Reclamation and Closure Measures for Cominco's Sullivan Mine, Kimberley, B.C.

by

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Kimberley Operations

History of Operation

Slide 1:

- Kimberley is located in the Kootenay Region of southeast B.C. in the foothills of the Purcell Mountains
- 85 km north of Canada - USA boundary
- 85 km west of B.C. - Alberta boundary

Slide 2: At present Kimberley Operations include the Sullivan mine, concentrator and drainage water treatment plant.

- all of these facilities are located on Cominco owned land within the municipal boundaries of the City of Kimberley,
- the operation produces zinc and lead concentrates which also contain silver and other minor metals,
- between 1953 and 1987 fertilizer, iron and steel were also produced at Kimberley.

Slide 3: The sullivan orebody was discovered more than 100 years ago in 1892.

Slide 4: It was a world class orebody -- roughly semi-circular in shape and approximately 2 km in diameter; the western part of the orebody is up to 90 m thick;

- eastward, ore thickness decreases from 30 m to less than 3 m at the margin,
- minerals include galena, sphalerite, pyrrhotite and pyrite.

Slide 5: Cominco acquired the orebody in 1909

- the portal and adit shown in this slide was completed in 1915 -- this was the main entrance to underground for 65 years -- until the introduction of mechanized mining in 1980.

Slide 6: Over the 85 years the mine has operated some 139 million tonnes of ore and 9 million tonnes of development waste rock have been removed from underground;

- the mine has been developed in an area of approximately 250 ha. between 730 m and 1400 m levels (2400 and 4600 ft. above sea level, respectively -- City of Kimberley elevation is between 3700 - 3900 ft. above sea level).
- total mine development exceeds a length of 650 km and comprises levels, raises, shafts and declines.

Slide 7: For most of the past 30 years mining has been primarily pillar recovery -- controlled caving of the hanging wall occurs as the pillar ore is removed -- this has resulted in subsidence and caving to surface.

Slide 8: The Sullivan Concentrator began operation in 1923 following development of a differential flotation process capable of separating the complex ore into lead, zinc and iron concentrates

- the lead and zinc concentrates were shipped to Cominco's smelter in Trail, B.C.
- between 1953 and 1987, iron concentrate (tailings) was used to produce fertilizer.

Slide 9: Since 1923 over 86 million tonne of tailings (including iron concentrate) have been discharged to impoundments.

Closure and Reclamation

Slide 10: The Sullivan mine will close in seven years in the year 2001;

- Due to the massive sulphide ore, the size of the operation and the early history of poor waste and tailing management -- there are significant acid rock drainage (ARD) and reclamation challenges that must be addressed. In addition, issues associated with the sites of the former fertilizer, iron and steel operations add to the complexity of closure.
- In May 1991, a decommissioning and closure plan was submitted to the Chief Inspector, MEMPR. This plan identified the closure issues and presented measures, that addressed these issues.

The major issues are:

1/ Land reclamation - 1000 ha of severely disturbed land that must be reclaimed to productive use,

2/ Protection of water resources - ARD abatement to protect watercourse and groundwater quality from acidic, metal containing drainage from underground mine workings and seepage from waste dumps and tailing ponds.

· Watercourses you will here reference to include Mark Creek, Lois Creek, Cow Creek and the St. Mary River. The St. Mary River is a major tributary of the Kootenay River.

3/ Public Safety - specifically, long term stability of engineered structures; sealing openings to underground, building demolition, contaminated sites and groundwater.

In addition to the plan, we have provided MEMPR with a detailed schedule of annual reclamation activities for the period 1994 through 2005 -- together with information on cost of those activities. Total cost of the program is $53 million -- of the total, about $16 million has been spent to the end of 1994 -- $23 million will be spent until the end of 2001 -- and $14 million will be required after closure. These costs do not include post closure treatment of ARD.

Watercourse Protection (ARD Abatement)

Slide 11: For the balance of this presentation, I will focus on measures being implemented to control discharge of ARD to watercourses and groundwater.

The main source of ARD, both in terms of volume and metal loading, is drainage from underground mine workings. Seepage and contaminated groundwater from waste dump and tailing disposal areas are other sources that must be addressed.

Abatement measures which are currently in place include:

- drainage water treatment plant and a variety of seepage and groundwater collection systems, and
- the Mark Creek diversion

Waste dumps and tailing ponds will be covered to reduce water entry and flushing of contaminants.

Drainage Water Treatment Plant

Slide 12: Kimberley Operations drainage water treatment plant was commissioned in 1979 to treat mine drainage and tailing effluent.

Slide 13: The plant uses lime in a high-density sludge process that neutralizes the acid and precipitates the metals into a free draining, non-leaching sludge.

The drainage water treatment plant will operate for an indefinite time following closure. There were compelling reasons for this decision:

1. there are no safe or effective means by which water can be prevented from entering the underground mine workings and becoming contaminated. The mine workings can be allowed to flood up to a certain elevation; drainage in excess of that volume must be pumped to the surface and treated;
2. government regulators will require collection and treatment as a contingency for any other technology that might be applied to prevent release of ARD from underground, waste dumps and tailing ponds.

The fact that the treatment plant must operate in perpetuity influenced decisions respecting closure techniques applied to waste dumps and tailing ponds.

Lower Mine Yard

Slide 14: The Lower Mine Yard is where most surface activity took place during the first seven decades of mine operation. Mark Creek flows through the Lower Mine Yard. Waste rock was cast downslope on the valley slopes on both sides of the creek. Prior to 1979, mine drainage discharged directly to the creek. Seepage from waste dumps and groundwater contaminated by waste dump seepage also discharged to the creek.

Measures implemented to date to protect the creek from ARD discharges include:

1. **Drainage Water Treatment Plant**:

   · since 1979 mine drainage is collected underground and is piped, through a buried pipeline, to the tailing pond

2. Mark Creek Diversion

Slide 15: Late in 1991, Mark Creek was diverted into the Mark Creek diversion channel, -- a new channel situated near the centre line of the valley away from the toe of the North waste dump.

Slide 16: The diversion consists of a concrete flume, some 275 m long, through a narrow section of the valley, and

Slide 17: a riprap lined channel, some 1175 m long, which connects back into the original creek channel downstream of the waste dumps. The flume and channel are designed for the 200 year flood event.

Slide 18: abandoned sections of the original creek channel are being used to collect seepage from the waste dump; the seepage is pumped into the pipeline that transports mine drainage to the tailing pond and then to the treatment plant.

3. Aquifer Dewatering

Slide 19: Groundwater contaminated with seepage from waste dumps was discharging to Mark Creek at a point 500 m downstream of the diversion. Hydrogeological investigations, conducted in 1992 and 1993, located the contaminated aquifer at a depth some 15 m below the surface. Two aquifer dewatering wells and pumps were installed in 1994. The system has proven effective for depressing the aquifer to an elevation which will not discharge to the creek. Contaminated groundwater is pumped into the "mine drainage pipeline".

4. **Waste Dump Reclamation**

Slide 20: The next phase of the Lower Mine Yard closure program is the reclamation of waste dumps. The dumps, as they exist, are not engineered structures. Final dump design will be based on stability investigations and Maximum Credible Earthquake standards. The final dump design must also be approved by the MEMPR.

The design and approval process for the South Dump, which is shown in this slide, has been completed. The dump will be reprofiled to provide a final slope of 2.5 H:IV. To achieve this slope it will be necessary to consolidate waste from two small dumps located west of the main dump and to cut back the crest of the main dump.

The surface of the dump will be covered with glacial till and revegetated. The cover system will be composed of a compacted till layer 0.5 m thick overlain by an uncompacted till layer also 0.5 m thick.

Slide 21: Reclamation of the dump on the north side of the valley will be more complicated because of the limited amount of space between the dump toe and the creek.

Slide 22: Abandoned buildings at the top of the dump must also be demolished. This aspect of the reclamation process has been complicated by a request from MELP to conduct a contaminated site assessment. The assessment must be completed before approval will be granted to demolish the buildings.

<u>Open Pit and Waste Dumps</u>

Slide 23: A small open pit mining operation was conducted from 1951 to 1957. Some 3 million tonne of ore and 2.5 million tonne of waste were removed from the pit. Waste was placed in dumps adjacent the pit.

For closure, all waste and contaminated soil will be excavated and placed back into the pit. Development waste generated during the last seven operating years will also be placed in the pit.

The backfilled pit will be covered with a low permeability till cover and the surface will be contoured so that surface drainage is directed of the pit area.

This closure option enhances safety, environmental and reclamation benefits without significantly affecting the cost relative to recontouring, covering and revegetating the waste dumps, providing seepage collection for the dumps and providing barriers to protect people from falling into the pit.

Tailing Ponds

Slide 24: There are 86 million tonnes of tailings stored in impoundments that occupy 380 ha. of land. Closure activities include:

Slide 25:
- stabilizing dyke structures to Maximum Credible Earthquake standard,
- construction of spillways designed to Maximum Probable Flood standard,

Slide 26:
- covering the tailing pond surface with a cover system designed to reduce water entry into the tailing mass and to sustain productive vegetation.

In addition to the above activities:

- Hydrogeological investigations, groundwater, seepage and receiving water monitoring programs are on going,
- seepage collection systems are in place and are being upgraded to improve effectiveness, and
- if necessary, groundwater collection systems will be installed.

Slide 27: The tailing cover system proposed in the closure plan consists of three layers:

Slide 28: ● capillary barrier: a layer of float rock at least 30 cm thick, that blocks upward migration of tailing moisture and protects overlying layers from contamination

Slide 29: ● moisture retention: a layer of glacial till, 45 cm thick, retains precipitation and is the growth medium for

Slide 30: ● erosion protection layer: which consists of drought tolerant grass vegetation.

The vegetation protects the till cover against wind and water erosion, uses water retained in the till layer thus reducing water entry to the tailing mass; and provides forage for animals.

The proposed tailing cover system is costly but affordable.

- it uses locally available material that is located within an affordable haul distance,
- it is capable of sustaining vegetation that exceeds biomass production on adjacent native rangeland,
- water balance calculations suggest than an average 35% of annual precipitation will percolate through the cover into tailings and this will generally only occur during snowmelt in the spring,
- based on long term mean annual precipitation, 500,000 m^3 of water will enter the tailing mass, on average each year,
- assuming the water reports as seepage, is collected and treated, reagent costs would total $25,000 per year (0.55 kg/m^3; 90$/tonne lime).

Slide 31: In 1993, a study was initiated to compare the "proposed tailing cover" with a cover system that incorporated a densely compacted layer of glacial till between the capillary barrier and the moisture retention/growth medium layer.

- The purpose of the compacted till layer was:

(1) reduce amount of precipitation entering tailings even further i.e. 5% to 10% of MAP

(2) if compacted till layer can be maintained in a saturated state, oxygen diffusion would also be reduced to a vary low rate -- in fact, the fourth plot shown in the slide, has the compacted till layer sandwiched between two capillary barriers in an attempt to prevent "drying" of the compacted layer.

- The supply of "affordable" glacial till is limited -- therefore, in designing the alternative cover systems, the thicknesses of the compacted till layer and the moisture retention/growth medium layers were limited to 30 cm each -- or a total till thickness of 60 cm (25% increase in thickness relative to the proposed cover).
- The glacial till contains stones and boulders, which exceed 30 cm in diameter; to construct a 30 cm thick compacted till layer using this material, it will be necessary to screen the material to remove, let us say, all plus 5 cm material; that was done to construct the test plots;
- The two till layers must be applied separately -- with the initial layer requiring compaction to specific engineering standards -- before the second layer can be applied.
- Therefore, in order to provide a cover system that will reduce precipitation entry to 5 to 10% of MAP, it is necessary to:

  - increase till requirement by 25%,
  - screen the till to remove stones,
  - apply the till in two lifts, and
  - compact the first lift

- These activities will certainly increase the cost of the cover system -- so what is the benefit and how confident can we be that the cover will perform as expected over the long term?
- With respect to the first question, if precipitation entry is reduced from 35% of MAP to only 5% -- the volume of tailing seepage to be treated may be reduced from 500,000 m^3/year to only 72,000 m^3/year; assuming lime consumption does not increase, then annual cost for lime will decrease from $25,000 per year to $3,600 per year -- resulting in an annual savings of between $21,000 and $22,000.
- At a real rate of return of 2% per annum, the savings would reduce a bond by approximately $1,000,000; this $1,000,000 is equivalent to an increase in cover cost of 7 to 8%; it is very unlikely that the cover system that incorporates the compacted till layer can be constructed for only 8% more than the system proposed in the closure plan.
- With respect to the second question, I am not confident that a cover system that is only 60 cm thick and which incorporates a compacted till layer that is only 30 cm thick will remain effective over the long term under climatic conditions that prevail in the Kimberley region. Eventually, with wetting/drying and freezing/thawing cycles, the compacted till layer will become less dense and more permeable. The only lasting benefit may be from the increased thickness of till i.e. increased moisture retention by 25% of volume.

SUMMARY OF RECLAMATION RELATED COSTS

Drainage Water Treatment Plant

Capital: $10,000,000 (1979 dollars) includes buried pipeline (10 km)
Operation: 700,000 - 900,000 $/yr. includes reagent costs which range $268,000 to $500,000 per year

Reclamation Costs

Public Safety

Tailing Dyke Stabilization	$ 3,236,000	
Gypsum Dyke Stabilization	1,339,000	
Mark Creek Dam Removal	651,000	
	$ 5,226,000	

Watercourse Protection

Cow Creek Clean-Up	$ 1,314,000	
Gypsum Release Pond	448,000	
	$ 1,762,000	

Lower Mine Yard

Mark Creek Diversion	$ 2,820,000	(incl. seepage coll.)
Waste Dump Reclamation - South	1,310,000	
(4 toone, 16 ha) - North	1,149,000	
Building Demolition	737,000	(incl. cont. site assess.)
	$ 6,016,000	

Open Pit and Waste Dumps (2.5 million tonne; 23.4 ha)	$ 2,283,000	
No. 1 Shaft Waste Dump (2.5 million tonne; 25 ha)	$ 3,051,000	
Tailing Ponds (86.4 million tonne; 380 ha 35,624 $/ha)	$13,537,000	(incl. $3,315,000 float placement; balance contouring; till placement)

DRAINAGE WATER TREATMENT PLANT

Parameter	Post Closure	Operation	
		Average	Range
Volume treated (MM^3/yr)	1.60	6.58	3.84-8.54
Mine drainage	1.10	-	
Tailing seepage	0.50	-	
Lime Consumption (kg/M^3)	-	0.55	0.45-0.78
Mine drainage	0.69		
Tailing seepage	0.51		
Lime Consumption (t/yr)	1,014	3,510	2,500-5,344
Mine drainage	759		
Tailing seepage	255		
Lime Cost at $90/tonne ($/yr)	91,260	315,900	225,000-480,960
Mine drainage	68,310		
Tailing seepage	22,950		
Operating Days (D/yr)	180	350	