DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY

FOLIO OF THE
GILLETTE AREA, WYOMING
I-848-F

POTENTIAL EFFECTS ON GROUND-WATER LEVELS

This section describes some of the potential effects on ground-water levels that may result from surface mining of the Wyodak-Anderson coal bed in the Gillette area. There are several hundred domestic and stock water wells in the area underlain by the strippable coal. Most of the wells are less than 500 feet deep. The aquifers in which these wells are completed generally can be separated into three systems: (1) shallow, partly-confined aquifers in discontinuous sandstone beds or lenses overlying the Wyodak-Anderson coal bed; (2) the Wyodak-Anderson coal-bed aquifer, and (3) partly-confined aquifers in sedimentary rocks underlying the coal. The occurrence of ground water in each of these aquifer systems is shown in the idealized block diagrams that are based on water-well data, and geologic and topographic mapping.

The bedrock is composed mainly of interbedded sandstone, siltstone, mudstone, shale and coal. The Wyodak-Anderson coal bed is a 5- to 125-foot thick continuous coal unit in the Gillette area. The rock units dip slightly westward about 45 feet per mile.

The water-bearing characteristics of the bedrock units vary with lithology. Sandstone lenses when saturated, generally yield small quantities of water sufficient for domestic and livestock use. However, the siltstone, mudstone, and shale are relatively impermeable and wells drilled in these rocks generally yield little or no water. Coal beds are generally good aquifers. Thick coal beds, like the Wyodak-Anderson coal, of broad areal extent are characterized by well yields of 10 to 30 gal/min (gallons per minute). Thin coal beds that occur in the bedrock units may also be aquifers and generally will yield sufficient water for a domestic or livestock well.

As shown on block diagram A, the ground-water level slopes generally eastward. On the western edge of the block, the water level is 60 feet below the upland surface and on the eastern edge, near the outcrop of the coal bed the water is near the surface. The ground-water level in the shallow aquifers is shown on the block diagrams as a solid blue line. This represents the level of saturation, or potentiometric surface, in the discontinuous sandstone lenses overlying the coal. The dashed blue line represents the potentiometric surface, or the level to which water will rise, in tightly cased wells finished in the coal-bed aquifer.

In the Gillette area, deeper water wells generally have water levels that are farther below the land surface than water levels in wells completed in shallow aquifers. This can be explained by the relationship of geologic structure to topography in the area. The bedrock units and the coal beds dip towards the west and the land surface slopes generally eastward. Therefore, the deeper wells tap aquifers that crop out farther east at altitudes lower than the outcrops of the shallow aquifers. Ground-water drainage in the discontinuous sandstone lenses is generally poor because of their lack of continuity resulting in steeper gradients on the potentiometric surface and shallow depths to ground water. Drainage of the fractured coal beds, which are continuous over large areas, results in flatter gradients of the potentiometric surface and greater depth to water.

Block diagram A illustrates the occurrence of ground water in the Gillette area where surface mining has not yet begun. Six water wells are shown that represent a variety of conditions based on well data collected in the area (King, 1974). Well 1 is completed in a discontinuous sandstone aquifer where the overburden above the Wyodak-Anderson coal is about 650 feet thick. The well is 120 feet deep and the water level is 60 feet below the land surface. Well 2 is completed in the Wyodak-Anderson coal and is 620 feet deep. The water level stands 230 feet below the land surface. This represents the potentiometric surface of the coal-bed aquifer. Well 3 is completed in a discontinuous sandstone aquifer at a depth of 740 feet. This aquifer is partly confined and underlies the Wyodak-Anderson coal. The water level stands 200 feet below the land surface at an altitude lower than the potentiometric surface shown for the coal-bed aquifers. Well 4 is completed at a depth of 200 feet in a discontinuous sandstone aquifer. The water level stands 40 feet below the land surface. Well 5 is completed in the same aquifers as well 4 and is 120 feet deep. The water level in well 5 is 40 feet below the land surface. The overburden above the Wyodak-Anderson coal at well 5 is only 140 feet thick. Well 6 is east of the surface outcrop of the coal and is completed in a discontinuous sandstone aquifer. The well is 120 feet deep and the water level is 10 feet below the land surface. All of these wells are used for domestic or livestock water and yield moderate amounts of water, generally less than 50 gal/min.

In block diagram B, a hypothetical surface-mining operation has been removed to a depth of 200 feet and the Wyodak-Anderson coal with an assumed thickness of 100 feet has been mined. With the removal of the overburden and coal, the impact on the shallow aquifers that is inferred is based on the assumption that the Wyodak-Anderson coal will be drained to the bottom of the pit, and overlying aquifers will be drained to the lowest point on the high wall where they are exposed instead of to the stream channels near the east edge of the block. Therefore, the water table probably will be lowered greatly in the vicinity of the open pit and wells 4 and 5 will be dewatered. Well 1 is far enough west of the mining operation so that the water level probably will be lowered only slightly.

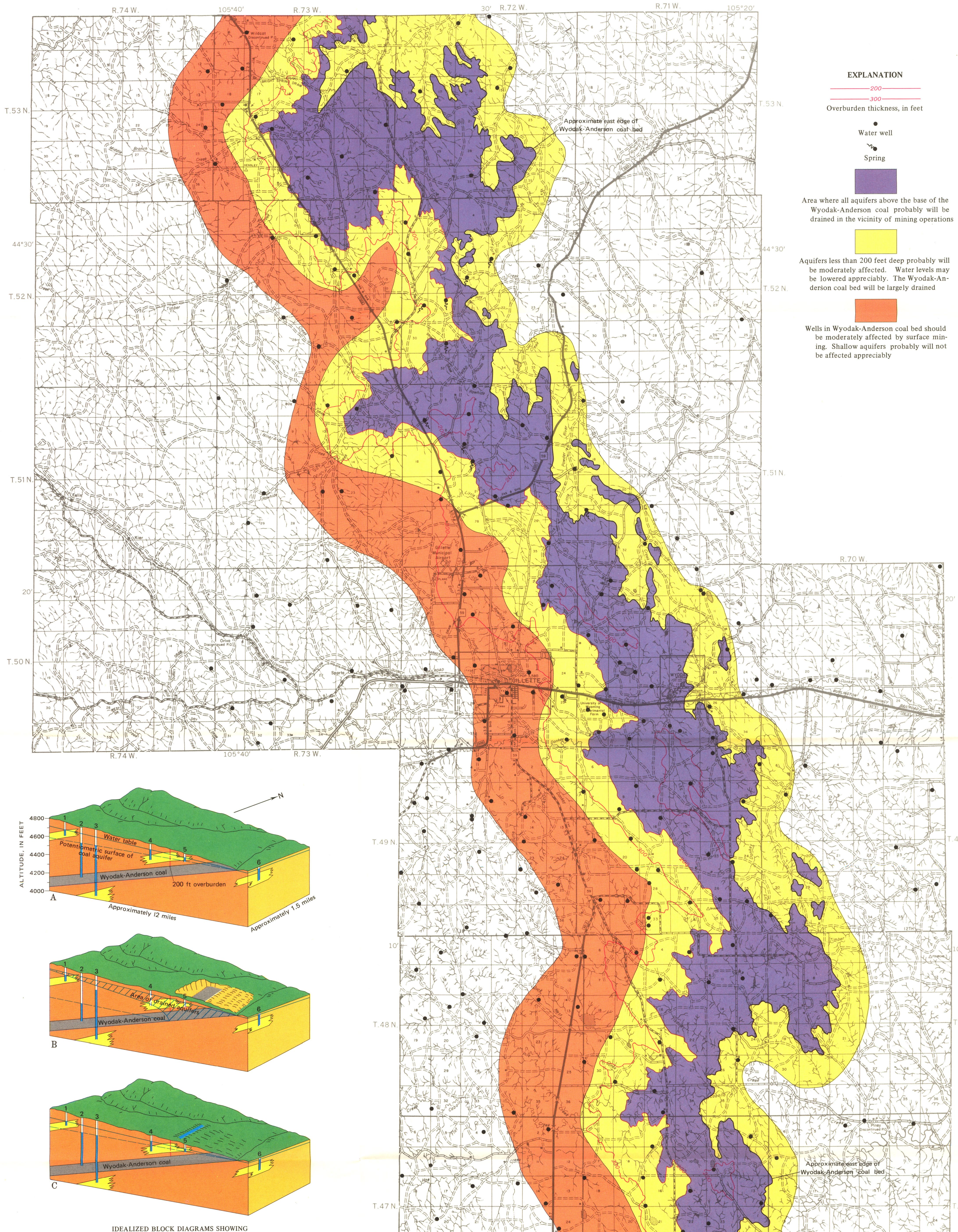
The potentiometric surface of the coal-bed aquifer will be lowered and graded to the bottom of the open pit but, because of the continuity and fracturing in the coal, the gradient should remain virtually the same to the west. The water level in well 2 will be lowered, thus requiring increased pumping lifts.

Well 3, which is completed below the coal bed, also will be affected, although to a lesser extent than well 2. There is a potential for movement of ground water from the sandstone aquifer into the overlying coal bed with the lowering of the point of discharge to the base of the high wall, thus lowering the water level in well 3.

Well 6, although east of the coal outcrop, may be affected by the mining operation to a small extent. The stream channel to which the water level is graded will be dewatered and there will be a general lowering of the potentiometric surface that may lower the water level in well 6.

The longevity of the described impacts on ground-water levels require further study. However, we can infer what will happen if the surface-mining pits are rehabilitated and the topography is reshaped properly. Block diagram C illustrates the topography as it may appear after rehabilitation of the mine in block diagram B. The overburden will become saturated and the point of discharge of ground water will again rise to the stream channel level on the east edge of the block. Therefore, water levels in the discontinuous sandstone aquifers and the coal-bed aquifer downdip from the mine will probably return to altitudes prior to mining.

The map showing the potential effects of surface mining on ground water shows the entire strip in the Gillette area that has potential for surface mining of coal and also the areas adjacent to this strip where shallow aquifers may be affected. However, it should be noted that the inferred impacts on shallow aquifers probably will be confined to an area within a few miles of an individual mining operation.



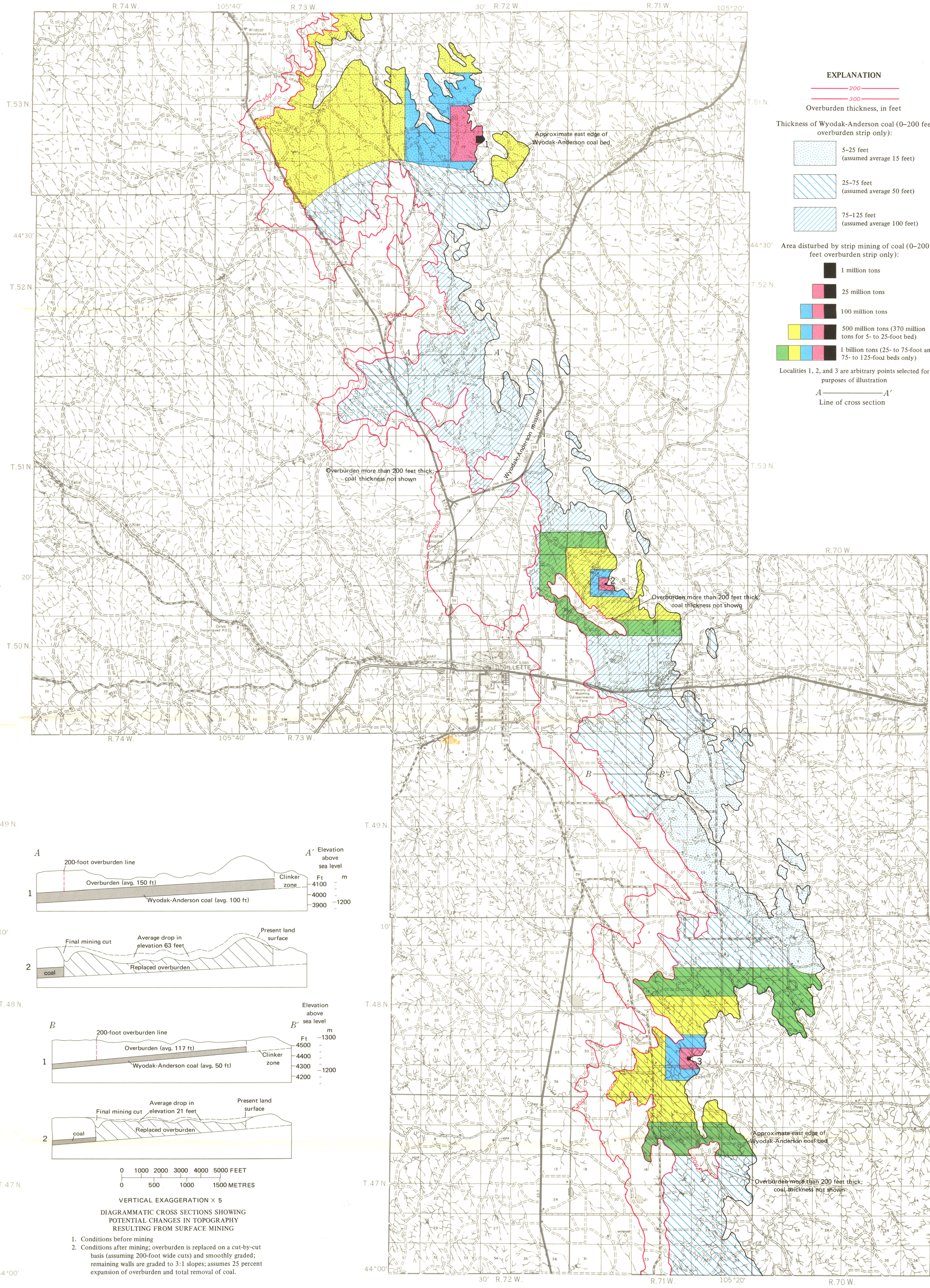
IDEALIZED BLOCK DIAGRAMS SHOWING POTENTIAL EFFECTS OF SURFACE MINING ON SHALLOW AQUIFERS

A Ground-water levels before mining (water levels in numbered wells explained in text)
B Inferred changes in ground-water levels caused by removal of 200 feet of overburden and 100 feet of coal
C Inferred recovery of ground-water levels after completion of mining and rehabilitation of mined area.

Base from Wyoming State Highway Commission, 1956, with main highway system updated to 1969

East edge of Wyodak-Anderson coal based on unpublished geologic mapping by N. M. Denson, G. L. Galyardt, S. L. Grazis, P. T. Hayes, B. E. Law, W. J. Mapel, G. D. Mowat, and E. M. Schell, U.S. Geological Survey

MAP SHOWING POTENTIAL EFFECTS OF SURFACE MINING ON GROUND WATER



DIAGRAMMATIC CROSS SECTIONS SHOWING POTENTIAL CHANGES IN TOPOGRAPHY RESULTING FROM SURFACE MINING

1. Conditions before mining
2. Conditions after mining; overburden is replaced on a cut-by-cut basis (assuming 200-foot wide cuts) and smoothly graded; remaining walls are graded to 3:1 slopes; assumes 25 percent expansion of overburden and total removal of coal.

Base from Wyoming State Highway Commission, 1956, with main highway system updated to 1969

Interior—Geological Survey, Reston, Va.—1975

East edge of Wyodak-Anderson coal based on unpublished geologic mapping by N. M. Denson, G. L. Galyardt, S. L. Grazis, P. T. Hayes, B. E. Law, W. J. Mapel, G. D. Mowat, and E. M. Schell, U.S. Geological Survey

MAP SHOWING THICKNESS AND OVERBURDEN, WYODAK-ANDERSON COAL BED, AND DIAGRAMMATIC PORTRAYAL OF EXTENT OF LAND-SURFACE DISTURBANCE THAT WOULD OCCUR AT VARIOUS LEVELS OF SURFACE-MINE DEVELOPMENT

POTENTIAL EFFECTS ON THE LAND SURFACE

This section (1) identifies the area where the Wyodak-Anderson coal is most accessible to surface mining; (2) indicates the extent of land disturbance that would occur at several levels of surface-mine development; and (3) describes broad-scale changes in topography that would result from surface mining.

Geologic, topographic, and drill-hole data in the Gillette area show that the Wyodak-Anderson coal is less than 200 feet deep in approximately 75,000 acres and less than 300 feet deep in an additional 39,000 acres, both tracts occupying narrow, north-northwest-trending strips 45 miles long. Beyond this area, the Wyodak-Anderson coal extends many miles both north and south. For purposes of this report, the economic limit of surface mining is arbitrarily placed at the 200-foot depth.

Within the tract where the Wyodak-Anderson coal is less than 200 feet below the surface, the thickness of the deposit ranges 5 to 25 feet over 22,000 acres, 25 to 75 feet over 33,000 acres, and 75 to 125 feet over 20,000 acres. The average thicknesses have not been calculated for each such area, but the averages are considered to closely approximate 15, 50, and 100 feet, respectively. Based on these average thicknesses and on the general fact that a deposit of sub-bituminous coal 1 acre across and 1 foot thick (1 acre foot) weighs 1,770 tons, the Wyodak-Anderson bed is estimated to contain about 7 billion tons of sub-bituminous coal in this 75,000-acre tract.

The tables given below show the numbers of acres of the land surface that would be disturbed by surface mining, depending upon the thickness and tonnage of coal being extracted, and assuming 100 percent recovery. The acreages shown in the body of the table represent the area disturbed if the annual production shown at the top of the table is produced for the number of years shown on the left side of the table. The acreage at the lower right-hand corner in each table, for example, is the acreage involved in mining 1 billion tons of coal.

TABLE 1. — Acreages involved in the mining of a coal bed averaging 15 feet in thickness (assumes 100 percent recovery)

Years of production	Annual production of coal (millions of tons) 1	2	3	4	5	10
1	38	75	113	150	188	376
5	188	376	564	752	940	1,880
10	376	752	1,128	1,504	1,880	3,760
25	940	1,880	2,820	3,760	4,700	9,400
50	1,880	3,760	5,640	7,520	9,400	18,800
100	3,760	7,520	11,280	15,040	18,800	37,600

TABLE 2. — Acreages involved in the mining of a coal bed averaging 50 feet in thickness (assumes 100 percent recovery)

Years of production	Annual production of coal (millions of tons) 1	2	3	4	5	10
1	11	23	34	45	56	113
5	56	113	170	226	282	565
10	113	226	339	452	565	1,130
25	282	565	847	1,130	1,412	2,825
50	565	1,130	1,695	2,260	2,825	5,650
100	1,130	2,260	3,390	4,520	5,650	11,300

TABLE 3. — Acreages involved in the mining of a coal bed veraging 100 feet in thickness (assumes 100 percent recovery)

Years of production	Annual production of coal (millions of tons) 1	2	3	4	5	10
1	6	11	17	23	28	56
5	28	56	85	113	141	282
10	56	113	170	226	282	565
25	141	282	424	565	706	1,412
50	282	565	847	1,130	1,412	2,825
100	565	1,130	1,695	2,260	2,825	5,650

For each of the three categories of thickness (15, 50, and 100 feet), a series of color bands are shown on the accompanying map to diagram the comparative extent of land disturbance that would occur at various stages of surface mining within the 0- to 200-foot depth-to-coal zone. The places for the start of mining (points labelled 1, 2, and 3 on the map) are selected arbitrarily for purposes of illustration, and have no significance with respect to present or planned development. The black squares show the amount of land affected by mining 1 million tons of coal at the particular places selected. Succeeding color bands then show the cumulative acreages involved in the mining of 25, 100, 500, and 1,000 million tons of coal in each area, respectively, assuming constant coal thicknesses. For the deposit that averages 15 feet in thickness (no. 1) at the north end of the strippable coal zone, only 370 million tons of coal could be mined. Because the amount of land disturbed by surface mining is in direct proportion to the thickness of coal, the acreages associated with a 50-foot coal bed (no. 3), for example, are exactly twice those of a 100-foot coal bed (no. 2).

The degree to which the existing topography of an area will be altered by surface mining depends upon many factors, most importantly the thickness and depth of coal being mined and the manner in which the overburden is replaced. Overburden "swells" in volume as the earth materials are broken up during mining. Hence, the overburden takes up more space where it is dumped than it did before being disturbed. The "swell" factor differs according to the kinds of rock involved, but it is not unusual for such materials to increase as much as 25 percent in volume. Thus, where coal 25 feet thick is overlain by 100 feet of overburden, a lesser thickness of coal would result in a higher land surface, and a greater thickness of coal would result in a lower land surface. As shown in the diagrammatic sections however, some compaction of the replaced overburden is likely to take place in ensuing years. Thus, where coal 25 feet thick is overlain by 100 feet of overburden, little change would take place in the average elevation of the land surface when the overburden has been returned to the mined-out pits. For the same amount of overburden, a lesser thickness of coal would result in a higher land surface and a greater thickness of coal would result in a lower land surface. It should be noted, however, that some compaction of the replaced overburden is likely to take place in ensuing years.

Two sections (A-A′ and B-B′) show diagrammatically some of the broad-scale changes in topography that can result from surface mining. Their locations are plotted on the accompanying map. The profiles of the present land surface were drawn directly from detailed topographic maps at a vertical exaggeration of five times the horizontal scale. Along section A-A′, where the coal bed is 100 feet thick beneath an average overburden of 150 feet, the general altitude of the land would be lowered an average of 63 feet by surface mining, assuming a "swell" factor of 25 percent. In contrast, along section B-B′, where the coal bed is 50 feet thick beneath an average overburden of 117 feet, altitudes will drop an average of only 21 feet. Profiles similar to those described above can be drawn for any number of places along the zone of strippable coal, and such profiles would provide a general picture of the post-mining terrain. This kind of information is especially important in evaluating the effects of surface mining on both the surface- and ground-water systems.

REFERENCES CITED

King, N. J., 1974, Maps showing occurrence of ground water in the Gillette area, Campbell County, Wyoming: U.S. Geol. Survey Misc. Inv. Ser. I-848-E.

SCALE 1:125 000
2 0 2 4 6 8 10 MILES
2 0 2 4 6 8 10 KILOMETRES

WYOMING
Area location

MAP SHOWING SOME POTENTIAL EFFECTS OF SURFACE MINING OF THE WYODAK-ANDERSON COAL, GILLETTE AREA, CAMPBELL COUNTY, WYOMING

By
R. F. Hadley and W. R. Keefer

1975

For sale by U. S. Geological Survey
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