Technical Report to the

U.S. Department of the Interior

Bureau of Land Management

Results of Environmental Monitoring from 2004 to 2007 at the Belle Eldridge Site, Lawrence County, South Dakota

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Executive Summary

This report describes monitoring during 2004, 2005, 2006, and the first half of 2007 at the Belle Eldridge Mine site in Lawrence County southeast of Deadwood, South Dakota. The abandoned mine is on property controlled by the U.S. Department of the Interior, Bureau of Land Management. The site was characterized in 1998 and was remediated by the Bureau of Land Management during 1999-2001. Environmental monitoring and analysis of water and sediment samples indicate that remediation of the site and the emplacement of tailings within a repository was appropriate. Values of pH in water samples from the mine adit and Spruce Gulch Creek were nearly neutral during the monitoring period, and specific conductance values were lower than before remediation, clearly indicating positive effects from remediation. During much of the monitoring period, particularly in 2005, water was not flowing from the Belle Eldridge adit. Water samples at the site showed some variability but in general were consistent from one sampling period to the next. Several arsenic concentrations exceeded the U.S. Environmental Protection Agency's maximum contaminant level of 10 parts per billion for drinking water. Dissolved lead concentrations did not exceed the maximum contaminant level of 50 parts per billion for drinking water in any of the samples; however, one analysis for total lead from the adit drainage showed a concentration of 75 parts per billion. Total cadmium concentrations also were above the maximum contaminant level of 10 parts per billion for drinking water at some locations, and zinc concentrations were above the recommended maximum contaminant level of 5 parts per million in some samples.

During remediation of the site in 1999-2001, nearly all tailings and sediment samples had significantly high heavy metal concentrations, including arsenic, cadmium, copper, iron, manganese, and zinc. Although some of the sediment samples were acidic and some were nearly neutral in pH, almost all were heavily contaminated, indicating the potential for downstream migration of contamination off-site if the sediment and tailings material had not been placed in a repository. This was especially important because the Grizzly Gulch forest fire of July, 2002, consumed much of the Belle Eldridge site and resulted in greater than normal erosion and sediment flushing during the months following the wildfire. Had the site not been remediated and the tailings emplaced within a capped repository, it is likely that off-site migration of heavy metals within sediments, and subsequent generation of acidity, would have been significant at downstream locations. During monitoring, Spruce Gulch Creek appeared to have little turbidity or suspended sediments at the Belle Eldridge site, including the area of the former tailings dam. Thus, little suspended sediment was transported off-site to downstream areas. In addition, concentrations of dissolved metals in Spruce Gulch Creek generally were low.

Iron staining on rocks below the adit drainage did not appear to be associated with acidity because only one pH value below 6 was measured during the monitoring period, and most values were nearly neutral. The iron staining is likely to be caused when the adit drainage, with dissolved iron concentrations, becomes oxygenated in the turbulent flow below the adit. Iron then precipitates as it is oxidized from ferrous iron to ferric iron and subsequently forms ferric hydroxide.

Introduction

The Belle Eldridge abandoned mine site is one mile southeast of Deadwood in NW ¼ NW ¼ sec. 25 and NE ¼ NE ¼ sec. 26, T 5 N, R 3 E, Lawrence County, South Dakota (Figure 1). The site is on land controlled by the U.S. Department of the Interior, Bureau of Land Management. The Belle Eldridge Mine was a lead-zinc mine that operated sporadically until the 1950s. The site was characterized in previous work by Webb and Davis (1998) and was remediated by the Bureau of Land Management during 1999-2001. At the time of characterization in 1998, the site had a mill, several smaller buildings, and an open portal with seasonal drainage. Tailings occurred at and below the mill site, behind a tailings dam, and along the banks of Spruce Gulch, a tributary of Whitewood Creek. Several residences are located on Spruce Gulch below the site.

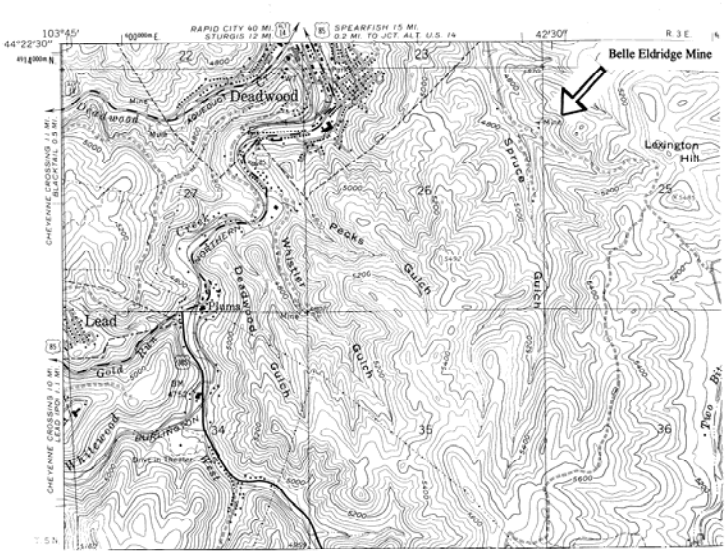

Figure 1. Belle Eldridge Mine location in Lawrence County, South Dakota (base map from U.S. Geological Survey's 1:24,000-scale Deadwood South topographic map).

During remediation of the site, tailings and waste rock were removed and emplaced first within a temporary repository and later in a capped, permanent repository. Contaminated sediments in Spruce Gulch and tributaries, as well as trapped material behind a dam, also were removed and emplaced in the permanent repository. Following remediation, the site was monitored. An earlier report (Davis and others, 2005) described monitoring during 2001, 2002, and 2003. This report describes field work and the results of sampling during 2004, 2005, 2006, and the first part of 2007, and provides conclusions to date about results of the remediation.

The mine site occupies approximately 2 ha (5 ac) in Spruce Gulch. The site was forested until the Grizzly Gulch forest fire of July, 2002, consumed most of the vegetation and several structures in Spruce Gulch. During the months following the fire, sediment erosion increased greatly in burned areas because of lack of vegetation.

Site Monitoring

Water samples were collected at the site during monitoring in 2004, 2005, 2006, and the first half of 2007, after the remediation activities of 1999-2001. Samples were collected from the Belle Eldridge adit at the site and from surface water in Spruce Gulch Creek and tributaries (Figure 2). Field notes from sampling Analyses of water samples are shown in Appendix 1. Samples were collected at the adit (Site 1), downstream from the adit near the mill site (Site 2), on Spruce Gulch upstream from the confluence of adit drainage with Spruce Gulch Creek (Site 3), on Spruce Gulch downstream from its confluence with the adit drainage (Site 4), and at a culvert on Spruce Gulch Creek near the Ott residence (Site 5). The sites are shown on Figure 2. These also are indicated after the sample numbers in Appendix 1. Site monitoring was performed primarily by Jenifer Sorensen during 2004, by Arden Davis in 2005 and 2006, and by Joshua Valder and Arden Davis in the last half of 2006 and the first part of 2007.

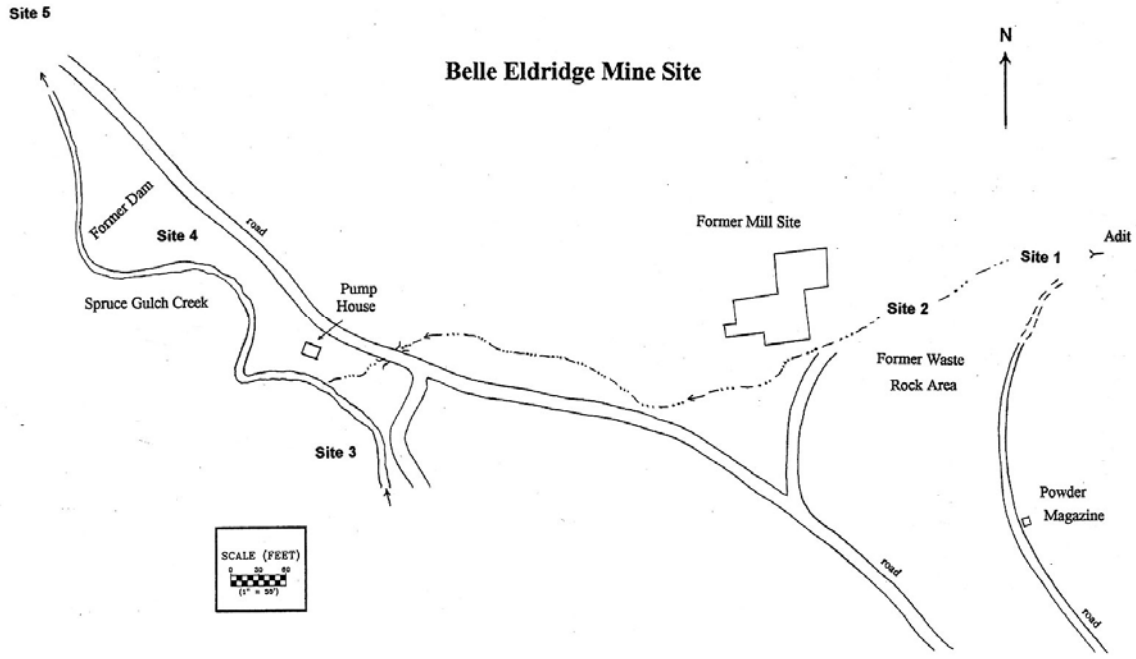

Figure 2. Sample locations during monitoring, shown as Site 1(adit drainage), Site 2 (downstream from adit near mill site), Site 3 (Spruce Gulch Creek above confluence with adit drainage), Site 4 (Spruce Gulch Creek below adit drainage), and Site 5 (Spruce Gulch Creek at culvert near Ott residence).

Field Measurements

When water samples were collected from the adit drainage and Spruce Gulch, field measurements of pH and specific conductance were taken at the same time. These parameter values and locations are shown below (Table 1). Field notes are shown in Appendix 1.

Table 1. Field values of pH and specific conductance during sampling.

Date	pH	Sp. Cond. (µmho/cm)	Location
04/10/2004	7.23	610	Site 1 (adit)
04/10/2004	7.92	645	below mill (near Site 2)
04/10/2004	7.98	213	Site 3 (just above adit drainage channel on Spruce Gulch Creek)
04/10/2004	7.92	229	Site 4 (just below adit drainage channel on Spruce Gulch Creek)
04/10/2004	8.04	229	Site 5 (Spruce Gulch Creek at Ott driveway crossing – culvert)
05/17/2004	5.35	1052	Site 1 (adit)
05/17/2004	dry	dry	below mill site (near Site 2) – dry
05/17/2004	7.71	238	Site 3 (just above adit drainage channel on Spruce Gulch Creek)
05/17/2004	8.09	241	Site 4 (just below adit drainage channel on Spruce Gulch Creek)
05/17/2004	8.22	239	Site 5 (Spruce Gulch Creek at Ott driveway crossing – culvert)
06/30/2004	no measurement	no measurement	Site 1 (adit)
06/30/2004	dry	dry	below mill site (near Site 2) – dry
06/30/2004	7.98	274	Site 3 (just above adit drainage channel on Spruce Gulch Creek)
06/30/2004	8.11	280	Site 4 (just below adit drainage channel on Spruce Gulch Creek)
06/30/2004	8.25	272	Site 5 (Spruce Gulch Creek at Ott driveway crossing – culvert)

Table 1 (continued). Field values of pH and specific conductance during sampling.

07/30/2004	6.12	1031	Site 1 (adit) – rained in past 24 hrs
07/30/2004	dry	dry	below mill site (near Site 2) – dry
07/30/2004	7.9	295	Site 3 (just above adit drainage channel on Spruce Gulch Creek)
07/30/2004	8.09	310	Site 4 (just below adit drainage channel on Spruce Gulch Creek)
07/30/2004	8.25	286	Site 5 (Spruce Gulch Creek at Ott driveway crossing – culvert)
08/31/2004	dry	dry	Site 1 (adit) – no flow
08/31/2004	dry	dry	below mill site (near Site 2) – dry
08/31/2004	8.03	312	Site 3 (just above adit drainage channel on Spruce Gulch Creek)
08/31/2004	8.21	310	Site 4 (just below adit drainage channel on Spruce Gulch Creek)
08/31/2004	8.38	307	Site 5 (Spruce Gulch Creek at Ott driveway crossing – culvert)
09/28/2004	dry	dry	Site 1 (adit) – no flow
09/28/2004	dry	dry	below mill site (near Site 2) – dry
09/28/2004	8.12	254	Site 3 (just above adit drainage channel on Spruce Gulch Creek)
09/28/2004	no measurement	302	Site 4 (just below adit drainage channel on Spruce Gulch Creek)
09/28/2004	8.64	304	Site 5 (Spruce Gulch Creek at Ott driveway crossing – culvert)
07/03/2005	dry	dry	Site 1 (adit) – no flow
07/03/2005	dry	dry	Site 2 (near mill site) – no flow
07/03/2005	8.1	281	Site 3 (just above adit drainage channel on Spruce Gulch Creek)
07/03/2005	8.14	286	Site 4 (just below adit drainage channel on Spruce Gulch Creek)
07/03/2005	8.2	280	Site 5 (Spruce Gulch Creek at Ott driveway crossing – culvert)

Table 1 (continued). Field values of pH and specific conductance during sampling.

12/28/2005	dry	dry	Site 1 (adit) – no flow
12/28/2005	dry	dry	Site 2 (near mill site) – no flow
12/28/2005	8.34	284	Site 3 (just above adit drainage channel on Spruce Gulch Creek)
12/28/2005	8.44	272	Site 4 (just below adit drainage channel on Spruce Gulch Creek)
12/28/2005	8.4	260	Site 5 (Spruce Gulch Creek at Ott driveway crossing – culvert)
03/28/2006	7.3	650	Site 1 (adit) ~ 2 to 5 gal/min
03/28/2006	6.9	640	Site 2 (near mill site) ~ 2 gal/min
03/28/2006	8.3	275	Site 3 (just above adit drainage channel on Spruce Gulch Creek)
03/28/2006	8.4	285	Site 4 (just below adit drainage channel on Spruce Gulch Creek)
03/28/2006	8.4	282	Site 5 (Spruce Gulch Creek at Ott driveway crossing – culvert)
06/24/2006	7.5	670	Site 1 (adit) ~ 2 gal/min
06/24/2006	7.3	690	Site 2 (near mill site) ~ 1 gal/min
06/24/2006	8.1	260	Site 3 (just above adit drainage channel on Spruce Gulch Creek)
06/24/2006	8.05	280	Site 4 (just below adit drainage channel on Spruce Gulch Creek)
06/24/2006	8.05	285	Site 5 (Spruce Gulch Creek at Ott driveway crossing – culvert)
11/17/2006	6.83	522	Site 1 (adit) – a few gal/min
11/17/2006	7.1	480	Site 2 (near mill site) – small flow
11/17/2006	8.1	170	Site 3 (just above adit drainage channel on Spruce Gulch Creek)
11/17/2006	8.2	180	Site 4 (just below adit drainage channel on Spruce Gulch Creek)
11/17/2006	8.2	220	Site 5 (Spruce Gulch Creek at Ott driveway crossing – culvert)

Table 1 (continued). Field values of pH and specific conductance during sampling.

03/08/2007	6.11	736	Site 1 (adit) < 2 gal/min
03/08/2007	dry	dry	Site 2 (near mill site) – no flow
03/08/2007	7.87	148	Site 3 (just above adit drainage channel on Spruce Gulch Creek)
03/08/2007	7.64	140	Site 4 (just below adit drainage channel on Spruce Gulch Creek)
03/08/2007	7.63	134	Site 5 (Spruce Gulch Creek at Ott driveway crossing – culvert)

Sample Analysis

Water samples were sent to MidContinent Testing Laboratories, Inc., in Rapid City, South Dakota. Water sample analyses are shown in Appendix 2. Unfiltered samples were taken in the field. Because some of the samples from the adit drainage were difficult to obtain at low flow and appeared to have some turbidity, both dissolved and total metals were analyzed on certain occasions (Appendix 2).

Discussion

Water Samples

Field measurements of pH in water samples from the adit and Spruce Gulch Creek were nearly neutral during the post-remediation monitoring period, and specific conductance values were lower than before remediation (Table 1). This clearly indicates positive effects from remediation, particularly in the area below the former waste rock pile and at the former abandoned tailings above the dam that was removed. During much of the period, particularly in 2005, water was not flowing from the Belle Eldridge adit.

Water samples at the site showed some variability but in general were consistent from one sampling period to the next (Appendix 2). Several arsenic concentrations exceeded the U.S. Environmental Protection Agency's maximum contaminant level (MCL) of 10 parts per billion (ppb) for drinking water. Cadmium, copper, and zinc also were elevated in some samples. These are discussed in more detail below.

Analysis of water samples indicates that arsenic concentrations exceeded the current maximum contaminant level of 10 ppb for drinking water at several locations, including the adit (Site 1), the mill site area (Site 2), below the adit drainage in Spruce Gulch Creek at Site 4, and in Spruce Gulch Creek downstream from the site at the Ott

driveway (Site 5). A sample analyzed for total arsenic from the adit drainage on November 17, 2006, showed 61 ppb. A sample from the adit on March 8, 2007, showed 63 ppb total arsenic. A sample from Site 4 (Spruce Gulch Creek below confluence with adit drainage) showed 15 ppb total arsenic on March 8, 2007. A sample from Site 5 (Spruce Gulch Creek at Ott driveway) showed 16 ppb on the same date.

Dissolved lead concentrations did not exceed the maximum contaminant level of 50 ppb for drinking water in any of the samples analyzed during the monitoring period. However, one analysis for total lead from the adit drainage on March 8, 2007, showed a concentration of 75 ppb (Appendix 2).

Dissolved cadmium concentrations did not exceed the maximum contaminant level of 10 ppb for drinking water at any of the sites during the monitoring period. However, samples taken on June 24, 2006, showed total cadmium concentrations of 189 ppb at Site 1 (adit) and 156 ppb at Site 2 (downstream from adit, near mill site). On that same day, total cadmium concentrations were less than 1 ppb at Site 3, Site 4, and Site 5 on Spruce Gulch Creek. Samples taken on November 17, 2006, showed total cadmium concentrations of 330 ppb at Site 1 and 63 ppb at Site 2, while concentrations were less than 1 ppb at Site 3, Site 4, and Site 5. Samples taken on March 8, 2007, showed total cadmium concentrations of 278 ppb at Site 1, with concentrations less than 1 ppb at Site 3, Site 4, and Site 5.

Copper concentrations did not exceed the recommended maximum contaminant level (RMCL) of 1 part per million (ppm) at any location during the sampling period.

Zinc concentrations exceeded the RMCL of 5 ppm at Site 1 and Site 2 in samples taken June 24, 2006. Zinc concentrations also exceeded this value at the same sites on November 17, 2006. An adit sample (Site 1) exceeded this value on March 8, 2007.

Grizzly Gulch Fire

The Grizzly Gulch wildfire of July, 2002, consumed much of the Belle Eldridge site (Figure 3; Figure 4) and resulted in greater than normal erosion and sediment flushing during the months following the wildfire (Figure 5). Had the site not been remediated and the tailings emplaced within a capped repository, it is likely that off-site migration of heavy metals within sediments, and subsequent generation of acidity, would have been significant at downstream locations. During monitoring from 2004 to the first half of 2007, Spruce Gulch Creek appeared to have little turbidity or suspended sediments at the Belle Eldridge site, including the area of the former tailings dam. Thus, little suspended sediment was transported off-site to downstream areas. In addition, concentrations of dissolved metals in Spruce Gulch Creek generally were low.

Figure 3. Photographs of the Grizzly Gulch forest fire in July, 2002.

Figure 4. Photograph of the Grizzly Gulch forest fire in July, 2002.

Figure 5. Photograph of erosion in Deadwood, South Dakota, following the Grizzly Gulch forest fire of July, 2002.

Iron Staining Below Adit Drainage

Some discoloration and iron staining were noted on rocks below the adit drainage. Although this resembled yellow-boy deposits, it did not appear to be associated with acidity because only one pH value below 6 (on May 17, 2004) was measured during the monitoring period, and most values have been nearly neutral. Analysis of water samples showed iron concentrations of about 0.13 to 0.26 mg/L and sulfate concentrations of about 190 mg/L in adit drainage at Site 1 and Site 2. The iron staining is likely to result when adit drainage, with dissolved iron and low dissolved oxygen, becomes oxygenated in the turbulent flow below the adit. Iron then can precipitate as it is oxidized from Fe^{2+} to Fe^{3+} and subsequently forms ferric hydroxide. Although somewhat unsightly, this does not indicate acidic drainage and can occur even at pH values above 7.

Summary and Conclusions

Environmental monitoring and analysis of water and sediment samples during 2004, 2005, 2006, and the first half of 2007 at the Belle Eldridge site indicates that remediation was appropriate. Field measurements of pH in water samples from the adit Spruce Gulch Creek were nearly neutral during monitoring, and specific conductance

values were lower than before remediation. This clearly indicates positive effects from remediation, particularly in the area below the former waste rock pile and abandoned tailings. Water samples at the site showed some variability but in general were consistent from one sampling period to the next. Several arsenic concentrations exceeded the U.S. Environmental Protection Agency's maximum contaminant level of 10 parts per billion for drinking water. Dissolved lead concentrations did not exceed the maximum contaminant level of 50 parts per billion for drinking water in any of the samples; however, one analysis for total lead from the adit drainage showed a concentration of 75 parts per billion. Total cadmium concentrations also were above the maximum contaminant level of 10 parts per billion for drinking water at some locations, and zinc concentrations were above the recommended maximum contaminant level of 5 parts per million in some samples.

During remediation of the site in 1999-2001, nearly all tailings and sediment samples had significantly high heavy metal concentrations, including arsenic, cadmium, copper, iron, manganese, and zinc. Although some of the sediment samples were acidic and some were nearly neutral in pH, almost all were heavily contaminated, indicating the potential for downstream migration of contamination off-site if the sediment and tailings material had not been placed in a repository. This was especially important because the Grizzly Gulch wildfire of July, 2002, consumed much of the Belle Eldridge site and resulted in greater than normal erosion and sediment flushing during the months following the wildfire. Had the site not been remediated and the tailings emplaced within a capped repository, it is likely that off-site migration of heavy metals within sediments, and subsequent generation of acidity, would have been significant at downstream locations. During monitoring, Spruce Gulch Creek appeared to have little turbidity or suspended sediments at the Belle Eldridge site, including the area of the former tailings dam. Thus, little suspended sediment was transported off-site to downstream areas. In addition, concentrations of dissolved metals in Spruce Gulch Creek generally were low.

Iron staining on rocks below the adit drainage did not appear to be associated with acidity because only one pH value below 6 was measured during the monitoring period, and most values were nearly neutral. The iron staining is likely to be caused when the adit drainage, with dissolved iron concentrations, becomes oxygenated in the turbulent flow below the adit. Iron then precipitates as it is oxidized from ferrous iron to ferric iron and subsequently forms ferric hydroxide.

References Cited

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