XIX. EXAMPLES OF GROUND-WATER INFORMATICS TO BE INCLUDED IN COAL-MINE PERMIT APPLICATIONS

Preface - MANDATORY READING

How does the applicant combine the various types of ground-water information presented in this manual, and listed below, to describe the geohydrologic conditions for the permit area? What are the formats for presenting the information suggested by the regulatory authority including:

- geologic map and cross sections
- driller's logs
- inventory of wells, springs, and streams
- potentiometric and water-table maps
- directions of ground-water flow
- water-level variations in aquifers
- aquifer test - drawdown, recovery, and slug test data
- low-flow stream data
- water-quality chemical results for ground water and streams
- ground-water pumpage information
- ground-water monitoring plan
- ground-water model and projected hydrologic impacts.

This chapter addresses these questions by demonstrating the use of maps, graphs, cross sections, and tables and interpreting the data. These examples supplement the illustrations and tables given in the previous chapters and are similar to documents prepared by the mining company, or its representative, to satisfy the requirements of the regulatory authority for the ground-water aspects of a permit application. The examples are taken from reports on geohydrologic investigations in several coal provinces of the United States; thus, the reader should infer NO relationship between the maps, graphs, cross sections, and tables of the various subunits unless so indicated.

The relationship between the tables and illustrations in this chapter, and other chapters, and the regulation categories and the ground-water investigation activities is shown in table XIX 1.1. The activities column includes the work tasks necessary to define the geologic and hydrologic settings (chapters IV and VI), the potential impacts of the proposed mining operation on the aquifer system(s) (chapter XIII), and the postmining hydrologic monitoring.

Note that strict adherence to the format of these examples DOES NOT GUARANTEE PERMIT APPROVAL by the regulatory authority because regulations differ among the States. Note also that the applicant need not adhere strictly to the size or formats illustrated in this chapter. (The maps and illustrations herein were scaled to publication size, and no attempt was made to address the map-scale requirements of the regulatory authorities.)

Table XIX 1.1 – Illustrations and tables that serve as examples to partially satisfy regulation requirements.
[F= figure; Fs= figures; T=table; Ts=Tables.]

Note: the chapter prefix number XIX has not been included in this table for simplicity, for example, fs.3.4,4.4 refer to figures XIX 3.4 and XIX 4.4; however, other chapter numbers have been included, for example , Ts.VII-2, 3.1 refer to tables VII-2 and Vi-3.1.

	REGULATION CATEGORIES						
GROUND-WATER INVESTIGATION ACTIVITIES (Presentations are in the form of figures and tables.)	Description of hydrology	Ground-water information	Surface-water Information as related to ground water	Alternative water-supply information	Cross sections, maps and plans	Protection of hydrologic balance	Operation plan
2. Geologic Setting							
Discussion of Geology and the Occurrence of Coal		f.3.4	f.3.4		fs.3.4,4.4		
Geologic Map and Cross Sections	fs.2.1,2.2				fs.2.1,2.2		
Driller's Log; Stratigraphic Col.	T.2.1				fs.VIII-1,2		
Structural Geology:					fs.X-3.0-2, X-3.0-4,		
Bedrock fractures(joints)					f.IV-7,		
Faults, fracture zones, and fracture traces					fs.XIV-2,3		
3. Hydrologic Setting							
Location, Climate, & Topography	fs.1.1,3.2,3.3	f.3.7					
Occurrence & Movement of Ground Water	f.4.4	T.3.2 f.3.7			f.3.2	T.3.2	
Well & Spring Inventory Table	T.3.1	Ts.VII-2,3.1		T.3.1		T.3.1	
Well & Spring Location Map					fs.VII-1,3.1		
Well Hydrograph		f.3.3				fs.XIII2-4,3.3	
Aquifer Test Information/Hydraulic Properties of Aquifer(s)		T.3.3			f.3.4	f.3.6	f.3.6
- graphical plot & tabulation of data	fs.4.1,4.4	f.3.5					
Base-Flow Discharge -tabulation & plotting of data		f.3.7	fs.3.7-3.9 Ts.3.4,3.5	f.VII-1	f.3.8	f.3.9 Ts.3.4,3.5	
Water Quality							
Ground water		Ts.VII-3,XII-2					
Surface water (base flow) - tabulation & plotting of data			T.XII-2 fs.3.8,XII-4				
Ground-Water Use		T.3.6		T.3.6	f.VII-1		
Ground-Water Monitoring Plan		Ts.IX-1,3.7 f.XIII 2-4			f.XIV-1	Ts.3.1, XIV-4,XIV-5	fs.XIII 2-4, XIV-1
4. Potential Impacts on Hydrologic System							
- Ground-Water Level Decline	fs.4.1-4.6	fs.4.1-4.6			fs.4.1-4.5	fs.4.1-4.6	
- Change in Ground-Water Storage and Modification of Ground Water-Surface Water Interrelationship					fs.XIII-3-1, XIII-3-2		
- Ground-Water Quality Modification					T.XIII-4-2 f.XIII-4-3		
- Overburden Analysis	f.4.7					f.4.7	f.4.7
5. Postmining Hydrologic Monitoring Ground-Water Monitoring plans	fs.5.2-5.4	fs.5.1-5.4			fs.5.1-5.4	fs.5.1,5.4	fs.5.1,5.4

1. INTRODUCTION

The following is selected information that might be included in the introduction chapter of a permit application describing the location of the permit site, the topography, and climate. (The emission of State designation is intentional to give the examples an apolitical unbiased presentation.)

Location

The proposed surface-mine permit area is in the James Fork watershed, which is tributary to the Polk River within Le Flore County and the Roosevelt coal field of the Interior coal province (fig. XIX 1.1). The permit area is also within the Drake gas field. The 96.4 acre tract is 0.6 miles east of the community of Williams and 0.4 miles north of James Pork, within section 14 of Township 1 North and Range 2 West.

Topography

The topography of the permit site is rolling as shown in the geologic map (fig. XIX 2.1) and the geologic sections (fig. XIX 2.2). The local relief within the adjacent area is less than 150 ft, and the area is characterized by narrow hogbacks, or ridges, and irregular hills generally capped with erosion-resistant sandstone. The broad valleys between the hogbacks have been formed by weathering and the erosion of the thick, easily eroded shales.

Climate

The climate in the coal field area is warm and temperate. Spring and autumn are usually mild, and summer is hot. Winter is comparatively mild, although an occasional outbreak of cold air keeps the temperature below freezing for about 7 days each year, on the average. Average annual precipitation ranges from 39 to 45 inches; an average of 35 percent of the year's total moisture falls in the spring, 27 percent in summer, 23 percent in autumn, and 15 percent in winter. January is the driest month, and May is the wettest. The hydrograph in the next section (fig. XIX 3.3) illustrates the correlation between rainfall and water level in an observation well in the permit area. Average annual lake evaporation is about 53 inches.

Much of the rainfall results from short-duration thunderstorms of varying intensity. Although such storms are most common in April, May, and June, they may occur any month of the year because of these storms are localized. Precipitation can vary significantly over short distances.

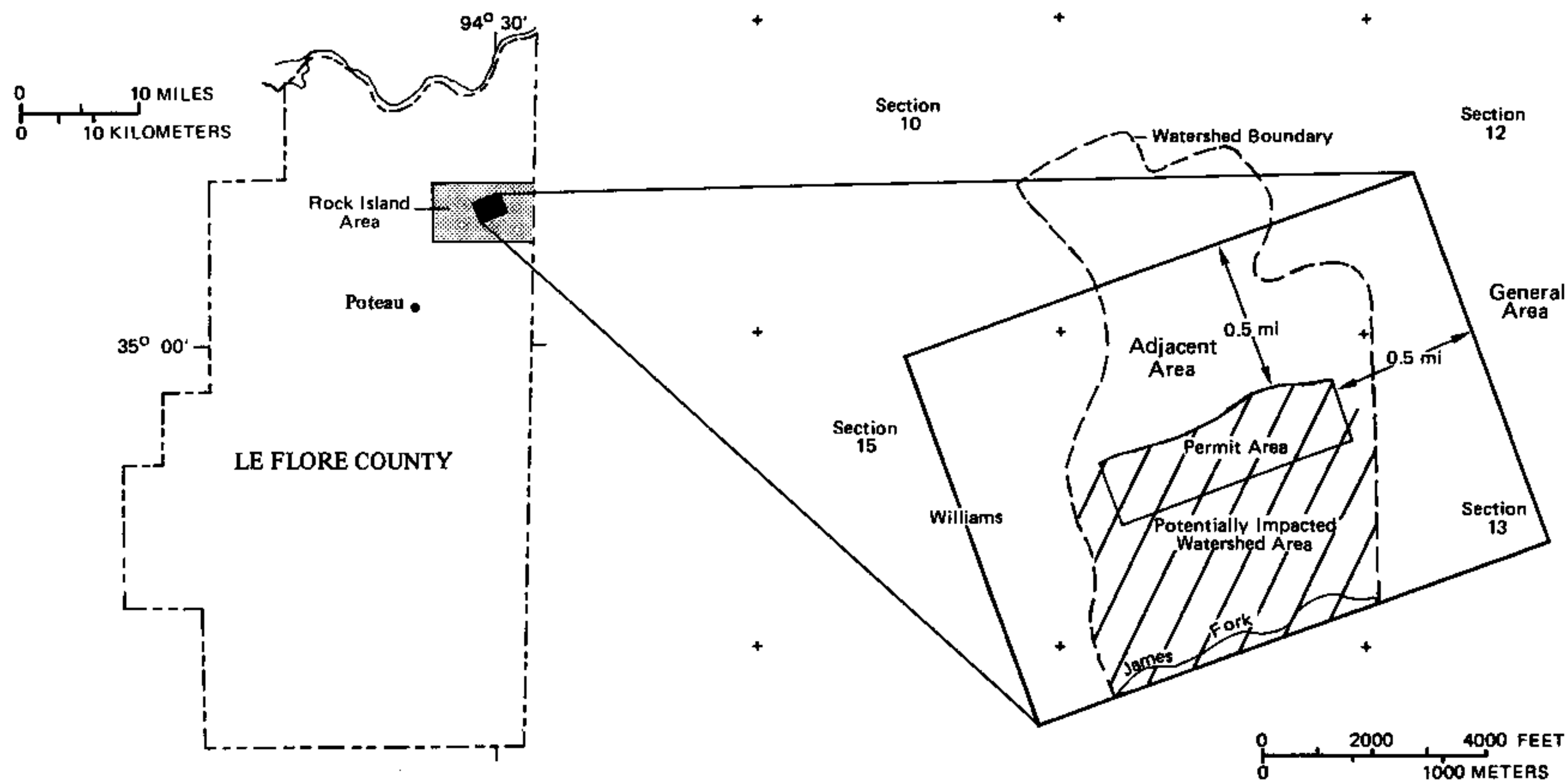


Figure XIX-1.1-1.—Example of permit-area location map.

2. GEOLOGIC SETTING

Geologic information on the general area was compiled from field mapping, log interpretation of the drill/core holes from the exploratory program, water-well information, and results of a geologic literature search.

Bedrock in the general area consists of interbedded siltstone, shale, and sandstone units of the McAlester, Hartshorne, and Atoka Formations (fig. XIX 2.1). About 70 percent of the bedrock is shale and siltstone. The Hartshone coal beds occur in the Hartshorne Formation, vary in thickness from 2 to 4 ft, and have potential for surface mining.

The permit area lies on the southern flank of the east-west-trending Backbone anticline, which is broken along its crest 1.8 mi. north of the permit area by the Backbone thrust fault. The rock layers dip to the south. The dip steepens from 5° to 10° near James Fork to 35° to 45° along the crest of Backbone Mountain. The dip of the Hartshorne coal is probably 10° to 15°, as inferred from measurements on the underlying Hartshorne sandstone, shown in the geologic cross sections in figure XIX 2.2. Bedrock fractures parallel and across the bedding and were formed during formation of the anticlinal structure. The depth of the weathered rock is variable and is saturated. Fractures beneath this weathered zone are the major source of ground water to springs and wells. Layers of sandstone are silty, fine grained, and cemented with silica and iron oxide.

The alluvium along James Fork may be as much as 30 ft thick, is absent along some of the reaches, where the stream flows directly on bedrock. The upper part of the alluvium consists of sandy and clayey silt; and the lower part may include beds of silty sand. James Fork in the general area is a gaining stream, that is, the low flow of James Fork is predominantly ground-water discharge.

The geologic setting of the permit area is classified as GS-4 because of the gently dipping (10° to 15°) sedimentary strata, as shown in figure XIX 2.2. Surface mining will proceed until the height of the high wall is about 150 ft. The mining operation will then proceed parallel to the strike of the outcrop.

Exploratory drill hole 17 was drilled in T 1N R 2W section 14 SE¼; the log is presented in table XIX 2.1. This log and other geologic information indicates that the shale beds confine the sandstone aquifer of the Hartshorne Formation. However, the thickness of the shale and siltstone beds are probably insufficient to prevent ground-water discharge into the proposed excavation. (A preliminary estimate of the hydrologic-setting classification for the coal bed is F(l), where the coal bed will act as a confined aquifer since it is probably in hydraulic connection with the underlying confined sandstone aquifer.)

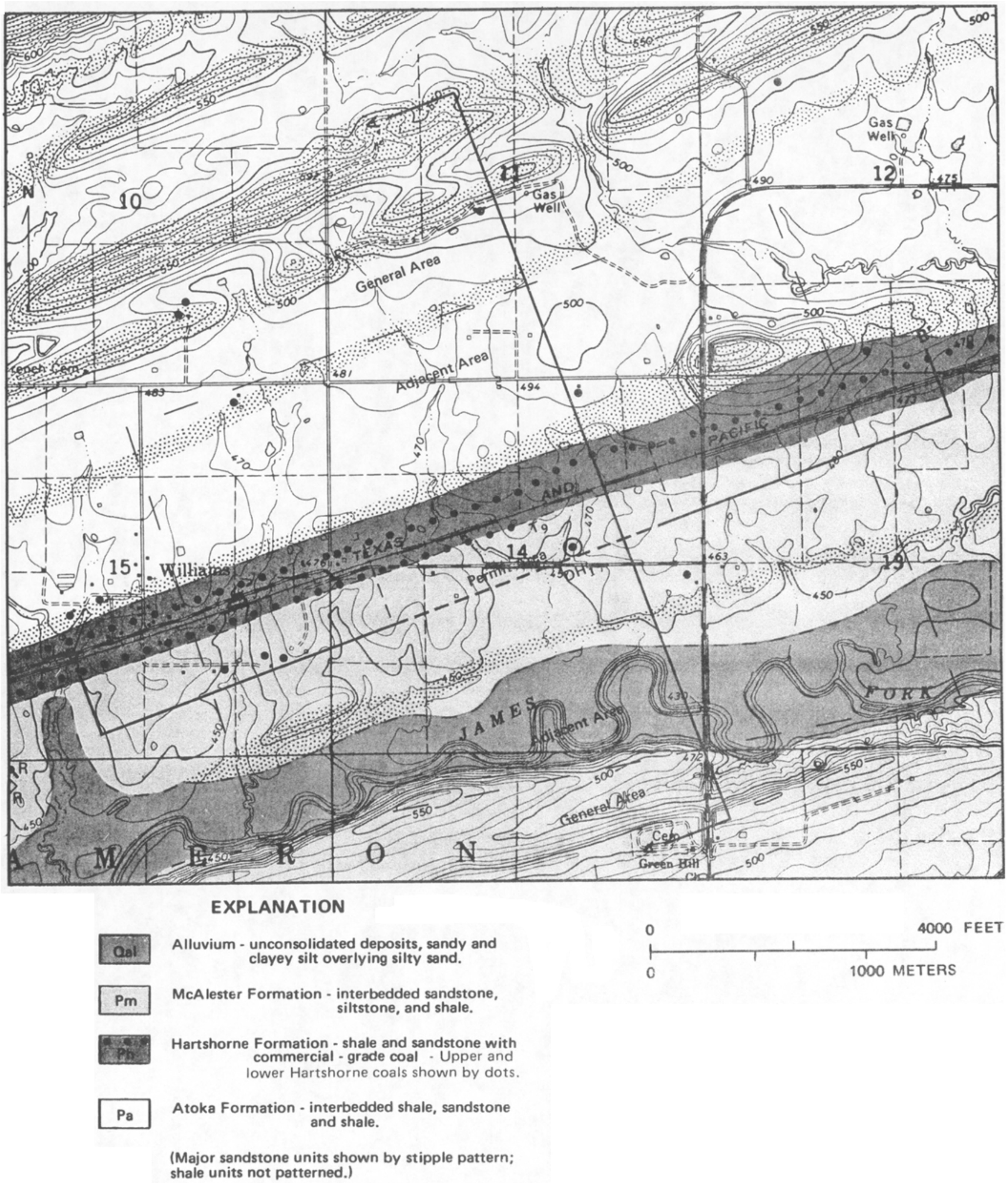


Figure XIX-2.1.— Example of geologic map of permit area, adjacent area, and general area. (Modified from Marcher and others, 1983, pl. 1)

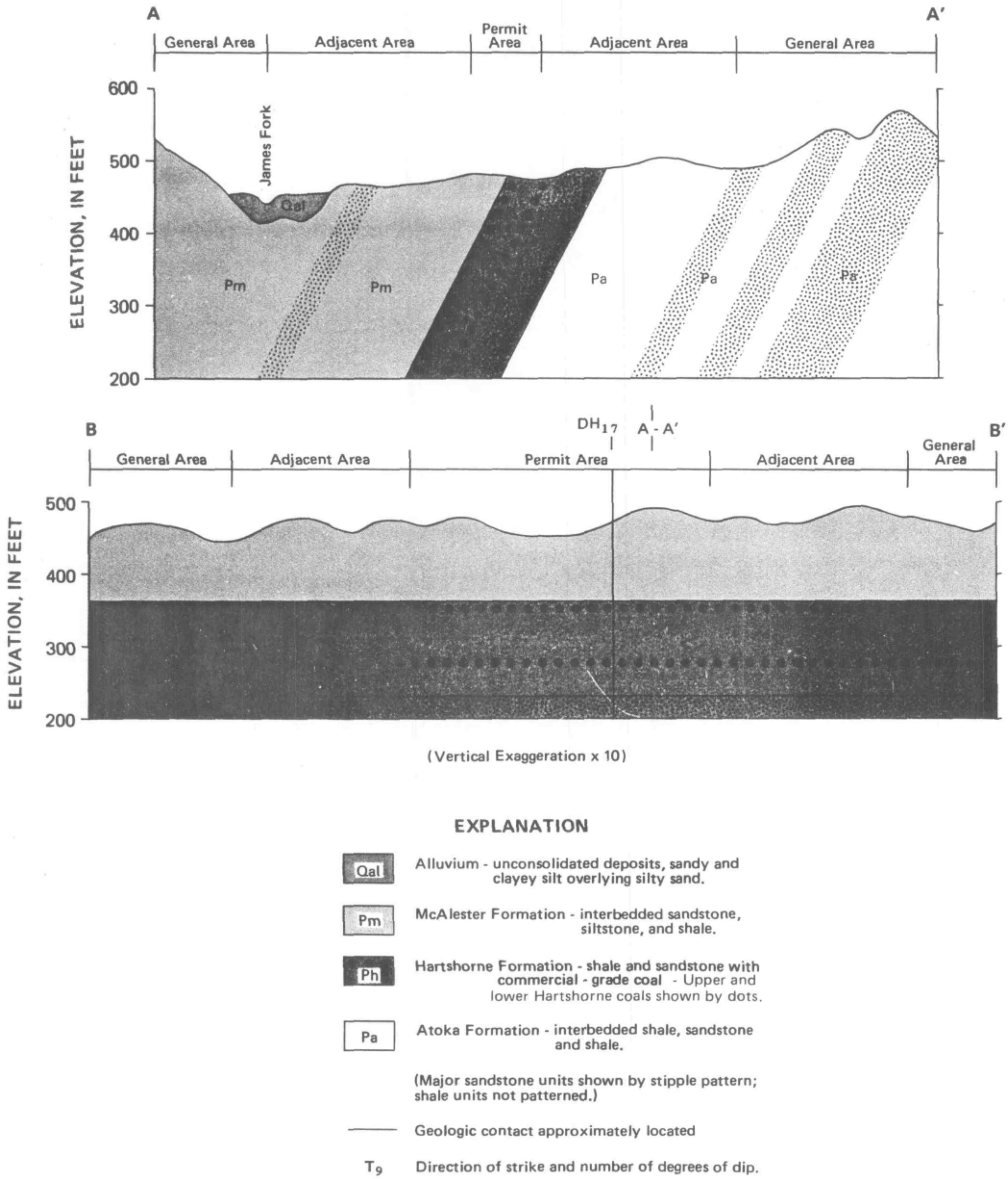


Figure XIX-2.2.— Example of geologic sections through permit area, adjacent area, and general area. (locations are shown in fig. XIX-2.1.)

Table XIX 2.1 - Drillers log of drill hole 17 (DH 17).
(From Marcher, U.S. Geological Survey, 1981, personal communication.)

[ft, feet.]

Latitude:42°42'42"	Aquifer: Hartshorne Formation
Longitude: 100°00'100"	Date Drilled: August 20, 1965
Land-surface altitude(LSD): 461 ft	Well Depth: 277.0 ft
Depth to water below LSD and date of measurement:	10 ft (October 4, 1965)

Lithologic description	Thickness (ft)	Depth (ft)
McAlester Formation		
Shale, decomposed to very intensely weathered	7.5	7.5
(saturated material at base of weathered zone) (no sample)	4.5	12.0
Shale, clayey, 10 to 20 percent silty interbeds	76.7	88.7
Siltstone, 25-35 percent shale interbeds	15.2	103.9
Hartshorne Formation		
Shale, carbonaceous, silty to clayey	11.9	115.8
Siltstone, 25 percent interbedded clayey shale	22.7	138.5
Shale, carbonaceous	0.7	139.2
Siltstone, 25 percent interbedded clayey shale.	52.2	191.4
Shale, carbonaceous	0.4	191.8
Coal	2.7	194.5
Shale, carbonaceous	0.9	195.4
Siltstone, 25 percent interbedded clayey shale	2.7	197.2
Sandstone, fine-grained, 20-30 percent fine grained silty shale. (water encountered during interval 198 to 230 feet and rose to 10 feet below land surface)	31.9	229.1
Shale, silty,20-30 percent fine grained sandstone	22.7	251.8
Sandstone, fine-grained, 5 percent shale	12.1	263.9
Shale, silty, 20-30 percent fine grained sandstone	13.1	277.0

3. HYDROLOGIC SETTING

Ground-Water Hydrologic Data Inventory

For a geographic area that is different than the area shown on figures XIX 2.1 and 2.2, well and spring inventory information were provided by the State Engineer's Office, from the drillers' water well completion reports, by the U.S. Geological Survey, by the State Geological Survey, and by the State Department of Health. Part of these reported data are shown in table XIX 3.1. Other wells within the permit area and general area ware visited and included table XIX 3.1. This table contains information necessary to define the premining hydrologic conditions, such as well depth, depth to water, driller's test well yield, duration of test, specific capacity, length of well casing, and aquifer(s) providing water supply. Other types of well information available on the government completion reports (not included in table XIX 3.1) include latitude and longitude, screened intervals, drilling method, topographic setting, driller's log, minor aquifer(s), depth to bedrock, and depth and yield of individual water-bearing zones.

Wells referred to in table XIX 3.1 are plotted on a planimetric map (fig. XIX 3.1), which also shows the locations of springs, test holes, the permit area, and the surface-water sources (creeks, lakes and reservoirs).

Integrating the ground-water information with the geologic formation information yields a definition of the aquifer groups and the confining beds, such as depicted as a stratigraphic section in figure VIII-2. The upper (first) aquifer group is the bedrock overlying the Lower Freeport coal, which is beneath the hilltops; the second aquifer group is between the Lower Freeport coal and the confining bed (the Logan Formation); and, the third aquifer group is the Black Hand Sandstone Member of the Cuyahoga Formation.

The specific capacity values given in table XIX 3.1 indicate a wide range of water-yielding capability within the aquifer groups. The unconsolidated deposits of the Quaternary alluvium has the greatest ground-water availability, however.

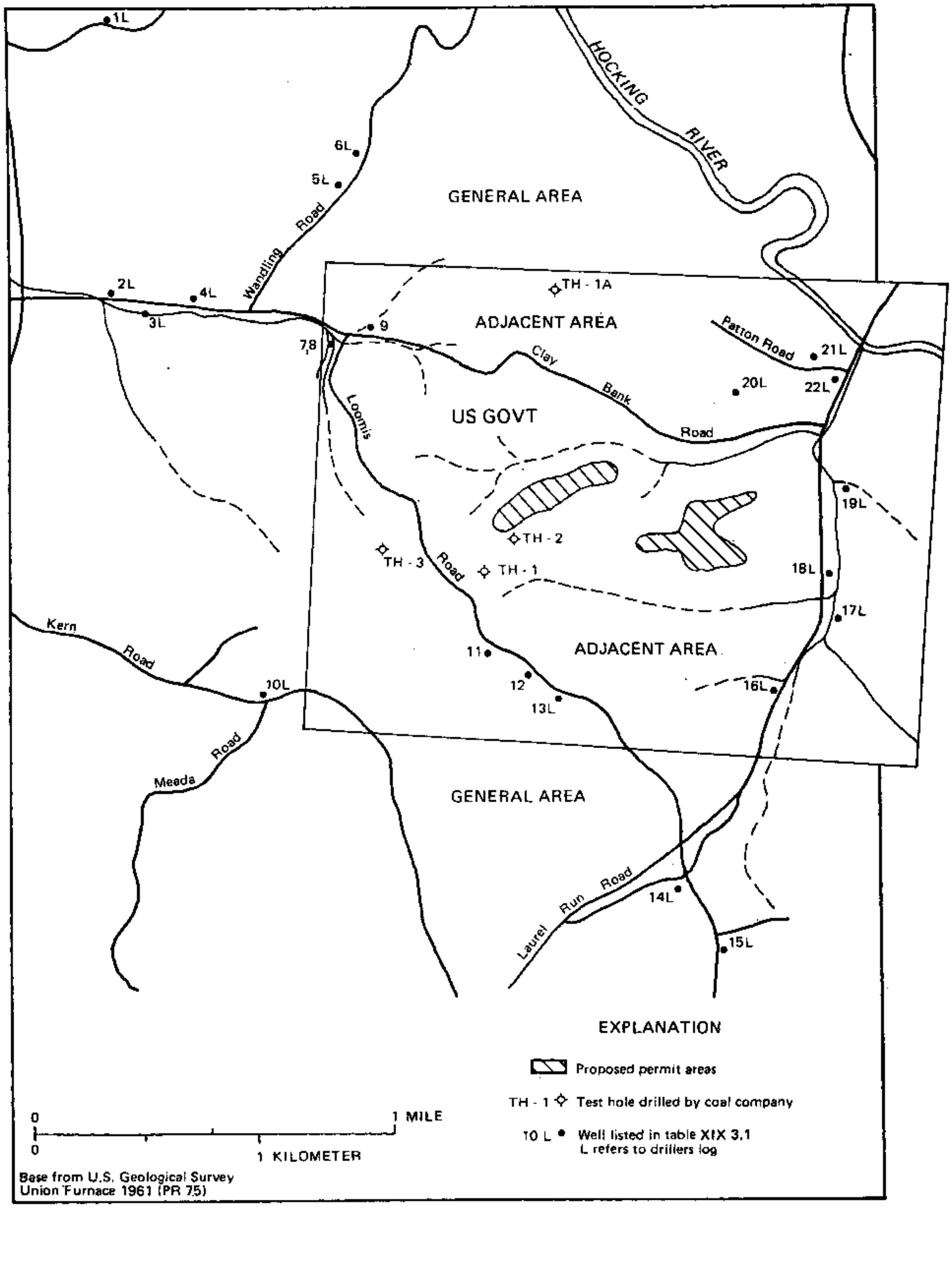


Figure XIX-3.1.— Example of planimetric map showing locations of inventoried wells, test toles, streams, roads, and proposed permit area. (Modified from Norris, 1981, p. 25)

Table XIX 3.1 – Example of records of representative wells in and near the permit area. (Modified from Norris, 1981, table 1)

[ft, feet; gal/min, gallons per minute; Qal, Quaternary alluvium; *, water-quality sample analyzed; —, no data.]
[Well locations are shown on figure XIX 3.1. Suffix 'L' after well number refers to the driller's log in Appendix of Morris reference.]

Well number	Owner	Altitude of land surface (ft)	Depth of well (ft)	Aquifer group (See fig. VIII-2)	Date drilled (month, day, year)	Well yield (gal/min)	Specific capacity (gal/min per ft of drawdown)	Duration of driller's test (hours)	Depth to water (ft)	Date of measure-ment	Length of casing
1 L	United Presbyterian Church	905	497	3	5-20-72	10	0.022	3	290		297
2 L *	Owen Peck	760	253	3	2-19-76	5	.067	2	51	4-10-79	67
3 L	Paul Bentley	760	250	3	5-30-64	1.3	—	0.5	48		57
4 L	Franklin Cherry	760	200	2	11-14-59	.5	.002	—	12		30
5 L *	William Snyder	960	68	2	7- 6-60	4	—	—	52		29
6 L	W. J. Reams	1005	47	1	8-18-60	20	1.3	2	20		24
7 *	Carl Loomis	810	200	2	49	.5	—	—	83	4-10-79	21
8 *	Carl Loomis	810	205	2	76	1.5	—	—	50	4-10-79	45
9	Hazel Michel	820	240	2	—	—	—	—	—		—
10 L	Roger Campbell	1020	442	2	9-11-72	3	—	—	—		143
11 *	Willard Sowers	1010	36	1	—	—	—	—	13.5	4-30-79	—
12	unknown	1045	565	3	—	—	—	—	—		—
13 L *	Max Malone	985	535	3	—	—	—	—	—		—
14 L	Leonard Dickerson	990	61	1	6-23-65	30	.70	.5	18		35
15 L	Mary Woodyard	1040	150	2	10- 2-68	2	—	—	40		40
16 L	William Seal	780	94	2	12-23-72	70	7.0	24	31.7	4-24-79	50
17	C. J. Baumgardner	660	49	Qal	—	—	—	—	4	4-24-79	49
18 L	Mrs. Hairy Todd	750	157	2	6-26-67	3.5	.026	—	20		40
19 L	Charles Wood	745	125	2	1- 5-65	—	—	—	28		30
20 L	Robert Price	790	27	Qal	5-24-78	10	.45	1	5		27
21 L	Claude Brandon	915	46	Qal	5-31-66	25	.83	1	1		46
22 L *	Richard Ansel	695	34	Qal	5-24-78	2	.20	2	12	4-24-79	36

Determination of Hydrologic Setting (s)

In reference to the permit area shown in figures XIX 1.1, 2.1, and 2.2, ground water is under water-table conditions in the shallow (less than 10 ft) weathered bedrock zone and is artesian in the Hartshorne sandstone. Below the weathered zone, the interbedded shale and siltstone of the McAlester Formation and within the Hartshorne Formation are the confining beds that restrict recharge to the Hartshorne sandstone. The saturated thickness of the weathered zone is generally thin and locally variable and is an insignificant factor in the water resources of the area. Domestic pumpage in the area surrounding the proposed permit area is from the Hartshorne sandstone aquifer and from the alluvium of the James Fork. Recent water-levels in the Hartshorne sandstone aquifer within the area are given in table XIX 3.2. Artesian pressure causes water levels in the wells tapping this bedrock unit to rise; the water level in most of the area is less than 20 ft below land surface. A few wells in favorable topographic locations have artesian flow during part of the year; wells have to be "shut in." A potentiometric map shaving the water surface of the confined aquifer, by means of contour lines, is shown in figure XIX 3.2. The general direction of ground-water flow in the sandstone aquifer is from north to south toward James Fork.

About 60 percent of the precipitation in this area falls during spring and sunnier, but water level measurements show that little recharge takes place at that time because most of the water is lost by evapotranspiration before it can reach the saturated zone. The observation-well hydrograph in figure XIX 3.3 indicates that the ground-water level is lowest in autumn or winter and is highest in early spring.

The determination of the hydrologic-setting of the permit area depends upon the position of the coal bed(s) to be mined relative to the aquifer(s), the thickness and impermeability of the confining beds, and the ground-water flow conditions in the aquifer(s). The hydrologic-setting classification could be:

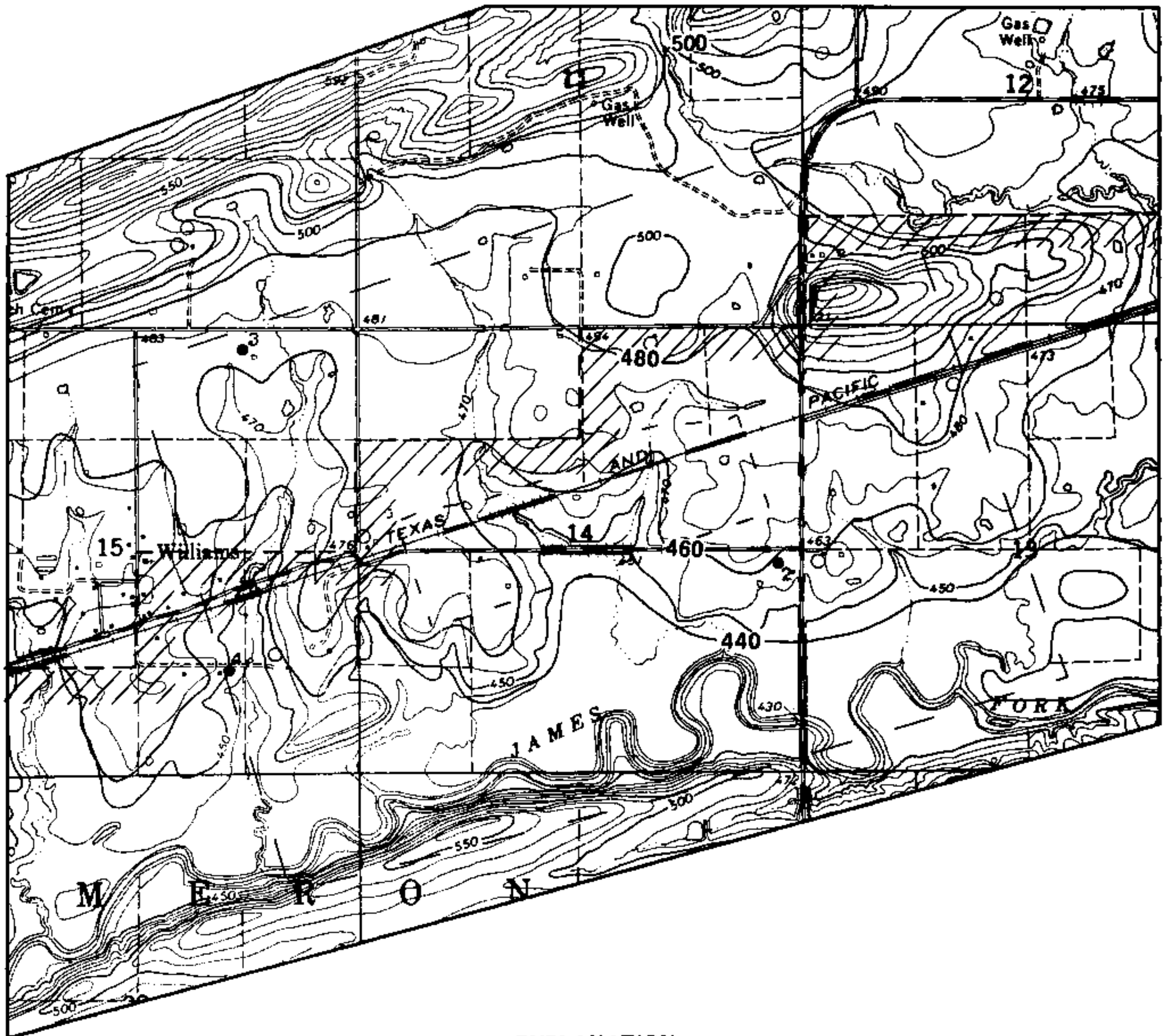
(a) HS-E, where the coal bed at the outcrop is in contact with weathered bedrock and is under water-table conditions;

(b) HS-B(2), where the coal bed(s) are separated from the confined aquifer by impermeable shale and siltstone beds, and the excavation would be dry; or

(c) HS-D, where the coal bed(s) are in hydraulic contact with the sandstone aquifer (figs. XIX 2.1, 2.2), via thin shale beds and bedrock fractures, and the excavation would be wet; or

(d) HS-F(l), where the coal bed(s) are aquifers owing to the fracture permeability and the infiltration of ground water from the coal outcrop area. Here the excavation would be wet.

The amount of ground-water infiltration into the excavation depends upon the hydraulic properties of the aquifer(s).



EXPLANATION

— 400 — Approximate potentiometric contour - Shows altitude at which water levels would have stood in tightly cased wells (1976). Contour interval 20 feet. Datum is sea level.

○ Well - See table 1 of Marcher and others, 1983.

Observation well equipped with a recorder. - D, discontinued

●2 Well for which a chemical analysis of the water has been made. Number refers to trilinear diagram.

Drill hole and number

Area of federally - owned coal

Figure XIX-3.2.— Example of potentiometric map and location of data-collection sites within the permit area, adjacent area, and general area. (Modified from Marcher and others, 1983, pl. 2)

Table XIX 3.2– Sample compilation of water-level elevations of wells within the permit and surrounding areas, February, 1978.
(Modified from Marcher and others, 1983)

[ft, feet; —, no data; Pa, Pennsylvanian Atoka Formation; Ph, Pennsylvanian Hartshorne Formation; Pm. Pennsylvanian McAlester Formation.]

Well no.	Location (township, range, section, ¼¼¼*)	Aquifer	Well depth (ft)	Land-surface elevation (LSE) (ft above sea level)	Depth to water below LSE (ft)	Water-surf ace elevation (above sea level)
**	T 1N R 2W sec. 10 SESWNW1	Pa	27	510	10.1	500
**	T 1N R 2W sec. 10 SESWNW2	Pa	102	521	1.0	520
**	T 1N R 2W sec. 11 SWNENE	Pa	56	525	14.4	511
**	T 1N R 2W sec. 12 NWSWSW	Pa	—	505	3.8	501
1	T 1N R 2W sec. 12 NWNWSE	Pa	80	502	flowing	502+
**	T 1N R 2W sec. 12 SWSESE	Pa	—	490	5.3	485
**	T 1N R 2W sec. 13 NWNESW	Ph	—	490	flowing	490+
**	T 1N R 2W sec. 13 SWNWNW	Pm	—	470	15.3	455
**	T 1N R 2W sec. 14 NENWNE	Pa	—	492	10.0	482
**	T 1N R 2W sec. 14 NESWSE	Ph	277	461	0.9	460
**	T 1N R 2W sec. 14 NWSWSW	Ph	106	476	11.1	465
**	T 1N R 2W sec. 14 SWNWNW	Ph	106	465	8.4	457
2	T 1N R 2W sec. 14 SENENE	Pm	62	465	7.2	458
3	T 1N R 2W sec. 15 NENWNE	Pa	89	473	10.9	462
**	T 1N R 2W sec. 15 SWNENE	Pa	70	455	13.3	442
**	T 1N R 2W sec. 15 SWNESW	Ph	166	450	12.2	438
4	T 1N R 2W sec. 15 SESWNE	Ph	109	449	12.1	437
**	T 1N R 2W sec. 15 SENESW	Ph	125	447	8.0	439
**	T 1N R 2W sec. 22 NWNWNW1	Pm	78	458	15.8	442
5	T 1N R 2W sec. 22 NWNWNW2	Pm	40	459	16.1	443

* read in the standard U. S. Bureau of Land Management's system of land subdivision: quarter-quarter-quarter section (located to the nearest 10 acres); for example, the well in section 13 NWNE9W is located in the northwest-quarter section, and in the northeast-quarter of this 160 acres, and in the southwest-quarter of this 40 acres.

** wells shown in figure XIX 3.2 (potentiometric map), but with no assigned number.

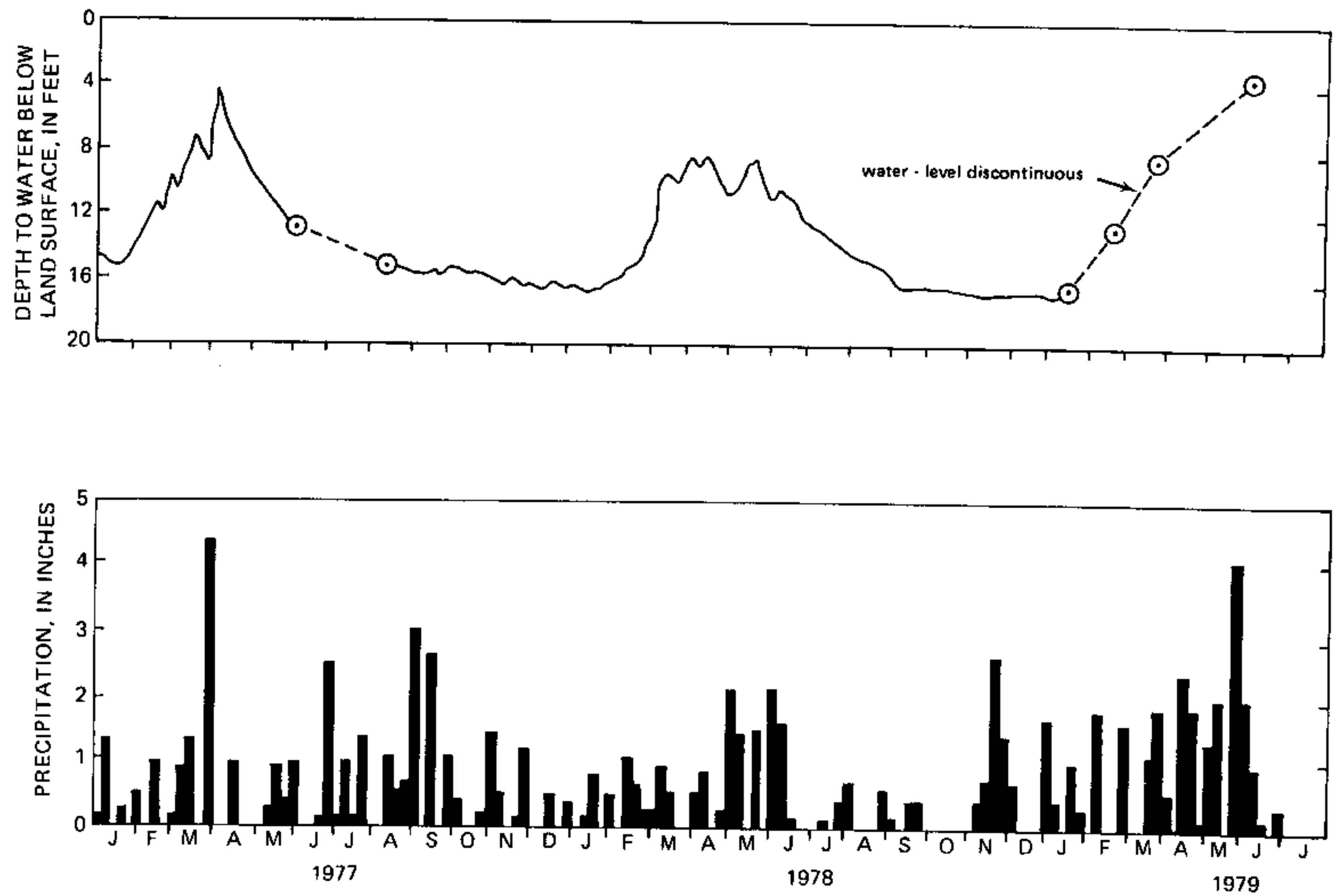


Figure XIX-3.3.— Example of water-level hydrograph of well (08N-26E-22 BBB 2) as related to precipitation.
(From Marcher and others, 1983, fig. 2)

Aquifer-Test Results

The initial hydrologic setting classification during the surface mining operation was HS-E, where the coal bed is saturated and in contact with the water-table aquifer of weathered McAlester Formation (figure XIX 3.2). After excavation of the overburden, the ground-water discharge from the weathered zone into the excavation will diminish significantly. With the unfractured bedrock formations, the hydrologic setting is possibly HS-D.

The rate of ground-water discharge into the excavation is controlled by the hydraulic properties of the aquifer units—transmissivity (T), storativity (S), and hydraulic conductivity (K). The hydrologic consequences of the dewatering are a lowering of the water table and potentiometric surface. The rate and extent of drawdown can be predicted after the aquifer properties have been calculated.

A pumping test on the Hartshorne sandstone aquifer was done at a flowing well that was converted from an exploratory core hole. Perforated casing was installed in the bottom 68 ft of the hole, which taps a sandstone aquifer, as shown on figure XIX 3.4. The constant-drawdown analysis of Jacob and Lohman (1952) was used, where discharge varies with time. This analysis can be used for testing period where the function u is less than or equal to 0.01. When the naturally flowing well has been 'shut in' for a sufficient time to represent equilibrium ground-water conditions, it is opened for a time during which flow-rate measurements are made at specified time intervals. The assumptions are that the aquifer is homogeneous, isotropic, and extensive laterally and that T and S are constant at all times and places. (Additional information on the method is available from Lohman, 1972, p. 23, and U.S. Department of Interior, 1981, p. 130.)

The pumping test data are listed in table XIX 3.3; the data plot and calculations are presented in figure XIX 3.5. Using equation X-2.3-2, table X-2.3-2, and given the T and S results, the u test, for the valid time period (t), is

$$t = \frac{r^2\ S}{4\ \ Tu} = \frac{7.48\ (0.49)^2}{4\ \ (1800)}\ \frac{(0.002)(1440)}{(0.01)} = 0.07 \text{ minutes} \qquad \text{XIX-1}$$

Thus, the aquifer test is valid for the testing period greater than 0.07 minutes.

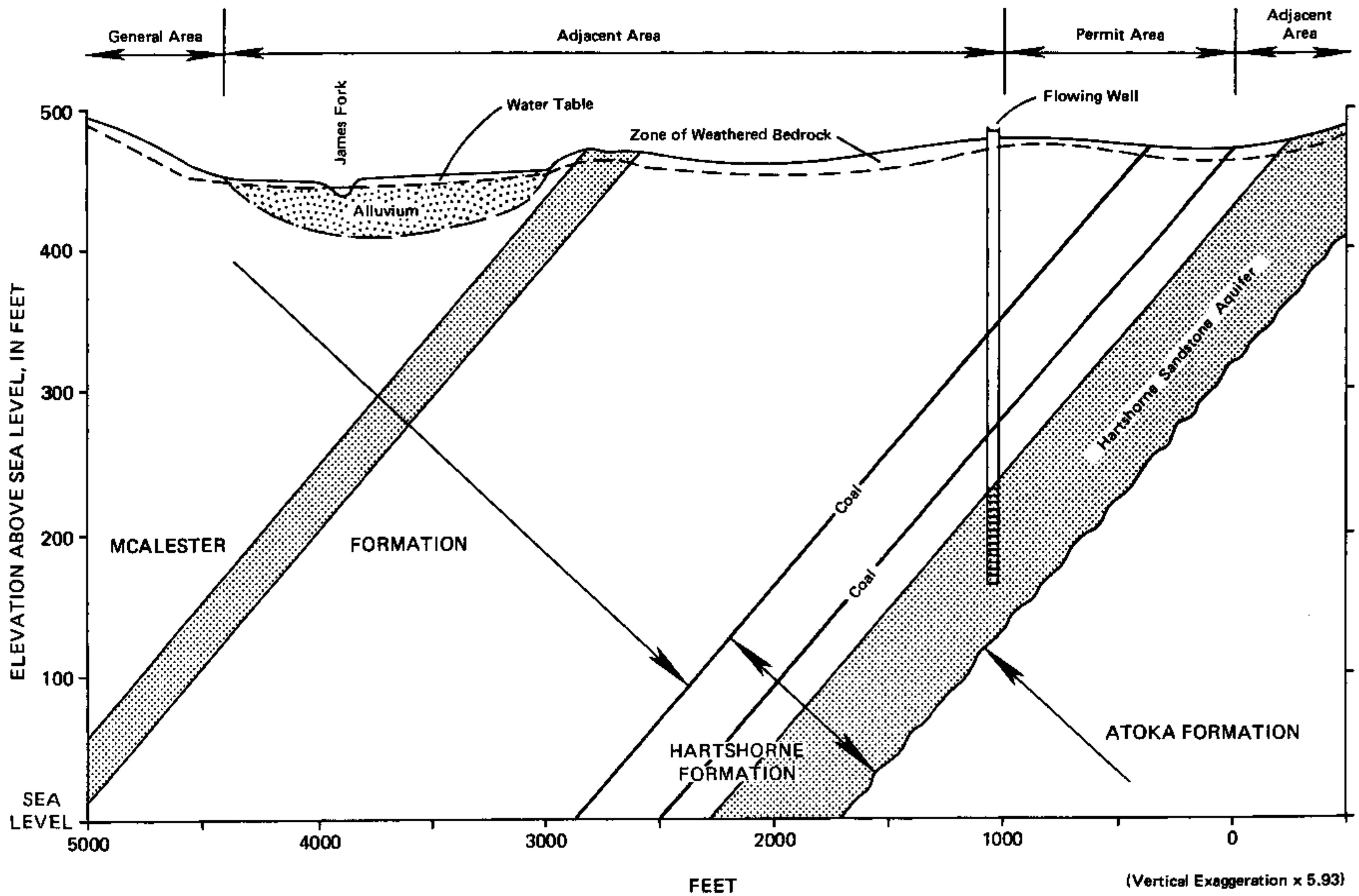


Figure XIX-3.4.— Example of geologic section through proposed permit area and vicinity showing location of flowing-well aquifer test.

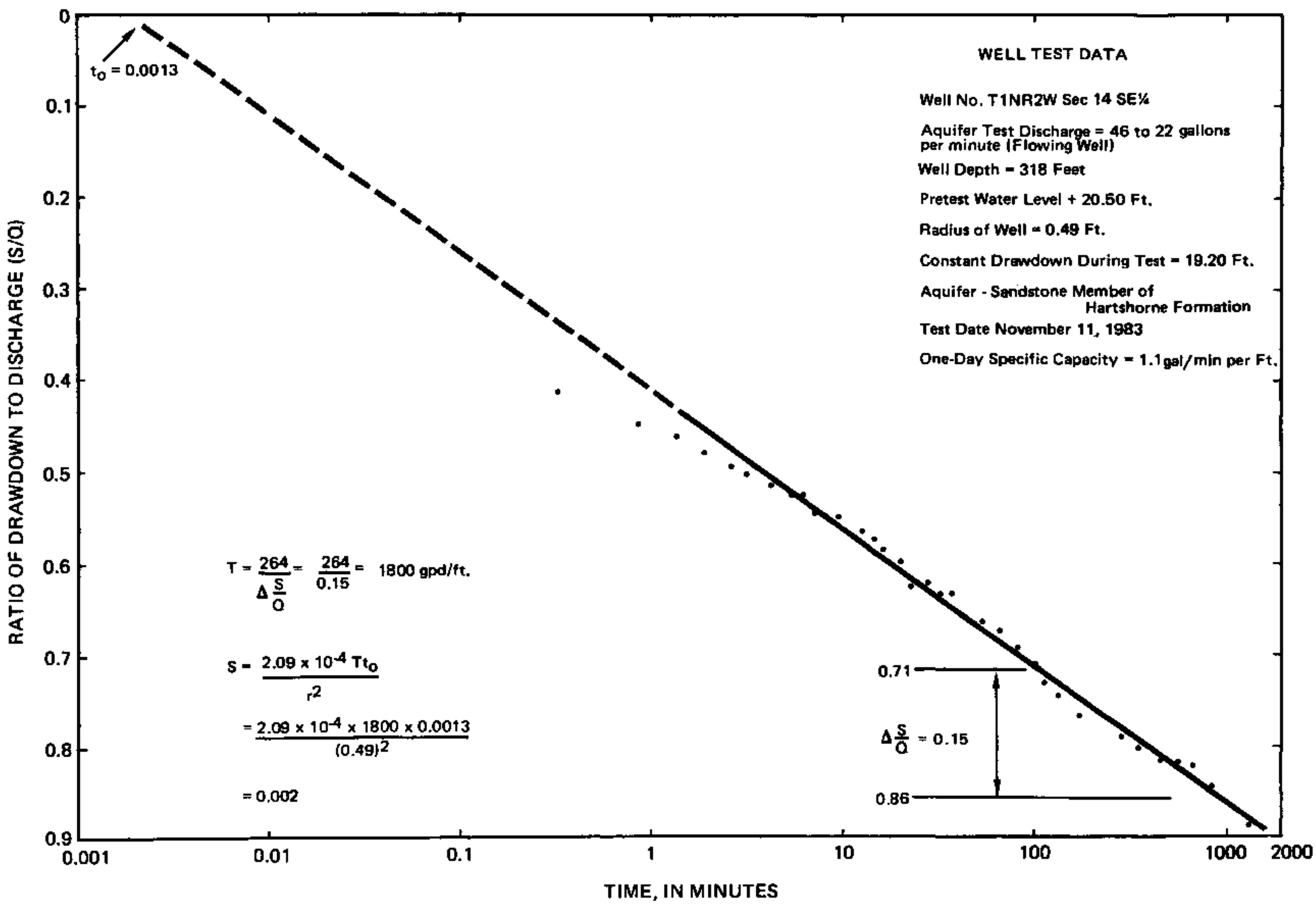


Figure X3X-3.5.— Semilogarithmic plot of s/Q versus time and analysis of constant-drawdown confined-aquifer test. (Modified from Wilson, 1965, p. 61)

The hydraulic properties determined from this testing can provide an estimate of the extent of the dewatered part of the aquifer. Drawdowns (s) at specific distances (r) from pumping wells and for specific periods of time (t) can be calculated from equations X-2.3-1 and X-2.3-2, but using "ordinary Survey units" (Ferris and others, 1962, p. 93), which are equations:

$$u = 1.87 \frac{r^2 S}{T t} \quad \text{and} \quad s = \frac{H4.6\, Q}{T} W(u)$$

where the terms are defined in table X-2.3-2 but have the following units:

s in feet; Q in gallons per minute; T in gallons per day per foot;
r in feet; S as a decimal fraction; and t in days since pumping started.

A plot showing the decrease in drawdown with distance from the well and the increase in drawdown after pumping for 1 month, 6 months, 1 year, and 10 years at a well discharge of 10 gal/min in an aquifer of T = 1,800 (gal/d)/ft and S = 0.002 is given in figure XIX 3.6. Drawdown is directly related to pumping rate. For example, the drawdown 1 mile from a well pumping 15 gal/min in an aquifer of T = 1,800 (gal/d)/ft and S = 0.002 for 1 year would be 1.5 times 1.0 ft (from the graph) and is estimated to be 1.5 ft. Graphs such as this are based on several assumptions (besides the homogeneous and isotropic characteristics); namely that pumpage is constant for the year, no recharge from rainfall reaches the aquifer, and no hydrologic boundaries are intersected by the cone of depression. Considering how poorly these are assumtptions are met in real time, use of graph interpretation requires caution.

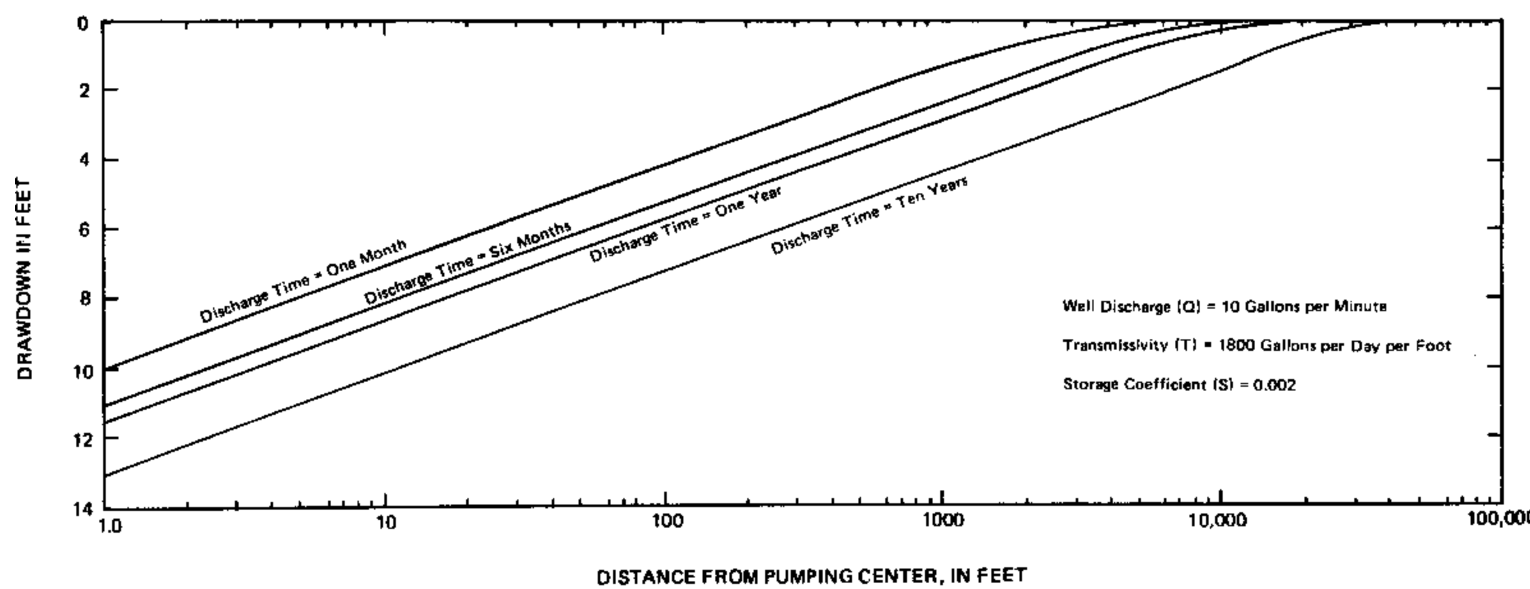


Figure XIX-3.6.—Relationship between drawdown and distance from pumping after selected time periods at constant pumping rate.

Table XIX 3.3– Example of constant-drawdown aquifer-test data. (Data in part from Wilson, 1965, p. 61.)

[ft, feet; min, minute; gal/min, gallons per minute; Valve opened at 6:00:00 a.m. Constant drawdown during test = 19. 20 ft]

Time of observation	Time interval (min)	Measured rate of flow (gal/min)	Time since flow started (min)	(s/Q) (ft/ (gal/min))
Day 1				
6:00:00a.m	0.00	0	0	—
6:00:20	.33	46.0	.33	0.417
6:00:52	.53	42.5	.86	.452
6:01:21	.49	41.4	1.35	.463
6:01:54	.55	39.8	1.9	.483
6:02:30	.6	38.6	2.5	.497
6:03:00	.5	38.2	3.0	.502
6:04:12	1.2	37.4	4.2	.514
6:05:12	1.0	36.6	5.2	.525
6:06	.8	36.5	6.0	.526
6:07	1	35.2	7.0	.546
6:08	1	34.9	8.0	.550
6:09	1	34.8	9.0	.552
6:10	1	34.2	10	.562
6:12	2	34.1	12	.563
6:14	2	33.6	14	.572
6:16	2	32.8	16	.585
6:19	3	32.1	19	.598
6:22	3	31.0	22	.620
6:26	4	30.9	27	.621
6:30	4	30.5	30	.630
6:35	5	30.4	35	.630
6:40	5	29.5	40	.651
6:50	10	29.1	50	.660
7:00	10	28.6	60	.670
7:15	15	28.0	75	.685
7:30	15	27.3	90	.703
7:45	15	27.0	105	.710
8:00	15	26.0	120	.738
8:30	30	25.2	150	.760
9:20	50	25.5	200	.752
10:10	50	24.6	250	.780
11:00	50	24.3	300	.791
1:40p.m.	100	23.9	400	.802

Base-Flow Discharge Determination

For the permit area presented in figure XIX 3.1, the topography of the proposed surface-mine permit site consists of deeply incised valleys separating narrow, flat-topped ridges. Drainage is by short streams tributary to the Hocking River. The upper reaches of these streams are ephemeral and have been affected by previous surface mining; the lower reaches are perennial and sustained by base flow from the second aquifer group (fig. VIII-2). This flow is somewhat modified by infiltration of ground-water from the upper (first) aquifer group through the spoils of the reclaimed-mine area. The topography, stream-drainage network, and directions of ground-water flow are shown in figure XIX 3.7; the drainage-basin boundaries and their respective drainage areas are delineated in figure XIX 3.8. No stream-gaging stations are within the general area.

The geologic-setting category of the permit area under discussion (figs. XIX 3.1, 3.7, and 3.8) is GS-1, where the Lower Freeport coal is flat lying. The hydrologic settings are HS-B(2) and HS-B(3) where the coalbed is dry and separated from the overlying first aquifer group (water-table aquifer) and the underlying second aquifer group (confined aquifer) by shale beds. Ground water from the first aquifer group will discharge into the excavation pits.

The base-flow term used in this mine permit application will be the 7 day-10 year discharge ($Q_{7,10}$) which is defined as the average minimum stream discharge for a period of 7 consecutive days that would occur, on the average, once in 10 years. Thus, the probability of this low flow occurring in a year's time is 0.1 or 10 percent.

Techniques of hydrologic analysis allow the transfer of base-flow data from distant gaging stations to ungaged stream locations if the drainage-basin characteristics of the gaged and ungaged basin are similar. These characteristics include geology, topography, vegetation, and size of drainage area.

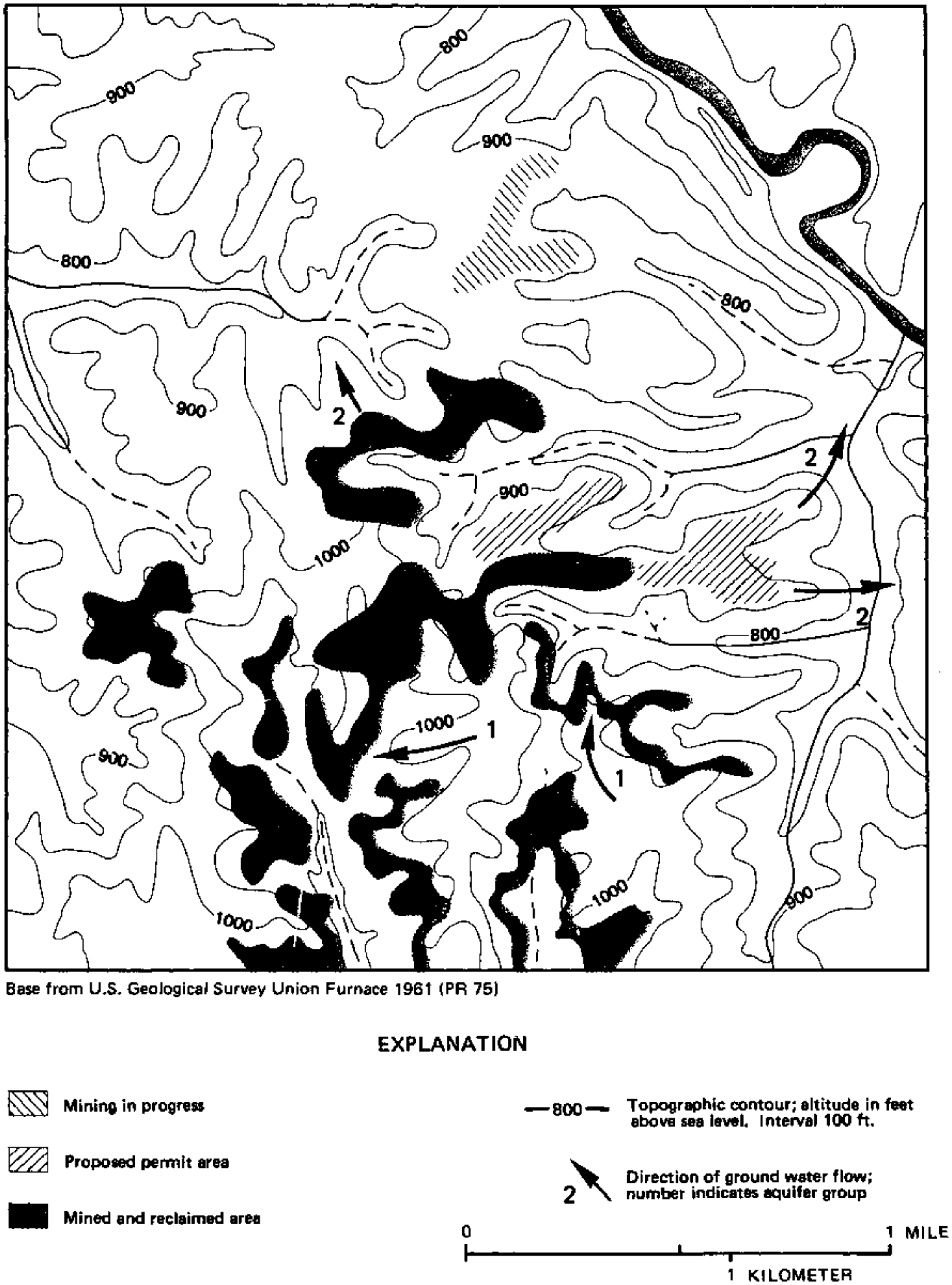


Figure XIX-3.7.— Example map showing surface drainage and directions of ground-water flow for first (upper) and second aquifer groups in permit area. (Aquifer positions are shown in fig. VIII-2.) (Modified from Norris, 1981, fig. 1)

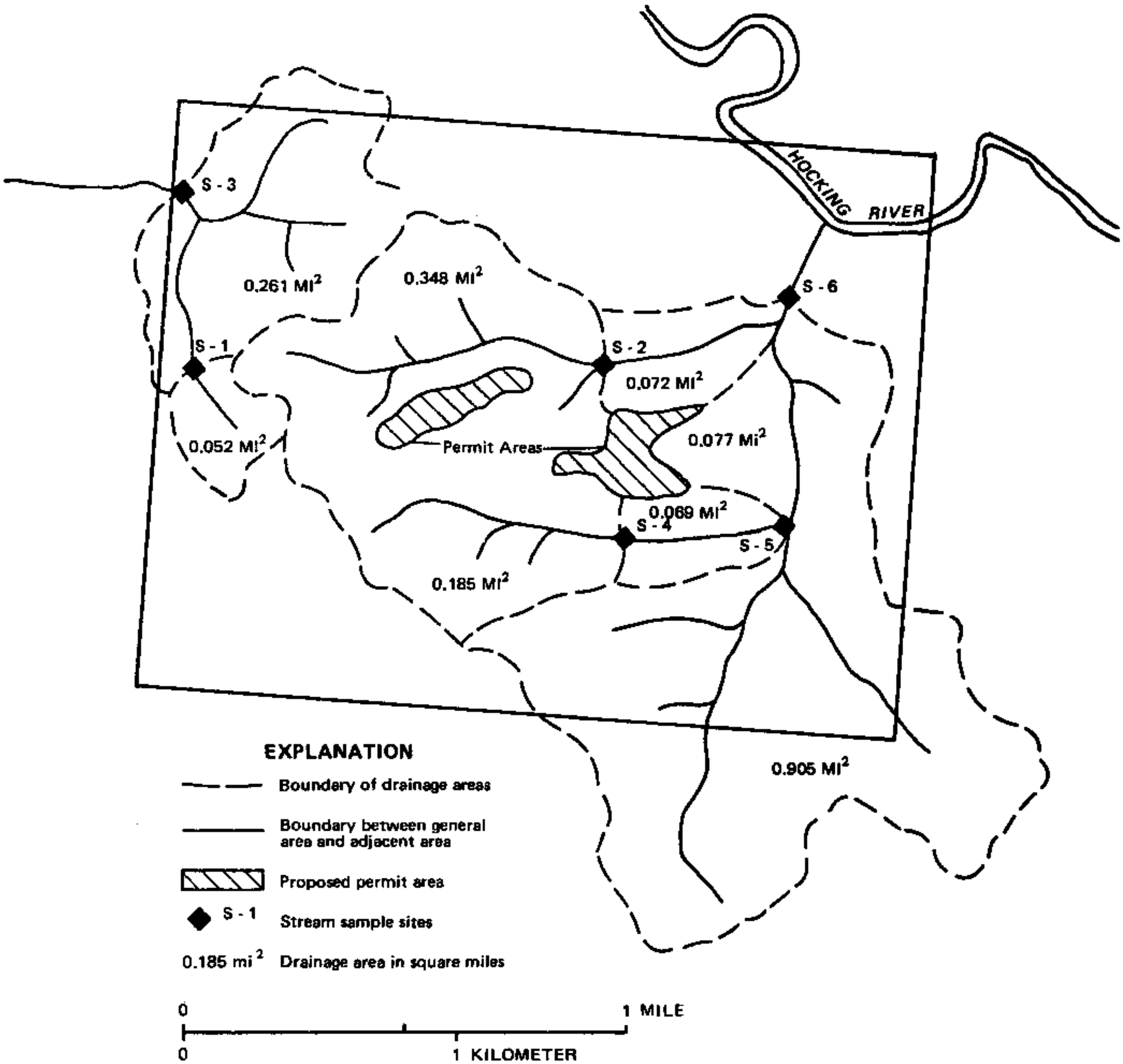


Figure XIX-3.8.— Example of map showing streams draining proposed permit area and vicinity and their drainage areas above sampling sites. (Modified from Norris, 1981, fig. 6)

7-Day, 10-Year Low-Flow Discharge

Low flow characteristics at ungaged stream sites near the permit area are estimated by comparing miscellaneous discharge measurements from these sites with the long-term records from nearby similar gaging stations. The low-flow site locations and their drainage areas within the permit area and adjacent areas are shown in figure XIX 3.8. The instantaneous discharge measured on three dates at two ungaged sites and the mean daily discharges calculated for two nearby gaged sites are tabulated in part A of table XIX 3.4. These data are then converted to unit discharge (discharge per mi^2) values by dividing the discharges by the respective drainage areas; the resulting values are given in table XIX 3.4, part B.

The low flow discharge values at the ungaged sites can be estimated by plotting on logarithmic graph paper the gaged unit discharge values against the ungaged unit discharge values, as illustrated in figure XIX 3.9. In this example, by extending the best-fit straight lines through the plotted points to the known unit discharge $Q_{7,10}$ values, the unit discharge $Q_{7,10}$ values at sites S-6 and S-4 can be estimated between 0.0015 and 0.005 $(ft^3/s)/mi^2$. Using an estimated unit discharge $Q_{7,10}$ value of 0.004 $(ft^3/s)/mi^2$ for the permit area, and the drainage areas shown on figure XIX 3.8, the unit discharge $Q_{7,10}$ values for the stream sites, S-l thru S-6 are shown in table XIX 3.5. These values are significant in determining when a stream is at base flow; and, this is important in determining the base-flow water quality. Stream discharge values significantly larger than the $Q_{7,10}$ value contain surface runoff, while values lower than $Q_{7,10}$ are ground-water base flow.

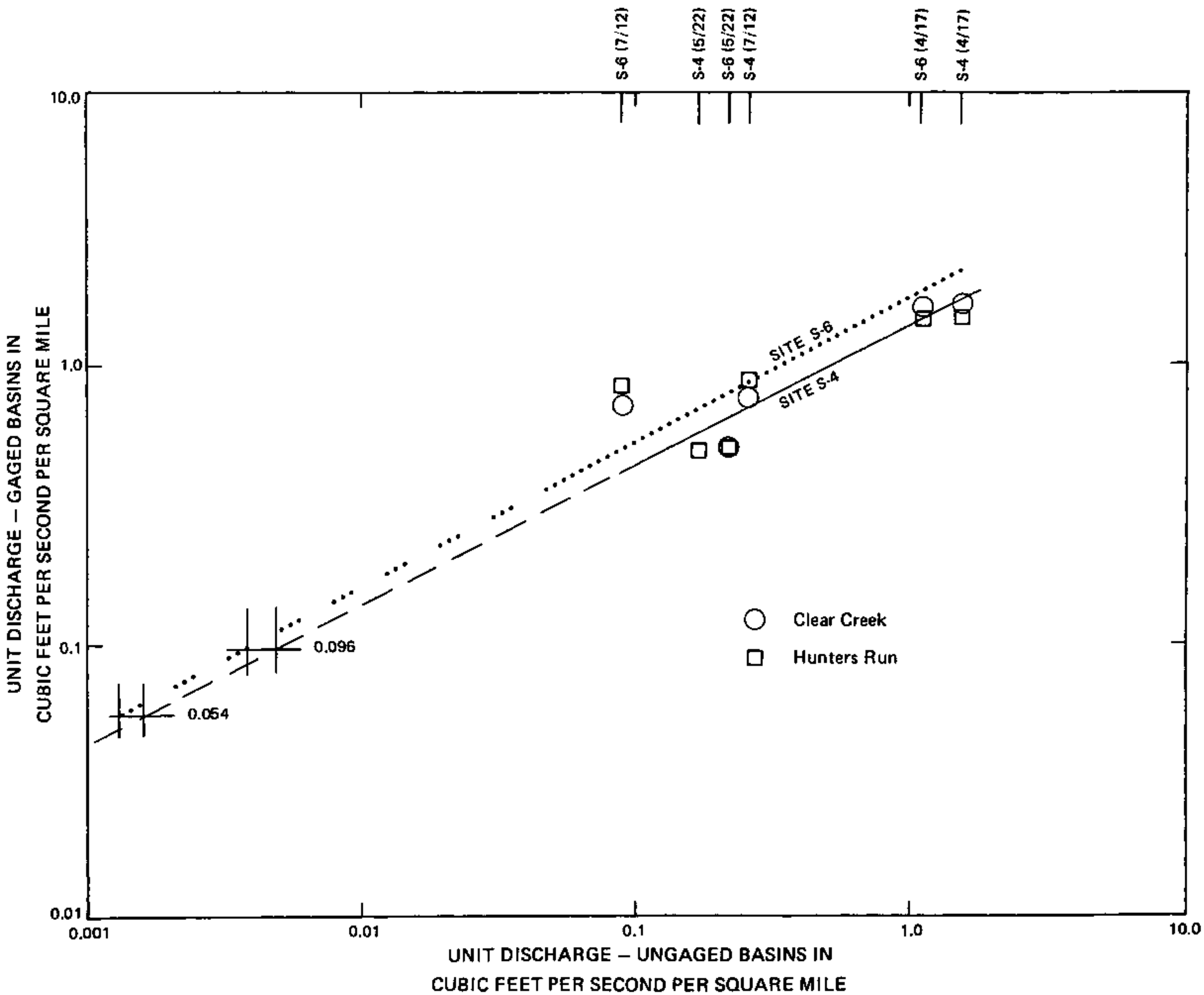


Figure XIX-3.9.— Example of plot showing relationship between unit discharge of gaged basins and that of ungaged basins.
(Modified from Norris, 1981, fig. 8)

Table XIX 3.4.– Example of low-flow discharge analysis between gaged stations and ungaged stations, in vicinity of permit area.

[ft^3/s, cubic feet per second; $(ft^3/s)/mi^2$, cubic feet per second per square mile; DA, drainage area]

A. Mean-Daily Discharges and Low-Flow Measurements

	Gaging Stations mean-daily discharges*		Sampling Sites Instantaneous low-flow measurements	
	Clear Creek near Rockbridge (DA=89.0 mi^2)	Hunters Run at Lancaster (DA=10.0 mi^2)	S-6 (DA=1.51 mi^2)	S-4 (DA=0.19 mi^2)
Date (1979)	(ft^3/s)	(ft^3/s)	(ft^3/s)	(ft^3/s)
April 17	148	15	1.66	0.29
May 22	45	5.1	.33	.033
July 12	69	8.2	.14	.05
B. Unit Discharge Values, in ($(ft^3/s)/mi^2$)				
April 17	1.66	1.5	1.10	1.53
May 22	.51	.51	.22	.17
July 12	.78	.82	.09	.26

*from U. S. Geological Survey, (1979)

Table XIX 3.5.– Example of low-flow stream sites drainage areas and estimated $Q_{7,10}$ flows, (Modified from Norris, 1981)

[mi^2 square miles; ft^3/s, cubic feet per second]

Stream site	Drainage area (mi^2)	$Q_{7,10}$ discharge (ft^3/s)
S-1	0.05	0.0002
S-2	.35	.0014
S-3	.31	.0012
S-4	.19	.0008
S-5	.25	.0010
S-6	1.51	.0060

Chemical Quality of Surface Water and Ground Water

A literature search of hydrologic data records of the U.S. Geological Survey and State Engineer's Office indicated no water-quality information (surface water or ground water) in the general area of the proposed mine was available. Several data stations listed below were established to obtain background water-quality information for premining conditions:

1) six stream sampling sites (fig. XIX-3.8).
2) spring and seep, and
3) six of the inventoried wells (indicated lay asterisk in table XIX 3.1).

Chemical analyses of samples from these sites are given in table XII-2.

Surface-Water Quality

Analyses of the surface-water samples indicate the presence of acid mine drainage from abandoned mines and reclaimed areas. The results from stream sites S-2, S-4, S-5, and S-6 (fig. XIX-3.8) indicated the surface water was affected by acid mine drainage based upon the criteria—low pH (less than 4.5), high specific conductance (greater than 800 umho/cm (micromhos per centimeter)), high concentrations of iron (greater than 5 mg/L) and of sulfate (greater than 250 mg/L). These concentrations are related to the oxidation of the iron sulfide minerals (pyrite and marcasite) associated with the coal (Norris, 1981, p. 50).

Ground-Water Quality

Ground-water quality is highly variable, from both natural causes and the effects of man's activities. Ground water from wells that tap the local flow system is more likely to be potable than water from wells in the same aquifer but distant from the outcrop, that is, in the regional flow system.

As indicated in table XII-2, ground-water analyses show large differences from well to well. Water samples from the third (deepest) aquifer group (See fig. VIII-2) are unaffected by coal mining, as evidenced by the high pH (near 8.0) and low concentrations of dissolved iron, manganese, and sulfate. Locally, water from this aquifer group is used for drinking and cooking. For this general area, the total dissolved solids (TDS) can be estimated from 0.6 times the specific conductance. The high specific conductance (1650 umho/cm) reflects natural water quality and an estimated TDS = 990 mg/L. (High conductance in some deep wells is related to local brine contamination associated with oil- and gas-well exploration and production. Inclusion of sodium and chloride in the chemical analyses verify the presence of brine.)

Ground water from alluvial deposits and the second aquifer group (See fig. VIII-2) indicates a possible effect from past mining or from exposure of coal beds to the atmosphere. The high concentrations of dissolved iron and suspended iron (6.2 mg/L and 3.8 mg/L, respectively) in well G-4 (table XII-2) might indicate some effect of acid-mine drainage from the mining already in progress. Ground-water flow through fractures in the coal beds could also discharge acid-mine drainage to the underlying aquifer.

The seep at this site (G-6) drains directly from a site that was surface mined in the early 1960's and shows severe effects of mining in terms of low pH (near 3.0), high specific conductance (2100 umho/cm), and high sulfate concentrations (1300 mg/L) (table XII-2).

Ground-Water Use

Two significant well-inventory tasks in the general area adjacent to the proposed permit area (See fig. VII-1) are to determine and document ground-water use and ground-water pumpage. For example, a domestic well needs to supply 20 to 80 gal/d per person, and the average per-capita supply figure for municipal water-supply systems is about 150 gal/d. Irrigation pumpage can be one or more acre-feet (325,850 gal/acre-ft) each day depending upon the temperature, rainfall, and crop. A planimetric map showing the ground-water use locations near the proposed surface-mine operations is shown in figure VII-1; a summary of ground-water pumpage in the area is given in table XIX-3.6. Prolonged ground-water pumpage could be one of several reasons for water-level declines being monitored in an observation-well network.

Ground-water pumpage at the individual wells could be determined from "in-line" water meters, which are commonly used by municipal, industrial, or commercial water users. The ground-water pumpage listed in.table XK-3.6 is estimated from the size of household, number of head of stock, or from the power consumed in pumping the water (kilowatt-hours of electricity, thousands of cubic feet of natural gas, or gallons of diesel fuel). The power technique involves the field determination of a conversion factor to convert the units of energy consumed into gallons of water pumped. This factor differs from well to well because of variable head lift, hydraulic properties, water-use needs, and pump efficiency.

Table XIX 3.6. – Example of pumpage tabulation in general area.
(well locations shown on fig. VII-1)
[D-l Cl = D-l Clinker ; Sub D-2, unspecified aquifers below mineable coal beds.]

Well Location		Water Use	Aquifer (s)	Estimated Daily Pumpage (gallons)
T 8S R39E section	25DBDD	Stock	D-l & D-2 Coal	2,000
	26BDBA	Stock	D-l Overburden	2,000
T 8S R40E section	28ABD	Stock	D-2 a*	2,000
	31ABD	Stock	D-2 Goal	2,000
	33ACDB	Stock	D-2 Goal	700
	33BCDB	Stock	D-l Cl & Goal	2,000
	$34EDAA_1$	Stock	D-l Cl	1,000
	$34BDAA_2$	Domestic	D-l Cl	1,000
	34BDEA	Domestic	D-2 Coal, Sub D-2	1,000
T 9S R39E section	25DDC	Stock	D-l Overburden	2,000
T 9S R40E section	3ACAB	Stock	Sub D-2	2,000
	4CDAB	Stock	D-2 Coal	2,000
	5BACC	Stock	Sub D-2	1,000
	70CAB	Stock	D-l Goal & Overburden	2,000
	10CDDD	Industrial	Sub D-2	85,000
	10DDBA	Industrial	D-2 Goal, Sub D-2	28,000
	21CACD	Domestic	D-l Overburden	1,000
	21CDBB	Domestic	Unknown	1,000
	21CDBD	Commercial	D-l Coal	9,000
	21DDBA	Stock	Sandstone	2,000
	22DMD	Stock	D-l Coal	2,000
	22DADA	Domestic	D-l Coal	1,000
	30BBA	Stock	D-l Coal	2,000

Ground-Water-Monitoring Plan

The ground-water monitoring plan includes a schedule for periodic measurement of water levels in observation wells and chemical analyses of water samples from aquifers that could be potentially impacted by proposed mining operations.

The major aquifers in the Decker surface-mine area are the D-l and D-2 coals of the Tongue River-Wasatch aquifer (figs. VII-1 and X-l.2-2). The location of observation wells selected for the monitoring plan are shown in figure XIV-1. Most of these wells are at the mine-permit boundary or within the adjacent area. An example well-inventory data for this well network are given in table XIX-3.7, which includes well location, land-surface elevation, well depth, and aquifer(s) tapped. Some water-level data for this network are given in table DC-1, which gives the initial (premining) water-level measurements and their dates, and water levels on a given postmining date (June 4, 1975), and the difference between the two. The water-level declines of some of these wells, during the mining period are plotted on the hydrograph in figure XIII-2-4. These data indicate that the greatest water-level declines were in the shallow D-l aquifer.

An example of chemical analyses from the monitoring plan is presented in table XIV-5. The wells selected for water quality analyses represent all three areas: permit area, adjacent area, and general area.

Table XIX 3.7– Example of hydrologic data for observation-well network. (From VanVoast and Hedges, 1975, plate 3.)

Well location*	Well number	Land-surface altitude (ft above sea level)	Well depth (ft below land surface)	Water-level altitude, April, 1975 (ft above sea level)	Aquifer
9S 40E 03 $DABA_1$	WRN 10	3,433	79	3,421	D-2 Coal
9S 40E 04 $CABC_2$	WRN 14	3,514	78	3,448	D-l Coal
9S 40E 09 MDD_1	WRN 15	3,500	140	3,426	D-2 Coal
9S 40E 09 $AADD_2$	WRN 16	3,500	89	3,418	D-l Clinker
9S 40E 16 ABCA	WR 1	3,498	104	3,404	D-l Coal
98 40E 08 DCAA	WR 3	3,612	215	3,431	D-l Coal
9S 40E 17 DACB	WR 4	3,585	220	3,428	D-l Coal
9S 40E 16 $ABCD_1$	WR 6	3,499	135	3,406	D-l Coal
9S 40E 16 $ABCD_2$	WR 7	3,498	207	3,445	D-2 Coal
9S 40E 21 $ACCA_1$	WR 8	3,537	165	3,426	D-l Coal
9S 40E 21 CADA	WR 10	3,537	169	3,426	D-l Coal
9S 40E 21 BCAC	WR 11	3,575	210	3,429	D-l Coal
9S 40E 17 DACC	WR 12	3,486	230	3,427	D-l Coal
9S 40E 09 $BDDA_1$	WR 14	3,598	192	3,419	D-l Coal
9S 40E 19 BAC	WR 15	3,685	390	3,445	D-l & D-2 Coal Combined
9S 40E 18 ABAD	WR 16	3,640	237	3,451	D-l & D-2 Coal Combined
9S 40E 29 BBAC	WR 17	3,570	300	3,455	D-l & D-2 Coal Combined

* Subscripted number indicates the number of the well inventoried within the acre area.

4.0 POTENTIAL IMPACTS OF MINING ON HYDROLOGIC SYSTEM

Predicted Water-Level Declines Due To Surface Mining

One of the impacts of surface mining is the dewatering of coal aquifers and (or) of aquifers overlying the coal seam. The decline of water levels in the D-l and D-2 coal seams near Decker, Mont., was illustrated on a hydrograph in figure XIII-2-4.

Examples of model-generated water-level declines due to the surface mining of a 10-ft thick coal aquifer are shown in figure XIX-4.1. The geologic setting is GS-l, which is flat lying coal seam; the hydrologic setting is HS-F(l), where the coal bed is a confined aquifer. The potentiometric surface at this site is 10 ft above the top of the aquifer and 5 ft below the land surface. The aquifer-test results gave a transmissivity value of 5 ft^2/d, hydraulic conductivity of 0.5 ft/d, and a storage coefficient (storativity) of 0.0001. The modeled excavation size was ¼xl mi.

The areal distribution of drawdown after 1 year and 20 years are plotted in fig. XIX-4.1, parts A, B, and C. The drawdown after 1 year of mining (part A) ranges from 20 ft at the mine pit to about 1.5 ft at a distance of 2 miles from the high wall. The drawdown after 20 years of mining (part B) at the 2-mi point has increased to 10 ft. These drawdowns are plotted in part C.

The water-level declines at a proposed permit are 1 mile from a reservoir (such as shown in figure XIV-1), or a perennial stream are shown in figure XIX-4.1, part D. This setting represents a hydraulic connection between the aquifer and the reservoir or stream.

Examples of model-generated extent and depth of water-levels declines resulting from 10 years of surface mining are shown in figure XIX-4.2. The geologic setting is GS-1; the hydrologic setting is HS-F(2), where the coal bed is a water-table aquifer. Aquifer test results yielded hydraulic conductivity of 2.3 ft/d and a specific yield of 0.05. An assumed recharge of 0.1 inches per year was included in the model. The maximum water-level decline is greater than 25 ft.

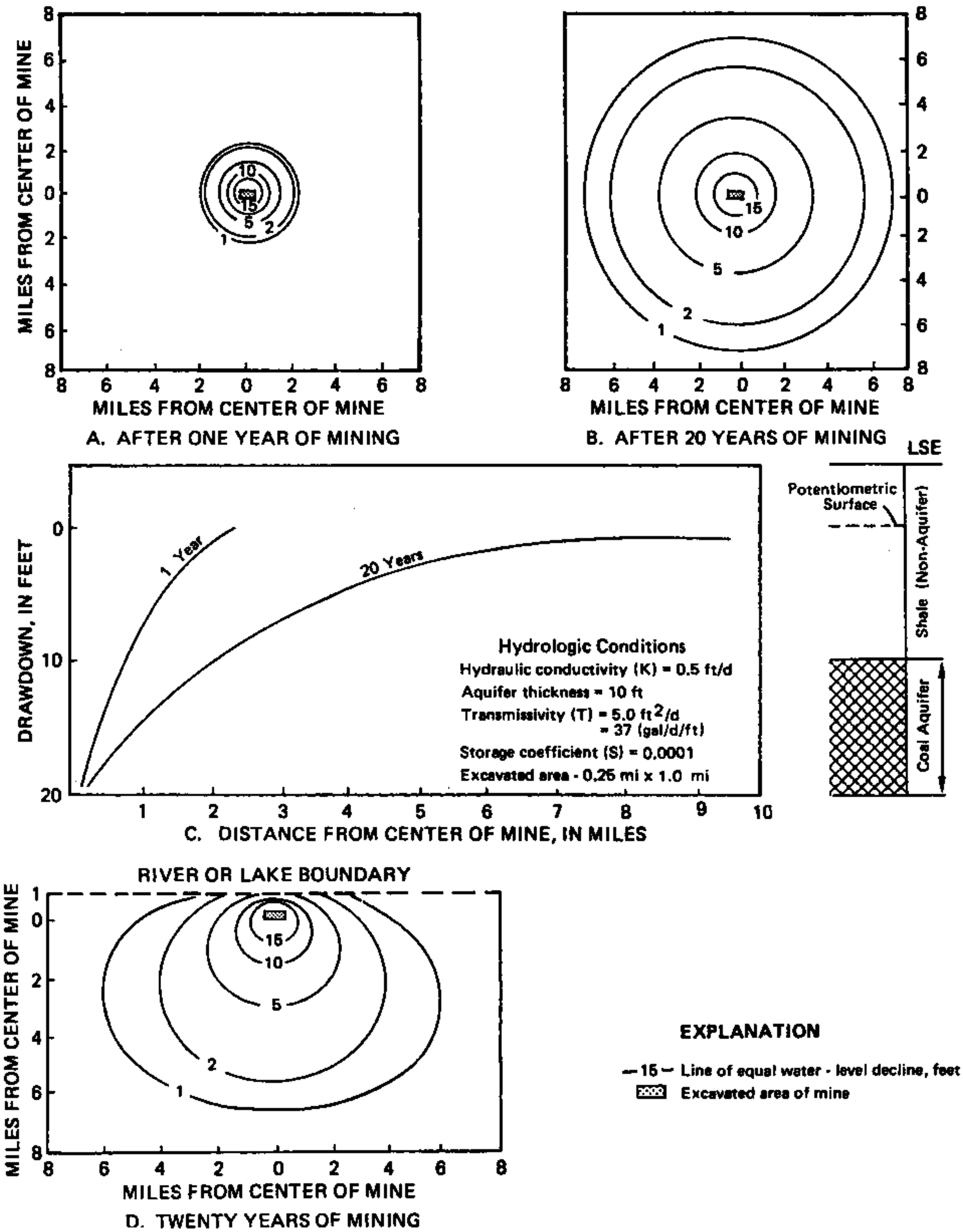


Figure XIX-4.1.— Examples of model-generated drawdown graph and maps for a dewatered surface-mine excavation in a homogeneous, isotropic aquifer after 1 year (A), 20 years(B) of continuous pumping, and as influenced by surface water after 20 years (D).
(From Slagle and others, 1985, figs, 8, 9, 11)

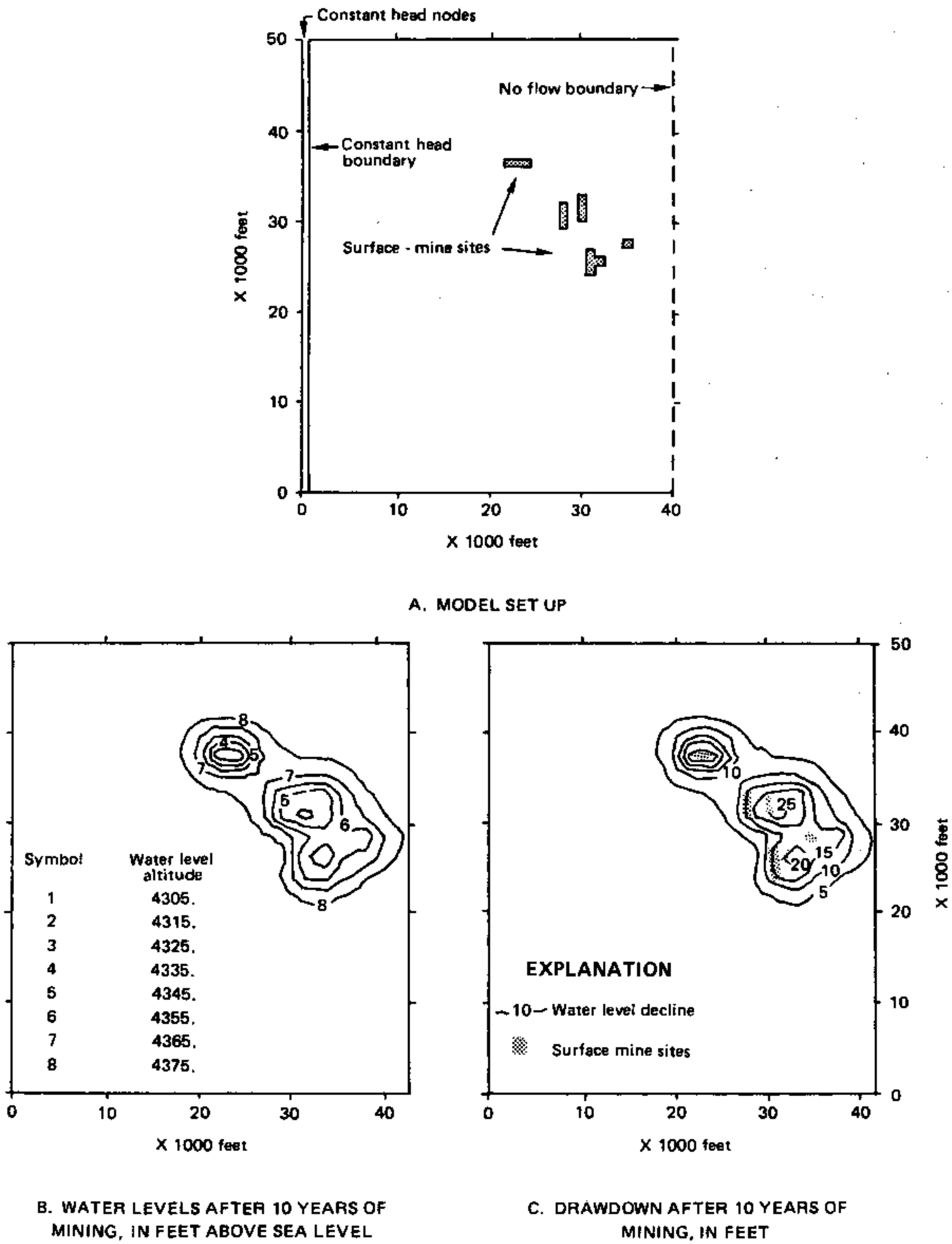


Figure XIX-4.2.— Examples of model-generated maps shaving (A) surface-mines locations, (B) water levels after 10 years of mining, and (C) corresponding water-level declines since start of mining. (Modified from U.S. Department of the Interior, Office of Surface Mining, 1981b, figs. IV-G-1, and V-G-3.)

Potential Water-Level Declines Due to Underground Mining

The hydrologic impacts due to underground mining can be predicted with the assistance of a ground-water flow model. An example of the layout of a proposed underground mine and the 5-year schedule for mining is presented in figure XIX-4.3. The geologic settings are GS-1 (flat lying coal bed in sedimentary rock sequence) and GS-6 (coal bed underlying alluvial valley floor); the hydrologic settings are HS-D (coal bed saturated and in contact with sandstone aquifer) and HS-F(l) (the coal bed is a confined aquifer). An example of a generalized geologic cross section through the permit area is given in figure XIX 4.4 which shows (1) overlying glacial sand and gravel deposits underlain by clay; (2) a thick sequence of interbedded shales, sandstones, coals, and limestones (confining layer); (3) the coal to be mined, and (4) the underburden which consists of a sandstone aquifer underlain by shale. These settings are illustrated in detail in figure VI-8, HS–D&F. The hydraulic properties given in figure XIX-4.4 were determined from routine aquifer tests. (Additional information on the test results can be obtained in Davis and Walton, 1982.)

During the first year, ground-freezing techniques are planned for the construction of the 20-foot diameter shaft through the sand and gravel deposits. During year 2, the shaft is to be excavated through the confining layer. The drainage rate during this construction period is estimated to be 50 gal/min. The estimated mine drainage rate due to shaft and drift completion during years 3, 4, and 5 are presented in figure XIX-4.5. The rate increases from 50 gal/min in years 2 and 3 to 233 gal/min in year 4 and to 446 gal/min in year 5. The estimated drawdown distribution in the coal and sandstone aquifer at the end of the 5-year period is shown in figure XIX-4.6. Drawdowns may range from 400 ft in the immediate vicinity of the mine drifts to less than 1 ft at distances of ½ mi from the mine drifts. Water levels in the unconsolidated deposits may decline as much as ½ ft near the center of the mine drifts (Davis and Walton, 1982, p. 847).

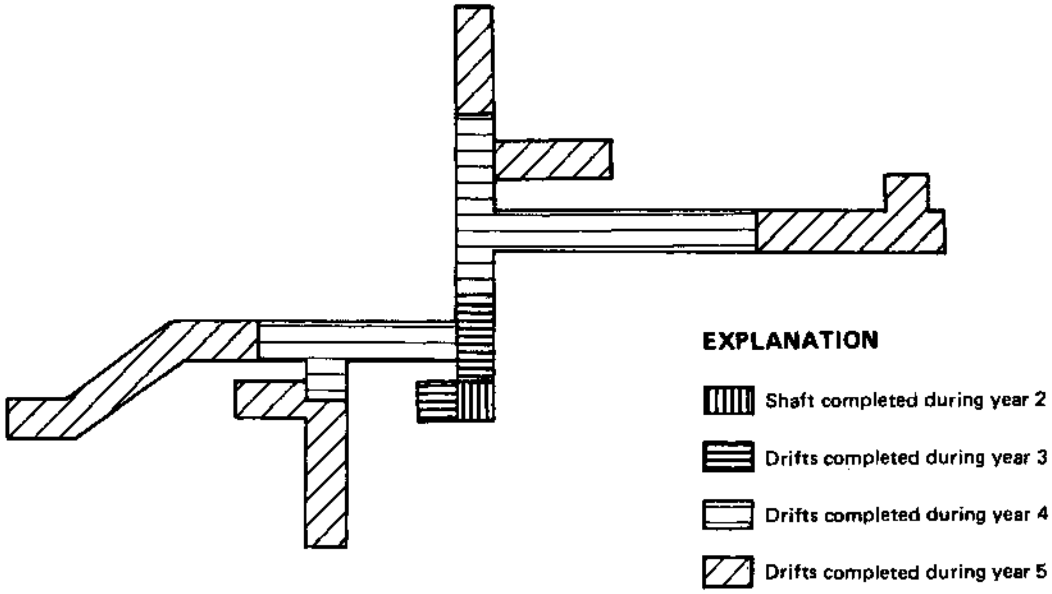


Figure XIX-4.4.— Generalized stratigraphic column with average hydraulic properties used in ground-water model. (Modified from Davis and Walton, 1982)

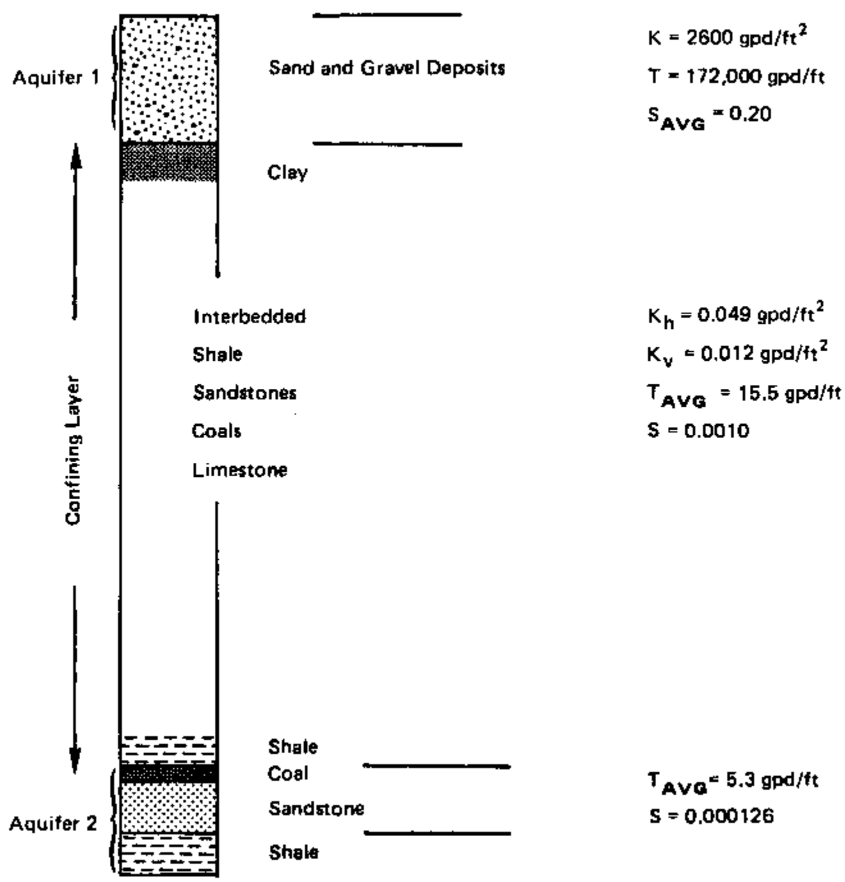


Figure XIX-4.3.— Example of underground mine layout and development schedule. (From Davis and Walton, 1982, fig. 8)

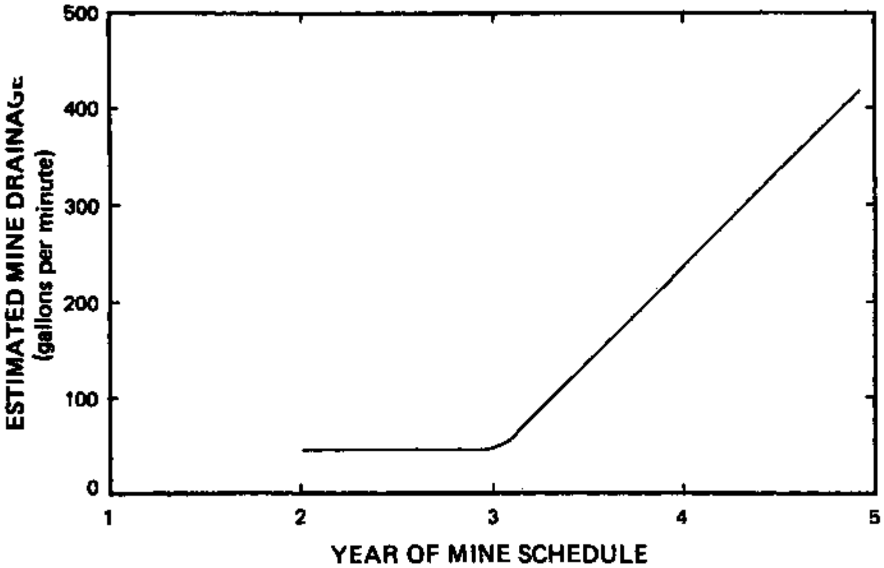


Figure XIX-4.5.— Example of curve showing projected mine drainage during 5-year development of deep underground coal mine. (From Davis and Walton, 1982, fig. 9)

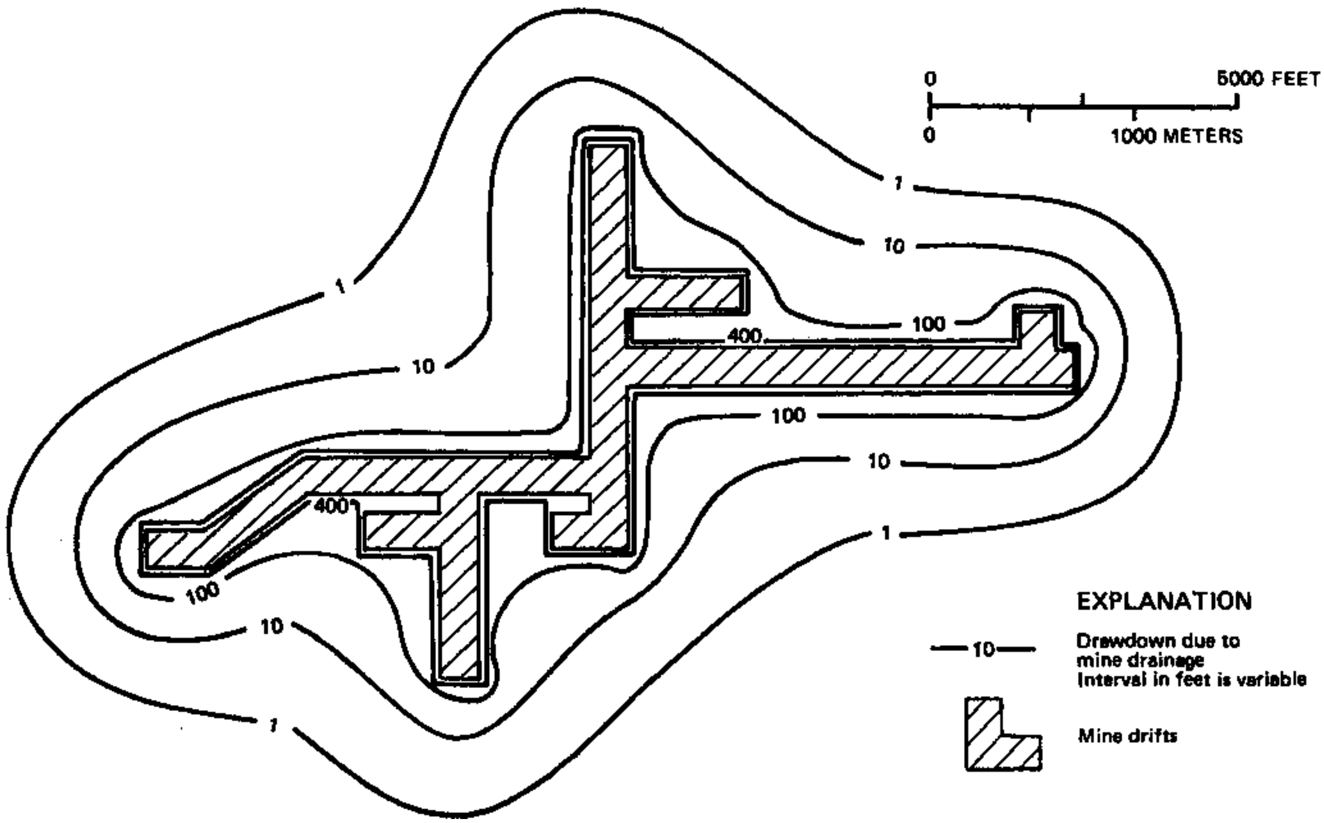


Figure XIX-4.6.— Example of water-level change map for the underburden sandstone aquifer after 5 years of deep underground coal-mine drainage. (From Davis and Walton, 1983, fig. 10)

Change in Ground-Water Storage and Ground-Water/Surface-Water Relationship

The proposed surface-mine shown in figure XIX-3.7 will be a mountaintop-removal operation. The postmining impact will be about a 10 percent increase in the size of the reclaimed spoil area, within the 0.751 mi^2 drainage area. This will provide additional ground-water storage, which will, in turn, cause an increase in ground-water (base-flow) discharge to tributary streams.

About 20 percent of the drainage areas above stream sites 2 and 4 (figure XIX 3.8) have been affected by past surface mining operations. The increase in areas of spoils within these two drainage areas, resulting from mining, will be 10 percent and 5 percent, respectively.

Overburden Analysis (Acid-Base Account)

Ground water in waste spoil banks generally contains high concentrations of total dissolved solids, is low in pH, and is a calcium magnesium-sulfate type water. Ground water discharging from spoil banks is called "acid-mine drainage," and is the product of oxidation of iron disulfide minerals (such as pyrite).

In the Appalachian and Midwestern coal basins, the coal-bearing overburden bedrock commonly consists of a complex series of shale and sandstones inter-bedded with generally thinner, more regular beds of limestone, siltstone, coal, and underclay. A method of chemical overburden analysis is the "acid-base account" (Sobeck and others, 1978). This method is concerned with the measurements of total or pyritic sulfur and neutralization potential (by calcium carbonate).

In the proposed permit area, 30 "soil extract" (rock) samples, were obtained from the drill-hole cuttings. These samples were pulverized into a rock slurry with distilled water and tested for (1) percent sulfur, (2) pH, and (3) alkaline carbonates such as $CaCO_3$. The sulfuric acid yielded by 1000 tons of overburden material containing 0.1 percent sulfur requires 3.125 tons of calcium carbonate to neutralize it (Sobeck, and others, 1978, p. 3). An example of a drill-hole log of the proposed surface-mine site and a corresponding plot of expected sulfur concentration (as percent of total overburden material) with depth is given in figure XIX-4.7, which also indicates zones of toxic and nontoxic materials. The depth zones of nontoxic materials are from 0 to 44 ft, 56 to 69 ft, and 80 to 83 ft. The nontoxicity of these zones results from excess $CaCO_3$. The toxic zones, as defined by pH values less than 4.0, are from 53 to 56 ft and from 69 to 71 ft. A zone of potentially toxic material is from 44 to 53 ft.

The toxic material will be selectively handled, or separated, to ensure favorable minesoils and economical reclamation for the intended land use.

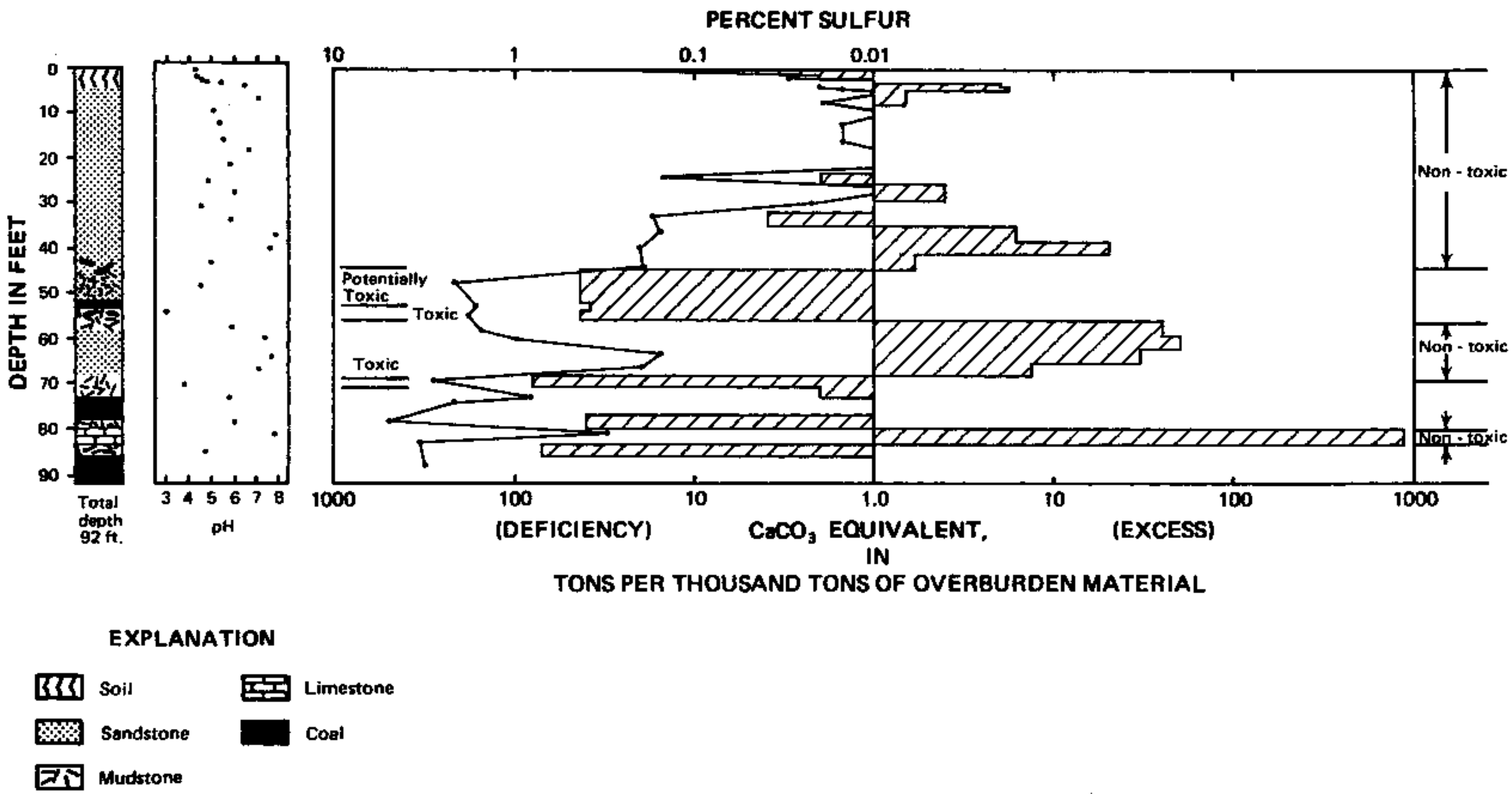


Figure XIX-4.7.— Example of overburden analysis, by acid-base account method, for proposed surface-mine permit area.
(From Sobek and others, 1978, fig. 1)

Potential Water-Quality Degradation Due to Surface Mining

Ground water and base flow of streams in the proposed permit area (figs. XIX-3.1, and XIX-3.8) are currently impacted by seepage from mined and reclaimed areas, as evidenced by the low pH, the corresponding high sulfate concentrations (370 to 990 mg/L), and specific conductance values (830 to 1500 umho/cm) at stream sites (See table XII-2). The seep water (G-6 in table XII-2) from the base of the spoils (pH = 3.2, zero bicarbonate, high dissolved iron, manganese, and sulfate) is indicative of typical acid-mine drainage-type water that causes degradation of surface water.

The chemical analysis of well G-4 (table XII-2) indicates infiltration of acid-mine drainage water into the alluvium from past and present mining operations; this will probably continue to degrade ground water in the alluvial deposits within the adjacent area. The sandstones of the Allegheny Formation (fig. VIII-2) also may be impacted by infiltration from mined and reclaimed area. The upper aquifer group will not be impacted, however, by mining operations by virtue of its higher topographic position. The Lower aquifer group also will not be impacted because it is overlain by confining beds of the Logan Formation (See fig. VIII-2).

5.0 POSTMINING HYDROLOGIC MONITORING

Ground-Water Monitoring Plan for Surface-Mine Operations

The postmining ground-water-monitoring plan for proposed surface-mine operations will monitor the reclaimed mined areas as well as the proposed surface-mine areas. An example of a location map of the plan is given in figure XIX 5.1. The plan, subject to approval by the regulatory authority, includes selected inventoried wells, a sampled spoil pile seep, inventoried base-flow sites, new observation wells, new seeps, and observation wells converted from company exploratory test holes.

The plan includes measurements of water levels and water quality analyses of both ground water and low-flow surface water. The previously inventoried and sampled wells and seep include sites 8, 13L, 19L, 20L, 22L, and G-6 (fig. X3X-3.1). The aquifers monitored will be the hydrogeologic groups 2 and 3 (fig. VIII-2) and the alluvial deposits. The previously established stream-sampling sites (S-2, S-4, and S-6) (fig. XII-4) will be included. Test hole 3 will be converted to an observation well for the Lower aquifer group.

The additional monitoring sites include the following; (site locations are shown in fig. XIX-5.1)

(1) observation wells 23, 24, 25, 26, and 27, which will be installed in the sandstones of the Allegheny and Pottsville Formations, primarily for the purpose of systematic water quality sampling.
(2) stream-flow sampling sites 5, 7, and 8, which will be necessary to define base-flow water quality and to plot water-quality degradation changes with respect to specific drainage areas.
(3) spoil-pile seeps G-9 and G-10, which will be necessary to separately define the background water quality and water quality related to the proposed mine site.

Cross sections through the permit area and adjacent areas are shown in figures XIX 5.2 and XIX 5.3. These sections illustrate the topographic setting of the permit area, the water levels in the aquifer groups 1 and 2, and the ground-water relationship between the aquifers and the streams.

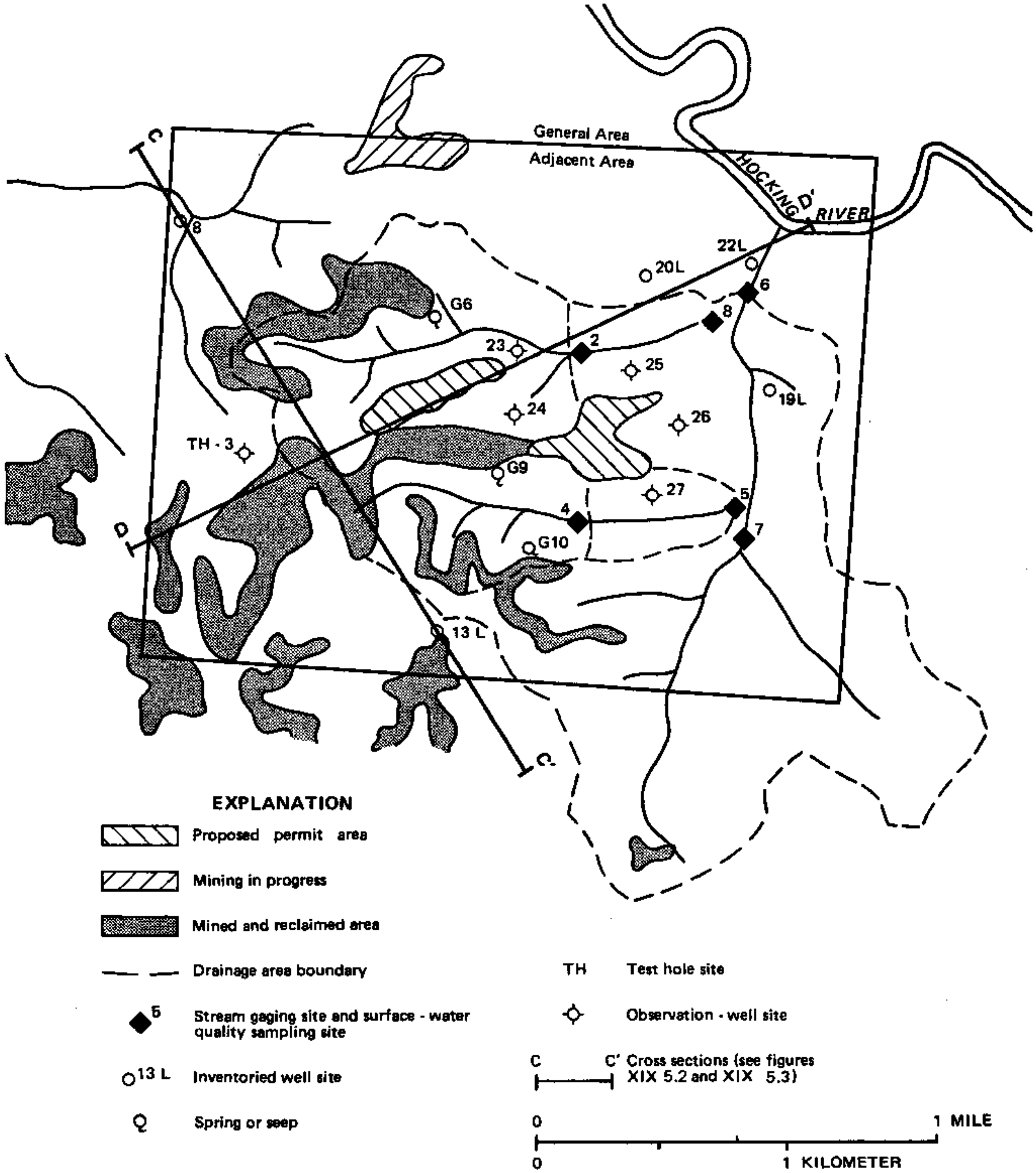


Figure XIX-5.1.— Example of postmining ground-water monitoring plan for surface mine operations.
(Modified from Norris, 1981, fig. 2)

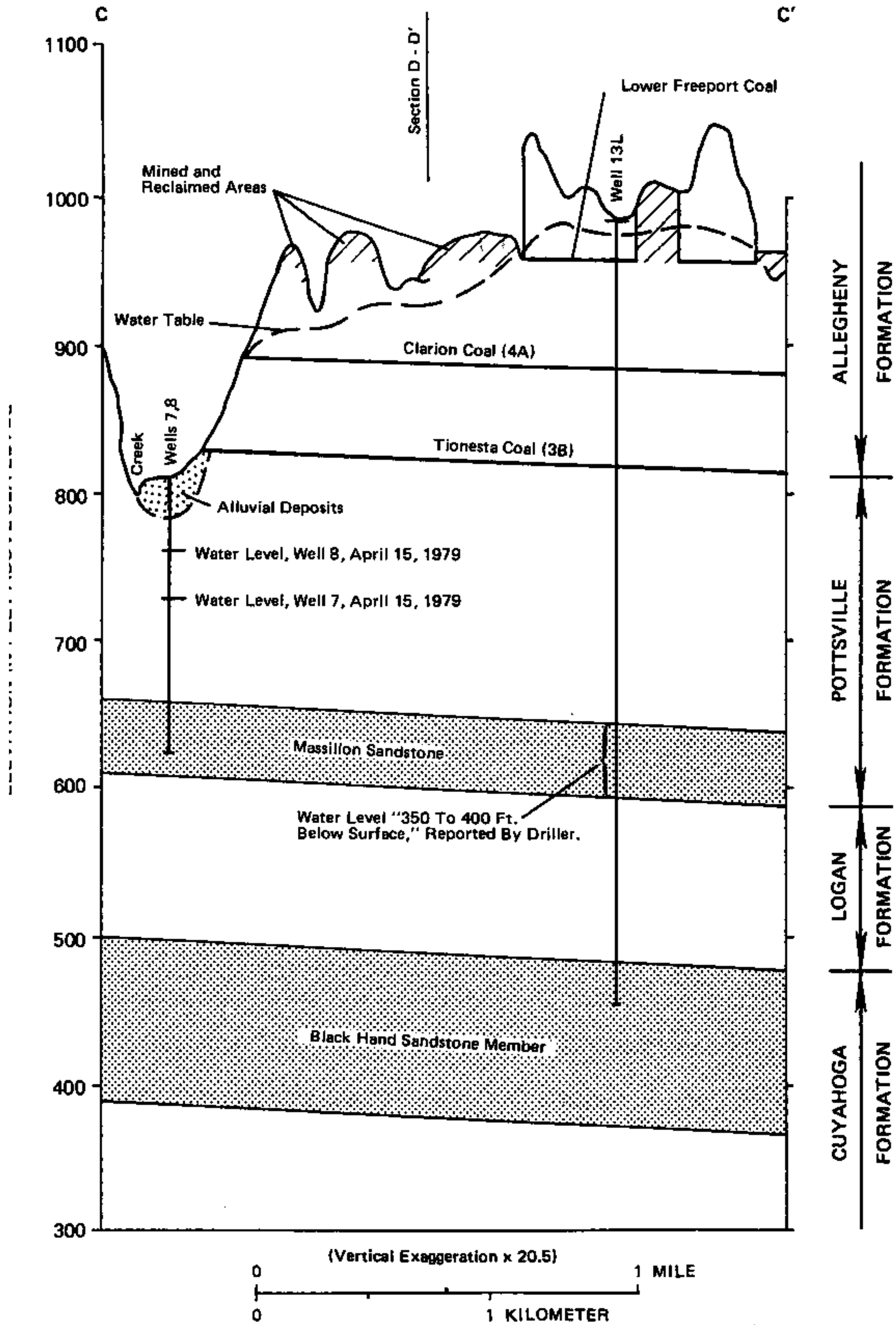


Figure XIX-5.2.— Example of geologic section(C-C') showing premining water levels in the upper two aquifers.
(Modified from Morris, 1981, fig. 5)

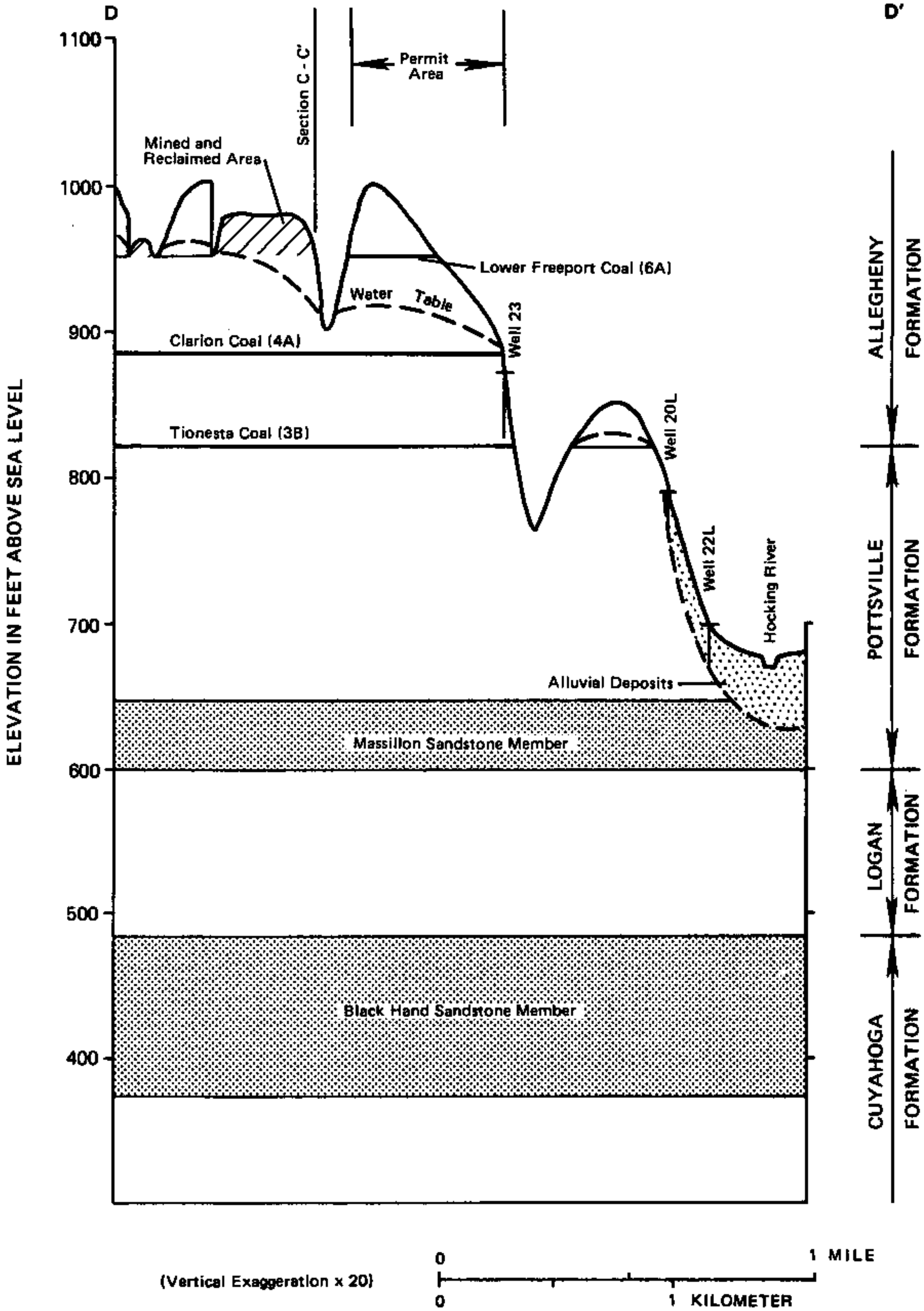


Figure XIX-5.3.— Example of geologic section (D-D') showing permit area and premining water levels in the upper two aquifers and the alluvial deposits.

Ground-Water Monitoring Plan for Underground-Mine Operations

The proposed postmining ground-water-monitoring plan for the terminated underground mining operation (fig. XIX 4.3) is shown in figure XIX 5.4. This plan, subject to approval by the regulatory authority, includes springs, observation wells, and water-quality sampling sites.

The water-table aquifer will be monitored at springs and shallow wells along the hills and valleys. The confined sandstone aquifer of the mined area will be monitored at the deep observation wells. Most pumping for local ground-water use is from wells shallower than 200 ft. Conversion of coal-exploratory holes to cased observation wells is planned. Unused and abandoned landowner wells will serve as observation wells for the shallow aquifer zones, Well-construction information will be needed to define the contributing water-bearing zones.

Initially, water levels will be measured monthly in all but two wells. Recorders will be installed on the two observation wells of the M-l well cluster (fig. XIX 5.4). Measurements will be reduced to quarterly when the trend of the analyses approaches the character of the natural background conditions (as in a nearby long-term observation well in the U. S. Geological Survey or State Geological Survey ground-water monitoring network). Additional wells will be added, or additional measurements will be scheduled, should water-level changes resulting from mining operations, extend beyond the mine boundary. The observation wells will be pumped annually to ensure adequate communication between the borehole and the aquifers. Water samples will be collected during the pumping tests for chemical analyses.

Well sites, Rl, R2, and R3 which penetrate the water-table aquifer downgradient from the storage pile, where any water-quality changes are likely to occur (fig. XIX-5.4) will be sampled monthly to document the changes in ground-water chemistry that result from infiltration of water from the waste-rock refuse facility. Additional wells will be added around the perimeter and at a greater distance from the refuse pile if leachate infiltration into the ground-water system is extensive. Springs downgradient from the refuse pile (SI and 52 in figure XIX 5.4) will also be sampled.

Water-quality samples will also be collected quarterly to document the ground-water quality during seasonal changes in recharge to the aquifer. More frequent sampling may be needed if significant changes in concentrations of sulfate, iron, manganese, acidity, and dissolved solids are noted in the quarterly samples.

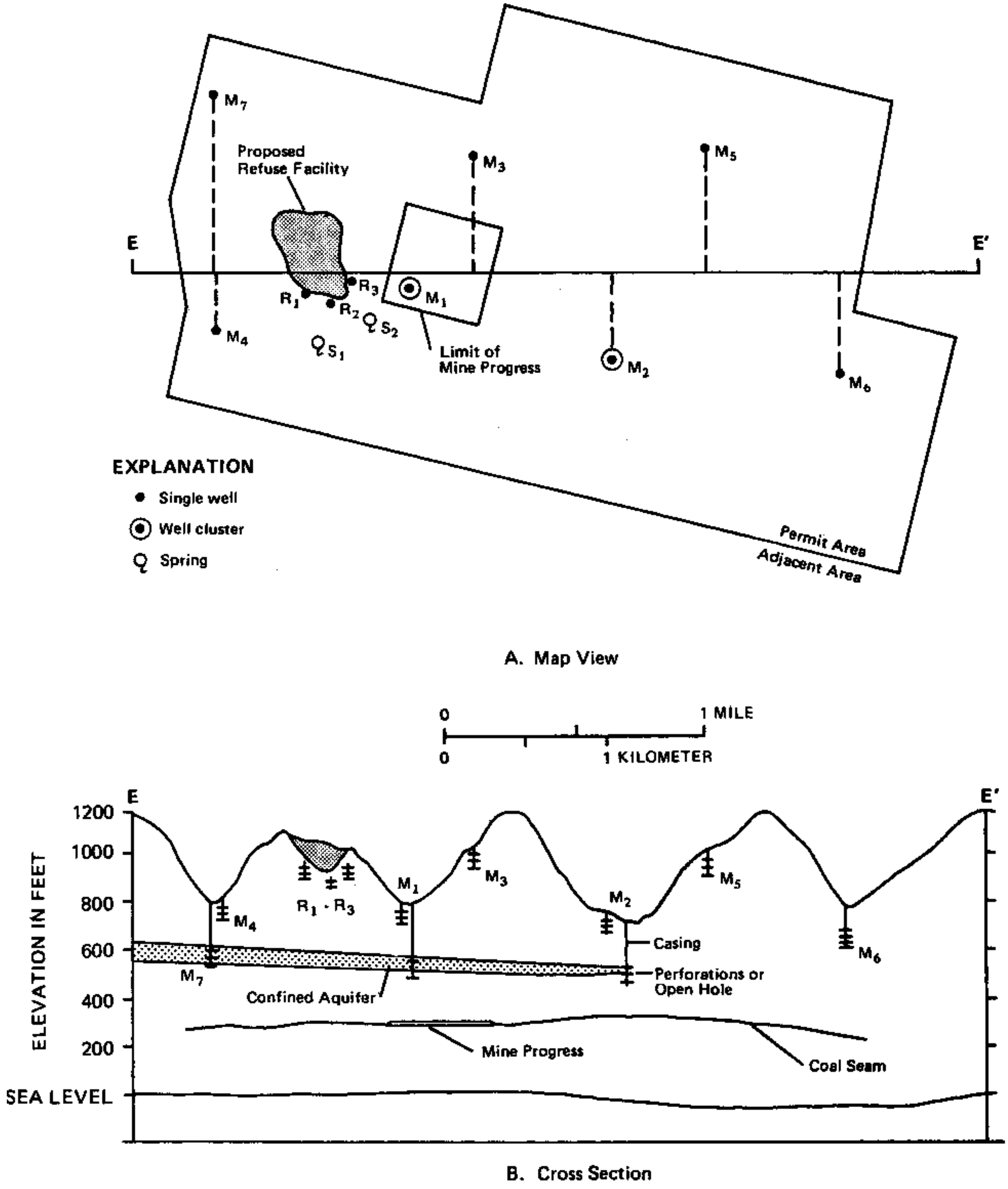


Figure X3X-5.4.— Example of map and vertical section showing locations of sampling sites and depths in observation well network for proposed underground mine.
(From Stoner, U.S. Geological Survey, 1981, written communication)

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