SPOIL AQUIFER RESATURATION FOLLOWING COAL STRIP MINING

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ABSTRACT

Coal beds in the Tongue River member of the Fort Union Formation are a source of small groundwater supplies in the shallow bedrock in much of southeastern Montana. Strip mining of these beds removes the coal and replaces it with overburden (spoil). With time, aquifers are reestablished in a rubble zone at the base of the spoil. The rate of resaturation and thickness of the resaturated layer depends on physical characteristics of the spoil, method of replacement, and availability of groundwater for recharge. Three major sources of groundwater for spoil recharge are adjacent, unmined coals, underlying aquifers undisturbed by mining, and surface infiltration.

Spoil recharge at West Decker comes mainly from adjacent, unmined coal beds that subcrop under the Tongue River Reservoir. A secondary source is underlying, unmined coal beds. Surface infiltration is considered insignificant due to the thickness and fine-texture of the spoil.

Recharge at the Rosebud mine is predominately from adjacent, unmined coals. In localized areas, recharge to the spoil is enhanced by thin spoil, coarse textured spoil, and the presence of surface water bodies.

INTRODUCTION

Recharge of mine spoil aquifers has generally been attributed to infiltration and downward percolation of moisture from the soil surface (Wayne Van Voast, personal comm.). Laws governing strip mine reclamation in Montana were written with this concept in mind, and little emphasis has been given to spoil recharge from lateral or subspoil sources. However, under some conditions, given the low precipitation and high evapotranspiration rates found in coal mining areas of the state, it is unlikely that surface recharge plays a significant role in spoil aquifer recharge. In this paper, two coal mining areas are considered, Western Energy Company's Rosebud Mine at Colstrip and Decker Coal Company's West Decker Mine near Decker.

The two areas have similar climates with comparable rates of precipitation and evapotranspiration, which effectively limit the amount of surface recharge. However, the potential for recharge from sources adjacent to and beneath spoil is strikingly different. The West Decker mine has two sources of groundwater recharge to the spoil aquifer. The first is unmined coal in hydrologic contact with the Tongue River Reservoir and Tongue River alluvium. The second is coal beds beneath the spoil which have piezometric heads higher than the coals being mined.

Sources of groundwater recharge at the Rosebud mine are less abundant. There are no major surface water bodies in the vicinity of Colstrip that could recharge spoil aquifers. Surface water bodies (sediment ponds) are generally located downgradient from spoil areas and have little effect on spoil recharge. A small impoundment in Pit 6 appears to be associated with a local zone of recharge. Secondly, vertical hydraulic gradients are downward; there is no upward flow to the spoil. The main source of recharge to spoil is water from adjacent coal beds.

LOCATION OF STUDY AREAS

The West Decker mine is located at the mouth of the Pond Creek drainage in Township 9 South, Range 40 East, about 4.8 km (3 miles) northeast of the Decker Post Office in Big Horn County (Figure 1). Portions of the Tongue River Reservoir and floodplain lie within .8 km to the east. The Rosebud mine lies in Townships 1 and 2 North, Range 41 East in Rosebud County (Figure 2). The mine straddles the East Fork Armells Creek drainage and also occupies the headwaters of the Cow Creek, tributary to Rosebud Creek to the east.

METHODS AND MATERIALS

Strip mine permits (1, 2) and permit applications contain detailed descriptions of the hydrology of active and proposed mine area describing the quantity and quality of groundwaters within and adjacent to the active and proposed mine areas, and changes in the hydrologic system that have occurred as a result of mining. Mining companies also submit semi-annual reports of water level and water chemistry data collected during the previous wateryear (3, 4, 5). Reports on the hydrology of the West Decker and Western Energy prepared by Van Voast and others of the Montana Bureau of Mines and Geology were also utilized (6, 7, 8). Representative monitoring wells in coal and spoil aquifers for each mine were selected and hydrographs utilizing all available water level data were plotted. The graphs were analyzed to correlate water level changes with seasonal fluctuations, pit openings and backfilling operations. Total dissolved solids, and common ion concentrations of water from spoil aquifers and adjacent coal beds were compared at West Decker to determine the source of groundwater in the spoil aquifers.

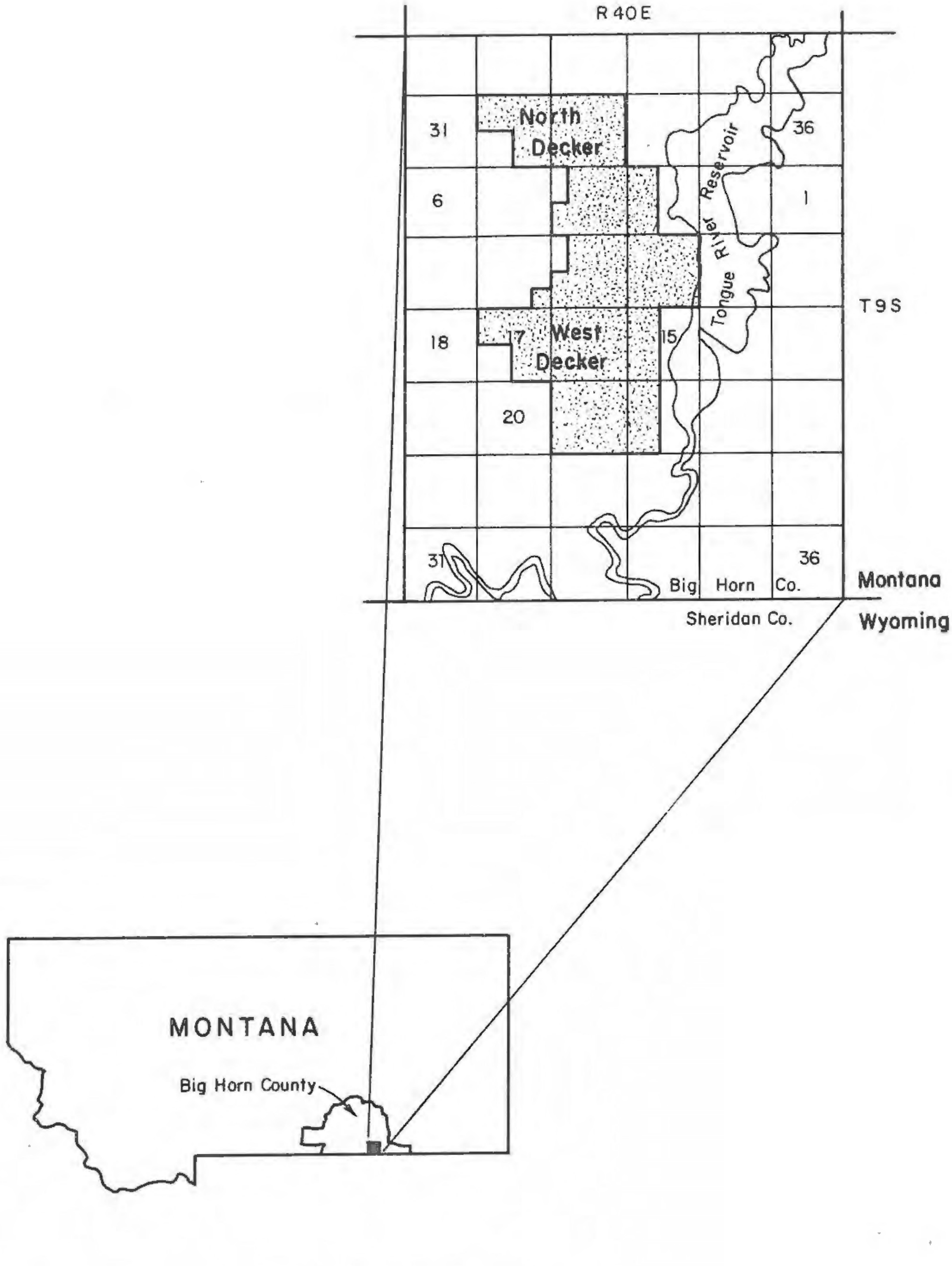

Figure 1. Location of the West Decker mine.

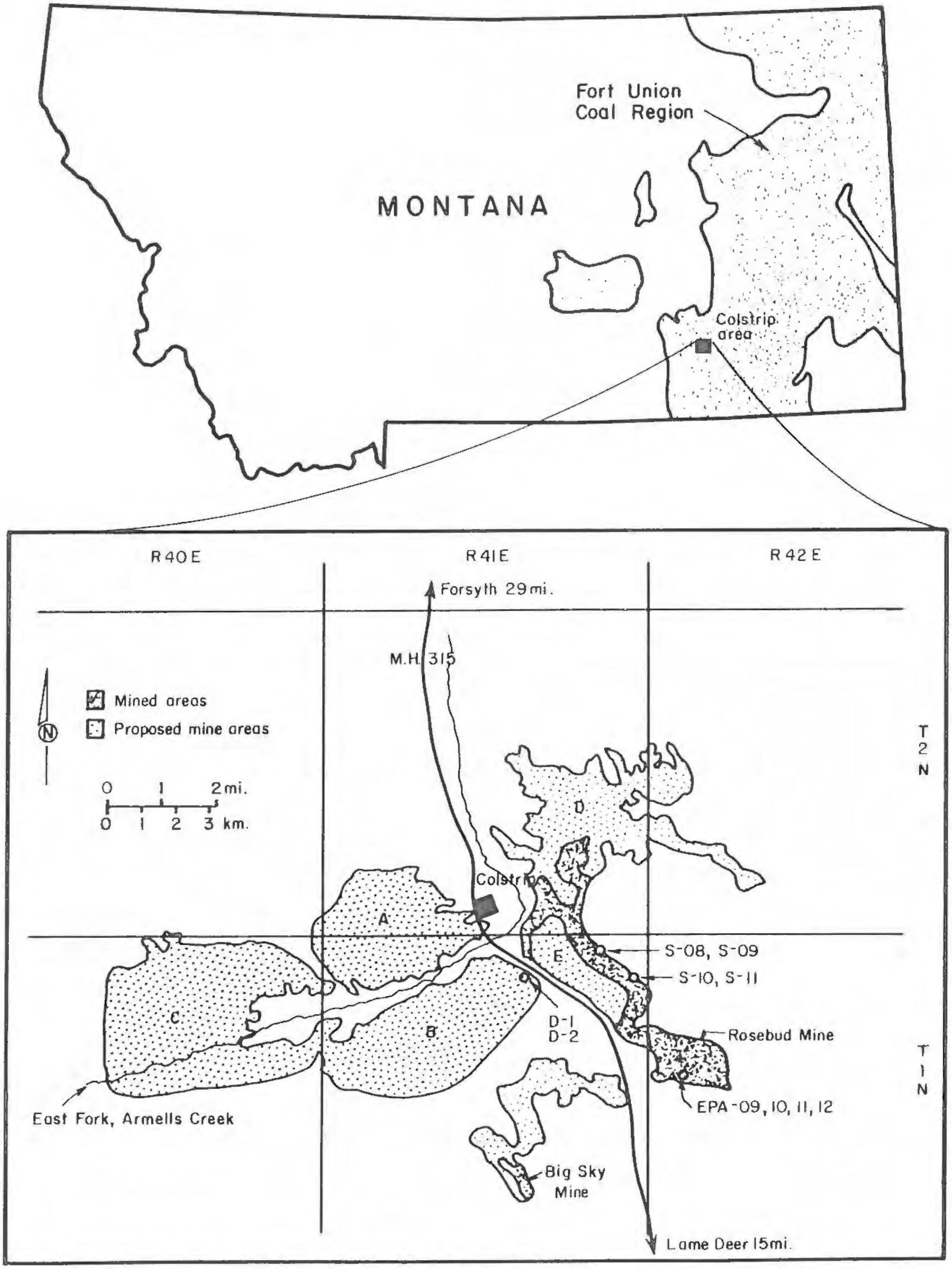

Figure 2. Locations of Colstrip, mined areas, and proposed mine areas. **(8)**

RESULTS

West Decker

Mining at West Decker began in the summer of 1972 with the opening of a test pit. By late summer, 1973, the first horseshoe-shaped mine cut was completed through the mine area. At that time, only the D-1 coal was being mined. An interior box cut was opened beginning in late 1981. In this cut, both the D-1 and D-2 coal are being mined, with mining of the D-2 commencing in 1982 (Figures 3 and 4).

Spoil recharge at West Decker comes from three sources; seasonal recharge from the Tongue River Reservoir, recharge from unmined coal (D-1) adjacent the spoil, and recharge from an unmined coal bed (D-2) more than 6.1 meters (20 feet) below the spoil. Hydrographs of the following wells and associated aquifers were constructed: WR-06 (D-1), WR-07 and DS-2A (D-2); and DS1A, DS3, and DS6A (Spoil).

The following observations pertaining to spoil recharge from the reservoir were made from analysis of the hydrographs; 1) Recharge peaks partially coincide with rising reservoir stage and increased rainfall in later spring and early summer (May-July), but are somewhat complicated by mining and dewatering activities (Figures 5 and 6). 2) Recharge peaks of unaffected coal wells to the west occur slightly earlier (April-June) in response to the earlier spring snow melt. (The spoil wells within the mine area are physically separated from the coal wells to the west by the mine pit, eliminating any possible connection between the seasonal reservoir effects and seasonal spring melt effects). 3) Pit inflows were observed along the east end of the interior box cut and the main pit, and from the fault plan of the southeast boundary fault into the mine pit. 4) Water levels in the D-1 showed a rapid response (Figure 5) to opening of the original pits. Even before water levels began to recover, a seasonal effect of the reservoir stage is evident during 1974-1977. Opening of the interior box cut in 1981 again produced a rapid decline in the D-1 water level. 5) The D-2 coal showed a distinct decline with the opening of the original mine pits in 1972. Its piezometric head reached a stable level with seasonal fluctuations from mid-1976 until late 1981 when mining began in the interior box cut. At that time, the head in the D-2 coal dropped sharply.

Evidence for recharge of spoil by unmined coal adjacent the spoil includes observations of inflows to the interior box cut from the D-1 coal, overburden and D-1/D-2 interburden. Inflows from the D-1, overburden and the southeast boundary fault plane are also present in the southeast end of the main pit.

Upward leakage from the D-2 coal is suggested by water levels higher in the spoil than in laterally adjacent sources.

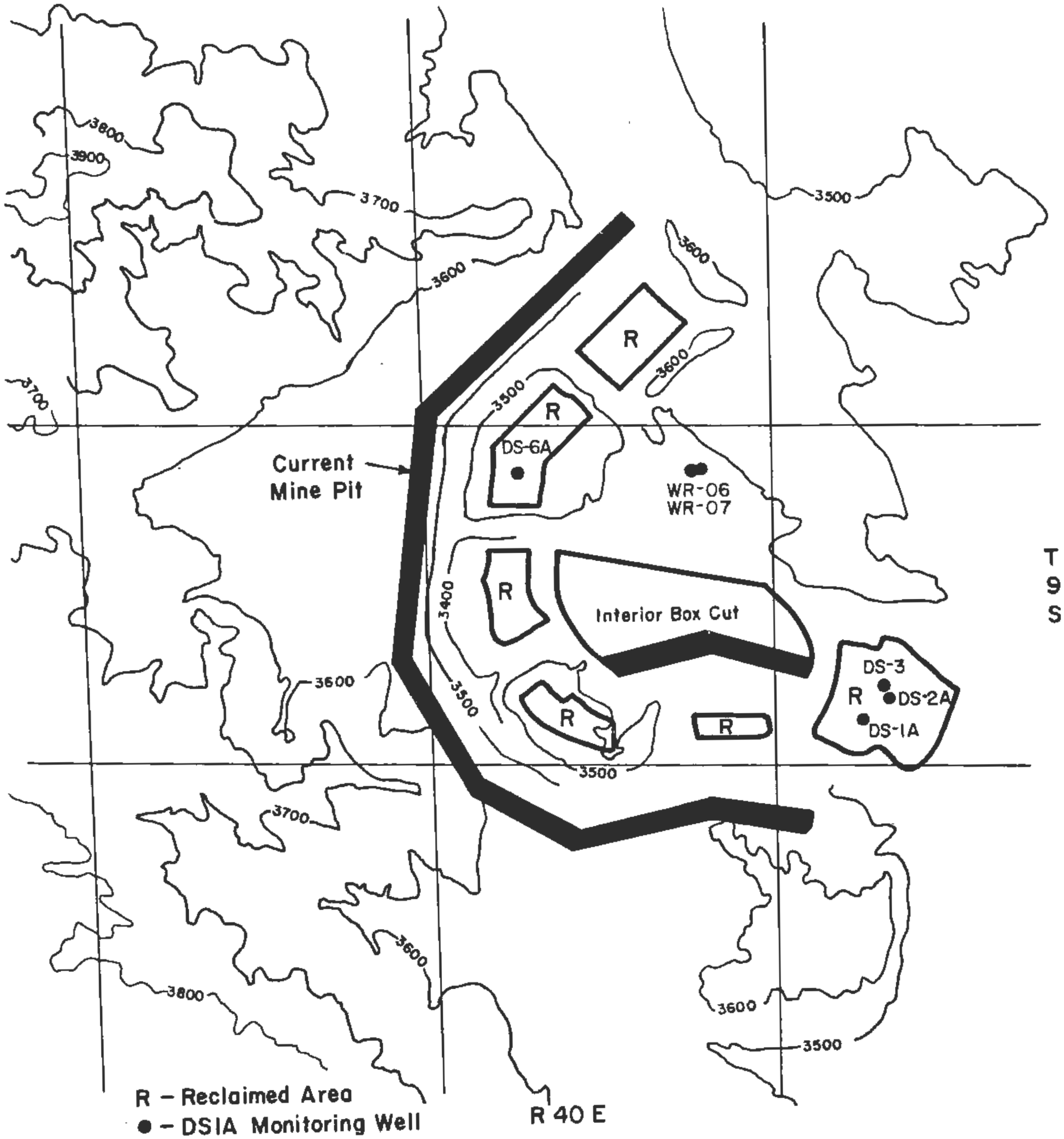

Figure 3. Existing topography at the West Decker Mine, including current mine pit, interior box cut, reclaimed areas and monitoring wells.

(9)

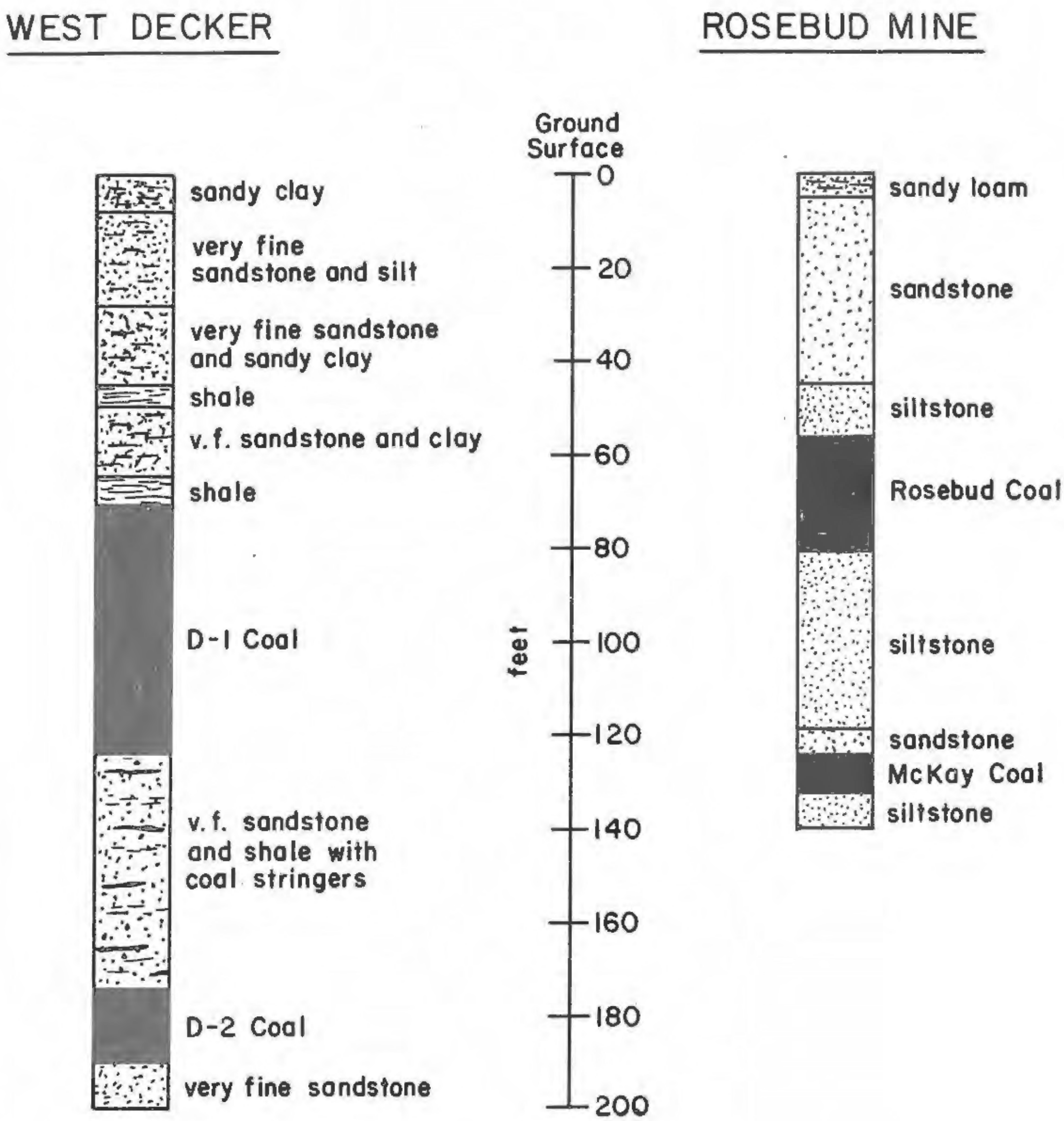

Figure 4. Typical stratigraphic columns for the West Decker and Rosebud mines.

(1,2)

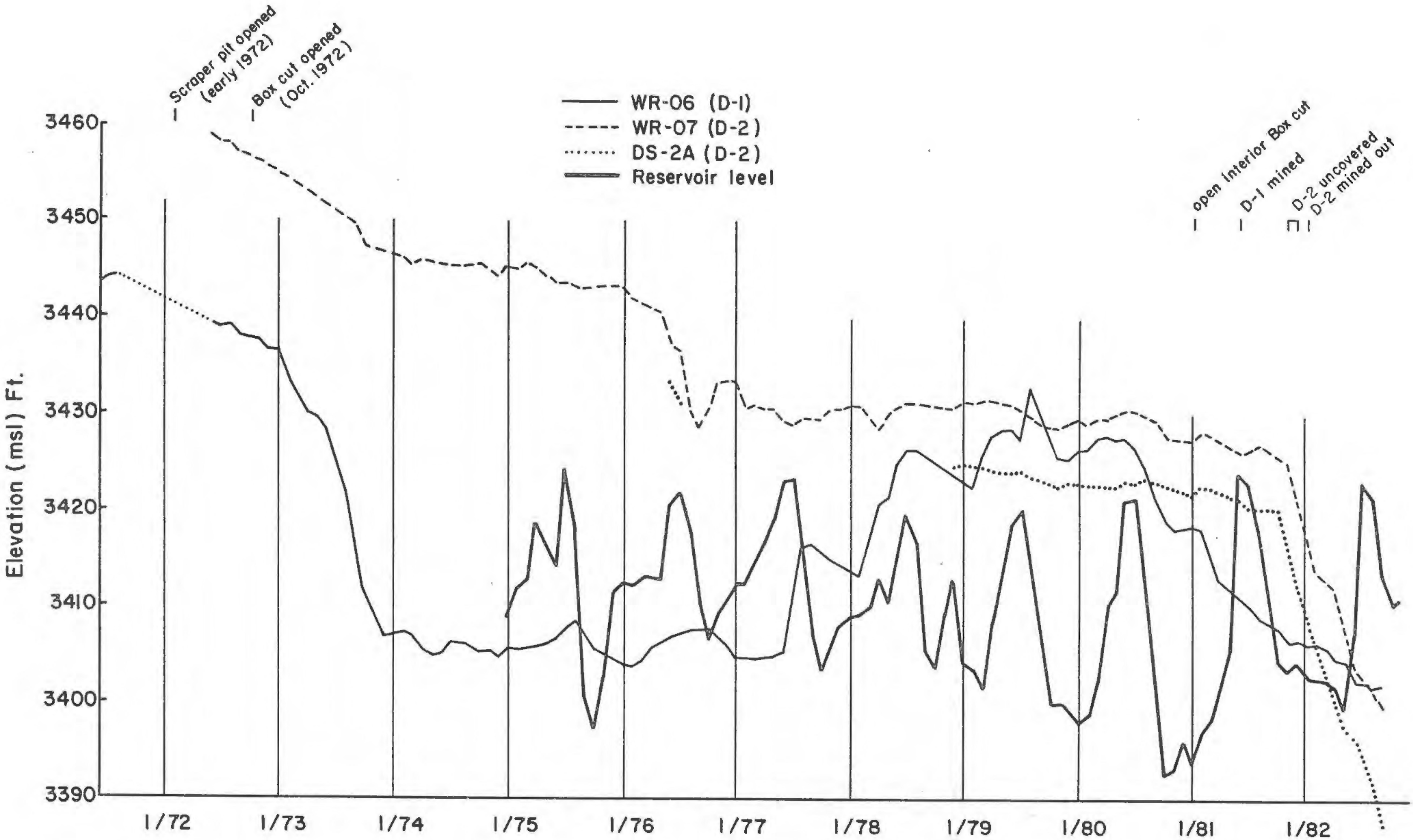

Figure 5. Hydrographs of D-1 and D-2 Coal Aquifers at West Decker for period July, 1972 to September, 1982.

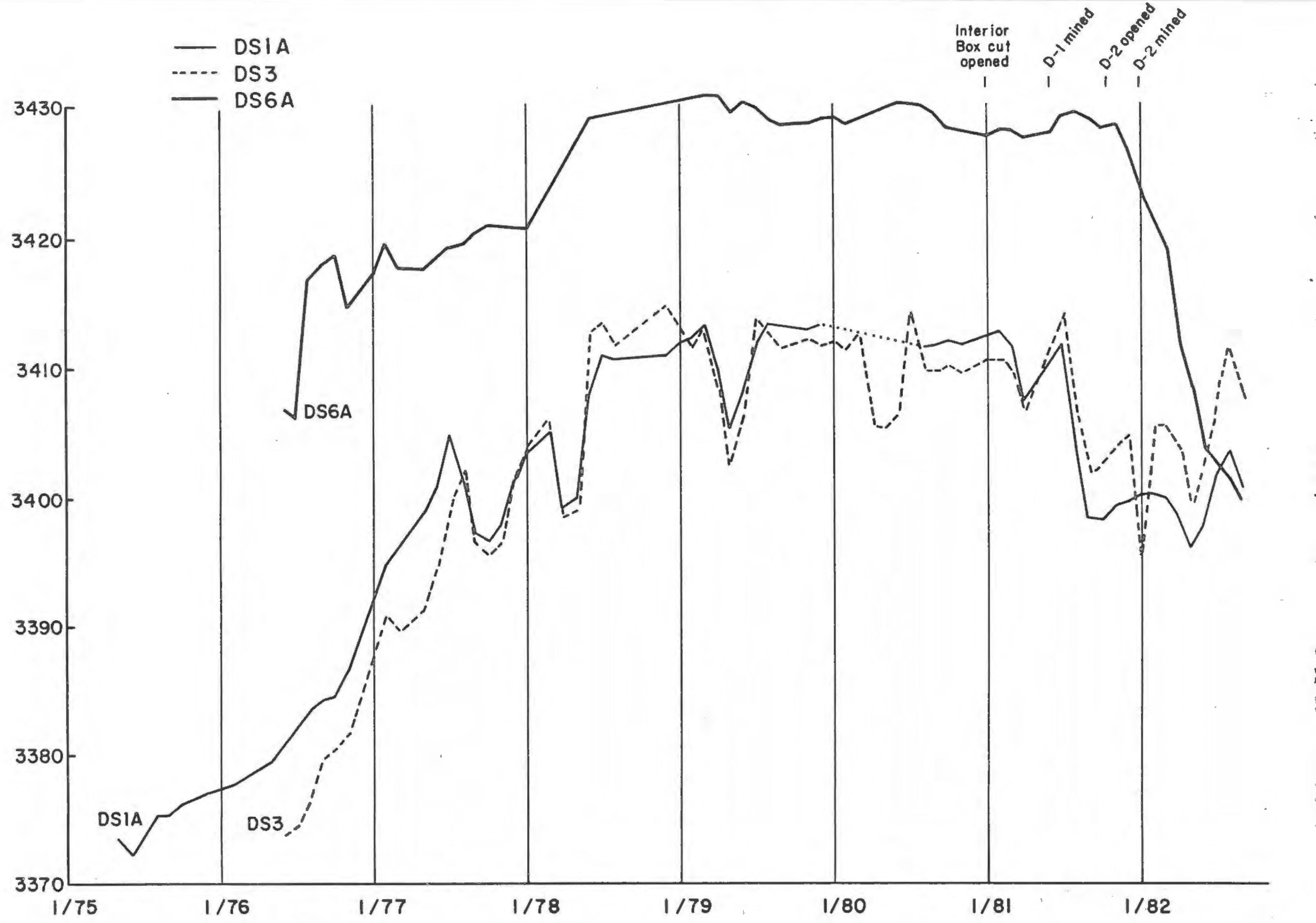

Figure 6. Spoils Aquifer Hydrographs at West Decker for period May,1975 through September,1982.

The chemical composition of water from both the spoil and coal aquifers is a sodium bicarbonate type, with the spoil waters containing higher concentrations of calcium, magnesium, and sulfate. The similar water types may indicate upward migration from the D-2 whereas the higher concentrations of other ions indicate leaching of the spoil materials.

Water levels rose steadily until 1978, when the levels stabilized. Seasonal recharge peaks are evident in June and July of years 1978-1981. These are coincident with water levels in coal monitoring wells in the same area between the mine spoil and the reservoir. In 1981, water levels in both the spoil and coal wells in the mine interior began dropping in response to the opening of the interior box cut.

These lines of evidence show a strong interrelation between water levels in the spoil, coal aquifers and the Tongue River Reservoir. The spoil aquifer is being recharged both laterally and from beneath, but the major factor controlling water levels in the spoil aquifer is the Tongue River Reservoir stage. Water level fluctuations in spoil and coal wells in the interior of the West Decker mine strongly reflect water level fluctuations in the reservoir, whereas wells west of the active pit, isolated from the reservoir, show an earlier yearly response related to recharge from spring snowmelt.

Western Energy

Mining began at Colstrip in 1924 when the Northern Pacific Railroad mined coal to fuel steam-powered locomotives. In 1959, Montana Power Company bought the Colstrip townsite and the mining leases owned by Northern Pacific, and in 1968, Western Energy Company, began mining in the Pit 6 area. Active mining has since extended into Areas A, B, C and E, and an application has been submitted for Area D (Figure 2).

The geology controlling the groundwater hydrology of the Rosebud mine differs from the West Decker mine. The coal beds are shallow aquifers, but there are no surface water bodies of sufficient size to significantly affect spoil aquifer recharge. The valley of East Fork Armells Creek, an ephemeral stream in the mine area, contains only small amounts of alluvium which could store water and provide recharge to mine spoil. One local source of spoil recharge water is a small pond in the Pit 6 area. Sediment ponds also contribute to groundwater recharge, but are generally located downgradient from mined areas and have little affect on mine spoil.

Surface infiltration is a more significant recharge factor at the Rosebud mine, especially in areas of thin overburden. The Rosebud overburden is coarser textured, and the clays are less sodic, (2, 1) indicating a greater potential for infiltration and downward movement of water (Figure 4).

Lateral recharge from unmined Rosebud coal and vertical recharge from the underlying McKay coal may contribute to spoil recharge, although definitive evidence is lacking for recharge from the McKay. Three sets of hydrographs of well pairs finished in the spoil and McKay coal were analyzed. The well pairs were chosen because of their long periods of record and their curves are believed to be typical for spoil and McKay wells in their respective locations. Two pairs of wells are along the eastern edge of the old Northern Pacific spoil (Figures 2, 7, and 8), two pairs are located adjacent the impoundment in Pit 6 (Figures 2 and 9), and 1 pair is in the older, reclaimed portion of Area B (Figures 2 and 10). Interburden thicknesses range from 0.6 to 4.0 m. (2 to 13 ft) in the Northern Pacific and Pit 6 areas, to 6.1 to 7.6 m. 20 to 25 ft) in Area B. All the well pair hydrographs indicate a good hydrologic connection between the spoil and underlying McKay coal.

In the first area, well pairs S-08 (McKay)/S-09 (Spoil) and S-10 (Spoil)/S-11 (McKay), with 0.6 to 1.8 m. (2 and 6 ft) of interburden, respectively, show that the McKay head is generally greater than the spoil head (Figures 7 and 8). At those locations, the spoil tends to be dry, becoming only partially saturated during periods of higher than normal precipitation. The McKay coal shows a similar response to precipitation patterns, but remains partially saturated during extended dry periods. The data are inadequate to indicate whether the source of the spoil water recharge is surface infiltration, lateral inflow derived from unmined coal, or recharge from the McKay coal. Undoubtedly, all three play parts of varying significance to spoil recharge.

Part of the reclaimed area in Pit 6 drains internally to a perennial pond. The pond is the main source of recharge to the spoil, and possibly to the McKay coal, in that area. The soils and spoil in the Pit 6 area are very sandy, and contribute to a higher recharge rate there. The interburden between the spoil and McKay coal is about 4.0 m. (13 ft) thick.

The hydrographs for McKay/spoil well pairs EPA-09 and 10 and EPA-11 and 12, shows that shortly after the wells were installed, piezometric levels in the spoil rose above those in the McKay, and have remained higher to the present (Figure 9). This suggests a downward movement of groundwater into the spoil from the pond. Response to yearly precipitation levels is evident. Years 1975, 1976, 1978 and 1979 show relatively rapid rises in the water levels, compared to a more gradual rise in years of lower precipitation. Both the spoil and McKay show the response, but it is more pronounced in the spoil because of higher water levels in wet years increased the rate of recharge. Thus, a perennial source of surface water, coarse textured soil and spoil materials, higher piezometric head in the spoil and a greater response to precipitation events in the spoil indicate surface recharge is the main factor in spoil recharge in the Pit 6 area.

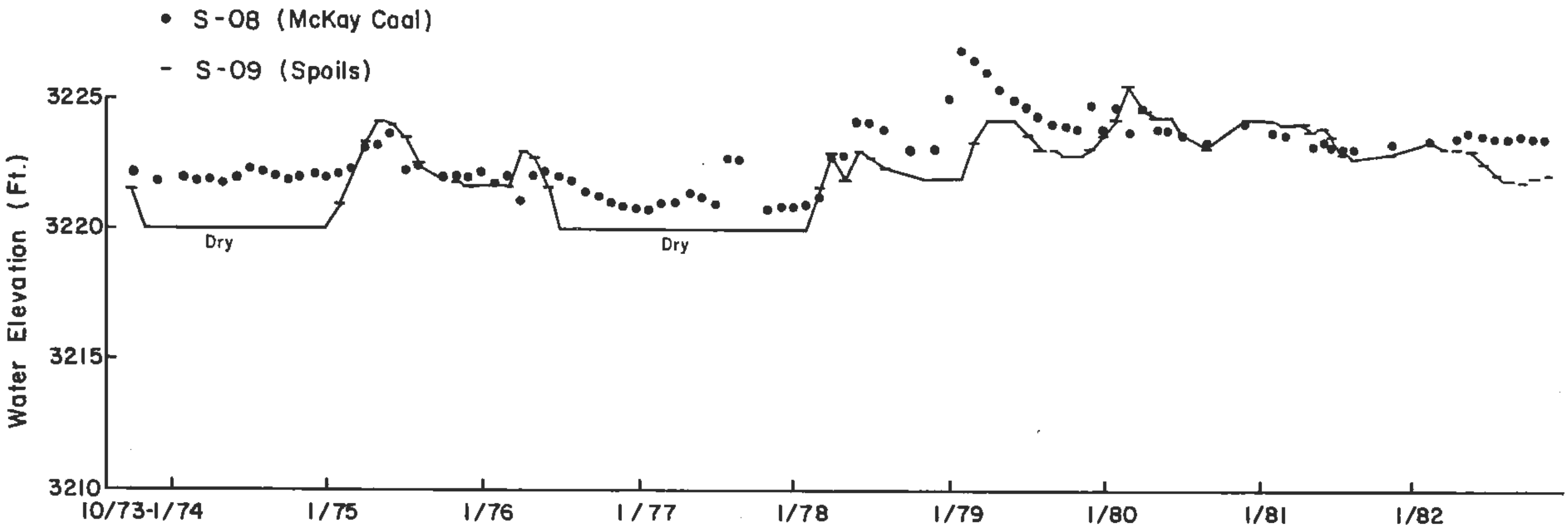

Figure 7. Hydrographs for wells S-08 and S-09, Rosebud Mine, for period October, 1973 to October, 1982.

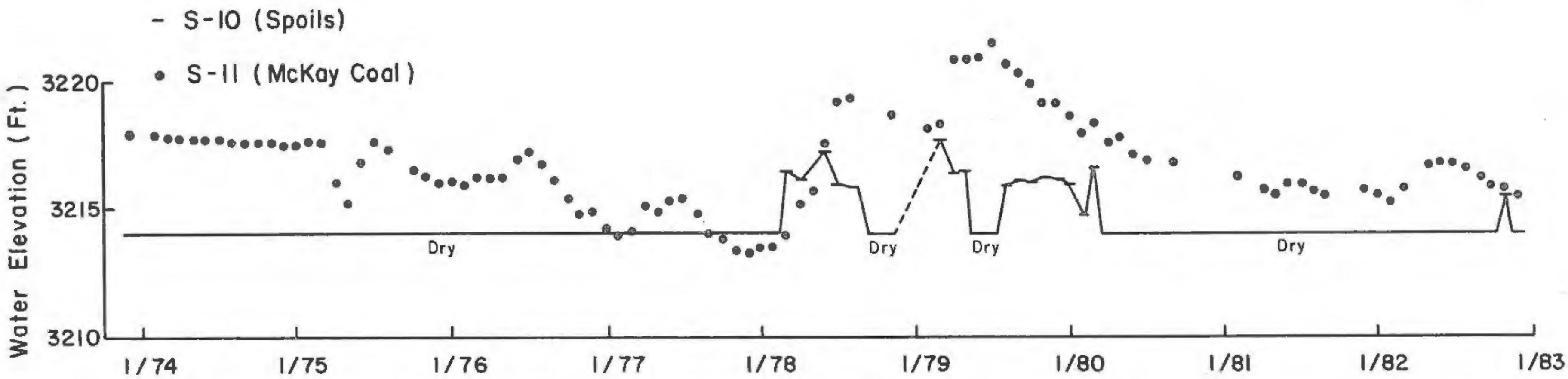

Figure 8. Hydrographs for wells S-10 and S-11, Rosebud Mine, for period October, 1973 to December, 1982.

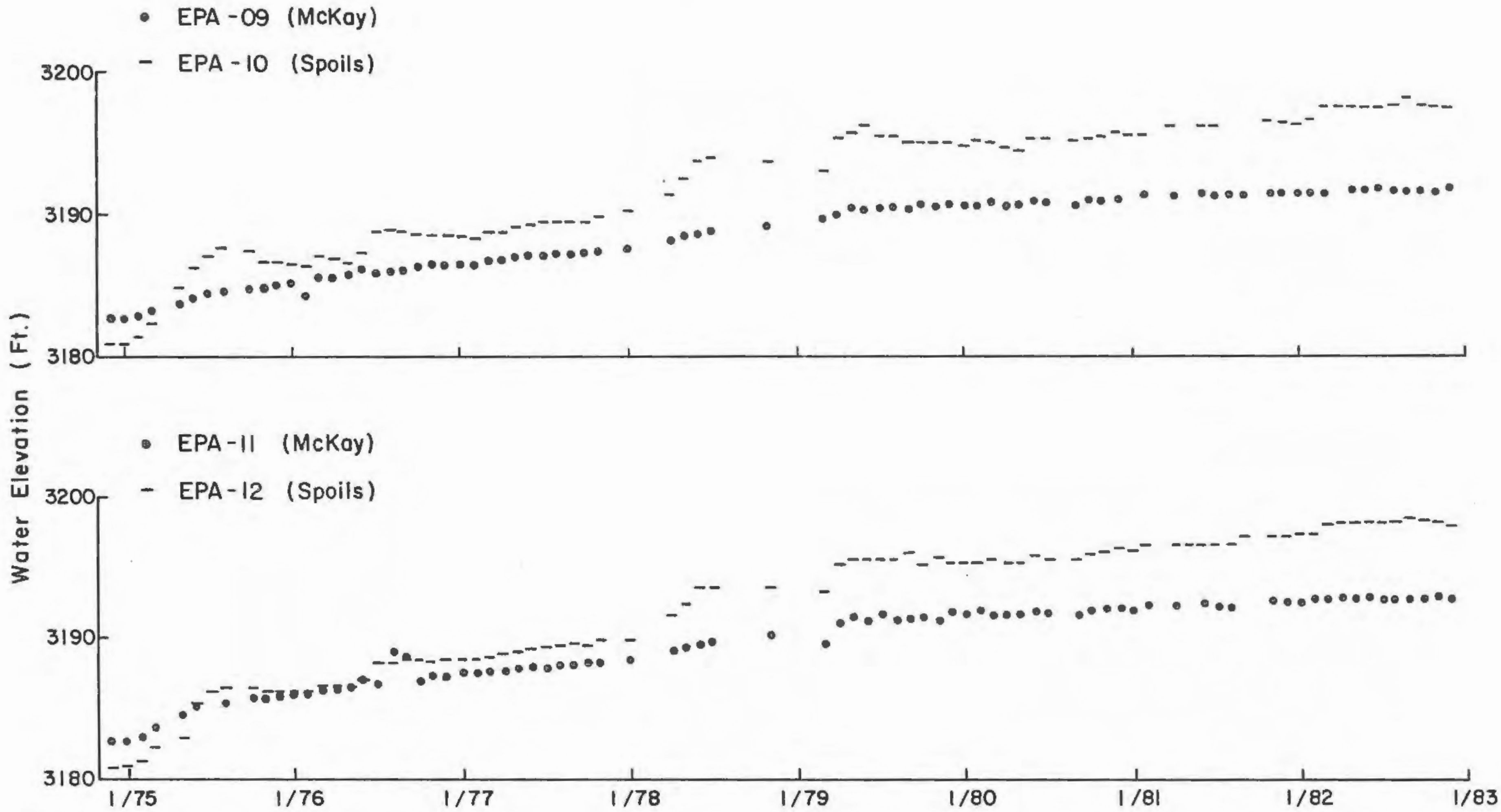

Figure 9. Hydrographs for wells EPA-09, 10, 11, 12, Rosebud Mine for period December, 1974 to December, 1983.

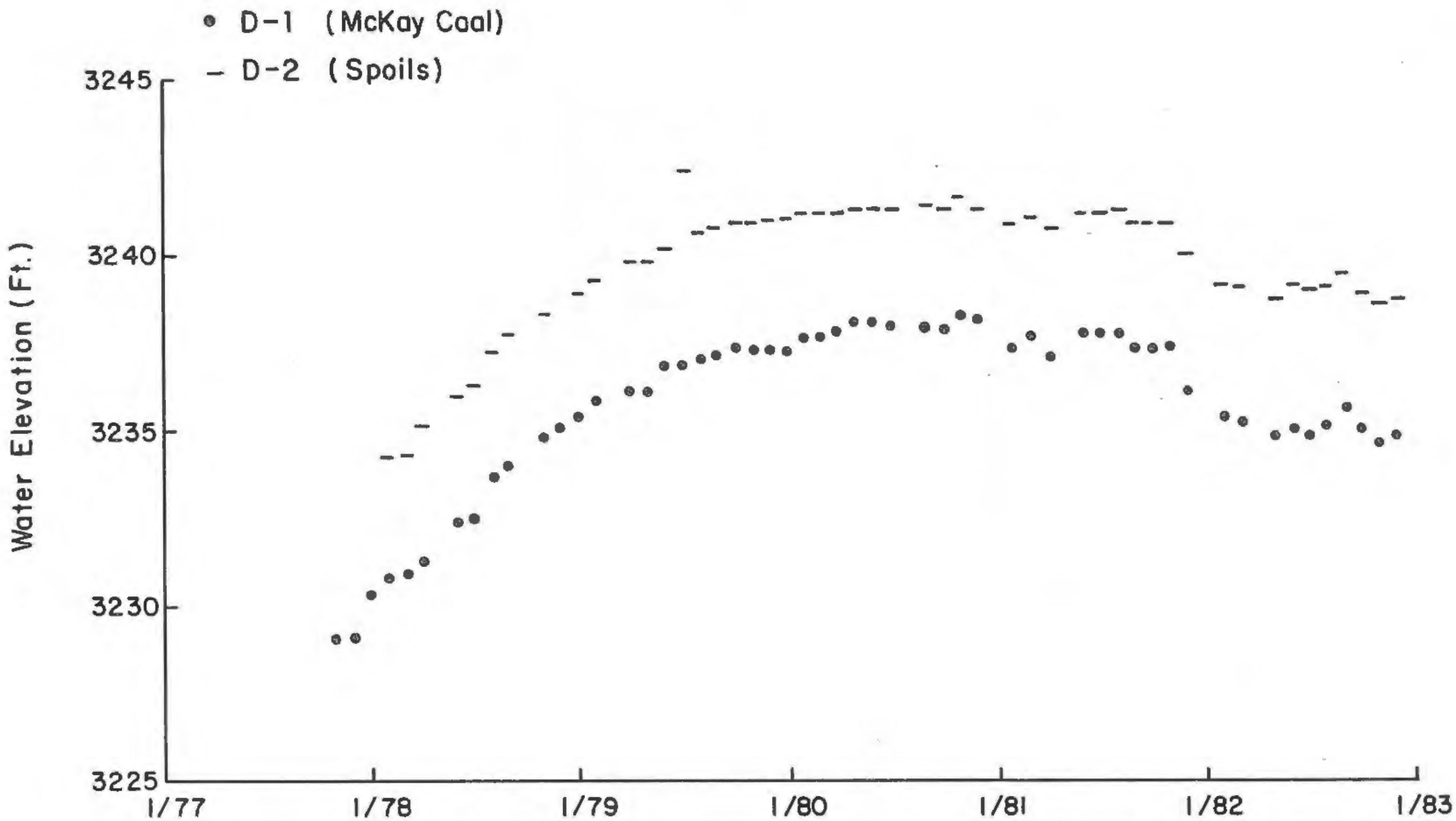

Figure 10. Hydrographs for D-1 (McKay Coal) and D-2 (Spoils) wells for period November, 1977 to December, 1982 Western Energy.

The third area analyzed is in the older portion of Area B spoil. The spoil/McKay interburden is 6.1 to 7.6 m. (20 to 25 ft) thick, and the area lies approximately on a north-south trending groundwater divide. Unmined Rosebud coal is present about 91 to 122 m. (300 to 400 ft) to the northeast. The hydrographs for wells D-1 (McKay coal) and D-2 (Spoil) (Figure 10) show that water levels in both the spoil and McKay coal rose steadily from the beginning of 1978 until about the middle of 1979. They remained stable until late 1981, after which they declined about 1.5 m. (5 ft) to a lower, relatively stable level in the spring of 1982. During the period of record, the spoil head has consistently been 1.8 to 2.4 m. (6 to 8 ft) higher than the head in the McKay coal.

The spoil is about 24 m. (80 ft) thick in this area, so it is unlikely that surface infiltration has had a large effect on the spoils' recharge. Given the head differential between the spoil and McKay coal, it is also unlikely recharge is coming from the McKay coal. The most likely source of recharge is adjacent unmined Rosebud coal. The smoothness of both the spoil and McKay curves indicates a constant rate of recharge to both the spoil and McKay coal following mining and spoil replacement.

SUMMARY AND CONCLUSIONS

Recharge to coal mine spoil in southeastern Montana comes from three principal sources: 1) laterally from unmined coal beds, 2) from lower aquifers with a higher piezometric head than the spoil, and 3) surface infiltration. The presence or absence of surface water bodies in the vicinity of mine spoil influence the rate of recharge from all three factors.

At West Decker, recharge is primarily from adjacent, unmined coals that subcrop under the Tongue River Reservoir and underlying coal beds with higher heads. Surface recharge is insignificant because of the thickness and fine texture of the spoil. At the Rosebud mine, recharge is predominantly from adjacent, unmined coal in Area B although in other areas, surface infiltration is enhanced by thin spoil, coarser texture of the spoil, and small, surface water bodies in certain parts of the mine. Recharge from the underlying McKay coal is insignificant.

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