CHAPTER 5

ENGINEERING

of the permit and adjacent areas, Plate 6-2 shows the locations of the coal-seam outcrops in the vicinity of the proposed surface facilities, and Figure 6-1, Plate 6-3, 6-3A and 6-3B provide geologic cross sections based on data collected from drill holes in the area. Furthermore, information related to the physical conditions which may affect mining is presented in Sections 622 (a discussion of the cross sections), 624.100 (a discussion of stratigraphic and structural conditions), and 624.300 (a discussion of rock clay content), as well as Appendix 6-1 (drill-hole logs).

Subsidence Control Measures. Most of the land within the permit area will eventually be affected by subsidence. Anticipated areas of subsidence are shown on Plate 5-7. This subsidence boundary was projected to the surface based on an angle of draw of 30 degrees as measured from the vertical as required in R645-301-525.542. It is presumed that the actual angle of draw will be less, based upon results of mining and subsidence in the general area. Plate 5-7 illustrates the projected extent of subsidence based on a 30 degree angle of draw . The primary areas where future subsidence is not anticipated are the areas overlying the previous workings shown on Plate 5-1 and 5-7(since these areas will not be re-mined). Plate 5-7 also illustrates a subsidence buffer zone that extends beyond the limits of Federal Lease U7064-027821 and State Lease ML-48435. This buffer zone does not suggest that CFC will mine outside of the lease boundaries, however, it does indicate the limit of projected subsidence.

Appendix 5-11 contains a report entitled "Prediction of Surface Deformation Resulting from Longwall Mining" which discusses subsidence. The specific sections within the report discuss, subsidence mechanism; mining, geologic conditions and subsidence characteristics; predicted ground movements and the monitoring program. This information is provided per deficiencies in the 2005 mid-term review of the M&RP.

In the "Prediction of Surface Deformation Resulting from Longwall Mining" report study "subsidence calculations (consisting of vertical movements and horizontal trains) were completed for four longwall panels of interest to this study, as illustrated in Figure 1." Mining panels GIL-5, GIL-6, GIL-7 and GIL-8 were part of the subsidence study for the Gilson Block 2 in this report located in Appendix 5-11. "The type of subsidence mechanism predicted for the study area is the trough-type subsidence. In the Gilson Block 2, CFC is utilizing panel-barrier designs to control overburden caving, seismicity and surface deformation. Considering panel width to average overburden depth rations for the project area (0.4 to 1.0), these longwall panels are considered to have a subcritical widths (Figure 3), and thus the majority of subsidence is expected during the mining of the individual longwall panels."

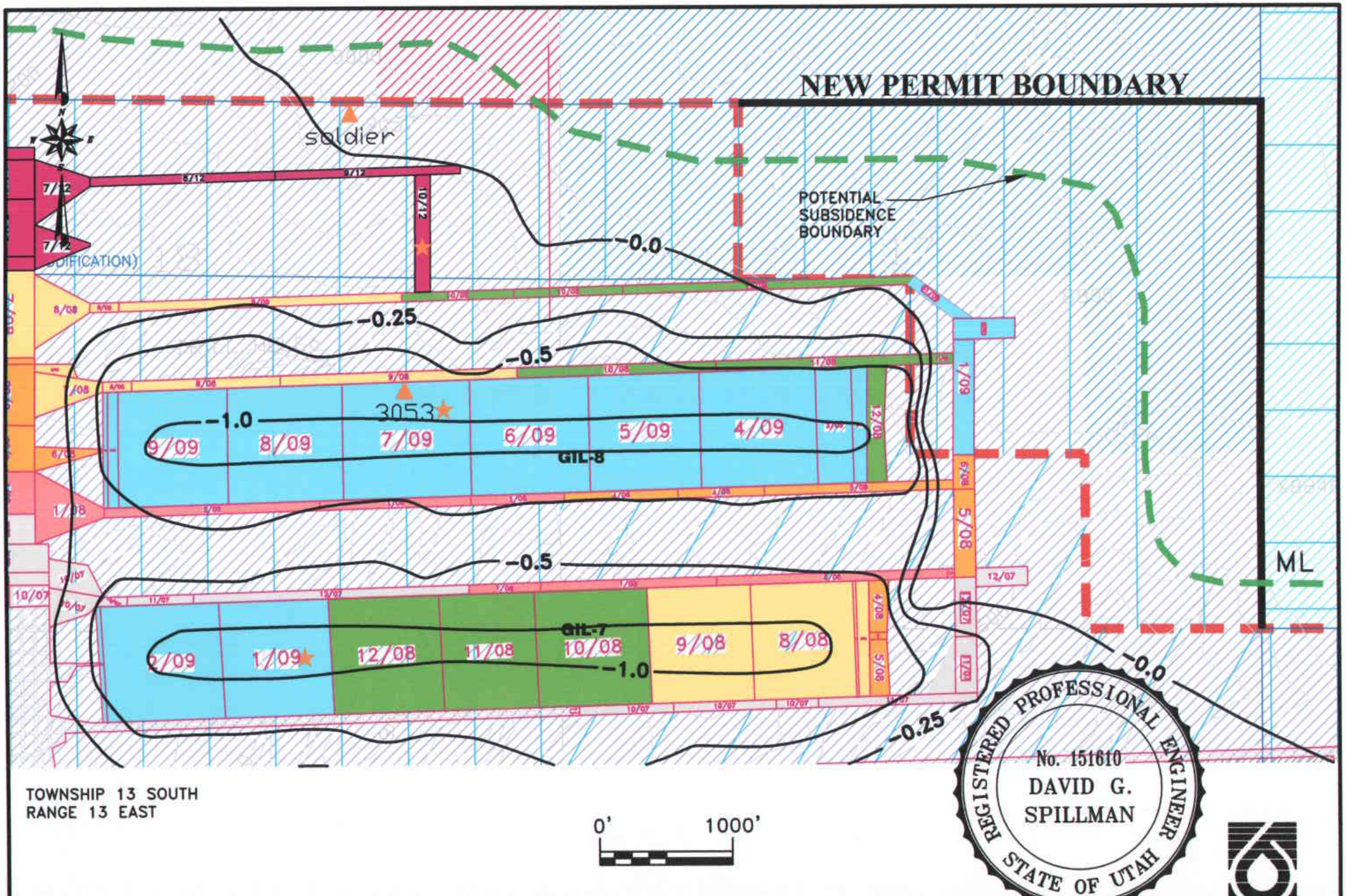
Section 3.3 on page 10 of the "Prediction of Surface Deformation Resulting from Longwall Mining" report discusses subsidence engineering parameters and measurements descriptions/calculations. Measured subsidence factor verses panel width to depth ratio for Utah operations is shown on Figure 5, typical subsidence profiles for the GIL- 5 through GIL-7 panels are shown on Figures 6 and 7.

Subsidence Monitoring. Numerous control points have been established within the permit and nearby areas to assist in subsidence surveys (see Plate 5-7). Coordinates and elevations of these control points (as established in January 1984) are provided in Table 5-2. Coordinates and elevations of control points are also provided in the Mine's Annual Reports. The control points consist of traverse monuments, benchmark monuments, and survey stations which have been constructed generally as follows:

- Traverse and Benchmark Monuments - These monuments are constructed with tap-on convex cap with a center punch mark and a center rod. The center rod has been emplaced in a 5.5- to 6-foot deep poured concrete casing. Where rock was encountered before the required depth, the rock was broken with a stone rod and an anchor point was grouted into the rock using a concrete patching material. Alternatively, monuments in rock were emplaced as described below ("Rock Monuments and Stations").

- Survey Stations - These stations consist of rebar rods with a length of 5 feet. Each rebar has been fitted with a aluminum cap. The caps are plain with a center punch mark and a concave label across the top. Where survey stations are installed in boulders or rock which did not allow the use of rebar, they were installed as indicated below ("Rock Monuments and Stations").

- Rock Monuments and Stations - Where survey monuments and stations are established in boulders and rock which do not allow the installation of a rod in a



APPENDIX 5-12 FIGURE 1. POTENTIAL SUBSIDENCE

APPENDIX 5-12 - Figure 1

Area and depth of potential subsidence were calculated/estimated by considering the following information and data:

Prediction of Surface Deformation Resulting from Longwall Mining Over the Gilson North-East Block, prepared by Maleki Technologies, Inc, located in Appendix 5-11 of this M&RP

Geologic features of the area such as cover and structure, including information in Chapter 6 of this M&RP.

Barrier pillars between longwall panels, 425' pillar between the GIL-6 and GIL-7 panel, 600 foot barrier pillar between the GIL-7 and GIL-8 panel and 528 foot pillar between the GIL-8 and GIL-9 panel.

Subsidence data submitted to UDOGM in annual reports (2004 - 2006) by coal mines both in the Bookcliff mining area and the Wasatch Plateau mining area.

Bookcliff Mining Area

Dugout Canyon Mine: Reports cover of 1800 - 1900 feet with a surveyed subsidence depth of 0.29 feet **or less**

Tower Mine: Reports cover of 2000 - 2500 feet with a subsidence survey depth averaging **less than** 1.0 foot

Reports cover of 2500 or greater with a subsidence survey depth averaging **less than** 0.5 feet

West Ridge Mine: Reports cover of 400 feet to 2500 feet with a subsidence survey depth of **less than**1.0 foot

Subsidence prediction method developed by the British National Coal Board.

CHAPTER 7
HYDROLOGY

712 Certification

All maps, plans, and cross sections presented in this chapter have been certified by a qualified, registered professional engineer.

713 Inspection

Impoundments associated with the mining and reclamation operations will be inspected as described in Section 514.300 of this M&RP.

720 ENVIRONMENTAL DESCRIPTION

721 General Requirements

This section presents a description of the pre-mining hydrologic resources within the permit and adjacent areas that may be affected or impacted by the proposed coal mining and reclamation operation.

722 Cross Sections and Maps

722.100 Location and Extent of Subsurface Water

A generalized hydrostratigraphic cross section of the permit and adjacent areas is presented in Figure 7-1 and in Appendix 7-4, Figure 19. A description of baseline groundwater conditions within the permit and adjacent areas, together with appropriate cross sections and maps as well as a discussion of seasonal variations in water levels, is provided in Section 724.100 of this M&RP.

722.200 Location of Surface Water Bodies

A description of baseline surface-water conditions within the permit and adjacent areas, together with appropriate maps and cross sections, is provided in Section 724.200 of this M&RP. A map showing the location of surface-water bodies and groundwater sources for which water rights exist or for which there are pending water rights applications is provided as Plate 7-2. A listing of water rights is presented in Appendix 7-1.

originally written by Mayo and Associates and included in Appendix 7-3 was prepared by the mine in October 2007 to address additional baseline data collected for the ~~600~~ 240 acre expansion in the northeast portion of the permit area. The update also includes the results of surface and ground water monitoring by the mine since 1998. This information is included in Appendix 7-3 and titled "Update to the Probable Hydrologic Consequences of Coal Mining at the Dugout Canyon Mine".

Groundwater Systems

Geologic conditions in the permit and adjacent areas are described in detail in Chapter 6 of this M&RP. Formal aquifer names have not been applied to any groundwater system in the permit and adjacent areas because the geometry, continuity, boundary conditions, and flow paths of the groundwater systems in the area are not fully understood. However, the data do suggest that groundwater systems in each of the bedrock formations are sufficiently different from each other to justify the informal designation of groundwater systems based on bedrock lithology. Thus, the informal designation of Colton, Flagstaff, North Horn, Price River, Blackhawk, Star Point, and Mancos groundwater systems is adopted herein.

Perched Groundwater Systems in the Colton Formation, Flagstaff Limestone, North Horn Formation, Price River Formation, and the Castlegate Sandstone

The nature and occurrence of groundwater systems in the Wasatch Plateau and Book Cliffs coal fields are described in a Geological Society of America Bulletin publication (Mayo et al., 2003). The Dugout Canyon Mine permit and adjacent area is included in the study area for this publication. This publication describes active and inactive groundwater flow systems in stratified mountainous terrains. Mayo et al. describe groundwater systems in the Dugout Canyon Mine area as occurring in one of two fundamental groundwater flow regimes. These include "active" groundwater flow systems, and "inactive" groundwater flow systems. Active zone groundwater flow paths are continuous, and responsive to annual recharge and climatic variability. Active zone groundwater systems support springs discharging at the surface in the area. Inactive zone groundwater systems have extremely limited or no communication with annual recharge. Inactive zone groundwater systems may be partitioned, occur as discrete bodies, and may occur in hydraulically isolated regions that do not have hydraulic communication with each other (Mayo et al, 2003; See also Mayo and Morris, 2000).

In the vicinity of the Dugout Canyon Mine, discharge of groundwater from geologic formations overlying mining areas occurs primarily from localized perched groundwater systems (See

Appendix 7-3 for further information on shallow groundwater systems). Perched groundwater systems in the near-surface bedrock formations overlying the Dugout Canyon Mine (including the region near the permit expansion area) were noted by Waddell et al. (1986). It is noteworthy that Waddell reports perched groundwater systems encountered in some drill holes, while perched groundwater systems were not encountered in some other nearby drill holes (See Figure 19 in Waddell et al., 1986). This condition demonstrates the lack of lateral continuity in the local perched groundwater systems present in the area and also highlights the fact that meaningful potentiometric surface maps cannot be constructed for these isolated perched groundwater systems.

The presence of local perched groundwater systems overlying unsaturated strata and the hydraulic disconnect between the shallow perched groundwaters and the deep Blackhawk Formation groundwater systems encountered during mining operations is fundamentally the result of the heterogeneity of the rock sequence in the region (Mayo et al, 2003). The flow of bedrock groundwater in quantities sufficient to support discharge to springs occurs primarily within permeable sandstone strata. Groundwater flow along fault planes, bedding planes, and through rocks with fracture-enhanced permeability also occurs locally. In the rock sequence overlying the Dugout Canyon Mine area, the permeable sandstone units commonly exist as discontinuous sandstone paleochannels. Annotated photographs showing sandstone fluvial channels in the Colton Formation near Colton, Utah are presented in Figures X and Y. Also shown on Figures X and Y are the fine-grained sediments with lower hydraulic conductivities that encase the more permeable sandstone rocks in the fluvial channels. Because of the depositional environments in which these rocks were formed, the fluvial sandstone paleochannels are commonly encased both vertically and horizontally by low-permeability rocks (shales, mudstones, and claystones; Mayo et al., 2003). Although the permeability of individual sandstone bodies may be of aquifer quality, the overall ability of these rocks to transmit water horizontally over great distances is low because of the discontinuous nature of the sandstones (Mayo et al., 2003). The surrounding low-permeability rocks impede the outward migration of groundwater from permeable strata both vertically and horizontally. The abundant presence of low-permeability strata in the rock sequence, and the discontinuous character of permeable strata prevent the appreciable downward migration of groundwater from the perched systems into deeper horizons (or into the underground mine environment; Mayo et al., 2003). As indicated in Appendix 7-3 and based on drilling data (Appendix 7-4 and Appendix 6-1, Confidential), large portions of the rock sequence overlying mining areas in the Dugout Canyon Mine area do not appear to be fully saturated in the vicinity of the Dugout Canyon Mine.

Unlike the Colton, Flagstaff, North Horn, and Price River formations, which consist largely of low-permeability rocks with interbedded sandstone strata, the Castlegate Sandstone in composed primarily of sandstone rocks. However, for several reasons, large aquifers do not form in the Castlegate Sandstone. The Castlegate Sandstone is not a uniform sand deposit. Rather, interbedded with the lenticular fluvial braided sandstone horizons are repeating sequences of mudstone drapes or depositional bounding surfaces (Mayo et al., 2003). The permeabilities of the mudstone drapes are typically many times lower than that of the surrounding sandstone. Consequently, although portions of the Castlegate Sandstone are sufficiently permeable to facilitate groundwater flow, the interbedded mudstones drapes partition and isolate these sandstone units such that the overall ability of the formation to transmit water both laterally and vertically over significant distances is poor (Mayo et al., 2003). Where Castlegate Sandstone discharge is present, it is most commonly associated with the presence of fracturing or jointing. Additionally, the potential for recharge to the Castlegate Sandstone is low. The pervasiveness of low-permeability strata in the geologic formations overlying the Castlegate prevents appreciable recharge to the formation from vertical leakage from the overlying formations. Additionally, because of the limited surface exposure of the Castlegate Sandstone in the area, the potential for groundwater recharge directly onto the Castlegate is low. As discussed above, the observation that the Castlegate Sandstone does not support many springs in the region and that much of the formation was dry when drilled supports these conclusions (See Appendix 7-4 and Appendix 6-1, Confidential). Because geologic and hydrogeologic conditions in the Castlegate Sandstone in the proposed expansion area are believed to be very similar to those in surrounding areas in the Book Cliffs coal field, it is considered probable that the hydrogeologic behavior of Castlegate Sandstone groundwater systems in the proposed expansion area will be consistent with the Castlegate Sandstone groundwater flow conditions described regionally by Mayo (2003).

It should be noted that although there appear to be large areas of unsaturated low-permeability rock surrounding the perched groundwater systems, saturated low-permeability strata are likely also present locally in the rock sequence. However, the rate of movement of water in the low permeability strata is commonly several orders of magnitude less than that in the permeable sandstone horizons (Mayo et al., 2003; Waddell, 1986). Consequently, groundwater in these horizons likely exists mostly under relatively stagnant conditions and is not of much consequence to the hydrologic balance.

The shallow, perched groundwater systems in the Dugout Canyon Mine area are likely recharged where the up-dip ends of the sandstone beds or fractured bedrock strata are exposed at the land surface in wet areas, or where the beds are directly overlain by water-bearing alluvial or colluvial sediments. Recharge to the sandstones from overlying saturated shallow fractured bedrock may also occur. Recharge to the sandstone strata via direct vertical leakage from overlying, competent, low-permeability strata is probably low (Waddell, 1986).

Discharge rates from shallow, perched groundwater systems overlying mining areas in the Dugout Canyon Mine generally exhibit both seasonal and climatic variability (see Appendix 7-3 and flow information submitted to the Division's online hydrology database). Most springs discharging from perched systems respond rapidly to the annual snowmelt recharge event, followed by a rapid waning of discharge rates later in the year. These conditions are indicative of shallow groundwater systems that are in good hydraulic communication with shallow, active recharge sources (i.e., active zone groundwater systems). These conditions are not commonly observed in springs discharging from large aquifers with large storage volumes (Waddell, 1986).

Groundwater flow directions in the perched groundwater systems are constrained largely by the geometry of the permeable sandstone strata through which the groundwater is conveyed. In the general sense, it may be stated that perched groundwaters flow from up-dip recharge areas to topographically lower discharge areas. However, because the sinuous geometries and subsurface locations of individual three-dimensional sandstone paleochannels (or other fractured or permeable strata) are difficult to delineate in the subsurface, the determination of concise groundwater flow directions within these bodies is problematic.

Discharge from the perched groundwater systems commonly occurs where the down-dip ends of the permeable sandstones or bedrock fractures or bedding planes intersect the land surface (Waddell, 1986; Mayo et al., 2003). In some localities, the presence of bedrock fracturing or jointing within sandstone channels enhances the hydraulic conductivity locally. It is not uncommon for the spring discharge locations from perched groundwater systems to coincide with the occurrence of local bedrock fracturing (Mayo et al., 2003). Where fracturing of the bedrock is present at groundwater discharge locations, spring discharge locations are commonly focused into discrete spring locations rather than as diffuse seepage through porous rock.

Potentiometric Surface Maps

A fundamental assumption underlying the construction of a potentiometric surface contour map is that there is a continuously saturated, interconnected aquifer that is present over a substantial aerial extent. Because there are no identified aerially extensive groundwater regimes in the strata overlying coal mining areas in the Dugout Canyon Mine area (See Appendix 7-3), and the probable lack of connection between the individual small perched groundwater systems, it is not possible or scientifically correct to draw potentiometric surface contour maps for these groundwater systems at a reasonable scale. While potentiometric surface contour maps of individual small, perched groundwater systems could conceivably be created at a local scale, it would be impractical and of limited value to do so. Consequently, potentiometric surface contour maps depicting groundwater conditions cannot be presented here.

Groundwater in the permit and adjacent areas occurs within perched aquifers overlying the coal-bearing Blackhawk Formation as well as within the Blackhawk Formation and the underlying Star Point Sandstone. Hydrogeologic conditions within the permit and adjacent areas are summarized below.

Colton Formation. The Colton Formation outcrops in the northeast portion of the permit and adjacent areas. This formation consists predominantly of fine-grained calcareous sandstone with occasional basal beds of conglomerates and interbeds of mudstone and siltstone. Data presented in Table 7-2 and Appendix 7-2 indicate that six springs issue from the Colton Formation within the permit and adjacent areas.

Waddell et al. (1986) evaluated the discharge of spring G-96 for the period of June to September 1980. At spring G-96 the measured discharge rate declined from 103 to 6.3 gpm during the 4-month period of evaluation. The slope of the hydrograph recession curve (which provides a relative index of the seasonal variability of discharge) was calculated by Waddell et al. (1986) to be 24 days per log cycle for the initial slope following snowmelt (designated as "S1") and greater than 365 days per log cycle for base-flow conditions (designated as "S2"). This suggests that, at this location, the groundwater system has a good hydraulic connection with surface recharge and that most of the annual recharge quickly drains out of the system.

Groundwater issuing from the Colton Formation has a total dissolved solids ("TDS") concentration of 300 to 500 mg/l (as measured by specific conductance and laboratory analyses of TDS). The pH of this water is slightly alkaline (7.5 to 8.1). Collected data suggests TDS concentrations do not significantly vary seasonally. The pH of the water appears to shift toward becoming more alkaline during periods of drought.

Based on one sample collected from G-96, the water is a calcium-magnesium-bicarbonate type (see Figure 7-2 and Appendix 7-2). This solute composition is consistent with the dissolution of calcite and dolomite in the presence of soil-zone carbon dioxide, together with ion exchange. The G-96 data also indicated a dissolved iron concentration of 0.02 mg/l. No total iron or manganese data are available for this spring. Samples obtained and analyzed from springs SC-65 and 260 support the conclusions the water discharging from the Colton Formation is a calcium-magnesium-bicarbonate type.

Flagstaff Formation. The Flagstaff Formation outcrops across much of the northern portion of the permit area. This formation consists of an interbedded sequence of sandstone, mudstone, marlstone, and limestone. Most springs and a major portion of the volume of groundwater discharging from the permit and adjacent areas issue from the Flagstaff Formation. According to Table 7-2 and Appendix 7-2, more than 40 springs issue from the Flagstaff Formation within the permit and adjacent areas.

Groundwater discharge rates for springs issuing from the Flagstaff Formation are greatly influenced by seasonal variations in precipitation and snowmelt, with most discharge corresponding to the melting of the winter snow pack during the spring months. Some springs in the Flagstaff Formation, which have been found to discharge 100 to 300 gpm following the spring snowmelt, decrease to flows of 15 gpm or less by the fall (Appendix 7-2). Many springs issuing from the Flagstaff Formation have been noted to dry up each year.

In an effort to quantify the seasonal variability of discharge rates of springs issuing from the Flagstaff Formation, Waddell et al. (1986) prepared hydrograph recession curves for several springs in the permit and adjacent areas. The hydrograph data summarized in Table 7-3 show an S1 recession average of 69 days and an average S2 recession 246 days. The longer duration of the S1 recession relative to the data collected from G-96 in the Colton Formation indicate that the storage capacity of the Flagstaff Formation is greater than that of the Colton Formation. Nonetheless, the data indicate that most of the annual recharge to the Flagstaff Formation drains out of the system within about two months, while the remainder of the annual recharge drains out prior to the next snowmelt recharge event. This conclusion was verified by isotopic data collected by Mayo and Associates, 1996, Appendix 7-3.

The groundwater regime in the Flagstaff Formation appears to be influenced predominantly by the combined effects of lithology and topographic expression. Because the Flagstaff Formation forms much of the upland plateau of the permit and adjacent areas, this formation is capable of receiving appreciable groundwater recharge from precipitation and snowmelt.

Waddell et al. (1986) concluded that the Flagstaff groundwater system is perched. They indicate that approximately 9 percent of the average annual precipitation recharges the Flagstaff groundwater system and that recharge water entering the Flagstaff Formation moves downward until it encounters low permeability shale or claystone layers in the North Horn Formation, where almost all of the water is forced to flow horizontally to springs. The hydrograph and isotopic data support this conclusion

Data presented in Appendix 7-2 indicate that groundwater issuing from the Flagstaff Formation has a mean TDS concentration of 335 mg/l. This water tends to be slightly alkaline and, similar to conditions encountered in the Colton Formation, is of the calcium-magnesium-bicarbonate type (Figure 7-3). The solute compositions of these groundwaters appears to be dominated by the dissolution of calcite and dolomite in the presence of soil zone carbon dioxide, together with ion exchange.

The data presented in Appendix 7-2 indicate that the dissolved iron concentration of groundwater discharging from springs in the Flagstaff Formation is generally less than 0.1 mg/l. Total iron concentrations of this water are typically about one order of magnitude higher. Total manganese concentrations in Flagstaff groundwater are generally less than 0.03 mg/l. These data do not exhibit seasonal trends.

North Horn Formation. The North Horn Formation outcrops across the center of the permit and adjacent areas but eventually pinching out in the eastern portions of the permit and adjacent areas. This formation consists of interbedded sandstone and calcareous mudstone.

According to Table 7-2 and Appendix 7-2, 27 springs issue from the North Horn Formation within the permit and adjacent areas. Although the number of reported springs is large, the maximum measured discharge from most of these springs is less than 5 gpm and the total maximum measured discharge is small compared to the total maximum measured discharge from the Flagstaff Formation. Given the gradational nature of the contact between the North Horn Formation and the overlying Flagstaff Formation (see Section 624.100), it is possible that some of the reported North Horn Formation springs may represent discharge from the lower part of the Flagstaff Formation.

Hydraulic and chemical conditions vary widely within the North Horn Formation. This variability caused Waddell et al. (1986) to conclude that water discharging from the North Horn Formation is probably recharged by upward leakage from the underlying formations, including the Blackhawk Formation. This conclusion was based on water levels in wells perforated in the Blackhawk Formation and on the solute chemistry of spring SP-10. However, this conclusion is considered to be in error since the Price River Formation and the Castlegate Sandstone, which are situated between the North Horn Formation and the Black Formation, are not saturated in the vicinity of Soldier Creek just downstream from SP-10. Furthermore, Soldier Creek loses water as it flows across the Price River Formation and the Castlegate Sandstone (see Waddell et al., 1986). Hence, the upward flow from the Blackhawk Formation does not appear to be the primary source of recharge to the North Horn Formation.

Sufficient data have been collected from two springs (SP-8 and SP-10) to provide diagnostic information regarding the groundwater system of the North Horn Formation in the permit and adjacent areas. The discharge from SP-8 is hydraulically and chemically similar to groundwater in the Flagstaff groundwater system. The spring exhibits substantial variability in discharge in response both to spring snowmelt events and to drought and wet years (Figure 7-4). Discharge rates as great as 20 gpm have been recorded from this spring during the high-flow season, and discharge rates as low as 1 gpm are not uncommon during late summer. The effects of the drought occurring in the late 1980s and early 1990s are clearly evident in the hydrograph.

Groundwater issuing from SP-8 typically has a mean TDS concentration that varies from 250 to 300 mg/l with a pH of 8.5 to 8.9. This water is of mixed cation-bicarbonate type (Figure 7-5) and is chemically distinct from most groundwater in the Blackhawk Formation.

Although spring SP-10 issues from the North Horn Formation, the spring may be fracture controlled and contain water from a deeper groundwater system. Although fracture systems have not been mapped on the surface in the vicinity of SP-10, the long-term hydrograph of SP-10 (Figure 7-4) is not consistent with hydrographs of "shallow-source" springs issuing from the Flagstaff, North Horn, or Price River groundwater systems, in that the discharge rate of SP-10 shows only limited seasonal variability.

According to Mayo and Associates (1996), the isotopic and solute compositions of SP-10 discharge water are more similar to groundwater encountered in the Blackhawk Formation. Groundwater discharging from SP-10 is of the sodium-bicarbonate type (Figure 7-5), which suggests that ion exchange of calcium and magnesium has occurred for sodium in a zone containing clay minerals or zeolites. This could occur in the Blackhawk Formation since the zeolite analcime has been identified in coal at the Skyline Mine located approximately 35 miles west of the proposed Dugout Canyon Mine (Mayo and Associates, 1994).

Groundwater issuing from SP-10 has an elevated sulfate content (Appendix 7-2 and Figure 7-5). In fact, this spring has been locally referred to as Sulfur Spring due to the odor of hydrogen sulfide gas which lingers in the air. The source of the gas is likely near-surface sulfate reduction caused by bacterial activity (Appendix 7-3). Sulfate reduction is consistent with the measured reducing potential of the water (Appendix 7-3).

According to information presented in Appendix 7-3, water issuing from SP-10 has a meteoric origin but an old age. Furthermore, the data indicate that water issuing from SP-10 is similar to water encountered in Soldier Canyon Mine, suggesting that the water issuing from the spring is mixed with water from the Blackhawk Formation (Appendix 7-3).

The old age of groundwater issuing from SP-10 relative to water from other springs in the North Horn and overlying formations is confirmed by the mean radiocarbon age of the water which has been calculated as 10,000 years (see Appendix 7-3). As a point of comparison, a mean radiocarbon age of 21,500 years has been calculated for a groundwater sample collected from the Blackhawk Formation in the 3rd West pillar area inside Soldier Canyon Mine (see Appendix 7-3).

It is likely that groundwater discharging at SP-10 flows upward from depth along a fracture. The major water-bearing fracture identified in the Soldier Canyon Mine is approximately coincident with the location of SP-10, validating this conclusion (see Appendix 7-3).

Wahler Associates (1982) indicate that monitoring well GW-19-1 (Plate 7-1) was initially completed within the North Horn Formation. However, according to Waddell et al. (1986), the well was initially unperforated and was then perforated on two separate occasions (first opening the well to the North Horn Formation and then later to the underlying Price River Formation, Castlegate Sandstone, and Blackhawk Formation). As a result, water levels have reportedly varied significantly in the well over very short periods of time due to the various conditions within the well. Due to these changing well conditions and multiple-zone perforations, the data cannot be used to ascertain water-level fluctuations in the North Horn Formation. However, given the decrease in water levels which occurred following the second round of well perforations (a decline in head of about 540 feet), it is apparent that the head in the North Horn Formation is several hundred feet greater than the composite head of the underlying formations. This suggests that groundwater in the North Horn Formation is probably not insignificant hydraulic connection with groundwater in the underlying formations.

The data presented in Appendix 7-2 indicate that the dissolved iron concentration of groundwater issuing from the North Horn Formation is generally less than 0.07 mg/l. Total iron concentrations of this water is slightly higher. Total manganese concentrations in North Horn groundwater are generally less than 0.02 mg/l. These data do not exhibit seasonal trends.

Price River Formation. The Price River Formation consists of interbedded mudstone and siltstone with some fine-grained sandstone and carbonaceous mudstone. Within the permit area, no springs have been found issuing from the Price River Formation, suggesting that it is not a significant aquifer. The absence of springs is of great significance, since this formation is situated between the overlying Flagstaff groundwater system and the underlying coal zone (in the Blackhawk Formation). The absence of springs is most likely the result of two factors: 1) clay horizons in overlying formations inhibit vertical recharge from groundwaters in the Flagstaff and North Horn Formations, and 2) the exposed recharge area of the Price River Formation is limited primarily to areas of steep cliff faces.

Wahler Associates (1982) indicate that monitoring well GW-11-2 (Plate 7-1) is completed within the Price River Formation. Data collected from this well (Appendix 7-4) indicate that water levels varied by approximately 8 feet during the period of December 1979 through November 1982, but showed no consistent trend. A measurement collected in September 1995 indicated that the water level was 1.2 feet lower than the last time it was measured nearly 13 years earlier. Hence, although a slight decline in water levels has occurred during the period of record, this decline is not considered significant. Since 1997, when this well became part of the mine's monitoring program, the water level dropped approximately 8 feet until 2005 when it rose about 12 feet. Mining activities do not appear to be the cause of the rise and fall of the water level within the well nor do cycles between wet and dry periods. The cause for these changes are unknown at this time.

Castlegate Sandstone. The Castlegate Sandstone consists of a fine- to medium-grained sandstone that is cemented with clay and calcium carbonate. The outcrops of this sandstone form prominent cliffs in the area.

Data presented in Table 7-2 and Appendix 7-2 indicate that only two springs (SC-80 and SC-81) have been found issuing from the Castlegate Sandstone within the permit and adjacent areas. The flow of these springs was 1 gpm or less in September 1995, with no measurable flow being observed in October 1995. Based on specific conductance measurements collected from these springs, the TDS concentration of water issuing from the Castlegate Sandstone varies from about 360 to 430 mg/l. The water is slightly alkaline, with a pH of 7.7 to 8.0. Subsequent field studies found another spring, 227, that appeared to discharge from the Castlegate Sandstone. However, since this site was added to the water monitoring program, this spring has not had measurable discharge. Therefore, this formation is not considered to be a significant aquifer.

Wahler Associates (1982) indicate that monitoring wells GW-10-2 and GW-24-1 (Plate 7-1) are completed in the Castlegate Sandstone. With the exception of early measurements which were likely influenced by the presence of drilling fluids prior to perforation of the casing (Waddell et al., 1986), data collected from GW-24-1 indicate that water levels varied by 4.5 feet during the period of March 1980 through November 1982 (Appendix 7-4), but no consistent trend was noted. The cap could not be removed from this well for a water-level measurement in September 1995. During the Winter of 1999-2000, Monitoring Well 24-1 became blocked. The water level in the well has been inaccessible since that time and was permanently removed from monitoring after the 4th Quarter of 2004.

Data collected from GW-10-2 indicate that water levels have declined approximately 30 feet during the 27-year period of record following an initial stabilization of drilling fluids after casing perforation (January 1980 through May 2007). The rate of this decline has been gradual.

The potentiometric surface of groundwater flow in the Castlegate Sandstone is to the north-northwest at an average gradient of 0.024 ft/ft based on measurements reported by Wahler Associates (1982) for November 1982. The datum reported for GW-11-2, under the assumption that the Price River Formation is in hydraulic connection with the Castlegate Sandstone was also used to determine the potentiometric gradient.

Groundwater recharge to the Castlegate Sandstone is from precipitation and snowmelt. However, as evidenced by the fact that the surface exposure of the Castlegate within the permit and adjacent areas is generally limited to steep cliffs within minimal horizontal surface area, total recharge is probably low. Recharge to the Castlegate Sandstone is further limited by the lack of significant developed soil resources over the formation to encourage infiltration and the presence of low-permeability shales in the overlying Price River Formation (see Waddell et al., 1981).

Discharge from the Castlegate Sandstone probably occurs mainly as springs along the outcrop and as through-flow to the underlying Blackhawk Formation. As indicated above, spring flow from the unit is limited in flow and in occurrence. Besides the monitoring wells completed in the Castlegate Sandstone, no known wells are completed in the formation.

Blackhawk Formation. The Blackhawk Formation underlies the Castlegate Sandstone and consists of interbedded sandstone, siltstone, shale, and coal. The Rock Canyon and Gilson coal seams, to be mined by Dugout Canyon Mine, are located in the lower portion of the Blackhawk Formation.

Only three springs have been identified as issuing from the Blackhawk Formation (SC-61, SC-62, and G-100 - see Table 7-2). Springs SC-61 and SC-62 issue near a stream channel in a tributary of Dugout Canyon. Limited data collected from these springs (Appendix 7-2) indicate that flows are typically less than 2 gpm, with a TDS concentration of 700 to 800 mg/l. The pH of this water is slightly alkaline (7.5 to 8.0).

Visits to spring G-100 in September and October 1995 indicated that this spring was dry on one visit and seeping at a sufficiently low rate on the second visit that it could not be sampled. Previous attempts by Mayo and Associates (1996) could not locate this spring. A sample collected by Waddell et al. (1986) indicated that water discharging from G-100 has a TDS concentration of approximately 650 mg/l and a pH of 7.2. The water is of the calcium-magnesium-bicarbonate-sulfate type (Figure 7-6). The solute composition of this water is chemically distinct from all other springs in the area. It has an elevated sulfate content relative to overlying groundwater and may be distinguished from Blackhawk Formation groundwater associated with coal seams inside Soldier Canyon Mine by its relatively low sodium and bicarbonate contents (Appendix 7-3 and Figure 7-6). The solute composition of water issuing from G-100 is consistent with the dissolution of calcite and dolomite in the presence of soil zone carbon dioxide and the dissolution of appreciable amounts of gypsum.

Four monitoring wells (GW-5-1, GW-6-1, GW-32-1, and G-58.5) have been completed in the Blackhawk Formation in areas north and northeast of the permit area (see Plate 7-1). As noted in Table 7-1, well GW-5-1 is perforated opposite the Sunnyside and Rock Canyon Coal seams in the Blackhawk Formation. Early water-level measurements in this well show the residual influence of drilling fluids in the hole immediately following casing perforation. Subsequently, in November 1982, Wahler Associates (1982) conducted a slug test in the well by filling it with water to within about 20 feet of land surface. Hence, early water-level measurements in this well are not indicative of hydraulic heads in the formation.

SCM began monitoring well GW-5-1 in June 1987. Between June 1987 and June 1993, water levels declined at a slow and nearly constant rate of about 0.02 ft/day (Figure 7-7). The initial water level in June 1987 was about the same as the water level prior to the slug test in 1982.

By mid-year 1993, development of the Soldier Canyon Mine, within the Sunnyside seam, had expanded to a point immediately adjacent to well GW-5-1. Well monitoring data show a slight rise in water level elevation between June 3, 1993 and August 24, 1993 which corresponded to mine development in the vicinity of the well. This rise in water level can be explained by the redistribution of vertical stress acting on the nearby coal (see Appendix 7-3). Following completion of the 1993 development, a sustained moist area was identified on the floor of the Soldier Canyon Mine No. 5 entry, adjacent to GW-5-1.

Furthermore, subsequent monitoring of the water level in the well indicated that, between August 24, 1993 and November 1, 1995, the average rate of water level decline increased to approximately 0.09 ft/day (an increase of about 4.5 times the previously observed rate). This decline was likely due to dewatering of the Blackhawk Formation in the immediate vicinity of the monitoring well.

Wahler Associates (1982) calculated a transmissivity of 0.009 gpd/ft (1.2×10^{-3} ft^2/day) from the falling-head slug test which they performed in GW-5-1. Sergent, Hauskins & Beckwith (1986) reported transmissivities of 2.3×10^{-3} to 6.7×10^{-4} cm^2/s (2.1×10^{-1} to 6.2×10^{-2} ft^2/day) for slug tests conducted in holes drilled into the Blackhawk Formation from within the Soldier Canyon Mine.

Based on monitored thicknesses of 22 feet in GW-5-1 (Table 7-1) and 120.8 feet in each of the in-mine holes (Sergent, Hauskins & Beckwith, 1986), the hydraulic conductivity of the Blackhawk Formation is calculated to vary from $5.5x10^{-5}$ to $1.7x10^{-3}$ ft/day, with a median of $5.1x10^{-4}$ ft/day.

Well GW-6-1 is perforated over a 200-foot long interval which includes the Sunnyside seam (see Table 7-1). Initial water level measurements collected from this well are believed to be associated with residual water remaining from drilling and casing operations and are, therefore, probably not representative of natural conditions. Water levels declined between November 1989 and August 1991 (Figure 7-7). From August 1991 through August 1993, water levels in GW-6-1 remained relatively stable at a depth of approximately 425 feet. Monitoring on June 3, 1994 found the well to be dry and plugged at a depth of approximately 470 feet. All subsequent attempts to monitor this well have found the plugged/dry condition unchanged.

Monitoring well GW-32-1 is perforated in the Blackhawk Formation immediately above the Sunnyside seam (see Table 7-1) in a location which is down dip of Soldier Canyon Mine workings. Water level monitoring information shows a fairly consistent rise in water elevation.

From November 1994 through August 1995, the water level appears to have stabilized at a depth of approximately 291 feet (Figure 7-7). There is no information at this time that would suggest that underground mining activities in the nearby Soldier Canyon Mine are effecting the water levels observed to date.

Monitoring well G-58.5 was completed by Mountain Fuel Supply Company into the Blackhawk Formation in 1979. Waddell et al. (1986) reported a depth-to-water in March 1980 in this well of 502.8 feet. Waddell et al. (1982) reported depths to water of 501.7 to 502.4 feet in April and September 1880. No additional water-level data are available for this well.

Attempts for this M&RP to construct a potentiometric surface for the Blackhawk Formation in the Soldier Canyon area based on data collected from GW-5-1, GW-6-1, and GW-32-1 proved fruitless. The difficulty in preparing this potentiometric surface may have been due to the influence of outcropping in the adjacent Soldier Canyon, the influence of mining in the nearby Soldier Canyon Mine, and/or varying lengths and stratigraphic locations of the perforated sections of the monitoring wells within the discontinuous strata which comprise most of the Blackhawk Formation. However, based on water-level data collected from one of the existing Dugout Canyon portals and from monitoring wells GW-5-1 and G-58.5, Waddell et al. (1986) concluded that the flow of groundwater in the Blackhawk Formation within the permit and adjacent areas is to the north away from the face of the cliffs (i.e., down dip as generally seen in the Castlegate Sandstone). They estimated the hydraulic gradient in the Blackhawk Formation to be 42 feet per mile (0.008 ft/ft). Waddell et al. (1986) indicate that the coal bearing zone to be mined in the Dugout Canyon operations will probably be saturated in most areas and will require dewatering during mining. However, since mining was initiated at the Dugout Mine, saturated coal zones have not been encountered. The majority of the water encountered during mining both the Rock Canyon and Gilson seams has entered the mine through the roof as discharges from isolated sandstone channels within the Blackhawk Formation and from the roof and floor through fractures and minor faults.

Recharge to the Blackhawk Formation is of limited magnitude, due primarily to the limited area of exposure on steep outcrops and the presence of low-permeability units in overlying formations. Data presented in Appendix 7-3 indicate that Blackhawk Formation groundwater which discharges into the Soldier Canyon Mine is of ancient meteoric origin (greater than 20,000 years), thereby supporting the conclusion that the rate of recharge to the formation is minimal. Mayo and Associates (1996) concluded that the old groundwater age and the isotopic compositions of water encountered in the Soldier Canyon Mine are evidence that the groundwaters are not part of actively flowing, shallow groundwater systems. The groundwater ages also demonstrate that the hydraulic connection between these old groundwaters and the overlying active (and younger) groundwater systems in the Flagstaff and North Horn Formations is very limited or does not exist.

The quality of groundwater in the Blackhawk Formation has been evaluated by Mayo and Associates (1996) based on data collected from leakage into the Soldier Canyon Mine (see Appendix 7-3). These data indicate that Blackhawk Formation groundwater has a mean TDS concentration of about 750 mg/l and is of the sodium-bicarbonate type (Figure 7-6). These waters are chemically distinct from groundwater in overlying groundwater systems. The solute compositions of mine groundwaters suggest a complex series of rock-water and gas-water reactions (Mayo and Associates, 1996).

The dissolved iron concentration of groundwater flowing into the Soldier Canyon Mine has historically been less than 0.5 mg/l and is generally less than 0.1 mg/l (see Appendix 7-2). The total iron concentration of this water has historically been less than 2.0 mg/l and generally less than 0.5 mg/l. The total manganese concentration of Blackhawk Formation water (as measured in the Soldier Canyon Mine) has historically been less than 0.5 mg/l and is typically less than 0.1 mg/l (see Appendix 7-2).

Four exploration holes (DUG0104, 0204, 0101, and 0201) were drilled within or immediately adjacent to the Dugout Canyon Mine SITLA Lease area and completed in the Blackhawk Formation. All holes were completed below the Gilson Coal Seam. No water was encountered in any of the exploration holes per personal communication with Mike Stevenson, Project Geologist, Ark Land Company, November 22, 2004.

Exploration Hole Number	Location (approximate)	Year Drilled
DUG0104	T13S, R13E, Section 20, NW1/4SE1/4	2004
DUG0204	T13S, R13E, Section 19, SE1/4NE1/4	2004
DUG0101	T13S, R13E, Section 30, NE1/4NW1/4	2001

DUG0201	T13S, R13E, Section 19, SE1/4SE1/4	2001

Star Point Sandstone. In those locations where the Star Point Sandstone exists within the permit and adjacent areas, it consists of a fine-grained calcareous sandstone with layers of siltstone and mudstone. In keeping with regional practice (see Lines, 1985), the Star Point Sandstone and Blackhawk Formation are considered to be hydraulically connected. However, only one spring (SC-64) has been discovered issuing from the Star Point Sandstone within the permit and adjacent areas. The near absence of springs in this formation suggests that the Star Point does not receive appreciable annual recharge and that it does not support active groundwater systems in the area.

Recharge to the Star Point Sandstone probably occurs via leakage from the overlying Blackhawk Formation. Hence, this water is likely of ancient origin.

Data collected from SC-64 indicated that the discharge of this spring declined from 2 gpm to 0.5 gpm in the period of September 1995 to October 1995 (see Appendix 7-2). The TDS of this water, as estimated from the specific conductance data, is approximately 700 mg/l, with a pH of about 7.5.

Mancos Shale. The Mancos Shale is exposed south of the permit area. This formation is a relatively impermeable marine shale and is not considered to be a regional or local aquifer. Groundwater samples collected from four monitoring wells located approximately 2 miles south of Soldier Canyon Mine have a mean TDS concentration of approximately 10,000 mg/l and is of the sodium-sulfate-chloride type (Appendix 7-3). Chemical compositions are consistent with the dissolution of halite and gypsum as well as cation exchange.

Recharge and Discharge Relations

Recharge within the permit area occurs primarily on the exposed upland outcrops of the Flagstaff Formation and the North Horn Formation. Waddell et al. (1986) estimated that the annual recharge to the Flagstaff Formation is 9 percent of the total annual precipitation. Recharge is probably greatest where surface fractures intersect the topographic highs where the Colton, Flagstaff, and North Horn Formations outcrop. Recharge to the Blackhawk Formation and the Star Point Sandstone probably occurs primarily from vertical movement of water through the overlying formations. The rate of recharge to the Blackhawk Formation and the Star Point Sandstone is very slow, as evidenced by the ancient age of groundwater within those formations (see Appendix 7-3).

Assuming mass-balance and stable hydrologic conditions, recharge will equal discharge over the long term. The relatively young age of groundwater discharging from the Flagstaff and North Horn Formations as compared with the underlying Blackhawk Formation suggests that the stratigraphically-higher water discharges rapidly and is not hydraulically connected with the Blackhawk Formation. Waddell et al. (1986) conclude that the perched nature of the Flagstaff Formation protects it from the influence of dewatering of the coal-bearing zone unless the upper zone is influenced by subsidence.

Waddell et al. (1986) performed seepage studies in Pine Canyon (located immediately north of the permit area) and found that significant increases in the flow of Pine Canyon occur near the contact of the North Horn Formation and the overlying Flagstaff Formation. They concluded that downward percolation from the Flagstaff Formation is impeded by the claystones and mudstones of the North Horn Formation, forcing the water to move laterally and emerge along the outcrop in the canyon bottom.

Expansion Area (240 acres, Section 17, T13S, R13E) - While it is not possible to precisely delineate the recharge areas for individual springs using the existing hydrogeologic data, a determination of the most probable recharge area is possible using existing geologic, hydrogeologic, and topographic information. A discussion of the most probable recharge areas for springs in the expansion area is presented below.

Two springs (260 and 260A) have been identified within the boundaries of the expansion area that has the possibility of being impacted by subsidence. The Division of Water Rights (DWRi) has indicated two other springs are located in the eastern portion of Section 17, T 13 S R 13 E and within the permit expansion area. However, these springs were not found in the original seep and

Formations. The majority of the flow appears to originate from springs within the North Horn and Flagstaff Formations. A surface water monitoring point (Fan) has been added on Pace Creek at a location approximately 600 feet upstream from the top of the Pace Canyon Fan facilities disturbed area boundary. Surface flows measured at monitoring point Fan indicate that the stream is intermittent and likely fluctuates in flow volume seasonally.

Rock Canyon Creek base flow in its upper reaches appears to originate from springs discharging from the Northhorn Formation. Flow data from monitoring site RC-1 near the mouth of Rock Canyon indicates the lower sections of Rock Creek generally flow in response to spring runoff and after summer precipitation events. In 2002 and 2003, flow measured at RC-1 occurred only after a significant precipitation event. Again, the lack of flow in this creek is most likely related to the drought conditions that appear to have begun in the area in 1999.

Springs within Cow Canyon were included in the original baseline survey conducted in the mid-1990's and again in the summer of 2007. The field parameters were measured at the springs in Cow Canyon (Plate 7-1) and the results are included in Attachment 1 of the "Probable Hydrologic Consequence Addendum, October 2007, Revised April 2008" in Appendix 7-3. Seasonal field data was collected in 2007 at the junction of two small drainages (323) in the unnamed tributary of Cow Canyon. Monitoring site 323 was inaccessible until mid-May. Three samples of pH, conductivity, temperature and flow were taken between May and August. The flow ranged from 13 to 20.5 gallons per minute, pH ranged from 7.8 to 8.4, conductivity ranged from 591 to 675 and temperature ranged from 11 to 14 degrees centigrade.

Observations were made in 2007 during sampling of the unnamed tributary of Cow Canyon that the surface water in the fork below monitoring site 260 ran intermittently between spring site 260 and spring site 261 (Plate 7-1). This tributary appears to become perennial a short distance above site 261. In 2008, during monitoring activities the perennial nature of the tributary will again be evaluated.

The fork of the unnamed tributary of Cow Canyon which contains monitoring sites 321, 263 and 263A is neither perennial or intermittent. The discharge from the three spring's runs for a short distance and disappears. Flow associated with storm events in this fork has not been observed, however a defined channel does not exist from site 321 to site 263.

No streamflow data are available for ephemeral drainages in the permit and adjacent areas. When it does occur, ephemeral runoff in the area is expected to occur predominantly in the months of April and May in response to snowmelt runoff and in the months of August and September as a result of thunderstorm activity. Snowmelt may result in flow durations of a few weeks, while thunderstorms are expected to result in runoff with a short duration and high intensity.

Several small impoundments have been constructed in the permit and adjacent areas to capture water for stock watering. Those impoundments where water rights applications have been filed are located as shown on Plate 7-2. The impoundments capture water either from an adjacent spring or from snowmelt.

A UPDES permit application has been issued by the Utah Division of Water Quality as indicated in Appendix 7-6. This application applies to discharge from the sedimentation pond. Discharge from this point occurs only infrequently as a result of pond dewatering or after significant precipitation events. The application also applies to discharges from the underground mine workings.

Surface-water quality samples have been periodically collected in the permit and adjacent areas from stations located on Soldier Creek, Dugout Creek, Pine Canyon, Pace Creek, and Rock Canyon Creek (Plate 7-1). Analytical data from these sources are summarized in Appendix 7-7. These data were obtained from multiple sources, including (but not limited to) the Soldier Creek Coal Company M&RP and annual reports, U.S. Geological Survey publications, the Sage Point-Dugout Canyon permit application filed by Eureka Energy Company in 1980, Appendix 7-3 of this M&RP, and various consultant reports. Since not all monitoring parties were responsible to adhere to UDOGM or SMCRA rules, the laboratory parameters varied between reports. However, the data are still considered valid and appropriate for determining baseline conditions within the permit and adjacent areas. It should be noted that most of the manganese data presented in Appendix 7-3 represent total (as opposed to dissolved) concentrations.

In general, TDS concentrations of surface waters in the permit and adjacent areas vary inversely with the discharge rate. These concentrations also tend to increase in the downstream direction (Waddell et al., 1986). Total suspended solids concentrations in the local surface waters tend to vary directly with the flow rate (Waddell et al., 1986).

The data presented in Appendix 7-7 indicate that the dominant ions in surface water during high-flow periods are calcium and bicarbonate, whereas the dominant ions in the low-flow periods are sodium, magnesium, sulfate, and bicarbonate. During high-flow periods, runoff is rapid and most surface waters only interact chemically with the uppermost regions of the soil zone. Thus, they are dominated by calcium and bicarbonate ions. Furthermore, groundwater contributions from the Flagstaff Formation (where calcium and bicarbonate are the primary ions) dominate the chemical quality of surface water during high-flow periods (see Figure 7-10).

During low-flow periods, groundwater contributes a larger percentage of the flow in the stream (see Figure 7-10). With its higher TDS concentrations and different solute types (particularly in the Blackhawk Formation), the solute composition of the surface water is altered during low-flow periods.

Data presented in Appendix 7-5 indicate that the TDS concentration of water in Dugout Creek at station DC-1 has varied from about 350 to 500 mg/l with a pH of 8.0 to 8.5. Total suspended solids concentrations have varied from 5 to 1,000 mg/l during the period of record.

Dissolved iron concentrations in Dugout Creek at station DC-1 have typically been less than 0.1 mg/l, while total iron concentrations are generally less than 1.0 mg/l. Dissolved manganese concentrations have typically been less than 0.01 mg/l, while total manganese concentrations are normally less than 0.1 mg/l. No seasonal variations in dissolved metals were noted. Total metals concentrations tend to vary directly with total suspended sediment concentrations.

It is important to note, the water chemistry data referenced was collected for Dugout Creek at DC-1 was obtained prior to the start of mine water discharge in 2002. Since mine water has been discharged, the TDS concentration in the water at DC-1 has varied between a minimum of 330 mg/L and maximum of 2160 mg/L and averages about 1000 mg/L. The pH has also varied in that time between a minimum of 7.3 and a maximum of 9.2 but typically is between 7.7 and 8.4. No appreciable increase in the total suspended solids concentration has been noted since the mine began discharging. Dissolved iron concentrations have risen slightly but average 0.11 mg/l. Total iron concentrations have also risen and average 0.74 mg/L. Dissolved manganese concentrations have risen but average 0.05 mg/L while total manganese concentrations average 0.06 mg/L. Additional discussions regarding the mine water discharge and participation in a total dissolved solids reduction project are included in the "Update to the Probable Hydrologic Consequences of Coal Mine at the Dugout Canyon Mine" in Appendix 7-3.

Historic data collected from Soldier Creek (Appendix 7-7) indicate that the total suspended solids concentration generally increases in the downstream direction and has varied from less than 10 to greater than 10,000 mg/l. Dissolved iron concentrations are typically less than 0.1 mg/l at stations G-1 and G-4, and less than 0.2 mg/l at G-5 (see Plate 7-1). The data do not indicate a seasonal variation in the concentration of dissolved iron. Total iron concentrations, which generally vary in accordance with the total suspended solids concentration, are typically less than 10 mg/l at all stations. Total manganese concentrations in Soldier Creek are generally less than 0.01 mg/l at G-1 and less than 0.10 mg/l at G-4 and G-5.

Data collected from Pine Canyon (Appendix 7-7) indicate that the total suspended solids concentration also tends to increase in the downstream direction and has varied from less than 10 to greater than 100 mg/l. Dissolved iron concentrations are typically less than 0.1 mg/l in Pine Canyon, with total iron concentrations typically being less than 1.0 mg/l. The data do not indicate a seasonal variation in the concentration of dissolved iron. However, total iron concentrations tend to vary in accordance with the total suspended solids concentration. Total manganese concentrations in Pine Canyon are generally less than 0.01 mg/l at G-2 and less than 0.03 mg/l at G-3.

Data collected from Pace Creek (Appendix 7-7) indicate dissolved iron concentrations are typically less than 0.1 mg/l, with total iron concentrations typically being less than 1.0 mg/l. The limited data do not indicate a seasonal variation in the concentration of dissolved iron. Total manganese concentrations in Pace Creek are generally less than 0.01 mg/l.

Surface runoff from the majority of the land surface in Sections 16 and 17 (T13S R13E) drains to the Cow Canyon drainage. Discharges from the localized perched Colton Formation groundwater systems in the vicinity contribute baseflow discharge to streams in the expansion area and sustain discharges in portions of the drainage. During the spring snowmelt event and in response to torrential precipitation events, streamflow in the drainages are augmented by surface runoff. Once the spring runoff season is complete many reaches of the stream drainages in the expansion area are dry. There is no discharge from a regional type aquifer system to the stream drainages in the Cow Canyon drainage area. Consequently, because impacts to the localized perched Colton Formation groundwater systems are not anticipated, detrimental impacts to baseflow in the stream drainages are likewise not anticipated.

724.300 Geologic Information

Geologic information related to the permit and adjacent areas is presented in Chapter 6 of this M&RP.

724.400 Climatological Information

Climatological data are summarized in Appendix 4-2 of this M&RP.

724.500 Supplemental Information

All information pertinent to a determination of the probable hydrologic consequences of the proposed Dugout Canyon Mine operation and reclamation are presented in this M&RP.

724.600 Survey of Renewable Resource Lands

The existence and recharge of groundwater systems in the permit and adjacent areas is discussed in Section 724.100 of this M&RP. A discussion of the potential for material damage or diminution of these groundwater systems and their recharge areas due to subsidence is provided in Section 728 of this M&RP.

724.700 Alluvial Valley Floor Requirements

Information regarding the presence or absence of alluvial valley floors in the permit and adjacent areas is presented in Chapter 9 of this M&RP.

725 Baseline Cumulative Impact Area Information

The hydrologic and geologic information required for the Division to develop a Cumulative Hydrologic Impact Assessment is presented in this M&RP under Chapters 6 and 7. Required information not available in these chapters is available from the Utah Divisions of Water Rights and Water Resources and from the U.S. Geological Survey and the U.S. Bureau of Land Management.

726 Modeling

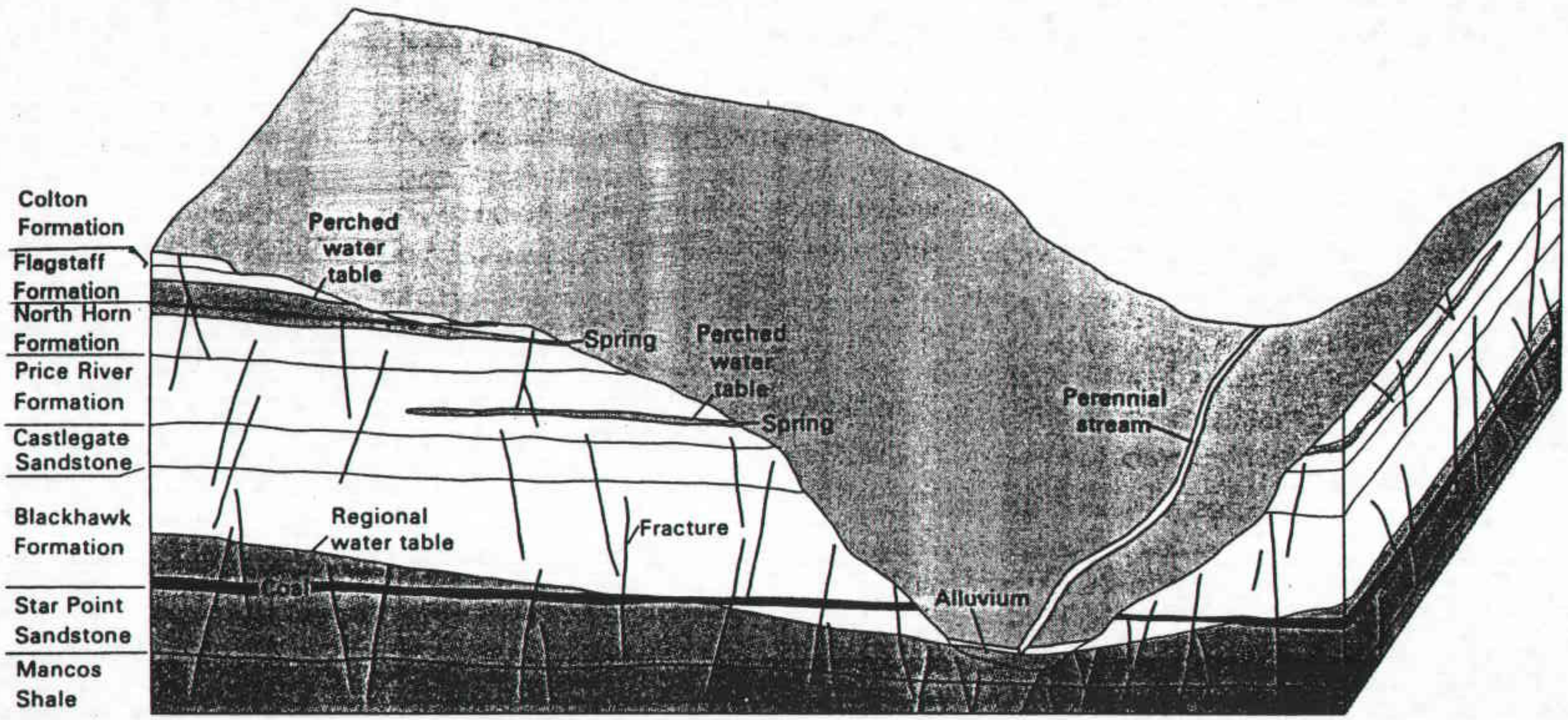
No numerical groundwater or surface water modeling was conducted in support of this M&RP, other than that which has been published by others and referenced herein.

727 Alternative Water Source Information

REFERENCES (Continued):

Mayo, A.L., Morris, T.H., Peltier, S., Petersen, E.C., Payne, K., Holman, L.S., Tingey, D., Fogel, T., Black, G.J., and Gibbs, T.D., 2003, Active and inactive groundwater flow systems: Evidence from a stratified, mountainous terrain, GSA Bulletin: December 2003: V. 115: no. 12; p. 1456-1472.

Mayo, A.L., and Morris, T.H., 2000, Conceptual model of groundwater flow in stratified mountainous terrain, Utah, USA in Groundwater: Past achievements and future Challenges, Sililo et al. ed: Proceeding XXX IAH Congress on Groundwater, Capetown South Africa, 26 November – 1 December, 2000, p. 225-229.



Modified from Lines (1985)

FIGURE 7-1. GENERAL HYDROSTRATIGRAPHIC CROSS SECTION

APPENDIX 7-2

Groundwater Monitoring Data

Appendix 7-2

SPRINGS
321 and 322

"321" Monitoring Data 2007

Date	Time	pH	Cond.	Temp.	Flow (gpm)	Comments
3/15/07	1220				NOA	Snow/Ice
5/18/07	1420	8.08	406	4	1.5	
6/21/07	1114	8.11	410	7.6	1.3	
7/24/07	834	7.38	469	8.5	0.75	
8/30/07	1205	7.42	471	8	0.7	

"322" Monitoring Data 2007

Date	Time	pH	Cond.	Temp.	Flow (gpm)	Comments
3/15/07	1220				NOA	Snow/Ice
6/21/07	905	7.84	704	7	18	
7/24/07	916	7.91	698	9	0.2	Livestock
8/30/07	1130	7.91	663	11	0.1	Livestock

APPENDIX 7-3

Mayo and Associates Report

PROBABLE HYDROLOGIC CONSEQUENCES ADDENDUM

OCTOBER 2007
Revised April 2008
Revised July 2008

Table of Contents (Continued)

Table of Contents

LIST OF FIGURES

ATTACHMENTS

1.0 INTRODUCTION

This addition to the Dugout Canyon Mine (Dugout) PHC is being prepared in conjunction with expansion of the mine permit area to include approximately 240 additional acres to the northeastern portion of the permit area. This addition includes updates to the surface and ground water monitoring plan, updated flow and water quality information for selected monitoring sites, additional monitoring sites, and the probable hydrologic impacts of mining to the approximate 240 acres of added permit area. This addition to the PHC does not address all sections of the existing PHC, rather only those sections that either need updating with current information and are pertinent to the Dugout Mine or sections that include new data. While all sections of the existing PHC are listed in the text of this addition, the sections not changed are indicated by the text "No Changes Made".

2.0 ANALYSIS OF SURFACE AND GROUNDWATER SYSTEMS

2.1 STUDY AREA

Section 12 of T13S R12E and Sections 16, 17, 18, and 21 of T13S R13E have been added to the study area as a result of permit area expansion. Portions of the drainage areas that intersect these sections have also been added to the study area (PHC Update Figure 1). The addition to the study area includes portions of the headwaters of Pace and Dugout Canyons as well as a small portion of the headwaters of unnamed tributary (Section 17) to Cow Canyon, a tributary to Nine Mile Canyon. The expanded area lies almost exclusively within the exposed Tertiary-age Colton Formation.

2.2 METHODS OF INVESTIGATION

Methods similar to the initial PHC investigation have been employed to determine possible hydrologic consequences due to proposed mining of the 240 acre expansion and in the updating of the existing Dugout Mine portion of the PHC. Also, measured flow and selected chemistry parameters have been reviewed for existing Dugout Mine monitoring sites to determine what, if any, impacts have occurred to surface and ground water resources. Baseline field data have been collected from surface and ground water sites in the expansion area and new monitoring sites have been selected to be added to the permit water monitoring schedule. Water quality samples have been obtained and analyzed for these selected sites.

2.3 DESCRIPTION OF DATA

The 240 acre expansion sample locations are identified on Plate 7-1 and tables listing the measured field parameters are listed in PHC Update Table 1 and included in Attachment 1. Laboratory analysis results for the selected water monitoring sites in the expansion area are also included in Attachment 1. Graphs supporting the discussion regarding mining impacts to existing monitoring sites are included in Attachments 2, 3 and 4 of this document.

2.4 EXPLANATION OF CHEMICAL REPORTING UNITS AND TERMS

No Changes Made

2.5 OVERVIEW OF MINE OPERATIONS

2.5.1 HISTORY OF MINE OWNERSHIP AND OPERATION

In this PHC update, this section pertains to the operation of Dugout Canyon Mine. The Soldier Canyon Mine was idled in 1998 and has not been actively mined since that date. Future mine plans potentially include reopening the mine once the reserves at the Dugout Canyon Mine are depleted. Monitoring of the majority of the water monitoring sites associated with the Soldier

Canyon Mine was suspended in 2003.

As an update to the history of the mine ownership, a brief discussion of the ownership of the Solder Canyon and Dugout Mine properties is presented herein. Arco Coal purchased the Soldier Canyon and Dugout Mine properties from Coastal Corporation in 1996 and combined this property with the Sufco and Skyline mines to form Canyon Fuel Company, LLC. Itochu purchased from Arco a portion of Canyon Fuel Company, LLC. Arco sold its interest in Canyon Fuel Company, LLC to Arch Coal, LLC in 1998. Itochu sold its interest in the Canyon Fuel properties in 2004 to Arch Coal.

Dugout Canyon Mine was opened in 1998 when mining activities began in the Rock Canyon seam. Longwall mining moved from the Rock Canyon seam to the Gilson seam in February 2004 and has continued through 2007. It is anticipated mining will continue to occur in either the Rock Canyon or Gilson seams at this mine through at least 2013.

2.5.2 MINING TECHNIQUES AND LOCATIONS

Since the Dugout Mine was opened, the primary method of coal extraction has been using longwall techniques supported by development mining using continuous mining equipment. Initial mining within the Rock Canyon seam began with typical two- or three-entry systems for the headgates and tailgates. However, difficulties in roof control and depth of cover forced the mine to develop longwall panels that were and currently are separated by thick coal barrier pillars. Most of the future panels will be separated by barrier pillars. Improved roof control has been obtained by using the barrier pillar technique and subsidence over those panels separated by the barriers is notably less than those panels lacking the barrier pillars.

2.5.2.1 Rock Dusting

No Changes Made

2.5.2.2 Water management and discharge to Dugout and Pace Creeks

Water is collected in the Dugout Mine from numerous roof drips, fractures and faults. The water is managed through as series of sumps that include flooded gob and abandoned workings. Discharge rates and total volumes have changed throughout the years since the mine opened in 1998. Overall, between 1998 and September 2007, the average discharge rate from the mine to Dugout Creek has increased from a few gallons per minute to a rate of about 1200 gpm, though recent (July 2007) discharges rates have occasionally been higher due to power failures and interception of additional ground water. Discharge to Pace Creek from the Pace Canyon Fan portals can also average as much as 700 gpm. Both discharge rates vary according to the volume of intercepted water, holding capacities within the sumps and gobs, and power availability.

Water discharged from the mine to both Dugout Creek and Pace Creek must be compliant with the limits of the mines UPDES permit. The mine has a limit of one ton per day of Total Dissolved Solids (TDS) as part of its UPDES permit. Dugout frequently cannot meet this limit and has entered into an agreement with the Utah Division of Water Quality to participate in a salinity reduction program within the Price River drainage. The agreement allows the mine to discharge additional tons of TDS provided the mine continues to participate in the salinity reduction program. The program was initiated in 2005 and will continue through at least 2013. Tons of TDS discharged from the mine has averaged between approximately one and nine tons per day.

2.5.2.2 Methane Extraction

Certain areas of the Dugout Mine contain methane gas. The gas is typically encountered at the mining face during both development and longwall mining. Methane gas is also released in the gob. To help reduce the volume of methane within the ventilation system of the mine, numerous methane drainage wells have been drilled and completed from the surface to above the coal seam in the developed longwall panels. The wells typically drain methane after the longwall has passed the well location. The methane drainage wells are operated until the methane concentration drops to a minimal level. The wells are then often shut in or abandoned.

Mining operations also have encountered hydrogen sulfide gases but not in the concentrations that methane gas has been encountered. Both the methane and hydrogen sulfide gasses appear to increase in volume as the depth of cover over the mined seam increases.

2.6 GEOLOGIC SETTING

2.6.1 GEOLOGY

The geologic setting of the Dugout Canyon Mine is discussed in some detail in Chapter 6 of the M&RP. The original PHC briefly describes the geologic setting of the Soldier Canyon. Other than the description of the physical location of that mine, the general description can be applied to some extent to the Dugout Canyon Mine.

2.6.2 BEDROCK FORMATIONS

No Changes Made

2.6.3 GEOLOGIC STRUCTURE

Bedrock in the Dugout Canyon Mine generally dips to the north-northeast at an average of 8 degrees. Normal faults do occur in the mine area but typically have throws measured in feet and not tens of feet. Most faults encountered underground have little or no obvious surface expression. A few faults encountered underground have produced water from the floor and roof. Typically, the flow from the roof will diminish significantly over a short period of time while flow from the roof will also diminish but may persist for several months or even years.

Fractures are also encountered during the mining process and some can produce water similar to the faults. The majority of both the fault and fracture systems trend northwest to southeast. A few fractures and faults trend east west in the Pace Canyon area.

2.6.4 PHYSIOGRAPHY

The description contained in the original PHC is adequate for the Dugout Canyon Mine. The same elements exist both at the Soldier Canyon and Dugout Canyon Mines.

2.7 HYDROLOGY

2.7.1 CLIMATE

This section of the original PHC is adequate to describe the general climate of the Dugout Canyon Mine area.

2.7.2 HYDROLOGY

As described in the original PHC, Dugout Canyon Mine is located within the Price River Drainage. It currently operates with in the Dugout Canyon, Pace Creek, Fish Creek, and Pine Creek drainages that are tributary to the Price River drainage. The 240 acre expansion will result in the mine operating within small portions of the unnamed tributary (Section 17) of Cow Canyon a tributary to Nine Mile Canyon. Both the Price River and Nine Mile drainages are tributary to the Green River.

The general description of the function and water chemistry of the ephemeral, intermittent, and perennial streams in this section of the original PHC is adequate to describe the conditions within the existing permit area. While the 240 acre expansion includes a small portion of the Cow Canyon drainage, the mining and related minor amounts of subsidence will not occur under or near perennial streams. The segments of drainages that will be undermined are ephemeral in nature. No significant surface disturbance that would impact the drainage are planned, except a pad for the drilling of a methane drainage well(s). Ground water samples have been obtained from a few springs within the drainage and are described in Section 2.8.2 of this addendum.

2.8 HYDROGEOLOGY

No Changes Made

2.8.1 CHEMICAL EVOLUTION OF GROUND WATERS

No Changes Made

2.8.2 DESCRIPTION OF GROUND WATER SYSTEMS

This update to the PHC will concentrate on the physical characteristics of the spring locations and the flow volumes discharging from the springs associated with the Dugout Mine area. Since most of the monitored springs are currently located outside of the mining area, flow rates where chosen to be the parameter that would most likely be impacted by mining activities. The general water chemistry of the monitored springs has not significantly changed since monitoring began.

Perched Groundwater Systems

A general discussion of perched groundwater systems in the Colton, Flagstaff, North Horn, Price River, and the Castlegate Sandstone formations, follows.

The nature and occurrence of groundwater systems in the Wasatch Plateau and Book Cliffs coal fields are described in a Geological Society of America Bulletin publication (Mayo et al., 2003). The Dugout Canyon Mine permit and adjacent area is included in the study area for this publication. This publication describes active and inactive groundwater flow systems in stratified mountainous terrains. Mayo et al. describe groundwater systems in the Dugout Canyon Mine area as occurring in one of two fundamental groundwater flow regimes. These include "active" groundwater flow systems, and "inactive" groundwater flow systems. Active zone groundwater flow paths are continuous, and responsive to annual recharge and climatic variability. Active zone groundwater systems support springs discharging at the surface in the area. Inactive zone groundwater systems have extremely limited or no communication with annual recharge. Inactive zone groundwater systems may be partitioned, occur as discrete bodies, and may occur in hydraulically isolated regions that do not have hydraulic communication with each other (Mayo et al, 2003; See also Mayo and Morris, 2000).

In the vicinity of the Dugout Canyon Mine, discharge of groundwater from geologic formations overlying mining areas occurs primarily from localized perched groundwater systems (See Appendix 7-3 for further information on shallow groundwater systems). Perched groundwater systems in the near-surface bedrock formations overlying the Dugout Canyon Mine (including the region near the permit expansion area) were noted by Waddell et al. (1986). It is noteworthy that Waddell reports perched groundwater systems encountered in some drill holes, while perched groundwater systems were not encountered in some other nearby drill holes (See Figure 19 in Waddell et al., 1986). This condition demonstrates the lack of lateral continuity in the local perched groundwater systems present in the area and also highlights the fact that meaningful potentiometric surface maps cannot be constructed for these isolated perched groundwater systems.

The presence of local perched groundwater systems overlying unsaturated strata and the hydraulic disconnect between the shallow perched groundwaters and the deep Blackhawk Formation groundwater systems encountered during mining operations is fundamentally the result of the heterogeneity of the rock sequence in the region (Mayo et al, 2003). The flow of bedrock groundwater in quantities sufficient to support discharge to springs occurs primarily within permeable sandstone strata. Groundwater flow along fault planes, bedding planes, and through rocks with fracture-enhanced permeability also occurs locally. In the rock sequence overlying the Dugout Canyon Mine area, the permeable sandstone units commonly exist as discontinuous sandstone paleochannels. Annotated photographs showing sandstone fluvial channels in the Colton Formation near Colton, Utah are presented in Figures X and Y. Also shown on Figures X and Y are the fine-grained sediments with lower hydraulic conductivities that encase the more permeable sandstone rocks in the fluvial channels. Because of the depositional environments in which these rocks were formed, the fluvial sandstone paleochannels are commonly encased both vertically and horizontally by low-permeability rocks (shales, mudstones, and claystones; Mayo et al., 2003). Although the permeability of individual sandstone bodies may be of aquifer quality, the overall ability of these rocks to transmit water horizontally over great distances is low because of the discontinuous nature of the sandstones (Mayo et al., 2003). The surrounding low-permeability rocks impede the outward migration of groundwater from permeable strata both vertically and horizontally. The abundant presence of low-permeability strata in the rock sequence, and the discontinuous character of permeable strata prevent the appreciable downward migration of groundwater from the perched systems into deeper horizons (or into the underground mine environment; Mayo et al., 2003). As indicated in Appendix 7-3 and based on drilling data (Appendix 6-1 and 7-4), large portions of the rock sequence overlying mining areas in the Dugout Canyon Mine area do not appear to be fully saturated in the vicinity of the Dugout Canyon Mine.

Unlike the Colton, Flagstaff, North Horn, and Price River formations, which consist largely of low-permeability rocks with interbedded sandstone strata, the Castlegate Sandstone in composed primarily of sandstone rocks. However, for several reasons, large aquifers do not form in the Castlegate Sandstone. The Castlegate Sandstone is not a uniform sand deposit. Rather, interbedded with the lenticular fluvial braided sandstone horizons are repeating sequences of mudstone drapes or depositional bounding surfaces (Mayo et al., 2003). The permeabilities of the mudstone drapes are typically many times lower than that of the surrounding sandstone. Consequently, although portions of the Castlegate Sandstone are sufficiently permeable to facilitate groundwater flow, the interbedded mudstones drapes partition and isolate these sandstone units such that the overall ability of the formation to transmit water both laterally and vertically over significant distances is poor (Mayo et al., 2003). Where Castlegate Sandstone discharge is present, it is most commonly associated with the presence of fracturing or jointing. Additionally, the potential for recharge to the Castlegate Sandstone is low. The pervasiveness of low-permeability strata in the geologic formations overlying the Castlegate prevents appreciable recharge to the formation from vertical leakage from the overlying formations. Additionally, because of the limited surface exposure of the Castlegate Sandstone in the area, the potential for groundwater recharge directly onto the Castlegate is low. As discussed above, the observation that the Castlegate Sandstone does not support many springs in the region and that much of the formation was dry when drilled supports these conclusions (See drilling data in Appendix 6-1 and Appendix 7-4). Because geologic and hydrogeologic conditions in the Castlegate Sandstone in the proposed expansion area are believed to be very similar to those in surrounding areas in the Book Cliffs coal field, it is considered probable that the hydrogeologic behavior of Castlegate Sandstone groundwater systems in the proposed expansion area will be consistent with the Castlegate Sandstone groundwater flow conditions described regionally by Mayo (2003).

It should be noted that although there appear to be large areas of unsaturated low-permeability rock surrounding the perched groundwater systems, saturated low-permeability strata are likely also present locally in the rock sequence. However, the rate of movement of water in the low permeability strata is commonly several orders of magnitude less than that in the permeable sandstone horizons (Mayo et al., 2003; Waddell, 1986). Consequently, groundwater in these horizons likely exists mostly under relatively stagnant conditions and is not of much consequence to the hydrologic balance.

The shallow, perched groundwater systems in the Dugout Canyon Mine area are likely recharged where the up-dip ends of the sandstone beds or fractured bedrock strata are exposed at the land surface in wet areas, or where the beds are directly overlain by water-bearing alluvial or colluvial sediments. Recharge to the sandstones from overlying saturated shallow fractured bedrock may also occur. Recharge to the sandstone strata via direct vertical leakage from overlying, competent, low-permeability strata is probably low (Waddell, 1986).

Discharge rates from shallow, perched groundwater systems overlying mining areas in the Dugout Canyon Mine generally exhibit both seasonal and climatic variability (see Appendix 7-3 and flow information submitted to the Division's online hydrology database). Most springs discharging from perched systems respond rapidly to the annual snowmelt recharge event, followed by a rapid waning of discharge rates later in the year. These conditions are indicative of shallow groundwater systems that are in good hydraulic communication with shallow, active recharge sources (i.e., active zone groundwater systems). These conditions are not commonly observed in springs discharging from large aquifers with large storage volumes (Waddell, 1986).

Groundwater flow directions in the perched groundwater systems are constrained largely by the geometry of the permeable sandstone strata through which the groundwater is conveyed. In the general sense, it may be stated that perched groundwaters flow from up-dip recharge areas to topographically lower discharge areas. However, because the sinuous geometries and subsurface locations of individual three-dimensional sandstone paleochannels (or other fractured or permeable strata) are difficult to delineate in the subsurface, the determination of concise groundwater flow directions within these bodies is problematic.

Discharge from the perched groundwater systems commonly occurs where the down-dip ends of the permeable sandstones or bedrock fractures or bedding planes intersect the land surface (Waddell, 1986; Mayo et al., 2003). In some localities, the presence of bedrock fracturing or jointing within sandstone channels enhances the hydraulic conductivity locally. It is not uncommon for the spring discharge locations from perched groundwater systems to coincide with the occurrence of local bedrock fracturing (Mayo et al., 2003). Where fracturing of the bedrock is present at groundwater discharge locations, spring discharge locations are commonly focused into discrete spring locations rather than as diffuse seepage through porous rock.

Potentiometric Surface Maps

A fundamental assumption underlying the construction of a potentiometric surface contour map is that there is a continuously saturated, interconnected aquifer that is present over a substantial aerial extent. Because there are no identified aerially extensive groundwater regimes in the strata overlying coal mining areas in the Dugout Canyon Mine area (See Appendix 7-3), and the probable lack of connection between the individual small perched groundwater systems, it is not possible or scientifically correct to draw potentiometric surface contour maps for these groundwater systems at a reasonable scale. While potentiometric surface contour maps of individual small, perched groundwater systems could conceivably be created at a local scale, it would be impractical and of limited value to do so. Consequently, potentiometric surface contour maps depicting groundwater conditions cannot be presented here.

Delineation of Likely Recharge Areas for Springs in the Expansion Area

While it is not possible to precisely delineate the recharge areas for individual springs using the existing hydrogeologic data, a determination of the most probable recharge area is possible using existing geologic, hydrogeologic, and topographic information. A discussion of the most probable recharge areas for springs in the expansion area is presented below.

Two springs (260 and 260A) have been identified within the boundaries of the expansion area that has the possibility of being impacted by subsidence. The Division of Water Rights (DWRi) has indicated two other springs are located in the eastern portion of Section 17, T 13 S R 13 E and within the permit expansion area. However, these springs were not found in the original seep and spring survey or subsequent surveys. Dugout has committed to take the water right owners to the DWRi mapped locations to verify whether or not these springs do indeed exist.

A few other springs, 261, 262, 262A, 263, 263A, have been identified in the nearby surrounding areas outside the permit area. These springs are outside the area where subsidence would potentially occur and are separated from the underlying coal seams by more than 2,000 feet of cover. Mining impacts to the recharge area of these springs will only occur in a very small portion of the recharge area and will likely be similar to spring 260. Because of this, the impacts to the springs outside the permit and subsidence area have not been considered individually. The potential for impacting these springs is considered negligible.

Spring 260 is part of the mine's water monitoring program and thus has several years of data that can be analyzed. Spring 260A is not part of the water monitoring program. Both springs appear to discharge from the same shallow groundwater system as they are in close proximity to one another and discharge at similar elevations. Therefore, it is assumed that mining induced impacts to these two springs would be similar in nature.

Spring 260 discharges from the east side of the canyon wall near the bottom of the local surface-water drainage. The spring discharges from the Colton Formation at an elevation of about 8600 feet above sea level. Because groundwater must recharge in an area topographically higher than the spring discharge location in order to provide driving hydraulic head, the recharge area for the spring must lie at an elevation greater than 8600 feet. As shown in Figure 2 and Plate 7-1, areas higher than 8600 feet in elevation that could potentially be recharge areas for spring 260 are present in the region to the southeast of the spring and also in the region to the northwest of the spring. Both of these areas are situated along the crest of the Book Cliffs escarpment and are truncated on both the north and south by incised drainages and escarpments.

Because of the considerable discharge from spring 260, which averaged 20.0 gpm between 2000 and 2007, it seems unlikely that sufficient recharge to support the spring could occur on the small surface area situated on the very steep slopes of the south-facing Book Cliffs escarpment above an elevation of 8600 feet immediately south of the spring area (Figure 2). Rather, it seems more likely that the relatively flat and broad high-elevation plateau surfaces above 8600 feet as depicted on Figure 2 and Plate 7-1 could provide recharge in sufficient quantities to support the observed discharge at the spring.

The sedimentary rocks in the vicinity of the Dugout Canyon Mine area dip at about 8 degrees to the north-northeast (Appendix 7-3). The strike of the rock formations in the area is approximately coincident with the trend of the Book Cliffs escarpment. Similarly, most minor fracture orientations in the coal seams and in the adjacent rock formations trend in roughly the same direction as the strike of the Book Cliffs escarpment (Appendix 7-3). Assuming a primarily northerly component to the bedrock dip in the area, the high- elevation area situated to the southeast of the spring seems more likely to be the recharge area for spring 260 than the high-elevation area to the northwest. This conclusion is based on the assumption that most of the northwest area would be stratigraphically down-dip of the spring area. The observation that spring 260 emanates from the east side of the canyon seems to support this conclusion. Consequently, the area to the southeast of spring 260 at an elevation above 8600 feet and stratigraphically up-dip of the spring location is considered the most likely recharge area for the spring (Figure 2). While the maximum lateral extent of the recharge area from the spring discharge location is not known, an arbitrary (and likely conservative) estimate of about 1.6 miles is delineated on Plate 7-1 and on Figure 2.

It is interesting to note that the maximum possible depth of circulation for the groundwater system that supports spring 260 is less than about 350 feet (maximum topographic elevation in the probable recharge area minus the spring discharge elevation). This observation supports the conclusion that spring 260 originates from a shallow, perched groundwater system and not from a large aquifer of regional extent.

It should be noted that although the spring discharges from the east side of the canyon, it is possible that the sandstone channel or fracture network that focuses discharge to the spring is continuous on both the east and west sides of the canyon near spring 260. Consequently, it is possible that the groundwater recharge area could also include portions of the high-elevation region to the northwest of the spring depicted on Figure 2, although this is considered a less likely scenario.

Spring 261 discharges from near the bottom of the canyon a short distance north of the expansion area boundary. As discussed above, the potential for impact to this spring is considered negligible and consequently a delineation of a most probable recharge area for this spring has not been performed. However, it is likely that this spring, as well as other similar nearby springs, recharge by mechanisms similar to that at spring 260. Like spring 260, the springs further north in the unnamed tributary of Cow Canyon (springs 261, 262 and 262A, Section 17) are likely not recharged from infiltration on the steep slopes of the north facing slopes of the Book Cliffs escarpment. Again, similar to spring 260, these springs probably receive recharge from broad upland areas to the east-southeast.

Surface runoff from the majority of the land surface in the expansion area drains to the Cow Canyon drainage. Discharges from the localized perched Colton Formation groundwater systems in the vicinity contribute baseflow discharge to streams in the expansion area and sustain discharges in portions of the drainage during the summer and fall months and during wet years. During the spring snowmelt event and in response to torrential precipitation events, streamflow in the drainages are augmented by surface runoff. After the spring runoff season is complete, there is typically not a sufficient contribution of groundwater to the surface water systems and many reaches of the stream drainages in the expansion area are dry. There is no discharge from a regional type aquifer system to the stream drainages in the expansion area. Consequently, because impacts to the localized perched Colton Formation groundwater systems are not anticipated, detrimental impacts to baseflow in the stream drainages are likewise not anticipated.

As shown on Plate 5-7 in Chapter 5 of the M&RP, the projected magnitude of subsidence in the area of the unnamed tributary to Cow Canyon Drainage in T13S, R13E, Section 17 is small (<1 foot). The thickness of the overburden above the coal seam to be mined in the vicinity of the drainage exceeds 2,000 feet. Because of the minimal projected subsidence and the thick overburden, the potential for large subsidence cracks to form at the surface is considered low. While subsidence cracking can occur along escarpment margins where confining pressures are low, the potential for large aperture subsidence cracks to form in the bottom of the stream channel is considered very low because of the confining pressures of the surrounding rock strata. Consequently, the potential for diminution of stream flow in the unnamed tributary of Cow Canyon due to direct interception of stream water into open subsidence cracks in the channel bottom is considered low.

Additionally, based on “rule-of-thumb” estimates for the height of upward propagation of fracturing above longwall mined areas commonly utilized in Utah coal mining areas, it is likely that a thick sequence of unfractured rock strata will persist above longwall mined areas after subsidence in the area is complete. As a conservative estimate, assuming a mining height of 10 feet and a 50:1 upward fracture propagation height to mining height ratio, it is estimated using these assumptions that the fractures overlying longwall mined areas would extend upward about 500 feet. Above this interval, rock strata (particularly the fine-grained shaley strata) tend to deform ductilly (i.e., the rocks tend to bend rather than fracture). Based on visual inspection, it is commonly assumed that surface tension cracks that sometimes form at the land surface overlying longwall panels extend for only a few tens of feet below the land surface. Thus, it is estimated that there would likely be many hundreds of feet of in-tact rock strata overlying longwall mined areas with relatively uncompromised hydraulic properties which would minimize the potential for downward migration of fluids. Consequently, the potential for the loss of stream water in the unnamed tributary to the Cow Canyon drainage to deep strata or into the mine workings is considered remote.

As described above, the potential for significantly diminished discharge rates from the perched groundwater systems that support springs and provide baseflow to the unnamed Cow Canyon tributary in the proposed expansion area as a result of coal mining in the Dugout Canyon Mine is considered low. This is primarily because of the large thickness of overburden and the small projected subsidence magnitude in the area. Additionally, the abundant presence of low-permeability strata in the geologic sequence of the overburden minimizes the potential for downward migration of surface-waters or groundwaters into deeper horizons. Accordingly, the potential for impacts to baseflow in the unnamed Cow Canyon tributary as a result of mining activities is considered low.

2.8.2.1 Colton Ground Water System

The Colton Formation forms the plateau within the expansion area and contains the additional springs to be monitored as part of the expansion. The original text discusses two springs that have been evaluated in the Soldier Canyon area, G96 and #45. Two springs have been included in the Dugout Canyon Mine water monitoring plan and are designated as Springs SC-65 and 260. Figures contained in Attachment 2 illustrate the history of the flow monitored at springs SC-65 and 260. Spring SC-65 has been monitored since October 1995 while Spring 260 has been monitored since June 2000. Both springs and their recharge areas are located north and outside the areas that have been undermined and subsided by Dugout Mine. Both springs demonstrate seasonal flows. The variability of the flow from SC-65 appears to follow the pattern of drought and wet cycles as illustrated on the Palmer Hydrologic Drought Index figure included in Attachment 2. Flow from Spring 260 somewhat follows the cycle of drought and wet but not quite as clearly as SC-65.

Two new Colton springs have been added to the water monitoring plan for Dugout Mine. These two springs are 321 and 322. Spring 321 is located in the NE1/4 of Section 18 T13S R13E and Spring 322 is located in the NW1/4 of Section 22 T13S R13E. Both springs are located outside the area that is planned to be mined and subsided. Flows from these two springs were first gathered in May 2007 followed by measurements obtained in June, July, August, and October. Graphs of these flows are contained in Attachment 2. Measured flows appear to drop from a high following spring runoff to baseline conditions by August.

2.8.2.2 Flagstaff Ground Water Systems

The Flagstaff Formation is present in the Dugout Canyon area and in the 600 acre expansion. However, the formation thins to the east and eventually pinches out near the eastern portion of the mine permit area. Currently, the mine monitors two springs in the Flagstaff Formation, SC-100 and SP-20. Spring SP-20 was monitored briefly between June 1976 and October 1979. Monitoring of the spring was resumed in August 1997 and has continued through the present (October 2007). Spring SC-100 has been monitored since 1995 and continues to the present.

The graph of measured flow for SP-20 clearly demonstrates seasonal flows that are impacted significantly by drought and wet cycles. This spring is located outside the area that has been undermined by Dugout Mine. The recharge area for this spring is also likely to be outside the area affected by current Dugout mining operations.

Spring SC-100 is located upstream of the mine operations in the Dugout Creek drainage. It issues from the side of a stream bank near the bottom of the channel. According to water monitoring personnel, flows monitored between 1997 and 2002 may have included portions of the adjacent creek. Changes in the stream channel and spring discharge have allowed the flow of the spring to be monitored separately from the stream flow. The spring is located at least three fourths of a mile north of the current mine workings and is unlikely to have been impacted by mining operations.

No new monitoring sites are proposed for the Flagstaff Formation as part of the 240 acre expansion.

2.8.2.3 North Horn Ground Water Systems

Dugout Mine currently monitors five springs discharging from the North Horn ground water system. These springs are SC-14, SC-116, SC-200, SC-203, 259, and spring 259A. Graphs illustrating the flow of the springs are located in Attachment 2. SC-14 was monitored briefly between 1976 and 1979. Dugout mine started monitoring the flows again in 1995 and the monitoring has continued through at least October 2007. Flows from the spring appear be influenced by seasonal and climatic variations in precipitation. This spring is located north and west of the current Dugout Mine workings and flow data obtained from this spring does not indicate impacts due to mining.

Spring SC-116 flow was first monitored at this site in October 1995 with regular monitoring initiated in November 1998. This spring is located in a tributary to Pace Creek and overlies a longwall panel Dugout Mine is likely to mine in 2008-2009. Historical flows indicate ground water discharge volume from the spring is related to cycles of drought and wet. Between June 2001 and November 2004, flow volumes were less than 2 gpm. Through the wetter cycle of 2005, flows increased. Then in the drier period of 2006, the flows once again diminished.

Spring SC-200 is located in a tributary to Rock Creek and is located southeast of current mine workings. This spring typically has no flow or flows less than 1 gpm. The recharge area for this spring is likely located south and east of the current mine plan and is unlikely to be impacted by planned future mining. Lack of flow at this site makes it difficult to determine how it is impacted by changes in climatic cycles. This site is important, however, since it appears to be the only accessible and reliable source of ground water discharge in this drainage.

Spring SC-203 is located in Pace Canyon and is east and outside of current and future mine workings. It is a developed spring that is used to water cattle. The flow graph of the spring illustrates flows typically between 2.5 and 5 gpm with occasional flows slightly less or greater. Flow was measured in the spring of 2003 at more than 20 gpm but that rate appears to be anomalous to other recorded flows. Spring flows do not appear to typically be impacted by climatic changes.

Spring 259 is associated with a slump in a side drainage of Pace Canyon. In 2002, the monitored discharge location moved as a result of renewed slumping. Monitoring of the original discharge point was continued even though groundwater no longer discharged from this location. The ground water currently discharges from a point a few hundred feet downstream of the original monitoring point. The slump was probably reactivated as a result of saturation from natural causes. Ground water continues to flow from the as reported through field observations noted by personnel monitoring the original site. A new monitoring point, 259A, was added to the monitoring program in July of 2007. This spring has been developed by the landowner for livestock watering and is located upstream of 259 and outside the slump area. Previous measurements of the discharge rates obtained in 2006 indicate the flow in early spring was about 1 gpm. The spring flows decrease by fall to approximately 0.25 gpm. In the 2007, the spring flows gradually deceased through the summer and by September, the flow essentially ceased. This spring and its recharge area have not been subsided to date. However, the area may be subsided in 2008.

2.8.2.4 Price River Ground Water System

The text of the original PHC includes the Castlegate Sandstone within the Price River Formation. For purposes of this text, the Castlegate Sandstone will continue to be included as part of the Price River Formation.

During early baseline studies of the Dugout Mine area two springs were reported to discharge from the Price River Formation, springs SC-80 and 227. Spring SC-80 was initially intended to be included in the mine ground water monitoring plan. However, subsequent visits to the site resulted in no spring being found. Therefore, the site was not added to the plan. Spring 227 has been monitored since 2000 but no flow has yet to be observed discharging at this location. The lack of flow is not surprising based on the data and observations presented in the original PHC.

2.8.2.5 Blackhawk Ground Water Systems

2.8.2.5.1 Springs

No Changes Made

2.8.2.5.2 Blackhawk Formation Wells

The format of the original PHC included most of the ground water wells in the Soldier Canyon Mine and Dugout Mine area within this section. However, several of the wells are completed in formations other than the Blackhawk. Two ground water wells in the immediate area of the mine are included in the Dugout Mine water monitoring plan. These two wells, GW-10-2 and GW-11-2, are located north and down dip of the current Dugout Mine workings.

The water level in GW-10-2, which is completed in the Castlegate Sandstone, has been monitored since June of 1987 as reported in the original PHC. Depth to water was initially 716.0 feet. Water level data presented in the original PHC indicate the level in the well more or less was dropping between June 1987 and May 1995. The last reading obtained in 1985 indicated a water level 726.5 feet below top of casing. Dugout Mine began reporting water levels in March 1998 when the water level was measured at 732.0 feet below top of casing. Data collected by the mine indicates the water level has continued its general decline to a low of 745.0 feet below top of casing in May 2007

(See graph in Attachment 3).

As discussed in the original PHC, the cause for the decline in water level is unknown. The relatively steady rate of decline of the water level in the well does not appear to be relatable to the timing of underground mining and subsidence at the Dugout Canyon Mine. The rate of decline before mining appears to have continued after mining at Dugout commenced.

The water level in GW-11-2, a well completed in the Price River Formation, has been measured by Dugout Mine since August 1997. An earlier measurement, November 4, 1982, presented in the original PHC indicates the water level in the well to be 1127.39 feet below the top of casing. Dugout Mine's first reported water level on August 27, 1997 indicates the water level was 1120.90 feet below top of casing. By June 30, 1998 the water level had dropped to1128.5 feet below top of casing. It remained within a few feet of that level until June 15, 2006 when the water level was measured at 1116.17 feet below top of casing. The cause of the fluctuations in the water level of about 12 feet is unknown.

<u>Soldier Canyon Mine</u>

The Soldier Canyon Mine was idled in 1998. The portals were temporarily backfilled with soil and mine water discharge ceased. No water has discharged from the mine since the portals were sealed.

<u>Dugout Canyon Mine</u>

Water is collected in the Dugout Mine from numerous roof drips, fractures and faults. Currently, the highest volume of water entering the mine appears to discharge from intercepted fractures and faults with minor offset. The majority of the water discharging to the mine from the fractures and faults flows up through the floor. Overall rates of inflow of ground water to the mine also increase, independently of the fracture flow, as longwall panels are mined. Often longwall mining will intercept isolated aquifers above the roof of the mine that discharge water at a few tens to a few hundred gallons per minute after the coal has been removed. The flows associated with these isolated aquifers typically are short lived and either cease flowing altogether or significantly diminish in rate. Inflows from faults or fractures also diminish over time but at a much slower rate.

The ground water entering the mine is managed through as series of sumps that include flooded gob and abandoned workings. Discharge rates have changed throughout the years since the mine opened in 1998. From 1998, all of the water discharged from the mine was directed into Dugout Creek. Overall, between 1998 and September 2007, the average discharge rate from the mine to Dugout Creek has increased from a few gpm to over 1200 gpm. Beginning in July of 2007, a portion of the mine water has been discharged to Pace Creek through the Pace Canyon Portals. Discharge to Pace Creek from the Pace Canyon Fan portals can also average 700 gpm or more. Both discharge rates vary according to the volume of intercepted water, holding capacities within the sumps and gobs, and power availability.

It is important to note that before the construction of the Dugout Canyon Mine, two abandoned mine workings within the Gilson Seam were flooded to near the mouth of their old portals. In fact, the old Gilson workings on the east side of the canyon actually discharged water at the surface at a few gallons per minute to Dugout Creek. These workings were eventually drained by the mine for use as a sump. The flooded old Gilson seam workings on the west side of the canyon has also been used as a sump by the Dugout Canyon Mine.

2.8.2.6 Star Point Sandstone Ground Water System

As was observed and reported in the original PHC, no springs had been found discharging from the Star Point Sandstone in the Soldier Canyon and Dugout Canyon Mine areas. However, subsequent field studies found one spring, SC-64, that may be related to the Star Point Sandstone. This spring, however, is not part of the monitoring plan. Two samples were obtained from the site and field parameters were measured. The samples indicate the water has a slightly alkaline pH (7.5) and relatively high specific conductance (1011 -1112 mmho)

2.8.2.7 Mancos Shale Ground Water System

No Mancos Shale ground water discharge has been observed in the Dugout Mine permit area. As noted in the original PHC, typical TDS concentrations of water associated with the Mancos Shale are about 10,000 mg/L. Water this brackish has not been found within the mine therefore suggesting water sources discharging to the mine are unlikely to include the Mancos Shale.

3.0 PROBABLE HYDROLOGIC CONSEQUENCES

This section contains a description of the probable hydrologic consequences of operating the Dugout Canyon since 1997 and the additional 240 acres to be added to the mine area in 2008. The consequences are based on the observations and conclusions of the original PHC, observed reactions of surface and ground water to mining at Dugout Canyon Mine since 1997, and projected future potential impacts to these water systems due to mining.

3.1 POTENTIAL ADVERSE IMPACTS TO THE HYDROLOGIC BALANCE (728.310)

Coal mining has the potential to impact the hydrologic balance by:

1. Decreasing creek flows and spring discharges by capturing surface or other ground waters,
2. Increasing creek flows and spring discharges by increasing discharge rate of ground water from the Blackhawk ground water system, and
3. increasing ground water recharge rates to overlying ground water systems.

3.1.1 Potential for Decreasing Creek Flows and Spring Discharges

Coal mining has the potential to decrease creek flows and spring discharges by capturing water from these sources as a result of mine related subsidence, bedrock fracturing, and aquifer dewatering.

Decreasing Creek Flows

Generally, since subsidence began at the Dugout Canyon Mine, surface tension cracks have been noted in limited locations, typically on canyon rims that have been undermined. On the surface of the plateau overlying the mine and at the base of the drainages that bifurcate the plateau, cracks have been noted in the soils and alluvium covering bedrock. However, these cracks soon naturally heal and are no longer obvious. Surface runoff continuously entering subsidence cracks has not been observed in this area. Graphs illustrating the monitored flow volumes of the surface drainages in the Dugout Creek Mine area are included in Attachment 4.

Four surface water monitoring points have been established to record, on a quarterly basis, the flows in the Dugout, Pace, and Rock Canyon Creeks. DC-1 is located in the main stem of Dugout Creek below the mine site. DC-2 is located in the Left Fork just upstream of the mine site. DC-3 is located in the Right Fork just upstream of the mine site. Additionally, DC-4 and DC-5 have been established in the Left Fork of Dugout Creek and are monitored on a five year basis at permit renewal. Site PC-1A is located on Pace Creek upstream of currently planned mining activity and at the eastern permit boundary. PC-2 is located on Pace Creek downstream of planned mining activities and near the permit boundary. PC-3 is located in Pace Creek just downstream of the confluence of Pace Creek and an unnamed tributary in the south half of Section 20, Township 13 South, Range 13 East. This site was established in September 2007. RC-1 is located on Rock Creek downstream of any planned mining activities and near the southeastern boundary of the permit area (Plate 7.1 of the MRP).

The monitored flows within the Dugout Creek drainage system will be discussed first followed by Pace Creek and then Rock Canyon Creek flows. Dugout Canyon Mine has subsided minor portions of the Right Fork of Dugout Creek with single seam mining in the Gilson seam. As stated earlier, DC-3 was established to monitor flows in the Right Fork. A graph of the monitored flows at DC-3 between August 1997 and May 2007 is included in Attachment 4. The peaks that occur in 1998 and 2001 appear to be flows measured during spring runoff. A short segment of the Right Fork of Dugout Creek was subsided when coal was extracted from the Gil 2 panel in April 2005. Flows in the stream appear to be impacted more from natural wet and drought cycles than by mining subsidence. No extra ordinary decreases in flow in the Right Fork were noted after mining and subsidence occurred.

The Left Fork of Dugout Creek has not been subsided. Flows measured at DC-2 appear to follow the drought-wet cycles noted in the Palmer Hydrologic Drought Index for this area.

The graph of Dugout Creek at site DC-1, which is located downstream of the mine, also does not show an abrupt change in flow volume at the time of subsidence in the Right Fork. However, it is important to note, the flow volume of Dugout Creek downstream of the mine is impacted by discharge from the mine to the creek at a point upstream of DC-1. Discharge from the mine began in March 2002.

Flows in Pace Creek have monitored on a quarterly basis at PC-1A and PC-2 since September 1999 and June 2000, respectively. Flow data was also collected at PC-2 from April 1978 to October 1979. Mining has not occurred upstream of PC-1A and no flow impacts from mining subsidence are anticipated. Flow measured at PC-2 also does not appear to have decreased as a result of mining and subsidence in the area. Mining and subsidence did not occur in the area upstream of this monitoring point until May 2005. Flows in Pace Creek at PC-2 currently appear to be controlled by the cycles of wet and drought. PC-3 was established at the time of the writing of this update and data will be collected at this site beginning in 1st quarter of 2007.

The flows in Rock Canyon Creek are monitored at site RC-1. The graph of the flows at site RC-1 illustrates the creek seldom contains water at this point. In fact, flows are typically seen in the creek bed at this site during significant snow melt runoff or after heavy precipitation events. No portions of the creek are currently planned to be subsided.

Surface runoff from the majority of the land surface in the expansion area drains to the Cow Canyon drainage. Discharges from the localized perched Colton Formation groundwater systems in the vicinity contribute baseflow discharge to streams in the expansion area and sustain discharges in portions of the drainage during the summer and fall months and during wet years. During the spring snowmelt event and in response to torrential precipitation events, streamflow in the drainages are augmented by surface runoff. After the spring runoff season is complete, there is typically not a sufficient contribution of groundwater to the surface water systems and many reaches of the stream drainages in the expansion area are dry. There is no discharge from a regional type aquifer system to the stream drainages in the expansion area. Consequently, because impacts to the localized perched Colton Formation groundwater systems are not anticipated, detrimental impacts to baseflow in the stream drainages are likewise not anticipated.

As shown on Plate 5-7 in Chapter 5 of the M&RP, the projected magnitude of subsidence in the area of the unnamed tributary to Cow Canyon Drainage in T13S, R13E, Section 17 is small (<1 foot). The thickness of the overburden above the coal seam to be mined in the vicinity of the drainage exceeds 2,000 feet. Because of the minimal projected subsidence and the thick overburden, the potential for large subsidence cracks to form at the surface is considered low. While subsidence cracking can occur along escarpment margins where confining pressures are low, the potential for large aperture subsidence cracks to form in the bottom of the stream channel is considered very low because of the confining pressures of the surrounding rock strata. Consequently, the potential for diminution of stream flow in the unnamed tributary of Cow Canyon due to direct interception of stream water into open subsidence cracks in the channel bottom is considered low.

Additionally, based on "rule-of-thumb" estimates for the height of upward propagation of fracturing above longwall mined areas commonly utilized in Utah coal mining areas, it is likely that a thick sequence of unfractured rock strata will persist above longwall mined areas after subsidence in the area is complete. As a conservative estimate, assuming a mining height of 10 feet and a 50:1

upward fracture propagation height to mining height ratio, it is estimated using these assumptions that the fractures overlying longwall mined areas would extend upward about 500 feet. Above this interval, rock strata (particularly the fine-grained shaley strata) tend to deform ductilly (i.e., the rocks tend to bend rather than fracture). Based on visual inspection, it is commonly assumed that surface tension cracks that sometimes form at the land surface overlying longwall panels extend for only a few tens of feet below the land surface. Thus, it is estimated that there would likely be many hundreds of feet of in-tact rock strata overlying longwall mined areas with relatively uncompromised hydraulic properties which would minimize the potential for downward migration of fluids. Consequently, the potential for the loss of stream water in the unnamed tributary to the Cow Canyon drainage to deep strata or into the mine workings is considered remote.

As described above, the potential for significantly diminished discharge rates from the perched groundwater systems that support springs and provide baseflow to the unnamed Cow Canyon tributary in the proposed expansion area as a result of coal mining in the Dugout Canyon Mine is considered low. This is primarily because of the large thickness of overburden and the small projected subsidence magnitude in the area. Additionally, the abundant presence of low-permeability strata in the geologic sequence of the overburden minimizes the potential for downward migration of surface-waters or groundwaters into deeper horizons. Accordingly, the potential for impacts to baseflow in the unnamed Cow Canyon tributary as a result of mining activities is considered low.

As described in the original PHC, the water intercepted underground during mining is likely moving north toward the Uinta Basin and eventually toward the Green River. The mine is currently removing only a small portion of the ground water contained in the overall regional system that would discharge to the Green River. Once mining is complete, it is likely the mine workings will flood to an elevation at or slightly below the mine portals, similar to the flooding of the old Gilson workings located in Dugout Canyon. Ground water in the Dugout Mine area will continue to migrate north and down dip toward the Uinta Basin.

<u>Decreasing Spring Flows</u>

As described in preceding sections of this PHC Update, flows in monitored springs do not appear to have been measurably decreased by mining activities. Two spring monitoring sites have recorded changes in flows: spring SC-100 as erosion has moved the stream channel away from the ground water discharge point allowing more accurate flow measurements and spring SC-259 as a result of reactivated movement of the slump from which is discharges. Neither of these two springs have been subsided nor has their likely recharge areas. Spring 227 was undermined in April 2007 but flow records of this spring indicate it is typically dry.

Mining will include subsiding springs in the Pace Canyon, Dugout Canyon, and Cow Canyon drainages (Plate 7.1 of the PHC). The majority of these springs are located in the same drainages as monitored springs. The potential exists that flow from these springs may be decreased for a short period of time or their discharge points moved. The springs generally discharge from the North Horn, Flagstaff or Colton Formation. The depth of cover between the spring discharge locations and their recharge area and the mine workings themselves exceed at least 1000 feet. While subsidence fracturing associated with mining at these depths does occur at the surface, it typically has not resulted in creating pathways from the surface to the mine workings. Typically, surface cracks only extend a few tens of feet into the bedrock before attenuating. Below that depth, the bedrock will typically react more plastically and bend, rather than break, as the ground over the mine longwall panels subside. The North Horn, Flagstaff, and Colton Formations contain significant beds of fine grained material, such as shale, siltstone, and claystone that will tend to heal if fractured. This healing process would likely stop or restrict rapid downward migration of water either from the surface or from aquifers.

Subsidence of a portion of the aquifers that feed these springs may cause recharge to temporarily "pool" in the subsided portion, thus temporarily decreasing discharge. Surface cracking of the aquifer may also result in the discharge point of the spring moving either laterally or vertically downward a few feet. While this phenomenon has not been noted in this area, it has been observed at other mine sites within the Book Cliffs area and the Wasatch Plateau. However, it is not anticipated there will be a loss of water to the Pace Canyon drainage system.

Springs within the Dugout Canyon drainage that may be undermined discharge from either the North Horn or Flagstaff Formations. As with the springs located in the Pace Canyon drainage, decreased flow or changes in discharge locations are possible. However as discussed in the preceding paragraphs, permanent decreases in flow volumes are unlikely and over all discharge of ground water volumes in the drainage are unlikely.

Several springs discharge from the Colton Formation north and east of the current permit area and the 240 acre expansion area within the Cow Canyon drainage. Spring 260 is currently part of the Dugout Canyon Mine water monitoring program. The monitored flows are included in graphic form in Attachment 2 of this document. Discharges of this flow show a strong relationship to seasonal variations in precipitation. The springs in the Cow Canyon drainages appear to be stratigraphically controlled. That is, they appear to discharge at the down dip end of an exposed stratigraphic unit within the Colton Formation. Because the Colton Formation contains interbedded sandstones, siltstones, and shales, it is likely these springs discharge at the base of a sandstone overlying a less permeable unit such as shale or siltstone. This observation is generally supported by the topography of the spring areas. The springs appear to discharge at a break in topography where there is change from a relatively steep slope to a more gentle slope. There is also a potential for some of the springs to be both stratigraphically and structurally controlled. In other words, the springs discharge from a fracture within a permeable layer overlying a less permeable layer. Unfortunately, the thick soil mantle in the area precludes observation of structure near the discharge location.

Mining in the northeastern most portion of the permit area and within the 240 acre expansion area could decrease flows at or alter the discharge location for spring 260 and 260A. It appears the recharge area for these springs is to the south/southeast and overlies a small portion of one panel. However, interruption of spring flow volume would likely be short-lived. Where Dugout Mine has designed longwall panels separated by thick barrier pillars, surface expressions of subsidence have been much less than where barrier pillars are not left in place. Projected surface subsidence at the spring locations is likely to be less than one feet. The recharge area is more than 2000 feet above the projected mine workings. Any interruption of flow would likely be temporary as the subsidence created low areas within the aquifer itself filled with recharge. Because of the fine-grained nature of the bedrock units, diversion of water from the aquifer into underlying bedrock units is unlikely. If the spring discharges are also structurally controlled, new surface fractures related to subsidence may move the springs a few tens of feet either laterally or vertically. Overall, continued flow from the springs will continue to enter the Cow Canyon drainage.

Two new springs will be added to the Dugout water monitoring plan, 321 and 322 (Plate 7.1 of the MRP). Spring 321 is located north east of 260 in a small tributary to Cow Canyon. Spring 322 is located southeast of 260 and 321 in a tributary drainage of Cow Canyon. Tributary containing 322 runs roughly parallel to the tributary that contains 260 and 321. Some development work has been performed at spring 321. Both springs are outside of the area to be subsided. Since all of the springs, with the exception of 260 and 260A, within the Cow Canyon drainage lie outside of the area to be mined and subsided, and the limited portions of the recharge area for the majority of the springs will be subsided, it seems unlikely a decrease in ground water discharge will occur. Also, it is unlikely discharge points will move for these springs as a result of mining.

3.1.2 Potential for Increasing Creek Flows and Spring Discharges

Increasing Creek Flows

Dugout Canyon Mine discharges mine water to both Dugout Creek and Pace Creek at permitted UPDES discharge points. Increases in stream flows are likely to be limited to Dugout Creek and Pace Creek, the mine has no other discharge points planned at this time. In the original PHC, Mayo and Associates estimated the maximum ground water discharge rate from Dugout Canyon Mine would be approximately 800 gpm. That estimate was based on the assumption that Dugout Canyon Mine would produce about 1.0 million tons of coal per year. However, the mine has produced and currently is planned to produce between three and four million tons per year. That is three to four times the initial rate of production described in the original PHC.

In the summer of 2007, the Dugout Canyon Mine has discharged at a rate between1900 and 2800 gpm through its UPDES discharge points. The rate at which the mine discharges water is based upon the volume of water intercepted, water contained in the sumps and old workings, and the reliability of electrical power delivered to the mine. Early in the mining of the Rock Canyon and Gilson seams, ground water generally discharged from perched aquifers encountered in the Blackhawk Formation. As mining has progressed down dip, water discharging from fractures encountered in the mine floor, and to a lesser degree the mine roof, have become more prominent. It is estimated that more than half the total inflow to the mine is currently associated with flows moving through fractures or faults.

For the next several years as mining progresses north and down dip in the coal seams and deeper into the potentiometric surface of the underlying aquifers that discharge through the floor of the mine, inflow rates are likely to increase. However, as mining is then shifted to the southeast portion of the permit area (between Pace and Rock Canyons) and up dip in the coal seams, inflow rates from sources below the mine will likely be much less. Inflows to the mine at that time will be more likely dominated by inflows from isolated perched aquifers in the overlying Blackhawk Formation.

Increasing Spring Flows

Temporary increases of spring flows may be noted as the aquifers are compressed during subsidence. This is typically a transient phenomenon that ceases once the compressive and tensional forces within the subsided bedrock become static. In a few cases, spring flows may experience more long term increases if fracturing in the aquifer allows additional stored ground water to discharge at the spring location.

3.1.3 Potential for Increasing the Ground Water Recharge to Overlying Ground Water Systems

No Changes Made

3.2 IMPACTS OF PROPOSED COAL MINING AND RECLAMATION OPERATION (728.330)

3.2.1 Whether Acid-forming or Toxic Forming Materials Are Present that Could Result in the Contamination of Surface or Ground Water Supplies (728.331)

The original PHC did not anticipate the construction, operation, reclamation of the Dugout Wasterock Site. However, subsequent revisions to the permit addressed the probable hydrologic consequences of creating the wasterock site. This issue is addressed in the document attached to the MRP titled "Refuse Pile Amendment, February 2003".

The remainder of this section has not been changed.

3.2.2 Impact on Acidity, Total Suspended and Dissolved Solids and Other Important Water Quality Parameters of Local Impact (728.332)

Mining in the Dugout Mine area should not affect the water quality of adjacent ground waters or springs since the ground water system in the mine layers is locally compartmentalized both vertically and horizontally.

Total Suspended Solids (TSS) above background concentration may increase in areas where road building or facilities construction may occur. Additionally, where subsidence occurs, down cutting may result and increase sediment load in the stream flow. It is also likely that subsidence will result in low areas where deposition of sediments will occur. TSS measured in the mine water discharge is typically at or near background levels.

Water discharged from the mine to Dugout Creek, and recently to Pace Creek, has contained total dissolved solid (TDS) concentrations ranging between 830 and 2440 mg/L. The concentration of TDS in the mine water is dependant upon the quality of the ground water encountered and residence time within the sumps and abandoned. It is apparent that the longer water is held underground in sumps and old workings, the higher the TDS values rise. Therefore, the mine has tried to balance the need for storage time to allow for the settlement of suspended solids while limiting the amount of time water stays in contact with the coal and overburden in the gob or abandoned flooded workings. Total iron concentrations in the water can either increase or decrease with the amount of oxygenation the mine water is subjected to or contact time the water has with exposed coal.

Initially in 2002 when mine water discharge began, Dugout mine discharged water with TDS concentrations between 1300 and 1500 mg/l at rates between 40 and 250 gpm with occasional higher spikes. Over time, the TDS concentration increased until the end of 2006. Since that time, discharge rates have nearly tripled but the TDS concentration has dropped to less than 1000 mg/l. The drop in TDS concentration is related in part to an increase in mine inflows and a reduction in residence time of the water.

The TDS level of the water discharged from the mine is currently about twice what the concentration in Dugout Creek was prior to mine water being discharged. However, it is important to note, prior to mine discharge, it was not uncommon for the creek to quit flowing within a few miles downstream of the mine location by mid to late summer. The water that was available was diverted a few miles downstream of the mine site east into the Pace Canyon drainage and used to grow alfalfa crops. The remaining water left the cultivated fields and flowed downstream across the Mancos Shale before eventually discharging to Grassy Trail Creek and then to the Price River. TDS concentrations in the stream, as it flowed downstream, continued to increase. Dugout Creek did not and currently does not contain a known fishery. Water in the stream is still used for cultivation of alfalfa. Wildlife and cattle also use the stream as a source of drinking water. The current TDS concentration of the water discharged from the mine is within the range established by the Utah Division of Water Quality for use by livestock.

Dugout Mine began discharging water to Pace Creek in the area of the mine's Pace Canyon Fan Portal. This water has been similar in quality to the mine water discharged at Dugout Creek. The water, when discharged from the mine, enters Pace Creek and eventually is diverted to water the same alfalfa fields as Dugout Creek waters. At this time, it is unknown if the mine will increase, decrease, or maintain the current discharge rates at the two locations.

To mitigate discharging into Dugout and Pace Creeks increased TDS volumes greater than one ton per day allowed by its UPDES permit, tributaries to the Colorado River System, the mine has participated in a salinity reduction program. To allow the mine to participate in the program, a cost per removal of a ton of TDS from the Price River Basin was determined by the appropriate State and Federal agencies. The mine determined the total projected life of the mine, the average tons of TDS per month over that period, and multiplied the total tons by the cost per ton of removal. That amount was then paid in three equal annual installments to the Utah Division of Water Quality. The money was then made available to pay for projects that would remove tons of TDS from the Price River equivalent to the tons of TDS the mine discharged in excess of one ton per day. To the best of the mine's knowledge, this program overall has been successful in reducing the TDS concentration in the upper Colorado River Basin.

Total iron concentrations with the mine discharge waters have on occasion been measured at levels higher than background numbers obtained from Dugout and Pace Creek. However, under normal operating conditions total iron concentrations in the mine water is less than 1 mg/l, the UPDES limit for the mine water discharge.

3.2.3 Impact on Ground Water and Surface Water Availability (728.334)

As described in Sections 3.1 and 3.2, it is anticipated that continued mining in the Dugout Canyon Mine and the 240 acre expansion will not affect the availability of ground water. However, mining will increase the baseflow of both Dugout Creek and Pace Creek. There should be no sustained increase of the surface water flows in Cow Canyon.

4.0 CONCLUSIONS

No significant changes are proposed for this section since the basic conclusions reached in the original PHC, only an addition of text. Monitoring of springs and surface waters in the Dugout Canyon Mine area since1998 has indicated there is no hydraulic connection between the mine and surface waters. Also, except for increasing the baseflow in Dugout and Pace Creeks, the effects of coal mining in the Dugout Canyon Mine within the Blackhawk Formation on overlying springs and surface water is and should continue to be negligible.

5.0 RECOMMENDATIONS

5.1 SOLDIER CANYON MINE

No Changes Made

5.2 DUGOUT CANYON MINE

5.2.1 Monitoring Wells

No new monitoring wells are proposed for the Dugout Canyon Mine at this time. It is recommended the wells included in the monitoring plan continue to be measured.

5.2.2 Streams

A new stream monitoring point, 323, associated with the 240 acre expansion area is proposed in Section 18, T13S R 13E for the Dugout Canyon Mine. It is recommended the stream be monitored as per the surface water monitoring plan contained in Chapter 7 of the MRP.

5.2.3 Springs

Two new spring monitoring points are proposed for the Dugout area. The springs are located adjacent to the 240 acre expansion in the northeast portion of the permit area and within the Cow Canyon drainage. The springs are designated as sites 321 and 322. It is recommended these springs be monitored as per the ground water monitoring plan contained in Chapter 7 of the MRP.

6.0 REFERENCES CITED

~~No Changes Made~~

Mayo, A.L., Morris, T.H., Peltier, S., Petersen, E.C., Payne, K., Holman, L.S., Tingey, D., Fogel, T., Black, G.J., and Gibbs, T.D., 2003, Active and inactive groundwater flow systems: Evidence from a stratified, mountainous terrain, GSA Bulletin: December 2003: V. 115: no. 12; p. 1456-1472.

Mayo, A.L., and Morris, T.H., 2000, Conceptual model of groundwater flow in stratified mountainous terrain, Utah, USA in Groundwater: Past achievements and future Challenges, Sililo et al. ed: Proceeding XXX IAH Congress on Groundwater, Capetown South Africa, 26 November – 1 December, 2000, p. 225-229.

Waddell, K.M., Dodge, J.E., Darby, D.W., and Theobald, S.M., 1986, Hydrology of the Price River Basin, Utah with emphasis of selected coal-field areas, U.S. Geological Survey Water-Supply Paper 2246.

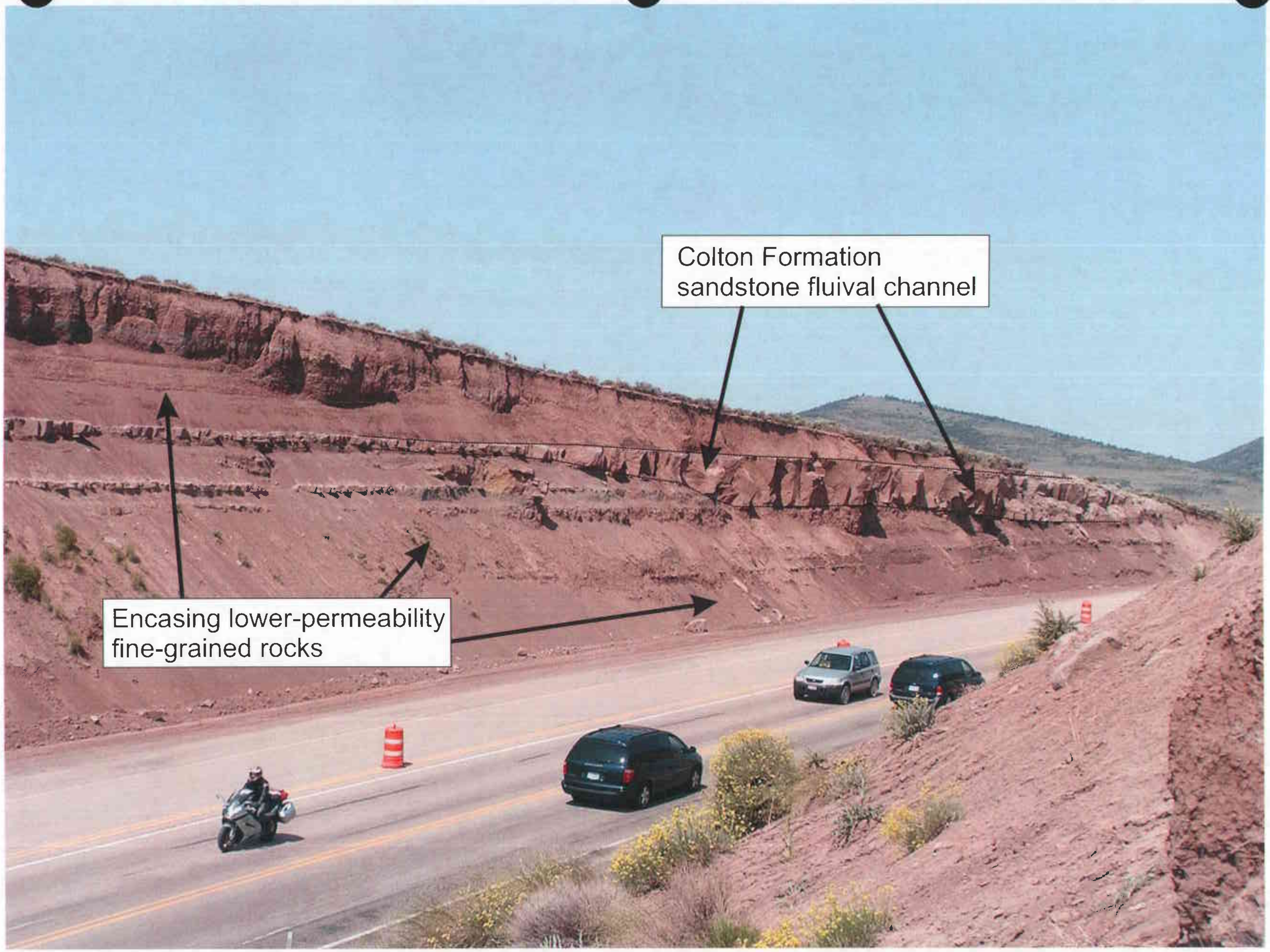


Figure X Annotated photograph showing fluvial channel and encasing lower-permeability fine-grained rocks in a road cut in the Colton Formation near Colton, Utah.

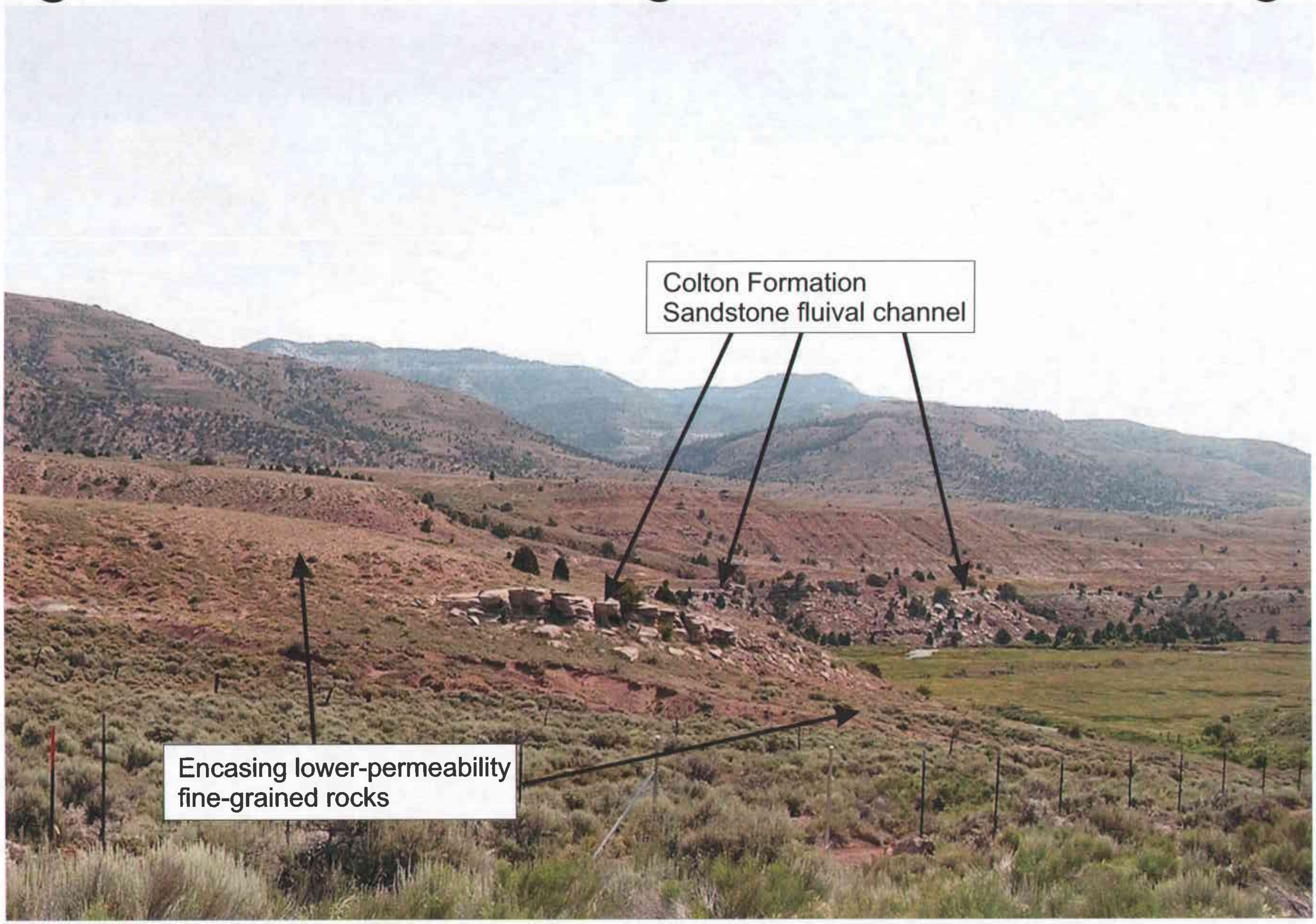


Figure Y Annotated photograph showing surface erosional exposure of fluvial channels and encasing lower-permeability fine-grained rocks in the Colton Formation near Colton, Utah.

ATTACHMENT 1

PHC Update Figure 1
Recharge Area Figure 2
Table 1 600 Acre Baseline Spring Field Data
Baseline Water Quality Data for Springs 321, 322 and 323

"321" Monitoring Data 2007

Date	Time	pH	Cond.	Temp.	Flow (gpm)	Comments
3/15/07	1220				NOA	Snow/Ice
5/18/07	1420	8.08	406	4	1.5	
6/21/07	1114	8.11	410	7.6	1.3	
7/24/07	834	7.38	469	8.5	0.75	
8/30/07	1205	7.42	471	8	0.7	

"322" Monitoring Data 2007

Date	Time	pH	Cond.	Temp.	Flow (gpm)	Comments
3/15/07	1220				NOA	Snow/Ice
6/21/07	905	7.84	704	7	18	
7/24/07	916	7.91	698	9	0.2	Livestock
8/30/07	1130	7.91	663	11	0.1	Livestock

"323 (Junction)" Monitoring Data 2007

Date	Time	pH	Cond.	Temp.	Flow (gpm)	Comments
3/15/07	1220				NOA	Snow/Ice
5/18/07	1340	7.80	591	11	17	
6/21/07	1220	7.9	621	12.5	20.5	
8/30/07	1345	8.4	675	14	13	Livestock Use

APPENDIX 7-4

Monitoring Well Water-Level Data
and Well Logs

SAGEPOINT/DUGOUT CANYON
BASIC HYDROGEOLOGIC DATA REPORT

Prepared for:

SUNEDCO COAL COMPANY
7401 W. MANSFIELD AVENUE
LAKEWOOD, COLORADO 80235

WAHLER ASSOCIATES
12477 W. CEDAR DRIVE, SUITE 206
LAKEWOOD, COLORADO 80228

December 15, 1982

Wahler Associates

Geotechnical and Water Resources Engineering

December 15, 1982
SED102

Mr. Charles W. Durrett
Environmental Coordinator
Sunedco Coal Company
7401 W. Mansfield Ave.
Lakewood, Colorado 80235

Dear Mr. Durrett:

Wahler Associates (WA) is pleased to submit with this letter a summary of work performed at Sunoco Energy Development Co.'s (Sunedco) Sage Point/Dugout Canyon property in Carbon County, Utah. The work performed is to be used in support of Sunedco's application (ACT/007/007) entitled Sage Point/Dugout Canyon Project, SMCRA Permit Application Chapter IV-B, Hydrology. The scope of work included the performance of static water levels, falling head tests, preparation and presentation of test results, and the preparation of a ground water potentiometric map for each of the aquifers on the property. Soldier Canyon Mine, which is adjacent to Sunedco's property, ground water data were also evaluated.

PROJECT OVERVIEW

The field work was directed by Mr. Joel Siegel, WA staff water resources engineer. The field work was initiated November 1, 1982. Water data were collected from five monitoring well locations (Figure 1) described below:

Rocky Mountain Region: 12477 W. Cedar Drive, Suite 206, Lakewood, Colorado 80228 • (303) 989-7990
Corporate Headquarters: Palo Alto, CA • Southwest Region: Newport Beach, CA, and at major project sites worldwide.

Well Number	Latitude	Longitude	Top of Casing Elevation In Feet Above Sea Level
5-1	394315	1103548	7186
10-2	384254	1103333	6626
11-2	394221	1103205	8204
19-1	394112	1103022	8254
24-1	394046	1103055	8416

The wells were established by Eureka Energy Co. (Eureka), the prior property owner, between 1976 and 1979. These wells are further described in Sunedco's application noted above.

Water level data were collected from all five wells. Only well 19-1 was found dry (Table 1). These data were used in conjunction with data previously collected by Eureka (Table 1) in developing the potentiometric level map (Figure 1) for the property.

Falling head tests were performed at three of the five wells. Wells 19-1 and 24-1 were not accessible owing to poor weather and road conditions.

TEST PROCEDURES

A 2000 gallon clean water truck, provided by Western Exploration, was used to carry water to each of the monitoring wells. Static water levels were taken at the wells, after which an additional head was applied to the aquifer. This was done via the injection of water into the wells from the water truck. Water level measurements were taken prior to and during all tests using an Olympic well probe. The levels were measured frequently during the early stages of the test, and several hours apart after a few hours had passed.

Because the representative value of elapsed time from which transmissivity values were calculated from the data is on the order of 1000 minutes, the significance of early time data is less than what was anticipated at the time of testng.

Wells 10-2 and 11-2 were filled to within 100 feet of the ground surface. Well 5-1 was filled to approximately 20 feet below ground surface. Time was allowed for each well to settle, which generally occurred 5 to 10 minutes after filling. Response of the Price River formation aquifer was slow at both test locations (wells 10-2 and 11-2).

Well 5-1 displayed a very slow decline in head. Therefore, the time between measurements was increased from minutes to hours after test initiation. This test was in the coal members of the Blackhawk formation.

DATA ANALYSIS

The basic equation for the residual head in a well, to which an initial excess is applied, was modified in order to determine the transmissivity of the Price River formation. Assumptions implicit in the analysis are that water levels in the formation are affected by the recharge only in the immediate vicinity of the well, and that the storativity is small. These assumptions are applicable for the Price River formation. This type of analysis does not allow for the determination of aquifer storativity.

Attachment I includes all data in tabular form for each of the 3 tests, and time-residual head plots for the Price River formation (wells 10-2 and 11-2). A simplified analysis for determining Blackhawk formation coal (well 5-1) transmissivity is included in Attachment I, as well as a description of the graphical procedures applied to the data from the Price River formation. All field test data is given in Attachment II.

RESULTS

The transmissivity of the Price River formation aquifer at the locations tested on the Sage Point/Dugout Canyon property is 1 gallon per day per foot (gpd/ft). This value is a reliable order of magnitude estimate. The transmissivity of the formation apparently decreased with time during falling head tests at wells 10-2 and 11-2. The stated confidence in the results is well within the normally expected range for falling head tests.

A simple analytical procedure for determining the coupled transmissivity of the Sunnyside and Rock Canyon coal members of the Blackhawk formation is described in Attachment I-C. The conclusion that can be drawn from well 5-1 data is that the coals of the Blackhawk formation are near-impermeable. The transmissivity is 0.009 gpd/ft.

The results of the aquifer tests indicate that the strata of the Price River formation and the coal seams of the Blackhawk formation have limited aquifer potential. The calculated transmissivities of the strata are so low that water development would be uneconomical, even for domestic or stock-watering uses. Therefore, the strata of the Price River and Blackhawk formations should not be considered aquifers.

POTENTIAL HEAD DATA AND MAP

Table 2 summarizes potential head data with reference to both ground elevation and mean sea level for all wells monitored by WA during the time period November 1-5, 1982. Figure 1 is a potentiometric map for the Price River formation, and was based upon data from Table 2.

WA is confident that the content of this report, inclusive of data and backup calculations, is sufficient for presentation to the Office of Surface Mining and Utah Division of Oil, Gas and Mining as a baseline hydrologic report for the Sage Point/Dugout Canyon property. Please call if we can be of any further assistance.

Sincerely,

WAHLER ASSOCIATES

John Reiss, Jr.
General Manager
Rocky Mountain Region

JR:br

TABLE 1

WATER LEVEL DATA COLLECTED BY EUREKA ENERGY CO.*

DATA	MONITORING WELLS				
	5-1	10-2	11-2	19-1	24-1
Formation Perforated	Sunnyside & Rock Canyon Coal	Middle Castlegate Sandstone	Price River	North Horn	Lower Castle gate Sandstone (PR)
Collar Altitude (FT MSL)	7186.38	7727.39	8203.79	8254	8416
Dates Sampled (ft below land surface)					
November, 1979					
16				--	--
23		--			
24			--		
26	139.90				
27		348.44		304.78	759.75
December, 1979					
12	159.91	640.62	1119.65	312.26	895.72
January, 1980					
10		709.03	1123.51		
19	180.77				
24				311.40	
February, 1980					
14			1123.32		
15	197.72	711.86			
March, 1980					
17	208.29	710.60			
18			1121.25	296.95	1019.92
April, 1980					
9	215.15	710.46	1121.15	228.29	1024.41
April, 1981					
1	275.92	711.23	1119.17		

*Data provided by Sunoco Energy Development Co.

TABLE 2

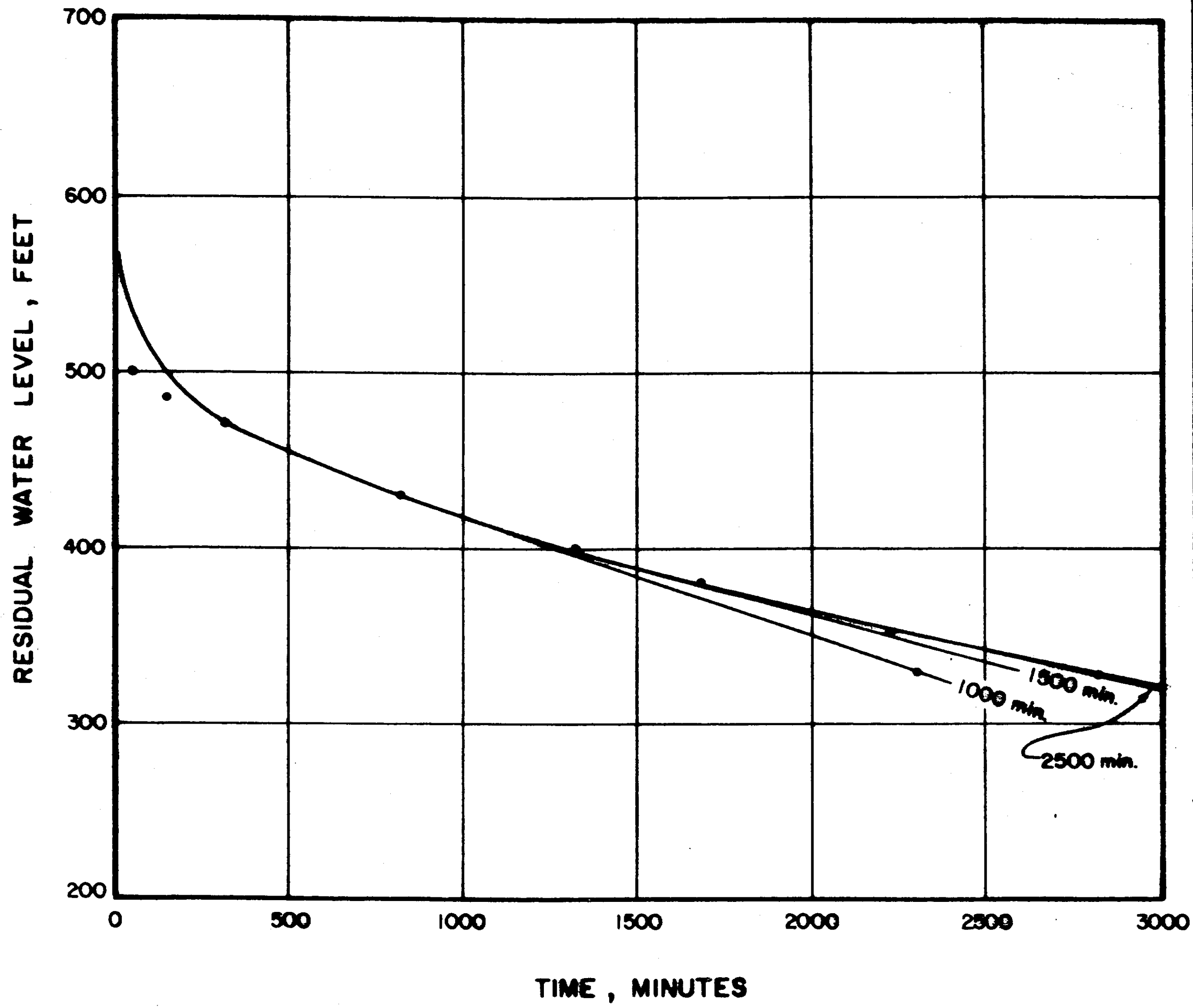
WATER LEVEL SUMMARY

SAGE POINT/DUGOUT CANYON PROPERTY

NOVEMBER, 1982

WELL NUMBER	GEOLOGIC FORMATION	TOP OF CASING ELEVATION IN FEET ABOVE MEAN SEA LEVEL	STATIC WATER LEVEL BELOW TOP OF CASING IN FEET	STATIC WATER LEVEL IN FEET ABOVE MEAN SEA LEVEL	DATE OF MEASUREMENT
5-1	Sunnyside and Rock Canyon Coals	7186	304.9	6881.1	11-4-82
10-2	Price River Formation	7727	715.8	7011.2	11-3-82
11-2	Price River Formation	8204	1127.6	7076.4	11-4-82
19-1	North Horn Formation	8254	Dry[1]	———	11-2-82
24-1	Price River Formation	8416	1020	7396	11-2-82

[1]Used two probes to depths of 750 feet; both verified as working; well has no water.



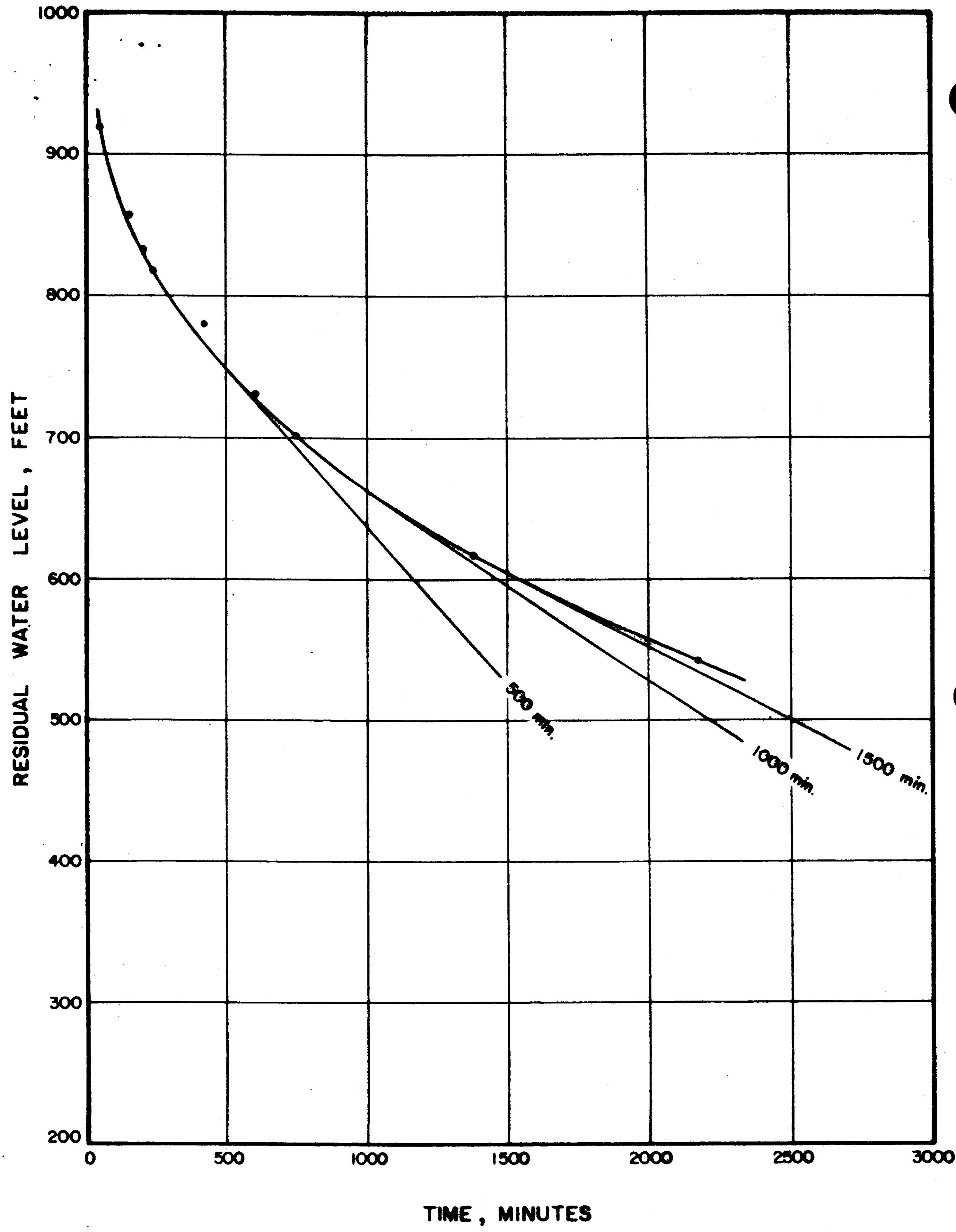
Wahler Associates

SUNEDCO COAL COMPANY

PALO ALTO • NEWPORT BEACH • DENVER

RESIDUAL HEAD VS. TIME, WELL 10-2

PROJECT NO.	DATE	FIGURE NO.
SED-102A	NOVEMBER 1982	1-1



Wahler Associates	SUNEDCO COAL COMPANY	RESIDUAL HEAD VS. TIME, WELL 11-2		
		PROJECT NO.	DATE	FIGURE NO.
	PALO ALTO • NEWPORT BEACH • DENVER	SED-102A	NOVEMBER 1982	1-2

ATTACHMENT I
GENERAL EQUATIONS

ATTACHMENT I

A. General Equation for the Residual Head in a Well

Theis (1935) presented the equation for the drawdown in an instantaneous vertical line source.[1] The equation provides a useful method for estimating the transmissivity of a formation in the vicinity of a well, which is a physical approximation of the theoretical vertical line source. Ideally, a "slug" of water is injected into a fully developed well at time t=0. The well theoretically penetrates the full length of the aquifer in question, a condition met by each well, 10-2 and 11-2. The equation for the residual head is then written as:

$$s = \frac{Q \exp(-r^2 S/4Tt)}{4\pi Tt} \qquad [1]$$

where

- s = residual water level after injection of the water, measured with respect to the original water table.
- r = distance from the injection well to an observation point
- t = time since injection of the slug
- Q = volume of the slug
- T = aquifer transmissivity
- S = aquifer storativity

Generally, only a small volume of water is injected into a well. For this reason, the reaction to the injected slug usually is not measurable in the aquifer beyond the immediate vicinity of the well. Therefore, the water-level measurements are made only in the injection well; the distance is then the radius of the well. For values of r as small as the well radius, especially where S is small (as for artesian aquifers), the argument of the exponential in equation 1 approaches zero as t becomes large and the value of the exponential terms approaches unity. Then, for a consistent set of units, transmissivity can be represented as:

$$T = \frac{Q}{4\pi st} \qquad [2]$$

A plot of s versus 1/t should be a straight line which passes through the origin. Any coordinate of the line should thus yield a value for T.

B. Specific Technique for Transmissivity Determination from test Data of Wells 11-2 and 10-2

Observed data for wells 11-2 and 10-2 did not plot on a straight line, nor was there a trend for any of the locally straight segments on either plot to pass through the origin. This may be attributed

[1] Theis, C.V., 1935, The relation between the lowering of the piezometric surface and the rate and duration of discharge of a well using ground-water storage: Amer. Geophys. Union Trans., 16th Ann. Mtg., pt.2, p. 519-524

to poor well construction techniques. The water levels in both wells were asymptotic not to the original static level, but to levels more than 200 feet higher. WA has speculated that all of the additional excess head was indeed necessary to force water into the formation and to overcome head loss associated with the perforations in the casing. At later time, the residual excess head in the well was not great enough to overcome severe head loss, through the perforations, thus causing a relatively slow decline in the water level and a correspondingly low apparent transmissivity.

Assuming that the water levels were displaced by some constant value due to well inefficiency during the tests, WA has employed a differential form of equation 2 to determine transmissivity from the graphs of Figures I-1 and I-2, which represent time-residual head data for wells 10-2 and 11-2 respectively. The key to the analysis is that T is determined from the predicted rate of fall of the water level rather than its actual position at various times during the test. Consequences of the analysis is that the apparent transmissivity of the formation is found at various points in time, with the gradual decrease being attributed more and more to poor well completion. In addition, the trend for the water table not to return to static is removed from the analysis.

Equation 2 is rearranged as:

$$T = \frac{-Q}{4\pi(ds/dt)t^2} \qquad [3],$$

and the slope of the time-residual head curve (always negative) is measured at various values of time, t. Table 1 summarizes the values of transmissivity for the Price River formation as obtained by equation 3. Using 1000 as a time during the test for which T is representative, the transmissivity of the Price River formation aquifer is approximately 1 gpd/ft.

C. Coal Transmissivities as Derived from Well 5-1 Data

An estimate of the transmissivity of the coal members of the Blackhawk formation is possible by applying Darcy's law to the observed data for well 5-1. This is done by calculating the volume of water lost to the formation from the well over a given time, and dividing it by the average gradient in the immediate vicinity of the well during the time period. As water is not likely to have penetrated too far radially into the formation, the assumption that the formation gradient is equal to the average excess head during the time period of interest is reasonable. Therefore,

$$T = Q/i\Delta t\pi d \qquad [4],$$

where:

Q = volume of water lost to formation during time Δt

i = average excess head during time Δt

πd = the "width" of well screen, if unfolded, normal to the flow.

For well 5-1, use i = 280.2 ft/ft between times of 2 and 1922 minutes. Then Δt = 1.33 days, and Q = 4.5 feet (7.48 gallons/ft^3) ($\pi d^2/4$), or 4.6 gallons. Then:

$$T = 4.6 \text{ gallons}/(280.2)(1.33 \text{ days})\ \pi(.417 \text{ ft})$$
$$T = 0.009 \text{ gpd/ft}$$

TABLE I-1

SUMMARY OF TRANSMISSIVITY VALUES FROM PRICE RIVER FORMATION AQUIFER TESTS

A. Well 10-2*

time t (min)	slope ds/dt (ft/min)	transmissivity T (gpd/ft)***
1000	90/1300	1.04
1500	30/550	0.59
2500	42/1000	0.27

B. Well 11-2**

time t (min)	slope ds/dt (ft/min)	transmissivity T (gpd/ft)***
500	110/500	2.19
1000	40/300	0.91
1500	30/300	0.54

*Volume of slug = Q = $(\pi d^2/4)$(initial excess head)(7.48 gal/ft^3)
= 627 gallons

**Volume of slug = Q = $(\pi d^2/4)$(initial excess head)(7.48 gal/ft^3)
= 1053 gallons

***$T = 114.6Q/(ds/dt)t^2$, for units used.

ATTACHMENT II

FIELD TEST DATA

FIELD PERMEABILITY TEST

FALLING HEAD

PROJECT SAGE POINT / DUGOUT CANYON TESTED BY JOEL SIEGEL DATE 11-4-82
PROJECT NO. SED102A CALCULATED BY Joel Siegel DATE 11-9-82
BORING NO. 5-1 CHECKED BY ______ DATE ______

DIAMETER OF BORING N/A
DIAMETER OF CASING 5 INCH. PERMEABILITY, K ______
HEIGHT OF CASING (REF. LEVEL)
ABOVE GROUND SURFACE 2.6 FT. PUMPING FROM: ______ TO ______
PERFORATED CASING FROM: ______ TO ______
TYPE OF PERFORATION: ______
DEPTH TO GROUND WATER
FROM TOP OF CASING (STATIC) 304.9 FT. PUMPING RATE: ______ gp

	DATE AND TIME	ELAPSED TIME (MIN)	DEPTH TO WATER (ft)	S.W.L.-DEPTH TO WATER(ft) H	H/Ho**	INVERSE TIME (MIN⁻¹)
11-4-82	13:41	0	304.9 *	—	—	—
	13:51	0	11.9	293.0	—	—
	13:53	2	22.5	282.4	1	50×10^{-2}
	13:53:30	2.5	23.5	281.4	0.99	40×10^{-2}
	13:55	4	23.7	281.2	0.99	25×10^{-2}
	13:58	7	23.8	281.1	0.99	14.3×10^{-2}
	14:02	11	23.9	281.0	0.99	9.1×10^{-2}
	14:17	26	24.0	280.9	0.99	3.85×10^{-2}
	14:41	50	24.0	280.9	0.99	2.00×10^{-2}
	21:53	482	24.9	280.0	0.99	0.21×10^{-2}
11-5-82	08:24	1113	25.9	279.0	0.99	0.09×10^{-2}
	21:53	1922	27.0	277.9	0.98	0.05×10^{-2}
			END	OF TEST.		

COMMENTS: * STATIC LEVEL

FIELD PERMEABILITY TEST

FALLING HEAD

PROJECT SAGE POINT/DUGOUT CANYON TESTED BY JOEL SIEGEL DATE 11-3-8
PROJECT NO. SED102A CALCULATED BY Joel Siegel DATE 11-9-8
BORING NO. 10-2 CHECKED BY ______ DATE ______

DIAMETER OF BORING N/A
DIAMETER OF CASING 5 INCH PERMEABILITY, K ______
HEIGHT OF CASING (REF. LEVEL)
ABOVE GROUND SURFACE 2.3 FT. PUMPING FROM: ______ TO ______
PERFORATED CASING FROM: ______ TO ______
TYPE OF PERFORATION: ______
DEPTH TO GROUND WATER
FROM TOP OF CASING (STATIC) 715.8 FT PUMPING RATE: ______ g

	DATE AND TIME	ELAPSED TIME (MIN)	DEPTH TO WATER (ft)	S.W.L.-DEPTH TO WATER(ft) H	H/Ho	INVERSE TIME (MIN^{-1})
11-3-82	8:31	0	715.8 *	—	—	—
	9:06	0	101.0	614.8	1	—
	9:09	3	125.4	590.4	.96	33.3×10^{-2}
	9:11	5	139.6	576.2	.94	20.0×10^{-2}
	9:13	7	146.5	569.3	.93	14.3×10^{-2}
	9:15	9	149.7	566.1	.92	11.1×10^{-2}
	9:18	12	150.8	565.0	.92	8.33×10^{-2}
	9:23	17	182.6	533.2	.87	5.88×10^{-2}
	9:27	21	195.3	520.5	.85	4.76×10^{-2}
	9:39	33	212.4	503.4	.82	3.03×10^{-2}
	9:47	41	213.8	502.0	.82	2.44×10^{-2}
	10:00	54	215.8	500.0	.81	1.85×10^{-2}
	10:34	88	220.6	495.2	.81	1.14×10^{-2}
	11:12	126	225.2	490.6	.80	0.79×10^{-2}
	11:39	153	229.5	486.3	.79	0.65×10^{-2}
	12:03	177	231.1	484.7	.79	0.56×10^{-2}
	12:41	215	235.0	480.8	.78	0.46×10^{-2}
	13:19	253	238.8	477.0	.78	0.39×10^{-2}
	14:26	320	245.1	470.7	.77	0.31×10^{-2}
	15:18	372	249.8	466.0	.76	0.27×10^{-2}
	20:13	667	273.2	442.6	.72	0.15×10^{-2}
	22:49	823	284.1	431.7	.70	0.12×10^{-2}
11-4-82	07:14	1328	315.6	400.2	.65	0.075×10^{-2}
	13:12	1686	335.0	380.8	.62	0.059×10^{-2}

COMMENTS: * STATIC LEVEL.

FIELD PERMEABILITY TEST

FALLING HEAD

PROJECT SAGE POINT/DUGOUT CANYON
PROJECT NO. SED102A
BORING NO. 10-2

TESTED BY JOEL SIEGEL DATE 11-3-
CALCULATED BY Joel Siegel DATE 11-9
CHECKED BY ______ DATE ______

DIAMETER OF BORING N/A
DIAMETER OF CASING 5 INCH
HEIGHT OF CASING (REF. LEVEL) ABOVE GROUND SURFACE 2.3 FT.
PERFORATED CASING FROM: ______ TO ______
TYPE OF PERFORATION: ______
DEPTH TO GROUND WATER FROM TOP OF CASING ______

PERMEABILITY, K ______
PUMPING FROM: ______ TO ______
PUMPING RATE: ______

DATE AND TIME	ELAPSED TIME (MIN)	DEPTH TO WATER (ft)	S.W.L.-DEPTH TO WATER(ft) H	H/Ho	INVERSE TIME (MIN^{-1})
11-4-82 22:10	2224	361.0	354.8	.58	0.045×10^{-2}
11-5-82 08:11	2825	386.9	328.9	.53	$0.035 \times$ [illegible]
21:36	3630	417.0	298.8	.49	0.027×10^{-2}
		END OF	TEST		

COMMENTS:

FIELD PERMEABILITY TEST

FALLING HEAD

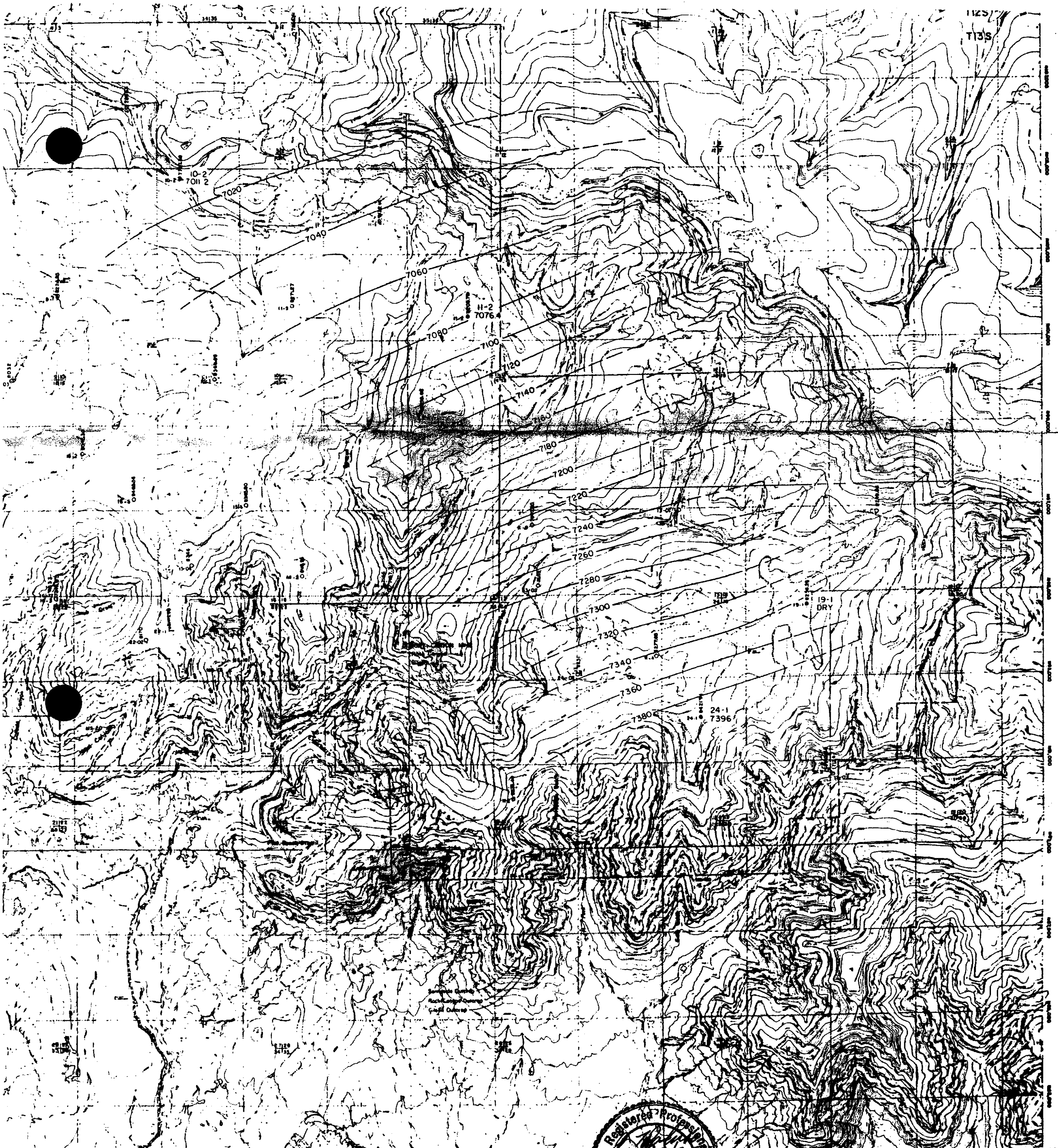
PROJECT SAGE POINT/DUGOUT CANYON
TESTED BY JOEL SIEGEL DATE 11-4-8
PROJECT NO. SED102A
CALCULATED BY Joel Siegel DATE 11-9-8
BORING NO. 11-2
CHECKED BY DATE

DIAMETER OF BORING N/A
DIAMETER OF CASING 5 INCH
PERMEABILITY, K
HEIGHT OF CASING (REF. LEVEL) ABOVE GROUND SURFACE 2.4 FT.
PUMPING FROM: TO
PERFORATED CASING FROM: TO
TYPE OF PERFORATION:
DEPTH TO GROUND WATER FROM TOP OF CASING (STATIC) 1127.6 FT
PUMPING RATE:

	DATE AND TIME	ELAPSED TIME (MIN)	DEPTH TO WATER (ft)	S.W.L.-DEPTH TO WATER(ft) H	H/Ho	INVERSE TIME (MIN^{-1})
11-4-82	7:40	0	1127.6 *	—	—	—
	8:53	0	95.3	1032.3	1	—
	8:56	3	119.2	1008.4	.98	33.3×10^{-2}
	9:01	8	130.0	997.6	.97	12.5×10^{-2}
	9:02	9	143.4	984.2	.95	11.1×10^{-2}
	9:06	13	172.1	955.5	.93	7.69×10^{-2}
	9:09	16	184.1	943.5	.91	6.25×10^{-2}
	9:15	22	187.9	939.7	.91	4.55×10^{-2}
	9:21	28	193.7	933.9	.90	3.57×10^{-2}
	9:28	35	198.9	928.7	.90	2.86×10^{-2}
	9:41	48	208.0	919.6	.89	2.08×10^{-2}
	10:00	67	221.3	906.3	.88	1.49×10^{-2}
	10:22	89	234.0	893.6	.87	1.12×10^{-2}
	10:45	112	247.9	879.7	.85	0.89×10^{-2}
	11:25	152	270.6	857.0	.83	0.66×10^{-2}
	11:48	175	281.3	846.3	.82	0.57×10^{-2}
	12:16	203	294.2	833.4	.81	0.49×10^{-2}
	12:40	227	303.5	824.1	.80	0.44×10^{-2}
	12:58	245	309.7	817.9	.79	0.41×10^{-2}
	15:00	427	348.3	779.3	.75	0.23×10^{-2}
	16:53	480	372.1	755.5	.73	0.21×10^{-2}
	18:52	599	397.1	730.5	.71	0.17×10^{-2}
	21:23	750	425.5	702.1	.68	0.13×10^{-2}
11-5-82	07:53	1380	512.3	615.3	.60	0.072×10^{-2}
	21:08	2175	584.6	543.0	.53	0.046×10^{-2}

COMMENTS: * STATIC LEVEL

END OF TEST



LEGEND

- Outline of Sunedco
- Measured Section of Outcrop
- Mined Out Areas
- Outcrop
- Proposed Road
- Proposed Railroad
- Oil & Gas Test Well

8203.78 — Surface Elevation

11-2 — Drill Hole Number

7076.4 — Static Water Level Elevation

7100 — Price River Formation Equal Potential Contour in Feet Above Mean Sea Level. Dashed Where Inferred

I, being a professional engineer hereby certify that this map was prepared by me or under my direct supervision and that all information contained thereon is true and correct to the best of my knowledge and information.

Registered Professional Engineer No. 4128 T. Thomas Palusc State of Utah

REVISED
SEP 0 8 1992

Scale: 0 1000 2000

Wahler Associates
PALO ALTO • NEWPORT BEACH • DENVER

SUNEDCO COAL COMPANY
SAGE PT.- DUGOUT CANYON PROJECT

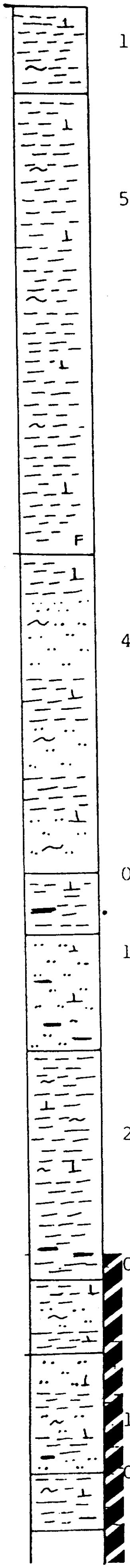
GENERALIZED PRICE RIVER FORMATION POTENTIOMETRIC LEVEL MAP

PROJECT NO	SED-102	FIGURE NO	1
SCALE:	1" = 2000	DATE	NOVEMBER 1982

GEOLOGIC lOGS
WATER LEVEL MONITORING WELLS

WELL 5-1

1540'



1.1' mudstone, sl. silty & dr. gray to black, calc., med. to sl. carb., plant frag.; bedding is v. thin & irreg. ox-ov; no fract.

5.9' mudstone, black, mod. carb.; abundant plant frag.; sl. calc.; occasional mollusc fossils (gast.); upper 1.0' contains some mottling of unit above; from 3.3' to 4.3' are brown globs (1/16" to 3/8") of calc. mudst; no fract.

1547' Core in 1.6' to 0.8' sections

4.1' interbedded, mixed & mottled mudst., dr. gray to black, sl. silty & sandy siltst.; lt. gray to gray, v. calc.; v.f.g.; ratio is 2:3; unit is calc.; mod. carb.; bedding is thin & convoluted; some of the mottling is due to bioturbation; basal 0.2' have a few v. thin coal streaks; no fract. ox-ov.

0.8' carb. mudst., sl. calc.; a few resin pods & coal streaks; sandy & silty in upper 0.2'; contact gradational; lower contact is sharp but irreg.; abund. plant frag.; no fract.

1.5' siltstone, lt. gray to gray, calc., contains thin irreg. laminae of darker muddy carb. material; a few thin coal streaks; rooted in upper 2/3 sharp irreg. lower contact.

2.95' carb. mudst., sl. calc. in upper 1.0' and also only sl. carb.; from 1.1' to 1.5' unit is coaly & resinous; lower portion contains a few thin coal streaks; vert. fract. from 0.1' to 0.9' & from 1.1' to 1.5'; closed & hairlike

0.95' interbedded mudst., dr. gray to gray & siltstone, lt. gray; ratio is 3:1; unit is calc.; sl. carb.; a few plant frags.; mod. bioturbation; bedding is thin to laminae & mostly horiz. w/some irreg. beds; siltst. shows some small syndepositional faulting (¼" displacements); no fract.

1557.3' Core in 4.4' to 1.0' sections

1.55' same as above; lower 1.0' contains numerous thin coal streaks & trace of resin; no fract.

0.7' mudstone, sl. silty; mod. carb.; sl. calc.; a few thin coal streaks; sharp irreg. lower contact; no fract.

WATER MONITORING ZONE - SUNNYSIDE SEAM

0.35' carb. mudstone; thin, numerous coal streaks; sl. resinous; no fract.

0.4' bone coal; sl. resinous; hard; vert. fract. throughout; closed; numerous coal streaks

0.5' carb. mudstone, sl. resinous; numerous thin coal streaks; no fract.

0.55' coal, hard, shiny; resinous; gassy, vert. fract. throughout; clos

0.25' bone coal; resinous w/coal streaks; vert. fract. throughout; closed, gassy

0.35' high-ash coal, resinous; small vert. fract. throughout; closed

5.75' coal, hard, shiny; sl. resinous; gassy, small vert. & oblique closed fract. (cleat); 0.05' pyrite streak at 0.0'; Sunnyside coal seam

WATER MONITORING ZONE - SUNNYSIDE SEAM

1567.7' Core in 3.9' to 1.1' sections

3.85' coal, as above; thin, closed cleat; fract. throughout, open vert. fract. from 1.5' to 3.7'; Sunnyside, sharp lower contact

0.3' carb. mudstone, sl. resinous; numerous v. thin coal streaks & plant frag.; sl. sandy; no fract.

1.45' sandstone, lt. gray to gray, v.f.g.; sub-rounded, mod. to well sorted; sl. calc.; mod. cementing; semi-porous; gassy; contains a few thin irreg. laminations of carb. mat. & a rare thin coal streak; lower contact is break in core-sharp; vert. fract. from 0.25' to end; closed; calcite filled

1.2' sandy siltst., lt. gray, sl. calc., ss. is v.f.g. as above; unit fines toward base; contains a few thin discont. lenses of dr. carb. mudst., thin coal streak at base; tr. pyrite; vert. fract. throughout; closed & calcite filled

2.35' interbedded sandy siltst.; sandstone of two units above & mudst., dr. gray to carb.; ratio is 3:3:2; sl. calc.; unit is v. thinly & mostly reg. horiz. bedded; finest units from 1.0' to 1.6'; upper 1.0' and lower 0.45' are semi-porous & gassy; unit is sl. bioturbated horiz. & vert.; vert. fract. from 0.0' to 0.4'; closed & calcite filled

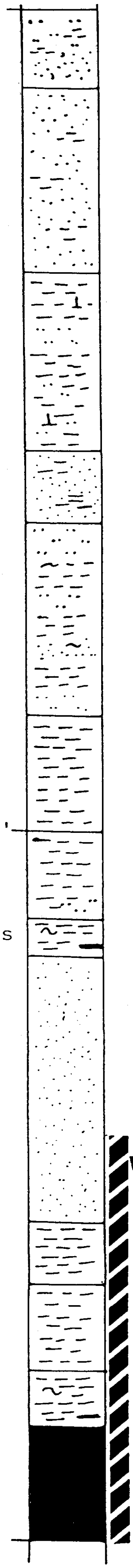
0.35' mudstone, black. sl. carb.; w/thin lentils of lt. gray siltst; vert. fract. from 0.1' to end-open

1578.05' Core in 2.4' to 0.2' sections

0.85' interbedded, mixed & mottled, sandstone, v.f.g. to f.g.; sub-angular to sub-rounded; poorly sorted; "salt & pepper"; mod. cem. semi-porous & mudst. gray to black; occasionally sl. carb.; ratic is 3:2; bedding is thin & irreg.; mottling is caused by intense bioturbation (horiz. & vert.); washover R.M.; vert. fract. 0.0' to 0.3', open.

Plugged to next core pt.

1687'



1.0' siltstone, dr. gray, muddy w/a few thin silty ss. beds in lower 0.3'; unit is intensely bioturbated (Chondrites, some ophiomorpha);ratio siltst. to ss. is 3:1; gradational lower contact; no fract.

2.3' ss., lt. gray, v.f.g.; sl. silty, mod. cemented; low-angle x-bedding & thin, horiz. laminae w/a few thin beds to laminae of dr. gray mudst.; large ophiomorpha burrows in upper 0.6'; sharp lower contact.

2.3' silty mudst. to siltst.; ratio is 4:1; thinly to med. bedded; sl. calc.; intensely bioturbated (mostly Chondrites); gradational lower contact; no fract.

0.95' muddy ss., dr. gray, v.f.g. to f.g.; poorly sorted, sub-rounded to sub-angular; mod. bioturbated; some plural curing tubes? no bedding; no fract.

2.4' interbedded siltst.; gray to dr. gray, mudst., black & silty ss.; ratio is 3:3:1; sl. carb. w a few v. thin coal streaks; bedding is thin to v. thin; mostly even w/some irreg. beds in upper portion; upper 1.0' is bioturbated by large mostly vert. burrows that are filled w/ss. of the overlying unit (R.M.?); some beds are mildly bioturbated; no fract.

1.5' mudstone, black; some hairlike streaks of lt. mudst.; no fract. Restricted Marine

1697.45'
Core in 5.5' to 0.5' sections

1.1' mudstone of above; sl. silty near base; no fract.

0.5' carb. mudstone w/numerous coal streaks (¼"); sl. resinous; sl. gassy; irreg. lower contact; no fract.

3.4' mixed & mottled muddy to sandy siltstone; black to gray, intensely bioturbated; mostly horiz. & oblique; some rooting; most bedding destroyed; some irreg. horiz. beds; numerous thin laminae of carb. material; sharp irreg. bioturbated lower contact; no fract. R.M.

WATER MONITORING ZONE - ROCK CANYON SEAM

0.8' mudstone, black w/numerous v. thin lenses of gray siltst.; ratio is 15:1; med. carb. w/a few v. thin coal streaks in basal 0.1'; sl. bioturbation; irreg. lower contact; no fract.; R.M.

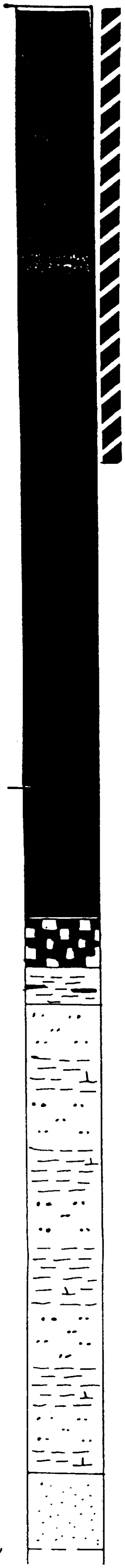
1.1' same unit as the one just above the overlying mudstone; no fract.; R.M.

0.7' mudstone, black, mod. carb. w/numerous thin lenses & pods of gray siltst.; mod. bioturbation; a few thin coal streaks in basal 0.05'; lower contact is sharp & sl. irreg.; bedding is thin & horiz. w/irreg. caused by bioturbation; no fract.

1.15' coal, hard, shiny, banded, pyritic lense at 0.2' which is 3/8" thick; vert. fract. throughout; open; gassy

1706.2'

1706.2'
Core in
3.6' to
broken
sections



10.0' coal, hard, shiny, a rare thin streak of resin; vert. open fract. from 0.0' to 1.0'; 1.3' to 1.9'; 3.3' to end; (50% lost from 8.7' to 10.0')coal is broken in this zone and sl. pyritic; gassy

WATER MONITORING ZONE - ROCK CANYON SEAM

1716.2'
Core in
5.4' to
broken
sections

1.7' coal, as above; sl. pyritic; banded; gradational lower contact; vert. open fract. throughout & broken; exact thickness is in question; gassy

0.65' bone coal; hard, banded, numerous coal streaks; sl. resinous; sl. pyritic; vert. open fract. from 0.0' to 0.3'

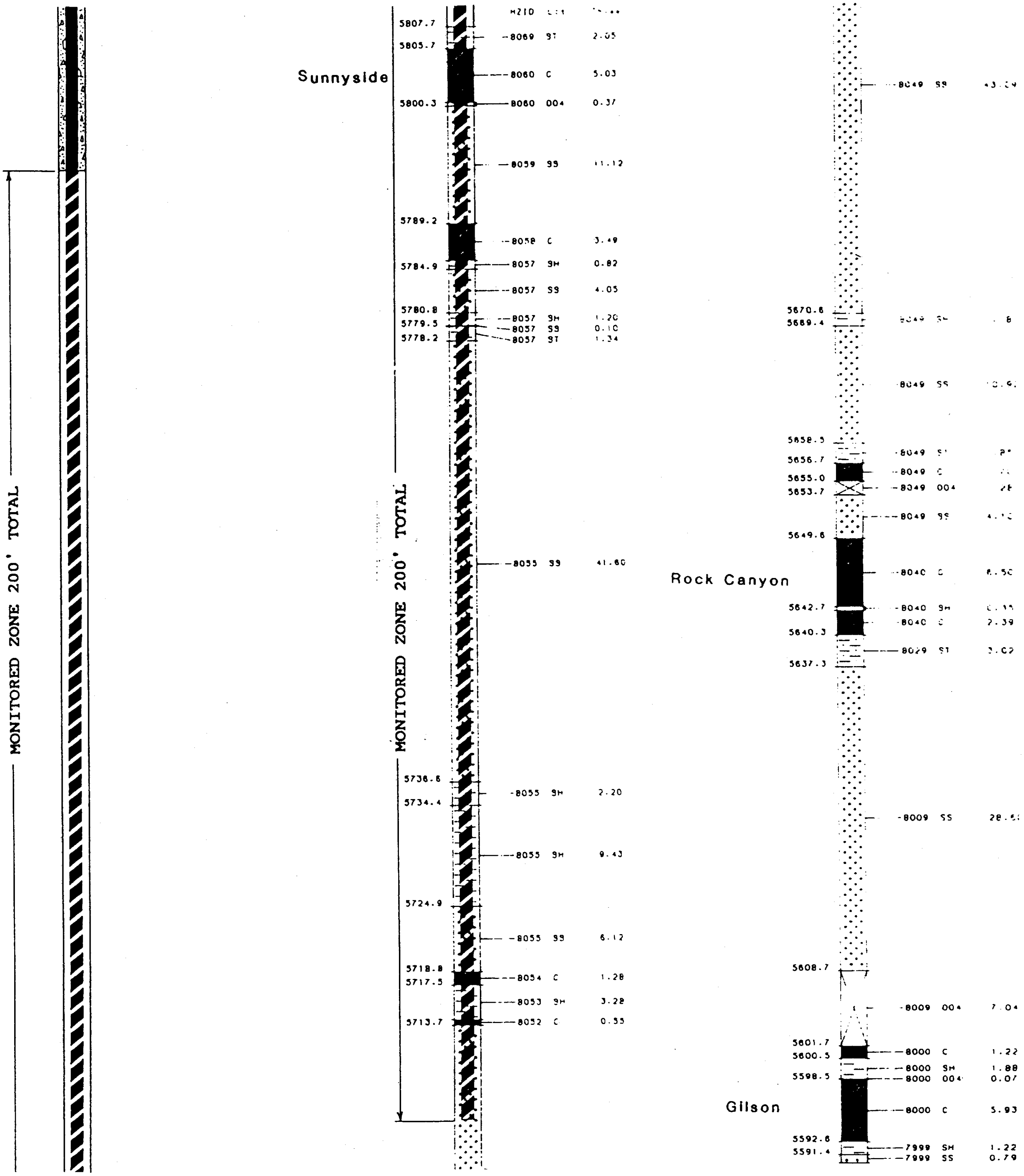
0.5' mudstone, carb. silty, black, a few v. thin coal streaks; irreg. grad. lower contact; no fract.

6.0' interbedded, mixed & mottled, sandy siltst.; lt. gray v.f.g.; silty to carb. mudstone; ratio is 1:1; bedding is mostly convoluted w/some thin horiz. bedding w/carb. laminae; sharp erosional contacts on sandy beds at 2.3' & at base of unit; some mottling caused by mod. bioturbation; lowest section contains some small clay intraclasts; unit is calc. below 3.0'; ve fract.(open) from 0.5' to end; two major sets running through the core; polished break at 1.8' & 4.0'

1.95' ss., gray, v.f.g., mod. sorting, sub-rounded to sub-angular; friable, calc.; semi to non-porous; upper ½ is x-bedded; lower portion is mostly horiz.; bedding planes contain (cont. next page)

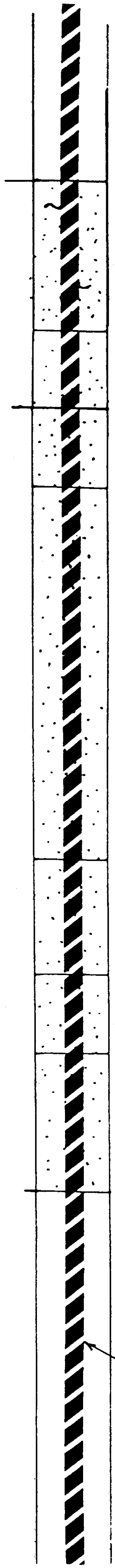
WELL 6-1

DRILL HOLE 6-1-89



WELL 10-2

Core: D.H. 10-2
Scale: 1"=2'
Castlegate Sandstone



1483'

Core #1 1483'-1486'; rec. 3'

2' ss., gray, v.f.g.; well sorted; sub-rounded; numerous interbedded laminations of carb. material

1' same as above w/o carb. material.

1486'

Core #2 1486'-1495.5'; rec. 5.5'

1' ss., med. gray, med. grained; subangular to subrounded; well sorted w/common carb. laminae, esp. heavy at 86.5'; lt. to dr. banded 1" (lam. perpendicular to core indicating flat bedding).

1487'-1492'

5' ss, med. gray; subang. to subrounded; well sorted; fair porosity w/occ. streaks black carb. lam. at 10° to 30° to core indicating x-lam.; core parting on 30° thin carb. lam. at 1489'; at 1488.5' top of vert. fract. running to 92.3'; fract. is partly healed in top with druzy white, crystalline quartz open voids ¼" to ½"; core badly broken along vert. fract. at 90' to 92'; ss. is mod. friable

1486-1489' solid core; no breaks
1489-1492' badly fract; vert. fracts. partly open w/ subhedral quartz lining.
1492-1496.5' solid core; no breaks

1492'-1493.5'

1.5' ss., med. gray, med. grained; well sorted subang.; tr. muscovite; w/scattered black, rounded granules of carbon (check out under binocs) massive or indistinctly lam.

1493.5'-1494.5'

1.0' ss, as above; being faintly to distinctly lam. w/ carb. partings at 80° to 85° to core (est. 5-10° from horiz.) in irreg. small-scale x-lam. trough sets.

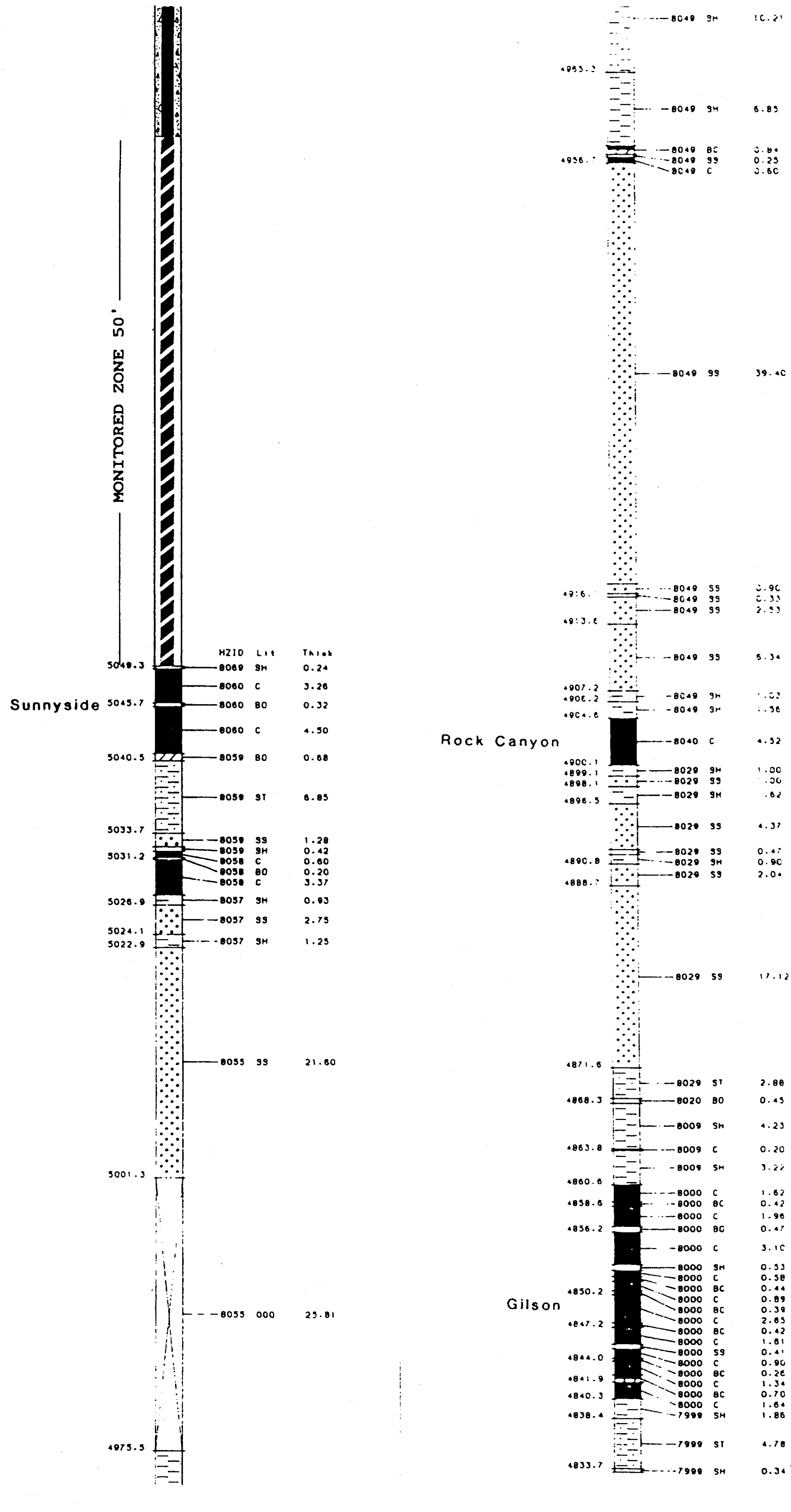
2.0' ss., as above; being slightly coarser grained to est. .3 to .4 mm (maximum) w/tr. angular chert or stained quartz, micas as above; sl. carb. w/faint lam. perpendicular to core; tr. white cherty infilling; fair to good porosity; faint sulfur odor on fresh break.

1496.5'

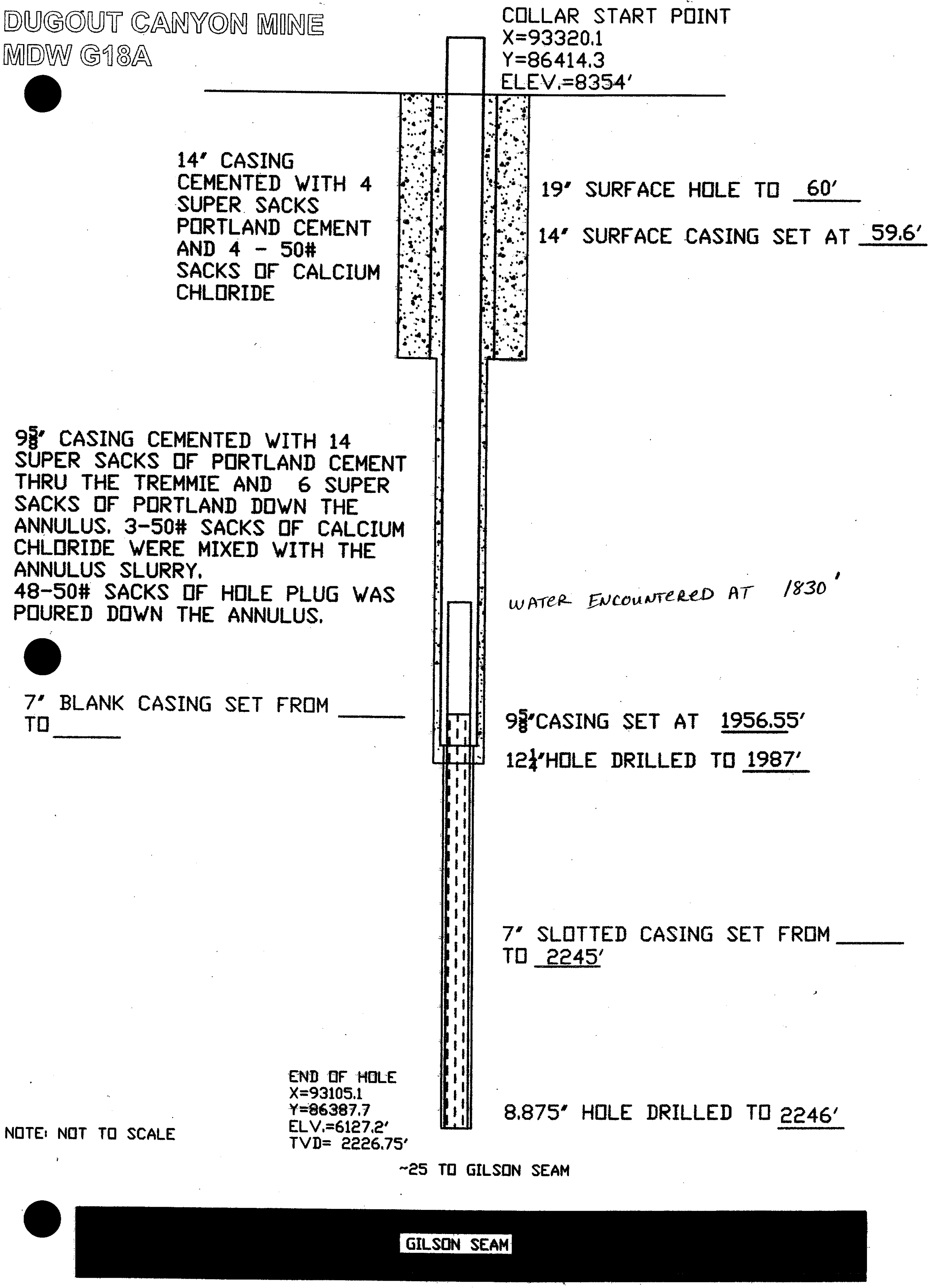
WATER MONITORING ZONE - 1400' TO 1650'

WELL 32-1

DRILL HOLE 32-1-90

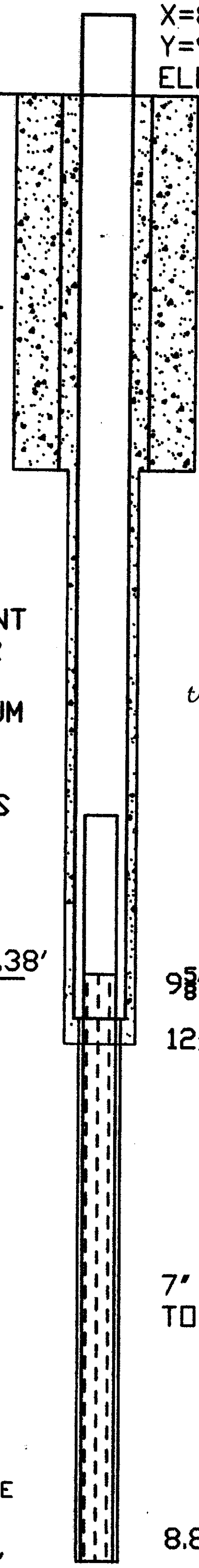


DUGOUT CANYON MINE
MDW G18A



DUGOUT CANYON MINE
MDW G31A

COLLAR START POINT
X=84681.1
Y=92982.8
ELEV.=8168.2'



14" CASING CEMENTED WITH 1 SUPER SACK PORTLAND CEMENT AND 1 50# SACK OF CALCIUM CHLORIDE

19" SURFACE HOLE TO 20'

14" SURFACE CASING SET AT 20'

9⅝" CASING CEMENTED WITH 15 SUPER SACKS OF PORTLAND CEMENT THRU THE TREMMIE AND 5 SUPER SACKS OF PORTLAND DOWN THE ANNULUS. 4-50# SACKS OF CALCIUM CHLORIDE WERE MIXED WITH THE ANNULUS SLURRY.
52-50# SACKS OF HOLE PLUG WAS POURED DOWN THE ANNULUS.

WATER ENCOUNTERED 1044'

7" BLANK CASING SET FROM 1665.38' TO 1709.97'

9⅝" CASING SET AT 1719.9'

12¼" HOLE DRILLED TO 1727'

7" SLOTTED CASING SET FROM 1709.97' TO 1954'

END OF HOLE
X=84867.1
Y=93068.8
ELV.=6239.0'

8.875" HOLE DRILLED TO 1954'

NOTE: NOT TO SCALE

~25' TO GILSON SEAM

GILSON SEAM

Hydrology of the Price River Basin, Utah with emphasis on Selected Coal-Field Areas

By K. M. Waddell, J. E. Dodge, D. W. Darby, *and* S. M. Theobald

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

PORTIONS ONLY OF PAPER

U.S. GEOLOGICAL SURVEY WATER-SUPPLY PAPER 2246

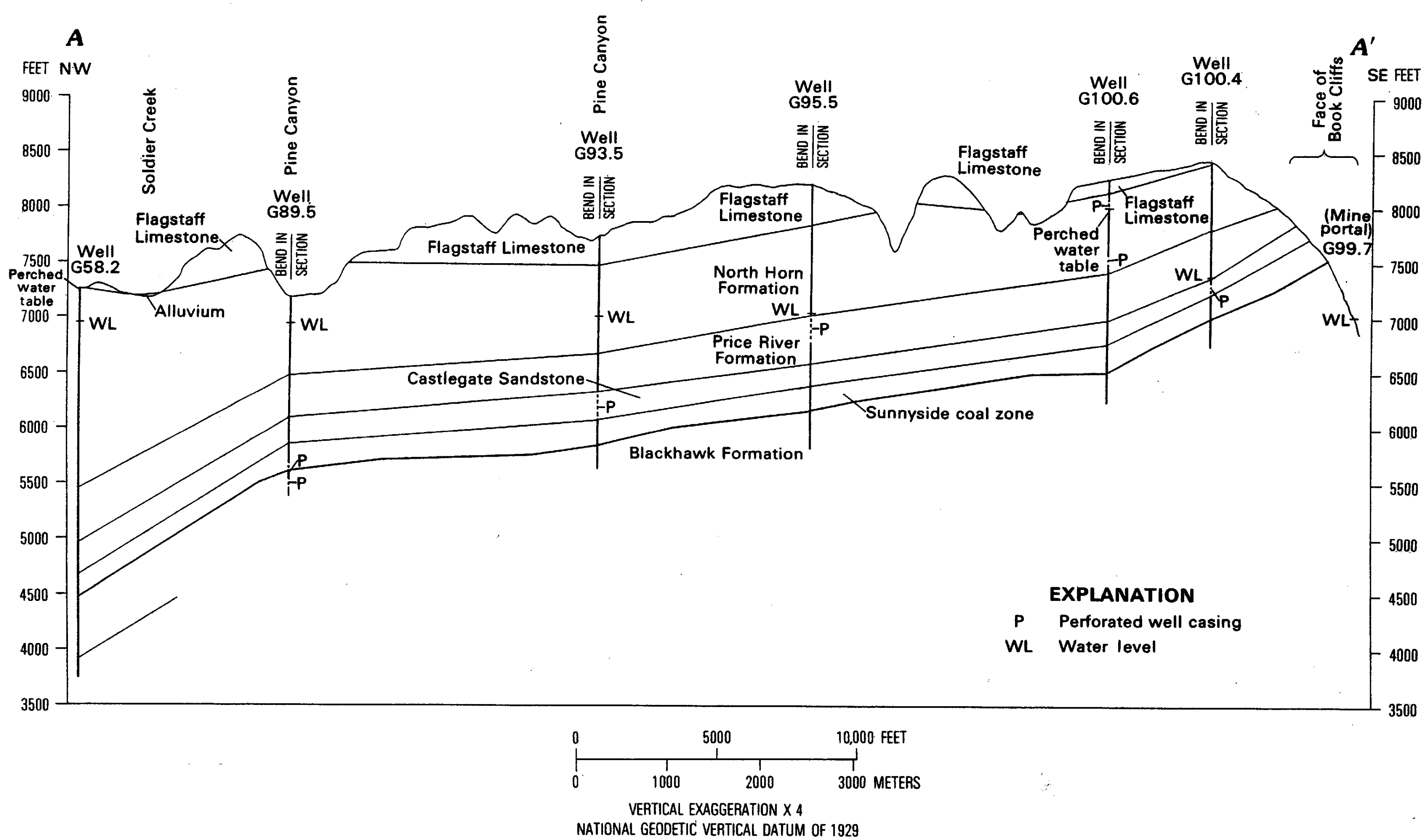


Figure 19. Generalized geologic section showing water levels in wells and a mine in the Soldier Creek area in the Book Cliffs, 1980. See plate 1 for line of section.

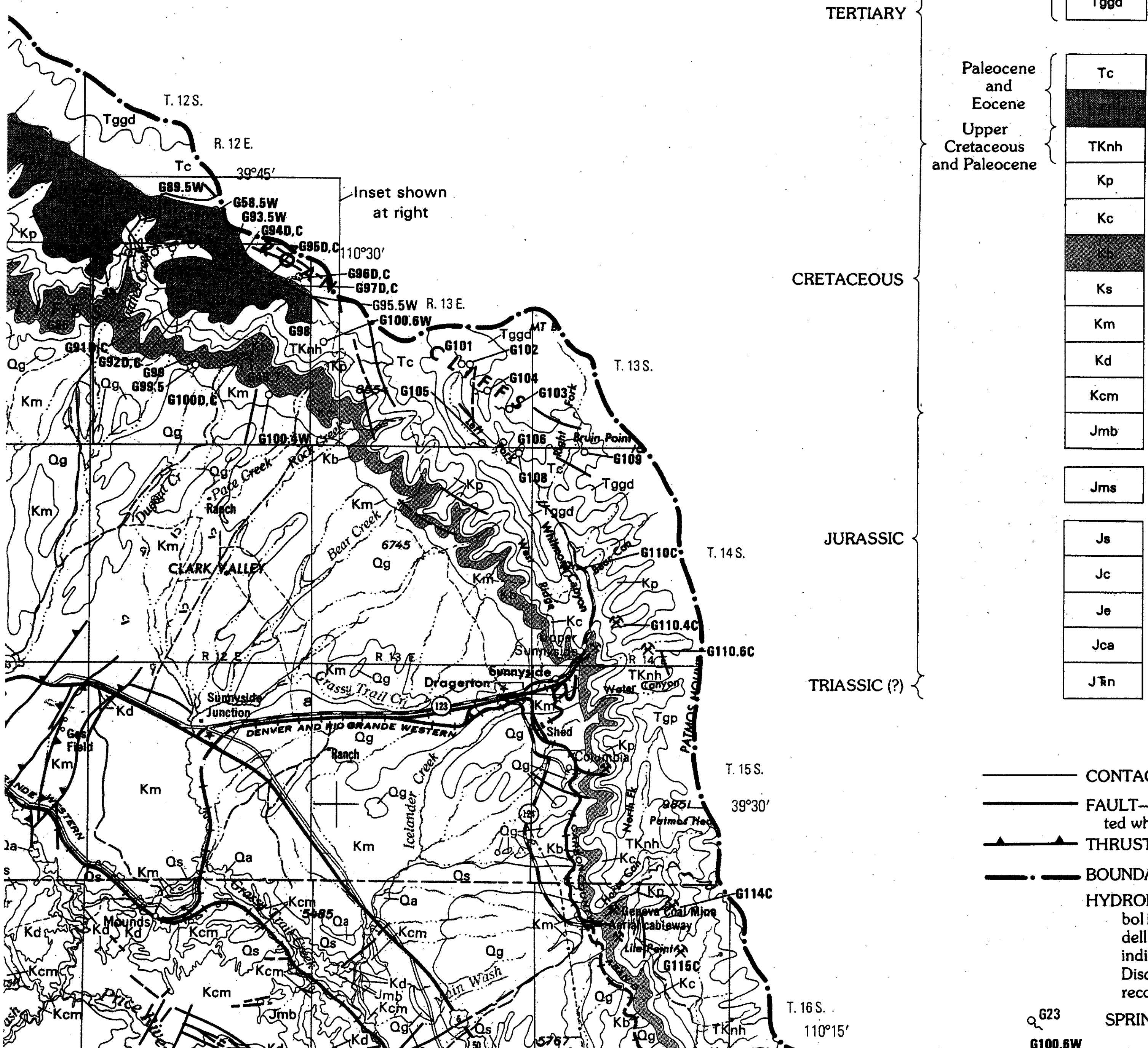
Wells G95.5, G100.6 and G100.4 shown on this drawing (Figure 19) are located within the 2008 permit boundary of the Dugout Canyon Mine. Refer to "Map Showing Geology and Data-Collection Sites for Ground Water, 1979 - 80 and Insert Showing Geology, Water Quality, and Hydrology Data-Collection Sites in a Part of the Soldier Creek Area, which follow this drawing.

MAP SHOWING GEOLOGY AND DATA-COLLECTION SITES FOR GROUND WATER, 1979-80

SCALE 1:250 000

5 0 5 10 MILES

5 0 5 10 KILOMETERS



Geology from Stokes, 1964

EXPLANATION

Age		Symbol	Unit
QUATERNARY	Of the same age	Qa	ALLUVIAL DEPOSITS—Chiefly along active streams
		Qg	GRAVEL SURFACES—Mainly on pediments and terraces
		Qs	COVERING DEPOSITS—Chiefly windblown slits lacking dune form, includes some alluvium
TERTIARY	Eocene	Tgp	LOWER UNIT OF PARACHUTE CREEK MEMBER OF GREEN RIVER FORMATION
		Tggd	GARDEN GULCH AND DOUGLAS CREEK MEMBERS OF THE GREEN RIVER FORMATION
	Paleocene and Eocene	Tc	COLTON FORMATION
			FLAGSTAFF LIMESTONE
	Upper Cretaceous and Paleocene	TKnh	NORTH HORN FORMATION
CRETACEOUS	Mesa Verde group	Kp	PRICE RIVER FORMATION
		Kc	CASTLEGATE SANDSTONE
		Kb	BLACKHAWK FORMATION
		Ks	STAR POINT SANDSTONE
		Km	MANCOS SHALE
		Kd	DAKOTA SANDSTONE
		Kcm	CEDAR MOUNTAIN FORMATION
JURASSIC		Jmb	BRUSHY BASIN MEMBER OF MORRISON FORMATION
		Jms	SALT WASH SANDSTONE MEMBER OF MORRISON FORMATION
		Js	SUMMERVILLE FORMATION
		Jc	CURTIS FORMATION
		Je	ENTRADA SANDSTONE
		Jca	CARMEL FORMATION
TRIASSIC (?)		JTin	NAVAJO SANDSTONE

CONTACT

FAULT—Dashed where approximately located; dotted where concealed

THRUST FAULT—Barbs on side of thrust plate

BOUNDARY OF PRICE RIVER DRAINAGE BASIN

HYDROLOGIC DATA SITES—Number by symbol indicates site number in data tables in Waddell and others (1982). Letter by symbol indicates type of data: C, Chemical analysis; D, Discharge measurement; W, Water level and records of wells and test holes.

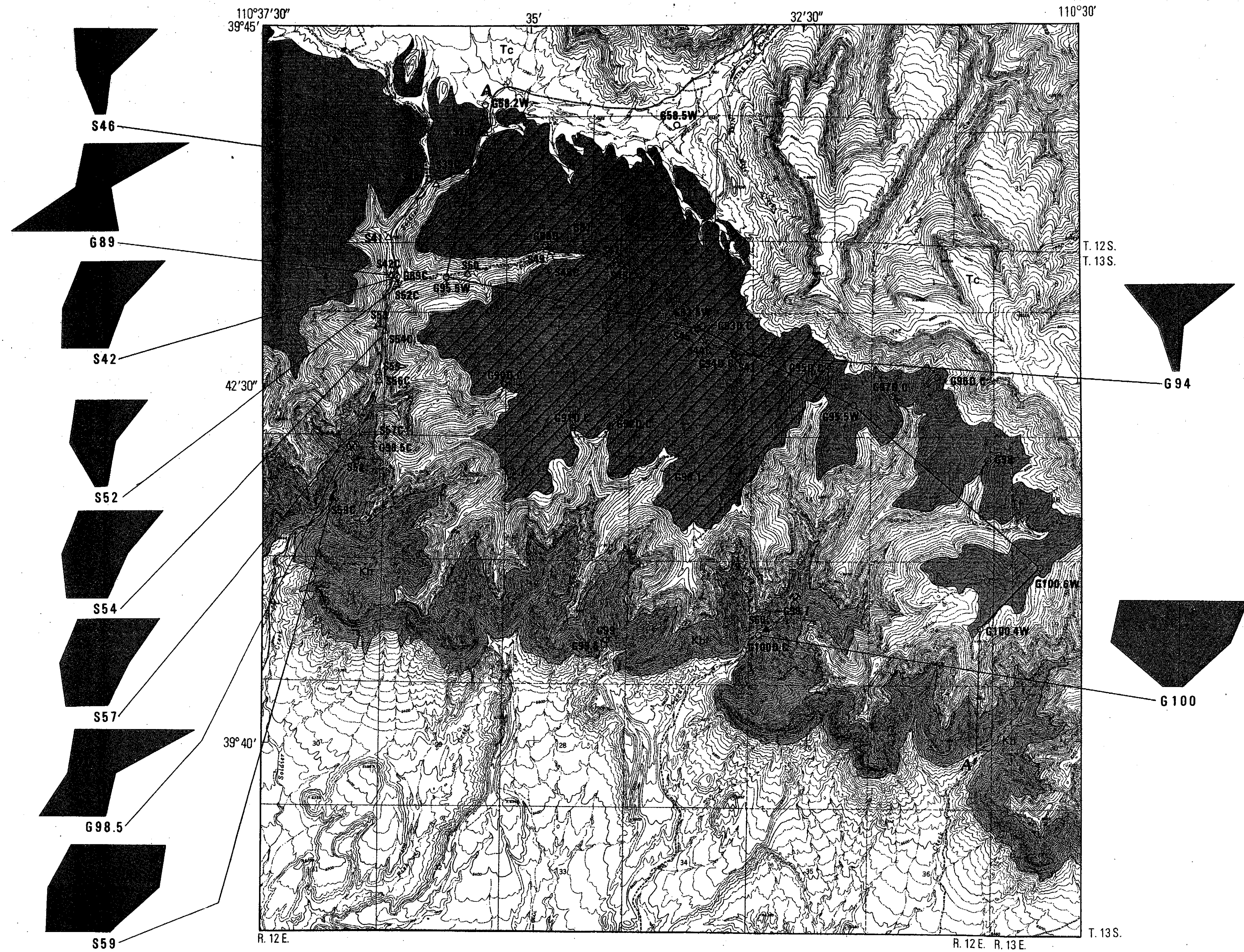
G23 SPRING

G100.6W WELL OR TEST HOLE

G110C MINE

WATER-SUPPLY PAPER 2246
PLATE 1

INSET SHOWING GEOLOGY, WATER QUALITY, AND HYDROLOGIC DATA-COLLECTION SITES IN A PART OF THE SOLDIER CREEK AREA



Base from U.S. Geological Survey Scofield, 1:24,000, 1979

SCALE 1:50 000

1 ½ 0 1 2 3 MILES

1 .5 0 1 2 3 KILOMETERS

CONTOUR INTERVAL 80 FEET
NATIONAL GEODETIC VERTICAL DATUM OF 1929

EXPLANATION

QUATERNARY
- Qa — ALLUVIUM

TERTIARY
- Tc — COLTON FORMATION
- FLAGSTAFF LIMESTONE
- TKnh — NORTH HORN FORMATION

CRETACEOUS
- Kp — PRICE RIVER FORMATION
- Kc — CASTLEGATE SANDSTONE
- Kb — BLACKHAWK FORMATION

CONTACT

AREA USED FOR ESTIMATING RECHARGE TO FLAGSTAFF LIMESTONE

HYDROLOGIC DATA SITE AND NUMBER—G preceding number indicates a ground water site; S preceding number indiactes a surface-water site; C, chemical analysis; D, discharge measurment; W, water level and records of wells and test holes

G99.7 MINE

G97D,C SPRING

G95.5W WELL

S60 GAGING STATION

S55 SEEPAGE-STUDY SITE

A——A' TRACE OF SECTION SHOWN IN FIGURE 19

WATER QUALITY DIAGRAM (FROM STIFF, 1951)

Calcium (Ca) — Bicarbonate (HCO_3) plus Carbonate (CO_3)

Magnesium (Mg) — Sulfate (SO_4)

Sodium (Na) plus Potassium (K) — Chloride (Cl)

8 4 2 0 2 4 6

MILLIEQUIVALENTS PER LITER

WATER-SUPPLY PAPER 2246
PLATE 1

APPENDIX 7-7

Surface-Water Monitoring Data

Appendix 7-7

SURFACE WATER MONITORING LOCATION 323

"323 (Junction)" Monitoring Data 2007

Date	Time	pH	Cond.	Temp.	Flow (gpm)	Comments
3/15/07	1220				NOA	Snow/Ice
5/18/07	1340	7.80	591	11	17	
6/21/07	1220	7.9	621	12.5	20.5	
8/30/07	1345	8.4	675	14	13	Livestock Use