CHAPTER VII

HYDROLOGY

Prepared for

TRAIL MOUNTAIN COAL COMPANY

Orangeville, Utah

BY

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Salt Lake City, Utah

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7.0 Introduction

This chapter decribes general and site-specific hydrologic conditions in the vicinity of the Trail Mountain Mine. The information presented herein was prepared by JBR Consultants Group under the direction of Trail Mountain Coal Company. The chapter addresses the applicable portions of the "General Guidelines for Organizational Format and Content" published by the Utah Division of Oil, Gas, and Mining (DOGM) for mining permit applications.

Section 7.1 of this chapter presents a discussion of groundwater conditions in the mine plan and adjacent areas, followed by a similar presentation of surface water conditions in Section 7.2. Section7.3 provides a determination of the potential for alluvial valley floors to be present within the mine plan area. References cited in the chapter are provided in Section 7.4.

7.1 Groundwater Hydrology

7.1.0 Scope

Setion 7.1 presents a discussion of groundwater conditions within the Tract 2 mine plan and adjacent areas. Conclusions drawn herein are based upon a detailed seep and spring survey of the area, limited drilling data, and the results of groundwater investigations conducted by others in the region of the mine.

7.1.1 Methodology

A seep and spring survey was conducted on October 29, 1985 in the vicinity of the Tract 2 application area. Data collected from this survey are supplemental to data collected in June 1981 as part of the investigation conducted for the Tract 1 PAP. The area was traversed by vehicle and on foot to allow springs and seepage points to be precisely located, examined, and sampled.

Geologic conditions at all seeps and springs were noted in the field, including lithologic and structural controls and the geologic formation from which the seepage issued. Signs of usage were also noted. The flow rate was determined by measuring the time required for the seep or spring discharge to fill a container with a known volume. If sufficent water was present a sample of the water was collected. The temperature of the water issuing from the spring was measured at the site. All samples were subsequently analyzed in the field for pH and specific conductance. In addition, three springs, representing the lithologic unit from which most springs in the area emanate, were sampled and the samples subjected to complete water chemistry analyses.

Regional groundwater conditions were determined from a review of available literature. Where appropriate, conclusions drawn from investigations elsewhere in the region were used to determine the approximate local conditions.

7.1.2 Existing Groundwater Conditions

See Appendix 7-D

7.1.2.1 Regional Groundwater Hydrology

Six formations outcrop within the Tract 2 mine plan and adjacent areas. These include (in ascending order) the Star Point Sandstone, the Blackhawk Formation, the Castlegate Sandstone, the Price River Formation, the North Horn Formation, and the Flagstaff Limestone (Lines, 1985).

As noted by Lines (1985), the Blackhawk Formation and the Star Point Sandstone are considered together in the region as an aquifer. Where these formations exist sufficiently far from the edges of canyons, they are typically saturated. However, near the canyons (as is the case in the existing Trail Mountain Mine workings) the

Blackhawk Formation tends to be drained. A copy of Lines (1985) paper follows this chapter as Appendix 7-B.

Strata that overly the Blackhawk Formation are not completely saturated but do contain perched aquifers (Lines, 1985 - Appendix 7-B). These perched zones provide water locally to springs and baseflow to some streams.

Investigations in the vicinity of the Trail Mountain Mine by Danielson et al. (1981) indicated that most, if not all, groundwater in the region is derived from snowmelt. Recharge tends to be limited in areas underlain by the Price River Formation and older rocks (relative to recharge in areas underlain by younger rocks) due to slope steepness and relative imperviousness (both of which promote runoff rather than infiltration of snowmelt).

The predominant chemical constituents in most springs in the region are calcium, magnesium, and bicarbonate (Lines, 1985). Dissolved solids concentrations generally range from about 250 to 750 milligrams per liter. Regionally, the concentrations of major dissolved constituents in water from individual geologic units is highly variable, due to lithologic complexity in the area.

7.1.2.2 Mine Plan Area Aquifers

Results of the 1985 seep and spring inventory conducted in the Tract 2 area and vicinity are presented in Table 7-1. Figure 7-1 shows the locations of the seeps and springs. The results of full chemical analyses of samples from three springs are presented in Appendix 7-C. Of the 15 springs identified during the survey, 13 issue from the North Horn Formation, and the other two issue from colluvium in the channel of a small side canyon. One of the latter two springs, T-10 issues from colluvium above the Castlegate Sandstone. The geologic controls on springs in the Tract 2 area are depicted in a generalized way in the block diagram, Figure 7-2.

Springs in the vicinity of the Tract 2 area generally issue from sandstone overlying a shale layer (see Figure 2). Lines (1985) found that the laboratory hydraulic conductivity of the sandstone and shale units within the Blackhawk Formation vary by four to six orders of magnitude. Similar relations are expected within other geologic formations in the area. The relative magnitude of the hydraulic conductivity of local sandstones compared with siltstones and shales indicates that the finergrained sediments of the formations serve as barriers to the downward movement of water. Recharge into local formations (either through snowmelt, rainfall, or subsurface seepage from an adjacent formation) percolates downward within the sandstone beds. However, upon reaching a less-permeable siltstone or shale layer, the water is forced to flow downdip to the surface, issuing at the interface between the two units.

Two wells have recently been drilled at the site to monitor groundwater conditions in the Star Point Sandstone (the Blackhawk Formation at these locations is unsaturated). Well TM-1 was drilled outside the mine near the main manway portal. The hole was drilled to a total depth of 650 feet, beginning at a point 5.0 feet below the top of the Star Point Sandstone. At this location, the Star Point was encountered to a depth of 350 feet, with a transition from the Star Point to the Mancos Shale existing from a depth of 350 feet to 500 feet. Below the 500-foot depth, the Mancos Shale is present.

The elevation of the ground surface at TM-1 is 7276.0 feet. Water in the Star Point is under artesian pressure, with the static water level standing 1.5 feet above the ground surface on October 24, 1985. Hence, the elevation of the potentiometric surface at TM-1 is 7277.5 feet.

Well TM-2 was drilled underground in crosscut 54 in the south mains. The hole was drilled to a total depth of 60 feet, beginning at the top of the Star Point. Only the Star Point Sandstone was encountered in this hole.

The elevation of the mine floor (and, hence, the top of the Star Point Sandstone) at TM-2 is 7167.0 feet. On October 24, 1985, the static water level in TM-2 was at a depth of 16.5

feet below the mine floor. Hence, the elevation of the potentiometric surface at this location is 7150.5 feet.

Results of complete chemical analyses from wells TM-1 and TM-2 are presented with other 1985 water monitoring data in Appendix 7-D.

Figure 7-1 also shows the elevation of the potentiometric surface in the greater Trail Mountain Mine area. This data is taken from Lines (1985) and modified using data from wells TM-1 and TM-2. As noted, the potentiometric surface surmised by Lines should be shifted to the south in the vicinity of Cottonwood Creek. Figure 7-1 indicates that the flow of groundwater in the Star Point Sandstone in the vicinity of the Trail Mountain Mine is to the south-southwest toward Straight Canyon.

As Table 7-1, Appendix 7-1 shows, springs in the vicinity of the Trail Mountain Mine are used by cattle, deer, elk, and other wildlife. Five of the springs (TM-4, TM-6, TM-8, TM-9, and TM-11) have been developed with watering troughs or ponds.

Data presented by Lines(1985) indicate that the total dissolved solids concentrations of water from springs in the North Horn Formation tends to increase in the direction of groundwater flow (i.e., in the south-southwest direction according to Lines, (1985). A review of specific conductance data presented in Table 7-1 substantiates this observation. In addition, the results of analyses of samples from T-5, T-7, and T-11 show that total dissolved solids increase in concentration toward the south. This pattern is due to the increased leaching of the bedrock in the downgradient direction.

Insufficient springs were available to determine if such a trend exists within other formations in the vicinity of the mine. However, Lines (1985 - Appendix 7-B) found that the pattern did not exist in the Blackhawk-Star Point aquifer.

The pH of water issuing from springs in the survey area showed no trends. Values varied from 7.3 to 8.5, generally falling in the range of 7.3 to 7.6. Hence, spring water in the study area is slightly alkaline.

7.1.3 Groundwater Development and Mine Dewatering

7.1.3.1 Water Supply

As noted previously, five of the springs inventoried during the October 1985 survey have been developed for beneficial use (stockwatering). However, no water supply wells are known to exist within the mine plan or adjacent areas.

A review of records on file with the Utah Division of Water Rights indicates that no groundwater rights exist within the Tract 2 mine plan and adjacent areas. Hence, although some of the springs in the area have been developed, no formal right to the water has been filed.

7.1.3.2 Mine Dewatering

Inflow to the existing underground workings is no greater than required for underground usage. (See Appendix 7-H for Rational used to calculate existing mine inflow).** Minor inflows are occasionally encountered from roof bolts near the active working face of the mine but these generally dry up within a short period of time. On occation excess water has been discharged from the mines main sump to Cottonwood Creek. This outfall location is 002 and is located on Figure 7-3 . NPDES Permit approval of outfall 002 and discharge dates and amounts can be found in Appendix 7-D(8).

Figure 7-1 shows the relationship of the pieziometric surface of the Blackhawk-Star Point aquifer to the elevation of the base of the Hiawatha coal seam (top of the Star Point). Figure 6-5, the geologic cross section, also demonstrates the relationship between this pieziometric surface and the Hiawatha seam. Both of these illustrations show that as mining expands downdip into Tract 2, the Blackhawk Formation should become increasingly saturated. As a result, inflows to the mine will increase.

When fully developed, the underground workings at the Trail Mountain Mine will have an approximate width of 5000 feet and a length of 9000 feet. According to Figure 7-1, the maximum steady-state inflow to the mine workings with the hydraulic gradient

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equal to 0.04 is estimated to be 0[1].15 cubic foot per second, (approximately 70 gallons per minute). This assumes that the Blackhawk-Star Point aquifer is saturated throughout the mine, a condition that does not exist at the Trail Mountain Mine. Hence, inflow to the mine workings when fully developed will be less than 70 gallons per minute. (See Appendix 7-G for calcualtions and rational used to calculate mine inflows)**

No major faults are known to exist in the Tract 2 area, suggesting that major inflows will not occur during mining. Since in-mine water requirements are projected to amount to approximately 100 gallons per minute, it is not anticipated that inflows to the mine will be sufficient to require that water be discharged to the surface.

7.1.4 Effects of Mining Operation on Groundwater

As discussed in Chapter 12, subsidence is expected to have no impact on bedrock-aquifer springs in the vicinity of the Trail Mountain Mine. Only two springs (T-10, and T-14) were found within the area of potential subsidence during the October 1985 survey. Both of these springs emit from colluvium in a small, steep canyon. Each of these springs flowed at a rate of approximately 1 gallon per minute and was used as a source of water for wildlife. T-10 also showed signs of usage by cattle. Neither of these springs was discovered during the June 1981 survey. Colluvial aquifers are less likely to be affected by subsidence than are bedrock aquifers because they are not brittle and thus will not fracture and because the permeability of the collumium is likely in almost all cases to exceed the fracture permeability induced by subsidence. Only in cases where fractures intercept channellized aquifers or the springs themselves is subsidence likely to eliminate spring discharge. It seems more likely that the impact of subsidence, if any, may alter the points of spring occurence.

Four run-off-fed ponds were also identified during the October 29, 1985 survey. Their locations are shown on Figure 7-1. These ponds, numbered 35-1P, 26-1P, 26-2P, and 26-3P, were sampled for water quality during the 1981 survey and the analytical results are presented in Chapter 7 of Trail Mountain Coal Coal Company's Tract 1 ACT/015/009 Mine Reclamation Permit. These ponds occur within the area of potential Tract 2 subsidence and, as is pointed out in Chapter 12, may be affected if mine subsidence occurs. The subsidence effects on the ponds may result in changes in retention capacity is subsidence fractures interecpt them; however, water quality is not likely to be adversely affected.

Thus, the maximum potential impact to springs due to mining in the Tract 2 area would be the loss of approximately 2 gallons per minute of flow from springs T-10 and T-14 and the possible loss of retention capacity of existing natural and man-made ponds. Loss of these sources of water would result in the displacement of wildlife and cattle approximately one mile to the northwest or southwest where water supplies are more plentiful.

Inflows to the mine are projected to be insufficient to require dewatering (see Section 7.1.3.2). Hence, impacts due to dewatering will be nonexistent.

The water supply for use at the mine (culinary and domestic) is obtained from Cottonwood Creek. Hence, groundwater is not withdrawn for use at the mine. Lines (1985 - Appendix 7-B) states that mining is not expected to adversely impact water quality in the vicinity of the Trail Mountain Mine.

7.1.5 Mitigation and Control Plans

Based on the information presented in Section 7.1.4, subsidence from mining in the Tract 2 area will have minimal impacts on Groundwater resources in the vicintiy of the mine. Flow rates encountered during the 1985 inventory within the area of potential subsidence were minimal.

mine. Flow rates encountered during the 1985 inventory within the area of potential subsidence were minimal.

Trail Mountain Coal Company will monitor selected groundwater sources in the vicinity of the mine as outlined in Section 7.1.6. If the mining operations are deemed to have an impact on local groundwater supplies, a mitigation plan for specific impacts will be developed in consultation with DOGM.

As also noted in Section 7.1.3, insufficient inflows are encountered in the existing underground workings to require mine dewatering. Since dewatering does not occur and is not anticipated to occur in the future, no plan is needed to mitigate the impacts of dewatering on the groundwater system.

7.1.6 Groundwater Monitoring Plan

Appendix 7-D of this chapter contains all Hydrological Monitoring information and data associated with Trail Mountain Coal Company's Tract 1 MRP (Act/015/009)

In addition to the above monitoring, flow and water-quality data for Tract 2 will be collected from springs T-10, T-14 and T-14A discovered during the October 1985 survey. These springs are found within the zone of potential subsidence for Tract 2 and will be monitored to determine if mining activities are affecting springs in the immediate vicinity of the mine. These springs will be monitored in accordance with the surface water baseline schedule and parameters as established by DOGM. (Appendix 7-3). (See also Appendix 7-I for additional water monitoring.)**

Trail Mountain Coal Company has also indentified several springs and ponds outside of the zone of potential subsidence that have been labeled in the field and PCV pipe has been installed to facilitate sampling. (See Figure 7-3) Trail Mountain Coal Company has taken field measurements and lab analysis. The results of the analysis can be found in Appendix 7-2.

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Groundwater monitoring for the Tract 2 permit area will also consist of collecting water quality and quantity data from points of significant inflow to the underground workings. On a quarterly basis (normally in January, April, July, and October), an inventory will be conducted of the active portion of the mine to identify the location and geologic occurrence of mine inflows that exceed three gallons per minute. In consultation with DOGM, certain of these inflows (if they occur) will be selected for continued monitoring.

Samples from all monitoring stations will be collected and analyzed according to Appendix 7-3. Groundwater monitoring data collected during a calendar year will be summarized and submitted to DOGM on an annual basis. Included in the annual report will be an analysis of the mine working water balance, accounting for mine inflows, outflows, consumptive uses, and sump storage.

7.1.7 Postming Monitoring

After mine closure, Trail Mountain Coal Company will monitor all sealed portal areas. In the event of any unplanned discharge from the underground workings, Trail Mountain Coal Company commits to the monitoring of discharge. Monitoring will be on a quarterly basis as accessible. Monitoring will be as such as to derive data pertinent to assessing whether discharges are in compliance with effluent standards of UMC 817.42 and other applicable state rules and federal regulations.

Trail Mountain Coal Company also makes the commitment, if determined necessary, to provide treatment for discharge during the discharge period or until Bond release.**

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7.2 Surface Water Hydrology

7.2.0 Scope

Section 7.2 presents a discussion of surface water conditions within the Tract 2 mine plan and adjacent areas. Conclusions drawn herein are based upon a field reconnaissance of the area, published hydrologic information, and the Hydrology chapter of the ACT/015/009 PAP.

7.2.1 Methodology

Information used to develop the description of surface water resources was obtained from field investigations and a literature review. A runoff- and sediment-control plan for the surface facilities associated with the ACT/015/009 lease was previously submitted to DOGM. Detailed methodologies used to determine required pond volumes, peak flows, spillway hydraulics, etc. are contained in those previous submittals. Since the Tract 2 lease area will not require the construction of additional surface facilities, no additional runoff- and sediment-control measures will be required for Tract 2.

7.2.2 Existing Surface Water Resources

7.2.2.1 Regional Surface Water Hydrology

The Trail Mountain Mine is located immediately adjacent to Cottonwood Creek, one of the major tributaries of the San Rafael River. Cottonwood Creek has had an annual flow near Orangeville of 70,700 acre-feet during the period of record that extends intermittently from 1909 through the present (U. S. Geological Survey, 1984). Approximately 50 to 70 percent of streamflow in the mountain streams of the region occurs during May through July (Waddell et al., 1981). Streamflow during this late spring/early summer period is the result of snowmelt runoff.

The quality of water in Cottonwood Creek and other similar streams in the area varies significantly with distance downstream. Waddell et al. (1981) found that concentrations of dissolved solids varied from 125 to 375 milligrams per liter in major streams in the region in reaches above major diversions to 1600 to 4025 milligrams per liter in reaches below major irrigation diversions and population centers. The major ions at the upper sites were found to be calcium, magnesium, and bicarbonate, wheras sodium and sulface became more dominant at the lower sites. They attributed these changes to (1) diversion of water containing low dissolved solids concentrations, (2) subsequent irrigation and return drainage from moderate to highly saline soils, (3) groundwater seepage, and (4) inflow of sewage and pollutants from population centers.

Average annual sediment yields within the Cottonwood Creek drainage basin range from approximately 0.1 acre-feet per square mile in the headwaters area to about 3.0 acre-feet per square mile near the confluence with the San Rafael River (Waddell et al., 1981).

7.2.2.2 Mine Plan Area Surface Hydrology

The Tract 2 area is drained entirely by ephemeral and intermittent watersheds. These watersheds are steep (with average slopes often exceeding 50 percent) and well vegetated (with cover also often exceeding 50 percent). Because of the near ridgetop location of the Tract 2 area, channels in the mine plan area are not generally deeply incised.

Surface water-quality data collected from Cottonwood Creek by Trail Mountain Coal Company indicate that the dominant ions in Cottonwood Creek near the mine are calcium, magnesium, and biocarbonate. Water quality data collected during 1985 is presented in Appendix 7-D. Total dissolved solids concentrations in the stream vary from about 250 to 300 milligrams per liter in the mine area, with ther lower concentrations normally occurring during the high-flow season. Little consistent variation has been noted between stations located upstream and downstream from the Tract 1 permit area.

Total suspended solids concentrations in Cottonwood Creek tend to vary inversely with the flow rate, as expected. Concentrations have varied during the period of record from less than 1 milligram per liter to greater than 1000 milligrams per liter. Additional discussions concerning the quality of surface water in the vicinity of the Tract 2 area are contained in the Chapter 7, Hydrology, of the ACT/015/009 PAP.

7.2.3 Surface Water Development and Control

7.2.3.1 Water Supply

Surface water in the mine plan and adjacent areas is utilized primarily for stockwatering purposes. In addition, Trail Mountain Coal Company pumps water from Cottonwood Creek for use underground and domestic use. (See Appendix 7-D (7) for quanity of water diverved from Cottonwood Creek).

A listing of surface water rights within the permit and adjacent areas is provided in (See Appendix 7-D (6) Cottonwood Irrigation Shares). A review of the files of the Utah Division of Water Rights indicated that additional rights have not been added to the area since that original submittal.

Trail Mountain Coal Company has applied for, and been granted approval from the State Water Rights, to drill a water well and divert water for domestic and in-mine usage. At the present time Trail Mountain Coal has not drilled this well. However, it will be drilled sometime in the near future. (See Appendix 7-D (10) for well approval)

7.2.3.2 Run-off and Sediment-Control Facilities

As noted previously, the Tract 2 area will not require the construction of any additional surface facilities. Hence, additional runoff- and sediment-control facilities will not be required for Tract 2.

7.2.4 Effects of Mining on Surface Water

Runoff- and sediment-control facilities for the existing Trail Mountain Mine surface facilities have been designed in accordance with applicable DOGM regulations. These facilities were designed to safely convey and control runoff from the specified design storm events. Since the Tract 2 area will not require the addition of surface facilities beyond those already required for the ACT/015/009 permit area, Tract 2 operations will not increase sediment loads to Cottonwood Creek.

No water is discharged currently from the Trail Mountain Mine, nor is it anticipated that mining in the Tract 2 area will result in a discharge in the future (see section 7.1). Thus, impacts will not occur to the quality of surface water from mine-water discharges.

Trail Mountain Coal Company currently pumps approximately 24,000 gallons per month from Cottonwood Creek for domestic and culinary usage. (See Appendix 7-D(7)) This usage rate is expected to continue during Tract 2 operations. This quantitiy equals 0.88 acre-feet per year.

The total usage of water from Cottonwood Creek results in the diversion of about .088 acre-feet per year from Cottonwood Creek. This quantity represents an insignificant portion of the flow of Cottonwood Creek. (See Appendix 7-D(7)) Shares in the Cottonwood Creek Consolidated Irrigation Company have been purchased to cover the usage of this water. (See Appendix 7-D(6))

7.2.5 Mitigation and Control Plans

As indicated in Section 7.2.3.2, runoff- and sediment-control facilities have been designed for theTract 1 area to protect the surface hydrologic balance of the area and mitigate potential impacts. These facilities will be periodically inspected following installation to ensure adequate functioning during Tract 2 operations. Required repairs will be implemented immediately. These facilities are described in detail in the Hydrology chapter from the ACT/015/009 PAP.

Impacts from mining to the quantity of water in the Cottonwood Creek watershed are expected to be minimal, as noted previously. Hence, alternative water supplies are not required to replace existing surface water supplies.

7.2.6 Surface Water Monitoring Plan

A surface-water monitoring program for the Trail Mountain Mine was outlined previously in the Tract 1 PAP and subsequent submittals. Water monitoring for the Tract 2 Area will be in accordance with the Division of Oil, Gas and Mining revised Water Monitoring Guidelines. (See Appendix 7-3).

7.3 Alluvial Valley Floor Determination

The Tract 2 mine plan area is located only in upland areas of the Cottonwood Creek watershed containing a thin veneer of colluvial deposits. As a result, the area is not underlain by an alluvial valley floor.

The area occupied by the surface facilities (adjacent to Cottonwood Creek) is a steep, narrow canyon with only limited amounts of rocky alluvium. No agricultural activities have been conducted in the area in the past nor will they be in the future due to the limited width of alluvium along the stream (less than 10 feet) and to restrictive climatic conditions. Hence, the Cottonwood Creek area adjacent to the surface facilities is also not an alluvial valley floor.

7.4 References

Danielson, T.W., M. D. ReMillard, and R. H. Fuller. 1981. Hydrology of the Coal-Resource Areas in the Upper Drainages of Huntington and Cottonwood Creeks, Central Utah. U. S. Geological Survey Water-Resources Investigations Open-File Report 81-539. Salt Lake City, Utah.

Lines, G. C. 1985. The Ground-Water System and Possible Effects of Underground Coal Mining in the Trail Mountain Area, Central Utah. U. S. Geological Survey Water-Supply Paper 2259. Washington, D.C.

U. S. Geological Survey. 1984. Water Resources Data for Utah, Water Year 1983. Water Resource Division. Salt Lake City, Utah.

Waddell, K. M., P. K. Contrati, C.T. Sumsion, and J. R. Butler. 1981. Hydrologic Reconnaissance of the Wasatch Plateau-Book Cliffs Coal-Fields Area, Utah. U. S. Geological Survey Water-Supply Paper 2068. Washington, D.C.

Appendix 7-1

Table 7-1 - Seep and Spring Inventory**

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Table 7-1. Results of Trail Mountain Tract #2 Seep and Spring Inventory, October 29,1985.

Site Number	Flow (gpm)	pH (Units)	Specific Cond.[a]	Temp. (°C)	Geology	Use and Notes
T-1	4	7.8	516	19	From contact of sandstone over shale in the North Horn Formation.	Cattle & deer
T-2	2	7.7	552	18	From contact of sandstone over shale in the North Horn Formation.	Cattle
T-3	1	7.3	693	18	From contact of sandstone over shale in the North Horn Formation.	Cattle
T-4	2	7.6	635	19	From colluvium covering probable sandstone/shale contact in North Horn Fm.	Cattle & deer
T-5	3	7.6	586	18	From contact of sandstone over shale in the North Horn Formation.	Cattle & deer (water quality sample)
T-6	5	7.5	932	18	From contact of sandstone over shale in the North Horn Formation.	Cattle & deer (cistern and trough)

Table 7-1 (Continued).

Site Number	Flow (gpm)	pH (Units)	Specific Cond.[a]	Temp. (°C)	Geology	Use and Notes
T-7	2	7.4	942	16	From contact of sandstone over shale in the North Horn Formation.	Horses, cattle and deer (water quality sample)
T-8 (TM-21)	2	7.3	710	18	From contact of sandstone over shale in the North Horn Formation.	Cattle & wildlife (cistern, trough, and pipe)
T-9 (TM-22)	3	7.5	521	18	From contact of sandstone over shale in the North Horn Formation.	Cattle & wildlife (cistern, trough, and pipe)
T-10	2	7.6	711	16	From colluvium in drainage channel overlying the North. Horn Formation.	Cattle & wildlife
T-11	8	7.6	820	17	Colluvium covering possible sandstone/shale contact in the North Horn Formation.	Cattle & wildlife (water quality sample)
T-12	1	8.4	847	17	From colluvium overlying the North Horn Formation - exposed in roadcut.	Cattle & wildlife
T-13	2	8.5	822	17	From colluvium overlying the North Horn Formation - exposed in roadcut.	Wildlife

Table 1. (Continued)

Site Number	Flow (gpm)	pH	Specific Cond.[(a)]	Temp. (°C)	Geology	Use and Notes
T-14	1	7.4	1630	13	From colluvium in drainage channel overlying Price River Formation.	Wildlife
T-15	4	7.5	705	13	From contact of colluvium and alluvium overlying the Blackhawk Fm.	Cattle & wildlife (cistern, trough, and pipe)

(a) specific conductivities are reported in micro-mohs at 25 °C.

Appendix 7-2 Table 1 - Tract 2 Seep and Spring Water Anaylses

October 29, 1985 Survey**

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CHEMTECH

28 EAST 1500 NORTH
OREM, UTAH 84057
(801) 226-8822

CERTIFICATE OF ANALYSIS

SAMPLE IDENTIFICATION

CLIENT: JBR Consultants
2556 East Oak Creek Circle
Sandy, UT 84092

LAB NO.: U008772

DATE SAMPLED: 10-29-85

TIME SAMPLED:

SAMPLED BY: R.B.

LOCATION: TM-GW-1 (T-5)
Trail Mountain

COMMENTS: Metals-Dissolved

PARAMETER	LEVEL
Alkalinity as $CaCO_3$, mg/l	246
Ammonia as NH_3-N, mg/l	<.1
Arsenic as As, mg/l	<.01
Barium as Ba, mg/l	0.155
Bicarbonate as HCO_3, mg/l	300
Boron as B, mg/l	0.33
Cadmium as Cd, mg/l	<.005
Calcium as Ca, mg/l	30.9
Carbonate as CO_3, mg/l	0
TSS, mg/l	6.8
Sulfide as S, mg/l	<.05
Settleable Solids, ml/l	<.1

PARAMETER	LEVEL
Chloride as Cl, mg/l	9.3
Chromium as Cr (Hex.), mg/l	--
Chromium as Cr (Total), mg/l	<.005
Conductivity, umhos/cm	568
Copper as Cu, mg/l	<.005
Fluoride as F, mg/l	0.21
Hardness as $CaCO_3$, mg/l	292
Hydroxide as OH, mg/l	0
Iron as Fe (Dissolved), mg/l	0.303
Iron as Fe (Total), mg/l	--
Lead as Pb, mg/l	<.01
Magnesium as Mg, mg/l	37.9
Manganese as Mn, mg/l	<.005
Mercury as Hg, mg/l	<.0002
Nickel as Ni, mg/l	<.005
Nitrate as NO_3-N, mg/l	0.21
Nitrite as NO_2-N, mg/l	0.007
Phosphate as PO_4-P, mg/l	0.011
Potassium as K, mg/l	1.15
Selenium as Se, mg/l	<.002
Silica as SiO_2 (Dissolved), mg/l	2.36
Silver as Ag, mg/l	--
Sodium as Na, mg/l	35.4
Sulfate as SO_4, mg/l	42.8
Total Dissolved Solids, mg/l	386
Turbidity, NTU	--
Zinc as Zn, mg/l	0.025
pH Units	7.40

CHEMTECH

CHEMTECH

28 EAST 1500 NORTH
OREM, UTAH 84057
(801) 226-8822

CERTIFICATE OF ANALYSIS

SAMPLE IDENTIFICATION

CLIENT: JBR Consultants
2556 East Oak Creek Circle
Sandy, UT 84092

LAB NO.: U008774

DATE SAMPLED: 10-29-85

TIME SAMPLED:

SAMPLED BY: R.B.

LOCATION: TM-GW-3 (T-7)
Trail Mountain

COMMENTS: Dissolved Metals

PARAMETER	LEVEL
Alkalinity as $CaCO_3$, mg/l	298
Ammonia as NH_3-N, mg/l	<.1
Arsenic as As, mg/l	<.01
Barium as Ba, mg/l	0.135
Bicarbonate as HCO_3, mg/l	363
Boron as B, mg/l	0.24
Cadmium as Cd, mg/l	<.005
Calcium as Ca, mg/l	25.4
Carbonate as CO_3, mg/l	0
TSS, mg/l	80
Sulfide as S, mg/l	<.05
Settleable Solids, ml/l	0.1

PARAMETER	LEVEL
Chloride as Cl, mg/l	14.1
Chromium as Cr (Hex.), mg/l	--
Chromium as Cr (Total), mg/l	<.005
Conductivity, umhos/cm	705
Copper as Cu, mg/l	<.005
Fluoride as F, mg/l	0.26
Hardness as $CaCO_3$, mg/l	456
Hydroxide as OH, mg/l	0
Iron as Fe (Dissolved), mg/l	0.045
Iron as Fe (Total), mg/l	--
Lead as Pb, mg/l	<.01
Magnesium as Mg, mg/l	50.6
Manganese as Mn, mg/l	<.005
Mercury as Hg, mg/l	<.0002
Nickel as Ni, mg/l	<.005
Nitrate as NO_3-N, mg/l	0.19
Nitrite as NO_2-N, mg/l	0.009
Phosphate as PO_4-P, mg/l	<.01
Potassium as K, mg/l	1.85
Selenium as Se, mg/l	<.002
Silica as SiO_2 (Dissolved), mg/l	3.38
Silver as Ag, mg/l	--
Sodium as Na, mg/l	50.4
Sulfate as SO_4, mg/l	68.1
Total Dissolved Solids, mg/l	543
Turbidity, NTU	--
Zinc as Zn, mg/l	0.018
pH Units	7.46

CHEMTECH

CHEMTECH
28 EAST 1500 NORTH
OREM, UTAH 84057
(801) 226-8822

CERTIFICATE OF ANALYSIS

SAMPLE IDENTIFICATION

CLIENT: JBR Consultants
2556 East Oak Creek Circle
Sandy, UT 84092

LAB NO.: U008773

DATE SAMPLED: 10-29-85

TIME SAMPLED:

SAMPLED BY: R.B.

LOCATION: TM-GW-2 (T-11)
Trail Mountain

COMMENTS: Metals - Dissolved

PARAMETER	LEVEL
Alkalinity as $CaCO_3$, mg/l	223
Ammonia as NH_3-N, mg/l	<.1
Arsenic as As, mg/l	<.01
Barium as Ba, mg/l	0.138
Bicarbonate as HCO_3, mg/l	272
Boron as B, mg/l	0.33
Cadmium as Cd, mg/l	<.005
Calcium as Ca, mg/l	36.1
Carbonate as CO_3, mg/l	0
TSS, mg/l	1.2
Sulfide as S, mg/l	<.05
Setteable Solids ml/l	<.1

PARAMETER	LEVEL
Chloride as Cl, mg/l	65.7
Chromium as Cr (Hex.), mg/l	--
Chromium as Cr (Total), mg/l	<.005
Conductivity, umhos/cm	767
Copper as Cu, mg/l	<.005
Fluoride as F, mg/l	0.14
Hardness as $CaCO_3$, mg/l	336
Hydroxide as OH, mg/l	0
Iron as Fe (Dissolved), mg/l	0.280
Iron as Fe (Total), mg/l	--
Lead as Pb, mg/l	<.01
Magnesium as Mg, mg/l	44.8
Manganese as Mn, mg/l	<.005
Mercury as Hg, mg/l	<.0002
Nickel as Ni, mg/l	<.005
Nitrate as NO_3-N, mg/l	0.32
Nitrite as NO_2-N, mg/l	0.003
Phosphate as PO_4-P, mg/l	0.013
Potassium as K, mg/l	2.27
Selenium as Se, mg/l	<.002
Silica as SiO_2 (Dissolved), mg/l	1.04
Silver as Ag, mg/l	--
Sodium as Na, mg/l	55.9
Sulfate as SO_4, mg/l	72.9
Total Dissolved Solids, mg/l	493
Turbidity, NTU	--
Zinc as Zn, mg/l	0.018
pH Units	7.53

CHEMTECH

TRAIL MOUNTAIN COAL COMPANY SPRING MONITORING

SPRING ID	DATE	ELEV.	WATER BEARING ZONE	DISCHARGE GAL/MIN	SPECIFIC CONDUCT.	TEMP ºC	PH
T-0 *	07-10-79			4	560	6	
T-0 ***	09-30-86	9100	TKn	1.3	535	5.7	8.7
T-1 **	10-28-85			4	516	19	7.8
T-1 ***	09-30-86	9100	TKn	1.82	430	7.2	8.6
T-4 *	07-18-79			4	580	6	
T-4 *	07-14-81			1.3	640	7.5	
T-4 *	07-30-81			1.3	660	7.5	
T-4 *	08-20-81			1.1	720	7	
T-4 *	09-23-81			1.2	650	7.5	
T-4 *	05-21-82			5	660	7	
T-4 *	06-23-82			5	670	6.5	
T-4 *	07-15-82			4.8	660	6	
T-4 *	08-10-82			3.6	640	7.5	
T-4 *	09-02-82			2.6	660	7.5	
T-4 **	10-28-85			2	635	19	7.6
T-4 ***	09-30-86	9200	TKn	0.17	685	6.4	7.7
T-5 *	08-16-79			4	500	6.5	
T-5 **	10-28-85			3	586	18	7.6
T-5 ***	09-30-86	9050	TKn	1.88	620	8.1	9.4
T-6 *	07-12-79			0.5	940	8	
T-6 *	07-15-81			0.6	1140	9	
T-6 **	10-28-85			5	932	18	7.5
T-6 ***	9-30-86	8100	TKn	2.15	996	7.7	8.6
T-7 *	08-16-79			3.2	650	7	
T-7 *	07-15-81			2.8	680	7	
T-7 **	10-28-85			2	942	16	7.4
T-7 ***	09-30-86	8800	TKn	1.4	831	8	9.2

TRAIL MOUNTAIN COAL COMPANY SPRING MONITORING

SPRING ID	DATE	ELEV	WATER BEARING ZONE	DISCHARGE GAL/MIN	SPECIFIC CONDUCT.	TEMP ºC	PH
T-10 **	10-28-85			2	711	16	7.6
T-10 ***	09-30-86	8600	TKn	0.78	730	6.1	9.3
T-11 *	07-12-79			5.1	560	6.5	
T-11 *	07-15-81			2.6	700	7.5	
T-11 *	07-30-81			2.5	740	7	
T-11 *	08-20-81			2.2	740	8.5	
T-11 *	09-23-81			2.6	720	8	
T-11 *	05-21-82			9.7	680	6.5	
T-11 *	06-23-82			6.4	690	7.5	
T-11 *	07-15-82			5.3	700	7	
T-11 *	08-10-82			5	690	7.5	
T-11 *	09-02-82			4.4	700	8	
T-11 **	10-28-85			8	820	17	7.6
T-11 ***	09-30-86	8700	TKn	4	865	8.4	8.8
T-12 **	10-28-85			2	822	17	8.5
T-12 ***	09-30-86	8680	TKn	0.67	833	6.6	9.6
T-14 **	10-28-85			1	1630	13	7.4
T-14 ***	09-30-86	8000	Kp	1.5	405	4	8.8
T-14A ***	09-30-86	8700	TKn	1.43	624	7.7	9
TM-21 *	07-10-79			32	520	6	
TM-21 *	07-14-81			12.4	560	7	
TM-21 *	07-30-81			10.3	580	6.5	
TM-21 *	08-20-81			7.6	600	7	
TM-21 *	09-23-81			7.6	580	6.5	
TM-21 *	05-21-82			44	570	6.5	
TM-21 *	06-23-82			28	580	6.5	
TM-21 *	07-15-82			20	580	6	
TM-21 *	08-10-82			12.6	620	7	
TM-21 *	09-02-82			13.5	600	7	
TM-21 **	10-28-85			2	710	18	7.3
TM-21 ***	09-30-86	9000	TKn	1.25	734	7.3	8.2

TRAIL MOUNTAIN COAL COMPANY SPRING MONITORING

SPRING ID	DATE	ELEV.	WATER BEARING ZONE	DISCHARGE GAL/MIN	SPECIFIC CONDUCT.	TEMP ºC	PH
TM-22 *	07-14-81			5	495	8	
TM-22 *	07-30-81			6.1	520	8	
TM-22 *	08-20-81			5.3	540	6	
TM-22 *	09-23-81			5.1	520	6.5	
TM-22 *	05-21-82			40	520	6.5	
TM-22 *	06-23-82			28	510	6.5	
TM-22 *	07-15-82			23	520	6	
TM-22 *	08-10-82			11.2	600	6.5	
TM-22 *	09-02-82			12.4	510	7	
TM-22 **	10-28-85			3	521	18	7.5
TM-22 ***	09-30-86	9200	TKn	4	555	7.7	8.7
TM-23 *	07-14-81			80	650	8.5	
TM-23 *	07-30-81			76	640	8	
TM-23 *	08-20-81			73	640	8	
TM-23 *	09-24-81			76	660	8	
TM-23 *	05-20-82			80			
TM-23 *	06-23-82			76	670	8	
TM-23 *	07-17-82			98	670	7.5	
TM-23 *	08-10-82			98	660	8.5	
TM-23 *	09-08-82			110	600	8.5	
TM-23 **	10-28-85			4	705	13	7.5
TM-23 ***	09-30-86	7600	Kb	22.56	694	8.2	8.7

* = USGS
** = JBR
*** = TMCC

NOTE: T-6, TM-21 AND TM-22 ARE DEVELOPED SPRINGS

CERTIFICATE OF ANALYSIS

STANDARD LABORATORIES, INC.

). Box 1140, Huntington, Utah 84528 801-653-2314

Lab. No. 8600
Date Rec'd 10-2-86
Date Sampled 9-30-86
Time Sampled 1345

Client: TRAIL MOUNTAIN COAL CO.
PO BOX 370
ORANGEVILLE, UT 84537

Sample ID: T-6

Acidity	< 1.0	mg/l $CaCO_3$
Alkalinity, Total	330	mg/l $CaCO_3$
Alkalinity, Bicarbonate	403	mg/l ~~$CaCO_3$~~ HCO_3
Alkalinity, Carbonate	< 1.0	mg/l $CaCO_3$
Chloride	55.0	mg/l
Coliform, Fecal		MPN/100 ml
Coliform, Total		MPN/100 ml
Conductivity	1100	umhos/cm
Fluoride	0.23	mg/l
Hardness, Total		mg/l $CaCO_3$
trogen, Ammonia		mg/l
trogen, Nitrate	0.11	mg/l
Nitrogen, Nitrite		mg/l
Oil & Grease	< 0.5	mg/l
pH	7.10	Units
Phosphorus, Ortho	0.03	mg/l
Phosphorus, Total	0.03	mg/l
Solids, Total Dissolved	618	mg/l
Solids, Total Suspended	< 0.5	mg/l
Sulfate	160	mg/l
Sulfide		mg/l
Turbidity	1.0	NTU
Total Cations	11.52	meq/l
Total Anions	11.50	meq/l

Aluminum	< 0.05	mg/l
Arsenic	< 0.001	mg/l
Barium	< 0.1	mg/l
Beryllium		mg/l
Boron	0.16	mg/l
Cadmium	< 0.005	mg/l
Calcium	62	mg/l
Chromium	< 0.05	mg/l
Copper	< 0.02	mg/l
Iron	0.06	mg/l
Lead	< 0.05	mg/l
Magnesium	58	mg/l
Manganese	< 0.01	mg/l
Mercury	< 0.2	ug/l
Nickel	< 0.04	mg/l
Potassium	2	mg/l
Selenium	< 0.005	mg/l
Silica		mg/l
Sodium	83	mg/l
Vanadium	< 0.2	mg/l
Zinc	0.016	mg/l

Analyst: [signature]

Respectfully submitted [signature]

Certified Environmental Laboratory

CERTIFICATE OF ANALYSIS

STANDARD LABORATORIES, INC.
). Box 1140, Huntington, Utah 84528 801-653-2314

Lab. No.	8601
Date Rec'd	10-2-86
Date Sampled	9-30-86
Time Sampled	1540

Client: TRAIL MOUNTAIN COAL CO.
PO BOX 370
ORANGEVILLE, UT 84537

Sample ID: T-10

Parameter	Result	Units
Acidity	<1.0	mg/l $CaCO_3$
Alkalinity, Total	315	mg/l $CaCO_3$
Alkalinity, Bicarbonate	384	mg/l ~~$CaCO_3$~~ HCO_3
Alkalinity, Carbonate	<1.0	mg/l $CaCO_3$
Chloride	33.9	mg/l
Coliform, Fecal		MPN/100 ml
Coliform, Total		MPN/100 ml
Conductivity	800	umhos/cm
Fluoride	0.22	mg/l
Hardness, Total		mg/l $CaCO_3$
...rogen, Ammonia		mg/l
...rogen, Nitrate	0.15	mg/l
Nitrogen, Nitrite		mg/l
Oil & Grease	<0.5	mg/l
pH	7.60	Units
Phosphorus, Ortho	0.04	mg/l
Phosphorus, Total	0.04	mg/l
Solids, Total Dissolved	500	mg/l
Solids, Total Suspended	89.0	mg/l
Sulfate	30	mg/l
Sulfide		mg/l
Turbidity	33	NTU
Total Cations	7.95	meq/l
Total Anions	7.89	meq/l

Parameter	Result	Units
Aluminum	<0.05	mg/l
Arsenic	<0.001	mg/l
Barium	<0.1	mg/l
Beryllium		mg/l
Boron	0.17	mg/l
Cadmium	<0.005	mg/l
Calcium	42	mg/l
Chromium	<0.05	mg/l
Copper	<0.02	mg/l
Iron	1.80	mg/l
Lead	<0.05	mg/l
Magnesium	49	mg/l
Manganese	0.01	mg/l
Mercury	<0.2	ug/l
Nickel	<0.04	mg/l
Potassium	2	mg/l
Selenium	<0.005	mg/l
Silica		mg/l
Sodium	41	mg/l
Vanadium	<0.2	mg/l
Zinc	<0.005	mg/l

Analyst: [signature]

Respectfully submitted Bob Cunningham

Certified Environmental Laboratory

CERTIFICATE OF ANALYSIS

STANDARD LABORATORIES, INC.
P.O. Box 1140, Huntington, Utah 84528 801-653-2314

Client: TRAIL MOUNTAIN COAL COMPANY Sample ID: T-11
PO BOX 370
ORANGEVILLE, UT 84537

Lab. No. 8602
Date Rec'd 10-2-86
Date Sampled 9-30-86
Time Sampled

Parameter	Result	Units
Acidity	<1.0	mg/l $CaCO_3$
Alkalinity, Total	275	mg/l $CaCO_3$
Alkalinity, Bicarbonate	336	mg/l ~~$CaCO_3$~~ HCO_3
Alkalinity, Carbonate	<1.0	mg/l $CaCO_3$
Chloride	88.6	mg/l
Coliform, Fecal		MPN/100 ml
Coliform, Total		MPN/100 ml
Conductivity	905	umhos/cm
Fluoride	0.23	mg/l
Hardness, Total		mg/l $CaCO_3$
Nitrogen, Ammonia		mg/l
Nitrogen, Nitrate	0.10	mg/l
Nitrogen, Nitrite		mg/l
Oil & Grease	<0.5	mg/l
pH	7.00	Units
Phosphorus, Ortho	0.03	mg/l
Phosphorus, Total	0.04	mg/l
Solids, Total Dissolved	461	mg/l
Solids, Total Suspended	69.0	mg/l
Sulfate	48	mg/l
Sulfide		mg/l
Turbidity	11	NTU
Total Cations	9.01	meq/l
Total Anions	9.01	meq/l

Parameter	Result	Units
Aluminum	<0.05	mg/l
Arsenic	<0.001	mg/l
Barium	<0.1	mg/l
Beryllium		mg/l
Boron	0.26	mg/l
Cadmium	<0.005	mg/l
Calcium	50	mg/l
Chromium	<0.05	mg/l
Copper	<0.02	mg/l
Iron	0.21	mg/l
Lead	<0.05	mg/l
Magnesium	47	mg/l
Manganese	0.04	mg/l
Mercury	<0.2	ug/l
Nickel	<0.04	mg/l
Potassium	2	mg/l
Selenium	<0.005	mg/l
Silica		mg/l
Sodium	60	mg/l
Vanadium	<0.2	mg/l
Zinc	0.009	mg/l

Analyst:

Respectfully submitted *Bil Cunningham*

Certified Environmental Laboratory

CERTIFICATE OF ANALYSIS

STANDARD LABORATORIES, INC.
). Box 1140, Huntington, Utah 84528 801-653-2314

Lab. No. 8603
Date Rec'd 10-2-86
Date Sampled 9-30-86
Time Sampled 1300

Client: TRAIL MOUNTAIN COAL CO.
PO BOX 370
ORANGEVILLE, UT 84537

Sample ID: T-12

Parameter	Result	Units
Acidity	< 1.0	mg/l $CaCO_3$
Alkalinity, Total	344	mg/l $CaCO_3$
Alkalinity, Bicarbonate	420	mg/l ~~$CaCO_3$~~ HCO_3
Alkalinity, Carbonate	< 1.0	mg/l $CaCO_3$
Chloride	57.2	mg/l
Coliform, Fecal		MPN/100 ml
Coliform, Total		MPN/100 ml
Conductivity	910	umhos/cm
Fluoride	0.36	mg/l
Hardness, Total		mg/l $CaCO_3$
Nitrogen, Ammonia		mg/l
Nitrogen, Nitrate	0.10	mg/l
Nitrogen, Nitrite		mg/l
Oil & Grease	< 0.5	mg/l
pH	7.95	Units
Phosphorus, Ortho	0.07	mg/l
Phosphorus, Total	0.08	mg/l
Solids, Total Dissolved	502	mg/l
Solids, Total Suspended	12.0	mg/l
Sulfate	60	mg/l
Sulfide		mg/l
Turbidity	5.0	NTU
Total Cations	9.83	meq/l
Total Anions	9.76	meq/l

Parameter	Result	Units
Aluminum	< 0.05	mg/l
Arsenic	< 0.001	mg/l
Barium	< 0.1	mg/l
Beryllium		mg/l
Boron	0.26	mg/l
Cadmium	< 0.005	mg/l
Calcium	42	mg/l
Chromium	< 0.05	mg/l
Copper	< 0.02	mg/l
Iron	0.05	mg/l
Lead	< 0.05	mg/l
Magnesium	47	mg/l
Manganese	< 0.01	mg/l
Mercury	< 0.2	ug/l
Nickel	< 0.04	mg/l
Potassium	2	mg/l
Selenium	< 0.005	mg/l
Silica		mg/l
Sodium	88	mg/l
Vanadium	< 0.2	mg/l
Zinc	< 0.005	mg/l

Analyst;

Respectfully submitted Bob Cunningham

Certified Environmental Laboratory

CERTIFICATE OF ANALYSIS

STANDARD LABORATORIES, INC.

). Box 1140, Huntington, Utah 84528 801-653-2314

Lab. No. 8606
Date Rec'd 10-2-86
Date Sampled 9-30-86
Time Sampled ______

Client: TRAIL MOUNTAIN COAL CO.
PO BOX 370
ORANGEVILLE, UT 84537

Sample ID: TM23

Parameter	Result	Units
Acidity		mg/l $CaCO_3$
Alkalinity, Total		mg/l $CaCO_3$
Alkalinity, Bicarbonate	359	mg/l ~~$CaCO_3$~~ HCO_3
Alkalinity, Carbonate	<1.0	mg/l $CaCO_3$
Chloride	14.8	mg/l
Coliform, Fecal		MPN/100 ml
Coliform, Total		MPN/100 ml
Conductivity		umhos/cm
Fluoride		mg/l
Hardness, Total	355	mg/l $CaCO_3$
·trogen, Ammonia		mg/l
trogen, Nitrate		mg/l
Nitrogen, Nitrite		mg/l
Oil & Grease		mg/l
pH		Units
Phosphorus, Ortho		mg/l
Phosphorus, Total		mg/l
Solids, Total Dissolved	385	mg/l
Solids, Total Suspended		mg/l
Sulfate	70	mg/l
Sulfide		mg/l
Turbidity		NTU
Total Cations	7.76	meq/l
Total Anions	7.77	meq/l

Parameter	Result	Units
Aluminum		mg/l
Arsenic		mg/l
Barium		mg/l
Beryllium		mg/l
Boron		mg/l
Cadmium		mg/l
Calcium	68	mg/l
Chromium		mg/l
Copper		mg/l
Iron Diss.	<0.05	mg/l
Lead		mg/l
Magnesium	40	mg/l
Manganese	<0.01	mg/l
Mercury		ug/l
Nickel		mg/l
Potassium	2	mg/l
Selenium		mg/l
Silica		mg/l
Sodium	14	mg/l
Vanadium		mg/l
Zinc		mg/l

Analyst: [signature]

Respectfully submitted [signature]

Certified Environmental Laboratory

MOUNTAIN
STATES
ANALYTICAL

CERTIFICATE OF ANALYSIS

Client:

Trail Mountain Coal Co.
P.O. Box 370
Orangeville, Utah 84537

Sample ID: T-0

Lab No. 8629
Date Rec'd 10-07-86
Date Sampled 09-30-86
Time Sampled

Acidity	<1.0	mg/lCaCO3
Alkalinity, Total	250	mg/lCaCO3
Alkalinity, Bicarbonate	305	mg/HCO3
Alkalinity, Carbonate	<1.0	mg/lCaCO3
Chloride	23.3	mg/l
Coliform, Fecal	----	MPN/100ml
Coliform, Total	----	MPN/100ml
Conductivity	550	umhos/cm
Fluoride	0.17	mg/l
Hardness, Total	----	mglCaCO3
Nitrogen, Ammonia	----	mg/l
Nitrogen, Nitrate	0.12	mg/l
Nitrogen, Nitrite	----	mg/l
Oil & Grease	<0.5	mg/l
pH	8.24	Units
Phosphorus Ortho	0.09	mg/l
Phosphorus, Total	0.10	mg/l
Solids, Total Dissolved	294	mg/l
Solids, Total Suspended	18.0	mg/l
Sulfate	17	mg/l
Sulfide	----	mg/l
Turbidity	18	NTU
Total Cations	5.98	meq/l
Total Anions	6.02	meq/l

Aluminum	<0.05	mg/l
Arsenic	<0.001	mg/l
Barium	<0.1	mg/l
Beryllium	----	mg/l
Boron	0.10	mg/l
Cadmium	<0.005	mg/l
Calcium	50.0	mg/l
Chromium	<0.05	mg/l
Copper	<0.02	mg/l
Iron	<0.05	mg/l
Lead	<0.05	mg/l
Magnesium	31.6	mg/l
Maganese	0.07	mg/l
Mercury	<0.2	ug/l
Nickel	<0.04	mg/l
Potassium	2.6	mg/l
Selenium	<0.005	mg/l
Silica	----	mg/l
Sodium	18.8	mg/l
Vanadium	<0.2	mg/l
Zinc	<0.005	mg/l

Respectfully submitted David [signature]

MOUNTAIN
STATES
ANALYTICAL

CERTIFICATE OF ANALYSIS

Client: Sample ID: T-1

Trail Mountain Coal Co.
P.O. Box 370
Orangeville, Utah 84537

Lab No.	8630
Date Rec'd	10-07-86
Date Sampled	09-30-86
Time Sampled	

Acidity	<1.0	mg/lCaCO3
Alkalinity, Total	304	mg/lCaCO3
Alkalinity, Bicarbonate	371	mg/HCO3
Alkalinity, Carbonate	<1.0	mg/lCaCO3
Chloride	10.8	mg/l
Coliform, Fecal		MPN/100ml
Coliform, Total		MPN/100ml
Conductivity	620	umhos/cm
Fluoride	0.27	mg/l
Hardness, Total		mglCaCO3
Nitrogen, Ammonia		mg/l
Nitrogen, Nitrate	0.10	mg/l
Nitrogen, Nitrite		mg/l
Oil & Grease	<0.5	mg/l
pH	8.20	Units
Phosphorus Ortho	0.09	mg/l
Phosphorus, Total	0.09	mg/l
Solids, Total Dissolved	348	mg/l
Solids, Total Suspended	18.0	mg/l
Sulfate	30	mg/l
Sulfide		mg/l
Turbidity	17	NTU
Total Cations	7.09	meq/l
Total Anions	7.02	meq/l

Aluminum	<0.05	mg/l
Arsenic	<0.001	mg/l
Barium	<0.1	mg/l
Beryllium		mg/l
Boron	0.09	mg/l
Cadmium	<0.005	mg/l
Calcium	50.0	mg/l
Chromium	<0.05	mg/l
Copper	<0.02	mg/l
Iron	0.11	mg/l
Lead	<0.05	mg/l
Magnesium	35.3	mg/l
Maganese	0.03	mg/l
Mercury	<0.2	ug/l
Nickel	<0.04	mg/l
Potassium	2.9	mg/l
Selenium	<0.005	mg/l
Silica		mg/l
Sodium	37.3	mg/l
Vanadium	<0.2	mg/l
Zinc	0.014	mg/l

Respectfully submitted David S[illegible]

MOUNTAIN
STATES
ANALYTICAL

CERTIFICATE OF ANALYSIS

Client: Sample ID: T-4

Trail Mountain Coal Co.
P.O. Box 370
Orangeville, Utah 84537

Lab No.	8631
Date Rec'd	10-07-86
Date Sampled	09-30-86
Time Sampled	

Acidity	<1.0	mg/1CaCO3	Aluminum	<0.05	mg/l
Alkalinity, Total	263	mg/1CaCO3	Arsenic	<0.001	mg/l
Alkalinity, Bicarbonate	321	mg/HCO3	Barium	<0.1	mg/l
Alkalinity, Carbonate	<1.0	mg/1CaCO3	Beryllium		mg/l
Chloride	16.5	mg/l	Boron	0.10	mg/l
Coliform, Fecal		MPN/100ml	Cadmium	<0.005	mg/l
Coliform, Total		MPN/100ml	Calcium	36.0	mg/l
Conductivity	700	umhos/cm	Chromium	<0.05	mg/l
Fluoride	0.29	mg/l	Copper	<0.02	mg/l
Hardness, Total		mg1CaCO3	Iron	0.33	mg/l
Nitrogen, Ammonia		mg/l	Lead	<0.05	mg/l
Nitrogen, Nitrate	0.11	mg/l	Magnesium	19.5	mg/l
Nitrogen, Nitrite		mg/l	Maganese	0.07	mg/l
Oil & Grease	<0.5	mg/l	Mercury	<0.2	ug/l
pH	8.26	Units	Nickel	<0.04	mg/l
Phosphorus Ortho	0.08	mg/l	Potassium	5.5	mg/l
Phosphorus, Total	0.11	mg/l	Selenium	<0.005	mg/l
Solids, Total Dissolved	400	mg/l	Silica		mg/l
Solids, Total Suspended	50.0	mg/l	Sodium	88.0	mg/l
Sulfate	75	mg/l	Vanadium	<0.2	mg/l
Sulfide		mg/l	Zinc	0.006	mg/l
Turbidity	45	NTU			
Total Cations	7.36	meq/l			
Total Anions	7.30	meq/l			

Respectfully submitted [signature]

MOUNTAIN
STATES
ANALYTICAL

CERTIFICATE OF ANALYSIS

Client: Sample ID: T-5

Trail Mountain Coal Co.
P.O. Box 370
Orangeville, Utah 84537

Lab No.	8632
Date Rec'd	10-07-86
Date Sampled	09-30-86
Time Sampled	

Acidity	<1.0	mg/lCaCO3
Alkalinity, Total	374	mg/lCaCO3
Alkalinity, Bicarbonate	456	mg/HCO3
Alkalinity, Carbonate	<1.0	mg/lCaCO3
Chloride	15.3	mg/l
Coliform, Fecal		MPN/100ml
Coliform, Total		MPN/100ml
Conductivity	750	umhos/cm
Fluoride	0.29	mg/l
Hardness, Total		mglCaCO3
Nitrogen, Ammonia		mg/l
Nitrogen, Nitrate	0.12	mg/l
Nitrogen, Nitrite		mg/l
Oil & Grease	<0.5	mg/l
pH	8.20	Units
Phosphorus Ortho	0.09	mg/l
Phosphorus, Total	0.11	mg/l
Solids, Total Dissolved	412	mg/l
Solids, Total Suspended	40.0	mg/l
Sulfate	25	mg/l
Sulfide		mg/l
Turbidity	38	NTU
Total Cations	8.45	meq/l
Total Anions	8.45	meq/l

Aluminum	<0.05	mg/l
Arsenic	<0.001	mg/l
Barium	<0.1	mg/l
Beryllium		mg/l
Boron	0.10	mg/l
Cadmium	<0.005	mg/l
Calcium	54.0	mg/l
Chromium	<0.05	mg/l
Copper	<0.02	mg/l
Iron	0.11	mg/l
Lead	<0.05	mg/l
Magnesium	45.0	mg/l
Maganese	0.04	mg/l
Mercury	<0.2	ug/l
Nickel	<0.04	mg/l
Potassium	4.0	mg/l
Selenium	<0.005	mg/l
Silica		mg/l
Sodium	44.8	mg/l
Vanadium	<0.2	mg/l
Zinc	0.015	mg/l

Respectfully submitted David Ganus [signature]

MOUNTAIN
STATES
ANALYTICAL

CERTIFICATE OF ANALYSIS

Client:

Trail Mountain Coal Co.
P.O. Box 370
Orangeville, Utah 84537

Sample ID: T-7

Lab No.	8633
Date Rec'd	10-07-86
Date Sampled	09-30-86
Time Sampled	

Acidity	<1.0	mg/lCaCO3	Aluminum	<0.05	mg/l
Alkalinity, Total	367	mg/lCaCO3	Arsenic	<0.001	mg/l
Alkalinity, Bicarbonate	448	mg/HCO3	Barium	<0.1	mg/l
Alkalinity, Carbonate	<1.0	mg/lCaCO3	Beryllium		mg/l
Chloride	26.6	mg/l	Boron	0.06	mg/l
Coliform, Fecal		MPN/100ml	Cadmium	<0.005	mg/l
Coliform, Total		MPN/100ml	Calcium	34.0	mg/l
Conductivity	850	umhos/cm	Chromium	<0.05	mg/l
Fluoride	0.34	mg/l	Copper	<0.02	mg/l
Hardness, Total		mglCaCO3	Iron	0.06	mg/l
Nitrogen, Ammonia		mg/l	Lead	<0.05	mg/l
Nitrogen, Nitrate	0.06	mg/l	Magnesium	49.9	mg/l
Nitrogen, Nitrite		mg/l	Maganese	<0.01	mg/l
Oil & Grease	<0.5	mg/l	Mercury	<0.2	ug/l
pH	8.21	Units	Nickel	<0.04	mg/l
Phosphorus Ortho	0.07	mg/l	Potassium	3.5	mg/l
Phosphorus, Total	0.09	mg/l	Selenium	<0.005	mg/l
Solids, Total Dissolved	424	mg/l	Silica		mg/l
Solids, Total Suspended	1.0	mg/l	Sodium	63.9	mg/l
Sulfate	25	mg/l	Vanadium	<0.2	mg/l
Sulfide		mg/l	Zinc	0.013	mg/l
Turbidity	1.0	NTU			
Total Cations	8.66	meq/l			
Total Anions	8.63	meq/l			

Respectfully submitted ______________________

MOUNTAIN STATES ANALYTICAL

CERTIFICATE OF ANALYSIS

Client:		Sample ID: T-14		Lab No.	8634
				Date Rec'd	10-07-86
Trail Mountain Coal Co.				Date Sampled	09-30-86
P.O. Box 370				Time Sampled	
Orangeville, Utah 84537					

Acidity	<1.0	mg/1CaCO3	Aluminum	<0.05	mg/1
Alkalinity, Total	366	mg/1CaCO3	Arsenic	<0.001	mg/1
Alkalinity, Bicarbonate	446	mg/HCO3	Barium	<0.1	mg/1
Alkalinity, Carbonate	<1.0	mg/1CaCO3	Beryllium		mg/1
Chloride	65.4	mg/1	Boron	0.08	mg/1
Coliform, Fecal		MPN/100ml	Cadmium	<0.005	mg/1
Coliform, Total		MPN/100ml	Calcium	56.0	mg/1
Conductivity	1550	umhos/cm	Chromium	<0.05	mg/1
Fluoride	0.29	mg/1	Copper	<0.02	mg/1
Hardness, Total		mg1CaCO3	Iron	<0.05	mg/1
Nitrogen, Ammonia		mg/1	Lead	<0.05	mg/1
Nitrogen, Nitrate	0.04	mg/1	Magnesium	86.3	mg/1
Nitrogen, Nitrite		mg/1	Maganese	0.02	mg/1
Oil & Grease	<0.5	mg/1	Mercury	<0.2	ug/1
pH	8.25	Units	Nickel	<0.04	mg/1
Phosphorus Ortho	0.07	mg/1	Potassium	6.5	mg/1
Phosphorus, Total	0.11	mg/1	Selenium	<0.005	mg/1
Solids, Total Dissolved	877	mg/1	Silica		mg/1
Solids, Total Suspended	<0.5	mg/1	Sodium	132.9	mg/1
Sulfate	310	mg/1	Vanadium	<0.2	mg/1
Sulfide		mg/1	Zinc	0.009	mg/1
Turbidity	1.0	NTU			
Total Cations	15.84	meq/1			
Total Anions	15.63	meq/1			

Respectfully submitted ____________

MOUNTAIN
STATES
ANALYTICAL

CERTIFICATE OF ANALYSIS

Client:

Trail Mountain Coal Co.
P.O. Box 370
Orangeville, Utah 84537

Sample ID: T-0

Lab No.	1003
Date Rec'd	10-21-86
Date Sampled	10-17-86
Time Sampled	1025

Acidity	0	mg/1CaCO3
Alkalinity, Total	260	mg/1CaCO3
Alkalinity, Bicarbonate	327	mg/HCO3
Alkalinity, Carbonate	0	mg/1CaCO3
Chloride	23.1	mg/1
Coliform, Fecal		MPN/100ml
Coliform, Total		MPN/100ml
Conductivity	562	umhos/cm
Fluoride	0.17	mg/1
Hardness, Total		mg1CaCO3
Nitrogen, Ammonia		mg/1
Nitrogen, Nitrate	0.10	mg/1
Nitrogen, Nitrite		mg/1
Oil & Grease	<0.5	mg/1
pH	8.24	Units
Phosphorus Ortho	0.10	mg/1
Phosphorus, Total	0.14	mg/1
Solids, Total Dissolved	297	mg/1
Solids, Total Suspended	10.0	mg/1
Sulfate	13	mg/1
Sulfide		mg/1
Turbidity	16	NTU
Total Cations	6.10	meq/1
Total Anions	6.13	meq/1

Aluminum	<0.05	mg/1
Arsenic	<0.001	mg/1
Barium	<0.1	mg/1
Beryllium		mg/1
Boron	0.10	mg/1
Cadmium	<0.005	mg/1
Calcium	50.0	mg/1
Chromium	<0.05	mg/1
Copper	<0.02	mg/1
Iron	0.07	mg/1
Lead	<0.05	mg/1
Magnesium	32.8	mg/1
Maganese	0.05	mg/1
Mercury	<0.2	ug/1
Nickel	<0.04	mg/1
Potassium	2.5	mg/1
Selenium	<0.005	mg/1
Silica		mg/1
Sodium	19.4	mg/1
Vanadium	<0.2	mg/1
Zinc	<0.005	mg/1

Respectfully submitted David Hanuy

MOUNTAIN
STATES
ANALYTICAL

CERTIFICATE OF ANALYSIS

Client:	Sample ID: T-1	Lab No.	1004
		Date Rec'd	10-21-86
Trail Mountain Coal Co.		Date Sampled	10-17-86
P.O. Box 370		Time Sampled	1100
Orangeville, Utah 84537			

Acidity	0	mg/1CaCO3	Aluminum	<0.05	mg/l
Alkalinity, Total	414	mg/1CaCO3	Arsenic	<0.001	mg/l
Alkalinity, Bicarbonate	492	mg/HCO3	Barium	<0.1	mg/l
Alkalinity, Carbonate	10	mg/1CaCO3	Beryllium		mg/l
Chloride	11.0	mg/l	Boron	0.11	mg/l
Coliform, Fecal		MPN/100ml	Cadmium	<0.005	mg/l
Coliform, Total		MPN/100ml	Calcium	50.0	mg/l
Conductivity	726	umhos/cm	Chromium	<0.05	mg/l
Fluoride	0.25	mg/l	Copper	<0.02	mg/l
Hardness, Total		mg1CaCO3	Iron	<0.05	mg/l
Nitrogen, Ammonia		mg/l	Lead	<0.05	mg/l
Nitrogen, Nitrate	0.10	mg/l	Magnesium	35.3	mg/l
Nitrogen, Nitrite		mg/l	Maganese	<0.01	mg/l
Oil & Grease	<0.5	mg/l	Mercury	<0.2	ug/l
pH	8.43	Units	Nickel	<0.04	mg/l
Phosphorus Ortho	0.09	mg/l	Potassium	2.9	mg/l
Phosphorus, Total	0.11	mg/l	Selenium	<0.005	mg/l
Solids, Total Dissolved	395	mg/l	Silica		mg/l
Solids, Total Suspended	10.0	mg/l	Sodium	38.4	mg/l
Sulfate	10	mg/l	Vanadium	<0.2	mg/l
Sulfide		mg/l	Zinc	<0.005	mg/l
Turbidity	14	NTU			
Total Cations	7.14	meq/l			
Total Anions	7.47	meq/l			

Respectfully submitted David Daniery

MOUNTAIN
STATES
ANALYTICAL

CERTIFICATE OF ANALYSIS

Client: Sample ID: T-4

Trail Mountain Coal Co.
P.O. Box 370
Orangeville, Utah 84537

Lab No.	1005
Date Rec'd	10-21-86
Date Sampled	10-17-86
Time Sampled	1133

Acidity	0	mg/1CaCO3
Alkalinity, Total	309	mg/1CaCO3
Alkalinity, Bicarbonate	377	mg/HCO3
Alkalinity, Carbonate	0	mg/1CaCO3
Chloride	18.0	mg/1
Coliform, Fecal		MPN/100ml
Coliform, Total		MPN/100ml
Conductivity	864	umhos/cm
Fluoride	0.26	mg/1
Hardness, Total		mg1CaCO3
Nitrogen, Ammonia		mg/1
Nitrogen, Nitrate	0.10	mg/1
Nitrogen, Nitrite		mg/1
Oil & Grease	<0.5	mg/1
pH	8.29	Units
Phosphorus Ortho	0.09	mg/1
Phosphorus, Total	0.11	mg/1
Solids, Total Dissolved	456	mg/1
Solids, Total Suspended	21.0	mg/1
Sulfate	80	mg/1
Sulfide		mg/1
Turbidity	30	NTU
Total Cations	8.49	meq/1
Total Anions	8.37	meq/1

Aluminum	<0.05	mg/1
Arsenic	<0.001	mg/1
Barium	<0.1	mg/1
Beryllium		mg/1
Boron	0.11	mg/1
Cadmium	<0.005	mg/1
Calcium	44.0	mg/1
Chromium	<0.05	mg/1
Copper	<0.02	mg/1
Iron	0.48	mg/1
Lead	<0.05	mg/1
Magnesium	19.4	mg/1
Maganese	0.19	mg/1
Mercury	<0.2	ug/1
Nickel	<0.04	mg/1
Potassium	5.1	mg/1
Selenium	<0.005	mg/1
Silica		mg/1
Sodium	105.0	mg/1
Vanadium	<0.2	mg/1
Zinc	0.013	mg/1

Respectfully submitted David Ramey

MOUNTAIN
STATES
ANALYTICAL

CERTIFICATE OF ANALYSIS

Client:

Trail Mountain Coal Co.
P.O. Box 370
Orangeville, Utah 84537

Sample ID: T-5

Lab No.	1006
Date Rec'd	10-21-86
Date Sampled	10-17-86
Time Sampled	1200

Acidity	0	mg/1CaCO3	Aluminum	<0.05	mg/1
Alkalinity, Total	424	mg/1CaCO3	Arsenic	<0.001	mg/1
Alkalinity, Bicarbonate	517	mg/HCO3	Barium	<0.1	mg/1
Alkalinity, Carbonate	0	mg/1CaCO3	Beryllium		mg/1
Chloride	18.2	mg/1	Boron	0.10	mg/1
Coliform, Fecal		MPN/100ml	Cadmium	<0.005	mg/1
Coliform, Total		MPN/100ml	Calcium	56.0	mg/1
Conductivity	972	umhos/cm	Chromium	<0.05	mg/1
Fluoride	0.29	mg/1	Copper	<0.02	mg/1
Hardness, Total		mg1CaCO3	Iron	<0.05	mg/1
Nitrogen, Ammonia		mg/1	Lead	<0.05	mg/1
Nitrogen, Nitrate	0.08	mg/1	Magnesium	53.5	mg/1
Nitrogen, Nitrite		mg/1	Maganese	<0.01	mg/1
Oil & Grease	<0.5	mg/1	Mercury	<0.2	ug/1
pH	8.10	Units	Nickel	<0.04	mg/1
Phosphorus Ortho	0.07	mg/1	Potassium	3.7	mg/1
Phosphorus, Total	0.09	mg/1	Selenium	<0.005	mg/1
Solids, Total Dissolved	469	mg/1	Silica		mg/1
Solids, Total Suspended	15.0	mg/1	Sodium	52.7	mg/1
Sulfate	30	mg/1	Vanadium	<0.2	mg/1
Sulfide		mg/1	Zinc	0.010	mg/1
Turbidity	20	NTU			
Total Cations	9.58	meq/1			
Total Anions	9.63	meq/1			

Respectfully submitted David Deaney

MOUNTAIN
STATES
ANALYTICAL

CERTIFICATE OF ANALYSIS

Client: Sample ID: T-6

Trail Mountain Coal Co.
P.O. Box 370
Orangeville, Utah 84537

Lab No.	1007
Date Rec'd	10-21-86
Date Sampled	10-17-86
Time Sampled	1335

Acidity	0	mg/lCaCO3	Aluminum	<0.05	mg/l
Alkalinity, Total	334	mg/lCaCO3	Arsenic	<0.001	mg/l
Alkalinity, Bicarbonate	407	mg/HCO3	Barium	<0.1	mg/l
Alkalinity, Carbonate	0	mg/lCaCO3	Beryllium		mg/l
Chloride	56.2	mg/l	Boron	0.09	mg/l
Coliform, Fecal		MPN/100ml	Cadmium	<0.005	mg/l
Coliform, Total		MPN/100ml	Calcium	60.0	mg/l
Conductivity	1086	umhos/cm	Chromium	<0.05	mg/l
Fluoride	0.30	mg/l	Copper	<0.02	mg/l
Hardness, Total		mglCaCO3	Iron	0.12	mg/l
Nitrogen, Ammonia		mg/l	Lead	<0.05	mg/l
Nitrogen, Nitrate	0.09	mg/l	Magnesium	54.7	mg/l
Nitrogen, Nitrite		mg/l	Maganese	<0.01	mg/l
Oil & Grease	<0.5	mg/l	Mercury	<0.2	ug/l
pH	8.26	Units	Nickel	<0.04	mg/l
Phosphorus Ortho	0.07	mg/l	Potassium	3.9	mg/l
Phosphorus, Total	0.09	mg/l	Selenium	<0.005	mg/l
Solids, Total Dissolved	570	mg/l	Silica		mg/l
Solids, Total Suspended	<0.5	mg/l	Sodium	74.5	mg/l
Sulfate	120	mg/l	Vanadium	<0.2	mg/l
Sulfide		mg/l	Zinc	0.015	mg/l
Turbidity	0.8	NTU			
Total Cations	10.83	meq/l			
Total Anions	10.78	meq/l			

Respectfully submitted [signature]

MOUNTAIN
STATES
ANALYTICAL

CERTIFICATE OF ANALYSIS

Client:

Trail Mountain Coal Co.
P.O. Box 370
Orangeville, Utah 84537

Sample ID: T-7

Lab No.	1008
Date Rec'd	10-21-86
Date Sampled	10-17-86
Time Sampled	1215

Acidity	0	mg/lCaCO3
Alkalinity, Total	388	mg/lCaCO3
Alkalinity, Bicarbonate	473	mg/HCO3
Alkalinity, Carbonate	0	mg/lCaCO3
Chloride	25.2	mg/l
Coliform, Fecal		MPN/100ml
Coliform, Total		MPN/100ml
Conductivity	870	umhos/cm
Fluoride	0.24	mg/l
Hardness, Total		mglCaCO3
Nitrogen, Ammonia		mg/l
Nitrogen, Nitrate	0.10	mg/l
Nitrogen, Nitrite		mg/l
Oil & Grease	<0.5	mg/l
pH	8.29	Units
Phosphorus Ortho	0.08	mg/l
Phosphorus, Total	0.09	mg/l
Solids, Total Dissolved	442	mg/l
Solids, Total Suspended	<0.5	mg/l
Sulfate	25	mg/l
Sulfide		mg/l
Turbidity	0.6	NTU
Total Cations	8.99	meq/l
Total Anions	9.00	meq/l

Aluminum	<0.05	mg/l
Arsenic	<0.001	mg/l
Barium	<0.1	mg/l
Beryllium		mg/l
Boron	0.08	mg/l
Cadmium	<0.005	mg/l
Calcium	40.0	mg/l
Chromium	<0.05	mg/l
Copper	<0.02	mg/l
Iron	<0.05	mg/l
Lead	<0.05	mg/l
Magnesium	48.6	mg/l
Maganese	<0.01	mg/l
Mercury	<0.2	ug/l
Nickel	<0.04	mg/l
Potassium	3.4	mg/l
Selenium	<0.005	mg/l
Silica		mg/l
Sodium	66.7	mg/l
Vanadium	<0.2	mg/l
Zinc	<0.005	mg/l

Respectfully submitted David Daniels

MOUNTAIN
STATES
ANALYTICAL

CERTIFICATE OF ANALYSIS

Client:	Sample ID: T-10	Lab No.	1009
		Date Rec'd	10-21-86
Trail Mountain Coal Co.		Date Sampled	10-17-86
P.O. Box 370		Time Sampled	1340
Orangeville, Utah 84537			

Acidity	0	mg/lCaCO3	Aluminum	<0.05	mg/l
Alkalinity, Total	340	mg/lCaCO3	Arsenic	<0.001	mg/l
Alkalinity, Bicarbonate	415	mg/HCO3	Barium	<0.1	mg/l
Alkalinity, Carbonate	0	mg/lCaCO3	Beryllium		mg/l
Chloride	34.5	mg/l	Boron	0.10	mg/l
Coliform, Fecal		MPN/100ml	Cadmium	<0.005	mg/l
Coliform, Total		MPN/100ml	Calcium	54.0	mg/l
Conductivity	840	umhos/cm	Chromium	<0.05	mg/l
Fluoride	0.26	mg/l	Copper	<0.02	mg/l
Hardness, Total		mglCaCO3	Iron	<0.05	mg/l
Nitrogen, Ammonia		mg/l	Lead	<0.05	mg/l
Nitrogen, Nitrate	0.06	mg/l	Magnesium	45.0	mg/l
Nitrogen, Nitrite		mg/l	Maganese	<0.01	mg/l
Oil & Grease	<0.5	mg/l	Mercury	<0.2	ug/l
pH	8.25	Units	Nickel	<0.04	mg/l
Phosphorus Ortho	0.09	mg/l	Potassium	3.4	mg/l
Phosphorus, Total	0.11	mg/l	Selenium	<0.005	mg/l
Solids, Total Dissolved	395	mg/l	Silica		mg/l
Solids, Total Suspended	1.0	mg/l	Sodium	37.3	mg/l
Sulfate	16	mg/l	Vanadium	<0.2	mg/l
Sulfide		mg/l	Zinc	0.016	mg/l
Turbidity	1.0	NTU			
Total Cations	8.11	meq/l			
Total Anions	8.12	meq/l			

Respectfully submitted David [signature]

MOUNTAIN
STATES
ANALYTICAL

CERTIFICATE OF ANALYSIS

Client: Sample ID: T-11

Trail Mountain Coal Co.
P.O. Box 370
Orangeville, Utah 84537

Lab No.	1010
Date Rec'd	10-21-86
Date Sampled	10-17-86
Time Sampled	1300

Acidity	0	mg/lCaCO3
Alkalinity, Total	278	mg/lCaCO3
Alkalinity, Bicarbonate	339	mg/HCO3
Alkalinity, Carbonate	0	mg/lCaCO3
Chloride	91.0	mg/l
Coliform, Fecal		MPN/100ml
Coliform, Total		MPN/100ml
Conductivity	936	umhos/cm
Fluoride	0.30	mg/l
Hardness, Total		mglCaCO3
Nitrogen, Ammonia		mg/l
Nitrogen, Nitrate	0.08	mg/l
Nitrogen, Nitrite		mg/l
Oil & Grease	<0.5	mg/l
pH	8.23	Units
Phosphorus Ortho	0.08	mg/l
Phosphorus, Total	0.11	mg/l
Solids, Total Dissolved	430	mg/l
Solids, Total Suspended	1.0	mg/l
Sulfate	20	mg/l
Sulfide		mg/l
Turbidity	0.8	NTU
Total Cations	8.58	meq/l
Total Anions	8.55	meq/l

Aluminum	<0.05	mg/l
Arsenic	<0.001	mg/l
Barium	<0.1	mg/l
Beryllium		mg/l
Boron	0.10	mg/l
Cadmium	<0.005	mg/l
Calcium	50.0	mg/l
Chromium	<0.05	mg/l
Copper	<0.02	mg/l
Iron	<0.05	mg/l
Lead	<0.05	mg/l
Magnesium	43.8	mg/l
Maganese	<0.01	mg/l
Mercury	<0.2	ug/l
Nickel	<0.04	mg/l
Potassium	3.7	mg/l
Selenium	<0.005	mg/l
Silica		mg/l
Sodium	55.0	mg/l
Vanadium	<0.2	mg/l
Zinc	<0.005	mg/l

Respectfully submitted David Garner

MOUNTAIN
STATES
ANALYTICAL

CERTIFICATE OF ANALYSIS

Client: Sample ID: T-14

Lab No.	1011
Date Rec'd	10-21-86
Date Sampled	10-17-86
Time Sampled	

Trail Mountain Coal Co.
P.O. Box 370
Orangeville, Utah 84537

Acidity	0	mg/lCaCO3
Alkalinity, Total	405	mg/lCaCO3
Alkalinity, Bicarbonate	495	mg/HCO3
Alkalinity, Carbonate	0	mg/lCaCO3
Chloride	56.2	mg/l
Coliform, Fecal		MPN/100ml
Coliform, Total		MPN/100ml
Conductivity	1560	umhos/cm
Fluoride	0.26	mg/l
Hardness, Total		mglCaCO3
Nitrogen, Ammonia		mg/l
Nitrogen, Nitrate	0.06	mg/l
Nitrogen, Nitrite		mg/l
Oil & Grease	<0.5	mg/l
pH	8.30	Units
Phosphorus Ortho	0.07	mg/l
Phosphorus, Total	0.09	mg/l
Solids, Total Dissolved	890	mg/l
Solids, Total Suspended	<0.5	mg/l
Sulfate	300	mg/l
Sulfide		mg/l
Turbidity	0.6	NTU
Total Cations	16.21	meq/l
Total Anions	15.95	meq/l

Aluminum	<0.05	mg/l
Arsenic	<0.001	mg/l
Barium	<0.1	mg/l
Beryllium		mg/l
Boron	0.12	mg/l
Cadmium	<0.005	mg/l
Calcium	72.0	mg/l
Chromium	<0.05	mg/l
Copper	<0.02	mg/l
Iron	0.07	mg/l
Lead	<0.05	mg/l
Magnesium	82.7	mg/l
Maganese	<0.01	mg/l
Mercury	<0.2	ug/l
Nickel	<0.04	mg/l
Potassium	6.3	mg/l
Selenium	<0.005	mg/l
Silica		mg/l
Sodium	130.1	mg/l
Vanadium	<0.2	mg/l
Zinc	0.015	mg/l

Respectfully submitted David Ramirez

MOUNTAIN
STATES
ANALYTICAL

CERTIFICATE OF ANALYSIS

Client: Sample ID: T-16

Trail Mountain Coal Co.
P.O. Box 370
Orangeville, Utah 84537

Lab No.	1012
Date Rec'd	10-21-86
Date Sampled	10-17-86
Time Sampled	

Acidity	0	mg/lCaCO3	Aluminum	<0.05	mg/l
Alkalinity, Total	343	mg/lCaCO3	Arsenic	<0.001	mg/l
Alkalinity, Bicarbonate	418	mg/HCO3	Barium	<0.1	mg/l
Alkalinity, Carbonate	0	mg/lCaCO3	Beryllium		mg/l
Chloride	58.6	mg/l	Boron	0.11	mg/l
Coliform, Fecal		MPN/100ml	Cadmium	<0.005	mg/l
Coliform, Total		MPN/100ml	Calcium	48.0	mg/l
Conductivity	960	umhos/cm	Chromium	<0.05	mg/l
Fluoride	0.26	mg/l	Copper	<0.02	mg/l
Hardness, Total		mglCaCO3	Iron	<0.05	mg/l
Nitrogen, Ammonia		mg/l	Lead	<0.05	mg/l
Nitrogen, Nitrate	0.06	mg/l	Magnesium	35.3	mg/l
Nitrogen, Nitrite		mg/l	Maganese	<0.01	mg/l
Oil & Grease	<0.5	mg/l	Mercury	<0.2	ug/l
pH	8.31	Units	Nickel	<0.04	mg/l
Phosphorus Ortho	0.07	mg/l	Potassium	3.7	mg/l
Phosphorus, Total	0.10	mg/l	Selenium	<0.005	mg/l
Solids, Total Dissolved	485	mg/l	Silica		mg/l
Solids, Total Suspended	<0.5	mg/l	Sodium	92.7	mg/l
Sulfate	40	mg/l	Vanadium	<0.2	mg/l
Sulfide		mg/l	Zinc	0.010	mg/l
Turbidity	0.6	NTU			
Total Cations	9.42	meq/l			
Total Anions	9.36	meq/l			

Respectfully submitted David [signature]

MOUNTAIN
STATES
ANALYTICAL

CERTIFICATE OF ANALYSIS

Client:
Trail Mountain Coal Company
P.O. Box 370
Orangeville, Utah 84537
Attn: Allen Childs

Lab. No. 1018
Date Rec'd. 11-17-86
Date Sampled 11-11-86
Time Sampled

Sample ID: T - 1

Acidity	0	mg/$CaCO_3$	Aluminum	<0.05	mg/l
Alkalinity, Total	318	mg/l$CaCO_3$	Arsenic	<0.002	mg/l
Alkalinity, Bicarbonate	388	mg/HCO_3	Barium	<0.1	mg/l
Alkalinity, Carbonate	0	mg/l$CaCO_3$	Boron	<0.2	mg/l
Chloride	8.8	mg/l	Cadmium	<0.005	mg/l
Conductivity	654	umhos/cm	Calcium	52.0	mg/l
Fluoride	0.29	mg/l	Chromium	<0.05	mg/l
Nitrogen, Nitrate	0.08	mg/l	Copper	<0.03	mg/l
pH	8.17	Units	Iron	0.18	mg/l
Phosphorus, Ortho	0.08	mg/l	Lead	<0.05	mg/l
Phosphorus, Total	0.10	mg/l	Magnesium	35.0	mg/l
Solids, Total Dissolved	368	mg/l	Manganese	<0.01	mg/l
Solids, Total Suspended	6.0	mg/l	Mercury	<0.2	ug/l
Sulfate	35	mg/l	Nickel	<0.04	mg/l
Turbidity	3.0	NTU	Potassium	1.7	mg/l
			Selenium	<0.005	mg/l
Total Cations	5.62	meq/l	Sodium	42.2	mg/l
Total Anions	5.78	meq/l	Vanadium	<0.2	mg/l
			Zinc	<0.01	mg/l

Supervisor [signature]
Reviewed and approved 12-24-86

Respectfully submitted [signature]

MOUNTAIN STATES ANALYTICAL

CERTIFICATE OF ANALYSIS

Client:
Trail Mountain Coal Company
P.O. Box 370
Orangeville, Utah 84537
Attn: Allen Childs

Lab. No. 1019
Date Rec'd. 11-17-86
Date Sampled 11-11-86
Time Sampled

Sample ID: T - 5

Acidity	0	mg/$CaCO_3$	Aluminum	<0.05	mg/l
Alkalinity, Total	435	mg/l$CaCO_3$	Arsenic	<0.002	mg/l
Alkalinity, Bicarbonate	531	mg/HCO_3	Barium	<0.1	mg/l
Alkalinity, Carbonate	0	mg/l$CaCO_3$	Boron	<0.2	mg/l
Chloride	15.4	mg/l	Cadmium	<0.005	mg/l
Conductivity	872	umhos/cm	Calcium	72.0	mg/l
Fluoride	0.33	mg/l	Chromium	<0.05	mg/l
Nitrogen, Nitrate	0.08	mg/l	Copper	<0.03	mg/l
pH	8.00	Units	Iron	0.05	mg/l
Phosphorus, Ortho	0.11	mg/l	Lead	<0.05	mg/l
Phosphorus, Total	0.11	mg/l	Magnesium	57.4	mg/l
Solids, Total Dissolved	512	mg/l	Manganese	<0.01	mg/l
Solids, Total Suspended	147.0	mg/l	Mercury	<0.2	ug/l
Sulfate	43	mg/l	Nickel	<0.04	mg/l
Turbidity	74	NTU	Potassium	2.7	mg/l
			Selenium	<0.005	mg/l
Total Cations	10.85	meq/l	Sodium	56.7	mg/l
Total Anions	10.02	meq/l	Vanadium	<0.2	mg/l
			Zinc	<0.01	mg/l

Supervisor ____________
Reviewed and approved 12-24-86

Respectfully submitted ____________

MOUNTAIN
STATES
ANALYTICAL

CERTIFICATE OF ANALYSIS

Client:
Trail Mountain Coal Company
P.O. Box 370
Orangeville, Utah 84537
Attn: Allen Childs

Lab. No. 1020
Date Rec'd. 11-17-86
Date Sampled 11-11-86
Time Sampled

Sample ID: T - 7

Acidity	0	mg/$CaCO_3$	Aluminum	<0.05	mg/l
Alkalinity, Total	409	mg/l$CaCO_3$	Arsenic	<0.002	mg/l
Alkalinity, Bicarbonate	489	mg/HCO_3	Barium	<0.1	mg/l
Alkalinity, Carbonate	8	mg/l$CaCO_3$	Boron	<0.2	mg/l
Chloride	21.7	mg/l	Cadmium	<0.005	mg/l
Conductivity	861	umhos/cm	Calcium	46.0	mg/l
Fluoride	0.39	mg/l	Chromium	<0.05	mg/l
Nitrogen, Nitrate	0.08	mg/l	Copper	<0.03	mg/l
pH	8.34	Units	Iron	<0.05	mg/l
Phosphorus, Ortho	0.10	mg/l	Lead	<0.05	mg/l
Phosphorus, Total	0.12	mg/l	Magnesium	52.3	mg/l
Solids, Total Dissolved	480	mg/l	Manganese	<0.01	mg/l
Solids, Total Suspended	19.0	mg/l	Mercury	<0.2	ug/l
Sulfate	40	mg/l	Nickel	<0.04	mg/l
Turbidity	8.0	NTU	Potassium	2.4	mg/l
			Selenium	<0.005	mg/l
Total Cations	9.78	meq/l	Sodium	71.8	mg/l
Total Anions	9.64	meq/l	Vanadium	<0.2	mg/l
			Zinc	0.015	mg/l

Supervisor David Denney
Reviewed and approved 12-24-86

Respectfully submitted ________________

MOUNTAIN
STATES
ANALYTICAL

CERTIFICATE OF ANALYSIS

Client:
Trail Mountain Coal Company
P.O. Box 370
Orangeville, Utah 84537
Attn: Allen Childs

Lab. No. 1021
Date Rec'd. 11-17-86
Date Sampled 11-11-86
Time Sampled

Sample ID: T - 11

Acidity	0	mg/$CaCO_3$	Aluminum	<0.05	mg/l
Alkalinity, Total	281	mg/l$CaCO_3$	Arsenic	<0.002	mg/l
Alkalinity, Bicarbonate	343	mg/HCO_3	Barium	<0.1	mg/l
Alkalinity, Carbonate	0	mg/l$CaCO_3$	Boron	<0.2	mg/l
Chloride	77.3	mg/l	Cadmium	<0.005	mg/l
Conductivity	774	umhos/cm	Calcium	48.0	mg/l
Fluoride	0.26	mg/l	Chromium	<0.05	mg/l
Nitrogen, Nitrate	0.08	mg/l	Copper	<0.03	mg/l
pH	8.14	Units	Iron	0.05	mg/l
Phosphorus, Ortho	0.07	mg/l	Lead	<0.05	mg/l
Phosphorus, Total	0.15	mg/l	Magnesium	47.4	mg/l
Solids, Total Dissolved	500	mg/l	Manganese	<0.01	mg/l
Solids, Total Suspended	<5.0	mg/l	Mercury	<0.2	ug/l
Sulfate	100	mg/l	Nickel	<0.04	mg/l
Turbidity	1.0	NTU	Potassium	2.5	mg/l
			Selenium	<0.005	mg/l
Total Cations	8.84	meq/l	Sodium	57.0	mg/l
Total Anions	8.48	meq/l	Vanadium	<0.2	mg/l
			Zinc	<0.01	mg/l

Supervisor ____________
Reviewed and approved 12-24-86

Respectfully submitted ____________

MOUNTAIN
STATES
ANALYTICAL

CERTIFICATE OF ANALYSIS

Client:
Trail Mountain Coal Company
P.O. Box 370
Orangeville, Utah 84537
Attn: Allen Childs

Lab. No. 1022
Date Rec'd. 11-17-86
Date Sampled 11-11-86
Time Sampled

Sample ID: T - 15

Acidity	0	mg/$CaCO_3$	Aluminum	<0.05	mg/l
Alkalinity, Total	338	mg/l$CaCO_3$	Arsenic	<0.002	mg/l
Alkalinity, Bicarbonate	412	mg/HCO_3	Barium	<0.1	mg/l
Alkalinity, Carbonate	0	mg/l$CaCO_3$	Boron	<0.2	mg/l
Chloride	52.6	mg/l	Cadmium	<0.005	mg/l
Conductivity	872	umhos/cm	Calcium	48.0	mg/l
Fluoride	0.40	mg/l	Chromium	<0.05	mg/l
Nitrogen, Nitrate	0.09	mg/l	Copper	<0.03	mg/l
pH	8.08	Units	Iron	<0.05	mg/l
Phosphorus, Ortho	0.07	mg/l	Lead	<0.05	mg/l
Phosphorus, Total	0.10	mg/l	Magnesium	36.2	mg/l
Solids, Total Dissolved	500	mg/l	Manganese	<0.01	mg/l
Solids, Total Suspended	17.0	mg/l	Mercury	<0.2	ug/l
Sulfate	61	mg/l	Nickel	<0.04	mg/l
Turbidity	9.0	NTU	Potassium	2.5	mg/l
			Selenium	<0.005	mg/l
Total Cations	9.50	meq/l	Sodium	93.3	mg/l
Total Anions	9.53	meq/l	Vanadium	<0.2	mg/l
			Zinc	<0.01	mg/l

Supervisor ______________
Reviewed and approved 12-24-86

Respectfully submitted ______________

MOUNTAIN STATES ANALYTICAL

CERTIFICATE OF ANALYSIS

Client:
Trail Mountain Coal Company
P.O. Box 370
Orangeville, Utah 84537
Attn: Allen Childs

Lab. No. 1023
Date Rec'd. 11-17-86
Date Sampled 11-11-86
Time Sampled

Sample ID: T - 17

Acidity	0	mg/CaCO₃	Aluminum	<0.05	mg/l
Alkalinity, Total	246	mg/lCaCO₃	Arsenic	<0.002	mg/l
Alkalinity, Bicarbonate	300	mg/HCO₃	Barium	<0.1	mg/l
Alkalinity, Carbonate	0	mg/lCaCO₃	Boron	<0.2	mg/l
Chloride	11.9	mg/l	Cadmium	<0.005	mg/l
Conductivity	458	umhos/cm	Calcium	42.0	mg/l
Fluoride	0.20	mg/l	Chromium	<0.05	mg/l
Nitrogen, Nitrate	0.11	mg/l	Copper	<0.03	mg/l
pH	8.12	Units	Iron	<0.05	mg/l
Phosphorus, Ortho	0.08	mg/l	Lead	<0.05	mg/l
Phosphorus, Total	0.11	mg/l	Magnesium	33.8	mg/l
Solids, Total Dissolved	280	mg/l	Manganese	<0.01	mg/l
Solids, Total Suspended	5.0	mg/l	Mercury	<0.2	ug/l
Sulfate	22	mg/l	Nickel	<0.04	mg/l
Turbidity	2.5	NTU	Potassium	1.4	mg/l
			Selenium	<0.005	mg/l
Total Cations	5.69	meq/l	Sodium	17.7	mg/l
Total Anions	5.73	meq/l	Vanadium	<0.2	mg/l
			Zinc	<0.01	mg/l

Supervisor ____________________
Reviewed and approved 12-24-86

Respectfully submitted ____________________

Appendix 7-3 Water Monitoring Guidelines**

**Ch 7 Rev. 1-11-87

(Revised January 1986)

STATE OF UTAH
DEPARTMENT OF NATURAL RESOURCES
DIVISION OF OIL, GAS AND MINING
355 West North Temple
3 Triad Center, Suite 350
Salt Lake City, Utah 84180-1203
(801) 538-5340

GUIDELINES FOR ESTABLISHMENT OF SURFACE AND GROUND WATER MONITORING PROGRAMS FOR COAL MINING AND RECLAMATION OPERATIONS

This guideline document provides suggestions to coal operators for compliance with Sections UMC 783.13, 783.15-.17, 817.41-.42, 817.52-.54, of the rules and regulations pursuant to the Coal Mining and Reclamation Operations Act of 1979, Chapter 10, Title 40, UCA.

The purpose of these guidelines is to provide direction in acquiring a data base to be used by the operator for determining the probable hydrologic consequences of proposed and existing mining and reclamation operations (UMC 784.14[c]). This information will allow the Division of Oil, Gas and Mining to assess the probable cumulative impacts of anticipated or existing mining operations on the hydrologic balance in the general area (UMC 786.19[c]). The determination and assessment will apply to the mine plan and adjacent area with respect to the hydrologic regime and include the quantity and quality of the water in the surface and ground water systems. Moreover, the assessment will help insure that a proper mining and reclamation plan is developed and adopted to minimize hydrologic impacts both on- and offsite. The Act and regulations require that hydrologic monitoring take place before, during and after mining and reclamation operations. The operator is responsible for minimizing the impact and/or disturbance to the prevailing hydrologic balance.

This document is intended to delineate and reference acceptable methodologies and procedures that may be used to collect, analyze and interpret hydrologic data as set forth in the requirements of the regulations. These methods are not considered mandatory but do represent the Division's best approximation of required information to address the regulations for most situations. These methods may be modified with the Division's approval to reflect the characteristics of a particular situation.

It is highly recommended that prior to initiating data acquisition (including exploration drilling) or monitoring programs, operators contact the Division to arrange a conference to develop a suitable approach for characterizing water resources and thereby cost effectively and expeditiously achieve regulatory compliance.

The Utah State Division of Oil, Gas and Mining reserves the right to alter these guidelines as field experience, research and practical demonstrations delineate a better understanding of hydrologic processes in Utah's coal mining regions.

I. Surface Water Hydrology

A. Identification of surface water systems.

1. Determine watershed basin characteristics (with map of a scale 1:24,000 or larger).

a. Delineate drainage basin boundaries and include watershed names.

b. Describe physical characteristics (topographic relief, slope, drainage patterns).

B. Baseline data to establish surface water conditions.

1. Compile existing flow and quality data on streams and reservoirs from state and federal agencies, private agencies, past and on-going mining operations, regulatory agencies, etc.

2. Inventory all streams, lakes, reservoirs and impoundments within permit area and adjacent and downstream areas which could potentially be affected by mining.

a. Stream information to be inventoried:

(1) location of primary channel and tributaries;

(2) historical and present seasonal variability of flows and water quality;

(3) categorization of stream (i.e., perennial, intermittent or ephemeral) based on above information;

(4) water usage, water rights and permission for sampling.

b. Lake, reservoir and impoundment information to be inventoried:

(1) location and relationship to local drainage;

(2) composition of material of impounding dam; length of crest and height of dam from upstream toe to top of crest;

(3) historical and present seasonal variability of water levels and water quality;

(4) water usage, water rights and permission for sampling.

3. Determine on-site erosion rates and sediment yields. Refer to B.5.c for acceptable methodology.

4. Selection of baseline monitoring sites:

B.4. (continued)

a. Sites shall include a combination of lake, reservoir, impoundment and stream locations.

b. The number of monitoring sites is dependent upon the:

(1) complexity of the surface water system;

(2) size of mine plan area.

c. In general for streams, samples should be taken upstream and downstream from affected areas.

All sites for measurement of stream flow need not be sampled for quality, but all quality samples should be accompanied by a flow measurement.

All quality samples should be accompanied by the current maximum water level measurement of reservoir or lake.

5. Data acquisition.

a. Stream flow measurement and analyses.

(1) Flow measurements can be made using a current meter, flume (portable or permanent), weir, stage recorder, or other applicable method as approved by the Division, giving a reliable flow estimate. Refer to Water Measurement Manual, U. S. Bureau of Reclamation 1974 for other accepted methods of flow determination.

(2) Water samples should be collected in accordance with: Methods for Collection and Analysis of Water Samples for Dissolved Minerals and Gases, National Handbook of Recommended Methods for Water Data Acquisition, 1977, and Methods for Chemical Analysis of Water and Wastes, EPA, March 1979.

(3) Ephemeral streams should be sampled by use of a crest gage (or similar device) and single stage sediment sampler.

(4) Stream sampling and analysis.

(A) Frequency and duration, refer to Table 2.

(B) Field measurements, refer to Table 1.

(C) Laboratory analyses, refer to Table 1.

B.5. (continued)

b. Lake, reservoir, impoundment measurement and analyses.

(1) Maximum lake level data should be collected by taking readings from a stadia staff installed in the lake itself.

(2) Water samples should be collected by use of a Kemmerer depth sampler, a similar weight- activated device or other device approved by the Division.

(3) Lake/reservoir sampling and analysis.

(A) Frequency and duration, refer to Table 2.

(B) Field measurements, refer to Table 1.

(C) Laboratory analyses, refer to Table 1. Other parameters determined to be specific to operational processes may be analyzed.

c. Soil loss and sediment yield analyses.

Onsite soil losses and sediment yields can be predicted using the Universal Soil Loss Equation (USLE), Modified Universal Soil Loss Equation (MUSLE), Pacific Southwest Interagency Committee (PSIAC), a sediment test plot or other applicable professionally practiced method(s) and models.

6. Predict or describe the consequences of mining and reclamation on the existing flow regime, including peak flows, low flows, water yield, chemical water quality, erosion and sediment and aquatic biota.

a. Submit a minimum of one year baseline data in the Permit Application Package (PAP) in accordance with Table 2.

b. Interpret baseline data to provide information in the PAP about the probable hydrologic consequences from mining of the quantity and quality of surface water.

C. <u>Operational</u> monitoring.

1. Construction monitoring.

a. Submit a monitoring plan which will demonstrate that on a weekly basis, total suspended solids and total settleable solids will not be excessive during construction activities.

b. Other water quality parameters may require analysis by the Division on a site-specific basis.

C. (continued)

2. Streams.

   a. Select, with Division approval, representative stream sites for operational monitoring.

   b. Monitor selected sites as described in Table 2.

   c. Parameter selection and analysis frequency as described in Table 1 and Table 2, respectively.

3. Lakes, reservoirs and impoundments.

   a. Select with Division approval representative lake locations for operational monitoring.

   b. Continue measuring and sampling selected sites as described in Table 2.

   c. Parameter selection and analysis frequency as described in Table 1 and Table 2, respectively.

4. Submit monitoring results quarterly, with an annual summary. The annual summary must analyze variance in flow characteristics and water quality and should include tables, graphs, hydrographs, etc.

D. Postmining monitoring--begins one year after cessation of earthmoving and site activity.

1. Identify representative stream and lake sites for measuring and sampling.

2. Continue monitoring representative sites as described in Table 2.

3. Parameter selection and analysis frequency as described in Table 1 and Table 2, respectively.

4. Submit monitoring data annually. Summarize and assess mining impacts and system recovery at the termination of the bonding period.

II. Ground Water Hydrology

A. Geology of the ground water system.

Describe the general geology for the mine plan and adjacent area down to and including the first aquifer below the lowest coal seam to be mined. Pertinent information may be derived from published literature. The description shall include:

1. Stratigraphic column(s) characteristic of the property.

A.1. (continued)

2. Cross-section(s) showing extent, thickness and continuity of all aquifers and confining layers.

3. Stratigraphy and geologic structure that may control or potentially affect aquifers.

    a. Depositional and/or erosional facies relationships.

    b. Intrusions.

    c. Faults, folds and joints.

    d. Regional and, if variable, local strike and dip.

4. Potential hydrologic boundaries (i.e., faults, incised drainages and other structural features) and:

    a. Recharge and discharge areas.

    b. Significant perched aquifers.

    c. Local and regional aquifer systems.

B. <u>Baseline</u> data to establish ground water conditions.

1. Inventory all ground water wells, springs and seeps, mine inflows and water usage and water rights within and adjacent to the permit area. Identify seasonal variability in water levels and/or flow and quality.

    a. Well information to be inventoried:

        (1) Location, total depth, diameter and owner(s) of well(s).

        (2) Well yield, water quality and local usage.

        (3) Casing depth, type of casing, perforated interval(s) and monitoring zone(s).

        (4) Elevation at well and static water level.

        (5) Past well problems, historic water level and water quality fluctuation records, and permission to utilize the well for monitoring purposes, if needed.

        (6) Formation name(s) and/or rock type(s) and lithologic properties of aquifer(s).

        (7) Geophysical and driller logs.

    b. Spring and seep information to be inventoried:

B.1. (continued)

(1) Location, elevation, geologic occurrence and formation or rock type governing discharge.

(2) Present and historic flow and water quality.

(3) Local usage and permission for spring sampling.

c. Sustained mine inflow (e.g., wall weeps, roof bolt drips) and discharge information to be inventoried:

(1) Location and geologic occurrence.

(2) Present and historic inflow, discharge and water quality.

2. Selection of baseline monitoring sites.

a. Sites shall include, but not be limited to, a combination of:

(1) Existing water wells (as determined from inventory in B.1. above);

(2) Surface and subsurface boreholes drilled explicitly for ground water monitoring;

(3) Properly developed, cased and completed exploration boreholes;

(4) A representative number of springs as approved by the Division; and

(5) Mine inflows and/or discharges at representative sites within the mine.

b. Location, distribution and number of monitoring sites shall delineate gradients and directions of ground water flow. The number and density of monitoring points must reflect site-specific conditions.

(1) Monitoring sites should be located up- and down-gradient in the mine plan and adjacent area.

(2) For water quality monitoring, emphasis should be placed on sites down-gradient from the mine plan area. This does not eliminate the need for up-gradient quality monitoring.

(3) The number of monitoring sites is dependent upon the:

(A) Complexity and continuity of aquifer systems above and below the coal to be mined.

B.2. (continued)

(B) Size of the mine plan area.

(C) Results of findings from observation wells drilled for quality and water level monitoring, unless:

i. Sufficiently detailed site-specific ground water information is available.

ii. Appropriate wells exist within and adjacent to the mine plan area that can be used for ground water monitoring.

3. Data acquisition.

a. Well testing and analyses.

The following pumping tests and water level data should be used to determine transmissivity, hydraulic conductivity, specific capacity, storage coefficients and other aquifer properties such as homogeniety, isotropy, hydrologic boundaries, leakage, etc.

If sufficient site-specific data exist for the permit and adjacent area, then the need for further borehole testing may be waived by the Division.

(1) Multiple well pumping tests.

Constant discharge pump tests with observation wells and/or piezometers to monitor effective drawdown and recovery rates are recommended.

(2) Single hole tests.

Single hole tests should not be utilized if precise control over the variables and measurements cannot be maintained in the field.

(A) Pump test;

(B) Slug test;

(C) Bailer test;

(D) Open-hole test;

(E) Packer test;

(F) or, any other appropriate single hole pumping tests.

(3) Well sampling and analyses.

B.3. (continued)

(A) Frequency and duration, refer to Table 4.

(B) Field measurements, refer to Table 3.

(C) Laboratory analyses, refer to Table 3.

b. Spring sampling and analyses.

(1) Frequency and duration, refer to Table 4.

(2) Field measurements, refer to Table 3.

(3) Laboratory analyses, refer to Table 3.

c. Mine inflow and/or discharge sampling and analyses.

(1) Frequency and duration, refer to Table 4.

(2) Fielo measurements, refer to Table 3.

(3) Laboratory analyses, refer to Table 3. Other parameters determined to be specific to operational processes may be analyzed.

4. Characterize ground water occurrence, quality and movement for the permit and adjacent area.

a. Submit a minimum of one year baseline data in the Permit Application Package (PAP) in accordance with Table 4.

b. Interpret baseline data to provide information in the PAP about the probable hydrologic consequences of mining on ground water occurrence, quality and movement.

C. <u>Operational</u> monitoring.

1. Springs and wells.

a. Select, with Division approval, representative springs and wells for operational monitoring.

b. Continue measuring and sampling selected springs and wells as described in Table 4.

b. Parameter selection and analysis frequency as described in Table 3 and Table 4, respectively.

2. Mine inflow and discharge monitoring.

C.2. (continued)

a. Quarterly inflow inventory in the working portion of mine; identify inflow location and geologic occurrence.

b. Select, with Division approval, representative sustained mine inflows for monitoring.

c. Frequency of inflow sampling and measurement as described in Table 4.

d. Laboratory and field inflow analyses as described in Table 3.

e. Collect quarterly discharge volume data.

3. Submit monitoring data and summarize quantity, quality and sources of water encountered in the annual hydrologic report. Include an analysis of the mine workings water balance by accounting for mine inflows, discharge, outflows, evaporation losses and sump storage.

D. Postmining monitoring.

1. Identify representative wells and springs for measuring and sampling.

2. Continue monitoring representative wells and springs as described in Table 4.

3. Parameter selection and analysis frequency as described in Table 3 and Table 4, respectively.

4. Submit monitoring data annually. Summarize and assess mining impacts and system recovery at the termination of the bonding period.

TABLE 1

SURFACE WATER BASELINE, OPERATIONAL AND POSTMINING WATER QUALITY PARAMETER LIST

Field Measurements:

	*	-	Water Levels or Flow
	*	-	pH
	*	-	Specific Conductivity (umhos/cm)
	*	-	Temperature (C^{o})
	*	-	Dissolved Oxygen (ppm) (perennial streams only)

Laboratory Measurements: (mg/l) (Major, minor ions and trace elements are to be analyzed in total and dissolved forms.)

#	*	-	Total Settleable Solids
#	*	-	Total Suspended Solids
	*	-	Total Dissolved Solids
	*	-	Total Hardness (as $CaCO_3$)
	*		Acidity ($CaCO_3$)
		-	Aluminum (Al)
		-	Arsenic (As)
		-	Barium (Ba)
		-	Boron (B)
	*	-	Carbonate (CO_3^{-2})
	*	-	Bicarbonate (HCO_3^{-})
		-	Cadmium (Cd)
	*	-	Calcium (Ca)
	*	-	Chloride (Cl^{-})
		-	Chromium (Cr)
		-	Copper (Cu)
		-	Fluoride (F^{-})
	*	-	Iron (Fe)
		-	Lead (Pb)
	*	-	Magnesium (Mg)
	*	-	Total Manganese (Mn)
		-	Mercury (Hg)
		-	Molybdenum (Mo)
		-	Nickel (Ni)
		-	Nitrogen: Ammonia (NH_3)
		-	Nitrite (NO_2)
		-	Nitrate (NO_3^{-})
	*	-	Potassium (K)
		-	Phosphate (PO_4^{-3})
		-	Selenium (Se)
	*	-	Sodium (Na)
	*	-	Sulfate (SO_4^{-2})
		-	Sulfide (S^{-})
		-	Zinc (Zn)
	*	-	Oil and Grease
	*	-	Cation-Anion Balance

Sampling Period:

-Baseline

*Operational, Postmining

#Construction

TABLE 2 SURFACE WATER SAMPLING

	Baseline	Operational	Postmining
Type of Sampling Site	Surface Water Bodies	Surface Water Bodies	Surface Water Bodies
Field Measurements (see Table 1)	Performed during water level/flow measurements.	Performed during water level/flow measurements.	Performed during water level/flow measurements.
Sample Frequency	Quarterly for lakes, reservoirs and impoundments (water level and quality); monthly flow measurements and quarterly water quality measurements (one sample at low flow and high flow each) for perennial streams. Monthly flow and water quality measurements during period of flow for intermittent streams. Sampling for ephemeral streams determined at pre-design conference.	Quarterly for lakes, reservoirs and impoundments (water level and quality); monthly flow measurements and quarterly water quality measurements (one sample at low flow and high flow each) for perennial streams. Monthly flow and water quality measurements during period of flow for intermittent streams. Sampling for ephemeral streams determined at pre-design conference.	Two per annum for perennial streams (high & low flow); two per annum during snowmelt and rainfall for intermittent streams.
Sampling Duration	Two years (one complete year of data before submission of PAP.	Every year until two years after surface reclamation activities have ceased.	Every year until termination of bonding.
Type of Data Collected and Reported	Flow and/or water levels and water quality.	Flow and/or water levels and water quality.	Flow and/or water levels and water quality per operational parameters.
Comments	All field measurements should be performed concurrently with water level/flow measurements.	All field measurements should be performed concurrently with water level/flow measurements.	All field measurements should be performed concurrently with water level/flow measurements

TABLE 2 (continued)

	Baseline	Operational	Postmining
Comments		For every fifth year preceding repermitting, one sample at low flow and high flow each should be taken for baseline water quality parameters. The construction monitoring program will be conducted on a site-specific basis in addition to the operational monitoring.	

TABLE 3

GROUND WATER BASELINE, OPERATIONAL AND POSTMINING WATER QUALITY PARAMETER LIST

Field Measurements:

*	-	Water Levels or Flow
*	-	pH
*	-	Specific Conductivity (umhos/cm)
*	-	Temperature (C^o)

Laboratory Measurements: (mg/l) (Major, minor ions and trace elements are to be analyzed in dissolved form only.)

*	-	Total Dissolved Solids
*	-	Total Hardness (as $CaCO_3$)
	-	Aluminum (Al)
	-	Arsenic (As)
	-	Barium (Ba)
	-	Boron (B)
*	-	Carbonate (CO_3^{-2})
*	-	Bicarbonate (HCO_3^{-})
	-	Cadmium (Cd)
*	-	Calcium (Ca)
*	-	Chloride (CL^-)
	-	Chromium (Cr)
	-	Copper (Cu)
	-	Fluoride (F^-)
*	-	Iron (Fe)
	-	Lead (Pb)
*	-	Magnesium (Mg)
*	-	Manganese (Mn)
	-	Mercury (Hg)
	-	Molybdenum (Mo)
	-	Nickel (Ni)
	-	Nitrogen: Ammonia (NH_3)
	-	Nitrite (NO_2)
	-	Nitrate (NO_3^{-})
*	-	Potassium (K)
	-	Phosphate (PO_4^{-3})
	-	Selenium (Se)
*	-	Sodium (Na)
*	-	Sulfate (SO_4^{-2})
	-	Sulfide (S^-)
	-	Zinc (Zn)

Sampling Period:

-Baseline
*Operational, Postmining

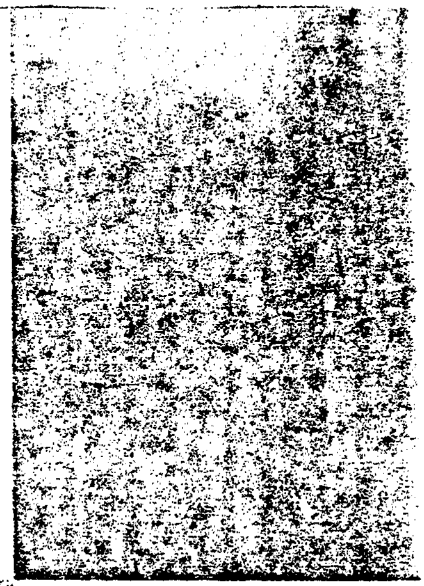
TABLE 4 GROUND WATER SAMPLING

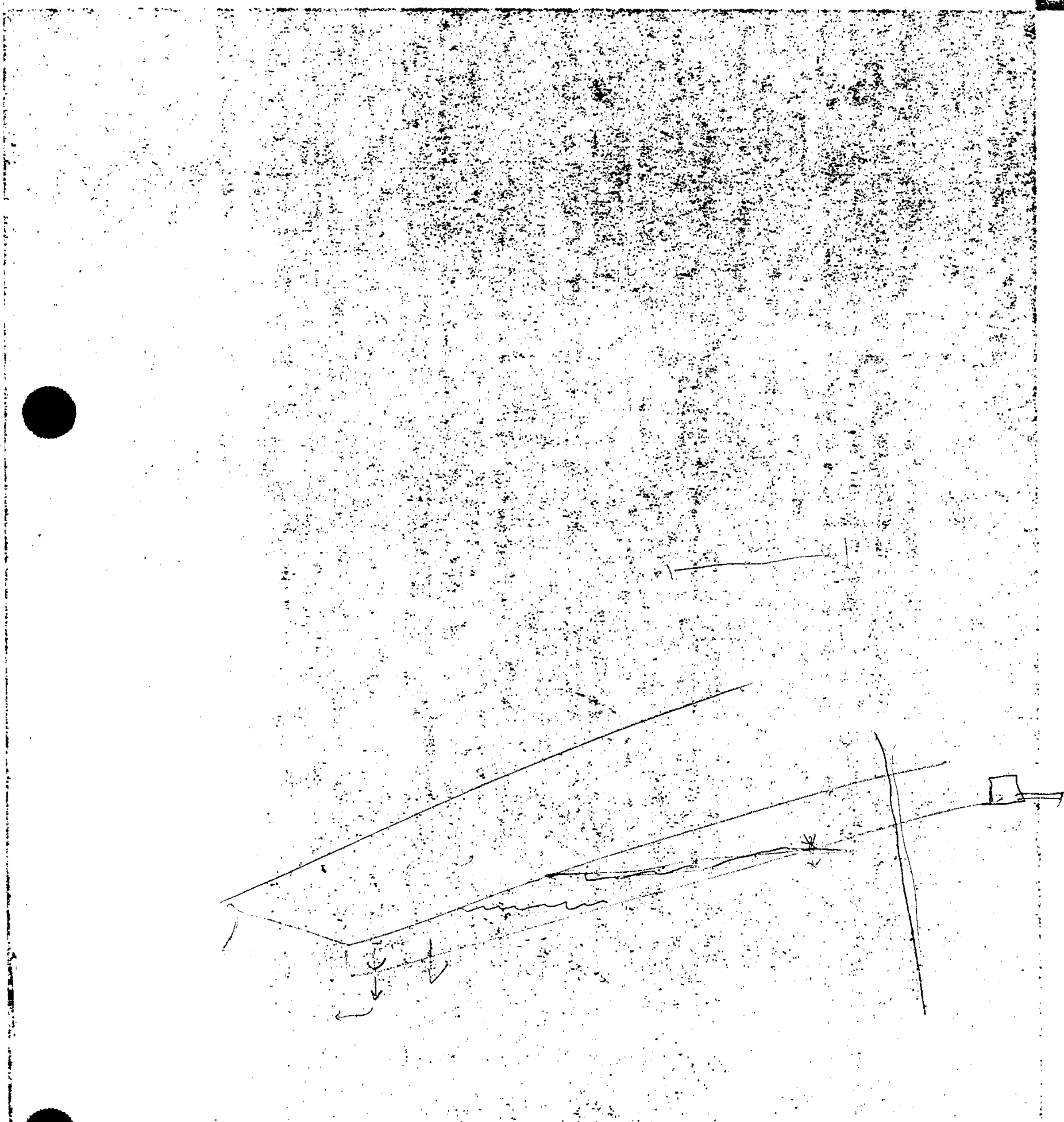
	Baseline Monitoring	Operational Monitoring	Postmining Monitoring
Type of Sampling Site	Springs, In-Mine Flows, Boreholes, Observation Wells	Springs, In-Mine Flows, Boreholes, Observation Well	Springs, Observation Wells
Field Measurements (see Table 3)	Yes	Yes	Yes
Sampling Frequency Each Site	At least four samples per annum, at fixed monthly intervals.	Quarterly samples for in-mine flows. For other sites, four samples per annum at fixed monthly intervals.	One sample per annum (spring sampling at low flow).
Sampling Duration	Two years (one complete year of data before submission of PAP).	Every year until two years after surface reclamation activities have ceased.	Every year until termination of bonding.
Type of Data Collected and Reported	Water levels and/or flow and water quality.	Water levels and/or flow. For springs, one water quality sample at low flow.	Water levels and/or flow and water quality per operational parameters.
Comments	First year of baseline monitoring and the year preceding repermitting; spring and seep inventory taken both during the Fall and Spring.	During the year preceding repermitting. For springs, one water quality sample at low flow per baseline parameters. For other sites, one sample per baseline parameter.	

Appendix 7-B U. S. G. S. Water Supply Paper 2259**

**Ch 7 Rev. 1-11-87

The Ground-Water System and Possible Effects of Underground Coal Mining in the Trail Mountain Area, Central Utah





United States Geological Survey Water-Supply Paper 2259

Prepared in cooperation with the U.S. Bureau of Land Management

The Ground-Water System and Possible Effects of Underground Coal Mining in the Trail Mountain Area, Central Utah

By Gregory C. Lines

Prepared in cooperation with the
U.S. Bureau of Land Management

U.S. GEOLOGICAL SURVEY WATER-SUPPLY PAPER 2259

DEPARTMENT OF THE INTERIOR
WILLIAM P. CLARK, Secretary

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CONVERSION FACTORS AND RELATED INFORMATION

For use of readers who prefer to use metric units, conversion factors for terms used in this report are listed below:

Multiply	By	To obtain
acre	0.4047	square hectometer
acre-foot (acre-ft)	0.001233	cubic hectometer
cubic foot (ft^3)	0.02832	cubic meter
cubic foot per second (ft^3/s)	0.02832	cubic meter per second
foot (ft)	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 (ft^2/d)	0.09290	meter squared per day
gallon per day (gal/d)	3.785	liter per day
gallon per minute (gal/min)	3.785	liter per minute
inch (in.)	2.540	centimeter
micromhos per centimeter at 25° Celsius (umho)	1.000	microsiemens per centimeter at 25° Celsius
mile (mi)	1.609	kilometer
pound per square inch (lb/in^2)	6.895	kilopascal
square mile (mi^2)	2.590	square kilometer
ton (short, 2,000 pounds)	0.9072	metric ton

Chemical concentration and water temperature are given in metric units. Chemical concentration is given in milligrams per liter (mg/L) or micrograms per liter. Milligrams per liter is a unit expressing the concentration of chemical constituents in solution as weight (milligrams) of solute per unit volume (liter) of water. One thousand micrograms per liter is equivalent to 1 milligram per liter. For concentrations less than 7,000 mg/L, the numerical value is about the same as for concentrations in parts per million.

Water temperature is given in degrees Celsius (°C), which can be converted to degrees Fahrenheit (°F) by the following equation:

$$°F=1.8(°C)+32$$

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, is referred to as sea level in this report.

The Ground-Water System and Possible Effects of Underground Coal Mining in the Trail Mountain Area, Central Utah

By Gregory C. Lines

Abstract

The ground-water system was studied in the Trail Mountain area in order to provide hydrologic information needed to assess the hydrologic effects of underground coal mining. Well testing and spring data indicate that water occurs in several aquifers. The coal-bearing Blackhawk-Star Point aquifer is regional in nature and is the source of most water in underground mines in the region. One or more perched aquifers overlie the Blackhawk-Star Point aquifer in most areas of Trail Mountain.

Aquifer tests indicate that the transmissivity of the Blackhawk-Star Point aquifer, which consists mainly of sandstone, siltstone, and shale, ranges from about 20 to 200 feet squared per day in most areas of Trail Mountain. The specific yield of the aquifer was estimated at 0.05, and the storage coefficient is about $1x10^{-6}$ per foot of aquifer where confined.

The main sources of recharge to the multiaquifer system are snowmelt and rain, and water is discharged mainly by springs and by leakage along streams. Springs that issue from perched aquifers are sources of water for livestock and wildlife on Trail Mountain.

Water in all aquifers is suitable for most uses. Dissolved-solids concentrations range from about 250 to 700 milligrams per liter, and the predominant dissolved constituents generally are calcium, magnesium, and bicarbonate.

Future underground coal mines will require dewatering when they penetrate the Blackhawk-Star Point aquifer. A finite-difference, three-dimensional computer model was used to estimate the inflow of water to various lengths and widths of a hypothetical dewatered mine and to estimate drawdowns of potentiometric surfaces in the partly dewatered aquifer. The estimates were made for a range of aquifer properties and premining hydraulic gradients that were similar to those on Trail Mountain. The computer simulations indicate that mine inflows could be several hundred gallons per minute and that potentiometric surfaces of the partly dewatered aquifer could be drawn down by several hundred feet during a reasonable life span of a mine. Because the Blackhawk-Star Point aquifer is separated from overlying perched aquifers by an unsaturated zone, mine dewatering alone would not affect perched aquifers. Mine dewatering would not significantly change water quality in the Blackhawk-Star Point aquifer.

Subsidence will occur above future underground mines, but the effects on the ground-water system cannot be quantified. Subsidence fractures possibly could extend from the roof of a mine into a perched aquifer several hundred feet above. Such fractures would increase downward percolation of water through the perching bed, and spring discharge from the perched aquifer could decrease. Flow through subsidence fractures also could increase recharge to the Blackhawk-Star Point aquifer and increase inflows to underground mines.

INTRODUCTION

Trail Mountain is in the Wasatch Plateau coal field in central Utah. (See figure 1.) The Wasatch Plateau is Utah's most developed coal field, and production was about 14 million tons during 1982. All coal was recovered with underground mining from a number of beds in the Blackhawk Formation of Cretaceous age. During 1982, there were 21 producing mines and about 60,000 acres of Federal land leased for coal mining in the Wasatch Plateau (T.F. Abing, U.S. Bureau of Land Management, written commun., 1983). There was one producing coal mine on Trail Mountain, and much of the Federally owned coal was unleased.

Data from previous hydrologic studies in the Wasatch Plateau (Danielson and others, 1981; Waddell and others, 1981; and Danielson and Sylla, 1983) indicate that the coal-bearing Blackhawk Formation and other geologic units contain water. Inflows of water to most underground mines in the Wasatch Plateau are sufficiently large to require mine dewatering. Aquifer characteristics, the degree of aquifer interconnection, recharge and discharge relationships, and the directions of ground-water movement usually are inadequately defined to accurately assess the hydrologic effects of mine dewatering. Data generally are not available to assess the hydrologic effects of subsidence associated with the underground mining.

Scope and Objectives

From March 1981 to September 1983, the U.S. Geological Survey in cooperation with the U.S. Bureau of Land Management studied ground-water conditions in the Trail Mountain area in order to provide hydrologic information needed to assess the hydrologic effects of coal mining. Trail Mountain was selected for study because of its apparent geologic and hydrologic similarities to much of the Wasatch Plateau and because of the availability of U.S. Geological Survey coal-test holes that could be used to construct wells for aquifer testing.

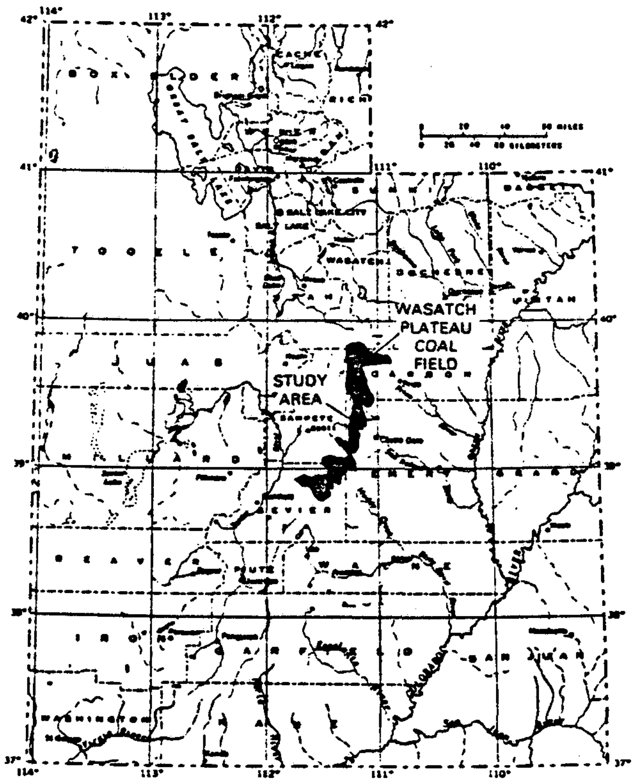

Figure 1. Location of study area in the Wasatch Plateau coal field.

The primary objective of the study was to determine aquifer characteristics, hydraulic connection between aquifers and with streams, recharge and discharge relationships, and chemical quality of water within, above, and immediately below the coal-bearing Blackhawk Formation. A second objective was to predict, quantitatively where possible, the effects of underground mining on the ground-water system.

Methods of Investigation

Fieldwork included the construction and testing of five wells on the south end of Trail Mountain; an extensive spring inventory; base-flow measurements along streams; and sampling of water from springs, wells, and underground mines for chemical analyses. Water discharged from the underground Trail Mountain Mine by pumping and by the ventilation system also was monitored.

A three-dimensional computer model was used to develop curves that may be used to estimate inflow to various lengths and widths of underground mine for various hydrologic conditions. Curves also were developed to estimate drawdowns at various distances from a mine that has been dewatered for various lengths of time.

Acknowledgments

The writer expresses his gratitude to Natomas Trail Mountain Coal Co. for allowing access to the mine property for data-collection activities and for supplying unpublished maps and data. Special thanks are given to Kerry Willardson who kept records on times of pumping from the Trail Mountain Mine and to Allen Childs who served as a guide underground.

Well-, Spring-, and Site-Numbering System

The system of numbering wells and springs in Utah is based on the cadastral land-survey system of the U.S. Government. The number, in addition to designating the well or spring, describes its position in the land net. By the land-survey system, the State is divided into four quadrants by the Salt Lake base line and meridian, and these quadrants are designated by the uppercase letters A, B, C, and D, indicating the northeast, northwest, southwest, and southeast quadrants. Numbers designating the township and range (in that order) follow the quadrant letter, and all three are enclosed in parentheses. The number after the parentheses indicates the section, and it is followed by three letters indicating the quarter section, the quarter-quarter section, and the quarter-quarter-quarter section—generally 10 acres[1]; the letters a, b, c, and d indicate the northeast, northwest, southwest, and southeast quarters of each subdivision. The number after the letters is the serial number of the well or spring within the 10-acre tract; the letter "S" preceding the serial number denotes a spring. If a well or spring cannot be located within a 10-acre tract, one or two location letters are used and the serial number is omitted. Thus (D-17-6) 24bdc-1 designates the first well constructed or visited in the SW¼SE¼NW¼ sec. 24, T. 17 S., R. 6 E., and (D-17-6) 24ab-S designates a spring known only to be in the NW¼NE¼ of the same section. Other sites where hydrologic data were collected are numbered in the same manner, but three letters are used after the section number and no serial number is used. The numbering system is illustrated in figure 2.

GEOLOGIC SETTING

Consolidated rocks exposed in the Trail Mountain area range in age from Cretaceous to Tertiary. Various types of unconsolidated deposits of Quaternary age also are

[1]Although the basic land unit, the section, is theoretically 1 mi², many sections are irregular. Such sections are subdivided into 10-acre tracts, generally beginning at the southeast corner, and the surplus or shortage is added to or subtracted from the tracts along the north and west sides of the section.

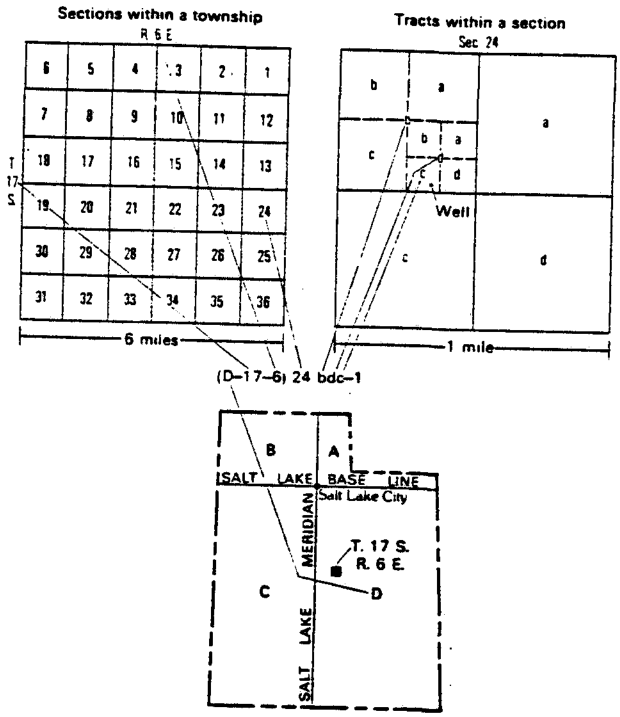

Figure 2. Well-, spring-, and site-numbering system used in Utah.

exposed in the area. The unconsolidated deposits are relatively thin and mainly consist of clay, sand, gravel, and boulders. Outcrop areas of geologic units are shown in figure 3.

The oldest geologic unit exposed in the area is the Masuk Member of the Mancos Shale of Cretaceous age. The Masuk consists of gray marine shale that is sandy in some places. About 600 ft of the Masuk is exposed at the base of Trail Mountain near the confluence of Straight Canyon and Cottonwood Creek. (See figure 4.) The Masuk is not fully exposed in the study area, therefore, total thickness is unknown.

The Star Point Sandstone of Cretaceous age is exposed in the lowermost cliffs on the southeast end of Trail Mountain. The Star Point consists of massive beds of tan medium-grained sandstone, and it intertongues with several thin shale beds of the Masuk. Where the unit is exposed on Trail Mountain, it is about 500 ft thick. The altitude of the top of the Star Point is shown in figure 5.

The coal-bearing unit in the Wasatch Plateau is the Blackhawk Formation. The Blackhawk consists of gray sandstone, gray to black siltstone and shale, and coal. Sediments in the Blackhawk were deposited in marine, flood-plain, deltaic, and lagoonal environments. Sandstone beds are lenticular, and individual beds can be traced only for short distances in the outcrop area. The sandstones mainly are fine grained, and lithologic logs of test holes on Trail Mountain indicate that the Blackhawk is 50 to 60 percent sandstone (Davis and Doelling, 1977, p. 23-54). The Blackhawk ranges in thickness from about 800 to 1,100 ft on Trail Mountain.

Most of the coal is in the lower one-half of the Blackhawk Formation. The Hiawatha coal bed, the thickest of the coal beds on Trail Mountain, is within a few feet of the base of the Blackhawk and has a maximum thickness of about 12 ft. The Hiawatha bed was mined along Straight Canyon at the Oliphant and Black Diamond Mines (fig. 7) from about the turn of the 20th century into the 1950's (Doelling, 1972, p. 87 and 90). Mining from the Hiawatha bed began in 1946 at the Trail Mountain Mine along Cottonwood Creek, and the mine was still operating in 1983. A view of the surface facilities at the Trail Mountain Mine is shown in figure 6.

The Castlegate Sandstone of Cretaceous age overlies the Blackhawk, and it forms cliffs similar to those shown in figure 4 along most of its outcrop. The Castlegate consists of gray, tan, and yellowish brown sandstone. The sandstone beds are massive, and the sandstones mostly are medium to coarse grained and conglomeratic in places. The Castlegate is about 170 ft thick along a section measured in sec. 20, T. 17 S., R. 6 E. on the west side of Trail Mountain (Davis and Doelling, 1977, p. 6). The Castlegate is about 200 ft thick at well (D-17-6) 27bda-1.

The Price River Formation of Cretaceous age crops out on steep slopes above the cliffs of the Castlegate Sandstone. The Price River Formation mainly consists of gray, tan, and brown sandstone and a few thin beds of conglomerate and shale. The sandstones mainly are medium to coarse grained. The unit is about 700 ft thick on Trail Mountain.

Exposures of the North Horn Formation of Cretaceous and Tertiary age cover about 56 percent of the surface of Trail Mountain. The North Horn generally forms gentle slopes that are hummocky in places. The unit mainly consists of shale, but it has some thin beds of sandstone and limestone. The shales are various shades of pink, green, purple, gray, and brown. The North Horn is about 980 ft thick along a section measured in secs. 21 and 22, T. 17 N., R. 6 E. (Davis and Doelling, 1977, p. 6).

The Flagstaff Limestone of Tertiary age is as much as 1,000 ft thick in other areas of the Wasatch Plateau, but only 100 ft remains atop the south end of Trail Mountain. The Flagstaff mainly consists of white and light gray limestone and some thin beds of shale and volcanic ash. The limestones are lacustrine in origin and are thin bedded.

The Joes Valley fault breaks the continuity of geologic units along the west edge of Trail Mountain. Davis and Doelling (1977, p. 9) estimate about 2,300 ft of vertical displacement along the fault in this area. The Joes Valley fault is the eastern fault boundary of a graben, approximately

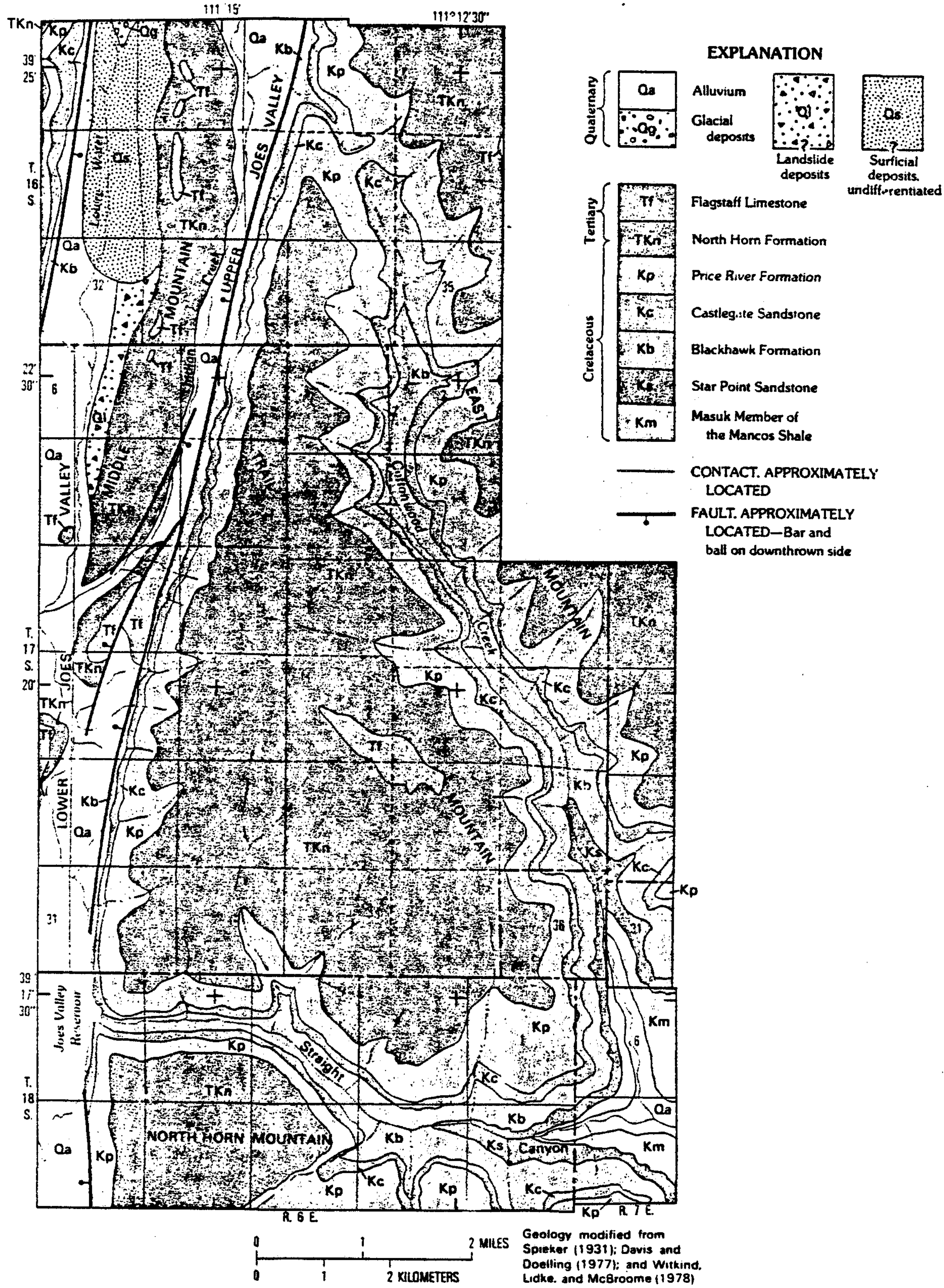

Figure 3. Surficial geology.

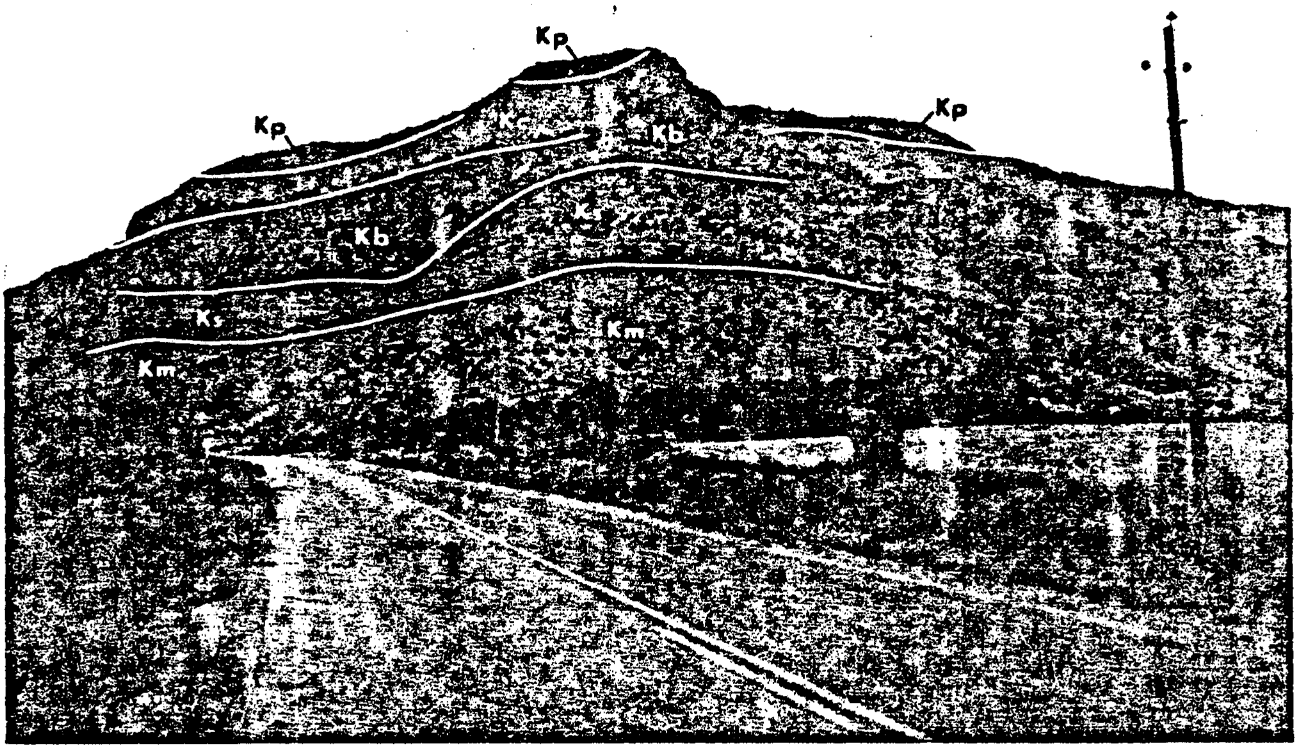

Figure 4. View of geologic units exposed on the southeast slopes of Trail Mountain. (Km, Masuk Member of the Mancos Shale; Ks, Star Point Sandstone; Kb, Blackhawk Formation; Kc, Castlegate Sandstone; Kp, Price River Formation.)

2 mi wide, that extends at least 20 mi north of Trail Mountain and at least 40 mi south.

Strata are gently folded into the Flat Canyon anticline in the northern part of Trail Mountain. Southward, the strata dip gently into the Straight Canyon syncline. (See figure 5.) Both structures trace about north 50° east and plunge to the southwest. The dip of strata on Trail Mountain generally is 2° or 3° and rarely exceeds 5°.

GROUND-WATER SYSTEM

The ground-water system in the Trail Mountain area was defined principally using data from wells and springs. Records of wells in the Trail Mountain area are listed in table 1, and spring records are listed in table 2. Location of the wells, springs, mines, and other data-collection sites is shown in figure 7.

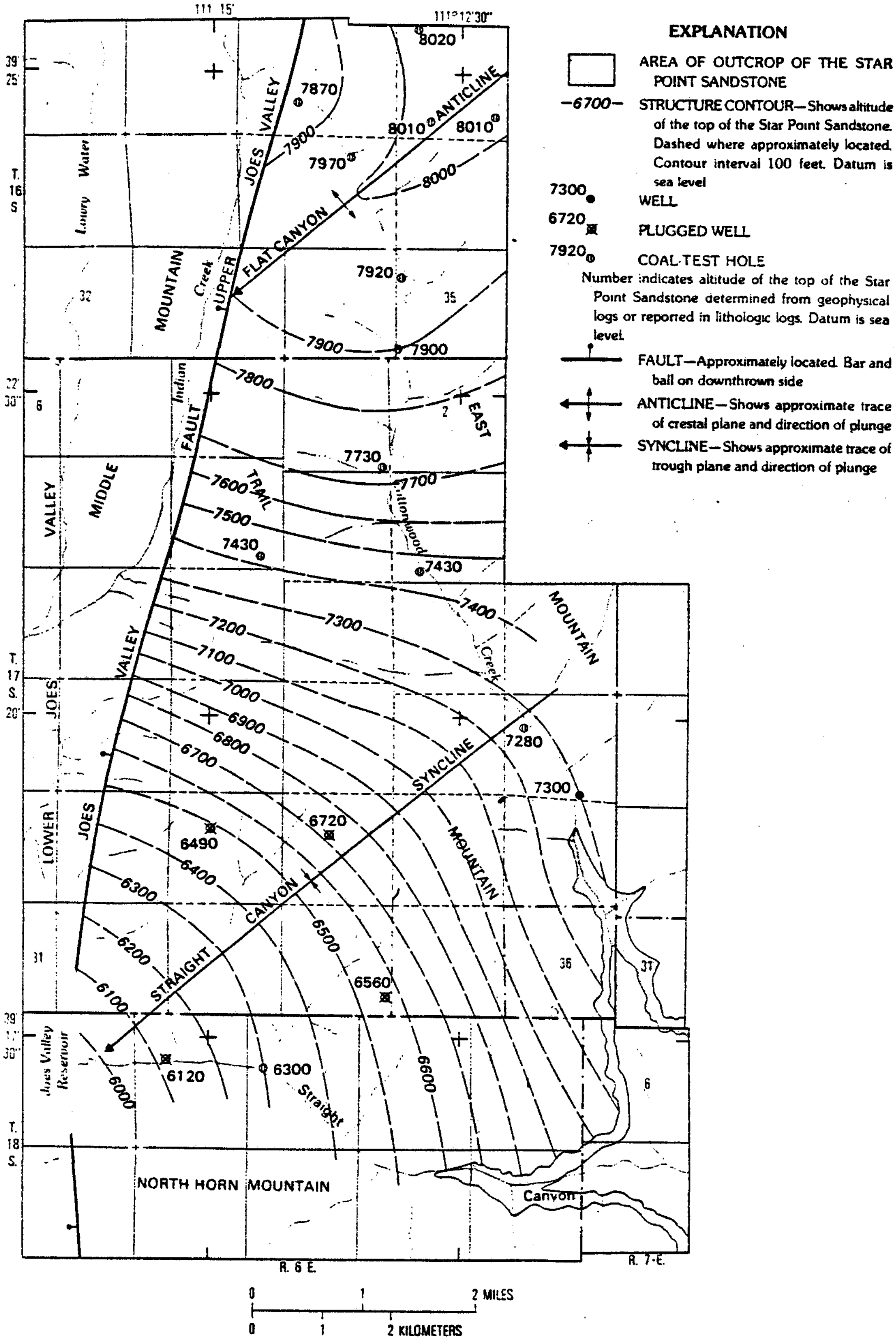

Figure 5. Altitude of the top of the Star Point Sandstone.

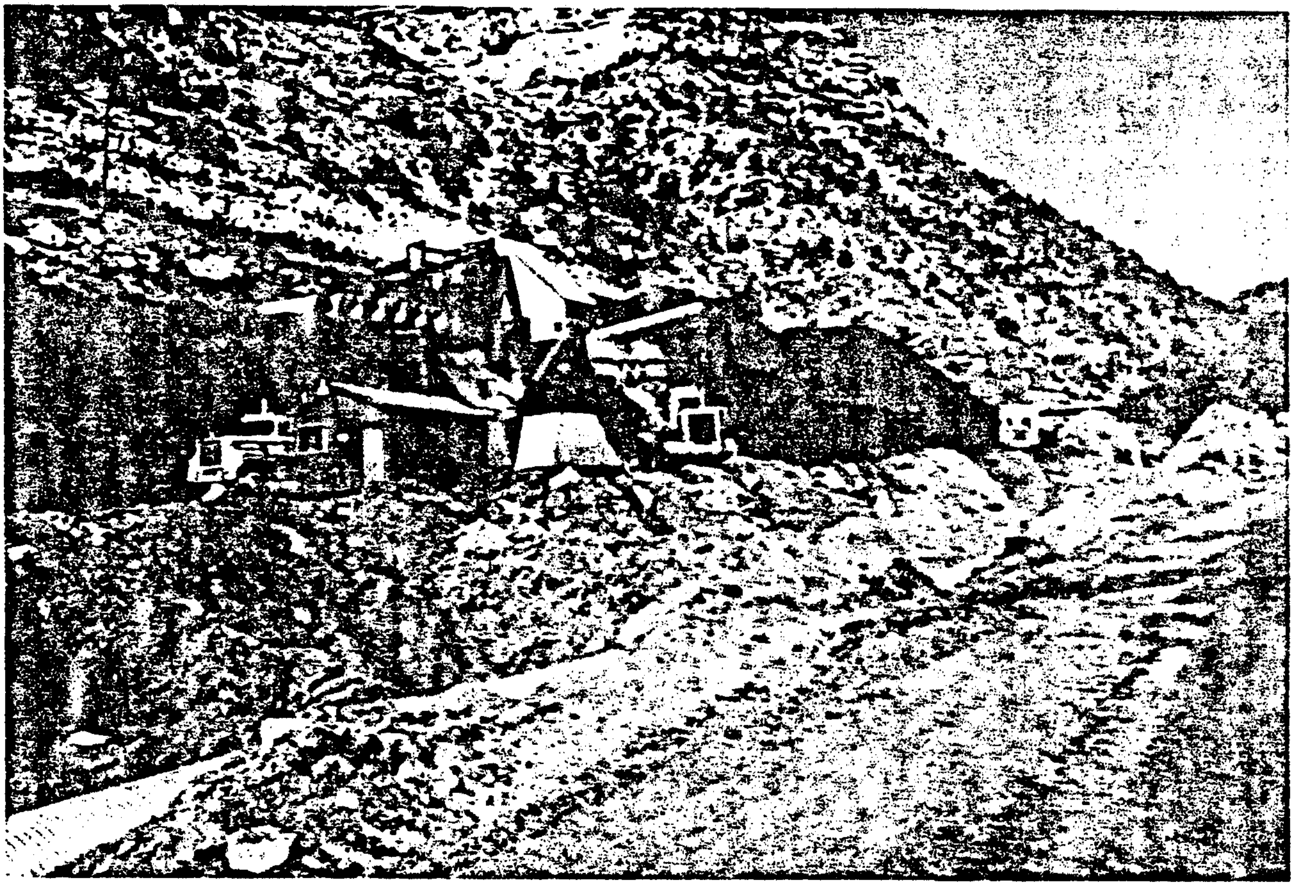

Figure 6. View of the Trail Mountain Mine along Cottonwood Creek. The stream has been diverted into the culvert to decrease sediment yields from the surface facilities of the mine.

Occurrence of Ground Water

The occurrence of ground water in Trail Mountain is depicted in the generalized block diagram in figure 8. Most of the Blackhawk Formation and Star Point Sandstone are saturated, except where they are drained naturally near the edges of deeply incised canyons. This saturated zone comprises the Blackhawk-Star Point aquifer, which extends throughout most of the Wasatch Plateau coal field. This regional aquifer is the source of most of the water in underground mines in the coal field.

Although the Masuk Member of the Mancos Shale probably is saturated beneath the Blackhawk-Star Point aquifer, it is not considered a part of the aquifer. Except where extensively fractured, less-permeable shales in the Masuk will transmit relatively small quantities of water compared to most rocks in the Blackhawk-Star Point aquifer.

Where strata that overlie the Blackhawk-Star Point aquifer are several hundred feet above the bottoms of canyons, as is the case for most of Trail Mountain, aquifers in the overlying strata are perched[2]. As depicted in figure 8, perched aquifers in the North Horn and Price River Formations are separated from each other and from the Blackhawk-Star Point aquifer by an unsaturated zone. Both of the perched aquifers have water tables that are several hundred feet above the regional water table in the Blackhawk-Star Point aquifer.

The perched aquifers are the source of most of the spring water consumed by livestock and wildlife on Trail Mountain. In some areas of the Wasatch Plateau, most of the base flow of streams originates as discharge from perched aquifers (Danielson and Sylla, 1983, p. 15).

The Castlegate Sandstone is depicted in figure 8 as being above the regional water table and containing no

[2]As defined by Lohman and others (1972, p. 7), "*Perched ground water* is unconfined ground water separated from an underlying body of ground water by an unsaturated zone. Its water table is a *perched water table*. It is held up by a *perching bed* whose permeability is so low that water percolating downward through it is not able to bring water in the underlying unsaturated zone above atmospheric pressure."

Table 1. Records of wells

Altitude of land surface: Interpolated from U.S. Geological Surgey topographic maps.
Casing: Depth—Depth to top of perforations or first opening; P, depth to bottom of expandable packer in open hole.
Water-bearing zone(s): Kb, Blackhawk Formation; Kc, Castlegate Sandstone; Kp, Price River Formation; Ks, Star Point Sandstone; Qa, alluvium; TKn, North Horn Formation.
Use(s) of well: A, aquifer test; D, domestic supply; M, water-level monitoring.
Remarks and other data available: A, aquifer test summarized in table 4 and data in files of U.S. Geological Survey, Salt Lake City, Utah; C, chemical analysis in table 6; T, analysis of dissolved trace metals in table 7.
Units: ft, feet; in., inches; gal/min, gallons per minute.

Well No.	Owner or user	Year constructed	Altitude of land surface above sea level (ft)	Depth of well (ft)	Casing: Diameter (in.)	Casing: Depth (ft)	Water-bearing zone(s)	Water level above (+) or below land surface (ft)	Discharge (gal/min)	Date	Use(s) of well	Remarks and other data available
(D-17-6)24dcd-1	Utah Power and Light Co.	1978	7,440	280	4	100	Kb,Ks	46	5.0	9-18-79	A,M	A
27bda-1	U.S. Geological Survey	1982	9,130	2,500	4	1,910P	Kb,Ka	1,484	6.5	10-20-82	A	First water at 130 ft in the North Horn Formation. 4-in. casing to 1,400 ft; 3-in. casing to 1,490 ft; and 3-in. open hole below. Plugged after testing. A,C,T
						2,420P	Ks	1,505	4.7	10-18-82		
28bad-1	do.	1982	8,920	664	4	50	TKn	49	.1	10-28-82	A	Casing perforated at 50-90 and 550-580 ft. Both perforated intervals tested with an expandable packer. Plugged after testing.
						550	TKn	Dry	---	10-26-82		
28bad-2	do.	1982	8,920	1,220	4	1,030	Kp	816	2.0	10-30-82	A	Casing perforated at 1,030-1,080 ft. Plugged after testing. A,C,T
29cbb-1	Jack World	1982	7,100	120	6	80	Qa	73	---	8-10-82	D	C,T
34dda-1	U.S. Geological Survey	1982	8,460	1,945	4	55	TKn	40	1.5	9-23-82	A	Casing perforated at 55-100; 722-742; 1,446-1,466; and 1-882-1,897 ft. Each perforated interval tested with an expandable packer. Plugged after testing. A
						722	Kc	Dry	---	9-25-82		
						1,446	Kb	1,414	.1	10- 6-82		
						1,882	Kb	1,478	.2	10- 9-82		
(D-18-6)4bac-1	do.	1981	6,800	696	4	85	Kb,Ks	+20	9.3	6-22-82	A	First water reported at 45 ft. in the Blackhawk Formation. Casing perforated at 85-410 ft. and 3-in. open hole below. Plugged after testing. A,C,T
5abd-1	U.S. Bureau of Reclamation	1980	7,010	188	.5	174	Kb	122	---	9- 3-82	M	Porous-tube piezometer.
5abd-2	do.	1980	7,010	160	.5	148	Kb	107	---	9- 3-82	M	Do.
5abd-3	do.	1980	7,010	154	.5	135	Kb	67	---	9- 3-82	M	Do.
5abd-4	do.	1980	7,010	132	.5	120	Kb	56	---	9- 3-82	M	Do.

Table 2. Records of springs

Altitude of land surface: Interpolated from U.S. Geological Survey topographic maps.
Water-bearing zone: Kb, Blackhawk Formation; Kc, Castlegate Sandstone; Kp, Price River Formation; TKn, North Horn Formation.
Units: ft, feet; gal/min, gallons per minute; μmho, micromhos per centimeter at 25 degrees Celsius; °C, degrees Celsius.

Spring No.	Altitude of land surface above sea level (ft)	Water-bearing zone	Date	Discharge (gal/min)	Specific conductance (μmho)	Water temperature (°C)
(D-16-6)21ddd-S1	8,570	TKn	6-22-79	9.4	650	6.0
			9-19-79	.5	—	10.0
22cda-S1	8,900	Kb	7-16-81	6.1	660	6.5
			7-29-81	5.0	690	6.0
			8-20-81	5.2	600	5.5
			9-23-81	4.8	560	6.0
			5-21-82	14.5	580	6.0
			6-23-82	13.7	600	6.5
			7-17-82	13.0	620	6.5
			8-10-82	10.4	600	6.5
			9- 2-82	10.9	600	6.5
22ddb-S1	9,400	Kp	6-28-79	3.8	540	5.5
27aaa-S1	9,460	Kp	6-19-79	9.4	430	3.5
27add-S1	9,180	Kc	6-20-79	.6	420	6.0
27bcd-S1	9,580	Kp	8-23-79	.8	400	6.0
27dcc-S1	9,480	Kp	8- 1-79	4.8	510	4.5
33bcd-S1	8,380	TKn	10- 1-80	13.0	580	7.0
34abd-S1	9,280	Kp	8- 1-79	.05	580	7.0
34acc-S1	9,560	TKn	6-20-79	13.0	440	5.0
34bdc-S1	9,700	TKn	6-20-79	17.1	470	5.0
34cad-S1	9,400	Kp	9- 6-78	.5	560	8.5
34dda-S1	8,760	Kp	8- 1-79	3.2	560	7.5
(D-17-6)3aac-S1	9,360	Kp	7-19-79	.8	560	7.5
3aac-S2	9,360	Kp	7-19-79	.4	500	8.0
3acb-S1	8,960	Kp	6-21-79	60	530	6.0
3adc-S1	8,960	Kc	10-14-77	26	540	7.0
			7- 4-79	24	550	7.5
3add-S1	8,760	Kc	7- 4-79	7.1	550	7.5
3bab-S1	9,640	TKn	6-20-79	.2	490	7.0
3bad-S1	9,440	Kp	7-19-79	1.3	490	6.5
3bda-S1	9,040	Kp	6-21-79	50	520	6.0
3cbd-S1	9,400	TKn	7-31-79	.6	470	7.0
3ddc-S1	8,700	Kc	7- 4-79	13	560	—
4bcc-S1	8,190	TKn	6-15-79	29	620	5.0
4cbb-S1	8,200	TKn	6-15-79	147	600	5.0
14bcb-S1	9,080	TKn	6-27-79	.6	470	—
			7-14-81	Dry	—	—
14ddd-S1	7,770	Kb	7-14-81	80	650	8.5
			7-30-81	76	640	8.0
			8-20-81	73	640	8.0
			9-24-81	76	660	8.0
			5-20-82	80	—	—
			6-23-82	76	670	8.0
			7-17-82	98	670	7.5
			8-10-82	98	660	8.5
			9- 8-82	110	600	8.5
15adc-S1	9,080	TKn	6-27-79	1.6	490	7.0

Table 2 Records of springs—Continued

Spring No.	Altitude of land surface above sea level (ft)	Water-bearing zone	Date	Discharge (gal/min)	Specific conductance (μmho)	Water temperature (°C)
(D-17-6)15cad-S1	8,840	TKn	7- 5-79	1.0	560	8.5
			7-29-81	.2	690	6.0
15cbd-S1	8,950	TKn	7-13-79	1.2	680	13.5
			7-29-79	Dry	---	---
15dda-S1	8,520	Kp	7- 5-79	1.5	650	8.0
21abb-S1	9,340	TKn	6-26-79	3.2	550	5.5
			7-14-81	.6	630	7.5
21dcd-S1	9,040	TKn	7-10-79	32	520	6.0
			7-14-81	12.4	560	7.0
			7-30-81	10.3	580	6.5
			8-20-81	7.6	600	7.0
			9-23-81	7.6	580	6.5
			5-21-82	44	570	6.5
			6-23-82	28	580	6.5
			7-15-82	20	580	6.0
			8-10-82	12.6	620	7.0
			9- 2-82	13.5	600	7.0
21dcd-S2	9,100	TKn	7-10-79	4.0	560	6.0
22cdc-S1	9,220	TKn	7-14-81	5.0	495	8.0
			7-30-81	6.1	520	8.0
			8-20-81	5.3	540	6.0
			9-23-81	5.1	520	6.5
			5-21-82	40	520	6.5
			6-23-82	28	510	6.5
			7-15-82	23	520	6.0
			8-10-82	11.2	600	6.5
			9- 2-82	12.4	510	7.0
23bcb-S1	8,860	TKn	7-13-79	14	620	4.0
23bcb-S2	8,780	Kp	7-13-79	24	630	4.5
26cba-S1	9,200	TKn	6-27-79	6.3	560	8.0
			7-14-81	1.1	600	11.0
26cbb-S1	9,180	TKn	7-18-79	4.0	580	6.0
			7-14-81	1.3	640	7.5
			7-30-81	1.3	660	7.5
			8-20-81	1.1	720	7.0
			9-23-81	1.2	650	7.5
			5-21-82	5.0	660	7.0
			6-23-82	5.0	670	6.5
			7-15-82	4.8	660	6.0
			8-10-82	3.6	640	7.5
			9- 2-82	2.6	660	7.5
26ccb-S1	8,960	TKn	7-18-79	18	700	5.0
27bbd-S1	9,050	TKn	8-16-79	4.0	500	6.5
27cbb-S1	8,800	TKn	8-16-79	3.2	650	7.0
			7-15-81	2.3	680	7.0
27ccc-S1	8,760	TKn	8-16-79	4.0	700	8.0
			7-15-81	1.7	660	7.5
27ccd-S1	8,800	TKn	8-16-79	3.2	620	7.5
			7-15-81	.6	710	8.5
28bac-S1	8,800	TKn	7-16-81	.8	740	10.0
28bbc-S1	8,500	TKn	8-29-79	6.0	800	8.0

Table 2 Records of springs—Continued

Spring No.	Altitude of land surface above sea level (ft)	Water-bearing zone	Date	Discharge (gal/min)	Specific conductance (µmho)	Water temperature (°C)
(D-17-6)28bbc-S2	8,340	Kp	8-29-79	6.0	540	9.0
			7-16-81	.8	600	10.5
32acb-S1	7,600	Kp	8-31-79	—	790	—
33cbb-S1	8,400	TKn	8-30-79	0.1	950	12.0
35cbb-S1	8,720	TKn	7-11-79	.9	750	8.0
			7-15-81	.2	780	12.0
35ccb-S1	8,720	TKn	7-12-79	5.1	560	6.5
			7-15-81	2.6	700	7.5
			7-30-81	2.5	740	7.0
			8-20-81	2.2	740	8.5
			9-23-81	2.6	720	8.0
			5-21-82	9.7	680	6.5
			6-23-82	6.4	690	7.5
			7-15-82	5.3	700	7.0
			8-10-82	5.0	690	7.5
			9- 2-82	4.4	700	8.0
(D-18-6)2bbd-S1	8,120	TKn	7-12-79	.5	940	8.0
			7-15-81	.6	1,140	9.0
4bab-S1	7,200	Kc	11- 9-77	6.7	660	2.0
4bbc-S1	7,000	Kb	8-31-79	1.6	800	12.5
			7-13-81	.6	870	17.0
			7-30-81	1.0	870	15.0
			8-20-81	1.1	920	15.0
			5-20-82	.1	900	12.5
			6-23-82	Dry	—	—
5abd-S1	6,920	Kb	5-21-82	200	410	3.0
			10-28-82	180	425	3.0

perched aquifer. This is an accurate depiction for most of the area. Four springs do issue from the Castlegate on the northeast slopes of Trail Mountain. The source of water for the Castlegate springs probably is a perched aquifer as the springs are several hundred feet higher in altitude than Cottonwood Creek, which is ephemeral in its upper reaches.

No springs issue from the small outcrop area of the Flagstaff Limestone on Trail Mountain. Most water recharged on the outcrop of the Flagstaff probably leaks downward into the perched aquifer in the North Horn Formation.

Despite the large quantity of rock with negligible permeability, there is hydraulic connection between aquifers. Most of the exchange of water probably occurs along fractures in perching beds where there is unsaturated flow downward. Leakage from overlying aquifers is a significant source or recharge to the Blackhawk-Star Point aquifer, and it is discussed in a following section of the report.

Occurrence of ground water as depicted in figure 8 is consistent with spring and test-hole data for other areas in the Wasatch Plateau. Danielson and Sylla (1983, figs. 10 and 11) completed an extensive spring inventory on North Horn, South Horn, and Ferron Mountains 2 to 20 mi south of Trail Mountain. Most of the springs in these areas issue from the North Horn and Price River Formations, and few springs issue from the Castlegate Sandstone and older rocks. Elsewhere in the Wasatch Plateau where the Flagstaff Limestone has an extensive outcrop area, they inventoried a large number of springs that issue from the Flagstaff. Danielson and Sylla (1983, p. 22) concluded from test-hole data that the Star Point Sandstone and Blackhawk Formation contain water in most areas of the southern Wasatch Plateau.

Aquifer Characteristics

Porosity was determined in the laboratory for eight core samples that are representative of lithologies in the Blackhawk-Star Point aquifer. The core samples were obtained while drilling the hole for well (D-17-6) 27bda-1. Hydraulic conductivity was determined in the horizontal direction in seven of the samples and in the vertical direction in six. The

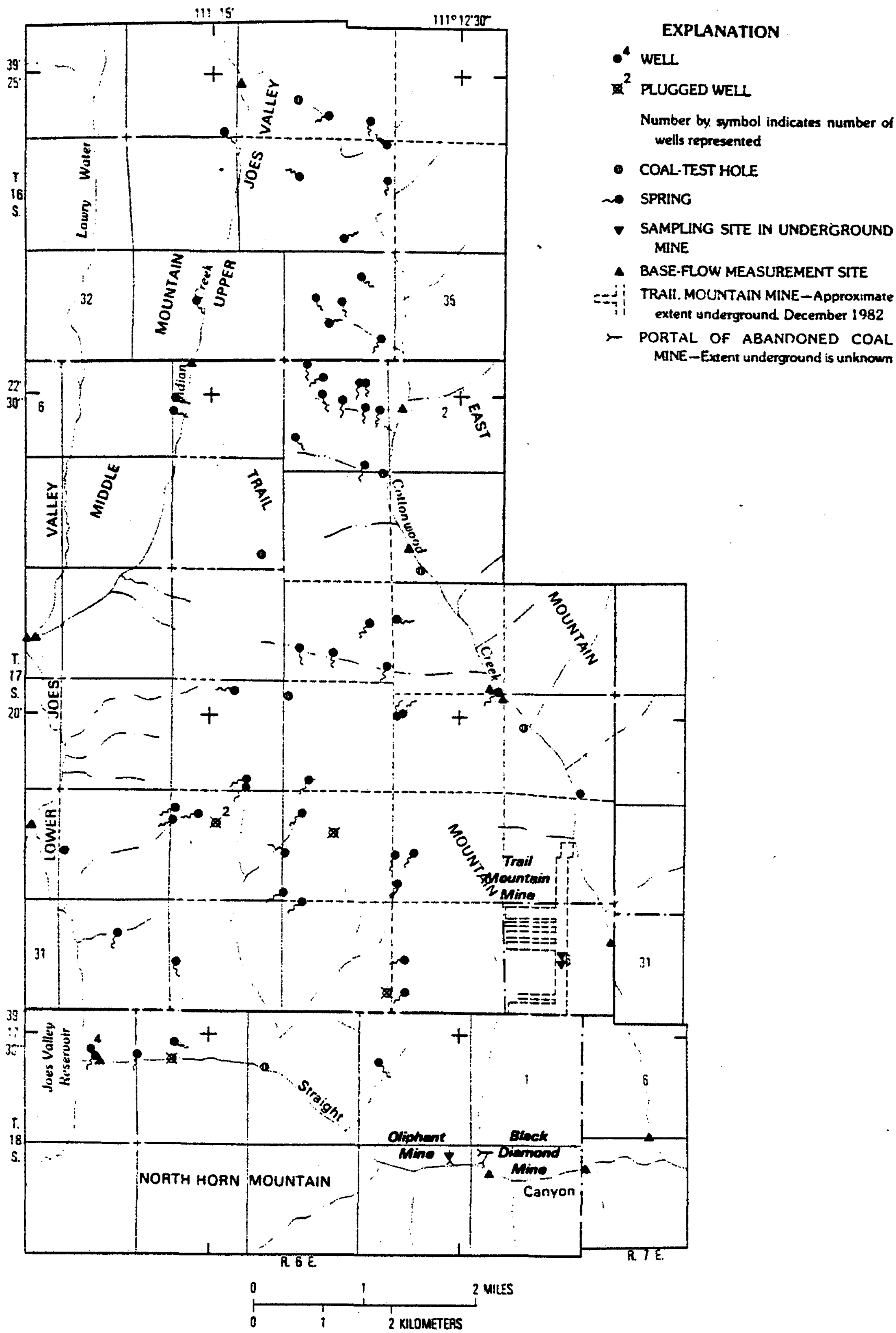

Figure 7. Data-collection sites and coal mines.

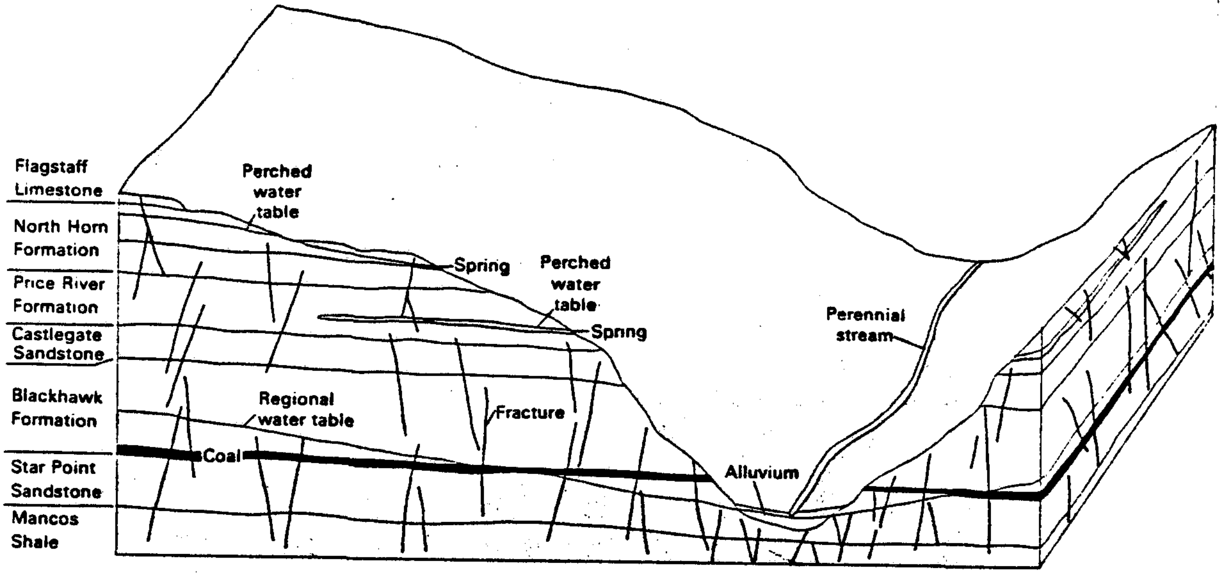

Figure 8. Generalized block diagram showing occurrence of ground water.

Table 3. Laboratory determinations of porosity and hydraulic conductivity of core samples from well (D-17-6)27bda-1

[Determinations by Core Laboratories, Inc., Dallas, Texas]

Lithology: Sh, shale; Slt, siltstone; Ss, sandstone; f, fine grained; m, medium grained.
Hydraulic conductivity: I, impermeable to water even at a pressure of 5,000 pounds per square inch.

Geologic unit	Lithology	Depth below land surface (feet)	Porosity (percent)	Hydraulic conductivity (feet per day)	
				Horizontal	Vertical
Blackhawk Formation	Ss, f	1,521	14	1.5×10^{-2}	3.7×10^{-3}
	Slt	1,545	3	9.3×10^{-8}	1.2×10^{-7}
	Sh	1,786	2	I	I
	Ss, f	1,792	14	1.1×10^{-2}	3.9×10^{-3}
	Sh	2,170	4	1.1×10^{-8}	—
	Slt	2,265	2	2.0×10^{-7}	2.2×10^{-6}
Star Point Sandstone	Ss, m	2,466	17	3.1×10^{-2}	1.1×10^{-2}
	Ss, m	2,493	11	1.5×10^{-2}	6.6×10^{-3}

laboratory determinations, listed in table 3, indicate a large variation in both porosity and hydraulic conductivity. Porosity of sandstone samples ranged from 11 to 17 percent, and hydraulic conductivity ranged from 3.7×10^{-3} to 3.1×10^{-2} ft/d. Horizontal hydraulic conductivities of all sandstone samples were greater than vertical hydraulic conductivities, but the differences were less than one order of magnitude. Porosity of the finer grained siltstone and shale samples ranged from 2 to 4 percent, and hydraulic conductivity ranged from 1.1×10^{-8} to 2.2×10^{-6} ft/d. One shale sample was effectively impermeable to water even at a pressure of 5,000 lbs/in^2. Unlike the sandstone samples, vertical hydraulic conductivities of the two siltstone samples were greater than the horizontal hydraulic conductivities.

Aquifer tests were conducted at five wells on Trail Mountain, and the results are summarized in table 4. No observation wells were available for the tests, and recovery in the discharge wells are used to compute transmissivity. A constant-drawdown test (Lohman, 1972, p. 23-26) also was conducted at well (D-18-6) 4bac-1, which flowed at the land surface. An expandable packer was used in wells (D-17-6) 27bda-1 and 34 dda-1 to isolate various zones for testing.

None of the test wells fully penetrated the Blackhawk-Star Point aquifer, and the transmissivity values in table 4 probably are most representative of the transmissivities of those parts of the aquifer open to the wells. Some transmissivity values computed from the tests agree fairly well with what would be expected from hydraulic conductivities determined

Table 4. Summary of aquifer tests, 1979–82

Method of test analysis: C, constant-drawdown method (Lohman, 1972, p. 23-26); R, straight-line recovery method (Lohman, 1972, p. 26 and 27).
Units: ft, feet; min, minutes; gal/min, gallons per minute; ft²/d, feet squared per day.

Well No.	Water-bearing zone(s)	Interval tested (ft below land surface)	Duration of test (min)	Discharge (gal/min)	Transmissivity (ft²/d)	K	Method of test analysis
(D-17-6)24dcd-1	Blackhawk Formation and Star Point Sandstone	100-280	43	5.0	2	1.1×10^{-2}	R
27bda-1	Blackhawk Formation and Star Point Sandstone	1,910-2,500	300	6.5	8	1.4×10^{-2}	R
	Star Point Sandstone	2,420-2,500	350	4.7	6	7.5×10^{-2}	R
28bad-2	Price River Formation	1,030-1,080	130	2.0	.8		R
34dda-1	North Horn Formation	55-100	150	1.5	10		R
	Blackhawk Formation	1,882-1,897	270	.2	.7	4.7×10^{-2}	R
(D-18-6)4bac-1	Blackhawk Formation and Star Point Sandstone	85-696	200	---	100		C
			200	9.3	100	1.6×10^{-1}	R

in the laboratory (table 3.) At well (D-18-6) 4bac-1, the computed transmissivity of 100 ft²/d is greater than would be expected from the laboratory data. This is believed due to secondary permeability in the form of fractures; much of the core from this hole was fractured. Transmissivity of the full thickness of the Blackhawk-Star Point aquifer probably ranges from about 20 to 200 ft²/d in most of Trail Mountain.

One aquifer test was conducted in each of the perched aquifers in the North Horn and Price River Formations. Computed transmissivities for these two tests, 10 and 0.8 ft²/d, are indicative of the low-permeability rock in most of the Cretaceous and Tertiary section on Trail Mountain.

Water is unconfined in the upper few tens of feet of the Blackhawk-Star Point aquifer and in the perched aquifers. Water is released from storage in unconfined aquifers mainly by gravity drainage, and the storage coefficient is virtually equal to specific yield. No tests were conducted that allowed for accurate estimates of storage coefficients. Other studies (Johnson, 1967), however, have found that specific yield ranges from about 0.01 in shales to about 0.1 in sandstones that are similar to those on Trail Mountain. Because the Blackhawk-Star Point aquifer consists of sandstone and finer grained shales and siltstones, the storage coefficient in the unconfined parts of the aquifer probably averages about 0.05.

Water in most of the Blackhawk-Star Point aquifer is confined under pressure between shale and siltstone beds within the aquifer. Water is released from storage from confined aquifers mainly by compression of the sandstones and less permeable confining beds as pressure in the aquifer declines. The quantity of water that can be released from storage is dependent on the storage coefficient, which is about 1×10^{-6} per foot of thickness for most confined aquifers (Lohman, 1972, p. 8).

Potentiometric Surfaces

Hydraulic head varies both areally and with depth in the Blackhawk-Star Point aquifer. The potentiometric surface (the altitude at which water stands in tightly cased wells) of the aquifer at approximately the level of the Hiawatha coal bed is shown in figure 9. The Hiawatha bed contains water in other areas of Trail Mountain, but data permit contouring of the potentiometric surface only on the south end of the mountain. Water moves horizontally through the aquifer at approximately right angles to the potentiometric contours shown in figure 9.

Water also moves vertically through the Blackhawk-Star Point aquifer as indicated by changes in altitude of the potentiometric surface with depth. At well (D-17-6) 27bda-1, an expandable packer was used to isolate various intervals of an open hole. With the packer set at a depth of 2,420 ft (a few feet below the Hiawatha coal bed) and the bottom 80 ft of the hole open to the testing string, the water level was 1,505 ft below land surface. With the packer set at a depth of 1,910 ft in the same hole, the water level was 1,484 ft below land surface. Similarly, the water level in well (D-17-6) 34dda-1 was 1,478 ft below land surface when the perforated interval from 1,882 to 1,897 ft (opposite the Hiawatha bed) was isolated for testing, and the water level was 1,414 ft when the interval from 1,446 to 1,466 ft was isolated. At these two wells, the potentiometric surface decreased in altitude with increased depth in the aquifer, and water was moving downward. This is probably the case elsewhere on Trail Mountain where the Blackhawk-Star Point aquifer is recharged by downward percolation of water.

In natural discharge areas, such as along most of Straight Canyon and Cottonwood Creek, the altitude of the potentiometric surface in the Blackhawk-Star Point aquifer probably increases with depth. When the hole was being drilled for well (D-18-6) 4bac-1 in Straight Canyon, the water table in the Blackhawk-Star Point aquifer was penetrated at a depth of about 45 ft at about the level of the stream. Water flowed from the drill hole at land surface when the hole had penetrated the Hiawatha coal bed at a depth of about 670 ft. On June 22, 1982, shut-in water pressure at the well was 20 ft above land surface. Had the well been constructed so that it was open only to the Hiawatha bed, the shut-in pressure probably would have been greater.

Similarly, water flowed from an oil-test hole along Cottonwood Creek in the NE¼SW¼NE¼ sec. 14, T. 17 S., R. 6 E. when 370 ft of the Blackhawk Formation had been drilled (H.E. Patterson, Vortt Exploration Co., Inc., written commun., 1981). In an abandoned 65-foot deep "rat hole" at the same site, the water level was 17 ft below land surface on May 20, 1982.

Four porous-tube piezometers in Straight Canyon near Joes Valley Reservoir, (D-18-6) 5abd-1, 2, 3, and 4 in table 1, are open at various depths in the upper part of the Blackhawk-Star Point aquifer. During 1982, water levels in the piezometers decreased in altitude with increased depth in the aquifer. Recharge from the reservoir probably was inducing downward movement of water through the upper part of the aquifer in this area.

The approximate configuration of the perched water table in the North Horn Formation during 1982 is shown in figure 10. The water-table map mainly is based on the altitude of springs that issue from the aquifer and on some water levels measured in wells and coal-test holes.

Water moves through the perched aquifer in the North Horn Formation approximately at right angles to the water-table contours. Comparison of the water-table map (fig. 10) and the land-surface contours in figure 11 indicates that the configuration of the perched water table closely approximates the configuration of the land surface. The differences between the altitude of the perched water table in the North Horn and the potentiometric surface of the Blackhawk-Star Point aquifer at the level of the Hiawatha

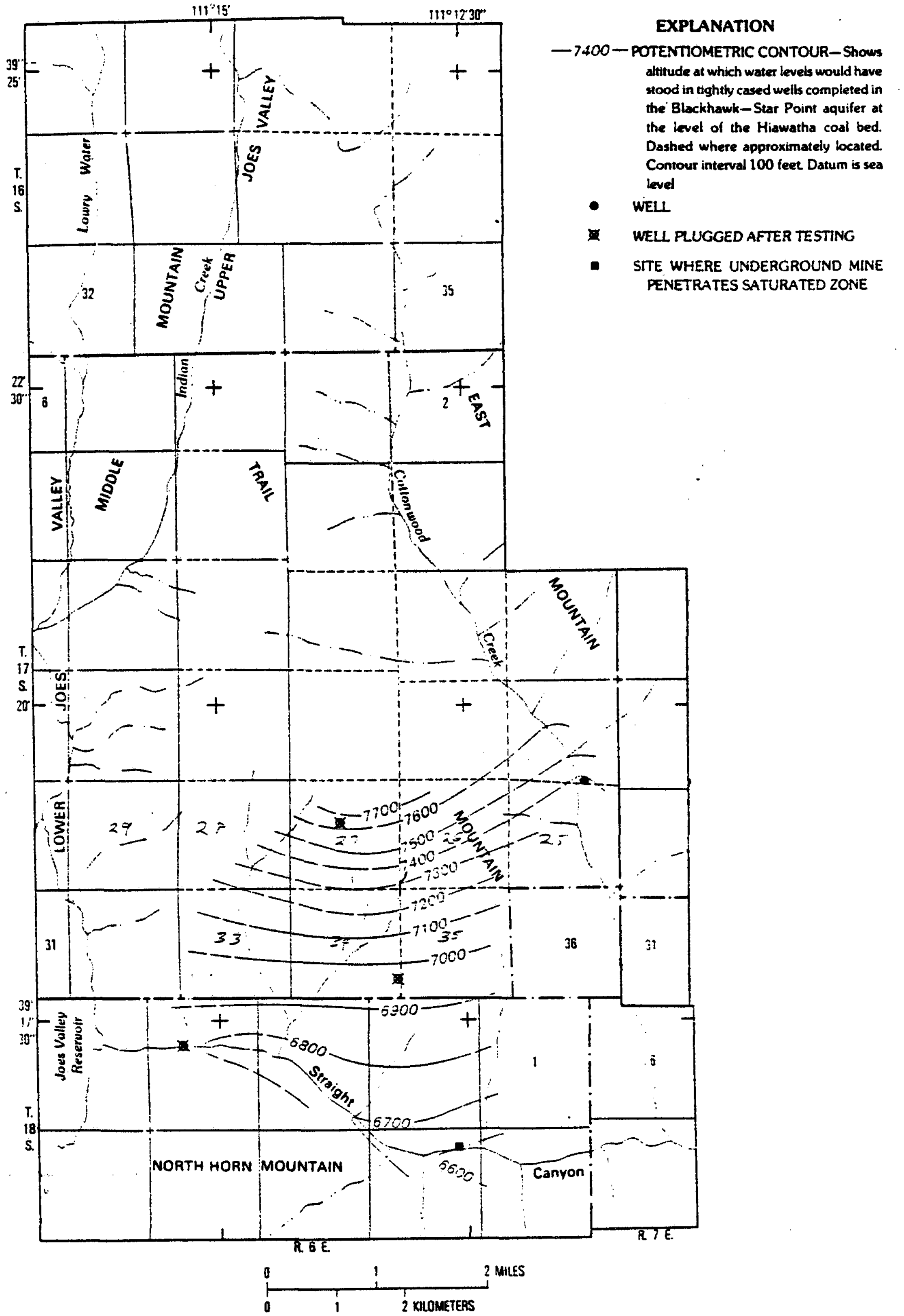

Figure 9. Potentiometric surface of the Blackhawk-Star Point aquifer at the level of the Hiawatha coal bed, 1982.

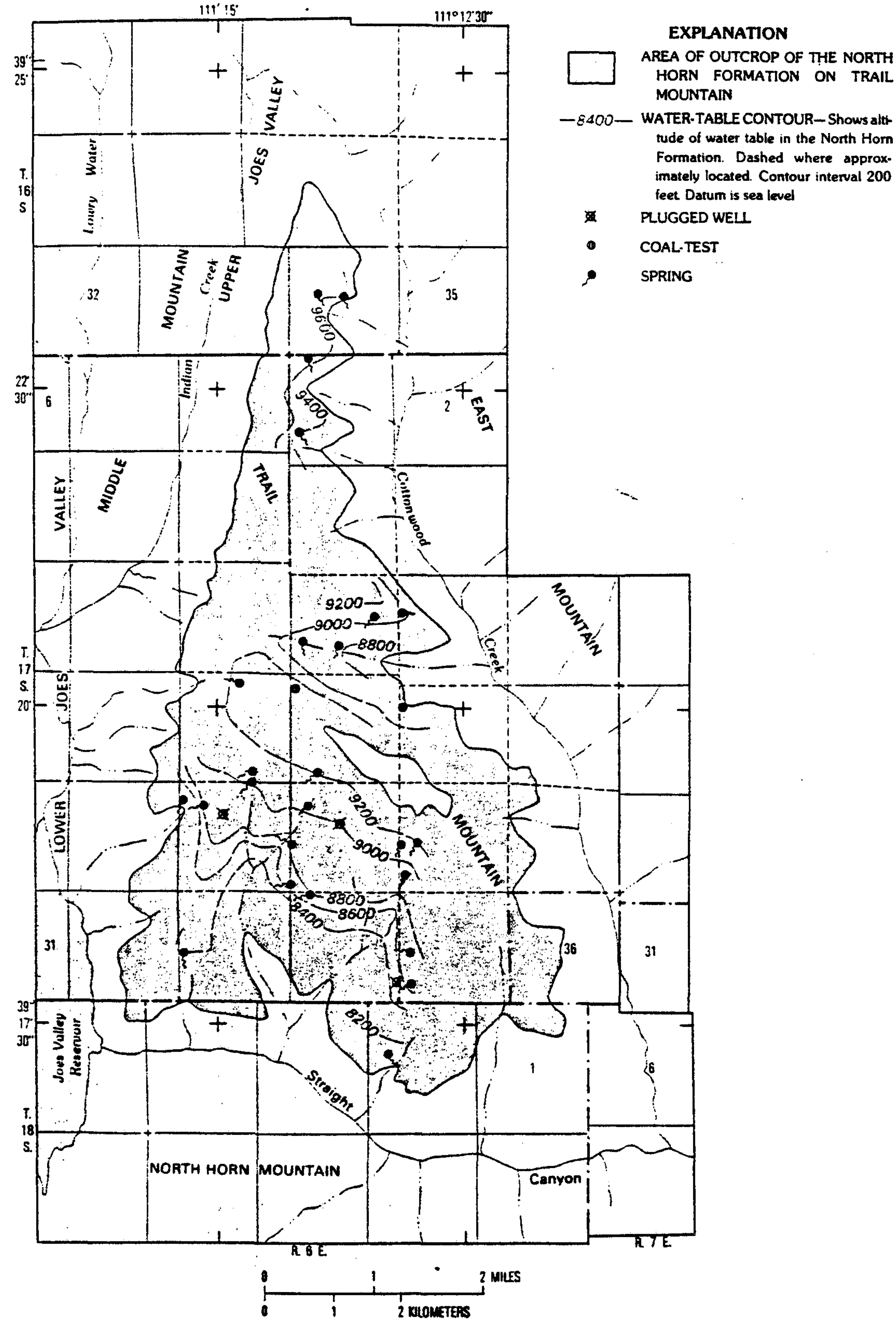

Figure 10. Altitude of the water table in the North Horn Formation on Trail Mountain, 1982.

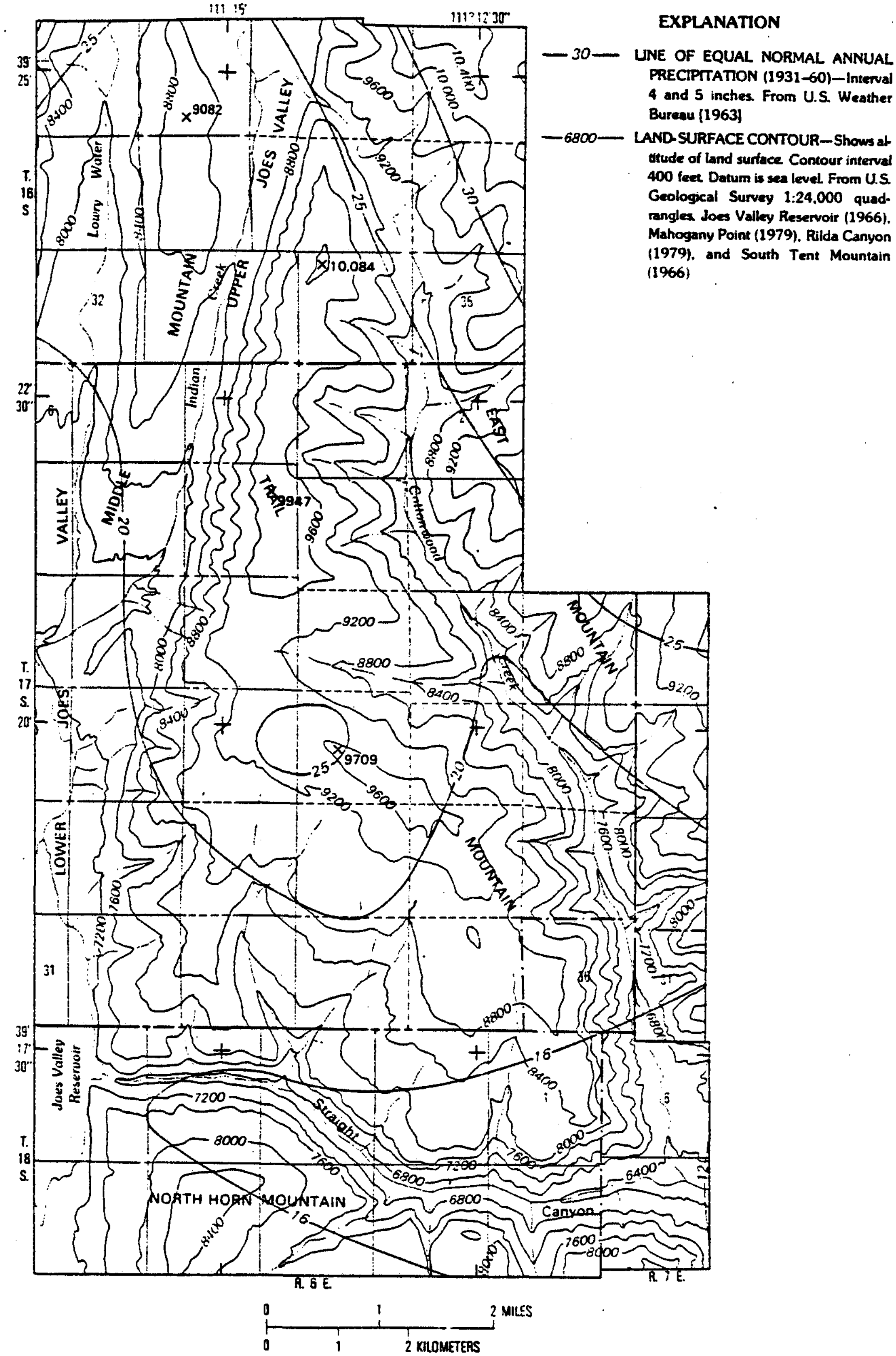

Figure 11. Normal annual precipitation and altitude of land surface.

coal bed range from about 1,000 to 1,700 ft on the south end of Trail Mountain.

It is apparent from the distribution of springs that a perched aquifer exists in most of the outcrop area of the North Horn. The perched aquifer probably exists in other areas of the North Horn outcrop that are not contoured in figure 10, but hydrologic data are not available to precisely define the extent of the aquifer. Sufficient data are not available to define the extent of other perched aquifers, such as in the Price River Formation or Castlegate Sandstone, or to define the configuration of their water tables.

Recharge and Discharge

Snowmelt and rain are the main sources of recharge to the ground-water system in Trail Mountain. Normal annual precipitation ranges from about 12 to 25 in. as shown in figure 11, and it occurs about equally as rain and snow.

Much of the recharge from precipitation is discharged by springs close to original recharge areas. The estimated total annual discharge of springs that issue from each geologic unit, expressed as a percentage of normal annual precipitation on the outcrop area, ranges from zero for three geologic units with no springs and relatively small outcrop areas to 18 percent for the Blackhawk Formation. (See table 5.) For those geologic units with outcrop areas greater than a fraction of a square mile, the percentages increase with increased geologic age. This reflects, in part, the relative permeabilities of geologic units and the relative ease with which they accept recharge. It probably also reflects significant downward percolation of water from overlying aquifers. The percentage is large for the Blackhawk also because of recharge from Joes Valley Reservoir, which is believed to be a large part of the water discharge at spring (D-18-6) 5abd-S1 in Straight Canyon.

The discharge of two springs that issued from the North Horn Formation is shown in figure 12 for parts of 1981 and 1982. Discharge of the springs varied markedly. The perched aquifer in the North Horn Formation receives most of its recharge from snowmelt and rain during late spring, and discharges of springs generally are largest during this period. Following the recharge period during late spring, the discharges of springs recede until the aquifer again receives a significant quantity of recharge, which may come as rain during the following summer and fall. A view of a typical spring that issues from the North Horn in a shallow depression on the upper slopes of Trail Mountain is shown in figure 13. The photograph was taken in late May of 1982, and most of the snow had melted on south-facing slopes. Discharge at spring (D-17-6) 22cdc-S1 was 40 gal/min (table 2).

The discharge of two springs that issue from the Blackhawk Formation is shown in figure 14. Like springs that issue from the North Horn, the discharges of Blackhawk springs vary markedly from season to season and from year to year. It is interesting to note that the discharge of spring (D-17-6) 14ddd-S1 was larger during the summer of 1982 than during late spring of the same year. The increase in discharge was undoubtedly due to recharge from summer rains, but it is unknown why the discharge of this spring increased while others that were measured did not. Perhaps summer rains were more intense in the recharge area of this spring than in other areas of Trail Mountain.

As mentioned earlier, water levels in piezometers near the head of Straight Canyon indicate that the Blackhawk-Star Point aquifer probably is recharged by Joes Valley Reservoir. Spring (D-18-6) 5abd-S1, shown in figure 15, is a short distance downstream from the dam on the reservoir, and it was the largest spring that issued from the Blackhawk-Star Point aquifer on Trail Mountain during 1982. Discharges of 200 and 180 gal/min were measured at the spring during 1982 (table 2), and a large part of the recharge to the Blackhawk-Star Point aquifer from the reservoir probably was discharged by the spring. According to Clyde Sherman (Emery Water Conservancy District, oral commun., 1982)

Table 5. Outcrop area, normal annual precipitation, and total annual discharge of springs for geologic units exposed on Trail Mountain

Geologic unit	Outcrop area (square miles)	Normal annual precipitation on outcrop (acre-feet)	Total annual discharge of springs	
			Acre-feet	Percent of normal annual precipitation on outcrop
Flagstaff Limestone	0.35	410	0	0
North Horn Formation	15	16,000	200	1.2
Price River Formation	5.9	6,100	160	2.6
Castlegate Sandstone	2.2	2,300	80	3.5
Blackhawk Formation	2.6	2,500	450	18
Star Point Sandstone	.37	380	0	0
Masuk Member of the Mancos Shale	.25	190	0	0
Total (rounded)	27	28,000	890	

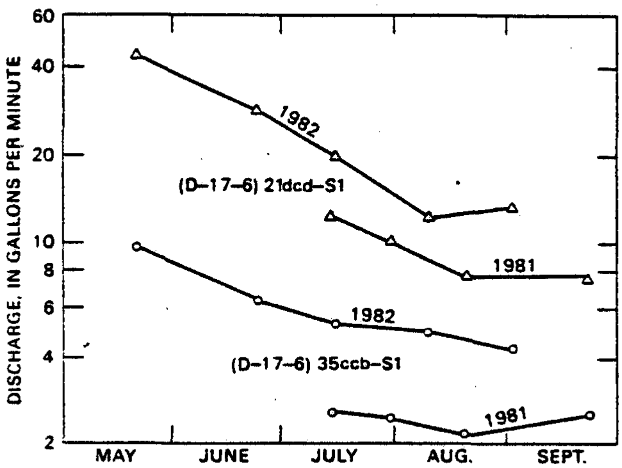

Figure 12. Discharge of two springs that issue from the North Horn Formation.

and other local residents, a spring issued from this location prior to construction of the dam, and a larger spring existed a few hundred feet upstream from the dam. The latter spring also issued from the Blackhawk-Star Point aquifer, but it was inundated by the reservoir. Thus, the head of Straight Canyon was a major discharge area for the Blackhawk-Star Point aquifer during 1982 and prior to construction of the dam in 1965.

Another source of discharge from the ground-water system was the dewatering of underground coal mines. A small quantity of water drained from the abandoned underground workings of the Oliphant Mine in Straight Canyon. On July 13, 1981, 1.0 gal/min was draining from the mine portal, and Sumsion (1979, p. 21) measured the discharge from the Oliphant Mine at 0.2 gal/min on June 1, 1977. The extent of the underground workings is unknown, but they probably intersect the regional water table in the Blackhawk-Star Point aquifer.

Discharge of water from the Trail Mountain Mine during 1982 was much larger than from the Oliphant Mine, although most of the water was derived from the unsaturated zone rather than from the Blackhawk-Star Point aquifer. Most of the Trail Mountain Mine was dry during 1982, except for a few areas where water dripped from the roof and where water had accumulated on the floor. An estimated 10 gal/min was pumped from Cottonwood Creek for use underground for dust suppression and for cooling of conveyor belts (J.R. Vasques, Natomas Trail Mountain Coal Co., oral commun., 1981). About 600 gal/d (0.4 gal/min) was pumped from a sump in the mine during 1982, and an average of

Figure 13. View of spring (D-17-6) 22cdc-S1 that issues from the perched aquifer in the North Horn Formation.

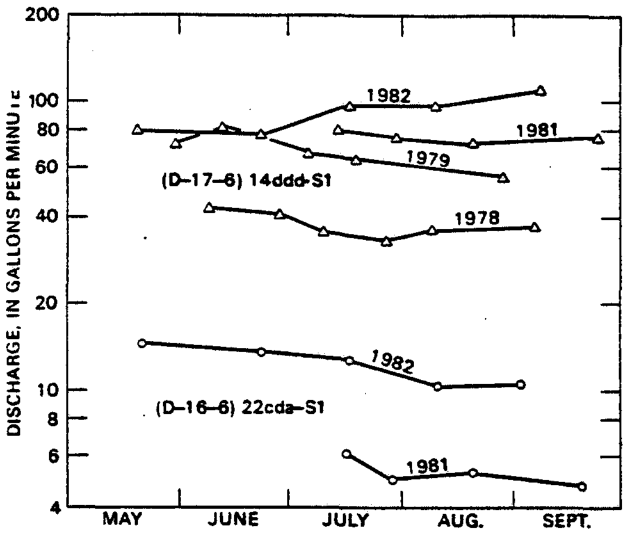

Figure 14. Discharge of two springs that issue from the Blackhawk Formation.

about 40 gal/min was removed by the mine ventilation system, which moved 159,000 ft^3 of air per minute. Water removed by the ventilation system was estimated by using wet- and dry-bulb thermometer readings to compute the water content of air entering the mine at the portal and exiting the mine at the exhaust fan. Measurements made on July 29 and September 1, 1982, and on February 11, 1983, indicate that about 13, 40, and 74 gal/min were removed by the ventilation system on those dates.

Very little water probably enters Trail Mountain through the Blackhawk-Star Point aquifer underlying Straight Canyon and the lower reaches of Cottonwood Creek. The streams are perennial in these areas, and ground water moving toward the streams from each side of the deeply incised canyons probably is discharged along the streams.

Streamflow measurements were made along streams that border Trail Mountain during two periods of base flow during 1981 and 1982 in order to determine ground-water discharge along the streams. Except for the discharge of spring (D-18-6) 5abd-S1 and water draining from the Oliphant Mine, ground-water discharge could not be detected along Straight Canyon. Discharge of the stream in Straight Canyon was about 60 ft^3/s on September 24, 1981, and about 50 ft^3/s on October 28, 1982, at the measurement sites shown in figure 7. The measurements were rated as "fair" (having an error of as much as 8 percent) due to flow conditions in the

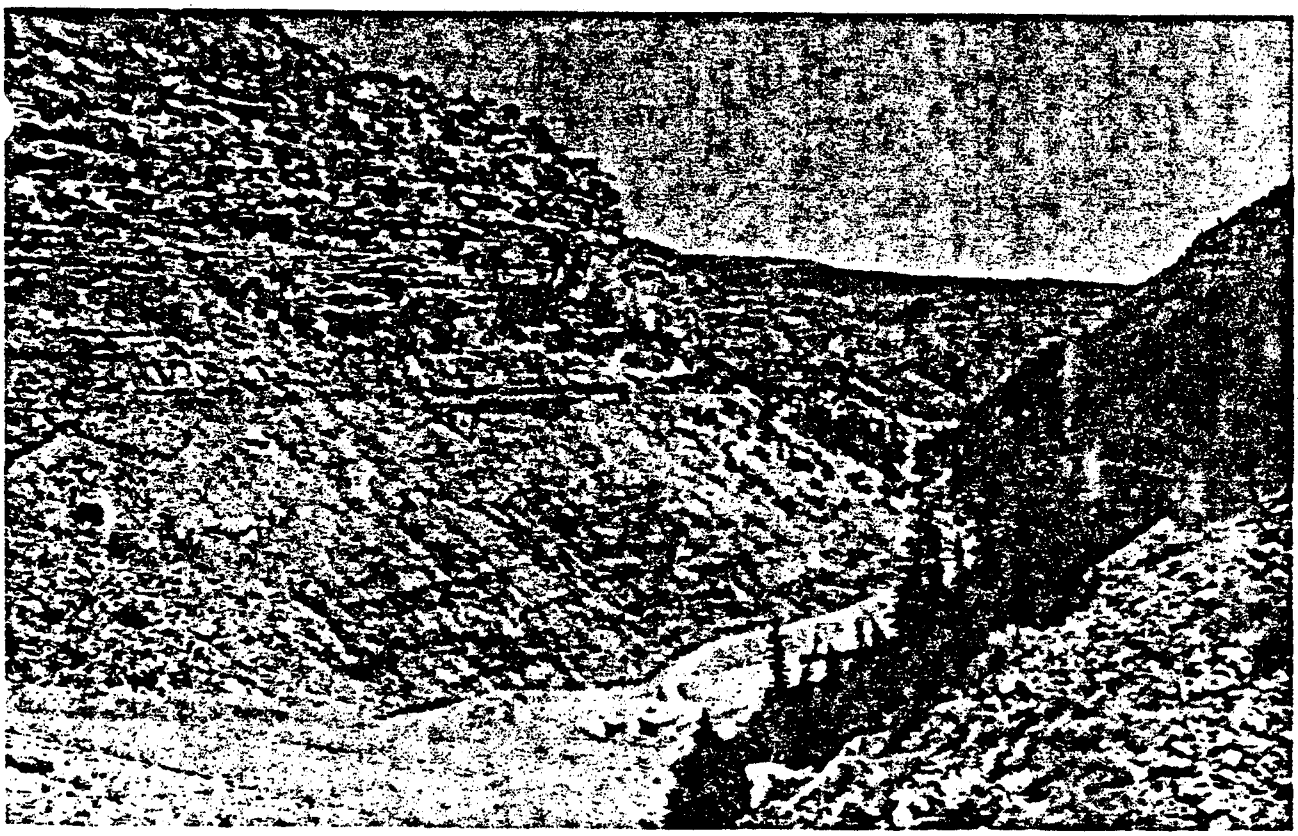

Figure 15. View of spring (D-18-6) 5abd-S1 that issues from the Blackhawk Formation in Straight Canyon a short distance downstream from the dam on Joes Valley Reservoir. Photograph was taken from the top of the dam; spring issues from dark-colored lower slopes in the bottom center of photograph.

measured sections. Ground-water discharge would have had to have been 4 to 5 ft³/s in order to be greater than the error inherent in the streamflow measurements, and it was not. Using Darcy's law (Ferris and others, 1962, p. 73) and assuming a transmissivity of 100 ft²/d and a hydraulic gradient of 250 ft/mi, an estimated 1 ft³/s was discharged along 4.4 mi of Straight Canyon from that part of the Blackhawk-Star Point aquifer underlying Trail Mountain.

As indicated in figure 16, streamflow in Cottonwood Creek increased by about 0.5 ft³/s on September 24, 1981, and by about 0.6 ft³/s on September 8, 1982, across the outcrops of the Blackhawk Formation and Star Point Sandstone. The streamflow measurements were rated as "good" (having an error of as much as 5 percent), and ground-water discharge exceeded the error inherent in the measurements. Probably about one-half of the water was discharged from that part of the Blackhawk-Star Point aquifer underlying Trail Mountain, and the other one-half was discharged by the aquifer beneath East Mountain.

There were small gains and losses in streamflow along Indian Creek on September 25, 1981, and on September 9, 1982; flow increased by 1.9 and 3.2 ft³/s along the lower reaches of Lowry Water on these same days. (See figure 17.) Some of the water discharged by the alluvium along these streams could be due to leakage from the Blackhawk-Star Point aquifer along the Joes Valley fault, but most of the water probably originates as recharge from snowmelt and rain on the alluvium in Upper and Lower Joes Valley. There are few springs on the west side of Trail Mountain near the Joes Valley fault. This could be due to increased fracture permeability that may allow water to move more readily downward through the system and into the alluvium rather than being retarded by perching beds and discharged by springs on the upper slopes of the mountain.

Also, some water may enter or leave the ground-water system by subsurface flow in the area of the Flat Canyon anticline (figure 5). As along the Joes Valley fault, however, subsurface flow in this area cannot be verified because of a lack of potentiometric-surface data.

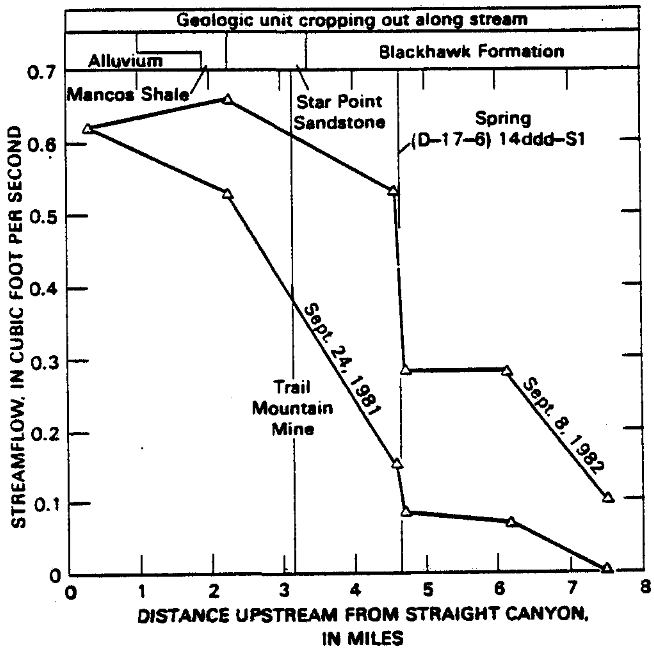

Figure 16. Streamflow in Cottonwood Creek during two periods of base flow. (Location of measurement sites shown in figure 7.)

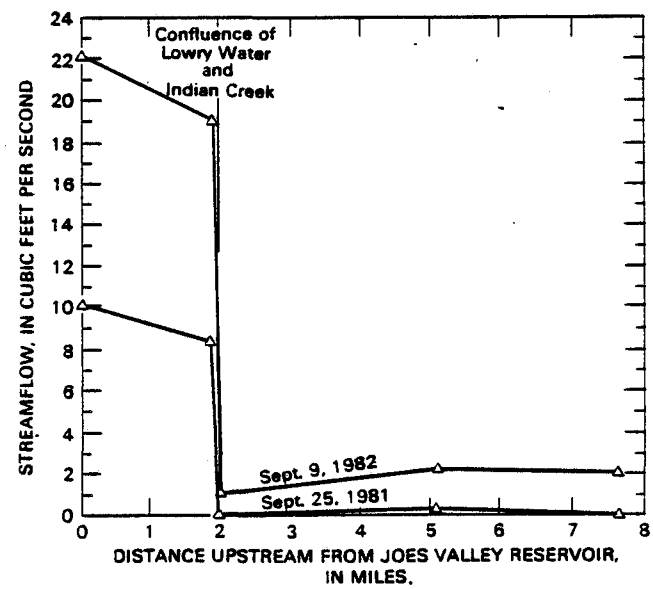

Figure 17. Streamflow in Indian Creek and in the lower reaches of Lowry Water during two periods of base flow. (Location of measurement sites shown in figure 7.)

Water Quality

Chemical analyses of selected ground-water samples collected on Trail Mountain are listed in table 6, and concentrations of selected dissolved trace metals are listed in table 7. The analyses indicate that the water is suitable for most uses.

Dissolved-solids concentrations ranged from 278 to 570 mg/L in seven water samples collected from the Blackhawk-Star Point aquifer. In two water samples that were collected from drips from the roof of the Trail Mountain Mine, dissolved-solids concentrations were 262 and 255 mg/L. (See (D-17-6) 36acc and 36dbb in table 6.) A small perched body of water in the Blackhawk probably was the source of the water dripping from the mine roof. In comparison, water in perched aquifers in the North Horn Formation, Price River Formation, and Castlegate Sandstone contained 254 to 695 mg/L of dissolved solids. The dissolved-solids concentrations in the perched aquifer in the North Horn during 1979–81 are shown in figure 18; the dissolved solids generally increased in the direction of ground-water flow. (See water-table contours in fig. 10.) No such pattern was apparent to the author when studying dissolved-solids

Table 6. Chemical analyses of water from selected wells, springs, and underground mines

Water-bearing zone(s): Kb, Blackhawk Formation; Kc, Castlegate Sandstone; Kp, Price River Formation; Ks, Star Point Sandstone; Qa, alluvium; TKn, North Horn Formation.
Units: °C, degrees Celsius; μmho, micromhos per centimeter at 25° Celsius.

						Milligrams per liter											
Well, spring, or site No.	Water-bearing zone(s)	Date	Water temperature (°C)	pH (units)	Specific conductance (μmho)	Dissolved calcium (Ca)	Dissolved magnesium (Mg)	Dissolved sodium (Na)	Dissolved potassium (K)	Alkalinity (as $CaCO_3$)	Dissolved sulfate (SO_4)	Dissolved chloride (Cl)	Dissolved boron (B)	Dissolved silica (SiO_2)	Hardness (as $CaCO_3$)	Non-carbonate hardness (as $CaCO_3$)	Dissolved solids (calculated sum)
(D-16-6)22cda-S1	Kb	10-14-77	---	7.2	600	64	27	4.8	1.0	250	15	4.8	<0.02	7.7	270	17	278
34bdc-S1	TKn	6-20-79	5.0	7.6	470	64	19	3.6	.6	220	25	3.5	<.02	5.2	240	18	254
34cad-S1	Kp	9- 6-78	8.5	7.6	560	87	22	3.7	1.8	290	86	3.8	.05	7.2	310	78	350
34dda-S1	Kc	10-14-77	6.5	7.4	560	54	30	4.8	1.6	300	14	4.4	<.02	7.5	260	0	299
(D-17-6)3acb-S1	Kp	6-21-79	6.0	7.6	530	75	23	6.2	1.1	270	17	4.4	.03	6.5	280	12	296
3add-S1	Kc	11-10-77	6.5	7.5	600	79	32	6.6	1.2	300	29	5.9	.03	7.2	330	26	344
3cbd-S1	TKn	7-31-79	7.0	7.4	470	81	21	7.5	.6	290	20	4.4	.03	5.5	290	0	315
14ddd-S1	Kb	7-14-81	8.5	7.3	650	67	39	15	1.8	280	65	9.3	.01	7.0	330	48	373
15cbd-S1	TKn	7-13-79	13.5	7.4	680	85	36	18	1.4	350	43	11	.04	8.4	360	11	414
15dda-S1	Kp	7- 5-79	8.0	7.8	650	66	42	17	.9	310	46	23	.04	8.1	340	28	390
21abb-S1	TKn	7-14-81	7.5	7.4	630	54	27	56	1.7	320	1.0	24	.02	6.5	250	0	363
21dcd-S1	TKn	7-14-81	7.0	7.4	560	41	34	18	.7	230	.7	28	.02	6.3	240	12	267
22cdc-S1	TKn	7-14-81	8.0	7.5	495	44	31	17	1.1	240	1.1	11	.01	6.5	240	0	256
26cba-S1	TKn	7-14-81	11.0	7.6	600	53	37	19	.8	290	10	9.3	.03	7.6	280	0	312
26cbb-S1	TKn	7-14-81	7.5	7.5	640	38	34	42	.8	300	.8	8.4	.03	8.1	230	0	313
27bda-1	Ks	10-16-82	12.0	7.9	570	27	21	67	4.0	287	10	9.7	.21	8.8	150	0	570
	Kb,Ks	10-20-82	11.5	8.0	550	25	18	70	4.2	286	<5	7.6	.19	8.2	140	0	550
27cbb-S1	TKn	7-15-81	7.0	7.7	680	48	35	49	.8	320	1.2	21	.02	8.2	260	0	356
27ccc-S1	TKn	7-15-81	7.5	7.7	660	50	34	49	1.0	320	2.4	21	.02	8.2	270	0	358
27ccd-S1	TKn	7-15-81	8.5	7.6	710	47	44	41	.7	330	5.4	22	.02	8.1	300	0	367
28bac-S1	TKn	7-16-81	10.0	7.7	740	60	52	40	.7	360	1.9	29	.03	8.5	360	4	409
28bad-2	Kp	10-30-82	8.0	7.8	730	51	29	44	26	288	70	22	.09	5.5	250	0	422
28bbc-S2	Kp	7-16-81	10.5	7.6	600	59	36	17	.8	240	59	19	.00	6.4	300	56	342
29cbb-1	Qa	8-10-82	9.0	8.4	850	61	71	51	2.8	239	170	67	.07	7.1	440	210	575
35cbb-S1	TKn	7-15-81	12.0	7.7	780	38	40	78	1.1	330	13	40	.05	7.2	260	0	416
35ccb-S1	TKn	7-15-81	7.5	7.6	700	43	40	47	1.2	270	40	34	.03	6.9	270	2	375
36acc	Kb	8-21-81	11.0	8.0	480	26	14	54	8.6	240	1.0	3.7	.36	8.5	120	0	262
36dbb	Kb	8-21-81	11.0	7.9	470	23	14	54	7.0	240	1.0	3.2	.27	9.1	120	0	255
(D-18-6)2bbd-S1	TKn	7-15-81	9.0	7.5	1,140	67	45	120	1.5	350	190	52	.07	8.9	350	3	695
4bac-1	Kb,Ks	10-25-81	13.5	7.6	510	45	32	16	3.7	260	11	8.1	.04	9.3	240	0	282
4bbc-S1	Kb	7-13-81	17.0	7.1	870	97	53	15	2.4	320	100	20	.02	7.8	460	140	488
11aac	Kb	7-13-81	9.5	7.5	600	53	36	20	3.7	220	100	6.6	.09	8.9	280	61	361

Table 7. Concentrations of selected dissolved trace metals in water from wells, springs, and underground mines

Water-bearing zone(s): Kb, Blackhawk Formation; Kp, Price River Formation; Ks, Star Point Sandstone; Qa, alluvium; TKn, North Horn Formation.

Well, spring, or site No.	Water bearing zone(s)	Date	Micrograms per liter																	
			Aluminum (Al)	Arsenic (As)	Barium (Ba)	Cadmium (Cd)	chromium (Cr)	Hexa-valent chromium	Cobalt (Co)	Copper (Cu)	Iron (Fe)	Lead (Pb)	Lithium (Li)	Manga-nese (Mn)	Mercury (Hg)	Nickel (Ni)	Sele-nium (Se)	Silver (Ag)	Zinc (Zn)
(D-17-6)14ddd-S1	Kb	7-14-81	0	0	90	<1	0	0	<3	2	60	0	20	<1	0.0	2	1	0	10
21abb-S1	TKn	7-14-81	0	0	100	<1	1	0	<3	1	20	0	30	<1	.1	1	4	0	8
22cdc-S1	TKn	7-14-81	0	1	200	<1	12	0	<3	1	<10	0	20	2	.0	1	2	0	6
26cba-S1	TKn	7-14-81	0	0	200	<1	1	0	<3	1	<10	0	30	<1	.1	1	1	0	4
27bda-1	Ks	10-18-82	20	10	400	<1	<1	<1	6	3	3,000	9	39	140	<.1	16	1	<1	190
	Kb,Ks	10-20-82	50	2	230	<1	<1	<1	2	4	350	5	30	130	.2	5	<1	<1	54
27ccc-S1	TKn	7-15-81	0	0	100	<1	0	0	<3	0	<10	1	30	<1	.0	1	1	0	10
28bac-S1	TKn	7-16-81	0	0	200	<1	0	0	<3	1	<10	0	30	<1	.1	2	0	0	6
28bad-2	Kp	10-30-82	30	2	240	<1	<1	<1	1	200	73	7	38	120	<.1	41	<1	<1	13
29cbb-1	Qa	8-10-82	10	1	28	<1	<1	<1	1	1	<3	3	33	170	<.1	1	3	<1	440
35ccb-S1	TKn	7-15-81	0	0	90	<1	0	0	<3	1	<10	0	30	<1	.0	0	3	0	<3
36acc	Kb	8-21-81	20	0	760	<1	0	0	<3	2	30	3	28	5	.0	1	0	0	57
36dbb	Kb	8-21-81	20	0	990	<1	0	0	<3	2	11	4	29	3	.0	1	0	0	14
(D-18-6)2bbd-S1	TKn	7-15-81	10	1	50	<1	2	0	<3	0	<10	0	50	3	.1	0	2	0	3
4bac-1	Kb,Ks	10-25-81	<10	0	220	<1	<1	<1	<3	4	<10	2	29	9	.0	2	<1	1	28
4bbc-S1	Kb	7-13-81	10	0	40	<1	0	0	<3	1	<10	0	30	30	.1	3	0	0	30
11aac	Kb	7-13-81	10	0	60	<1	1	0	<3	2	<10	0	40	<1	.1	2	0	0	6

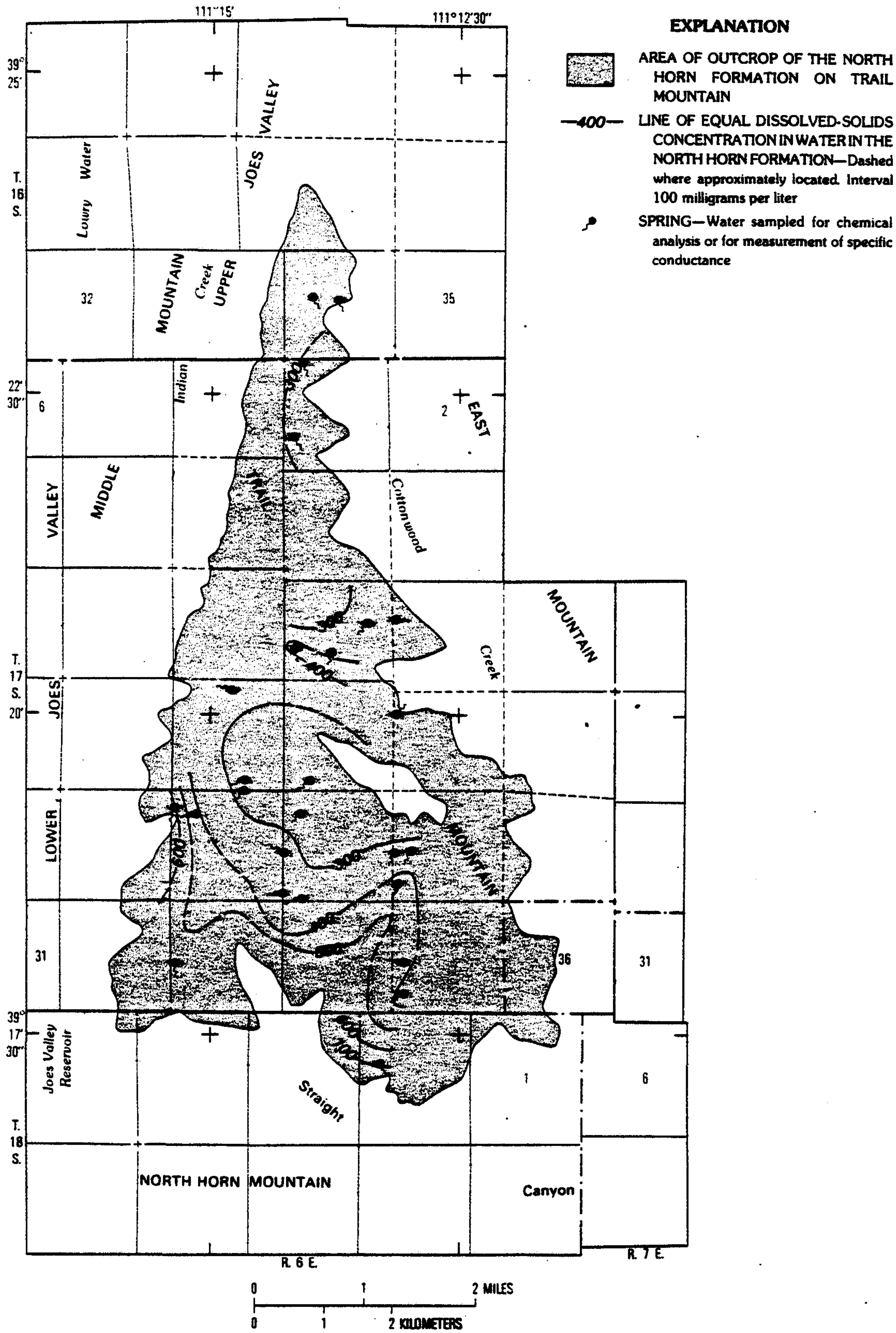

Figure 18. Concentration of dissolved solids in water in the North Horn Formation, 1979–81. (Map is based, in part, on chemical analyses listed by Danielson and others, 1981, p. 80 and 81.)

concentrations in the Blackhawk-Star Point aquifer, and this is believed due to differences in the quantity and quality of water that percolates downward into the aquifer from overlying perched zones.

Calcium and magnesium were the predominant cations in most of the water samples; sodium generally was the predominant cation in the more mineralized samples. In all samples, the pH and the alkalinity concentration indicated that bicarbonate was the predominate anion. Comparison of trace-metal concentrations in table 7 indicates that water in the Star Point and Blackhawk consistently contained larger concentrations of aluminum, iron, and zinc than water in the perched aquifer in the North Horn.

Other chemical analyses of ground water from the area are included in reports by Sumsion (1979, p. 22 and 23) and by Danielson and others (1981, p. 80 and 81).

HYDROLOGIC EFFECTS OF UNDERGROUND MINING

Effects of Mine Dewatering

Future underground coal mines in the Trail Mountain area will require dewatering when they penetrate the Blackhawk-Star Point aquifer. Water produced in the mines will be derived primarily from a decrease in storage in the aquifer. Several hundred feet of aquifer above the mines could be dewatered. and the cone of depression could extend several miles from the mines after a few years. Because the Blackhawk-Star Point aquifer is separated from overlying perched aquifers by an unsaturated zone, mine dewatering alone would not affect the perched aquifers. Mine dewatering would not significantly change water quality in the Blackhawk-Star Point aquifer.

A finite-difference, three-dimensional computer model (McDonald and Harbaugh, 1984) was used to analyze the effects of dewatering various lengths and widths of a hypothetical underground mine in the Hiawatha coal bed on the Blackhawk-Star Point aquifer. The model was used to compute mine inflow and drawdowns around the mine for a range of aquifer properties and premining hydraulic gradients that were similar to those on Trail Mountain. It was beyond the scope of this study to evaluate the effects of every possible mine configuration; nor did the lack of historic water-level and mine-discharge data allow for the calibration and verification of a model that simulated hydrologic boundaries in every possible position with respect to future mining. Rather, the model was used to simulate the aquifer in a simplified manner in order to make order-of-magnitude estimates of mine inflow and drawdown. Although the estimates of mine inflow and drawdown can be used with less confidence than those made for a specific mine plan and set of boundary conditions using a calibrated and verified model, the estimates are more reliable than those that could be made with other more simplified analytical techniques.

The Blackhawk-Star Point aquifer was simulated with three model layers as shown diagrammatically in figure 19. Layers 1 and 2 were used to simulate the Blackhawk and layer 3 to simulate the Star Point. The total number of active cells varied depending mainly on the saturated thickness of the simulated aquifer, but it averaged about 1,200. The model area was 11.5 mi long and 23 mi wide; but since the effects of mine dewatering were very small at the model boundaries, an aquifer of infinite areal extent was in effect simulated.

Boundaries in the model were simulated as impermeable except for the upper surface where constant and uniform recharge was applied. The impermeable model boundaries are similar to ground-water divides or edges of the aquifer where the saturated thickness approaches zero. Recharge to the upper surface represented recharge from precipitation on the outcrop area and from downward percolation of water from overlying perched aquifers. Along one side of the model, the heads in layer 3 were held constant. This row of constant-head cells acted as the natural discharge area for the aquifer and was similar to discharge along a stream. By applying recharge to the upper surface of the model and discharging the water along the row of constant-head cells in layer 3, steady-state hydraulic gradients were simulated that were similar to those in the Blackhawk-Star Point aquifer on Trail Mountain.

The steady-state flow system was then stressed by simulating the dewatering of a hypothetical horizontal underground mine in the Hiawatha coal bed at the base of the Blackhawk Formation. Dewatering of the mine was simulated by lowering and holding constant the potentiometric surface of layer 2 at an altitude of 1 ft above the base of the layer in the appropriate mine cells. Flow rates into the constant-head mine cells and drawdowns around the dewatered mine were then calculated for various aquifer properties, premining horizontal hydraulic gradients, mine lengths and widths, and lengths of time.

The calculated steady-state mine inflow to various mine lengths (M_l) and widths (M_w) for three premining horizontal hydraulic gradients (I) is shown in figure 20. The premining horizontal gradient is the slope of the potentiometric surface of layer 2 in the mine area. (See fig. 19.) For these simulations, the hydraulic conductivities of the Blackhawk Formation (K_b) and the Star Point Sandstone (K_s) were 0.01 and 0.02 ft/d, and both units were simulated as isotropic. Considering the relative proportions of sandstone and finer grained rocks in each unit and the laboratory hydraulic conductivities (table 3), these hydraulic conductivities probably are representative of the units where they are not extensively fractured. With hydraulic conductivities of 0.01 and 0.02 ft/d, the Blackhawk-Star Point aquifer would have a transmissivity of about 20 ft^2/d where both units are fully saturated. By increasing the hydraulic conductivities one order of magnitude to 0.1 and 0.2 ft/d, the computed steady-state mine inflow would be one order of magnitude larger than those in figure

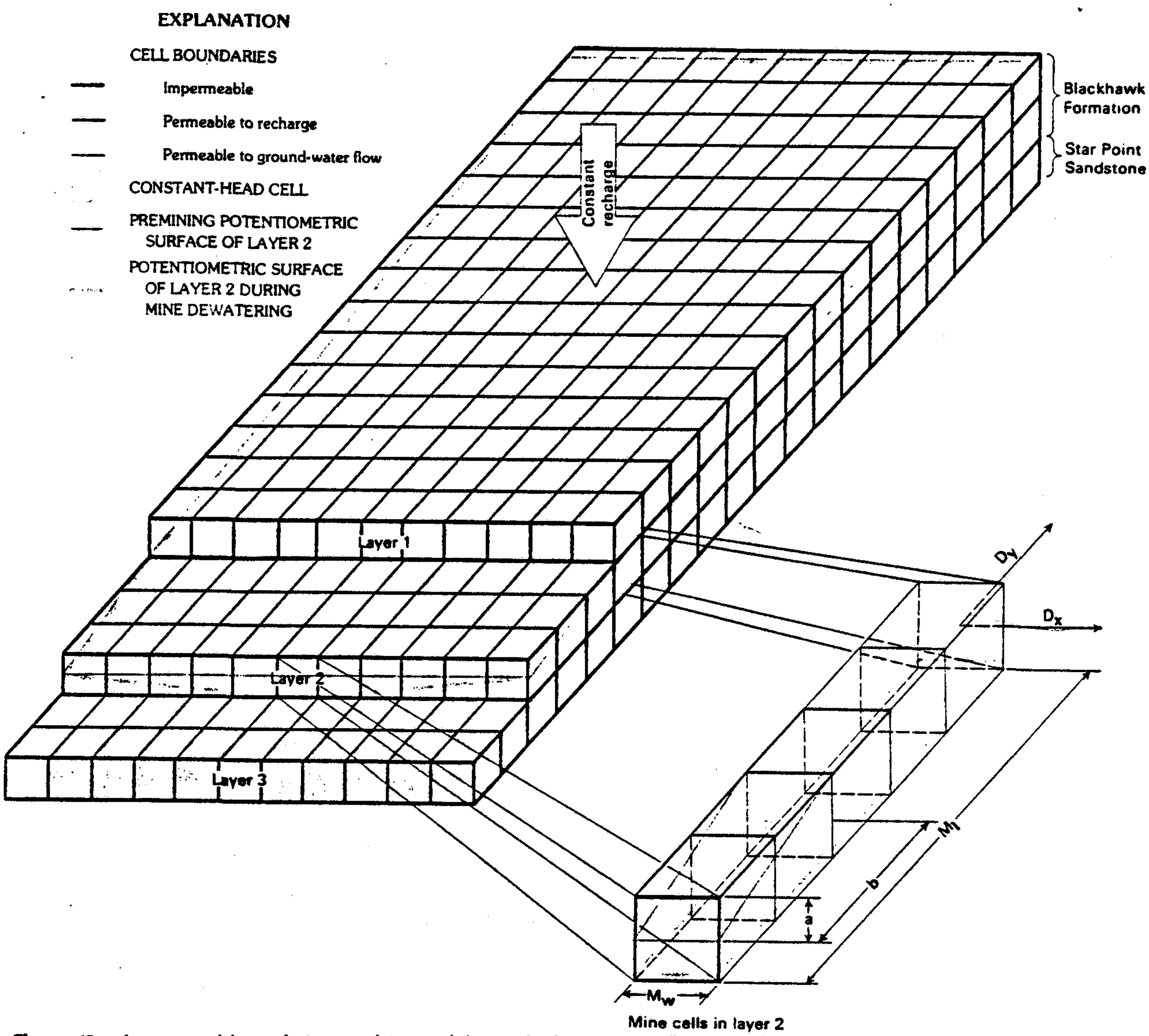

Figure 19. Layers and boundaries used in model to calculate mine inflow and drawdowns at various distances D_x and D_y from a hypothetical dewatered horizontal mine at the base of the Blackhawk Formation. (M_w, mine width; M_l, mine length; I=a/b, premining horizontal hydraulic gradient.)

20, as long as premining horizontal hydraulic gradients are the same as those shown.

The drawdowns produced at distances D_x and D_y (fig. 19) from a dewatered mine that is 1,000 ft wide and as much as 10,000 ft long after the system reaches steady state are shown in figure 21 for three premining horizontal hydraulic gradients. The drawdowns in figure 21 were computed for layer 2 of the model, and they are declines that could be expected in the potentiometric surface of the Blackhawk-Star Point aquifer at the level of the Hiawatha coal bed. The steady-state drawdowns in figure 21 were calculated for hydraulic conductivities of 0.01 and 0.02 ft/d for the Blackhawk Formation and Star Point Sandstone. The steady-state drawdowns would be the same as those shown in figure 21 for any combination of hydraulic conductivities where the Star Point is twice as permeable as the Blackhawk, as long as premining horizontal hydraulic gradients are the same as those shown.

Curves in figure 22 indicate not only that mine inflow increases with increased hydraulic conductivity, but that a large part of the water that flows into a mine will be derived from ground water stored in the aquifer. Also, the quantity of mine inflow derived from ground-water storage is dependent on the specific yield (Sy). For example, the top curves (where K_b=0.01 ft/d, K_s=0.02 ft/d, and Sy=0.05) indicate that total mine inflow after 100 years would be about 0.5 ft^3/s, of which about 0.4 ft^3/s would be derived from ground-water storage. The remaining 0.1 ft^3/s would be derived from a decrease in natural discharge from the aquifer. Similarly, the bottom curves (where K_b=0.1 ft/d, K_s=0.2

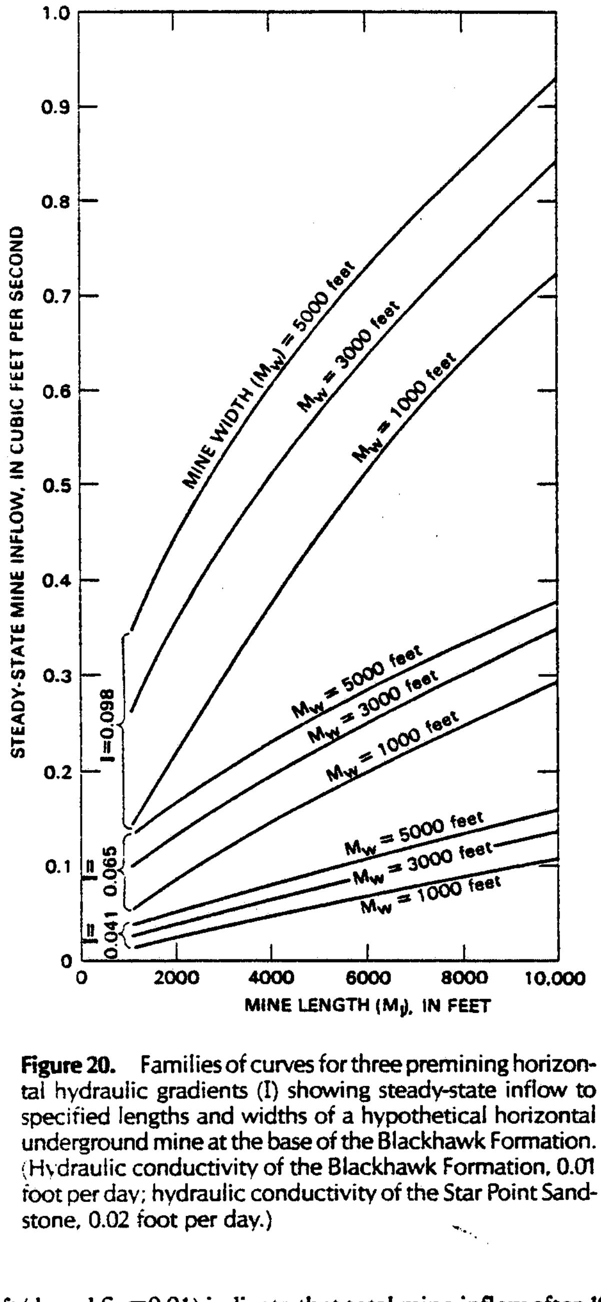

Figure 20. Families of curves for three premining horizontal hydraulic gradients (I) showing steady-state inflow to specified lengths and widths of a hypothetical horizontal underground mine at the base of the Blackhawk Formation. (Hydraulic conductivity of the Blackhawk Formation, 0.01 foot per day; hydraulic conductivity of the Star Point Sandstone, 0.02 foot per day.)

ft/d. and Sy=0.01) indicate that total mine inflow after 100 years would be about 3 ft^3/s, of which about 0.8 ft^3/s would be derived from ground-water storage. The remaining 2.2 ft^3/s would be derived from a decrease in natural discharge from the aquifer. The curves also indicate that the larger the specific yield, the greater the proportion of mine inflow that initially will be derived from ground-water storage and the longer the time it will take for the system to reach steady state. In the transient model simulations that were used to develop the curves in figure 22, a storage coefficient (S) of $1x10^{-7}$/per foot was used for the confined parts of the aquifer.

Drawdowns at distances D_x and D_y from a mine that has been dewatered for various lengths of time are shown in figure 23. The drawdowns were computed for layer 2, and they are declines that could be expected in the potentiometric surface of the Blackhawk-Star Point aquifer at the level of the Hiawatha coal bed. One pair of curves is for hydraulic conductivities of the Blackhawk (K_b) and Star Point (K_s) of 0.01 and 0.02 ft/d and the other pair is for hydraulic conductivities of 0.1 and 0.2 ft/d. In both cases, the premining horizontal hydraulic gradient (I) was 0.065, specific yield (Sy) was 0.05, and the storage coefficient (S) was $1x10^{-6}$ per foot of confined aquifer. Comparison of the two pairs of curves indicates that when hydraulic conductivities are increased by one order of magnitude, the potentiometric surface is drawn down about 10 times as quickly. Drawdowns of several hundred feet can be expected around a dewatered underground mine within 50 years (a reasonable life span of a mine), and the cone of depression will extend several miles from the mine after a few years unless a hydrologic boundary is intercepted. It would take 10,000 years for the aquifer to reach steady state.

The curves in figures 20-23 may be used to evaluate the effects of dewatering a mine in the Hiawatha coal bed, but calculated mine inflows and drawdowns need to be considered as order-of-magnitude estimates. The curves are based on calculations that assume that the aquifer is isotropic and, for all practical purposes, infinite in areal extent in three directions from the simulated mine. In actuality, boundaries could limit the continuity of the Blackhawk-Star aquifer around a mine, in one or more directions, to distances varying from a few feet to a few miles. When the time-drawdown curves in figure 23 indicate that the cone of depression will intercept a boundary and that the drawdown at the boundary cannot be considered as negligible, use of the curves in figures 20-23 may be precluded. When an aquifer boundary can be treated as an abrupt vertical discontinuity, the curves in figures 21 and 23 can be used with image theory to estimate drawdown. Image theory is discussed in detail by Ferris and others (1962, p. 144-161).

Further errors will be introduced if the computed mine inflows and drawdowns in figures 20-23 are applied to a mine that dips more than a few degrees from the horizontal. For example, computed steady-state inflows to a mine that dips 5° downward were about two times greater than those computed for a horizontal mine, and steady-state drawdowns were about 50 percent greater. Similarly, computed steady-state inflows to a mine that dips 5° upward were about one-half those computed for a horizontal mine, and steady-state drawdowns were about 50 percent less. The curves do not account for increased downward movement of water from overlying perched aquifers or increased permeability in the Blackhawk-Star Point aquifer that could result from subsidence above underground mines.

Effects of Subsidence Above Underground Mines

Subsidence is the movement or deformation that occurs in overburden above all underground mines, and it needs to be considered when evaluating the effects of mining

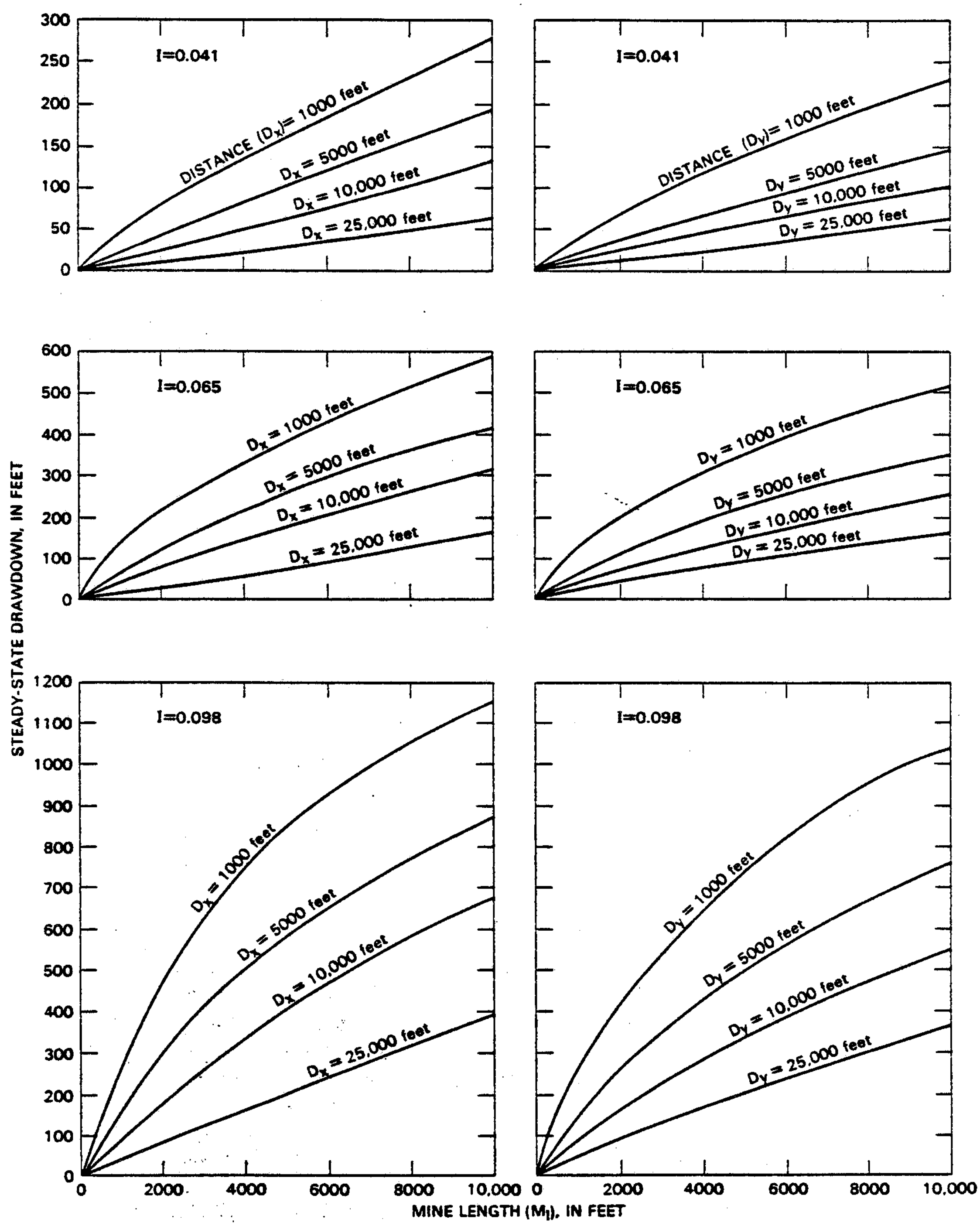

Figure 21. Families of curves for three premining horizontal hydraulic gradients (I) showing steady-state drawdown produced at various distances from the specified lengths of a hypothetical horizontal underground mine at the base of the Blackhawk Formation. (Mine width, 1,000 feet; hydraulic conductivity of the Blackhawk Formation, 0.01 foot per day; hydraulic conductivity of the Star Point Sandstone, 0.02 foot per day.)

on a ground-water system. Subsidence includes fracturing and downwarping of overburden, and its effects may reach the land surface. Dunrud (1976, p. 34-36) points out that subsidence is related to: (1) The geometry of mine workings, (2) the lithology, structure, and thickness of overburden, (3) the direction of dip of the mined coal bed relative to its outcrop, and (4) the proximity of mine workings to the coal outcrop. Dunrud also points out that the type and rate of coal extraction affects subsidence. Unfortunately, the degree of subsidence cannot be predicted, nor can the effects on

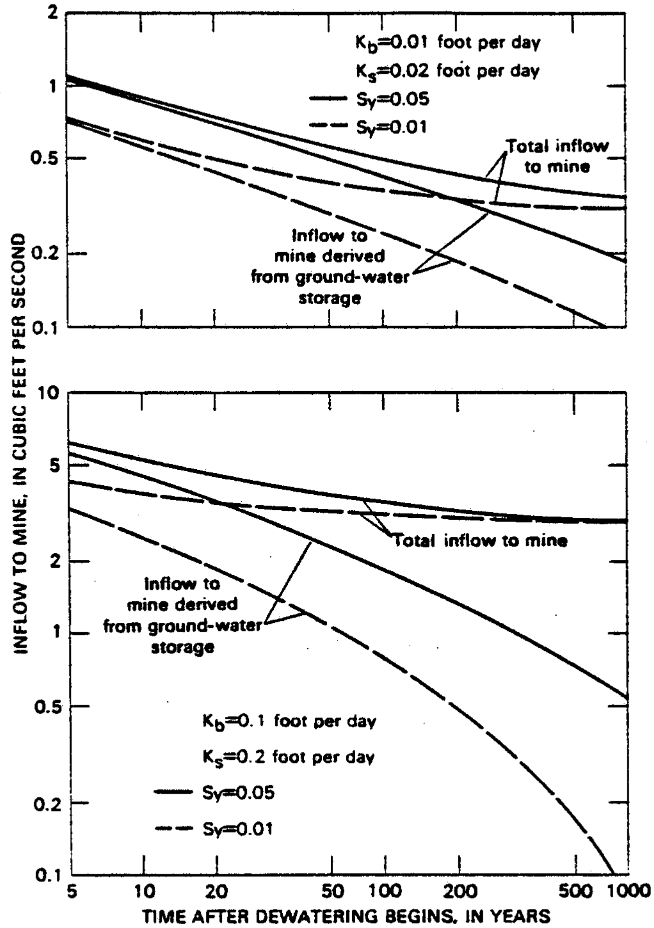

Figure 22. Logarithmic curves for various specific yields (Sy) and hydraulic conductivities of the Blackhawk Formation (K_b) and Star Point Sandstone (K_s) showing total mine inflow and that part of the inflow derived from a decrease in ground-water storage at the specified times after dewatering begins in a hypothetical horizontal underground mine at the base of the Blackhawk Formation. (Premining horizontal hydraulic gradient, 0.065; mine width, 1,000 feet; mine length, 10,000 feet; storage coefficient, 1×10^{-6} per foot of confined aquifer.)

the ground-water system be quantified. Mines can be planned, however, to keep subsidence at a minimum.

In the Book Cliffs coal field about 50 mi northwest of Trail Mountain, subsidence fractures have formed in the Price River Formation at the land surface about 900 ft above an underground mine in the Blackhawk Formation. The fractures are as much as 3 ft wide at the land surface and according to Dunrud (1976, p. 9) "These cracks divert all surface- and ground-water flow in this area to lower strata or to the mine workings."

It is possible that subsidence fractures could extend from the roof of a mine in the Hiawatha coal bed into a perched aquifer several hundred feet above. Such fractures would increase hydraulic connection between the perched aquifer and the unsaturated zone and would increase downward percolation through the perching bed. The discharge of springs that issue from the perched aquifer could decrease. Some of the water that flows through the perching bed along subsidence fractures could reach the Blackhawk-Star Point aquifer. Thus, recharge to the Blackhawk-Star Point aquifer and inflow to the mine could increase.

Because water quality is similar in all aquifers in Trail Mountain, subsidence would not significantly change water quality in the ground-water system. Water quality could improve slightly in the Blackhawk-Star Point aquifer if increased permeability due to subsidence fractures increased flow rates through the aquifer and decreased time that water is in contact with the rock.

SUMMARY

Ground water occurs in several aquifers in Trail Mountain. The coal-bearing Blackhawk-Star Point aquifer is regional in nature and is the source of most water in underground mines in the Wasatch Plateau coal field. In Trail Mountain, the Blackhawk-Star Point aquifer is overlain by one or more perched aquifers in the North Horn and Price River Formations, and in the Castlegate Sandstone.

Snowmelt and rain are the main sources of recharge to this multiaquifer system. The Blackhawk-Star Point aquifer also is recharged by Joes Valley Reservoir. Water is discharged from the system mainly by springs and by leakage along streams. Springs that issue from the perched aquifers are sources of water for livestock and wildlife on Trail Mountain. About 40 gal/min was discharged from the Trail Mountain Mine during 1982 mainly by the mine ventilation system. Some of this mine water was pumped from Cottonwood Creek for use underground, but most of the water was evaporated from the unsaturated zone in the Blackhawk Formation.

Water in all aquifers in Trail Mountain is suitable for most uses. Dissolved-solids concentrations range from about 250 to 700 mg/L, and the predominant dissolved constituents are usually calcium, magnesium, and bicarbonate.

Future underground mines that penetrate the Blackhawk-Star Point aquifer will require dewatering as mine inflows probably will be several hundred gallons per minute. Initially, most of the mine inflow will be derived from ground water in storage in the partly dewatered aquifer; some of the water will be derived from a decrease in natural discharge from the aquifer. Potentiometric surfaces in the partly dewatered aquifer could be drawn down several hundred feet during a reasonable life span of a mine. Because the Blackhawk-Star Point aquifer is separated from overlying perched aquifers by an unsaturated zone, mine dewatering alone would not affect the perched aquifers. Most dewatering would not significantly change water quality in the Blackhawk-Star Point aquifer.

The degree of subsidence above underground mines cannot be predicted, nor can the effects on the ground-water system be quantified. It is possible that subsidence

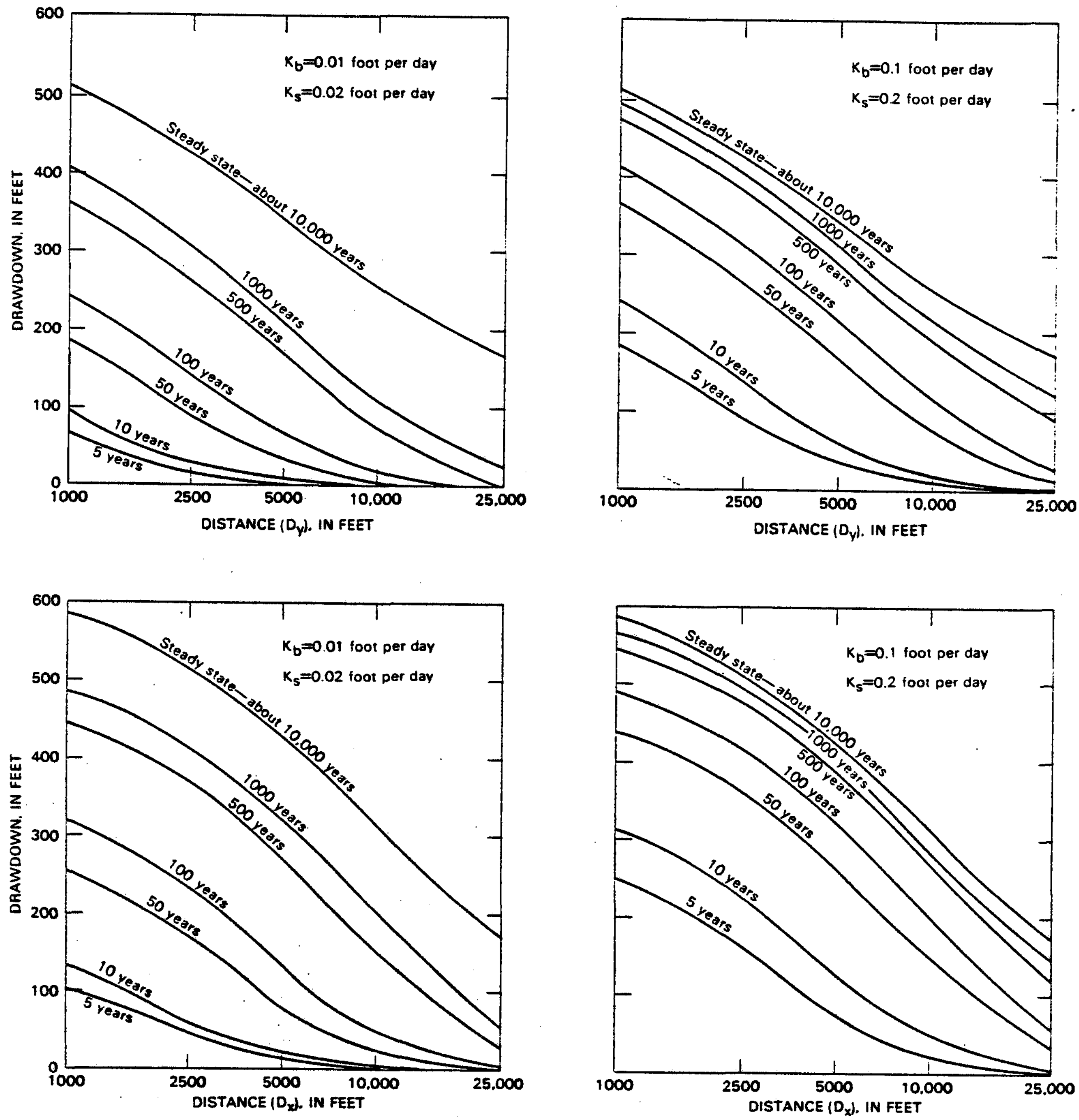

Figure 23. Semilogarithmic curves for various hydraulic conductivities of the Blackhawk Formation (K_b) and Star Point Sandstone (K_s) showing drawdown produced at specified distances from a hypothetical horizontal underground mine at the base of the Blackhawk Formation that has been dewatered for various lengths of time. (Premining horizontal hydraulic gradient, 0.065; mine width, 1,000 feet; mine length, 10,000 feet; specific yield, 0.05; storage coefficient, 1×10^{-6} per foot of confined aquifer.)

fractures could extend from the roof of a mine into an overlying perched aquifer. Such fractures would increase downward percolation through the perching bed, and spring discharge from the perched aquifer could decrease. Some of the water that flows through the perching bed along subsidence fractures could reach the Blackhawk-Star Point aquifer.

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Appendix 7-D

Tract 1 Hydrological Monitoring Data
(ACT/015-009)**

(1) Request for an Amendment to Trail Mountain Coal Company Hydrological Monitoring Program ACT/015/009

(2) Approval for MPR Amendment Request for Change in Trail Mountain Coal Company Hydrological Monitoring Plan ACT/015-009

(3) Parameters:
  Surface Waters
  Springs
  Groundwater
  Observtion Wells

(4) Tract 1 Water Monitoring Locations (Figure 7-9)

(5) 1985-1986 Tract 1 Act/015/009 Water Quality Monitoring Data:
  Surface
  Groundwater
  Springs
  Observation wells
  Slug Test

(6) Cottonwood Creek Irrigation Shares

(7) Log of Water Pumped from Cottonwood Creek

(8) In-Mine Discharge (NPDES 002 Outfall Location)

(9) Exchange of Water Rights

(10) Well Approval

(11) Analytical Comparison of Spring TM 23 & Underground Location UG-1

(12) Field Measurements

**Ch 7 Rev. 1-11-87

Appendix 7-E	Macroinvertebrate Study - Locations SW-1 SW-2 SW-3
Appendix 7-F	Probable Hydrologic Consequences Determination (PHC) for Trail Mountain Coal Company
Appendix 7-G	Calculations and Rational used to Calculate Mine inflow for Trail Mountain Coal Company Tract 2 Mine Plan Area**

**Ch 7-Rev 1-10-87

APPENDIX 7-D

TRACT 1 HYDROLOGICAL MONITORING DATA

(ACT/015/009)

APPENDIX 7-D (1)

REQUEST FOR AN AMENDMENT TO
TRAIL MOUNTAIN COAL COMPANY
HYDROLOGICAL MONITORING PROGRAM ACT/015/009

Diamond Shamrock
Coal Company

June 16, 1986

Mr. Wayne Hedberg
State of Utah
Division of Oil, Gas and Mining
355 West North Temple
3 Triad Center/Suite 350
Salt Lake City, Utah 84180-1203

RE: Request for change in Hydrological Monitoring Program - TMCC ACT/015/009

Dear Wayne;

In response to your letter of June 3, 1986, I am submitting to you and the Division a corrected version of Attachment I.

In this update of Attachment I, the North Fork of Cottonwood Creek (monitoring locations SW-1, SW-2, and SW-3) will be monitored monthly for field measurable parameters (ie discharge, PH, specific conductivity, temperature and dissolved oxygen).

Once again we request to enter into an operational phase monitoring program. The enclosed material is formated for insertion into the approved Trail Mountain Coal Company Mining and Reclamation Plan upon approval of the Division.

If you need further information or have any questions concerning this matter, please feel free to contact me at 748-2140.

Sincerely;

TRAIL MOUNTAIN COAL COMPANY

Allen

Allen P. Childs
Mine Engineer

Enclosures

APC/gg

ATTACHMENT I

SURFACE WATER

SW-1, SW-2, AND SW-3

TRAIL MOUNTAIN MINE, COTTONWOODCANYON

PERENNIAL STREAM - NORTH FORK OF THE COTTONWOODCREEK

FIELD MEASUREMENTS: MONTHLY

Discharge
PH
Specific conductivity
Temperature (Air and Water)
Dissolved Oxygen

LABORATORY MEASUREMENTS: QUARTERLY

Total Settleable Solids
Total Suspended Solids
Total Dissolved Solids
Total Hardness (as $CaCo_3$)
Acidity ($CaCo_3$)
Carbonate (CO_3-2)
Bicarbonate (HCO_3-)
Calcium (Ca)
Chloride (CL-)
Dissolved Iron (Fe)
Total Iron (Fe)
Magnesium (Mg)
Total Manganese (Mn)
Potassium (K)
Sodium (Na)
Sulfate (SO_4-2)
Oil and Grease
Cation - Anion Balance

ATTACHMENT II

SPRINGS

TM-21-1, TM 22-1 AND TM 23-1

TRAIL MOUNTAIN MINE - COTTONWOODCANYON

AND THE TOP AND TRAIL MOUNTAIN

FIELD MEASUREMENTS: Four samples per annum when weather conditions permit

Discharge
PH
Specific conductivity
Temperature (Air and Water)

LABORATORY MEASUREMENTS: Four samples per annum when weather conditions permit

Total Dissolved Solids
Total Hardness (as $CaCo_3$)
Carbonate (CO_3-2)
Bicarbonate (HCO_3-)
Calcium (Ca)
Chloride (CL-)
Dissolved Iron (Fe)
Magnesium (Mg)
Manganese (Mn)
Potassium (K)
Sodium (Na)
Sulfate (SO_4-2)

ATTACHMENT III

GROUND WATER

UG-1 - TRAIL MOUNTAIN MINE

FIELD MEASUREMENTS: QUARTERLY

- Discharge
- PH
- Specific conductivity
- Temperature (Air and Water)

LABROATORY MEASUREMENTS: QUARTERLY

- Total Dissolved Solids
- Total Hardness (as $CaCo_3$)
- Carbonate (CO_3-2)
- Bicarbonate (HCO_3-)
- Calcium (Ca)
- Chloride (CL-)
- Dissolved Iron (Fe)
- Magnesium (Mg)
- Manganese (Mn)
- Potassium (K)
- Sodium (Na)
- Sulfate (SO_4-2)

ATTACHMENT IV

OBSERVATION WELL

TM-1 (SURFACE LOCATION)

TM-2 (UNDERGROUND LOACAITON)

TRAIL MOUNTAIN MINE

FIELD MEASUREMENTS: QUARTERLY

Level
PH
Specific Conductivity
Temperature

LABORATORY MEASUREMENTS: QUARTERLY

Total Dissolved Solids
Total Hardness
Aluminum
Arsenic
Barium
Baron
Carbonate
Bicarbonate
Cadmium
Calcium
Chloride
Cromium
Copper
Flouride
Dissolved Iron
Lead
Magnesium
Manganese
Mercury
Molybdenum
Nickel
Nitrogen: Ammonia
Nitrate
Nitrate
Potassuim
Phosphate
Selenium
Sodium
Sulfate
Sulfide
Zinc

After two years of Baseline Monitoring, Trail Mountain Coal Company will request of the Division to enter into the operational phase hydrological monitoring with reduced parameter.

APPENDIX 7-D (2)

APPROVAL FOR MRP AMENDMENT REQUEST FOR CHANGE IN TRAIL MOUNTAIN COAL COMPANY HYDROLOGICAL MONITORING PLAN ACT/015/009

STATE OF UTAH
NATURAL RESOURCES
Oil, Gas & Mining

Norman H. Bangerter, Governor
Dee C. Hansen, Executive Director
Dianne R. Nielson, Ph.D., Division Director

355 W. North Temple • 3 Triad Center • Suite 350 • Salt Lake City, UT 84180-1203 • 801-538-5340

July 7, 1986

CERTIFIED RETURN RECEIPT REQUESTED
P402 459 385

Mr. Allen P. Childs
Mine Engineer
Trail Mountain Coal Company
P.O. Box 370
Orangeville, Utah 84537-0370

Dear Mr. Childs:

Re: Final Approval, MRP Amendment, Request for Change in Hydrological Monitoring Program, Trail Mountain Coal Company, ACT/015/009, Folder #3, #4 & #9, Emery County, Utah

The Division has completed its review of Trail Mountain Coal Company's latest (June 13, 1986) submittal concerning the above referenced MRP Permit Amendment. The proposed plans are now acceptable and approval is hereby granted by the Division to proceed with implementation.

Thank you for your cooperation in this matter. Please contact me or Dave Wham should you have any questions.

Sincerely,

D. Wayne Hedberg
Permit Supervisor/
Reclamation Hydrologist

Review Chronology:

A. Operator Submittals
1. 8/3/84
2. 5/19/86
3. 6/18/86

DOGM Responses
1. 9/21/84
2. 6/3/86
3. 7/3/86

DMW:jvb
cc: Allen Klein
Lowell Braxton
John Whitehead
Jim Fricke
0851R-14

APPENDIX 7-D (3)

PARAMETERS:

SURFACE WATERS

SPRINGS

GROUND WATER

OBSERVATION WELLS

ATTACHMENT I

SURFACE WATER

SW-1, SW-2, AND SW-3

TRAIL MOUNTAIN MINE, COTTONWOODCANYON

PERENNIAL STREAM - NORTH FORK OF THE COTTONWOODCREEK

FIELD MEASUREMENTS: MONTHLY

Discharge
PH
Specific conductivity
Temperature (Air and Water)
Dissolved Oxygen

LABORATORY MEASUREMENTS: QUARTERLY

Total Settleable Solids
Total Suspended Solids
Total Dissolved Solids
Total Hardness (as $CaCo_3$)
Acidity ($CaCo_3$)
Carbonate (CO_3-2)
Bicarbonate (HCO_3-)
Calcium (Ca)
Chloride (CL-)
Dissolved Iron (Fe)
Total Iron (Fe)
Magnesium (Mg)
Total Manganese (Mn)
Potassium (K)
Sodium (Na)
Sulfate (SO_4-2)
Oil and Grease
Cation - Anion Balance

ATTACHMENT II

SPRINGS

TM-21-1, TM 22-1 AND TM 23-1

TRAIL MOUNTAIN MINE - COTTONWOODCANYON

AND THE TOP AND TRAIL MOUNTAIN

FIELD MEASUREMENTS: Four samples per annum when weather conditions permit

Discharge
PH
Specific conductivity
Temperature (Air and Water)

LABORATORY MEASUREMENTS: Four samples per annum when weather conditions permit

Total Dissolved Solids
Total Hardness (as $CaCo_3$)
Carbonate (CO_3-2)
Bicarbonate (HCO_3-)
Calcium (Ca)
Chloride (CL-)
Dissolved Iron (Fe)
Magnesium (Mg)
Manganese (Mn)
Potassium (K)
Sodium (Na)
Sulfate (SO_4-2)

ATTACHMENT III

GROUND WATER

UG-I - TRAIL MOUNTAIN MINE

FIELD MEASUREMENTS: QUARTERLY

Discharge
PH
Specific conductivity
Temperature (Air and Water)

LABROATORY MEASUREMENTS: QUARTERLY

Total Dissolved Solids
Total Hardness (as $CaCo_3$)
Carbonate (CO_3-2)
Bicarbonate (HCO_3-)
Calcium (Ca)
Chloride (CL-)
Dissolved Iron (Fe)
Magnesium (Mg)
Manganese (Mn)
Potassium (K)
Sodium (Na)
Sulfate (SO_4-2)

ATTACHMENT IV

OBSERVATION WELL

TM-1 (SURFACE LOCATION)

TM-2 (UNDERGROUND LOACAITON)

TRAIL MOUNTAIN MINE

FIELD MEASUREMENTS: QUARTERLY

Level
PH
Specific Conductivity
Temperature

LABORATORY MEASUREMENTS: QUARTERLY

Total Dissolved Solids
Total Hardness
Aluminum
Arsenic
Barium
Baron
Carbonate
Bicarbonate
Cadmium
Calcium
Chloride
Cromium
Copper
Flouride
Dissolved Iron
Lead
Magnesium
Manganese
Mercury
Molybdenum
Nickel
Nitrogen: Ammonia
Nitrate
Nitrate
Potassuim
Phosphate
Selenium
Sodium
Sulfate
Sulfide
Zinc

After two years of Baseline Monitoring, Trail Mountain Coal Company will request of the Division to enter into the operational phase hydrological monitoring with reduced parameter.

APPENDIX 7-D (4)**

TRACT 1 WATER MONITORING LOCATIONS (FIGURE 7-9)

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