POTENTIAL EFFECTS OF SURFACE COAL MINING ON THE HYDROLOGY OF THE HORSE CREEK AREA, SHERIDAN AND MOORHEAD COAL FIELDS, SOUTHEASTERN MONTANA

By Neal E. McClymonds

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CONVERSION FACTORS

The following factors can be used to convert inch-pound units in this report to the International System (SI) of units.

Multiply inch-pound unit	By	To obtain SI unit
acre-foot	1233	cubic meter
cubic foot (ft^3)	0.02832	cubic meter
cubic foot per day (ft^3/d)	0.02832	cubic meter per day
cubic foot per second (ft^3/s)	0.02832	cubic meter per second
foot	0.3048	meter
foot per day (ft/d)	0.3048	meter per day
foot per mile (ft/mi)	0.1894	meter per kilometer
foot squared per day	0.09290	meter squared per day
gallon per minute (gal/min)	0.06309	liter per second
gallon per minute per foot	0.2070	liter per second per meter
inch	25.40	millimeter
micromho per centimeter at 25° Celsius (micromho)	100	microsiemens per meter at 25° Celsius
mile	1.609	kilometer
square mile (mi^2)	2.590	square kilometer
ton (short)	0.9072	megagram

Temperature can be converted to degrees Fahrenheit (°F) or degrees Celsius (°C) by the equations:

$$°F = 9/5\ (°C) + 32$$
$$°C = 5/9\ (°F - 32)$$

POTENTIAL EFFECTS OF SURFACE COAL MINING ON THE HYDROLOGY OF THE HORSE CREEK AREA, SHERIDAN AND MOORHEAD COAL FIELDS, SOUTHEASTERN MONTANA

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ABSTRACT

The Horse Creek area is located about 16 miles east-northeast of the West Decker and East Decker Coal Mines near the Tongue River. The area contains large reserves of Federally owned coal that have been identified for potential lease sale. A hydrologic study has been conducted in the area to describe existing hydrologic systems and to assess potential effects of surface mining on local water resources.

Hydrologic data collected from private wells, observation wells, test holes, and springs indicate that the shallow aquifers are primarily coal and sandstone beds in the upper part of the Tongue River Member of the Fort Union Formation (Paleocene age) and valley alluvium (Pleistocene and Holocene age). The principal aquifers in the area are the Canyon, Dietz, and Anderson coal beds and sandstone beds above and between the coal beds. Alluvial sand and gravel is also a productive aquifer. Two stock wells, one spring, and three stock ponds receiving spring discharge supply most of the water used within the Horse Creek basin; the only use is watering of livestock.

Surface-water flow is limited to short periods after intense rainfall or snowmelt. Except for three ponds receiving seep or spring discharge in the upstream part of the basin, ponds in the Horse Creek area are generally dry by midsummer.

The water supplied by wells from the Tongue River Member sandstone and coal aquifers is generally a sodium bicarbonate type, although some ground water has a large sulfate content, particularly in the Dietz coal bed and some sandstone beds. Dissolved-solids concentrations of water from the Tongue River Member range from 1,560 to 1,760 mg/L (milligrams per liter) for the Canyon coal bed; 1,920 to 7,690 mg/L for the Dietz coal bed; 2,320 to 2,550 mg/L for the Anderson coal bed; 820 to 6,240 mg/L for sandstones; and 198 to 543 mg/L for clinker. Dissolved-solids concentrations of water from alluvium range from 2,460 to 9,770 mg/L, and the water type is sodium magnesium sulfate.

Mining the approximately 50 million tons of Anderson and Dietz coal would destroy one stock well and two ponds receiving spring discharge. The potentiometric surface of the Anderson and Dietz coal aquifers would decline, particularly to the northeast of the potential mine. The lowered water levels would not affect any existing wells in the vicinity of the mine. After mining, ground water downgradient from the mine area might show long-term degradation in quality as a result of leaching of soluble minerals from overburden materials used to backfill the mine pits. This

degradation could be lessened by structuring the spoils to permit minimum water flow through the spoils material. Although mining would alter the existing hydrologic systems, alternative supplies of water are available. The two ponds that would be destroyed by mining could be replaced near their present sites. The well that would be destroyed could be replaced by drilling a new well to a sandstone aquifer about 250 feet below land surface.

INTRODUCTION

Development of western coal to meet national energy needs is receiving increased emphasis. A large part of the western coal is under Federal ownership; therefore, considerable demand exists for the leasing and development of Federal coal lands. To ensure orderly leasing and development of Federal coal, a Federal Coal Management Program was developed, which requires the U.S. Bureau of Land Management to identify tracts of coal for potential lease, analyze the tracts for potential environmental effects, and schedule selected tracts of coal for lease sale.

One of the primary considerations in the selection of tracts for lease is potential adverse effects to the water resources of an area during mining and reclamation operations, and after abandonment. To determine potential effects and reclamation potential of coal tracts, the U.S. Geological Survey is cooperating with the Bureau of Land Management under the EMRIA (Energy Minerals Rehabilitation Inventory and Analysis) program. As part of this program, the U.S. Geological Survey is conducting hydrologic studies on several potential coal-lease tracts in the Powder River structural basin of southeastern Montana. The Horse Creek area (fig. 1) of the Sheridan and Moorhead coal fields is one of these tracts.

Purpose and scope

The purpose of the study was to describe existing hydrologic systems, to obtain data on the water quality in the area, and to assess potential effects of surface coal mining on local water resources. Specific objectives of the study were to:

(1) Identify ground-water resources;
(2) identify surface-water resources and runoff characteristics;
(3) determine quality of the water resources;
(4) determine probable effects on existing water resources from mining operations, including possible changes in the quantity and quality of water; and
(5) evaluate the potential for reclamation of local water resources.

To accomplish these objectives, hydrogeologic and lithologic data were collected from existing wells, springs, and drill holes. Eight additional observation wells and test holes were completed where data were lacking in the bedrock aquifers and 16 observation wells were completed in the alluvial aquifer at four sites along Horse Creek valley. Aquifer tests were conducted at all producing observation wells and a network of wells was established to observe long-term fluctuations of ground-water levels. Ground-water samples were collected from wells and springs and analyzed for chemical quality. Channel-geometry measurements were made to estimate runoff characteristics in the Horse Creek basin.

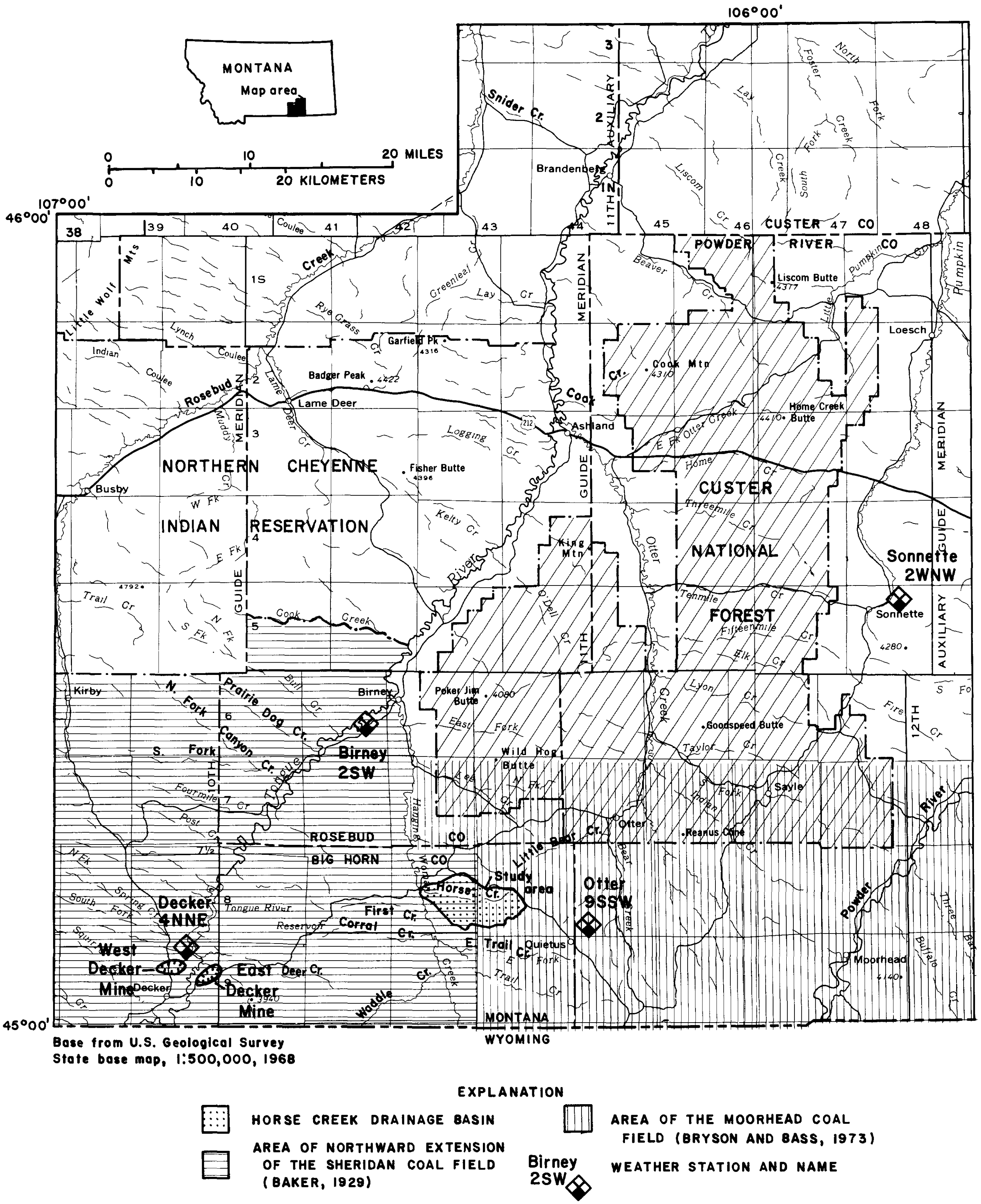


Figure 1.--Location of the Horse Creek drainage basin in southeastern Montana.

The information in this report emphasizes the potential effects of mining and the potential for reclamation of the hydrologic systems. Supporting technical information on geology, water resources, and water quality is given for the interested reader who may want to verify the conclusions reached.

Location and description of the area

The Horse Creek area includes the entire Horse Creek drainage basin, 16.0 mi^2 in extent, in Big Horn County, southeastern Montana. In addition, some information was collected in parts of the Stroud Creek drainage to the north, the Little Bear Creek drainage to the northeast, the East Trail Creek drainage to the south and southeast, and the Hanging Woman Creek valley to the west. The Horse Creek basin is about 16 miles east-northeast of the Tongue River Reservoir at the East Decker and West Decker Coal Mines, about 14 miles south of Birney, about 9 miles west-southwest of Otter, and 8 miles north of the Montana-Wyoming State line (fig. 1).

Horse Creek drains westward from the Otter Creek-Hanging Woman Creek divide, with a maximum altitude of about 4,190 feet above sea level, to Hanging Woman Creek, at an altitude of about 3,450 feet just south of the OW Ranch headquarters (fig. 2). The drainage basin is 7.3 miles long and 3.2 miles wide. Horse Creek divides the basin almost equally, with small tributaries from north and south; the largest tributary basin has a drainage area of 1.4 mi^2. Horse Creek and all tributaries are ephemeral, flowing only after intense spring or summer rainstorms or spring snowmelt.

The land surface has benches, buttes, ridges, and valleys formed by differential erosion of the harder and softer layers of sandstone, siltstone, shale, and coal beds of the Tongue River Member of the Fort Union Formation. Erosion-resistant clinker beds, created by burned coal beds and scorched overlying sediments, form the ridges of the north and south divide at the lower, west end of the basin. This clinker layer approaches the level of Horse Creek channel about 3.7 miles upstream from the mouth of Horse Creek.

Climate

The climate in the Horse Creek area is typical of the northern Great Plains--semiarid with warm summers, cold winters, moderate humidity, and generally little but variable rainfall. Air temperatures vary from a monthly average of about 19°F in January to about 72°F in July at the Otter 9 SSW station (fig. 1) about 4 miles east of the upstream end of the basin (fig. 3); the average annual temperature is about 46°F during the 20 years of record, 1962-81.

The average annual precipitation in nearby areas ranges from about 13 inches at low altitudes (Decker 4 NNE, Birney 2 SW, and Sonnette 2 WNW stations; fig. 1) to about 19 inches at higher altitudes (Otter 9 SSW station). The precipitation in the Horse Creek basin is between these averages. As shown in figure 4, during average years about 40 percent of the annual precipitation occurs during April, May, and June, with June usually being the wettest month. Monthly precipitation during 1980 and 1981 (fig. 4) gives an indication of the wide variability of precipitation from year to year and from station to station.

Previous investigations

One of the earliest investigators of the geology and ground-water resources in the region was Darton (1906); the Horse Creek area was a small part of his broad study of the central Great Plains. Taff (1909) studied the coal deposits around Sheridan, Wyo., and later Baker (1929) extended the studies northward around the Decker area and eastward to Horse Creek. Warren (1959) worked in the Birney-Broadus coal field, north of Horse Creek basin, in 1938 and 1939, mapping and defining the multiple coal beds of the Tongue River Member of the Fort Union Formation. Bryson conducted similar mapping in the upstream part of Horse Creek basin and eastward across the Powder River in 1940, 1941, and 1946 (Bryson and Bass, 1973). Matson and Blumer (1973) described the quality and quantity of strippable coal in the Tongue River Member in a comprehensive report on coal deposits of southeastern Montana. Culbertson and others (1976) mapped the northern part of the Horse Creek basin in detail, as part of the Stroud Creek quadrangle study. Culbertson and Klett (1979a,b) mapped the southern part of the basin in detail, as part of their Forks Ranch and Quietus quadrangles studies.

Ground-water resources and hydrologic characteristics of rocks in southeastern Montana, partly including the Horse Creek basin, have been studied by Perry (1931), Lewis and Roberts (1978), and Stoner and Lewis (1980). Slagle and Stimson (1979) compiled ground-water data from 1,924 wells in the northern Powder River Basin.

The quality of ground water and geochemical processes that control the quality of water in the Tongue River Member have been investigated by Lee (1979, 1981) and Dockins and others (1980). The quality of surface water in the region has also been investigated by Knapton and McKinley (1977) and Knapton and Ferreira (1980).

Potential effects of coal mining on water resources in the Tongue River drainage basin have been the focus of several studies. Effects of coal mining on water resources in the Decker area were studied by Van Voast (1974) and Van Voast and Hedges (1975). Woods (1981) developed a computer model for assessing potential increases in dissolved solids of streams as a result of leaching of mine spoils. The U.S. Department of the Interior (1977) also conducted a study of the East Trail Creek area, for which the U.S. Geological Survey conducted the hydrologic studies. McClymonds (1984) completed a similar study on the hydrology and effects of surface mining in the Corral Creek area, 3 miles south of Horse Creek basin on the west side of Hanging Woman Creek.

WATER USE AND SUPPLY

Ground-water and surface-water supplies are used only for livestock watering within the Horse Creek basin. No residences are present inside the basin, but the headquarters of the OW Ranch is about 0.2 mile north of the mouth of Horse Creek (fig. 2). A well and a spring supply domestic water to houses at the headquarters.

Wells, springs, and stock ponds supply all water used by livestock within the study area. One developed spring and two wells equipped with windmills provide year-round water supplies. Three ponds receiving spring discharge (fig. 2) are reliable during all but the driest years. Other stock ponds are filled only after intense rainfall or melting of a large snowpack; these ponds commonly become dry by midsummer.

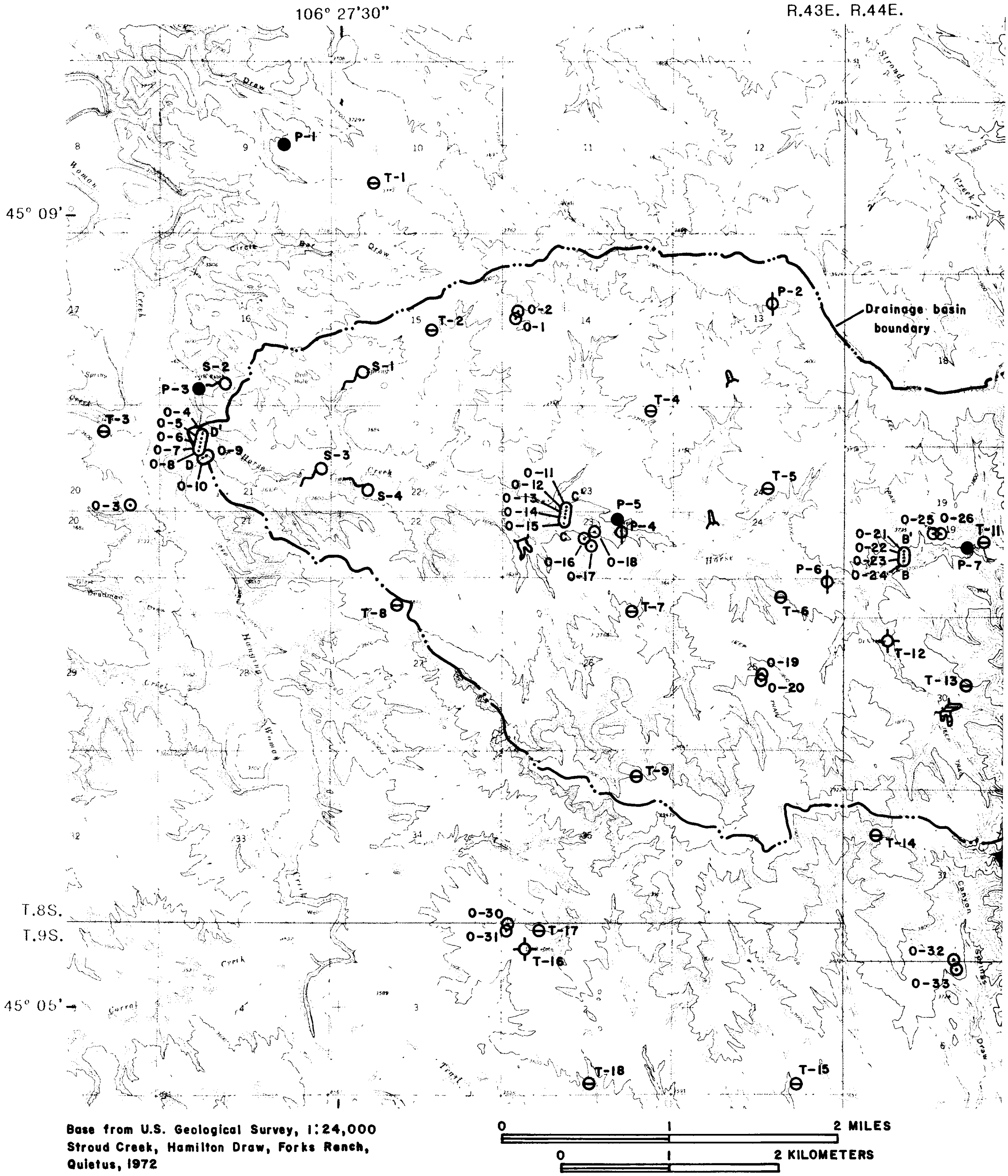
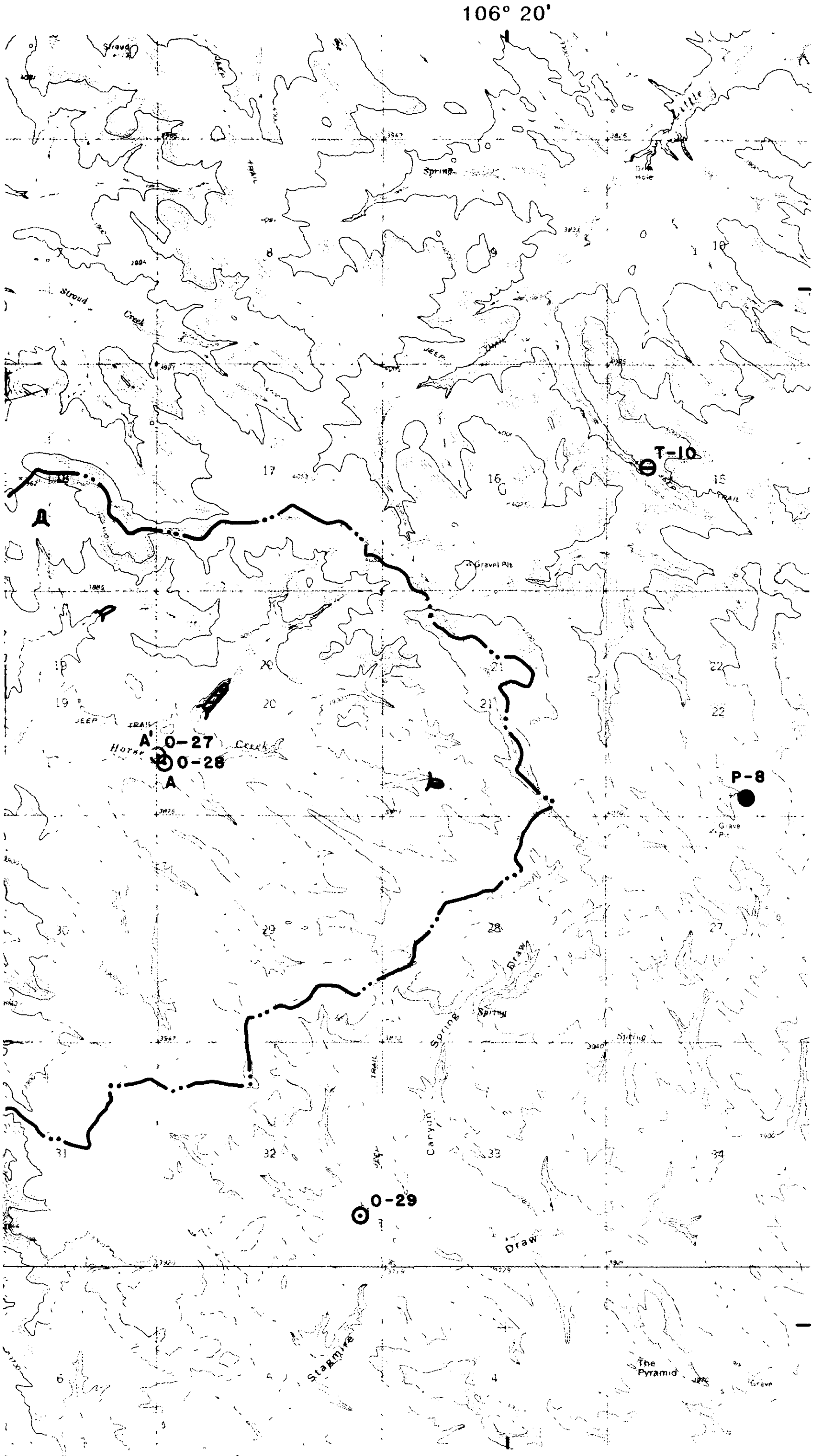


Figure 2.--Location of private and observation wells, test holes, springs,



EXPLANATION

DATA SITE AND NUMBER

P-1 ● Private well, used

P-2 Private well, unused

O-1 Observation well

T-1 Test hole, uncased, filled in

T-12 Oil test hole--casing intact but inaccessible

S-1 Spring

STOCK POND--Maintains water by spring seeps except during driest years

STOCK POND--Usually maintains water for short intervals during spring and early summer

C C' LINE OF ALLUVIAL GEOLOGIC SECTIONS (fig. 13)

and stock ponds in the Horse Creek and adjacent areas.

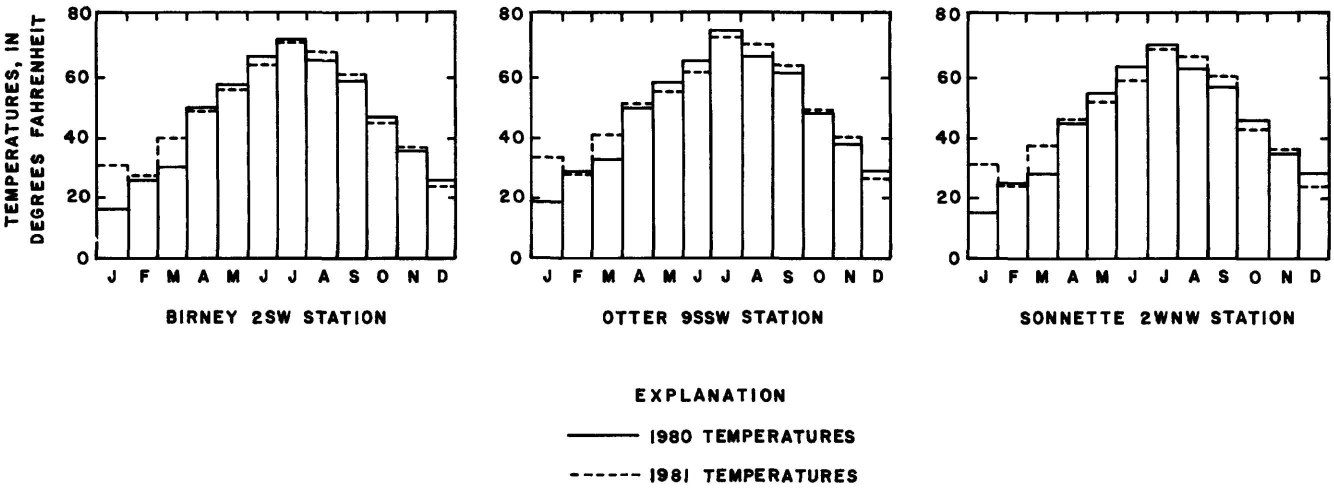


Figure 3.--Monthly average air temperatures at three weather stations near the Horse Creek area.

Surface-water supply, other than the stock ponds, exists only in Horse Creek channel, about 1 mile upstream from the mouth, where water from an undeveloped spring flows into the broad, marshy channel. Upstream and downstream from this area, Horse Creek flows only intermittently.

POTENTIAL EFFECTS OF MINING ON AREA HYDROLOGY

Assumptions

The effects of mining on local hydrologic systems can be predicted most accurately if a mine plan is available that details the location of mine cuts, direction and rate of mine expansion, and duration of mining. The timing and location of mine cuts are particularly important for calculating transient ground-water flow into the mine pit and for evaluating the temporal and spatial changes on the potentiometric surface created by excavation of the pits.

No mine plan for the Horse Creek area is available. Therefore, predicted effects of mining on the local hydrologic systems are based on the assumptions that: (1) all mining of the Anderson and Dietz coal beds would take place within the mine boundaries as shown in figure 5; (2) mining would begin with the excavation of one long box cut along Horse Creek valley and expand northward, eastward, and southward from the cut; (3) the entire Anderson and Dietz coal beds would be removed from the mined area to a place where the overburden of the Anderson bed is about 200 feet thick; and (4) all mining regulations established by the U.S. Office of Surface Mining and the Montana Department of State Lands would be followed during mining and reclamation.

Effects during mining

Multiple aquifers transmit water through the site of the potential mine pit (see figs. 5 and 6). Several sandstone beds and lenses above and below the Anderson coal bed and the Smith, Anderson and Dietz coal beds all would yield water to

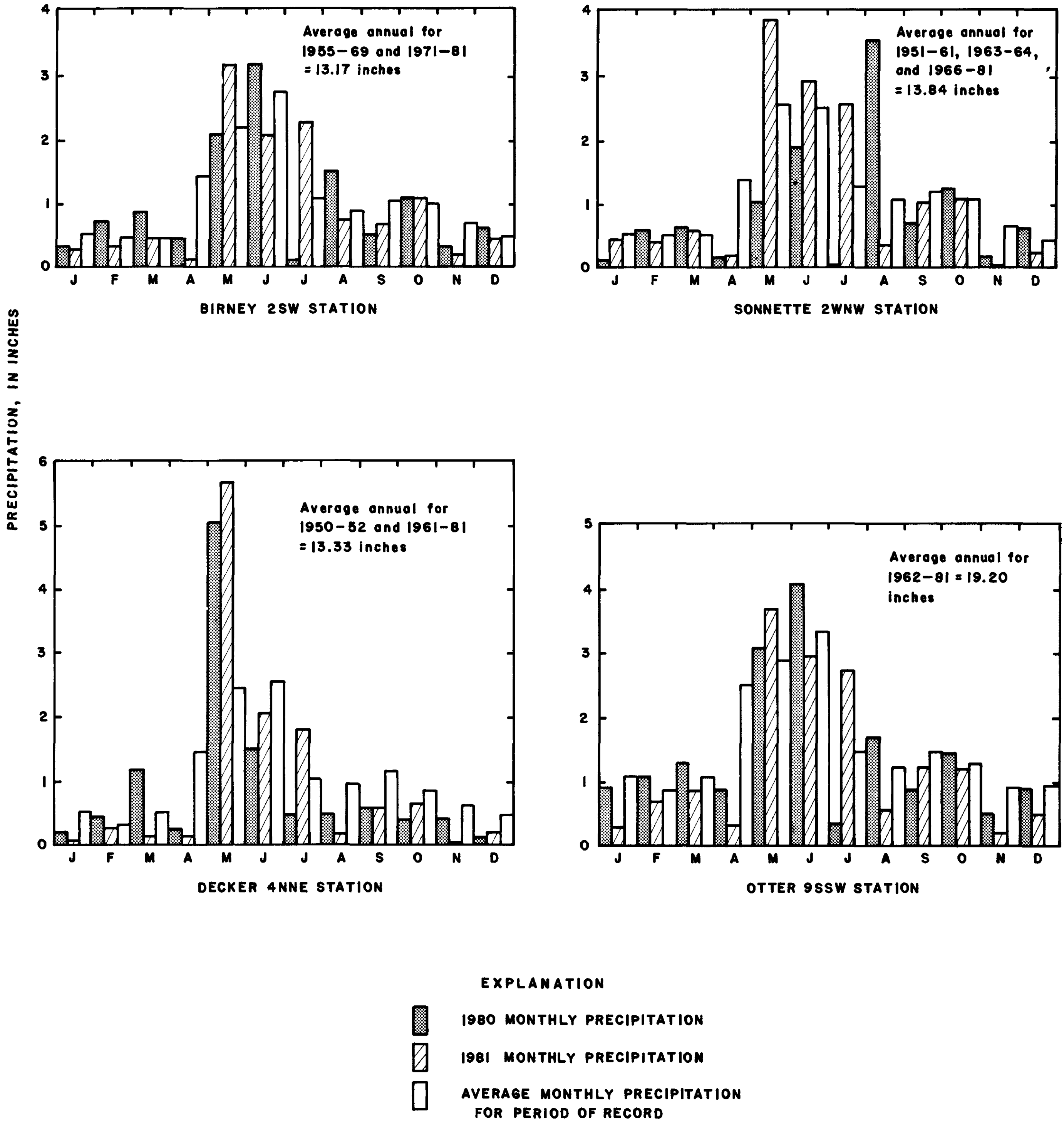


Figure 4.--Monthly, average monthly, and average annual precipitation at four weather stations near the Horse Creek area.

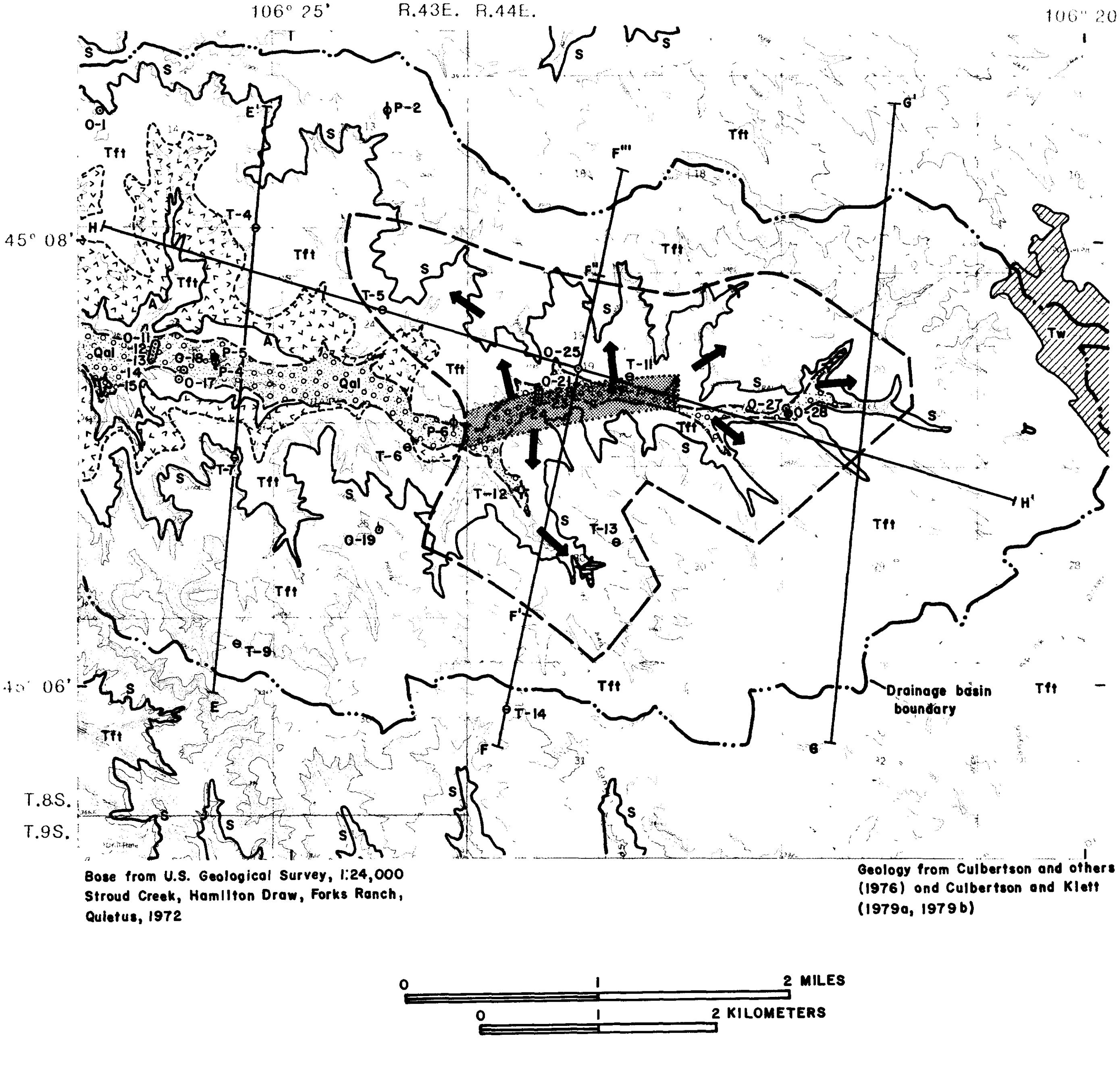


Figure 5.--Presumed location of the potential mine pit, direction of mining,

EXPLANATION

Qal — ALLUVIUM (HOLOCENE AND PLEISTOCENE)

Tw — WASATCH FORMATION (EOCENE)

Tft — TONGUE RIVER MEMBER OF FORT UNION FORMATION (PALEOCENE)

ANDERSON CLINKER, BURNED COAL, AND SCORCHED OVERBURDEN

CONTACT OF WASATCH FORMATION WITH TONGUE RIVER MEMBER

CONTACT OF ALLUVIUM WITH TONGUE RIVER MEMBER SEDIMENTS

UPPER CONTACT OF CLINKER--Approximately located

COAL BED, BASAL CONTACT

- S — Smith coal
- A — Anderson coal

INITIAL MINE BOX CUT

DIRECTION OF MINE PIT ADVANCE

POTENTIAL MINE-PIT FINAL BOUNDARY

E—E' — TRACE OF IDEALIZED STRATIGRAPHIC SECTION ACROSS POTENTIAL MINE PIT (figs. 6 and 7)--Based on projected test-hole and observation-well data

DATA SITE AND NUMBER

- P-5 — Private well, used
- P-2 — Private well, unused
- O-18 — Observation well
- T-4 — Test hole, uncased, filled in
- T-12 — Oil test hole--casing intact but inaccessible

STOCK POND--Maintains water except during driest years by spring flow

STOCK POND--Usually maintains water for short intervals during spring and early summer

geology, and data sites.

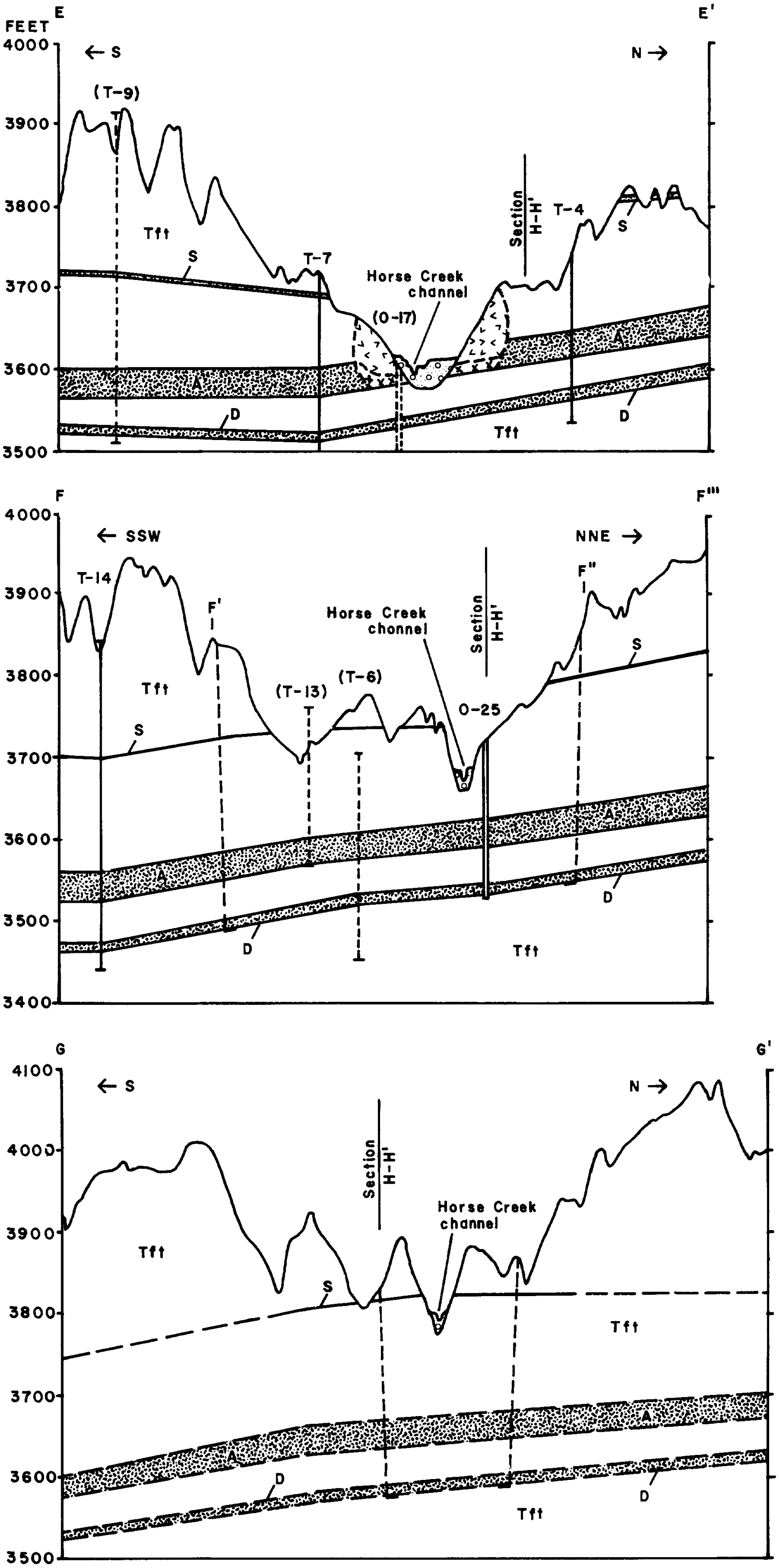
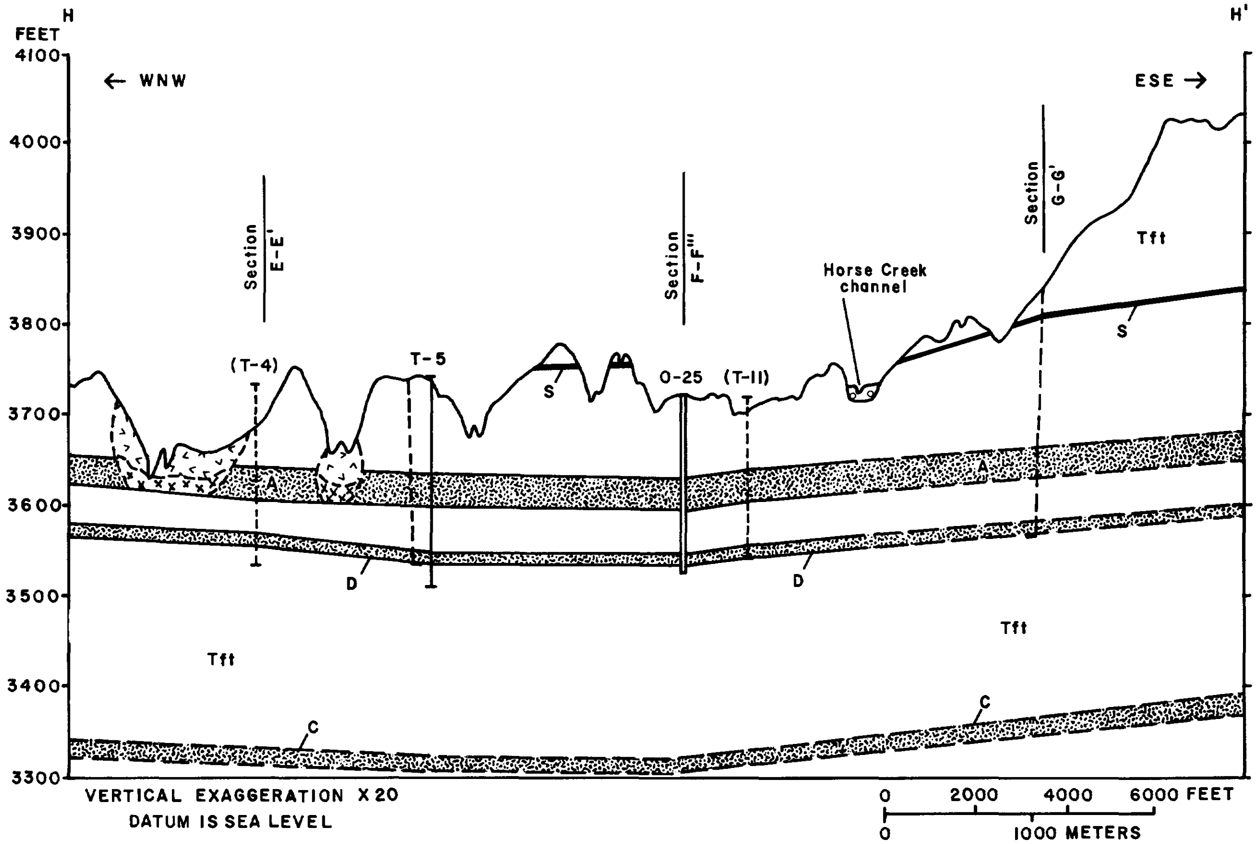


Figure 6.--Idealized stratigraphic sections across the potential mine pit showing



EXPLANATION

ALLUVIAL SAND, GRAVEL, AND MUD (HOLOCENE AND PLEISTOCENE)--Minor thicknesses not shown

Tft — SHALE, SILTSTONE, AND SANDSTONE OF THE TONGUE RIVER MEMBER, FORT UNION FORMATION, UNDIFFERENTIATED (PALEOCENE)

CLINKER--SCORCHED OVERBURDEN

CLINKER--BURNED COAL

COAL BED OF THE TONGUE RIVER MEMBER AND LETTER

S -SMITH COAL BED

D -DIETZ COAL BED

A -ANDERSON COAL BED

C -CANYON COAL BED

CONTACT BETWEEN BEDS--Dashed where approximately located

HIGHWALL OF POTENTIAL MINE

0-25 — OBSERVATION WELL AND NUMBER--On trace of section

T-4 — TEST HOLE AND NUMBER--On trace of section

(0-17) — OBSERVATION WELL AND NUMBER--Projected at right angle to trace of section

(T-6) — TEST HOLE AND NUMBER--Projected at right angle to trace of section

the relative positions of the coal beds. Traces of sections are shown in figure 5.

the potential mine. In addition, the alluvial sands and gravels along Horse Creek and probably sands and gravels along the main tributaries would contribute water to the mine pit. Mining of the Anderson and Dietz coal beds probably would have little or no effect on the hydraulic properties of the underlying Canyon coal bed and all deeper coal beds.

Mining would begin along the flood plain of Horse Creek (fig. 5). The mechanics of diverting flood flow from the potential mined area is not detailed in this report, but the mine probably would progress northward, diverting the floodwaters on the south side of the box cut, then progress southward diverting the water on the north side over replaced spoils. The destruction and reconstruction of the alluvial aquifer under the flood plain, however, are considered in this report.

The alluvial aquifer in the area of the potential mine pit has characteristics similar to those determined along section B-B' (fig. 2). There, using the aquifer characteristics as determined from aquifer tests at wells 0-22, 0-23, and 0-24, a calculated 1,000 ft^3/d of water passed through the alluvial aquifer at the September 1980 water levels. This amount decreases to about 600 ft^3/d at the September 1981 water levels. Upstream, at section A-A', the volume of flow was about 10 ft^3/d in September 1981.

Because a fairly large tributary enters the main Horse Creek valley downstream from section B-B', the volume of flow in the alluvial aquifer at higher water levels probably would be about 1,500 ft^3/d at the western edge of the potential mine pit.

The approximate amount of water that will discharge into the mine pit when the initial box cut from surface through the Dietz coal bed is excavated can be calculated from the formula by R. W. Stallman (Ferris and others, 1962, p. 127) for constant drawdown in a channel. The equation was modified to apply to one side of the channel (one mine pit wall). The formula:

$$Q = \frac{2s_o}{\sqrt{\pi t}} \sqrt{ST} \qquad (1)$$

was thus modified to:

$$Q = \frac{s_o}{\sqrt{\pi t}} \sqrt{ST} \qquad (2)$$

where Q = volume of water inflow, in cubic feet per day per foot of mine-pit length;
s_o = water-level drawdown along the channel, in feet;
t = time, in days;
S = storage coefficient, in units; and
T = transmissivity of the aquifer, in feet squared per day.

The values used in the calculations were selected from information available from aquifer tests conducted during the study and knowledge of the Tongue River Member aquifers from studies in other areas. Storage coefficient is one of the most sensitive factors in the formula and one that is least known from aquifer tests. The 0.005 value used was estimated by W. A. Van Voast in his study on the Tongue River Member aquifers near Colstrip, about 50 miles north of the study area (Van Voast and others, 1977).

Transmissivity was calculated by averaging the hydraulic conductivities and thickness of aquifers. Hydraulic conductivities were averaged at wells 0-10, 0-18, 0-20, 0-25, and 0-26, which mixes coal and sandstone aquifers and excludes the extremely small and extremely large values. The average hydraulic conductivity is about 0.6 ft/d. The thickness of the combined aquifers varies with depth and height to the potentiometric surface of the highest aquifer. In the middle part of the initial box cut (near observation well 0-25, fig. 7), the depth from the water level to the bottom of the Dietz coal bed is about 160 feet and the contributing coal and sandstone aquifers are about 84 feet thick; thus the value of the transmissivity in this site would be about 50 ft^2/d. Applying equation 2, using 100 days duration and a 1,000-foot front of exposed aquifers, about 4,500 ft^3/d of water will enter the mine pit along one wall of the box cut. Because the aquifers would become dewatered and the potentiometric surface would be lowered, this rate of inflow would decrease as time of mining increased assuming other factors remained constant.

As the mining progresses toward the maximum overburden level, the thickness of contributing coal and sandstone aquifers will increase to about 104 feet; thus, the transmissivity will be about 64 ft^2/d. The amount of water entering the pit from the mine wall could increase to about 7,000 ft^3/d owing to the larger transmissivity and greater initial saturated thickness of 230 feet.

The general hydraulic gradient of water in the Tongue River Member coal and sandstone beds is to the southwest. Therefore, the water from the north and east walls of the mine will continue to flow into the mine in larger amounts than will the water flowing from the south and west walls.

Long-term effects

If the potential mine is about the size and outline of those presented in figure 5, then the mine would encompass an area of about 3.5 mi^2; about 37 million tons of Anderson coal and 13 million tons of Dietz coal would be removed. All the sandstone, coal, and alluvial aquifers within the boundaries of the mine would be destroyed. The natural flow of ground water in and near the mine pit would be disrupted. One existing stock well and two perennial stock ponds receiving spring discharge would be destroyed.

The potential exists for a long-term change in the quality of water in the aquifers downgradient from the mine area. Downgradient, the flow is toward East Trail Creek through the sandstone and coal aquifers, as well as toward the mouth of Horse Creek valley. After mining, ground-water flow systems would be reestablished through the mine area. Water would enter the mine spoils from aquifers on the north and east sides, flow through the mine spoils, and discharge to the east and south. Additional flow would come from direct recharge from rainfall and snowmelt vertically down into the spoils. The water moving through the spoils would acquire a chemical quality dependent upon the mineralogy of the spoil materials (Van Voast and others, 1977).

POTENTIAL FOR RECLAMATION OF HYDROLOGIC SYSTEMS

Reclamation of the potential mined area would depend on careful planning during the mining process. The breaking of overburden and interburden between the Anderson and Dietz coal beds would expose soluble minerals that could be leached

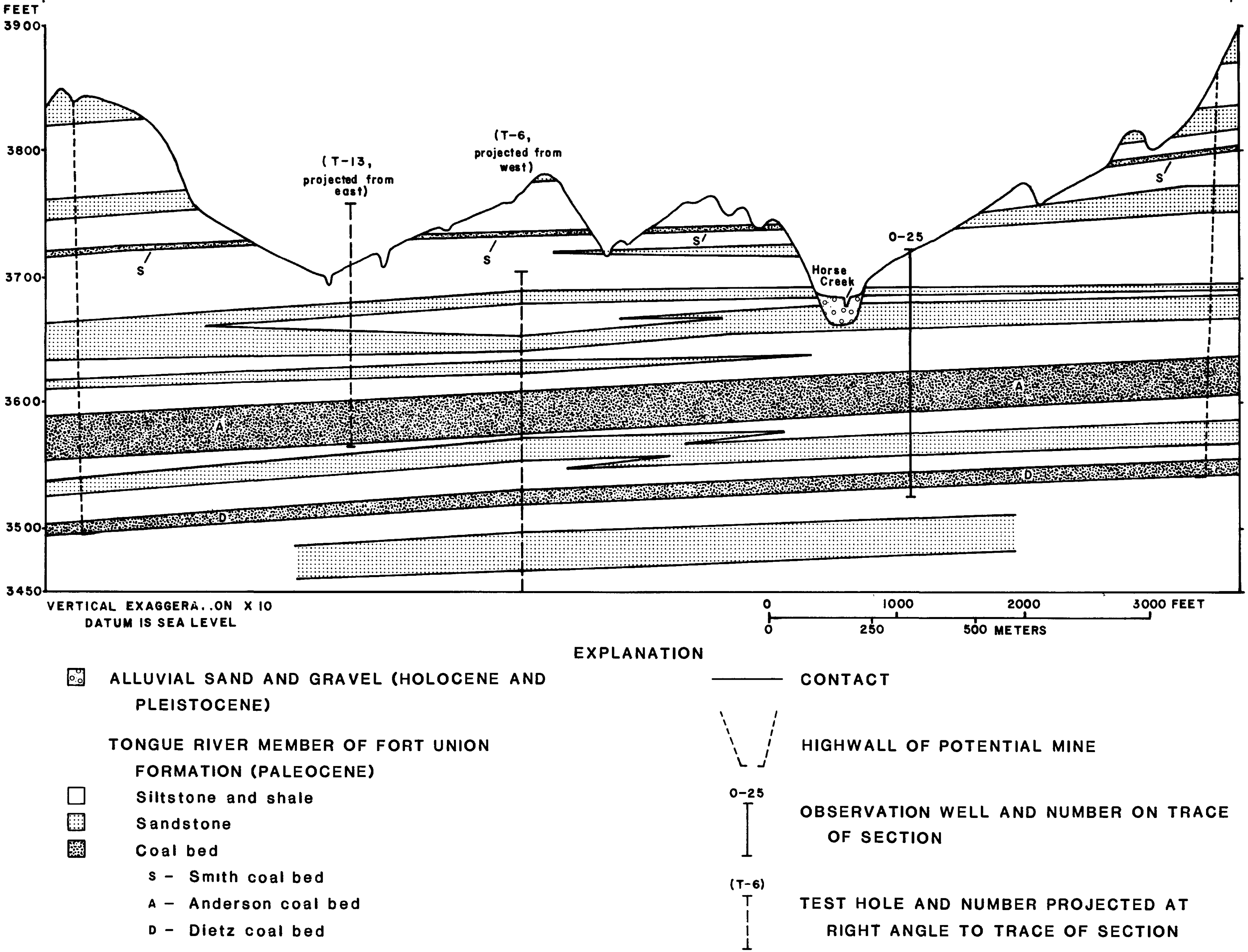


Figure 7.--Idealized stratigraphic section across the potential mine pit showing relative positions of the major aquifers of alluvium, sandstone, and coal. Trace of section is shown in figure 5.

by ground water, surface water, and precipitation. The planned reclamation could be successfully completed by containment of the mineralized materials in the pit in compact, impermeable layers. Success in such containment would minimize the volume of water passing into and from the chemically active spoils material.

The alluvial aquifer beneath Horse Creek could be reconstructed by placing and compacting a clayey layer as a base, then overlaying the previously collected sand and gravel, and finally replacing alluvial muds and soils. Water in the alluvium in the potential mine area contains the largest premining concentration of dissolved solids in the Horse Creek basin. Less mineralized water exists downstream where water from the Anderson clinker layers dilutes the alluvial waters. This dilution would still be effective during and after mining. With a properly planned and reconstructed alluvial aquifer through the mine area, improvement in the quality of water in the downstream alluvium might be possible.

The existing well (P-7), which would be destroyed by the potential mine, could be replaced by drilling a new well to the sandstone aquifer above the Canyon coal bed; the depth would probably be less than 250 feet. The quality of the water would be better than that from the existing well, which obtains water from the alluvial aquifer and the Anderson coal bed. The two ponds that would be destroyed by mining could be replaced near their present sites.

SUPPORTING TECHNICAL DISCUSSION

Geology

Stratigraphy

The sedimentary rocks exposed in the Horse Creek drainage basin are the upper 600 feet of the Tongue River Member of the Fort Union Formation (Paleocene age) and the lower 100 feet of the Wasatch Formation (Eocene age). The top of the Lebo Shale Member of the Fort Union Formation is well beneath the basin, at a depth of about 1,400 feet; therefore, the total thickness of the Tongue River Member in this vicinity is about 2,000 feet. The Lebo, the Tullock Member of the Fort Union Formation, and deeper formations (Cretaceous age and older) are too deep to be affected by mining activity on the surface. An idealized sketch of the strata cropping out and underlying the Horse Creek basin is shown in figure 8.

The material comprising the Tongue River Member and the Wasatch Formation is similar; both units are mostly gray shale and siltstone, with some sandstone layers and lenses and coal beds. The top of the Roland coal bed arbitrarily marks the boundary between the Wasatch Formation and the Tongue River Member; this coal bed is not at the level of the Eocene-Paleocene boundary at all places (Baker, 1929). The named coal beds in the upper part of the Tongue River Member are, in descending order: Smith coal bed, about 260 feet below the Roland; Anderson coal bed, about 120 feet below the Smith; Dietz coal bed, about 40 to 50 feet below the Anderson; and Canyon coal bed, about 190 to 220 feet below the Dietz. Below the Canyon coal bed, to the base of the Tongue River Member, are several broadly lenticular coal beds which are mostly less than 10 feet thick. The White and Cook coal beds are the first coals below the Canyon.

Clinker layers are prominent in the central and downstream parts of the Horse Creek basin where the Anderson coal bed has been burned. The clinker includes

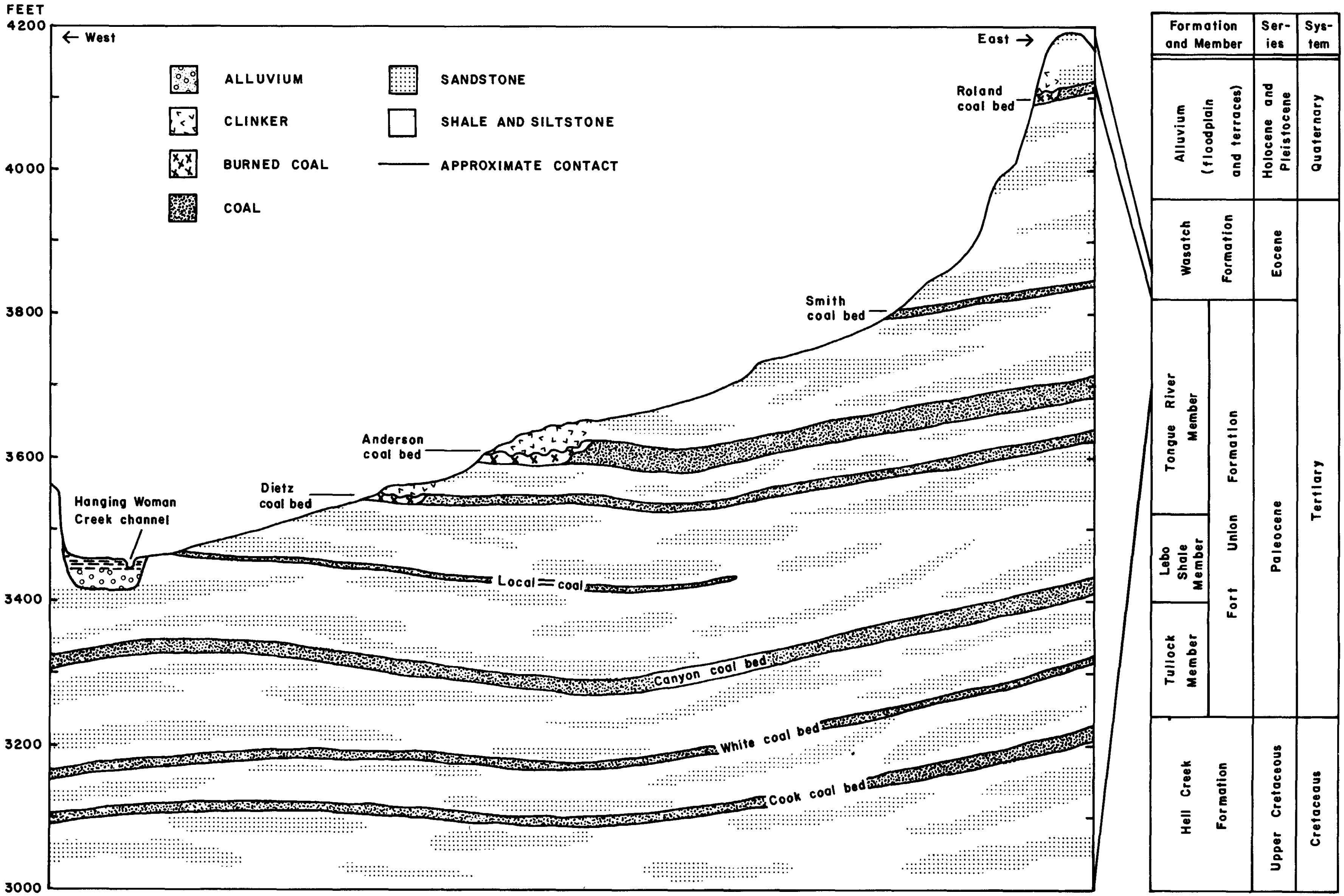


Figure 8.--Idealized sketch showing coal and interburden intervals and relative thicknesses within the Tongue River Member of the Fort Union Formation and the Wasatch Formation in the Horse Creek area.

scoria of the burned coal and scorched overburden, and forms layers as much as 100 feet thick. These layers exist as caprock on the ridges north and south of the mouth of Horse Creek. The burning has destroyed large amounts of Anderson coal in the downstream parts of the valley. In the central part of the valley, unburned coal lies under more than 80 feet of overburden; the coal bed becomes increasingly deeper farther upvalley.

The Horse Creek drainage was eroded and then partly filled with alluvial mud, sand, and gravel as much as 35 feet thick under the higher terraces, from the mouth to nearly 5 miles upstream. Subsequent erosion has formed the present flood plain of Horse Creek; the flood plain is 13 feet above the original channel cut at the mouth and about 25 feet above the channel cut in the middle part of Horse Creek valley.

Local structure

The general dip of Tongue River Member strata is generally less than 30 ft/mi to the southwest. Dip increases gradually from about 30 ft/mi in the eastern part of the Horse Creek valley to about 50 ft/mi in the southwestern part of the basin. Some minor flexures under the Horse Creek-East Trail Creek divide form a series of very gentle anticlines and synclines, trending northeast and plunging southwest (figs. 9 and 10). The flexures are more subdued than they appear in figure 10, which has a greatly exaggerated vertical scale. No faults were observed in the Horse Creek area. Several west-trending faults exist to the southwest and south of Horse Creek basin; almost all are downthrown on the south side.

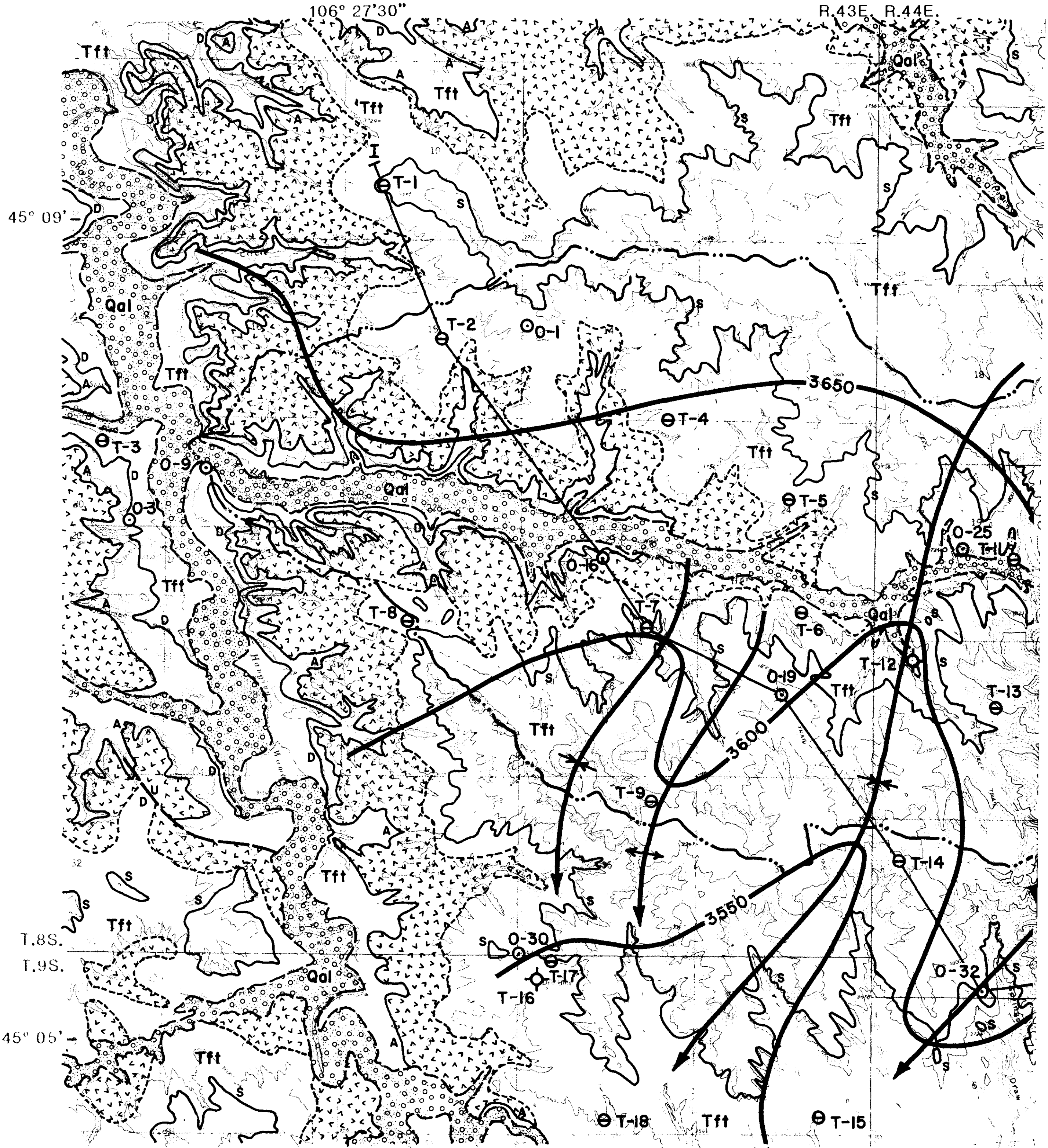
Ground-water resources

Coal and sandstone beds of the Tongue River Member comprise major aquifers throughout the Horse Creek area. Clinker layers contain water in the lowest parts; in some areas the water emerges onto the land surface, forming springs. Alluvium along the Horse Creek channel forms a fairly productive aquifer from about 5 miles upstream to the mouth at Hanging Woman Creek.

Five private wells existed in the Horse Creek drainage basin before the present study; two of these were in use (fig. 2). Information from these five wells and an additional three wells outside the basin is given in table 1. Additional information on the aquifers of the area was obtained from 18 test holes drilled in and near the Horse Creek basin; these data are presented in table 2. Most of the information given in the following sections of this report was obtained from aquifer tests and chemical analyses of water samples from the 27 observation wells inside the Horse Creek basin and 6 observation wells nearby. Most of the aquifer tests were conducted by pumping the wells at near capacity and measuring the water-level drawdown. The results were obtained by applying the Cooper and Jacob constant-discharge formula, as described in Lohman (1972):

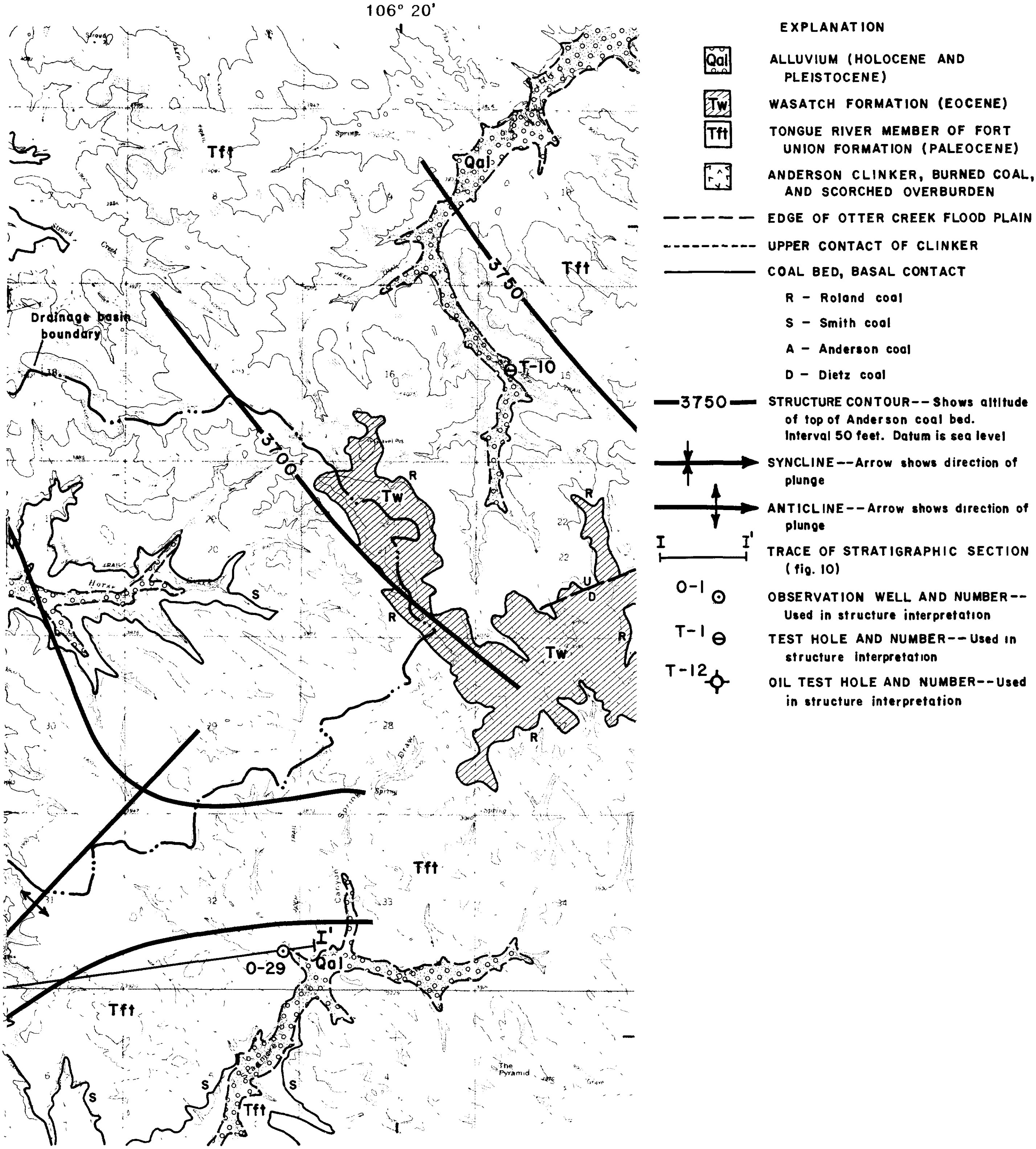
$$T = \frac{2.3 \times Q}{4\pi \cdot \Delta s} \qquad (3)$$

where T = Transmissivity of the aquifer, in feet squared per day;
Q = discharge of well, in feet cubed per day; and
Δs = discharge of water level (drawdown), in feet.



Base from U.S. Geological Survey 1:24,000,
Stroud Creek, Hamilton Draw, Forks Ranch, Quietus 1972

Figure 9.--Geologic map of the Horse Creek drainage basin and adjacent areas showing



Geology modified from Culbertson and others (1976), and Culbertson and Klett (1979a, 1979b)

exposed coal beds, major clinker layers, and generalized structure.

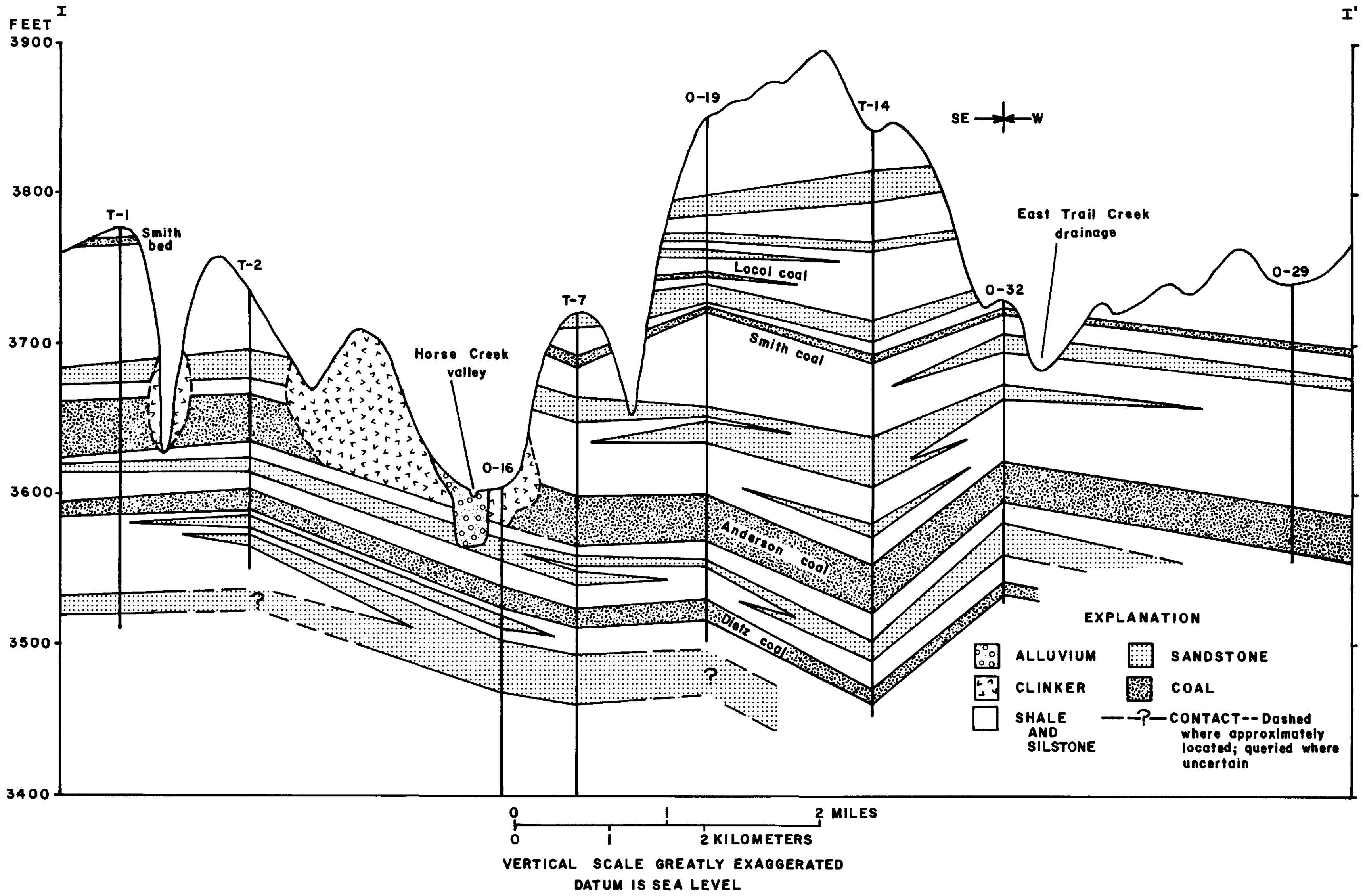


Figure 10.--Idealized stratigraphic section across Horse Creek basin showing structural features. Trace of section is shown in figure 9.

Some wells, which had very small yields, were bailed to near the bottom of the hole and the recovering water levels were recorded; the results were obtained by applying the Theis recovery formula and the residual drawdown method described in Ferris and others (1962). Construction details and hydrologic data for the observation wells are given in tables 3 and 4.

Tongue River aquifers

Canyon coal bed

The Canyon coal bed is about 120 feet below land surface at the mouth of Horse Creek. Two observation wells within the Horse Creek basin (0-9 and 0-16) and one just outside the basin (0-3) are completed in the Canyon coal bed. The casing in well 0-9 is perforated opposite the Canyon coal and an underlying sandstone bed; water from this well is, therefore, a mixture from the two aquifers.

The Canyon coal bed is 17 feet thick in wells 0-3 and 0-9, and 22 feet thick in well 0-16. In all the wells, the coal is apparently massive, without shale partings. Wells completed in the Canyon coal bed yield from 5 to 10 gal/min in the vicinity of the Horse Creek study area.

Aquifer characteristics

Aquifer tests were conducted at all three wells. The test results, based on wells 0-3 and 0-16, indicate that the Canyon coal bed has hydraulic conductivities of 0.3 and 0.6 ft/d. The larger (1.5 ft/d) hydraulic conductivity calculated at well 0-9 is probably an indication of the greater permeability of the sandstone beds also tapped by this well (see table 5). The median hydraulic conductivity of the Canyon coal aquifer is about 0.5 ft/d.

Water-level fluctuations

The water-level fluctuation in the Canyon coal bed is much like the fluctuations in the other Tongue River Member aquifers. Some of the peaks and troughs in the hydrographs (fig. 11) are the same for all the wells. The similarity is a reflection of the response of the potentiometric surface in all these artesian wells to barometric pressure changes; it does not indicate seasonal or annual trends of water-level rises or declines. The two wells, 0-9 and 0-16, with casing perforated in the Canyon coal aquifer show no definite upward or downward trend of water-level change throughout the interval observed. The water level in both wells is at about 3,440 feet above sea level; therefore, the direction of flow in the Canyon coal bed cannot be ascertained from available data.

Quality of water

Analyses of water from the three wells completed in the Canyon coal bed are given in table 6. The chemical quality of water from the Canyon coal aquifer was fairly consistent--dissolved-solids concentration ranged from 1,560 to 1,760 mg/L (milligrams per liter). The water was a sodium bicarbonate type. The most deeply buried aquifer, in well 0-16, yielded water having slightly larger amounts of dis-

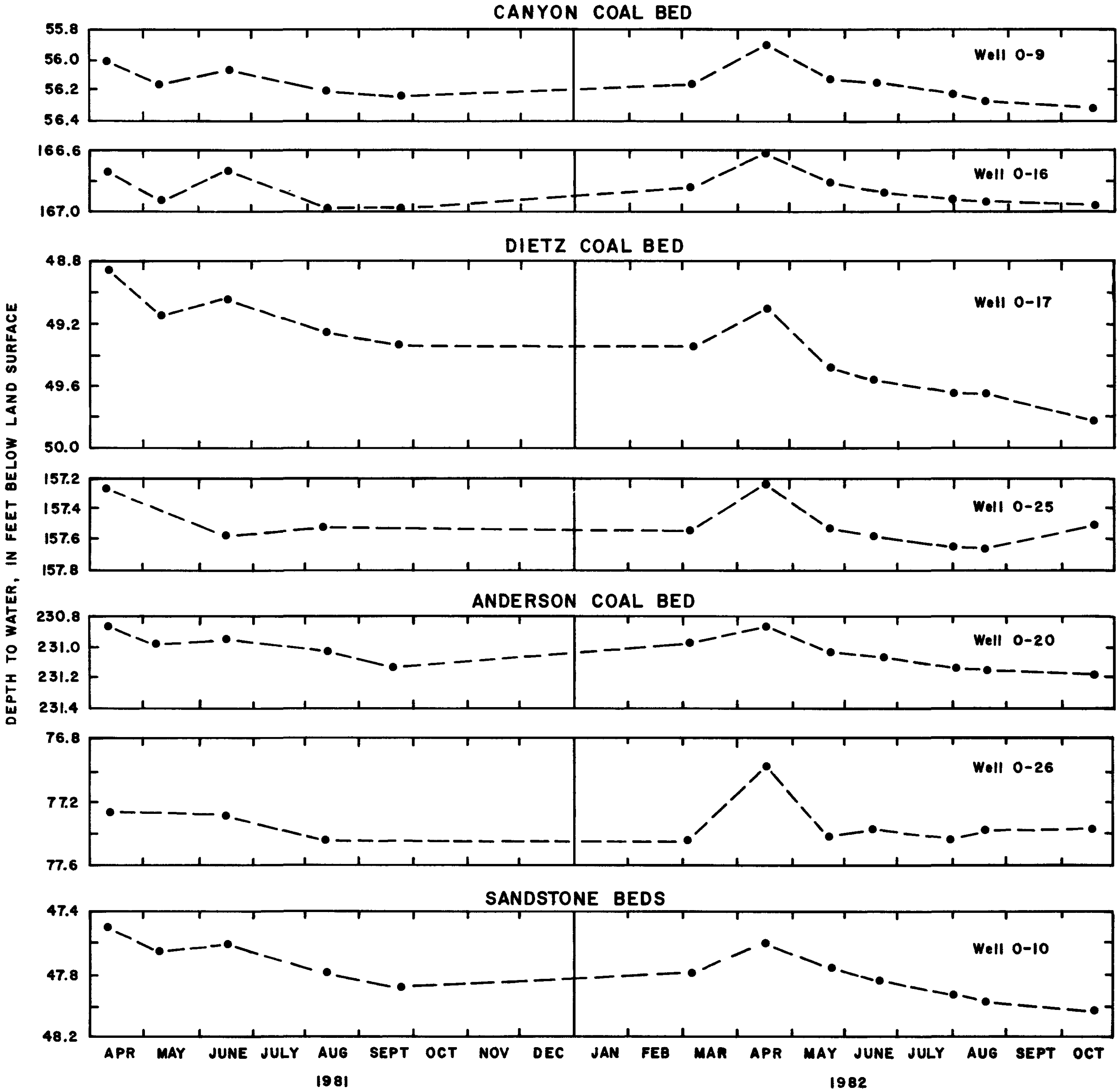


Figure 11.--Water-level fluctuations in observation wells completed in coal-bed or sandstone aquifers of the Tongue River Member of the Fort Union Formation.

solved constituents--1,900 mg/L of bicarbonate and 730 mg/L of sodium, with less than 6 mg/L each of calcium, magnesium, and potassium. The fluoride concentration in the Canyon coal aquifers was large--3.7 to 4.0 mg/L--in the water analyzed from the three wells.

Dietz coal bed

The Dietz coal bed is as much as 250 feet above the Canyon coal aquifer in the central part of the area, but the interburden thins to the south, where, in the downstream part of East Trail Creek, the Dietz is only about 150 feet above the Canyon. The Dietz bed is between 11 and 13 feet thick in most of the Horse Creek basin, except under the divide with East Trail Creek where it ranges from 7 to 10 feet thick. The coal bed is usually massive in the Horse Creek basin, but southward a shale break near the top increases to 2 feet thick. Discharge from a well perforated only opposite the Dietz coal bed probably would be 4 gal/min, and may be as little as 0.1 gal/min.

Aquifer characteristics

In the Horse Creek basin, five observation wells are completed in Dietz coal bed--O-1, O-17, O-18, O-19 and O-25 (fig. 2). All these wells were pumped to determine the hydrologic characteristics of the aquifer. The calculated hydraulic conductivity of the Dietz ranged from 0.03 to 10 ft/d, with most aquifer tests indicating a value of less than 1 ft/d. The Dietz in well O-17, which is in a topographically low part of Horse Creek valley and underlies a massive burn area of the Anderson coal bed, had the largest hydraulic conductivity. Well O-18 is in the same area but the well casing was perforated partly in the Dietz coal bed and partly in a silty sandstone. The smallest hydraulic conductivities were determined in wells O-1 and O-19, located on the sides of the valley, on ridges away from the drainage divides to the north and south. Well O-25, which is considered to be completed in coal having a hydraulic conductivity that is about average for the Dietz coal, 0.8 ft/d, is located in the Horse Creek valley; in this well an unburned sequence of sandstone, shale, and Anderson coal bed overlies the Dietz. The median hydraulic conductivity of the Dietz coal aquifer is about 0.5 ft/d.

Water-level fluctuations

Water-level fluctuations in the Dietz coal aquifer are represented by hydrographs for wells O-17 and O-25 (fig. 11). Well O-17, in the east-central part of the Horse Creek area, is the only Tongue River Member well showing a definite decline of water level in 1981 and 1982. The Dietz bed occurs at the level of the alluvial aquifer about 0.5 mile to the east; the Dietz aquifer at well O-17 probably is reflecting the decline of water levels in the alluvium during this interval. Water-level fluctuations in the other Dietz wells generally reflect barometric-pressure changes rather than water-level rises or declines.

Based on water levels in the seven Dietz wells--five inside the Horse Creek basin and two in East Trail Creek basin to the south--flow within the coal bed is to the south or southwest. The flow is in the general direction of the dip of the coal bed. The ground-water divide in the Dietz coal is probably north and east of the topographic divide between Horse Creek, Stroud Creek, and Little Bear Creek basins. Also, water apparently flows from Horse Creek basin to East Trail Creek basin across that topographic divide.

Quality of water

Water from five wells completed in the Dietz were analyzed for major ions. The water from the Dietz was greatly variable in dissolved-solids concentration, ranging from 1,920 mg/L in well 0-25 in the upstream part of the valley and 1,970 mg/L in well 0-19 in the south-central part of the basin to 7,690 mg/L in well 0-1 in the north-central part of Horse Creek basin (table 6). The other two wells are in the valley about 2.4 miles upstream from the mouth of Horse Creek; dissolved-solids concentration was 4,560 mg/L in well 0-17 and 3,920 mg/L in well 0-18. Well 0-18 has perforations open to the upper part of the Dietz coal and an overlying silty sandstone.

In three of the five wells completed in the Dietz coal bed, water was a sodium sulfate type. In wells 0-19 and 0-25, where the Dietz bed is farther from outcrop areas, the type was sodium bicarbonate. The depth of the bed does not seem to have an effect on the water type. The other chemical constituents were present in small or moderate amounts (table 6). Dissolved fluoride concentrations were moderate (about 1.5 mg/L) in wells 0-1, 0-17, and 0-18; and large (3.1 and 2.5 mg/L) in wells 0-19 and 0-25.

Anderson coal bed

Throughout most of the Horse Creek area, the Anderson coal bed is separated from the Dietz bed by 40 to 50 feet of interburden. The interburden is thicker southward in the East Trail Creek basin, and thinner northward in the Stroud Creek basin.

The Anderson coal is about 34 feet thick along the northern divide of Horse Creek and thins to about 27 feet thick in the downstream part of East Trail Creek basin. The Anderson coal bed is 32 to 33 feet thick near the middle of the Horse Creek basin, where the coal is massive. To the west (downstream), the Anderson coal is mostly burned. To the south and east, the coal contains thin shale layers near the middle. In test hole T-18, in the downstream part of East Trail Creek, a 4-foot thick shale bed exists near the base, separating a 3-foot thick basal coal seam from the main body. Wells completed in the Anderson coal aquifer could be expected to have yields of from 2 to 5 gal/min, at most places.

Aquifer characteristics

Six observation wells are completed in the Anderson coal aquifer in the Horse Creek area and vicinity. Well 0-2, on the north side of the valley, penetrated 33 feet of Anderson coal, but because of its vicinity to deeply eroded side drainages where the Anderson is burned, the Anderson contains no water at this location. Well 0-20 is high on the south side of Horse Creek valley. It yielded 2.2 gal/min, but the calculated hydraulic conductivity is 0.15 ft/d--the smallest for the Anderson. Well 0-26 is located in the valley about 4.5 miles upstream from the mouth of Horse Creek. It was pumped at 2.9 gal/min with 15 feet of drawdown; the calculated hydraulic conductivity is 1.5 ft/d. This value is probably near the median for the Anderson coal in the Horse Creek area. Of the three other observation wells (0-29, 0-31, and 0-33) located in the East Trail Creek drainage, only well 0-29 was tested. Well 0-29 yielded 4.4 gal/min with 13 feet of drawdown; the calculated hydraulic conductivity is the largest of the wells tested--4 ft/d. The well is located on a main tributary to East Trail Creek and the top of the Anderson is 144 feet below land surface; the reason for the Anderson coal being so permeable at this location is unknown.

Water-level fluctuations

The water-level fluctuations in the Anderson coal aquifer show only the effect of barometric-pressure changes, as indicated in wells 0-20 and 0-26 (fig. 11). Long-term monitoring is needed to determine annual rises or declines of the potentiometric surface in this aquifer.

Only two points of reference (wells) exist in the Horse Creek basin to determine the direction of flow in the Anderson coal bed, but from the projection of two points in East Trail Creek and one point in Little Bear Creek basins, flow is probably toward the southwest, at about the same dip as the coal bed. Observation wells near T-10 in Little Bear Creek basin have water-level altitudes 110 feet higher than in well 0-26, which indicates that the ground-water divide is northeast of the topographic divide between Horse Creek and Little Bear Creek basins. The difference in water-level altitude in well 0-20 in the Horse Creek basin and well 0-31 in the East Trail Creek basin is about 80 feet, a decline of 40 ft/mi to the southwest. The decline indicates a flow from the Horse Creek basin into the downstream part of East Trail Creek basin.

Quality of water

One analysis each from wells 0-20 and 0-26 completed in Anderson coal indicate that water from this aquifer was a sodium bicarbonate type, with respective dissolved-solids concentration of 2,550 and 2,320 mg/L (table 6). The water analyzed from the two wells was similar, having small concentrations of calcium, magnesium, potassium, and chloride; moderate concentrations of sulfate and silica; and relatively large concentration of fluoride--about 2.0 mg/L.

A water sample was analyzed from well 0-29, but a concentration value for sulfate was not given. The specific-conductance value along with constituent concentrations of other ions indicated that the dissolved-solids concentration was slightly smaller than in water from wells 0-20 and 0-26, but ions were generally present in the same ratios.

Sandstone aquifers

Sandstone beds and lenses exist throughout the Tongue River Member stratigraphic interval. The thickness of the sandstones that are water-bearing range from about 5 to 50 feet. The sandstones thin and thicken or split and join in short lateral distances of less than 1 mile; some pinch out altogether. Discharges from wells completed in a sandstone aquifer would depend on the thickness of the bed, grain size of the sand particles, and amount of silt or shale in the interstitial area. A relatively clean sandstone, 20 feet thick, probably could yield 10 gal/min or more; a sandstone with large fine-grained components probably would yield less than 1 gal/min. The interpreted relationship of sandstone and coal beds in the Horse Creek area is illustrated in figure 12.

EXPLANATION

COAL

SHALE OR SILTSTONE

SANDSTONE

CLINKER

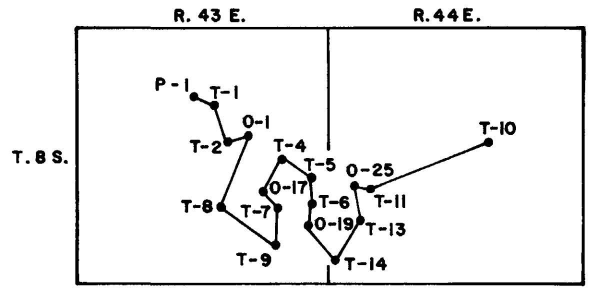
———— – – –? CONTACT--Dashed where approximately located; queried where well logs are incomplete and where correlation is uncertain

DATA SITE AND NUMBER--Location shown in figure 2

O-1 Observation well

P-1 Private well

T-2 Test hole



LOCATION MAP

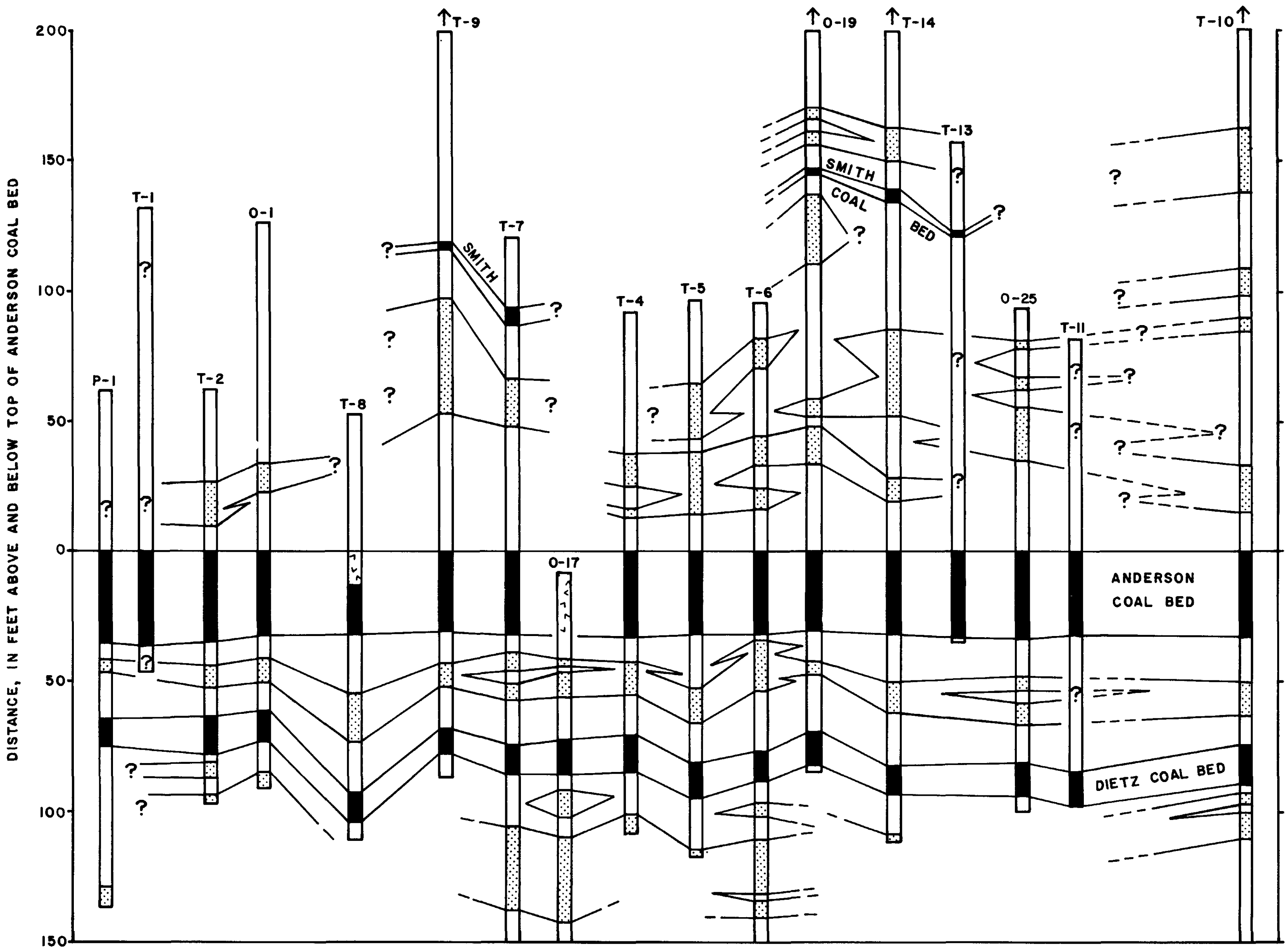


Figure 12.--Interpretive stratigraphic correlation showing relationship between the coal-bed and sandstone aquifers of the Tongue River Member, Fort Union Formation. Datum is top of Anderson coal bed. Horizontal spacing not to scale. Correlation queried where doubtful.

Aquifer characteristics

Only one observation well (0-10) was drilled specifically to a sandstone aquifer in the Horse Creek area. Two other wells (0-9 and 0-18) have perforations opposite sandstone and coal beds. None of the wells are considered typical, or representative, of most of the sandstone aquifers in the Horse Creek basin. All three wells were pumped to determine aquifer characteristics.

Well 0-10 is perforated in a sandstone aquifer between the Canyon and Dietz coal beds. Although the casing is perforated opposite 36 feet of sandstone, the lithologic logs indicate that only about 25 feet of sandstone is permeable enough to contribute water. The aquifer test indicated that the hydraulic conductivity is about 0.2 ft/d. In nearby areas, the median hydraulic conductivity is commonly about 10 ft/d, which implies that well-10 is not a typical sandstone well. Well 0-9 was perforated opposite 6 feet of Canyon coal bed and 4 feet of sandstone. The aquifer test is described in the Canyon coal bed section. The third well, (0-18) is perforated partly in a very silty sandstone and partly in the Dietz coal aquifer. The aquifer test is described in the Dietz coal-bed section. The OW Ranch well (P-5) is perforated opposite a sandstone between the Dietz and Canyon coal beds. This well could not be tested, but is reported to yield about 15 gal/min. Other stock wells (P-1, P-2, and P-8) in or near the Horse Creek basin and the OW Ranch headquarters well (P-3) probably yield water from sandstone aquifers. None of these wells have data to determine the aquifer characteristics.

Water-level fluctuations

Well 0-10 has water-level fluctuations similar to the coal wells of the area (see fig. 11), which indicates the effects of barometric pressure on the aquifer. Information was insufficient to determine the direction of flow in these sandstone aquifers. However, the direction is probably similar to that of the coal aquifers of the area, which is south to southwest--the direction of dip of the beds.

Quality of water

Water samples from sandstone aquifers were collected for chemical analysis from two private wells (P-3 and P-5) presently (1982) in use, one unused private well (P-2), and one observation well (0-10) in the Horse Creek basin, and one private stock well (P-8) east of the basin (table 6). Well P-2 is located near the northern divide of the basin and was completed in a shallow sandstone near the top of the Tongue River Member section, about 20 to 50 feet above the Smith coal bed. The well had a magnesium sodium bicarbonate type water when sampled in June 1975. The dissolved-solids concentration of 820 mg/L was the least mineralized of all the sandstone-aquifer wells in the area. Well P-3 is at the OW Ranch headquarters and is completed in a sandstone 20 to 50 feet above the Canyon coal bed. Well 0-10 has casing perforated opposite this same sandstone. Both of these wells yielded a sodium bicarbonate type water, with dissolved-solids concentrations of about 1,600 mg/L.

Well P-5 is located in the downstream part of Horse Creek valley about 2.5 miles upstream from the mouth; it is apparently perforated (driller's record says perforated in "water veins") in two sandstones--one 16 feet thick just below the Dietz coal bed and one 20 feet thick about 40 feet above the Canyon coal bed. The water from well P-5 was a sodium magnesium sulfate type with the largest dissolved-solids concentration (6,240 mg/L) of all sandstone waters in the Horse Creek area. Well P-8, located in the upstream reaches of Little Bear Creek basin, obtains water from a sandstone aquifer above the Smith coal bed. The water was a magnesium sulfate type, with dissolved-solids concentration of 2,290 mg/L.

Most of the water from the sandstone aquifers in the Horse Creek basin is potable for stock. The most mineralized water, from well P-5, had a deleteriously large sulfate concentration--4,000 mg/L. Water from well O-10 had the largest concentration of fluoride (4.9 mg/L) of water from any source in the basin.

Clinker aquifer

Much of the downstream one-third of the Horse Creek area is covered by Anderson coal clinker between about 3,600- and 3,700-foot altitudes. The material is slag or scoria-like at the base where the coal bed has been burned, and is reddish orange to reddish brown and slate-like where the overburden of shale, siltstone, and sandstone was scorched or burned. At some locations, burning of the approximately 32-foot thick Anderson coal has affected materials as much as 100 feet above the coal.

No observation wells were completed in the clinker. The material is very difficult to drill and keep the hole open long enough to install the casing.

Two springs have been developed from natural flow from the Anderson clinker. Spring S-1 is in a tributary valley north of the Horse Creek channel, and spring S-2 is in a small valley above OW Ranch headquarters. S-1 was flowing about 4 gal/min in June 1980 and S-2 was flowing about 1 gal/min in June 1982; both springs are reported to be perennial and to have had constant flows for many years. Other springs may exist from the clinker layers in the area, but none were observed. Most of the water from the clinker aquifer probably flows directly into talus or alluvial material without reaching the land surface.

Springs S-1 and S-2 have some of the best quality of water in the Horse Creek area (table 7). Water from spring S-1 had 543 mg/L of dissolved solids; the water was a sodium bicarbonate type, with relatively large concentrations of calcium (60 mg/L) and sulfate (180 mg/L). The fluoride concentration was moderate (0.9 mg/L). The best quality spring (S-2) supplies the OW Ranch headquarters. There, the dissolved-solids concentration was 198 mg/L; the water was a calcium magnesium bicarbonate type, with relatively small sulfate (17 mg/L) concentrations. The fluoride concentration was moderate at 1.5 mg/L.

Alluvial aquifer

At September 1981 water levels, the saturated thickness of the alluvial aquifer in the Horse Creek area was about 4 feet in the upstream end of the basin (fig. 13, section A-A'), about 7 feet 4.4 miles upstream from the mouth (section B-B'), about 12 feet 2.3 miles upstream from the mouth (section C-C'), and about 8 feet across a flat-bottomed, 680-foot wide, gravel-filled channel at the mouth (section D-D'). At each line of observation wells the bottom of the alluvial-filled channel appears broad and with low relief; there are apparently no narrow, sharply incised buried channels. Apparently the erosion, prior to deposition of the alluvium, was

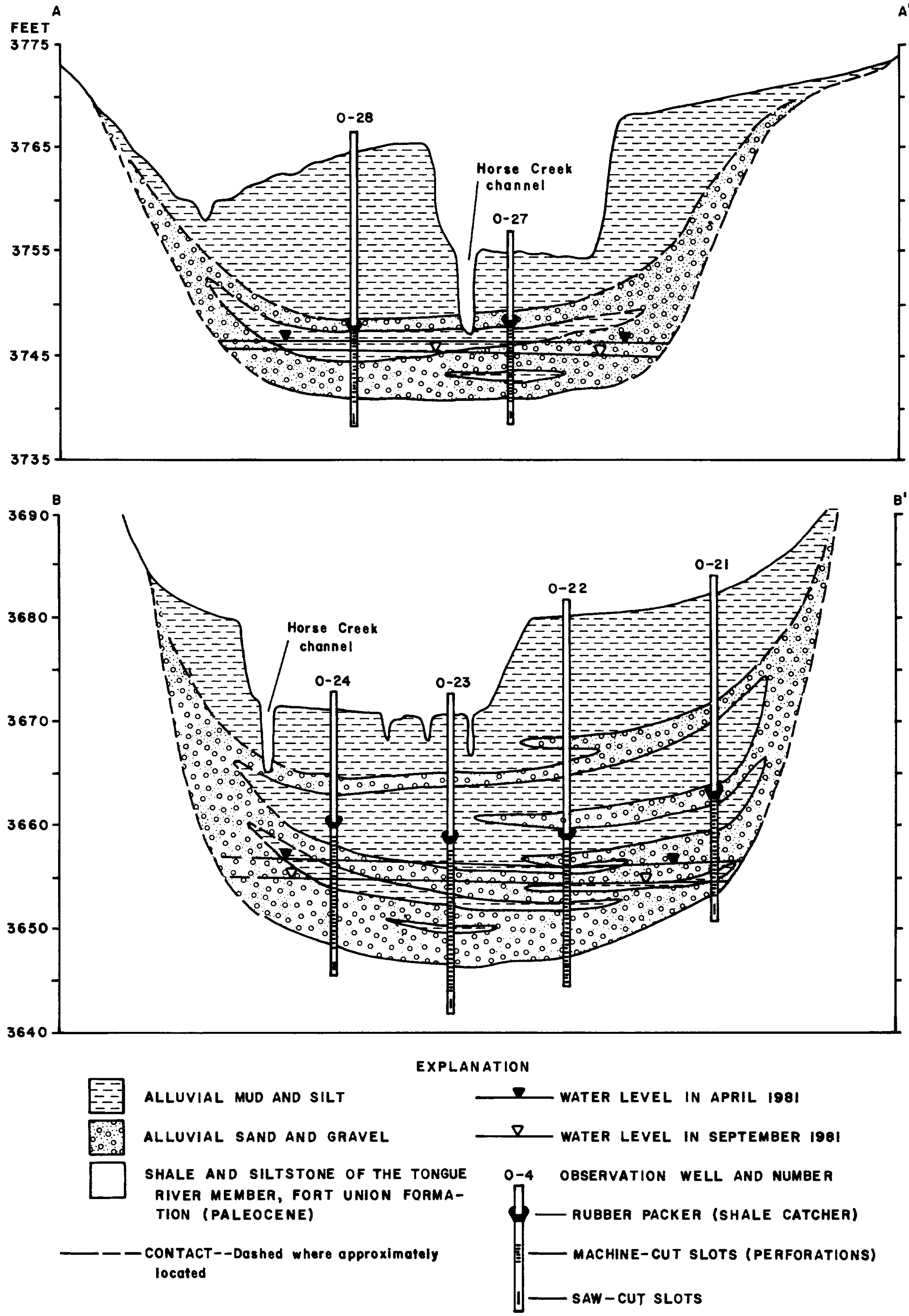
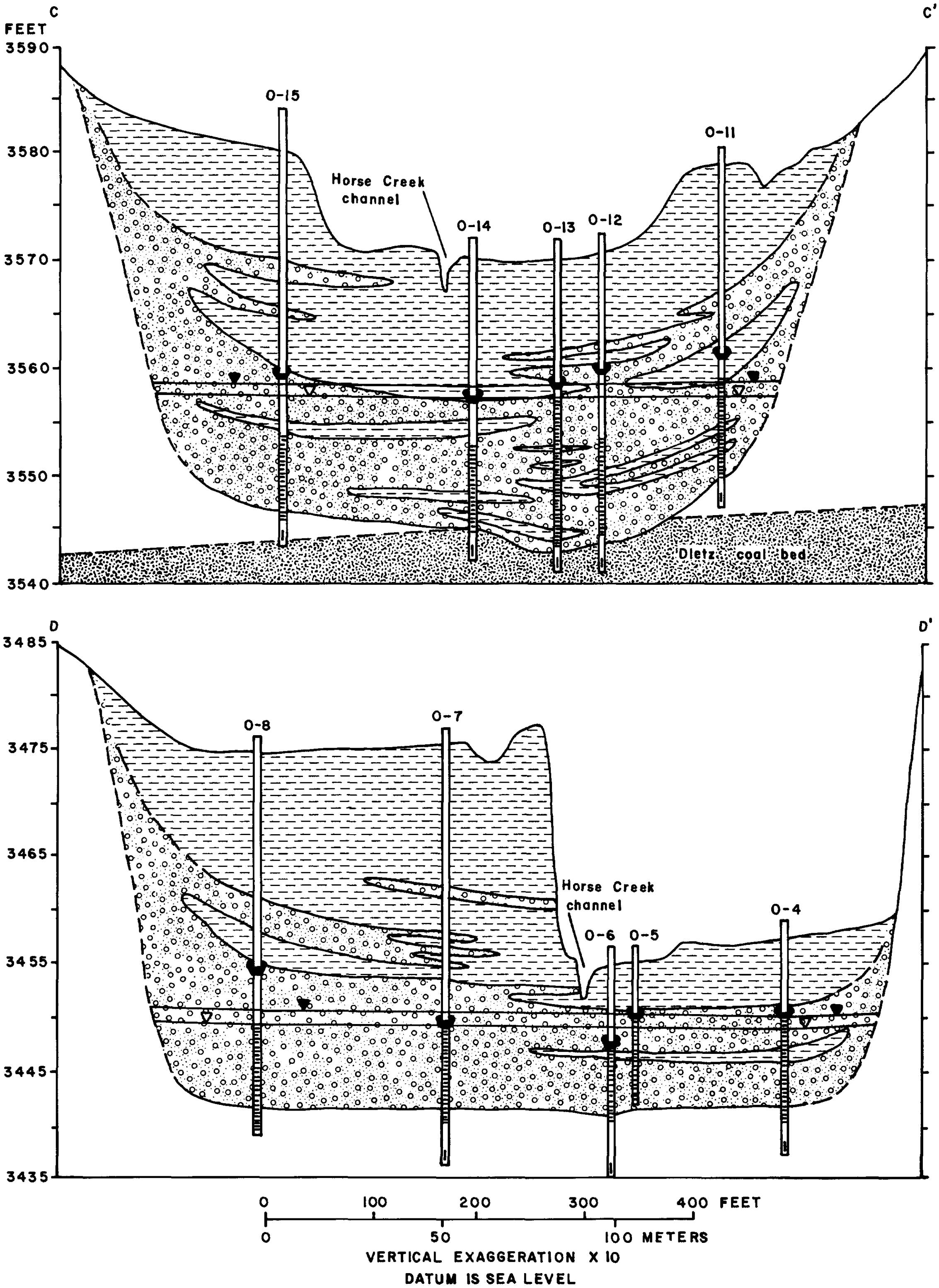


Figure 13.--Idealized geologic sections showing lithology of alluvium at observa-



tion-well sites. Traces of sections are shown in figure 2.

one stage without a secondary deepening of the channel. The materials of the alluvial aquifer are cobble-sized and smaller gravel and sand derived from Tongue River Member siltstone and sandstone along the entire valley, and from clinker layers in the downstream part of the valley. Mud and silty or sandy mud lenses exist throughout the alluvial section, but are dominant in the upper one-half and are commonly above the water level. The idealized sections (fig. 13) illustrate a possible correlation of sand and gravel layers and mud layers between the wells in individual well lines.

Aquifer characteristics

The most-upstream line of observation wells (fig. 13, section A-A') is located about 5.7 miles from the mouth of Horse Creek. At this location the alluvial material is fine grained and the sand and gravel layers are thinnest, resulting in small well yields. Well 0-27 is situated on the flood plain of the main stem of Horse Creek. This well was pumped at 0.4 gal/min with a drawdown of 3.5 feet; the hydraulic conductivity was calculated to be about 1 ft/d. Well 0-28, about 150 feet to the southeast on a terrace near a tributary to Horse Creek, could only be tested by bailing and observing the recovery; the hydraulic conductivity was calculated to be 0.02 ft/d, less than at many coal or sandstone wells.

At the next line of wells downstream, (fig. 13, section B-B') the alluvium is thicker than upstream and the sand and gravel are coarser. Three of the wells, 0-22, 0-23, and 0-24 were completed in the main water-bearing part of the alluvium. These wells were pumped at discharges ranging from 2 to 11 gal/min. Tests conducted in June 1982 indicate a range of hydraulic conductivity of 11 to 60 ft/d. These tests were conducted at water levels nearly 6 feet lower than when the wells were drilled in September 1980. Well 0-21 penetrated the north edge of the alluvial aquifer and it yielded very little water.

The third line of wells (fig. 13, section C-C') is in an area where the alluvium is most productive. The wells are downgradient from the beginning of the Anderson coal bed burn area, so much of the gravels composing the alluvial aquifer are coarse clinker fragments; the ratio of gravel to sand is greater along this reach of the valley than either upstream or downstream. The discharge from these wells varied from 3 to 24 gal/min. Results of aquifer tests in September 1981 indicate that the two outside wells had the smallest calculated hydraulic conductivities--16 ft/d at well 0-11 and 10 ft/d at well 0-15. The most productive well of this line was 0-13, with a calculated hydraulic conductivity of 220 ft/d. Well 0-14 was tested in June 1982, when the water level was only slightly different from September 1981; the hydraulic conductivity was calculated to be 150 ft/d.

The most-downstream line of wells (fig. 13, section D-D') is located about 0.1 mile upstream from the mouth of Horse Creek. All five wells were tested for aquifer characteristics in September 1981 and well 0-7 was tested again in June 1982. The wells were pumped at discharges ranging from 7 to 25 gal/min. The results of the aquifer tests indicate that the hydraulic conductivity ranges from about 70 to 660 ft/d. As upstream, the smallest hydraulic conductivity was near the edge of the alluvial aquifer--200 ft/d in well 0-4 and 70 ft/d in well 0-8. The well of the line having the greatest discharge with least drawdown is well 0-7, located on the terrace south of Horse Creek channel; the aquifer in this well had a calculated hydraulic conductivity of 660 ft/d. The variability of the alluvial aquifer is apparent from analyzing wells 0-5 and 0-6, which are only 20 feet apart. The calculated hydraulic conductivity was 240 ft/d in well 0-5 and 170 ft/d in well 0-6. The difference seems attributable to the variation of contributing thickness of the sand and gravel aquifer--5 feet in well 0-5 and 7 feet in well 0-6--because both wells had a calculated transmissivity of 1,200 ft^2/d.

Water-level fluctuations and discharge

The fluctuation in water levels of the alluvial aquifer is illustrated in figure 14, which includes one representative well in each of the four lines of wells. Hydrographs for the three most-upstream wells (0-13, 0-22, and 0-27) show a decline of water levels throughout the study--from September 1980 to October 1982. The declines were slowed during the winter and spring months in wells 0-13 and 0-27, but in well 0-22 the water level decline continued during the winters. Well 0-5, near the mouth, shows an annual fluctuation--water level rising during the winter as transpiration of water from the plants in Hanging Woman Creek ceases and in the spring during the May-June rainy season, and declining during the summer and early autumn. During the next rainy cycle, like that in 1977, 1978, and 1979, water levels in the alluvium probably will rise again to near or higher than the level in September 1980.

A gross approximation of the amount of water passing through the alluvium at each of the four well lines was determined by Darcy's Law (Lohman, 1972) using the formula, $Q = KIA$, where Q equals the volume of flow past the well line in cubic feet per day, K equals the median hydraulic conductivity of the alluvial materials in feet per day, I equals the gradient of the water table in feet per foot, and A equals the saturated cross-sectional area at the well line in square feet. The water levels used in the calculations are those measured in September 1981. The approximate median values of the hydraulic conductivity used at each well line are: Section A-A', 0.5 ft/d; section B-B', 20 ft/d; section C-C', 80 ft/d; and section D-D', 200 ft/d. Approximately 10 ft^3/d flows through the alluvium at section A-A'. More flow enters the valley from the downstream tributaries, so that at section B-B' about 600 ft^3/d passes. Farther downstream, more water from the tributaries plus underflow from the coal beds and clinker increases the flow to about 4,000 ft^3/d at section C-C'. Near the mouth of Horse Creek at section D-D', the flow is about 7,500 ft^3/d; this water flows out of the Horse Creek area into the alluvium of Hanging Woman Creek.

Quality of water

Water from the alluvial aquifer was sampled for chemical analysis at each of the four sections in the Horse Creek valley (see table 6). Water from wells along section A-A' contained the largest concentration of dissolved solids. The dissolved-solids concentration of the water was 9,470 mg/L at well 0-27 and 9,770 mg/L at well 0-28. The water was a sodium magnesium sulfate type and had a small concentration of fluoride (about 0.7 mg/L) and silica (about 10 mg/L). This water had near the maximum concentration of dissolved solids for consumption by cattle.

Water from wells along section B-B' showed a decrease in the concentration of dissolved solids; the range there for three samples was 7,710 to 8,890 mg/L. The largest dissolved-solids concentration was in well 0-24 near the south edge of the valley; the least was in well 0-22 near the middle of the valley. The water in all wells was a sodium magnesium sulfate type, with relatively small concentrations of

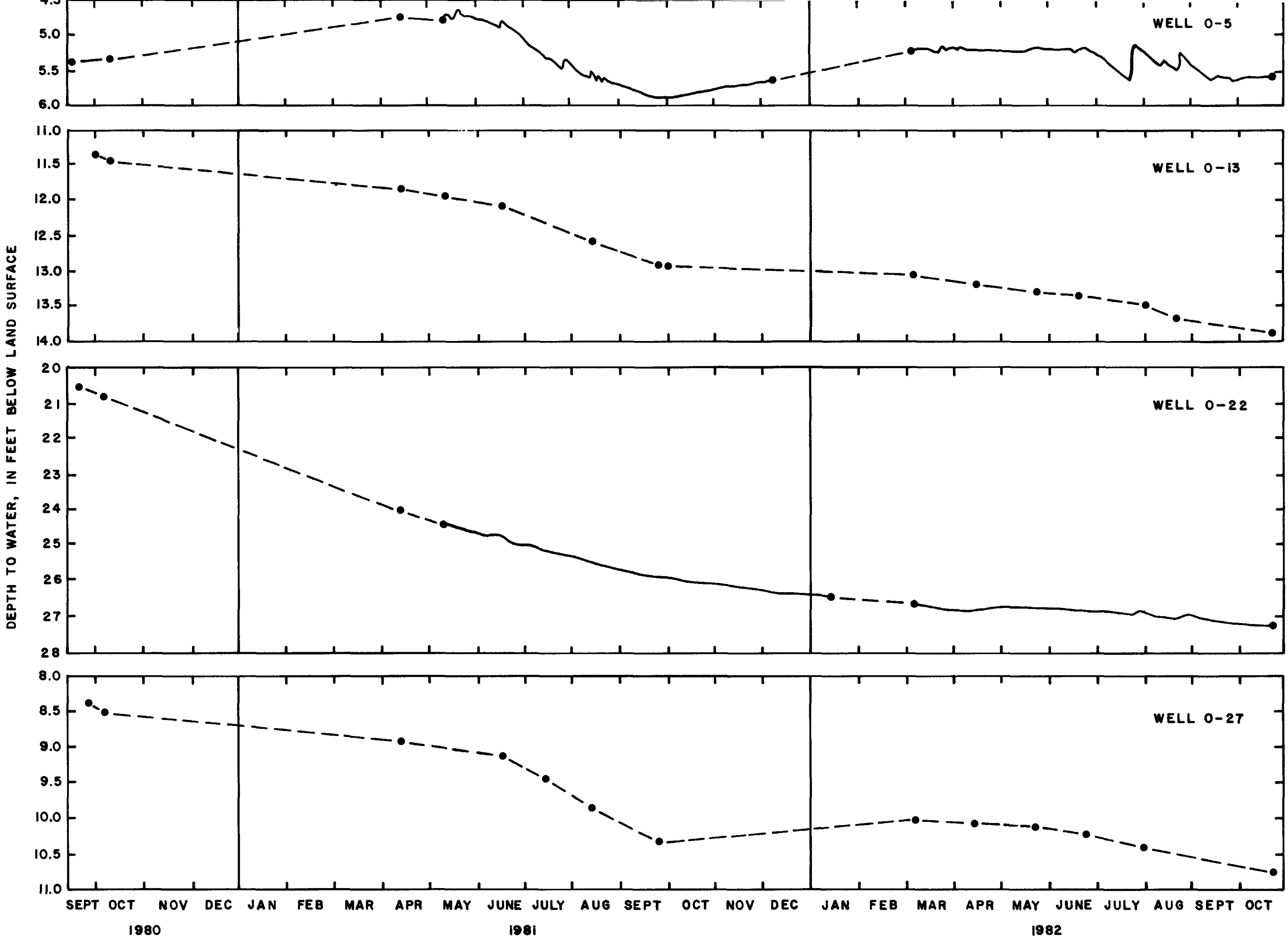


Figure 14.--Water-level fluctuations in observation wells completed in alluvium. Solid line is based on digital-recorder records; dashed line is based on periodic measurements.

silica (10 to 11 mg/L), and small concentrations of fluoride (0.7 to 0.8 mg/L). The windmill well (P-7), 0.4 mile upvalley, had water similar to that in this well line, although part of its water was obtained from the Anderson coal aquifer.

Downvalley, at section C-C', the quality of water became less mineralized, ranging in dissolved-solids concentration from 3,560 mg/L at well O-11 on the north side of the valley to 5,800 mg/L at well O-15 on the south side. The water type changed from sodium magnesium sulfate in the north and central parts of the well line to magnesium sodium sulfate in well O-15 on the south side. The calcium concentration was fairly large in the line, ranging from 170 to 330 mg/L. Except for the north edge of the valley, where the silica concentration was 20 mg/L in well O-11, the concentration of silica was moderate--16 to 17 mg/L. The fluoride concentration was small at 0.6 to 0.8 mg/L.

Near the mouth, across section D-D', the alluvial water was the least mineralized. The dissolved-solids concentration ranged from 2,460 mg/L in well O-5 near the center of the valley to 2,850 mg/L in well O-8 on the south side. The water was a sodium magnesium sulfate type. Most other constituent concentrations were small to moderate, although the silica concentration of about 20 mg/L was the largest for alluvial waters in the Horse Creek area. Fluoride was present in small concentrations across the well line, averaging about 0.8 mg/L.

Surface-water resources

Horse Creek

The Horse Creek channel and flood plain and the main tributaries compose the surface-water network in the study area. At least three stock ponds receiving water from springs retain the otherwise ephemeral supply; the ponds had water throughout the 1980-82 study. However, all were losing water to consumption by stock and by evaporation in 1982, when recharge from the springs apparently was less than pond usage and evaporation. Other manmade stock ponds hold water for only short periods after intense rainfall or snowmelt.

The Horse Creek drainage was observed monthly from October 1979 through September 1981 and from May through September 1982. In September 1980, a crest-stage gage was installed about 0.1 mile upstream from the mouth. No flow was observed in the channel during the monthly inspections. The crest-stage gage indicated flow only once--after a severe storm on July 24-25, 1982. The gage indicated that the water was about 2 feet deep in the channel. No water sample was collected from the stream for chemical analysis.

Flow was not observed during the study and the staff gage near the mouth of Horse Creek had minimal data. Using the regional prediction equations developed by Omang and others (1983) through regression analysis of streamflow and dimensions of the channel of streams in southeastern Montana, the mean discharge for the ungaged site is estimated to be about 470 acre-feet during a year of average rainfall. In 1980 and 1981, the rainfall was less than average; the volume of water reaching Hanging Woman Creek was probably less than 470 acre-feet. To determine peak-flow runoff, the regional prediction equations of Parrett and Omang (1981) were used. For Horse Creek, the maximum instantaneous flow at the mouth was calculated to be about 600 ft^3/s once every 10 years, and about 1,800 ft^3/s once every 100 years. In recent years, the only actual onsite measurement of a flood, calculated by the slope-area method, was 340 ft^3/s occurring on July 25, 1979 (R. J. Omang, U.S. Geological Survey, written commun., 1983).

Springs

Four springs were observed within or near the Horse Creek basin during this study (fig. 2). Spring S-1 issues from a clinker layer of burned Anderson coal in a small tributary north of Horse Creek valley in sec. 15, T. 8 S., R. 43 E. This spring was flowing about 4 gal/min in June 1980; it is reported to have had little variation of flow for years. The spring flows into a tile pipe which leads to a discharge line and a cattle trough downvalley. Spring S-2 also issues from a clinker layer of burned Anderson coal on the hill east of the OW Ranch headquarters in sec. 16, T. 8 S., R. 43 E. There, the tile pipe leads to a stilling basin, from which the water is piped to the houses at the ranch. Flow of the spring is reported to be about 1 gal/min, with little seasonal or annual variation.

The other two springs are undeveloped and issue directly into the Horse Creek channel; the upper (S-4) is 1.0 mile upstream from the mouth of Horse Creek and the lower (S-3) is 0.8 mile upstream. Spring S-4 receives water from the Dietz coal bed on the south side of the valley; the water flows onto a broad marshy area near the stream channel. Spring S-3 seeps from a sandstone outcrop on the north side of the valley, just downstream from the small tributary in which spring S-1 is located. The flow from S-3 seeps directly into colluvium and then combines with flow from S-4 in the Horse Creek channel.

In June 1980, a weir was installed in the Horse Creek channel below spring S-4. At that time water was flowing in Horse Creek channel from about 200 feet upstream from the weir to about 1,000 feet downstream. The flow at the weir was 5 gal/min when installed; this flow decreased to about 1.5 gal/min in October 1980. In 1981, the largest flow observed was 6.5 gal/min on May 9; this flow decreased to zero in August. In 1982, the flow was 11 gal/min on April 15 and the channel was dry by the end of July. Except in 1980, flow in the channel seldom extended more than 100 feet downstream from the weir. Flow from spring S-3 ceased in late 1980 and did not resume in 1981 or 1982.

SUMMARY

Ground-water and surface-water supplies are used only for livestock watering within the Horse Creek basin. Wells, springs, and stock ponds supply all water used by livestock. One developed spring and two wells equipped with windmills provide year-round water supplies. Three ponds receiving seep or spring discharge contain water during all but the driest years. Other stock ponds are filled only after intense rainfall or melting of a large snowpack; these ponds commonly become dry by midsummer. Surface-water supply, other than the stock ponds, exists only in Horse Creek channel, about 1 mile upstream from the mouth, where water from an undeveloped spring flows into the broad, marshy channel. Upstream and downstream from this area, Horse Creek flows only intermittently.

The Horse Creek basin was eroded into the upper part of the Tongue River Member of the Fort Union Formation (Paleocene age) and the Wasatch Formation (Eocene age), and had alluvium deposited during Pleistocene and Holocene time. Aquifers include sandstone beds throughout the Tongue River Member stratigraphic interval,

the Canyon coal bed under the entire basin, the Dietz coal bed under all the basin except near the mouth of Horse Creek, and the Anderson coal bed. The Anderson underlies the topographically higher parts of the basin, but is exposed and mostly burned between 3,600- and 3,700-foot altitudes, and is eroded from the central valley westward. Alluvial sand and gravel also is a productive aquifer in the area.

The general hydrologic characteristics of each of the aquifers are as described below:

1. Canyon coal bed: 17 to 22 feet thick, mostly massive coal, with a hydraulic conductivity of about 0.5 ft/d; capable of yielding 5 to 10 gal/min of sodium bicarbonate type water having about 1,600 mg/L of dissolved solids and about 4 mg/L of fluoride.

2. Dietz coal bed: 11 to 13 feet thick, mostly massive in the Horse Creek area but thinning and including shale breaks to the south, with a hydraulic conductivity of about 0.5 ft/d; capable of yielding 0.1 to 4 gal/min of sodium sulfate or sodium bicarbonate type water with a large range of dissolved-solids concentrations (about 1,900 to 7,700 mg/L).

3. Anderson coal bed: 32 to 33 feet thick, mostly massive coal in the Horse Creek area but thinning and including shale breaks to the south, with hydraulic conductivity of about 1.5 ft/d; capable of yielding 2 to 5 gal/min of sodium bicarbonate type water with a dissolved-solids concentration of about 2,500 mg/L.

4. Sandstone beds from above the Canyon coal to above the Anderson coal: about 5 to 50 feet thick, mostly with shale breaks or layers when more than 10 feet thick, always thickening or thinning laterally, with hydraulic conductivity of about 0.2 ft/d. The sandstone is capable of yielding 0.3 to about 10 gal/min of water with a wide range of dissolved-solids concentration (about 800 to 6,200 mg/L) and variable water types.

5. Alluvial sand and gravel: Saturated thickness of contributing permeable layers differs throughout the valley, and, because of fluctuating water levels, seasonally and between wet and dry years. In September 1981, the thickness of saturated alluvium was about 4 feet at 5.7 miles upstream from the mouth, 7 feet at 4.4 miles upstream, 12 feet at 2.3 miles upstream, and about 8 feet near the mouth; from September 1980 to October 1982 water levels declined 2.5 feet in the wells 5.7 miles upstream from the mouth, declined nearly 7 feet in the wells 4.4 miles upstream, declined 2.5 feet in the wells 2.3 miles upstream, and fluctuated 1.2 feet in the wells near the mouth. Hydraulic conductivities differed throughout the valley length and across the valley. The approximate median value of the hydraulic conductivity was 0.5 ft/d for the alluvium 5.7 miles upstream from the mouth of Horse Creek, was 20 ft/d for the alluvium 4.4 miles upstream, was 80 ft/d for the alluvium 2.3 miles upstream, and was 200 ft/d for the alluvium near the mouth. The discharge from the wells ranged from less than 0.4 gal/min 5.7 miles upstream from the mouth, to 2 to 11 gal/min 4.4 miles upstream, to 3 to 24 gal/min 2.3 miles upstream, and to 7 to 25 gal/min near the mouth. The water type was sodium magnesium sulfate throughout the valley. The dissolved-solids concentrations decreased from about 9,600 mg/L at 5.7 miles upstream from the mouth, to about 8,000 mg/L at 4.4 miles upstream, to near 4,000 mg/L 2.3 miles upstream, and to about 2,600 mg/L near the mouth.

To predict the probable effects of surface mining on the hydrologic system of the Horse Creek area, a mine outline was assumed. This mine, when completed, would encompass an area of about 3.5 mi^2 and would remove about 37 million tons of Anderson coal and 13 million tons of Dietz coal. The initial box cut would probably be east-west along the middle part of the Horse Creek valley, about 4 miles upstream from the mouth; the mine would expand northward, eastward, and southward.

The potential mine would destroy one stock well and two stock ponds receiving spring discharge. The mine would also temporarily destroy the alluvial aquifer from 4.0 miles upstream from the mouth of Horse Creek to the upstream reaches of the basin. Along the highwall to the north and east, the mine would lower the water levels in the sandstone and coal aquifers; because of the southwest dip of these beds, water would continue to flow from the sandstone and coal aquifers throughout the life of the mine. To the south and west, the sandstone and coal aquifers would eventually be drained to the level of their outcrops in the highwall. The lowered water levels would not affect any existing wells in the vicinity of the mine. Ground water downgradient from the mine area might show long-term degradation in quality as a result of leaching of soluble minerals from overburden materials used to backfill the mine pits.

To mitigate the effects of mining on the aquifers of the Horse Creek area, the alluvial aquifer would have to be reconstructed by laying a base of clayey, nearly impermeable spoils. The spoils would be overlain by replaced sand and gravel below and mud above; this material would then be overlain by a top-soil layer. The structuring of the spoils outside Horse Creek valley flats could be completed in such a manner to allow a minimum of water to flow through and out of the mined area. The well and ponds destroyed could be replaced near their present sites. The new well could be completed in sandstone aquifers between the Dietz and Canyon coal beds, at a depth of about 250 feet.

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Table 1 begins on next page

Table 1.--*Construction and hydrologic data for private wells in the Horse Creek and adjacent areas*

[°C, degrees Celsius; micromhos, micromhos per centimeter at 25° Celsius]

Well No.	Owner	Location	Date drilled	Altitude of land surface (feet above sea level)	Drilled depth (feet below land surface)	Aquifer material	Depth to top of aquifer (feet below land surface)	Aquifer thickness (feet)	Casing diameter (inches)
P-1	C.C. Stevens	SW¼SW¼SE¼NE¼ sec. 9, T. 8. S., R. 43 E.	11/--/65	3,725	199	Sandstone	104	4	4
						Sandstone	191	8	4
P-2	Powell Cattle Co.	NE¼SW¼SW¼NE¼ sec. 13, T. 8 S., R. 43 E.	--	3,925	110	Probably sandstone.	--	--	4
P-3	Kendrick Cattle Co.	NE¼SE¼SW¼SW¼ sec. 16, T. 8 S., R. 43 E.	--/--/26	3,510	100	Probably sandstone.	--	--	4
P-4	Kendrick Cattle Co.	SW¼SE¼NW¼SE¼ sec. 23, T. 8 S., R. 43 E.	12/--/50	3,595	175	Sandstone	59	16	3
						Sandstone	161	6	
P-5	Kendrick Cattle Co.	NW¼SE¼NW¼SE¼ sec. 23, T. 8 S., R. 43 E.	03/--/59	3,605	274	Sandstone	65	16	4
						Sandstone	174	20	--
P-6	Kendrick Cattle Co.	NW¼NE¼NE¼NE¼ sec. 25, T. 8 S., R. 43 E.	10/--/60	3,660	187	Coal	53	32	4
						Sandstone	174	10	
P-7	Kendrick Cattle Co.	SE¼NW¼NW¼SW¼ sec. 19, T. 8 S., R. 44 E.	12/--/71	3,700	50	Sand and gravel.	23	3	6
						Coal	43	7	
P-8	Lloyd Cattle Co.	NW¼SE¼SW¼SE¼ sec. 22, T. 8 S., R. 44 E.	09/--/67	4,109	190	Sandstone	178	8	4

Casing depth (feet below land surface)	Casing perforations (feet below land surface)	Date of hydrologic data	Static water level (feet below land surface)	Discharge (gallons per minute)	Onsite pH (units)	Onsite water temperature (°C)	Onsite specific conductance (micromhos)	Water quality analysis available	Remarks
--	100-110	11/--/65	83	4	--	--	--	no	Sandstone aquifer about 20 feet above Dietz coal bed.
199	190-199								Sandstone aquifer about 55 feet below Dietz coal bed.
--	--	06/19/75	78	3	7.6	11	960	yes	Probable sandstone aquifer about 30 feet above Smith coal bed.
100	--	04/--/68	55	10	7.2	10	2,460	yes	Probable sandstone aquifer about 70 feet above Canyon coal bed.
175	"in water veins"	01/--/54	45	8	--	--	--	no	Original well was 51 feet deep, yielded water from alluvial gravels and Dietz coal bed. Well deepened in January 1954. Upper aquifers sealed off; casing perforated opposite Tongue River Member sandstones, about 20 feet and 120 feet below Dietz coal bed.
274	"in water veins"	06/17/82	--	15	7.3	10	7,000	yes	Alluvial aquifer cased off. Sandstone aquifers about 20 feet and 120 feet below Dietz coal bed.
187	"in water veins"	10/--/60	58	12	--	--	--	no	Anderson coal aquifer from 53 to 85 feet below land surface. Sandstone aquifer about 30 feet below Dietz coal bed.
50	30-50	06/17/82	23	10	7.3	8.5	9,400	yes	Water a mixture of alluvial and Anderson coal-bed waters. Alluvial water enters well via gravel pack outside casing.
190	"in water veins"	06/19/75 10/17/82	144 --	5 --	-- 7.3	-- 10.5	-- 2,900	-- yes	Sandstone aquifer about 80 feet above Smith coal bed.

Table 2.--*Records of test holes in the Horse Creek and adjacent areas*

Test-hole No.	Identification No.	Location	Date drilled	Altitude of land surface (feet above sea level)	Drilled depth (feet below land surface)	Probable aquifer material	Probable water-bearing interval (feet below land surface)	Probable aquifer thickness (feet)	Remarks
T-1	SH-11	SW¼SW¼NE¼SW¼ sec. 10, T. 8 S., R. 43 E.	08/13/69	3,763	180	Sandstone	101-117	5	Hole 0.8 mile north of Horse Creek area.
						Anderson coal bed.	133-167	34	Probably massive coal.
T-2	U.S. 77-96	NE¼NE¼NE¼SW¼ sec. 15, T. 8 S., R. 43 E.	08/13/77	3,730	160	Anderson coal bed.	62-96	33	Hole near clinker outcrop. One-foot shale layer near base. Anderson bed probably has water only in lower part.
						Sandstone	105-114	7	Shale layer interbedded.
						Dietz coal bed.	127-140	13	Massive coal.
T-3	Birney 8-A	NW¼SE¼NW¼NE¼ sec. 20, T. 8 S., R. 43 E.	09/09/78	3,530	247	Sandstone	132-186	19	Shale layers interbedded.
						Canyon coal bed.	206-229	20	Three-foot shale layer near base.
T-4	U.S. 77-97	NW¼NE¼NE¼NE¼ sec. 23, T. 8 S., R. 43 E.	08/13/77	3,738	201	Anderson coal bed.	92-125	33	Lenses or beds of sandstone above Anderson aquifer are probably dry.
						Sandstone	137-146	7	Shale layers interbedded.
						Dietz coal bed.	164-177	13	Thin shale layers near middle.
T-5	U.S. 77-98	SE¼SW¼SW¼NE¼ sec. 24, T. 8 S., R. 43 E.	08/13/77	3,728	215	Anderson coal bed.	97-129	32	Massive coal, probably completely saturated.
						Sandstone	150-163	8	Shale layers interbedded.
						Dietz coal bed.	180-192	12	Massive coal.
T-6	U.S. 77-91	NW¼SE¼NW¼NE¼ sec. 25, T. 8 S., R. 43 E.	08/11/77	3,710	250	Anderson coal bed.	96-128	32	Massive coal.
						Sandstone	131-150	13	Shale layers interbedded.
						Dietz coal bed.	173-184	11	Thin shale layer near top.
						Sandstone	195-235	28	Shale layers interbedded.
T-7	U.S. 77-92	SW¼SW¼NE¼NE¼ sec. 26, T. 8 S., R. 43 E.	08/11/77	3,720	501	Anderson coal bed.	121-154	33	Shaly in upper part.
						Sandstone	160-175	9	Shale layers interbedded.
						Dietz coal bed.	196-207	11	Thin shale layer near top.
						Sandstone	218-257	22	Shale layers interbedded.
						Sandstone	415-440	16	Shale layers interbedded.
						Canyon coal bed.	453-481	23	Two- and three-foot shale layers near base.

Table 2.--*Records of test holes in the Horse Creek and adjacent areas*--Continued

Test-hole No.	Identification No.	Location	Date drilled	Altitude of land surface (feet above sea level)	Drilled depth (feet below land surface)	Probable aquifer material	Probable water-bearing interval (feet below land surface)	Probable aquifer thickness (feet)	Remarks
T-8	U.S. 77-93	NE¼SE¼NE¼NW¼ sec. 27, T. 8 S., R. 43 E.	08/12/77	3,662	164	Anderson coal bed.	67-90	21	Upper part of Anderson burned. Anderson bed probably dry. Two-foot shale layer near base.
						Sandstone	108-127	12	Shale layers interbedded.
						Dietz coal bed.	146-157	11	Thin shale layer near top.
T-9	U.S. 77-94	NW¼SW¼NE¼NE¼ sec. 35, T. 8 S., R. 43 E.	08/11/77	3,912	400	Sandstone	216-260	26	Shale layers interbedded. Interval may be dry.
						Anderson coal bed.	314-344	29	One-foot shale layer near base.
						Sandstone	356-365	6	Shale layers interbedded.
						Dietz coal bed.	382-391	9	Massive coal.
T-10	Otter No. 4	NW¼SE¼SW¼NW¼ sec. 15, T. 8 S., R. 44 E.	08/30/80	3,925	675	Sandstone	74-85	9	Shale layers interbedded.
						Sandstone	157-169	8	Shale layers interbedded.
						Anderson coal bed.	185-217	32	Thin shale layers in middle.
						Sandstone	234-247	7	Shale layers interbedded.
						Dietz coal bed.	262-274	12	Massive coal.
						Sandstone	340-373	20	Shale layers interbedded.
						Canyon coal bed.	438-466	28	Thin shale layers near base.
T-11	SH-13	SE¼NE¼NW¼SW¼ sec. 19, T. 8 S., R. 44 E.	08/19/69	3,720	180	Anderson coal bed.	82-114	32	Thin shale layers near top.
						Dietz coal bed.	167-179	12	Probably massive coal.
T-12	30-3 Federal/ White	NW¼SW¼NW¼NW¼ sec. 30, T. 8 S., R. 44 E.	--	3,675	1,700+	Anderson and Dietz coal beds.	--	--	Well penetrated these coal beds, but no log was kept in this interval.
						Canyon coal bed.	373-390	17	Massive coal.
T-13	SH-14	NW¼SE¼SW¼NW¼ sec. 30, T. 8 S., R. 44 E.	08/15/69	3,780	192	Anderson coal bed.	157-189	32	Water-bearing sandstone beds probably exist above Anderson aquifer in this vicinity.
T-14	U.S. 77-95	NW¼NW¼SW¼NW¼ sec. 31, T. 8 S., R. 44 E.	08/11/77	3,842	400	Sandstone	202-268	30	Shale layers interbedded. Lenses and beds of sandstone above 200-foot depth probably dry.
						Anderson coal bed.	287-319	31	One-foot shale layer near base.
						Dietz coal bed.	370-380	10	Massive coal.

Table 2.--*Records of test holes in the Horse Creek and adjacent areas*--Continued

Test-hole No.	Identification No.	Location	Date drilled	Altitude of land surface (feet above sea level)	Drilled depth (feet below land surface)	Probable aquifer material	Probable water-bearing interval (feet below land surface)	Probable aquifer thickness (feet)	Remarks
T-15	U.S. 77-89	SE¼SE¼SW¼SE¼ sec. 1, T. 9 S., R. 43 E.	08/11/77	3,605	340	Anderson coal bed.	40-70	28	Two-foot shale layer near base.
						Sandstone	94-101	5	Shale layers interbedded.
						Dietz coal bed.	124-133	7	Two-foot shale layer near top.
						Sandstone	148-199	26	Shale layers interbedded.
						Sandstone	275-304	14	Shale layers interbedded.
						Canyon coal bed.	316-332	16	Massive coal.
T-16	Vessels/Shell No. 2	NW¼SE¼NW¼NW¼ sec. 2, T. 9 S., R. 43 E.	--	3,640	1,700+	Anderson and Dietz coal beds.	--	--	Well penetrated these coal beds, but no log was kept in this interval.
						Canyon coal bed.	334-348	14	Massive coal.
T-17	SH-15	NE¼NE¼NW¼NW¼ sec. 2, T. 9 S., R. 43 E.	08/21/69	3,690	210	Anderson coal bed.	101-129	27	One-foot shale layer near top.
						Dietz coal bed.	191-201	10	Thin shale layers near top.
T-18	U.S. 77-87	NW¼SW¼SW¼SE¼ sec. 2, T. 9 S., R. 43 E.	08/03/77	3,580	362	Anderson coal bed.	71-105	30	Four-foot shale layer near base.
						Sandstone	109-130	14	Shale layers interbedded.
						Dietz coal bed.	155-166	9	Two-foot shale layer near top.
						Sandstone	220-255	22	Shale layers interbedded.
						Sandstone	286-300	11	Shale layers interbedded.
						Canyon coal bed.	318-333	15	Massive coal.

Table 3 begins on next page

Table 3.--*Construction and hydrologic data for observation wells completed in the Tongue River Member of the Fort Union Formation in the Horse Creek and adjacent areas*

[°C, degrees Celsius; micromhos, micromhos per centimeter at 25° Celsius; <, less than]

Well No.	Identification No.	Location	Date drilled	Altitude of land surface (feet above sea level)	Drilled depth (feet below land surface)	Aquifer material	Depth to top of aquifer (feet below land surface)	Depth to bottom of aquifer (feet below land surface)	Casing depth (feet below land surface)	Casing perforations (feet below land surface)	Packer depth (feet below land surface)	Date of hydrologic data	Static water level (feet below land surface)
0-1	HC#21	NE¼SW¼SW¼NW¼ sec. 14, T. 8 S., R. 43 E.	12/07/80	3,810	218	Dietz coal bed.	189	200	218	191-202	188	06/21/82	184.2
0-2	HC#22	NE¼SW¼SW¼NW¼ sec. 14, T. 8 S., R. 43 E.	12/08/80	3,811	162	--	--	--	160	130-160	129	06/15/82	below 160
0-3	HWC#01	NE¼NW¼NE¼SE¼ sec. 20, T. 8 S., R. 43 E.	05/08/74	3,530	232	Canyon coal bed.	209	226	232	209-224	207	07/16/80	90.0
0-9	HC#23	NW¼NW¼SE¼NW¼ sec. 21, T. 8 S., R. 43 E.	12/18/80	3,500	238	Canyon coal bed.	162	179	223	150-165	143	09/22/81	56.2
						Sandstone	181	200		178-185			
0-10	HC#24	NW¼NW¼SE¼NW¼ sec. 21, T. 8 S., R. 43 E.	12/28/80	3,500	150	Sandstone	108	150	150	110-150	109	09/23/81	47.8
0-16	HC#20	NE¼NE¼SE¼SW¼ sec. 23, T. 8 S., R. 43 E.	12/10/80	3,605	342	Canyon coal bed.	302	324	342	306-334	302	09/30/81	167.0
0-17	HC#19	NE¼NE¼SE¼SW¼ sec. 23, T. 8 S., R. 43 E.	12/08/80	3,605	82	Dietz coal bed.	66	79	82	66-80	62	06/20/82	49.5
0-18	U.S. 77-90	SW¼SW¼NW¼SE¼ sec. 23, T. 8 S., R. 43 E.	08/12/77	3,600	342	Sandstone	35	40	58	35-55	35	06/17/82	35.8
						Dietz coal bed.	52	65					
0-19	HC#17	NW¼NW¼NW¼SE¼ sec. 25, T. 8 S., R. 43 E.	12/12/80	3,850	334	Dietz coal bed.	321	333	334	320-332	314	06/20/82	286.3
0-20	HC#18	NW¼NW¼NW¼SE¼ sec. 25, T. 8 S., R. 43 E.	12/15/80	3,850	282	Anderson coal bed.	249	281	282	252-282	242	09/29/81	231.1
0-25	BC#10	NW¼NW¼NW¼SW¼ sec. 19, T. 8 S., R. 44 E.	07/02/75	3,720	194	Dietz coal bed.	176	188	194	177-189	175	06/19/82	157.6
0-26	BC#11	NW¼NW¼NW¼SW¼ sec. 19, T. 8 S., R. 44 E.	06/30/75	3,720	132	Anderson coal bed.	94	127	132	95-129	91	06/16/82	77.4
0-29	HWC#28	NW¼NE¼SE¼SE¼ sec. 32, T. 8 S., R. 44 E.	05/10/77	3,740	183	Anderson coal bed.	144	175	183	147-178	144	07/07/77	105.1
0-30	HWC#21	NW¼NW¼NW¼NW¼ sec. 2, T. 9 S., R. 43 E.	08/27/76	3,665	217	Dietz coal bed.	203	213	217	200-211	196	08/27/76	160±
0-31	HWC#22	NW¼NW¼NW¼NW¼ sec. 2, T. 9 S., R. 43 E.	08/27/76	3,665	145	Anderson coal bed.	114	142	145	113-143	109	08/27/76	126±
0-32	HWC#24	NW¼NW¼NW¼NW¼ sec. 6, T. 9 S., R. 44 E.	09/14/76	3,700	201	Dietz coal bed.	189	198	201	187-196	184	09/14/76	178±
0-33	HWC#23	NW¼NW¼NW¼NW¼ sec. 6, T. 9 S., R. 44 E.	09/04/76	3,730	172	Anderson coal bed.	137	167	172	138-167	135	09/04/76	136±

Pumping water level (feet below land surface)	Discharge (gallons per minute)	Specific capacity (gallons per minute per foot of drawdown)	Onsite pH (units)	Onsite specific conductance (micromhos)	1981-82 water-level fluctuation (feet below land surface)	Remarks
204	0.15	0.007	7.5	9,700	183.0-184.4	Discharge too small to pump; well was bailed to near bottom.
--	--	--	--	--	--	Anderson coal bed, from 127 to 160 feet, dry at this site; water drained to adjacent clinker layers.
210	9	.07	7.8	2,450	89.1-89.7	Well is on west side of Hanging Woman Creek valley, opposite mouth of Horse Creek. Bottom 10 feet of well filled with mud; lower 4 feet of Canyon coal aquifer not contributing to well.
129	17	.2	8.4	2,400	55.9-56.3	Casing installation problems left perforated interval above and below the coal bed and partly opposite a sandstone aquifer. Well produces a mixture of coal and sandstone waters.
126	8	.1	8.2	2,600	47.5-48.0	Bottom 4 feet of well filled with mud; lower 4 feet of sandstone aquifer not contributing to well. Sandstone aquifer probably hydrologically connected with adjacent alluvial aquifers.
226	8	.1	8.0	2,650	166.6-167.0	Casing installation problems left perforated interval 4 feet too deep to be opposite entire Canyon coal aquifer. Recorder installed 10/01/81.
57.0	3.5	.4	7.3	6,250	48.8-49.8	Recorder installed 09/26/81.
50	.35	.02	7.3	4,650	35.7-35.9	Test hole drilled to depth of 342 feet; hole reamed and cased to 58 feet.
318	.4	.01	7.9	3,250	286.0-287.0	Bottom 3 feet of well filled with mud; lower 1 foot of Dietz coal aquifer not contributing to well.
276	2.2	.05	7.7	4,200	230.8-231.2	--
184	2.1	.08	7.7	3,050	157.3-157.8	--
92	2.9	.2	7.5	3,620	77.0-77.5	--
118	4.4	.3	7.6	2,900	--	Well is in East Trail Creek drainage, southeast of Horse Creek study area.
210±	1±	--	--	--	--	Well is in Trail Creek drainage, southwest of study area. Well never tested. Yield reported when well drilled.
140±	<1	--	--	--	--	Well never tested. Yield reported when well drilled.
200±	<1	--	--	--	--	Well is in East Trail Creek drainage, south of study area. Well probably not developed.
170±	2+	--	--	--	--	Well never tested. Yield reported when well drilled.

Table 4.--*Construction and hydrologic data for observation wells completed in alluvial aquifers*
[°C, degrees Celsius; micromhos, micromhos per centimeter at 25° Celsius; <, less than]

Well No.	Identification No.	Location	Date drilled	Altitude of land surface (feet above sea level)	Drilled depth (feet below land surface)	Aquifer material	Depth to top of aquifer (feet below land surface)	Depth to bottom of aquifer (feet below land surface)	Casing depth (feet below land surface)	Casing perforations (feet below land surface)	Packer depth (feet below land surface)	Date of hydrologic data	Static water level (feet below land surface)
0-4	HC#01	NE¼SE¼NW¼NW¼ sec. 21, T. 8 S., R. 43 E.	09/15/80	3,457	20	Sand and gravel.	8	15	19.7	7.1-17.1	6	09/22/81	7.8
0-5	HC#05	SE¼SE¼NW¼NW¼ sec. 21, T. 8 S., R. 43 E.	09/17/80	3,455	13	Sand and gravel.	6	11	12.9	5.3-12.9	4	09/23/81	5.9
0-6	HC#02	SE¼SE¼NW¼NW¼ sec. 21, T. 8 S., R. 43 E.	09/16/80	3,455	20	Sand and gravel.	6	13	20.0	7.3-15.5	6	09/26/81	5.7
0-7	HC#03	SE¼SE¼NW¼NW¼ sec. 21, T. 8 S., R. 43 E.	09/16/80	3,475	38	Sand and gravel.	26	33.5	37.8	26.2-35.1	25	06/19/82	25.2
0-8	HC#04	NE¼NE¼SW¼NW¼ sec. 21, T. 8 S., R. 43 E.	09/17/80	3,474	35.5	Sand and gravel.	25	33	35.4	25.4-34.9	19	09/22/81	25.2
0-11	HC#09	SE¼NW¼NE¼SW¼ sec. 23, T. 8 S., R. 43 E.	09/19/80	3,577	32.1	Sand and gravel.	20	29	32.1	19.8-29.1	17	09/24/81	20.4
0-12	HC#08	SE¼NW¼NE¼SW¼ sec. 23, T. 8 S., R. 43 E.	09/18/80	3,570	30	Sand and gravel.	13	27	29.5	17.2-26.1	10	09/28/81	13.3
0-13	HC#10	NE¼SW¼NE¼SW¼ sec. 23, T. 8 S., R. 43 E.	09/19/80	3,570	29	Sand and gravel.	12.5	25	28.9	13.1-26.4	11	09/30/81	12.9
0-14	HC#07	NE¼SW¼NE¼SW¼ sec. 23, T. 8 S., R. 43 E.	09/18/80	3,570	28.2	Sand and gravel.	13	25	28.2	17.6-26.1	12	06/18/82	13.7
0-15	HC#06	NE¼SW¼NE¼SW¼ sec. 23, T. 8 S., R. 43 E.	09/17/80	3,580	37	Sand and gravel.	20	33	36.9	26.2-33.7	21	09/24/81	23.2
0-21	HC#14	NW¼SW¼NW¼SW¼ sec. 19, T. 8 S., R. 44 E.	09/22/80	3,682	32	Sand and gravel.	26	29.5	31.4	19.3-29.1	18	06/21/82	28.2
0-22	HC#13	NW¼SW¼NW¼SW¼ sec. 19, T. 8 S., R. 44 E.	09/20/80	3,680	36	Sand and gravel.	24	34.5	35.9	22.6-35.9	21	06/21/82	26.8
0-23	HC#12	NW¼SW¼NW¼SW¼ sec. 19, T. 8 S., R. 44 E.	09/20/80	3,670	29	Sand and gravel.	14	26	28.9	12.5-26.5	12	06/18/82	16.9
0-24	HC#11	SW¼SW¼NW¼SW¼ sec. 19, T. 8 S., R. 44 E.	09/20/80	3,670	26	Sand and gravel.	14	22.5	25.7	11.4-23.2	10	06/16/82	17.0
0-27	HC#15	SW¼SW¼NW¼SW¼ sec. 20, T. 8 S., R. 44 E.	09/22/80	3,755	17	Sand and gravel.	8.5	13.5	16.7	7.7-14.5	7	07/14/81	9.5
0-28	HC#16	NW¼NW¼SW¼SW¼ sec. 20, T. 8 S., R. 44 E.	09/22/80	3,765	26.5	Sand and gravel.	19	23.5	26.2	17.6-23.8	17	07/14/81	18.7

Pumping water level (feet below land surface)	Discharge (gallons per minute)	Specific capacity (gallons per minute per foot of drawdown)	On-site pH (units)	On-site specific conductance (micromhos)	1981 water-level fluctuations (feet below land surface)	1982 water-level fluctuations (feet below land surface)	Remarks
13.6	17	2.9	7.6	3,200	6.6-7.8	6.9-7.4	Well is one of five in line near mouth of Horse Creek.
10	7.2	1.7	7.5	3,150	4.7-6.0	5.1-5.5	Well is 141 feet south of well 0-4. Recorder installed 05/09/81.
9.3	25	6.9	7.4	3,400	4.5-5.8	4.9-5.3	Well is 20.5 feet south of well 0-5.
26.7	13	8.6	7.4	3,520	24.8-26.0	25.2-26.6	Well is 157 feet south of well 0-6.
28	16	5.7	7.5	3,800	24.0-25.2	24.5-24.8	Well is 167 feet south of well 0-7 and 485 feet south of well 0-4.
26	6.7	1.2	7.3	5,400	19.2-20.5	20.6-21.6	Well is one of five in line, 2.3 miles upstream from mouth of Horse Creek.
15.5	3	1.3	7.7	5,800	12.2-13.3	13.3-14.2	Well is 115 feet south of well 0-11.
14.0	24	22	7.5	6,400	11.8-12.9	13.0-13.9	Well is 40 feet south of well 0-12.
14.4	2.9	4.1	7.3	6,200	12.2-13.3	13.4-14.4	Well is 79 feet south of well 0-13.
31	3	.4	7.5	8,100	21.6-22.8	22.8-23.8	Well is 178 feet south of well 0-14 and 412 feet south of well 0-11.
31	<.001	--	--	--	26.5-27.5	27.8-28.9	Well is one of four in line, 4.4 miles upstream from mouth of Horse Creek. Well 119 feet north of well 0-22.
30.5	11	3.0	7.3	8,500	24.0-25.9	26.6-27.3	Well is 119 feet south of well 0-21. Recorder installed 05/09/81.
21.5	3.6	.8	7.3	9,000	14.2-16.0	16.7-17.3	Well is 111 feet south of well 0-22.
19.2	2.3	1.0	7.2	9,700	14.5-16.2	16.8-17.3	Well is 111 feet south of well 0-23 and 341 feet south of well 0-21.
13	.4	.1	7.3	12,000	8.9-10.3	10.0-10.7	Well is one of two in line, 5.7 miles upstream from mouth of Horse Creek.
25.9	.03	.004	7.5	13,000	18.3-19.0	18.7-19.2	Well is 152 feet southeast of well 0-27.

Table 5.--*Aquifer characteristics of the Tongue River Member of the Fort Union Formation in the Horse Creek and adjacent areas*

Well No.	Aquifer material open to perfor-ated casing	Water intake interval (feet below land surface)	Contrib-uting thick-ness of aquifer (feet)	Date of test	Static water level (feet below land surface)	Drawdown during test (feet below static water level)
0-1	Dietz coal bed.	190-200	10	06/21/82	184.2	20
0-3	Canyon coal bed.	209-222	13	07/16/80	90.0	120
0-9	Canyon coal bed.	162-166	4	09/22/81	56.2	73
	Canyon coal bed.	177-179	2			
	Sandstone	181-185	4			
0-10	Sandstone	110-146	25	09/23/81	47.8	78
0-16	Canyon coal bed.	305-324	19	09/30/81	167.0	59
0-17	Dietz coal bed.	66-79	13	06/20/82	49.5	7.5
0-18	Sandstone	35-38	3	06/17/82	35.8	14
	Dietz coal bed.	52-55	3			
0-19	Dietz coal bed.	321-332	11	06/20/82	286.3	32
0-20	Anderson coal bed.	251-281	30	09/29/81	231.1	45
0-25	Dietz coal bed.	176-188	12	06/19/82	157.6	27
0-26	Anderson coal bed.	94-127	33	06/16/82	77.4	15
0-29	Anderson coal bed.	146-175	29	07/07/77	105.1	13

Discharge (cubic feet per day)	Transmissivity (feet squared per day)	Hydraulic conductivity (feet per day)	Remarks
30	0.5	0.05	Transmissivity calculated from recovering water-level data, after bailing well.
1,730	4	.3	Well 2,600 feet southwest of well O-9.
3,300	15	1.5	Well 8.5 feet northeast of well O-10.
1,540	5	.2	Water level unaffected by pumping well O-9.
1,540	12	.6	Well 6.2 feet northwest of well O-17.
670	140	10	Water level unaffected by pumping well O-16.
65	2	.3	Well 285 feet northeast of well O-17. Water is mixture from sandstone and coal. Transmissivity calculated from recovering water-level data, after bailing well.
75	.4	.03	Well 18 feet north of well O-20.
420	4	.15	Water level unaffected by bailing well O-19.
410	10	.8	Well 12 feet west of well O-26.
560	50	1.5	Water level unaffected by pumping well O-25.
850	120	4	Test conducted by Montana Bureau of Mines and Geology.

Table 6.--*Chemical quality of water from private and observation wells in the Horse Creek and adjacent areas*

[Constituents are dissolved and concentrations are reported in milligrams per liter. Analyses by Montana Bureau of Mines and Geology. Abbreviations: micromhos, micromhos per centimeter at 25° Celsius; °C, degrees Celsius]

Well No.	Date sample collected	Well casing depth (feet below land surface)	Onsite specific conductance (micromhos)	Onsite pH (units)	Onsite water temperature (°C)	Hardness (as $CaCO_3$)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)
				Canyon coal bed					
0-3	07/16/80	232	2,450	7.8	13	23	4.8	2.6	670
0-9	09/22/81	223	2,400	8.4	13	19	4.5	1.9	660
0-16	09/30/81	342	2,650	8.0	13.5	26	5.9	2.7	730
				Dietz coal bed					
0-1	06/21/82	218	9,700	7.5	12	470	92	59	2,400
0-17	06/20/82	82	6,250	7.3	11	840	120	130	1,200
0-18	06/17/82	58	4,650	7.3	11	1,500	200	240	670
0-19	06/20/82	334	3,250	7.9	13	67	12	8.9	780
0-25	06/19/82	194	3,050	7.7	11	42	8.4	5.2	790
				Anderson coal bed					
0-20	09/29/81	282	4,200	7.7	12	66	14	7.5	990
0-26	06/16/82	132	3,620	7.5	10	75	15	9.1	900
0-29	07/07/77	183	2,900	7.6	12	53	10	6.7	690
				Sandstone beds					
P-2	06/19/75		960	7.6	11	330	43	53	92
P-3	06/19/82	100	2,460	7.2	10	440	58	73	440
P-5	06/17/82	274	7,000	7.3	10	2,600	290	460	920
P-8	10/17/82	190	2,900	7.3	10.5	1,400	190	230	220
0-10	09/23/81	150	2,600	8.2	12	17	3.9	1.7	670
				Alluvium					
P-7	06/17/82	50	9,400	7.3	8.5	3,400	330	640	1,300
0-4	09/22/81	19.7	3,200	7.6	10	1,130	150	180	400
0-5	09/23/81	12.9	3,150	7.5	10	1,110	150	180	400
0-6	09/26/81	20.0	3,400	7.4	10	1,120	150	180	400
0-7	06/19/82	37.8	3,520	7.4	9.5	1,240	170	200	430
0-8	09/22/81	35.4	3,800	7.5	9.5	1,340	180	220	430
0-11	09/24/81	32.1	5,400	7.3	10	1,400	180	240	600
0-12	09/28/81	29.5	5,800	7.7	10	1,600	170	290	760
0-13	09/30/81	28.9	6,400	7.5	10	2,000	220	340	780
0-14	06/18/82	28.2	6,200	7.3	9.5	2,100	260	360	830
0-15	09/24/81	36.9	8,100	7.5	10	2,700	330	460	840
0-22	06/21/82	35.9	8,500	7.3	10	3,200	340	580	1,200
0-23	06/18/82	28.9	9,000	7.3	10	3,400	360	610	1,300
0-24	06/16/82	25.7	9,700	7.2	9	3,800	390	680	1,400
0-27	07/14/81	16.7	12,000	7.3	10	3,900	370	720	1,600
0-28	07/14/81	26.2	13,000	7.5	10	3,700	380	680	1,700

Sodium-adsorption ratio (SAR)	Potassium (K)	Bicarbonate (HCO_3)	Carbonate (CO_3)	Alkalinity (as $CaCO_3$)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Silica (SiO_2)	Dissolved solids, sum of constituents	Remarks
61	4.8	1,700	0	1,400	14	26	3.7	9	1,580	
66	2.7	1,700	0	1,400	2.8	23	4.0	9	1,560	Mixed water from Canyon coal and underlying sandstone.
62	3.1	1,900	0	1,600	16	27	3.7	10	1,760	
48	16	1,500	0	1,200	4,300	24	1.6	11	7,690	
18	16	830	0	680	2,700	17	1.5	9	4,560	
8	18	530	0	440	2,500	20	1.5	10	3,920	Mixed water from Dietz coal bed and overlying sandstone.
41	8.8	2,200	2	1,800	42	40	3.1	7	1,970	
52	5.1	2,100	0	1,700	25	36	2.5	8	1,920	
53	3.9	2,200	0	1,800	410	42	2.0	12	2,550	
45	5.5	2,200	0	1,800	240	30	2.1	10	2,320	
42	5.4	1,900	0	1,500	--	18	1.8	9	--	
2	7.0	470	0	390	130	8.7	.5	12	820	Homestead well; not in use in 1981.
9	8.1	1,200	0	980	430	19	1.9	14	1,630	OW Ranch headquarters domestic well.
8	10	1,000	0	820	4,000	21	.8	17	6,240	OW Ranch range well.
2	6.3	630	0	520	1,300	13	.5	12	2,290	Lloyd Ranch range well.
71	2.9	1,760	0	1,440	3.8	25	4.9	8	1,590	
10	8.0	750	0	620	5,700	33	.8	10	8,440	Mixed water from alluvium and Anderson coal bed via gravel pack.
5	10	630	0	520	1,400	13	.8	19	2,470	
5	10	630	0	520	1,400	13	.8	20	2,460	
5	11	650	0	530	1,400	13	.9	20	2,480	
5	11	580	0	480	1,700	18	.8	22	2,800	
5	11	640	0	530	1,700	13	.7	20	2,850	
7	12	710	0	580	2,100	15	.6	20	3,560	
8	11	660	0	540	2,600	17	.7	17	4,190	
8	10	670	0	550	3,000	16	.7	17	4,680	
8	9.7	640	0	530	3,400	19	.8	16	5,190	
7	9.3	600	0	490	3,800	21	.6	16	5,800	
9	7.4	730	0	600	5,200	32	.8	11	7,710	
9	7.4	710	0	580	5,400	30	.7	11	8,040	
10	7.2	760	0	620	6,000	32	.8	10	8,890	
11	8.8	740	0	610	6,400	24	.7	9	9,470	
12	14	850	0	700	6,500	29	.8	10	9,770	

Table 7.--*Chemical quality of water from springs in the Horse Creek and adjacent areas*

[Constituents are dissolved and concentrations are reported in milligrams per liter. Analyses by Montana Bureau of Mines and Geology. Abbreviations: micromhos, micromhos per centimeter at 25° Celsius; °C, degrees Celsius]

Spring No.	Local iden-tifi-cation	Location	Date sample collected	Altitude of land surface at dis-charge point (feet above sea level)	Dis-charge (gal-lons per minute)	Onsite spe-cific conduc-tance (micro-mhos)	Onsite pH (units)	Onsite water temper-ature (°C)	Hard-ness (as $CaCO_3$)	Cal-cium (Ca)	Mag-ne-sium (Mg)	So-di-um (Na)	So-dium-ad-sorp-tion ratio (SAR)
S-1	Clinker Spring.	08S43E15CCAA01	06/26/80	3,625	4	840	7.1	15	270	60	29	78	2
S-2	OW Ranch Spring.	08S43E16CDBD01	06/19/82	3,610	1±	320	7.3	9	140	28	16	16	.6
S-3	HC Lower Spring.	08S43E21ADAC01	06/26/80	3,515	3±	3,000	8.1	20	1,100	130	190	420	6
S-4	HC Upper Spring.	08S43E22CBAA01	06/26/80	3,520	4	4,100	7.9	21	1,500	170	260	600	7

[1] Consists of burned Anderson coal and overburden.

Potassium (K)	Bicarbonate (HCO_3)	Carbonate (CO_3)	Alkalinity (as $CaCO_3$)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Silica (SiO_2)	Dissolved solids, sum of constituents	Formation or unit from which spring issues	Remarks
5.1	320	0	260	180	2.9	0.9	27	543	Clinker[1]	Sampling-point water warmed by sun. Spring developed by perforated pipe in boggy outlet area used to pipe water to trough for cattle.
1.9	180	0	150	17	1.2	1.5	25	198	Clinker[1]	Spring developed; outlet flows into covered concrete sump. Water piped to OW Ranch headquarters buildings by gravity flow.
12	550	0	450	1,500	18	.5	5	2,550	Sandstone below Dietz coal bed.	Sampling-point water warmed by sun. Sandstone spring and Dietz coal water from upstream source.
12	650	0	530	2,200	18	.4	7	3,590	Dietz coal bed, unburned.	Sampling-point water warmed by sun. Sampling point is about 600 feet downstream from spring outlets. Ground between outlets and sampling point is marsh in Horse Creek channel; marsh is contaminated by cattle.

Table 8.--*Aquifer characteristics of alluvial aquifers*

Well No.	Aquifer material open to perforated casing	Water intake interval (feet below land surface)	Contributing thickness of aquifer (feet)	Date of test	Static water level (feet below land surface)	Drawdown during test (feet below static water level)
0-4	Sand and gravel.	8-15	5	09/22/81	7.8	5.8
0-5	Sand and gravel.	6-11	5	09/23/81	5.9	4.1
0-6	Sand and gravel.	6-13	7	09/26/81	5.7	3.6
0-7	Sand and gravel.	26-33.5	6	06/19/82	25.2	1.5
0-8	Sand and gravel.	25.2-33	6	09/22/81	25.2	2.8
0-11	Sand and gravel.	20.4-29	6	09/24/81	20.4	5.6
0-12	Sand and gravel.	13.3-27	8	09/28/81	13.3	2.2
0-13	Sand and gravel.	12.9-25	9	09/30/81	12.9	1.1
0-14	Sand and gravel.	13.7-25	6	06/18/82	13.7	.7
0-15	Sand and gravel.	23.2-33	4	09/24/81	23.2	8
0-22	Sand and gravel.	26.8-34.5	6	06/21/82	26.8	3.7
0-23	Sand and gravel.	16.9-26.0	7	06/18/82	16.9	4.6
0-24	Sand and gravel.	17.0-22.5	5	06/16/82	17.0	2.2
0-27	Sand and gravel.	9.5-13.5	3	07/14/81	9.5	3.5
0-28	Sand and gravel.	19-23.5	4	07/14/81	18.7	7.2

Effects of pumping on adjacent wells

Discharge (cubic feet per day)	Transmissivity squared (feet per day)	Hydraulic conductivity (feet per day)	Adjacent well No.	Distance from pumped well (feet)	Water-level decline (feet)	Calculated storage coefficient
3,250	1,000	200	0-5	141	0.00	--
1,380	1,200	240	0-4	141	.02	--
			0-6	20	.25	0.0025
			0-7	177	.00	--
4,800	1,200	170	0-4	161	.01	--
			0-5	20	1.27	.005
			0-7	157	.04	--
2,500	4,000	660	0-6	157	.03	--
			0-8	167	.01	--
3,000	420	70	0-7	167	.00	--
1,280	100	16	0-12	115	.01	--
580	100	12	0-11	115	.00	--
			0-13	40	.03	--
			0-14	119	.00	--
4,600	2,000	220	0-12	40	.28	.055
			0-14	79	.08	--
550	900	150	0-13	79	.01	--
580	40	10	0-14	178	.00	--
2,100	100	16	0-21	119	.00	--
			0-23	111	.00	--
690	80	11	0-22	111	.00	--
			0-24	111	.00	--
440	300	60	0-23	111	.00	--
80	3	1	0-28	152	.00	--
6	.1	.02	0-27	152	.00	--