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BLUEBELL MINE - REMEDIATION OF A HISTORIC MINE SITE

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ABSTRACT

The Bluebell Mine was a lead, zinc and silver mine discovered circa 1820 that had been exploited by a number of owners until its final closure in 1972. It is located in the hamlet of Riondel, BC. Kootenay Lake surrounds the mine site on three sides. Cominco Ltd. acquired the surface and mineral rights in the 1930s and operated a mine and concentrator from 1952 to 1972. The mine was reclaimed to the standards of the day upon closure. In 1997, Cominco initiated a series of phased investigations to identify potential environmental and public safety issues at the site. The site contains waste rock dumps, process fines (residual tailings and concentrates) and deposits of Mine Water Discharge (MWD) fines that had been pumped to surface during mine operations. The process fines and MWD fines existed both on land and in Kootenay Lake, including the foreshore areas of Galena and Bluebell Bays. The site had surface and groundwater issues related to both Acid Rock Drainage (ARD) and neutral pH metal leaching (ML). In 2000, Cominco initiated a remedial program to substantially improve both the environmental and public safety aspects of the site. The Phase 1 program in 2000 focused on the remediation of the contaminated soils and ARD/ML issues in upland areas of the site. Phase 2 work initiated in the first half of 2001 focused on removal of potential ARD generating materials from the foreshore and near shore areas of Galena and Bluebell Bays. During the second half of 2001, the objectives are to address outstanding Phase 1 issues and potential hazards from near surface mine workings. A program to monitor and confirm the resulting improvements in the environmental quality of the soils, surface and groundwater at the site has been initiated.

INTRODUCTION

The Bluebell Mine was operated by a number of companies early in its history and by Cominco from 1952 to 1972. The mine held one of the early Reclamation Permits under the Mine Act and was reclaimed to the standards of the day upon closure. Since closure in 1972, Cominco has continued to own and manage the site. Internal reviews identified a number of environmental and public safety issues that Teck Cominco is committed to address.

[1] In July 2001, Cominco Ltd. (Cominco) and Teck Corp. Ltd. merged to form Teck Cominco Metals Ltd. (Teck Cominco).

In 1997, Cominco retained Morrow Environmental Consultants Inc. (MECI) to complete an Environmental Site Assessment of the Bluebell Mine. The assessment provided the data necessary to plan a remedial program with the objective of substantially improving the environmental quality of the site. The remedial program is being completed as Independent Remediation as defined under the Contaminated Sites Regulation[1] (CSR) and under other terms and conditions agreed to with provincial and federal regulators.

All assessment work has been completed in a phased manner where data from early work directs and supports subsequent work. Work done in 1997 provided an "environmental perspective" of the mill areas and Galena and Bluebell Bays. In 1998, 1999 and 2000, the understanding of site conditions was improved by additional intrusive investigations. Remedial work at the site began in August of 2000 and targeted the terrestrial portion of the site, while work in early 2001 focused on the foreshore areas of Galena and Bluebell Bays. During the balance of 2001, the security of the mine openings will be assessed and upgraded, the environmental remediation will be refined based on confirmatory sampling results, and the site will be revegetated upon completion.

HISTORY AND SETTING

The Bluebell Mine is located on the east shore of Kootenay Lake in the trench between the Purcell and Selkirk mountain ranges in southeastern British Columbia. The mine occupies the Riondel Peninsula stretching approximately 1,700 metres from north to south. The Village of Riondel abuts the site along its eastern edge.

The Bluebell Mine produced lead, zinc and silver. Rocks on the Riondel Peninsula comprise a north-trending and a steep west-dipping succession of Lower Cambrian quartzites, pelitic schists, calcareous schists, and marble. The Bluebell ore deposit consists of three main zones spaced approximately 500 metres apart along the strike of the Badshot marble: the Comfort zone at the north end of Riondel Peninsula, the Bluebell zone in the centre, and the Kootenay Chief at the south end. The ore consists of galena, sphalerite, pyrrhotite, pyrite, arsenopyrite, and chalcopyrite. The gangue occurring with the sulphides consists of carbonates, coarsely-grained quartz and knebelite, an iron manganese silicate."

Production of ore from the Bluebell zone commenced under the ownership of the Kootenay Mining and Smelting Co. in 1895. A concentrator was built on the shore of Bluebell Bay ("Old Mill") in 1908. The Bluebell claims changed ownership several times between 1905 and 1924. Only lead concentrates were produced during this period. The Bluebell ore zone was initially developed by open pit mining in the Glory Hole. As mining progressed, a tunnel was driven in from Bluebell Bay, a shaft was sunk on the Comfort Claim and an adit was driven on the Kootenay Chief Claim. High zinc tailing from the concentrator at the Old Mill was discharged to Kootenay Lake at a point west of Bluebell Bay. The tailing (containing zinc), consisted of both hand sorted waste and, later, rejects from jig tables. Mine waste rock was used to develop level areas at the shore of Bluebell Bay (i.e., dumped into the lake). Operations at the Old Mill were suspended in 1927. Ore mined by pre-Cominco interests totalled approximately 500,000 short tons.

The Bluebell property and adjacent Kootenay Chief and Comfort claims were bought by Cominco in approximately 1931. The mine was dormant from this time until Cominco initiated an exploration program in 1942. The results of the exploration program resulted in construction of a concentrator on the shore of Galena Bay ("New Mill") and development of a new shaft beside the mill. Production of lead and zinc concentrates commenced in 1952. Concentrates were loaded into rail cars on barges from a dock on the west side of Galena Bay, towed to Procter, and then transferred on to the Canadian Pacific Railway line and taken to Cominco's smelter in Trail, BC.

The finer fraction of the tailing (i.e., slimes) was subaqueously disposed via a launder into the south end of Galena Bay. The coarser fraction of tailing was used to backfill underground slopes. Waste rock was deposited primarily at the northeast quadrant of the New Mill site. Mine water pumped from the No. 1 Mine Shaft was discharged to the eastern edge of the mill area and drained downslope to the east lobe of Galena Bay. The mine water contained suspended solids generated during the mining process and dissolved calcium bicarbonate generated from limestone deposits and geothermal water in the mine. Calcium carbonate precipitated when exposed to the atmosphere, developing a deposit of Mine Water Discharge (MWD) fines at the southeast quadrant of the New Mill area.

Approximately 5,318,000 tons of ore *were* mined between 1952 and 1972.

SITE QUALITY AND CONTAMINANTS OF CONCERN

The site soil quality has been evaluated in relation to Residential and Industrial land use (RL/DL) standards contained in the CSR. Groundwater standards have been compared to the Aquatic Life (AW) standards contained in the CSR. Surface water quality has been compared to the BC Criteria[1]". Various other criteria and guidance documents published by the BC Ministry of Energy and Mines (MEM), the BC Ministry of Water, Land and Air Protection (MWLAP) (formerly known as the Ministry of Environment, Lands & Parks), Environment Canada (EC) and scientific sources have also teen referenced.

Information regarding the site quality and waste distribution has been obtained by a variety of methods including:

- Historical research;
- Geophysical methods;
- Surface soil sampling;
- Drilling;
- Creek sampling;
- Benthic invertebrate sampling;
- Lake sediment coring;
- Underwater video survey;
- Stressed vegetation inventory;
- Aerial photography;
- Test-pitting;
- Groundwater sampling;
- Lake water sampling;
- Fish sampling;
- Lake sediment grab sampling;
- Calculation of wave heights.

Once samples were collected, they were subjected to a variety of analyses including grain size distribution, total and leachable metals in soils, ARD/ML characteristics (i.e., acid base accounting, pétrographie analysis, humidity cell testing), dissolved and total metals in ground and surface water, indicator parameters in water (acidity/alkalinity, nitrate, total organic carbon, sulphate), sediment quality triad analysis (chemistry, toxicity and benthic community analysis), metal concentrations in biota tissue and acid volatile sulphides/simultaneously extracted metals in sediment. Organic contaminant analyses were also completed in areas with hydrocarbon impacts.

The above described work was completed by the following consultants:

- Morrow Environmental Consultants Inc. - design and completion of terrestrial site assessment work, remedial action plan, confirmatory sampling, environmental monitoring, reporting and co-ordination of other consultants.

- EVS Environmental Consultants Ltd. - assessment of aquatic environment.
- Westmar Consultants Inc. - beach design.
- Steffen Robertson & Kirsten (Canada) Inc. - review of ARD/ML characterization work.
- Harris Exploration Services - mineralogical examination.
- Frontier Geosciences Inc. - geophysical survey.

Based on the site assessment work, the site wastes were divided into categories in accordance with their contaminant concentrations and potential to impact the environment. Table A summarizes the main contaminant groups.

TABLE 1: Potential Contaminants of Concern at the Bluebell Mine Site

Material Type	Contaminants[A]		Mobility/Reactivity	Management Methods and Considerations
	Contaminant	Concentration Range		
New Mill Waste Rock	As Cd Cu Pb Ag Sn Zn	<10 – 5640 mg/kg 6.3 – 85.5 mg/kg 19 – 627 mg/kg 908 – 10,800 mg/kg <2 – 24 mg/kg <5 – 74 mg/kg 601 – 24,200 mg/kg	Although the New Mill Waste rock contained elevated metal concentrations, the ARD/ML characterization work determined that the material was non-acid generating. However, neutral pH leaching of zinc to groundwater was identified as a concern.	It was decided to use the New Mill waste rock to fill an open pit. This would remove the material from a groundwater discharge zone, reduce the footprint of the waste dump, direct runoff away from a large mine opening and address a public safety concern (open pit).
Old Mill Waste Rock	As Cd Cu Pb Ag Sn Zn	216 – 3,560 mg/kg 2.7 – 83.9 mg/kg 191 – 1,260 mg/kg 1,970 – 6940 mg/kg 4 – 60 mg/kg <5 – 102 mg/kg 3,700 – 22,700 mg/kg	Although total metal concentrations are similar to the New Mill waste rock, the ARD/ML characterization work determined that the Old Mill waste rock was acid generating and causing a groundwater impact.	It was decided to blend the acid generating Old Mill waste rock with MWD fines to take advantage of the high buffering capacity of MWD fines. The blended material was used to fill caverns at the back of an open pit.
Onshore Process Fines	Sb As Cd Cu Pb Ag Sn Zn	<10 – 37 mg/kg 181 – 8280 mg/kg< <0.3 – 308 mg/kg 70 – 2610 mg/kg 171 – 28,500 mg/kg <2 – 37 mg/kg <5 – 80 mg/kg 471 – 64,500 mg/kg	The ARD/ML characterization work determined that the on-Shore process fines were acid generating and causing a groundwater impact. The grain size of this material (i.e., primarily fines) resulted in part in their elevated reactivity.	It was decided to transfer residual on-shore process fines off site to a tailing pond at the Sullivan Mine where an ARD/ML management system exists.

Material Type	Contaminants[A]		Mobility/Reactivity	Management Methods and Considerations
	Contaminant	Concentration Range		
Mine Water Discharge Fines	Sb As Cd Cu Pb Zn	<10 – 20 mg/kg 181 – 1340 mg/kg 18 – 93.8 mg/kg 71 – 366 mg/kg 2,820 – 11,900 mg/kg 4,760 – 21,700 mg/kg	Although the MWD fines contain elevated metal concentrations and have the potential for neutral pH leaching of zinc, they were comprised primarily of calcium carbonate and thus have a high neutralization potential.	Due to the high buffering capacity of the MWD fines, it was decided to blend them with the acid generating Old Mill waste rock and dispose of the mix in caverns at the rear of an open pit.
Native Soils (metals)	Sb As Cd Cu Pb Sn Zn	<10 – 33 mg/kg <10 – 5,790 mg/kg <0.3 – 134 mg/kg 5 – 2,240 mg/kg <30 – 2,080 mg/kg <5 – 55 mg/kg 52 – 15,500 mg/kg	Elevated metal concentrations in native soils were due either to elevated natural background concentrations or the precipitation of secondary minerals from ARD/ML. The reactivity and mobility of metals depended on the source and concentration of metals.	Native soils were not directly targeted for remediation. The intent was to evaluate residual metal concentrations after the mine waste was removed to determine if they presented a concern.
Hydrocarbons in soil	LEPH[2] HEPH[3]	<250 – 8,600 mg/kg <250 – 14,000 mg/kg	Hydrocarbon impacts were identified at former fuel storage areas at both the Old and New Mill areas. The contamination at the Old Mill area was considered mobile.	It was decided to excavate and transfer all hydrocarbon impacted soils to a bio-remediation cell constructed at the former on site landfill
Lake Sediment	As Cd Cu Pb Ag Zn	<10 – 5640 mg/kg 2.7 – 319 mg/kg 19 – 2060 mg/kg 336 - 34,700 mg/kg <2 - 82 mg/kg 601 – 61,400 mg/kg	Although the off-shore tailing are potentially acid generating, the water cover greatly restricts their reactivity. The sediment triad analysis and biota testing determined that moderate impacts in Galena Bay were confined to the northwest end of the bay. Bluebell Bay sediments were non-functional from an ecological perspective.	No effort would be made to recover process fines below the depth of potential lateral transport by wave action.
Groundwater at the Old Mill area	Sulphate Cd Cu Pb Zn	391 – 5,540 mg/L 0.013 – 2.52 mg/L 0.34 – 9.98 mg/L 0.036 – 2.94 mg/L 13.3 – 473 mg/L	The impact to groundwater was inferred to be associated with the surface deposits of process fines and/or waste rock. Naturally elevated metal concentrations were considered possible as well due to nearby mineral outcrops.	Changes in groundwater quality after the removal of the inferred sources would be monitored.

[2] LEPH = light extractable petroleum hydrocarbon

[3] HEPH = heavy extractable petroleum hydrocarbon

Material Type	Contaminants[A]		Mobility/Reactivity	Management Methods and Considerations
	Contaminant	Concentration Range		
Groundwater at the New Mill Area	Sulphate Cd Cu Pb Zn	97.5 – 3020 mg/L <0.0002 – 0.158 mg/L <0.001 – 0.042 mg/L 0.001 – 0.254 mg/L 0.008 – 100 mg/L	Due to the good upgradient groundwater quality, impacts to groundwater were inferred to be associated with the residual process fines or, in the case of the east side of the New Mill area, neutral pH metal leaching from waste rock and/or MWD fines.	Changes in groundwater quality after the removal of the inferred sources would be monitored.
Total Metals In Lake Water	Cd Pb Ag Zn	<0.04 – 0.15 µg/L 0.5 – 17 µg/L <0.02 – 0.23 µg/L <0.5 – 67 µg/L	Although concentrations of the indicated metals sporadically exceeded the BC Criteria, concentrations were similar or worse at a remote reference bay. An impact to lake water from the site was not indicated	No remediation necessary. Generally excellent water quality.
Hydrocarbons in Groundwater	LEPH	0.59 mg/L	Localized impact to groundwater identified in a monitoring well at the Old Mill area.	Monitor groundwater quality after the source area is removed.
Metals in Invertebrates	As Cd Cu Fe Pb Mn Ag Zn	36.6 – 350 µg/g wet 0.19 – 0.81 µg/gm wet 5.4 – 11 µg/gm wet 1140 – 5760 µg/g wet 47.1 384 µg/gm wet 41.8 – 199 µg/g wet 0.071 –0.27 µg/gm wet 87.8 – 214 µg/gm wet	Tissue samples from invertebrates in Galena Bay contained elevated metal concentrations. Metal concentrations in fish tissue were well below guideline concentrations.	Due to presence of elevated metal concentrations in invertebrates as well as the presence of ARD/ML, Teck Cominco decided to proceed with the remediation of the Galena Bay foreshore.

[A] in relation to the previously identified standards/criteria.

SITE REMEDIATION

Regulatory Approval Process

The site assessment results and the development of staged remedial plans were presented to the Kootenay Mine Development Review Committee (KMDRC). The KMDRC is chaired by the MEM and has representation from a number of government ministries and non-government stakeholders. Through the KMDRC, discussions were held with the MWLAP (several branches), EC (who in turn interfaced with the Department of Fisheries and Oceans), the Ministry of Transportation & Highways, and the Canadian Columbia River Inter-tribal Fisheries Commission. The co-ordination of the review and the approval process through the KMDRC ensured that all the parties were informed, and had input into the plans, and this prevented duplication of reviews and comments. This was important as in excess of a dozen permits, approvals, authorizations and variances were required for the remedial work program. Two local community open houses and a public meeting were held to inform the local residents of the plans and to address any concerns or issues.

Phase 1 Terrestrial Remediation

The Phase 1 remedial action commenced in late August 2000 and proceeded until early December 2000. Table 2 summarizes the work completed.

TABLE 2; Summary of Phase 1 Remediation Work

Source Material	Volume Excavated (approximately)	Disposal Location	Comment
New Mill waste rock	83,000 m^3	Glory Hole Open Pit	Northwest quadrant of area not excavated to leave a working surface for Phase 2 remedial work.
Old Mill waste rock	14,000 m^3	Glory Hole Open Pit (caverns)	Excavated down to high water level pending regulatory approval to proceed below (i.e., Phase 2).
Comfort Pit waste rock	5,000 m^3	Comfort Pit	Material from around the Comfort Pit was used to fill the pit.
Process Fines	6,000 m^3	Sullivan Mine in Kimberley	Trucked to Kimberley by a licensed waste carrier as the material was defined as a Special Waste under the Transportation of Dangerous Goods Act.
MWD fines	18,000 m^3	Glory Hole Open Pit (caverns)	Blended with Old Mill waste rock at an approximate 1:1 ratio as the material was placed.
Hydrocarbon Impacted Soil	2,500 m^3	Bio-cell	Soil placed in an engineered bio-remediation cell at the former landfill area north of Bluebell Bay.
Total	128,500 m^3		

Confirmatory soil samples were collected using several site specific protocols after the completion of remedial activities to document the success of the effort and to identify "hot spots" that could be reasonably targeted for additional remedial action in 2001. Samples were submitted for analysis of the primary contaminants of concern (As, Pb and Zn) and/or total metals. Samples from hydrocarbon remedial excavations were submitted for analysis of BETX/VPH[4], and/or LEPH/HEPH to document closure to the CSR RL standards.

A water management program was required to prevent the discharge of silt and metal-containing water to Kootenay Lake. The management plan included the diversion of Hammil Creek around the work area in a high-density polyethylene pipe and the collection of groundwater seepage. Groundwater seepage was collected by a temporary dyke located at the high water line in the east foreshore of Galena Bay. Seepage was pumped to the No. 1 Shaft. The effluent was sampled on a weekly basis to ensure quality remained within that specified in the MWLAP Approval.

[1] BETX / VPH = benzene, ethylbenzene, toluene, xylenes / volatile petroleum hydrocarbons

Approximately 9,200 m^3 of water were pumped into the No. 1 Mine Shaft during the Phase 1 work.

Phase 2 Foreshore Remediation

The design for the Phase 2 foreshore remedial action was completed in December 2000 and January 2001. Design challenges included:

- Determining the depth to which waves and currents could cause lateral movement of submerged process fines (i.e., the necessary depth of excavation or extent of soil cover);
- Designing a beach that would be stable and resist becoming recontaminated should process fines be mobilized due to wave action (i.e., be self cleaning);
- Selection of a cost effective remedial approach that would allow excavation to proceed below low water and would minimize the release of turbid water to Kootenay Lake;
- Identification of and development of a gravel pit and quarry; and
- Presentation of the Sediment Remediation and Contingency Plan to the KMDRC and obtaining all necessary approvals and permits by early March, such that commencement of work would coincide with seasonal low lake water levels in early April.

The above challenges were met and the Phase 2 remediation of the foreshore of Bluebell and Galena Bays commenced the third week of March as summarized in Table 3.

TABLE 3: Summary of Phase 2 Remedial Action

Area	Work Methods	Materials Handled	Comment
Bluebell Bay Excavation	Using excavators working from shore remove all contaminated material to 0.5 m below low water.	10,600 m^3 Waste Rock 1,000 m^3 Hydrocarbon Contaminated Soil	Approximately 1,000 m^3 of unexpected hydrocarbon impacted soil and waste rock were intercepted beneath the north foreshore waste rock dump.
Bluebell Bay Reconstruction	Rebuild the foreshore with rip-rap fill to prevent erosion.	4,700 m^3 rip-rap	The beach was rebuilt to above high water with rip-rap. The Phase 1 remedial excavation was left open pending the evaluation of confirmatory sampling and drilling data.
Galena Bay Excavation	Using excavators working from shore and a barge, excavate process fines to approximately 2 m below low water.	16,600 m^3 Waste Rock 6,800 m^3 Process Fines 4,600 m^3 MWD fines	MWD fines recovered from the east lobe of Galena Bay were blended with Old Mill waste rock and placed in an open pit. Process fines were dewatered and trucked to Kimberley.

Area	Work Methods	Materials Handled	Comment
Galena Bay Reconstruction	A self cleaning beach with a 8:1 slope was constructed of pit-run to 5 m below low water using excavators working from shore and a barge. The pit-run was capped with 1 m of 0.08-0.15 m angular rock.	24,000 m^3 Pit Run Gravel 11,800 Sized Angular Rock	The Pit-run total includes 7,200 m^3 that were used to build haul roads. An on site quarry was developed to produce the rock. The rock was crushed and screened to ensure the correct sizing was obtained.
Control of Suspended Solids in Kootenay Lake	At Bluebell Bay, a single floating barrier was used to control the expected small increases in lake water turbidity generated by remedial work. At Galena Bay, two floating silt barriers and a log wave break spanned the bay.	n/a	Twice daily turbidity readings were taken from several stations to track the suspended solids loadings inside and outside of the contained areas. Routine weekly lake water sampling was undertaken at the same stations. The silt barriers were custom manufactured due to their size.
Water Management at Remedial Excavations	All groundwater seepage was intercepted on or above the foreshore to prevent a discharge to Kootenay Lake. Collected water was pumped into the No. 1 Mine Shaft.	7,000 m^3	Flow readings were taken on a daily basis and characterization samples were collected on a weekly basis to document the quality and quantity of water being pumped into the underground workings.
Process Fines Infiltration Pond	Saturated process fines were placed in an infiltration pond at the northwest quadrant of the New Mill area. Pore water drained through waste rock to bedrock or glacial till before being collected in an interception trench and pumped to the No. 1 Mine Shaft.	n/a	The infiltration pond was constructed on waste rock purposely left in place during the Phase 1 work. Weekly characterization samples were collected from the seepage collection trench.
Hammil Creek Diversion	The Hammil Creek diversion remained in place for the duration of the Phase 2 work.	n/a	Once the foreshore of Galena Bay was reconstructed, the diversion was removed and a new creek channel constructed. The channel was planted with indigenous riparian vegetation.
	Total soil/sediment handled.	80,100 m^3	

FOLLOW UP PHASE 1 REMEDIAL EXCAVATION WORK AlSfD POST REMEDIATION MONITORING

The Phase 1 confirmatory sampling program data was evaluated as the Phase 2 remedial program was being completed. The review determined that the CSR RL standards for soils were being approached at the New Mill area. At the Old Mill site, all mine wastes above the low water level have been removed, however, the underlying soils contain metals concentrations above the CSRIL standards. Background sampling suggests that some of the metals are naturally occurring. Along the tailing backfill pipeline route, sampling and visual observations indicated that traces of process fines were intermittently present. Accordingly, an additional 0.3 m of peat was removed from the entire route. Closure to the CSR standards is not anticipated in this area as elevated background metal concentrations were identified during the assessment work.

Assessment of near surface and exposed mine workings is currently underway. Once the remedial activities at the site are completed in fall 2001, a re vegetation plan will be implemented.

A series of groundwater monitoring wells were installed across the site to replace wells lost during remedial excavation work and to refine the site hydrogeologic model. Monitoring of water quality in the monitoring wells, Hammil Creek and Kootenay Lake will continue for several years according to a schedule defined in the Sediment Remediation and Contingency Plan submitted to the KMDRC as part of the Phase 2 approval process.

i Waste Management Act, *Contaminated Sites Regulation* (CSR), [includes amendments up to BC Reg. 244/99, dated 1999 07 19], BC Reg. 375/96, deposited 1996 12 16, Q.C. 1480/96, effective 1997 04 01.

ii Hoy, Trygve (1980): Geology of the Rionidel Area, Central Kootenay Arc, Southeastern British Columbia, BC Ministry of Energy, Mines and Petroleum Resources, Bulletin 73.

iii British Columbia Water Quality Guidelines (Criteria) - 1998 Edition for freshwater Aquatic Life (BCWQG AL) and/or Compendium of Working Water Quality Guidelines for British Columbia: 1998 Edition for freshwater Aquatic Life (Compendium).