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REDUCING SURFACE HAZARDS AND MINIMIZING ENVIRONMENTAL DISTURBANCE AT THE AURORA-GUINDON MINE IN SOUTH EASTERN B.C.

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ABSTRACT

There are numerous mine sites across Canada and throughout the world that are considered inactive. Falconbridge Limited (Falconbridge) has developed a method of property management to reclaim such sites. The process involves a property assessment with the objective of determining the best-fit reclamation solution based on social, technical and economical realities, which can then be implemented. This management tool has been proven as an effective method for the company, to meet the regulatory requirements for reclamation and closure.

This approach to inactive property management was applied to the historic Aurora-Guindon mine. Lakefield Research Limited (LRL) conducted the site assessment on behalf of Falconbridge in 1995, characterizing waste dump materials and water quality. Based on this assessment, a reclamation proposal for the property was submitted to the BC Ministry of Energy and Mines (BCMEM) for approval. Reclamation work was conducted on the property in August of 1998, and two post-construction sampling events have taken place to monitor the effect on water quality.

This paper and presentation will exhibit the cooperation between government, industry and consultants to determine the best reclamation option for an inactive property.

INTRODUCTION

Site Description

The Aurora-Guindon mine site is comprised of two properties, the Aurora and Guindon mines, situated parallel to one another on the west shore of Moyie Lake, 40 kilometres south of Cranbrook, B.C.. St. Eugene Mining Corp. Limited (subsidiary of Falconbridge) is the holder of land title. Limited mining of the

lead-zinc-silver deposit occurred approximately between 1900 and 1927. Mining activity at the site predated permitting under provincial and federal legislation.

Management Process Overview

An environmental site assessment of the mine site was conducted by LRL on behalf of Falconbridge in July 1995. The report titled *Environmental Site Assessment Report for the Aurora-Guindon Property, Moyie, British Columbia* (February, 1996) was submitted with the report titled *1998 Reclamation Program Proposal, Aurora-Guindon Mine Site, Moyie Lake, British Columbia* to BCMEM in June 1998. Following approval in August, 1998, reclamation work took place over a three week period in August and September, 1998 under the supervision of LRL. In March, 1999 a summary report of the reclamation program titled *1998 Reclamation Program, Aurora-Guindon Mine Site, Moyie, British Columbia* was submitted to BCMEM. Post-construction water quality was assessed in spring, 1999, with results submitted to BCMEM, and in late summer, 1999. Based on the reclamation program and results of water quality monitoring, Falconbridge has requested that BCMEM provide the company with a statement on the results of the reclamation program.

RECLAMATION PROGRAM

Obtaining Necessary Approvals and Permits

Necessary approvals and permits were obtained from BCMEM and B.C. Ministry of Forests (BCMOF) regional offices located in Cranbrook.

Issues of greatest priority during review of the program by BCMEM included the character of the waste rock, public safety, and water quality. Approval was given to secure openings and control water, with approval to reslope, cap and revegetate waste dumps contingent on additional characterization of waste rock materials. Access to the site was restricted and monitored. Minimizing the impact on water quality was addressed through method and timing of reclamation activities, water control measures, and water quality monitoring.

A Free Use Permit was granted by BCMOF, authorizing timber harvest for the purpose of constructing an access road to the Aurora mine site.

Site Access

The original access route on Falconbridge property to the site required improvement. It was recommended a temporary Bailey bridge be installed to provide access for the equipment that would be required during the reclamation program. From this water crossing approximately 7 kilometres of trails would require widening and subsequent reclamation. This option was very expensive.

Three private property owners held parcels of land adjacent to the Falconbridge claims. One property owner agreed to allow site access, encouraged that the Aurora-Guindon mine site would be reclaimed. It was negotiated that access on their property be reclaimed to its original condition. The access utilized their existing driveway and crossed along the foreshore of Moyie Lake on the original trail to the mine site. This route decreased road construction by 5 kilometres.

Once construction of access had advanced to the Falconbridge property, the trail was upgraded to a typical haulage road (5 metre width) to the location of Aurora Adit 1. This allowed all equipment and service vehicles required to access the mine site. Road construction was completed utilizing on-site timbers to construct the down slope cribbing. Access from Adit 1 onward, was developed with native till (sandy gravel) for the road bed.

WASTE ROCK ANALYSIS

Environmental Site Assessment

Waste rock samples collected during the environmental site assessment conducted in 1995 were subjected to metal scan by ICP and Acid Base Accounting (ABA) using the B.C. Initial Static Test. Reports *Environmental Site Assessment Report for the Aurora-Guindon Property Moyie B.C.* (February, 1996) and the *1998 Reclamation Program Proposal, Aurora-Guindon Minesite, Moyie Lake, B.C.* (June, 1998) present the results.

All samples showed a positive net acid consuming ability, although all but one sample on the Guindon property had an ACA/APP ratio greater than the accepted safety factor ratio of four.

Additional Analysis

Additional testwork was requested by BCMEM prior to approval of the reclamation plans for the waste dumps. Dump samples on both properties were collected from a vertical profile developed with minimal disturbance, in order to determine the extent of oxidation. Samples were screened in the lab to recover the minus 10 mesh (2mm) fraction.

Test procedures to determine the metal leaching/acid rock drainage potential of the minus 10 mesh (2mm) fraction included:

- Shake flask testing on oxidized product;
- Acid base accounting (ABA) (Sobek Lawrence);
- Surface rinse pH;
- Carbonate NP determinations;
- Inductively coupled plasma (ICP) total metal scan; and,
- Analyses followed the *Guidelines and Recommended Methods for the Prediction of Metal Leaching and Acid Rock Drainage atMinesites in British Columbia* (BCMEM, 1998).

SUMMARY OF ANALYSIS

The following three tables present the results of the additional sampling work requested of Falconbridge, and are discussed below.

TABLE 1; Summary of ABA (Sobek Lawrence) Results

Sample ID	AU1S Comp	AU180 Comp	AU2S Comp	AU232 Comp	AU3S Comp	AU362 Comp	GU2S Comp	GU233 Comp
Paste pH [units]	4.77	5.49	5.74	8.84	3.64	4.68	3.9	4.65
Initial [sample pH]	2.11	2.33	2.23	2.34	2.24	2.68	2.01	2.2
NaOH to [pH=7.0]	20.9	19.35	19.4	15.4	21.05	22.15	22.0	19
HCl (mL) [consumed]	0.1	0.3	0.3	0.6	0.1	0	0.02	0.29
NP [*]	2.99	6.53	6.29	15.5	2.66	0.16	0.49	7.29
AP [*]	4.69	7.81	0.63	1.25	45.6	7.81	40.3	19.7
Net NP [*]	-1.7	-1.28	5.66	14.3	-42.9	-7.65	-39.8	-12.4
NP/AP [*]	0.64	0.84	9.98	12.4	0.06	0.02	0.01	0.37
S [%]	0.49	3.14	0.2	0.09	3.87	0.83	1.29	0.63
S= [%]	0.15	0.25	0.02	0.04	1.46	0.25	0.11	0.08
CO3 [%]	0.27	0.13	0.23	0.18	0.39	0.41	<0.05	<0.05
TOC [%]	0.61	0.07	0.38	0.18	1.14	0.7	1.87	0.28
SO4 [%]	0.7	7.7	< 0.4	< 0.4	5.7	1.1	3.5	1.6

Note:
[*] NP (Neutralization Potential)=50xHCLx(Total HCL added-(N of NaOH/N of HCL))xNaOH added / weight of sample
[*] AP (Acid Potential) = %Sulfur x 31.25
[*] Net NP (Net Neutralization Potential) = NP-AP
[*] NP/AP Ratio = NP/AP
Results expressed as tonnes CaCO3 equivalent/1000 tonnes material
TOC – Total Organic Carbon

AU – Aurora GU – Guindon 1 – Waste Rock Dump Number S – Surface 80 – Depth in Inches

TABLE 2: Summary of Shake Flask Test Pulp Using an ICP Total Metal Scan

Sample ID	AU1S Comp	AU180 Comp	AU2S Comp	AU232 Comp	AU3S Comp	AU362 Comp	GU2S Comp	GU233 Comp
Surface [pH units]	3.93	4.17	4.15	7.31	2.89	4.18	3.00	3.56
Ag [mg/L]	< 0.003	< 0.003	< 0.003	< 0.003	< 0.003	< 0.003	< 0.003	< 0.003
Al [mg/L]	0.26	0.15	0.22	0.05	7.1	6.44	13.0	21.0
As [mg/L]	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
B [mg/L]	0.04	0.02	0.04	< 0.02	0.02	< 0.01	0.05	0.01
Ba [mg/L]	0.038	0.028	0.035	0.014	< 0.002	0.054	0.018	0.025
Be [mg/L]	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	0.004	0.004
Ca [mg/L]	68.5	644	38.8	50.2	4.55	7.47	19.5	24.4
Cd [mg/L]	0.13	0.29	0.039	< 0.002	1.49	2	0.22	0.087
Co [mg/L]	0.14	0.36	0.13	< 0.004	0.12	0.15	0.074	0.64
Cr [mg/L]	< 0.004	< 0.004	< 0.004	< 0.004	< 0.004	< 0.004	< 0.004	< 0.004
Cu [mg/L]	0.024	0.009	0.029	< 0.003	0.33	0.21	0.34	0.22
Fe [mg/L]	0.027	0.21	0.006	0.009	1.39	0.077	1.73	0.40
K [mg/L]	10.2	30.6	15.2	7.13	4.74	5.1	10.5	9.85
Mg [mg/L]	3.78	3.69	2.08	2.04	7.11	2	12.0	6.93
Mn [mg/L]	13.2	23.1	10.7	0.03	5.29	4.48	1.34	5.87
Mo [mg/L]	< 0.007	< 0.007	< 0.007	0.007	0.013	< 0.007	< 0.007	<0.007
Na [mg/L]	0.81	0.87	0.58	0.75	0.64	1	0.80	1.23
Ni [mg/L]	0.09	0.28	0.1	< 0.01	0.02	0.01	0.15	0.13
P [mg/L]	0.05	0.06	< 0.03	0.05	0.05	0.07	< 0.03	<0.03
Pb [mg/L]	0.23	0.67	< 0.02	< 0.02	3.63	3.43	4.42	4.13
S [mg/L]	86.5	573	51.7	23	192	111	89.0	84.8
Sb [mg/L]	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02
Se [mg/L]	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02
Si [mg/L]	11.7	10.1	10.2	3.23	17.3	22	23.2	27.0
Sn [mg/L]	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02
Te [mg/L]	< 0.04	< 0.04	< 0.04	< 0.04	< 0.04	< 0.04	< 0.04	< 0.04
Zn [mg/L]	15.7	52	3.18	0.013	277	181	19.2	8.21

TABLE 3: Summary of Shake Flask Test Solution Using an ICP Total Metal Scan

Sample ID [µg/g]	AU1S Comp	AU180 Comp	AU2S Comp	AU232 Comp	AU3S Comp	AU362 Comp	GU2S Comp	GU233 Comp
Ag	< 5.0	<5.0	< 5.0	< 5.0	< 91	< 18	20	8.7
Al	55000	51000	55000	21000	21000	57000	42000	52000
As	61	31	132	59	2310	38.5	226	16
Ba	450	400	440	540	200	590	360	460
Be	1.8	1.7	2.1	2.4	0.9	1.8	1.8	1.8
Ca	1900	35000	1300	8400	940	7400	410	4900
Cd	10	13	1.7	1.2	94	49	2.0	0.7
Co	22	17	23	18	20	27	10	15
Cr	27	27	15	18	17	18	32	37
Cu	160	130	85	39	170	82	190	94
Fe	100000	83000	46000	200000	210000	53000	140000	67000
Hg	2.3	1.6	2.5	0.7	17.0	4.1	8.6	1.4
K	27000	27000	31000	25000	13000	16000	25000	26000
Mg	5100	4500	3300	8100	2800	7000	4000	7400
Mn	890	780	740	530	490	830	240	370
Mo	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	7.4	6.3
Na	2100	1700	2400	11000	1700	12000	1600	8500
Ni	16	11	20	28	7.9	28	<2.0	4.7
P	260	190	210	330	260	900	490	440
Pb	1140	2020	182	60	74300	13700	12300	5540
Sb	20	15	11	13	130	38	9.8	7.3
Se	<10	<10	<10	<10	<10	<10	< 10.0	< 10.0
Sn	<10	<10	<10	<10	<10	<10	< 5.0	< 5.0
Te	<10	<10	<10	<10	<10	<10	< 10	< 10
Zn	1700	1600	370	170	16000	6400	800	300

Interpretation of Analysis

ABA data for both properties indicated generally acidic paste pH, low sulphide sulphur, high sulphate sulphur, low NP and low NPR. It was observed that although samples had low sulphide sulphur, they were extensively oxidized, had stored oxidation and metal products, and were clearly generating acidic conditions and leaching metals. Shake flask testing exhibited levels of Zn, Pb, Cd, Mn, Cu, Ni, Al, Hg and As (Aurora samples only), and Fe (Guindon samples) which exceeded British Columbia Water Quality Criteria for aquatic life (B.C. Ministry of Environment, Lands and Parks, August, 1998).

Based on the results, it was recommended that reclamation of dumps involve minimal disturbance. The recommendation for minimal disturbance was supported by the lack of significant seepage from all adits, and the progress of natural revegetation on the smaller dumps on both properties. However, the dump below Aurora Adit 2 was an exception, due to the presence of wooden cribbing of questionable integrity. It was recommended the cribbing be removed to ensure dump stability, and that the work be done in dry weather. Further reclamation of the Guindon dumps was not warranted given the fact there is no significant drainage from the dumps and the dumps are small, stable, and revegetating naturally.

RECLAMATION PROGRAM: AURORA PROPERTY

On the Aurora property, work was conducted at three adits, 1 shaft, and waste dumps below Adits 1 and 2. The opening of Adit 2 was closed naturally and is stable, and therefore did not require additional securing.

Removal of Compressor and Underground Storage Tank at Adit #1

A compressor was located adjacent to Adit 1 with piping running horizontally into the underground workings and vertically into the ground. The vertical piping was attached to an underground storage tank. The empty steel tank was filled with clean water. The compressor was removed off-site.

Waste Rock at Adit 1

At Adit 1, waste rock had been dumped over a steep slope, which extended below the surface of Moyie Lake. The resultant angle was approximately 1.5:1. Reclamation work was not done at this dump so as to prevent waste material from entering the lake.

The small dump adjacent (north) of the main dump was covered with till (sandy gravel) from the on-site borrow pit, placed to a depth of 30 cm. The slope was then hydroseeded with fertilizer (18-18-18 slow release N-P-K), and wood cellulose mulch with tackifier. The seed mix was composed of: 18% creeping red fescue, 18% brome grass, 18% tall fescue, 13% rangelander alfalfa, 13% single cut red clover, 10% okay orchardgrass, 5% timothy and 5% white clover. The mulch, seed, fertilizer was applied at 1750 kg/ha, 75 kg/ha, and 400 kg/ha respectively. Following hydroseeding, the surface was covered with an erosion control blanket, constructed of a biodegradable straw and coconut fiber held together with a woven nylon mesh.

Terracing the Waste Rock at Adit 2

Due to the concern regarding the integrity of the wooden cribbing in the dump below adit 2, it was recommended the timber be removed and the dump terraced. Following removal, the dump was terraced with lifts approximately 5 metres, which acts to increase overall dump stability. Work was conducted in dry weather, to reduce the potential for metal leaching.

Following terracing, the dump was covered with till (sandy gravel) borrowed on-site, placed to a depth of 30 cm. The slope was hydroseeded using the same materials and at the same rates of application. Erosion control blankets were affixed to the lower portion of the dump face with a final grade of 1.5:1. The objective was to increase surficial stability, reduce erosion and promote vegetative growth. The upper face of the dump was at an angle of 2:1.

Managing Seepage from Adit 2

An interceptor ditch was constructed from Adit 2, along the top of the terraced dump, and down the south edge of the dump to a constructed french drain at the toe. The dump terraces were constructed to drain toward the ditch along the side of the dump, in order to facilitate overland drainage. The ditch and french drain were lined with rip-rap collected on-site. In addition, larger riprap was placed in the ditch to act as velocity diffusers, that would reduce the velocity of the intercepted water and in return reduce erosion.

Water collected on and above the dump (including seepage from Adit 2) will report to the french drain where it will filter through the native material off the south end of the dump. In the event that capacity of the drain is exceeded, water would report to a natural valley adjacent to the dump on the south side. Based on discussions with local authorities and contractors, there is historically low volumes of flow during freshet in that particular location. Also, seepage from Adit 2 is minimal year-round.

Aurora Shaft

The shaft is located mid slope between Adits 2 and 3. The opening of the shaft was sealed by blasting rock from the above hanging wall. Blasting was done by a certified blaster contracted by MacKay Contracting. The shaft is now secured with rock.

Adit 3

Due to the small size and relatively remote location, a polyurethane foam was used to seal the opening of Adit 3. The foam plug was approved by BCMEM, Cranbrook. The foam sealant was purchased from and installed by Foam Concepts Inc. from Aurora, Minnesota. The foam was activated on-site and installed to secure the opening. Following; setting, the foam product was covered with local till material.

RECLAMATION PROGRAM: GUINDON PROPERTY

Work was proposed for the four adits on the Guindon property. Adit 1 is approximately 3 metres above the surface of Moyie Lake, with waste rock dumped over the original slope below. Adit 2 and Shaft 2 were located approximately 30 metres above the surface of Moyie Lake. Adit 3 was located approximately 52 meters up slope of Adit 2. Adit 4 was located approximately 50 metres above Adit 3.

Road access was advanced from the toe of the dump at Aurora Adit 2 to the Guindon Adit 2 dump.

Adit 1

Work was not required at Adit 1, which had collapsed and was stable, with natural revegetation and minimal evidence of seepage.

Securing Shaft 2 and Adit 2

It was determined on site with BCMEM inspectors and through company reports that Shaft 2 was located within the workings of Adit 2. The shaft area was backfilled with local till material and hydroseeded as previously described. Local material which had collected in the adit over time was removed to expose the adit, which was then backfilled using local till material, and hydroseeded.

Waste Rock at Adit 2

No work was done at the Adit 2 waste dump due to its relatively small size and the progression of natural revegetation. It was determined that the dump was stable, and was not a safety concern.

Securing Adit 3

Adit 3 is located within a talus rock area, and has filled naturally. The small dump below the adit was resloped, and the adit was further secured with local talus material.

Securing Adit 4

Adit 4 was sealed by blasting, over a period of four days.

Road Reclamation

The access constructed from the property (driveway) of the private landowner to the Aurora mine, and from Aurora to Guindon was pulled back, ripped, and hydroseeded, using materials and at rates previously described.

Access on the land of the private holder was returned to original contour and seeded, and gravel was replaced for the driveway.

WATER QUALITY

Quality of water discharging from mine openings and of Moyie Lake adjacent to waste rock dumps was reported in the environmental site assessment conducted in 1995, and monitored following completion of reclamation activities in the spring and late summer of 1999. The *British Columbia Water Quality Guidelines (Criteria): 1998 Edition* (August, 1998) provided a tool for assessment, using specifically the drinking water guidelines. A primary objective in carrying out the reclamation program at the site was to prevent/minimize negative effects on water quality.

The results of the 1995 assessment showed zinc, lead and cadmium in seepage from Aurora Adit 2 in excess of the drinking water criteria. Also, the level of lead in the Moyie Lake sample from adjacent to the lowest Aurora waste dump was in excess of the drinking water criteria.

Sampling conducted in June, 1999 demonstrated that all substances analysed for, including cadmium, lead, and zinc, were within the guidelines for drinking water criteria. A second sampling event was conducted in late August, 1999.

PROJECT COMPLETION

Operation of the Aurora-Guindon mine site predated provincial and federal legislation pertaining to mining activity and environmental protection. With regard to provincial mining legislation, there are no requirements for reclamation at the site.

Falconbridge and LRL proposed a reclamation program which met with BCMEM approval. The program was reviewed and conducted in a timely and efficient manner. Post-construction monitoring over the following year as compared with pre-construction data has demonstrated a positive change in water quality exiting mine openings and in the adjacent waters of Moyie Lake.

The BCMEM has agreed that the reclamation program conducted by Falconbridge and LRL achieved objectives of ensuring public safety and minimizing environmental! disturbance.

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