Appendix A20

M. Nelson, *"DENR Report on Homestake Mine Underground Inspections Water Quality Summary"*, July 2003

Homestake Mine Underground Inspections
Water Quality Summary

Prepared by:
Mark Nelson, PG, Senior Hydrologist, Minerals and Mining Program
SD Department of Environment and Natural Resources
July, 2003

Executive Summary

The primary purpose of department inspections completed on May 28, June 6, and June 13, 2003, was to ascertain if Homestake Mining Company had accomplished the mine decommissioning work that it had committed to. The department also wanted to determine if Homestake was in compliance with state and federal environmental laws. In conjunction with this work, an investigation was conducted to evaluate water quality in the mine.

The purpose of the water quality investigation was to understand potential environmental risks related to acid mine drainage, neutral pH mine drainage, residual process reagents, residual petroleum products, and polychlorinated biphenols (PCB's). 14 water samples and 29 water quality field measurements were collected during the three underground inspections. In addition, the department collected four samples from the mine reservoir during the period of August, 2002, to January, 2003, and two samples from the B&M mine sump in April 2003. Approximately 1100 chemical analyses were completed during the investigations at Midcontinent Laboratories, Rapid City, South Dakota.

This investigation increased the department's understanding of water quality issues at the Homestake mine significantly. Although some water quality concerns exist, the results indicate that mine water quality is relatively good. No indications of acid mine drainage were observed. No detectable concentrations of contaminants related to residual process reagents, residual petroleum products, and polychlorinated biphenols (PCB's) were identified. Potential environmental liabilities related to neutral pH mine drainage are present at the site, including arsenic, sulfate, and total dissolved solids.

Introduction

The Homestake mine is an immense network of tunnels, shafts, and stopes estimated to extend approximately 300 miles in total length (Davis, 2001). The mine extends from the surface to a depth of 8100 feet and underlies an area of approximately 3000 acres. The subsurface open volume of the mine workings is estimated at 15,000 acre-feet (Zahn, 2002). For a general comparison, this is roughly 1/3 the volume of Pactola Reservoir in the central Black Hills.

The three department inspections encompassed only a small portion of the total mine workings. This was due to access problems resulting from safety concerns such as unstable rock conditions, oxygen deficiency, and inundation hazards, as well as time limitations. The department inspections did include a range of depths from the 1700 Level to the 8000 Level and a range of areas in the mine from Main Ledge in the eastern part of the mine to 17 and 21 Ledges in the western part of the mine. The sections that follow include a general discussion of the occurrence of water within the mine followed by an evaluation of the investigation results in relation to potential environmental risks.

Water within the underground workings

Much of the mine served as a sub-surface conveyance system for infiltrating water. The water moved through the mine in a complex system of ditches, pipelines, and boreholes to centrally-located mine sumps associated with the shafts. The water was then pumped from the mine into the mine reservoir located on the surface prior to water treatment. The average infiltration rate of water into the mine is 700 gallons per minute (Zahn, 2002). All dewatering activities at the mine ceased on June 19, 2003. The mine closed June 27, 2003, and all underground access, ventilation, and maintenance ceased.

Most of the water observed in the mine was present in these conveyance systems, so samples and field measurements were collected from water in ditches, pipelines, and mine sumps at the various mine levels. The water quality changes as it passes through the conveyance system, mine workings, tailings backfill, and fractures as a result of water-rock interactions. In the deepest part of the mine, ground water was observed to be infiltrating into the mine directly through abandoned exploration drill holes. Photos 1 through 3 show representative areas where water was observed in the mine.

The sampling program included both mine reservoir samples and underground samples. This provides data on both the overall average water quality and the variation of water quality within the mine. The average concentration from the mine reservoir samples is effectively the overall flow-weighted average of water from all parts of the mine. The samples collected underground represent a sample population that is biased by the accessible areas of the mine actually inspected by the department. These samples provide data to understand the variation of water quality within the mine as well as the causes of this variation. However, this biased sample set is not statistically valid to use in calculations of mean or median water chemistry in the mine.

Photo 1. Water draining from pipe conveyance into ditch conveyance, 2000 Level. Water reported to be primarily surface water infiltrating from Open Cut area being conveyed to Ross Shaft sump.

Photo 2. Ground water entering mine through exploration drill hole (with valve) and entering ditch conveyance, 8000 Level.

Photo 3. Water draining from bottom of 7 Shaft towards ditch conveyance, 8000 Level.

Potential Water Quality Concerns

<u>Acid Mine Drainage</u>

Acid mine drainage (AMD) represents a major environmental liability at mines where it occurs, so an important facet of this water quality investigation focused on identifying any evidence of acid mine drainage within the mine. The Homestake ore contains a high quantity of potentially acid generating sulfide minerals estimated at 8% by volume (Caddey et al., 1991, Noble 1950). The ore and the surrounding waste rock also contain a large quantity of acid neutralizing carbonate minerals. The balance of acid generating and acid neutralizing minerals controls the propensity for a mine to develop AMD.

A number of factors can be evaluated to ascertain if a mine will develop acid mine drainage. In the case of Homestake, a long history of mining provides an opportunity to investigate if acid generation is occurring within the mine based on chemical measurements of water quality. A lag period exceeding decades may occur prior to the onset of acid generation, so this does not prove acid generation will never occur. However, the 125 year operational history of the Homestake mine provides a time period long enough to develop a comfort factor that the balance of acid generating and acid neutralizing minerals will not change significantly.

Evaluation of potential acid generation in the mine included several factors. The primary factor was collection of as many field pH measurements as possible. Additional factors include chemical analysis of the alkalinity of the mine water and the concentration of trace metals associated with acid mine drainage such as copper, cadmium, nickel and zinc.

29 field pH measurements were collected within the mine. These measurements included all types of mine water including ditch water, effluent flowing from tailings backfills,

water within silt dams and other impoundments, and water draining from wall rock fractures. pH is a measure of the hydrogen ion concentration of the water, which is the primary indicator of AMD. Figure 1 is a histogram of the pH values showing the summary statistics of the investigations. No acid pH values were identified in any part of the mine.

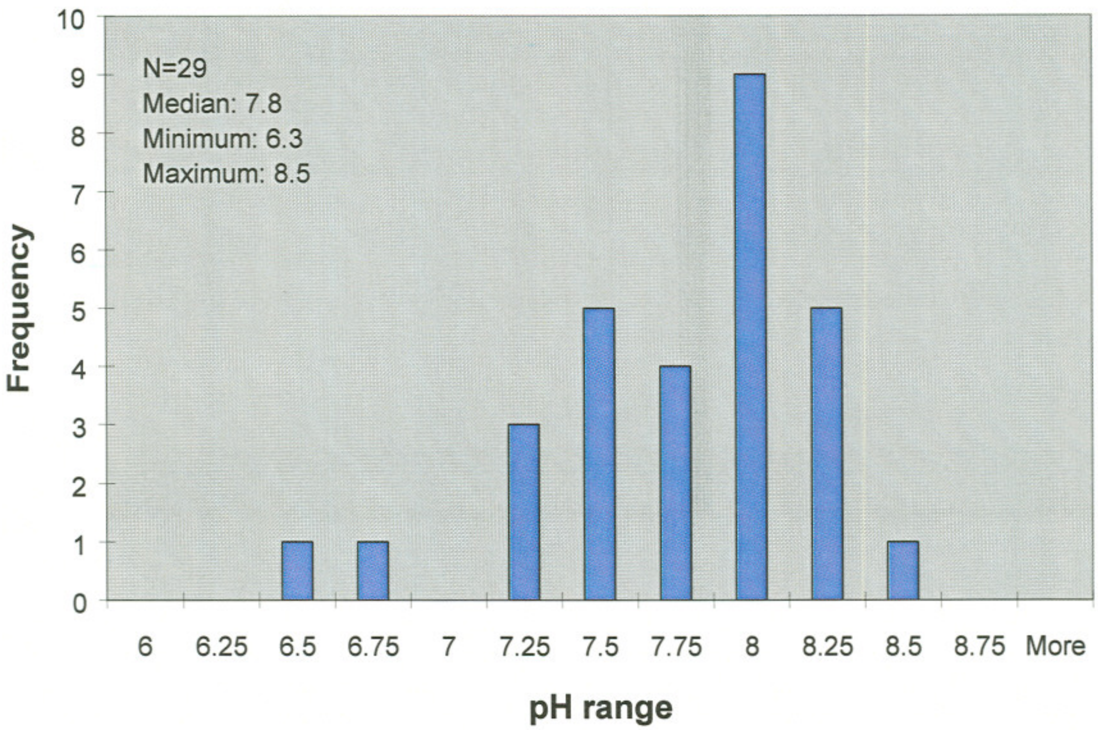

Figure 1. Field pH measurements from Homestake mine water.

A second criterion evaluated to understand the potential for AMD in the Homestake mine is the alkalinity of the mine water. Alkalinity is the ability of the water to neutralize acid (Stednick, 1991). High values of alkalinity indicate that the water will resist changing pH when acid is added. For example, if a local zone within the mine began to generate a small amount of acidity, excess alkalinity in the mine water would cause the pH of the water to remain approximately stable. This resistance to a change in pH is referred to as buffering capacity. The mine reservoir samples have a mean alkalinity of 288.3 mg/l $CaCO_3$ eq. This is within the range of alkalinities commonly observed in ground water that is in contact with rock containing carbonate minerals (Langmuir, 1997). The 14 water samples collected from various sites within the mine provide an indication of the range of alkalinity within the mine. These samples have alkalinities ranging from 181 mg/l $CaCO_3$ eq. to 674 mg/l $CaCO_3$ eq. with a median of 292 mg/l $CaCO_3$ eq. These data indicate that excess alkalinity is present in the mine water samples, which will provide buffering capacity to help counteract local zones of acid generating rock that may be present.

A third criterion evaluated was concentrations of trace metals commonly associated with AMD. In cases where AMD has been neutralized by carbonate minerals, it is possible for trace metals to remain in solution at concentrations exceeding regulatory thresholds. Important trace metals include copper, cadmium, nickel and zinc. Dissolved cadmium, nickel or zinc were not detected in any of the samples collected by the department. Trace levels of dissolved copper were present in concentrations ranging from 0.006 to 0.030 mg/l in the underground samples. The mean copper concentration of the mine reservoir samples is 0.009 mg/l. This trace concentration of copper meets both ground water and surface water standards.

It should be noted that sulfate concentrations in the mine water are generally high. These data will be described below. The high sulfate concentrations indicate that sulfide minerals are oxidizing within the mine releasing sulfate into the water. However neutralization potential in the form of carbonate minerals is apparently sufficient to counteract production of acid. No indications of acid mine drainage were observed within the mine.

Neutral pH mine drainage

A number of contaminants may be mobilized into water under neutral pH conditions. These contaminants are relatively innocuous as compared to AMD, however they can cause violations of water quality standards, require water treatment prior to discharge, and represent significant economic mine-closure liabilities (Nelson, 2003). This investigation evaluated the potential for neutral pH mine drainage through chemical analyses and field measurements. Potentially problematic contaminants evaluated include arsenic, selenium, sulfate, total dissolved solids, and sodium adsorption ratio.

The Homestake ore contains arsenic in the form arsenopyrite (FeAsS). Local arsenic concentrations in ore can be as high as 6 wt. % (Caddey, et al., 1991). The average arsenic concentration of the backfilled tailings is unknown. As a result of this concern, arsenic was evaluated in all water samples. Arsenic is present in most mine water samples, although the arsenic concentrations are relatively low. The mean dissolved arsenic concentration in the mine reservoir samples is 0.061 mg/l. Dissolved arsenic concentrations observed in samples collected from within the mine range from <0.005 to 0.049 with a median of 0.013. The mean concentration of 0.061 mg/l exceeds the South Dakota ground water standard of 0.050 mg/l. The concentration is below the surface water aquatic life standard of 0.190 mg/l.

Selenium is present in water discharging from the Sawpit and East waste rock dumps at the Homestake Open Cut. Homestake is currently evaluating water treatment options at these sites. Selenium concentrations were evaluated in all water samples, and no detectable selenium was identified.

As discussed above, oxidation of sulfide minerals in backfilled tailings and wall rocks releases sulfate into the mine water. Water that has interacted with the mine rock exhibits high sulfate concentrations. Sulfate concentrations observed within the mine range from <10 mg/l to 5848 mg/l. The lowest sulfate value occurred in ambient deep ground water entering the mine through a drill hole on the 8000 Level. The highest sulfate value occurred in water discharging from a tailings backfill on the 1850 Level. The mean concentration of the mine reservoir samples is 1527 mg/l, which exceeds the South Dakota ground water standard of 500 mg/l.

The total dissolved solids concentration in the mine water is also high. The dominant dissolved solids are sulfate, bicarbonate, magnesium, calcium, and sodium. Total dissolved solids and conductivity are two closely related water quality parameters. The mean total dissolved solids concentration from the mine reservoir samples is 2392 mg/l. This exceeds the ground water standard of 1000 mg/l, and is lower than the surface water standard of 2500 mg/l. The mean conductivity of the reservoir samples is 2803 micromhos/cm, which is higher than the surface water standard of 2500 micromhos/cm.

Sodium adsorption ratio is a surface water quality criterion related to the effect of surface water on soils. The sodium adsorption ratio of mine reservoir samples is 9.86, which is below the surface water standard of 10.

It should also be noted that the temperature of the mine water is quite warm. The temperature of the water ranged from 51° F to 131° F with a median value of 72° F.

Residual process reagents

Tailings were backfilled in the mine from the mid 1930's to mine closure in 2001. An estimated 54 million tons of backfill is present in the mine (Zahn, 2002). During this time period, ore treatment used both cyanide and mercury as process reagents. The use of mercury as a process reagent ceased in the late 1970's (R. Karsten, personal communication, 2003). In both the cyanide treatment and mercury amalgamation processes, efficient gold recovery required capturing as much cyanide and mercury as possible from the processed ore. However, residual quantities of cyanide and mercury may be associated with the tailings backfills.

Mercury was analyzed in all water samples collected in the mine as well as the mine reservoir samples. Detectible mercury was observed in only one sample, which was collected from water discharging from a timber stope backfilled with tailings on the 3800 Level. This sample contained a large quantity of solids estimated at 2.4%. The mercury identified in the sample is thought to be associated with these solids.

Cyanide was also evaluated in the sampling program. Cyanide occurs in a number of forms and cyanide toxicity is dependant of the forms of cyanide present (Mudder and Botz, 2001). This study evaluated weak acid dissociable cyanide complexes (WAD cyanide) and total cyanide. Both surface and ground water standards are based only on the WAD cyanide concentration. The total cyanide concentration includes strong cyanide complexes such as iron cyanide, which are much less toxic then the weak complexes. No WAD cyanide was observed in any of the water quality samples. Total cyanide in the mine was commonly observed in low concentrations ranging from <0.010 to 0.071 mg/l. The mean value in the mine reservoir samples is 0.028 mg/l.

The nitrogen compounds nitrate, ammonia, and nitrite are residual products of cyanide degradation (Davis et al., 1992). They are also residual products of blasting agents. These compounds were analyzed in the water samples. Nitrate was detected in most samples, although the concentrations were well below the surface and ground water standards. Nitrite was detected much less frequently, and at concentrations well below the standards. Ammonia is only regulated in surface water as unionized ammonia nitrogen. Calculating the allowable limit of unionized ammonia nitrogen requires both the temperature and pH. Based on the mean pH of the mine reservoir samples and a temperature of 65° F, the warmest temperature allowed in cold water fisheries, the allowable ammonia concentration is 0.5 mg/l. Ammonia was present in some mine samples. However, the mean ammonia concentration of the mine reservoir samples is below the surface water standard.

Residual petroleum products, solvents, or polychlorinated biphenols (PCB's)
This group of potential contaminants is composed of materials that were transported into the mine to operate or maintain mining equipment or mine infrastructure. Evaluation of potential environmental liabilities related to these compounds is based primarily on the underground inspections of mine decommissioning work at fuel storage areas, maintenance shops, and former transformer sites as well as inspections of Homestake's mine closure documentation. These activities are described in previous reports. Water samples were also collected and analyzed to test for the presence of these compounds.

Homestake used diesel equipment in the mine and operated a number of underground facilities to maintain this equipment. So the potential exists for contaminants such as diesel fuel, waste oil, and solvents to be present in the mine. The department has no data regarding the specific types or quantities of solvents that may have been used in the mine. In order to address this issue, a sample collected from the mine reservoir in January, 2003, was analyzed for a large suite of volatile organic compounds as well as total petroleum hydrocarbons in the diesel, waste oil and gasoline ranges. This screen included 56 volatile organic compounds including compounds related to fuel additives and solvents. All analyses were below detection levels.

Homestake also operated numerous transformers as part of the underground electrical system, some of which contained PCB's prior to the early 1990's (S. Mitchell, personal communication, 2003). So the potential exists for PCB's to be present in the mine water. A sample collected from the mine reservoir was analyzed for PCB's. This analysis was also less than detection.

Conclusions

This investigation increased the department's understanding of water quality issues at the Homestake mine significantly. Although some water quality concerns exist, the results indicate that mine water quality is relatively good. No indications of acid mine drainage were observed. The pH is in the neutral range and significant alkalinity is present in the water. No indications of contamination related to petroleum hydrocarbons, volatile organic compounds, or PCB's were identified.

Potential environmental liabilities related to neutral pH mine drainage are present at the site. The mine water contains concentrations of arsenic, sulfate, and total dissolved solids that are above state ground water standards. The mine water has measured levels for electrical conductivity that are above state surface water quality standards.

Changes to mine water quality may occur over time as a result of mine flooding, cessation of ventilation, inundation of backfilled tailings and other factors that may potentially impact surrounding ground and surface water resources in the future. Homestake has developed a hydrogeochemical model that predicts water quality trends as the mine floods. In the report *Geochemical Evolution of Water Quality During the Re-filling of the Homestake Mine* (Geochimica, 2003), Homestake predicts both underground and surface waters to remain neutral to slightly alkaline in pH, with low concentrations of metals and metalloids. Homestake also predicts water quality in both the flooded underground mine and Open Cut will meet water-quality criteria. As the model has uncertainties, Homestake will need establish and maintain a monitoring program to check the model as the mine floods.

References

Davis, A.D., 2001, Underground lab to mine secrets of the universe, Engineering Times, August/September 2001, 12-13.

Davis, A.D., Heriba, A., Davis, B., Webb, K.J., 1992, A testing and predictive procedure for fate of nitrate degradation products from cyanide in spent ore, South Dakota Ground-water research and public education program, USD Science Center, Vermillion, South Dakota, 33 p.

Caddey, S. W., Bachman, R.L., Campbell, T.J., Reid, R.R., and Otto, R.P., 1991, The Homestake gold mine, an early Proterozoic iron-formation-hosted gold deposit, Lawrence County, South Dakota, USGS Bulletin 1857, 67 p.

Geochimica, Inc., 2003, Geochemical evolution of water quality during re-filling of the Homestake Mine, unpublished report prepared for Homestake Mining Company, 500 p.

Langmuir, D., Aqueous Environmental Geochemistry, 1997, Prentice Hall, Upper Saddle River, New Jersey, 600 p.

Mudder, T., and Botz, M., 2001, A guide to cyanide, Mining Environmental Management, Vol. 9, No. 3, p. 8-12.

Nelson, M.R., 2003, Circumneutral pH contaminant mobility at Black Hills gold mines: Environmental concerns and long-term mine closure liability, Society of Mining Metallurgy and Exploration, Preprint 03-125, 12 p.

Nobel, J.A., 1950 Ore mineralization in the Homestake gold mine, Lead, South Dakota, Geological Society of America Bulletin, v. 61, no. 3, p. 221-252.

Stednick, J.D., 1991, Wildland Water Quality Sampling and Analysis, Academic Press, Inc., San Diego, California, 217 p.

Zahn, J., 2002, Homestake mine open cut: evaluation of the pit water recovery, Homestake Mining Co., unpublished report submitted to South Dakota Department of Environment and Natural Resources, 17 p.

Appendix 1: Underground water quality field Measurements

Location	pH	Conductivity (µS/cm)	Temperature (°C)
4850 lab access drift (ditch)	6.3		
4850 drift to 17 ledge(ditch)	7.6		
4850 by maintenance shop (ditch)	7.4	>2000	
4850 ramp 17 ledge (ditch)	7.8	1616	
4950 ramp 17 ledge (ditch)	8	1610	
7400 near 6 shaft (ditch)	7.8	>2000	
7400 33 x-cut silt dam	7.2	>2000	25
7400 drift to maintenance shop (ditch)	7.7		
7800 ramp (ditch)	8.2	1960	
7900 wall rock seep	7.8		
7950 hot spring (drill hole)	7.9	1420	54.8
8000 emergency storage dam	7.8		40.2
8000 diamond drill hole	7.6	1081	44.9
8000 7 shaft (ditch)	8.5		25.9
8000 Dunn and Bush (ditch)	8.1		34.3
8000 main pipeline (leak)	8.1		30
1700 north drift (ditch)	8.2		12.7
1700 north drift (ditch)	8.1		11.9
1700 north drift after Yates y (ditch)	7.1	>2000	10.8
1700 timber wall (puddle)	7.4		12.08
1850 sand wall (tailings backfill seep)	7.2	>2000	13.8
1850 below on ramp (ditch)	7.3	>2000	14.4
2000 bottom of 7 ledge ramp (ditch)	7.6	1010	15.5
2000 Ellison header (ditch)	7.4		15.9
2000 near Ross Shaft (pipe)	7.9	>2000	15.3
3800 #2 crosscut (tailings backfill seep)	6.6	>2000	25.9
3800 drift (ditch)	7.3		25.9
3950 ramp (ditch sump)	7.9	>2000	22
4100 near Ross Shaft (pipe)	7.9	>2000	22.1

Appendix 2: Water Quality Chemical Analyses

Parameter	Unit	HMC-17 Ledge Ramp, 4850 Level May 28, 2003		HMC-21 Ledge, 7400 Level Silt Dam May 28, 2003		HMC-21 Ledge, 8000 Level Hot Spring May 28, 2003	
Conductivity	umhos/cm	1755		6400		1310	
Hardness	mg/l	269		3969		44.3	
pH		8.72		7.82		7.91	
TDS	mg/l	1056		6679		805	
TSS	mg/l	<10		14		<10	
Acidity		0		10		<10	
Alkalinity		552		181		674	
Bicarbonate	mg/l	607		221		823	
Carbonate	mg/l	32.8		0		0	
Chloride	mg/l	15.5		33.5		24	
CN Total	mg/l	<0.010		0.052			
CN WAD	mg/l	<0.010		<0.010			
Fluoride	mg/l	4.31		1.33		3.84	
Ammonia	mg/l	<0.050		2.1		0.446	
Nitrate	mg/l	0.071		2.22		<0.050	
Nitrite	mg/l	<0.050		<0.050		<0.050	
Sulfate	mg/l	352		4698		15.2	
<u>Trace elements</u>		**<u>Dissolved</u>**	**<u>Total</u>**	**<u>Dissolved</u>**	**<u>Total</u>**	**<u>Dissolved</u>**	**<u>Total</u>**
Aluminum	mg/l	<0.050	<0.050	0.073	0.074	<0.050	<0.050
Antimony	mg/l	0.002	0.004	0.022	0.023	0.002	0.002
Arsenic	mg/l	0.016	0.016	0.006	0.021	0.026	0.031
Barium	mg/l	0.01	0.013	0.098	0.13	0.1	0.167
Beryllium	mg/l	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Cadmium	mg/l	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Calcium	mg/l	19.4		341		12.8	
Chromium	mg/l	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Cobalt	mg/l	0.015	0.015	0.056	0.077	0.004	0.004
Copper	mg/l	0.006	0.007	0.022	0.025	<0.005	<0.005
Gold	mg/l	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Iron	mg/l	<0.050	0.275	<0.050	0.823	<0.050	<0.050
Lead	mg/l	<0.001	<0.001	<0.001	0.017	0.001	0.001
Magnesium	mg/l	53.6		757		2.99	
Manganese	mg/l	<0.050	<0.050	0.214	0.338	<0.050	<0.050
Mercury	mg/l		<0.0002		<0.0002		<0.0002
Molybdenum	mg/l	0.002	0.003	0.011	0.014	0.002	0.002
Nickel	mg/l	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Potassium	mg/l	12.7		69		17.5	
Selenium	mg/l	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Silicon	mg/l	4.61	8.33	4.01	7.94	25.9	27
Silver	mg/l	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Sodium	mg/l	295		413		286	
Strontium	mg/l	<1	<1	3.06	3.28	1.43	1.55
Vanadium	mg/l	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Zinc	mg/l	<0.050	<0.050	<0.050	0.05	<0.050	<0.050

Appendix 2: Water Quality Chemical Analyses (continued)

Parameter	Unit	HMC-8000 Level Emergency Sump June 6, 2003		HMC-8000 Level, Diamond Drill Hole, June 6, 2003		HMC-8000 Level, Dunn and Bush Refrigeration Plant Site June 6, 2003	
Conductivity	umhos/cm	1419		1039		2180	
Hardness	mg/l CaCO3	126		31.8		568	
pH		8.45		8.26		8.41	
TDS	mg/l	839		609		1439	
TSS	mg/l	<10		<10		<10	
Acidity							
Alkalinity		626		533		536	
Bicarbonate	mg/l	740		651		633	
Carbonate	mg/l	12		0		10.4	
Chloride	mg/l	25.5		8.50		24.5	
CN Total	mg/l	<0.010		<0.010		<0.010	
CN WAD	mg/l	<0.010		<0.010		<0.010	
Fluoride	mg/l	3.01		2.28		3.06	
Ammonia	mg/l	0.194		0.185		<0.050	
Nitrate	mg/l	0.104		<0.050		1.32	
Nitrite	mg/l	<0.050		<0.050		0.093	
Sulfate	mg/l	103		<10		684	
Trace elements		**Dissolved**	**Total**	**Dissolved**	**Total**	**Dissolved**	**Total**
Aluminum	mg/l	<0.050	<0.050	<0.050	<0.050	<0.050	0.060
Antimony	mg/l	0.001	0.001	<0.001	<0.001	0.001	0.008
Arsenic	mg/l	0.009	0.009	<0.005	<0.005	0.014	0.014
Barium	mg/l	0.176	0.201	0.194	0.207	0.127	0.143
Beryllium	mg/l	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Cadmium	mg/l	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Calcium	mg/l	19.9		7.48		62.4	
Chromium	mg/l	<0.001	<0.001	<0.001	0.002	<0.001	<0.001
Cobalt	mg/l	0.008	0.009	0.002	0.002	0.014	0.019
Copper	mg/l	0.007	0.007	<0.005	<0.005	0.008	0.010
Gold	mg/l	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Iron	mg/l	<0.050	0.076	<0.050	0.182	<0.050	0.119
Lead	mg/l	<0.001	<0.001	<0.001	0.002	<0.001	0.002
Magnesium	mg/l	18.6		3.19		100	
Manganese	mg/l	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050
Mercury	mg/l		<0.0002		<0.0002		<0.0002
Molybdenum	mg/l	0.015	0.015	0.003	0.005	0.030	0.032
Nickel	mg/l	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Potassium	mg/l	16		8.07		25.6	
Selenium	mg/l	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Silicon	mg/l	16.7	17.3	15.1	15.1	16.9	17.8
Silver	mg/l	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Sodium	mg/l	287		224		303	
Strontium	mg/l	<1.00	<1.00	<1.00	1.03	<1.00	<1.00
Vanadium	mg/l	<0.001	<0.001	<0.001	<0.001	<1.00	<0.001
Zinc	mg/l	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050

Appendix 2: Water Quality Chemical Analyses (continued)

Parameter	Unit	HMC-8000 Level 7 Shaft June 6, 2003		HMC-8000 Level Main Pipeline June 6, 2003	
Conductivity	umhos/cm	4700		2560	
Hardness	mg/l	2568		1079	
pH		8.32		8.31	
TDS	mg/l	4573		2054	
TSS	mg/l	<10		<10	
Alkalinity		273		331	
Bicarbonate	mg/l	332		403	
Carbonate	mg/l	<5.00		<5	
Chloride	mg/l	39		22	
CN Total	mg/l	0.062		0.011	
CN WAD	mg/l	<0.010		<0.010	
Fluoride	mg/l	2.49		2.21	
Ammonia	mg/l	<0.050		<0.050	
Nitrate	mg/l	3.66		1.78	
Nitrite	mg/l	<0.050		0.191	
Sulfate	mg/l	3145		1240	
Trace elements		**Dissolved**	**Total**	**Dissolved**	**Total**
Aluminum	mg/l	0.050	2.19	<0.050	0.052
Antimony	mg/l	0.003	0.003	0.001	0.001
Arsenic	mg/l	0.014	0.060	0.021	0.024
Barium	mg/l	0.056	0.067	0.080	0.083
Beryllium	mg/l	<0.001	<0.001	<0.001	<0.001
Cadmium	mg/l	<0.001	<0.001	<0.001	<0.001
Calcium	mg/l	283		147	
Chromium	mg/l	<0.001	0.006	<0.001	<0.001
Cobalt	mg/l	0.029	0.029	0.015	0.017
Copper	mg/l	0.030	0.057	0.011	0.012
Gold	mg/l	0.001	0.002	<0.001	<0.001
Iron	mg/l	0.054	15.2	<0.050	0.380
Lead	mg/l	<0.001	0.002	<0.001	<0.001
Magnesium	mg/l	452		173	
Manganese	mg/l	<0.050	0.846	0.184	0.196
Mercury	mg/l		<0.0002		<0.0002
Molybdenum	mg/l	0.036	0.038	0.025	0.025
Nickel	mg/l	<0.005	0.009	<0.005	<0.005
Potassium	mg/l	73.1		32.9	
Selenium	mg/l	<0.005	<0.005	<0.005	<0.005
Silicon	mg/l	10.5	14.8	11.5	12.1
Silver	mg/l	<0.001	<0.001	<0.001	<0.001
Sodium	mg/l	401		232	
Strontium	mg/l	1.88	2.05	1.16	1.25
Vanadium	mg/l	0.002	0.005	<0.001	<0.001
Zinc	mg/l	<0.050	0.194	<0.050	0.054

Appendix 2: Water quality chemical analyses (continued)

Parameter	Unit	HMC-1850 Level Backfill Seep June 13, 2003		HMC-2000 Level, 7 Ledge Ramp Ditch June 13, 2003		HMC-2000 Level, Near Ross Shaft June 13, 2003	
Hardness	mg/l CaCO3	4970		711		3231	
TDS	mg/l	8593		918		4285	
Acidity		16		<10		<10	
Alkalinity		266		183		303	
Bicarbonate	mg/l	325		223		370	
Carbonate	mg/l	0		0		0	
Chloride	mg/l	30		24		37	
CN Total	mg/l					0.071	
CN WAD	mg/l					<0.010	
Nitrate	mg/l	1.22		1.85		0.220	
Sulfate	mg/l	5848		596		2979	
Trace elements		**Dissolved**	**Total**	**Dissolved**	**Total**	**Dissolved**	**Total**
Aluminum	mg/l	0.477	0.980	<0.050	0.062	0.062	0.130
Arsenic	mg/l	<0.005	0.012	0.006	0.009	0.049	0.060
Cadmium	mg/l	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Calcium	mg/l	442		172		329	
Chromium	mg/l	0.005	0.005	<0.001	<0.001	<0.001	<0.001
Copper	mg/l	0.020	0.020	<0.005	<0.005	0.007	0.010
Iron	mg/l	<0.050	10.3	<0.050	0.100	<0.050	0.085
Lead	mg/l	<0.005	<0.005	<0.001	<0.001	<0.001	<0.001
Magnesium	mg/l	939		68.3		585	
Manganese	mg/l	0.152	0.342	<0.050	<0.050	<0.050	<0.050
Mercury	mg/l		<0.0002		<0.0002		<0.0002
Nickel	mg/l	<0.005	0.006	<0.005	<0.005	<0.005	<0.005
Potassium	mg/l	63		10.6		33.7	
Selenium	mg/l	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Silver	mg/l	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Sodium	mg/l	518		39.7		96.0	
Zinc	mg/l	<0.050	0.070	<0.050	<0.050	<0.050	0.053

Appendix 2: Water quality chemical analyses (continued)

Parameter	Unit	HMC-3800, 2 Crosscut, Backfill Seep, June 13, 2003		HMC-3950, Ramp Ditch June 13, 2003		HMC-4100 Level, Near Ross Shaft June 13, 2003	
Hardness	mg/l CaCO3	3751		2176		2057	
TDS	mg/l	4941		3309		2795	
TSS	mg/l	24100					
Acidity		40		<10		0	
Alkalinity		281		247		249	
Bicarbonate	mg/l	343		301		304	
Carbonate	mg/l	0		0		<5	
Chloride	mg/l	22		24		27	
CN Total	mg/l			0.028		0.018	
CN WAD	mg/l			<0.010		<0.010	
Nitrate	mg/l	0.293		1.85		0.641	
Sulfate	mg/l	3629		2370		1879	
Trace elements		**Dissolved**	**Total**	**Dissolved**	**Total**	**Dissolved**	**Total**
Aluminum	mg/l	0.208	10.1	0.101	0.114	0.094	0.194
Arsenic	mg/l	0.012	8.18	0.011	0.011	0.037	0.051
Cadmium	mg/l	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Calcium	mg/l	493		263		240	
Chromium	mg/l	<0.001	0.016	<0.001	0.001	<0.001	<0.001
Copper	mg/l	0.009	0.096	0.012	0.012	<0.005	0.009
Iron	mg/l	<0.050	141	<0.050	0.098	<0.050	0.442
Lead	mg/l	<0.001	0.003	<0.001	<0.001	<0.001	<0.001
Magnesium	mg/l	612		369		354	
Manganese	mg/l	2.06	4.72	<0.050	<0.050	<0.050	<0.050
Mercury	mg/l		0.0040		<0.0002		<0.0002
Nickel	mg/l	<0.005	0.010	<0.005	<0.005	<0.005	<0.005
Potassium	mg/l	69.2		38.8		15.8	
Selenium	mg/l	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Silver	mg/l	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Sodium	mg/l	85.8		230		99.8	
Zinc	mg/l	<0.050	0.101	<0.050	0.062	<0.050	0.051

Appendix 2: Water quality chemical analyses (continued)

Parameter		Mine Reservoir 8/26/02		Mine Reservoir 9/20/02		Mine Reservoir 1/21/03	
Conductivity	umhos/cm	2760		2850		2760	
Hardness	mg/l CaCO3	1274		1574		1364	
pH		8.17		8.09		8.15	
TDS	mg/l	2335				2421	
TSS	mg/l	<5		10		<5	
Turbidity	mg/l	2.2				5	
Acidity		<10		<10		<10	
Alkalinity		309		248		309	
Bicarbonate	mg/l	376		303		377	
Carbonate	mg/l	0		0		0	
Chloride	mg/l	26.5		21		25	
CN Total	mg/l	0.031		0.036		0.017	
CN WAD	mg/l	<0.010		<0.010		<0.010	
Fluoride	mg/l	1.88		1.46		1.82	
Ammonia	mg/l	0.14		0.088		0.077	
Nitrate	mg/l	2.47		2.24		1.95	
Nitrite	mg/l	<0.050		<0.050		<0.050	
Sulfate	mg/l	1425		1656		1503	
Trace elements		Dissolved	Total	Dissolved	Total	Dissolved	Total
Aluminum	mg/l	<0.050	<0.050		0.211	<0.050	0.053
Antimony	mg/l	<0.001	<0.001		<0.001	<0.001	<0.001
Arsenic	mg/l	0.07	0.089		0.107	0.063	0.077
Barium	mg/l	0.071	0.08		0.092	0.047	0.051
Beryllium	mg/l	<0.001	<0.001		<0.001	<0.001	<0.001
Cadmium	mg/l	<0.001	<0.001		<0.001	<0.001	<0.001
Calcium	mg/l	149		210		162	
Chromium	mg/l	<0.001	0.002		<0.001	<0.001	<0.001
Cobalt	mg/l	0.032	0.033		0.016	0.014	0.015
Copper	mg/l	0.011	0.012		0.018	0.005	0.008
Gold	mg/l	<0.001	<0.001			<0.001	0.001
Iron	mg/l	0.055	0.295		<0.050	<0.050	0.787
Lead	mg/l	<0.001	<0.001		<0.001	<0.001	<0.001
Lithium	mg/l	0.178	0.182		0.154	0.155	0.165
Magnesium	mg/l	219		255		233	
Manganese	mg/l	<0.050	0.053		0.303	0.367	0.442
Mercury	mg/l	<0.0002	<0.0002		<0.0002		<0.0002
Molybdenum	mg/l	0.005	0.007		0.003	0.003	0.003
Nickel	mg/l	<0.005	<0.005		0.006	<0.005	<0.005
Potassium	mg/l	37.6		5.93		35.3	
Selenium	mg/l	<0.005	<0.005		<0.005	<0.005	<0.005
Silicon	mg/l	4.82	4.92		5.11	9.39	9.89
Silver	mg/l	<0.001	<0.001		<0.001	<0.001	<0.001
Sodium	mg/l	221		166		222	
Strontium	mg/l	3.2	3.99		3.37	1.44	1.57
Vanadium	mg/l	<0.001	<0.001		<0.001	<0.001	<0.001
Zinc	mg/l	<0.050	0.058		0.055	<0.050	0.061

Appendix 2: Water quality chemical analyses (continued)

		Mine Water 1/21/03		B&M Tunnel 4/22/03		B&M Tunnel 4/22/03	
Cond	umhos/cm	2840		2850		2830	
Hardness	mg/l CaCO3	1409		2066		2037	
pH		8.24		8.12		8.12	
TDS	mg/l	2480		2934		2861	
TSS	mg/l	<10		<10		<10	
Turbidity	mg/l	3.6		1.6		1.4	
Acidity		<10		<10		<10	
Alkalinity		307		205		205	
Bicarbonate	mg/l	375		250		250	
Carbonate	mg/l	0		0		0	
Chloride	mg/l	24		28		27	
CN Total	mg/l	0.017		<0.010		<0.010	
CN WAD	mg/l	<0.010		<0.010		<0.010	
Fluoride	mg/l	1.88		0.373		0.369	
Ammonia	mg/l	<0.050		<0.050		<0.050	
Nitrate	mg/l	1.69		0.054		0.054	
Nitrite	mg/l	<0.050		<0.050		<0.050	
Sulfate	mg/l	1500		1894		1861	
Trace element		Dissolved	Total	Dissolved	Total	Dissolved	Total
Aluminum	mg/l	<0.050	<0.050	0.052	0.14	0.052	0.213
Antimony	mg/l	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Arsenic	mg/l	0.042	0.065	<0.005	<0.005	<0.005	<0.005
Barium	mg/l	0.064	0.066	0.039	0.039	0.033	0.035
Beryllium	mg/l	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Cadmium	mg/l	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Calcium	mg/l	165		260		242	
Chromium	mg/l	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Cobalt	mg/l	0.017	0.018	0.016	0.017	0.017	0.017
Copper	mg/l	0.006	0.007	<0.005	<0.005	<0.005	<0.005
Gold	mg/l	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Iron	mg/l	0.055	0.51	<0.050	0.203	<0.050	0.145
Lead	mg/l	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Lithium	mg/l	0.157	0.171	0.046	0.05	0.043	0.051
Magnesium	mg/l	242		344		348	
Manganese	mg/l	0.059	0.069	0.107	0.148	0.106	0.126
Mercury	mg/l		<0.0002		<0.0002		<0.0002
Molybdenum	mg/l	0.003	0.004	0.002	0.002	0.002	0.002
Nickel	mg/l	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Potassium	mg/l	35.3		11.9		11.8	
Selenium	mg/l	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Silicon	mg/l	9.6	9.67	3.47	3.62	3.22	3.79
Silver	mg/l	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Sodium	mg/l	205		33.9		33.5	
Strontium	mg/l	1.9	1.92	2.69	3.04	2.67	2.67
Vanadium	mg/l	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Zinc	mg/l	<0.050	0.056	<0.050	0.059	<0.050	0.055

Appendix 3. Volatile organic compounds in sample from mine reservoir, 1/22/03.

Parameter	Concentration (µg/l)
Benzene	<1.0
Bromobenzene	<1.0
Bromochloromethane	<1.0
Bromodichloromethane	<1.0
Bromoform	<1.0
Bromomethane	<1.0
N-Butylbenzene	<1.0
Sec-Butylbenzene	<1.0
T-Butlbenzene	<1.0
Carbon Tetrachloride	<1.0
Chlorobenzene	<1.0
Chloroethane	<1.0
Chloroform	<1.0
Chloromethane	<2.0
2-Chlorotoluene	<1.0
4-Chlorotoluene	<1.0
Dibromochloromethane	<1.0
1,2-Dibromo-3-Chloropropane	<5.0
1,2-Dibromethane	<1.0
Dibromethane	<1.0
Dichlorodifluoromethane	<1.0
1,2-dichlorobenzene	<1.0
1,3-dichlorobenzene	<1.0
1,4-dichlorobenzene	<1.0
1,1-Dichloroethane	<1.0
1,2-Dichloroethane	<1.0
1,1-Dichloroethene	<1.0
Cis-1,2-Dichloroethene	<1.0
Trans-1,2- Dichloroethene	<1.0
1,2-Dichloropropane	<1.0
1,3- Dichloropropane	<1.0
2,2- Dichloropropane	<5.0
1,1- Dichloropropene	<1.0
Ethylbenzene	<1.0
Hexachlorobutadiene	<2.0
Cumeme (Isopropylbenzene)	<1.0
Isopropyltoluene	<1.0
Methylene Chloride	<5.0
Napthalene	<5.0
N-Propylbenzene	<1.0
Styrene	<1.0
1,1,1,2-Tetrachloroethane	<1.0
1,1,2,2-Tetrachloroethane	<1.0
Tetrachloroethene	<1.0
Trichlorofluoromethane	<1.0
1,2,3-Trichloropropane	<1.0
1,2,4-Trimethylbenzene	<1.0
1,2,5-Trimethylbenzene	<1.0
Vinyl Chloride	<2.0
Total Zylenes	<2.0

Appendix 4. Petroleum hydrocarbon analyses from mine reservoir water sample.

Sample date	**TPH-Waste Oil (mg/l)**	**TPH-Diesel (mg/l)**	**TPH-Gas (µg/l)**
1/22/03	<1.0	<0.050	
1/28/03			<100

Sample Date	**MTBE (µg/l)**	**Benzene (µg/l)**	**Toluene (µg/l)**	**Ethyl Benzene (µg/l)**	**Xylenes (µg/l)**
1/22/03	<2.0	<1.0	<1.0	<1.0	<3.0

Appendix 5. PCB analysis of mine reservoir sample collected 4/7/03.

Parameter	**Concentration (µg/l)**
Aroclor 1016	<1.0
Aroclor 1221	<1.0
Aroclor 1232	<1.0
Aroclor 1242	<1.0
Aroclor 1248	<1.0
Aroclor 1254	<1.0
Aroclor 1260	<1.0