C1-Objection Exhibit F

BIG HORN COAL COMPANY

BIG HORN MINE

GROUNDWATER RESTORATION DEMONSTRATION

FOREWORD

The Administrator of the Wyoming Department of Environmental Quality, Land Quality Division, has declared that requests for final incremental bond release at coal mines must be preceded by: 1) a demonstration that the postmining groundwater conditions support the postmining land use as per Coal Rules and Regulations Chapter 4, Section 2.(h)(i) and Chapter 4, Section 2.(i)(i) and; 2) verification of the accuracy of the Probable Hydrologic Consequences (PHC) predictions for groundwater as per Coal Rules and Regulations Chapter 4, Section 2.(i). One of the principal objectives in Big Horn Coal's reclamation has been to restore the quantity of groundwater in the mine backfill and adjacent areas to a level suitable for livestock use and meeting the livestock use water quality standards set forth under the Wyoming Department of Environmental Quality, Water Quality Division's Rules and Regulations, Chapter VIII. Section 5, Table 1. Groundwater quality data are presented in this report demonstrating how these standards have been met at Big Horn Mine. In terms of restoring groundwater quantity characteristics, Big Horn's specific objectives have been to re-establish infiltration and recharge capacities, aquifer storage and groundwater flow, and aquifer saturated thicknesses.

This report is intended to fulfill the requirements for demonstrating postmining groundwater conditions at Big Horn Mine and more specifically to verify that the quantity and quality of groundwater has been restored throughout the majority of all reclaimed mine lands and throughout all adjacent areas to conditions suitable for livestock watering. Data and analyses are provided for reclaimed mine spoil sites not yet fully meeting livestock watering criteria showing trends in groundwater recovery which allow forecasts to be made of meeting the restoration goals. Groundwater conditions now existing within and contiguous to Big Horn Mine are compared to predictions made in the PHC assessments of the mine permit document.

This report is inclusive of all of Big Horn Mine and has been prepared intentionally well in advance of any request for Final Incremental Bond release because, as demonstrated in this report, coal bed methane gathering activities have begun to significantly impact groundwater conditions in areas adjacent to the mine. This submittal does not request any changes in Big Horn Mine's currently approved groundwater monitoring program nor does it request any release from liability for postmining groundwater conditions.

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I POSTMINING GROUNDWATER QUANTITY

Groundwater conditions within and adjacent to Big Horn Mine were influenced by nearly 100 years of surface and underground coal mining activities. This chapter begins with an overview of the historic mining developments that are inferred to have or are known to have affected groundwater conditions within and proximate to Big Horn Mine.

1903 to 1963 - According to records compiled by Dunrud and Osterwald (1980), coal mining near Big Horn Mine began at the underground Dietz No. 5 Mine in 1903 immediately south of present-day Big Horn Mine. From 1904 to 1940, underground coal mines including the Dietz No. 8 Mine, the Hotchkiss Nos. 1 and 2 Mines, the Model Mine, the Carney Mine and the Acme and Acme No. 2 Mines were developed over large areas within and contiguous to Big Horn Mine. The Plachek strip coal mine on Goose Creek (the Plachek Pit reservoir of Section 22) operated from 1957 to 1963 and the B and W strip coal mine operated from 1948 to 1953 within a portion of what ultimately became Big Horn's Pit 3. In essence, Big Horn Coal Company, which consolidated Big Horn Mine in 1963, was restricted in its mining to "islands" of coal separating the historic mines.

1965 – Large-scale stripping operations are underway along the east side of Goose Creek east of the former Plachek Pit within Big Horn's Pit 1.

1973 - Tongue River immediately below the mouth of Goose Creek is diverted 500 feet north into the old B and W Mine coal pits to allow mining in Pit 2.

Summer 1978 – Tongue River is routed into its permanent postmining channel after the final backfilling and grading of Pit 2. Mining begins in the Pit 3 area.

Early 1980's – Mining in Pit 3 intercepts alluvium of Tongue River causing local drawdown of the alluvial water table.

1984 – Pit 1 was extensively backfilled, leaving open only the "Southeast Triangle" groundwater sump.

1985 – Pit 3 advancement ceases and most exposed coal faces are covered. This reduces the groundwater inflow rate to Pit 3.

December 1996 – Backfilling of the Pit 1 "Southeast Triangle", which began in 1994, is completed and the groundwater sump is closed. Pit pumpage of groundwater from the Dietz 2, Dietz 3 and Monarch coal aquifers ceases.

1999 – Coal bed methane gathering activities begin pumping groundwater from the Dietz 3, Monarch and Carney coal seams in areas south and southeast of Big Horn Mine.

2000 – Backfilling and grading of Pit 3 is completed late in the year and Pit 3 Reservoir begins filling.

In Section 6.1.5 of the Reclamation Plan, alluvial groundwater from Tongue River and Goose Creek valleys is predicted to be a significant recharge source to the postmining coal aquifers in areas adjacent to the mine reclamation and to the mine backfill (spoils) as well via, in part, groundwater recharge from resaturated spoils along the downgradient coal/spoils contacts (see Exhibits RP-14, RP-15 and RP-16 of the Reclamation Plan). The mined edges of the Dietz 2 coal, Dietz 3 coal and, particularly, Monarch coal seams contact reclaimed spoils which in turn contact Goose Creek and/or Tongue River channels or the native alluvium underlying the stream valleys over broad lengths along the perimeters of reclaimed Pits 1, 2 and 3. Streamflow infiltration from Goose Creek and from Tongue River together with subsurface flow from the alluvium of these valleys has recharged the mine backfill, which has in turn recharged the native coal aquifers at the coal/spoils contacts. Groundwater in the alluvium of Tongue River valley south of Pit 3 Reservoir and streamflow in Tongue River north of the reservoir were also identified as the principal recharge sources to Pit 3 Reservoir via the South French Drain and North French Drain, respectively (see Sections 7.3.1.1 and 7.3.1.4 of the Reclamation Plan). Very little, if any, groundwater resaturation was predicted at Pits 4 and 5 because the coals mined in these areas naturally existed as remnants isolated from recharge sources of the Tongue River and Goose Creek valley floors. No groundwater aquifers were identified before or during mining in Pits 4 and 5 and none has been projected to develop after mining in either area (see Section 6.1.5, Reclamation Plan).

Chapter 4, Section 2.(h)(i) of the Wyoming Department of Environmental Quality, Land Quality Division Rules and Regulations states that "the recharge capacity of reclaimed lands shall be restored to a condition which supports the approved postmining land use". Big Horn Coal's objective to restore the mine backfill and adjacent aquifers to a condition suitable for livestock watering would be greatly compromised were the spoils sufficiently impermeable so as to not readily transmit water horizontally as groundwater movement, or vertically as infiltration of surface water, inclusive of rainfall, snowmelt and streamflow. The infiltration rate of a soil or of strata where soil is absent is defined as the rate at which water infiltration takes place, expressed in depth of water per unit of time, usually in inches per hour. The following section of this text explores the approximate, effective infiltration rate of the mine backfill where the effective infiltration rate is broadly defined as the rate at which the backfill resaturated as a result of water infiltration from all sources including stream channel and other surface water infiltration combined with lateral groundwater inflow from unmined aquifers.

I.A Groundwater Recovery In Backfill Aquifer In Pits 1, 2, 3, 4 And 5

I.A.1 Infiltration Rates

No direct measurements have been made of infiltration rates on reclaimed lands at Big Horn Coal beyond those presented in the 1993-1994 Annual Report (Table 16). No attempt has been made to convert the infiltration rates of the 1993-1994 Annual Report into groundwater recharge or spoil resaturation rates. Instead, effective infiltration rates, as defined in the previous section, have been estimated for portions of Pits 1 and 2 corresponding to four topsoil request areas formerly approved by LQD before topsoil was applied on the regraded spoils. These areas, shown on Exhibit 1 accompanying this document, were selected for effective infiltration rate calculations because the timing and sources of groundwater recharge within Pits 1 and 2 can be estimated with some accuracy. The resaturation of spoils within these areas is credited almost exclusively to the infiltration of streamflow in Tongue River and Goose Creek and lateral groundwater flow from the alluvium of these valleys. Lateral groundwater flow to spoils from the Dietz 3 and Monarch coal seams and the infiltration of precipitation and snowmelt over the spoils probably constituted a very small fraction of the total spoil resaturation.

Pits 1 and 2

As of October 2001, groundwater in the backfill at Big Horn Mine had recovered to the potentiometric elevations shown on Exhibit 1. This exhibit also shows potentiometric elevations in Monarch coal adjacent to the mine and in Tongue River alluvium between Pits 2 and 3 near the South French Drain as of October 2001. The first step in estimating effective infiltration rates was to convert the potentiometric elevations shown within the topsoil request areas into volumes of saturated spoils. This was accomplished by first preparing a digital map of structure contours on the top of the Monarch coal from Exhibit D5-12 (Appendix D5) and then subtracting from this surface a unit amount of 22 feet representative of the average thickness of the coal (see Exhibit D5-11, Appendix D5) to derive structural contours on the bottom of Monarch coal. Using surface modeling software, this intermediate product was then subtracted from the potentiometric contour elevations (Exhibit 1) to derive approximate volumes of saturated spoils above the original Monarch floor (assumed pit floors) within each topsoil request area.

Having estimated the volumes of saturated spoils within the topsoil request areas of Pits 1 and 2, the final elements needed for computing approximate effective infiltration rates were an estimate of the effective porosity of the spoils and estimates of the time elapsed between when the spoils began resaturating and ending with the October 2001 groundwater level measurement date. Although the backfill of Pits 1 and 2 was undoubtedly constantly subject to some resaturation in the form of seepage from Goose Creek and Tongue River even as mining continued in the area, the date resaturation began was assumed to be equivalent to the date Tongue River was turned into its final channel, July 1978. Under this assumption, the time elapsed between July 1978 and October 2001 was constant for the four topsoil request blocks of Exhibit 1 at 23.2 years. The effective porosity of the spoils was assumed to be 20 percent in the effective infiltration rate calculations. A porosity of 23 percent was found for the spoils at the Plachek Pit through multiple well testing but all other multiple well tests at Big Horn Mine returned storage coefficients that were much lower (see Table RP-12, Reclamation Plan). The low storage coefficients were thought to be indicative of coarse-grained spoils being overlain by fine-grained materials (see Section

6.1.2, Reclamation Plan). While this hydraulic differentiation can be expected after the spoils are fully or nearly fully saturated, an effective porosity of approximately 20 percent is probably more indicative of the spoils in their dry, loose state.

Effective infiltration rates computed per the above procedure are presented on Table 1. The rates range from 5.9 to 13.9 inches per year, which is very high relative to what would be expected for the vertical infiltration of rainfall and snowmelt alone. As an example, Davis and Zabolotney (1996) found through groundwater flow modeling that the premining infiltration rate from surface water sources (precipitation, snowmelt, overland runoff, etc.) to shallow overburden aquifers at Belle Ayr coal mine was about 0.16 inches per year. Reclaimed lands at the mine were found to have an infiltration rate of about 2 inches per year. The authors concluded that the postmining infiltration rates will likely diminish over time as the spoils settle and as evapotranspiration losses increase with increasing vegetal growth. Big Horn Mine reported infiltration rates ranging from 0.10 inches per hour to 3.00 inches per hour from eight, double ring infiltration tests conducted on backfill in Pits 1, 3 and 4 (see Table 16, 1993-1994 Annual Report). The average infiltration rate from these tests was 0.82 inches per hour.

The reader is again advised that the effective infiltration rates of Table 1 are not true soil infiltration rates but are inclusive instead of groundwater recharge from all sources. The rates may also be biased somewhat high by the assumption that the total recharge period for Pits 1 and 2 was only 23.2 years prior to October 2001 when in fact the backfill of both pits was subject to some constant recharge that was probably not entirely captured by pit pumpage before July 1978, the assumed starting date for recharge. Conversely, resaturation in the Pit 1/Pit 2 area has not been limited to the topsoil application areas alone but has also occurred contiguous to these areas in pre-law portions of the mine. This could tend to bias the estimated effective infiltration rates low. Regardless of the analytical technique's limitations, the resultant infiltration rate values (recharge values) clearly indicate that the backfill of Pits 1 and 2 has resaturated very quickly and there are no apparent properties of the spoils that retard water infiltration or movement in either the vertical or horizontal planes.

Pit 3

As shown more fully in Section I.A.2. below, all indications are that the Pit 3 spoils have resaturated very rapidly, virtually in phase with the filling of Pit Three Reservoir. Effective infiltration rates were not computed for the Pit 3 spoils because the topsoil application dates (hence, the approximate backfilling dates) ranged over 16 years (1985 through 2000), but a large portion of the recharge was probably supplied by Pit 3 Reservoir as it began filling beginning in late 2000. Because of the diversity of recharge sources and the temporal duration of backfilling activities at Pit 3, it would be very difficult to establish a starting date for recharge with any accuracy.

I.A.2 Subsurface Flows

I.A.2.a Water Level Recovery Within Mine Backfill And Adjacent Affected Aquifers

Figures A-1 through A-28 in Addendum A are hydrographs of groundwater elevations versus time for wells monitoring the backfill aquifer and Carney coal, and wells monitoring all aquifers affected by mining, including the alluvium of Tongue River and Goose Creek valleys, and the Dietz 2, Dietz 3 and Monarch coal seams. Although some of the non-backfill wells were removed from the monitoring program in March 2001 (Change No. 6 to Permit 213-T5; partially approved April 20, 2001), groundwater elevations were measured in most wells as recently as October 2001. Groundwater saturation, as portrayed by hydrographs, is considered fundamental to understanding subsurface flow because the groundwater elevation in a well is a product of both horizontal and vertical water movement.

The text of the following sections identifies evidence of potentiometric declines in the coal aquifers caused by coal bed methane (CBM) gathering activities that began near Big Horn Mine in 1999. This is particularly true for the Monarch and Carney coals. Gas and groundwater production records of the Wyoming Oil and Gas Commission were interrogated via internet link on April 29, 2002 to obtain information relating to CBM activities for selected areas adjacent to Big Horn Mine. These areas include Sections 13 and 22 through 27 south and southeast of the mine (sections of land shown on Exhibit 1). The search revealed the existence of 120 CBM wells in various stages of permitting and development (expired, cancelled or abandoned permits not included), although groundwater production data were recorded for only 20 wells; one in section 13 and the other 19 in section 26. All 20 wells are developed in either the Monarch or Carney coal seams. Many of the other wells not having groundwater production records also have no indication of the coal completion interval in the records reviewed for this search. The groundwater production data of the 20 wells are temporally variable, suggesting that the wells have been intermittently operated. What can be stated is that, in the period 1999 through early 2002, the cumulative groundwater production of the 20 wells was 799 acre-feet (AF); 50 AF from the one well in Section 13 and 749 AF from the 19 wells in Section 26. The well in Section 13 is in Carney coal and had an average groundwater production rate of 25 gpm from May 1999 through August 2000. The two wells with the largest cumulative water production in Section 26 (both in Carney coal) had average water production rates of 30 to 31 gpm from May 1999 through August 2000. The two wells with the lowest cumulative water production in Section 26 (both in Carney coal) produced at rates between 4 and 5 gpm. CBM development activities remain brisk around Big Horn Mine and the volumes of groundwater produced will almost certainly increase in the near future.

Hydrographs of alluvial wells

Hydrographs for the alluvial aquifers are presented as Figures A-1, A-2, A-3, A-9 and A-13. Those for wells 206-76 and 397-78 (Figures A-1 and A-2), located near the South French Drain (Exhibit 1), suggest water table recovery of about one to two feet from 1989 to present (fall 2001), probably as the result of the final backfilling of Pits 1 and 2. The water table elevation fluctuations within these two wells over the past several years appear to be within the ranges seen in 1979 and 1980. The hydrographs for the remaining three alluvial wells, Nos. 403-78, 508-79 and 644-80 (Figures A-3, A-9 and A-13, respectively), show no apparent influence of mining upstream of the mine on Goose Creek and Tongue River (wells Nos. 508-79 and 403-78, respectively) and downstream of the mine on Tongue River (No. 644-80; see Exhibit 1). Underflow in the alluvium of the stream valleys, as evidenced by the groundwater elevation trends of the five wells, appears to have fully or nearly fully re-established, as predicted in the Reclamation Plan (Sections 6.1.5 and 6.2.2).

The Reclamation Plan concludes that the only drawdown observed in alluvium historically monitored by Big Horn Mine occurred in the immediate vicinity of South French Drain (Section 6.2.2), and this drawdown will be permanent as a result of the high water line of the reservoir always remaining below the base of alluvium intercepted by the drain. Permanent, postmining water table elevations predicted for the alluvium contiguous to South French Drain are shown on Exhibit RP-16. Water table elevations in alluvium of the same area as recorded in October 2001 are also shown on Exhibit 1 accompanying this text. The water table elevations of the two drawings are very similar and the inferred flow patterns vary only slightly with Exhibit 1 showing a somewhat smaller area of the valley floor underflow being affected by Pit 3 Reservoir drainage. Based on Exhibit 1 and Exhibit RP-16, it is concluded that the alluvial underflow conditions have been restored and the affects of Pit 3 Reservoir on alluvial water table elevations and flow patterns are as predicted.

Hydrographs of Dietz 2 coal wells

Groundwater elevations in Dietz 2 coal were predicted to return to premining conditions quickly after mining because saturated Dietz 2 coal was mined only in Pit 1 and the alluvial subcrop recharge zones of the aquifer were not disturbed by mining (see Section 6.1.5, Reclamation Plan). Groundwater hydrographs through October 2001 are presented in Addendum A for Dietz 2 coal wells Nos. 469-79, 596-80, 686-81, 687-81 and 828-84 as Figures A-8, A-12, A-18, A-19 and A-26, respectively. The wells are located on Exhibit 1. The hydrographs show that the potentiometric surfaces in wells Nos. 469-79, 686-81 and 687-81, located south and southeast of Pits 1 and 2, have recovered significantly since about 1994 to elevations equivalent or greater to those of the early 1980's. The mechanisms of aquifer recharge and subsurface flow in the Dietz 2 coal are clearly fully re-established south and southeast of Big Horn Mine. Groundwater elevations in wells Nos. 596-80 and 828-84 remain about four feet and two feet, respectively, below peak elevations observed in the early to mid-1980's. Water levels in these wells fluctuate from about one to two feet between readings, indicating variable recharge and subsurface flow rates that are probably associated with cyclical precipitation changes and seasonal changes in Tongue River flow rates/stages. This is considered evidence of the aquifer flow functioning normally in response to natural changes in recharge volumes and rates. The differences in water elevations in wells 596-80 and 828-84 over what they were 15 to 20 years ago are small relative to the potentiometric heads existing above the top of the coal.

Hydrographs of Dietz 3 coal wells

Like the Dietz 2 coal, groundwater flow and potentiometric elevations in the Dietz 3 coal were projected to recover from drawdown quickly after reclamation at Big Horn Mine because none of the coal's alluvial recharge subcrop zones were disturbed by mining (see Section 6.1.5 Reclamation Plan). Groundwater hydrographs are presented in Addendum A for five Dietz 3 monitor wells: Nos. 462-79, 468-79, 576-80, 660-81 and 827-84 corresponding to Figures A-4, A-7, A-10, A-17 and A-25, respectively. The wells are located on Exhibit 1. In all cases, notes on the hydrographs indicate that the wells have become affected by CBM gas gathering activities beginning at various times from 1999 to October 2001. CBM wells have been withdrawing groundwater and gas from the Dietz 3, Monarch and Carney coal seams in areas immediately south and southeast of Big Horn Mine since approximately 1999. With the exception of well 576-80, all the Dietz 3 wells show water level recovery to potentiometric elevations slightly less than to significantly greater than what was observed in the early 1980's. By 1998, potentiometric elevations at well 576-80 had recovered to within less than four feet of peak elevations observed in 1986, but beginning in late 1999 the well has experienced renewed drawdown presumably as a result of CBM activities. The recovery of mining-related drawdown and reduction of flow in the Dietz 3 aquifer appears to have been substantially complete by 1998 or 1999 but since that time there has been significant renewed drawdown associated with CBM gathering activities. These activities are projected to locally escalate in the future and drawdown in the Dietz 3 will undoubtedly increase in areas within and adjacent to Big Horn Mine.

Hydrographs of Monarch coal wells

Mining at Big Horn Coal removed the Monarch coal's alluvial recharge subcrop zones and replaced them with spoils. The coal's postmining groundwater recharge is primarily via the spoils which in turn are recharged by underflow in the alluvium of Tongue River and Goose Creek, by seepage from Tongue River along its reconstructed length between Pits 2 and 3, and by seepage from Pit 3 Reservoir. Because the spoil recharge sources are areally extensive and supported by perennial water bodies, the recovery of potentiometric elevations and groundwater flow in the Monarch aquifer was projected to be relatively rapid after final reclamation (see Section 6.1.5, Reclamation Plan).

Addendum A contains groundwater hydrographs for three Monarch wells: Nos. 467-79, 584-80 and 825-84 corresponding to Figures A-6, A-11 and A-24, respectively. The hydrographs of all three wells show significant groundwater level recovery beginning in 1996 that was likely a result of substantially closing the Pit 1 final opening, but the recovery periods were relatively short lived until potentiometric declines began again in 1999 or 2000. Beginning in year 2000, the potentiometric trends in wells 467-79 and 584-80 reversed and the water levels rose abruptly to elevations unmatched in the history of the wells. This phenomenon is almost certainly indicative of gas buoyancy reducing the specific weight of the groundwater and causing the water levels in the wells to rise. This has not been observed to date in well 825-84 where the groundwater surface has steadily declined since late 1999. The potentiometric declines that began in the Monarch in late 1999 or 2000 are ascribed to local CBM gathering activities as is the apparent gas buoyancy found in wells 467-79 and 584-80. Although potentiometric elevations and groundwater flow in the coal had significantly recovered as the mine pits were backfilled, the recovery was not entirely complete by the time CBM activity-related drawdown began in 1999 and 2000. Ignoring the effects of gas buoyancy, up to about 10 feet of additional recovery to historic peak groundwater elevations remained at well 584-80, some 8 feet remained at well 825-84 and about 5 feet remained at well 467-79.

The potentiometric surface shown for the Monarch coal on Exhibit 1 adjacent to the reclaimed spoils is very similar in pattern and value to the projected postmining potentiometric surface of the coal shown on Exhibit RP-16 of the Reclamation Plan. The drawings differ slightly in that the potentiometric contours of Exhibit 1, drawn with October 2001 water level measurements, are shifted slightly upgradient from those of Exhibit RP-16. This is due to the stage in Pit 3 Reservoir still being some six feet below its projected average elevation. As the reservoir fills, groundwater elevations in the spoils and adjacent Monarch coal will rise, causing the potentiometric contours of Exhibit 1 to shift downgradient in better agreement with the same contours of Exhibit RP-16.

Hydrograph of Carney coal well

The Carney coal seam was not physically or hydraulically affected by mining at Big Horn since it lies some 100 feet below the Monarch coal (see Section 6.2.2, Reclamation Plan). A hydrograph is presented for one Carney well in Addendum A - well 465-79 corresponding to Figure A-5. The hydrograph clearly shows no effect from mining, although potentiometric elevations in the well declined over 100 feet from 1999 through year 2000 as a result of local CBM gathering activities. The pattern and timing of the drawdown in well 465-79 is similar to that seen in wells Nos. 462-79, 468-79 and 660-81, developed in Dietz 3 coal, and to Monarch coal well 467-79.

Hydrographs of mine backfill wells

As previously mentioned, saturation of the mine backfill and establishment of groundwater flow through the backfill were also projected to be relatively rapid after mine reclamation because of the large, perennial recharge sources provided by Goose Creek, Tongue River and the Pit 3 Reservoir. Groundwater hydrographs illustrating recharge trends are provided for nine spoil wells in Addendum A. These include wells Nos. 655-81, 656-81, 657-81, 745-82, 816-83, 819-84, 823-84, 906-90 and 907-90 corresponding to Figures A-14 through A-16, A-20 through A-23, A-27 and A-28, respectively. A tenth spoil well, labeled "C-2001" on Exhibit 1, was constructed in late August 2001 near the north shore of Pit 3 Reservoir. No hydrograph has yet been prepared for this well because of the well's short period of record. The reader is also advised that well 816-83 in Pit 4 spoils and wells 906-90 and 907-90 in Pit 5 spoils are recording only minor groundwater saturation in keeping with the prediction set forth in Section 6.1.5 of the Reclamation Plan that there would be very little, if any, resaturation of the spoils in either of these two pits.

As predicted, all of the Pit 1, 2 and 3 spoil wells show relatively rapid and, in most cases, generally consistent groundwater recovery beginning up to 20 years ago in the early 1980's. Well 745-82, located north of Tongue River in Pit 3 spoils, and well 819-84, located east of Goose Creek in Pit 2 spoils, are showing pronounced seasonal water elevation fluctuations that are ascribed to changes in stream stages and alluvial water table elevations of the respective valleys. This phenomenon, also apparent to a lesser degree in wells 657-81 and 823-84, is demonstrative of the spoils' ability to rapidly transmit water from vertical and horizontal recharge sources (ie. high infiltration and horizontal groundwater movement rates). Groundwater recovery rates in Pits 1 through 3 spoils began diminishing between late 1997 to 2000, indicating that the potentiometric surface was approaching hydrostatic equilibrium with recharge and discharge sources. Groundwater elevations in the Pit 3 spoils contiguous to Pit 3 Reservoir will likely continue to ascend slightly, perhaps another two to four feet, as the stage in the reservoir ascends the final six feet above the approximate elevation observed October 2001 to its average operating elevation of 3560.5 feet.

Well 816-83 in Pit 4 spoils is 50 feet deep and with a groundwater elevation of 3634.0 (Oct. 2001) there is only some 5.5 feet of water in the well. This is insufficient for any practical use; therefore and as predicted, the Pit 4 spoils are not identified as an aquifer. Wells 906-90 and 907-90 developed in Pit 5 spoils are 75 and 160 feet deep, respectively. The groundwater elevations shown on Exhibit 1 for October 2001 translate to water column heights of 6.9 feet and 5.2 feet for wells 906-90 and 907-90, respectively. Again, these small water columns are insufficient for any practical well development and the Pit 5 spoils are not identified as an aquifer. The hydrographs for the Pits 4 and 5 wells do not suggest that the water levels may rise significantly. Instead, the groundwater elevations appear to be in dynamic equilibrium with local recharge and discharge sources. Further evidence that the Pit 4 and Pit 5 backfill does not/will not constitute an aquifer was seen in October 2001 when wells 816-83 and 906-90 were sampled for water quality analyses. Each well was bailed dry after yielding less than 10 gallons of groundwater.

I.A.2.b Potentiometric Surface In Backfill Aquifer

Exhibit 1 illustrates the potentiometric surface in backfill and adjacent Monarch coal at Big Horn Mine as of October 2001. The drawing also shows water table elevations in Tongue River alluvium adjacent to the South French Drain, as discussed above under the title *Hydrographs of alluvial wells*. Exhibit 1 shows that the groundwater gradient in Pit 1 is from west to east, from recharge provided by Goose Creek. In Pit 2 and between Pits 2 and 3, the Tongue River has a profound effect on the water table configuration. This is particularly evident with the 3580-foot water table contour traversing nearly parallel to the river between Pits 2 and 3, indicating flow directly from the river into the spoils and thence into Pit 3 Reservoir. The 3580-foot contour in the spoils of Pits 1 and 3 join the same water table contour in Tongue River alluvium south of South French Drain. Overall, the salient feature of Exhibit 1 is that the spoils of Pits 1, 2 and 3 are in direct hydraulic continuity with the alluvium of Goose Creek and Tongue River.

The potentiometric surfaces of the backfill, Monarch coal and Tongue River alluvium near the South French Drain on Exhibit 1 agree in form and value with the potentiometric surfaces projected for the same aquifers on Exhibit RP-16 of the Reclamation Plan. Potentiometric elevations shown on Exhibit 1 for the spoils are up to about 10 feet lower than those projected on Exhibit RP-16, especially through the northwestern portion of Pit 3 adjacent to Pit 3 Reservoir. The difference is due in part to the fact that the stage in the reservoir was still some six feet below it normal projected stage when Exhibit 1 was prepared (October 2001), and due in part to the fact that Exhibit 1 was drawn using additional backfill groundwater control points not available when Exhibit RP-16 was created. Overall, the potentiometric configurations of Exhibit 1 agree remarkably well with those of Exhibit RP-16, allowing the conclusion that the goal of restoring groundwater quantity has been met.

Exhibit 1 illustrates one groundwater feature in the spoils that is not shown on Exhibit RP-16. It is that Reservoir 14 contains a permanent pool supplied by groundwater in Pit 2 spoils. Although the pool depth is only some two to three feet, the reservoir did not go dry in year 2001 despite the occurrence of a severe drought that began in year 2000.

The 3580-foot groundwater contour encircling Reservoir 14 on Exhibit 1 indicates that the reservoir's evaporative losses locally suppress the spoils' potentiometric surface.

I.A.2.c Groundwater Production Rates In Backfill

No conventional aquifer tests have been completed in Big Horn Mine spoils beyond those that are reported in Section 6.1.2 of the Reclamation Plan; however, eight test holes and one monitor well (well C-2001) were drilled in Pits 1 and 3 in August 2001 and from this work additional data are available on approximate groundwater production rates in the spoils. The results of the tests described in the Reclamation Plan show a wide diversity in spoil hydraulics with transmissivities ranging from about 5 gallons per day per foot (gpd/ft) to over 22,000 gpd/ft. Production rates in those tests ranged from less than one gpm to 37 gpm. Overall, the transmissivity (a measure of an aquifer's total yield available to a well) of the spoils was projected to be at least as great as the undisturbed coals.

The eight test holes that were drilled in the spoils, together with monitor well C-2001, are located on Exhibit 1 and geologic logs for the sites are presented in Addendum A. The test holes were drilled in repeated attempts to construct five additional monitoring wells that would be used for assessing postmining groundwater elevations, water quality and aquifer hydraulic characteristics. The test holes could not be completed as monitoring wells because the spoils consistently caved into the boreholes at such large volumes and rates so as to preclude successful insertion of well casing. While sloughing of mine backfill in boreholes is not unique, the problem at Big Horn was obviously exacerbated in some cases by the boreholes producing large groundwater flows that washed out the unconsolidated materials. Groundwater yields estimated by experienced personnel during airlifting of the open boreholes are noted on the logs of three of the sites in Addendum A. Holes A-A and A-A1 produced approximately 20 to 25 gpm while hole B-A2 was noted as producing some 25 to 30 gpm, all from airlifting near the base of the spoils. Well C-2001 was noted as yielding 10 gpm during final airlift development. While the permeability and transmissivity of the spoils will probably diminish as the materials settle and compact, all evidence now indicates that groundwater yields in Pits 1 through 3 are more than sufficient to supply livestock watering wells.

I.A.3 Backfill Storage Characteristics

I.A.3.a Backfill Storage Characteristics Reported In Mine Permit Document

The groundwater storage characteristics of the backfill at Big Horn Mine are quantitatively and qualitatively assessed in the Reclamation Plan. Table RP-12 quantifies storage coefficients in spoils from four multiple-well pumping tests. The results range from a high of 0.23 for spoils of the Plachek Pit to a low of 0.0002 for a test completed in Pit 3 spoils. The high value is indicative of unconsolidated strata under water table conditions while the low value and others found like at the mine are indicative of groundwater under confined to semi-confined conditions. Similar storage coefficient values characterized the native coal and overburden strata of Big Horn Mine, with the largest storage found in the alluvium of Goose Creek and Tongue River valleys and the smallest values found in the deeper coal seams. By reference to studies conducted at strip coal mines in southeastern Montana (Van Voast et al., 1978), the Reclamation Plan cites low spoil storage coefficients indicative of rubble-strewn pit floors and cites further the conclusion that the premining and postmining occurrence and flow of groundwater are not expected to be dissimilar (Section 6.1.2, Reclamation Plan).

I.A.3.b Current Status Of Groundwater Storage In Mine Backfill

There have been no direct measurements of backfill storage coefficients at Big Horn Mine beyond those referenced above in the previous text section. However, indirect evidence of groundwater storage in the spoils exists in the findings and products presented above including the groundwater hydrographs of wells in the backfill (Addendum A), the potentiometric surface map of the spoils (Exhibit 1) and the logs of the test holes drilled in the spoils (Addendum A).

The hydrographs of the spoil wells in Pits 1 through 3 together with the potentiometric surface map of the spoils show groundwater recovery to predicted elevations over nearly all portions of the backfill. Below the phreatic surface of the spoils, groundwater is held in storage, as is true for any aquifer. Both the effective porosity (unconfined storage) and confined storage properties of the spoils probably vary considerably over the mine as a result of the spoils' textural diversity, but overall, the effective porosity appears to be large as evidence by the geologic logs of the spoils test holes (Addendum A) describing loose, caving materials with noticeable voids. The large porosity of the spoils described in the test holes is also demonstrative of materials exhibiting large permeabilities, and hence, large groundwater yields, which indeed was the case for the several test holes where yields were estimated. Groundwater also readily moves into and out of storage in the spoils, as evidence by the seasonal water elevation fluctuations that are very apparent in the hydrographs of several of the spoil wells, most notably wells Nos. 745-82 and 819-84. These seasonal fluctuations are caused by the water table in the spoils rapidly responding to changes in recharge (river stage) and discharge (evapotranspiration losses), which in turn is indicative of an aquifer having large porosity and permeability.

Finally, groundwater storage releases and flow through the spoils have been sufficient to maintain a permanent pool in Reservoir No. 14 within Pit 2 through over a year of drought (2000-2001) when recharge from precipitation and runoff was very small and evaporative losses were high.

I.A.4 Recharge Capacity Of Mine Backfill

The data and findings presented in the previous sections of this text fully demonstrate the recharge capacity of the reclaimed lands within Big Horn Coal Mine.

II POSTMINING GROUNDWATER QUALITY

As defined in Section I, the intended post mining use of groundwater at the Big Horn Mine will be for livestock consumption. The Wyoming Department of Environmental Quality defines groundwater quality standards for this use (Class III) and others in Chapter VIII of Wyoming Water Quality Rules and Regulations (March 1993). Chapter VIII constituent and concentration suitability criteria for domestic (Class I), agricultural (Class II) and livestock uses are presented in Table 4. Based upon the intended use of groundwater from Big Horn Coal's restored and adjacent aquifer systems, the following evaluation is restricted to the assessment of groundwater for Class III laboratory analytical constituents and concentration limits. By mutual agreement with the WDEQ, Big Horn Coal Company also includes the analytical results and assessment for ammonia nitrogen.

Big Horn Coal Company commits to Class III groundwater quality restoration objectives for Big Horn Coal Company's Pits 1, 2, and 3 disturbance areas and adjacent aquifers. Premining assessments in the Pit 4 and Pit 5 areas conclusively demonstrated the lack of groundwater in the mine-affected geologic units of both areas. It was anticipated there would never be usable quantities of groundwater within either of these areas when fully reclaimed. This prediction has been confirmed, as discussed above under Section I.

A relevant water quality assessment which included backfill wells from several northern Powder River Basin (Gillette, Wyoming) coal mines has been compiled by the WDEQ (Ogle, 2002). Wells represented in this assessment were monitored for upwards of 15 years and demonstrated steady but only relatively slow recharge rates. Only one of the referenced wells had recharged to the premining level. Typically dissolution of sodium, calcium, magnesium, and sulfate during initial saturation resulted in an elevated TDS in sampled groundwater from these sources. Elevated sulfate and TDS routinely exceeded Class III limits during initial saturation. In general, elevated TDS and sulfate concentrations in the backfill aquifers declined as the aquifers continued to be recharged and flushed. In summary, with sufficient time, TDS and sulfate concentrations are expected to meet Class III limits.

The WDEQ's assessment also references generalized historic backfill water quality research from southeastern Montana as summarized by Van Voast et al (1976). The research indicated that backfill groundwater tends to contain increased concentrations of minerals and chemically resemble that of the associated inorganic aquifers rather than that of coal aquifers. Additionally, TDS concentrations generally range from 1,500 to 3,500 mg/L but were found to occur as high as 6,000 mg/L. The research also concluded that notable percentages of available salts were dissolved during initial backfill saturation and the concentrations of salts declined with exposure to subsequent pore volumes. Research indicates that, although trace metals might occur in undisturbed groundwater locally, they generally are more common in backfill area groundwater. The distribution and concentrations of dissolved trace metals in backfill groundwater was, however, determined to be of no great significance.

As discussed in Section 6.2.2 of the Reclamation Plan, there has historically been no mine-attributed change of water quality in the affected (Dietz 2, Dietz 3 and Monarch) coal aquifers, or in the two alluvial aquifer systems. The Carney coal aquifer, underlying the Monarch coal, was not physically or hydraulically affected by mining.

Big Horn Coal Company's groundwater monitoring database indicates that several different laboratories provided groundwater analytical services to the mine over the years. Northern Testing Laboratory of Billings, Montana, and Inter-Mountain Laboratories of Sheridan, Wyoming, provided much of the groundwater quality analytical services from 1980 through 1983. Records indicate virtually all of the groundwater analyses from about 1983 through most of 1990 were conducted by the Peter Kiewit & Sons' corporate laboratory, historically located in Sheridan, Wyoming. Inter-Mountain Laboratories resumed contract groundwater analytical services in late 1990 and continues to provide these services. Other than small differences in the reported quantifiable limits for lead, chromium, arsenic and selenium, there does not appear to be significant analytical variability resulting from changes in the laboratories used, or changes in the regulatory and industry-accepted laboratory practices that would have occurred within Big Horn's period of record.

II.A Constituents For Class III Water Quality Assessment

In consultation with the WDEQ/LQD, fourteen analytical water quality constituents of Class III criteria were selected for evaluating postmining groundwater quality characteristics at Big Horn Mine. These include: pH, total dissolved solids (TDS), the combined nitrate and nitrite compounds (reported as nitrogen), chloride, and sulfate along with dissolved concentrations of aluminum, arsenic, cadmium, cadmium, copper, lead, selenium, and zinc. With exception to the analysis of pH, which is a unitless measurement, all analytical results are reported in milligram per liter (mg/L) concentrations. Regulatory-defined maximum concentration limits or allowable ranges of each constituent are presented with the analytical result summary tables in Addendum B.

II.A.1 Monitoring Results For Class III Water Quality Criteria

Laboratory analytical data are compiled from 15 monitoring wells that are sampled annually during the current monitoring regime. The monitoring well sample locations are shown on Exhibit 1. The number of samples obtained from these wells varies, based upon well installation dates and historic monitoring frequencies. Analytical result summaries are presented in tabular format numerically by aquifer and include life of well minimum, maximum and arithmetic mean concentrations for each of the targeted constituents (Addendum B, Tables B-1 through B-15). Figures B-1 through B-6 illustrate graphic constituent concentrations for those wells that have exceeded one or more Wyoming Class III quality criteria. Big Horn Coal Company did not analyze combined nitrogen compounds as nitrate plus nitrite from approximately 1982 to 1996; however there are sufficient data to assess this constituent.

II.A.1.a Groundwater Quality In Mine Spoils

The analytical results of historic groundwater sampling from nine well locations within the reclaimed spoils of Big Horn Coal Company's five pit disturbances are presented in well identification numeric sequence in Tables B-1 through B-8.

Pits 1 and 2 spoils

Analytical results obtained from monitoring wells 656-81, 819-84, and 823-84 are used to assess backfill water quality of Pits 1 and 2. Results of the analytical assessment for these wells are presented respectively as Tables B-1, B-5, and B-6.

The water quality at wells 656-81and 819-84 reflects the major influence to the backfill materials from the high quality waters of Goose Creek and its alluvium. With exception of a single occurrence of chromium (0.08 mg/L in 1986 at 819-84), targeted Class III constituent concentrations from both wells have not been exceeded. Four individual analytical results from 656-81 are considered anomalous and are not utilized in the assessment. Out of 37 samples from 819-84, two analytical results are considered outliers. Concentrations of dissolved solids at both wells are typically on the order of 1000 mg/L. Concentrations of all of the Class III constituents from these wells are considered stable.

The analyses presented in Table B-6 from reclaimed spoils well 823-84 confirm overall very high quality backfill recharge. Readily dissolved ions were apparently flushed from the newly saturated backfill at this location by approximately 1986. Since 1987, dissolved solids have ranged from 42 to 710 mg/L. Although primary recharge to the aquifer at this is location is from the Tongue River, the unusually low concentrations of dissolved solids at this location likely result from the influence of nearby Reservoir 14. Sulfate concentrations continue to fluctuate somewhat, but average less than 150 mg/L. Since 1987, of the eight-trace metals targeted, zinc was detected twice at 0.02 and 0.05 mg/L, and copper was detected once at 0.02 mg/L. Records indicate that, from 1987 through 1991, pH laboratory analyses of samples from this well consistently were above the Class III limit of 8.5, with a maximum pH measurement of 10 occurring in October 1990. Since 1992, three pH measurements have exceeded 8.5 while the life of well average pH from 37 samples is 7.6. These occurrences of elevated pH indicate not only the presence of soluble carbonate in the backfill matrix, but more importantly, these occurrences further confirm the nearly pristine backfill groundwater's initial lack of buffering capacity resulting from low concentrations of dissolved cations. Figure B-2 graphically illustrates the historical pH values of well 823-84.

Pit 3 spoils

Three additional backfill wells are situated in Pit 3 reclaimed spoils on the north side of the Tongue River. These include 745-82, 657-81 and the recently installed C-2001. Analytical results of Class III constituents for these three wells correspond respectively with Tables B-3, B-2, and B-8.

Analytical results from 745-82 have never exceeded any of the Class III constituent limits. Historically, TDS concentrations demonstrate a conclusive downward trend from 3760 mg/L in 1982 to approximately 1100 mg/L in recent years. The peak sulfate concentration has declined from 2230 to less than 600 mg/L since 1999. With exception to copper and zinc occurring near the detection limit on isolated occasions, Class III trace metals are generally no longer detected in well 745-82.

The analytical results presented in Table B-2 for spoils well 657-81 are atypical of those obtained from other wells in Big Horn Coal Company's Pits 1, 2, and 3 backfill. Several factors contribute to the delayed stabilization of groundwater quality at 657-81. These factors include localized low aquifer transmissivity and probable infiltration of low quality groundwater resulting from exposure to numerous active underground coal fires burning in the partially saturated areas of the adjacent Monarch coal seam to the northwest. The underground coal fires are located outside of Big Horn Coal's Pit 3 disturbance in areas of historical underground mine workings and are currently observed approximately 1,000 feet northwest of 657-81. Water temperature measurements during sampling of 657-81 have historically fluctuated and have exceeded 20° Celsius on several occasions. Elevated groundwater TDS concentrations potentially attributable to underground combustion of local coal aquifers is found in the results of baseline monitoring presented in Appendix D6 of the Welch No.1-North Mine's Permit 497-T3 (1999). The Welch Mine is located north and adjacent to Big Horn Mine property. There are documented, active burns in dry or partially saturated zones of the Dietz 2, Dietz 3, and Monarch seams within and adjacent to the Welch Mine that are believed to be associated with the abandoned Acme underground coal mine. One of the historic Welch Mine Dietz 3 monitoring wells (D3-M1), located within one half mile downdip (and hydraulically downgradient) from a documented active burn, consistently yielded elevated TDS concentrations of approximately 5800 mg/L in the early and mid-1980's, prior to the well's abandonment. Other Dietz 3 monitoring wells closer to the burn were dry, however, down hole temperature measurements at these locations exceeded 70° C. Additionally, several Monarch coal wells located less than one mile downgradient from the burn contained elevated baseline TDS concentrations on the order of 2500 mg/L, over two times the concentration observed in Big Horn Mine's 825-84 Monarch monitoring well.

Since sampling commenced at 657-81, peak TDS concentrations (6440 mg/L in 1984) have declined to less than 6000 mg/L in recent years, but typically remain above target Class III limits. Several times throughout monitoring, concentrations of dissolved solids have shown dramatic fluctuations, apparently from subtle temporary shifts in the principal source of recharge or infiltration paths. In 1991, TDS concentrations abruptly fell to 546 mg/L with another significant temporary reduction in TDS occurring in 1999. Maximum sulfate concentrations of 3280 mg/L have fallen and continued to remain below Class III limits since 1996. Although chromium concentrations intermittently exceeded 0.05 mg/L from 1982 to 1989, since 1990 this element has not been detected at 657-81. Analytical results for pH, TDS, sulfate and chromium are provided in graphical format as Figures B-3 through B-5.

A single water sample (Table B-8) has been collected from the recently installed Pit 3 spoils monitoring well (C-2001) that was completed in the northern area of the backfill. Initial water quality testing confirmed all constituents to be below the targeted livestock criteria limits. Currently, sulfate concentrations are at 2100 mg/L and the TDS results are reported to be 3960 mg/L. With exception to zinc, which was found to be present at 0.02 mg/L, there were no detectable concentrations of the Class III trace metals present. Water quality in the adjacent spoils is expected to continue to improve quickly as a result of further influence from the new Pit 3 Reservoir.

Pit 4 spoils

Although there is insufficient quantity of water to develop for livestock use in the reclaimed Pit 4 backfill, sufficient volume is available to sample. Because of very limited infiltration, the water quality at the single monitoring well (816-83, Table B-4) has been slow to stabilize. Water quality at the well has, however, shown significant improvement. Historically, the pH has fallen below the targeted range of 6.5 to 8.5 and TDS, sulfate and chromium have exceeded the targeted Class III limits. These constituent concentrations are presented in graphical format as Figures B-6 through B-8. Additionally, at one time or another, all of the other seven Class III trace metals have been detected. As of the most recent three samples collected since 1997, only TDS has exceeded target Class III limits from a single sample.

Pit 5 spoils

Due to the lack of groundwater in the Pit 5 area prior to mining, as anticipated, the backfill contains insufficient quantity of groundwater to develop for livestock use. Sufficient water is available to sample well 906-90 by purging slowly with a hand bailer. The well produced less than 10 gallons during the most recent sampling event. Analytical results for this well are summarized in Table B-7 and with some exceptions mentioned below, are generally within Class III limits. A single sample collected in April 1998 contained TDS concentrations above 5000 mg/L. Also, there have been three radical single sample spikes in nitrate and nitrite concentrations at the well occurring in 1998, 1999, and 2001 that have ranged from 113 to 338 mg/l. Figures B-9 and B-10 graphically show concentrations of TDS and nitrate and nitrite compounds from 1992 through the present. Ammonia concentrations show simultaneous spikes ranging from approximately 62 to 133 mg/L. Very low concentrations of aluminum, copper, selenium and zinc have been present on occasion in samples from well 906-90; however these trace metals are typically not detected. With exception to the occurrences of the three nutrient concentration spikes mentioned earlier, backfill water quality at Pit 5 appears relatively stable and the groundwater has otherwise consistently met livestock use limits.

Livestock grazing probably has not contributed to the intermittently elevated nitrogen compounds observed at 906-90, based upon the limited amount of seasonal unconfined grazing conducted within and above the reclaimed Pit 5 area. Although there is the potential for isolated remnants of nitrogen based blasting agents to occur within surface coal mine backfill, in this case the source for the elevated concentrations of nitrogen compounds is more likely attributed to backfill recharge water that is exposed to the underground coal fires known to exist in the adjacent, abandoned underground Acme Mine workings. Baseline ammonia concentrations at the Welch No.1 Mine's historic D3-M1 monitoring well (discussed earlier in this section), intermittently exceeded 15 mg/L. During the same period of baseline groundwater monitoring, several other Welch Mine Dietz 3 and Monarch monitoring wells located within one mile downgradient from areas of the Acme Mine underground burn also demonstrated erratic low-level fluctuations in ammonia and combined nitrate and nitrite concentrations.

Tongue River alluvium

Groundwater quality of the Tongue River alluvium aquifer is monitored at a single downgradient well location from the Big Horn Mine (644-80, Table B-9). Groundwater quality of the alluvium at this location has been and continues to be of excellent livestock quality. With exception to a single anomalous occurrence of lead, Class III limits have not been exceeded in over twenty years of routine monitoring. For this assessment, one analytical result for nitrate and nitrite (1.22 mg/L) and one lead result (0.24 mg/L) are considered anomalies and were not included for the statistical assessment.

Dietz 2 coal

The analyses from two recent Dietz 2 coal aquifer water samples obtained downgradient from the Big Horn Mine at well 828-84 (Table B-10) confirm excellent livestock water quality. Sulfate is not a detectable constituent at this location and TDS averages 1250 mg/L. Trace metal concentration averages are below detectable levels.

Dietz 3 coal

Analytical results from wells 468-79 and 827-84 are assessed in Tables B-11 and B-12. These results characterize the water quality downgradient from the Big Horn Mine in the adjacent Dietz 3 coal aquifer. The data from both wells confirm excellent water quality for livestock use and indicate no degradation of water quality in approximately two decades of monitoring.

Monarch coal

Two downgradient Monarch coal aquifer wells (467-79 and 825-84) are located to the east and northeast of the Big Horn Mine. The analytical results obtained from over 15 years of monitoring both wells are presented in Tables B-13 and B-14. As with the water quality from the overlying Dietz 2 and Dietz 3 coal aquifers, groundwater quality from the Monarch coal continues to meet livestock use criteria. Class III constituents have never exceeded target limits to date, and there have been no apparent changes in constituent concentrations resulting from Big Horn Mine's operations.

Carney coal

The analytical results obtained from 35 samples collected since 1979 from monitoring well 465-79 are presented in Table B-15. The data represents historic water quality monitored from the Carney coal aquifer. As stated previously, Big Horn Coal did not physically or hydraulically impact the Carney coal. Water quality of the Carney aquifer has and continues to be suitable for livestock use.

III VERIFICATION OF POSTMINING PROBABLE HYDROLOGIC CONSEQUENCES

III.A Review Of Predicted Probable Hydrologic Consequences

As stated in Section 6.2.2 of the Reclamation Plan, the coal seams mined at Big Horn Coal, in descending order the Dietz 2, Dietz 3 and Monarch coals, together with the alluvium of Goose Creek and Tongue River valleys, were identified as the only strata physically mined that is capable of yielding enough groundwater to be classified as aquifers. The Carney coal seam, another aquifer found about 100 feet beneath the Monarch, was not physically or hydrologically affected by mining. Prior to mining, the Dietz and Monarch coal seams were locally recharged primarily by groundwater where the coals subcropped in saturated alluvium of Goose Creek and Tongue River valleys. Mining within Pits 1, 2 and 3 variously affected groundwater elevations in the coal seams depending upon the positions of the pits relative to the coals' alluvial subcrop zones. Potentiometric declines of 10 feet and more were recorded in the Dietz 2 and Dietz 3 seams up to about one mile downdip (southeast and east) of mining and up to about 1.5 miles downdip of the mine in Monarch coal (Section 6.2.2, Reclamation Plan). The coal seams were dry in Pits 4 and 5 and no aquifers were intercepted in these areas. The southern boundary of Pit 3 intercepted saturated alluvium of Tongue River along a length of about 2,000 feet. This caused the water table in the alluvium to decline over a portion of the valley floor between the river and the mine pit. Mining did not cause water table declines in alluvial wells monitored by the mine other than those proximate to the southern boundary of Pit 3 (Section 6.2.2, Reclamation Plan). No unnatural groundwater quality changes were observed in either the affected coal seam aquifers or in the alluvium of the stream valleys (Section 6.2.2, Reclamation Plan). The channel and alluvial deposits of Goose Creek were also mined in the 1950's and 1960's but hydrologic impacts were not predicted for this mining because it was pre-law.

With the creation of Pit 3 Reservoir, the postmining hydrology of Big Horn Mine will be significantly different than premining. Beyond the existence of the reservoir where none existed prior to mining, the changes will be rather limited with regard to postmining groundwater quantity and quality. The reservoir will be supplied primarily by the North

French Drain, which connects the reservoir to channel flows in Tongue River, and by the South French Drain, which connects the reservoir to saturated alluvium of Tongue River upstream of the North French Drain. Other, projected water supplies to Pit 3 Reservoir include groundwater sources from reclaimed saturated spoils and the Dietz 3 and Monarch coal seams but these sources will be minor relative to what will be provided by the two French drains (Section 7, Reclamation Plan). The average pool elevation of the reservoir will be below the floor of Tongue River alluvium where the alluvium connects to the South French Drain, meaning that the water table in the alluvium proximate to the drain will be permanently lower than premining. Permanent drawdown of the alluvial water table is projected to occur only proximate to the South French Drain where is will extend slightly less than half-way across Tongue River valley south from Pit 3 Reservoir to the river channel (see Exhibit RP-25 and Section 7.3.1.1.1, Reclamation Plan). The mined edges of the Dietz 3 and Monarch coal seams will be below the normal operating level of the reservoir and, although the edges of both seams were covered with backfill, the reservoir should act as a constant head recharge source to the coals similar to the natural subcrops of the coals in saturated alluvium of both Tongue River and Goose Creek (see Exhibits RP-15 and RP-16, Reclamation Plan).

III.A.1 Groundwater Elevations, Recharge And Infiltration Rates, Water Quality And Aquifer Yields

Groundwater elevations

Groundwater elevations in the affected coal seam aquifers and in the reclaimed spoils are projected to recover relatively rapidly to equilibrium conditions after final backfilling of the mine pits and after Pit 3 Reservoir fills (Section 6.2.2, Reclamation Plan). Groundwater elevations will recover quickly in the aquifers because of significant recharge in the form of seepage from perennial channel flows in Tongue River and Goose Creek, as well as by groundwater flow from the saturated alluvium of these valleys where the alluvium contacts the spoils and where the alluvium contacts remaining coal subcrops. Groundwater elevations in Dietz 2 coal are projected to fully recover within two years after final backfilling of Pit 1 (by year 1999). Groundwater elevations in the Dietz 3 and Monarch seams are predicted to fully recover within two to three years after filling of Pit 3 Reservoir. Postmining groundwater elevations in the coal seam aquifers are expected to be similar to premining groundwater elevations. Groundwater elevations and gradients in the reclaimed spoils of Pits 1 through 3 were projected to be approximately the same as the premining Monarch coal. Attainment of hydrostatic equilibrium within the spoils is projected to occur within five years of final Pit 3 reclamation (Section 6.2.2, Reclamation Plan). Pit 3 Reservoir began filling in late 2000, and as of January 2002, it appears that the reservoir will reach its normal pool elevation (3560.5 feet) before the end of the first quarter 2002.

Infiltration and recharge rates

Section 6.1.5 of the Reclamation Plan describes how the reclaimed backfill will be recharged simultaneously with and by the same mechanisms as the coal aquifers since the backfill is physically connected to the same alluvial recharge sources and to the reconstructed Tongue River channel adjacent to Pit 2. Recharge to all affected aquifers and to the backfill of Pits 1 through 3 is projected to be relatively rapid, as described above. A backfill aquifer will not be restored in Pits 4 and 5 because these areas lie stratigraphically and topographically above the Tongue River valley where lateral groundwater recharge is inadequate to sustain significant groundwater saturation (Section 6.2.2, Reclamation Plan). Recharge to the Pits 4 and 5 spoils is predicted to be restricted to precipitation infiltration as opposed to the significant lateral groundwater recharge provided by the alluvium of Tongue River and Goose Creek valleys.

Postmining infiltration rates are qualitatively discussed in Section 6.2.2 of the Reclamation Plan in the context of referencing groundwater elevation recovery rates observed in coal monitoring wells. Postmining water table elevations in the backfill of Pits 1 through 3 are predicted to be hydraulically connected to the Monarch coal and to the saturated alluvium of Goose Creek and Tongue River. Based on these observations and conclusions, groundwater resaturation rates (groundwater infiltration rates) are projected to be relatively rapid for the affected coal and Tongue River alluvial aquifers as well as for the backfill itself.

Groundwater quality

The groundwater quality of the postmining spoils is predicted to be diverse but total dissolved solids concentrations are projected to decline over time as saturation levels and groundwater flow patterns stabilize. Ultimately, the groundwater quality of the spoils is predicted to be suitable for the same uses that the coal aquifers had prior to mining (Section 6.2.2, Reclamation Plan).

Aquifer yields

Section 6.1.5 of the Reclamation Plan concludes that premining groundwater flow directions and gradients will be restored in the coal aquifers proximate to the reclaimed spoils of Pits 1 through 3; hence it can be inferred that the groundwater yields, transmissivities and storage characteristics of these aquifers will be restored. Section 6.2.2 of the Reclamation Plan concludes that the transmissivities of the resaturated spoils in Pits 1 through 3 appear to be at least that of the undisturbed coal aquifers; therefore it can be inferred that these spoils will yield sufficient groundwater for livestock watering as did the premining coal aquifers.

III.A.2 Projected Surface Water/Groundwater Interactions

In Section 6.2.3 of the Reclamation Plan, the most significant source of postmining coal recharge is stated to be Tongue River and its alluvium. The coal seams, particularly the Monarch, are projected to be the principal source of groundwater recharge to the backfill of Pits 1 through 3. Streamflow depletion in Tongue River associated with aquifer drawdown is described as minute, if any, and projected to cease after reclamation is complete and groundwater elevations in the coals and spoils aquifers have recovered. Section 7 of the Reclamation Plan describes the functions of the French drains on Pit 3 Reservoir to permanently connect the reservoir to the channel flow and alluvial groundwater flow of Tongue River. The South French Drain will permanently lower the water table in the alluvium of the river proximate to the drain. These projections taken together, it is clear that the Tongue River fluvial system is projected to remain a critical component in the surface and groundwater functions of Big Horn Mine.

III.B Demonstration Of Groundwater Restoration

This document has shown that the quantity of groundwater in the affected aquifers and backfill at Big Horn Mine has been essentially fully restored. Lateral groundwater flow from the alluvium of Tongue River and Goose Creek valleys together with direct infiltration of streamflow in Tongue River over its reconstructed reach have been predominate recharge sources restoring subsurface flow and water storage in the backfill of Pits 1 through 3 and the affected coal aquifers. Resaturation (effective infiltration) rates in Pits 1 through 3 have been high while the backfill of Pits 4 and 5 remain essentially dry, as predicted. As of October 2001 or before, groundwater elevations and patterns of groundwater movement in the backfill and in the affected coal seams proximate to the backfill closely matched those predicted for equilibrium conditions in the Reclamation Plan. The storage characteristics of the coal seam aquifers have been restored with the recovery of the aquifers' potentiometric elevations. The backfill rapidly transmits water from surface sources as evidenced by groundwater elevations in the backfill changing seasonally in response to changes in stream stages and changes in alluvial water table elevations in Tongue River and Goose Creek valleys. Groundwater moving in to and out of storage in the backfill has been sufficient to provide a perennial pool in Reservoir 14 of Pit 1. Evidence obtained from test holes and most monitor wells indicates moderate to high rates of groundwater movement and storage in the spoils. Groundwater yields recorded from test holes and monitor wells completed in Pits 1 through 3 spoils are generally more than adequate to supply conventional livestock watering wells.

Water table elevations in the alluvium of Tongue River valley adjacent to the South French Drain on the Pit 3 Reservoir show permanent drawdown, as predicted. The alluvial groundwater will remain a principal supply source for the reservoir. Groundwater elevations and flow patterns now found within the alluvium near South French Drain agree with predictions made in the Reclamation Plan and appear to be in equilibrium with recharge provided by the Tongue River fluvial system.

With the exception of well 657-81 in Pit 3, groundwater quality data for Pits 1 through 3 spoils overwhelmingly indicate that the water is acceptable for livestock use per standards set forth by the WDEQ/WQD (Rules and Regulations, Chapter VIII, Section 5, Table 1). Solute concentrations exceeding the livestock use standards have been relatively rare in the backfill groundwater with the exception of well 657-81 in Pit 3 and well 823-84 in Pit 1. Over the past 20 years, total dissolved solids and sulfate concentrations in the groundwater of well 657 have frequently exceeded the livestock use standards, although the concentrations have diminished somewhat over time. High solute concentrations in well 657-81 are probably due to the fact that the transmissivity (groundwater flow rate) of the spoils is known to be very small there. The elevated sulfate and TDS concentrations at well 657-81 will very likely continue to diminish over time as the spoils continue to be recharged and flushed, as has been observed at mines in the northern Powder River Basin (see Section II). The groundwater quality in well No. 823-84 in Pit 1 is uniquely different from all other spoil aquifer wells in that the solute concentrations there are very low but pH values frequently exceeded the livestock use standard prior to 1992. The high pH values in this well have diminished over time as the carbonate buffering capacity of the water increased with increasing solute concentrations. With the exception of the high pH values, the quality of the water at well 823-84 has otherwise frequently been excellent, meeting even the domestic use criteria of the Wyoming Department of Environmental Quality, Water Quality Division (R&R, Chapter VIII, 1993). The groundwater quality at both wells 657-81 and 823-84, while continuing to improve over time, is not indicative of Big Horn Mine's spoils aquifer as a whole having water quality suitable for livestock consumption.

Groundwater elevations in the backfill will continue to rise some two to four feet in areas proximate to Pit 3 Reservoir as the reservoir fills to its normal operating elevation. The patterns of groundwater flow will remain the same as shown in this document and water table elevations in the backfill and in the spoils proximate to the backfill will continue to fluctuate together in phase with seasonal changes in the stages of Tongue River and Goose Creek. Solute concentrations in groundwater of the Pit 1 through 3 spoils will continue to diminish and become more areally consistent as soluble mineral constituents are flushed out of the spoils.

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REPORT TABLES

TABLE 1 DOUBLE RING INFILTRATION TEST RESULTS

SITE NO.		MINE AREA	LOCATION COORDINATES NORTHING	LOCATION COORDINATES EASTING	SOIL TYPE	DATE TESTED	INFILTRATION RATE (INCHES/HOUR)
BH1	*	PIT 1	1544320	595950	NATIVE RESIDUAL	10/31/1978	1.85
BH3		PIT 3	1548550	594850	NATIVE ALLUVIAL/COLLUVIAL	05/22/1979	1.42
BH4		PIT 3	1548590	594510	NATIVE ALLUVIAL	05/22/1979	0.95
BH5		PIT 3	1549720	594940	NATIVE ALUVIAL/COLLUVIAL	05/22/1979	0.77
BH6		PIT 3	1550550	594980	NATIVE COLLUVIAL	05/23/1979	1.74
BH8	*	PIT 4	1550094	589195	NATIVE COLLUVIAL		0.42
BH9	*	PIT 4	1549922	589013	NATIVE COLLUVIAL	05/15/1979	0.07
BH10	*	PIT 4	1549777	590248	NATIVE COLLUVIAL	05/15/1979	0.14
BH11	*	PIT 4	1550106	589479	NATIVE COLLUVIAL	05/15/1979	0.12
BH12	*	PIT 4	1549566	590512	NATIVE COLLUVIAL	05/15/1979	0.15
BH13	*	PIT 4	1549508	590702	NATIVE COLLUVIAL	05/15/1979	0.32
BH14		TONGUE RIVER	1545981	586156	NATIVE COLLUVIAL	05/15/1979	0.62
BH15		TONGUE RIVER	1546581	585818	NATIVE COLLUVIAL	06/04/1979	8.58
BH16		TONGUE RIVER	1545921	586765	NATIVE COLLUVIAL	06/05/1979	0.96
BH17		TONGUE RIVER	1545527	585226	NATIVE COLLUVIAL	06/05/1979	0.39
BH18		TONGUE RIVER	1545515	585819	NATIVE COLLUVIAL	06/05/1979	1.09
BH23		TONGUE RIVER	1547182	594578	NATIVE COLLUVIAL	06/04/1979	1.22
BH24		TONGUE RIVER	1547160	595008	NATIVE COLLUVIAL	05/23/1979	3.06
BH25		TONGUE RIVER	1547164	595229	NATIVE COLLUVIAL	05/23/1979	1.92
BH27		PIT 3	1548684	594249	NATIVE COLLUVIAL	05/22/2007	3.67
BH32		PIT 3	1551117	594412	NATIVE COLLUVIAL	05/23/1979	1.54
BH34		PIT 3	1547606	592807	RECLAIMED	06/01/1979	0.28
BH35		PIT 1	1545466	593034	NATIVE RESIDUAL	06/05/1979	7.25
BH36		GOOSE CREEK	1541865	590222	NATIVE ALLUVIAL	06/01/1979	3.74
BH37		GOOSE CREEK	1541806	590370	NATIVE ALLUVIAL	06/01/1979	8.24
BH48	*	PIT 1	1543157	592479	RECLAIMED	09/15/1981	0.10
BH49	*	PIT 1	1544349	592109	RECLAIMED	09/15/1981	0.65
BH50	*	PIT 3	1549126	593083	RECLAIMED	09/16/1981	0.46
BH51	*	PIT 3	1549902	593295	RECLAIMED	09/16/1981	0.54
BH52	*	PIT 3	1542090	591965	RECLAIMED	09/17/1981	1.15
BH53	*	PIT 3	1541715	592150	RECLAIMED	09/16/1981	0.39
BH54	*	PIT 3	1544985	597378	NATIVE RESIDUAL	08/21/1987	4.35
BH55	*	PIT 4	1549520	590015	RECLAIMED	08/21/1987	3.00
BH56	*	PIT 4	1549950	588045	NATIVE RESIDUAL	08/20/1987	1.41

* INDICATES THE TEST DATA/RESULTS ARE NOT INCLUDED IN APPENDICES D6 AND D11 OF PERMIT 213-T3.

This is reprinted Table 16 from Big Horn Coal Company's 1993-1994 Annual Report.

Table 2 **Spoil aquifer hydraulic properties - Big Horn Coal Area**

Aquifer	Spoils	Spoils	Spoils	Spoils		Spoils	Spoils	Spoils	Spoils	Spoils
Well #	Plachek Pit Wells	655	656	657		658	745 746	819	823	818
Date of Test	15-Jul-75	21-Jul-81	14-Jul-81	10-Aug-82	06-Oct-81	06-Oct-81	09-Jul-82	20-Mar-84	21-Mar-84	
Source	Rahn	KM&E	KM&E	KM&E		KM&E	KM&E	KM&E	KM&E	
TYPE OF TEST	Time-Drawdown; leaky type curves	Jacob Time - Drawdown Time-Calc. Recovery Theis Nonequilibrium	Jacob Time-Recovery	Jacob Time Drawdown/ Recovery	Slug Method	Slug Method	Jocob Time Drawdown/ Recovery; Theis Time-Calc Recovery	Jacob Time Drawdown/ Recovery	Jacob Time Drawdown/ Recovery; Theis Non-Leaky	
Length of Test (HRS)	46.30	26.00	5.83	3.25	1.58	1.92	6.32	4.08	22.20	
Discharge (GPM)	6.50	37.00	1.29	0.65	----	----	1.67	0.55	1.73	
Final Drawdown (FT)	19.12	0.82	25.78	5.28	10.35	12.82	2.72	51.97	100.90	
Specific Capacity (GPM / FT)	0.30	----	0.10	0.12	----	----	0.60	0.00	0.20	
Hydraulic Conductivity (GPD/FT2)	4.00	1182?	0.85?	58?	7?	14.25?	930?	1.2?	10.1?	481.7? 509.0?
Transmissivity (GPD/FT)	172	22466	11	58	26	57	17662	5	191	9153 9671
Storage Cooefficient	0.23	6.0x10-3	----	----	----	----	2.0x10-4	----	----	1.4x10-2 1.2x10-2
COMMENTS	From Rahn report (Gerlach Thesis)	Pumped well 654. Unable to measure its water level; all aquifer coefficients derived from observation well 655. Saturated thickness questionable	Saturated thickness is questionable	Two tests ran; Base of spoils not exactly known		Saturated thickness is questionable; base of spoils questionable	745 pumped well; 746 observation. Saturated thickness is questionable	Base of spoils questionable; good test	Pumped well, well efficiency poor; base of spoils questionable	Observation well; base of spoils questionable

This is reprinted Table RP-12 from Big Horn Coal Company's Reclamation Plan (Permit 213-T5).

Table 3 Effective Infiltration Rates In Backfill For Selected Areas Of Pits One And Two At Big Horn Mine[1]

Coal Thickness (ft)	22
Porosity	20%
Last Groundwater Sample	Oct-01
Recharge Starting Date	Jul-78

Topsoil Application Area 1-1	
Sampled	May-85
Approved	02/20/1998
Area (ft^2)	1,370,094
Saturated Spoils Volume (ft^3)	77,544,000
Water Volume (ft^3)	15,508,800
Recharge Time (years)	23.2
Groundwater Movement (ac-ft/day)	0.04
Effective Infiltration Rate (in/yr)	5.9

Topsoil Application Area 1-2	
Sampled	Jun-87
Approved	07/14/1987
Area (ft^2)	2,031,313
Saturated Spoils Volume (ft^3)	117,126,000
Water Volume (ft^3)	23,425,200
Recharge Time (years)	23.2
Groundwater Movement (ac-ft/day)	0.06
Effective Infiltration Rate (in/yr)	6.0

Topsoil Application Area 1-3	
Sampled	Apr-96
Approved	10/24/1996
Area (ft^2)	1,438,327
Saturated Spoils Volume (ft^3)	193,077,000
Water Volume (ft^3)	38,615,400
Recharge Time (years)	23.2
Groundwater Movement (ac-ft/day)	0.10
Effective Infiltration Rate (in/yr)	13.9

Topsoil Application Area 1-4	
Sampled	3rd Qtr. 97
Approved	06/16/1998
Area (ft^2)	5,523,236
Saturated Spoils Volume (ft^3)	493,506,000
Water Volume (ft^3)	98,701,200
Recharge Time (years)	23.2
Groundwater Movement (ac-ft/day)	0.27
Effective Infiltration Rate (in/yr)	9.3

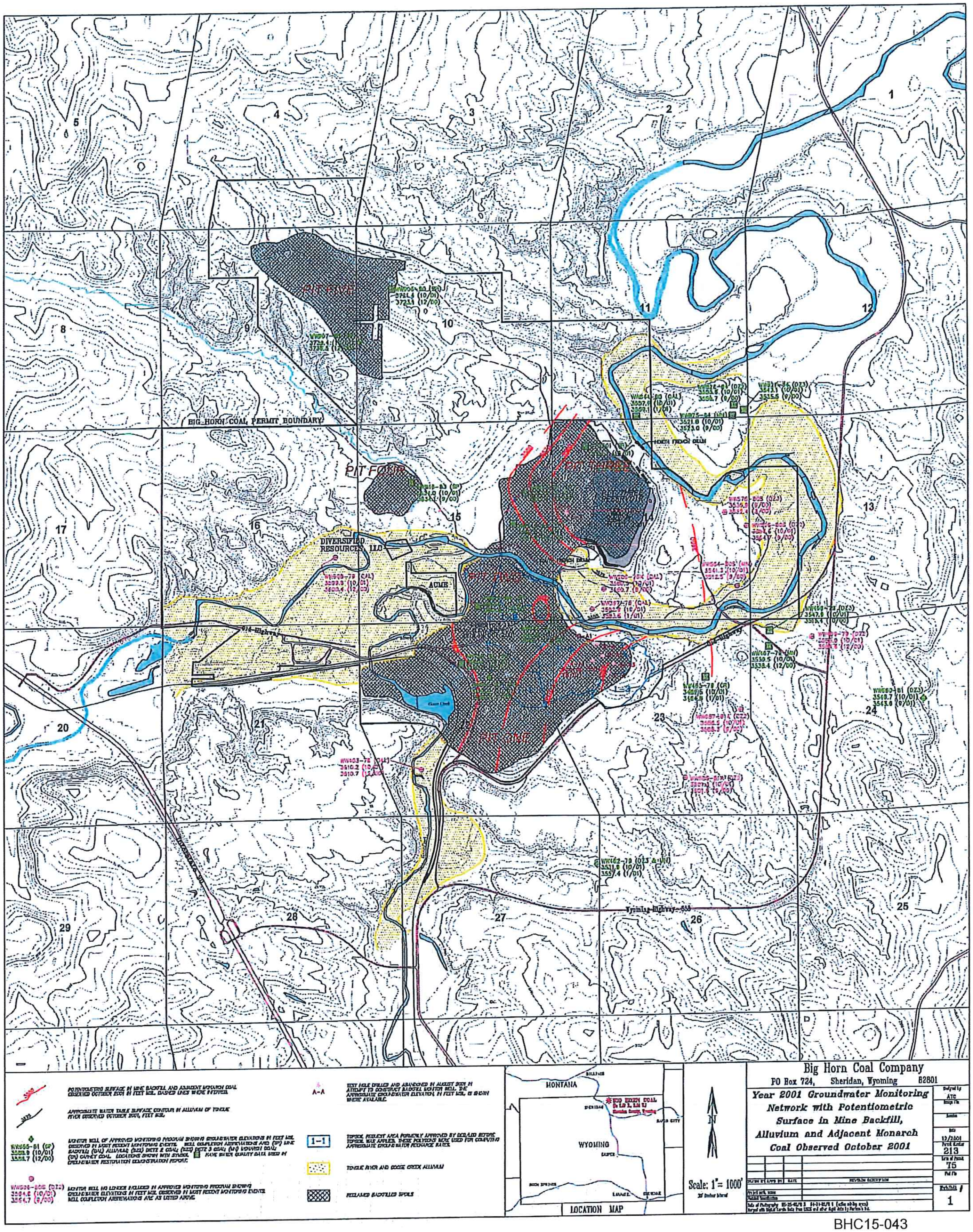
1. As used in this analysis, the effective infiltration rate is the rate at which the spoils resaturated from all surface water and groundwater sources expressed as inches per year of water applied over each respective topsoil application unit.

TABLE 4 UNDERGROUND WATER CLASS USE SUITABILITY

Constituent or Parameter	I Domestic Concentration*	II Agriculture Concent.*	III Livestock Concent.*
Aluminum (Al)	---	5.0	5.0
Ammonia (NH_3-N)	0.5[8]	---	---
Arsenic (AS)	0.05	0.1	0.2
Barium (Ba)	1.0	---	---
Beryllium (Be)	---	0.1	---
Boron (B)	0.75	0.75	5.0
Cadmium (Cd)	0.01	0.01	0.05
Chloride (Cl)	250.0	100.0	2000.0
Chromium (Cr)	0.05	0.1	0.05
Cobalt (Co)	---	0.05	1.0
Copper (Cu)	1.0	0.2	0.5
Cyanide (CN)	0.2	---	---
Fluoride (F)	1.4-2.4[7]	---	---
Hydrogen Sulfide ($H_2$5)	0.05	---	---
Iron (Fe)	0.3	5.0	---
Lead (Pb)	0.05	5.0	0.1
Lithium (Li)	---	2.5	---
Manganese (Mn)	0.05	0.2	
Mercury (Hg)	0.002	---	0.00005
Nickel (Ni)	---	0.2	---
Nitrate (NO_3-N)	10.0	---	---
Nitrite (NO_2-N)	1.0	---	10.0
(NO_3+NO_2)-N	---	---	100.0
Oil & Grease	Virtually Free	10.0	10.0
Phenol	0.001	---	---
Selenium (Se)	0.01	0.02	0.05
Silver (Ag)	0.05	---	---
Sulfate (SO_4)	250.0	200.0	3000.0
Total Dissolved Solids (TDS)	500.0	2000.0	5000.0
Uranium (U)	5.0	5.0	5.0
Vanadium (V)	---	0.1	0.1
Zinc (Zn)	5.0	2.0	25.0
pH	6.5-9.0s.u.	4.5-9.0s.u.	6.5-8.5s.u
SAR	---	8	---
RSC	---	1.25 meq/l	---
Combined Total Radium 226 and Radium 228[9]	5pCi/l	5pCi/l	5pCi/l
Total Strontium 90	8pCi/l	8pCi/l	8pCi/l
Gross alpha particle radioactivity (including Radium 226 but excluding Radon and Uranium)[9]	15pCi/l	15pCi/l	15pCi/l

*mg/l, unless other wise indicated

This is reprinted from Table 1, Chapter VIII, Wyoming Water Quality Rules And Regulations, March 1993.


PIT FOUR
PIT FIVE
DIVERSIFIED RESOURCES, LLC
ACME
BIG HORN COAL PERMIT BOUNDARY
POTENTIOMETRIC SURFACE IN MINE BACKFILL AND ADJACENT MONARCH COAL OBSERVED OCTOBER 2001 IN FEET MSL. DASHED LINES WHERE INFERRED.
APPROXIMATE WATER TABLE SURFACE CONTOUR IN ALLUVIUM OF TONGUE RIVER OBSERVED OCTOBER 2001, FEET MSL.
TONGUE RIVER AND GOOSE CREEK ALLUVIUM
RECLAIMED BACKFILLED SPOILS
MONTANA
WYOMING
LOCATION MAP
Scale: 1" = 1000'
Big Horn Coal Company
PO Box 724, Sheridan, Wyoming 82801
Year 2001 Groundwater Monitoring Network with Potentiometric Surface in Mine Backfill, Alluvium and Adjacent Monarch Coal Observed October 2001
ATC
12/2001
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