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CUMULATIVE HYDROLOGIC IMPACT ASSESSMENT IN THE MUD CREEK DRAINAGE BASIN WITH RESPECT TO VALLEY CAMP OF UTAH'S BELINA MINES

PREPARED FOR

U.S. OFFICE OF SURFACE MINING

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ENGINEERING-SCIENCE

DESIGN • RESEARCH • PLANNING

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CHAPTER 1

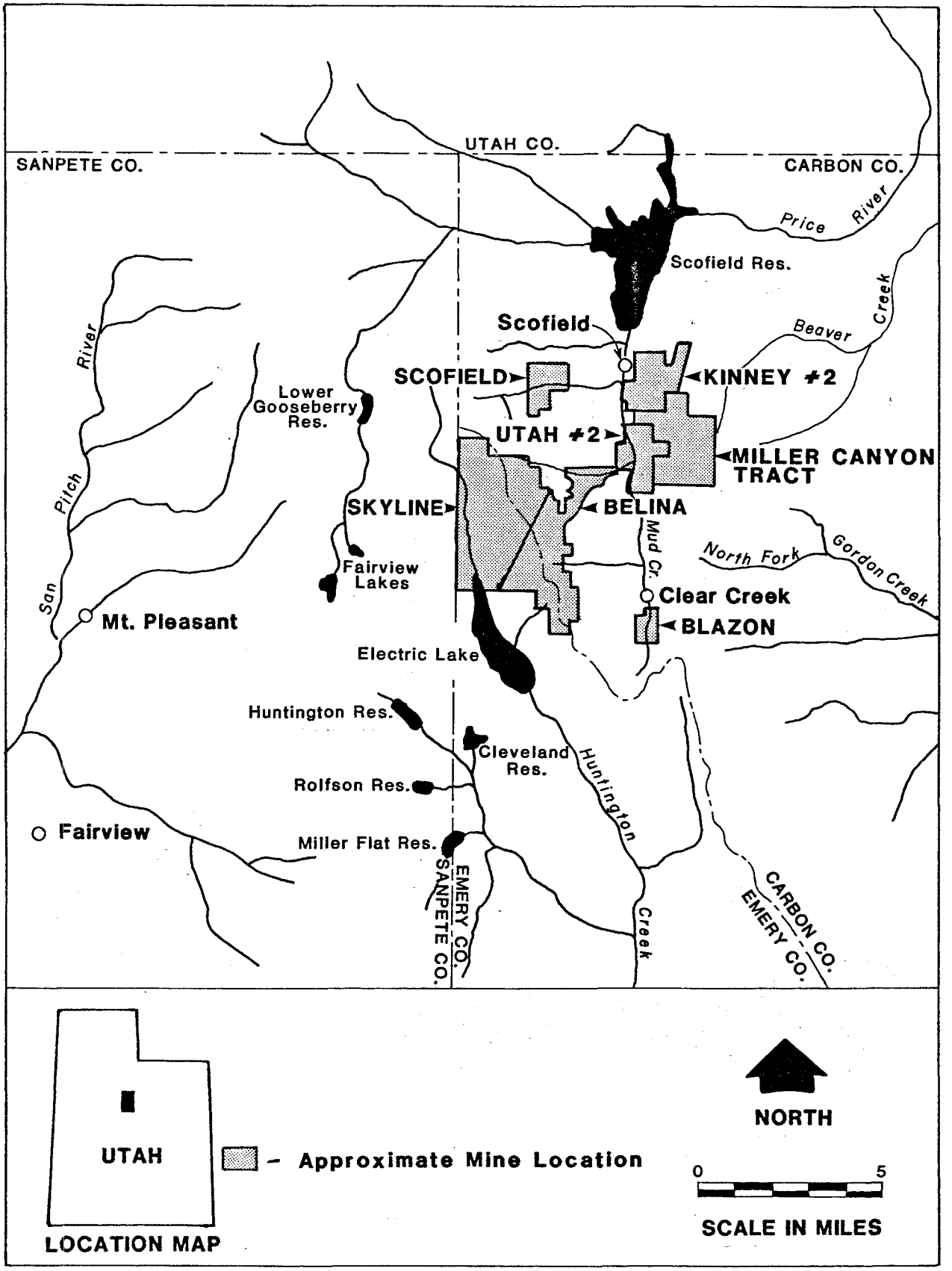
INTRODUCTION

The Surface Mining Control Act of 1977 (P.L. 95-87) requires that prior to the approval of a permit application to conduct surface coal mining and reclamation operations, the regulatory authority must make an assessment of the cumulative hydrologic impacts on the hydrologic balance of all anticipated mining in the area. A finding must be made by the regulatory authority that demonstrates the proposed mining operation has been designed to prevent material damage to the hydrologic balance outside of the permit area. The purpose of this document is to provide a cumulative hydrologic impact assessment (CHIA) with respect to Valley Camp of Utah Inc.'s Belina Mines and other existing or anticipated mining in the cumulative impact area (CIA) of the Belina Mines.

This CHIA determines what the cumulative hydrologic impact of mining within the CIA will be and presents standards for measuring the degree of the impacts. Where impacts are small, a determination of no material damage is made. Where users of water may be adversely affected, the material damage determination is deferred. The final determination of material damage should be made following the technical analysis and the composition of stipulations. However, the determination of material damage with respect to the cumulative hydrologic impacts is left to the regulatory agency.

The Belina Mines are located in Carbon and Emery Counties, Utah, approximately 20 miles northwest of Price and four miles southwest of Scofield, Utah (Figure 1). The mines are located in the headwaters of the Price River basin and the Huntington Creek basin on the northern end of the Wasatch Plateau. The mine portals for the Belina Mines are located within the Mud Creek basin, a tributary to the Price River. Furthermore, all mines considered in this CHIA are within the Mud Creek drainage basin upstream of Scofield Reservoir. It should be noted that the report refers to Mud Creek as the surface water drainage but the correct name of the topographic valley, Pleasant Valley, is also used.

Figure 1



STUDY AREA

Chapter 2 develops the CIA used for this CHIA on the basis of knowledge of the local surface and ground water resources, anticipated mining in the area, and the extent of impacts associated with mining (developed in Chapter 4). It should be noted that the CIA for surface water resources was developed separately from the CIA for ground water resources. Therefore, the Mud Creek basin is considered the surface water CIA while a much smaller area in the vicinity of the Belina Mines is considered the CIA with respect to ground water resources (see Figure 2).

Within the surface water CIA the effects of all anticipated mining to the quality and quantity of Mud Creek down to the U.S. Geological Survey (USGS) gaging station near the town of Scofield are analyzed. The cumulative impact assessment for Mud Creek considers the variation in the quality and quantity of ground water discharge associated with mining in relation to Mud Creek. All anticipated mining considered in this CHIA within the surface water CIA includes UCO Inc.'s Scofield Mine, Coastal States Energy and Getty Mineral Resource Company's Skyline Mines, Valley Camp of Utah, Inc.'s Utah No. 2, Belina Nos. 1 and 2 Mines, Energy Fuel Company's Kinney No. 2 Mine, and Blazon Company's Blazon No. 1 Mine. It should be noted that three sets of portals are considered for the Belina Mines, two in Whiskey Canyon and the O'Connor Portal in Boardinghouse Canyon. Mining at Utah No. 2 includes the effects of future mining of the Miller Canyon Tract lease.

The hydrologic effects of historic mining in the Belina CIA are considered to be baseline conditions. However, documented impacts from historic mining were used to assess the impacts of all anticipated mining considered in this CHIA. With respect to ground water resources the effect of the Belina Mines on the local ground water system is considered together with the cumulative effect of other mines in the immediate vicinity. This approach to limiting the ground water CIA is justified because the impacts of the Belina Mines to the ground water system are considered local in extent. To address the isolated ground water impacts of the individual mines in the Mud Creek basin would not be a cumulative assessment but rather would be a restatement of the probable hydrologic consequences for each mine, which is not the

function of the CHIA process. The mines considered within the ground water adjacent area are the Skyline and Belina Mines.

Chapter 3 identifies the critical surface and ground water hydrologic concerns that are then analyzed in Chapter 4.

Chapter 4 provides a quantitative cumulative impact assessment of all anticipated mining to the quality and quantity of flow in Mud Creek. In addition, this chapter provides a semi-quantitive assessment of the impacts of the Belina and Skyline Mines to local ground water systems.

Chapter 5 discusses the cumulative impacts projected in Chapter 4 in relation to surface and ground water utilization.

Chapter 6 is a summary of the findings in this report and draws conclusions regarding the cumulative hydrologic impacts of mining in the Belina Mines CIA. In addition, possible mitigating measures that can be implemented to alleviate some of the impacts predicted by this CHIA are recommended.

CHAPTER 2

DEFINITION OF THE CUMULATIVE IMPACT AREA IN RELATION TO SURFACE AND GROUND WATER RESOURCES

INTRODUCTION

The term cumulative impact area (CIA) is used to describe the area within which impacts of the proposed operation are likely to have a cumulative hydrologic impact with any anticipated mining outside the proposed permit area. This study focuses on the cumulative hydrologic impacts associated with the Belina Nos. 1 and 2 Mines and all anticipated mining in the area.

All anticipated mining is defined as all existing mines, all proposed mines with mining and reclamation plans submitted, and all proposed mines with diligent development requirements for leased Federal coal for which there is actual mine development information available. Hydrologic impacts from all anticipated mining will be assessed. However, impacts from historic mining will be considered as baseline data only. Historic mining will be discussed in order to familiarize the reader with the magnitude of mining that has taken place in the study area.

Because the ground water system in the vicinity of the Belina Mines is localized, the surface and ground water cumulative impact areas for the Belina Mines are not identical. Complex faulting in the Belina area divides the ground water into zones that are hydrologically separate. Therefore, the ground water CIA for the Belina Mines is an area immediately adjacent to the Skyline and Belina Mines.

The ground water zones interact with the surface water both in terms of recharge and discharge to spring flow/streamflow and by mine water discharge. In addition, the surface water from all anticipated mining drains via Mud Creek into Scofield Reservoir. Therefore, the surface water CIA for the Belina Mines includes all of Mud Creek and its tributaries down to the USGS gaging station above the town of Scofield.

Mining History

Underground mining has occurred in Pleasant Valley for over 100 years. The previous mining has left behind large areas of unreclaimed, unvegetated land near perennial streams. Erosion and contribution of sediment into the drainage system is widespread throughout the basin. Very few of the watersheds, especially on the west side of the valley, can be classified as "undisturbed." A map showing the approximate locations of the historic mines in the study area is presented in Figure 3.

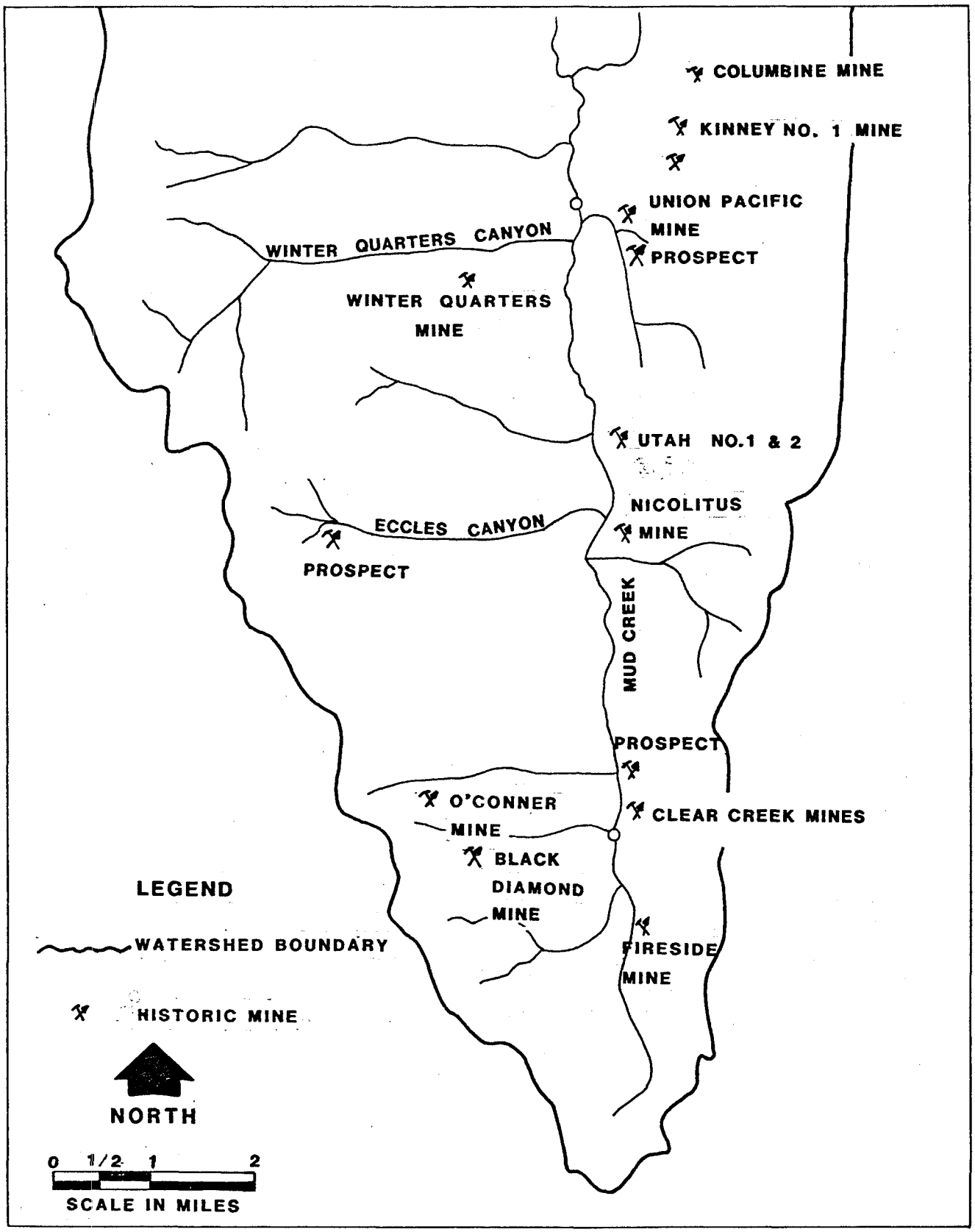
In 1878, Utah Fuel Co. opened the Mud Creek Mine (now called the Utah No. 1 Mine) near the mouth of Mud Creek. Much of the coal mined was used by the Denver and Rio Grande Railroad. Total production over the life of the mine was estimated to be 713,800 tons (Doelling, 1972).

Union Pacific Railroad opened the Pleasant Valley Mine just east of the town of Scofield in 1884. Mining terminated after the lower seam caught fire. Several other mines operated in the vicinity of Scofield, including the Jones, Blue Seal, Kinney, and Columbine Mines. The only mine of major significance was the Kinney Mine, located northeast of the town boundaries. A later operation, the Columbine Mine, was near the same locality. The Columbine Mine closed in 1970.

The Winter Quarters Mine was the largest mining operation in Pleasant Valley. The mine was owned by Pleasant Valley Coal Company and it had six separate openings in Winter Quarters Canyon. Mining operations started in 1884. By 1899, production was over 438,000 tons per year (Report of the State Coal Mine Inspector, 1901). Mining continued until 1928. Total production was nearly 11 million tons of coal (Valley Camp, 1983). On May 1, 1899, an explosion occurred in Winter Quarters Canyon, killing 200 men.

The Clear Creek Mines were opened in 1899 by the Utah Fuel Company. Most of the mining was in the lower seam on the east side of the valley near the town of Clear Creek. Mining moved eastward until it was terminated by a major fault zone. (The actual fault zone was not identified in the Report of the State Coal Mine Inspector, 1901. However, it is assumed that is was the Pleasant Valley Fault.) A

FIGURE 3



HISTORIC MINES IN STUDY AREA

1,700-foot-long rock tunnel was driven across the fault zone into the coal on the other side of the fault, and mining continued in the Clear Creek Nos. 3 and 4 Mines (Valley Camp, 1983). Water is presently discharging from the Clear Creek Mines immediately east of the town of Clear Creek at an average rate of about 0.5 cubic feet per second (cfs) or 225 gallons per minute.

Several small mines operated intermittently from the 1920's into the 1960's. The Black Diamond Mine operated in upper Finn Canyon, west of the town of Clear Creek. Mining was intermittent between 1923 and 1941. The O'Connor Mine operated in Boardinghouse Canyon. Mining from Boardinghouse Canyon connected the old works in Finn Canyon (Valley Camp, 1983). Other small prospect and wagon mines occurred in Eccles Canyon (near the site of the existing Skyline Mines) and on the east side of Mud Creek. Mining techniques for these prospect and wagon mines included drift and slope underground mining and contour strip mining.

In 1974, Valley Camp of Utah opened the Utah No. 2 Mine across from Green Canyon. This mine was projected to produce between 500,000 and 750,000 tons per year. However, severe faulting caused Valley Camp to cease operations in July, 1978 (Valley Camp, 1983). During mining, mine water discharged at a rate varying between 0.2 and 1.1 cfs (100 and 500 gpm. A well near the mine portal and a spring near the mine dried up during mining (Hotchkiss, et al., 1980) but recovered after mining ceased.

Existing Mines

Three operators currently mine in Pleasant Valley: Valley Camp of Utah, Inc. (Valley Camp); Coastal States Energy Company and Getty Mineral Resources Company (Coastal States); and Blazon Company. These three operators mine Belina Nos. 1 and 2; Skyline Nos. 1, 2, and 3; and Blazon No. 1, respectively (See Figure 1).

Because of the regional faulting in the area, the coal seams have been separated into four mining areas: the area west of the Conneville

Fault, the Conneville Block situated between the Conneville Fault and the O'Connor Fault, the area between the O'Connor Fault and the Pleasant Valley Fault, and the area east of the Pleasant Valley Fault (USGS, 1979).

The Belina Nos. 1 and 2 Mines operate from the Upper and Lower O'Connor Coal Seams of the same leasehold. In 1976, construction for the Belina Mines began. Portals are located in Whiskey Canyon off Eccles Canyon. Valley Camp operates a tipple near the Utah No. 2 Mine site. Federal approval was granted in 1977 to mine coal from the Belina No. 1 (USGS, 1979). Temporary approval of mining in the Belina No. 2 Mine was given by both the Office of Surface Mining (OSM) and the Utah Division of Oil, Gas, and Mining in 1982 (OSM, 1982). Production is estimated at 2.4 million tons per year. The entire mining area covers 6,338 acres. Surface facilities occupy approximately 50 acres in Whiskey Canyon and 21 acres at the tipple (Vaughn Hansen, 1980). Mining at the Belina Mines is in the Conneville Block in the area between the O'Connor Fault and the Pleasant Valley Fault. Mining is underground by room and pillar mining methods. The life of the Belina Mines is anticipated to be another 25 years.

The Skyline Mines are located immediately west of the Belina Mines. Portals for the Skyline Mines are located at the confluence of the Left Fork, Middle Fork, and Right Fork of Eccles Creek. The mine plan area covers 6,400 acres, of which approximately 100 acres are used for surface facilities. A tipple for the Skyline Mines is being constructed near the mouth of Eccles Canyon. Construction of the surface facilities began in the summer of 1981 and is still ongoing.

Mining at the Skline Mines has been limited to date. Mining is in the area west of the Conneville Fault in the Upper O'Connor, Lower O'Connor B, and Lower O'Connor A Coal Seams. Production is projected to reach 5.4 million tons per year by 1991 (Coastal States, 1979). Mining is underground, incorporating room and pillar, paneling, and longwall mining methods. The life of the Skyline Mine is anticipated to be 40 years.

Two secondary activities are presently ongoing in conjunction with the development of the Skyline Mines. The Utah Department of Transportation is constructing an all-weather highway up Eccles Canyon to join Utah State Highways 31 and 96. Road development started in 1982 and has resulted in a large increase in sediment into Eccles Canyon Creek. It is expected that the amount of sediment will remain high during construction and taper off after construction and paving.

The second activity is a rail spur being constructed by the Denver and Rio Grande Western Railroad next to Mud Creek. The rail spur will provide rail service for the Skyline tipple. An increase in sediment in Mud Creek has occurred during the construction of this rail spur.

The Blazon No. 1 Mine is located upstream of the town of Clear Creek along Mud Creek. Construction of the surface facilities began in 1981. The mine plan area covers 280 acres, including about 20 acres associated with surface facilities at the mine site. A tipple for the Blazon No. 1 Mine is located near U.S. Highway 6. The Blazon No. 1 Mine operates in the Upper O'Connor Coal Seam in the area east of the Pleasant Valley Fault. Mining is underground, incorporating room and pillar mining methods. The Blazon No. 1 Mine has been temporaily closed since 1982. It is assumed that the mine will reopen at a later date.

Proposed Mining

Mining and reclamation plans have been filed with the Division of Oil, Gas, and Mining for two other mines in Pleasant Valley: the Scofield Mine in Winter Quarters Canyon and the Kinney No. 2 Mine southeast of the town of Scofield. Both of these mines will be underground.

The Scofield Mine, owned by UCO Inc., has a proposed mine plan area of 680 acres of which 26.5 acres will be for surface facilities. Mining will occur in the Lower O'Connor Coal Seam, using room and pillar mining methods. Life of mine is anticipated to be 10 years with a maximum production of 700,000 tons per year (UCO, 1981).

The Kinney No. 2 Mine owned by Energy Fuels Co. is proposed to be located just east of the town of Scofield. Mining will be by room and pillar in the U.P. and Kinney Coal Seams. Maximum production is anticipated at 800,000 tons per year. The proposed mine plan area is about 1,900 acres, of which 30 acres will be for surface facilities.

All Anticipated Mining

All anticipated mining is defined for this study as the existing and proposed mines discussed in the sections above. In addition, all anticipated mining will include the O'Connor Portal of the Belina Mines and the Miller Canyon Tract Lease. Both of these mines have been discussed in previous environmental impact assessments and have leased Federal coal for which mine development information is available (USGS, 1979).

The O'Connor Portal is proposed by Valley Camp, Inc. Surface facilities will be constructed in Boardinghouse Canyon in a previously disturbed area. Surface facilities will require two acres of new surface disturbance. Mining will be in the area between the O'Connor Fault and the Pleasant Valley Fault in the Upper and Lower O'Connor Coal Seam. Mining will be underground by room and pillar mining methods (USGS, 1979).

Access to the Miller Canyon Lease Tract will probably be through the old Utah No. 2 portals and entries. A detailed mining plan is not available at this time. However, this lease tract was included in the definition of all anticpated mining because of the high probability that access will be through the Mud Creek side. No new surface disturbance is proposed for the mining of the Miller Canyon Tract Lease.

SURFACE WATER RESOURCES OF THE AREA

Mud Creek is located in the Colorado River drainage basin in central Utah (see Figure 1). Mud Creek was formerly called Pleasant Valley Creek, named after the topographic valley. However, in 1978, the U.S. Geological Survey changed the name of the creek on its topographic maps and gaging stations. Therefore, the name Mud Creek is used in this study.

Mud Creek has a drainage area of approximately 22,000 acres before it discharges into Scofield Reservoir. Scofield Dam is located on the Price River about five miles north of the town of Scofield. The original dam was built in 1925. However, it partially failed in 1927 and a new dam was built 800 feet downstream in 1946. The present dam impounds water from Mud Creek, Fish Creek, Pondtown Valley Creek, Dry Valley Canyon Creek, and Miller Canyon Creek. Mud Creek provides approximately 16 percent of the annual flow into Scofield Reservoir. Scofield Reservoir has a useable storage of about 65,780 acre-feet and inactive storage of about 8,000 acre-feet. Scofield Reservoir provides the municipal water supply for the town of Price, Utah.

Scofield Reservoir is protected for domestic (Class 1C), primary recreation (Class 2B), cold water fisheries (Class 3A), and agricultural (Class 4) water uses. The town of Scofield has a year-round residency of 35, which increases to 150 during summer months. Some additional year-round homes are located at the town of Clear Creek. Clear Creek has a year-round residency of 25.

The coal mining area is mostly south of Scofield Reservoir along Mud Creek and its tributaries in the Wasatch Plateau. All of the coal is being mined from the Blackhawk and Star Point Formations. Elevations range from 7618 feet mean sea level (MSL) at the reservoir to over 10,100 feet at the top of the watershed. The average stream gradient in Mud Creek is five percent while canyon side slopes range up to 72 percent. Average annual precipitation ranges from 25 inches in the valley to over 30 inches on the peaks, with 70 to 80 percent occurring primarily as snow during October through April.

Water quality is in general good. Both surface and ground water is largely calcium bicarbonate in type. Calcium concentration is at or above saturation at times in Scofield Reservoir and precipitation of calcium and bicarbonate as calcium carbonate in the reservoir is suggested (Waddell, et al., 1983a).

Streamflow in Mud Creek varies from about three cfs to over 100 cfs. Peak discharges occur as a result of spring snowmelt. Low flow

usually occurs between August and March. The high magnitude peak streamflow stimulates high sediment production in spring and summer (in excess of 500 milligrams per liter even in undisturbed areas.

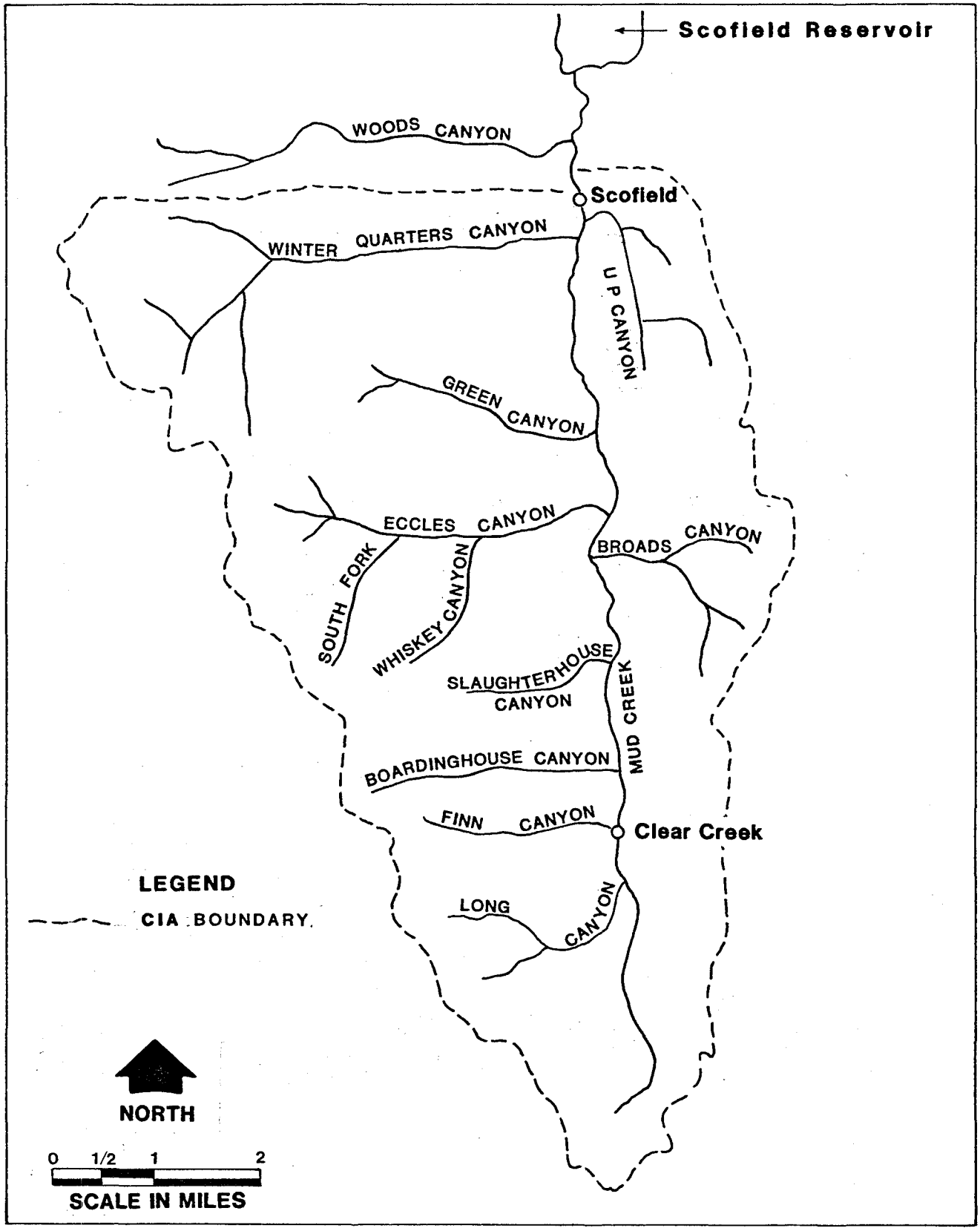
DETERMINATION OF THE SURFACE WATER CUMULATIVE IMPACT AREA

The cumulative impact area (CIA) for surface water is shown on Figures 2,4, and 5. Boundaries include all of the Mud Creek drainage above the USGS gaging station near the town of Scofield. Drainage from all of the portal facilities of the mines previously defined as all anticipated mining is included in the boundaries for the CIA. However, some of the surface drainage over the underground workings (i.e. Skyline, Belina, and Utah No. 2 involving the Miller Canyon Tract Lease) does not contribute to Mud Creek. Drainage that does not contribute to Mud Creek was assumed to be outside the limits of the Belina Mines CIA. This drainage will be addressed in other CHIAs.

GROUND WATER RESOURCES IN THE AREA

The purpose of this part is to give an understanding of the geohydrologic system that will provide the basis for the assessment of cumulative hydrologic impacts in Chapter 4. All aspects of the geohydrologic system are discussed here, including recharge, geologic setting, and discharge. It should be mentioned at the onset that the ground water system in the Belina Mines CIA is very complex primarily because of the extensive geologic structure and nature of strata in the area. Therefore, the analysis of ground water impacts in Chapter 4 is quantitative where sufficient information is available to warrant such an analysis and semi-quantitative where data are not available to fully describe this complex ground water system. More specifically, this chapter sets up two approaches to impact analyses for Chapter 4. The first type of analysis involves an estimate of discharge from mines within the CIA and a quantitative evaluation of the effect of mine discharges on Mud Creek. The second type of impact analysis discusses the semi-quantitative impacts the Belina Mines will have on the local ground water system and what cumulative impacts to the local ground water system will occur from all anticipated mining in the area.

Figure 4



SURFACE WATER CIA

The greatest emphasis is put on developing the geohydrologic setting around the Belina Mines and vicinity. For the other mines in Pleasant Valley a more general geohydrologic setting that is adequate to justify the estimates of ground water discharge from the mines is provided.

Recharge

Ground water flow in the vicinity of the Belina Mines generally occurs from topographically high recharge areas along the upper ridges to discharge areas in the lower valleys. The upper ridges receive approximately 30 inches of annual precipitation compared to 25 inches of precipitation within Pleasant Valley. In addition, the ridges allow greater snowpack to accumulate because of the higher elevation and position with respect to the easterly storm track in the area. The higher elevation and topographic setting also allow the snow to melt over an extended period thereby allowing a longer recharge period. Approximately 77 percent of the precipitation falls in the period between October through April, primarily in the form of snow (Jeppson et al., 1968 in Vaughn Hanson, 1980). The remainder of the precipitation (seven inches) occurs as rainfall throughout the remainder of the year. The annual loss of moisture to evapotranspiration was estimated for the vicinity of the Belina Mines to be approximately 17 inches. Therefore, excess precipitation is available on an annual basis for runoff and ground water recharge.

Waddell, et al. (1983b) documented that well 60.7 drilled in Eccles Canyon (see Figure 5) by Coastal States Energy Company had decreasing water levels as depth of penetration increased. This observation of falling head with increasing depth indicates that water in the upper part of the canyon has the potential to move from the Blackhawk Formation down to recharge the Star Point Sandstone. At the approximate location of the Blackhawk/Star Point contact along Eccles Canyon, Waddell, et al. report that the potential in the Star Point Sandstone is greater than the potential in the Blackhawk Formation, resulting in discharge from the Star Point Sandstone at that point. Ground water discharge will be discussed in detail in subsequent text.

No estimates have been made of the amount of annual recharge in the Mud Creek basin. The amount of recharge in the Mud Creek basin is difficult to assess because the data are not available to determine the amount of ground water flow out of the Mud Creek basin. The normal procedure for making an assessment of recharge would be to analyze the amount of baseflow out of the basin and assume that baseflow is equal to the discharge from the ground water system. Next, the assumption is made that the ground water system is experiencing steady state flow and that ground water discharge (including losses such as evapotranspiration) is equal to ground water recharge in the basin. In the Mud Creek basin it is not possible to make these assumptions because the fractured Star Point Sandstone occurs beneath Pleasant Valley and carries an unknown amount of water out of the basin. This unknown component of ground water discharge from the Mud Creek basin could be quite significant (Clyde, et al., 1981), thereby potentially making the corresponding evaluation of recharge seriously wrong. A water balance approach to the impact assessment in Chapter 4 was avoided because all inputs and outputs to the ground water system could not be assessed within a reasonable level of accuracy. However, Waddell, et al. (1983b) determined in 1980 that the discharge from the Blackhawk and Star Point Formations to Mud Creek was 1,340 acre-feet per year. It should be emphasized that the amount of ground water movement through the Star Point Sandstone out of the area remains unknown.

Geologic Setting

The topography and geology in the area strongly influence the ground water flow system. The following text develops the concept of ground water flow in the Belina Mines CIA from the recharge areas to discharge zones. All geologic strata in the area outcrop to the east in Pleasant Valley or to the west in the Huntington Creek Valley. Therefore, the ground water flow system (i.e., from the recharge areas along the ridges to discharge along the valleys) is a balance between the amount of recharge available, the hydraulic characteristics of the strata and geologic structures in the area, and the opportunity for discharge. The dip of the strata in the vicinity of the Belina Mines is generally to the west, ranging from two to five degrees.

Stratigraphy

The geologic units present in the CIA for the Belina Mines include the Masuk member of the Mancos Shale, the Star Point Sandstone, the Blackhawk Formation, and the Castlegate Sandstone of the Price River Formation. Figure 6 illustrates a generalized stratigraphic sequence in the vicinity of the Belina Mines CIA and gives the lithologic description and hydraulic characteristics of each. Figure 7 illustrates the nature of the intertonguing between these formations.

Mancos Shale Group

The Mancos Shale forms the broad slope at the base of the Wasatch Cliffs several miles to the east of the Belina Mines CIA. It consists largely of marine shale with occasional interbeds of sandstone and minor limestone. Only the uppermost portion, the Masuk Shale Member, of the Mancos Shale is of importance in the vicinity of the Belina Mines. The Masuk Shale grades upward into, and interfingers westward with, the lower deltaic sandstone tongues of the Star Point Sandstone. These westward-thinning wedges of the Masuk Shale which interfinger with the basal units of the Star Point Sandstone (Figures 6 and 7) make it difficult to set a stratigraphic boundary between the two units. The boundaries of the Mancos Shale and the Star Point Sandstone overlap.

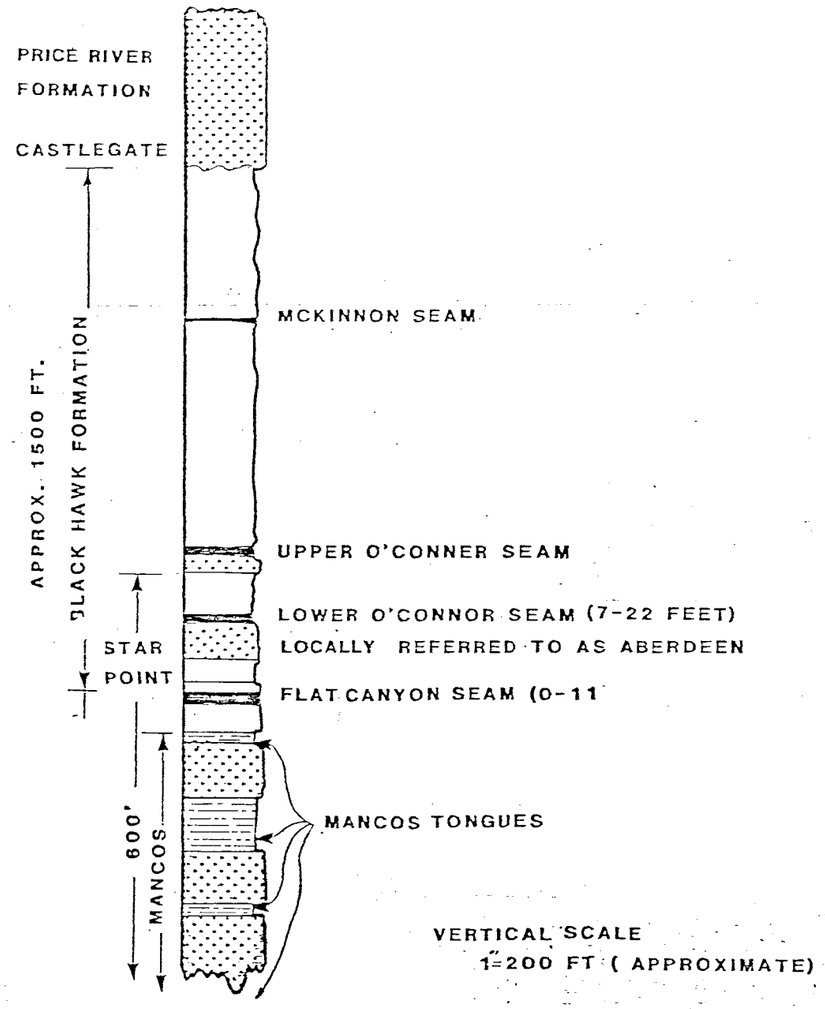
The hydrologic characteristics of the Masuk Shale are very poor. These shale interbeds are good aquicludes characterized by low vertical and horizontal permeabilities even when associated with faulting.

Star Point Sandstone

The Star Point Sandstone is generally represented by a marine fore-shore and shoreface, massive, fine- to medium-grained, coarsening upward, sandstone sequence on the western and southern sides of the Wasatch Plateau. It thins eastwardly into prominant sandstone tongues that interfinger into the Masuk Shale Member of the Mancos Shale below and the Blackhawk Formation above (Blanchard, 1981). The Star Point Sandstone in the CIA generally consists of three sandstone tongues. From the bottom upward, these are the Panther, Storrs, and Spring Canyon tongues. Similar sandstone tongues exist eastward in the Book

FIGURE 6

GENERALIZED BELINA CIA STRATIGRAPHIC SECTION WITH LITHOLOGIC DESCRIPTION AND HYDRAULIC CHARACTERISTICS



NOTE:

(AFTER,BLANCHARD 1981, UTAH GEOLOGICAL AND MINERAL SURVEY 1982, VALLEY CAMP 1980, SKYLINE 1979 ,SPIEKER,1931 U.S. GEOLOGICAL SURVEY 1979, VALLEY CAMP 1983)

UPPER CRETACEOUS

PRICE RIVER FORMATION

Castlegate Sandstone: consists of about 300 feet of course, grained, fluvial sandstones, pebble conglomerates, and subordinant zones of mudstones. Cliff former. High permeability but unsaturated. Springs with seasonal variability common.

BLACKHAWK FORMATION: 1500 feet of fine to medium grained, thin to thick, but generally massive bedded fluvial channel sandstones alternating with subordinate siltstones, mudstones and shales. Fluvial channel sandstones more common in upper portion.

Poor aquifer material even where faulted due to the discontinuous nature of the channel sands and the swelling properties of the shales. Relatively low transmissivities. Springs have seasonal variability. In-mine flows up to 200 gpm with rapidly decreasing discharge.

Star Point Sandstone: 600 feet of fine to medium grained, generally massive and moderately well sorted, coarsening upward sandstones with subordinate siltstones, carbonaceous shale and coal intertonguing with the Masuk. Upper most portion contains fluvial channel sandstones.

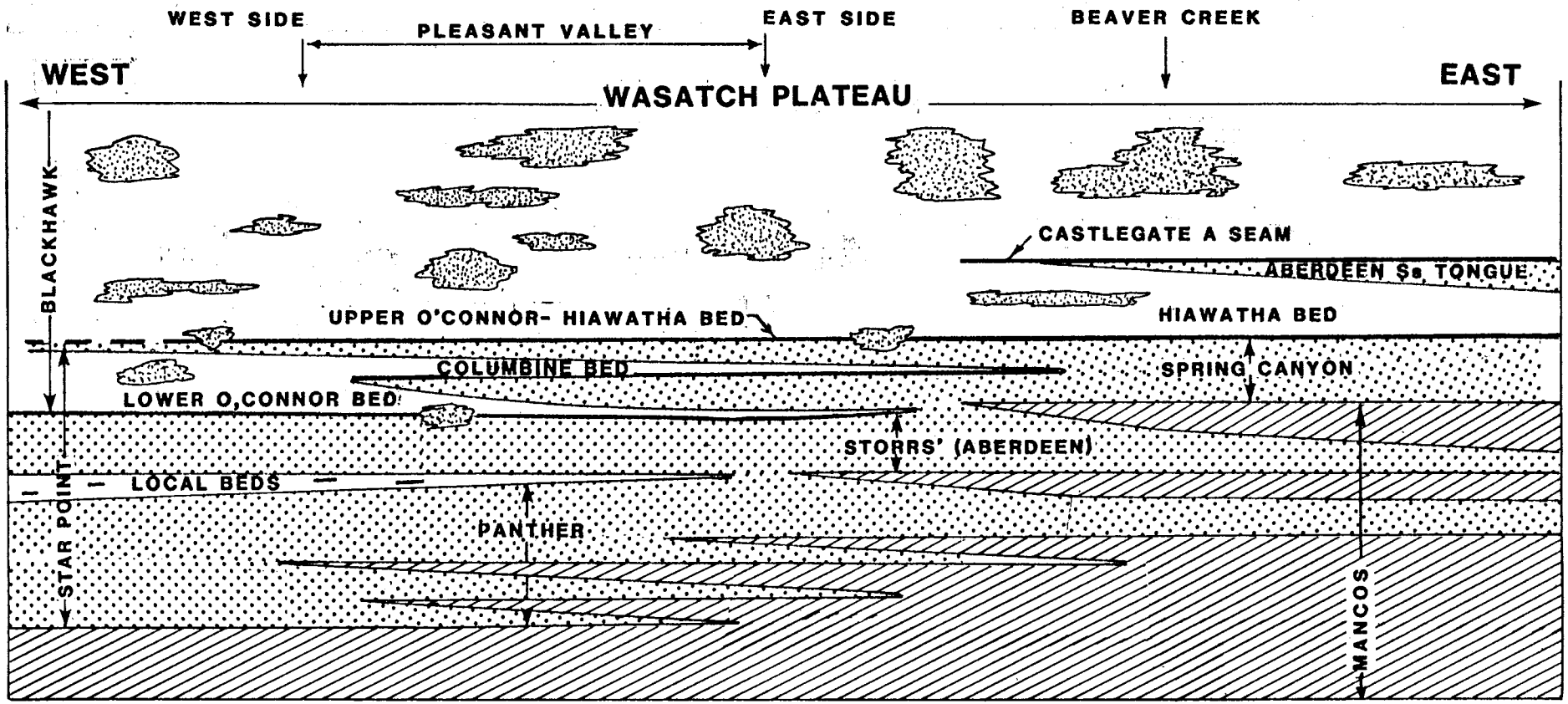
Generally poor aquifer material yielding generally <10 gpm, except where faulted and fractured where it yields up to 300 gpm. Springs have low seasonal variation in discharge. Relatively high transmissivities and storativities where fractured and faulted.

MANCOS SHALE

Masuk Shale: 1100 feet of marine sandy shales and mudstones that readily weathers which intertongues with the overlying Star Point. Generally devoid of water.

FIGURE 7

GENERALIZED CROSS SECTION ACROSS THE NORTHERN WASATCH PLATEAU INCLUDING THE BELINA CIA SHOWING THE INTERTONGUING RELATIONSHIP OF THE FORMATIONS (FROM BLANCHARD, 1981).



SANDSTONE

MANCOS SHALE

CHANNEL SANDSTONES

HORIZONTAL SCALE: 1 INCH = 1 MILE (APPROX.)

VERTICAL SCALE: 1 INCH = 200 FEET (APPROX.)

Cliffs coal field. However, they are not usually referred to as Star Point Sandstone, but as members of the Blackhawk Formation. These are, from bottom to top, the Aberdeen, Kenilworth, Sunnyside, Grassy, and the Desert tongues (Blanchard, 1981). The Aberdeen tongue is believed to occur locally.

The Star Point Sandstone is generally 600 feet thick in the Wasatch Plateau, although there is confusion over its local thickness. It was originally reported by Spieker (1931) to be on the order of 1,000 feet, but most believe it to be only 600 feet (Blanchard 1981; Roger Fry, geologist, Utah Power and Light, personal communication, October 1983; Mark Bunning, geologist, Coastal States, personal communication, August, 1983).

The Star Point Sandstone tongues are generally massive and medium grained and are occasionally broken by shale lenses of low permeability. This unit is generally a poor aquifer but the water bearing characteristics of the more massive units are greatly enhanced by the localized faulting and secondary fracturing and jointing that has occurred. Springs and seeps are common. The Star Point Sandstone tongues can be characterized by two zones that differ significantly in permeability. The upper zone is represented by a foreshore (beach) depositional environment and is characterized by well cemented and well sorted sands that have very low permeability. The lower zone is represented by a shoreface depositional environment and is characterized by less cemented and less well sorted coarse sands that exhibit much higher permeability. One permeability test showed about 260 millidarcys for the shoreface sandstone compared to less than 10 millidarcys for the foreshore sandstone (Roger Fry, geologist, Utah Power and Light, personal communication, October 1983). Along the Pleasant Valley Fault, the large discharge and low seasonal variability indicate that the fractured Star Point Sandstone has a relatively large storage coefficient and high transmissivity.

Blackhawk Formation

The Blackhawk Formation contains the important coal-bearing strata of the region and has been historically separated from the Star Point Sandstone. In the Mud Creek area, however, intertonguing makes it

difficult to set a boundary between these two geologic units (Figures 6 and 7). The Blackhawk Formation consists of about 1,500 feet of fluvial channel sandstones, shale, siltstone, mudstone, and coal. The fluvial channel sands were deposited in a coastal plain-deltaic setting and are lithologically dissimiliar to the littoral sandstones of the Star Point Formation. The channel sandstones increase in number in the upper portion of the Blackhawk Formation. The lower 350 feet of the Blackhawk Formation contain the important coal seams but contain a significant number of channel sandstones.

The nomenclature for the coal seams in the area changes depending on which side of the Pleasant Valley Fault the seams occur. East of the Pleasant Valley Fault the coal seams are referred to (from bottom to top) as the Flat Canyon, U.P., Columbine, Hiawatha and the Kinney Seams. The coal seams on the west side of the Pleasant Valley Fault (from bottom to top) are referred to as the Flat Canyon, Lower O'Connor A, Lower O'Connor B, Upper O'Connor, and McKinnon Seams. The Upper O'Connor Seam is correlated to the Hiawatha Seam of the region (Blanchard, 1981). The Columbine Seam does not extend to the west side of Pleasant Valley (Blanchard, 1981).

The stratigraphic sequence in the upper Blackhawk Formation includes primarily sandstones and shales. The fluvial channel sandstones in the Blackhawk Formation are generally local in extent, fine grained, well cemented, and have locally high clay contents (Spieker, 1931). These fluvial sandstone deposits are relatively narrow across their axes but are continuous along their axes, meandering like fluvial deltaic systems. The discontinuous nature of these channel sandstones in the Blackhawk Formation makes ground water movement through this unit slow with frequent aquicludes that encourage the lateral movement of ground water to local discharge zones (i.e., springs and faults). Due to the number of perched water table systems, springs and seeps are common.

Price River Formation

The Price River Formation uncomformably overlies the Blackhawk Formation, but in the Belina Mines CIA the contact is gradational (Fry, geologist, Utah Power and Light, personal communication, October,

1983). The lower part of the Price River Formation consists of a massive basal sandstone member called the Castlegate Sandstone. The Castlegate Sandstone is a cliff-forming, coarse-grained, fluvial sandstone and pebble conglomerate with subordinate zones of mudstones that is about 300 feet thick in the Belina Mines CIA. It occurs only in the northwestern corner of the CIA. The Castlegate Sandstone is considered good aquifer material because of its high permeability. Springs and seeps are common in the gradational contact of the Castlegate Sandstone and the Blackhawk Formation (see Figure 2).

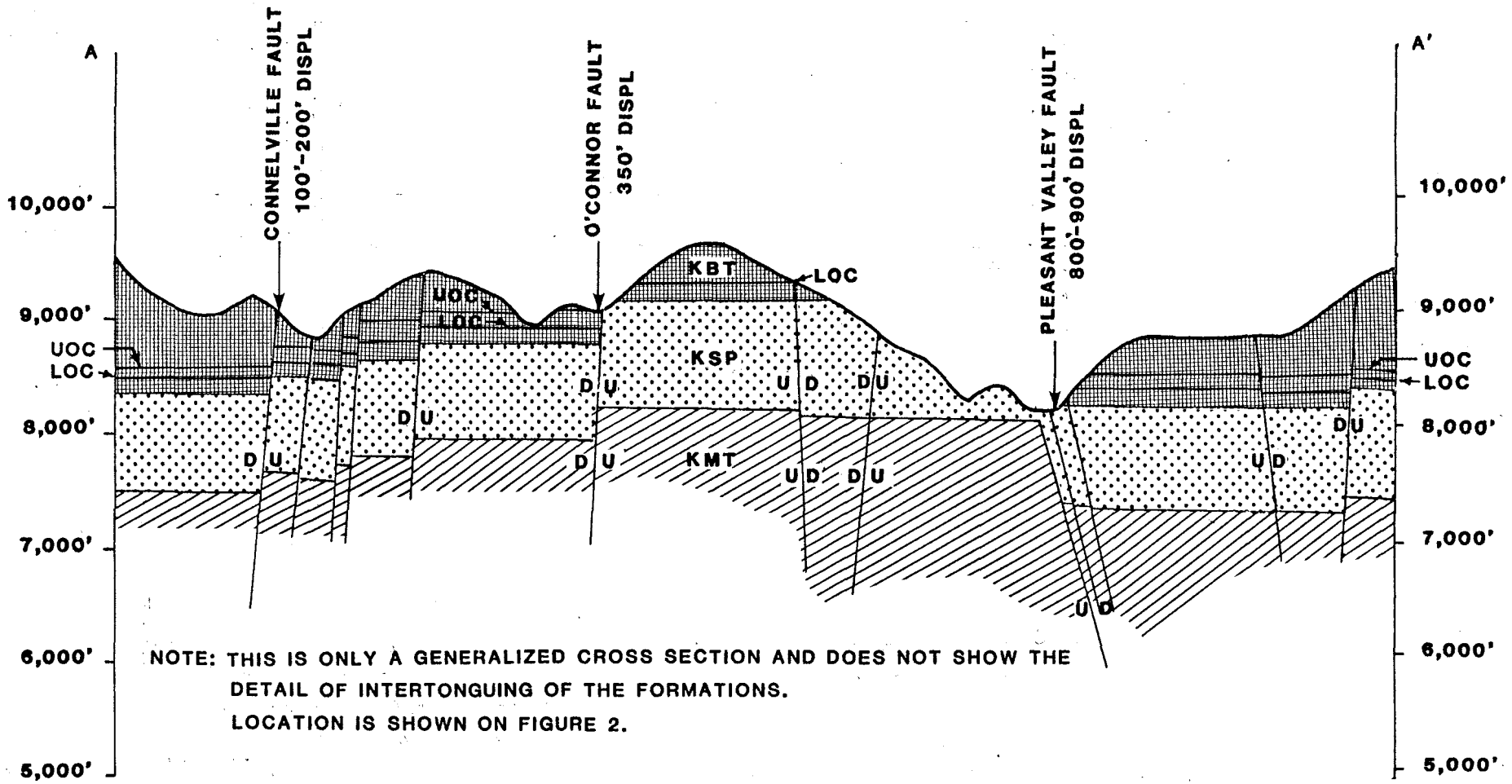
Geologic Structure

The topographic divide to the west of Pleasant Valley is the western flank of the Clear Creek Anticline (Doelling, 1972 in Vaughn Hansen, 1980). Several major en echelon faults trending northeast-southwest and a dike trending east-west extend through the CIA.

The major faults that will be encountered in the mines in the Belina Mines CIA, from east to west, are the Pleasant Valley Fault, the O'Connor Fault, the Connelville Fault, and the Valentine Fault (see Figures 2 and 8). The faults are generally scissors faults with varying amounts of displacement at the northern and southern ends of the faults. In addition, the faults are generally high angle, normal faults down dropped to the west. Pleasant Valley Fault just upstream of Scofield Reservoir is a graben, an area down dropped relative to the east and west sides of the valley. The O'Connor and Connelville Faults tend to die out north of the Belina Mines before reaching the Scofield Mine. Within the Belina Mines surface water CIA no major fault zones extend through the Scofield Mine. The Connelville Fault forms the lease area boundary between the Skyline and Belina Mines. The O'Connor Fault extends through the central portions of the Belina Mines and separates the coal reserves that will be approached from Whiskey Creek (between the Connelville Fault and the O'Connor Fault) and from Boardinghouse Canyon (see Figure 2). The Pleasant Valley Fault intersects the Kinney, Utah No. 2, and Blazon Mines. The Valentine Fault occurs within the western half of the Skyline Mine. Following parts of this chapter will discuss the importance of the faults in the geohydrologic flow system. It is apparent that fault zones and associated fracture

Figure 8

GENERALIZED EAST-WEST CROSS SECTION ACROSS BELINA CIA IN MUD CREEK BASIN.



BLACKHAWK FORMATION WITH COAL SEAMS (KBT)
UOC UPPER O'CONNOR COAL SEAM
LOC LOWER O'CONNOR COAL SEAM
STAR STARPOINT SANDSTONE (KSP)
MANCOS SHALE (KMT)

zones form one of the major pathways for ground water movement in the CIA, particularly as these faults relate to the Star Point Sandstone. In the Blackhawk Formation the faults are thought to exert much less influence on the ground water flow system. These points will be further developed in the following text.

Detailed studies were conducted by Vaughn Hansen Associates (1980) and Waddell, et al. (1983b) to determine what influence faulting had on ground water flow in the area. Both investigators conducted seepage runs along Eccles Creek and Waddell, et al. (1983b) also evaluated Mud Creek. Both studies concluded that faulted zones in Blackhawk Formation (i.e., the Connelville Fault between the Belina and Skyline Mines) do not yield significant discharge to the baseflow of local streams. This observation agrees with the amount of ground water inflow that has been experienced from the Blackhawk Formation exposed in faulted zones in mines in the area (i.e., that the only large inflow of ground water is of short duration from storage in discontinuous sandstones or highly fractured areas associated with folded strata). The general inflow rates to the mine from the Blackhawk Formation are quite low. Conversely, both studies agreed that the Star Point Sandstone is a major conduit for ground water flow where it has been fractured by major fault zones (i.e., Pleasant Valley or O'Connor Faults).

A lamprophyre dike up to 230 feet thick has been encountered in the Belina Mines. The dike was also observed in a drill hole associated with the Skyline Mine to the east of the Belina Mines, along the road up Boardinghouse Creek, and in Pleasant Valley near the town of Clear Creek (Trevor Whiteside, Valley Camp of Utah Inc., personal communication, August, 1983, see Figure 2). The importance of the dike with respect to ground water flow will be presented in the subsequent section dealing with observations of ground water.

Ground Water Quality

Almost without exception, the ground water in the area is of a strong calcium bicarbonate type. Springs in the area generally have better water quality than water from deeper sources (i.e., wells or mine water discharges).

Data show that two distinctive qualities of spring water can be found in the project area. Springs issuing from near the outcrop of the Castlegate Sandstone have very low dissolved solids content, usually less than 180 milligrams per liter (mg/l). This results from the absence of shaley or marine layers in the Castlegate Sandstone. Springs issuing over the remainder of the study area have total dissolved solids (TDS) concentrations which generally range from 200 to 330 mg/l and average about 255 mg/l.

Well water generally has a higher total dissolved solids concentration than does water from streams in the area. (See Table 1). TDS concentrations for well water generally range from about 180 to 480 mg/l. Dissolved iron ranges from 0.22 to 2.45 mg/l. Mine discharge water quality is generally similar to the well water quality. A more detailed discussion of trace elements is presented in Chapter 3.

Observations of Ground Water Occurrence and Discharge

Within Mines

A review of reports, mine permit applications, and discharge records on file with the Utah Department of Oil, Gas, and Mining and the U.S. Environmental Protection Agency was made to assess ground water inflow to mines. In addition, a field trip was conducted and mine personnel were interviewed to discover how much water was encountered in the mines and the geologic conditions associated with the points of ground water inflow. The information is summarized in Appendix A and an interpretation is presented here.

Two mines in the Belina Mines CIA have encountered completely saturated conditions (i.e., inflow into the Belina and Utah No. 2 Mines) that has persisted as mining progressed down dip. The strata that yielded the water to the mine face were the coal and associated roof channel sands of the Blackhawk Formation. In all mines the water yielded from the Blackhawk Formation was produced at low rates, except from fluvial channel sandstones exposed in the faulted zones in the Belina Mine. The exposed fluvial channel sandstones and minor fracture zones associated with folded and faulted strata produced the greatest amount of water from the Blackhawk Formation at rates that averaged

TABLE 1

RESULTS OF CHEMICAL ANALYSES OF WATER SAMPLES COLLECTED FROM VARIOUS MINES AND WELLS (FROM VAUGHN HANSEN ASSOCIATES, 1980)

Date of Sample	O'Connor Well March 1979	Alpine Well March 1979	Belina No. 1 Mine March 1979	Belina No. 1 Mine October 1979	Upper Eccle Well (W13-1) November 1979	Lower Eccles Well (W17-1) November 1979	Whiskey Canyon Well (W19-1) December 1979
Parameter	Concentration in milligrams per liter[1/]						
Arsenic	----[2/]	0.004	----	----	----	----	----
Barium	----	0.06	----	----	----	----	----
Bicarbonate	241.56	197.64	258.64	312.32	278.60	329.40	309.88
Cadmium	----	<0.001	----	----	----	----	----
Calcium	82.40	32.00	92.00	69.60	43.20	112.80	75.20
Chloride	2.0	2.0	2.0	<1.0	<1.0	3.0	4.0
Chromium	----	<0.001	----	----	0.005	----	----
Conductivity	510	285	580	370	740	540	500
Fluoride	0.17	0.84	----	0.11	----	0.13	----
Iron	----	0.530	----	----	0.225	2.450	0.465
Magnesium	25.92	9.60	12.00	21.12	30.72	11.52	21.12
Mercury	----	<0.0002	----	----	<0.00005	<0.00005	<0.0002
Nitrate	----	<0.02	----	----	<0.01	<0.01	0.24
Orthophosphate	----	<0.01	----	----	----	----	----
Potassium	2.213	1.289	3.65	0.836	12.50	2.117	1.419
Selenium	----	<0.001	----	----	----	----	----
Silver	----	<0.001	----	----	----	----	----
Sodium	1.84	21.32	25.65	1.75	76.50	3.89	2.51
Sulfate	118	6.0	115	6.0	185	63.0	26.0
TDS	335	182	380	250	480	364	300
pH	7.47	7.39	7.30	7.49	7.35	7.40	7.60

1/ Conductivity in micromhos per centimeter at 25°C; pH is standard unit.
2/ Data not available.

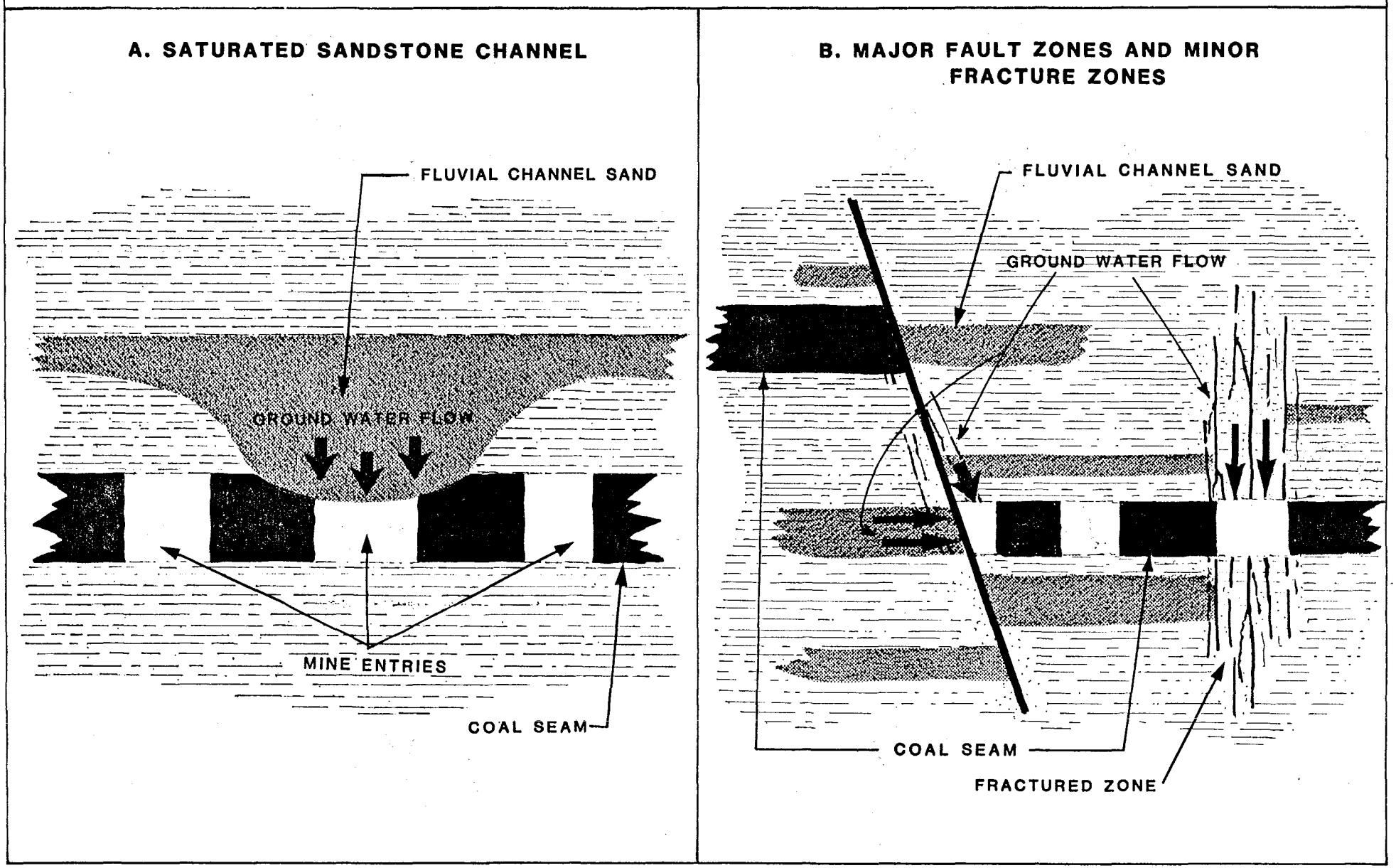
approximately 10 gallons per minute per active face with drifts completely dewatered 500 feet up dip from the mine face (Vaughn Hansen, 1980) (see Figure 9) but with flows as high as 200 gallons per minute in the faulted and folded Connelville Fault Zone (Valley Camp, 1983). In all cases, water yields from the Blackhawk Formation declined over short periods of time. This observation indicates that the Blackhawk Formation is only locally permeable and the more permeable zones (i.e., saturated portions of the fluvial channel sandstones and folded/fractured zones) do not receive extensive recharge. It was also noted that the mines experienced some seasonal fluctuation in ground water inflow. This was attributed in part to the cyclic recharge/ discharge characteristics of permeable strata in the upper Blackhawk Formation but also to subsided areas that intercepted some surface runoff.

Major fault zones and associated folded strata with decompression fractures produced the most water in all mines that encountered such zones (i.e., Belina Mines/Connelville Fault, Utah No. 2 Mine/Pleasant Valley Fault, and Clear Creek Mine/Pleasant Valley Fault) (see Figures 2 and 9). These zones produced up to 450 gallons per minute at the Utah No. 2 Mine (Hotchkiss, et al., 1980) and 200 gallons per minute in the Belina Mines (Valley Camp, 1983). The Pleasant Valley Fault encountered in the Clear Creek Mine continues to yield water at a rate of approximately 250 gallons per minute. According to Waddell, et al. (1983b), water is being contributed to the Clear Creek Mine from Mud Creek. It is assumed that the Star Point Sandstone along Pleasant Valley is fractured by the Pleasant Valley Fault and provides ample opportunity for recharge along the faulted zone. Therefore, when mines in the Blackhawk Formation east of the Pleasant Valley Fault encounter the fault zone, a considerable amount of water is expected and the yield of water can continue for long perids of time.

By comparison, the ground water encountered from a fluvial sandstone channel along the large Connelville Fault in the Belina Mines decreased from 200 gallons per minute to 10 to 15 gallons per minute over a four-day period (Vaughn Hansen, 1980). This yield of ground water from the Blackhawk Formation is consistent with other observations of flow from the Blackhawk Formation presented in other parts of

Figure 9

PRIMARY SOURCES OF GROUND WATER INFLOW TO MINES



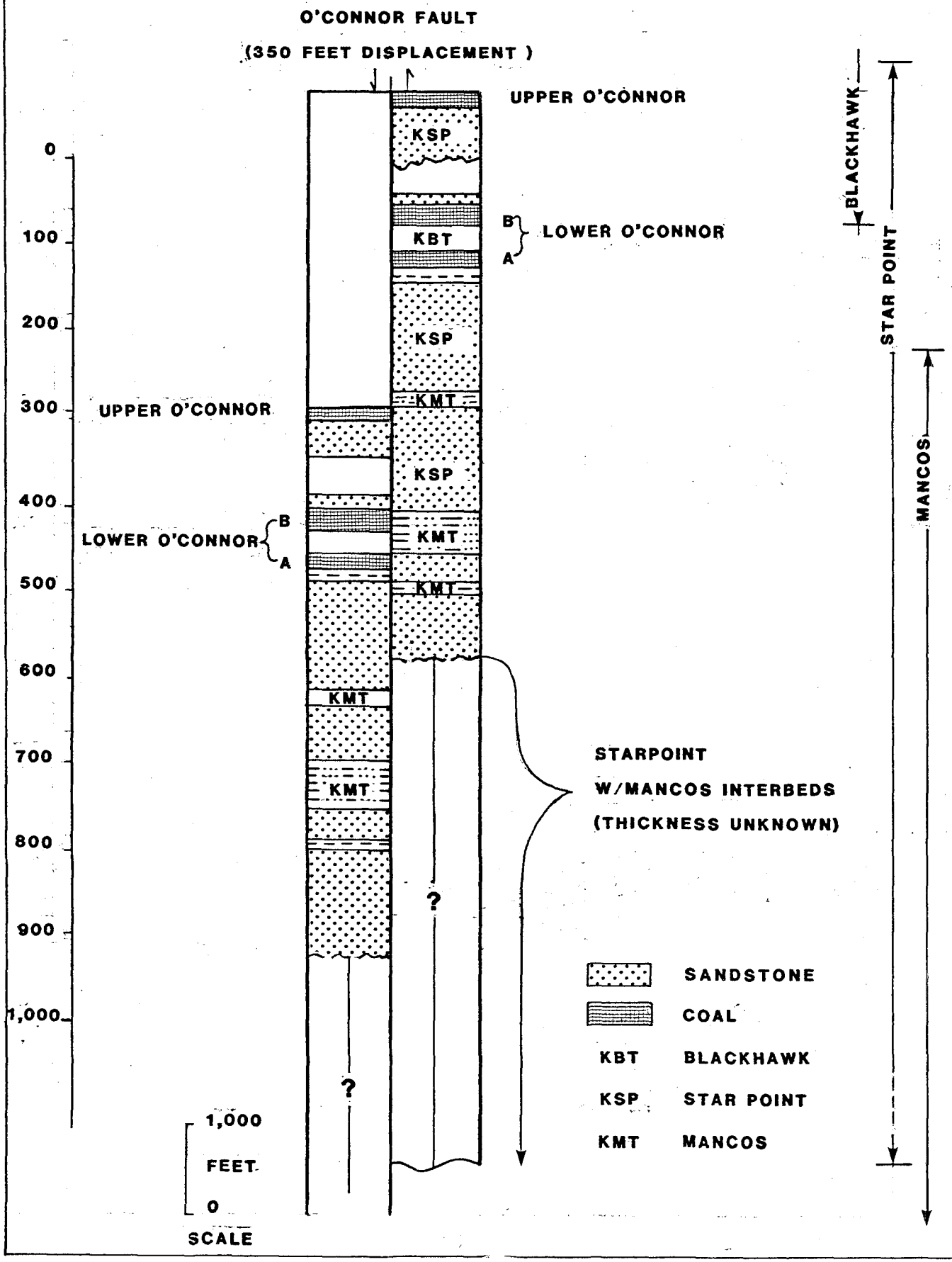
this chapter. Apparently the more permeable sandstone zones in the Blackhawk Formation are capable of yielding large quantities of water from storage over a short period of time. However, the sandstones are not laterally continuous enough to have sufficient recharge to maintain the high rate of discharge. It is therefore concluded that the Connelville Fault, which will be encountered in the Skyline and Belina Mines in the Blackhawk Formation, can produce the same high quantity of water that was produced along the Pleasant Valley Fault when a more permeable fluvial channel sandstone has also been encountered in the fault zone. However, a decrease in flow will occur over a short period of time after the initial surge of ground water derived from storage is depleted from the fluvial channel sandstone.

The upthrown bedrock east of the O'Connor Fault is displaced 350 feet. As a result, the Star Point Sandstone east of the fault is in contact with the Upper and Lower O'Connor Seams (and possibly fluvial channel sandstones somewhere along the fault) being mined from the Belina No. 1 and Belina No. 2 Mines (see Figure 10). Assuming that the Star Point Sandstone is saturated east of the O'Connor Fault, there is the potential for significant ground water inflow (i.e., at least 0.5 cfs) similar to the ground water encountered in the Clear Creek Mine, to the mine via the fractured Star Point Sandstone. This contribution of ground water to the mine will continue for a long period of time because the Star Point Sandstone is a more continuous aquifer with greater opportunity for recharge compared to the discontinuous water-yielding fluvial channel sandstones in the Blackhawk Formation. It is assumed that the mining operation will minimize the contact with the fault to minimize ground water inflow along the fault zone.

A similar condition occurs within the permit boundary of the Skyline Mine at the Valentine Fault. In this case, the downthrown block west of the Valentine Fault places Star Point Sandstone in contact with the Lower O'Connor B Seam (Mark Bunnell, Geologist, Coastal States Energy, personal communication, August 1983).

DISPLACEMENT AT THE O'CONNOR FAULT
SEC. 30, T13S,R7E
(AFTER BLANCHARD, 1981)

FIGURE 10



Therefore, both the Pleasant Valley Fault and the large faults west of the Pleasant Valley Fault are capable of producing large quantities of water in the mines. However, only those faults in contact with extensively recharged sandstones (i.e., the Pleasant Valley Fault, the O'Connor Fault, and the Valentine Fault) are capable of maintaining the large flows of water into the mines.

The lamprophyre dike encountered in the Belina Mines (see Figure 2) apparently serves as a ground water no flow boundary. As described in Appendix A, the occurrences of ground water north and south of the dike in the Belina Mines appear to be independent of each other. Assuming that the dike is a no flow boundary, it breaks the continuity of ground water flow along strata in the area and along the faults in the area. In addition, the occurrence of springs in Boardinghouse Canyon along the dike indicates that interruption of flow along the dike or recharge to the more permeable zone along the dike may also interrupt the flow to the springs.

Castlegate Sandstone

Several springs have been observed discharging from the Castlegate Sandstone at the contact with the Blackhawk Formation (see Figure 2). These springs have a very localized recharge area contributing to them and, therefore, have high yields after the spring snow melt period for short durations (Mark Bunnell, Geologist, Coastal States Energy Company, personal communication, August 1983).

Blackhawk Formation

Springs issuing from the Blackhawk Formation are dispersed over the valley sides above Mud Creek and Huntington Creek (see Figure 2). These springs are reported to discharge randomly where sandstone layers are exposed over shale layers (Vaughn Hansen, 1980). Discharge from the Blackhawk Formation was observed in early summer and in the fall in the vicinity of the Belina Mines. During an early summer survey, 74 seeps and springs were located; however, only eight springs with flows greater than 10 gallons per minute were located. Later in the fall, many springs could not be located and most springs were flowing less than 1 gallon per minute (Vaughn Hansen, 1980).

In late June of 1983, Blackhawk Formation springs above the Skyline Mine were observed by OSM contract staff to be discharging at a very high rate of flow. One discharge zone was observed flowing at approximately 300 gallons per minute in late June. However, in early August it was flowing approximately 4 gallons per minute. Similarly, another spring nearby had been flowing at over 100 gallons per minute in June and could not be located during the August visit. The quantity of flow during the June visit was extremely high and corresponded to the very wet winter that preceded these observations. The high discharge rate indicates that when water is available to the sandstone zones it can be transmitted at a high rate (i.e., high transmissivity). The extreme fluctuation in discharge is indicative of the limited extent of the water bearing zones and the limited amount of recharge that is available to the water bearing strata (i.e., low storage).

Vaughn Hansen (1980) conducted a series of aquifer tests, including drawdown and recovery tests, at two different depths in a Coastal States Energy test well located in Eccles Canyon approximately 4,000 feet north of the Valley Camp proposed permit area. The aquifer tests were run for 65 minutes each. It is acknowledged that a longer aquifer test would have provided a more reliable interpretation of the aquifer characteristics; however, the transmissivity values obtained from these tests are considered to be at least the correct order of magnitude. The aquifer tests were conducted in an open hole at depths of 200 feet (i.e., within the coal zone of the Blackhawk Formation, above the Storrs tongue of the Star Point Sandstone) and at 300 feet (i.e., below the Storrs tongue of the Star Point Sandstone). Transmissivities of 16.3 and 17.9 gallons per day per foot were calculated for the aquifer tests at the 200 and 300 foot depths, respectively. These tests show the low water yielding characteristics of both the composited Blackhawk Formation and the composited Star Point Sandstone-Blackhawk Formation. The fact that Coastal States Energy abandoned their first well completed in the Star Point Sandstone and the fact that both Coastal States Energy (Skyline Mines) and Valley Camp (Belina Mines) rely on wells completed in the Connelville and O'Connor Faults, respectively, further substantiated that the Blackhawk and the Star Point Formations are not capable of producing more water than what would be required for

stockwatering or single households. However, the two mine wells also demonstrate that fractured Star Point Sandstone along the O'Connor and Connelville Faults is capable of producing large sustained quantities of water.

Star Point Formation

Springs issuing from the Starpoint Formation are frequently associated with faulted zones that give the sandstone increased secondary permeability. Waddell, et al. (1983b) studied a spring issuing from the Starpoint Sandstone at a location associated with the Pleasant Valley Fault near the mouth of Eccles Creek (see spring 66 on Figure 2). Waddell, et al. (1983b) measured discharge from this spring 14 times during 1980 and found the flow to vary from 90 to 107 gallons per minute. In addition, they determined the recession curve of the spring flow over this period to be greater than 365 days. A long recession time for this spring indicates that the fractured Star Point Sandstone at this location has a relatively large storage capacity and a high transmissivity. Three other springs issuing from alluvium along the Pleasant Valley Fault (springs 62, 41, and 37) studied by Waddell, et al. (1983b) are considered to originate from the fractured Star Point Sandstone. These springs were observed to have discharges ranging from 1.6 to 296 gallons per minute but all springs were observed to have recession times greater than 365 days, again indicating that the fractured Star Point Sandstone has a relatively large storage capacity and a relatively high transmissivity. The range of discharge for these springs was 2.6 to 3.0, 15 to 26, and 189 to 296 gallons per minute for springs 62, 41, and 37, respectively.

As previously noted, Waddell, et al. (1983b) documented the loss of stream flow into the Clear Creek Mine via the Pleasant Valley Fault zone, which indicates that in the valley bottom the fractured Star Point Sandstone can readily accept recharge from surface water and shallow ground water in the area. Therefore, the Star Point Sandstone along the Pleasant Valley Fault is considered a ground water system that is buffered from changes which may occur to the overlying Blackhawk Formation as a result of mining. In other words, the fractured Star Point Sandstone along the Pleasent Valley Fault has a large amount

of recharge available to it, including losses from Mud Creek and shallow alluvial ground waters. Therefore, any losses of recharge to the Star Point Sandstone as a result of mining withdrawal of ground water in the Blackhawk Formation above Pleasant Valley will be compensated by induced recharge from shallow ground water in the Pleasant Valley alluvium or losses directly from Mud Creek.

Wells in the Star Point Formation in the vicinity of the Belina and Skyline Mines (i.e., wells 60.7, 60.9, 60.8, and 66.5) are located on Figure 5. The potentiometric surface interpreted by Waddell, et al. (1983b) using these wells shows a surface that generally follows the topography. The ground water gradient in the Star Point Sandstone east of the topographic divide shows ground water flow from west to east and the potential in the sandstone is the same as the elevation of the Eccles Creek Valley at the location of the Star Point-Blackhawk contact (i.e., a point of ground water discharge). As previously discussed, this location is where the O'Connor Fault transects the Eccles Creek Valley and the steady discharge of baseflow from the fractured Star Point Sandstone has been documented to be approximately 200 gallons per minute (Vaughn Hansen, 1980; Waddell, et al., 1983b). The baseflow of Eccles Creek is sustained primarily from discharge from the Star Point Sandstone and the largest and most consistent discharge of ground water to Eccles Creek occurs in the vicinity of the O'Connor Fault.

Summary of the Ground Water Flow System

The ground water system has been described in the previous narrative by presenting all information available regarding the components of the ground water system in the area. This part synthesizes all of the information presented previously in order to describe a ground water flow system for the Belina Mines CIA. The concepts provided here are interpretive but provide a reasonable basis for later sections of this report.

The description of the ground water system presented here is intended to support estimates of discharge from all mines in the surface water CIA and to identify the boundary of the ground water CIA. Both the surface and ground water CIAs are assessed for cumulative hydrologic impacts in Chapter 4.

The flow of ground water begins with recharge along the topographic divide between Huntington Creek and Mud Creek. This watershed boundary is also assumed to be the approximate divide for ground water flow toward Huntington and Mud Creeks. This assumption is justified because this is commonly the case in ground water systems and no data are available to suggest otherwise. In addition, the water levels obtained from wells compositing several hundred feet of strata also suggest there is a ground water divide in the vicinity of the topographic divide (Vaughn Hansen, 1980). Limited areas of Castlegate Sandstone are recharged locally and discharged at the contact with the Blackhawk Formation. Additional recharge occurs to the areally extensive Blackhawk Formation. The fluvial channel sandstones that outcrop over shale strata of low permeability result in numerous springs dispersed along the valley sides of Pleasant Valley. These springs have extremely seasonal discharge rates indicating the limited extent of the more permeable zones and limited opportunity for recharge. Ground water flow in the Blackhawk Formation occurs primarily from areas of recharge to localized intermittent springs. The upper Blackhawk Formation is interpreted to be characterized by perched ground water zones that discharge where numerous fluvial channel sandstones outcrop over shale beds.

Small quantities of ground water move downward through the Blackhawk Formation aided by the extensive faulted zones to recharge the Star Point Sandstone tongues. Lateral ground water movement and discharge from the faulted zones in the Blackhawk Formation to streams is negligible (Vaughn Hansen, 1980; Waddell, et al. 1983b). Ground water in the Star Point Sandstone tongues moves preferentially along fractured zones such as the Pleasant Valley and O'Connor Faults and is discharged where these fractured sandstones are exposed along the valley margins. The discharge of ground water from the fractured Star Point Sandstones occurs at a high rate with very little seasonal fluctuation. The Star Point Sandstone, therefore, provides the predominant source of base flow in the Mud Creek and Eccles Creek drainages.

A lamprophyre dike transects the Belina Mines from northeast to southwest in the vicinity of Boardinghouse Canyon. This geologic structure is interpreted to be a barrier to the continuity of ground water flow in a north/south direction (i.e., along faulted zones) in the area.

Ground water flow in Star Point Formation is assumed to move from topographically high areas to the lower valleys that provide the opportunity for discharge. In addition, ground water is interpreted to move along Pleasant Valley in the fractured sandstones of the Star Point Formation. The Pleasant Valley Fault zone receives extensive discharge from up-gradient Star Point and Blackhawk Formations and the faulted sandstone along Pleasant Valley also discharges to and takes in water from Mud Creek and Mud Creek alluvium, depending on site-specific circumstances. Therefore, the Pleasant Valley Fault zone is interpreted to be the major ground water flow system in the area. Ground water then moves down the valley towards Scofield Reservoir.

DETERMINATION OF THE GROUND WATER CUMULATIVE IMPACT AREA

The determination of the ground water CIA for the Belina Mines is made here on the basis of the preceding discussion of the ground water flow system and predicted mining effects discussed in Chapter 4. The western extent of the ground water CIA is designated as the topographic divide between the Huntington and Mud Creek drainages. This boundary is assigned not because impacts associated with the Belina Mines (and other nearby mines) will be limited to the Mud Creek drainage basin but because the CHIA for the Huntington Creek basin will consider mining effects within that drainage. The eastern boundary of the Belina Mines CIA is placed along the axis of the Pleasant Valley Fault zone because this major ground water flow system will buffer ground water effects from the Belina Mines from occurring east of the fault. The northern and southern boundaries of the Belina CIA have been placed on arbitrary topographic boundaries. The northern ground water CIA boundary was placed above Green Canyon just north of all mining associated with the Skyline and Belina Mines. This boundary is justified because it is not expected that ground water impacts will radiate very far from the

Belina Mines in the Blackhawk Formation because of the limited extent of the fluvial channel sandstone lenses and the lack of ground water flow along faulted Blackhawk Formation zones in the area. For similar reasons, the CIA boundary to the south was placed on a topographic boundary near the Belina Mines.

CHAPTER 3

IDENTIFICATION OF CRITICAL HYDROLOGIC CONCERNS

SURFACE WATER

Several reports have already addressed water quality impacts on Scofield Reservoir (Denton, et al., 1983; Clyde, et al., 1981; Waddell, et al., 1983a and 1983b; and Keith, et al., 1978). In addition, two areawide and one site-specific (Belina/O'Connor Mines) environmental impact statements have been prepared on the coal development in the area (USGS, 1979; BLM, 1982).

Sediment, total nitrate, phosphorus, and dissolved oxygen have been identified as water quality concerns for Scofield Reservoir (Denton, et al., 1983; Waddell, et al., 1983a). Nutrients seem to be strongly correlated with sediments carried by the streams (Denton, et al., 1983).

Mud Creek contributes about 16 percent of the total water inflow to Scofield Reservoir. In contrast, Mud Creek contributes about 18 percent of the total nitrogen inflow, 24 percent of the total phosphorus inflow, 18 percent of the total dissolved solids inflow, and 28 percent of the total suspended solids inflow (Waddell, et al., 1983a; Denton, et al., 1983). Essentially all of the influent suspended solids settle out in the reservoir. Sediment deposition in Scofield Reservoir between 1943 and 1979 was 3,000 acre-feet or 0.5 acre-feet per mile square per year (Waddell, et al., 1983a). The Soil Conservation Service rated the sediment load at 0.10 to 0.50 acre-feet per square mile per year (U.S. Department of Agriculture, 1973).

Eccles Canyon is a major contributor of nutrients to Mud Creek. Most of the nutrient load occurs in the form of suspended organic matter (Waddell, et al., 1983a). Most of the nitrogen and phosphorus load occurs during snowmelt runoff. Eccles Canyon contributes 18

percent of the water flow to Mud Creek (20 percent according to Waddell, et al., 1983a), 18 percent of the total phosphorus, 41 percent of the orthophosphate, 19 percent of the inorganic nitrogen, and 36 percent of the total suspended solids (Denton, et al., 1983).

Because of the strong indications that nutrients, total dissolved solids, and total suspended solids are having a negative impact on Scofield Reservoir, these water quality parameters were included in the CHIA analysis. In addition, the Office of Surface Mining is planning to perform a CHIA for the entire Price River drainage. Their model will project impacts on calcium, sodium, and magnesium. Therefore, these water quality parameters were also included in the CHIA analysis. Changes in trace metals were also investigated. A detailed discussion of trace metals is presented in the ground water part of this chapter.

GROUND WATER

In previous cumulative hydrologic impact assessments, issues that have been addressed include:

- Changes to ground water quality;
- Changes in ground water discharge; and
- Changes in potentiometric water levels in surrounding aquifers.

The importance of these issues varies depending on the significance of ground water resources and the extent of ground water use in the area. These issues are evaluated here to determine what critical hydrologic concerns need to be addressed with respect to the Belina Mines CHIA. The area being considered in this discussion with regard to mine discharges of intercepted ground water includes the entire Mud Creek basin. The area being considered for specific cumulative impacts of the Belina Mines to the ground water system surrounds the Skyline and Belina Mines as discussed in Chapter 2 and shown on Figure 2. Impacts of these mines on the Huntington Creek (Belina and Skyline Mines) and Miller Creek (Kinney No. 2 Mine) basins are being considered in separate CHIA's and, therefore, are not considered here.

The ground water systems described in Chapter 2 are considered very complex because of the discontinuous sandstones in the Blackhawk Formation and the extent of geologic structures in the area. In addition, very little information is available to quantitatively define the components of the ground water systems in the area. For example, all wells in the Blackhawk or Star Point Formations are open to the entire thickness of the Formation, thereby giving only a composite water level for numerous water-bearing sandstones. In addition, all aquifer tests of the Blackhawk and Star Point Sandstone Formations were run for approximately 60 minutes, which only allowed for an approximate interpretation of the hydraulics of the water-bearing zones involved. Therefore, the issues raised here with respect to ground water and mining are only addressed in as much detail as was available in the area. Mine discharges are reasonably predicted using previous ground water inflow data from other mines. Mining impacts to the local ground water system are based on an understanding of the ground water system and effects that mines have had in the area. Furthermore,the analysis of mining impacts to the local ground water system in Chapter 4 is necessarily semi-quantitative in nature.

Changes in Ground Water Quality

The water quality of springs and baseflow (i.e., ground water discharge) to streams in the Belina Mines CIA is very good. The Utah Division of Health has classified all water in the vicinity of the Belina and Skyline Mines as:

- 1C - Protected for domestic use with prior treatment by standard complete treatment processes;
- 2B - Protected for recreational uses, including swimming;
- 3A - Protected for cold water aquatic life; and
- 4 - Protected for agricultural uses.

Changes in ground water quality related to mining are an issue. In the Belina Mines CIA, the major constituents that have been previously described with respect to surface water resources (i.e., total dissolved

solids, sodium, calcium and magnesium) are considered in Chapters 4 and 5. These parameters are recognized as important to continued cumulative impact studies on the Price River Drainage.

Trace metals, including boron, chromium, copper, iron, lead, lithium, mercury, selenium, strontium, and zinc, were studied by Waddell, et al. (1982, 1983a). Waddell concluded that the concentrations of most trace metals associated with streams, springs, and mine discharges in the Mud Creek basin were lower than criteria established by the Utah Division of Health (see Table 2). Slightly elevated levels of copper were observed at the mouth of Eccles Canyon and at the same location an elevated zinc concentration was also observed. Neither of these constituents were observed at elevated levels from the Clear Creek Mine or the Belina Mine; however, additional trace element data were not available from mining operations in the CIA. It is concluded that the elevated levels of copper and zinc are not a result of mining in the CIA. The only high concentration of trace metals associated with mining was dissolved iron in waters issuing from the Clear Creek Mine (mine discharge point 71 on Figure 2), assumed to be ground water inflow from the Star Point Sandstone, and discharge from the Star Point Sandstone spring 66 (see Figure 2). The iron concentrations observed at the Clear Creek Mine and spring 66 were 720 and 800 micrograms per liter respectively. By comparison, the criterion for domestic water supplies is 300 micrograms per liter (U.S. EPA, 1976) and 1,000 micrograms per liter for freshwater aquatic life (U.S. EPA, 1976; Utah Division of Health). The criterion for domestic water of 300 micrograms per liter is based on the color and staining properties of water with iron at concentrations above the recommended concentration. The criteria for freshwater aquatic life, however, is based on an iron concentration above which aquatic organisms have been adversely affected. Therefore, of all trace elements studied by Waddell, et al., (1983a) some concern is raised with respect to potential elevated iron concentrations that may be associated with mine discharges.

TABLE 2

OBSERVED CONCENTRATIONS OF DISSOLVED TRACE ELEMENTS IN STREAMS AND MINE WATERS IN THE BELINA MINES CIA WITH ASSOCIATED UTAH DIVISION OF HEALTH WATER QUALITY STANDARDS[1/]

All concentrations in micrograms per liter

Location		Arsenic	Boron	Copper	Iron	Lead	Mercury	Selenium	Zinc
Mouth of Eccles Canyon	Maximum	<1	40	9	50	5	<0.1	<1	180
	Minimum	<1	<5	<1	10	<1	<0.1	<1	<3
	Number of measurements	9	9	5	9	8	6	9	9
Mud Creek just above Scofield Reservoir	Maximum	2	60	<10	30	28	<0.1	<1	10
	Minimum	<1	10	<1	10	<1	<0.1	<1	<3
	Number of measurements	9	9	6	8	9	4	9	9
Clear Creek Mine		1	110	<2	720	2	<1	0	10
Belina Mine inflow		1	20	0	40	0	0.0	0	6
Utah Division of Health water quality standards for dissolved constituents in micrograms per liter									
Domestic (1C)		50	--[2/]	--	--	50	2	10	--
Recreation/Aesthetics (2B)		--	--	--	--	--	--	--	--
Aquatic/Wildlife (3A)		--	--	5	1,000	50	0.05	50	50
Agriculture (4)		--	750	--	--	100	--	50	--

1/ Samples of stream waters were collected from October 1, 1979 - August 31, 1980.
2/ No State standard for this constituent.

Data concerning dissolved iron concentrations were not available for the Belina or Skyline Mine discharges. The subsequent discussion of iron in the Belina Mines CIA, therefore, relies on the limited dissolved iron analyses available for streams within the Mud Creek basin.

Iron concentrations in natural waters and mine waters in the vicinity of the Belina Mines CIA are not considered to be a problem for several reasons. First, spring 66 is a natural source of iron in the Belina Mines CIA and the iron concentrations associated with Clear Creek Mine may also be natural because the inflow to the Clear Creek Mine is thought to be from fractured Star Point Sandstone (i.e., the same source as spring 66). Next, the dissolved iron concentrations below the Belina Mines in Whiskey Creek were reviewed and were found to not exceed 390 micrograms per liter. Similarly, dissolved iron concentrations below the Skyline Mine in Eccles Creek were found to not exceed 130 of micrograms per liter, with the average of 10 observations being approximately 45 micrograms per liter. Values for dissolved iron below the Belina and Skyline Mines in Whiskey Creek and Eccles Creek, respectively, were slightly above the domestic water iron criterion during one observation, but for all other observations the values were well below the domestic and fresh water aquatic life criteria. In addition, Waddell, et al. (1983a) reviewed the available dissolved iron data (eight measurements) for the year from October 1, 1979 to August 31, 1980 for the gaging station at Mud Creek above Scofield Reservoir. All mine effluent from the abandoned Clear Creek Mine and the active Belina Mines would have entered Mud Creek above this point. The range of dissolved iron concentrations observed in Mud Creek, including the mine effluent previously described, ranged from 10 to 30 micrograms per liter. These observations indicate that iron concentrations in Mud Creek resulting from mining in the Belina Mines CIA are not posing any problems to domestic or freshwater aquatic life.

Changes in Ground Water Discharge

Changes in ground water discharge are an important issue with respect to the analysis of cumulative impacts within the Belina Mines CIA. Any change in ground water discharge associated with mining

provides another measure for determining the severity of water quality changes to Mud Creek. The surface water model that has been selected to assess the cumulative impacts of mining to Mud Creek maintains a mass balance of additions of mining-affected water to the stream. Therefore, estimates have been made of the amount of ground water discharge from mines both during and after mining. In addition, consumption of ground water associated with mining is addressed. Another issue involving ground water discharge is the water rights in the area associated with springs and wells. Figure 5 shows the locations of ground water rights and Appendix B provides a list of ground water rights in the Belina Mines CIA. This CHIA also evaluates changes in streamflow and changes which may occur to springs in the area that may result from subsidence.

Changes in Potentiometric Water Levels

There is insufficient data to calculate changes in potentiometric levels of wells in the area, however, the effects of mining on wells in the Belina CIA has been presented in general terms in Chapter 4.

CHAPTER 4
APPROACH TO THE DETERMINATION OF CUMULATIVE HYDROLOGIC IMPACTS

SURFACE WATER CUMULATIVE IMPACTS

Two separate approaches were used for the surface water portion of this CHIA in an attempt to evaluate impacts of existing and proposed mine development. For the parameters of streamflow, total dissolved solids, calcium, sodium, and magnesium, a modeling study of the Mud Creek drainage was made. Sodium adsorption ratios (SAR) were calculated from existing data. Total suspended solids, total nitrate, and total phosphate were also evaluated to predict changes in these water quality parameters based on analysis of the available water monitoring data. These parameters were selected because of concerns raised in previous reports. Parameters to be studied were selected with concurrence from the OSM. Methodologies used for the different parameters are discussed in the following sections.

Approach for Determining Effects to: Streamflow, Total Dissolved Solids, Calcium, Magnesium, and Sodium

A surface water model written by A.W. Burns (U.S. Geological Survey) was used to estimate the hydrologic impacts due to mining. Use of the model does not imply endorsement by the USGS for the applicability of the model or for the accuracy of the results. However, the model has already been used for a cumulative hydrologic impact assessment on the Colorado River in northwest Colorado (Parker and Norris, 1983) and for salt loading studies on other major stream systems in Colorado. Therefore, this model is considered applicable to the Belina Mines CHIA.

Most of the data for the model needs, including streamflow rates and total dissolved solids, calcium, sodium, and magnesium concentrations were obtained from the hydrologic monitoring reports for the existing and proposed coal mines in the CIA. Length of data records varied, but for the most part there were at least two years of data (see Table 3). Coastal States (1979) and Valley Camp (1980) provided

most of the data. Coastal States collected grab samples on a monthly basis from May, 1979 through March, 1983. Valley Camp collected bimonthly data from June, 1980 through December, 1982. Blazon and UCO collected data on a monthly basis for one year. Almost half of the monthly reports from all of the operators indicated that the monitoring stations were inaccessible. For these months (usually in the winter time), no data were collected and data had to be extrapolated from months with data. The procedure used to extrapolate the data is described in detail later in this section.

TABLE 3

NODES USED IN COMPUTER MODEL

Node Number	Node Description	Drainage Area above Node (acres)	Length of Record (years)	Source of Record
1	Mud Creek above Blazon No. 1	3,400	1	Blazon MRP
2	Blazon No. 1	0	0	
3	Long Canyon	1,300	3	Belina MRP
4	Finn Canyon	1,170	3	Belina MRP
5	Boardinghouse Canyon above O'Connor Portal	1,400	3	Belina MRP
6	O'Connor Portal*	0	0	
7	Eccles Canyon Upstream	780	5	Skyline MRP
8	Skyline Mines*	0	0	
9	Eccles Canyon South Fork	870	5	Skyline MRP
10	Whiskey Canyon above Belina Mines	500	3	Belina MRP
11	Belina Mines*	0	5	Belina MRP
12	Eccles Canyon near Mud Creek	3,460	5	WATSTORE
13	Utah No. 2*		0	
14	Winter Quarters Canyon above Scofield Mine	4,300	1	Scofield MRP
15	Scofield Mine	0	0	
16	Kinney No. 2 Mine*	0	0	
17	Mud Creek at USGS Gaging Station	21,750	5	WATSTORE

*Denotes mine discharge point; therefore, no drainage area.

Data from the hydrologic monitoring reports were supplemented with information from the USGS WATSTORE data base. Two USGS gaging stations were used: Eccles Canyon near Mud Creek and Mud Creek above the town

of Scofield. The length of data records for the USGS Eccles Canyon station is 36 months (October, 1979 through September, 1982). The length of data records for the Mud Creek station is 56 months (August, 1978 through March, 1983). WATSTORE provided streamflow data on a daily and mean monthly basis. Mean monthly streamflow valves were used in the model. Water quality data were provided on approximately a monthly basis until September, 1981. After September, 1981, there were very little water quality data available for the USGS gaging stations.

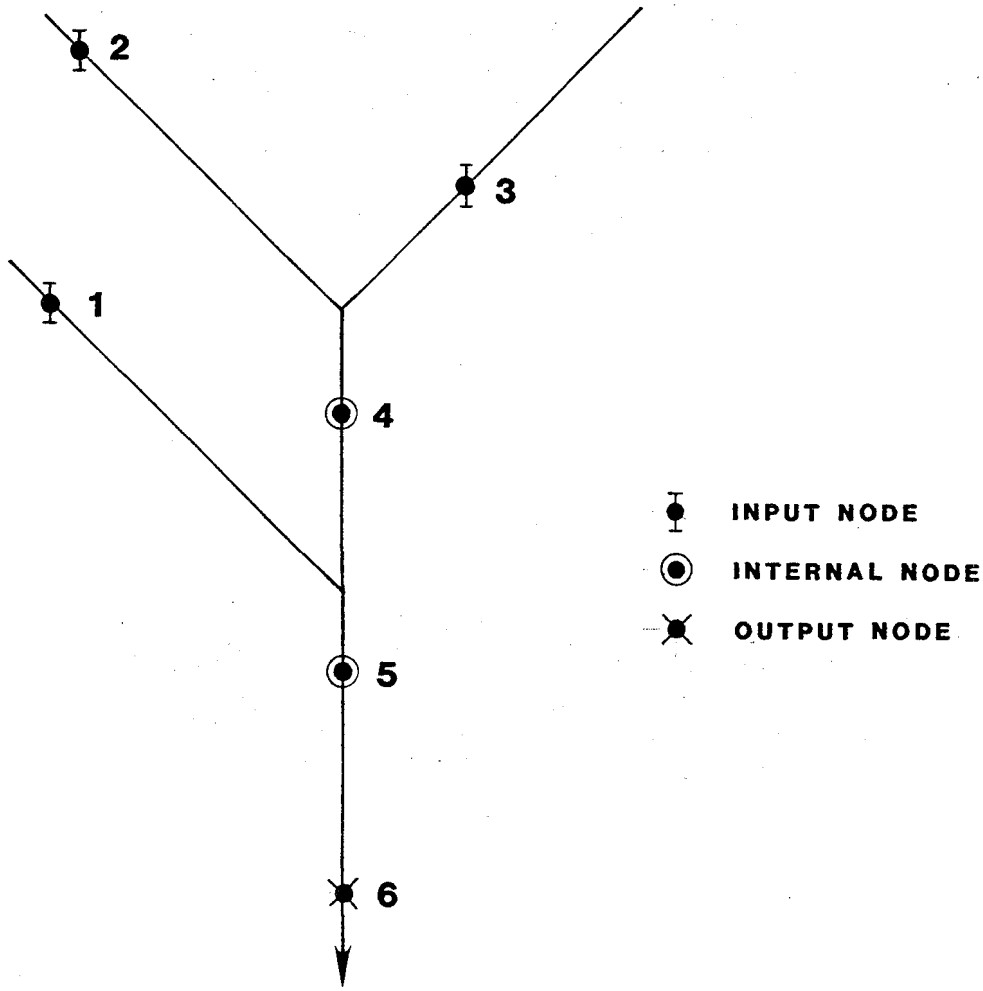
The model was originally designed to route streamflow and dissolved solids through the stream network. However, the model was modified for this report to include estimates of calcium, sodium, and magnesium.

The algorithm is an accounting procedure that sums water quantity and quality in monthly time steps from one or more upstream points to a downstream point. The addition of water quantity and quality is done at individual points called nodes. A reach is defined as the stream segment between nodes. Data can be entered, modified, or produced at each node. Although the data are manipulated at nodes, the changes in quantity and chemical composition of the water are attributed to the reach upstream from any particular node. As an example, a simple stream network with a series of nodes is shown in Figure 11. If the concentration in dissolved solids is increased at node 5, this increase is not necessarily due to a point source at node 5 but may be due to diffused sources of increased salinity in the reach bounded by nodes 1 to 5 and 4 to 5.

There are three kinds of nodes (Figure 11): input nodes, internal nodes, and output nodes. Input nodes are the upstream nodes (nodes 1, 2, and 3 in Figure 11) in the stream network. Water quantity and quality (concentration) are added using a conservation of mass equation shown later as equation 3. Because the summation process of water downstream starts at these nodes, the ideal case is to have streamflow gaging stations for the input nodes. This is not always possible and some estimated data must be used.

Figure 11

DIAGRAM OF A SIMPLE STREAM NETWORK
WITH NODES AND NODE NUMBERS FOR THE MODEL
(From Parker and Norris, 1983)



Water and dissolved solids from upstream nodes are accumulated by the model at internal nodes (nodes 4, 5, and 6 in Figure 11). Internal nodes also are used to enter proposed changes in water quantity and quality at individual coal mines. These changes can be point sources of water from dewatering activities or diffuse sources of water such as drainage from a portal area within the reach upstream from the node. Internal nodes can also serve as an output node.

An output node is any node at which there is an interest in observing the model estimates through time and examining differences in these estimates with various anticipated mining activities. The furthest downstream node (node 6 in Figure 11) usually would be an output node. If the cumulative effects of coal mining in the area upstream from node 4 in Figure 11 are of interest, node 4 also could be an output node. For this study, node 17, USGS gaging station on Mud Creek, was the output node and all calibrations were based on this station (see Figure 12).

At any node, the surface-water quantity component, which is mean monthly discharge in cubic feet per second, is calculated by the equation:

$$Q_i = \sum_{u=1} Qu) + Qr \qquad (1)$$

where: Q_i = discharge at node i;

Q_u = discharge at adjacent nodes immediately upstream from node i;

n = number of adjacent nodes immediately upstream from node i; and

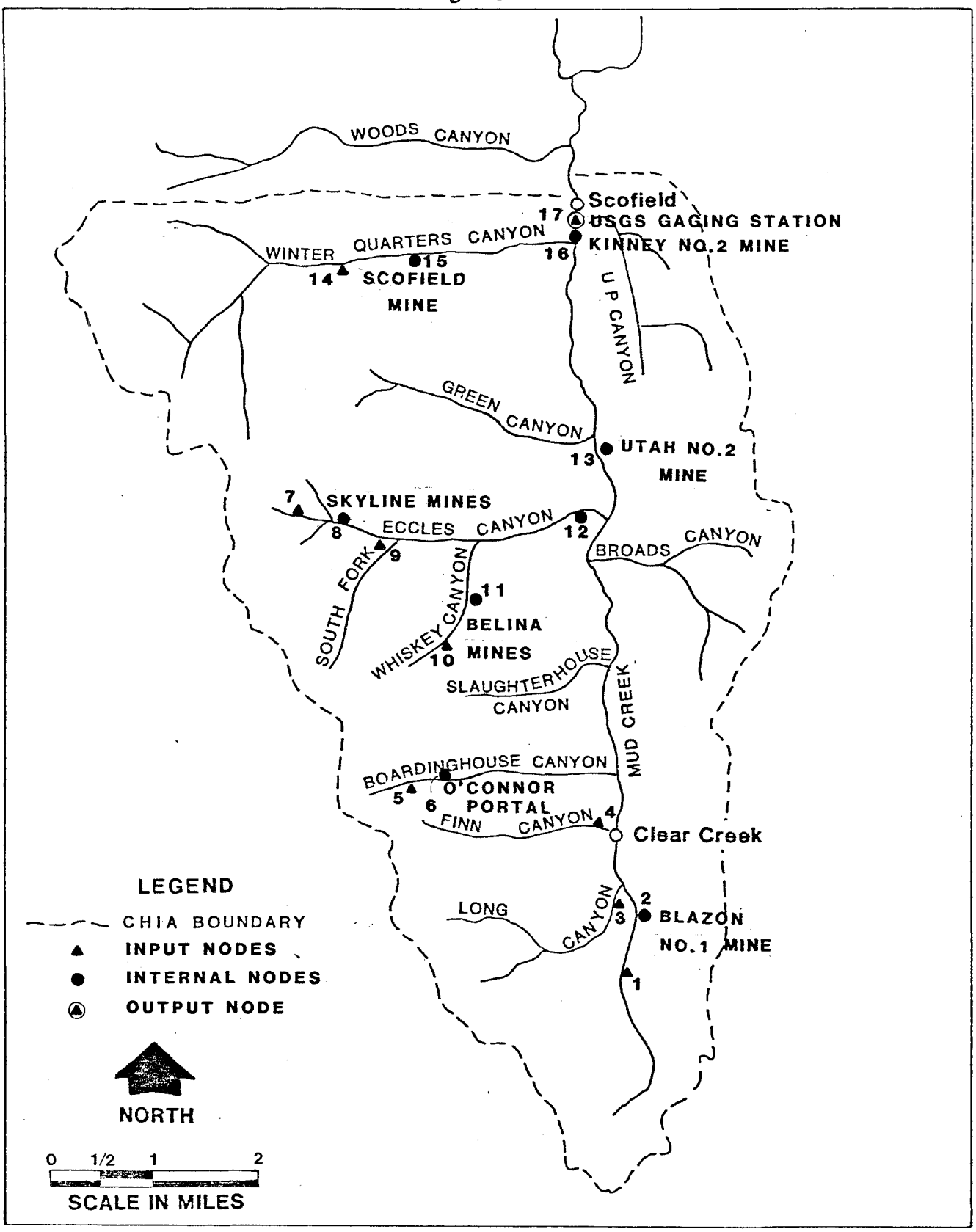
Q_r = incremental discharge (increase or decrease) within the reach between node i and adjacent nodes immediately upstream.

The estimate of incremental discharge within the reach can be obtained by reading observed data or by estimating the data by the equation:

$$Qr = a + bQ \qquad (2)$$

where: Q_r = incremental discharge (increase or decrease) within the reach;

Figure 12



NODES USED IN COMPUTER MODEL

a, b = the regression coefficients from simple linear regression,

Q = discharge at some nearby streamflow gaging stations.

Simple linear regressions were developed comparing mean monthly flow from the USGS gaging station on Mud Creek with the available data from the streams in Mud Creek downstream of Snyder Canyon, Long Canyon, Finn Canyon, Boardinghouse Canyon, Eccles Canyon (Middle Fork, South Fork, and near Mud Creek), Whiskey Canyon, and Winter Quarters Canyon. There were usually two or more years of data either on a monthly or a bimonthly basis. Exceptions to this were Eccles Canyon near Mud Creek and Winter Quarters Canyon. Eccles Canyon near Mud Creek has had a continuous USGS recording station since October 1979. Winter Quarters Canyon has less than one year of data.

Wherever possible, actual data were used. However, regressions were used to fill in the data gaps in order to match the length of data available for Mud Creek. Mud Creek had 56 months of continuous flow record. Mean monthly flow values for the period between August, 1978 and March, 1983 were used. All regressions were developed with the mean monthly flows from the USGS station on Mud Creek as the independent variable. Standard error of the regression (as percentage of the mean for the dependent variable) varied from 15 to 219 percent, with an average of 91 percent, and the coefficient of determination (r^2) ranged from 0.12 to 0.99 (see Table 4). There was a strong inverse correlation between the length of data record and the standard error and a positive correlation between length of data record and the coefficient of determination. Because of the low correlation between the USGS station on Mud Creek and Winter Quarters Canyon, the intercept and slope for this regression equation was modified. It turned out that an intercept and slope similar to the one developed for Eccles Canyon Creek near Mud Creek provided the best fit for observed versus predicted for the USGS gaging station at Mud Creek.

Calibration of the streamflow portion of the model included insertion of mine discharge from the Belina Nos. 1 and 2 Mines and flow from the abandoned Clear Creek Mines. Belina Nos. 1 and 2 Mines and the abandoned Clear Creek Mine were the only mines with a ground water discharge during the baseline period. Discharges from the other mines included under all anticipated mining were not included at this point. Calibration was determined by comparing predicted versus observed values at the output node.

TABLE 4

STANDARD ERROR OF REGRESSION AND COEFFICIENT OF DETERMINATION FOR OBSERVED STREAMFLOW VALUES

	Standard Error of Regression	s as % of mean	r^2	Length of Record (years)
Mud Creek vs. Eccles Canyon	0.99	29	0.99	5
Mud Creek vs. Long Canyon	0.57	68	0.93	3
Mud Creek vs. Finn Canyon	0.36	65	0.94	3
Mud Creek vs. Boardinghouse Canyon	0.27	15	0.97	3
Mud Creek vs. Whiskey Canyon	0.09	219	0.74	3
Mud Creek vs. Eccles Canyon South Fork	1.20	99	0.74	5
Mud Creek vs. Eccles Canyon Upstream	1.66	115	0.56	5
Mud Creek vs. Winters Quarters	0.09	118	0.12	1

At each node the surface water quality component, mean monthly dissolved solids concentration in milligrams per liter, is calculated by the mass balance equation:

$$C_i = \left[\left(\sum_{u=1}^{n} Q_u C_u \right) + Q_r Cr \right] \Big/ \left[\left(\sum_{u=1}^{n} Q_u \right) + Q_r \right] \qquad (3)$$

where: C_i = dissolved solids concentration at node i;

n = number of nodes immediately upstream from node i;

Q_u = discharge at nodes immediately upstream from node i;

C_u = dissolved solids concentration at nodes immediately upstream from node i; and

C_r = dissolved solids concentration associated with the incremental discharge (Q_r) within the reach.

The dissolved solids concentration within the reach (C_r) is obtained from the linear-regression equation:

$$C_r = aQ_r^{\ b} \tag{4}$$

where: a and b = the regression coefficients from simple linear regression.

Initial estimates of C_r are obtained from observed data at each node. For input nodes, the observed data reflect the actual value of C_r because it is the integrated dissolved solids concentration for the total reach above that node. However, for internal and output nodes, observed data reflect integrated dissolvedsolids concentrations for the total length of the stream above the node and do not reflect the reach between nodes. Thus, the observed data are not an estimate of C_r. Because data are not available to estimate C_r directly, final estimates of the regression coefficients in equation 4 were obtained in the calibration process.

One special case must be discussed. If the discharge at the upstream node or nodes is greater than the discharge at the next node downstream (that is, if Q_r <0), then the quantity of dissolved solids is reduced in proportion to the water quantity lost. Reducing the quantity of dissolved solids in this manner assumes that water lost in the reach is lost to ground water. Therefore, the water that is lost takes with it the associated dissolved solids. Unfortunately, some of the dissolved solids assumed lost to ground water may remain on the bed and banks of the stream channel to be removed with the next high flow. In addition, water lost to evapotranspiration leaves the associated dissolved solids in the streamflow. To accommodate these problems, a calibration factor was added to increase the dissolved solids concentration in this situation. This factor was adjusted during the model calibration. Thus, in a losing reach, C_i is reduced to the minimum value and adjusted upward by:

$$C_i = C_i Q_i E_i / \sum_{u=1}^{n} Q_u \quad (5)$$

where: E_i = calibration coefficient >1.0

Final calibration was achieved by adding TDS from the Belina Mines after the spring of 1980. TDS was increased at the same concentration as the TDS concentration of the mine discharge. Mean monthly calcium, sodium, and magnesium concentrations were developed in the same way as total dissolved solids concentrations.

Water quality data were generally available for at least two years, with the exception of Winter Quarters Canyon. The regressions for the water quality parameters had a lower level of confidence than for streamflow. Total dissolved solids had the highest average level of confidence, followed by calcium, magnesium, and sodium.

Regression slope and intercept values developed for the water quality parameters as well as average water quality values showed three distinct groupings. The group with the lowest slope, intercept, and water quality values was associated with the watersheds with low current land use. Land use is defined as any activity that removes the vegetative cover from the area. These watersheds include Snyder Canyon, Long Canyon, Finn Canyon, Boardinghouse Canyon, Whiskey Canyon, and Winter Quarters Canyon. For the next group, the values were usually a third or more greater in value than the first group. The watersheds in this group were associated with the upper part of Eccles Canyon. The last group is the downstream output stations: Eccles Canyon near Mud Creek and Mud Creek near the town of Scofield. The water quality parameters at these two stations had values greater than the other two groups.

An exception to this trend is for sodium. Sodium had the highest concentration in the first group (low land use) and the lowest concentration in the last group (high land use). It is assumed that some of the sodium is becoming attached to the sediment and dropping out in the stream channels.

Once the model was calibrated, the internal nodes were modified to simulate discharges from the mines. An analysis of the water monitoring data from the Blazon No. 1 and Utah No. 2 Mines (the mines without

current mine discharge) showed no trend of increasing or decreasing calcium, magnesium, or sodium from runoff from surface facility areas. Therefore, it is assumed that these parameters would remain constant for mines in the CIA except for the influence of ground water discharge from mines.

The model allows for simulating a discharge from a mine using water already in the drainage system (old water) or water derived from another drainage system or taken from storage (new water). For the Blazon No. 1, Kinney No. 2, and the O'Connor Mines, it is assumed that water discharge from the mines was water taken from spring/streamflow. Therefore, discharges from these mines were considered to be old water. For the Belina, Skyline, Scofield, and Utah No. 2 Mines, it was assumed that the water discharged from the mines was water that was taken from storage or that would normally provide recharge to the Huntington Creek or Gordon Creek Basins. Therefore, discharges from these mines were considered to be new water.

The result of distinguishing between old water and new water not only affects predicted streamflow values, but it also affects predicted water quality values. For old water, water is added in at the mine at a given flow rate and quality concentration. Water is then subtracted out at the downstream node at the same rate but at the background concentration. Therefore, the effect of the mine discharge at the output node will be zero for streamflow, but it may increase the concentration of water quality constituents. In contrast, both the streamflow rate and the water quality constituents may be affected by mine discharges of new water.

Approach for Total Suspended Solids, Phosphate, and Nitrate

An attempt was made to evaluate the changes in total suspended solids (TSS) and total phosphate by analyzing available water monitoring data without using the model. The model was not used because of the complexities of defining a defendable predictable relationship with these parameters. Generally, a multiple regression is needed to define the relationship. The model used above is a simple regression model, relying on streamflow relationships.

Data for these water quality parameters were obtained from the same sources as described in the previous section. The number of observations of TSS was usually equivalent to the number of observations of flow. However, the data available for total phosphate were much less, and the data available for total nitrate were usually limited to less than one sample per year. Therefore, nitrate was dropped from the study.

Water monitoring data for TSS and total phosphate were plotted for upstream and downstream water monitoring stations associated with existing mines. These included Mud Creek above and below Blazon No. 1; Whiskey Canyon above and below Belina Nos. 1 and 2; Eccles Canyon above Skyline, below Skyline, and near Mud Creek; and Mud Creek above and below Utah No. 2 Mine. This graphical representation is considered the best way to document the impacts of mining for this study.

Graphs showing the upstream and downstream concentrations for the four mine areas were developed and are shown in Appendices C and D. The annual suspended sediment and phosphate load was estimated by measuring the area under the curves, multiplying the area by the flow rate, and converting to tons per year. The annual suspended sediment and phosphate load from mining was determined by subtracting the values for stations above mining from stations below mining.

GROUND WATER CUMULATIVE IMPACTS

The CHIA for ground water resources in the CIA of the Belina Mine was conducted in two parts. The first part considered the ground water discharge from mines in the surface water CIA. The impact of this water on the flow and quality of Mud Creek was evaluated in the surface water parts of Chapter 5. The second part of the ground water CHIA takes an indepth look at the specific ground water impacts, including loss of flow and changes in quality, of the Belina Mines and the Skyline Mines that contribute cumulative impacts to the local ground water system within the Belina ground water CIA.

Mine Discharges to Mud Creek

Several approaches were considered to predict the amount of ground water that may be discharged from the various mines in the CIA. However, as described in Chapter 2, the ground water resources in the CIA are very complex and can not be characterized using standard mathematical modeling techniques. Therefore, this analysis relied on an understanding of the geohydrologic setting and previous experience regarding ground water interception and discharge at mines in the area. Several mines in the area were toured and the mine employees were interviewed in order to better understand the ground water flow system as it relates to mining (see Chapter 2 and Appendix A). In addition, the discharge records and permit applications for all mines in the Mud Creek basin were examined in order to better assess discharge quality and quantity.

A general trend was found in the descriptions of ground water interception in the mines. The primary sources of ground water inflow to the mines are derived from major fault zones such as those along the Pleasant Valley Fault or the Connelville Fault. Ground water discharge from the faulted zones can occur at a rate as great as several hundred gallons per minute. For example, the Clear Creek Mine discharged approximately 224 gallons per minute on an average basis and or the Utah No. 2 Mine discharged approximately 450 gallons per minute when it closed in 1978 (Hotchkiss, et al., 1980).

Considering the description of the geohydrologic system presented in Chapter 2, it is predicted that mines encountering the Pleasant Valley Fault including Kinney No. 2, Utah No. 2, and Blazon No. 1 Mines, will experience high rates of ground water inflow that can be sustained for long periods of time. This fault zone extends through the Star Point Sandstone which develops high secondary permeability when fractured. In addition, the fractured Star Point Sandstone receives recharge not only from the Blackhawk and Star Point Formations up-gradient from the Pleasant Valley Fault Zone, but also from surface water and alluvial ground water along the Pleasant Valley Fault Zone. Therefore, for the purposes of the assessment of mining impacts to Mud Creek, it is assumed that the Kinney No. 2, Utah No. 2, and Blazon No.

l Mines will yield 0.5 cfs during the entire period of mining. In addition, it is predicted that mine discharges will continue at approximately the same rate for these mines after the mining operations have ceased. This prediction is justified because the Clear Creek Mine has experienced a sustained postmining discharge and the hydrogeologic source of this ground water inflow to the mines, fractured Starpoint Sandstone associated with the Pleasant Valley Fault Zone, is capable of maintaining the high rate of mine discharge.

The water yielded from the Pleasant Valley Fault is considered to be water taken from Mud Creek or shallow alluvial ground water already part of the Mud Creek discharge. Therefore, this water is "old water" (see discussion of surface water in Chapter 4) to Mud Creek. The quality of water used for the assessment of mining impacts to Mud Creek is taken from the records of discharge from the Belina Mines and Utah Power and Light's Wilberg Mine in order to provide a range of water quality impacts. Therefore, the range of predicted mining effluent concentrations of total dissolved solids, calcium, and magnesium are 393 to 526, 59 to 155, and 18 to 41 milligrams per liter, respectively. Over the long term it is expected that ground water quality associated with mining will not degrade beyond the range presented above. This is justified because the quality of discharge from the abandoned Clear Creek mine falls in the ranges presented above. Please refer to the surface water section of Chapter 5 for the assessment of the impacts of mine water discharges on Mud Creek.

Mines above Pleasant Valley, including the Scofield, Skyline, and Belina Mines, may encounter relatively high rates of ground water inflow from the fluvial channel sandstone strata in the Blackhawk Formation; however, the limited amount of recharge available to these localized water bearing zones will cause the mine inflow to diminish soon after they are exposed. In addition, the greatest opportunity for exposing significant channel sandstone lenses in the Blackhawk Formation is along major faults such as the Connelville Fault, the O'Connor Fault, or the Valentine Fault in the Belina or Skyline Mines. The Star Point Sandstone can be encountered along the O'Connor or Valentine Faults and would produce relatively high rates of discharge for extend-

ed periods of time. Therefore, in the Skyline and Belina Mines along these faults it is predicted that a large flow of ground water discharge of 0.5 cfs (224 gpm) may occur. The amount of discharge would decrease significantly over a few days to a month if the source was from the Blackhawk Formation but would occur at a high rate for a long period from the Star Point Sandstone.

The Scofield Mine will not expose any major fault zones and, therefore, will likely experience its major ground water discharge from sand channels exposed in the roof or floor of the mine. A discharge rate of 0.1 cfs (45 gpm) is considered representative of the average discharge expected under mining conditions without major geologic structures. A maximum discharge rate of 0.25 cfs (110 gpm) is also predicted for the Scofield Mine. These estimates are based on ground water inflow experienced under similar circumstances in the area (see Appendix A).

It should be emphasized that major inflow of ground water from the Blackhawk Formation is expected to be an unusual circumstance in the mines above Pleasant Valley which will only occur along major fault zones. In addition, the actual discharge of water from the mines is dependent on an unknown amount of storage and the consumption of ground water during mining activities.

Impacts to the Local Ground Water System

Two mechanisms are evaluated here that can result in impacts to ground water systems in the CIA. First, the impacts of mine subsidence are evaluated as they relate to disruption of ground water flow systems in the CIA. The second mechanism evaluated concerns ground water dewatering that occurs in the mines and the resultant effect on surrounding surface and ground waters. Chapter 2 describes two shallow ground water systems in the vicinity of the Belina Mines. An upper discharge zone has been identified along the contact of the Castlegate Sandstone and the Blackhawk Formation. This ground water system should not be impacted by mining because the Castlegate Sandstone occurs only in the highest topographic locations where the overburden over the coal is greatest (i.e., approximately 1,000 feet of cover) and subsidence effects should, therefore, be minimal. To date, subsidence effects

have been observed to not extend into areas with over 400 feet of overburden (Valley Camp, 1980). In addition, if minor fracturing occurs as a result of mine subsidence just above the mine, it is assumed that the shales and shaley sandstones of the upper Blackhawk Formation will deform plastically and will remain as an impermeable perching bed for water in the Castlegate Sandstone.

The second shallow, localized ground water system described in Chapter 2 is the upper Blackhawk Formation. Recharge occurs seasonally to sandstone lenses that discharge locally where the sandstones outcrop. The Belina and Skyline Mines are predicted to locally dewater the Blackhawk Formation in areas with less than 400 feet of overburden as a result of mine subsidence that breaks the continuity of the channel sandstones. In areas where the overburden over the Upper O'Connor Coal Seam is less than 400 feet, Valley Camp (1983) has projected that subsidence may cause springs to dry up. Figure 5 shows the extent of areas with less than 400 feet of overburden associated with the Belina and Skyline Mines. Using the assumption that springs within this low overburden area will likely dry up as a result of subsidence, it is concluded that the water rights listed in Table 5 will be impacted by mine subsidence. In addition, where sandstone lenses are dewatered within the mines, the premining discharge of this sandstone lense at ground surface will also be diminished. The loss of flow from Blackhawk Formation springs affected in this manner may be locally important if a water right was associated with the discharge.

TABLE 5

WATER RIGHTS POTENTIALLY AFFECTED BY MINE SUBSIDENCE
OVER THE BELINA AND SKYLINE MINES

Water Right Claim No.	Owner	Source	Flow (cfs)	Use
91-1058	Valley Camp	Well	7.7 A.F	Industrial of Utah, Inc.
91-1643	Jack Thomas	Spring	.011	Stock
91-3499	Lavern Jensen	Finn Spring	.011	Stock
91-3500	Lavern Jensen	Spring	.011	Stock

Other than the fact that four water rights may be affected, decreases in existing discharge from the upper Blackhawk Formation in the Mud Creek basin is not considered very important because of the seasonal variation of the discharge. Discharge from the upper Blackhawk Formation occurs primarily during the spring snowmelt period, a time when surface water discharges are greatest throughout the Belina Mines surface water CIA. Thus, slight decreases in peak flow of streams in the CIA would not be noticeable.

Another impact of dewatering the Blackhawk Formation centers on the fact that some of this water would normally be conveyed downward along faulted zones or would be recharged to sandstones of the Star Point Formation. A circumstance where the loss of recharge water is locally significant is the discharge which occurs along the O'Connor Fault, via fractured Star Point Formation Sandstones, to Eccles Creek. This discharge point provides the major source of base flow of approximately 200 gallons per minute for Eccles Creek. At the present time Coastal States Energy Company removes approximately 30 gallons per

minute from their well (well 60.8 and water right 91-1560 on Figure 5) in this zone of fractured Star Point Sandstone. In addition, if the recharge area for this significant discharge point is reviewed in light of the dike, an assumed ground water barrier, which extends through the Belina Mines (see Figure 2) it is apparent that a high percentage of the recharge area adjacent (upgradient) to the fault will be dewatered by mining. Valley Camp of Utah's well, water right 91-1058, is also located in the O'Connor fault zone.

Ground water inflow to the Belina Mines has been predicted to occur at a relatively high rate of at least 224 gallons per minute, or 0.5 cfs, that could occur for as long as the saturated Star Point Sandstone could produce the water at this rate. The ground water production from the vicinity of the O'Connor Fault would, therefore, exceed the amount of discharge that has been sustained from the faulted zone in Eccles Creek (200 gpm or approximately 0.44 cfs). Therefore, the discharge from the O'Connor Fault is expected to decrease as mining intercepts more water that would otherwise move to the faulted zone. The loss of spring flow at this location will also diminish the base flow of Eccles Creek, because the O'Connor Fault is the major source of flow in Eccles Creek during periods of low flow. The possible practice of holding ground water inflow to the mine inside the mine in the vicinity of the O'Connor Fault Zone would alleviate some concern with respect to diminishing the baseflow of Eccles Creek.

The withdrawal of ground water from mines high in the Mud Creek basin, including the Belina, Skyline, and Scofield Mines will be removing water that would otherwise migrate slowly down through the Star Point Sandstone to discharge points along Pleasant Valley. The net result of this removal of ground water from storage high in the basin is that streamflow will increase in the headwaters from mine discharge and the constant source of baseflow from the Star Point Formation will decrease lower in the basin. Stream flow will fluctuate more as a result of this process, particularly during baseflow periods. An example of this process has been observed in Mud Creek where, during the baseflow period, the ratio of flow from major springs to the flow at the mouth of Mud Creek remains constant. However, lower in the

basin, downstream of the Belina and Skyline Mines, the ratio of spring flow to discharge at the mouth of Mud Creek varies considerably (Waddell, et al., 1983b). This variation in flow will continue as mine discharges are developed more extensively in the Mud Creek basin.

The quantity of discharge within the Mud Creek basin will also increase because ground water will be imported into the Mud Creek basin from the Huntington Creek basin (via the Skyline and Belina Mines) and the Miller Creek basin (via the Kinney Mine No. 2 and Utah No. 2 Mine in the Miller Creek Tract Lease). An estimate of the amount of water that will be imported into the Mud Creek basin is difficult to make because of the surges of ground water inflow that occur when more permeable zones such as faults or sandstones are encountered. It should be noted that impacts outside of the Belina Mines surface and ground water CIAs are not considered in this CHIA but rather are considered in CHIAs being conducted for the Huntington and Miller Creek drainage basins.

Changes of ground water discharge to springs that appear to be associated with the northwest-southeast trending dike extending through the Belina Mines are also likely. The interruption of ground water flow along the dike within the mine will result in the loss of ground water supplied to these springs. It should be noted that the dike extends from the Skyline and Belina Mines to Pleasant Valley and may direct flow to the springs in lower Boardinghouse Creek that supply water to the town of Clear Creek. A more indepth field investigation of the relationship of recharge from the Belina Mines to the discharge of the Boardinghouse Springs would allow a more definitive assessment of mine impacts to the springs in question.

Withdrawal of ground water from storage during mining will leave water bearing zones depleted after mining. Therefore, there will be a time where ground water recharge will be taken up to resaturate the formations at the expense of ground water discharge in the area. In the Blackhawk Formation, which has a very seasonal discharge pattern, it is expected that within a year the shallow lensey channel sandstones in the formation will resaturate. However, it is not possible to calculate how long it will take for ground water storage and discharge

from the Star Point Formation to be restored. Over time, saturated zones will be restored and ground water gradients will resume in the general pattern from recharge areas to discharge areas that occurred prior to mining. The practice of retaining ground water in sumps in the mine would help alleviate the dewatering of strata below the coal seams.

An assessment of the potential for postmining discharges of ground water from the mines is important to understanding what long-term water quality effects the mines may have on receiving streams. Numerous historic mines were described in Chapter 2. Of all the mines previously described, only the abandoned Clear Creek Mine is currently known to discharge water (Trevor Whiteside, Valley Camp of Utah, Inc., personal communication, August, 1983; Waddell, et al., 1983a; Randy Harden, Utah Division of Oil, Gas and Mining, personal communication, October, 1983). It is assumed that the long-term ground water inflows to these abandoned mine workings which do not discharge at the portal move through the ground water system to unknown discharge points. Ground water movement out of abandoned mines to dispersed ground water discharge points is not considered a potential water quality problem to receiving waters at the points of discharge because the water originating in abandoned mines would mix with other ground waters and would not be discharged as a point source of mining-affected waters.

The following evaluation regarding the potential for postmining mine entry discharges is separated to consider the mines along Pleasant Valley east of the Pleasant Valley Fault, Kinney, Utah No. 2, and Blazon Mines, separately from the mines that are located above Pleasant Valley west of the Pleasant Valley Fault, the Scofield, Belina, and Skyline Mines.

No information is available concerning the potentiometric surface of water bearing strata in the vicinity of the mines along Pleasant Valley. However, the description of the geohydrologic settting provided in Chapter 2 identified the source of water that discharges from the abandoned Clear Creek Mine to be from Mud Creek via the shallow alluvium and fractured Star Point Sandstone along Pleasant Valley. Mud Creek has been determined to be a gaining stream over most of its

length. Therefore, the water table along Pleasant Valley is assumed to be at least at the elevation of Mud Creek (i.e, with a gradient toward Mud Creek). With shallow alluvial ground waters present at the elevation of Mud Creek that have the potential to migrate into mines that encounter the Pleasant Valley Fault, as evidenced by the inflow to the Clear Creek Mine from Mud Creek, it is likely that mines associated with the Pleasant Valley Fault Zone will fill with water and discharge ground water. The ground water discharge associated with the mines along the Pleasant Valley Fault can flow for extended periods of time at rates of approximately 0.5 cfs (224 gpm) as evidenced by the discharge at the Clear Creek Mine.

In the vicinity of the Belina, Skyline and Scofield Mines above Pleasant Valley west of the Pleasant Valley Fault, ground water discharge associated with local ground water systems occurs where sandstones are present over shale beds. After mining, it is expected that ground water seepage into the abandoned mine workings will primarily move along the dip of the strata towards the west. Ground water will likely accumulate in the mines to a maximum elevation equal to the water levels observed in monitor wells in the composite Blackhawk Formation in the area. The premining potentiometric elevations for the composite Blackhawk Formation in the vicinity of the Skyline and Belina Mines show water levels lower than ground surface. Therefore, ground waters do not have the potential to discharge at the Scofield, Belina, or Skyline mines after mining ceases. Waddell, et al. (1983a) documented a decrease in hydraulic head with increasing depth in the vicinity of upper Eccles Creek. The decrease in head with depth in this area indicates that the Belina, Skyline, and Scofield Mines are in a ground water recharge area. Therefore, the potential is for water that accumulates in these mines to percolate down into deeper strata such as the Star Point Sandstone tongues.

With respect to potential water quality problems associated with postmining discharges of ground water from the Kinney, Utah No. 2, and Blazon Mines along the Pleasant Valley Fault, the effects of during mining discharges have been assessed in Chapter 5. Because the source of the ground water discharge is expected to be from shallow alluvial

ground water and from Mud Creek, as at the Clear Creek Mine, it is not expected that postmining discharge will differ from the quality of water presently issuing from the Clear Creek Mine. The impacts of postmining discharges from these mines on Mud Creek are, therefore, the same as the mining impact assessed in Chapter 5.

Ground water impacts associated with mine subsidence are not well understood. Subsidence effects to springs and wells in the ground water CIA have been previously discussed. Valley Camp has agreed to leave pillars beneath the perennial streams in areas with less than 400 feet of overburden where subsidence effects may reach ground surface. Additional work is being done to assure that the erosional stability of streams will be maintained. It is assumed that the requirements of the Rules of the Utah Board and Division of Oil, Gas, and Mining (UMC 817.126) will provide adequate protection for streams that will be undermined. In addition, several mines in the area were toured and the occurrence of surface subsidence was observed at several locations. There was no indication that recharge to ground water resulting from mining in the Mud Creek CIA would change significantly. The observed subsidence effects varied considerably from gentle swails to cracks and joints; however, the manifestation of surface subsidence was not observed to be extensive. The cracks also appeared to fill with unconsolidated erosional debris. Therefore, it is assumed that recharge rates to ground water resources will not change noticably as a result of mine subsidence.

Consumption of ground water occurs as a result of mining in two ways. First, the mining equipment requires approximately 3.2 gallons of water per ton of coal mined (Dan Guy, Beaver Creek Coal Company, personal communication, August 1983). Using this estimate of ground water consumption, an estimate of in mine water consumption in the Mud Creek basin can be developed (Table 6). Maximum water consumption from direct mining processes in the Mud Creek CIA is estimated at about 93 acre-feet per year (58 gpm). This is the worse case assumption with mines at their maximum production.

TABLE 6

CONSUMPTIVE USE OF WATER IN MINES IN THE BELINA MINE'S CIA
DUE TO EQUIPMENT USE AND VENTILATION EVAPORATION

Mine	Maximum Projected Production (tons/year)	Area of UG Workings (acres)	Consumptive Equipment Use (acres-ft/yr)	(gpm)	Loss Due to Ventilation Evaporation (acre-ft/yr)	(gpm)	Total (acre-ft/yr)
Belina[1/]	2.4×10^6	1,935	24	15	26	16	50
Skyline	5.4×10^6	4,840	53	33	65	41	118
Scofield	7×10^5	640	7	4	9	6	16
Kinney No. 2	8×10^5	1,600	8	5	22	14	30
Blazon No. 1	1.1×10^5	300	1	1	4	3	5
Total			93	58	126	80	219

1/ Includes mining at O'Connor Portal and Utah No. 2 facilities.

Evaporation is another source of water loss in the mines. Ventilation air entering the mine has a low relative humidity (usually between 20 and 70 percent). As air travels through the mine, water is evaporated from the coal seam until the air becomes nearly saturated. Ventilation air leaving the mine, therefore, has a higher water content than the incoming air. Consumptive use of water due to mine ventilation is directly proportional to the areal extent of the underground mine. Evaporation loss has been calculated to consume as much as 45 acre-feet of water annually from Utah Power and Light's Wilberg Mine in the Huntington Creek drainage basin (Utah Power and Light, 1982). Valley Camp of Utah, Inc. (1980, Volume VI, Appendix N) estimates that the Belina Mines will evaporate approximately 26 acre-feet of water per year. Assuming the same general relationship between aerial extent and evaporation loss, a maximum of 126 acre-feet of water will be lost annually from ground water evaporated due to ventilation from all mines in the CIA (Table 6).

Combining consumptive use due to equipment use and consumptive use due to ventilation evaporation, consumptive use experienced at all of the mines in the CIA will be a maximum of 219 acre-feet per year (135 gpm). This volume of water is derived from ground water storage and will ultimately result in reduced surface discharge in the basin.

CHAPTER 5
DISCUSSION OF HYDROLOGIC IMPACTS IN RELATION TO SURFACE AND GROUND WATER UTILIZATION

SURFACE WATER CUMULATIVE IMPACTS

Because of the lack of long-term monitoring data, the results of both the model and the monitoring data analysis only have a moderate level of confidence. The results should be used as an order of magnitude estimate. More long-term monitoring data with additional detailed analyses are needed to increase the level of confidence of the results.

Calibration of water quality values was extremely difficult because of the dynamic nature of the land use activities in the Mud Creek drainage. Land use activities include coal mining related portal construction activities and road building. From 1978 through the summer of 1981, the only active coal mine was the Belina No. 1 Mine. During the summer of 1981, both the Skyline and Blazon No. 1 Mines started construction operations. Construction for the Skyline Mines as well as the associated State highway and rail spur continued through 1983. All of these developments changed the water quality of the Mud Creek drainage and all of the developments occurred at different overlapping time periods. Because there was no real period to establish baseline conditions and because there were changing land use activities throughout the calibration period, calibration of the water quality parameters resulted in only moderate to low levels of confidence in the model results.

Because of the moderate level of confidence in the predictive model, the results of the model were not used verbatum. Instead, the calibrated levels were used as a baseline from which increases in concentrations and loads could be estimated. The model predicted both flow rates and concentrations associated with different scenarios of water production by mines. Assuming that the calibrated level represented current conditions, the increases in concentration and flow rate would represent the increases due to coal mining activities. It is these increases in concentration and load (flow rate times concentration) that will be discussed.

Four ground water inflow scenarios were analyzed: (1) constant flow rate of 0.1 cfs for the Skyline, O'Connor, and Scofield Mines and 0.5 cfs for all other mines, with a low concentration for water quality parameters; (2) constant flow rate of 0.1 cfs for the Skyline, O'Connor, and Scofield Mines and 0.5 cfs for all other mines, with a high concentration for water quality parameters; (3) constant flow rate of 0.5 cfs for all mines, with a low concentration for water quality parameters; and (4) constant flow rate of 0.5 cfs for all mines, with a high concentration for water quality parameters (see Table 7). It is assumed that all anticipated mining is ongoing during all four mining scenarios. The scenarios represent full development of all of the mines at the same time. Therefore, the scenarios represent the worse case condition.

Values for the low concentration for water quality parameters came from water monitoring data for the Utah Fuel Nos. 3 and 4 Mines (old Clear Creek Mines near the town of Clear Creek) and for the Belina Mines. Values for the high concentration for the water quality parameters came from the water monitoring data for Utah Power and Light's Wilberg Mine. The Wilberg Mine is located approximately 25 miles south of the town of Clear Creek. These values are shown in Table 7.

Streamflow

Observed versus predicted streamflow showed a high level of confidence with a coefficient of determination of 0.99 a standard error of the regression of five percent of the mean (Figure 13). Projected mine discharge resulted in predicted increases in streamflow for all four scenarios. For mines producing old water, there was a transfer of water from the stream to the mine discharge.

Predicted results for the mine discharge indicate an increase in baseflow for Mud Creek during mining. Predicted streamflows were higher than current streamflows because of the addition of new water associated with the mine discharges. The largest change is predicted for baseflow conditions (August through March). Current stream baseflow for Mud Creek at the USGS gaging station is usually between 2 cfs and 4 cfs (898 gpm and 1,795 gpm). Predicted stream baseflows are almost double the current stream baseflow, 5 to 7 cfs (2,240 to 3,140 gpm).

TABLE 7

SCENARIOS USED IN SURFACE WATER COMPUTER MODEL

Scenario	Skyline Node 8 (cfs)	O'Connor Node 6 (cfs)	Scofield Node 15 (cfs)	Blazon Node 2 (cfs)	Belina Node 11 (cfs)	Utah Node 13 (cfs)	Kinney Node 16 (cfs)
1*	0.1	0.1	0.1	0.5	0.5	0.5	0.5
2**	0.1	0.1	0.1	0.5	0.5	0.5	0.5
3*	0.5	0.5	0.5	0.5	0.5	0.5	0.5
4**	0.5	0.5	0.5	0.5	0.5	0.5	0.5

	TDS (mg/l)	Ca (mg/l)	Mg (mg/l)
*Low concentration for Water Quality	393	59	15
**High concentration for Water Quality	526	155	41

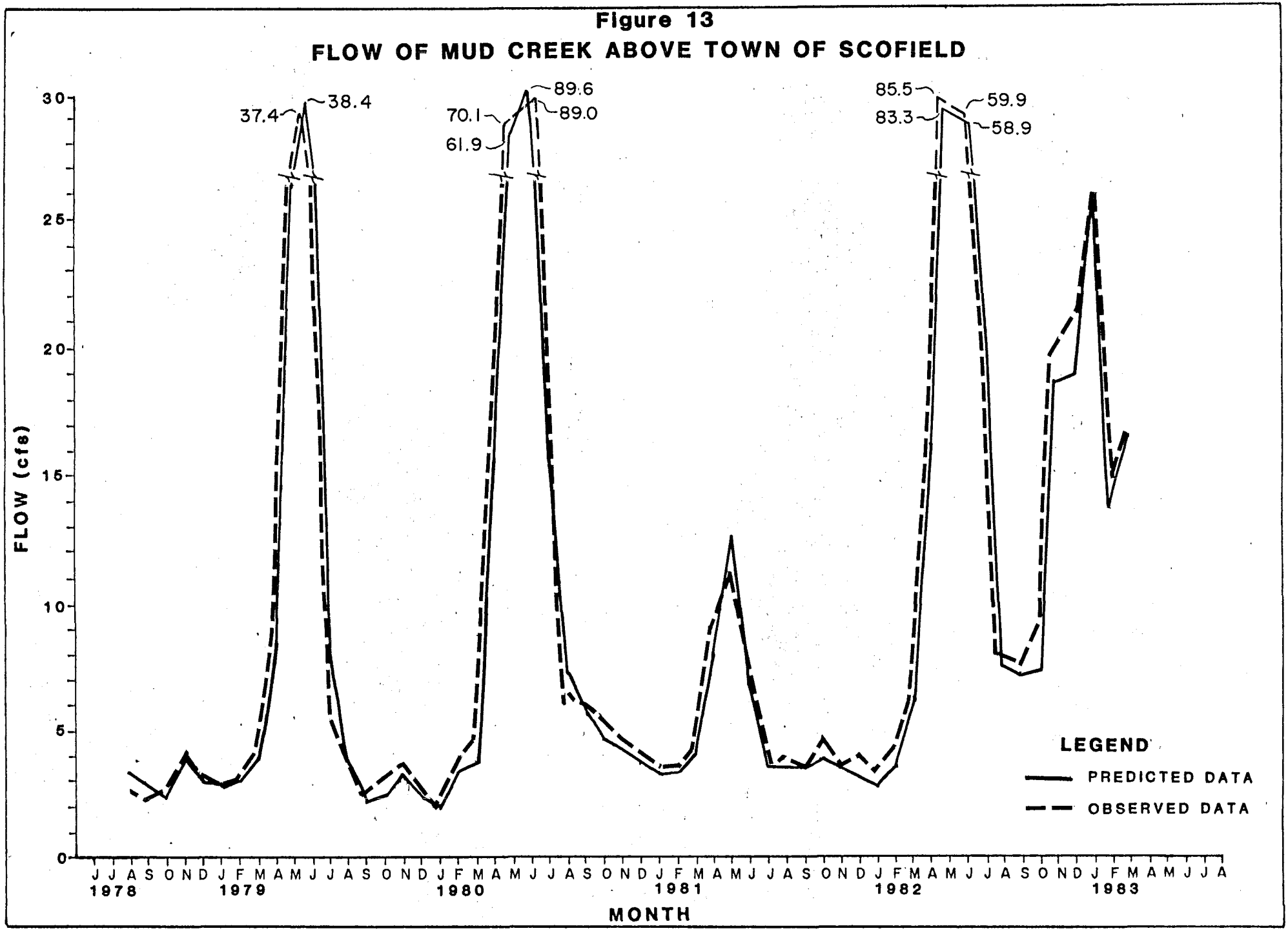


Figure 13
FLOW OF MUD CREEK ABOVE TOWN OF SCOFIELD
FLOW (cfs)
30
25
20
15
10
5
0
37.4
38.4
70.1
61.9
89.6
89.0
85.5
83.3
59.9
58.9
LEGEND
PREDICTED DATA
OBSERVED DATA
J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A
1978
1979
1980
1981
1982
1983
MONTH

Predicted stream baseflows may be a little high because mine discharges will include some ground water that may have naturally recharged the streams down gradient of the mine.

Because the dip of the coal is down away from the portals for all of the existing and proposed mines, no mine discharges are anticipated after the mines close. Therefore, streamflow should go back to a pre-mining condition over the long term.

Total Dissolved Solids

There was only a moderate correlation between observed and predicted TDS values (see Figure 14). Correlation of observed versus predicted TDS concentrations resulted in a coefficient of determination of 56 and a standard error of 142 percent of the mean. Baseline TDS concentrations for Mud Creek at the USGS gaging station ranged from 171 to 391 mg/l with a mean of 315 mg/l. The total annual dissolved solids load for the baseline period ranged from 1,690 to 4,320 tons per year with a mean of 3,000 tons per year (see Table 8). The predicted increased in TDS load ranged from 210 tons per year for scenario No. 1 to 720 tons per year for scenario No. 4 (see Table 9). The increase in TDS load caused by mining represents an increase of 7 to 25 percent of the current mean annual load.

TDS was the only parameter studied that had an established water quality criterion. EPA's primary drinking water criterion for TDS is 500 mg/l. However, Utah State Department of Health has set the primary drinking water criteria; if the TDS concentration is greater than 1,000 mg/l, then the supplier must show that no better water is available. Under the worse case assumption, the TDS concentration of the mine discharges will exceed 500 mg/l. However, with dilution from receiving streams, no predicted values were above 500 mg/l for the USGS gaging station on Mud Creek. Therefore, the predicted values for TDS concentration do not violate either the EPA or the Utah State Department of Health criteria. Because of the absence of mine discharges after the closure of the mine portals, increases in TDS concentrations should cease after reclamation of the portal areas.

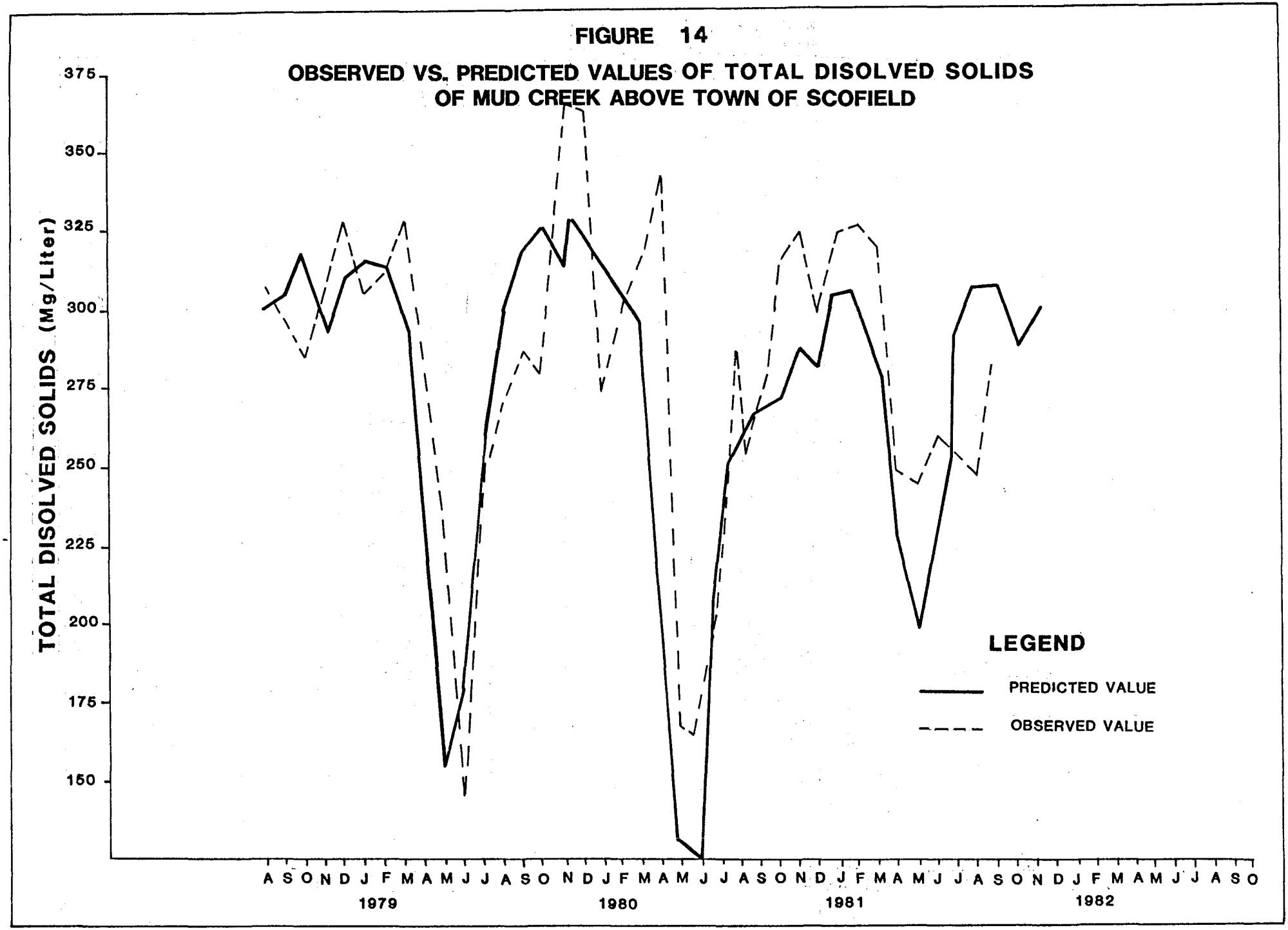


FIGURE 14
OBSERVED VS. PREDICTED VALUES OF TOTAL DISOLVED SOLIDS
OF MUD CREEK ABOVE TOWN OF SCOFIELD
TOTAL DISOLVED SOLIDS (Mg/Liter)
375
350
325
300
275
250
225
200
175
150
A S O N D J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O
1979
1980
1981
1982
LEGEND
PREDICTED VALUE
OBSERVED VALUE

TABLE 8

HISTORIC AVERAGE TOTAL ANNUAL LOAD AT THE MUD CREEK GAGING STATION FOR TDS, CALCIUM, AND MAGNESIUM

Parameter	Average Annual Load (mg/l)	Average Annual Load (tons/yr)
TDS	308	3,000
Calcium	72	471
Magnesium	23	153

TABLE 9

PREDICTED CHANGE IN TOTAL ANNUAL LOAD AT MUD CREEK GAGING STATION FOR TDS, CALCIUM AND MAGNESIUM

Scenairo	Mine Water Discharge (cfs)	TDS Mine Water Quality (mg/l)	Predicted Increase in TDS Load (tons/year)	Calcium Mine Water Quality (mg/l)	Predicted Increase in Ca Load (tons/year) Low	Predicted Increase in Ca Load (tons/year) High	Magnesium Mine Water Quality (mg/l)	Predicted Increase in Mg Load (tons/year)
1	0.1 or 0.5[1/]	393	210	59	62.6	131	15	15.5
2	0.1 or 0.5[1/]	526	340	155	138	217	41	41.1
3	0.5	393	490	59	83	131	15	22.5
4	0.5	526	720	155	225	273	41	60.0

[1/] Constant rate of 0.1 cfs for the Skyline, O'Connor, and Scofield mines and 0.5 cfs for all other mines.

Earlier reports (Waddell, et al., 1983a; Denton, et al., 1983) have identified that the inflow into Scofield Reservoir has a higher average TDS concentration than the outflow because of precipitation of calcium and bicarbonate within the reservoir as calcium carbonate. Therefore, the mining caused increase in TDS concentration may not result in increases in TDS concentrations in the Price River. Future studies should examine the effects of Scofield Reservoir on limiting TDS concentrations in the Price River.

Calcium

Observed versus calcium concentrations predicted with the model showed a moderate level of confidence (coefficient of determination of 0.32 and a standard error of 50 percent of the mean - see Figure 15). Current calcium loads range from 360 to 677 tons per year with a mean of 470 tons per year (see Table 8). The model predicted an increase in calcium load in Scofield Reservoir of between 63 and 273 tons per year (see Table 9).

Calcium increases are probably associated with rock (lime) dusting. Rock dust is used to reduce the amount of airborne coal fines and use of rock dust is a standard underground mining practice. Elevated concentrations of calcium from mine discharges will continue during mining but they should return to near baseline conditions after the closing and sealing of the portals.

Scofield Reservoir is already saturated with respect to calcium during parts of the year. Therefore, some of the calcium will precipitate out in the reservoir as calcium carbonate, thereby reducing the concentration of calcium in the discharge from the reservoir. Future studies should examine the effects of Scofield Reservoir on reducing calcium additions to the Price River.

Magnesium

The level of confidence for observed versus predicted values of magnesium concentrations was high, with a coefficient of determination of 0.75 and a standard error of six percent of the mean (see Figure 16). The predicted concentration of magnesium with all anticipated mining varied from 15 to 41 mg/l (See Table 9).

FIGURE 15

OBSERVED VS. PREDICTED VALUES FOR CALCIUM OF MUD CREEK ABOVE TOWN OF SCOFIELD

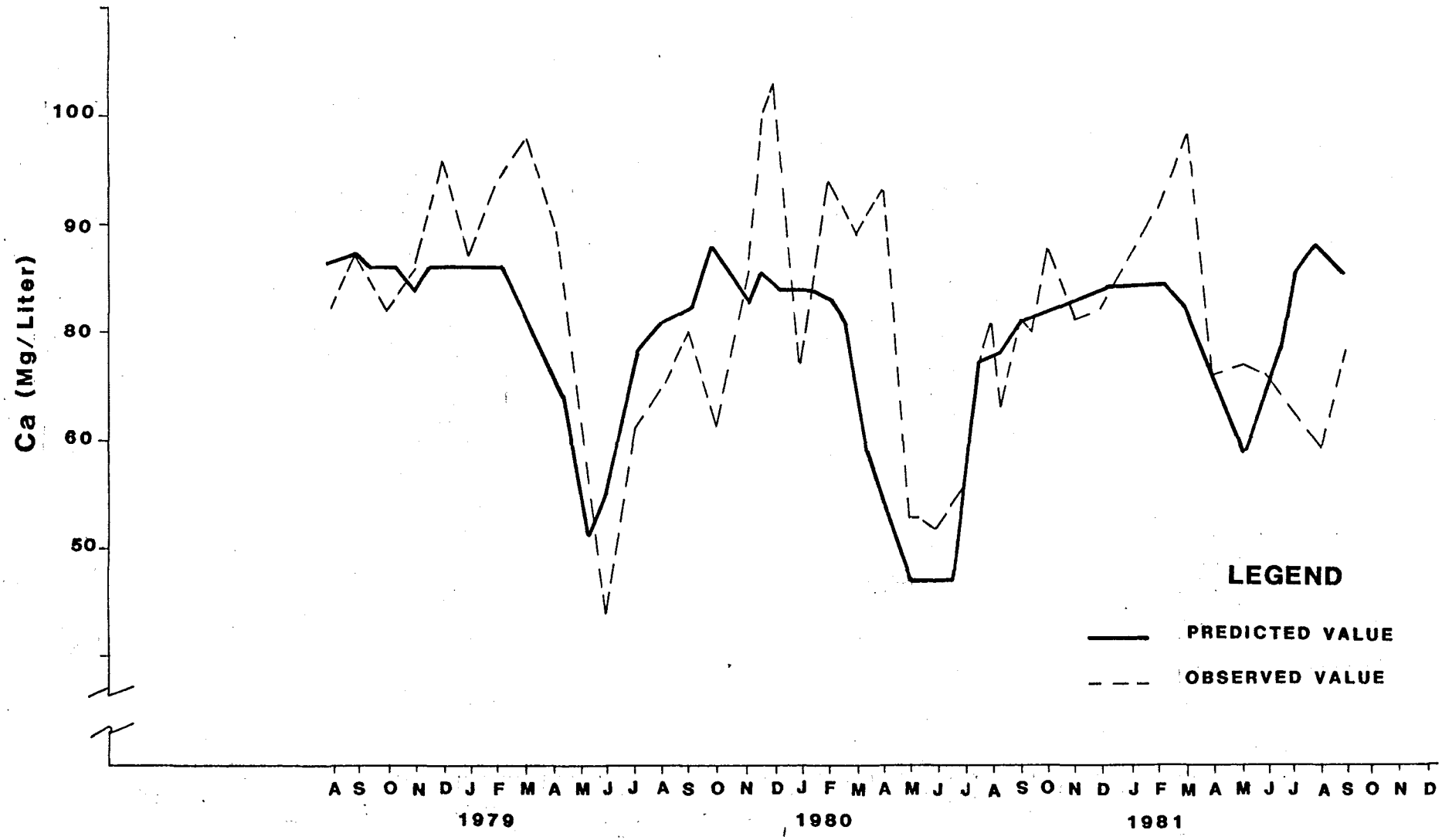
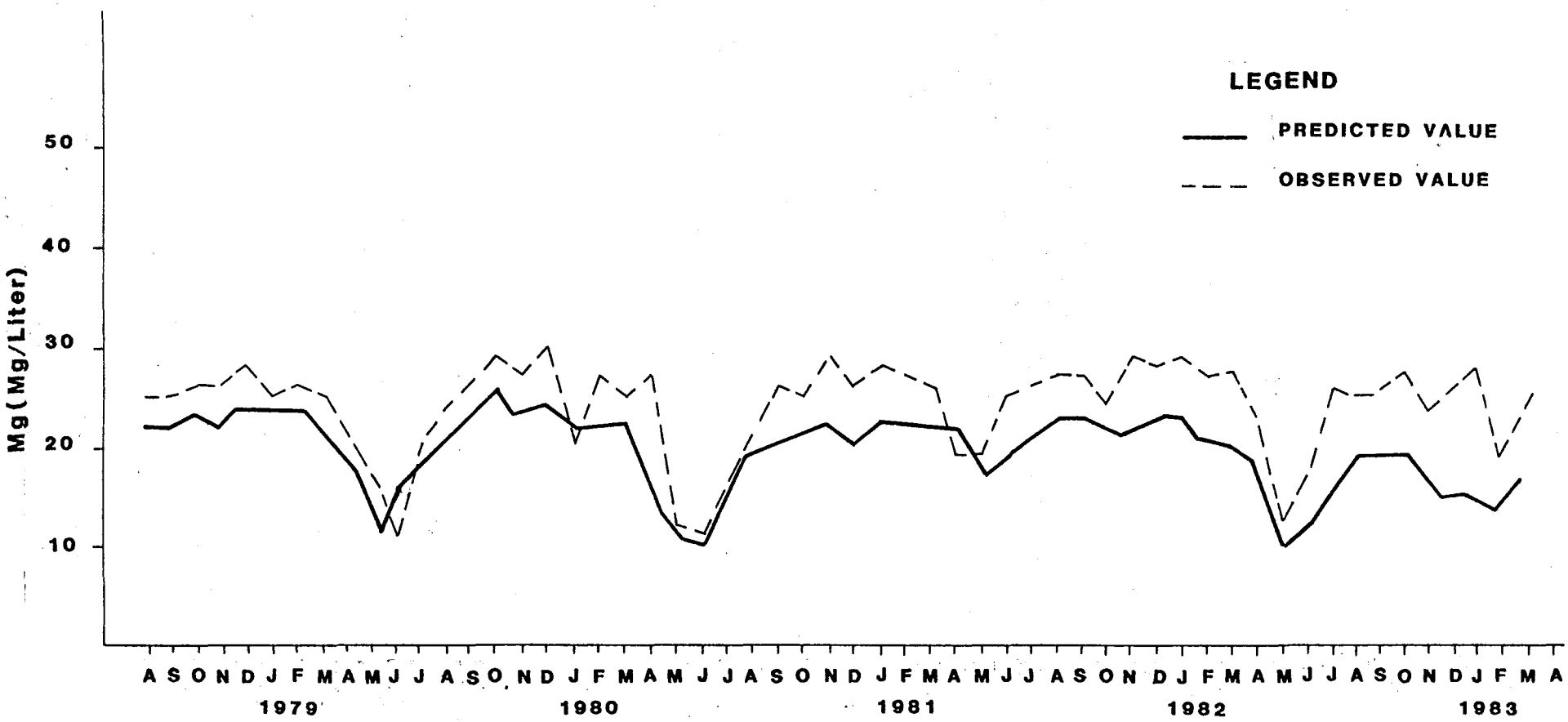


FIGURE 16

OBSERVED VS. PREDICTED VALUES FOR MAGNESIUM OF MUD CREEK ABOVE TOWN OF SCOFIELD



Based on the predicted increase in concentration and flow rate, the model predicted an increase in magnesium load ranging from 15.5 tons per year under scenario No. 1 to 60 tons per year under scenario No. 4 (See Table 9). Current magnesium loads range from 130 to 20 tons per year with a mean of 155 tons per year (see Table 8). Magnesium levels will continue to be elevated throughout mining, but they should return to near baseline levels after closure and sealing of the portals.

There are no water quality criteria established for magnesium by the EPA or the Utah State Department of Health. However, the 1946 U.S. Public Health Service's Drinking Water Standards recommended a limit of 125 mg/l. Even under the worse case conditions, the projected magnesium concentrations will be less than this level.

Sodium

Calibration of sodium in the model was not possible. Available data for sodium showed several spikes that were unrelated to streamflow (see Figure 17). These spikes were usually in the wintertime and they almost always were accompanied by a high calcium concentration. Therefore, the high sodium values may be associated with winter salting of the roads.

Sodium Adsorption Ratio

Observed SAR values (including those from mine discharges) and the associated standard error are presented in Table 10. All mean values were less than one, which indicates a low sodium hazard. SAR values were highest for watersheds with current low land use (Long Canyon, Finn Canyon, Boardinghouse Canyon, Whiskey Canyon, and Winter Quarters Canyon). SAR values at the USGS gaging station on Mud Creek had the lowest mean value.

Figure 17

OBSERVED VS. PREDICTED VALUES FOR SODIUM

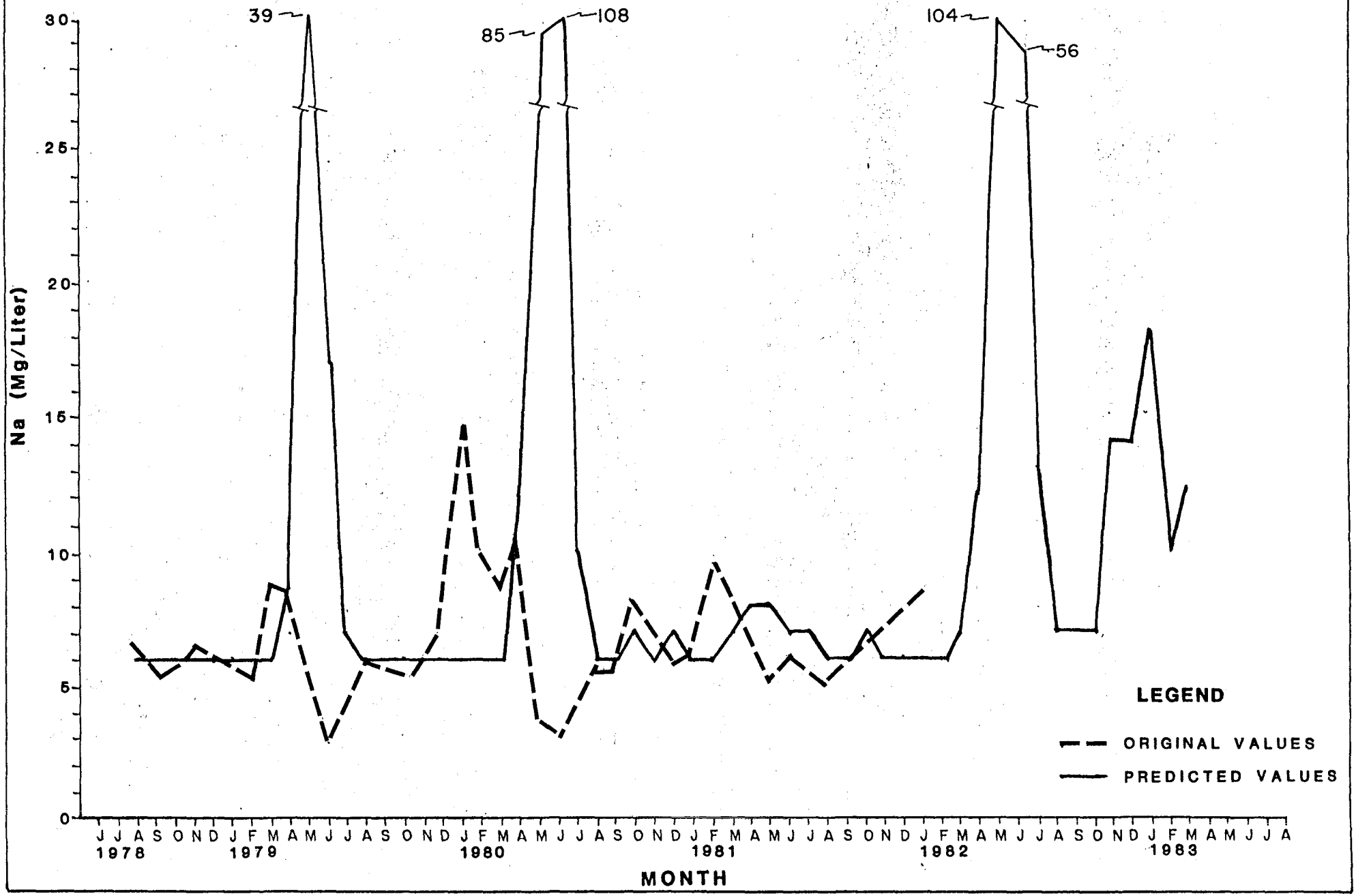


TABLE 10

SAR VALUES FOR CIA

Location	Mean SAR Value	Standard Error	Length of Record (years)
Long Canyon	0.30	0.40	3
Finn Canyon	0.25	0.26	3
Boardinghouse Canyon	0.33	0.45	3
South Fork Eccles Canyon	0.15	0.15	5
Whiskey Canyon above Belina	0.44	0.48	3
Eccles Canyon near Mud Creek	0.17	0.19	5
Mud Creek above Utah No. 2	0.24	0.21	5
Winter Quarters Canyon	0.29	0.18	1
Mud Creek at USGS Gaging Station	0.14	0.05	15
Mine Discharge	0.38	0.19	2

A pattern of high sodium and low calcium and magnesium concentrations for low land use areas was noted in the previous chapters. It is assumed that sodium is attaching itself to the sediment and dropping out in the channel. Calcium concentrations are increasing in mine discharges due to rock dust sprayed onto the mine walls. Therefore, sodium concentrations are decreasing and calcium concentrations are increasing for the higher land use areas, resulting in a lower SAR at the USGS gaging station on Mud Creek. No information was available to predict SAR for Scofield Reservoir.

Total Suspended Sediment

Background (above portal) total suspended sediment concentrations for Eccles Canyon and Whiskey Canyon often exceeded the 70 mg/l effluent limitation established by the Environmental Protection Agency (see Appendix C). However, there is insufficent information to determine whether the settleable solids criterion was exceeded for baseline conditions or as a result of mining activities.

The analysis of four areas indicates that there is generally an increase in annual sediment load below the portal areas as compared to above the portal areas. The increase in sediment load ranged from 8 tons per year for Whiskey Canyon in 1981 to 1,780 tons per year for Eccles Canyon in 1980 (see Table 11). The increase in sediment load

for Eccles Canyon resulted not only from mine portal activities but also from road construction and road use activities.

TABLE 11

OBSERVED CHANGES IN TOTAL SUSPENDED SEDIMENT LOAD

Site	1979 (tons/year)	1980 (tons/year)	1981 (tons/year)	1982 (tons/year)
Mud Creek d/s[1/] of Blazon No. 1	*[2/]	**	50	**
Whiskey Canyon d/s of Belina	140	1,110	8	**
Eccles Canyon Creek near Mud Creek	**	1,780	240	700
Mud Creek d/s of Utah No. 2	78	-100	30	-28,000

1/ d/s = downstream
2/ * = no data
** = insufficient data

It appears that the reach of Mud Creek adjacent to the Utah No. 2 mine is aggrading and has been for several years. This sediment deposition is consistent with field observations and the high sinousity and low gradient of Mud Creek in this area. Earlier studies (Waddell, et al., 1983a) also indicated that sediment was dropping out in the reach of Mud Creek below Eccles Canyon. Sediment deposition between Eccles Canyon and the inlet of Scofield Reservoir is expected due to the reduction in stream gradient caused by the elevation of the water surface in Scofield Reservoir. Because of the aggrading conditions, it is assumed that Utah No. 2, including future development of the Miller Canyon Lease Tract out of Utah No. 2, will not contribute an increase in sediment into Scofield Reservoir. More work is needed to determine the extent of aggrading. Table 12 summarizes the calculated suspended sediment load for Mud Creek at the USGS gaging station.

TABLE 12

TOTAL SUSPENDED SEDIMENT LOAD ON MUD CREEK

1979 (tons/year)	1980 (tons/year)	1981 (tons/year)	1982 (tons/year)
7,400	22,570	660	*[1/]

1/* = insufficient data.p

Table 11 shows a wide variation in change in total suspended sediment load above and below existing mining activities. In 1980, there was a large increase in suspended sediment load on Eccles Canyon Creek. Most of the suspended sediment came out of Whiskey Canyon and downstream of where the haul road parallels the creek. According to the mining and reclamation plan (Valley Camp, 1980), the observed increase in suspended sediment occurred as a result of construction activities on the Belina Mines which were started four years previously. In addition, neither the haul road from the Belina Mines nor a U.S. Forest Service road up Eccles Canyon was paved. It is assumed that sediment was contributed from both the mine complex and the unpaved haul road. The total disturbed area for Eccles Canyon was assumed to be about 90 acres (50 acres for the portal complex and 40 acres for the haul road and U.S. Forest Service road and related disturbance). For the 1,780 tons of additional suspended sediment, this averages to be about 20 tons per acre of disturbance per year. Because of the high streamflow in 1980, it is assumed that transportation of suspended sediment was higher than in a low-flow year. A streamflow hydrograph for the baseline period is shown on Figure 13.

In 1981, streamflow was lower and increases in suspended sediment were lower than in 1980. Most of the increases in suspended sediment were coming out of the Main Fork of Eccles Canyon. This is reasonable since construction had lessened at the Belina Mines and construction at the Skyline Complex (along with the associated road) had started. Table 11 also shows the results of the only data available for the Blazon No. 1 Mine. There is an increase in suspended sediment load of 50 tons per year associated with the construction phase of mining. For the 20 acres of disturbance, this averages out to be 2.5 tons per acre of disturbance per year.

There are two extreme conditions: 20 tons per acre of disturbance per year in a year of high streamflow and 2.5 tons per acre of disturbance per year in a year of low streamflow. This order of magnitude range makes it difficult to predict the increases in suspended sediment load from the proposed mining activities and the resulting impact on Scofield Reservoir. However, both of these values are above the Soil Conservation Service rated sediment load of 0.3 to 1.6 tons per acre per year expected from undisturbed soils representative of this area (U.S. Department of Agriculture, 1973).

All of the TSS monitoring data are from the development stage of the mines with unpaved roads. It is unknown for how many years the increase in sediment will continue before the area stabilizes. For the purpose of this study, it is assumed that the increase in sediment will continue for three years after portal development and three years after reclamation of the portal areas.

Table 13 presents the estimated increase in suspended sediment load resulting from the existing mines and the proposed Scofield, Kinney No. 2, and O'Connor Mines on Mud Creek. It is assumed that all of this sediment will eventually end up in Scofield Reservoir. Therefore, the total suspended sediment load on Scofield Reservoir for the life of the mines is expected to be somewhere between 4,120 tons (2.0 acre-feet) and 33,000 tons (16.1 acre-feet). This sediment load will reduce the storage capacity of Scofield Reservoir by a maximum of 0.02 percent.

Total Phosphate

Total phosphate was measured at the four existing disturbed sites (see Appendix D and Table 14). The difference between total phosphate load above and below each site is presented in Table 14. Based on the available data, it appears that the increase in total phosphate in Scofield Reservoir resulting from existing mining activities is less than one ton per year. Eighty percent of the total phosphate is associated with the suspended sediment (Denton, et al., 1983).

TABLE 13

PREDICTED MINING CONTRIBUTION OF TOTAL SUSPENDED SEDIMENT TO SCOFIELD RESERVOIR

Site	Acres of Disturbed Land	Contribution of Total Suspended Sediment[1/] Low	High
Blazon No. 1	20	300	2,400
Belina Nos. 1 & 2	90	1,350	10,800
Skyline	100	1,500	12,000
Scofield	27	400	3,240
Kinney No. 2	30	450	3,600
O'Connor	8	120	960
Total Suspended Sediment Load (tons)		4,120	33,000
Total Suspended Sediment Load (acre-feet)[2/]		2.0	16.1

1/ Based on six years of increase in suspended sediment load
2/ Using 94 pounds per cubic foot (Design of Small Dams, U.S. Department of the Interior, Bureau of Reclamation, 1977)

Therefore, the same relationship developed for the sediment load was assumed for phosphate. However, the variations in the data precludes developing a defensible prediction for total phosphate.

No total phosphate or total phosphorus water quality criteria have been established by the EPA or the Utah State Department of Health. The current load of total phosphorous into Scofield Reservoir is estimated to be 9.16 tons per year of which 2.41 tons per year is contributed by the Mud Creek draingage (Denton et al., 1983). Total phosphate (studied in this report because of the lack of total phosphorus information) was estimated to be about one ton per year, about one-quarter of which is contributed by the Mud Creek drainage (Denton, et al., 1983). Predicted increases in total phosphate for the cumulative impact area over the entire life of the mines is about one ton.

An earlier report used the Vollenweider Model to predict trophic levels in Scofield Reservoir (Denton, et al., 1983). Total phosphate, total phosphorus, and total nitrogen were measured. The modeling results indicated nitrogen was possibly the limiting nutrient in the

TABLE 14

OBSERVED CHANGES IN TOTAL PHOSPHATE LOAD

Site	1979 (tons/year)	1980 (tons/year)	1981 (tons/year)	1982 (tons/year)
Mud Creek d/s*** of Blazon No. 1	*	**	0.35	**
Whiskey Canyon d/s of Belina	**	1.08	**	**
Eccles Canyon near Mud Creek	0	0.84	-0.11	0.55
Mud Creek d/s of Utah No. 2	**	0	0	-5.9

1/ d/s = downstream
2/ * = no data, ** = insufficient data

reservoir. This means that as long as the nitrogen concentration in the lake remains low, eutrophication of the lake should not increase. Total nitrate and total phosphorus concentrations were strongly correlated with TSS concentrations.

Denton, et al. (1983) identified that the impacts of phosphorus on the reservoir are dependent on the storage mechanism associated with the phosphorus. Apatite-phosphorus is usually associated with the inflow of suspended sediments eroded from the watershed. Apatite-phosphorous will have little effect on the trophic state of the reservoir because this form of phosphorus is permanently removed from circulation when the suspended sediment settles out in the reservoir. Therefore, mining related additions of total phosphate and other sediment induced phosphorus additions are minor and should not change the trophic state of Scofield Reservoir.

GROUND WATER CUMULATIVE IMPACTS

Ground water rights for wells and springs for the Belina Mines CIA are delineated on Figure 5 and are presented in Appendix B. All wells within the ground water CIA have water rights associated with either Coastal States Energy Company's Skyline Mine (well 91-1114 and 2 wells with water right 91-1560), Valley Camp of Utah Inc.'s Belina and Utah No. 2 Mines (wells 91-1058 and 91-1691) or the Alpine School well 91-3460). All of these wells are designated for domestic, irrigation, and industrial uses.

Two of the Coastal States Energy wells, 91-1114 and 91-1560, are known to be completed into the Star Point Formation in the O'Connor Fault (Keith Welsh, Coastal States Energy Company, personal communication, August 1983). Well 91-1114 did not produce adequate water supplies and was abandoned. A new well, 91-1560, was located in the Connelville Fault Zone in order to provide the approximately 30 gallons per minute required for the mine. As described in Chapter 4, recharge to the faulted zone being utilized by Coastal States Energy will be diminished by dewatering associated with the Skyline and Belina Mines. It is, therefore, expected that with the decreased recharge to the faulted zone, well 91-1560 may experience some decrease in yield. The

second Coastal States Energy well with water right 91-1560 is located near the mouth of Eccles Creek. At this location, near Pleasant Valley, it is expected that adequate recharge to the Starpoint Sandstone from Mud Creek alluvium would be available to offset any decrease in ground water upgradient from the well.

Valley Camp of Utah's well 91-1058, an exchange water right with the Price River Water User's Association, is located in the Star Point Formation along the O'Connor Fault. This well could experience the same type of decline in water supply as described above and in Chapter 4.

In addition, three water rights, 91-1691, 91-3596, and 91-3595, also belong to Valley Camp of Utah and are associated with the water produced from the Beline Mines and the abandoned O'Connor Mine (the latter's water rights) respectively. The quantity of water produced from the Beline Mine will fluctuate depending on the amount of water encountered in the mine as discussed in Chapter 4. Ground water associated with the abandoned O'Connor Mine will likely decrease in flow upgradient as the Belina Mines are actively dewatering however, the O'Connor mine water right is not in current use.

The Alpine School well (water right 91-3460) is located in the Star Point Sandstone adjacent to Pleasant Valley where mining effects will not occur.

Three springs, listed in Table 5, with water rights of .011 cubic feet per second each, will likely be impacted by subsidence fractures resulting from mining. These impacts were previously discussed in Chapter 4.

The closer a spring is to the mining operations associated with the Belina and Skyline Mines, the greater the probability that the sandstone lense responsible for the spring will be dewatered. Based on Given the discontinuous nature of the water yielding strata in the Blackhawk Formation (sandstone lenses) and the limited recharge area available to these strata, it is likely that springs adjacent to the Belina and Skyline Mines will not be affected by the dewatering activities.

As discussed in Chapter 4, the effect of dewatering within the Skyline, Belina, and Scofield Mines high in the Mud Creek basin will be to remove ground water from storage and increase streamflow where this water is discharged from the mines. The dewatering of the Blackhawk Formation ultimately removes discharge that might otherwise move into the Star Point Sandstone, as well as feeding springs or providing baseflow. Therefore, over the long term, discharge from the Star Point Sandstone will decrease. This loss in discharge will be most noticeable during periods of low flow when Star Point is the major contributor of baseflow to the streams. While the precise decrease in discharge from the Star Point Sandstone cannot be calculated, the most direct impact of this process will occur to the spring along the O'Connor Fault that is the major source of baseflow to Eccles Creek. This discharge point will be most affected by mine dewatering because the Belina and Skyline Mines occur over the majority of the areas that are available to provide recharge to the fault zones that are responsible for the spring. The ultimate impact of this loss of ground water will be masked by water being discharged to the tributaries of Mud Creek. However, after mining ceases and the previously dewatered strata are resaturating, the loss of ground water discharge from the mine will cause a decrease in streamflow in Mud Creek. Other areas downsteram in Pleasant Valley will not likely experience detectable decreases in ground water flow because of the greater opportunity for uninterrupted recharge directly to the Star Point aquifer in the lower valley and along the Pleasant Valley Fault Zone.

The spring in lower Boardinghouse Canyon that provides water to the town of Clear Creek may experience a direct loss of flow resulting from mining if the dike that is projected through the Belina Mines is in hydraulic contact with the springs. However, while this spring may receive ground water flow from the vicinity of the Belina Mines that could flow along the ground water barrier (i.e., the dike), it is highly unlikely that all of the flow associated with this spring would be lost. Fractured Star Point Sandstone almost certainly contributes a portion of the flow at this discharge point. Therefore, although mining may impact a portion of the discharge from the Boardinghouse Springs, it is unlikely that mining will consume the total flow of the

springs. In addition, the installation of a well at the current location of the springs into the highly transmissive fractured Star Point Sandstone would provide an alternative source of high quality water for the town of Clear Creek to use. Additional investigation is necessary to verify impacts to this important ground water discharge point.

In summary, a few minor stock water springs, two Star Point Sandstone wells, the Boardinghouse Springs, and the major source of base flow to Eccles Creek are most likely to experience decreases in available ground water as a result of mining in the Belina Mines CIA. Opportunities are available to mitigate these potential impacts which will be addressed in the mine permitting process.

CHAPTER 6
CONCLUSIONS

SURFACE WATER

This study was designed to assess the cumulative hydrologic impacts associated with the Belina Mines and all anticipated mining. Of key concern was the assessment of both water quantity and quality impacts on Scofield Reservoir. Scofield Reservoir is a municipal reservoir for the town of Price, Utah.

Data to analyze the existing conditions and the impacts caused by existing mining were obtained from the surface water monitoring reports and NPDES reports of the mines in the CIA, WATSORE data for Eccles Canyon and Mud Creek, and data from several reports that addressed water quantity and quality concerns for the Scofield Reservoir area. The period of record for water quality and quantity data ranged from about one year to a maximum of 4.5 years. The longest data record covered the period from August 1978 through March 1983.

Several study methods were used to define the magnitude of changes in water quantity and quality due to coal mining operations. Where sufficient data were available, a computer model (Parker and North, 1983) was used to simulate baseline conditions and to project future mine development loads. The computer model was used to project changes in streamflow, total dissolved solids, calcium, magnesium, and sodium. Model calibration tests for streamflow and magnesium showed a good correlation between observed versus predicted values ($r>0.75$), and predictive results are given with a moderate to high level of confidence for these parameters. Difficulties in establishing good calibration for total dissolved solids, calcium, and sodium resulted in moderate to poor levels of confidence in the results. More long-term data are needed to increase the level of confidence of the results.

There were insufficient data to use the model for total suspended solids and total phosphate. For these parameters, historic data were used to estimate the changes asociated with coal mining activities. Predictions based on these analyses are given only a moderate level of confidence because of the lack of long-term data to support the conclusions. More data are needed to increase the level of confidence of the results.

Results of the analyses indicate that there will be an increase in streamflow, total dissolved solids, calcium, magnesium, total suspended solids, and total phosphate. Increases in streamflow will be caused by mines draining underground aquifers and discharging the water into the streams. Increases in streamflow will increase baseflow about two-fold (to about 6 cfs during maximum development), but streamvflow will return to near normal baseflow after mining.

Increases in total dissolved solids, calcium, and magnesium at the USGS gaging station on Mud Creek will be below levels of any established water quality standard or criterion. TDS and calcium increases will be offset by precipitation of calcium carbonate in Scofield Reservoir. Increases in TDS, calcium, and magnesium should continue through mining, but the concentrations should return to near baseline conditions after mining. Therefore, no material damage asscoiated with these parameters is anticipated.

Predicted increases in total suspended sediment load range from 4,100 to 33,000 tons of sediment over the life of mining. This sediment load is equivalent to between 2 and 16 acre-feet of sediment, and would reduce the capacity of Scofield Reservoir by a maximum of less than 0.02 percent. Because of this small reduction in capacity of the reservoir, no material damage is anticipated because of suspended sediment.

Total phosphorus concentrations and loads are higher below the disturbed area than above the disturbed area. However, most of the phosphorus occurs as apatite-phosphorus, which is attached to the suspended sediment. Apatite-phosporus will have little effect on the trophic state of the reservoir because this form of phosphorus is permanently removed from circulation when the suspended sediment

settles out in the reservoir. Therefore, additions of total phosphorus are minor and should not change the trophic state of Scofield Reservoir. No material damage is anticipated.

Nitrogen and sodium were dropped from the study because of the lack of data. Sodium concentrations have increased, downstream of mining probably because of salting of the roads during the winter. However, there wereinsufficient data to isolate the effect due to mining from the effect due to county and State road salting. Nitrogen plays a key role in the eutrophication of Scofield Reservoir. Nitrogen should be required in all future monitoring programs for the cumulative impact area.

Scofield Reservoir serves to buffer the effects of mining downstream in the Price River. Future studies should evaluate the effects of Scofield Reservoir on the changes in total dissolved solids, calcium, total suspended solids, and total phosphorus.

In summary, no material damage is anticipated either the short or long term for streamflow, total dissolved solids, calcium, magnesium, total suspended solids, or total phosphate for all anticipated mining in the cumulative impact area. There is insufficient information to determine the level of changes for sodium and nitrogen. Therefore, a material damage assessment for these parameters is not impossible at this time.

GROUND WATER

Changes in ground water discharge were predicted within the ground water CIA. Decreases in flow are expected for several small springs with water rights of 0.011 cfs each which are used for stock watering and are in close proximity to the Skyline and Belina Mines. In addition, a decrease in ground water flow was projected from the O'Connor Fault Zone, which provides the major baseflow for Eccles Creek (approximately 0.44 cfs). This mining effect will be masked by the mine discharges during the mining term. The loss of flow to Eccles Creek will be most noticable after mining, while the dewatered strata resaturate. More work is necessary to quantify this effect to Eccles Creek.

An additional change in ground water discharge could occur to the Boardinghouse Springs because of their location along the trace of a dike that act as a ground water barrier and is located in the Belina Mines. However, alternative sources of ground water are available from deeper fractured Star Point Sandstone at the location of the current Boardinghouse Springs. Should a decline in spring flow occur, the installation of a well into the fractured Star Point Aquifer would provide adequate water supplies to the current user, the town of Clear Creek. Further documentation is needed regarding the relationship of ground water flow along the dike to the mining operations. Two wells within faulted zones that extend through the Belina Mines (Coastal State's and Valley Camp's wells) will also experience decreased yield because of reduced recharge to the fault zones resulting from mine dewatering. Other mining effects to ground water discharge from the Star Point Sandstone will not be detectable because this ground water system has extensive recharge areas, including exposed Star Point Sandstone along the lower Pleasant Valley and along the Pleasant Valley Fault Zone that will not be disturbed by mining.

Over the long-term (postmining) it is expected that only the Kinney, Utah No. 2, and Blazon Mines will continue to discharge ground water from mine entries. As strata at other mines are recharged, ground water flow should resume at approximate premining rates, although the point of discharge may be relocated. The relocated discharge points will occur primarily in the Blackhawk Formation because of mining associated subsidence and fracturing.

UPDATE

This cumulative hydrologic impact assessment (was written prior to the final negotiations with the regulatory authority concerning the content of Valley Camp of Utah's permit application (PAP) for the Belina Mines Complex. Numerous changes relating to hydrology that were stimulated by the findings in this CHIA took place in the PAP for the Belina Mines Complex. Therefore, while the original findings of the

CHIA can be found previously in this document, this update describes recent changes that have been made in the PAP to alleviate the hydrologic impacts that were originally identified.

The applicant made a commitment to allow ground water to accumulate in abandoned mine workings along the O'Connor Fault in order to maintain recharge to the fractured geologic materials that currently provide a significant discharge of baseflow to Eccles Creek. By allowing ground water to accumulate in the abandoned mine workings rather than pumping all ground water out of the mine, the baseflow to Eccles Creek will continue during mining. It is anticipated that this procedure will alleviate declines in baseflow to Eccles Creek after mining. In addition, greater ground water volume will be available to pump from Valley Camp's well which is located in the O'Connor Fault Zone.

Three springs within the Belina CIA (see Table 5) were projected to probably have diminished flow resulting from subsidence effects of mining. In the revised PAP, Valley Camp has committed to several alternatives to replace these stock watering sources should they be impacted.

Additional information in the revised PAP shows that the dike located in the Belina Mines extends from the mines to the vicinity of the Boardinghouse Springs, currently used by the town of Clear Creek. This continuity of this ground water barrier to the springs further suggests a potential hydraulic connection with the Belina Mines Complex via the no flow boundary. As mentioned in Chapter 5 of the CHIA, the springs should not totally dry up and an alternate source of water is readily available in the fractured Star Point Sandstone. In addition, during the approximately 15 years of mining operations of the O'Connor Mine located in upper Boardinghouse Canyon, there was no apparent decrease in flow in Boardinghouse Springs (Jack Otanni, personal communication, January, 1984). The O'Connor Mine is located closer to the springs than the proposed Belina operations and would, therefore, have a greater impact than the Belina operations. Since the O'Connor Mine has had no apparent impact, then the proposed Belina operations should not have any significant impact either.

The updated information provided above reflects the content of the PAP for the Belina Mines Complex as of April, 1984. Based on the additional measures that Valley Camp has incorporated into the PAP, it appears that material damage to the ground water resources in the area will not occur.

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APPENDIX A

OBSERVATIONS OF GROUND WATER INFLOW TO MINES WITHIN THE BELINA CIA

The following text describes the amount of water that has been encountered within various mines in the Belina CIA. The observations of ground water interception at the mines were obtained from mine discharge records and from interviews of mine personnel. The observations of ground water inflow to the mines will be utilized in this document to help verify the ground water flow systems and to estimate discharges that may be experienced from the various mines.

SCOFIELD MINE

The Scofield Mine is a developing mine that has not compiled any record of ground water inflow. This mine is located in an area where no major geologic structures will be encountered. The mine permit application projects that roof leakers may contribute five gallons per minute at unknown locations in the mine, that are expected to dry up within a few days or weeks. In addition where tension cracks are encountered in the mine it is projected that larger ground water inflows of up to 150 gallons per minute may be experienced. No estimate of discharge from the mine site was made.

SKYLINE MINE

The permit application for the Skyline Mine predicts that "less than 10 gallons per minute per active face (will be encountered in the mine) with drifts dry approximately 500 feet up-dip from the face. Once a section dries up, leaks reappear only very occasionally in the future. This condition has been observed locally in the O'Connor and Belina No. 1 Mines. Apparently only a zone of saturated rock immediately adjacent to the mine is dewatered by the drift. Should the mines encounter sandstone lenses at the face of a fault, this flow rate to the mine could change rapidly for a short period of time, as noted at the nearby Beline No. 1 Mine. Such a condition is expected at the Connelville Fault (as occurred in the Belina No. 1 Mine) and at the Valentine Fault (as noted in increased flows while drilling W-35-1).

Under these conditions, inflow rates could exceed 1,000 gallons per minute for a short period, decreasing rapidly to a more normal rate (10 to 25 gallons per minute). ...Only those mine inflows that temporarily exceed storage and mine use requirements should be discharged to the surface."

In August, 1983 investigators interviewed the geologist for Coastal States Energy, Mark Bunnel, concerning the occurrences of ground water inflow to the Skyline Mine. The Skyline Mine has been developed to a limited extent to date and has not encountered any major fault zones. Minor faults (i.e., displacements of 3-6 feet) have been encountered that have not yielded water. Most of the ground water encountered in the Skyline Mine has been from sandstone channels in the roof and floor, from bolt holes, and minor fracture zones. In all cases the ground water discharge from these source areas dries up within a few weeks to a month. Mr. Bunnel hypothesized that major fault zones have greater secondary permeability than surrounding strata and receive recharge from strata that are truncated by the faults. He noted that they use springs to locate faults.

BELINA MINE

The Belina Mine is an active mine that has been developed extensively into the Upper O'Connor Coal Seam (Belina #1 Mine) and to a lessor extent into the Lower O'Connor Coal Seam (Belina No. 2 Mine). Ground water has been constantly encountered at low discharge rates from the Belina #1 mine face and roof (Trevor Whiteside, Valley Camp of Utah, Inc., personal communication, August, 1983). The Belina #1 Mine apparently is advancing into a saturated zone that has very low permeability. The Belina Mine has encountered considerable seasonal fluctuations in ground water inflow. In addition as mine ovas subsided, Mr. Whiteside observed greater ground water inflow.

Two geologic structures were encountered in the Belina Mine that influence the hydrogeology of the area. An andesite dike extends through the Belina Mines trending northwest-southeast (see map 2). In the mine the rock dike was dry on the side of the mine where it was

first encountered and was wet on the south side of the fault. Apparently, the dike acts as a ground water barrier across the Belina Mine property with preferred water movement along the coked coal on the south side of the dike. It should be noted that a series of springs occur in Boardinghouse Canyon along the trace of the dike. These springs may be the discharge points associated with the ground water movement along the dike.

The Belina Mines also encountered the Connelville fault and experienced a maximum ground water inflow of approximately 200 gallons per minute (Vaughn Hausen, 1980). The discharge from the fault zone decreased to approximately 10-15 gallons per minute within four days of hitting the fault. Vaughn Hansen (1980) reports that the sudden inflow was from a sandstone lense.

The Belina No. 2 Mine (Lower O'Connor Seam) has been generally dry, probably because of dewatering in the Upper O'Connor Seam in the Belina No. 1 Mine above. It should be noted that no water has been experienced through the mine floor from the Aberdeen Sandstone.

UTAH NO. 2 MINE

The Utah No. 2 Mine was developed extensively into the upper O'Connor Coal Seam prior to the cessation of mining operations in 1978. During the mining operation ground water was encountered from the mine face and mine roof. As the mine advanced down-dip strata were dewatered approximately two cross cuts back. A well in the vicinity of the mine portal (i.e., 80 feet deep completed between the Upper and Lower O'Connor Seams) went dry as mining continued. In addition flow from a nearby spring diminished (Trevor Whiteside, Valley Camp of Utah Inc., personal communication, August, 1983). Subsequent to the cessation of mining water levels in the wells recovered and spring flow has been restored.

At one point as the mine advanced into the Pleasant Valley Fault water was yielded at a high rate. Ground water inflow occurred at an average rate of 450 gallons per minute when mining ceased in 1978 (Hotchkiss et al., 1980).

KINNEY NO. 2 MINE

The Kinney No. 2 Mine is a proposed operation in the Belina CIA that therefore has no record of ground water discharge.

CLEAR CREEK MINE

The Clear Creek Mine is an abandoned operation which occurred in Pleasant Valley and encountered the Pleasant Valley Fault. Currently the mine discharges water at an average rate of approximately 0.5 cfs (Waddell et al., 1983b). Waddell (1983b), documents that the Clear Creek Mine is gaining water from Mud Creek via the faulted zone.

This observation of ground water flow along the Pleasant Valley Fault demonstrates the direct recharge opportunity to the Pleasant Valley Fault Zone from Mud Creek.

BLAZON NO. 1 MINE

No records of ground water inflow or discharge are available for the Blazon No. 1 Mine.

APPENDIX B

GROUND WATER RIGHTS IN THE BELINA CUMULATIVE IMPACT AREA

Water Use Claim No.	Owner	Source	Flow (cfs)	Purpose of Use	Period of Use
91-119	U.S. Forest Service	Spring	0.03	Domestic, Irrigation	March 1 to November 30
91-136	U.S. Forest Service	Beaver Dam Ridge Spring	0.006	Stockwatering	May 1 to October 31
91-200	Utah Natural Gas Company (½ interest)	Underground Water, well	0.134	Domestic Irrigation	January 1 to December 31
91-201	Earl Thomas	Spring with storage	0.068	Stockwatering	April 15 to November 1
91-288	U.S. Forest Service	Gooseberry Campground Spring	0.098	Domestic	May 1 to October 31
91-408	Calvin K. Jacob	Spring	0.011	Stockwatering	May 1 to November 30
91-424	Nick Marakis (½ interest)	Spring with storage	0.011	Stockwatering	January 1 to December 31
91-425	Nick Marakis (½ interest)	Spring	0.022	Stockwatering	January 1 to December 31
91-432	Nick Marakis (½ interest)	Spring	0.011	Stockwatering	January 1 to December 31
91-433	Nick Marakis (½ interest)	Spring with storage	0.011	Stockwatering	January 1 to December 31
91-434	Nick Marakis (½ interest)	Spring with storage	0.011	Stockwatering	January 1 to December 31
91-435	Nick Marakis (½ interest)	Spring	0.011	Stockwatering	January 1 to December 31
91-455	Robert Radakovich	Spring	0.011	Stockwatering	May 1 to December 15
91-463	John Marakis Estate (½ interest)	Spring with storage	0.011	Stockwatering	January 1 to December 31
91-464	John Marakis Estate (½ interest)	Spring	0.022	Stockwatering	January 1 to December 31
91-472	John Marakis Estate (½ interest)	Spring	0.011	Stockwatering	January 1 to December 31

Water Use Claim No.	Owner	Source	Flow (cfs)	Purpose of Use	Period of Use
91-473	John Marakis Estate (½ interest)	Spring with storage	0.011	Stockwatering	January 1 to December 31
91-474	John Marakis Estate (½ interest)	Spring with storage	0.011	Stockwatering	January 1 to December 31
91-475	John Marakis Estate (½ interest)	Spring	0.011	Stockwatering	January 1 to December 31
91-481	Robert Radakovich	Spring	0.011	Stockwatering	May 1 to December 15
91-1035	U.S. Forest Service	Spring	0.015	Stockwatering	July 1 to September 30
91-1036	U.S. Forest Service	Spring	0.015	Stockwatering	July 1 to September 30
91-1039	U.S. Forest Service	Spring	0.015	Stockwatering	July 1 to September 30
91-1045	U.S. Forest Service	Spring	0.015	Stockwatering	July 1 to September 30
91-1046	U.S. Forest Service	Spring	0.015	Stockwatering	July 1 to September 30
91-1122	U.S. Forest Service	Spring	0.015	Stockwatering	July 1 to October 10
91-1123	U.S. Forest Service	Spring	0.015	Stockwatering	July 1 to October 5
91-1124	U.S. Forest Service	Spring	0.015	Stockwatering	July 1 to October 5
91-1125	U.S. Forest Service	Spring	0.015	Stockwatering	July 1 to October 5
91-1126	U.S. Forest Service	Spring	0.015	Stockwatering	July 1 to October 5
91-1127	U.S. Forest Service	Spring	0.015	Stockwatering	July 1 to October 5
91-1144	U.S. Forest Service	Gooseberry Campground Spring	0.015	Stockwatering	June 6 to October 10
91-1150	U.S. Forest Service	Spring	0.015	Stockwatering	July 1 to October 5
91-1151	U.S. Forest Service	Spring	0.015	Stockwatering	July 1 to October 5
91-1153	U.S. Forest Service	Summer Home Area Spring	0.015	Stockwatering	June 1 to November 1

Water Use Claim No.	Owner	Source	Flow (cfs)	Purpose of Use	Period of Use
91-1158	N.M. Jensen Investment Co.	Aagard Spring	0.638	Irr.,Stock., Domestic	June 1 to October 31
91-1643	Jack Thomas	Spring with storage	0.011	Stockwatering	January 1 to December 31
91-1644	Lee Thomas (1/3 interest)	Spring	-----	Stockwatering	May 1 to October 31
91-1679	Calvin K. Jacob	Spring	0.011	Stock. and Domestic	May 1 to November 30
91-1680	Calvin K. Jacob	Spring	0.011	Stockwatering	May 1 to November 30
91-1681	Calvin K. Jacob	Spring	0.011	Stockwatering	May 1 to November 30
91-1699	N.M. Jensen Investment Co.	Spring	0.022	Stockwatering	June 1 to October 31
91-1700	N.M. Jensen Investment Co.	Spring	0.022	Stockwatering	June 1 to October 31
91-1701	N.M. Jensen Investment Co.	Spring	0.022	Stockwatering	June 1 to October 31
91-1702	N.M. Jensen Investment Co.	Spring	0.022	Stockwatering	June 1 to October 31
91-1710	N.M. Jensen Investment Co.	Spring	0.022	Stockwatering	June 1 to October 31
91-1711	N.M. Jensen Investment Co.	Spring	0.022	Stockwatering	June 1 to October 31
91-1714	N.M. Jensen Investment Co.	Spring	0.022	Stockwatering	June 1 to October 31
91-1986	Angelo Georgedes	Spring with storage	0.05	Fish Culture	January 1 to December 31
91-2049	John Jouflas Estate (2/3 interest)	Spring	0.011	Stockwatering	May 1 to October 31
91-2144	Elrie and Bertha Simonsen (½ interest)	Simonsen Spring	0.022	Domestic	January 1 to December 31
91-2145	Robert Radakovich (½ interest)	Simonsen Spring	0.022	Domestic	January 1 to December 31
91-2288	Elrie & Bertha Simonsen	Spring	0.011	Stockwatering	June 1 to November 30
91-2494	Elrie & Bertha Simonsen	Mooney Mine Spring	----	Irrigation Stockwatering	March 1 to November 30

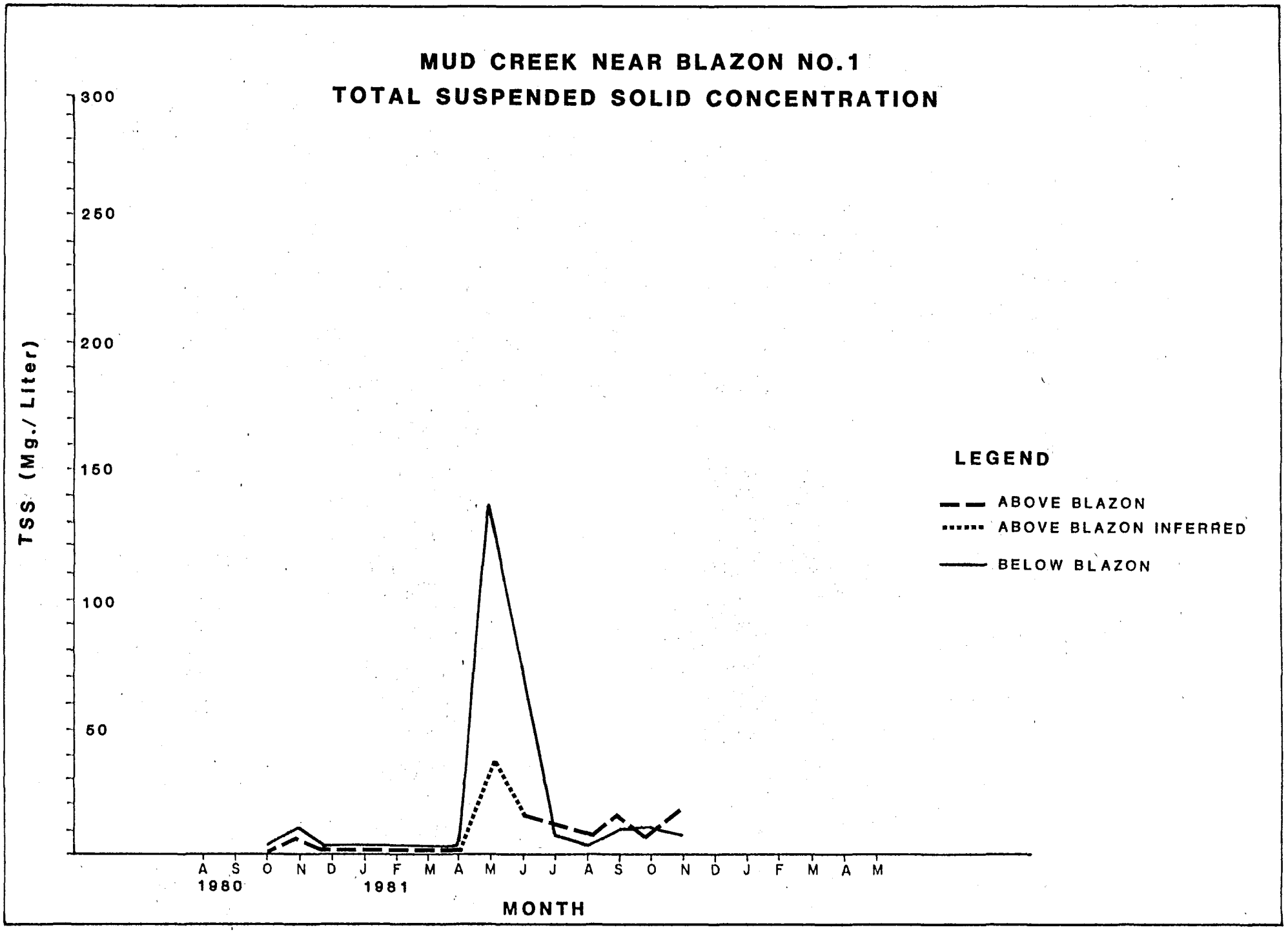
Water Use Claim No.	Owner	Source	Flow (cfs)	Purpose of Use	Period of Use
91-2669	Della Simonsen	Spring	0.011	Stockwatering	April 1 to November 30
91-2970	Angelo Georgedes	Spring	0.015	Stockwatering	May 1 to October 31
91-2975	Justus O. Seely	Spring	0.011	Irrigation, Stock.	January 1 to December 31
91-2976	Justus O. Seely	Spring	0.011	Irrigation, Stock.	January 1 to December 31
91-3012	Angelo Georgedes	Spring	0.015	Irrigation, Stock.	January 1 to December 31
91-3076	Milton A. Oman	Spring	0.011	Stockwatering	January 1 to December 31
91-3078	Milton A. Oman	Spring	0.011	Stockwatering	January 1 to December 31
91-3087	Anton Michelog	Spring with storage	0.011	Stockwatering	January 1 to December 31
91-3094	Scofield Town	3 Springs	0.033	Municipal	January 1 to December 31
91-3163	Pete Frandsen	Spring	0.011	Stockwatering	June 1 to November 30
91-3401	Waino E. Burton	Underground water, well	0.011	Stock. and Domestic	January 1 to December 31
91-3402	Waino E. Burton	Underground water, well	0.011	Stock. and Domestic	January 1 to December 31
91-3406	Della L. Madsen	Spring	0.011	Stockwatering	April 1 to November 30
91-3460	Mountain Fuel Supply Co. (½ interest)	Underground Water, well	0.134	Domestic, Irr., Misc.	January 1 to December 31
91-3499	Lavern Jensen	Finn Spring	0.011	Stock. and Domestic	January 1 to December 31
91-3500	lavern Jensen	Spring	0.011	Stock. and Domestic	January 1 to December 31
91-3586	North American Coal Corp.	Clear Creek Spring Area	0.50	Domestic, Stock., Irr., Industrial	January 1 to December 31
91-3590	North American Coal Corp. (Underground Water)	Clear Creek Mine Tunnel No. 3	0.446	Industrial	January 1 to December 31
91-3596	North American Coal Corp. (Underground Water)	O'Connor Mine Tunnel No. 2	0.047	Industrial	January 1 to December 31

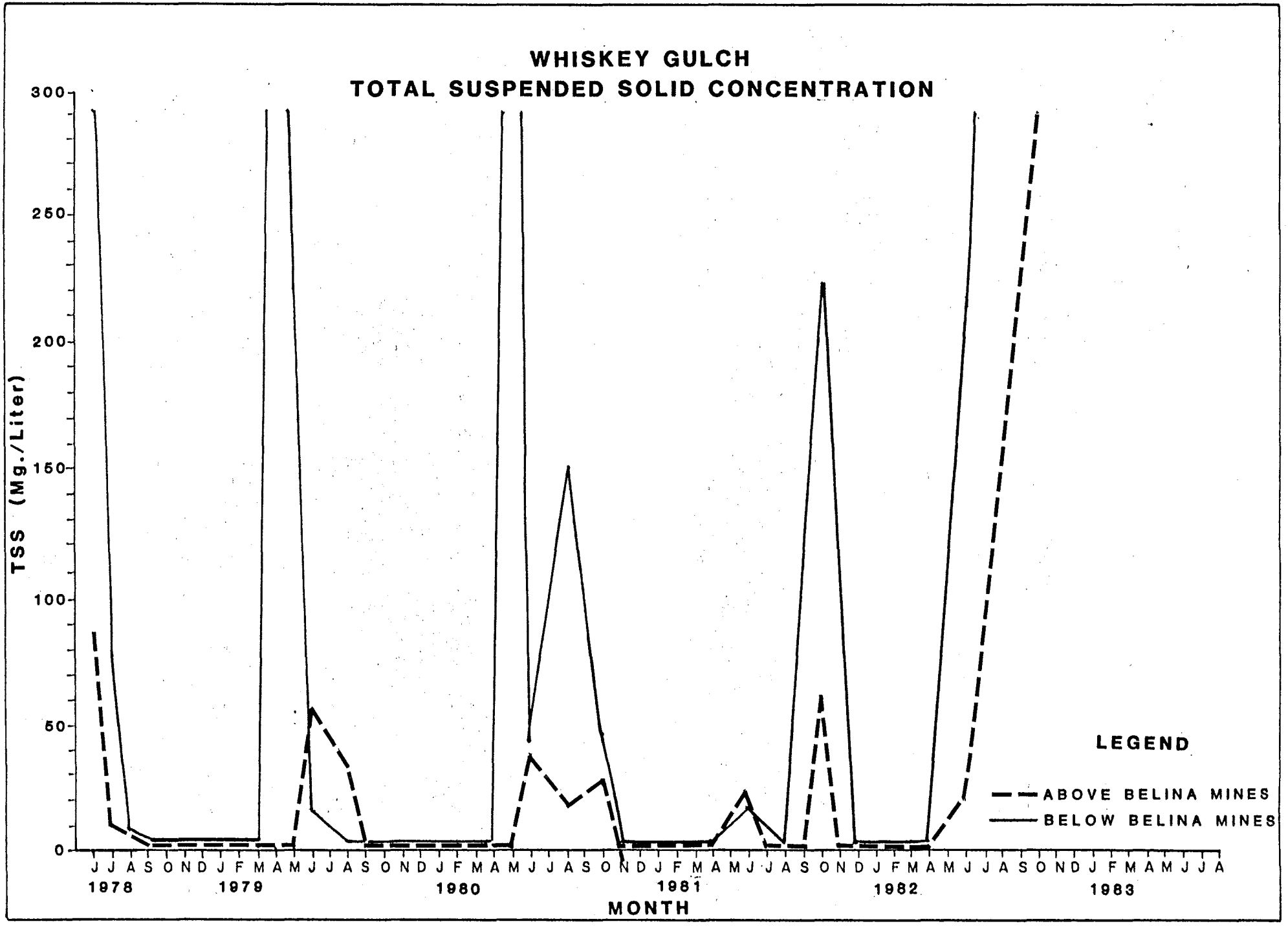
Water Use Claim No.	Owner	Source	Flow (cfs)	Purpose of Use	Period of Use
91-3601	Della L. Madsen	Spring	0.011	Stockwatering	June 1 to November 30
91-3634	D. Euray Allred	Spring	0.011	Stockwatering	May 1 to November 30
91-3638	D. Euray Allred	Spring	0.011	Stockwatering	May 1 to November 30
91-3642	John B. Jones	Spring with storage	0.011	Stockwatering	January 1 to December 31
91-3668	Angelo Georgedes	Spring	0.015	Stockwatering	May 1 to October 31
91-3971	Lionel L. Peterson	Spring	0.022	Stock. and Domestic	May 1 to November 30
91-3973	Lionel L. Peterson	Spring	0.022	Stock. and Domestic	May 1 to November 30
91-3974	Lionel L. Peterson	Spring	0.022	Stock. and Domestic	May 1 to November 30
91-3975	Lionel L. Peterson	Spring	0.022	Stock. and Domestic	May 1 to November 30
91-3976	Lionel L. Peterson	Spring	0.022	Stock. and Domestic	May 1 to November 30
91-3977	Lionel L. Peterson	Spring	0.022	Stock. and Domestic	May 1 to November 30
91-3978	Lionel L. Peterson	Spring	0.022	Stock. and Domestic	May 1 to November 30
91-3979	Lionel L. Peterson	Spring	0.022	Stock. and Domestic	May 1 to November 30
91-3980	Lionel L. Peterson	Spring	0.022	Stock. and Domestic	May 1 to November 30
91-3981	Lionel L. Peterson	Spring	0.022	Stock. and Domestic	May 1 to November 30
91-3982	Lionel L. Peterson	Spring	0.022	Stock. and Domestic	May 1 to November 30
91-3983	Lionel L. Peterson	Spring	0.022	Stock. and Domestic	May 1 to November 30
91-3985	Lionel L. Peterson	Spring	0.022	Stock. and Domestic	May 1 to November 30

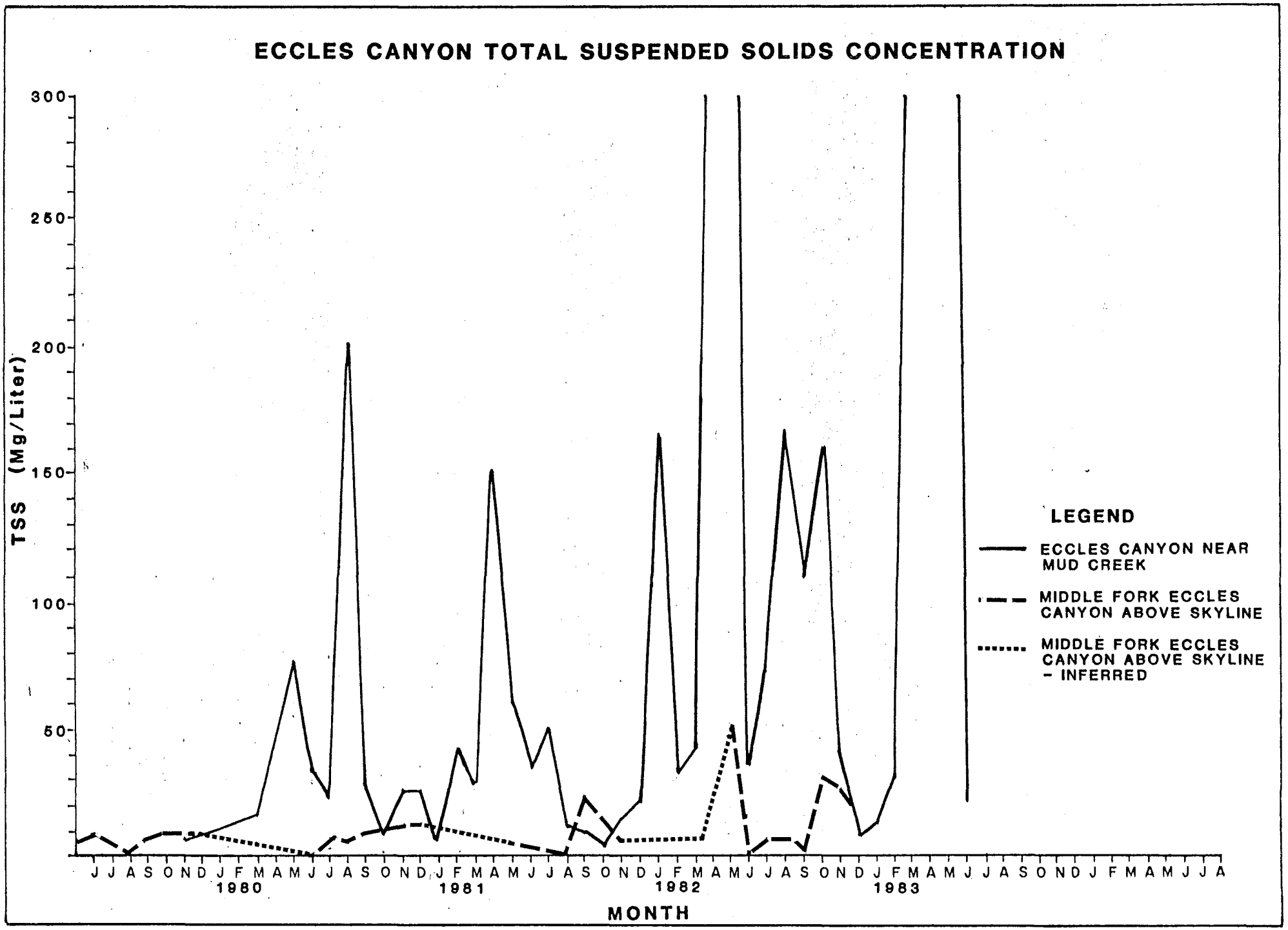
Water Use Claim No.	Owner	Source	Flow	Purpose of Use	Period of Use
91-164	Louise Gorishek	Well	1.0 A.F.	Domestic	January 1 to December 31
91-452	Robert Radakovich	Well	1.0 A.F.	Stockwatering	March 1 to November 30
91-772	Valley Camp Coal Company	Well	0.446 cfs	Industrial Domestic	January 1 to December 31
91-940	Gooseberry Enterprise Inc.	Springs	66.0 A.F.	Domestic	January 1 to December 31
91-1058	Price River Water Users Assoc.	Well	7.7 A.F.	Industrial Domestic	January 1 to December 31
91-1114	Coastal States Energy Co.	Wells	30.0 A.F.	Industrial Domestic	January 1 to December 31
91-1560	Coastal States Energy Co.	Wells	118.0 A.F.	Industrial Domestic	January 1 to December 31

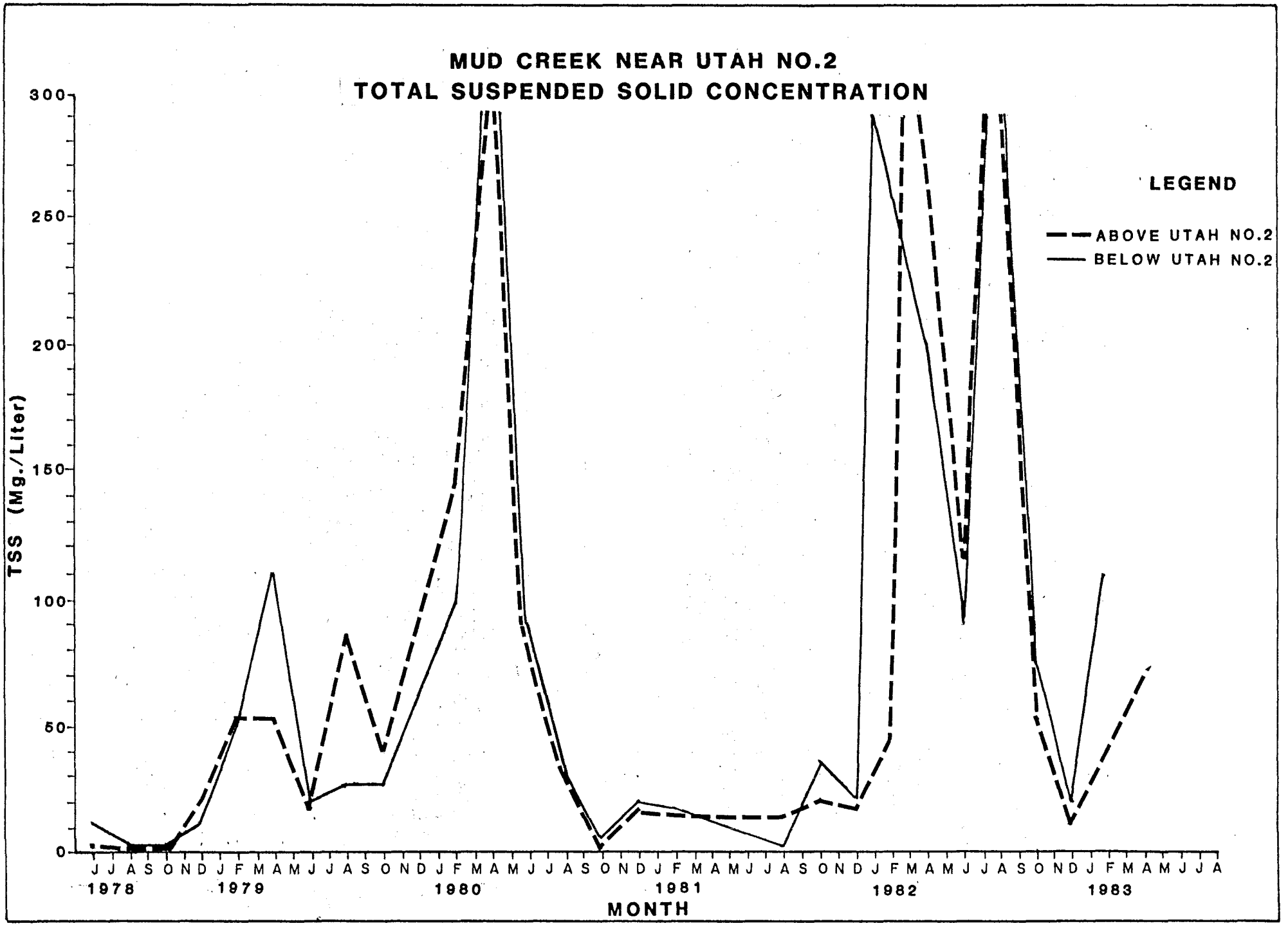
APPENDIX C

CHANGES IN TOTAL SUSPENDED SEDIMENT LOADS AT EXISTING MINES


MUD CREEK NEAR BLAZON NO.1
TOTAL SUSPENDED SOLID CONCENTRATION
TSS (Mg./ Liter)
300
250
200
150
100
50
A S O N D J F M A M J J A S O N D J F M A M
1980
1981
MONTH
LEGEND
ABOVE BLAZON
ABOVE BLAZON INFERRED
BELOW BLAZON

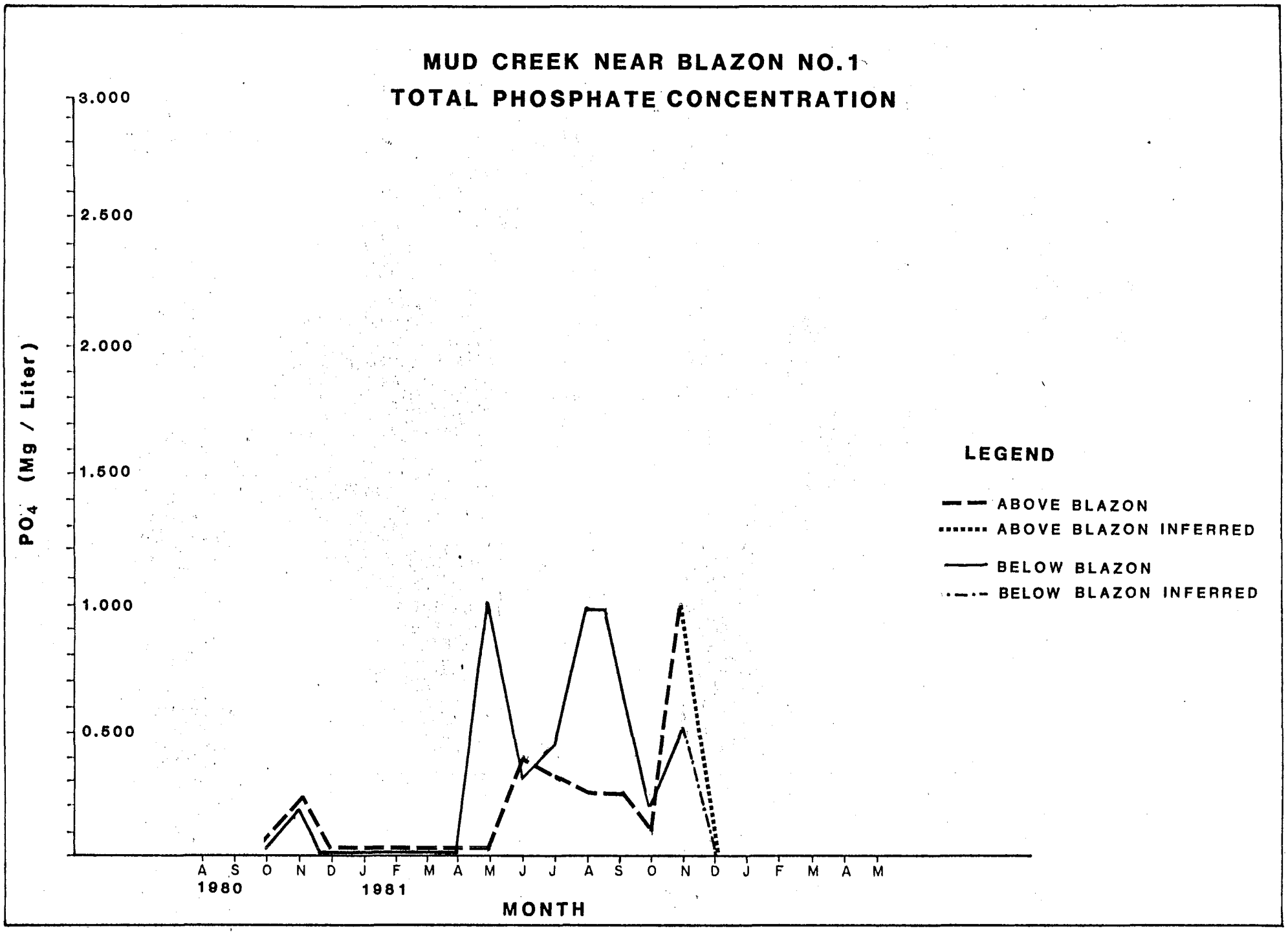

WHISKEY GULCH
TOTAL SUSPENDED SOLID CONCENTRATION
TSS (Mg./Liter)
300
250
200
150
100
50
0
J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A
1978
1979
1980
1981
1982
1983
MONTH
LEGEND
ABOVE BELINA MINES
BELOW BELINA MINES

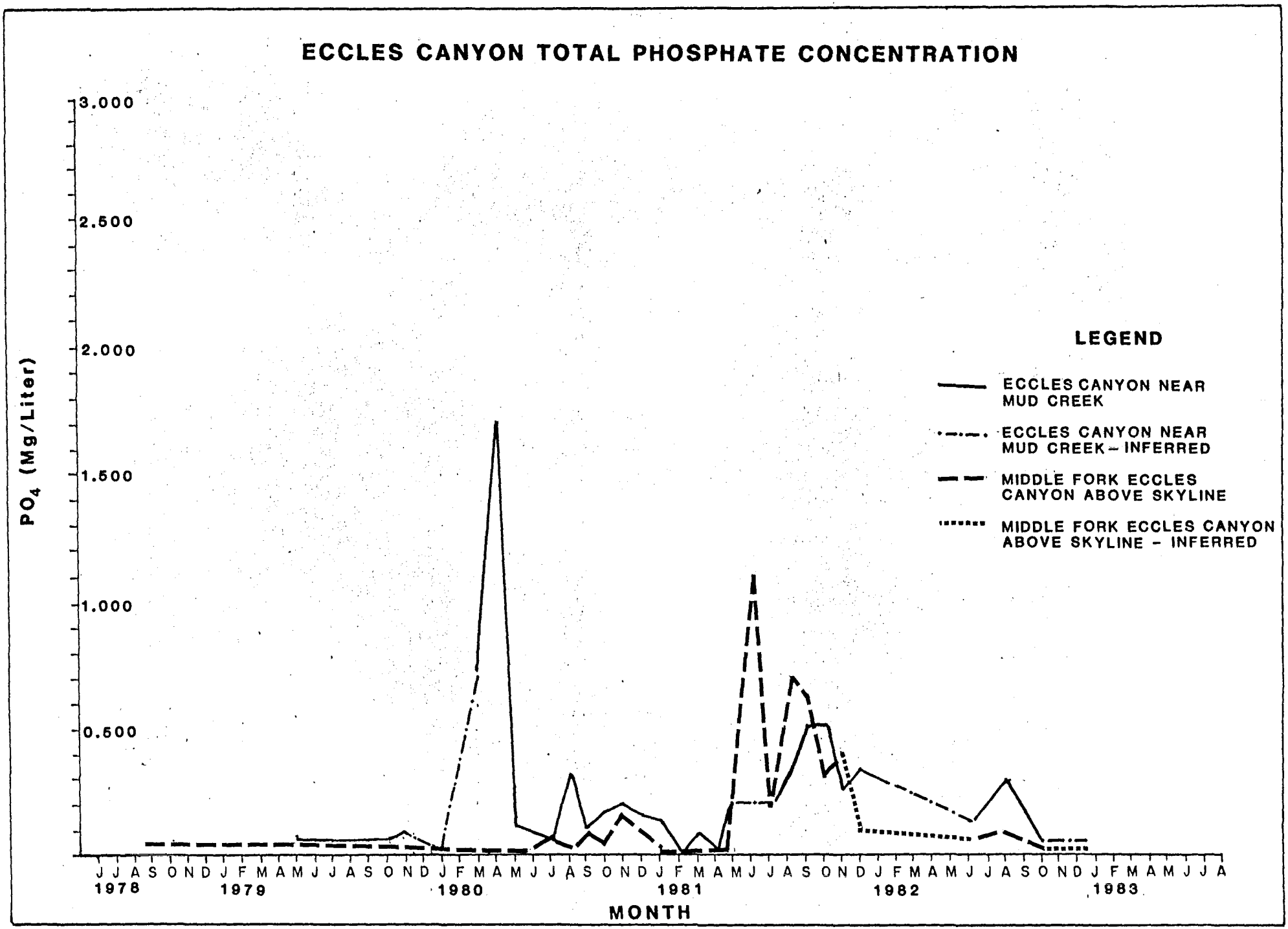

ECCLES CANYON TOTAL SUSPENDED SOLIDS CONCENTRATION
TSS (Mg/Liter)
300
250
200
150
100
50
J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A
1980
1981
1982
1983
MONTH
LEGEND
ECCLES CANYON NEAR MUD CREEK
MIDDLE FORK ECCLES CANYON ABOVE SKYLINE
MIDDLE FORK ECCLES CANYON ABOVE SKYLINE - INFERRED


MUD CREEK NEAR UTAH NO.2
TOTAL SUSPENDED SOLID CONCENTRATION
LEGEND
ABOVE UTAH NO.2
BELOW UTAH NO.2
TSS (Mg./Liter)
300
250
200
150
100
50
0
J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A
1978
1979
1980
1981
1982
1983
MONTH

APPENDIX D

CHANGES IN TOTAL PHOSPHATE LOADS AT EXISTING MINES


MUD CREEK NEAR BLAZON NO.1
TOTAL PHOSPHATE CONCENTRATION
3.000
2.500
2.000
1.500
1.000
0.500
PO4 (Mg / Liter)
A S O N D J F M A M J J A S O N D J F M A M
1980
1981
MONTH
LEGEND
ABOVE BLAZON
ABOVE BLAZON INFERRED
BELOW BLAZON
BELOW BLAZON INFERRED


ECCLES CANYON TOTAL PHOSPHATE CONCENTRATION
3.000
2.500
2.000
1.500
1.000
0.500
PO4 (Mg/Liter)
J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A
1978
1979
1980
1981
1982
1983
MONTH
LEGEND
ECCLES CANYON NEAR MUD CREEK
ECCLES CANYON NEAR MUD CREEK – INFERRED
MIDDLE FORK ECCLES CANYON ABOVE SKYLINE
MIDDLE FORK ECCLES CANYON ABOVE SKYLINE – INFERRED