PSC-11

2.3 – GROUNDWATER HYDROLOGY

A. REGIONAL HYDROLOGY

The following narrative, synthesized mainly from Croft (1970), describes the hydrostratigraphy and hydrologic properties of the major water bearing units which represent potential replacement sources for water supplies which are adversely impacted by mining. A brief description of the geology of these units is contained in Section 2.1.A.

Upper Hell Creek and Lower Cannonball-Ludlow Aquifer

Fine to medium grained sandstones in the upper part of the Hell Creek and lower part of the Cannonball-Ludlow Formations form a regional aquifer in the Mercer County area. This aquifer underlies the permit area at a depth of about 800 feet. Transmissivity values on the order of $2.6(10^{-5})\ m^2 \cdot s^{-1}$ to $6(10^{-4})\ m^2 \cdot s^{-1}$ have been calculated for this aquifer, and wells tapping this unit should produce from 5 to 100 gpm. Chemically the water in this aquifer is very similar to that in the Fox Hills-Basal Hell Creek aquifer which lies beneath.

Fox Hills-Basal Hell Creek Aquifer

Sandstone units in the Upper Fox Hills and Basal Hell Creek Formations form an extensive regional aquifer which underlies the permit area at depths ranging from 1000 to 1300 feet. These fine to medium grained sandstones are interbedded with siltstones and claystones and the total aquifer thickness varies from about 150 to 350 feet (Croft, 1970).

Based on a series of recovery tests, a hydraulic conductivity ranging from $5.0(10^{-7})\ m \cdot s^{-1}$ to $5.6(10^{-5})\ m \cdot s^{-1}$ and averaging $7.4(10^{-6})\ m \cdot s^{-1}$ was calculated. Specific capacities for these wells average 0.3 gpm/foot, and the storage coefficient ranged from 0.0001 to 0.00001.

Water quality in the Fox Hills-Basal Hell Creek aquifer is a sodium bicarbonate type with ~~a~~ TDS range between 1200 and 2000 mg/l.

Lower Bullion Creek Aquifer

The last major regional aquifer of interest with respect to this permit is the Lower Bullion Creek aquifer. The areal extent of the Lower Bullion Creek aquifer zone is much more limited than that of the other major aquifers, being restricted largely to the Knife River Basin and adjacent areas to the north and south.

The lower part of the Bullion Creek Formation consists of numerous discontinuous sand units rather than a single widespread unit. The total composite thickness varies from 0-200 feet and includes sand units within the Hanson, Harmon, and Weller Slough intervals. This composite sand unit is referred to as an “aquifer zone” rather than as a distinct aquifer.

There is a very limited amount of data on the hydraulic properties of the Lower Bullion Creek aquifer zone within the Knife River basin. Several cores were analyzed from Dunn County and these cores showed an average hydraulic conductivity of $4.0(10^{-7})\ m^2 \cdot s^{-1}$. Water production from this zone seldom exceeds 10 gallons per minute.

The potentiometric levels in aquifers in the Sentinel Butte Formation are generally higher than those in the Lower Bullion Creek aquifer zone. The potentiometric levels in the Upper Hell Creek and Lower Cannonball-Ludlow aquifer are also generally higher than those in the Lower Bullion Creek aquifer zone. It is evident, therefore, that water flows downward into the Lower Bullion Creek from overlying aquifers and upward into it from underlying aquifers and that the Lower Bullion Creek aquifer zone functions as a regional groundwater sink.

B. HYDROGEOLOGY OF THE GENERAL, ADJACENT AND PERMIT AREA

1. Introduction

Hydrologic instrumentation of the permit and general area was initiated in 1979 in conjunction with the exploration program which provided much of the information presented in the geology section of this permit application. Monitoring wells in the 900 and 1000 series were installed at that time along with a water quality monitoring program for selected wells. Succeeding these initial well installations, the following is a summary of wells drilled since then.

Wells	Year drilled
1100 series	1981
1300 series	1982, 1984
1400 series	1985
1500 series	1986, 1987, 1994 (1537-R replacement well)
1700 series	1989, 1990, 1995
1800 series	1997, 1998, 2001
2001-2004	2004 - added to begin monitoring Section 15-T143N-R88W
*2005-2014	2005 - added to monitor area added to Permit 8603 Rev. No. 19
2015-2019	2005 - installed for additional monitoring for Permit 8802
2020-2028	2008 - added to monitor area added to Permit 8603 Rev. No. 22
2029	2008 - added to monitor ground water in reclaimed land
2030-2035	2012 - added to monitor area added to Permit 8603 Rev. No. 27
2036-2037	2012 - added to monitor ground water in & under reclaimed land
2038-2042	2015 - added to monitor area to be added to Permit 8603 Rev.31

*Well 2008 was installed on October 6, 2005 by Interstate Drilling Services, LLP from Thompson, ND. Their drilling log shows the well drilled to a depth of 69 feet with the lignite seam being screened at 65-68 feet. Given those elevations, DWC determined that the lignite was the Spaer bed. However, at the onset of static water level (SWL) readings, it became apparent that the drilling log had to be incorrect. SWL readings were averaging 25 feet lower than the shown well depth. After numerous unsuccessful attempts to have Interstate Drilling research their data and correct their log, DWC hired Mohl Drilling of Beulah, ND to drill an adjacent well to resolve this matter. Mohl installed this well (2008-R) on April 5, 2012 and found the Spaer lignite seam to be at 90-92 feet. Thus well 2008-R will now be considered a Spaer aquifer well and the original well 2008 to be in the Hazen B lignite bed.

Well 2029 was installed on October 29, 2008 to monitor the SWL and water quality on reclaimed land in Permit 8603. It was drilled at the site of pre-mining well 1373 in the SE¼SW¼ of Section 16-143-88.

Wells 2030-2035 were drilled in April, 2012 to monitor the area added with Revision No. 27. Wells 2030 and 2031 are a two well cluster in the SW¼ of section 20; wells 2032-2035 are a four well cluster in the SW¼ of section 27.

Wells 2036 and 2037 are a two well cluster in the SE¼ of section 17. Well 2037 was drilled in the vicinity of mined-through Beulah-Zap well 959 to monitor reestablishment of ground water in that location and elevation. Well 2036 was installed in the Spaer lignite bed aquifer at that same location. Static water level readings and water quality sampling for wells 2030-2037 began during the 2nd and 3rd quarters of 2012.

Five new wells, 2038-2042, were installed by Mohl Drilling, Inc. on October 13 & 14, 2015 in the S½ Sec.29-143-88 (Lyle Winkler ownership) to monitor ground water in the area added with Revision 31. 2038-2040 is a 3-well cluster located in the SE¼ and wells 2041-2042 in the SW¼. Static water level readings and quality samples were began in the 4th quarter of 2015.

The locations of all monitoring wells are shown on Exhibit 2.3.1, Groundwater Monitoring Sites. All of the wells shown in yellow on this exhibit have been mined through, destroyed, or abandoned due to casing or grout failure.

The geophysical logs, drilling logs and original completion reports for these wells are included in Exhibits 2.1.1 and Exhibit 2.1.2. Well completion summaries are presented in this section as Exhibit 2.3.2.

Exhibit 2.3.5 is a spreadsheet presenting historic static water levels of all ground water monitoring wells since the commencement of the Beulah Mine's ground water monitoring program. It displays quarterly and lifetime average SWL readings for each well.

The hydrostratigraphy of those units which will be disturbed or otherwise potentially impacted by mining is defined by the geology of the lignite intervals as described in Section 2.1. In the permit and general areas, the fractured lignite beds are the most permeable near-surface units, sometimes providing water for domestic uses or livestock watering while the interlayered sediments function as aquitards.

In general terms the permit area could be considered a recharge area as indicated by the falling potentiometric head with depth at the paired or nested piezometer locations. How much actual groundwater recharge (net addition of water to the zone of saturation) is actually occurring within the permit area is difficult to quantify; however, previous studies of groundwater recharge in western North Dakota have found that recharge is both spatially and temporally variable (Rehm et. al., 1980). The higher potentiometric levels to the south and west and the fact that the Beulah-Zap bed is unsaturated near the center of Section 16, suggest that groundwater recharge may be greater in the adjacent area than within the permit area itself.

Recharge to the Schoolhouse Bed is by vertical infiltration during exceptional precipitation or snowmelt events; the Schoolhouse Bed discharges where it outcrops to form springs or sloughs and by slow vertical flow to the underlying sediments. The Beulah-Zap and Spaer Beds are recharged by direct infiltration and leakage from overlying saturated sediments. Within the permit area, the Beulah-Zap Bed discharges as spring flow and by vertical infiltration to sediment layers below. Due to its greater depth, no springs associated with the Spaer Bed have been observed in the general area; with the exception of spring 17ABB-W/SP (located ½ mile north of the permit boundary). Typically discharge from this bed is by slow leakage to the underlying sediments.

A series of single-well drawdown tests were used to define the hydraulic conductivities of the Schoolhouse, Beulah-Zap, and Spaer lignite beds. The results of these tests are discussed below for the individual beds.

No site specific testing was conducted to determine storativity or specific yield values within the permit area. Previous pump testing and computer modeling suggest that storativities of about 0.0005 to 0.00001 and specific yields of about 0.01 to 0.07 are reasonable for the lignite aquifers of the upper Great Plains (Rehm et. al., 1980).

2. Twin Buttes Bed

The Twin Buttes bed overlies the Schoolhouse bed south and up gradient of the current permit area. Geologically, the bed is located between 50 and 110 feet above the Schoolhouse lignite. (C.G. Carlson, 1973). Pockets of Twin Buttes lignite will be encountered in the area added to this permit in Revision No. 27 (SE¼, Sec. 21 and SW¼, Sec. 22) but are not in the current mine plan. [The drilling log for drill hole No. 21-08 shown in Exhibit 2.1.2 shows 8 feet of Twin Buttes coal.] Well 2035 was added in 2012 to monitor the Twin Buttes lignite bed that was found to be present in the SW¼ of Section 27-143-88.

3. Schoolhouse Bed

The Schoolhouse bed overlies the Beulah-Zap bed throughout most portions of the permit area, most specifically in the east halves of SE¼ of Section 16 and NE¼ of Section 21. It reaches a maximum depth of 110 feet below land surface (bls) at monitoring well 2034 ½ mile south of the permit area, and subcrops near the surface to form the slough in the SW¼ of the NW¼ of Section 21 (Weil Slough). This slough has not been mined through but has been replaced with Pond 87. Its outcrop is represented by springs in the area of the valley fill, as shown on Exhibit 3.6.4. Generally, the Schoolhouse bed ranges from about 20 to 50 feet bls in depth.

Due to its high permeability relative to the underlying sediments of the Beulah-Zap interval, the Schoolhouse bed is typically partially saturated, forming a perched water table. It is likely that this perched water table merges with the true water table (potentiometric surface) somewhere in the southeastern corner of the permit area where the Schoolhouse bed is found at greater depth; however, there is not sufficient instrumentation in place to substantiate this.

Table 2.3.1 displays the Permit 8603 Schoolhouse monitoring wells and their average static water levels.

Table 2.3.1

Schoolhouse Wells Static Water Level (SWL) Averages

Well	Avg. SWL (feet above Sea Level)
1372	1978.59
1394	2008.66
1395	1991.31
1444	2007.12
1447	2011.50
1448	2010.07
2002	1956.19
2022	2020.59
2025	2013.40
2028	2024.47
2034	2049.32
2040	2023.77

Exhibit 2.3.3 is a potentiometric map generated from these static water levels. Well 2034 shows the highest potentiometric levels begin south of the permit area in Sections 27 and 28, then decrease northward across Sections 21 and 22, eventually reaching its lowest elevations in Sections 15 (dry Well 2002) and 16 (Well 1372).

Water quality within the Schoolhouse bed, as illustrated by samples taken from wells 1394, 1444, 1447, 1448, 2002, 2022, 2025, 2028, 2034, and 2040 varies greatly, even for sampling locations in relatively close proximity of each other. Exhibit 2.3.6 (Ground Water Quality Data) displays quality parameters of the wells selected for WBM's ground water quality monitoring program. The bottom row of each well shows the lifetime averages of parameters. The exhibit shows that the total dissolved solids values for this group range from an average of 664 mg/l at well 1444 to 8,317 mg/l at well 2022. It is likely that the samples from 1448 and 1394, while they were in existence prior to mining, were influenced by interaction with evaporation-affected water from the nearby slough. The high TDS in well 2022 could be explained by the well being near the outcrop of the Schoolhouse bed and thus being affected by adjacent non-lignite material. The remaining wells are probably most representative of the quality of water in the Schoolhouse bed. Wells 1444, 1447, 2025, 2028, and 2034 have TDS's in the range of 664 –

2,814 mg/l and all except 1447 consist of a sodium bicarbonate sulfate type water with average SARs in the 10–30 range. (Well 1447 is calcium bicarbonate type with an average SAR of 40.3).

Hydraulic conductivity and transmissivity values for three piezometers in the Schoolhouse bed show two orders of magnitude difference, ranging from 3.1(10^{-5}) to 2.6(10^{-7}) ($m \cdot s^{-1}$) and 2.4 (10^{-5}) to 3.2 (10^{-7})($m^2 \cdot s^{-1}$), respectively.

4. Beulah-Zap Bed

Hydrologically, the Beulah-Zap bed shows considerably more variation than the Schoolhouse. It occurs within the permit area as a confined aquifer, a partially saturated water table aquifer, and in a dry condition. Table 2.3.2 lists all the Permit 8603 Beulah-Zap wells that have been installed to monitor the B-Z aquifer and their lifetime average static water levels (obtained from Exhibit 2.3.5).

Table 2.3.2

Beulah-Zap Wells Static Water Level (SWL) Averages

Well	Avg. SWL (feet above Sea Level)
952	1933.52
955	1954.58
959	2001.90
966	1932.29
1078	1932.99
1358	1959.94
1359	1955.77
1360	1956.44
1371	1933.16
1373	1938.60
1441	1939.00
1443	1978.33
1445	1929.69
1446	1948.68
1528	1949.45
1732	1958.97
2001	1920.19
2004	1934.22
2005	1959.99
2006	1958.25
2007	1955.52
2009	1961.57

2010	1960.37
2011	1950.11
2013	1938.43
2021	1954.33
2024	1954.42
2027	1950.90
2030	1938.60
2033	1951.50
2039	1948.56
2042	1941.40

Exhibit 2.3.4 displays the potentiometric contours derived from the SWL's. While caution should be exercised when interpreting flow directions due to such factors as head loss and changes from confined to unconfined conditions (i.e. well 959), the following conclusions can be drawn from this exhibit : 1) The highest contour of +1960' exists in the SW¼ of Section 17 and N½ of Section 20 (Silver Pit area). This dome of high contours flows in all directions – south and southwestward towards tributaries of Coyote Creek, eastward towards tributaries of Brush Creek, and northward towards direct tributaries of the Knife River. 2) The flow outside and along the southern perimeter of the permit area in the south halves of Sections 21 and 22 travels north/northeastward across the NE¼ of Section 21 and N½ of Section 20 towards a tributary of Brush Creek in the S½ of Section 15 and SE¼ of Section 16. 3) The flow outside and along the southern perimeter of the permit area in the S½ of Section 20 and N½ of Section 29 travels west/northwestward toward tributaries of Coyote Creek.

Transmissivities and hydraulic conductivities for the Beulah-Zap bed were calculated based on bailer tests conducted at wells 1358, 1360 and 1443. These values show a variation of four orders of magnitude, suggesting that the calculated transmissivity and hydraulic conductivity values are largely a function of the degree of fracturing at the particular location. At these locations hydraulic conductivity values ranged from a high of $2.9(10^{-5})$ $m \cdot s^{-1}$ to a low of $3.0(10^{-9})$ $m \cdot s^{-1}$. Previous work (Rehm, et al., 1980) suggests that hydraulic conductivity values on the order of $3(10^{-6})$ $m \cdot s^{-1}$ to $3(10^{-7})$ $m \cdot s^{-1}$ are typical of North Dakota lignite. (See Table 2.3.2)

Chemically, the waters in the Beulah-Zap bed in the general area display both similarities and differences.

Twenty-one past and present wells have been/are used to monitor B-Z ground water quality. The following table (Table 2.3.3) displays the lifetime averages of the parameters pH, Total Dissolved Solids, Sodium Adsorption Ratio, and water type of these 16 wells. The averages were obtained from Exhibit 2.3.6.

Table 2.3.3

Beulah-Zap Wells Water Quality Averages

Well	Temp.	pH	TDS	SAR	Water Type
952*	10.9	7.4	1806	43.8	Sodium sulfate
959	10.7	6.8	6338	4.4	Sodium sulfate
966	10.0	6.7	1930	15.3	Sodium sulfate
1078*	11.7	7.4	1652	23.8	Sodium bicarbonate
1358	10.3	7.7	2772	40.1	Sodium bicarbonate
1359	9.7	6.7	3304	11.4	Sodium sulfate
1360	10.0	6.7	4643	9.3	Sodium sulfate
1441	10.4	8.3	1316	44.6	Sodium bicarbonate
1443	8.8	12.1	2296	26.4	Sodium carbonate
1445	10.6	8.1	1784	40.3	Sodium bicarbonate
1732	9.5	7.9	2038	52.3	Sodium bicarbonate
2001*	13.8	6.9	862	5.7	Sodium bicarbonate
2004	Insufficient Quantity				
2013	Dry				
2021	11.2	7.5	2121	10.4	Sodium bicarbonate
2024	9.6	8.1	2010	42.6	Sodium bicarbonate
2027	9.0	8.1	1723	42.3	Sodium bicarbonate
2030	10.3	6.7	1940	1.3	Calcium sulfate
2033	9.6	8.0	1273	38.8	Sodium bicarbonate
2039	9.9	8.0	1450	20.2	Sodium bicarbonate
2042	10.7	6.7	1250	3.3	Sodium bicarbonate

*denotes one sample

One of the most consistent parameters is pH, which ranges from 6.7 to 8.3. Well 1443 was abandoned in 1989 due to well grout failure. This grout failure is a possible cause of the high 5-year lifetime average of 12.1 (possible leaching of shallower groundwater, perhaps even surface water via voids around the well casing). Temperature is relatively consistent, around 8-12ºC. Total dissolved solids are one of the more variable qualities, ranging from around 1,300 to

6,300 mg/l. However, the present active wells have average TDS values between 1,297 and 2,121 mg/l.

Sodium is the dominant cation in the Beulah-Zap waters, usually exceeding the combined concentrations of calcium and magnesium by an order of magnitude; sodium concentrations from 500 to 1000 mg/l are common. Sulfate and bicarbonate are the predominant anions having a combined concentration of approximately 2000 mg/l.

5. Spaer Bed

The Spaer lignite occurs throughout the permit area at a depth of between 20 and 40 feet below the base of the Beulah-Zap lignite. The interval, or aquatard, separating the Beulah-Zap and Spaer lignite consists of relatively tight silty clay with a permeability ranging between 10^{-8} and 10^{-9} cm/sec. Similar stratigraphy occurs east of the permit area in permit KRSB-8802.

Table 2.3.4 records all Permit 8603 Spaer wells and their lifetime average static water levels (obtained from Exhibit 2.3.5).

Table 2.3.4

Spaer Wells Static Water Level (SWL) Averages

Well	Avg. SWL (feet above Sea Level)
1440	1927.16
1442	1931.54
1526	1919.79
1527	1936.20
1731	1939.77
2003	1917.47
2008-R	1919.41
2012	1936.76
2014	1922.22
2020	1938.34
2023	1947.06
2026	1938.7
2031	1926.11
2032	1946.62
2036	1937.59
2038	1941.26
2041	1941.40

Wells 2020, 2023, and 2026 were installed in the year 2008; 2008-R, 2031, 2032, and 2036 in the year 2012; 2038 and 2041 in the year 2015 to further define the hydrologic properties of the Spaer. (Well 2008-R was drilled adjacent to well 2008 when it was discovered 2008's drilling log showed an erroneous depth. DWC has made the determination that given its actual depth, well 2008 is screening the Hazen B lignite seam.) Exhibit 2.3.10 is a potentiometric map of the Spaer which shows highest contours south of the permit in Sections 27 and 28 with a strip extending north into the E½ of Section 20 and W½ of Section 21. From there it declines in both westerly and easterly directions. The data essentially shows flow moving west and northwest towards Coyote Creek and east towards Brush Creek.

The Spaer lignite averages approximately three feet in thickness. It is not used as a water supply in this area. The source of recharge to the Spaer and all other water bearing strata within the area occurs to the south of the permit area. The Spaer is confined in the southern extension of the permit area as demonstrated in wells 2012, 2020, 2023, 2036, and 2031. To the north, the Spaer transitions to an unconfined or dry condition, as demonstrated by well 1527. North of the permit area, the Spaer outcrops, and should discharge in valleys located north (Sections 17 and 18) of the permit area. For the exception of Spring 17ABB-W/SP, there is no evidence of spring flow from this system within the tributaries located north of the permit area.

Possible impacts to the Spaer system would be infiltration of spoil water through the clay interburden, or aquatard, which could contribute water of the quality described in the PHC to the Spaer. The clay interburden may attenuate these impacts. Possible impacts would be limited in extent since the Spaer outcrops immediately north of the permit area.

The Spaer has been monitored and will continue to be monitored because it represents a logical stratigraphic location for potential groundwater impacts from mining. Water levels have remained relatively constant over time.

As mentioned in previous paragraphs, DWC has installed nine new wells beginning in the year 2008 to supplement monitoring of the Spaer aquifer. Water quality analyses from these and older wells show they are chemically similar, though of somewhat better quality than the overlying Beulah-Zap bed. Lifetime average TDS values vary from a low of 904 mg/l at well 1731 to a high of 3,500 mg/l at well 2003 (only one sample before being mined through). All but five of the sixteen Spaer wells which have been sampled are a sodium bicarbonate type. Wells 2003 (one sample only), 2014, 2020, and 2041 are sodium sulfate. Well 1527 is a sole calcium bicarbonate type.

Should groundwater quality or quantity within the Spaer show a significant change over time, additional monitoring wells will be installed downgradient or within the northern portions of the permit area.

Table 2.3.5
Hydrologic Properties of the Schoolhouse,
Beulah-Zap and Spaer Lignite Beds

Piezometer Number	Transmissivity ($m^2 \cdot s^{-1}$)	Hydraulic Conductivity ($m^2 \cdot s^{-1}$)	Stratigraphic Unit
1444	3.2×10^{-7}	2.6×10^{-7}	Schoolhouse
1447	2.4×10^{-5}	3.1×10^{-5}	Schoolhouse
1448	1.5×10^{-6}	1.1×10^{-6}	Schoolhouse
1358	9.1×10^{-9}	3.0×10^{-9}	Beulah-Zap
1360	2.7×10^{-5}	2.9×10^{-5}	Beulah-Zap
1443	1.0×10^{-8}	3.0×10^{-9}	Beulah-Zap
1440	8.6×10^{-7}	8.1×10^{-7}	Spaer
1442	3.2×10^{-8}	3.5×10^{-8}	Spaer

6. "Hazen B" Bed

The "Hazen B" lignite occurs throughout the permit area at a depth of between 80 and 150 feet below the Spaer lignite within the Sentinel Butte formation (Carlson, 1973). Very little is known of this coal seam because of its depth from surface. Wells 953, 1514, and 1515 intersected this coal seam prior to them being mined through. Well 2008, installed in the year 2005 is the remaining active well monitoring this coal seam. Wells 957 and 951 extended to the sands above this coal seam before they also were mined through.

The Hazen B wells have been monitored and well 2008 will continue to be monitored to assess potential groundwater impacts from mining. The static water levels for wells 953, 1514, and 1515 dropped 2.5', 4.09', and 3.55' respectively over their lifetimes. These changes are based on the relationship between precipitation and infiltration from the Spaer bed.

No water quality samples have been collected from the wells within Hazen B aquifer. WBM feels that mining activities do not impact this aquifer.

7. Reclaimed Land Saturated Zones

The first monitoring well located on reclaimed land in Permit 8603, Well 2029, was installed on October 29, 2008. It is located in the SW¼SW¼, Section 16, and was drilled at the exact location of pre-mining well 1373. Well 1373 monitored the groundwater within the Beulah-Zap bed, screened at an elevation of 1948.6-1938.6 feet. It was a dry well during its entire course. Spoil well 2029 now screens the spoil at the same elevation. Data from well 2029 started being collected during the second quarter of 2009. Exhibit 2.3.5 shows the same basically dry condition with an average SWL of 1938.9', 0.3' off the well bottom.

On April 5, 2012, well 2037 was installed as a second well to study ground water recharge in mined land. It is located in the SW¼SE¼, Section 17, and screens the interval where the B-Z coal existed at that location. (The locations of Saturated Zones well 2037 and 2029 are depicted on Exhibit 2.3.4 to demonstrate that their average static water levels align with the pre-mining contours at their respective sites.) On the same date, well 2036 was drilled ten feet west of 2037 to monitor the next lowest significant aquifer in that location, the Spaer aquifer,

Well 2029 has not had enough recharge since installation to collect samples for water quality sampling. Well 2037 began having enough recharge ground water to sample two years after installation. Samples were collected in the years 2014 and 2015 and analyses show the water to be very mineralized with it to be a sodium sulfate water type.

Where appropriate, a nest or cluster of two wells will be installed. One well screened in the base of the spoils and one well screened in the next lowest significant aquifer, on future spoil and post-mining well locations.

C. KNOWN USES OF GROUNDWATER

Several local domestic and stock watering wells and spring sources are located within the permit and adjacent areas. Their locations are shown on Exhibit 2.3.7. Table 2.3.6 summarizes their uses, intake depths and probable sources.

Table 2.3.6

Known Uses of Groundwater

Well Identification	Use	Intake Depth	Probable Source	Well/Spring Cert. Date
Fetch Well No. 1	Stock watering[1]	98-115	Beulah-Zap Coal	9-30-05
Fetch Well No. 2	Domestic supply[1]	35	Schoolhouse Coal	5-24-91
Fetch Well No. 3	Domestic supply[1]	45	Schoolhouse Coal	9-30-05
Fetch Seep	Stock Watering	Natural	?	No cert.
Fetch Pond	Stock Watering	Developed	Schoolhouse Coal	No cert.
WBM* Well No.1	Domestic supply[1]	18	Beulah-Zap Sand	9-30-05
WBM * Well No.2	Domestic supply[1]	65	Beulah-Zap Coal	9-30-05
WBM * Spring No. 1	Stock watering	Developed	Beulah-Zap Sand	9-30-05
WBM * Spring No. 2	Stock watering	Developed	Beulah-Zap Sand	9-30-05
WBM * Spring No. 3	Stock watering	Developed	Beulah-Zap Sand	9-30-05
Unruh No. 1	Domestic supply[1]	30	Twin-Buttes Coal	10-2-85
Unruh No. 2	Stock Watering	40	Twin-Buttes Coal	10-17-05
Unruh No. 3	Stock Watering	46	Twin-Buttes Coal	10-17-05
Unruh No. 4	Stock Watering	30	Twin-Buttes Coal	10-17-05
Reich/Unruh	Domestic supply	1450	Fox Hills Fm.	10-17-05
Reich No. 2	Stock Watering	37	Twin-Buttes Coal	10-17-05
S. Winkler (Weil) No. 1	Stock/Domestic[1]	382	Bullion Creek Fm.	9-30-05
S. Winkler (Weil) No. 2	Stock/Domestic[1]	50	Beulah-Zap Coal	9-30-05
Welk	Domestic Supply	70	Beulah-Zap Coal	9-26-05
Endreson	Domestic Supply	120	Beulah-Zap Coal	9-26-05
M. Gunsch Spring	Stock watering	Developed	Schoolhouse Coal	9-27-05

R. Gunsch Spring No. 1	Stock watering	Natural	Schoolhouse Coal	9-27-05
R. Gunsch Spring No. 2	Stock watering	Developed	Beulah-Zap Coal	9-27-05
R. Gunsch Well No. 1	Stock watering	71	Beulah-Zap Coal	9-27-05
R. Gunsch Well No. 2	Irrigation	86	Beulah-Zap Sand	9-27-05
Reich	Stock/Domestic	62	?	9-30-05
Erickson Well No. 7	Stock Watering	272	Bullion Creek Fm.	10-17-05
Erickson Spring No. 3	Stock watering	Natural	?	10-17-05
L. Winkler Spring No. 1	Stock Watering	Natural	?	9-26-05
L. Winkler Spring No. 2	Stock Watering	Natural	?	9-26-05
Voigt Spring No. 1	Stock Watering	Developed	?	9-30-05
Voigt Spring No. 2	Stock Watering	Natural	?	9-30-05
17ABB-W/SP	Stock Watering	Developed	?	No cert.
17DAC-W/SP	No Flow	Natural	?	No cert.
Schmidt Seep No. 1	Stock Watering	Developed	?	No cert.
Schmidt Seep No. 2	Stock Watering	Natural	?	No cert.
Schmidt et al Seep	Stock Watering	Developed	?	No cert.

* WBM – Westmoreland Beulah Mining LLC
[1]Presently unused

A discussion of the Gunsch spring located in the SE¼ of Section 16 can be found in Section D-2. Probable Hydrologic Consequences, Impacts to Known Sources. Further information regarding the Gunsch spring and valley fill may be found in Section 3.6 Backfilling and Grading – Special Considerations. Section 3.6-D contains a discussion regarding groundwater management within the valley fill area.

The following discussion relates to wells and springs in and adjacent to the revision area. In October 1985, Water Supply, Inc certified and sampled these water sources to determine the quality and quantity of water available at that time.

Water Supply, Inc. re-certified the sites listed in Table 2.3.3 in the fall of 2005. The results of this certification program are presented in Exhibit 2.3.8. Most of these wells and springs are shallow and low yielding (<5 gpm) sources which tap either the Beulah-Zap or Schoolhouse coal beds.

In general these wells provide water which is of satisfactory quality for its intended purpose and although most of it is not desirable as a domestic source, it is typical of the waters often utilized in western and central North Dakota. The following is a synopsis of the water supplies listed in Table 2.3.3. These sites may be found on Exhibit 2.3.7 – Water Supply Locations.

Fetch Farmstead

Fetch well No. 1 is located inside a corral and has high nitrate content. Fetch well No. 2 was the sole source for the abandoned farmstead. It was classified by the State Health Department as usable, but not desirable for a domestic supply. Well No. 2 is located inside the pump house as shown on the certification photo. The well was drilled in 1935 and is screened in the Schoolhouse, its use was discontinued some time prior to 1991. Fetch well No. 3 was drilled in 1985 and is screened within the Schoolhouse. Use of the well was discontinued prior to 1991.

The Fetch Pond was a dugout excavated into the Schoolhouse within a small coulee. It is a saline slough used for stock watering. The area where the dugout is located has not been disturbed by mining. Fetch well No. 1 is located hydraulically up-gradient of the Red pits, but slightly downgradient from the middle of the Silver Pit (See Exhibit 2.3.4). Although mining impacts are expected to the minimal for Fetch Well No. 1, some flow from the Silver pit might be reduced. The Fetch Well No.1 has not been used since prior to mining activities west of Highway 49 because of poor quality water for livestock; specifically, the well has a high nitrate (36.1 mg/L), sulfate (1,280 mg/L), and total dissolved solids (2,550 mg/L) concentration as sampled in 1991. Mining impacts to Fetch Well No. 1 are negligible in that the water has no use based on its baseline quality.

Fetch Wells No. 2 and No. 3 are located in the northern part of the Revision 27 addition and are not anticipated to be affected by mining. Because of poor water quality in both Fetch Wells No. 2 and No. 3, the wells are currently abandoned.

Westmoreland Beulah Mining LLC (WBM) Farmstead

WBM well No. 1 was the sole domestic source for the pre-mining house which was rented out by the former owner, Pleasant Valley Farming Co. This water ~~is~~ was not considered potable and drinking water was hauled from Beulah. WBM wells No. 1 and No. 2 were removed as mining progresse~~s~~d through the area. Because the house was removed (and will not be replaced post-mining), and because the current landowner has no need for water replacement, no plans are in place to replace either of the wells.

WBM spring numbers 1, 2 and 3 were piped into adjacent stock water tanks prior to mining. Mining has proceeded through the NW¼ of Section 21 and N½ of Section 20 (T.143N, R.88W) north~~east~~ of the two wells and three spring sites. The local groundwater gradient for both the Beulah-Zap and Schoolhouse in this area is from the west and north moving to the south. See Exhibits 2.3.3 and Exhibit 2.3.4. All three springs were certified in 1986 and recertified in the fall of 2005 (Exhibit 2.3.8). WBM's final "Silver" pit located immediately north of the springs was excavated inn 2014. Because the springs originate from the Beulah-Zap sand, impacts to the springs should be limited to the time in which the pit does remain ~~an~~ open. pit is unfilled north of their location. Once the final pit has been reclaimed, the springs should re-establish in the vicinity of their original location based on the post-mine topography. These springs are different than other springs impacted because of mining due to the fact that their source is not coal that is being removed. Likewise, the impacts will be minimal simply because the stock pond located downstream (surface fed) is the major source of water for livestock in the area. The downstream stock pond will not be impacted by mining.

Reich/Unruh Farmsteads [formerly Altavilla/Unruh (Erdman/Neuberger)]

Reich/Unruh well is a deep (Fox Hills), high yield well which provides domestic water for two residences which share this farmstead site. The Unruh well No. 1 is suitable but not a desirable domestic source. This well is not presently utilized.

The Reich/Unruh domestic well is screened within the Fox Hills, far too deep to be affected by mining. The Fox Hills represents the best of several possible replacement sources for any shallower wells impacted by mining.

There are several shallow wells located at both the Reich/Unruh farmsteads, which are used for purposes other than household use. The wells are shallow with depths ranging from 30 to 50 feet. All are screened within the Twin Buttes lignite.

The Twin Buttes bed outcrops in drainage divides in the western part of the county. It reaches a maximum thickness of about 5 feet in T. 143 N. R. 90 W., and in scattered localities north and south of that area (R. A. Brant, 1953). Geologically, the bed is located between 130 and 150 feet above the Beulah Zap lignite. (C.G. Carlson, 1973)

The Twin Buttes lignite is not present within the proposed permit area. The Bed is located up gradient and isolated from mining activities. No adverse effects to the aquifer system from mining are possible.

Weil Farmstead (Sharon Winkler)

Weil well No. 1 is a potential wintertime livestock watering source. The well has a total depth of 382 feet. Well No. 2 is likely screened within the Beulah-Zap lignite. The Weil farmstead is presently not occupied and has not been occupied for nearly twenty years. Pond 87 is located where the Weil slough was located, which was not disturbed by mining. The pond is currently recharged by the Schoolhouse and is a reliable source for livestock watering. Since the wells were last certified there has not been and will not be coal taken from the immediate area of either wells. Since all of the Weil sites are located up-gradient of mining, no impacts have been observed or are anticipated.

Welk Farmstead

The Welk well is located approximately 3/5 of a mile S of the permit area. The well is screened within the Beulah-Zap coal and is used as a domestic source. No impacts are anticipated due to its location.

Roger Endreson

The Endreson well is located SW of the Welk farmstead. The well is screened within the Beulah-Zap coal and is used as a domestic source. No impacts are anticipated due to its location.

Martha Gunsch Spring

This spring was located in the NW¼ of Section 22 south of the permit within a minor tributary to Brush Creek. It was mined through as part of the Gold Pit series in 2012. It consists of a concrete spring box piped to a water tank. It appeared to be screened in the Schoolhouse lignite. The spring was not functioning and was in need of repair prior to mining. WBM will replace this pre-mining water source with a well in the near vicinity. The spring was mined through in 2011.

R. Gunsch Springs 1 & 2

Spring No. 1 consists of an undeveloped spring feeding a dug-out stock pond located in the SW¼ of Section 28, or approximately 3/5 of a mile south of the Permit area. At the time of certification, no free flowing water was observed but the down stream pond was holding water. Impacts to this site are not anticipated due to its location. Spring No. 2 is a developed spring discharging to a minor tributary to Brush Creek. The spring is in good condition with a discharge rate of 1.4 gpm at the time of inspection. This site it is located approximately 3/5 of a mile SW of where mining is scheduled to occur between 2008 through 2016 (See Exhibit 3.1.1). Since Spring No.2 is located down-gradient of mining, it is possible this site may be impacted by mining. Alternate groundwater sources are available as a replacement source, if needed.

Gunsch Wells 1 & 2

Well No. 1 is located in the NW¼ of the SW¼, Section 18 approximately 3,800 feet from the western boundary of mining. It is screened within BZ lignite with a total depth of 71 feet. The well produced approximately 15 gpm at the time of certification. Well No. 1 may be impacted by mining; however, due to its location impacts may only be negligible. Alternate groundwater supplies are available if necessary.

Well No. 2 is located in the NW¼ of SW ¼ of Section 7 and is screened in the Beulah-Zap Sand. The well is permitted for 656.5 acre feet to irrigate 125.5 acres at 566.7 gpm. Impacts to this well from mining are not anticipated. The B-Z Sand is recharged from the Knife River alluvial aquifer system.

Gunsch Spring located in SE ¼ of Section 16

Detailed discussions regarding the Gunsch Spring may be found below in Section D, Probable Hydrologic Consequences. Further discussion relating to this spring may be found in Section 3.6 Backfilling and Grading – Special Considerations. In the event the Valley Fill Drainage System fails to provide the necessary quantities for the intended post mining land use at the time of bond release, alternate groundwater sources are available for use at this location.

Voigt Springs located in the E ½ of Section 19

Voigt Spring #1 is located in the SW¼ of the NE¼, Section 19, approximately 1,500 feet from the western boundary of mining. The spring is not associated with any coal seam or any geologic strata, and recharges from a small, sandy zone located west of the spring. Another drainage is located between mining activities to the west and the spring. The spring appears to only produce water after precipitation events. Impacts to this well from mining are not anticipated because the drainage area into the spring is small and isolated from mining activities.

Voigt Spring #2 is located in the NW¼ of the SE¼, Section 19, approximately 0.5 miles from the western boundary of mining. The spring is located adjacent and south of Tributary #1 of Coyote Creek. The flow originates from a small drainage area located south of the tributary. It is difficult to determine if the spring is associated with a coal aquifer; nonetheless, impacts to this spring will not occur because mining with not impact any area south of Tributary #1 to Coyote Creek.

Schmidt Seeps #1 & 2, located in the NE ¼ of Section 22

Schmidt Seep #1 is located in the NE¼ of the NE¼, Section 22, approximately 200 feet east of the mining boundary. Temporary pond 102 is proposed to go where seep #1 is currently located. The seep is undeveloped and has minimal flow. Cattle can occasionally access the seep for limited use. The seep is located at the top of a wooded drainage that drains to the east toward West Brush Creek. The seep is only present in the top 1/3 of the drainage. The seep has minimal flow.

Schmidt Seep #2 is undeveloped. The seep has minimal flow and is smaller than Schmidt Seep #1. Schmidt Seeps #1 & 2 are shown on Exhibit 2.3.7. They are also shown on Exhibit 2.6.9 as class III wetlands. The reclamation of these seeps is referenced in Narrative 2.7.The upper reaches of Schmidt Seep #2 is planned to be mined through. If Schmidt Seep #2 does not re-establish after mining, WBM will replace this pre-mining water source with a well in the near vicinity.

WBM Monitored Springs

Springs 17ABB-W/SP and 17DAC-W/SP are located in the E½ of section 17. Both springs are monitored as part of WBM's approved ground water monitoring program under permit KRSB-8603. Spring 17ABB-W/SP is suitable for livestock watering and has a developed concrete watering tank. Spring 17ABB-W/SP has maintained an average flow of approximately 1.2 gpm over the past 25 years. Results of sampling at the spring located at 17ABB reported TDS values ranging from 129 to 4496 mg/l with an average of 1778 mg/l with a sample size of 62. No impacts are expected to this spring from mining. This spring is fed by the Spaer lignite, located below the Beulah-Zap coal bed.

Spring 17DAC-W/SP sporadically produces flow, the last of which was recorded in March of 2000. Alternate water supplies are available for these sites if necessary.

L. Winkler Wells #1 and #2

L. Winkler wells #1 and #2 are located adjacent to the L. Winkler home in the S1/2 of Section 29. L. Winkler well #1 was previously used for potable water for the L. Winkler residence. L. Winkler well #1 is currently disconnected, and was replaced with L. Winkler well #2. L. Winkler well #2 is used for potable water for the L. Winkler residence. L. Winkler plane to replace well #2 with rural water in the near future. L. Winkler well #2 has a measured flow of 7 gpm but is restricted to 4gpm with a flow restrictor.

L. Winkler well #2 is screened from 294 to 314 feet below the surface and is recharged from lignite and silty clay at the screened interval. The B-Z coal seam to be mined in this area is approximately 40-100 feet below the surface; thus, impacts to this well from mining are not anticipated

D. PROBABLE HYDROLOGIC CONSEQUENCES

1. General Quality and Quantity Changes

Possible impacts to the surface and groundwater systems within the permit, adjacent and general areas involve the issues of water quality and water quantity. Whereas these systems are highly interdependent, the probable hydrologic consequences for both systems will be addressed together in this section. Other than as noted above, minimal impacts to surface waters of the extended mine plan area are expected to result from the proposed mining activities. This statement is based on mining and hydrologic monitoring experience conducted in the area for over the past forty years. However, any active water supply that is diminished, interrupted or quality-affected will be replaced with a water source of equal or better quantity and quality if the quality and quantity of such water source has been adversely effected by the mining and reclamation process.

Pond No. 81 is proposed to remain as a permanent impoundment; however, Pond No. 86 will be removed during final mine reclamation. Because Pond No. 81 is located in the upper reaches of its respective drainage basins and intercepts only a small portion of the receiving basins total runoff, its effect on the quantity of surface water available downstream following mining will be minimal. Although WBM does not expect spring flow to reestablish to historical quantities, Pond No. 81 has been designed to allow flow-through of spring discharges. In the late 1980's a valley fill project began in the SE¼ of Section 16 to allow optimum coal recovery in that area. (See Section 3.6 Backfilling and Grading – Special Considerations for the detailed discussion of this project) A 4” perforated pipe was entrenched at various depths along the sides of the fill to intercept the spring flows issuing from the Beulah-Zap and Schoolhouse lignite beds. These flows were collectively drained to the perforated pipe outflow located near the downstream end of the valley into Pond 81. Section 3.6-D describes that a Baski cutthroat flume was installed in the valley bottom in 1985 to quantify the pre-mining spring flow. A nearly constant flow of 30 gpm occurred in October 1985. As continuous portions of the B-Z and Schoolhouse lignite was mined out, the spring flows subsequently decreased. By the time the final pit was stripped and the coal removed in 2005, the spring flow had diminished to 1.0 to 1.5 gpm. The remnant of exposed pipe was buried during final grading and SPGM respreading of the downstream valley fill slope. A small seep does emerge approximately 50-100 feet downstream from the buried pipe outflow at the north edge of drainage bottom and the base of a northern native hillside. It is conjectured that this seep is a combination of the aforementioned 1.0 to 1.5 pgm resurfacing and a trace spring flow from the undisturbed lignite beds to the north of the mined area. The remaining flows from Ponds 86 & 81 are due to pit dewatering activities and surface runoff. Pond 81 dewatering volumes and quality are reported to the Public Service Commission and North Dakota Department Environmental Quality via quarterly Discharge Monitoring Reports.

Table 2.3.7 lists the watersheds and the difference between their pre-mine and post-mine size and runoff quantity. Ponds 90, 91, 92, and 93 will all have acre-ft changes greater than 5%. However, these ponds were over-built and will be able to handle the increase in capacity. The largest watershed change occurs at Pond 93, which will have a post-mine runoff quantity smaller than the original. Ponds 95, 96, 97, 98, and 99 all have a runoff quantity change greater than 5%. In the case of these ponds, the change is so small it will be a non-factor. Each pond drains into the same valley, which flows into Coyote Creek. Pond 95’s watershed will increase in size significantly but it has the capacity to support this increase in runoff quantity. Ponds 101 and 102 will each have watershed changes greater than 5% but also have the capacity to handle such changes. Drainage basins are depicted on Exhibit 2.2.7, Surface Water Monitoring Map.

Table 2.3.7

Watershed	Pre Mine		PMT		Difference (Pre-Mine-PMT)			
	Acres	Ac-ft	Acres	Ac.-ft	Acres	%Difference Acres	Ac-ft	%Difference
Pond 81	40.0	2.8	32.3	2.3	-7.7	-19.21%	-0.5	-19.21%
Pond 82	58.0	2.6	53.4	2.4	-4.6	-7.94%	-0.2	-7.94%
Pond 83	108.0	5.5	103.9	5.3	-4.1	-3.78%	-0.2	-3.78%
Pond 84	37.0	5.7	37.0	5.7	0.0	0.00%	0.0	0.00%
Pond 85	514.0	58.4	518.3	58.8	4.3	0.84%	0.4	0.68%
Pond 87	125.0	9.2	130.8	9.6	5.8	4.66%	0.4	4.66%
Pond 88	18.0	2.3	18.0	2.3	0.0	0.00%	0.0	0.00%
Pond 89	62.0	6.7	62.0	6.7	0.0	0.00%	0.0	0.00%
Pond 90	52.3	6.6	57.0	6.5	4.7	8.99%	-0.1	-1.52%
Pond 91	58.3	6.6	72.0	8.2	13.7	23.50%	1.6	24.24%
Pond 92	30.8	3.5	38.3	4.4	7.5	24.35%	0.9	25.71%
Pond 93	314.1	35.7	272.5	31.0	-41.6	-13.24%	-4.7	-13.17%
Pond 94	67.2	7.6	69.7	7.9	2.5	3.72%	0.3	3.95%
Pond 95	51.4	5.8	41.5	4.7	-9.9	-19.26%	-1.1	-19.15%
Pond 96	49.3	5.6	30.6	3.5	-18.7	-37.93%	-2.1	-37.50%
Pond 97	35.0	4.0	33.1	3.8	-1.9	-5.43%	-0.2	-5.00%
Pond 98	53.3	6.1	58.9	6.7	5.6	10.51%	0.6	9.84%
Pond 99	89.8	10.2	77.3	8.8	-12.5	-13.92%	-1.4	-13.73%
Pond 100	14.6	1.7	14.6	1.7	0.0	0.00%	0.0	0.00%
Pond 101	32.2	3.7	27.6	3.1	-4.6	-14.29%	-0.6	-16.22%
Pond 102	36.6	4.3	43.7	5.0	7.1	19.40%	0.7	16.28%
Pond 103	84.4	9.5	88.0	9.9	3.6	4.27%	0.4	4.21%
Pond 104	182.3	20.6	181.7	20.5	-0.6	-0.33%	-0.1	-0.49%
Pond 105	79.5	9.0	75.5	8.5	-4.0	-5.03%	-0.5	-5.56%
Pond 106	24.0	2.7	28.0	3.2	4.0	16.67%	0.5	18.52%
Pond 107	81.2	9.2	63.0	7.1	-18.2	-22.41%	-2.1	-22.83%
~~Pond 108~~	~~53.6~~	~~6.1~~	~~73.0~~	~~8.2~~	~~19.4~~	~~36.19%~~	~~2.1~~	~~34.43%~~
Pond 108	53.6	6.1	53.6	6.1	0.0	0.00%	0.0	0.00%
Pond 112	209.0	23.6	209.0	23.6	0.0	0.00%	0.0	0.00%
Pond 113	171.0	19.3	171.0	19.3	0.0	0.00%	0.0	0.00%

Assume CN=80

Assume 10yr 24hr event

Spring flows from the Gunsch spring (16ADA-W/SP) have diminished while mining has been, and currently is, occurring in the immediate area. Thus, pre-mining water levels are not expected to re-establish to pre-mining levels as discussed below. Currently, groundwater originated from the south, and discharges into the Red Pit. The groundwater is then intercepted and pumped to the 86 and 81 pond system. Discharge quantities from Pond 81 (NDPDES discharge point 081) over the past 18 months average 40 gpm, excluding water used for dust suppression. Due to the limited drainage area above Pond 86 & 81, most of this flow is intercepted groundwater from the Red Pit.

After mining in the West Brush Creek area is completed, a small percentage of the groundwater emerging from south of the Red Pit (up gradient), will migrate through the spoils and will eventually reach the springs located down gradient, i.e. the Valley Fill drainage system. The remaining, larger portion of the groundwater will infiltrate through the spoil material into the Spaer coal bed aquifer. Groundwater levels within the spoils will be less variable than observed in the lignite due to a relatively consistent texture of the spoil materials versus the fractured nature of the lignite. Most wells within both lignite seams are either dry or contain little groundwater prior to mining.

Regarding groundwater quantity, in summary, WBM expects flows to increase in relation to current spring flows (1 to 1.5 gpm), but decrease in relation to pre-mining flows (60 to 70 gpm). WBM does not expect flows to return to pre-mining levels.

Regarding groundwater quality, studies at other mines in North Dakota (Groenewold, et al., 1983) indicate that water levels in the spoils approach pre-mining levels within a few years after mining and that these resulting spoils aquifers show a range of hydraulic conductivities similar to the coal aquifers in the pre-mining setting. The Company's experience at the Beulah

Mine (KRSB-8802) indicates that water quality in the spoils was found to be approximately 2 to 3 times as mineralized as prior to mining and enriched in sodium and sulfate. (Refer to the PHC section, Permit KRSB-8802.)

Post mining hydraulic conductivities are similar to coal aquifers in the pre-mining setting. The post mining topography resembles the pre-mining topography and resembles that of pre-mining conditions (land use.) With the previously mentioned post mining conditions, the recharge capacity is likely to approximate that of pre-mining conditions.

Due to both the decrease in groundwater quantity, and the expected increase of mineralized post-mining groundwater quality, WBM will replace the pre-mining Gunsch spring with a well in the SE¼ of Section 16; likewise, WBM will replace a well in the N1/2 of Section 16 to provide a source of water for livestock watering. Wells installed in an aquifer below mining disturbance will provide the most viable source of water for livestock. As mentioned on page 2.3.1, the Upper Hell Creek and Lower Cannonball-Ludlow Aquifer is the next hydrostratigraphic unit whose transmissivity values make it capable of supporting wells when tapped. However, WBM is not aware of any wells within the area that are drilled into this aquifer. This, coupled with the fact that there are wells drilled down to the Fox Hills Aquifer in this region [Reich Farmstead (see Table 2.3.3) – 1450' ; Dale Neuberger residence (NE1/4, Section 8 T143NR87W) – 1455'], suggest that this aquifer is the most likely hydrostatigraphic unit that will be used to replace the pre-mining Gunsch spring. The Reich Farmstead well was sampled for quality during a round of well recertifications in October 2005. Exhibit 2.3.8 contains the lab analysis (titled M & S Altavilla) of the sample taken from this Fox Hills well. Immediately following this analysis is a page listing the constituents measured and parameter levels needed to meet U.S. Public Health Service Drinking Water Standards. It also displays the North Dakota State Health Department's Classification System relating to those same constituents. All the well sample constituents, with the exception of TDS (1300 mg/l), are well below the USPHS drinking water standard limits. The 1300 mg/l is shown as being within the Average range in the NDSDOH Classification System. For livestock consumption, TDS levels below 3000 mg/l are considered satisfactory (Boyles, 1988). Wells tapped into the Fox Hills aquifer are also capable of meeting production (quantity) requirements for human and livestock consumption. Most well owners limit their well flows to 5 to 10 gpm. Fox Hills wells generally flow at unrestricted rates of 10 to 25 gpm (Croft, 1973).

In June of 1979, the Beulah Mine drilled two wells in coal that were never mined (outcrop coal). These two wells represent baseline wells that are used to compare pre-mining and post-mining groundwater quality. In August 1984 the Beulah Mine installed four base-of-spoils wells to monitor spoil water quality after coal extraction. These four wells represent post-mining wells used to compare water quality and static water levels in the spoils, versus pre-mining water quality and static water levels. Exhibit 2.3.9 presents the water quality analyses for the two baseline wells (929 and 930), and the four base-of-spoil wells (1352, 1354, 1355 and 1357). By comparing the baseline wells to the base-of-spoil wells, the data supports the conclusion that the post-mining water quality will be approximately 2 to 3 times more mineralized than the pre-mining water quality. Three of these four wells however, show enrichment in Ca and Mg relative to Na, as well as elevated SO4 levels.

When reviewing the historical data from baseline well 930, it appears as though the first two readings of TDS concentrations are skewed high due to drilling. In some instances after drilling, TDS readings are artificially high from downhole disturbance related to the drilling process.

There are three intermittent stream systems located in portions of the revision No. 27 area. The first stream has headwaters in Section 21 and continues westward through the S½ of Section 20. This stream is fed by the Fetch Seep identified in Exhibit 2.3.7. Another intermittent stream begins in the SW¼ of Section 22, continuing through the NW22 and the W½ of Section 15 before joining up with Brush Creek a little further north. This stream is fed by the Schmidt et al. seep identified in Exhibit 2.3.7. The third stream cuts diagonally through the SE¼ of Section 22 and the W½ of Section 23, where it empties into Brush Creek. This stream is fed by Erickson Spring #3 in Section 27, identified in Exhibit 2.3.7, these streams will be subject to differing degrees of mining-related disturbance. Coal removal activities will surround much of the stream in Section 20, but the stream profile will remain intact. Upstream areas will be largely unaffected, although some surface disturbance for support facilities may occur. The stream in sections 15 and 22 will have the largest percentage of its watershed impacted, including removal of the stream section located primarily in the NW22, although relatively little of the SW22 will be affected by mining. Coal will be removed to the north of the third intermittent stream but the stream will not be subject to direct impacts.

For all of these streams, the quantity and/or quality of water produced by some of the seeps and springs that serve as groundwater-based sources will be negatively impacted to some degree. Fortunately, groundwater flows that use the Schoolhouse and Beulah-Zap coal beds as conduits and surface as springs and seeps, particularly in the case of the Schoolhouse bed, emanate principally from the south. Considering the location and direction of planned coal removal, this source direction will insure that many of the springs and seeps currently supporting the intermittent streams will continue to do so with minimal, if any effect. With reclamation of a stable and productive postmining landscape to the approximate original topography, institution of common land uses, and implementation of sound agronomic practices, restoration of the surface water supply component to these streams is anticipated.

The impacts to certain springs in Section 15 were described in prior narrative, as were commitments for replacement of these water supplies. In other locales where the water supply will be reduced or removed, mitigation can be provided by one or more permanent ponds that will capture and store surface water for use by livestock, the principal user. In some cases, development of a reemerging seep or spring area, or a well, may be the best solution to fulfill the commitment for water supply replacement given in the first paragraph of this section.

During the mining and reclamation phases, the permittee has and will continue to employ practices to reduce erosion and sedimentation. These measures may include erosion control fabric, wattles, silt fences, straw mulching, and others as tools to expeditiously provide a suitable replacement source of water, particularly with respect to surface water supplies.

2. Pit Water Inflows

The following discussion was an attempt to predict initial pit in-flows using analytical methods written in 1986. The final predicted results of inflows have proven quite reasonable based on observed flows since 1986.

McWhorter (1982, pgs 60-66) presents an analytical solution which allows the calculation of inflows to the first cut and to the extent to which the potentiometric surface is lowered in affected aquifers, for the case where a surface mine is initiated by a box cut into aquifer materials, which extend laterally to great distances from the area to be mined.

This solution is applicable to the N-S box cut proposed in this permit and its attendant hydrologic impacts; analysis of those impacts based on the results of pre-mining hydrology investigations is presented below:

The discharge to one side of the pit is given by;

$$Q = 2R \quad \frac{S_{ya}\ Tb^2}{12} + \frac{STH_O^2}{4} \quad ½\ t^{½},\ t \le \frac{L}{R} \qquad (1)$$

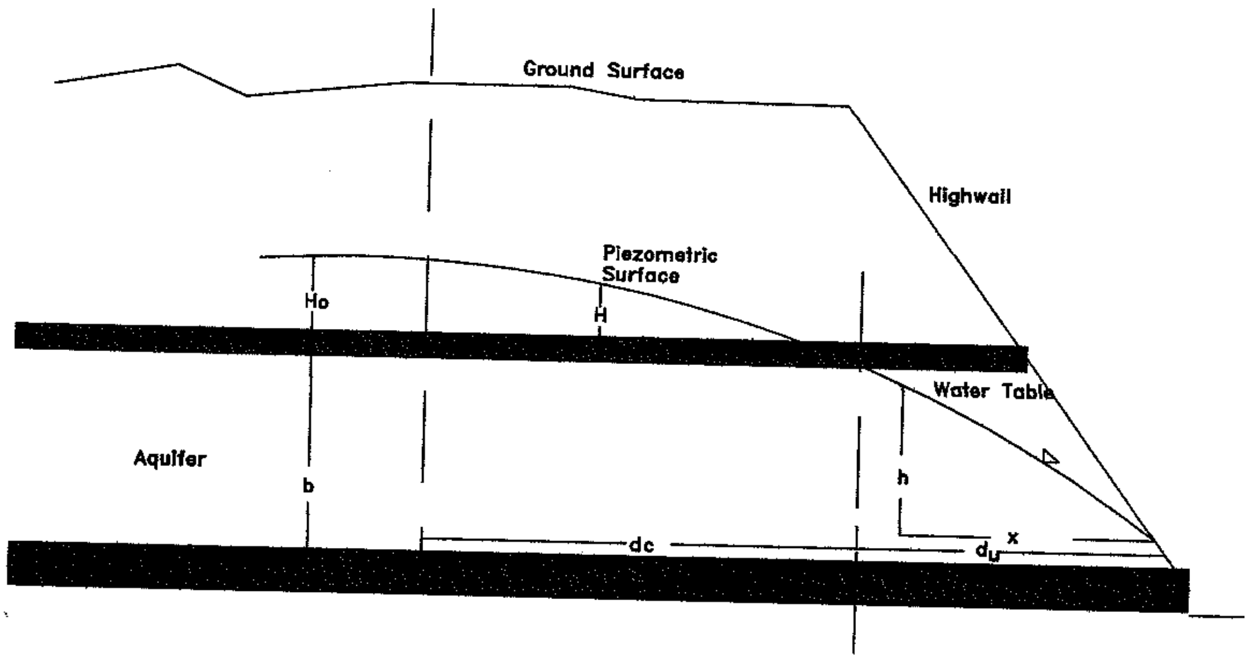
which holds for all times during the advancement of the pit (i.e., for $t \le L/R$, where L is the maximum length of the pit).

Figure 2.3.1 is a definition sketch for this analytical solution, and the terms defined therein and in equation (1) are:

- S_{ya} = apparent specific yield
- S = storage coefficient (storativity)
- b = aquifer thickness (saturated)
- H = height of water table above floor of aquifer
- H_O = piezometer height above top of aquifer
- d_U = extent of unconfined zone
- d_C = distance between the boundary of the confined and unconfined zones and the point at which $H = H_O$
- R = average rate of pit advancement
- T = transmissivity
- L = maximum length of pit
- Q = total discharge to the pit
- t = time since initiation of pit

<u>Figure 2.3.1</u>

Definition Sketch for Flow to Box Cut Pit



a. Flows To Box Cut Pit

Inflows to the box cut pit are expected from both the Beulah-Zap and Schoolhouse beds. Because field data indicates that both coals contain significantly more water at the south end of the pit, flows for the southern one-third and northern two-thirds of the pit are calculated separately.

Aquifer parameters and other terms used in this calculation are as follows:

S_{ya} = 0.1

b = Beulah-Zap N2/3:0.6m,S1/3:2.3m   Schoolhouse N2/3:0.6m,S1/3:1.2m

R = 15 m$\cdot$day^{-1}

T_1 = Beulah-Zap North 1.8 x 10^{-7} $m^2\cdot s^{-1}$

T_2 = Beulah-Zap South 6.9 x 10^{-7} $m^2\cdot s^{-1}$

T_3 = Schoolhouse North 6.6 x 10^{-7} $m^2\cdot s^{-1}$

T_4 = Schoolhouse South 1.3 x 10^{-6} $m^2\cdot s^{-1}$

L_1 = North 2/3 975m

L_2 = South 2/3 488m

Maximum discharge will occur at $t = \frac{L}{R}$ therefore from equation (1)

$$Q_1 = 2R \quad \frac{S_{ya} \ Tb^2}{12} \quad ½ \ t^{½} \qquad \text{for } H_O = O$$

$$Q_1 = 2 \cdot 15 \text{ m} \cdot \text{day}^{-1} \qquad 0.1 \ 1.8 \times 10^{-7} \text{ m}^2 \text{ s}^{-1} (0.6\text{m})^2 \quad ½ \quad 65 \text{ days}^{½}$$

$$Q_1 = 2 \text{ m}^3 \cdot \text{day}^{-1} \qquad \text{(Beulah-Zap North)}$$

Calculations for Q_2, Q_3 and Q_4 are performed in a similar manner using the appropriate numbers yielding: Q_2 = 50 $m^3 \cdot day^{-1}$ (Beulah-Zap South)

Q_3 = 3 $m^3 \cdot day^{-1}$ (Beulah-Zap North)

Q_4 = 36 $m^3 \cdot day^{-1}$ (Beulah-Zap South)

Total inflow for one side of the pit therefore equals 91$m^3 \cdot day^{-1}$, and for both sides equals 182$m^3 \cdot day^{-1}$ or 33 gpm.

E. GROUND WATER MONITORING PLAN

Figures 2.3.2 through 2.3.11 are Piper trilinear chemistry plots for wells historically monitored for ground water quality. With the exception of wells 1359 and 1443, these wells show virtually no water quality variation since monitoring was begun in 1985. Revised Exhibit 2.3.6 contains the complete water quality analyses for these wells for the period of record. Groundwater levels and quality will be monitored according to the schedule presented in Table 2.3.5. Water levels will be measured quarterly and reported to the Commission by the end of the month following the close of the quarter. In the event that severe climatic conditions, which prevent access for water level measurement persist throughout the quarter, documentation to this effect will be submitted along with the quarterly report.

Revision No. 27 will implement the following changes to the monitoring program. Six of the nine new wells mentioned earlier in the narrative of Section 2.3.B will supplement the documentation of the effects mining has on the three lignite beds in this permit. Wells 2034 will be added to the Schoolhouse bed wells; 2030 and 2033 to the Beulah-Zap wells; 2031, 2032, and 2036 to the Spaer wells.

The current active wells to document the effects of mining on the Beulah-Zap bed are: 1441, 1528, 1732, 2001, 2005, 2011, 2021, 2024, 2027, 2030, and 2033. The Schoolhouse bed will continue to be monitored by current active wells 2002, 2022, 2025, 2028, and 2034. The current Spaer bed wells are1731, 2008-R, 2012, 2020, 2023, 2026, 2031, 2032, and 2036.

Water quality samples will be collected annually and analyzed according to the schedule outlined above for the parameters required by NDAC 69-05.2-08-06.e. The analytical results will be reported to the Commission by the end of the month following the sampling quarter. Those wells which produce sufficient water are sampled using a dedicated WaTerra sampling system. Prior to sampling, approximately three well volumes are removed. The non-pumping wells are evacuated with a bailer, allowed to recover overnight and sampled the following day. Because of water level fluctuations, some of the wells scheduled for sampling contain insufficient water to allow for collection of a representative sample. When this occurs it will be specifically stated in the quarterly monitoring report.

As mining progresses, some of the monitoring wells will be destroyed and additional base-of-spoils wells will be installed as close as possible to previous monitoring well locations and added to the monitoring program. WBM submits an annual Ground Water Monitoring Performance Standard Report each year as required by NDAC 69-05.2-16-14(3). This report includes a listing of all the monitoring wells which were mined through, destroyed, abandoned due to casing or grout failure, or lost by any other means during the previous year. Within this report, recommendations will be presented for replacement of wells deemed unusable. The groundwater monitoring plan contained herein will be updated as needed by a permit revision at the midterm review and prior to renewal.

Exhibit 2.3.1 depicts the locations of the groundwater monitoring wells. It is not intended that this map represent all wells, but only those wells in the approved monitoring program. The wells in the approved monitoring program are listed in Table 2.3.8.

Prior to abandonment, these wells will be cut off below plow depth and filled with grout by a North Dakota certified monitoring well contractor. All test holes drilled to date have been reclaimed by plugging potential aquifer zones with coarse bentonite. Any monitoring wells subsequently drilled within the permit area which will not be disturbed by mining will be reclaimed to those same standards.

Exhibit 2.3.7 also depicts six springs that are monitored annually for water quality and quantity. Water quality and quantity results from the six springs can be found in Exhibit 2.2.4 and Exhibit 2.2.8. Spring sites will be sampled in the fall during low flow, which should be worst case.

Table 2.3.8
Groundwater Monitoring Plan

Well/Spring Number	Water Levels (Quarterly)	Water Quality	Screened Bed
949	X		Brush Creek Alluvium
1441	X	X	B-Z
1528	X		B-Z
1731 replacement	X	X	Spaer
1732 replacement	X	X	B-Z
2001	X	X	B-Z
2002	X	X	SCH
2005	X		B-Z
2008	X		Spaer
2011	X		B-Z
2012	X	X	Spaer
~~2020~~	~~X~~	~~X~~	~~Spaer~~
~~2021~~	~~X~~	~~X~~	~~B-Z~~
~~2022~~	~~X~~	~~X~~	~~SCH~~
2023	X	X	Spaer
2024	X	X	B-Z
2025	X	X	SCH
2026	X	X	Spaer
2027	X	X	B-Z
2028	X	X	SCH
2029	X	X	Spoil
2030	X	X	B-Z
2031	X	X	Spaer
2032	X	X	Spaer
2033	X	X	B-Z
2034	X	X	SCH
2035	X	X	Twin Buttes
2036	X	X	Spaer
2037	X	X	Spoil
2038	X	X	Spaer
2039	X	X	B-Z
2040	X	X	Spaer
2041	X	X	SCH
2042	X	X	B-Z
17ABB-W/SP	N/A (Spring)	X	Spaer
17DAC-W/SP	N/A (Spring)	X	B-Z
16ADA-W/SP	N/A (Spring)	X	N/A
P.V. Spring #1	N/A (Spring)	X	N/A

P.V. Spring #2	N/A (Spring)	X	N/A
P.V. Spring #3	N/A (Spring)	X	N/A

References:

Brant, R.L. 1953. Lignite Resources of North Dakota. Geological Survey Circular 226. North Dakota Geological Survey, U.S Department Of Interior. Washington, D.C.

Carlson, C.G. 1973. Geology of Mercer and Oliver Counties, North Dakota. Bulletin 56 – Part 1. North Dakota Geological Survey, County Ground Water Studies 15 – Part 1. North Dakota State Water Commission. Bismarck, ND. U.S. Geological Survey, Washington, D.C.

Boyles, S.; Wohlgemuth, K.; Fisher, G.; Lundstrom, D.; Johnson, L. 1988. Livestock and Water. North Dakota State University Extension Service Bulletin AS-954. Fargo, ND

Croft, M.G. Ground Water Resources – Mercer and Oliver Counties, North Dakota. U.S. Geological Survey. Huron, SD