seams, from less than 0.001 to greater than 160 ft^2/d in sandstone, from less than 0.001 to greater than 170 ft^2/d in siltstone and shale, and from less than 0.001 to greater than 20 ft^2/d at lithologic contacts. Coal seams had a median transmissivity of 0.15 ft^2/d, whereas other rock types and lithologic contacts had median transmissivities less than or equal to 0.001 ft^2/d. All rock types tested usually were permeable to a depth of approximately 100 ft; however, at depths greater than 200 ft only coal seams consistently had measurable permeability (transmissivity greater than 0.001 ft^2/d). Injection testing of intervals immediately adjacent to coal seams usually indicated lower transmissivity than that obtained when the coal seams were isolated within the test interval, indicating that most lateral ground-water flow is associated with the coal seams. Potentiometric-head measurements for these coal seams coupled with the presence of low-transmissivity intervals between the seams indicate that some of the coal seams could be partly saturated, confined, or semiconfined and, in some instances, that water could be perched above these coal seams.

The mean depth to standing water below land surface was 221 ft in coreholes located on hilltops, 109 ft in coreholes located on hillslopes, and 39 ft in coreholes located in valleys. Potentiometric-head measurements indicate downward flow on hilltops, lateral and downward flow on hillslopes, and upward, lateral, and downward flow in valleys. Because of the high topographic relief (600–1,000 ft) in the area, ground-water-flow systems are of small areal extent. Head relations indicate that high topographic areas function as recharge areas; water infiltrates through the surface, percolates into the regolith, and moves downward and laterally through the fractures in the shallow bedrock. Permeability decreases with increasing depth, and most water may move laterally along fractures or bedding planes or through coal seams until encountering more permeable rock through which to move downward. If more permeable rocks are not encountered, water continues to move laterally, discharging as a spring or seep on the hillslope. Where vertical permeability is appreciable, water follows a stair-step path through the regolith, fractures and bedding planes, and coal seams, discharging to streams and (or) recharging permeable coal seams at depth. Although permeable coal seams may underlie valleys in the region, data from this study indicate that the permeability of coal is a function of depth and may decrease under adjacent hills because of increased overburden pressures. Therefore, ground water beneath valleys that does not discharge to streams probably flows downgradient as underflow beneath the streams.

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TABLE 3

Table 3. Lithologic descriptions, potentiometric heads, and transmissivities for test intervals in coal-exploration coreholes in the coal fields of southwestern Virginia

[S, indicates corehole is located on a hillslope; H, indicates corehole is located on a hilltop; V, indicates corehole is located in a valley; <, indicates less than value shown; >, indicates greater than value shown; --, indicates no value was determined; corehole number and location shown in plate 1; USGS, U.S. Geological Survey]

Corehole number	USGS local number	Altitude of land surface (feet above sea level)	Topographic setting	Altitude of standing water (feet above sea level)	Depth to top of test interval (feet below land surface)	Formation name or lithologic description	Potentiometric head (feet above sea level)	Transmisivity (feet square per day)		
								Constant-head injection test	Modified slug test	Standard slug test
10	9D19	2,509	S	2,289	237	Clintwood coal	2,276	--	0.0006	--
					270	Shale	--	<0.001	--	--
					297	Sandstone-siltstone contact	2,297	--	.0001	--
					315	Blair coal	2,294	--	.005	--
					378	Lyons coal	--	<.001	--	--
					407	Boney coal	2,263	--	--	--
					427	Dorchester coal	2,153	--	--	--
					460	Gladeville Sandstone	2,251	--	.00007	--
					496	Siltstone with sandstone	--	<.001	--	--
					510	Norton coal	2,138	--	--	--
11	14F91	1,784	S	1,702	85	Kennedy coal	--	62	--	--
					120	McClure Sandstone Member of the Norton Formation	--	<.001	--	--
					146	Sandstone-siltstone contact	--	<.001	--	--
					165	Shale	--	<.001	--	--
					220	Raven 2 coal	1,627	--	.0005	--
					270	Siltstone	1,600	--	--	--
					300	Raven 1 coal	1,534	--	.0005	--
					326	Clay	--	<.001	--	--
					390	Siltstone	--	<.001	--	--
					415	Jawbone Rider coal	1,465	--	.0007	--
					435	Sandstone	--	<.001	--	--
					458	Jawbone coal	1,406	--	.0005	--
					505	Council Sandstone	--	<.001	--	--
					540	Siltstone-sandstone contact	--	<.001	--	--
					565	Lee coal	1,457	--	.00006	--
					610	Siltstone	--	<.001	--	--
12	10E10	2,139	S	1,963	180	Blair coal	1,963	--	--	--
					200	Sandstone-siltstone contact	--	<.001	--	--
					215	Lyons coal	1,915	.24	--	--
					230	Sandstone	--	<.001	--	--
					255	Sandstone with siltstone, coal	1,922	<1	--	--

Table 3. Lithologic descriptions, potentiometric heads, and transmissivities for test intervals in coal-exploration coreholes in the coal fields of southwestern Virginia—Continued

Corehole number	USGS local number	Altitude of land surface (feet above sea level)	Topographic setting	Altitude of standing water (feet above sea level)	Depth to top of test interval (feet below land surface)	Formation name or lithologic description	Potentiometric head (feet above sea level)	Transmissivity (feet square per day)		
								Constant-head injection test	Modified slug test	Standard slug test
12—Continued										
					270	Sandstone	--	<0.001	--	--
					285	Dorchester coal	1,890	--	0.003	--
					300	Sandstone with siltstone	--	<.001	--	--
					315	Sandstone with siltstone	--	<.001	--	--
					340	Siltstone	1,819	--	.0009	--
13	10E14	2,305	H	2,205	105	Sandstone	--	>63	--	--
					170	Siltstone	--	<.001	--	--
					235	Siltstone	--	<.001	--	--
					280	Clintwood marker coal	2,023	<.01	--	--
					295	Clintwood coal	2,003	<.03	--	--
					320	Lower Clintwood coal	1,980	.25	--	--
					335	Sandstone-siltstone-sandstone	--	<.001	--	--
					350	Siltstone-sandstone contact	--	<.001	--	--
					368	Blair coal	1,935	.05	--	--
					398	Sandstone	--	<.001	--	--
					412	Lyons coal	1,915	.07	--	--
					431	Sandstone	--	<.001	--	--
					463	Dorchester coal	1,847	--	.002	--
					485	Siltstone	--	<.001	--	--
					505	Siltstone	--	<.001	--	--
					563	Norton coal	1,799	--	.0002	--
14	10F3	2,066	H	1,766	290	Clintwood 2 coal	--	.26	--	--
					300	Clintwood 1 coal	--	.2	--	--
					335	Sandstone	--	<.001	--	--
					380	Lyons coal	--	<.001	--	--
					410	Siltstone	--	<.001	--	--
					435	Dorchester coal	1,661	.08	--	--
					450	Siltstone	--	<.001	--	--
					485	Sandstone	--	<.001	--	--
					500	Norton coal	--	<.001	--	--
					530	Siltstone	--	<.001	--	--
					555	Sandstone	--	<.001	--	--

Table 3. Lithologic descriptions, potentiometric heads, and transmissivities for test intervals in coal-exploration coreholes in the coal fields of southwestern Virginia—Continued

Corehole number	USGS local number	Altitude of land surface (feet above sea level)	Topographic setting	Altitude of standing water (feet above sea level)	Depth to top of test interval (feet below land surface)	Formation name or lithologic description	Potentiometric head (feet above sea level)	Transmisivity (feet square per day)		
								Constant-head injection test	Modified slug test	Standard slug test
15	8D6	2,354	S	2,314	45	Sandstone	2,325	7.5	--	--
					65	Taggart marker coal	2,319	<4.9	--	--
					80	Clover Fork Sandstone Member of the Wise Formation	--	<.001	--	--
					90	Clover Fork Sandstone Member of the Wise Formation	2,314	>96	--	--
					105	Clover Fork Sandstone Member of the Wise Formation	--	<.001	--	--
					136	Clover Fork Sandstone Member of the Wise Formation	--	<.005	--	--
					155	Siltstone	--	<.001	--	--
					170	Wilson coal	2,264	1.8	--	--
					185	Siltstone-sandstone-siltstone	2,264	<.003	--	--
					198	Upper St. Charles coal	2,250	.9	--	--
16	10D20	2,076	S	2,018	55	Shale	--	>172	--	--
					75	Kennedy coal	2,018	45	--	--
					123	Aily coal	2,014	.15	--	--
					160	Siltstone	2,016	1.1	--	--
					205	Siltstone	--	<.006	--	--
					245	Sandstone	--	<.001	--	--
					272	Raven coal	2,004	.4	--	--
					300	Siltstone	--	<.007	--	--
17	10D21	2,050	V	2,015	70	Siltstone	2,015	6.2	--	--
					92	Siltstone	2,015	<.001	--	--
					103	Sandstone-shale contact	2,015	.06	--	--
					117	Sandstone	2,015	10.3	--	--
					148	Raven coal	2,005	.65	--	--
					172	Sandstone	--	<.001	--	--
					191	Sandstone with shale	--	<.001	--	--
21	14G 9	1,360	S	1,308	45	Siltstone, sandy	--	.35	--	--
					64	Raven coal split	--	<.001	--	--
					95	Sandstone-siltstone contact	--	<.001	--	--
					135	Siltstone	--	<.001	--	--
					157	Jawbone coal	--	<.001	--	--
					180	Council Sandstone	--	<.001	--	--

Table 3. Lithologic descriptions, potentiometric heads, and transmissivities for test intervals in coal-exploration coreholes in the coal fields of southwestern Virginia—Continued

Corehole number	USGS local number	Altitude of land surface (feet above sea level)	Topographic setting	Altitude of standing water (feet above sea level)	Depth to top of test interval (feet below land surface)	Formation name or lithologic description	Potentiometric head (feet above sea level)	Transmissivity (feet square per day)		
								Constant-head injection test	Modified slug test	Standard slug test
21—Continued										
					217	Tiller coal	--	<0.001	--	--
					254	Siltstone with sandstone	--	<.001	--	--
					280	Siltstone with sandstone	--	<.001	--	--
					340	Siltstone with sandstone	--	<.001	--	--
					360	Upper Seaboard coal	--	<.001	--	--
					415	Sandstone with siltstone	--	<.001	--	--
					440	Sandstone with siltstone	--	<.001	--	--
					480	Sandstone	--	<.001	--	--
					530	Sandstone	--	<.001	--	--
					540	Seaboard coal	--	<.001	--	--
					557	Siltstone with coal	--	<.001	--	--
					580	Siltstone with coal	--	<.001	--	--
22	8D 7	2,582	S	2,462	35	Shale	--	<.001	--	--
					67	Low Splint A coal	--	.1	--	--
					115	Sandstone	--	<.001	--	--
					147	Low Splint C and D coal	2,455	4.5	--	--
					180	Sandstone	--	<.001	--	--
					202	Sandstone	--	<.001	--	--
23	10D23	2,620	V	2,568	70	Siltstone with coal	2,568	.84	--	--
					87	Blair coal	2,568	1.6	--	--
					115	Sandstone	2,568	>85	--	--
					140	Lyons coal	2,554	.46	--	--
					155	Sandstone	--	<.001	--	--
					184	Upper Dorchester coal	2,538	.9	--	--
					200	Lower Dorchester coal	2,542	4.0	--	--
24	10D22	2,580	S	2,562	53	Sandstone	2,562	1.4	--	--
					80	Blair coal	2,543	2	--	--
					100	Sandstone	--	<.001	--	--
					135	Lyons coal	2,536	1.1	--	--
					155	Siltstone	--	<.001	--	--
					173	Upper Dorchester coal	2,514	.2	--	--
					193	Lower Dorchester coal	2,513	.06	--	--

Table 3. Lithologic descriptions, potentiometric heads, and transmissivities for test intervals in coal-exploration coreholes in the coal fields of southwestern Virginia—Continued

Corehole number	USGS local number	Altitude of land surface (feet above sea level)	Topographic setting	Altitude of standing water (feet above sea level)	Depth to top of test interval (feet below land surface)	Formation name or lithologic description	Potentiometric head (feet above sea level)	Transmissivity (feet square per day)		
								Constant-head injection test	Modified slug test	Standard slug test
26	10E11	2,010	V	1,934	24	Clintwood marker coal	--	2.3	--	--
					55	Sandstone	--	1	--	--
					89	Blair coal	1,934	.14	--	--
					121	Lyons coal	1,932	.37	--	--
					138	Sandstone-siltstone contact	--	<.001	--	--
					165	Sandstone	--	<.001	--	--
					183	Dorchester coal	1,908	.02	--	--
					205	Siltstone	--	<.001	--	--
					222	Siltstone	--	<.001	--	--
27	10E12	2,600	V	2,585	25	Sandstone	2,585	.2	--	--
					45	Sandstone with siltstone	2,588	.1	--	--
					80	Siltstone-sandstone-siltstone	2,575	.2	--	--
					106	Blair coal	2,560	.6	--	--
					125	Sandstone	--	<.001	--	--
					152	Lyons coal	2,552	.4	--	--
					180	Sandstone	--	<.001	--	--
					215	Dorchester coal	2,527	.3	--	--
					245	Sandstone with siltstone	--	<.001	--	--
					285	Sandstone	--	<.001	--	--
28	8D 8	1,900	S	1,840	32	Sandstone	--	>118	--	--
					60	Sandstone	1,840	>118	--	--
					80	Sandstone	1,840	>168	--	--
					107	Sandstone with coal	1,840	>101	--	--
					140	Shale, sandy	--	.06	--	--
					175	Shale with sandstone	--	<.001	--	--
					205	Shale, sandy	1,865	<.001	--	--
					245	Shale	--	<.001	--	--
					285	Sandstone with shale	--	<.001	--	--
					310	Shale, sandy	--	<.001	--	--
					343	Clintwood coal	1,759	<.005	--	--
					370	Sandstone with shale and coal	--	<.001	--	--
					418	Blair marker coal	1,758	<.007	--	--

Table 3. Lithologic descriptions, potentiometric heads, and transmissivities for test intervals in coal-exploration coreholes in the coal fields of southwestern Virginia—Continued

Corehole number	USGS local number	Altitude of land surface (feet above sea level)	Topographic setting	Altitude of standing water (feet above sea level)	Depth to top of test interval (feet below land surface)	Formation name or lithologic description	Potentiometric head (feet above sea level)	Transmisivity (feet square per day)		
								Constant-head injection test	Modified slug test	Standard slug test
29	14F92	2,160	S	2,140	15	Siltstone	--	50	--	--
					35	Splashdam coal	2,140	2.6	--	--
					50	Siltstone	--	<.001	--	--
					65	Sandstone	--	<.001	--	--
					80	Upper Banner coal	2,132	.05	--	--
					115	Siltstone-sandstone-siltstone	--	<.001	--	--
					130	Siltstone	--	<.001	--	--
					157	Lower Banner coal	2,110	.02	--	--
					185	Siltstone	--	<.001	--	--
					220	Big Fork coal	2,090	.01	--	--
					270	Siltstone-sandstone-siltstone	--	<.001	--	--
					286	Bearwallow coal	--	<.001	--	--
					315	Sandstone with coal	--	<.001	--	--
					335	Siltstone	--	<.001	--	--
					373	Kennedy coal	2,020	.02	--	--
32	13G15	1,920	S	1,557	153	Sandstone	--	.02	--	--
					198	Lyons coal	--	.15	--	--
					310	Sandstone with coal	--	.37	--	--
					445	Siltstone	--	<.001	--	--
					495	Hagy coal	1,542	.15	--	--
					515	Sandstone	--	<.001	--	--
					565	Siltstone	--	<.001	--	--
					590	Splashdam 2 coal	1,498	.5	--	--
					605	Sandstone	--	<.001	--	--
					621	Splashdam 1 coal	1,479	<.05	--	--
33	16F 1	2,340	S	2,229	65	Sandstone with siltstone	--	<.001	--	--
					130	Siltstone	--	<.001	--	--
					168	Jawbone coal	2,243	.05	--	0.25
					195	Siltstone with coal	2,219	<.001	--	--
					215	Tiller coal	2,197	.05	--	--
					235	Sandstone	--	<.001	--	--

Table 3. Lithologic descriptions, potentiometric heads, and transmissivities for test intervals in coal-exploration coreholes in the coal fields of southwestern Virginia—Continued

Corehole number	USGS local number	Altitude of land surface (feet above sea level)	Topographic setting	Altitude of standing water (feet above sea level)	Depth to top of test interval (feet below land surface)	Formation name or lithologic description	Potentiometric head (feet above sea level)	Transmisivity (feet square per day)		
								Constant-head injection test	Modified slug test	Standard slug test
35	15F25	2,327	S	2,305	264	Raven 1 coal	2,230	0.46	--	0.26
					300	Sandstone	--	--	0.005	--
					335	Sandstone	--	<.001	--	--
					400	Siltstone	--	<.001	--	--
					447	Jawbone A and B coal	2,164	.01	--	--
36	13G16	1,940	S	1,928	35	Sandstone	--	<.001	--	--
					70	Sandstone	--	<.001	--	--
					100	Siltstone-sandstone contact	--	<.001	--	--
					129	Lyons 2 coal	1,901	.25	--	--
					154	Lyons 1 coal	1,856	.2	--	--
					169	Siltstone	--	<.001	--	--
					234	Sandstone-siltstone-sandstone	--	<.001	--	--
					255	Norton coal	1,773	<.07	--	--
					309	Sandstone with shale	--	<.001	--	--
					341	Sandstone	--	<.001	--	--
					399	Siltstone	--	<.001	--	--
					464	Hagy 2 coal	1,950	<.001	--	--
					489	Hagy coal	1,621	.15	--	--
					529	Siltstone-sandstone contact	--	<.001	--	--
					564	Siltstone	--	<.001	--	--
37	13D 3	2,423	S	2,257	110	Siltstone with sandstone	--	<.001	--	--
					190	Siltstone	--	<.001	--	--
					220	Siltstone-sandstone contact	--	<.001	--	--
					250	Kennedy coal	2,273	.17	--	--
					280	Sandstone	--	<.001	--	--
					335	Siltstone	--	<.001	--	--
					385	Sandstone	--	<.001	--	--
					430	Raven 2 coal	--	<.001	--	--
					470	Siltstone	--	<.001	--	--
					547	Raven 1 coal	--	<.001	--	--
					610	Sandstone	--	<.001	--	--

Table 3. Lithologic descriptions, potentiometric heads, and transmissivities for test intervals in coal-exploration coreholes in the coal fields of southwestern Virginia—Continued

Corehole number	USGS local number	Altitude of land surface (feet above sea level)	Topographic setting	Altitude of standing water (feet above sea level)	Depth to top of test interval (feet below land surface)	Formation name or lithologic description	Potentiometric head (feet above sea level)	Transmissivity (feet square per day)		
								Constant-head injection test	Modified slug test	Standard slug test
38	13D 4	2,415	S	2,326	100	Siltstone	--	<0.001	--	--
					160	Siltstone	--	<.001	--	--
					200	Sandstone-siltstone-sandstone	2,314	<.001	--	--
					245	Kennedy coal	2,293	.22	--	--
					280	Sandstone	--	<.001	--	--
					312	Sandstone-siltstone contact	--	<.001	--	--
					330	Siltstone	--	<.001	--	--
					380	coal	--	<.001	--	--
					427	Raven 2 coal	--	<.001	--	--
					460	coal	--	<.001	--	--
					505	Siltstone-sandstone contact	--	<.001	--	--
					530	Sandstone	--	<.001	--	--
					555	Raven 1 coal	--	<.001	--	--
					600	Sandstone	--	<.001	--	--
39	10F 4	2,060	H	1,795	277	Clintwood coal	1,801	.2	--	0.06
					305	Siltstone	--	<.001	--	--
					330	Lyons coal	--	<.001	--	--
					388	Dorchester coal	1,779	<.001	--	--
					410	Siltstone	--	<.001	--	--
					450	Sandstone	--	<.001	--	--
					477	Norton coal	1,721	.42	--	.27
40	10F 5	1,800	V	1,759	65	Sandstone	--	<5.7	--	--
					100	Lyons coal	1,759	<4.7	--	--
					120	Siltstone	--	<.001	--	--
					148	Dorchester coal	1,752	.04	--	--
					165	Siltstone	--	<.001	--	--
					185	Siltstone-shale-siltstone	--	<.001	--	--
					210	Sandstone-siltstone contact	--	<.001	--	--
					237	Norton coal	1,689	1.8	--	--
41	11F 7	1,980	H	1,604	120	Clintwood coal	--	.16	--	--
					185	Sandstone	--	<.001	--	--
					230	Sandstone-siltstone contact	--	<.001	--	--
					255	Lyons coal	--	.15	--	--
					310	Siltstone	--	.28	--	--

Table 3. Lithologic descriptions, potentiometric heads, and transmissivities for test intervals in coal-exploration coreholes in the coal fields of southwestern Virginia—Continued

Corehole number	USGS local number	Altitude of land surface (feet above sea level)	Topographic setting	Altitude of standing water (feet above sea level)	Depth to top of test interval (feet below land surface)	Formation name or lithologic description	Potentiometric head (feet above sea level)	Transmisivity (feet square per day)		
								Constant-head injection test	Modified slug test	Standard slug test
41—Continued										
					377	Norton coal	1,604	0.26	--	--
					400	Sandstone-siltstone contact	1,604	.37	--	--
					425	Sandstone	--	<.001	--	--
					470	Siltstone	--	<.001	--	--
					505	Sandstone-siltstone contact	--	<.001	--	--
					540	Sandstone	--	<.001	--	--
					585	Hagy coal	--	<.001	--	--
42	10E15	1,920	S	1,864	30	Siltstone	--	3.45	--	--
					70	Siltstone	--	<.001	--	--
					88	Lyons coal	1,852	.8	--	--
					105	Siltstone-sandstone-siltstone	1,847	.98	--	--
					113	Siltstone	--	<.001	--	--
					133	Dorchester coal	1,831	1.2	--	--
					150	Siltstone	--	<.001	--	--
					170	Siltstone	1,822	.01	--	--
					190	Siltstone	1,805	.77	--	--
					210	Sandstone-siltstone contact	--	<.001	--	--
					226	Norton coal	1,821	.31	--	--
43	10E16	1,920	S	1,871	42	Sandstone-siltstone contact	--	18.9	--	--
					60	Sandstone-siltstone-sandstone	1,871	3	--	--
					75	Siltstone	--	<.001	--	--
					90	Lyons coal	1,859	.18	--	--
					115	Siltstone	--	<.001	--	--
					132	Dorchester coal	1,846	.11	--	--
					150	Siltstone	--	<.001	--	--
					170	Sandstone-siltstone contact	--	<.001	--	--
					190	Siltstone	--	<.001	--	--
					212	Sandstone-siltstone contact	--	<.001	--	--
					225	Norton coal	1,806	.14	--	--

Table 3. Lithologic descriptions, potentiometric heads, and transmissivities for test intervals in coal-exploration coreholes in the coal fields of southwestern Virginia—Continued

Corehole number	USGS local number	Altitude of land surface (feet above sea level)	Topographic setting	Altitude of standing water (feet above sea level)	Depth to top of test interval (feet below land surface)	Formation name or lithologic description	Potentiometric head (feet above sea level)	Transmissivity (feet square per day)		
								Constant-head injection test	Modified slug test	Standard slug test
44	9E9	2,420	S	2,288	82	Sandstone	--	<0.001	--	--
					110	Sandstone-shale-sandstone	--	<.04	--	--
					135	Sandstone-siltstone-sandstone	2,318	<.006	--	--
					159	Shale	2,288	36	--	--
					185	Siltstone	--	<.001	--	--
					213	Kelly coal	2,283	.42	--	--
					240	Sandstone	--	<.001	--	--
					280	Sandstone	--	<.001	--	--
					312	Imboden coal	2,269	.3	--	--
					335	Sandstone-siltstone contact	--	<.001	--	--
					351	Imboden marker coal	2,265	.17	--	--
45	11E12	1,800	V	1,790	80	Siltstone	1,790	>66	--	--
					125	Sandstone	--	<.001	--	--
					145	Kennedy coal	1,790	.05	--	--
					200	Sandstone-siltstone contact	--	<.001	--	--
					230	Siltstone	1,798	.07	--	--
					273	Aily coal	1,794	.04	--	--
					330	Siltstone	--	<.001	--	--
					369	Raven coal	1,775	.05	--	--
					410	Sandstone	--	<.001	--	--
46	11E13	2,000	S	1,950	85	Siltstone	--	<.001	--	--
					120	Siltstone-shale-siltstone	1,940	<.001	--	--
					210	Sandstone-siltstone contact	--	<.001	--	--
					310	Siltstone	--	<.001	--	--
					392	Kennedy coal	1,886	.04	--	--
					420	Sandstone	--	<.001	--	--
					470	Siltstone-sandstone contact	--	<.001	--	--
					500	Sandstone	--	<.001	--	--
					531	Aily coal	1,883	.03	--	--
					557	Sandstone-siltstone contact	--	<.001	--	--
					580	Siltstone	--	<.001	--	--
					628	Raven coal	1,846	.1	--	--
					660	Sandstone	--	<.001	--	--
47	17F1	2,820	S	2,653	100	Siltstone	--	<.001	--	--
					150	Lee coal	--	.12	--	--
					183	Shale-sandstone contact	2,654	.02	--	--

Table 3. Lithologic descriptions, potentiometric heads, and transmissivities for test intervals in coal-exploration coreholes in the coal fields of southwestern Virginia—Continued

Corehole number	USGS local number	Altitude of land surface (feet above sea level)	Topographic setting	Altitude of standing water (feet above sea level)	Depth to top of test interval (feet below land surface)	Formation name or lithologic description	Potentiometric head (feet above sea level)	Transmissivity (feet square per day)		
								Constant-head injection test	Modified slug test	Standard slug test
47—Continued					220	Sandstone	--	<0.001	--	--
					245	Castle coal	2,655	.6	--	--
					320	Siltstone	--	<.001	--	--
					358	Upper Seaboard coal	2,581	.05	--	--
					390	Sandstone	--	.02	--	--
					420	Siltstone	--	<.001	--	--
					440	Lower Seaboard 2 coal	2,574	.04	--	--
					451	Lower Seaboard 1 coal	2,568	.05	--	--
48	12F3	2,000	H	1,887	150	Lyons 1 coal	1,874	2	--	--
					165	Sandstone	--	<.001	--	--
					183	Sandstone-shale-sandstone	--	<.001	--	--
					203	Dorchester coal	1,848	.6	--	--
49	12F4	1,900	H	1,773	65	Sandstone-siltstone-sandstone	--	5.3	--	--
					85	Sandstone	--	29.2	--	--
					103	Sandstone-siltstone contact	--	3	--	--
					123	Sandstone-siltstone-sandstone	--	22	--	--
					140	Lyons 2 coal	1,770	2.1	--	--
					155	Lyons 1 coal	1,767	.7	--	--
50	12G2	1,840	H	1,571	135	Sandstone-siltstone contact	--	<.001	--	--
					165	Splashdam 2 coal	--	.4	--	--
					185	Splashdam 1 coal	--	<.04	--	--
					212	Sandstone-shale contact	--	<1.2	--	--
					240	Siltstone-sandstone contact	--	<.001	--	--
					270	Siltstone	--	<.001	--	--
					285	Sandstone-siltstone contact	--	<.001	--	--
					305	Sandstone with coal	1,577	<8	--	--
					325	Sandstone-siltstone contact	--	<.001	--	--
					360	Siltstone	--	<.001	--	--
					440	Kennedy coal	1,533	.25	--	--
					481	Siltstone-sandstone-siltstone	--	<.001	--	--

Table 3. Lithologic descriptions, potentiometric heads, and transmissivities for test intervals in coal-exploration coreholes in the coal fields of southwestern Virginia—Continued

Corehole number	USGS local number	Altitude of land surface (feet above sea level)	Topographic setting	Altitude of standing water (feet above sea level)	Depth to top of test interval (feet below land surface)	Formation name or lithologic description	Potentiometric head (feet above sea level)	Transmissivity (feet square per day)		
								Constant-head injection test	Modified slug test	Standard slug test
51	12G3	1,900	H	1,681	135	Hagy coal	--	8.9	--	--
					160	Sandstone	--	.09	--	--
					215	Siltstone	--	>59	--	--
					242	Splashdam coal	1,676	.96	--	--
					270	Sandstone	--	<.001	--	--
					320	Siltstone	--	<.001	--	--
					365	Sandstone	--	<.001	--	--
					420	Siltstone	--	<.001	--	--
					472	Siltstone	--	<.001	--	--
					500	Kennedy coal	1,585	.14	--	--
					535	Sandstone-siltstone contact	--	<.001	--	--
					580	Sandstone	--	<.001	--	--
52	15G18	2,160	S	1,713	280	Kennedy coal	--	.14	--	--
					320	Sandstone	--	<.001	--	--
					438	Sandstone	--	.33	--	--
					449	Raven 2 coal	--	<.001	--	--
					460	Sandstone	--	<.001	--	--
					490	Siltstone	--	<.001	--	--
					570	Siltstone	--	<.001	--	--