2.04.7 Hydrology Description

The purpose of this section is to provide a broad overview of surface water and groundwater hydrology for the permit area. Important subjects relative to hydrology are also addressed in other sections including: Geology (2.04.6), Climatology (2.04.8), Soils (2.04.9), and Vegetation (2.04.10). For information pertaining to alternate water supply, refer to Section 2.05.6.

To complete specialized research and evaluation, and devote particular attention to hydrologic and subsidence phenomena resulting from mining, including the probable hydrologic consequences of mining, MCC retained Wright Water Engineers, Inc. (WWE) of Denver, and Glenwood Springs, Colorado. WWE has more than 50 years of experience on diverse water resource assignments. MCC also retained HydroGeo, Inc. (now Hydrogeology Solutions, Inc. (HSI)) to review the Hydrologic Characterization of the South of the Divide, Southern Panels, and Sunset Trail areas, as well as the monitoring plans. HydroGeo and HIS have completed the hydrologic monitoring and Annual Hydrology Reports for the WEM since 2001.

2.04.7(1) Groundwater Information

West Elk Mine had historically been considered a dry mine. Previous studies by MCC and its consultants have shown that groundwater inflows encountered within the mine workings were associated with perched conditions within the Upper and Lower Coal Members of the Mesaverde Formation. These studies concluded that there was no stratigraphic unit above the Rollins Sandstone that had the stratigraphic continuity or water-yielding capacity to be considered a potential regional aquifer (see previous Figures 5A, 5B, 5C, 5D, 5E, and 5F). See Section 2.04.6 (Geology Description) for a detailed discussion of the geologic units associated with, and in close proximity to, the West Elk Mine workings. See also Exhibits 17A, 18, and 18B for additional discussions relative to groundwater conditions and relationships.

Within West Elk Mine, groundwater inflows have largely manifested themselves as dripping roof inflows from sandstone channels located in the lower portion of the Mesaverde Formation, floor inflows associated with the underlying sandstone unit, rib/roof inflows associated with fractures storing finite volumes of groundwater, and, as manifested in early 1996, damage zones associated with fault systems. Conceptual groundwater flow is shown on Figure 7F and the potentiometric surface of the groundwater in the E Seam is presented on Map 1 of Exhibit 71.

In early March 1996, B Seam development mining of the B East Mains near the Northeast Panels intersected a SE-NE trending fault system (B East Mains (BEM) Fault) which initially produced about 500 gpm. This same fault was subsequently crossed by mining several times with observed groundwater inflows reaching as much as 2,500 gpm. Each progressive mining intersect of the BEM Fault was generally down-dip from the previous one resulting in a relatively large initial inflow that diminished over time. Each new intersection with the fault system generally resulted in the loss of inflow from the previous mined crossing of the BEM Fault.

In mid-January 1997, a second SW-NE trending fault system was intersected in the 14 Southeast Headgate. Inflows from this fault system (14 Southeast Headgate (14 HG) Fault) were initially about 150 gpm but intersects with this fault system in adjacent entries produced an inflow of approximately 8,000 gpm.

As a result of the BEM and 14HG Fault intersects and large respective inflows, Mayo and Associates conducted an investigation to characterize these fault-related groundwater inflows and the potential for encountering additional water-filled fault systems. A report was issued on this subject in August 1998 (Mayo and Associates, 1998). A more thorough discussion of these inflows and the results of the Mayo and Associates investigation can be found later in this section.

Mayo and Associates also conducted a hydrogeologic characterization of the permit and adjacent area in 1999. A complete copy of this report is included as Exhibit 18. That characterization was based on 1) A synthesis of existing hydrogeologic information, 2) Isotopic data collected in 1998, and 3) The results of Dr. Mayo's in-mine, fault-related, groundwater inflow investigation (Mayo and Associates, 1998).

A 2004 Mayo and Associates study, considered the information obtained from previous investigations both in the North Fork Valley and in eastern Utah coal mines in similar geologic formations and hydrogeologic conditions as they pertained to mining of the E Seam in West Elk Mine. A discussion of the potential projected effects on groundwater from E Seam mining from that study can be found later in this section and in Section 2.05.7 (Probable Hydrologic Consequences). A complete version of this report is included as Appendix 18B in this permit revision text.

As a result of these investigations (Mayo and Associates, 1999, Mayo and Koontz, 2000 and Mayo and Associates, 2004), it was concluded that groundwater inflows to West Elk Mine issue from groundwater systems that are part of the inactive groundwater regime as it relates to the genesis, composition and storage of the water. As discussed in Section 2.04.6 (Other Geologic Factors That May Affect Mining Conditions), the inactive zone includes ancient stored water residing in sand channel bodies, porous sections of fluvial or marine sand lenses or the damaged zones of fault and fracture systems. Conversely, the active zone includes water derived from rain and snowmelt stored in the near surface colluvium, alluvium or shallow bedrock formations (generally less than 500 feet in depth). Demonstration of the ancient characteristics of the water contained in strata surrounding West Elk Mine are indicated by the 10,500 year age date assigned to groundwater encountered in the BEM and 14HG Fault systems based on isotopic studies (Mayo and Associates, 1998).

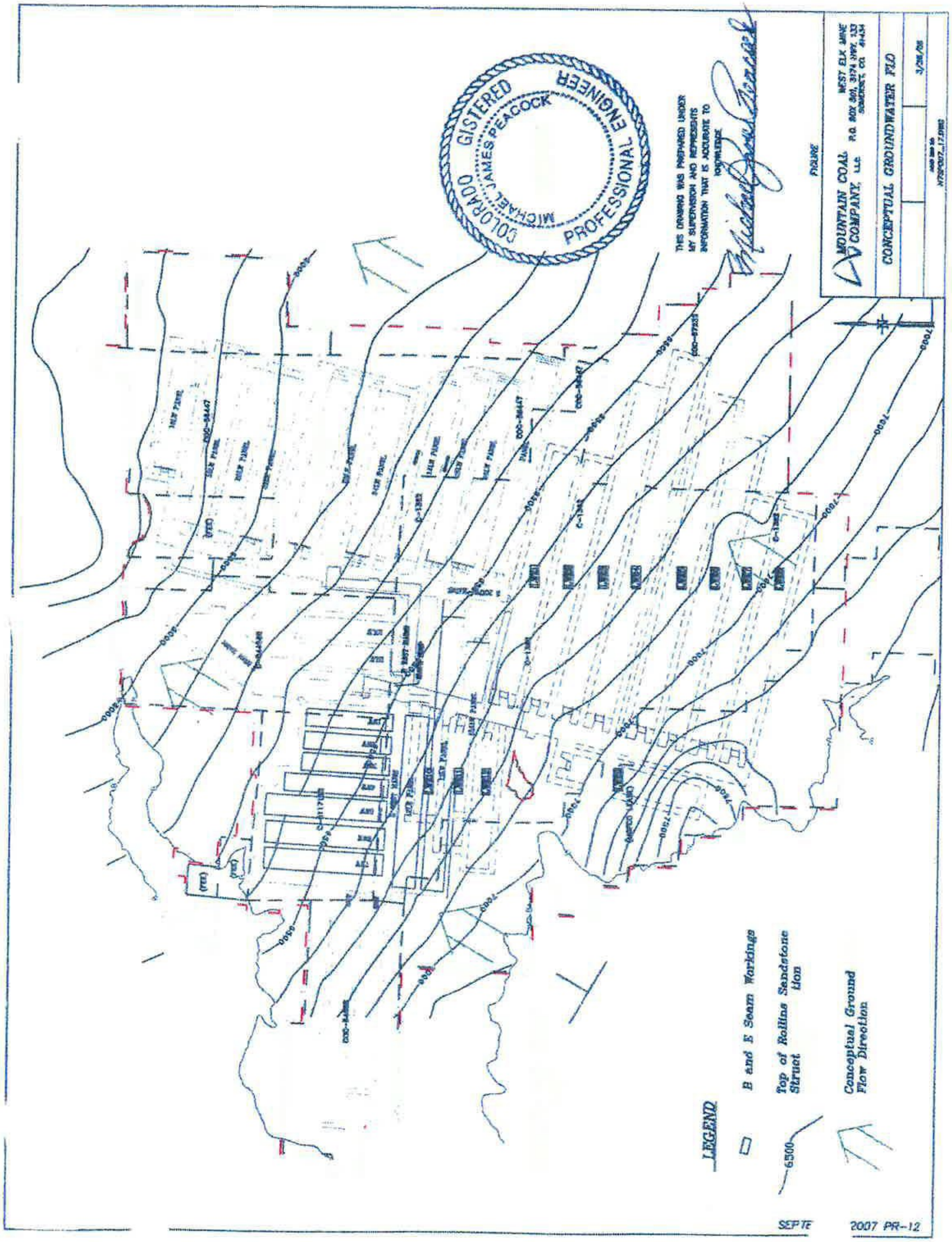

Figure 7F Conceptual Groundwater Flow

Regional Groundwater Conditions

For the most part, the Mesaverde Formation is dry or the rock units are of such low permeability that they yield insufficient water for sustained use. Even the extensive Rollins Sandstone, a thick basal sandstone immediately above the Mancos Shale, has been found to be highly cemented and a low water producer (an aquitard). Due to its areal extent, the Rollins Sandstone was thought to be a potential aquifer of regional importance, but the Rollins Sandstone has been found to have insufficient yield to sustain groundwater supply wells (Bowie No.1 MRP). In addition, petrographic analysis revealed that the sandstone units within the Rollins Sandstone are depositionally immature and have been designated as a "tight gas sand" by the Colorado Oil and Gas Conservation Commission (Mayo and Associates, 1998 and 1999).

Furthermore, groundwater monitoring wells completed in the Rollins Sandstone do not provide predictable information regarding Rollins Sandstone groundwater conditions, as determined by Mayo and Associates during their investigation of fault-related groundwater inflows from the Rollins Sandstone at West Elk Mine (1998). In that study, and their hydrogeologic study completed in 1999, it was determined that the groundwater systems associated with the Rollins Sandstone are not areally extensive and not in hydrodynamic communication with each other. For these reasons, MCC does not plan to continue monitoring or complete any additional monitoring wells in the Rollins Sandstone.

Most of the stratigraphic members of the Mesaverde Formation above the Rollins Sandstone outcrop within close proximity to West Elk Mine. Up-dip B Seam outcrops occur 0.6 to 4 miles from underground workings. Most workings intercept the B Seam within 2 miles of the up-dip outcrop. Mining areas in the overlying Upper Coal Member have similar distances to the up-dip outcrop. The Lower Coal Member (i.e., B Seam) extends down dip beneath the North Fork of the Gunnison River (North Fork) and does not crop out down-dip in the permit area. Down-dip outcroppings of rock units from the Bowie Sandstone and higher occur along the North Fork and in Sylvester Gulch in the mine permit area. Up-dip outcrops of rocks units associated with mineable coal tend to occur on steep slopes and thus have limited potential for groundwater recharge from the active zone.

The stratigraphic sequence, observed spring locations and topography suggests groundwater recharge is from snowmelt and precipitation and discharges mainly from bedrock and colluvial springs on steeper slopes above the major drainages and is restricted to active zone groundwater systems. A small amount of water infiltrates downward through the bedrock units, while most moves laterally on top of relatively impermeable rock units, discharging where more permeable units outcrop/subcrop.

Sandstone units within the Mesaverde Formation are generally lenticular, regionally discontinuous and are usually highly cemented. In general, the only extensive units are the persistent coal seams, especially the B Seam, and the Rollins Sandstone. The dip of these formations is to the northeast at generally less than 5 degrees.

Due to low permeabilities within the Rollins Sandstone and the B Seam, local groundwater flow is controlled by secondary porosity (i.e., fractures). However, there is a general regional trend within these formations for the groundwater to flow in the direction of the northeast dip.

No private, commercial, or industrial water supply wells other than those owned by MCC are presently located within the permit area based on a February 2003 review of the Colorado State Engineer's Office (SEO) well permit database. A summary of the permitted wells within the permit area are provided in Table 3A. This table summarizes the well location, permit number, owner's name, reported well yield and permitted use for each of the wells listed. Of the 29 permitted wells within the West Elk Mine permit boundary, 22 are permitted to MCC or its mining company predecessors. The remaining seven wells are permitted to private individuals. Of these seven permits, three have expired. Each of the remaining four wells is now under the ownership of MCC and are no longer in use. Reported well yields are generally low (less than 2 gpm with one monitoring well reporting 4 gpm) throughout the area except in alluvial wells located along the North Fork in Sections 9, 10 and 11 where reported yields range from 9.7 to 30 gpm.

Table 3A

Permitted Well Summary [(1)]

West Elk Mine Permit Boundary Area, Gunnison County, Colorado

Permit No.	Permit Suffix	Activity Code	Activity Date	Twn.	Rng.	Sec.	Qtr. 40	Qtr. 160	Coordinates N/S line	Coordinates E/W line	Applicant	City	Use Code	Aquifer	Depth	Yield	Wtr. Level
31713	MH	MH	9/11/1997	13S	90W	09	SW	SE	0000	0000	MOUNTAIN COAL CO	CEDAREDGE	mon	GW	146	--	122
32016	MH	MH	10/15/1997	13S	90W	09	SW	SE	0000	0000	MOUNTAIN COAL CO	CEDAREDGE	mon	GW	63	0.25	50
32642	MH	MH	1/29/1998	13S	90W	09	SW	SE	0000	0000	MOUNTAIN COAL CO	CEDAREDGE	mon	GW	89	0.25	84
32643	MH	MH	2/2/1998	13S	90W	09	SE	SE	0000	0000	MOUNTAIN COAL CO	CEDAREDGE	mon	GW	55	1.00	20
25748	F	NP	10/26/1981	13S	90W	09	SE	SE	0000	0000	ARCO COAL CO	SOMERSET	dom	GW	--	--	--
174726		NP	10/15/1993	13S	90W	10	SW	SW	128S	5W	MOUNTAIN COAL CO	SOMERSET	mon	KMV	--	0.00	--
43469				13S	90W	10	NE	SE	0000	0000	WESTERN SLOPE CARBON INC	SALT LAKE	dom	GW	63	28.00	29
80254				13S	90W	10	SE	SW	500S	2470W	NORRIS KEN	SOMERSET	dom	GW	37	30.00	7
182236		NP	8/25/1994	13S	90W	11	NW	SE	2100S	2000E	MOUNTAIN COAL COMPANY	SOMERSET	mon	GW	--	0.00	--
2146				13S	90W	11	NW	SE	0000	0000	CHAMPION COAL MNG CO	SOMERSET	dom	GW	55	20.00	51
23918	F			13S	90W	11	NW	SE	2815N	1560E	WESTERN SLOPE CARBON INC	SALT LK CTY	ind	GW	10	9.70	--
31714	MH	MH	9/11/1997	13S	90W	15	NW	NW	0000	0000	MOUNTAIN COAL CO	CEDAREDGE	mon	GW	83	--	77
182237		NP	8/25/1994	13S	90W	15	SE	SW	150S	2200W	MOUNTAIN COAL COMPANY	SOMERSET	mon	GW	--	0.00	--
31715	MH	MH	9/11/1997	13S	90W	16	NW	NE	0000	0000	MOUNTAIN COAL CO	CEDAREDGE	mon	GW	191	4.00	106
32015	MH	MH	10/15/1997	13S	90W	16	NE	NE	0000	0000	MOUNTAIN COAL CO	CEDAREDGE	mon	GW	26	--	6
32216	MH	MH	11/4/1997	13S	90W	16	SE	NW	0000	0000	MOUNTAIN COAL CO	CEDAREDGE	mon	GW	--	--	--
32412	MH	MH	12/9/1997	13S	90W	16	NE	NE	0000	0000	MOUNTAIN COAL CO	CEDAREDGE	mon	GW	166	1.00	158
32413	MH	MH	12/9/1997	13S	90W	16	NW	NE	0000	0000	MOUNTAIN COAL CO	CEDAREDGE	mon	GW	115	--	112
90413		NP	4/21/1977	13S	90W	16	NE	NE	0000	0000	ROSS H B	DELTA	stock	GW	--	--	--
90414		NP	4/21/1977	13S	90W	16	NE	SE	0000	0000	ROSS H B	DELTA	stock	GW	--	--	--
189368		NP	6/22/1995	13S	90W	26	SE	SW	50S	1900E	MOUNTAIN COAL COMPANY	SOMERSET	mon	GW	--	--	--
182238		NP	8/25/1994	13S	90W	27	NW	NE	350N	2450E	MOUNTAIN COAL COMPANY	SOMERSET	mon	GW	--	0.00	--
182239		NP	8/25/1994	13S	90W	29	NE	SE	1600S	750E	MOUNTAIN COAL COMPANY	SOMERSET	mon	GW	--	0.00	--
182240		NP	8/25/1994	13S	90W	29	SE	NW	2200N	1800W	MOUNTAIN COAL COMPANY	SOMERSET	mon	KMV	--	0.00	--
92017		EP	6/7/1977	13S	90W	32	SW	SW	250S	450W	INDERGARD LAWRENCE	GRAND JCTN.	stock	GW	--	--	--
174725		NP	10/15/1993	13S	91W	25	NE	NW	20N	2500W	MOUNTAIN COAL CO	SOMERSET	mon	KMV	--	0.00	--
92018		EP	6/7/1977	14S	91W	04	SW	SW	550S	600W	INDERGARD LAWRENCE	GRAND JCTN.	stock	GW	--	--	--

Permit No.	Permit Suffix	Activity Code	Activity Date	Twn.	Rng.	Sec.	Qtr. 40	Qtr. 160	Coordinates N/S line	E/W line	Applicant	City	Use Code	Aquifer	Depth	Yield	Wtr. Level
92019				14S	91W	08	SW	NE	1900N	2000E	INDERGARD LAWRENCE	GRAND JCTN.	stock	GW	140	2.00	110
92016		EP	6/7/1977	14S	91W	09	NE	SE	2000S	500E	INDERGARD LAWRENCE	GRAND JCTN.	stock	GW	--	--	--

(1) Based on well permit records obtained directly from a CD purchased from the Colorado State Engineer's Office (Gunnison County, Colorado - 2/2003)

29 permit wells within West Elk Mine permit boundary:

4 wells permitted for domestic uses (3 to mining companies and one to a private individual); all wells owned by MCC and unused

6 wells permitted for stock uses (all 6 permitted to private individuals); 3 permits have expired (EP); 3 remaining wells now owned by MCC and unused

1 well permitted for industrial use (predecessor of MCC)

18 wells permitted for monitoring purposes (all permitted to MCC or its predecessors)

Groundwater use in the general area around West Elk Mine is generally confined to shallow wells in the alluvium of the North Fork and its tributaries. There is an existing well permit for a groundwater well completed in the SW¼NE¼, Section 8, T14S, R90W. This well was completed in a localized sandstone unit at a depth of approximately 120-140 feet and yielded approximately 2 gpm on completion. MCC owns this well, which is no longer utilized due to its limited capacity. The Rollins Sandstone was thought to be the source of water for two stock and domestic wells completed along the North Fork near the reclaimed Hawk's Nest East Mine, although these wells (designated 17 and 16) are probably completed above the Rollins Sandstone (Brooks and Ackerman, USGS, 1986). These "Rollins Sandstone wells" are thought to have a surface water connection with the alluvium due to the close proximity of the wells to the river and the lower salinity of the water (Prince and Arrow, 1974). Water levels for these wells indicated a gradient paralleling the North Fork.

The relative lack of groundwater within the Mesaverde Formation can be further demonstrated by reviewing information obtained during the drilling of boreholes. Figures 5A through 5F in Section 2.04.6, are stratigraphic cross-sections between drill holes that indicate those intervals within each hole where groundwater was encountered. The general lack of these notations indicates the insignificance of the groundwater quantity and availability within the coal bearing strata.

Mayo et al. (1997) developed a conceptual model of groundwater flow in the Book Cliffs and Wasatch Plateau. This model was based on an analysis of physical hydrology, solute and isotopic data, and stratigraphic sequences in the coal district. The analysis included more than 300 stable and radiogenic isotopic compositions of in-mine, spring, and surface samples; hydrographs of more than 300 springs; tens of hydrographs of mine inflows; solute compositions of more than 500 in-mine, spring, and stream waters; and more than 30 monitoring well hydrographs. The data and observations from the West Elk Mine area, which are summarized in the reports contained in Exhibits 18 and 18B (specifically for the E Seam mining in the South of Divide permit area), are consistent with their observations elsewhere, and support the conceptual model of Mayo et al. (1997) when describing the hydrogeologic conditions of the West Elk Mine site.

The overall pattern of groundwater flow and surface water-groundwater interactions in the study area can be described by a conceptual model involving both active and inactive groundwater flow regimes. Active groundwater flow systems contain abundant ^{3}H, have excellent hydraulic communication with the surface and thus are dependent on annual recharge events and are affected by short-term climatic variability. Groundwater in these systems circulates shallowly and has short flow paths. The active regime includes alluvial groundwater and near-surface exposures of all bedrock formations except, perhaps, the Mancos Shale. The "near surface" extends about 500 to 1,000 feet into cliff faces or exposed ridgelines where flow is controlled by fractures and channel sands. Further into the cliff faces and ridgelines the discontinuous character of channel sands prevents active groundwater flow. Monitoring well hydrographs suggest that the vertical movement of active zone groundwater is less than 100 feet below the ground surface; however, it is likely that the active zone may locally extend for 200 to 500 feet below ground surface.

Inactive groundwater flow regimes contain old groundwater (i.e., thousands of years), have very limited hydraulic communication with the surface and active groundwater flow systems, and are not influenced by either annual recharge events or short term climatic variability. Inactive groundwater systems occur more than about 200 to 500 vertical feet from the surface and greater than about 500 to 1,000 feet from cliff faces. Groundwater in these systems located above coal bearing horizons tends to occur in sandstone channels. These sandstone channels are vertically and horizontally isolated from each other and when encountered in mine workings are usually drained quickly. Swelling clays and impermeable shales in the rocks in the unsaturated zone between the near-surface active systems and deeper inactive systems effectively prohibit downward vertical migration of waters from the active systems.

In the study area, the active zone includes alluvial, mantle cover and landslide materials, and near surface exposures of the Barren Member and Upper and Lower Coal Members. The inactive zone includes deeper rocks of the Barren Member, Upper and Lower Coal Members and the Rollins Sandstone.

Exhibit 18 contains Mayo and Associates' complete hydrogeologic analyses of the permit and adjacent areas. A 2004 Mayo and Associates report (Exhibit 18B) provided an assessment of the hydrogeologic conditions associated with the E Seam in the South of Divide permit area. Section 2.05.6 of this permit document addresses important findings from permit revision submittals and decision documents regarding the general lack of groundwater at the mine. Reference these exhibits and permit sections for specific details.

In summary, areally extensive groundwater systems and aquifers do not occur in the study area. This is due to: 1) the steep cliff-face exposures of many bedrock formations, and 2) the heterogeneous lithologies of bedrock formations, which prevent significant vertical or horizontal movement of the limited recharge to bedrock groundwater systems. Groundwater encountered in mine workings is associated with the inactive zone and not in hydraulic communication with groundwater in the active zone represented by the near surface colluvium and alluvium. These mine inflows are localized and do not form areally extensive systems having hydrodynamic communication with each other. Therefore, neither the coal seams nor the overburden units within the permit area transmit groundwater in sufficient quantity to sustain water supplies.

Site Hydrogeology

The most significant hydrogeologic units present within the West Elk Mine property include (from bottom to top) the Mancos Shale, Mesaverde Formation (including the Rollins Sandstone, Lower Coal Member, Upper Coal Member, and the Barren Member), and the colluvium and alluvium along the drainage side-slopes and valley bottoms, respectively (Map 9). A more detailed discussion of the stratigraphic units within the permit area can be found in Section 2.04.6, Geology Description. The general significance of these stratigraphic units from a hydrogeological perspective is discussed below.

The extent and orientation of these units is best depicted in a representative stratigraphic section through the permit area as compiled from drill hole information (Figure 4 in Section 2.04.6). This stratigraphic section has been prepared using the top of the Lower Marine Sandstone unit as a datum reference and the "best fit" method. This technique "matches," to the nearest degree possible, the rock types and sequences of lithologies portrayed on the graphic logs of adjacent drill holes.

The Mancos Shale, which underlies the Mesaverde Formation within the West Elk Mine property, is a marine shale formation of considerable thickness (approximately 2,000 to 3,000 feet thick). Due to its extremely low permeability, this shale unit acts as an aquitard, inhibiting the downward migration of groundwater from the basal sandstone member (Rollins Sandstone) of the Mesaverde Formation.

The Mesaverde Formation is typically 2,500 feet thick at the mine and consists of sandstone, shale, clay, and interbedded coal. As mentioned in Section 2.04.6 - Geology Description, this formation is the coal-bearing formation in the region and is divided into five main members; the Rollins Sandstone Member, the Lower Coal Bearing Member, the Upper Coal Bearing Member, the Barren Member, and the Ohio Creek Member (Dunrud 1989). Within these members, locally continuous permeable sands may contain groundwater, which generally is recharged in the active zone from meteoric waters. However, the discontinuous nature of the more permeable zones within this formation clearly indicate that the Mesaverde Formation at and in the vicinity of West Elk Mine does not contain any formations which could be classified as aquifers. Only the Rollins Sandstone, and to a lesser degree, the Upper and Lower Marine Sandstones between the Lower and Upper Coal Members, provide the most continuous sandstone units within the Mesaverde Formation.

The colluvium within the West Elk Mine property is generally comprised of locally-derived materials carried down slope by rain wash, rock fall, landslides or other gravitational means. Colluvium is typically thin, but may be up to 30 feet thick in landslide debris deposits. Numerous springs are known to emanate from these deposits, indicative of the active groundwater regime discussed previously in this section.

Alluvial deposits within the coal lease area are generally confined to relatively continuous, but narrow strips in the lower reaches of the larger drainages and are usually less than 25 ft. thick. Where these deposits contain sufficient saturated thickness, the more permeable nature of these materials can yield sufficient water to sustain domestic and livestock supplies. Locally, only wells in the alluvium of the North Fork supply such yields.

A more detailed discussion of the hydrogeologic characteristics of these units can be found later in this section.

Baseline Monitoring Program

This section discusses the program that MCC has implemented to monitor ground water quantity and quality resources in the permit area. At least one year of baseline data will be collected prior to longwall mining under or within the angle-of-draw of a monitored water resource. Monitoring data are presented in the Annual Hydrology Reports (AHR).

Groundwater Level and Quantity

The currently monitored groundwater wells are described and listed in Exhibit 71. Exhibits 71 and 71A present both the hydrologic monitoring program as well as monitoring site locations within the permit area. Locations of monitoring wells are presented on Map 1 in Exhibit 71 and Table 3 in the exhibit provides a summary of groundwater monitoring well characteristics. A complete listing of all monitoring data is presented in the AHRs.

Appendix A of Exhibit 71 is a technical memo entitled, "2016 Recommended Modifications to the West Elk Mine Hydrologic Monitoring Network". This memo was the basis of Technical Revision TR-139 that revised the hydrology monitoring program that is detailed in Exhibit 71.

Groundwater Quality

As with groundwater level and quantity, the groundwater quality monitoring program (as revised in 2016) is detailed in Exhibit 71. Analyses are completed as outlined in the *Guidelines for Collection of Baseline Water Quality and Overburden Geochemistry Data* (CDMG, 1982). Results are reported in the AHRs. If not already provided in AHRs, baseline data will be provided to CDRMS prior to longwall mining under or within the angle-of-draw of a monitored water resource.

Table 4 in Exhibit 71 provides a summary of groundwater quality data from the South of Divide and Dry Fork permit areas. Table 5 of the Exhibit provides the baseline and routine monitoring frequencies. Table 9 of Exhibit 71 provides another summary of the groundwater monitoring well characteristics and Table 10 provides a summary of the groundwater monitoring program.

Groundwater Quantity Characteristics

Over 238 exploration holes have been drilled on or near the West Elk Mine coal lease area. Records and consultation with project geologists indicate that water was encountered only sporadically in the Mesaverde Formation, indicating groundwater is localized and of limited areal extent. As defined in the CDRMS rules, an aquifer is "a zone, stratum or group of strata acting as a hydraulic unit that can store or transmit water in sufficient quantities for beneficial use." Based on information presented in the next several sections of this document (i.e., permeability analyses, and water level observations), it is the contention of MCC that none of the geologic members of the Mesaverde Formation are aquifers within the West Elk Mine permit area.

The most immediate assessment of whether a geologic formation can be considered an aquifer is to assess whether water supply wells (a demonstration of beneficial use) have been completed into the formation. As shown in Table 3A, there are 29 permitted wells within the West Elk Mine permit boundary. Of these, 17 have reported well yields and 13 have provided well depths (ten wells less than 100 feet, three wells between 140 and 191 feet). These values range from a low of 0.0 gpm to a high of 30.0 gpm. The four highest reported yields are from wells drilled to a depth of 10 to 63 feet in Sections 9, 10 and 11 (i.e., in the alluvium of the North Fork). These four wells are not completed in the bedrock members of the Mesaverde Formation. The other 13 wells with reported yields have a range of 0.0 to 4.0 gpm (seven wells have reported yields of 0.0 gpm) and an average production rate of 0.65 gpm. Closer inspection of the remaining 6 wells with reported well yields above 0.0 gpm shows that all but one is permitted as a monitoring well. As such, only one of the 29 permitted wells appears to have obtained a useable supply (2.0 gpm reported) for beneficial use (stock watering). This well has a depth of 140 feet, within the active groundwater flow zone where there is hydraulic communication with the surface and thus dependence on annual recharge events. Given the lack of beneficial use of these formations as a water supply, it is concluded that these formations are not aquifers. Further evidence to support this conclusion is provided by the low permeability data described later in this section.

Wells have been completed in a variety of formations for varying purposes. Formations in which groundwater monitoring data have been collected include the Rollins Sandstone, various members of the Mesaverde Formation, and colluvial and alluvial deposits.

In addition to water level data collection, hydrogeologic characteristics (i.e. transmissivity, hydraulic conductivity, and yield) of many of these formations have been obtained from pumping and slug test analysis. Transmissivity values from pumping tests were estimated from Lohman (1975), using the following equation:

$$\frac{Q}{s} = \frac{4\pi T}{2.30\log_{10}\left(\frac{2.25Tt}{r^2 S}\right)}$$

Where:

Q = discharge (gal/day)
T = transmissivity (gal/day/ft)
r = radius of the well (ft)
t = duration of pumping (days)
s = drawdown (ft)
S = storage coefficient (estimated 0.001)

The following sections discuss each of the monitored formations within the permit area and their hydrogeologic characteristics. For the most part, the bedrock units represent the inactive groundwater zone particularly at depths greater than about 500 feet below the ground surface and a distance of approximately 1,000 feet inward from exposed cliff faces. The colluvium and alluvium, along with the near surface exposures of the bedrock units, represent the active groundwater zone.

Rollins Sandstone

In the past, the Rollins Sandstone was thought to be a potential aquifer of regional importance, due to its areal extent. However, more recent data and analyses indicate that the Rollins Sandstone is not a regional aquifer (Mayo, 1998). Additional discussions are provided in Exhibits 17A, 18, and 18B.

MCC has constructed four monitoring wells completed in the Rollins Sandstone. These wells included R-1, LP-1, SOM-128-H, and So.W-3 (See Map 34). No water was ever noted in LP-1 primarily because the Rollins Sandstone is exposed to the atmosphere upgradient of this area. LP-1 was removed from the monitoring program in June 1998 when the Lone Pine Gulch ventilation portals were closed and reclaimed. SOM-128-H and So.W-3 were also removed from the monitoring program in 1999. Monitoring well So.W-3 was rendered useless when B Seam mining cut through the well.

Considerable hydrogeologic parameter estimations have been conducted on the Rollins Sandstone in the vicinity of the mine, particularly in the areas associated with the BEM and 14HG Faults. As shown in Table 5, a pumping test conducted on monitoring hole R-1 for just the Rollins Sandstone portion of the well indicated that the formation was capable of producing only approximately 3 gpm. Mayo and Associates (1998) reported both horizontal and vertical hydraulic conductivity values for various intervals within the Rollins Sandstone. In general, horizontal hydraulic conductivity values range from 1.0×10^{-4} to 1.2×10^{-2} ft/d while measured vertical values ranged from 1.7×10^{-4} to 1.8×10^{-2} ft/d.

In addition, Mayo and Koontz (2000) reported horizontal hydraulic conductivity values for the Rollins Sandstone from in-mine permeameter testing between 2.4×10^{-3} and 1.3×10^{-1} ft/d. These data show that, with the exception of the fractured portion of the formation, the permeability of the Rollins Sandstone is low. In fact, Mayo (1998) states that of the fifteen analyzed core samples taken from the Rollins Sandstone between the BEM and 14HG Faults, only one “had sufficient permeability to transmit water” and “the low permeability of all other samples make them effective barrier to groundwater flow.”

This is further documented in CDRMS permit revision decision documents, where it was reported that drill holes that penetrated the Rollins Sandstone near the Orchard Valley Mine (later called Bowie No. 1 Mine) had an insufficient yield to sustain groundwater supply wells.

As discussed previously, groundwater monitoring wells completed in the Rollins Sandstone do not provide reliable information on the groundwater systems within the unit (Mayo and Associates 1998 and 1999). In addition, the groundwater systems are not areally extensive and not in hydrodynamic communication with each other. For these reasons, MCC does not plan to continue monitoring or complete any additional monitoring wells in the Rollins Sandstone, because it has concluded that this formation does not produce sufficient quantities of groundwater for beneficial use. A review of SEO permitted wells in the vicinity of the West Elk Mine confirms that there are no water wells producing from the Rollins Sandstone.

However, the information obtained from Rollins Sandstone monitoring well observations have played an important role in understanding the interaction of this major beach/offshore bar deposited sand with the damaged zones associated with the BEM and 14HG Faults. From these observations, Mayo and Associates (in Exhibit 18B) has been able to make correlations to the Bowie Sandstone (of similar depositional history, mineralogical composition, geometry, and structural architecture to the Rollins Sandstone) as it relates to mining in the South of Divide permit area.

Assuming an average gradient of 0.05 in the mine workings, an average horizontal porosity of 0.01 (Mayo and Associates, 1998), and a horizontal connectivity of 1.0 x 10^{-4} to 1.0 x 10^{-2} ft/d, the average horizontal seepage velocity in the Rollins Sandstone would range from .18 to 1.8 ft/yr. However, these calculations have limited value for predicting flow rates in the compartmentalized Rollins Sandstone. The journal article Mayo and Koontz (2000), demonstrated that the Rollins Sandstone ground water systems, in the mine permit area, occur as hydraulically isolated bodies that are not horizontally continuous.

Lower Coal Member (Mesa Verde Formation)

The Lower Coal Member contains approximately 300 feet of interbedded shales, fine-to-medium-grained sandstones and relatively persistent coal seams. The Lower Coal Member of the Mesaverde Formation includes the A, B, and C coal seams. This member is generally considered to be that portion of the Mesaverde Formation between the Rollins Sandstone and the D-Seam, and includes the Upper and Lower Marine Sandstones. These sandstone units are not a single, persistent bed but actually several thick lenticular sandstones occurring at progressively lower stratigraphic horizons.

The Lower Coal Member contains some sandstone units that locally may produce water. This is supported by observations within the B Seam mine workings, which show that the average annual inflow to the mine, prior to 1996, was approximately 12 gpm. While this observation continues to hold true for sandstone units near the B Seam, development mining has encountered faults which can contain significant quantities of water (see *Permeability and Factors Influencing Permeability* later in this section).

Information from mines that operated in the Lower Coal Member (i.e., Somerset and Bear No. 1 and No. 2 Mines) demonstrated that there is a lack of water in this member. Even after the onset of subsidence during retreat mining, there was no reported increased flow of groundwater from this formation into the Somerset Mine, even though it is located down-dip of the North Fork of the Gunnison River (U.S. Steel Somerset Mine MRP, Section 2.04-7, Hydrology Description).

Of specific importance in this Lower Coal Member of the Mesaverde Formation is the B Seam coal itself. A pumping test analysis was conducted on well SOM-23-H-1, completed into the B Seam. However, the very low flow rate (estimated at 1 gpm) was insufficient to be able to quantify any hydrogeologic parameters and therefore no meaningful conclusions could be drawn from this analysis. SOM-23-H-1 was removed from the monitoring program in June 1998.

Slug-test analyses were performed on B Seam monitoring wells SOM-127-H (now sealed) and SOM C-72-H. Permeability measurements from these analyses (presented in Table 5) indicate that the in-situ values are less than 10 feet per year (1 x 10^{-5} cm/sec). This value was also confirmed in core plug analysis of samples between the A and B Seam coals by Mayo and Associates (1998). Based on observations during drilling and development of well SOM-3E the permeability of the B-Seam is estimated to be about $2.3x10^{-3}$ ft/day ($1x10^{-6}$ cm/sec) (HydroGeo, 2003).

Upper Coal Member (Mesa Verde Formation)

The Upper Coal Member contains approximately 230 feet of interbedded shales, siltstones, lenticular sandstones, and three persistent coal seams. These seams include the D, E, and F coal seams. In portions of the Apache Rocks permit area and all of the South of Divide permit area, the E Seam was determined to be of sufficient thickness and quality to be mined. This stratigraphic member of the Mesaverde Formation lies between the underlying marine sandstones (principally the Bowie Sandstone) and an overlying, similar but less persistent, massive, cliff-forming discontinuous channel sandstone.

Groundwater inflows into the E Seam workings were projected to occur from two potential sources:

1. Sandstone channels in and near the roof of the E Seam workings.
2. Fault-related inflows from the underlying Bowie Sandstone.

Extensive sandstone channels were mapped above the E Seam in the South of Divide permit area. The extent of these sandstone channels was presented in Exhibit 18B on Figure 17. Because 800 or more feet of overburden generally covers the channel sandstones, it is unlikely that they have received appreciable recharge by vertical infiltration from the overlying rocks or are in active hydraulic communication with either surface water or near surface groundwater (Mayo and Associates, 1999). The most likely recharge locations are along up-dip regions in the vicinity of Minnesota Creek and possibly near the contact with the Mt. Gunnison intrusion. However, no known sandstone channel outcrops have been positively identified along the Minnesota Creek drainage due to colluvial cover. While monitoring well data have documented saturation in these channel sandstones, appreciable quantities of water or unusual water pressures have not been encountered in the numerous boreholes that have penetrated these channels. In addition, no water was encountered when constructing three ventilation shafts, numerous mine ventilation boreholes, or in the development workings and longwall panels mined in the SOD area in the E Seam.

Inflows from these sandstone channels are expected to be minor, but in association with faults such as the 14 HG could be as great as 500 gpm. Damaged zones associated with these fault zones have the potential to locally increase both the permeability and storage capacity of the sandstone channels thus potentially increasing roof inflows in the vicinity of the faults. Such roof inflows are not expected to persist for more than a few weeks (see Exhibit 18B).

Mayo and Associates Exhibit 18B describes the Bowie Sandstone as having a similar depositional history and mineralogical composition to that of the Rollins Sandstone. As a result, fault-related inflows from the Bowie Sandstone beneath the E Seam have the potential to be as great as those associated with the Rollins Sandstone. However, given the lack of continued significant roof inflows into the B Seam workings, it is thought that most, if not all, of the saturation within the Bowie Sandstone near the fault zones encountered by the B Seam workings have been drained. Only a few minor seeps discharge from Bowie Sandstone outcrops between

Sylvester Gulch and the Bear Mine. The absence of appreciable spring discharges further supports the idea that the Bowie Sandstone is not saturated.

As mentioned above, the current groundwater monitoring program can be found in Exhibit 71 and the results of monitoring in AHRs.

Pumping tests were conducted in monitoring wells completed in the alluvium, colluvium, the Barren Member, Lower Coal Member, and Upper Coal Member of the Mesaverde Formation. Pumping test data from these wells are contained in Table 5. Also see discussions in Exhibits 17 and 18.

Table 5
Summary of Pumping Test Data

Well	Date of Test	Geologic Unit Tested	Hole Type	Pumping Rate	Yield	Estimated Transmissivity
SOM C76	10/18/75	F Seam	Cased	3 gpm	0.012 gpm/ft.	16.68 gpd/ft.
SOM C76A[1]	10/29/75	F Seam & Barren Member	Cased	3 gpm	0.012 gpm/ft.	---
SOM 22-H-2	09/25/74	Barren Member	Cased	0.75 gpm	0.003 gpm/ft.	2.46 gpd/ft.
SOM 22-H-3	05/19/75	F Seam	Cased	1 gpm	---	---
SOM 64	07/30/74	Barren Member	Open	0.75 gpm	0.005 gpm/ft.	---
SOM 55	06/11/74	Barren Member	Open	0.75 gpm	0.005 gpm/ft.	---
SOM C35	---	F Seam	Cased	---	Dry Hole	---
SOM 23-H1	10/08/74	B Seam	Cased	1 gpm	---	---
SG-1	11/11/76	Sylvester Gulch Alluvium	Cased	1 gpm	---	121 gpd/ft.
R-1	11/01/75	Rollins Sandstone	Open	3 gpm	---	---
R-1	05/26/76	Lower Coal Member[2]	Cased	120 gpm	3.3 gpm/ft.	1723 gpd/ft.
AL-1	05/27/76	North Fork Alluvium	Cased	17.4 gpm	---	498 gpd/ft.
SOM 23-H2	10/09/74	E Seam	Cased	0.6 gpm	---	---

Notes:
(1) Same hole as C76 only open to Barren Member and F Seam
(2) Suspected connection with North Fork Alluvium

Slug tests were also conducted in monitoring wells completed in the alluvium, colluvium, the Barren Member, Lower Coal Member, and Upper Coal Member of the Mesaverde Formation. Slug test data from these wells are contained in Table 6. Also see discussions in Exhibits 17, 18 and 18B.

Table 6 Summary of Slug Test Data[1]					
Well No.	**Geologic Unit Tested**	**Screened Interval**	**Transmissivity (gpd/ft.)**	**Permeability[2] (gpd/ft²)**	**Permeability[2] (cm/sec)**
A-1	Colluvium		66	--	--
A-2	Alluvium		1234		
A-3	Colluvium		59	--	--
SOM-1-H	Barren Member		600	6.67	3×10^{-4}
SOM-22-H-1	Barren Member	Sandstone, Shale & Coal	2283	--	--
SOM-38-H-1	Barren Member	Sandstone & Shale	49.5	1.1	5×10^{-5}
SOM-38-H-2	Barren Member	Sandstone & Shale	0.4	0.004	2×10^{-7}
SOM-45-H-1	Barren Member	Sandstone	--	--	--
SOM-45-H-2	Barren Member	Sandstone, Shale & Coal	1.56	--	--
SOM-80	Barren Member	Sandstone & Shale	0.52	0.006	3×10^{-7}
03-11-1[3]	E Seam	Coal	--	--	5×10^{-5}
SOM-2-H	F Seam	Coal	0.028	--	--
SOM-16	F Seam	Coal	--	--	--
SOM-23-H-1	B Seam	Coal	15.6	1.04	5×10^{-5}
SOM-C76A	F Seam	Coal	61	4.1	2×10^{-4}
SOM-127-H[4]	B Seam	Coal	3.3	0.083	4×10^{-6}
SOM-C72[4]	B Seam	Sandstone Above B Seam	9.01	0.19[5] 0.042[6]	9×10^{-6} 2×10^{-6}
03-11-1 [3]	E-Seam	Coal	10.0	1.04	5×10^{-5}

Footnotes:
(1) See also Exhibits 17 and 71
(2) Permeability calculated from transmissivity unless otherwise noted
(3) Permeability calculated using a rising head permeability test
(4) Permeability calculated by the Hvorslev Method
(5) Calculated from the first 14 points of the slug test data
(6) Calculated from the last 6 points of the slug test data

Barren Member (Mesaverde Formation)

The Barren Member of the Mesaverde Formation was so named because it does not contain any persistent coal seams. The formation is generally comprised of interbedded shales and lenticular sandstones with small, discontinuous coal seams with limited lateral extent.

Monitoring wells that were completed in the Barren Member of the Mesaverde Formation are presented in Exhibit 71. The results of that monitoring are provided in AHRs.

Pumping tests were conducted on several wells completed into the Barren Member. Pumping test data from these wells are contained in Table 5. Also see discussions in Exhibits 17 and 18.

Ohio Creek Member (Mesaverde Formation) and Wasatch Formation (Tertiary Age)

Overlying the Barren Member is the Ohio Creek Member of the Mesaverde Formation and, above it is the Tertiary-age Wasatch Formation. These formations cap West Flatiron Mesa, located in the eastern portions of the permit area, and the other high mesas occurring further to the east. Like the Barren Member, these formations are generally comprised of interbedded shales and discontinuous lenticular sandstones with occasional conglomeratic zones.

Drilling data indicated that these rock units are largely devoid of groundwater. The high stratigraphic position of these rock units, limited area of distribution, and outcrop exposure is not conducive to water recharge and storage.

Colluvium

The colluvium, which overlies the Barren Member of the Mesaverde Formation, is the principal water-bearing unit above the F Seam, as indicated in the *Spring Geology and Hydrology Report* (Watec, 1984 AHR). The colluvium consists of discrete, localized units that generally follow topography. The colluvial units recharge and discharge on a seasonal basis in response to snow-melt and precipitation events.

Monitoring wells WR-2 and WR-3 were located immediately up-slope and down-slope of the initial waste rock pile in the area that is now the site of West Elk Mine's Maintenance Shop and Warehouse. Falling head permeability tests were performed on these wells in order to estimate the permeability of the colluvial soils in this area. Field permeability values were determined to be between 2.1 and 3.9 x 10^{-6} centimeters per second (2 to 4 feet per year). Permeability tests were also performed on two shallow boreholes (10 and 15 feet deep) at the initial waste rock pile to determine the permeability of the upper portion of the colluvial soils. The falling head tests indicated a permeability of approximately 1.0 to 1.2 x 10^{-6} cm/sec (1.0 to 1.2 feet per year).

Alluvium

The alluvium of the North Fork consists of mixed sand, cobbles, and boulders capped by finer sands and silts. In the vicinity of West Elk Mine, the North Fork alluvium is relatively narrow and ranges from 40 to 70 feet in thickness. Alluvial deposits within the coal lease area are generally less than 25 feet thick and are part of the active groundwater regime. Where sufficient saturated thickness can be found, alluvial deposits may yield more abundant groundwater.

Pumping tests were conducted within well SG-1 within the alluvium of Sylvester Gulch that indicated a sustained production of about 1 gpm and an extremely low transmissivity of about 120 gpd/ft (Table 5). In the South of Divide permit area, the Dry Fork of Minnesota Creek represents the most significant alluvial deposit. Three wells, A-1 (AV-1), A-2 (AV-2), and A-3 (AV-3), were completed in the alluvium of Dry Fork of Minnesota Creek in August of 1984 (Exhibit 12). Of the three wells completed in the alluvium of the Dry Fork, only well A-2 showed transmissivity results characteristic of an alluvial aquifer and consistent with results from tests on wells on the North Fork or its tributaries. As previously stated, the alluvial materials are part of the surface and near-surface active groundwater regime in the Dry Fork drainage and thus in direct hydraulic communication with seasonal and climatic events. This is in contrast to the E Seam groundwater, which is part of the inactive groundwater zone, which does not have direct hydrologic communication with the near-surface groundwater system within the Dry Fork drainage.

Permeability and Factors Influencing Permeability

Table 5 and Table 6 summarize the available permeability data for the mine property obtained from pumping and slug tests. Permeability information was presented in the early F Seam permit applications, and has been updated as mining continued in the B and E Seams. This information can be found in Exhibits 17, 18 and 18B, including laboratory permeability analyses that were performed on core plugs obtained from the lower Mesaverde Formation and the Rollins Sandstone per Mayo and Associates (1998).

In general, it can be stated that the alluvium and colluvium are more permeable than the bedrock units and that the uppermost bedrock units are more permeable than those at depth. The permeability of the alluvium is approximately 1 x 10^{-6} cm/sec to 1 x 10^{-4} cm/sec. The slug and pumping tests provide a measure of horizontal permeability. Vertical permeability is typically at least a factor of three to five times lower than horizontal permeability.

A major factor that influences permeability of the bedrock in the permit area is jointing, other fracture discontinuities, and faulting. Fractures differ from faults in that fractures have no relative offset across fracture planes. The location of fractures and faults within the bedrock is sometimes difficult to assess particularly if bedrock units are poorly exposed or if there is minimal offset at the surface. As a result, significant linear features can be mapped as an initial means to assess potential faulting and fracturing of the bedrock formations. Site-specific evaluation of exposed bedrock outcrops are used to assess joint spacing and openings (apertures).

Major lineaments (longer than 2,000 feet in length) are shown on Map 24. Several drainages within the property appear to be fracture controlled. Although not evident from aerial photos, the North Fork most likely represents a major fracture zone. Jointing can be observed in the steep cliff outcrops along the North Fork and springs are occasionally seen discharging from the joints. The hydrologic investigations conducted by MCC have shown that most springs on the property discharge near or above the F Seam. This indicates the fracture zones are tighter or have not propagated through shale seams below the F Seam to the same extent as above the F Seam. As discussed previously in Section 2.04.7, there are a few springs discharging between the F and E Seams and little indication of groundwater discharge below that level.

There is little data available for joint spacing or aperture at the site. MCC collected a limited amount of joint mapping information in 1973-1974. The three major joint orientations at the site are E-W with a 90E dip or slight eastward dip, N-S with 90E or slight eastward dip and N 50E with a 90E dip. The shallowest dip measured as part of this study was 71E. Joint spacing measured in surface outcrops was normally greater than one foot and typically six feet or more. Based on theoretical considerations and the measurements performed at the site, fractured rock permeability at the site can be high, greater than 1 x 10^{-3} cm/sec (1,000 feet per year).

The fracture opening necessary for relatively high permeability can only occur near the surface in the active groundwater zone. Permeability at depth is typically much lower than near the surface because of higher in-situ stresses and limited hydraulic communication with the active zone. Maps 14 and 19 show the overburden thickness above the B and E Seams respectively. The overburden is typically greater than 375 feet for both the B and E Seams in the South of Divide permit revision area and Apache Rocks area, and for the B Seam in the Box Canyon area. Maximum overburden thickness for the E Seam is in excess of 1,200 feet and in excess of 2,300 feet for the B Seam. Based on the joint spacing measured in the field, the tightness of the joints expected at greater overburden depths, and the theoretical permeabilities, fracture-related permeability in and near the B and E Seams under more than 500 feet of cover is expected to be very low, on the order of 5×10^{-6} cm/sec (5 feet per year), or less.

Fault-Related Groundwater Inflows

In March and April 1996, MCC mined through a fault system (known as the BEM Fault) containing a significant amount of water. Initial inflow rates were measured in excess of 2,000 gpm. Similar to other observed inflows to the mine, these flows decreased over time. By early May the discharge from this fault system had declined to about 250 gpm and, from August 1996 to July 1997, generated a relatively constant inflow rate of approximately 85 gpm. In early July 1997, this inflow ceased when the same fault system was encountered to the northeast in the 14SE Tailgate. Flow from this area was initially approximately 200 gpm but quickly diminished to less than 100 gpm.

Fault discharges remained relatively constant until the BEM fault system was again encountered in February 1998 in the 24SE Headgate. At that time, inflows were estimated to be approximately 200 gpm from the floor at crosscut 8 and flow from the 14SE Tailgate area ceased. On May 28, 2003, the BEM Fault was once again encountered between crosscut 20 and 21 in the 22SE Headgate. Initial inflow from this location was estimated at 3,500 gpm, but rapidly declined to about 200 gpm within about 2 weeks.

In January 1997, a second water-bearing fault system (known as the 14HG Fault) was encountered. Initial flow rates were near 8,000 gpm, tapering off to less than 250 gpm by early March 1997. An exploratory horizontal borehole penetrated this same fault system in July 2003 about 200 feet south of Cross Cut 32 in the 22SE Headgate. Mine development work crossed the fault system in August of 2003 resulting in an estimated initial inflow rate of 100 gpm, which decreased to about 35 gpm within a few days.

Mapping of these fault systems by Mayo and Associates (1998) indicated that the BEM Fault exhibits an *en echelon* pattern, as it strikes northeast toward the 14SE Tailgate. The primary fault zone splays into a horsetail fault as it extends northeast from the B East Mains to the Box Canyon Mains, eventually transferring to the 14HG Fault zone. The transition area between the two fault zones has an abundance of slips, shear zones, small faults, and short duration faults with unusual orientations. Although the trend of both fault systems may be projected to the cliff faces in the Minnesota Creek drainage, neither fault has been identified on the surface and borehole, and monitoring well data showed no indication of the fault or associated water.

Stephen Robertson and Kirsten (SRK, 1998) also evaluated the style, geometry and origin of faulting in the vicinity of West Elk Mine. SRK mapped three inferred, extensional faults parallel to and south of the BEM and 14HG fault systems. These inferred faults, named the West Flat-

Iron, Deep Creek, and Gunnison Faults, are spaced approximately equal distances apart and are projected to be down-thrown to the south. Because of the small vertical displacement projected on each of these faults, SRK further concluded that the faults appear to have developed due to a very small amount of applied stress and may have developed in response to intrusion of igneous rocks.

Each of these fault systems are thought to be the result of an igneous intrusive related to the Mt. Gunnison laccolith, which intruded the Mancos Shale beneath the West Elk Mine area. Intrusion-related doming of the Mancos Shale induced a low rate of stress, which produced extensional normal faults that propagated upwards into the Rollins Sandstone and overlying coal measures of the Mesaverde Formation. As the faults propagated upward, the applied stress and the strength of the strata decreased. Thus the magnitude of faulting decrease upward and surface expressions of these faults may not be present. Fault-related fracture density is greatest in the Rollins and decreases upward as the overlying sediments accommodated the strain.

As stated in Exhibit 18B, each of the fault-related groundwater inflows is the result of pressure release from hydraulically distinct groundwater systems associated with individual fault-related damage zones (Mayo and Associates, 1998; Mayo and Koontz, 2000). The parallel damage zones are about 2,000 feet apart. The general absence of groundwater inflows from the coal seams or mudstone overlying the B Seam indicate that the Rollins Sandstone waters are not in hydraulic communication with coal seams located above the B Seam.

Water quality and age-dating analysis was conducted on samples obtained from the BEM and 14HG fault systems (Mayo and Associates, 1998). This analysis suggests that the various groundwater samples are: 1) Not part of a regionally continuous or really extensive groundwater system, 2) Hydraulically connected to the surface or active groundwater regime, and 3) Have a mean residence time (or age) of approximately 10,500 years. Details of this analysis can be found in Exhibit 18 and its relevance to E Seam mining in the South of Divide permit area can be found in Exhibit 18B.

E Seam mining is expected to encounter many of the same fault systems and possibly two inferred zones not intercepted in the B Seam workings. Mayo and Associated (2004) projects that the previously intercepted fault zones may have insignificant nuisance waters associated with the fault zones and inflows from the Bowie Sandstone beneath the E Seam will be small or non-existent. The exception may be where tectonic faults have crossed sandstone roof channels allowing the channel sandstones and fractured damage zones to store water. Inflows from these sandstone channels may reach as much as 500 gpm in that instance.

In summary, the West Elk Mine site can be characterized as having decreasing permeability with depth as a result of lithologic changes and smaller fracture aperture, limiting downward percolation of groundwater through the bedrock units, and resulting in localized discharge via springs generally above the F Seam. The exceptions are the damaged zones associated with fault systems encountered in the eastern portion of the mine as described above. Additional discussion of these fault-related inflows can be found in Section 2.05.6.

Groundwater Quality Characteristics

MCC selected the water quality parameters listed in Table 7 for baseline laboratory analysis to characterize baseline and ongoing groundwater quality. These include iron and manganese, because the detection of these elements (or changes in their observed concentrations) may represent conditions in which metals are mobilized. Additionally, changes in conductivity and TDS can indicate changes in water quality that need to be further investigated. As a result, monitoring of these selected parameters provides a detection system for mining-induced changes in water quality. Groundwater monitoring details are provided in Exhibit 71.

Analyses are completed as outlined in the Guidelines for Collection of Baseline Water Quality and Overburden Geochemistry Data (CDRMS, 1982). Results are reported in the Annual Hydrology Reports. If not already provided in AHRs, baseline data will be provided to CDRMS prior to longwall mining under or within the angle-of-draw of a monitored water resource.

Regional Groundwater Quality

Data collected on groundwater quality from representative wells within the permit area are summarized in Table 7. As this table shows, the highest average levels of TDS were in well SOM-3B completed in the B Seam coal. This is consistent with the elevated TDS concentrations in other B Seam wells such as SOM-129-H and JMB-12. The highest average total and dissolved iron concentrations occurred in wells SOM-3B and SOM-3E. These wells also produced the highest average manganese values. The water chemistry results from these two wells demonstrated a striking similarity between the B and E Seams. This is consistent with the geologic (depositional and lithologic) similarities noted in Section 2.04.6 (Geology Description). The relatively high levels of iron in groundwater (Table 7) are consistent with the levels found in surface water (Table 19) and indicated some groundwater discharge to the streams and a similarity in terms of geology.

The only applicable water quality standards for the parameters monitored are secondary drinking water standards. Comparison of these standards to groundwater quality data showed numerous dissolved iron exceedances and pH levels above 8.5 in three groundwater wells (SOM-38-H-1, SOM-2, and SOM-16). The causes of elevated levels of these parameters are natural and not due to mining activities.

Seasonal Variations in Groundwater Quality

Data from selected wells in the permit area with relatively long records covering different seasons were evaluated for seasonal trends. In general, the parameters evaluated did not exhibit defined seasonal changes in concentration. Levels of TDS, TSS, and pH did not vary appreciably over the year. This was due to the poor aquifer characteristics of the formations in the permit area and lack of recharge and connection to surface water sources. However, wells installed in shallow sediments including alluvium, showed seasonal water quality and water level trends. Typically, concentrations of iron and manganese were elevated during fall and winter months, along with low water levels.

Table 7
Summary of Groundwater Quality for Monitoring Wells in the Permit/Lease Areas

		TDS (mg/L)				TSS (mg/L)				pH (s.u.)			
Well Number	**Well Depth (ft)**	**Mean***	**Min**	**Max**	**Sample Count**	**Mean***	**Min**	**Max**	**Sample Count**	**Mean***	**Min**	**Max**	**Sample Count**
SG-1	84	535	302	926	26	128	4	514	26	7.8	7.0	10.2	26
GP-1	58	640	444	912	27	312	6	4272	18	7.4	6.6	9.2	25
Upper Dry Fork	29	326	290	390	13	--	--	--	0	8.0	8.0	8.1	3
Lower Dry Fork	22.5	297	250	310	13	--	--	--	0	7.9	8.0	7.8	3
03-11-1	22.5	2032	1850	2130	12	--	--	--	0	8.2	8.1	8.3	3
SOM-38-H-1	960	378	356	404	18	68	2	316	17	9.0	7.8	11.6	18
SOM-38-H-2	580	495	404	540	4	628	240	1065	4	8.9	8.2	9.3	4
SW-3	55.6	342	342	342	1	88	88	88	1	7.6	7.6	7.6	1
SOM-C-72	1140	1303	942	1674	12	--	--	--	0	8.9	8.2	9.6	6
SOM-13	188	528	36	984	27	350	2	2944	27	7.7	6.6	10.6	27
SOM-80	142.5	808	27	1888	28	20	2	143	28	7.5	6.2	10.4	27
SOM-129-H	365	1624	1624	1624	1	--	--	--	0	7.3	7.3	7.3	1
B-32	68	911	446	1282	7	3951	20	23000	7	7.4	7.0	7.7	7
JMB-12	627	1294	1294	1294	1	--	--	--	0	7.8	7.8	7.8	1
SOM-2	716	1717.4	1618	1900	22	--	--	--	0	9.32	8.2	11.4	22
SOM-3B	1415	2117	1920	2370	13	--	--	--	0	7.8	7.7	7.9	3
SOM-3E	1035	1423	1330	1540	13	--	--	--	0	8.3	8.2	8.4	3
SOM-16	1034	1927.1	34	2900	18	--	--	--	0	11.73	10.5	13.1	18
		Total Fe (mg/L)				**Dissolved Fe (mg/L)**				**Total Mn (mg/L)**			
Well Number	**Well Depth (ft)**	**Mean***	**Min**	**Max**	**Sample Count**	**Mean***	**Min**	**Max**	**Sample Count**	**Mean***	**Min**	**Max**	**Sample Count**
SG-1	84	43	0.02	261	26	1.15	LD	5.50	9	0.14	LD	0.69	26
GP-1	58	29.8	0.02	248	27	--	--	--	0	0.62	0.010	8.55	27
Upper Dry Fork	29	13.6	1.32	25.9	2	0.19	0.03	0.49	12	0.229	0.109	0.349	2
Lower Dry Fork	22.5	0.26	0.08	0.51	3	0.15	-0.01	0.83	13	1.72	1.13	2.48	3
03-11-1	22.5	0.51	0.3	0.73	3	0.3	0.02	0.82	13	0.120	0.067	0.153	3
SOM-38-H-1	960	67.5	0.02	760	18	0.08	LD	0.21	3	0.14	0.01	0.50	18
SOM-38-H-2	580	119.5	69	165	4	0.33	0.01	0.92	4	0.02	LD	0.08	4
SW-3	55.6	7.75	7.75	7.75	1	--	--	--	0	0.18	0.18	0.18	1
SOM-C-72	1140	0.49	0.02	4.18	9	--	--	--	0	0.03	0.01	0.16	9
SOM-13	188	5.47	0.02	53.2	26	0.03	LD	0.11	9	0.09	LD	1.63	26
SOM-80	142.5	0.92	0.02	6.80	27	0.24	LD	0.82	10	0.08	0.01	0.557	27
SOM-129-H	365	0.34	0.34	0.34	1	--	--	--	0	0.02	0.02	0.02	1
B-32	68	9.88	1.09	21	7	1.01	0.15	2.80	7	0.40	0.142	0.87	7
JMB-12	627	0.1	.01	0.10	1	--	--	--	0	0.02	0.02	0.02	1
SOM-2	716	9.7	0.02	59.8	18	0.02	LD	0.11	5	0.05	0.003	0.14	18
SOM-3B	1415	275	156	445	3	45.7	1.7	383	13	2.98	1.71	4.64	3
SOM-3E	1035	151	8.95	419	3	1.17	0.05	127	13	1.87	0.139	5.21	3
SOM-16	1034	6.0	0.70	22.3	14	LD	LD	LD	1	0.08	0.010	0.32	14

* = The detection limit was used in mean value calculations for concentrations less than the detection limit. Data includes pre-mining baseline and operational information through **2003.**
LD = Less than the detection limit.

Note: Exhibit 71 contains water quality data from 2000 to 2007 for characterization of the SOD and Dry Fork areas.

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