APPENDIX 2.5-6

WATER QUALITY RESULTS FOR GROUND WATER AND SEEPS AND SPRINGS

Introduction

Monitoring wells and seeps/springs identified in Table 2.5-2A and Table 2.5-2B and shown on Figure 2.5-1 of SHLM Permit Application Section 2.5 were sampled for water quality analysis during the baseline investigation. Data were evaluated using EPA accepted quality assurance and quality control (QA/QC) procedures and are considered valid and representative. The results of water quality analysis are summarized in Table 2.5-6-1 and Table 2.5-6-2 and discussed below.

General Water Quality Data Summary

~~The majority of wells in the Study Area sampled during the baseline study show relatively consistent water quality data between sampling events. For example, total dissolved solids (TDS) concentrations vary by less than 10 percent from the baseline (December 2006 to August 2007) average of a given well, with the exception of sampling events at four wells (SHMW-06D, SHMW-07D, SHMW-12C, and SHMW-13C) which vary by up to 17 percent. Sodium concentrations vary by less than 10 percent from the baseline average of a given well in all instances but sampling events at four wells (SHMW-03C, SHMW-03D, SHMW-06D, and SHMW-13C), which vary by up to 33 percent. Values of pH vary by less than 5 percent in all instances.~~

Water quality parameters are within the range of values reported in the literature for the Upper Tongue River – Sentinel Butte aquifer system, as discussed in Section 2.5.1 of the SHLM Permit Application. For example, TDS concentrations for all wells are between 424 and 12,000 milligrams per liter (mg/L), corresponding with the range of 574 to 11,700 mg/L reported by Trapp and Croft (1975) and Armstrong (1984). Additionally, sodium adsorption ratio (SAR) values range from 0.5 to 63.7 for all monitoring wells, which are similar to ranges reported by Trapp and Croft (1975) and Armstrong (1984) of 0.51 to 71.

~~Water quality parameters are also within the range of values reported in the literature for the Upper Tongue River – Sentinel Butte aquifer system, as discussed in Section 2.5.1 of the SHLM Permit Application. For example, TDS concentrations for the overburden (including D Coal), underburden, and alluvial wells are between 457 and 8,900 mg/L, corresponding with the range of 574 to~~

~~11,700 mg/L reported by Trapp and Croft (1975) and Armstrong (1984). Additionally, sodium adsorption ratio (SAR) values range from 0.5 to 63.7 for all monitoring wells, which are similar to ranges reported by Trapp and Croft (1975) and Armstrong (1984) of 0.2 to 68.~~

Water Quality Data for Wells Completed in Overburden

Water quality characteristics vary among the wells completed in the overburden. Well SHMW-13S has sodium-bicarbonate type ground water, wells SHMW-15S and SHMW-08S have sodium-sulfate-bicarbonate type ground water, well SHMW-03S has calcium-magnesium-bicarbonate type water, and well SHMW-09S has sodium-sulfate type water. Well SHMW-05S, which is also completed in the overburden, has always been dry. All of the wells plot with different signatures on a Piper plot (Figure 2.5-6-1). Laboratory pH values range from 7.2 to 8.4, with higher values recorded at SHMW-13S. Concentrations of TDS and laboratory electrical conductivity (EC) values range from 424 to 5,540 mg/L and 685 to 7,020 micromhos per centimeter (μmhos/cm), respectively. Higher values of TDS and EC are reported in SHMW-09S, whereas, lower than average values are reported in SHMW-03S Values of SAR range from 0.67 to 58.2, with values generally decreasing downgradient, SHMW-15S has a higher SAR than expected given its location. Despite the variation between wells, measured analyte values generally remain fairly constant between sampling events at any individual location.

~~Water quality characteristics vary among the wells completed in the overburden. Well SHMW-13S has sodium-bicarbonate type ground water, wells SHMW-15S and SHMW-08S have sodium-sulfate-bicarbonate type ground water, well SHMW-03S has calcium-magnesium-bicarbonate type water, and well SHMW-09S has sodium-sulfate type water. All of the wells plot with different signatures on a Piper plot (Figure 2.5-6-1). Laboratory pH values range from 7.2 to 8.4, with higher values recorded at SHMW-13S. Concentrations of TDS and laboratory electrical conductivity (EC) values range from 476 to 4,570 mg/L and 764 to 5,449 micromhos per centimeter (μmhos/cm), respectively. Values of SAR range from 0.67 to 56.0, with values generally decreasing downgradient, SHMW-15S has a higher SAR than expected given its location. Despite the variation between wells, measured analyte values remain fairly constant between sampling events at any individual location.~~

Water Quality Data for Wells Completed in D Coal

Ground water from wells completed in the D Coal consistently ranges from sodium-bicarbonate type to sodium-sulfate type waters, as shown on Figure 2.5-6-2, with the exception of SHMW-03C, SHMW-01S and SHMW-11S, which typically have a higher proportion of calcium and magnesium.

There is no clear correlation between the relative amount of sulfate or bicarbonate and location along the direction of ground water flow (i.e., upgradient versus downgradient wells). However, deeper wells are generally more sodium-bicarbonate type waters. This roughly follows the conceptual evolution of ground water quality presented by Moran et al. (1978). Briefly, this conceptual model assumes that recharge water flows downward from the surface. Ground water near the surface is influenced by dissolution of evaporation-concentrated salts, such as gypsum (calcium sulfate). As water percolates deeper, sodium exchange from the abundant clays quickly increases the relative sodium content and calcite (calcium carbonate) dissolution increases the bicarbonate content, resulting in a shift to sodium-bicarbonate type waters. With the exception of wells SHMW-03C, SHMW-01S and SHMW-11S, calcium and magnesium concentrations are proportionally low compared to sodium concentrations (Figure 2.5-6-2), likely due to cation exchange with the clays

For all wells screened in the D Coal, values for laboratory pH range from 6.5 to 8.2 with an average of 7.4. The lowest pH values are primarily located at well SHMW-06C and SHMW-01S. Concentrations of TDS and laboratory EC range from 486 to 4,810 mg/L and 733 to 6,130 μmhos/cm, respectively. Ground water from well SHMW-06C is outside these ranges with an average TDS concentration of 8,681 mg/L and EC of 9,312 μmhos/cm, for samples collected between December 2006 through the end of 2009. Oxidation of pyrite associated with the coal produces acidity that is generally consumed by the calcite in the materials (Moran et al. 1978). This process would result in a slightly lower pH (depending on the degree of oxidation and neutralization occurring), higher calcium concentrations as calcite is consumed to neutralize the acid-producing reaction, and elevated TDS from the sulfate and bicarbonate produced in these reactions. These processes match the conditions observed in well SHMW-06C, indicating that relatively higher abundance of pyrite may be present in the coal at this location.

Values of SAR in wells completed in the D Coal range from 0.51 to 64.7. These values generally decrease downgradient, similar to wells completed in the overburden. The exception to this trend is well SHMW-04C, where SAR values are higher than expected given the location of the well and the direction of ground water flow. For every analyte, values remain fairly constant from one sampling event to the next in all wells except SHMW-13C. However, water levels in SHMW-13C do not fully recover between sampling events, indicating the formation in which the well is screened is of low permeability. As such, it may be difficult to get representative water samples from this well.

~~Ground water from wells completed in the D Coal consistently ranges from sodium-bicarbonate type to sodium-sulfate type waters, as shown on Figure 2.5-6-2, with the exception of SHMW-~~

03C,SHMW-01S and SHMW-11S, which typically have a higher proportion of calcium and magnesium. There is no clear correlation between the relative amount of sulfate or bicarbonate and location along the direction of ground water flow (i.e., upgradient versus downgradient wells). However, deeper wells are generally more sodium bicarbonate type waters. This roughly follows the conceptual evolution of ground water quality presented by Moran et al. (1978). Briefly, this conceptual model assumes that recharge water flows downward from the surface. Ground water near the surface is influenced by dissolution of evaporation concentrated salts, such as gypsum (calcium sulfate). As water percolates deeper, sodium exchange from the abundant clays quickly increases the relative sodium content and calcite (calcium carbonate) dissolution increases the bicarbonate content, resulting in a shift to sodium bicarbonate type waters. With the exception of wells SHMW-03C,SHMW-01S and SHMW-11S, calcium and magnesium concentrations are proportionally low compared to sodium concentrations (Figure 2.5-6-2), likely due to cation exchange with the clays

For all wells screened in the D Coal, values for laboratory pH range from 6.5 to 8.2 with an average of 7.5. The lowest pH values are primarily located at well SHMW-06C and SHMW-01S. Concentrations of TDS and laboratory EC range from 506 to 4,440 mg/L and 758 to 6,070 μmhos/cm, respectively. Ground water from well SHMW-06C is outside these ranges with a baseline average TDS concentration of 8,470 mg/L and EC of 9,180 μmhos/cm. Oxidation of pyrite associated with the coal produces acidity that is generally consumed by the calcite in the materials (Moran et al. 1978). This process would result in a slightly lower pH (depending on the degree of oxidation and neutralization occurring), higher calcium concentrations as calcite is consumed to neutralize the acid-producing reaction, and elevated TDS from the sulfate and bicarbonate produced in these reactions. These processes match the conditions observed in well SHMW-06C, indicating that relatively higher abundance of pyrite may be present in the coal at this location.

Values of SAR in wells completed in the D Coal range from 0.53 to 55. These values generally decrease downgradient, similar to wells completed in the overburden. The exception to this trend is well SHMW-04C, where SAR values are higher than expected given the location of the well and the direction of ground water flow. For every analyte, values remain fairly constant from one sampling event to the next in all wells except SHMW-13C. However, water levels in SHMW-13C do not fully recover between sampling events, indicating the formation in which the well is screened is of low permeability. As such, it may be difficult to get representative water samples from this well.

Water Quality Data for Wells Completed in Underburden

Ground water from wells completed in the underburden is generally sodium-bicarbonate type water. Monitoring well SHMW-05D has a slightly elevated proportion of sulfate, but similar to wells completed in the D coal, this pattern does not correlate to distance along the flow path (Figure 2.5-6-3). Values for laboratory pH range from 8.1 to 8.8, with an average of 8.5, slightly higher than that observed in wells completed in the overburden and D Coal. Concentrations of TDS and laboratory EC range from 1,070 to 1,560 mg/L and 1,680 to 2,310 μmhos/cm, respectively. A range of SAR values is observed, from 25.7 to 70.8 and, as with wells completed in the overburden and D Coal, and values generally decrease downgradient. For the majority of analytes there is a more constrained range of values relative to the ranges observed for wells completed in the overburden and D Coal. For every analyte and all wells completed in the underburden, values generally remain fairly constant from one sampling event to the next.

~~Ground water from wells completed in the underburden is generally sodium-bicarbonate type water. SHMW-05D has a slightly elevated proportion of sulfate, but similar to wells completed in the D coal, this pattern does not correlate to distance along the flow path (Figure 2.5-6-3)). Values for laboratory pH range from 8.1 to 8.8, with an average of 8.5. This is slightly higher than that observed in wells completed in the overburden and D Coal. Concentrations of TDS and laboratory EC range from 1,070 to 1,520 mg/L and 1,700 to 2,260 μmhos/cm, respectively. A range of SAR values is observed, from 25.7 to 63.7 and, as with wells completed in the overburden and D Coal, and values generally decrease downgradient. For the majority of analytes there is a more constrained range of values relative to the ranges observed for wells completed in the overburden and D Coal. For every analyte and all wells completed in the underburden, values remain fairly constant from one sampling event to the next.~~

Water Quality Data for Wells Completed in the HT Butte

Ground water from wells completed in the HT Butte is generally sodium-bicarbonate type water and plot with similar signatures on a Piper diagram (Figure 2.5-6-4). Values for laboratory pH range from 8.2 to 8.7, with an average of 8.3. Concentrations of TDS and laboratory EC range from 1,310 to 1,800 mg/L and 1,880 to 2,420 μmhos/cm, respectively. A range of SAR values is observed, from 46.5 to 62.2.

~~Ground water from wells completed in the underburden is generally sodium-bicarbonate type water and plot with similar signatures on Figure 2.5-6-4. Values for laboratory pH range from 8.2 to 8.4,~~

~~with an average of 8.3. Concentrations of TDS and laboratory EC range from 1,310 to 1,360 mg/L and 1,880 to 2,060 μmhos/cm, respectively. A range of SAR values is observed, from 46.5 to 56.3.~~

Water Quality Data for Wells Completed in Alluvium

Ground water from the majority of wells completed in the alluvium varies in the sulfate and bicarbonate proportion and has no dominate cation but is a mixture of calcium, magnesium and sodium.~~,~~ ~~e~~Each well shows a consistent water type across sampling events~~does form a cluster on~~ (Figure 2.5-6-5). Water~~s~~ from SHMW-14A is slightly different, as depicted on Figure 2.5-6-5, and is generally sodium sulfate bicarbonate type. ~~-~~Values for laboratory pH range from 6.3 to 7.8, with an average of 7.1. Concentrations of TDS and laboratory EC range from 1,060 to 12,000 mg/L and 1,290 to 10,400 μmhos/cm, respectively, with the highest concentrations at SHMW-09A2. A range of SAR values is observed, from 3.8 to 19.3.

~~Ground water from wells completed in the alluvium varies in both the sulfate and bicarbonate proportion as well as in the calcium, magnesium and sodium proportion as displayed on Figure 2.5-6-5. Values for laboratory pH range from 6.3 to 7.8, with an average of 7.2. Concentrations of TDS and laboratory EC range from 1,100 to 5,880 mg/L and 1,453 to 6,389 μmhos/cm, respectively, with the highest concentrations at SHMW-09A2. A range of SAR values is observed, from 4.3 to 19.3.~~

Water Quality Data for Seeps and Springs

Of the eight seeps and springs identified, four have been sampled. All eight seeps and springs are shown on Figure 2.5-1 of SHLM Permit Application Section 2.5. Water from the seeps and springs locations SHSS-16, SHSS-17A and SHSS-17ST is sodium-sulfate and sodium-sulfate-bicarbonate type ~~water~~ (Figure 2.5-6-6). For these sampling locations, values for pH range from 6.2 to 8.8, with an average of 7.4. Concentrations of TDS and EC values range from 2,750 to 6,240 mg/L and from 3,314 to 7,909 μmhos/cm, respectively. A range of SAR values is observed, from 17.9 to 38.3.

Seeps SHSS-20 and SHSS-20A, are located immediately downgradient from storm water detention ponds for a Western Area Power Authority (WAPA) substation adjacent to the Study Area. Only SHSS-20 was sampled and displays distinctly different water chemistry from that of the other locations. This spring water quality is not considered representative of that occurring elsewhere in the Study Area. While water from SHSS-20 is sodium-magnesium-sulfate type with a range of SAR values from 23.1 to 24.2, there is a higher concentration of calcium, magnesium, and sodium than in

the other seeps and springs. Values for pH average 4.9, which is lower than all of the other seeps/springs and ground water pH values in the Study Area. Concentrations of TDS and EC values are considerably higher, with an average of 20,700 mg/L and 16,780 μmhos/cm, respectively. WAPA has been notified of the water quality results by SHC or its affiliates. A WAPA representative in the field requested that the site no longer be sampled.

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TABLES

FIGURES