PREPARING A HIGH ELEVATION TAILINGS IMPOUNDMENT FOR FINAL CLOSURE

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ABSTRACT

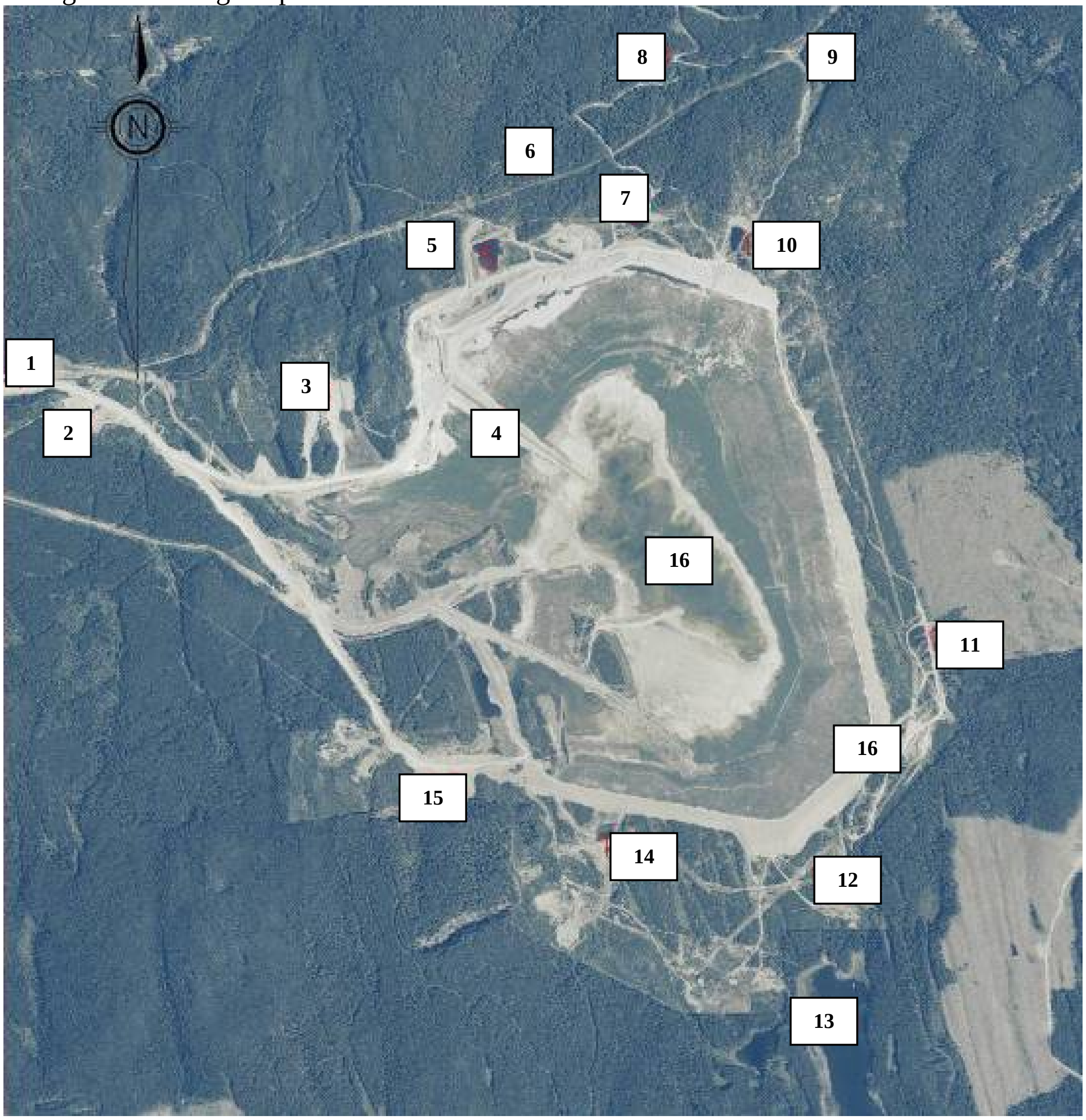
Highland Valley Copper (HVC), located in south-central British Columbia, 75 kilometres southwest of Kamloops, operates one of the world's largest copper and molybdenum mines. This paper discusses the Highmont Tailings impoundment concerning its various steps toward final closure. After Highmont Mining ceased operations in 1984, it joined the partnership with HVC in 1988 and moved its concentrator to Lornex. Since then the Highmont tailings have been under care and maintenance and have slowly proceeded towards final closure. As we are now approaching the final phases, this paper explains the various steps taken to bring the Highmont tailings impoundment toward final closure.

INTRODUCTION

Highmont tailings impoundment is located in Southern Central British Columbia, 75 kilometres southwest of Kamloops, and 5 kilometres west of Logan Lake. It is located 5 kilometres east of the HVC plant site on a relatively flat area on the ridge south of the Highland Valley. The area drains in three directions: to the north towards Witches Brook; to the east towards Mamit Lake in the Guichon Creek Valley and via Dupuis Creek to Mamit Lake; and to the south to Billy Lake and Dupuis Creek to Mamit Lake.

Highmont Mining Corporation discharged into the tailings facility from the fall of 1980 until mine shutdown in October of 1984. The tailing facility covers an area of approximately 220 ha, bounded on the north, east and south sides by five peripheral rock fill dams and the west side by high ground. The maximum heights of the as-built dams are 47 metres (compared to the design height of 82 metres). The dams are low in height because of the premature closure of Highmont as a result of a depressed molybdenum market. The starter dams were constructed of compacted till. The dams were raised by the centre-line method with a downstream section of rock fill, an upstream section of spigotted tailings, and two filter zones separating the two sections. The dams are founded on shallow, competent glacial materials which are expected to perform well for static and seismic conditions. Stability test results show that the dams have a static safety factor of at least 2.5. The dams are considered relatively low risk and could withstand a low to moderate earthquake. Figure 1 indicates the various items that are discussed in this paper.

Figure 1: Highmont tailings impoundment site locations



1	Haul road access from pits & plant site	2	North Borrow Pit
3	S9 Seepage Pond	4	Spillway
5	S2 Seepage Pond	6	Pipeline Booster Station to Gnawed Lake
7	S8 Seepage Pond & SRB Facility	8	Road to Highmont Booster Station
9	Highmont Booster Station	10	S1 Seepage Pond
11	S5 Seepage Pond & SRB Facility	12	S3 Seepage Pond
13	Billy Lake	14	S4 Seepage Pond
15	South Borrow Pit	16	Tailings Pond

WATER

Seepage Ponds Flow Management

Seepage through the tailings dam and its foundations is captured behind seven downstream dykes, S1 to S5, S8 and S9. Dykes S4 and S9 were breached in 1997 after a provincial approval was granted. The five dams were designed as impervious embankment dams with impervious foundations. Seepage is intercepted and channelled to the containment ponds by a network of collector ditches. The locations of the containment ponds and collector ditches are shown in Figure 1. S3 and S4 Ponds are on the south side of the pond while seepage pond S5 is located on the east side. Seepage ponds S1, S2 and S8 are on the north side of the tailings pond.

The collected seepage from S3 and S5 is currently pumped across to the S1 pond on the north side, where it is piped by gravity to the Highmont booster station. Similarly, water from S2 and S8 is pumped to S1. Prior to the mine closure in the fall of 1984, seepage from the tailings pond was estimated to total about 550 USgpm. Diversion ditches have been built to move most of the natural flow either north towards Witches Brook or south towards Billy Lake. This has reduced the water inflow to the pond and is reflected in the reduction in seepage. Estimated seepage was about 85 USgpm in October 1991, 70 USgpm in 1995 and 42 USgpm in 2004. The large reduction in 2004 is a reflection of the steady-state pond level made possible by the construction of the spillway.

From the booster station, the water is pumped up to Gnawed Lake where it is stored prior to being used as process water in the Highland Mill. Highmont well water is also pumped to Gnawed Lake via the Highmont booster station. The Highmont booster pump house is equipped with 3 vertical turbine pumps each capable of pumping 92.6 L/second (1470 USgpm) to the Gnawed Lake Reservoir. With all pumps running the capacity of the pump house is 264 L/second (4200 USgpm).

Under Permit PE-376, Highland Valley Copper can discharge overflow at seepage ponds S1, S2, and S8 to the environment from freeze-up until July 1.

Water Quality – Tailings Impoundment Supernatant

Upon closure in 1984 the pond level was 1484.7 m-asl. The pond level has been pumped down periodically since 1994 to maintain a 1481 metre elevation, to facilitate tailings reclamation. In 2003 a spillway with an invert elevation of 1480.2 metres was constructed. Since then the pond elevation has remained relatively close to this elevation.

Generally, the trend in the copper levels in the pond water has been decreasing despite a minor rise in 2004 caused by the reclamation and spillway construction activities in 2003. The molybdenum level appears to be on a slight increase with a recent spike also attributable to spillway construction. Prior to 1991 the seepage pond effluent from S5 and S3 was pumped back to the tailings pond. When this practice stopped the supernatant copper and molybdenum quality improved. It is expected that upon completion of reclamation of the dams' surface areas and the establishment of aquatic vegetation, supernatant quality will improve. With enough time, this will allow for the direct discharge of the tailings supernatant into Witches Brook.

Water Quality - Seepage Ponds

The quality of the seepage, in terms of copper content, has improved with time in each of the ponds. In terms of molybdenum, the trend has been upward. Erratic swings in the readings may be due to rain water or melting snow percolating through the rock fill portions of the dam. The dam is currently being capped with overburden which will lessen the impact of melting snow and rain on seepage flowing from the toe of the dam.

In general the copper levels in the seepage ponds have decreased and levelled off to such an extent that the water can be discharged to the environment. These levels are below the allowable provincial aquatic standards for agriculture/irrigation. The molybdenum values have behaved oppositely with modest increases from 1992 to 2002, and a substantial increase in 2004. Again, this recent rise is attributable to activity including the resloping of the dam and construction of the spillway, and should reverse with ongoing reclamation efforts.

It is further expected that as the phreatic line under the tailings beaches inside the pond continues to drop, both the metal concentration and flow rate of the seepage will decrease. However, it is likely that even with the collective improvements in seepage quality; the allowable level of 0.35 mg/L of molybdenum will not be attained in the very near future.

SEEPAGE WATER TREATMENT THROUGH SRB

S5 Sulphate-Reducing Bacteria Passive Treatment

Figure 2: Seepage Pond S5

Highland Valley Copper has two passive metal removal systems in seepage ponds containing sulphate-reducing bacteria (SRB) to treat Highmont water. In 1998, a sulphate reducing bacteria (SRB) pond was built within S5. The treatment process involves passing the molybdenum rich water through a porous anaerobic substrate inhabited by SRB. The substrate consists primarily of 1.5” to 3” rock, cow manure and wood chips. The rock provides pore space and attachment surfaces for the SRB; the manure is a rapidly depleted nutrient source and the wood chips provide a long-term carbon source. The SRB produce H2S that precipitate metals.

The largest biochemical constraint on the S5 system is low water temperature, followed by available simple carbon molecules. The largest restraint on the volume of water that can be treated is the SRB bed permeability, followed by bacterial output of sulphides. This condition was exacerbated after freshet inflows from 2001 to 2003 exceeded the pond's throughput capacity, causing fines to be washed from the berms onto the beds. As the SRB bed clogs with migrating fines, the effective treatment window without short-circuiting is shrinking. The maximum treatable volume has dropped from about 60 L/minute to 30 L/minute over the eight years of operation.

The water quality parameters that improved in S5 included lower molybdenum, copper, nitrate and sulphate concentrations[1]. The net effect of the S5 SRB treatment pond on downstream Dupuis Creek and Mamit Lake is positive. There is a significant reduction in molybdenum concentrations leaving the Highmont S5 area. The small amount of nutrients from S5 that may ultimately reach Mamit Lake will not significantly impact it as Mamit Lake is already eutrophic (nutrient-rich). However, due to the inability of the SRB to remove sufficient molybdenum on a full-time basis, the water is currently collected downstream of the SRB beds and pumped back to S1 pond.

S8 Sulphate-Reducing Bacteria Passive Treatment

In 2002, a custom SRB pond was built downstream of the existing S8 pond. The pond is engineered for either up or down flow through the permeable SRB media. It was inoculated in August 2002 and allowed to stand over the winter while the SRB populations expanded. Seepage can be discharged under the amendment to Permit PE-376, Section 1.5 (September 18, 2002). Although molybdenum removal in excess of 90% has been achieved, the outflow has still contained levels of molybdenum too high to be released. It is very clear from the S8 data that metal removal is tied to temperature. If water temperature is low, then the retention time in the pond must increase to compensate for lower rates of bacterial activity. At 20 L/ minute inflow, S8 achieved 80% total molybdenum removal at water temperatures exceeding 10C. Treatment tapers off when SRB bed pore water temperatures decline. With five months of winter detention at 2 to 3C, removals reached 97–99%. Water quality parameters that improved after treatment in S8 include lower molybdenum, nitrate, total nitrogen, and sulphate concentrations. Water quality parameters that increased during passage through S8 include: ammonia, phosphorus, total iron and manganese. S8 also performed a genuine removal of nitrogen, not just a conversion from nitrate to other forms. Inflowing nitrate concentrations exceeded the guidelines while S8s outflow contained <0.005 mg/L. At the same time, total nitrogen dropped 47% during passage through S8.

[1] Passive Sulphate Reducing Bacteria Treatment Ponds: Research and Operation at Highmont Seepage Ponds, 2005, Larratt

Figure 3: S8 SRB Pond under construction in 2002

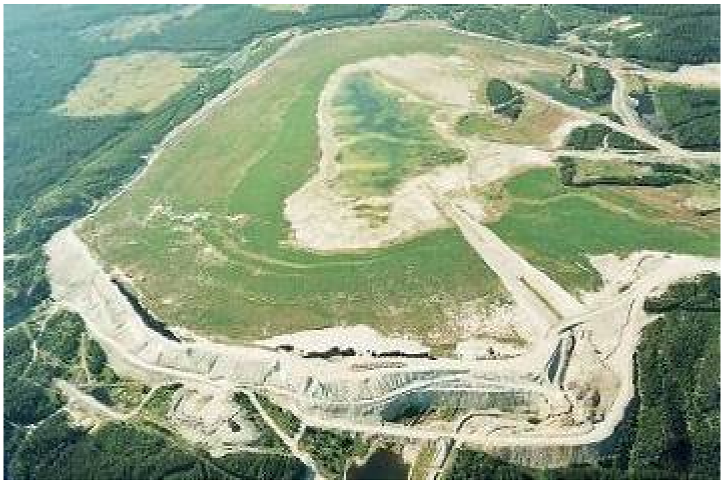
A PVC liner prevents seepage into or out of the treatment area, and the piping arrangement allows for up or down flow through the substrate. Cement curbs limit short circuiting when the system is in down flow mode while plywood baffles prevent short circuiting in up flow mode. The substrate media in the pond is composed of one part horse manure, one part wood chips and two parts clean 0.75" crush. The manure is used to provide a short-term carbon supply and unlike the manure used in S5, contains no fine silt or clay. The wood chips provide a long-term, slow release nutrient and carbon source. In this substrate, the rock provides the bulk of the pore space as well as surface area for SRB development. The pond was inoculated in autumn 2002 with the addition of porous bags of SRB containing mud from S5. Additional SRB were added in July 2003 from a natural pond near S8. Further testing in 2005 proved that this system was more controllable and therefore more encouraging. Additional testing is planned for 2006 by reversing the flow to determine whether better results can be obtained by forcing the flow up through the substrate.

Figure 4: Highmont Spillway under construction

HIGHMONT SPILLWAY DESIGN AND OPERATION

A permanent spillway design was built in 2003 on the west end of the north face of the dam. The invert of the spillway channel at the sill is 1480.2 m and has a capacity to pass a probable maximum flood (PMF) while keeping the pond level reasonable. The maximum pond elevation is at 1481m and 1482.8m respectively, after a 24-hour 200-year rainfall event and a 24-hour PMF event. The freeboard to the beach top surface is 3.7m or 1.9m respectively. The tailings pond was recorded at 1483.2 in June 1990 (about 0.4m above the PMF elevation), without any incident. The pond level in October 2005 was at 1480.1 m, about 0.1 m below the spillway invert at the sill.

Figure 5: Aerial view of Highmont Impoundment to SE



Spillway flow is normally diverted, via a weir and gravity pipe structure, to the S1 seepage pond for use as process water at Highland mill. The gravity pipeline is buried on the downstream slope of the north dam. Diversion of this water will be required until the quality improves such that it can be permitted for release to Witches brook.

The Highmont spillway diversion is designed to take flow that would normally discharge into the S2 seepage pond, and redirect it through a gravity pipe to S1 pond. The inlet spans the base and forms the east wall of the spillway. Normal flow is directed through an 18" gate valve to an 18" diameter pipe which is progressively reduced in diameter to 14". Flow into S1 is regulated to 4400 Usgpm (278 Lps), well in excess of the 10 year maximum of 3500 Usgpm (220 Lps), by an orifice plate at the discharge. Flow rates in excess of the 860 m3/hr capacity (approximately a 65-year event), is permitted to flow over the spillway and down to the S2 pond. S2 is used as a secondary holding structure to retain surge volumes. A barge mounted pump transfers water from S2 to S1 pond. Under extreme flow conditions, in excess of 4400 Usgpm (278 Lps) and greater than the S2 pond capacity, water will continue down the spillway and discharge to Witches Brook via existing water courses.

The diversion ditches on the uphill side of the tailings pond have been re-established to reduce the volume of water entering the pond.

SLOPING AND CAPPING OF HIGHMONT DAM

During the period 2003 to 2005, approximately 33 hectares of dam surface was recontoured and subsequently capped with approximately 722,000 tonnes of overburden. This required 2100 bulldozer, 1171 haulage truck, and 665 loader operating hours to accomplish. This work was unique in Highland Valley Copper's experience because the capping material was excavated from two borrow pits close to the dam. Capping projects elsewhere in the mine have always enjoyed a supply of overburden that was mined in the pit and hauled directly to where it was needed, saving handling costs. While the dam's entire surface is now capped, about ten hectares of adjacent area remain to be prepared for seeding. This work will take place in 2006 and 2007. The following text describes the work completed to prepare the dam structure for seeding up to 2005.

2003 Ground Preparation

Figure 6: Plan of dam areas prepared in 2004

During the field season of 2003, approximately 24 hectares of dam surface area was resloped to an angle of about 27-degrees (2:1 slope). Using a single D-10 bulldozer, the dam's outside face was recontoured to allow for the subsequent placement of an overburden cap. The height of the slope ranged from 5 to 20 metres in height, with an initial slope angle of 38-degrees. The material was very abrasive, consisting of mainly large, coarse angular rock. Dozer productivity was in the order of 20 operating hours per hectare. Cuts were started by the dozer at the crest of the dump and progressed downwards until the toe blended in with the natural terrain. As the finished slope was prepared, the dozer moved laterally from one end of the dam to the other. A minor amount of resloping had to be completed in 2004.

2004 Ground Preparation

Figure 7: Active borrow pit operation, 2004

Figure 6 indicates the 16.1 Ha of new area capped in May and June used a total of 841 dozer, 543 truck, and 321 L-1400 loader hours. A borrow pit (Figure 7) situated at the western tip of the capping extent provided the source for 352,100 tonnes (2,134 loads) of good quality overburden. One dozer worked full-time at the borrow pit to loosen the material for the loader. This dozer was critical to maintain a loader productivity of about 1,100 tonnes per hour. This allowed two trucks to operate for most of the project in an efficient manner (up to 650 tph each). For closer hauls, only one truck was used. A second dozer received the loads and used the material to build out a berm over the resloped face of the dam. The dozer would place only enough material to ensure adequate coverage before moving over to continue. Occasionally, the dozer pushed the berm down to the toe of the dam to confirm whether sufficient material existed on the crest. Once the loader and trucks were finished hauling, one dozer pushed the material from the berm to the toe along the entire length of the dam's east and south sides (Figure 8).

Records show that 21,509 tonnes/Ha were placed, resulting in a capping thickness of 1.08 metres on average. As with all other capping projects, a specific gravity value of 2.00 is assumed. This value is considered to be reasonable for overburden that is only slightly more swelled than when mined, after being re-compacted through spreading. A minimum capping thickness of 0.5 metres was used; however, the final thickness was greater due to operating constraints. Unevenness of the ground, varying arc lengths along crests and toes on corners, long pushing distances, equipment vision limitations, the requirement to maintain a safety berm while hauling (which prevented spreading of overburden until virtually all of the hauling was complete) and difficulty in measuring placed thickness, all created logistical challenges. At the same time, it was vital to place enough material so that once the capping was spread there would be no need to come back in to add more. Table 1 describes the equipment productivity at Highmont in 2004. These values are reasonable given the equipment-intensive nature of the project. Truck productivity was 33.2 hours/Ha as measured. The adjusted rate of 29.6 is a normalized value when thickness is corrected to 1.0 metres and truck payload is set to 172 tonnes.

Figure 8: View of completed cap on south face of the dam

Subsequent to overburden capping, Environmental Services commenced placement of biosolids, and seeding was completed in 2005.

Table 1: Highmont Dam operating statistics for 2004

Capping Statistics				**Productivity**			**Adjusted**
[loads/Ha]	[tnes./Ha]	[tnes/m3]	[metres]	[op hr/Ha]	[op hr/Ha]	[op hr/Ha]	[op hr/Ha]
Loads/UA	Mass/UA	S.G.	Thickness	Dozer	Truck	Loader	Truck
130.4	21,509	2.00	1.08	43.4	33.2	19.6	29.6

2005 Ground Preparation

Figure 9: Plan of north face capped in 2005

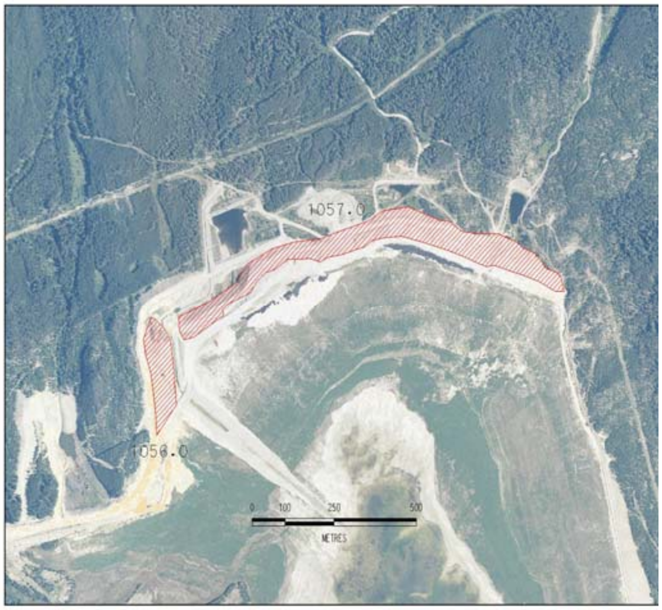
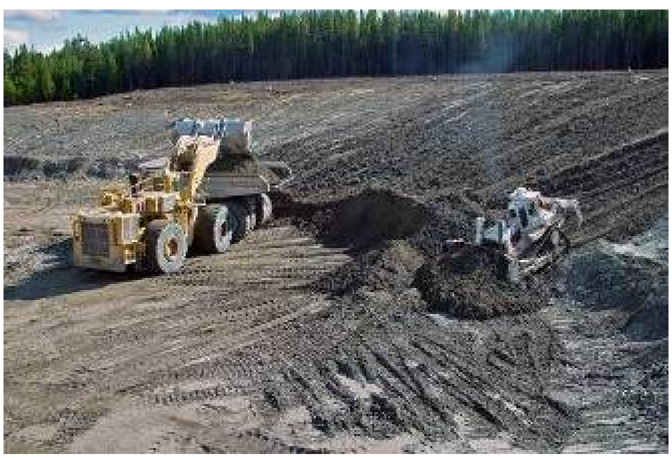


Figure 9 outlines the 15.42 ha of new and 1.62 ha of reworked capping completed in 2005 from August through the first week of November. This project became active after there was no reclamation overburden available from #16 shovel to haul to Bethlehem. A total of 810 dozer, 628 truck, and 344 L-1400 loader hours were required to complete this project. A borrow pit (Figure 10) situated at the entrance to the impoundment area provided the source for 370,422 tonnes (2,251 loads) of overburden. A dozer worked with the loader to loosen the material for easy excavation. This dozer facilitated loader productivity at about 1,100 tonnes per hour. Three trucks operated for most of the project efficiently at 590 tph average each. On closer hauls, only two trucks were needed. A second dozer received the loads and used the material to build out a berm over the resloped face. The berm was pushed out, with enough material left for adequate coverage before continuing. As in 2004, the dozer conducted test pushed to confirm sufficient material existed on the crest. Once the loader and trucks finished , a single dozer pushed the overburden to cover the dam's entire north face. Because of wet weather during this project, the overburden proved very difficult to spread. The dozer became stuck often and could not back up the slope, forcing it to walk to the bottom to turn around. This was not possible where there were drop-offs or forested areas at the toe of the slope, thus impeding the work. Further, the dozer churned up the resloped surface when descending to the bottom and the uneven surface produced was even more challenging to cap neatly. For this reason, two contractor D-8 dozers with lower bearing pressures were hired to finish the spreading to the toe of the dam. This was successfully completed on November 5 as snow began to fall heavily.

Figure 10: Second borrow pit used for 2005 project



The total cost per unit area was the highest of all of the projects completed at Highland Valley Copper in 2005. This reflects the large amount of equipment hours needed here to excavate, transport, and spread the capping material. Records show that 21,738 tonnes/ha were placed, resulting in an average capping thickness of 1.09 metres. As with all other capping projects, a specific gravity value of 2.00 is assumed. A minimum capping thickness of 0.5 metres was mandated; however, the final thickness was greater due to material and operating constraints.

Table 2 describes the equipment productivity at Highmont in 2005. These values are reasonable given the equipment-intensive nature of the project. Truck productivity was 36.8 hours/ha as measured. This is higher than in 2004 due mainly to the longer haul distance this year.

Table 2: Highmont operating statistics for 2005

Capping Statistics				**Productivity**			**Adjusted**
[loads/Ha]	[tnes./Ha]	[tnes/m3]	[metres]	[op hr/Ha]	[op hr/Ha]	[op hr/Ha]	[op hr/Ha]
Loads/UA	Mass/UA	S.G.	Thickness	Dozer	Truck	Loader	Truck
132.1	21,738	2.00	1.09	47.5	36.8	20	32.4

WETLAND DEVELOPMENT

With the completion of the spillway, the water level in the pond will fluctuate less and the high water line will stabilize making it more conducive to wetland development. Water-covered Highmont tailings are very fine and suspend easily when disturbed, resulting in increased interaction between tailings and water. Samples with large loads of suspended solids also have higher metal and phosphorus concentrations. Large metal concentrations in the Highmont tailings cause the highest aqueous molybdenum and copper concentrations of all of the HVC tailings ponds. Before the spillway construction, total molybdenum (T-Mo) averaged 1.76 mg/L and total copper (T-Cu) average 0.042 mg/L. After re-flooding, the 2004 growing season averages were much higher at 2.94 mg/L T-Mo and 0.06 mg/L T-Cu[2].

Nitrate levels dropped from 1995 to 2003; most likely due to denitrifying bacterial activity. The Highmont tailings pond is usually nitrogen-limited with most of its nitrogen in organic forms. This was not the case in 2004; all the major nutrient concentrations increased substantially as re-flooding picked up nutrients from oxidized sediments. While Trojan tailings (Bethlehem) vented sediment gas evenly, other tailings ponds, like Highmont, develop channels where streams of bubbles carve holes 4-10 metres in diameter and several meters deep. The sediment gasses are bacterial decomposition products; methane, non-methane hydrocarbons, nitrogen gas and hydrogen sulphide. Basic tailings ponds like Highmont can offset large influxes of high nitrate mine water with vigorous bacterial denitrification.

Adding fertilizer to the reclaimed periphery of Highmont tailings po.nd improved algae growth and diversity. After the 2003 draw-down and reflooding in spring 2004, fourteen algae species were detected and three species of green filamentous algae bloomed throughout the summer. The amount of organic carbon represented by the bloom rivals the scale of organic production by aquatic macrophytes. Filamentous algae caused a bioaccumulation of 208 ppm of molybdenum and 167 ppm of copper during

[2] Biological Enhancement of Mine Ponds and Assessment of Adjacent Lakes, Larratt, 2004

the 2004 growing season. A steady increase in invertebrate diversity and density matched the increased algal diversity after fertilizer additions.

Twelve native milfoil and aquatic buttercup plant sandwiches were introduced during 1996, and in seven years the plants had expanded to cover thirteen hectares in low density weed beds with occasional high density milfoil patches. These aquatic plants survived the 2003 drawdown only in the deepest sections of the pond.

A mixture of cattails, sedge, large cottonwood and willow stakes and willow branch wattling were planted along the new high waterline. Although literature indicates that riparian shrubs such as cottonwood and willow do not tolerate water levels above the height of the stake or emerging leaves for more than a week during active growth, the majority of the willow stakes survived these conditions during freshet. Similarly, the cattails grew impressively, while sedge growth was delayed until the leaves were in the air. Patches of willow stakes were planted around the entire periphery of Highmont pond. Stabilizing the shore with shrubs/emergents should reduce sediment re-suspension and therefore improve the ultimate water quality.

A jetty was built into the tailings pond in 2004 that provides safe footing for animals. This has completely solved the problem of wildlife access to drinking water. During 2004, deer, moose and coyotes made extensive use of the jetty. From mid-summer through fall, up to 250 waterfowl were observed using the pond. Several of the dominant aquatic macrophytes are a waterfowl favourite, which explains the extensive use of this area by geese, ducks and shore birds.

FORAGE MONITORING

Since the commencement of reclamation, Highland Valley Copper has retained a consultant company to sample and monitor the vegetation. Reclamation activities are guided by the mine's End Land Use Plan, submitted in 1998, which has been approved in principle by the Ministry of Mines. The reclamation assessment and research program provides information to assess the progress toward achieving end land use objectives on a site-specific basis.

The reclamation assessment program includes monitoring forage establishment and sustainability through measurements of biomass production, species composition and foliar nutrient status in forage, as well as assessment of tree and shrub survival and growth. Each of these programs provides a quantitative measure that is used to predict sustainability on reclaimed areas. Assessments are conducted on a schedule that includes an initial assessment of reclaimed waste rock dumps and tailings deposits two years following seeding on both biosolids treated and non biosolids treated sites. All non-biosolids sites are fertilized at the time of seeding and receive a maintenance fertilizer application for three years on waste rock and four years on tailings. These areas are then assessed after the second year of seeding and are then sampled and assessed for the second time in the fourth and fifth years respectively for the waste rock and tailings areas. The 2^{nd} assessment is in the third year following the last maintenance fertilizing application or 6 years (7 for tailings) after the initial seeding. All assessments are conducted during the peak of the growing season during July and August.

Biomass production, species composition and foliar nutrient status are measured over time as an indicator of site sustainability. Biomass production provides a measure of the live vegetation material present on a site. A sudden decline in plant biomass production following withdrawal of maintenance fertilization, or within a few years of biosolids application, could indicate that the site is not yet self-sustaining. The objective of the species composition assessment is to provide a measure of species diversity and vegetative cover that is used in conjunction with biomass production to evaluate the self-sustaining capacity of vegetation or reclaimed sites. The species composition monitoring program provides a quantitative measure of species diversity and vegetation cover on reclaimed sites after fertilizer is discontinued or six years after the initial seeding. This data is used to assess site sustainability, evaluate progress toward achieving end land use objectives and identify significant shifts in the number of species present and percentage cover. The vegetation cover is considered to be stable and self-sustaining if there is no significant decline in these parameters between the initial and second assessment.

There are three objectives for assessing nutrient levels in forage. The first is to assess the stability of nutrient content in vegetation on sites where maintenance fertilizer has been discontinued; and the second is to evaluate the amount and composition of maintenance fertilizer that is required for a site to ensure optimum vegetation growth. The third objective is to identify potentially high levels of molybdenum and sulphur in the foliage.

Cattle Grazing Studies

Revegetation and sustainable cattle and wildlife grazing are major objectives in the End Land Use Plan for the Highmont tailings area. Residual molybdenum in the tailings is taken up by the vegetation and can accumulate to extremely high levels. At Highmont, given that the tailings are from a molybdenum mine, the molybdenum nutrient levels are the highest on the mine site, exceeding 100 ppm, and representing the highest values at HVC. In addition, the seepage water available for drinking for the cattle contains, on average 7 ppm of molybdenum, which is well in excess of the recommended acceptable limit of 0.06 ppm of molybdenum for cattle (Puls, 1994).

Highmont 1999-2001

Clinical evaluation of cows and calves at Highmont revealed signs of lameness, severe diarrhoea and hair coat depigmentation after the animals grazed the tailings pasture from July to September. Cattle with abnormalities displayed a stiff, shuffling gait and favoured their tiptoes when traveling. Other functions including temperature, pulse, respiration and body condition appeared to be normal. The clinical abnormalities did not persist and each animal had fully recovered without treatment by the end of the trial in both the 1999 and 2000 trials.

In 2001, the focus of the project was shifted from clinical observations to therapy that may alleviate the disorders. A study was initiated to test the efficacy of a copper bolus to rectify the copper deficiency. Clinical disorders were again evident for both treated and not-treated and it was concluded that the copper bolus was neither beneficial nor therapeutic.

Supplement Trials (2002-2004)

The second three-year study was initiated to test the efficacy of a copper supplement to prevent the onset of clinical signs. The supplement trials at Highmont were conducted for five weeks from August to October each year. The herd was randomly divided into two groups and released to separate pastures. Copper sulphate in loose salt was provided to one group while the other group was without copper sulphate. Within a week the group without the copper sulphate showed signs of lameness.

In 2003 the trial was inconclusive, due to the substantially reduced precipitation and elevated temperatures. The lack of regrowth due to dryness restricted the forage molybdenum availability. Exacerbating the drought conditions at the site, the tailings pond was also pumped dry to allow for the construction of the spillway. Consequently, less moisture was available through ground seepage which reduced the forage resource in the pasture.

In 2004, twenty six control and twenty five supplement cows were used. The results from the 2004 grazing trials were definitive. Eight control cows and one supplement cow suffered from varying degrees of lameness and no calves showed signs of lameness. The control group accounted for 86% of documented sights of lameness, 78% of the cases of diarrhoea and 88% of hair coat problems. These results demonstrated the efficacy of the supplement and, when combined with results from 2002 and 2003, confirmed that copper sulphate was beneficial in the prevention of lameness and other clinical disorders. In short, the three year grazing trial at Highmont clearly demonstrated the efficacy of the copper supplement for the prevention of clinical disorders due to high molybdenum forage. Although clinical signs were not completely eliminated, the supplement dramatically reduced the incidence and severity of affliction in the treatment group.

Elimination of Molybdenum from Tissues

Elimination studies on molybdenum conducted in 2003 and 2004 demonstrated that muscle and fat tissues from cows grazing at Highmont could be safely introduced into the human food chain within one month of departure from the site. Liver tissue would require three months before acceptable clearance of molybdenum was evident. These are considered very conservative estimates to accommodate differences due to years and animal variability.

BIOSOLIDS APPLICATION

Since 1998, biosolids have been incorporated on the tailings on the south-west side of the tailings impoundment. Biosolids application on the grazing trials pastures was avoided in order to prevent any affects on the studies. Research and monitoring of biosolids-applied forage since the 1996 has proven that the foliar molybdenum concentrations are reduced substantially. However, foliar concentrations from the 2^{nd} assessment sites (7 years after application) suggest that biosolids may not reduce molybdenum permanently. Rather, a downward trend may initially develop, but molybdenum concentrations may return to close to original levels over the long term. More sampling over a longer period is required to confirm steady-state foliar molybdenum concentrations.

Continuing research on the effects of biosolids application on soil moisture regimes supports previous findings that there are no significant effects on static soil retention. However, further research and monitoring is required to determine the overall positive effect of biosolids application to the soil and/or vegetation.

CONCLUSIONS

The reclamation of the high elevation tailings impoundment has advanced closer to final decommissioning with the complete construction of the spillway. This is further supported through ongoing revegetation and the highly successful results of aquatic and wetland ecosystems development. The cattle grazing trials have generated a method by which end land users may prevent molybdenosis. This overcomes a major hurdle in the way of achieving the requirements of final decommissioning. The avifaunal usage of the tailings pond is further proof that Highland Valley Copper is closer to its goal of leaving behind a reclaimed ecosystem that is fully self-sustaining and diverse in suitable species of plants and animals.

An outstanding issue that remains is the handling of seepage water and pond overflow through the spillway. If water cannot be passively treated for excessive molybdenum levels, an independent, active system involving diversion of streams will need to be implemented.

Sampling and monitoring will continue beyond the completion of all decommissioning works until such time that all concerned regulatory agencies release Highland Valley Copper from the terms of its various permits.