POTENTIAL EFFECTS OF SURFACE COAL MINING ON THE HYDROLOGY OF THE CORRAL CREEK AREA, HANGING WOMAN CREEK COAL FIELD, 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 metric units.

Multiply inch-pound unit	By	To obtain SI unit
acre-foot	1,233	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
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 in degrees Celsius (°C) can be converted to degrees Fahrenheit (°F) by the equation:

$$°F = 9/5\ (°C) + 32$$

National Geodetic Vertical Datum of 1929 (NGVD of 1929): A geodetic datum derived from a general adjustment of the first-order level nets of both the United States and Canada, formerly called mean sea level. NGVD of 1929 is referred to as sea level in this report.

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ABSTRACT

The Corral Creek area of the Hanging Woman Creek coal field, 9 miles east of the Decker coal mines near the Tongue River, contains large reserves of Federal 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 coal mining on local water resources.

Hydrologic data collected from stock wells, observation wells, and test holes indicate that shallow aquifers exist within the upper part of the Tongue River Member of the Fort Union Formation (Paleocene age) and within valley alluvium (Pleistocene and Holocene age). The main aquifers in the area are the Anderson coal bed and sandstone beds above and below the Anderson. Wells supply most of the water used for livestock watering, the only water use in the Corral Creek study area. The water supplied by wells is a sodium bicarbonate or sodium sulfate type; its dissolved-solids concentrations exceed the standards recommended by the U.S. Environmental Protection Agency for drinking water.

Surface-water resources are limited. Flow in the upstream parts of Corral Creek and South Fork Corral Creek, plus all other tributary drainages, is ephemeral. The downstream part of Corral Creek flows intermittently. Most of the stock ponds in the area become dry by midsummer.

Mining the approximately 190 million tons of the Anderson coal bed would remove three wells used for watering stock and one well that is unused. The potentiometric surface of the Anderson coal aquifer and the alluvial aquifer would decline during mining. Lowered water levels in these aquifers might substantially affect water levels in one well outside the potential mine boundary. After mining, ground water in the mine area might show a long-term degradation in quality as a result of leaching of soluble minerals from overburden materials used to backfill mine pits. Although mining would alter the existing hydrologic systems and remove several shallow wells, alternative ground-water supplies are available at deeper levels that could be developed to replace those lost by mining.

INTRODUCTION

Development of western coal to meet national energy needs has received increased emphasis. A large part of the western coal is under Federal ownership; therefore, considerable demand exists for 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 the area during mining and reclamation operations and after abandonment. To determine potential effects and reclamation potential of a coal tract, the U.S. Geological Survey, in cooperation with the Bureau of Land Management, is conducting hydrologic studies on several potential coal lease tracts in the Powder River structural basin of southeastern Montana. The Corral Creek area of the Hanging Woman Creek coal field is one of these tracts.

Purpose and scope

The purpose of this report is to describe the existing hydrologic systems, to obtain data on the water quality of 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 of the area;
(2) determine chemical quality of the ground-water resources;
(3) identify surface-water resources and runoff characteristics;
(4) determine probable effects on existing water resources from mining operations, including changes in the quantity and quality of water; and
(5) evaluate the potential for reclamation of local water resources.

To accomplish these objectives, all pertinent data on local geology and hydrology were compiled. Hydrogeologic data were collected from existing wells and observation wells. Six observation wells had been drilled from 1974 to 1977--two within the Corral Creek drainage basin and four in adjacent basins. Also, 19 test holes (uncased and filled in) had been drilled in 1969, 1977, and 1978 to evaluate the coal potential in the area. Twenty-four additional wells and three test holes were drilled in 1979, 1980, and 1981 where data were lacking. The final network of observation wells was monitored for water-level fluctuation, was tested by pumping to determine aquifer characteristics, and was sampled for chemical analysis of the water. Surface-water data were meager. Corral Creek flowed only after spring snowmelt and some periods of intense rainfall; no surface-water samples were collected during these brief intervals.

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 also is given for the interested reader.

Location and description of area

The Corral Creek study area includes the entire Corral Creek drainage basin on the west side of Hanging Woman Creek (fig. 1). The drainage basin is in Big Horn County, and is about 17 miles south of Birney, Montana. The western divide of the study area, which also is the divide between the Hanging Woman Creek and Tongue River drainages, is 9 miles east of the Tongue River valley near West Decker and

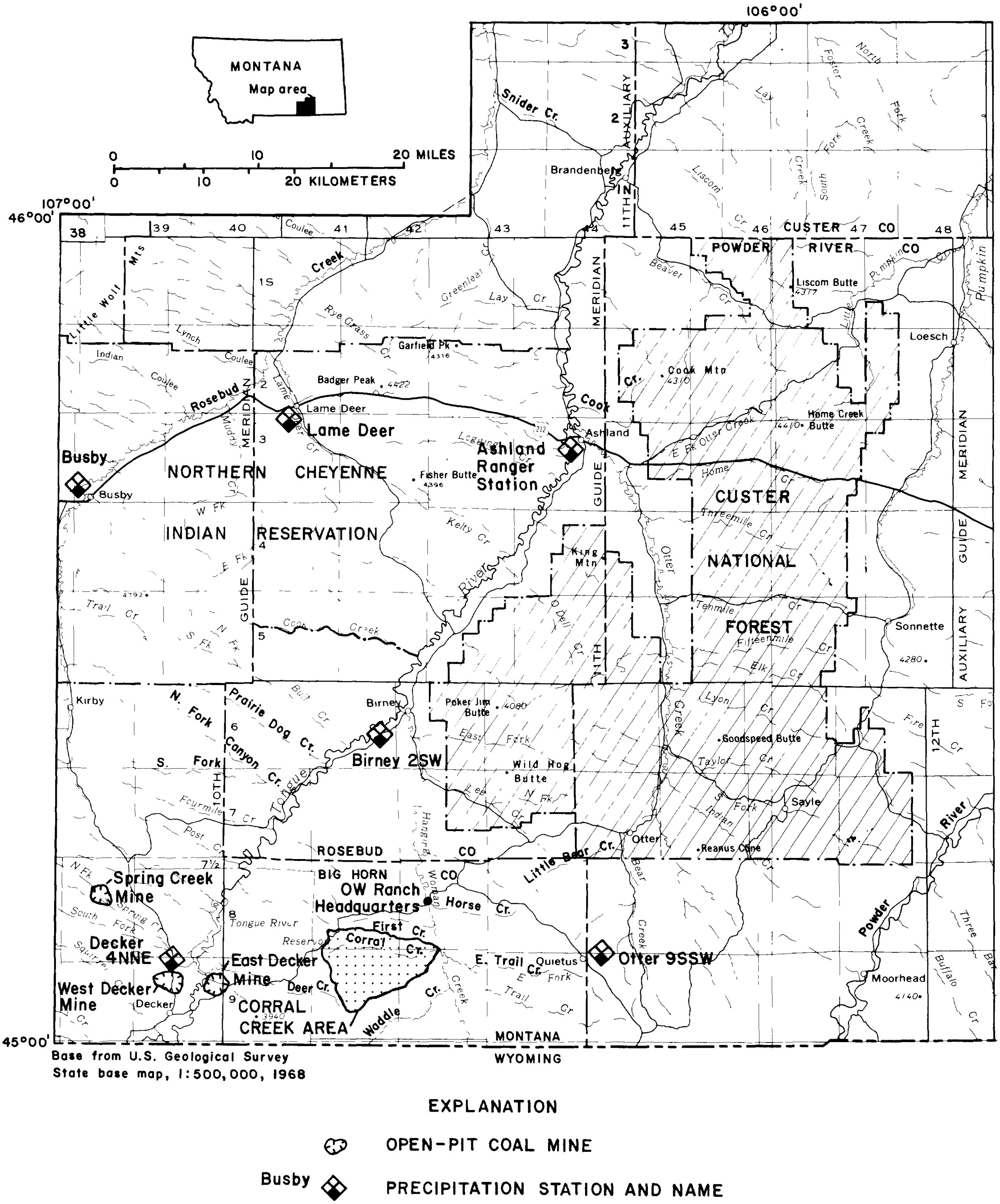


Figure 1.--Location of the Corral Creek study area.

East Decker Mines and about 12 miles east of Decker, Mont. The mouth of Corral Creek is 3.5 miles south of the OW Ranch (Kendrick Cattle Company) headquarters. The drainage basin of Corral Creek is 26.5 mi^2 in area, is about 9 miles from the mouth westward to the upstream divide, and is, at most, about 5 miles wide between First Creek drainage to the north and Waddle Creek drainage to the south.

Corral Creek is joined by South Fork, 2.1 miles upstream from the mouth. Corral Creek is longer than South Fork, but Corral Creek valley is narrower, being 1.5 to 2 miles wide. The highest point in the drainage area is a rounded hill near the western extremity; its altitude is about 4,225 feet above sea level. The South Fork valley broadens upstream to a maximum of 3 miles wide; part of the area has rolling terrain. The altitude at the mouth of Corral Creek, where it flows into Hanging Woman Creek, is about 3,495 feet. Several high buttes rise to altitudes of slightly more than 3,900 feet within 1 to 1.5 miles west of the Hanging Woman Creek valley. From these buttes westward, the north and south divides of the Corral Creek basin are mostly between 3,800 and 4,100 feet above sea level. Few trees exist in the basin, except on the high ridges and buttes and along the principal stream channels.

Previous investigations

The geology and coal deposits of the Corral Creek area have been studied by several investigators. Mapel (1978) studied the geology and coal beds in detail in the Pine Butte quadrangle, and Culbertson and Klett (1979) made a similar study of the Forks Ranch quadrangle. Cole and Sholes (1980) mapped the Anderson and Dietz coal beds from east of Decker to the Hanging Woman Creek valley. Matson and Blumer (1973), in a more general compilation of a larger area, described the quality and quantity of strippable coal deposits of southeastern Montana.

Ground-water resources and hydrologic characteristics of the rocks in the area have been studied on a regional scale. Investigators include Perry (1931), Lewis and Roberts (1978), Slagle and Stimson (1979), and Lewis and Hotchkiss (1981).

Chemical quality of ground water and geochemical processes that control the quality of water in the Fort Union Formation have been investigated by Lee (1979, 1980) and Dockins and others (1980). The quality of surface water in the region was studied by Knapton and Ferreira (1980).

Potential effects of surface coal mining on the water resources in the Tongue River drainage basin have been the focus of studies by Van Voast (1974) and Van Voast and Hedges (1975). Woessner and others (1979) investigated the potential effects of coal mining on the quality of ground water and surface water on the Northern Cheyenne Indian Reservation.

WATER USE AND SUPPLY

Ground-water and surface-water supplies are used for livestock watering within the Corral Creek study area. No residential or irrigation water wells exist at the present time (1982).

Five wells supply most of the water used by livestock (table 1, fig. 2). Another well (P-5), near the mouth of Corral Creek, is no longer used because of the large mineral content of its water. The five wells used for livestock watering are equipped with windmills and most are capable of discharging 2 to 5 gal/min.

Surface-water supply is limited to intermittent streamflow, stock ponds, and springs in the upstream parts of the Corral Creek area. Corral Creek had a small flow beginning about 1.5 miles upstream from the mouth from early spring to August 1980, but the channel was dry, except for intermittent seeps, from September 1980 to November 1981. Upstream from the point 1.5 miles above the mouth, flow in the main channel and South Fork is ephemeral throughout the year. Sixteen stock ponds were located in the study area -- eight in the main-channel drainage basin and eight in the South Fork basin. Most of the ponds contained water during the spring and early summer of 1980 and 1981, but were dry later in the year. One pond near the upstream reach of Corral Creek receives spring discharge and maintained water throughout the study. The other springs observed in the study area were marshy spots with water seeping to the surface and evaporating. All springs observed were contaminated by livestock wading through them.

Water samples were collected from four of the five used stock wells and from the unused well near the mouth of Corral Creek (see fig. 2 and tables 1, 6, and 7). Chemical analyses of these samples indicated that the concentrations of all constituents tested were less than the maximum limits recommended by McKee and Wolf (1963) for use by livestock; one exception was the water from the unused well near the mouth, which exceeded the recommended limits of 4,000 mg/L (milligrams per liter) of sulfate. Water from all used wells in the area, however, exceeds the maximum concentrations of 250 mg/L of sulfate and 500 mg/L of dissolved solids recommended by the U.S. Environmental Protection Agency (1979) for public supply. The ground water of the Corral Creek area generally is typical of the quality of water in the Tongue River Member of the Fort Union Formation in the northern Powder River basin.

Ground-water use in the Corral Creek study area is less than the potential yield, based on average rates of ground-water recharge and discharge. The water supply in the alluvium in the middle parts of Corral Creek and South Fork, and downstream from their confluence, could support several additional livestock wells. Expected yields from the alluvial sources are 5 to 10 gal/min along South Fork, 5 to 20 gal/min along Corral Creek upstream from the mouth of South Fork, and as much as 30 gal/min at the confluence of the two streams. Downstream from the mouth of South Fork, water in the alluvium probably would be too mineralized for stock use. The Anderson coal bed and sandstone aquifers also could support additional wells almost everywhere in the Corral Creek drainage area. Probable yields of wells completed in coal and sandstone aquifers are about 2 to 10 gal/min. Deeper aquifers exist in the Tongue River and Tullock Members of the Fort Union Formation (Lewis and Hotchkiss, 1981).

POTENTIAL EFFECTS OF MINING ON AREA HYDROLOGY

Assumptions

The effects of mining on local hydrologic systems could be predicted more accurately if a mine plan were 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-

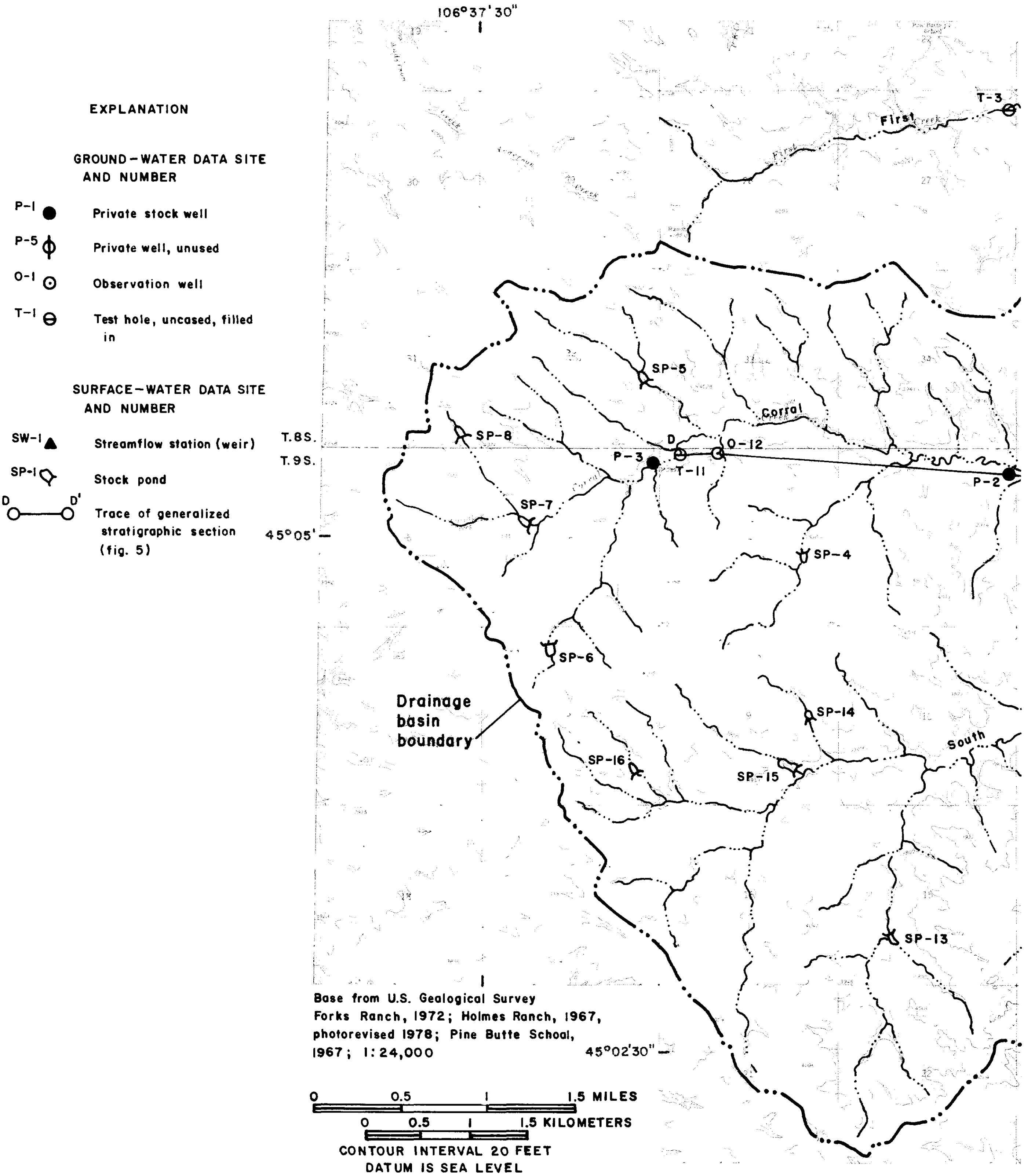
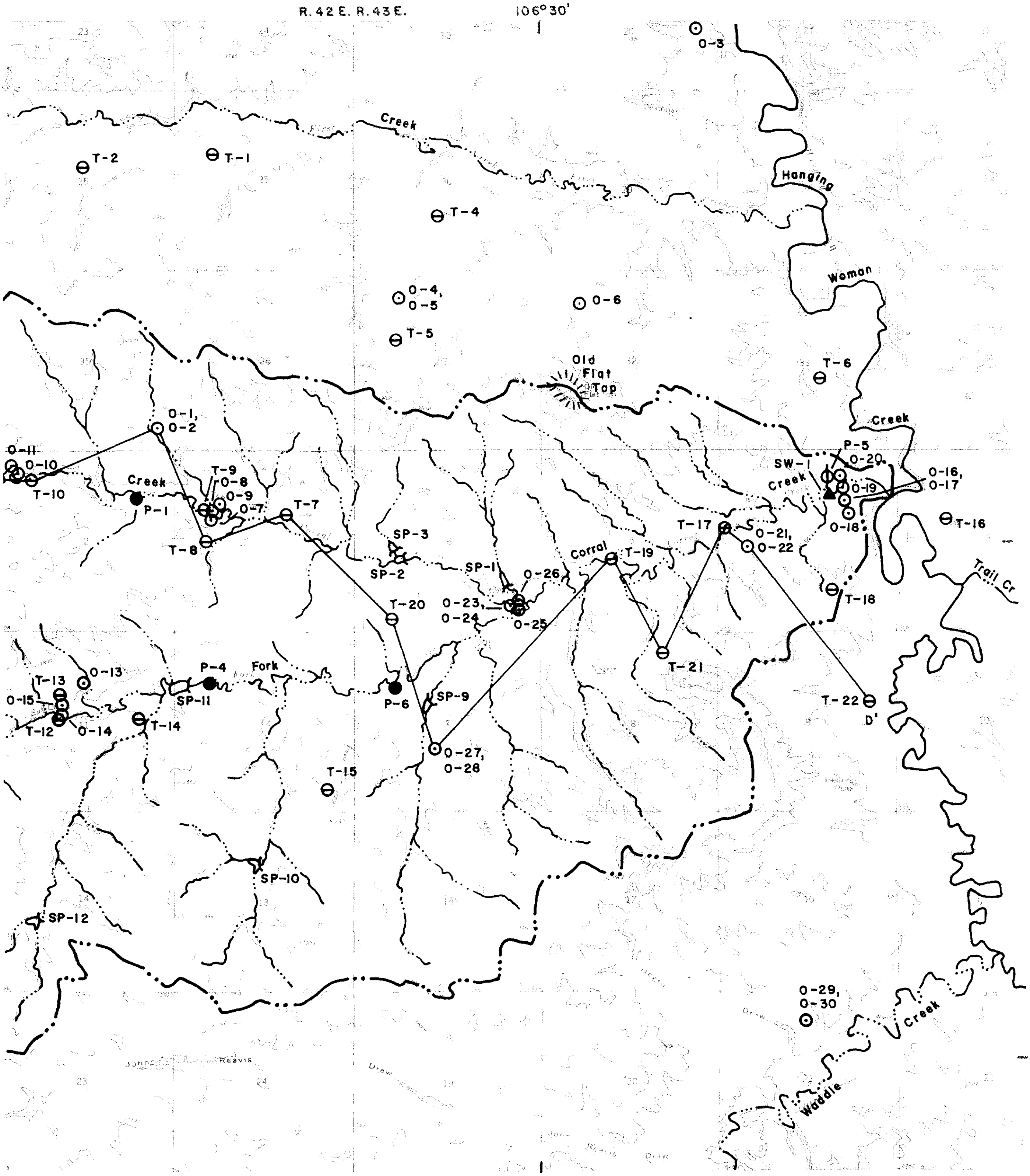


Figure 2.--Location of private and observation wells, test holes, a surface-water



site, and stock ponds in the Corral Creek and adjacent areas.

water flow into mine cuts and for evaluating the temporal and spatial changes in the potentiometric surface created by excavation of mine pits.

Detailed mine plans for the Corral Creek area are not available. Therefore, an assumed mine plan was drawn showing the potential location and configuration of the open-pit mine as well as potential direction of mining (fig. 3). The potential mine is located from near the mouth of Corral Creek to about 4.5 miles upvalley, is nearly 2 miles wide at the maximum extent, and has an area of 5.9 mi^2. Sections across the potential mine are depicted in figure 4. It was assumed that the Anderson coal bed would be mined where the maximum overburden thickness is 200 feet or less. About 190 million tons of Anderson coal could be mined, plus a few million tons of Smith coal. Additional assumptions are: (1) Mining would begin with the development of a box cut at the east end of the mine and mining would progress westward; (2) the entire Anderson coal bed would be removed within the potential mine area; and (3) all mining regulations established by the U.S. Office of Surface Mining Reclamation and Enforcement and the Montana Department of State Lands would be followed during mining and reclamation operations.

Effects during mining

Three principal aquifers transmit water along the course of the potential mine pit--the alluvial sands and gravels, the sandstone beds and lenses above the Anderson, and the Anderson coal bed itself. Near the initial mine box cut, which would remove the Anderson bed to depths below the alluvial water level, the alluvial aquifer of the Hanging Woman Creek valley would contribute water to the mine box cut from the east. Thin sandstone lenses, local coal beds, and the Smith coal bed would contribute minimal quantities of water. At the north end of the initial box cut, the Anderson coal bed and sandstones of the overburden are dry.

The main inflow of water to the box cut would be from Corral Creek alluvium and the Anderson coal bed near the mouth of Corral Creek. Based on local aquifer characteristics, this discharge would be about 1,100 ft^3/d from the alluvium and 400 ft^3/d from the Anderson across the southern 1 mile of the box cut. This water may require treatment or special handling during mining operations because it is very mineralized. However, once the mine has progressed about 1 mile up Corral Creek valley and the aquifers containing the mineralized water are removed, the water reaching Hanging Woman Creek valley via Corral Creek probably would improve in quality, provided the quantity of runoff from the reclaimed spoils is kept small.

As the Anderson coal is removed along with the overburden shales, sandstones and alluvium, and the mine pit reaches the mouth of South Fork (about the half-way point of the potential open-pit mine), water inflow from alluvial materials would increase to about 3,600 ft^3/d. Flow of water from the Anderson coal bed would remain about the same -- 400 to 500 ft^3/d -- from the front wall of the mine. Water from the side walls of the mine also would be discharging at a rate of about 100 ft^3/d for each 1,000 feet of the coal face exposed, but this volume would decrease as the aquifer is dewatered on the north side and as the water level is lowered on the south side. Relatively permeable sandstone aquifers also would be contributing water; an estimated 1,000 ft^3/d would discharge from the aquifers for each 10-foot thickness and 1,000-foot length exposed. These volumes also would decrease with time, as the potentiometric surface in the aquifers declines.

During mining operations, the quality of water discharging from the mine area would depend on the quality of ground water and surface water entering the mine and on any contamination caused by the mining operations. The incoming water from the alluvium, sandstone, and coal beds contains dissolved-solids concentrations ranging from about 1,500 to 11,000 mg/L and sulfate concentrations ranging from about 2.5 to 3,700 mg/L.

Long-term effects

Mining would remove the Anderson coal aquifer and the overlying sandstone aquifers from the area within the potential mine boundary. The Anderson is not used as a source of supply by any of the ranch wells at the present time (1982). Three existing used stock wells and one unused well would be destroyed by the assumed mine pit, and one well (P-2) probably would be nearly dewatered as the water levels declined west of the potential mine pit.

The potential exists for a long-term change in the quality of water. After mining, ground-water flow systems would be reestablished through the mine area. Water would enter the mine spoils from upgradient aquifers, flow through the mine spoils, and eventually discharge to the alluvium of Hanging Woman Creek valley. Some water probably would percolate downward to deeper sandstone and coal aquifers and laterally to the unmined Anderson coal bed. Water flowing through the spoils would acquire a chemical quality dependent on the mineralogy of the spoil material. In the upstream reaches of Corral Creek, there might be a long-term degradation in quality as a result of leaching of soluble salts from overburden materials used to backfull the mine pit. Near the mouth of Corral Creek, however, the quality might actually improve compared to present conditions. This improvement would be possible because the Anderson coal bed, which is at least partly the source of mineralized water, would be removed.

POTENTIAL FOR RECLAMATION OF HYDROLOGIC SYSTEMS

The existing hydrologic system no doubt would be altered by the removal of shallow aquifers. However, alternative ground-water supplies at the site could be developed to replace livestock wells destroyed by mining. Alternative supplies could be sandstones above and below the Canyon coal bed, at depths of 200 to about 300 feet, which are probably beyond the depths of spoil-water effects. Deeper alternative water supplies are other sandstone and coal beds within the Tongue River and Tullock Members of the Fort Union Formation of Paleocene age, and the lower part of the Hell Creek Formation and the Fox Hills Sandstone, both of Cretaceous age. Data on the quality and quantity of water from these alternative sources (Lee, 1979; Slagle and Stimson, 1979) indicate that they are suitable sources for all present water uses. No evidence indicates that any of these alternative ground-water sources would be detrimentally affected by mining.

Effects of mining and reclamation on the local water resources can be mitigated by initial planning. Proper reconstruction of the alluvial aquifer beneath Corral Creek and South Fork could minimize the increase in mineral content of water flowing through the spoils. The reconstruction could be accomplished by stockpiling the soils of the flood plain and lower terraces and, separately, the alluvial sands and gravels. After the coal is removed, the replaced spoil material could be well compacted up to the level of the present base of the alluvium, pref-

EXPLANATION

INITIAL MINE BOX CUT

DIRECTION OF MINE PIT ADVANCE

POTENTIAL FINAL MINE-PIT BOUNDARY

A A' TRACE OF APPROXIMATE GEOLOGIC SECTIONS ACROSS POTENTIAL MINE PIT (fig. 4)--Based on projected test-hole and observation-well data

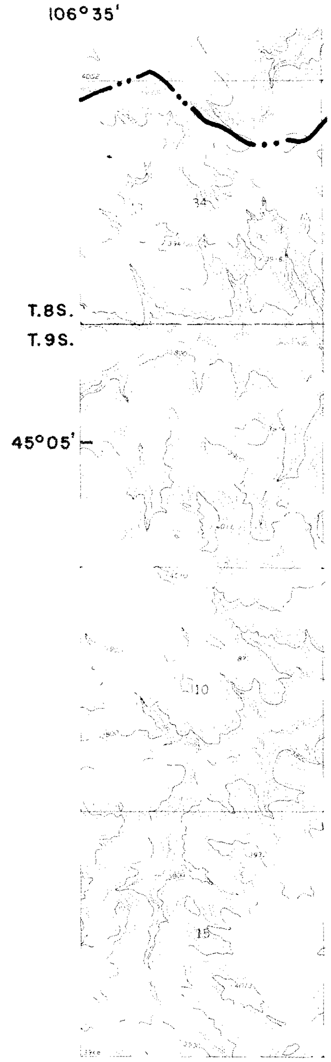
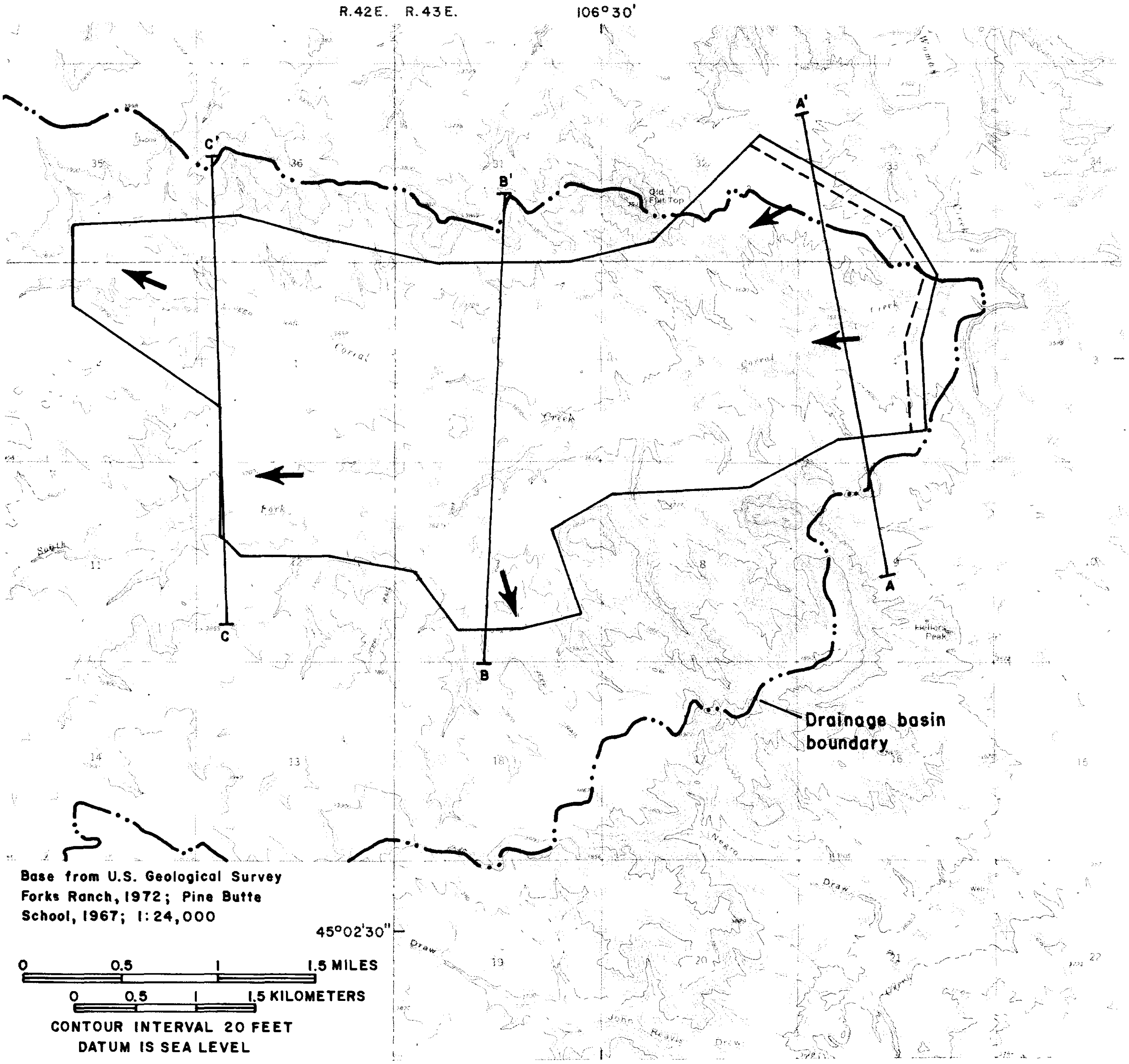


Figure 3.--Outline of the potential open-



pit mine and direction of mining.

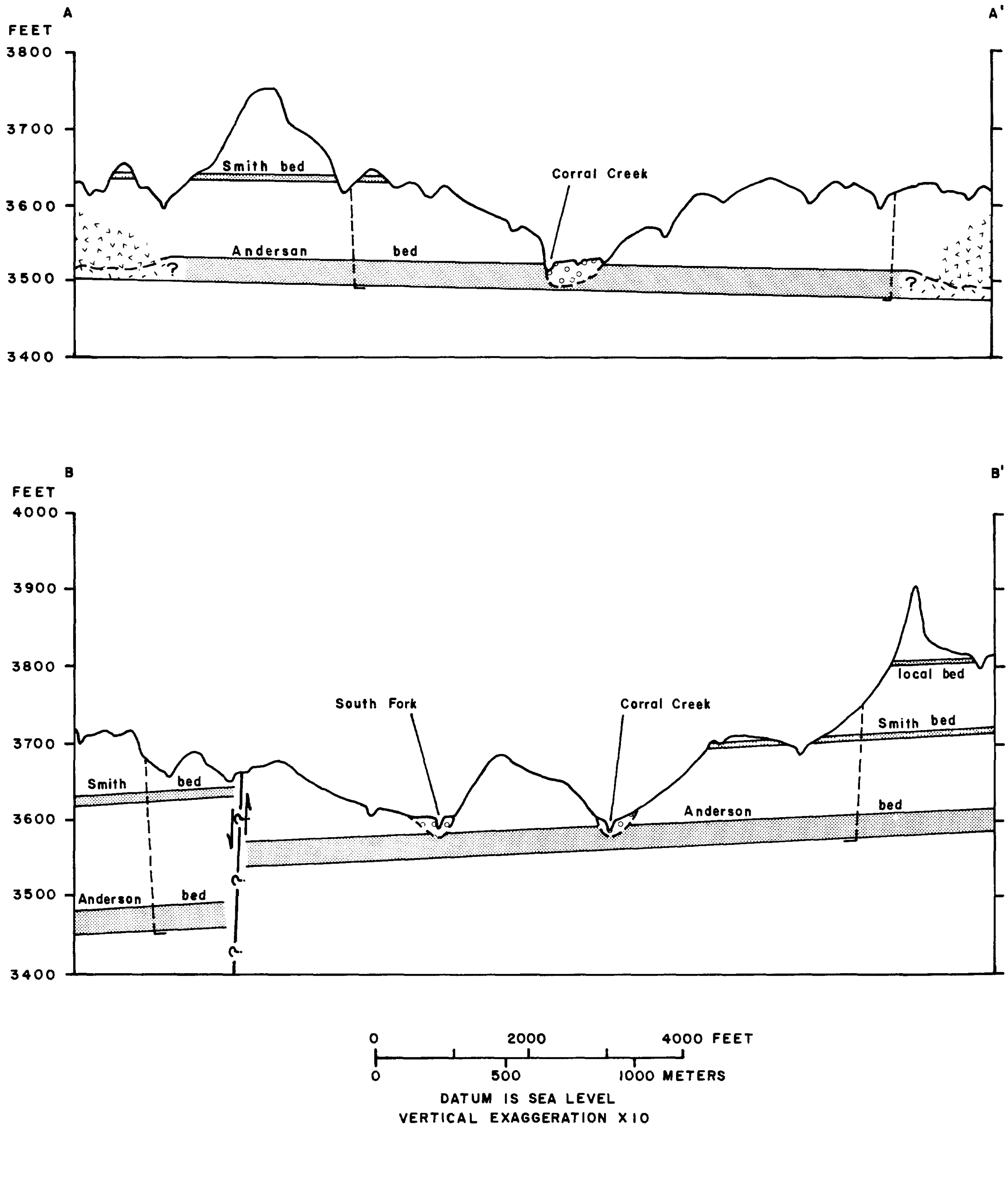
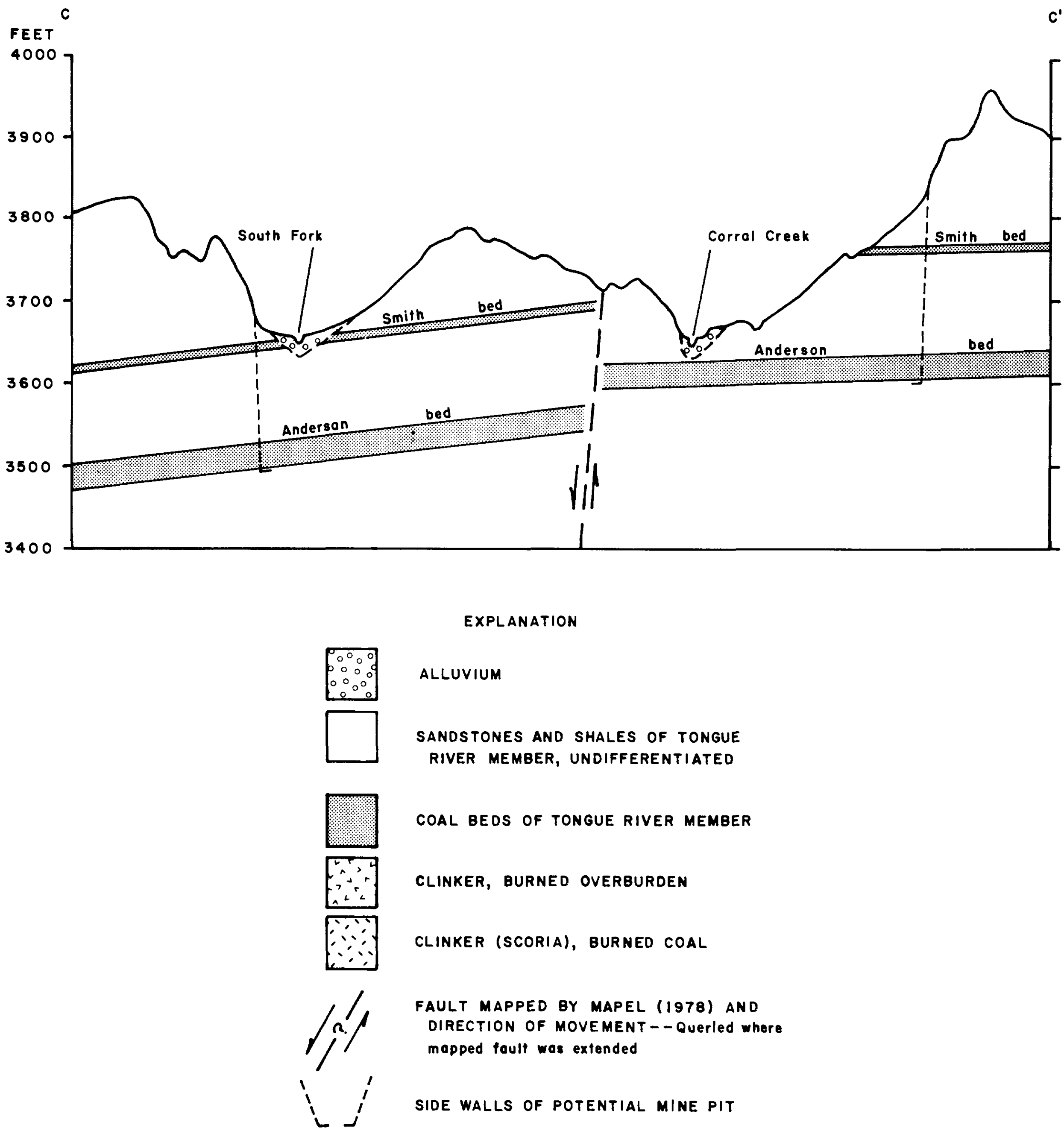


Figure 4.--Approximate geologic sections across potential open-pit mine. Traces



of the sections are shown in figure 3. Horizontal scale is X2 that of figure 3.

erably with a cap of tightly packed clay or shale material which would allow a minimum of infiltration. The graded sands and gravels could be replaced and then topped with finer grained materials and finally with the stockpiled soils.

Techniques that could be used to decrease the adverse effects on the hydrology in the area include proper surface contouring to eliminate ponding of precipitation in local depressions, planting adequate vegetation on gently rolling terrain to encourage evapotranspiration, and increasing recharge of surface water into a reconstructed alluvial aquifer having a relatively impermeable bottom. By keeping the topography subdued, such as gently rolling slopes, the soils could retain more precipitation and increase evapotranspiration. The result would be a decrease in the volume of sedimentation from surface runoff and a decrease in volume of mineralized waters from the spoil materials entering the downstream alluvial aquifer.

SUPPORTING TECHNICAL DISCUSSION

Geology

Stratigraphy

Most outcrops in the Corral Creek drainage basin are of the Tongue River Member of the Fort Union Formation of Paleocene age. These rocks are predominantly shale, siltstone, sandstone, and coal. Small areas of clinker were observed within the basin, where thin coal beds were burned locally. Massive clinker deposits exist near the mouth of Corral Creek, particularly north of the Corral Creek drainage in the interbasin area and in First Creek drainage. The principal coal beds are, in ascending order, Canyon, Dietz, Anderson, and Smith (fig. 5 and table 2).

The Canyon coal bed is 10 to 20 feet thick. Because it lies at depths of about 300 feet or more, it probably would not be mined. The Dietz coal bed is split into an upper and a lower bed, both of which pinch out locally, and neither of which is much thicker than 5 feet. This coal probably would not be considered for mining.

The Anderson coal bed is 26 to 32 feet thick. It ranges in depth from land surface near the mouth of Corral Creek to about 650 feet along the western divide. In a large area within the Corral Creek basin, the Anderson bed is at a depth that permits economical surface mining.

About 150 feet above the Anderson is the Smith coal bed, which is 18 feet thick in the western part of the basin, but thins to about 7 feet thick in the central part. The Smith would be a mineable coal bed in areas where it is within the overburden of the Anderson coal bed being mined. Local coal beds generally are thin, less than 2 feet thick, and extend only short distances laterally.

Above the 3,860-foot topographic contour along the south border of the Corral Creek basin, and above the 4,000-foot topographic contour to the northwest, the Wasatch Formation of Eocene age is exposed. The Wasatch Formation is composed mostly of siltstone and fine-grained sandstone, with some layers of gray shale and a few thin coal beds. The Roland coal bed, which lies at the base of the Wasatch Formation, is as much as 9 feet thick.

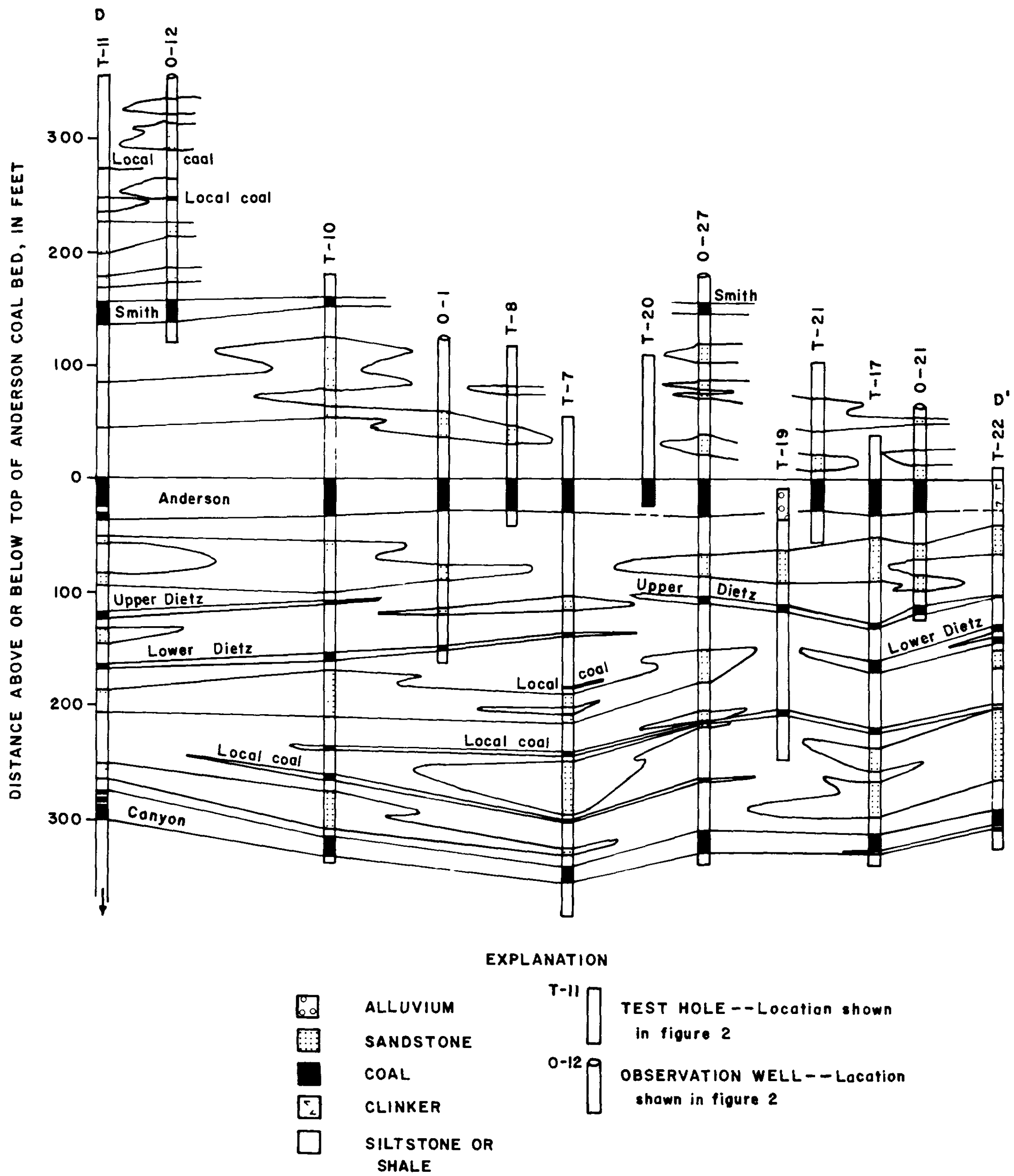


Figure 5.--Interpretive east-west stratigraphic section showing relationship of coal beds to lenses of sandstone. Datum is top of Anderson coal bed. Horizontal spacing not to scale. Trace of section is shown in figure 2.

Alluvium of Pleistocene and Holocene age underlies the main stream channels in the Corral Creek area. The alluvium is as much as 40 feet thick along South Fork, about 35 feet thick along the middle reaches of Corral Creek, and about 30 feet thick near the mouth of Corral Creek. Throughout the area where the alluvium is thicker than 20 feet, the materials are sand and gravel with interbedded layers of mud and silt.

Local structure

The Tongue River Member beds dip gently to the south or southeast across the Corral Creek basin. A very broad anticline with gently sloping limbs can be traced from the First Creek basin, north of Corral Creek, to the valley of Corral Creek; the limbs of the anticline steepen slightly near the Hanging Woman Creek valley. The beds dip from about 25 ft/mi to the southeast in the north-central part of Corral Creek basin to 100 ft/mi to the south and east in the southern and northeast parts of the basin. Mapel (1978) identified one fault trending southeast between Corral Creek and South Fork from sec. 2, T. 9 S., R. 42 E., to sec. 7, T. 9 S., R. 43 E.; the largest displacement is about 50 feet, upthrown on the northeast side. No other faulting was noted in the Corral Creek basin, but several faults occur along Waddle Creek valley to the south and Hanging Woman Creek valley to the southeast.

Ground-water resources

Tongue River aquifers

Dietz coal beds

One observation well (0-1) was drilled to the lower Dietz coal bed; the upper Dietz is missing at this site (fig. 5). The well yielded little water (0.02 gal/min) and had to be bailed rather than pumped (tables 3 and 4). However, the water level recovered to near-static level after a week, so the aquifer-test results probably are valid. After bailing, water-level-recovery measurements indicated that the lower Dietz coal bed, at this site, had a hydraulic conductivity of about 0.05 ft/d.

Three observation wells were completed in the upper Dietz coal bed: 0-5, 0-21, and 0-29; none of these wells was deep enough to penetrate to the lower Dietz coal bed. Well 0-29 is in the Waddle Creek drainage south of the study area and was not tested. Well 0-5 is in the First Creek drainage and was tested, but the water level was below the level of the coal bed, and the water apparently came from a sandstone aquifer below the upper Dietz coal bed. Well 0-21, in the downstream part of Corral Creek basin, was pumped at about 2 gal/min with 112 feet of drawdown; the test indicated that the hydraulic conductivity of the coal aquifer was 0.2 ft/d. The coal is 5 feet thick at this site, thicker than at the other two sites; the hydraulic conductivity calculated from the results of the test probably is representative of the upper Dietz coal bed aquifer in the Corral Creek area.

The static water levels in 1980 and 1981 of all four wells in the Dietz coal bed are within 12 feet of the same altitude. Direction of flow in the aquifer is not well established, but the potentiometric surface seems to have a slope of about 10 ft/mi toward the southwest.

Anderson coal bed

The Anderson coal bed is the thickest coal interval in the Corral Creek area. Six observation wells and one unused private well have casings perforated in this coal interval. After drilling and casing some of these wells, cavings partly filled the hole inside the casing, so the wells were not open to the entire thickness of the Anderson bed.

The wells completed in the Anderson that have aquifer-test data are: P-5, 0-2, 0-4, 0-13, 0-22, and 0-28 (table 4). Well 0-30, in the Waddle Creek drainage, also was completed in the Anderson coal bed but was not tested. In well P-5, located near the mouth of Corral Creek, the Anderson coal bed is near the surface and the upper part, at least, is weathered, which restricts the fracture permeability of the coal. The calculated hydraulic conductivity of the Anderson coal aquifer at well P-5 was 0.05 ft/d.

Well 0-2 is partly filled inside the casing opposite the perforated interval, so only 9 feet of coal is contributing water to the well. This condition adversely affects the calculated transmissivity, but the calculated hydraulic conductivity (0.015 ft/d) probably is representative of the entire coal aquifer in this vicinity. The Anderson coal aquifer yielded the most water from well 0-22; the well was pumped at a discharge of 6.7 gal/min and the calculated hydraulic conductivity was 0.7 ft/d. This well is located about 0.8 mile upstream from the mouth of Corral Creek, where the Anderson probably is discharging directly into the alluvium of Corral Creek valley. Well 0-13 had a calculated hydraulic conductivity of about 0.3 ft/d; this well is located about midway along the South Fork valley where the Anderson coal is fairly deep (189-218 feet beneath the land surface). This well was pumped at 2.0 gal/min with 10 feet of drawdown.

In well 0-4, the Anderson coal bed is saturated only in the lowest 4 feet; the water probably is draining to the clinker in the First Creek valley. The hydraulic conductivity for well 0-4 is 0.05 ft/d, calculated from recovering water-level measurements after bailing the well.

Well 0-28 is located on the slopes south of South Fork, just southeast and on the downthrown side of a suspected extension of the fault mapped by Mapel (1978). The hydraulic conductivity was calculated to be 0.07 ft/d, which may reflect the nearly immobile flow of water in the coal aquifer caused by the proximity to the fault.

From the seven data points available, an attempt was made to show the altitude of the potentiometric surface in the Anderson coal bed (fig. 6). The contours seem to follow a generalized and greatly subdued land surface. Based on this interpretation, water in the Anderson aquifer flows first toward South Fork or Corral Creek, then down the Corral Creek basin toward the Hanging Woman Creek valley.

EXPLANATION

U/D — FAULT--As mapped by Mapel (1978). Dashed where approximately located. U, upthrown side; D, downthrown side

FAULT--As extended by McClymonds (this report)

3600 ? GENERALIZED POTENTIOMETRIC-SURFACE CONTOUR--Shows approximate altitude at which water level would have stood in tightly cased wells, 1981. Queried where uncertain. Contour interval 20 feet. Datum is sea level

DIRECTION OF FLOW IN ANDERSON COAL BED

0-4 (3608) WELL AND NUMBER--Number in parentheses is altitude of water level, in feet above sea level

- Private well, unused
- Observation well

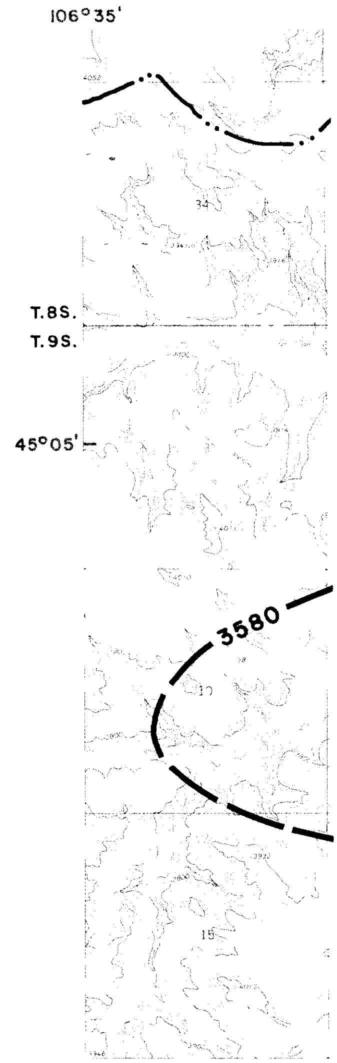
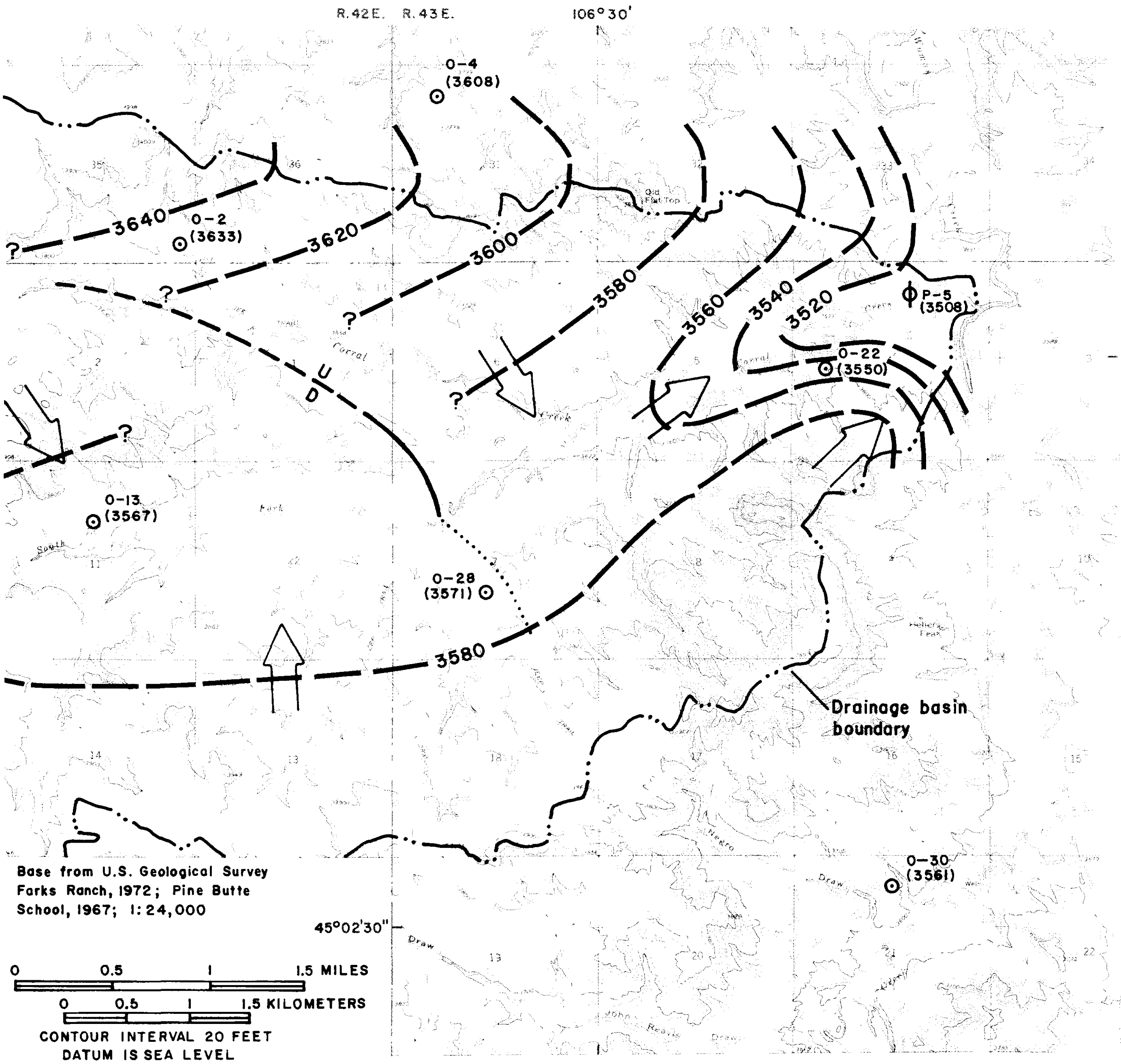


Figure 6.--Generalized altitude and configuration of the potentiometric surface



of water in the Anderson coal bed in the Corral Creek and adjacent areas.

Smith coal bed

Only one well, 0-12, was cased and perforated opposite the Smith coal bed; the well is located near the upstream end of Corral Creek. There, the Smith bed is 17 feet thick; farther eastward, the Smith thins to about 7 feet. The aquifer test conducted at well 0-12 indicated that the Smith coal bed has a hydraulic conductivity of 0.4 ft/d. The average well discharge was 3.6 gal/min with about 63 feet of drawdown during the test.

No attempt was made to construct a potentiometric-surface map of the Smith coal-bed aquifer. The water probably flows toward the outcrop areas, then discharges as springs or seeps into the talus cover.

Sandstone aquifers

Although all observation wells penetrated water-yielding sandstones in the Corral Creek area, only one 4-inch-casing well, 0-27, was screened in sandstone. This well, 0-27, is located on the south side of South Fork, next to a well completed in the Anderson coal bed (0-28). The sandstone, to which the well is open, is about 15 feet thick and lies 22 feet above the Anderson bed. When well 0-28 was drilled, the water level in well 0-27 dropped about 11 feet, probably because vibration during drilling sealed the packer in well 0-27 (fig. 7). The aquifer test at well 0-27 was conducted before well 0-28 was drilled, and overlying aquifers were probably contributing water via leakage. During the test, well 0-27 was pumped at 6.8 gal/min, with 28 feet of drawdown. The calculated hydraulic conductivity of the sandstone aquifer was 4 ft/d, which is about average for sandstone aquifers of other areas of southeastern Montana.

One other observation well, 0-6, is open to a sandstone aquifer. Well 0-6 is located near the First Creek-Corral Creek drainage divide, about 1.2 miles west of Hanging Woman Creek valley. The 2-inch casing precluded pumping this well. Well 0-6 is perforated opposite sandstone beds 38 feet below the Anderson coal, which is probably dry at this site. The 2-foot-thick upper Dietz coal bed is within the perforated zone. No attempt was made to contour the water level in the sandstone aquifers.

Sandstone aquifers exist throughout the section of the Tongue River Member from above the Smith coal bed to below the Canyon coal bed, but few are laterally extensive. As interpreted in figure 5, the sandstones thin and thicken; some sandstones could be 50 feet thick and very permeable at one site but be thinner, more shaly, and less permeable at a site one-half mile away.

Recharge to Tongue River aquifers

Recharge to the coal and sandstone aquifers within the Tongue River Member is from infiltration and percolation of precipitation through the overlying sediments. The rate of infiltration is slow because of the clay and silt content of the overburden, the small quantity of annual precipitation, and the consumptive use of soil moisture by vegetation. Most of the recharge is from local areas, probably within a mile or so from any particular site, although some water is transmitted laterally through the aquifer from the divide area between the Hanging Woman Creek and Tongue River drainages. Annual recharge from local precipitation is estimated to be

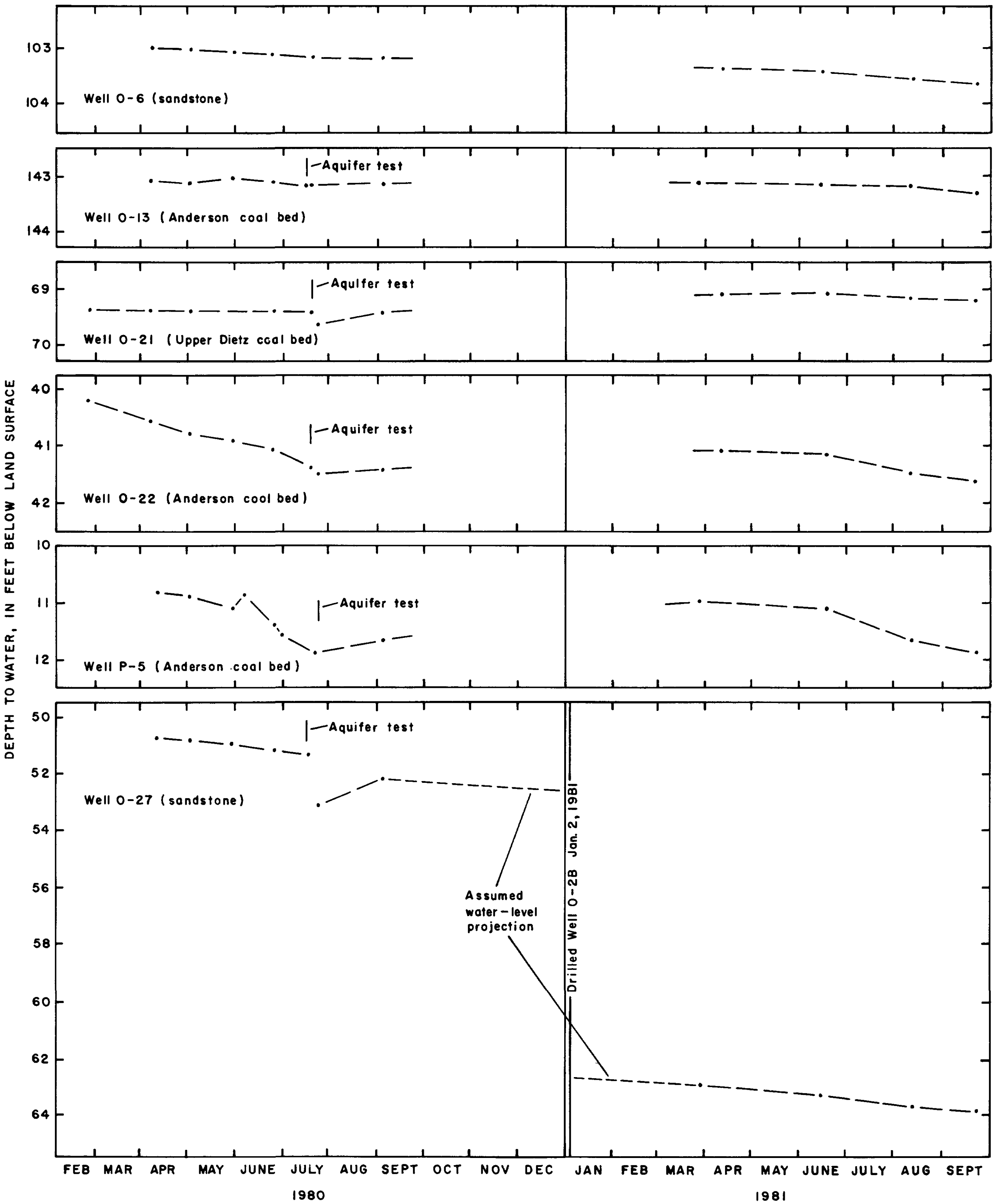


Figure 7.--Water-level fluctuations in wells completed in sandstone or coal-bed aquifers of the Tongue River Member of the Fort Union Formation in the Corral Creek and adjacent areas, February 1980 through September 1981.

between 0.01 and 0.1 inch, based on the calculated discharge rates. Woessner and others (1979), using 2 years of hydrograph records from wells completed in unconfined coal, sandstone, and shale on the Northern Cheyenne Indian Reservation, calculated an average recharge of 0.12 inch per year. The deeper aquifers probably receive less recharge from local sources than do the shallower aquifers.

Alluvial aquifer

Nineteen holes were drilled at five sites across South Fork and Corral Creek valleys to assess the alluvial aquifer. Sixteen of these holes were cased and used as observation wells. The lithology penetrated at the five sites is illustrated in figure 8. Aquifer tests at these wells indicated a significant range of transmissivities and hydraulic conductivities, both between sites and across the valley at one site. The results of the aquifer tests on these observation wells are listed in table 5. The construction of the wells is described in table 3.

Wells 0-10 and 0-11 are located 5.1 miles upstream from the mouth of Corral Creek, in a fairly narrow (about 350 feet wide) part of the valley. Here, the alluvium is about 35 feet thick, from the level of the terrace down to bedrock (section E-E', fig. 8); the lower 6 feet was saturated when the aquifer was tested. The aquifer tests were conducted in September 1980, when water levels were about 1 foot higher than when some of the other sites were tested. The calculated values of hydraulic conductivity are 50 ft/d for well 0-10 and 80 ft/d for 0-11, which are among the largest hydraulic conductivities in the area.

Three wells, 0-7, 0-8, and 0-9, were completed across the valley 3.9 miles upstream from the mouth of Corral Creek. A fourth hole (T-9) was drilled at this site to attempt to find a possible deeper buried channel; the attempt was unsuccessful, so the hole was backfilled and abandoned. The valley here is broader than at wells 0-10 and 0-11, but the water-bearing part of the alluvium seems to be only about 500 feet wide. The alluvium, below the higher terrace, is about 35 feet thick (section F-F', fig. 8); the saturated thickness of the alluvium was about 6 feet in October 1980. Hydraulic conductivity of the alluvium was calculated from aquifer tests conducted in June 1981. Based on the tests, the hydraulic conductivity was 4 ft/d at well 0-7 on the south side of the valley, 0.4 ft/d at well 0-8 in the middle, and 0.7 ft/d at well 0-9 on the north side. These small values may be misleading; it is probable that a channel with larger hydraulic conductivity exists, but was not encountered by the observation wells or test hole.

Four test holes were drilled across the South Fork valley, 2.8 miles upstream from the mouth of South Fork. Only well 0-15 was completed in an apparently narrow buried channel and was productive (section G-G', fig. 8). In drilling T-12 and T-13, no aquifer was found so these holes were backfilled and abandoned. Well 0-14 was cased for possible observation during the testing of well 0-15, but the low 1980 and 1981 water levels precluded its use. The narrowness of the water-bearing channel, which probably is about 100 feet wide and has a saturated thickness of about 6 feet, is confirmed by the relatively large hydraulic conductivity of well 0-15 and by the shallow alluvium in the well to the south and in the test hole to the north. The hydraulic conductivity is calculated to be about 60 ft/d from the June 1981 aquifer test.

Near the confluence of Corral Creek and South Fork channels, three observation wells were drilled in line; a fourth well (0-23) was drilled 20 feet from the middle well for observation. Data from these wells, 0-23, 0-24, 0-25, and 0-26, indicate that the alluvium is nearly 35 feet deep in the central part of the valley and about 30 feet deep in the wells to either side (section H-H', fig. 8). The alluvium lies directly on the Anderson coal bed, which apparently has been slightly eroded. Well 0-24 was drilled and the casing perforated opposite 12 feet of alluvium and 23 feet of Anderson coal. The other three wells were drilled just to the coal bed. The saturated thickness of the alluvial aquifer is 18 to 24 feet in this vicinity.

Aquifer tests were conducted in June 1981. The hydraulic conductivity at well 0-24, which was drilled through and perforated opposite alluvium and coal beds, was calculated to be 40 ft/d. At other wells, perforated only in the alluvial aquifer, the calculated hydraulic conductivities were 10 ft/d at well 0-23, 70 ft/d at well 0-25, and 40 ft/d at well 0-26.

Five observation wells were completed in the alluvial aquifer west of Hanging Woman Creek, 0.3 mile upstream from the mouth of Corral Creek (section I-I', fig. 8). There, the valley is about 900 feet wide. The thickness of alluvial materials is about 27 feet under the higher terrace and about 22 feet under the lower terrace. The saturated thickness of the aquifer ranges from 10 to 15 feet. An indication that the lateral permeability of the alluvial aquifer is not as great as might be expected is the variability of the annual water-level fluctuations between well 0-18, on the south end of the well line, and well 0-20, on the north end (fig. 9). The wells are 580 feet apart. From September 1980 to September 1981, the maximum water-level fluctuation in well 0-18 was 0.7 foot, while it was 1.9 feet in well 0-20. Water levels in other wells in the line show a fluctuation between these extremes.

Aquifer tests were conducted at the wells in July, September, and October 1980. The static water levels were only about 0.2 foot higher in July than in October, so the tests generally are comparable. Calculated hydraulic conductivities were, from south to north: 15 ft/d at well 0-18, 25 ft/d at 0-16, 5 ft/d at 0-19, and 30 ft/d at 0-20. Thus, the alluvium near the edges of the valley may be more permeable than alluvium near the center. An inconsistent aspect of the results of aquifer testing was that the smallest calculated hydraulic conductivity and transmissivity was at well 0-19. This well was drilled into the deepest part of the alluvial buried channel and was completed in sand and gravel that was apparently as thick as, or thicker than, that at the other wells.

Water flow in the alluvium was calculated by the Darcy equation:

$$Q = KIA \tag{1}$$

where

Q is volume of water moving through the area, in cubic feet per day;
K is hydraulic conductivity of the aquifer, in feet per day;
I is gradient of the potentiometric surface, in feet per foot; and
A is cross-section area of the aquifer, in square feet.

Calculations were made at the five lines of wells across the valley. The results were not consistent. Across well line 0-10 and 0-11 (section E-E', fig. 8) on Corral Creek about 1,500 ft^3/d of water passes. Only 60 ft^3/d is calculated to pass well line 0-7, 0-8, and 0-9 (section F-F', fig. 8); this probably is too

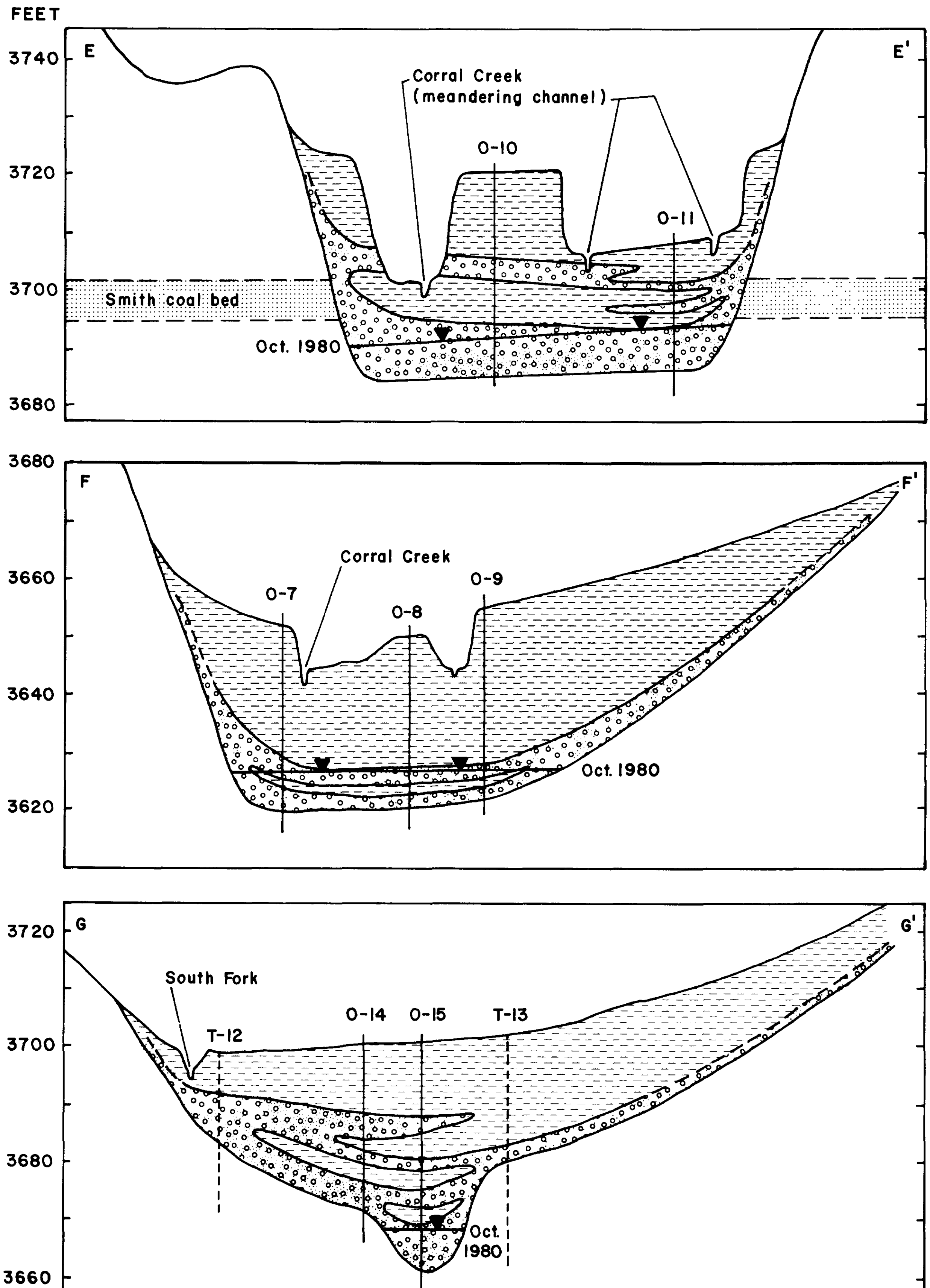
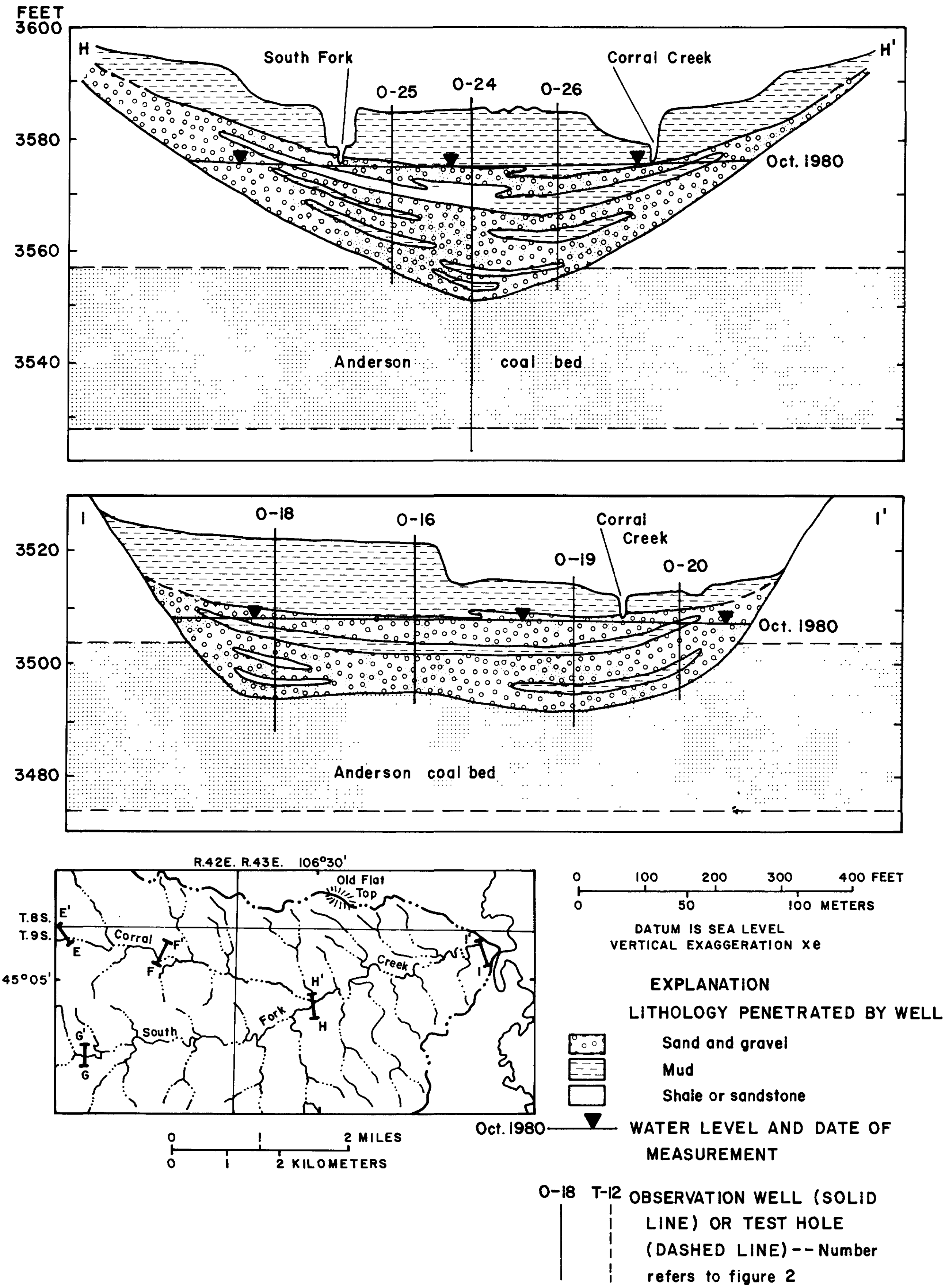


Figure 8.--Interpretive geologic sections showing lithology



of alluvium at observation-well sites.

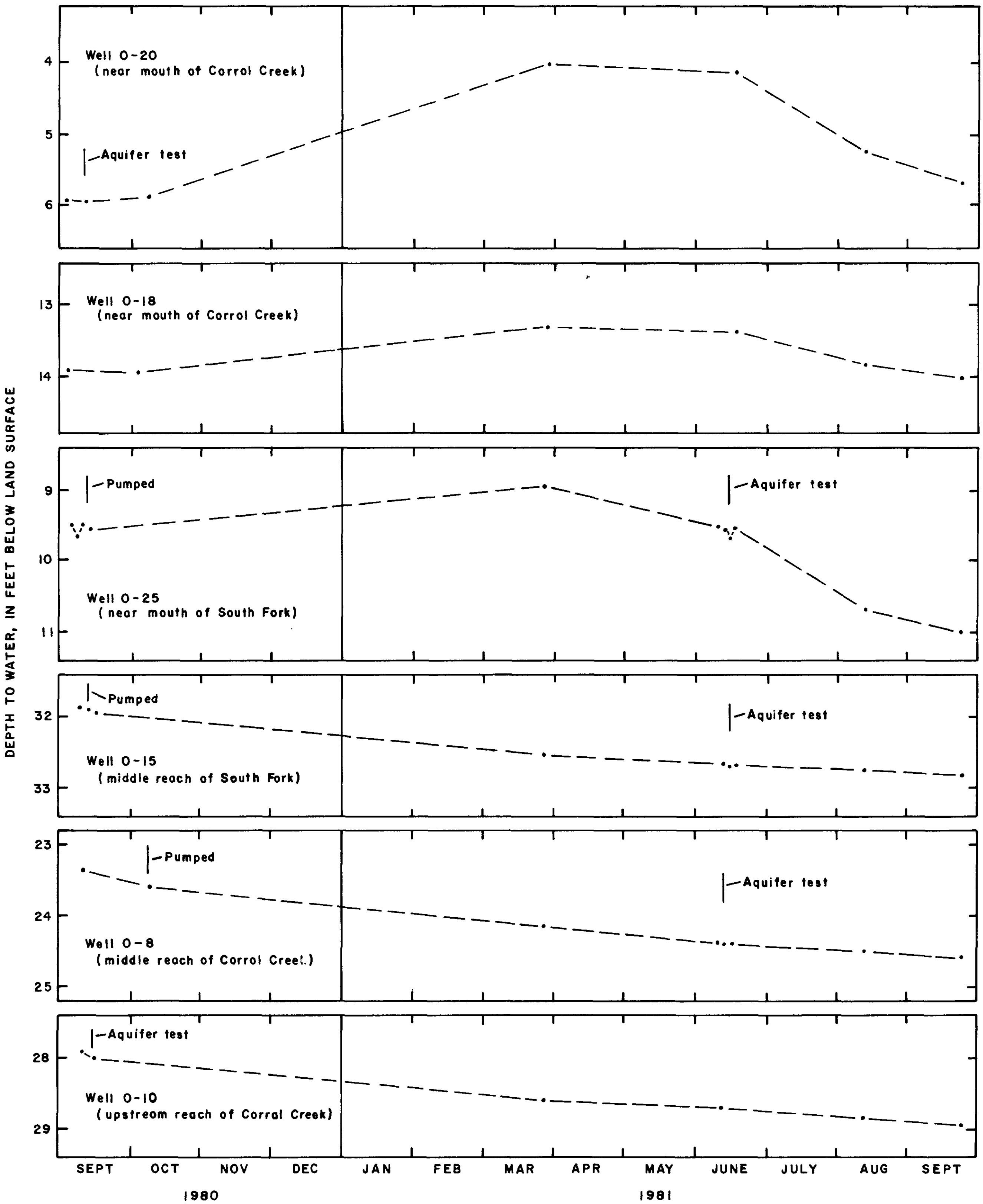


Figure 9.--Water-level fluctuations in wells completed in alluvial aquifers, September 1980 through September 1981.

small. Apparently a narrow channel, which was not penetrated by any of the three wells, is buried beneath this area. On the South Fork (section G-G', fig. 8), well 0-15 was completed in an apparently narrow channel; there, calculations indicate that about 300 ft^3/d of water passes. At well line 0-24, 0-25, 0-26 (section H-H', fig. 8), upstream from the confluence of Corral Creek and South Fork channels where the alluvium from the two drainages join, about 3,600 ft^3/d of water passes. Therefore, about 1,500 ft^3/d of water from the middle reaches of Corral Creek, 300 ft^3/d from the middle reach of the South Fork, the inflow from the sides of the valley between the middle reaches to the confluence, and the water from the underlying Anderson coal bed, add up to about 3,600 ft^3/d of total ground-water flow.

Well line 0-16, 0-18, 0-19, and 0-20 (section I-I', fig. 8), near the mouth of Corral Creek valley, has a calculated volume of subsurface flow of about 1,500 ft^3/d. This value is less than one-half of the volume calculated for the aquifer 1.9 miles upstream. An explanation for the difference could be that a buried alluvial channel was not penetrated by the observation wells, or, more likely, that water is moving from the alluvium through the Anderson coal bed and into clinker beds on the south side of the valley. Additionally, the water table in this vicinity is near the land surface; therefore, some of the flow is discharged by evapotranspiration. Thus, the calculated 1,500 ft^3/d of water probably is only part of the ground water being discharged to the Hanging Woman Creek valley. The volume of water leaving the area probably is about 4,000 ft^3/d.

The alluvial aquifer is recharged by direct infiltration of precipitation, runoff, and subsurface seepage from sandstone and coal aquifers in the Tongue River Member. The total volume of recharge would be equal to the volume of water passing from the area, which varies from year to year depending on the precipitation. If the 4,000 ft^3/d is approximately correct, then an estimated 30 to 35 acre-feet of water was recharged to the alluvium in 1980.

Deep aquifers

Aquifers below the Dietz coal beds in the Corral Creek area are unlikely to be affected by mining of the Anderson coal. These aquifers are: the Canyon coal bed, about 300 feet deep near the mouth of Corral Creek; sandstone and other coal beds at several horizons in the middle and lower parts of the Tongue River Member of the Fort Union Formation, to depths of about 1,700 feet; sandstones of the Tullock Member of the Fort Union Formation, at depths from about 2,200 to 2,800 feet; and Upper Cretaceous sandstones of the combined lower part of the Hell Creek Formation and the Fox Hills Sandstone, beginning at depths of about 3,200 feet (Lewis and Hotchkiss, 1981). No wells are completed in sandstone of the lower part of the Tongue River Member or deeper formations in the vicinity of Corral Creek.

One well, 0-3, was completed in the Canyon coal bed; this observation well is on the west side of Hanging Woman Creek valley, about 3 miles north of the mouth of Corral Creek and outside of the study area. At this site the Canyon coal bed is 210 feet deep, the coal is 17 feet thick and the water level is 90 feet below land surface, which is about 20 feet below the level of the water in Hanging Woman Creek valley alluvium, 1,000 feet to the east. Well 0-3 was pumped in July 1980 at 7.5 gal/min during an aquifer test; the results indicated a hydraulic conductivity of the coal aquifer of 0.3 ft/d. The Canyon coal, in the downstream part of the Corral Creek drainage, has about the same thickness as in well 0-3 and probably has similar aquifer characteristics.

Ground-water quality

Coal-bed aquifers

Waters from wells 0-1, 0-3, and 0-21 completed in the Canyon and Dietz coal beds are fairly similar in chemical composition, and are some of the least mineralized water in the Corral Creek area (table 6). The water is a sodium bicarbonate type, with very small concentrations of calcium and magnesium (less than 12 mg/L) and small concentrations of sulfate (4.3 and 14 mg/L) in two of the wells. The sodium-adsorption ratio (SAR) in these wells is large (41 to 61) and the fluoride concentration ranges from 3.1 to 3.7 mg/L--too large for continuous human consumption. The pH values generally are greater (7.8 to 8.4) than in water from most other coals, sandstones, or alluvial sources.

The Anderson coal bed contains water of variable quality. Two wells, 0-13 and 0-28, which are both along the South Fork, have water that is about the same chemical composition as in the deeper Dietz and Canyon coal beds. The water is a sodium bicarbonate type, with moderate concentration of sodium (620 and 700 mg/L); small concentrations of magnesium (3.5 mg/L) and sulfate (2.5 and 4.3 mg/L); large SAR (50 and 56); and moderate to large fluoride (1.7 and 3.1 mg/L). Two other wells completed in the Anderson, 0-2 and 0-4, are north of Corral Creek (0-4 is in the First Creek drainage basin). These wells have water with relatively large concentration of minerals--4,420 and 4,740 mg/L of dissolved solids. The water is a sodium sulfate type, with significant concentrations of bicarbonate (about 1,200 mg/L) and relatively small concentrations of fluoride (0.9 and 1.4 mg/L). The third group of Anderson wells, 0-22 and P-5, is located near the mouth of Corral Creek where the Anderson coal bed is at or near land surface. These wells have water with large concentrations of minerals--6,090 and 8,710 mg/L of dissolved solids. The water is a sodium sulfate type; the sulfate accounts for almost the entire anion content. The bicarbonate concentration is relatively small (900 and 1,030 mg/L), as is fluoride (0.4 and 1.2 mg/L). The calcium and magnesium concentrations are large (from 300 to 520 mg/L), but relative to the dissolved solids, no larger than in water from other wells in the area.

Based on one sample from a well completed in the Smith coal bed, constituent concentrations are seemingly average for coal aquifers in the study area. The water from well 0-12 is a sodium sulfate type with a bicarbonate concentration of 680 mg/L, and with moderate calcium (130 mg/L) and magnesium (120 mg/L) concentrations, and small potassium (7.0 mg/L), chloride (15 mg/L), and fluoride (0.5 mg/L) concentrations. The dissolved-solids concentration is 2,360 mg/L.

Sandstone aquifers

Two observations wells (0-5 and 0-27) completed in sandstone aquifers of the Tongue River Member were sampled for chemical analysis. Well 0-5, which yielded water from a sandstone below the upper Dietz coal bed, has a sodium bicarbonate sulfate type water, with a fairly large concentration of fluoride (2.4 mg/L) and dissolved solids (2,260 mg/L). Water in well 0-27 is from a sandstone above the Anderson coal bed; this water is a sodium sulfate type, with a large concentration of bicarbonate (1,380 mg/L) and a moderate concentration of fluoride (1.2 mg/L); the dissolved-solids concentration is 3,980 mg/L.

Three private wells obtain most of their water from a sandstone above the Smith coal bed (P-3) and a sandstone above the Anderson coal bed (P-2 and P-6). Well P-1 probably obtains some of its water from a sandstone in the Tongue River Member, but most of the water is apparently from alluvial sand and gravel. The water from wells P-2, P-3, and P-6 is a sodium sulfate type, with moderate concentrations of calcium (200 to 240 mg/L), magnesium (160 to 270 mg/L), and bicarbonate (489 to 600 mg/L), and small concentrations of potassium (4.2 to 7.0 mg/L), chloride (7.0 to 25 mg/L), and fluoride (0.1 to 0.5 mg/L). The water from P-3, in the middle reach of Corral Creek valley, is more mineralized (3,510 mg/L of dissolved solids) than the water from P-6 (2,200 mg/L of dissolved solids) along South Fork.

Alluvial aquifer

Water from alluvial aquifers in the middle and upstream parts of the basin has an average dissolved-solids concentration of about 3,200 mg/L (table 7). The water is of the sodium sulfate type, with moderate concentrations of calcium (170 to 290 mg/L), magnesium (170 to 270 mg/L), and bicarbonate (472 to 693 mg/L), and small concentrations of potassium (3.9 to 9.4 mg/L), chloride (7.3 to 28 mg/L), and fluoride (0.4 to 0.8 mg/L). The waters are very hard (average--about 1,450 mg/L hardness), and have relatively small SAR (average 5.9). The water is much like that from the sandstones in the Tongue River Member, but slightly more mineralized.

Near the mouth of Corral Creek, however, the alluvium is in contact with weathered Anderson coal, which is very mineralized; the quality of alluvial water is very much affected by the water moving through the coal. Evaporation of the water, when the water table is near the surface, probably further concentrates the minerals in the alluvial waters. Along the well line, O-16 to O-20, the least mineralized water is along the south margin of the valley, near the clinker zone; water from well O-18 has a dissolved-solids concentration of 4,520 mg/L. The most mineralized water is along the north edge, over unburned, weathered coal; water from well O-20 has a dissolved-solids concentration of 11,100 mg/L. All alluvial water near the mouth of Corral Creek is a sodium sulfate type, is very hard (more than 1,900 mg/L), with relatively moderate concentrations of calcium (220 to 410 mg/L), magnesium (340 to 710 mg/L), and bicarbonate (178 to 1,000 mg/L), and relatively small concentrations of potassium (8.2 to 13 mg/L), chloride (17 to 72 mg/L), and fluoride (0.6 to 0.8 mg/L). The silica concentration, which is about 11 mg/L in water from the upstream part of the Corral Creek valley, is about 17 mg/L near the mouth.

Surface-water resources

Corral Creek runoff

No permanent streamflow-gaging station has been established on Corral Creek, but the stream was observed periodically from February 1980 through September 1981. The flow was estimated to be about 0.7 ft^3/s in February 1980; by April, when a temporary weir was installed 0.3 mile upstream from the mouth, the flow had decreased to 0.12 ft^3/s. Streamflow continued to decrease during the spring of 1980 until it stopped in late May, began in early June after a rainstorm, then stopped for the rest of the year. In 1981, flow was observed in March but stopped by May. The flow occurs mostly from the mouth to about 1.5 miles upstream, where high water tables in the alluvial aquifer intersect the land surface. Farther upstream, flow in the Corral Creek channel is ephemeral, occurring only after intense spring or summer rains or during spring snowmelt.

Because Corral Creek is ungaged, the mean annual discharge and the magnitude of floods were estimated indirectly. The method used for mean annual discharge included measurements of channel geometry and was developed through regression analyses based on the correlation of flow characteristics with the dimensions of the channel (Omang and others, 1983). Flood-peak estimates were made from a regression equation using drainage area, percentage of forest cover within the drainage, and a geographical location factor (Parrett and Omang, 1981). Mean annual flow estimates are about 500 acre-feet for the 26.5-mi^2 area of the Corral Creek drainage. The calculated magnitude of a flood would be, on the average, about 250 ft^3/s once every 2 years, about 980 ft^3/s once every 10 years, and about 2,800 ft^3/s once every 100 years.

Stock ponds

Of the eight stock ponds located in the Corral Creek drainage (fig. 2), five were observed not to contain water during 1980-81. Pond SP-3, 0.8 mile upstream from where South Fork joins Corral Creek, held water for a couple of weeks in June 1981. Pond SP-7, in the upstream reaches of the drainage, was almost full throughout 1980 and 1981. This pond receives discharge from springs, but flow from the springs could not be measured in the marshy seeps upstream from the pond. Pond SP-4, on the south side of the Corral Creek drainage, was dry in June 1981; springs seep from a sandstone bed downstream from this pond.

Pond SP-9, on a south-side tributary valley of the South Fork drainage in sec. 7, T. 9 S., R. 43 E., contained water intermittently after spring snowmelt runoff and after intense rainfall during the summer. Pond SP-10, higher on a south-side tributary drainage, probably contains water perennially; it was one-quarter full in October 1980. This pond probably receives spring discharge, but seeps are not evident in the upstream valleys. Pond SP-11 is located in the South Fork stream channel, 2.1 miles upstream from the mouth. This pond held water all summer and fall of 1980, but was dry by the end of July 1981. It is about one-half full of sediment. The highest five ponds in the South Fork drainage (SP-12 to SP-16) were not observed during the study.

Springs

No springs are located on the topographic quadrangle maps covering the Corral Creek area, but several seeps were noted during the study. Water discharges from the sandstone and coal aquifers where the beds intersect the surface at their outcrop line, but most seep into alluvium or talus slopes rather than emerge onto the land surface. The seeps that were observed had flow too small to measure, and no place was found where the water was uncontaminated enough to collect a sample for chemical analysis. It is probable, however, that some uncontaminated, flowing springs exist in the higher part of the basin.

SUMMARY

Wells completed in the Tongue River Member of the Fort Union Formation and in alluvium supply most of the water used for livestock watering, the only water use in the Corral Creek study area. The Tongue River Member is composed of the Canyon coal bed, about 300 feet below the land surface in the downstream reaches of the creek; the lower Dietz coal bed, from 110 to 200 feet above the Canyon; the upper Dietz coal bed, from 30 to 50 feet above the lower Dietz; the Anderson coal bed, from 70 to 100 feet above the upper Dietz; the Smith coal bed, about 150 feet above the Anderson in the middle part of the area; and silty or clayey shales interbedded with sandstone layers or lenses between the coal beds. The principal aquifers within this sequence are the Anderson coal bed, which is about 30 feet thick, and sandstone beds above and below the Anderson. Alluvial sands and gravels beneath Corral Creek and South Fork form the third principal aquifer.

The hydraulic conductivity of the Anderson coal bed, based on aquifer tests conducted at five widely separated observation wells and one private well, ranges from 0.015 to 0.7 ft/d; the average hydraulic conductivity probably is about 0.2 ft/d. The hydraulic conductivity of the sandstone beds, based on an aquifer test at one well, is 4 ft/d. Aquifer tests conducted on wells completed in alluvial sands and gravels indicated widely varying hydraulic conductivities. The approximate hydraulic conductivity along South Fork is about 60 ft/d, along the middle reaches of Corral Creek it is about 60 ft/d, near the mouth of South Fork it is about 40 ft/d, and near the mouth of Corral Creek it is about 20 ft/d.

Water in the Corral Creek area generally contains large dissolved-solids concentrations. Excluding the highly mineralized water at the downstream end of the basin, dissolved-solids concentrations are about 2,500 mg/L in the coal aquifers, about 2,960 mg/L in the sandstone aquifers, and about 3,200 mg/L in the alluvial aquifers. Near the mouth of Corral Creek the water in the Anderson coal bed has about 8,700 mg/L of dissolved solids, and the alluvial aquifer water, in places, contains concentrations of as much as 11,100 mg/L.

Surface-water supply is limited to stock ponds, springs, and intermittent streamflow. The stock ponds receive water from spring and summer rainfall and late winter to spring snowmelt runoff. Some stock ponds are supplied by subsurface seepage from coal and sandstone aquifers, into the alluvial aquifer, then to the ponds. Most of the stock ponds become dry by midsummer. Springs, where water reaches the surface, were observed only as seeps in boggy areas; no substantial flow was seen at any of the seeps. Corral Creek flows in its lowermost 1.5-mile reach during the spring months when water levels in the alluvium are high. The channel generally is dry during the summer and fall.

Mining of the Anderson coal bed, and the Smith bed when it is in the overburden, would remove three stock wells and an unused well near the mouth of Corral Creek. No springs were located in the area of the potential mine pit. The potentiometric surface in the coal and sandstones would be lowered, affecting one stock well along Corral Creek about 0.5 mile west of the final cut. The alluvial aquifer beneath Corral Creek and South Fork would be removed.

After mining, if the spoils material and alluvial sands and gravels are replaced properly, the quality of water in the alluvium near the mouth of Corral Creek might actually improve. This condition would be possible because the Anderson coal bed, which is the source of highly mineralized water, would be removed.

Downward and lateral infiltration of water through the spoils materials would cause larger concentrations of soluble salts to move into the sandstones and coal beds adjacent to and under the backfilled mine pit. This flow would cause a long-term deterioration of the water quality near the mine site.

Post-mining water supplies for stock could be obtained by drilling deeper wells. Alternative water supplies are other sandstone or coal beds within the Tongue River and Tullock Members of the Fort Union Formation, the lower part of the Hell Creek Formation, and the Fox Hills Sandstone. Well depths could range from 200 to 3,200 feet, depending upon which aquifer was used for supply.

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DATA

Table 1.--*Construction and hydrologic data for private wells*

[°C, degrees Celsius; micromhos, micromhos per centimeter at 25° Celsius; TRM, Tongue River Member of Fort Union Formation]

Well No.	Owner	Location	Date drilled	Altitude of land surface (feet above sea level)	Depth drilled (feet below land surface)	Aquifer material	Depth to top of aquifer (feet below land surface)	Aquifer thickness (feet)	Casing diameter (inches)	Depth cased (feet below land surface)	Casing perforations (feet below land surface)
P-1	Kendrick Cattle Co.	NW¼NW¼SE¼NE¼ sec. 2, T. 9 S., R. 42 E.	06/--/69	3,685	59	Sand, gravel, and sandstone	29 45	13 14	4.0	59	39 to 59
P-2	Kendrick Cattle Co.	NE¼SE¼NE¼NE¼ sec. 3, T. 9 S., R. 42 E.	07/--/52	3,730	146	Sandstone	114	11	6.0	146	--
P-3	Kendrick Cattle Co.	SE¼NE¼NE¼NE¼ sec. 5, T. 9 S., R. 42 E.	05/--/41	3,891	380	Sandstone and Smith coal bed	130 248	22 18	6.0 4.5	220 380	-- --
P-4	P. Buckley	NE¼NE¼SW¼NW¼ sec. 12, T. 9 S., R. 42 E.	--	3,655	45	Sand and gravel	25	10	6.0	36	--
P-5	Kendrick Cattle Co.	NE¼SW¼NW¼NE¼ sec. 4, T. 9 S., R. 43 E.	06/--/49	3,520	65	Anderson coal bed	15	17	6.0	--	--
P-6	Kendrick Cattle Co.	SE¼NE¼SW¼NW¼ sec. 7, T. 9 S., R. 43 E.	--	3,627	128	Sandstone	30±	--	6.0	--	--

Date of hydro-logic data	Static water level (feet below land sur-face)	Dis-charge (gal-lons per minute)	On-site spe-cific conduc-tance (micro-mhos)	On-site pH (units)	On-site water temper-ature (°C)	Chemi-cal analy-sis avail-able (table 6 or 7)	Remarks
06/--/69	29±	5	4,200	7.4	10.0	yes	From driller's log. Well probably completed in alluvial sand and gravel and TRM sand-stone. Chemical constituents indicate that water is withdrawn primarily from alluvial sources.
07/--/52	25±	10	4,000	7.5	10.0	yes	From driller's log. Perforated interval(s) not stated. Log indicates water from sand-stone beds above Anderson coal bed.
05/--/41	105±	10	3,650	7.3	11.0	yes	From driller's log. Perforated interval(s) not stated. Probably other sandstone beds in interval below Smith coal bed--266 to 380 feet--also contributing water.
10/14/73	15.9	--	--	--	--	no	From driller's log.
06/--/49	12±	10	9,500	7.5	12.0	yes	Aquifer-material designation is based on gamma log. Well is unused (1982). Well tested in July 1980; discharge was 1 gallon per minute.
09/15/80	15±	5	2,700	7.4	8.0	yes	No driller's log available. Correlation with well O-28 indicates water from sandstone beds above Anderson coal bed.

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

Test-hole No.	Local identification	Location	Date drilled	Altitude of land surface (feet above sea level)	Depth drilled (feet below land surface)	Material of probable aquifer zones	Depth to top of probable aquifer (feet below land surface)	Aquifer thickness (feet)	Remarks
T-1	U.S. 77-63	NE¼SE¼SW¼NW¼ sec. 25, T. 8 S., R. 42 E.	07/18/77	3,761	500	Coal	104	29	Anderson bed. Probable water level about 100 feet below land surface.
						Sandstone	154	78	Interbedded with shale layers. At least 55 feet of the aquifer thickness probably productive.
						Coal	255	3	Upper Dietz bed.
						Coal	479	14	Canyon bed.
T-2	U.S. 77-64	NE¼SE¼SE¼NW¼ sec. 26, T. 8 S., R. 42 E.	07/19/77	3,750	110	Coal	77	26	Anderson bed. Probable water level about 85 feet below land surface.
T-3	U.S. 77-59	SE¼SE¼NE¼NE¼ sec. 27, T. 8 S., R. 42 E.	07/17/77	3,775	500	Coal	88	27	Anderson bed. Location could not be verified by onsite inspection.
						Coal	192	4	Upper Dietz bed.
						Sandstone	215	51	Interbedded with shale layers. About 40 feet of the aquifer thickness probably productive.
						Sandstone	343	41	Interbedded with shale layers. About 30 feet of the aquifer thickness probably productive.
						Coal	435	10	Canyon bed.
T-4	U.S. 77-62	SE¼SE¼NE¼SW¼ sec. 30, T. 8 S., R. 43 E.	07/20/77	3,681	415	Sandstone	83	49	Interbedded with shale layers. About 30 feet of the aquifer thickness probably productive.
						Coal	179	4	Upper Dietz bed.
						Sandstone	286	38	Interbedded with shale layers. About 30 feet of the aquifer thickness probably productive.
						Coal	383	15	Canyon bed.
T-5	S.H. -27	NW¼SE¼SW¼NW¼ sec. 31, T. 8 S., R. 43 E.	09/05/69	3,770	163	Coal	135	27	Anderson bed. Probable water level about 155 feet below land surface.
T-6	U.S. 77-81	SE¼NW¼NW¼SE¼ sec. 33, T. 8 S., R. 43 E.	07/31/77	3,542	380	Coal	36	21	Anderson bed, partial thickness; top eroded or burned. Probable water level about 45 feet below land surface.
						Sandstone	109	34	Interbedded with shale layers. About 20 feet of the aquifer thickness probably productive.
						Coal	175	12	Upper Dietz bed. Two coal beds separated by a 3-foot shale layer.
						Sandstone	296	27	Interbedded with shale layers. About 20 feet of the aquifer thickness probably productive.
						Coal	335	15	Canyon bed.

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

Test-hole No.	Local identification	Location	Date drilled	Altitude of land surface (feet above sea level)	Depth drilled (feet below land surface)	Material of probable aquifer zones	Depth to top of probable aquifer (feet below land surface)	Aquifer thickness (feet)	Remarks
T-7	U.S. 77-66	SW¼NE¼SW¼NE¼ sec. 1, T. 9 S., R. 42 E.	07/21/77	3,650	440	Coal	56	29	Anderson bed. Probable water level about 25 feet below land surface.
						Sandstone	158	12	Probably fairly clean sandstone.
						Coal	192	3	Upper Dietz bed. Probable water level about 150 feet below land surface.
						Sandstone	302	51	Interbedded with shale layers. About 35 feet of the aquifer thickness probably productive.
						Coal	397	15	Canyon bed.
T-8	U.S. 77-65	NE¼NE¼NW¼SW¼ sec. 1, T. 9 S., R. 42 E.	07/21/77	3,683	160	Coal	119	29	Anderson bed. Probable water level about 55 feet below land surface.
T-9	CC#19	SE¼NE¼SW¼NW¼ sec. 1, T. 9 S., R. 42 E.	09/10/80	3,650	32	Sand and gravel	25	4	Alluvial sand and gravel, with some mud layers. Probable water level about 28 feet below land surface.
T-10	U.S. 77-67	NE¼SE¼NW¼NW¼ sec. 2, T. 9 S., R. 42 E.	07/27/77	3,722	520	Coal	180	32	Anderson bed. Probable water level about 80 feet below land surface.
						Sandstone	235	45	Interbedded with shale layers. About 25 feet of the aquifer thickness probably productive.
						Coal	287	3	Upper Dietz bed.
						Sandstone	348	42	Interbedded with shale layers. About 30 feet of the aquifer thickness probably productive.
						Coal	497	17	Canyon bed.
T-11	Birney 5A	SE¼NW¼NW¼NW¼ sec. 4, T. 9 S., R. 42 E.	09/25/78	3,890	906	Sandstone	104	30	Interbedded with shale layers. About 25 feet of the aquifer thickness probably productive.
						Coal	201	18	Smith bed. Probable water level about 90 feet below land surface.
						Sandstone	276	33	Interbedded with shale layers. About 30 feet of the aquifer thickness probably productive.
						Coal	357	31	Anderson bed. A 4-foot shale layer separates the basal 4 feet of coal from the main Anderson bed.
						Sandstone	543	17	Interbedded with shale layers. About 15 feet of the aquifer thickness probably productive.
						Coal	634	20	Canyon bed. Two coal beds separated by a 2-foot shale layer.

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

Test-hole No.	Local identification	Location	Date drilled	Altitude of land surface (feet above sea level)	Depth drilled (feet below land surface)	Material of probable aquifer zones	Depth to top of probable aquifer (feet below land surface)	Aquifer thickness (feet)	Remarks
T-12	CC#12	SE¼SW¼SE¼NW¼ sec. 11, T. 9 S., R. 42 E.	09/05/80	3,699	28	Sand and gravel	8	7	Alluvial sand and gravel; bottom of alluvium is above 1981 water table.
T-13	CC#14	NE¼SW¼SE¼NW¼ sec. 11, T. 9 S., R. 42 E.	09/08/80	3,702	40	Sand	19	3	Alluvial sand with mud layers; bottom of alluvium is above 1981 water table.
T-14	U.S. 77-68	NW¼NW¼NE¼SE¼ sec. 11, T. 9 S., R. 42 E.	07/27/77	3,681	220	Coal	69	7	Smith bed. Probable water level about 55 feet below land surface.
						Coal	179	29	Anderson bed. Probable water level about 120 feet below land surface.
T-15	U.S. 77-69	NE¼SW¼SE¼SE¼ sec. 12, T. 9 S., R. 42 E.	08/11/77	3,800	440	Coal	216	8	Smith bed. Probable water level about 180 feet below land surface.
						Coal	345	31	Anderson bed. Probable water level about 215 feet below land surface.
						Sandstone	387	43	Interbedded with shale layers. About 35 feet of the aquifer thickness probably productive.
T-16	U.S. 77-86	SW¼NW¼SE¼NW¼ sec. 3, T. 9 S., R. 43 E.	08/03/77	3,525	300	Sandstone	18	42	Interbedded with shale layers. About 35 feet of the aquifer thickness probably productive.
						Coal	117	11	Lower Dietz bed. Coal is split into two seams, 3 and 8 feet thick, separated by a 4-foot shale layer. Upper Dietz coal bed missing.
						Sandstone	212	53	Sandstone probably is relatively impermeable or has large silt and clay content. Probably not a productive aquifer.
						Coal	275	13	Canyon bed.
T-17	U.S. 77-82	SW¼SW¼SW¼NW¼ sec. 4, T. 9 S., R. 43 E.	08/01/77	3,562	380	Coal	40	30	Anderson bed. Probable water level about 40 feet below land surface.
						Sandstone	90	38	Interbedded with shale layers. About 30 feet of the aquifer thickness probably productive.
						Coal	166	4	Upper Dietz bed.
						Coal	199	9	Lower Dietz bed.
						Sandstone	292	46	Interbedded with shale layers. About 30 feet of the aquifer thickness probably productive.
						Coal	351	15	Canyon bed. A 2-foot-thick coal seam exists 2 feet below the base.
T-18	S.H.-22	NW¼NE¼SW¼SE¼ sec. 4, T. 9 S., R. 43 E.	08/20/69	3,619	120	Coal	90	29	Anderson bed. Probable water level about 70 feet below land surface.

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

Test-hole No.	Local identification	Location	Date drilled	Altitude of land surface (feet above sea level)	Depth drilled (feet below land surface)	Material of probable aquifer zones	Depth to top of probable aquifer (feet below land surface)	Aquifer thickness (feet)	Remarks
T-19	U.S. 77-83	SW¼NE¼NE¼SW¼ sec. 5, T. 9 S., R. 43 E.	08/02/77	3,562	240	Sand and gravel	10±	19	Alluvial gravels with some clayey layers; probably 15 feet of water-yielding material. Probable water level about 10 feet below land surface.
						Sandstone	53	30	Interbedded with shale layers. About 20 feet of the aquifer thickness probably productive.
						Coal	103	4	Upper Dietz bed.
T-20	S.H. -26	NW¼SE¼SW¼SW¼ sec. 6, T. 9S., R. 43 E.	09/09/69	3,696	135	Coal	111	23+	Anderson bed; hole not deep enough to penetrate entire coal bed. Probable water level about 120 feet below land surface.
T-21	U.S. 77-84	NE¼SE¼NW¼NE¼ sec. 8, T. 9 S., R. 43 E.	08/02/77	3,630	160	Coal	106	27	Anderson bed. Probable water level about 50 feet below land surface.
T-22	U.S. 77-85	NW¼SW¼SE¼NE¼ sec. 9, T. 9 S., R. 43 E.	08/02/77	3,559	340	Sandstone	52	24	Interbedded with shale layers. About 20 feet of the aquifer thickness probably productive.
						Coal	113	2	Upper Dietz bed.
						Coal	140	8	Lower Dietz bed. Coal is split into two 4-foot seams separated by a 7-foot shale layer.
						Sandstone	214	63	Interbedded with shale layers. About 35 feet of the aquifer thickness probably productive.
						Coal	303	17	Canyon bed. A 1-foot-thick shale layer near base not included in thickness.

Table 3.--*Construction and hydrologic data for observation wells in the Corral Creek and adjacent areas*

[TRM, Tongue River Member of Fort Union Formation; °C, degrees Celsius; micromhos, micromhos per centimeter at 25° Celsius]

Well No.	Local identification	Location	Date drilled	Altitude of land surface (feet above sea level)	Depth drilled (feet below land surface)	Aquifer material	Top of aquifer (feet below land surface)	Bottom of aquifer (feet below land surface)	Thickness of aquifer contributing water (feet)	Depth cased (feet below land surface)	Casing perforations (feet below land surface)	Packer setting (feet below land surface)	Date of hydrologic data
O-1	CC#22	NW¼SE¼SE¼SE¼ sec. 35, T. 8 S., R. 42 E.	01/05/81	3,755	287	Lower Dietz coal bed	273	276	3	287	274-279	267	06/14/81
O-2	CC#23	NW¼SE¼SE¼SE¼ sec. 35, T. 8 S., R. 42 E.	01/03/81	3,755	155	Anderson coal bed	125	154	9	155	127-154	115	06/14/81
O-3	HWC#01	NE¼NW¼NE¼SE¼ sec. 20, T. 8 S., R. 43 E.	05/08/74	3,530	232	Canyon coal bed	210	227	13	232	209-224	207	07/16/80
O-4	FC#01	NE¼SE¼NW¼NW¼ sec. 31, T. 8 S., R. 43 E.	12/30/80	3,735	133	Anderson coal bed	128	132	4	133	106-133	93	06/16/81
O-5	FC#02	NE¼SE¼NW¼NW¼ sec. 31, T. 8 S., R. 43 E.	12/31/80	3,735	260	Sandstone below upper Dietz coal bed	232	254	0	260	207-213	200	06/16/81
O-6	U.S. 77-77	NE¼SE¼NW¼NW¼ sec. 32, T. 8 S., R. 43 E.	07/30/77	3,682	200	Sandstone below Anderson coal bed	115	164	18	170	131-164	131	06/16/81
O-7	CC#16	SE¼NE¼SW¼NW¼ sec. 1, T. 9 S., R. 42 E.	09/08/80	3,652	37	Alluvial sand and gravel	26	32	5.5	36.5	17.0-36.0	16	06/16/81
O-8	CC#17	SE¼NE¼SW¼NW¼ sec. 1, T. 9 S., R. 42 E.	09/09/80	3,650	34	Alluvial sand and gravel	23	29.5	4.5	33.6	14.1-33.1	13	06/13/81
O-9	CC#18	SE¼NE¼SW¼NW¼ sec. 1, T. 9 S., R. 42 E.	09/09/80	3,655	36	Alluvial sand and gravel	28	33	4	36.0	16.5-35.5	15.5	06/10/81
O-10	CC#20	NE¼SW¼NW¼NW¼ sec. 2, T. 9 S., R. 42 E.	09/10/80	3,720	38	Alluvial sand and gravel	28	34	5	36.4	16.9-35.9	16	09/15/80
O-11	CC#21	SE¼NW¼NW¼NW¼ sec. 2, T. 9 S., R. 42 E.	09/10/80	3,708	26	Alluvial sand and gravel	15	22	6	25.6	15.5-25.0	13.5	09/14/80
O-12	CC#25	NE¼NW¼NE¼NW¼ sec. 4, T. 9 S., R. 42 E.	01/07/81	3,875	233	Smith coal bed	197	214	17	233	196-233	193	06/12/81
O-13	HWC#12	NE¼NE¼SE¼NW¼ sec. 11, T. 9 S., R. 42 E.	08/01/75	3,710	222	Anderson coal bed	189	218	28	221	189-218	187	07/17/80
O-14	CC#13	NE¼SW¼SE¼NW¼ sec. 11, T. 9 S., R. 42 E.	09/05/80	3,700	34	--	--	--	--	33.9	14.4-33.4	13.5	06/12/81
O-15	CC#15	NE¼SW¼SE¼NW¼ sec. 11, T. 9 S., R. 42 E.	09/08/80	3,700	43	Alluvial sand and gravel	32	39	6	42.6	23.1-42.1	16	06/15/81

Static water level (feet below land surface)	Pumping water level (feet below land surface)	Discharge (gallons per minute)	Specific capacity (gallons per minute per foot of drawdown)	Onsite specific conductance (micromhos)	Onsite pH (units)	Onsite water temperature (°C)	1980-81 water-level fluctuation (feet below land surface)	Remarks
246.9	283	0.02	0.0005	2,950	8.4	14.5	246.6-246.9	Water-level fluctuations March-September 1981 only. Well 19 feet NNW of well 0-2.
121.7	133.7	.02	.002	6,200	7.4	12.0	121.2-125.0	Water-level fluctuations March-September 1981 only. Measured depth 135.3 feet below land surface; well perforations may be partly plugged, causing discharge calculations not to be representative of the aquifer.
90.1	210	7.5	.06	2,450	7.8	13.0	88.4-90.3	Well outside Corral Creek area in Hanging Woman Creek drainage. Measured depth 222 feet below land surface, after test in July 1980; lower part of Canyon coal aquifer not directly accessible to the well.
127.5	130.7	.025	.008	6,500	7.8	14.5	127.3-127.5	Water-level fluctuations April-September 1981 only. Anderson coal bed from 105 to 132 feet; only bottom 4 feet contained water in 1981.
244	257	.015	--	3,400	8.1	15.5	243.6-244.5	Water-level fluctuations June-September 1981 only. Well casing perforated opposite the upper Dietz coal bed, but water level is 32 feet below the coal, which apparently contains no water.
103.4	--	--	--	--	--	--	103.0-103.5	Well contains 2-inch plastic casing; not tested. Anderson coal bed from 66 to 93 feet (27 feet thick); coal probably is dry. Dietz coal bed from 158 to 160 feet.
26.0	32.4	1.6	.2	4,200	7.4	12.0	25.4-26.2	One of three wells inline across Corral Creek valley; well 177 feet SW of well 0-8 and 278 feet SW of well 0-9.
24.4	29.6	.4	.08	4,800	7.5	12.0	23.3-24.6	One of three wells inline across Corral Creek valley; well 177 feet NE of well 0-7 and 101 feet SW of well 0-9.
28.9	33	.4	.1	4,200	7.4	12.0	28.1-29.2	One of three wells inline across Corral Creek valley; well 101 feet NE of well 0-8 and 278 feet NE of well 0-7.
28.1	31.0	12.0	4	4,700	7.9	9.0	27.9-28.9	One of two wells inline along Corral Creek valley; well about 250 feet SE of well 0-11.
15.8	17.7	7.5	4	3,900	7.2	9.0	15.8-17.0	One of two wells inline along Corral Creek valley; well about 250 feet NW of well 0-10.
81	140	3.6	.06	3,200	7.2	12.0	61-81	Water-level fluctuations March-September 1981 only. Measured depth 212 feet below land surface; lower part of Smith coal bed not directly available to well. Water level dropped about 20 feet after June 1981 test; packer probably sealed during test and lower level (81 feet) is more accurate.
143.1	153	2.1	.2	2,700	7.5	14.0	143.0-143.6	--------
31.1	--	--	--	--	--	--	30.9-31.3	Material consists of about 5 feet of sand and gravel (the lowest 1 foot is gravel); the water level is below the basal gravel. Water apparently seeps into the well through the TRM shales.
32.7	36.2	9.3	2	4,100	7.4	10.0	31.8-32.8	Well apparently completed in a narrow alluvial channel. Well 0-14, 50 feet to the south, and test hole T-13, 100 feet to the north, penetrated TRM shales above the alluvial water level.

Table 3.--*Construction and hydrologic data for observation wells in the Corral Creek and adjacent areas*--Continued

Well No.	Local identification	Location	Date drilled	Altitude of land surface (feet above sea level)	Depth drilled (feet below land surface)	Aquifer material	Top of aquifer (feet below land surface)	Bottom of aquifer (feet below land surface)	Thickness of aquifer contributing water (feet)	Depth cased (feet below land surface)	Casing perforations (feet below land surface)	Packer setting (feet below land surface)	Date of hydrologic data
0-16	CC#01	SE¼SE¼NW¼NE¼ sec. 4, T. 9 S., R. 43 E.	12/12/79	3,520	28	Alluvial sand and gravel	13	27	11	28	14-27	11	10/07/80
0-17	CC#02	SE¼SE¼NW¼NE¼ sec. 4, T. 9 S., R. 43 E.	12/12/79	3,520	27	Alluvial sand and gravel	13	26	9	27	14-27	11	07/23/80
0-18	CC#03	NE¼NE¼SW¼NE¼ sec. 4, T. 9 S., R. 43 E.	12/13/79	3,521	35	Alluvial sand and gravel	13	28	8	34	17-33	14	07/21/80
0-19	CC#04	SE¼SE¼NW¼NE¼ sec. 4, T. 9 S., R. 43 E.	12/18/79	3,511	25	Alluvial sand and gravel	5	22	9	25	5-24	3	10/08/80
0-20	CC#05	NW¼SE¼NW¼NE¼ sec. 4, T. 9 S., R. 43 E.	12/18/79	3,510	19	Alluvial sand and gravel	4	16	6	19	4-17	3	09/11/80
0-21	CC#06	NW¼NE¼NW¼SW¼ sec. 4, T. 9 S., R. 43 E.	12/20/79	3,590	187	Upper Dietz coal bed	175	180	5	187	175-185	173	07/19/80
0-22	CC#07	NW¼NE¼NW¼SW¼ sec. 4, T. 9 S., R. 43 E.	12/21/79	3,591	97	Anderson coal bed	65	94	28	97	66-94	64	07/20/80
0-23	CC#08	SE¼NW¼SE¼SE¼ sec. 6, T. 9 S., R. 43 E.	09/03/80	3,585	40	Alluvial sand and gravel	10	31	15	31.2	11.7-30.7	7	06/09/81
0-24	CC#09	SE¼NW¼SE¼SE¼ sec. 6, T. 9 S., R. 43 E.	09/04/80	3,585	61	Alluvial sand and gravel and	10	34	12	60.7	21.6-60.2	17	06/13/81
						Anderson coal bed	34	57	23				
0-25	CC#10	NE¼SW¼SE¼SE¼ sec. 6, T. 9 S., R. 43 E.	09/04/80	3,585	31	Alluvial sand and gravel	10	28	13	30.3	10.8-29.8	10	06/15/81
0-26	CC#11	SE¼NW¼SE¼SE¼ sec. 6, T. 9 S., R. 43 E.	09/04/80	3,585	32	Alluvial sand and gravel	12	30	13	30.5	11.0-30.0	10	06/11/81
0-27	U.S. 77-70	NW¼SE¼NE¼SW¼ sec. 7, T. 9 S., R. 43 E.	08/01/77	3,655	520	TRM sandstone beds	137	158	15	165	140-160	140	07/18/80
0-28	CC#24	NW¼SE¼NE¼SW¼ sec. 7, T. 9 S., R. 43 E.	01/02/81	3,656	222	Anderson coal bed	180	211	28	222	179-213	175	06/14/81
0-29	HWC#10	NE¼SE¼NE¼NW¼ sec. 21, T. 9 S., R. 43 E.	07/22/75	3,610	229	Upper Dietz coal bed	182	185	3	229	183-185	180	06/17/81
0-30	HWC#11	NE¼SE¼NE¼NW¼ sec. 21, T. 9 S., R. 43 E.	07/28/75	3,610	135	Anderson coal bed	108	133	25	135	107-133	106	06/17/81

Static water level (feet below land surface)	Pumping water level (feet below land surface)	Discharge (gallons per minute)	Specific capacity (gallons per minute per foot of drawdown)	Onsite specific conductance (micromhos)	Onsite pH (units)	Onsite water temperature (°C)	1980-81 water-level fluctuation (feet below land surface)	Remarks
13.8	17.5	4.2	1	7,100	7.3	11.0	12.6- 13.8	One of five wells across Corral Creek valley, near mouth. Well 23 feet east of well 0-17, 199 feet NNW of well 0-18, 231 feet SSE of well 0-19, and 380 feet SSE of well 0-20.
13.8	20	2.5	.4	8,600	7.1	11.0	12.8 to 14.0	Well has a continuous recorder. One of five wells across Corral Creek valley. Well 23 feet west of well 0-16, 200 feet NNW of well 0-18, 230 feet SSE of well 0-19, and 380 feet SSE of well 0-20.
13.7	31.0	4.6	.2	5,200	7.2	10.0	13.1 to 14.0	One of five wells across Corral Creek valley. Well 199 feet SSE of well 0-16, 430 feet SSE of well 0-19, and 580 feet SSE of well 0-20.
7.1	20	4.8	.4	8,000	7.3	11.0	5.0 to 7.1	One of five wells across Corral Creek valley. Well 231 feet NNW of well 0-16, 430 feet NNW of well 0-18, and 149 feet SSE of well 0-20.
5.9	7.4	3.8	2	14,000	7.1	11.0	3.5 to 6.0	One of five wells across Corral Creek valley. Well 149 feet NNW of well 0-19, 380 feet NNW of well 0-16, and 580 feet NNW of well 0-18.
69.5	181	2.0	.02	2,400	7.9	14.0	69.0 to 69.5	When this well pumped, water level in well 0-22, 13 feet to the east, not affected; apparently packer set properly in both wells.
41.4	87.0	6.7	.1	9,000	6.8	11.5	40.2 to 41.6	-------------------
10.0	27.5	15	.8	4,050	7.4	10.5	9.4 to 11.6	One of four wells across Corral Creek valley, near confluence of Corral Creek and South Fork. Well 20 feet west of well 0-24, 119 feet NNW of well 0-25, and 125 feet south of well 0-26.
10.3	15.0	21	4	4,250	7.6	10.0	9.7 to 11.9	One of four wells across Corral Creek valley. Well 20 feet east of well 0-23, 116 feet NNW of well 0-25, and 122 feet SSE of well 0-26.
9.7	26.5	20	1	2,900	7.4	9.0	8.9 to 11.0	One of four wells across Corral Creek valley. Well 119 feet SSE of well 0-23, 116 feet SSE of well 0-24, and 238 feet SSE of well 0-26.
9.6	20.6	5.9	.5	3,300	7.4	10.0	8.8 to 11.1	One of four wells across Corral Creek valley. Well 125 feet north of well 0-23, 122 feet NNW of well 0-24, and 238 feet NNW of well 0-25.
51.3	79	6.8	.2	5,600	7.2	11.5	50.6 to 63.9	Static water level declined from 52 to 63 feet when well 0-28 drilled. There is no effect on either well when the other is pumped. Vibration during drilling well 0-28 apparently caused packer in well 0-27 to seal more firmly. Static water level of sandstone open to well probably 62 to 64 feet below land surface.
84.8	191	2.8	.02	2,450	7.8	13.5	84.7 to 85.2	Water-level fluctuation March-September 1981 only. Well 19 feet east of well 0-27.
102.1	--	--	--	--	--	--	102.1 to 102.5	Well south of Corral Creek area in Waddle Creek drainage. Well 19 feet SW of well 0-30.
48.6	--	--	--	--	--	--	48.6 to 50.0	Well south of Corral Creek area in Waddle Creek drainage. No record of well being pumped.

Table 4.--*Aquifer characteristics of the Tongue River Member of the Fort Union Formation in the Corral Creek and adjacent areas*

[TRM, Tongue River Member of Fort Union Formation]

Well No.	Altitude of land surface (feet above sea level)	Aquifer material open to perforated casing	Water intake interval (feet below land surface)	Thickness of aquifer contributing water (feet)	Date of test	Static water level (feet below land surface)	Drawdown of water level (feet)	Discharge (cubic feet per day)	Transmissivity (feet squared per day)	Hydraulic conductivity (feet per day)	Remarks
0-1	3,755	Lower Dietz coal bed	273-276	3	06/14/81	246.9	36	4	0.15	0.05	Aquifer characteristics based on measurements of recovering water levels after bailing.
0-2	3,755	Anderson coal bed	125-135	9	06/14/81	121.7	12	3	.15	.015	Hole had backfilled from 155 feet below land surface and about 19 feet of lower Anderson coal not contributing water to well. Aquifer characteristics based on recovery measurements after bailing.
0-3	3,530	Canyon coal bed	210-227	13	07/16/80	90.1	120	1,440	4	.3	Well pumped at about constant 7.5 gallons per minute for last 130 minutes of 160-minute test.
0-4	3,735	Anderson coal bed	128-132	4	06/16/81	127.5	3.2	5	.2	.05	Basal Anderson coal bed; upper 23 feet of bed above water level. Aquifer characteristics based on recovery measurements.
0-12	3,875	Smith coal bed	197	17	06/12/81	81	59	690	7	.4	Well pumped at about constant 3.6 gallons per minute for last 120 minutes of 180-minute test.
0-13	3,710	Anderson coal bed	189-218	28	07/17/80	143.1	10	400	10	.3	Well pumped at constant 2.1 gallons per minute from 10 to 150 minutes during 200-minute test.
0-21	3,590	Upper Dietz coal bed	175-180	5	07/19/80	69.5	112	380	1	.2	Well pumped at about constant 2 gallons per minute for last 160 minutes of 220-minute test.
0-22	3,591	Anderson coal bed	65-94	28	07/20/80	41.4	46	1,280	20	.7	Water level in well 0-21, 13 feet to the west, was not affected during pumping in well 0-22.
0-27	3,655	TRM sandstone	137-158	15	07/18/80	51.3	28	1,300	60	4	Well pumped at about constant 6.8 gallons per minute for last 180 minutes of 200-minute test.
0-28	3,656	Anderson coal bed	180-211	28	06/14/81	84.8	106	540	2	.07	Well pumped at about constant 2.8 gallons per minute for last 160 minutes of 190-minute test.
P-5	3,520	Anderson coal bed	15-44	17	07/24/80	11.8	47	190	1	.05	No accurate information on casing perforations. Well is assumed to be open from 27 to 61 feet.

Table 5.--*Aquifer characterisitics of alluvial aquifers*

Well No.	Altitude of land surface (feet above sea level)	Aquifer material open to perforated casing	Water intake interval (feet below land surface)	Thickness of aquifer contributing water (feet)	Date of test	Static water level (feet below land surface)	Drawdown of water level (feet below land surface)	Discharge (cubic feet per day)	Transmissivity (feet squared per day)	Hydraulic conductivity (feet per day)	Remarks
0-7	3,652	Sand and gravel with intervening mud layers	26.0-32.0	5.5	06/16/81	26.0	6.4	300	25	4	Water level in well 0-8, 177 feet NE, declined 0.08 foot. Water level in well 0-9, 278 feet NE, was unchanged.
0-8	3,650	Sand and gravel with thin intervening mud layers	24.4-29.5	4.5	06/13/81	24.4	5.2	80	2	.4	Water level in well 0-9, 101 feet NE, declined 0.02 foot. Water level in well 0-7, 177 feet SW, declined 0.02 foot.
0-9	3,655	Sand and gravel with intervening mud layers	28.9-33.0	4	06/10/81	28.9	4	75	3	.7	Water level in well 0-8, 101 feet SW, declined 0.01 foot. Water level in well 0-7, 278 feet SW, declined 0.01 foot.
0-10	3,720	Sand and gravel with thin intervening mud layers	28.0-34.0	5	09/15/80	28.1	2.9	2,300	260	50	Water level in well 0-11, about 250 feet NW was unchanged during test.
0-11	3,708	Sand and gravel with thin intervening mud layers	15.8-22.0	6	09/14/80	15.8	1.9	1,400	500	80	Water level in well 0-10, about 250 feet SE, was unchanged during test.
0-15	3,700	Sand and gravel with thin intervening mud layers	32.7-39.0	6	06/15/81	32.7	3.5	1,800	350	60	Single well test.
0-16	3,520	Sand and gravel with thin intervening mud layers	13.8-26.0	11	10/07/80	13.8	3.7	800	300	25	Water level in well 0-17, 23 feet west, declined 1.1 feet; estimated storage coefficient of 0.001. Other nearby wells were minimally affected by pumping of well 0-16.

Table 5.--*Aquifer characteristics of alluvial aquifers*--Continued

Well No.	Altitude of land surface (feet above sea level)	Aquifer material open to perforated casing	Water intake interval (feet below land surface)	Thickness of aquifer contributing water (feet)	Date of test	Static water level (feet below land surface)	Drawdown of water level (feet below land surface)	Discharge (cubic feet per day)	Transmissivity (feet squared per day)	Hydraulic conductivity (feet per day)	Remarks
0-17	3,520	Sand and gravel with thin intervening mud layers	13.8-25.0	9	07/23/80	13.8	6	480	40	4	Water level in well 0-16, 23 feet E, declined 0.6 foot. Estimated storage coefficient of 0.0004. Other nearby wells were little affected.
0-18	3,521	Sand and gravel with intervening mud layers	17.0-33.0	8	07/21/80	13.7	17.3	880	120	15	Transmissivity calculations from recovery water-level data. Water levels in wells 0-16 and 0-17, 200 feet NNW, declined about 0.03 foot during pumping.
0-19	3,511	Sand and gravel with intervening mud layers	7.1-22.0	9	10/08/80	7.1	13	920	50	5	Water level in well 0-20, 149 feet NNW, declined 0.03 foot. Water level in well 0-16, 231 feet SSE, had no change during pumping.
0-20	3,510	Sand and gravel with intervening mud layers	5.9-16.0	6	09/11/80	5.9	1.5	730	180	30	Water level in well 0-19, 149 feet SSE, declined 0.03 foot.
0-23	3,585	Sand and gravel with intervening mud layers	10.0-31.0	15	06/09/81	10.0	17.5	2,900	150	10	Water level in well 0-24, 20 feet east, declined 0.42 foot.
0-24	3,585	Sand and gravel with thin intervening mud layers	21.0-57.0	12	06/13/81	10.3	4.7	4,000	1,400	40	Water level in 0-23, 20 feet west, declined 0.41 foot; estimated storage coefficient of 0.0003. Water level in well 0-25, 116 feet SSE, declined 0.12 foot. Water level in well 0-26, 122 feet NNW, declined 0.12 foot.
		Anderson coal bed		23							
0-25	3,585	Sand and gravel with intervening mud layers	10.0-28.0	13	06/15/81	9.7	16.8	3,800	1,000	70	Water level in well 0-24, 116 feet NNW, declined 0.16 feet; storage coefficient about 0.0001.
0-26	3,585	Sand and gravel with intervening mud layers	12.0-30.0	13	06/11/81	9.6	11.0	1,100	600	40	Discharge too small to significantly affect water levels in wells 0-23 and 0-24.

Table 6 begins
on next page

Table 6.--*Chemical quality of water from wells completed in the Tongue River Member of the Fort Union Formation in the Corral Creek and adjacent areas*

[Except as indicated otherwise, constituents are dissolved and constituent values are reported in milligrams per liter. Analyses by Montana Bureau of Mines and Geology. Abbreviations: micromho, micromhos per centimeter at 25° Celsius; °C, degrees Celsius]

Observation well No.	Private well No.	Date sample collected	Depth cased (feet below land surface)	Onsite specific conductance (micromho)	Onsite pH (units)	Onsite water temperature (°C)	Hardness as $CaCO_3$ (Ca,Mg)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Sodium adsorption ratio (SAR)
O-1	--	06/14/81	287	2,950	8.4	14.5	61	11	7.8	730	41
O-2	--	06/14/81	155	6,200	7.4	12.0	940	140	140	1,200	17
O-3	--	07/16/80	232	2,450	7.8	13.0	23	4.8	2.6	670	61
O-4	--	06/16/81	133	6,500	7.8	14.5	190	39	22	1,400	45
O-5	--	06/16/81	260	3,400	8.1	15.5	260	35	43	720	19
--	P-2	09/15/80	146	4,000	7.5	10.0	1,710	240	270	480	5.1
O-12	--	06/12/81	233	3,200	7.2	12.0	820	130	120	480	7.3
--	P-3	06/12/81	380	3,650	7.3	11.0	1,170	200	160	480	6.2
O-13	--	07/17/80	221	2,700	7.5	14.0	30	6.1	3.5	700	56
--	P-5	07/24/80	--	9,500	7.5	12.0	2,900	300	520	1,700	14
O-21	--	07/19/80	187	2,400	7.9	14.0	24	4.8	2.9	620	56
O-22	--	07/20/80	97	9,000	6.8	11.5	2,190	320	340	1,100	11
--	P-6	09/15/80	46	2,700	7.4	8.0	1,300	200	190	220	2.6
O-27	--	07/18/80	165	5,600	7.2	11.5	540	74	85	1,200	22
O-28	--	06/14/81	222	2,450	7.8	13.5	29	5.8	3.5	620	50

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	Source of water
8.9	1,440	0	1,180	450	16	3.2	8.3	1,940	Lower Dietz coal bed.
14	1,180	0	972	2,600	40	.9	9.3	4,740	Anderson coal bed.
4.8	1,720	0	1,410	14	26	3.7	8.8	1,580	Canyon coal bed.
22	1,270	0	1,040	2,200	24	1.4	9.5	4,420	Anderson coal bed.
15	1,160	0	948	840	20	2.4	8.9	2,260	Sandstone beneath upper Dietz coal bed.
6.3	569	0	467	2,200	16	.4	11	3,510	Tongue River Member sandstone.
7.0	680	0	558	1,300	15	.5	12	2,360	Smith coal bed.
7.0	600	0	492	1,700	14	.5	11	2,860	Sandstones and Smith coal bed.
4.5	1,850	0	1,520	2.5	21	3.1	8.8	1,660	Anderson coal bed.
13	900	0	740	5,700	24	1.2	12	8,710	Anderson coal bed, partly weathered.
4.4	1,630	0	1,340	4.3	26	3.1	7.9	1,480	Upper Dietz coal bed.
25	1,030	0	847	3,700	22	.4	14	6,090	Anderson coal bed.
4.2	489	0	401	1,300	7.0	.3	12	2,200	Sandstone above Anderson coal bed.
9.7	1,380	0	1,130	1,900	35	1.2	10	3,980	Sandstone above Anderson coal bed.
4.0	1,710	0	1,400	4.3	20	1.7	8.6	1,510	Anderson coal bed.

Table 7.--*Chemical quality of water from wells completed in alluvium*

[Except as indicated otherwise, constituents are dissolved and constituent values are reported in milligrams per liter. Analyses by Montana Bureau of Mines and Geology. Abbreviations: micromho, micromhos per centimeter at 25° Celsius; °C, degrees Celsius; TRM, Tongue River Member of Fort Union Formation]

Observation well No.	Private well No.	Date sample collected	Depth cased (feet below land surface)	Onsite specific conductance (micromho)	Onsite pH (units)	Onsite water temperature (°C)	Hardness as $CaCO_3$ (Ca,Mg)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Sodium adsorption ratio (SAR)
0-7	--	10/08/80	36.5	4,400	7.8	10.5	1,130	170	170	640	8.2
		06/16/81		4,200	7.4	12.0	1,170	180	180	610	7.8
0-8	--	10/09/80	33.6	4,600	7.8	11.0	1,270	190	190	720	8.8
		06/13/81	33.6	4,800	7.5	12.0	1,270	200	190	710	8.7
0-9	--	10/09/80	36.0	4,000	7.7	11.0	1,470	210	230	460	5.2
		06/10/81	36.0	4,200	7.4	12.0	1,500	220	230	530	6.0
--	P-1	09/15/80	59	4,200	7.4	10.0	1,630	240	250	480	5.2
0-10	--	09/15/80	36.4	4,700	7.9	9.0	1,800	250	290	510	5.2
0-11	--	09/14/80	25.6	3,900	7.2	9.0	1,270	200	190	430	5.3
0-15	--	09/13/80	42.6	4,300	7.1	10.0	1,660	250	250	470	5.0
		06/15/81	42.6	4,100	7.4	10.0	1,700	250	260	440	4.6
0-16	--	10/07/80	28	7,100	7.3	11.0	2,680	330	450	930	7.8
0-17	--	07/23/80	27	8,600	7.1	11.0	2,250	320	350	980	9.0
0-18	--	07/21/80	34	5,200	7.2	10.0	1,920	220	340	740	7.4
0-19	--	10/08/80	25	8,000	7.3	11.0	2,810	290	510	1,200	9.7
0-20	--	09/11/80	19	14,000	7.1	11.0	3,940	410	710	2,000	14
0-23	--	06/09/81	31.2	4,050	7.4	10.5	1,430	200	230	570	6.6
0-24	--	09/10/80	60.7	4,900	8.1	10.0	1,370	190	220	560	6.6
		06/13/81		4,250	7.6	10.0	1,390	190	220	540	6.2
0-25	--	09/12/80	30.3	2,900	7.0	10.0	1,220	180	190	300	3.8
		06/15/81		2,900	7.4	9.0	1,270	180	200	290	3.5
0-26	--	06/11/81	30.5	3,300	7.4	10.0	1,150	170	180	380	4.8

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	Source of water
7.8	651	0	534	1,900	13	0.5	11	3,270	Sand and gravel.
8.1	656	0	538	1,900	14	.8	11	3,270	
8.7	676	0	554	2,200	14	.5	11	3,680	Do.
9.4	677	0	555	2,200	16	.8	10	3,650	
6.2	595	0	488	1,900	13	.4	11	3,120	Do.
7.5	614	0	504	2,000	11	.6	11	3,370	
5.4	593	0	486	2,100	28	.4	11	3,390	Alluvial sand and gravel and TRM sandstone.
6.0	578	0	474	2,300	20	.4	11	3,720	Sand and gravel.
5.6	547	0	449	1,600	21	.4	12	2,780	Do.
5.2	481	0	394	2,200	16	.4	11	3,460	Do.
5.4	472	0	387	2,200	16	.4	11	3,370	
8.9	619	0	508	4,000	40	.6	18	6,110	Do.
8.2	178	0	146	4,500	26	.8	18	6,300	Do.
9.9	700	0	575	2,800	17	.8	19	4,520	Do.
11	781	0	641	4,500	43	.7	15	6,890	Do.
13	1,000	0	824	7,300	72	.7	16	11,100	Do.
4.8	654	0	536	2,000	16	.8	11	3,380	Do.
5.6	693	0	568	1,900	14	.5	11	3,280	Sand and gravel and Anderson coal bed.
4.9	628	0	515	1,900	16	.6	11	3,220	
3.9	530	0	435	1,400	7.3	.4	11	2,380	Sand and gravel.
4.3	527	0	432	1,400	8.7	.5	11	2,360	
4.5	598	0	490	1,400	14	.7	11	2,490	Do.