2012 MPMC Vegetation Metal Uptake Monitoring

Background

As part of the reclamation research program, vegetation is sampled and analyzed for metal content. Data from these studies are compared to relevant baseline data collected in 1989 (1990), 1995, and 1996. Since progressive reclamation will continue throughout the mine life, many of the long-term trends of vegetation metal update can be predicted prior to mine closure, which will limit the need for a large-scale post-closure research program. A post closure monitoring program will be developed based on the mine footprint and results of ongoing sampling.

In 2007, vegetation metal uptake samples were taken in the tree research plots. This data was analyzed by Ron Meister of Forestmeister Services (report was included as an appendix of the Mount Polley Mining Corporation (MPMC) *2007 Annual Environmental and Reclamation Report.*

2012 Sampling Locations

In July and August 2012, vegetation samples were taken at current reclamation projects to assess the metal concentrations of vegetation planted in waste dump reclamation:

- Northeast Zone (NEZ) Dump 2010 reclamation site: each of 9 native species plots on 3 treatment regimes
- North Bell Dump (NBD) 2011 reclamation site: 2 plots replicated 5 times each
- Tree research plots: each of the 36 plots which contain various treatment regimes (this data will be analyzed by Ron Meister of Forestmeister Services in the 2012 tree pot assessment).

In 2012, a new sample location (T12-01) was established. This site is in the vicinity of previous baseline samples, and represents metal levels in forest sites unaffected by mining.

Figure 1 provides a map of all 2012 vegetation sample locations.

Methodology

Historically, no standardized sampling protocol has been used on site. The methodology developed in 2012 works toward creating a procedure that is repeatable, utilizes some of the same approaches applied in the past, and allows MPMC to link to individual native species trial plots on the NEZ Dump (based on recommendations from Moss Giasson of Montane Environmental Services, and the *Vegetation Sampling and Metal Uptake Monitoring Protocol* (Jones & Associates Ltd., 2001). Further sampling and methodology recommendations to complete development of a standardized procedure that fits the above goals and provides a complete assessment of vegetation metal uptake on site are included in the Conclusion of this document.

2012 Methodology

When establishing new monitoring locations, the site was flagged, a photo was taken referencing obvious landmarks, and the GPS waypoint was recorded.

The optimum timing for vegetation sampling is prior to seed head emergence for grasses, and prior to the bloom stage in legumes (approximately late June/early July). 2012 sampling occurred in July, with one sample being taken in August. Only the current year's growth was sampled, and plants that were damaged, dead or heavily contaminated with dust or soil were excluded.

Sample collection included:

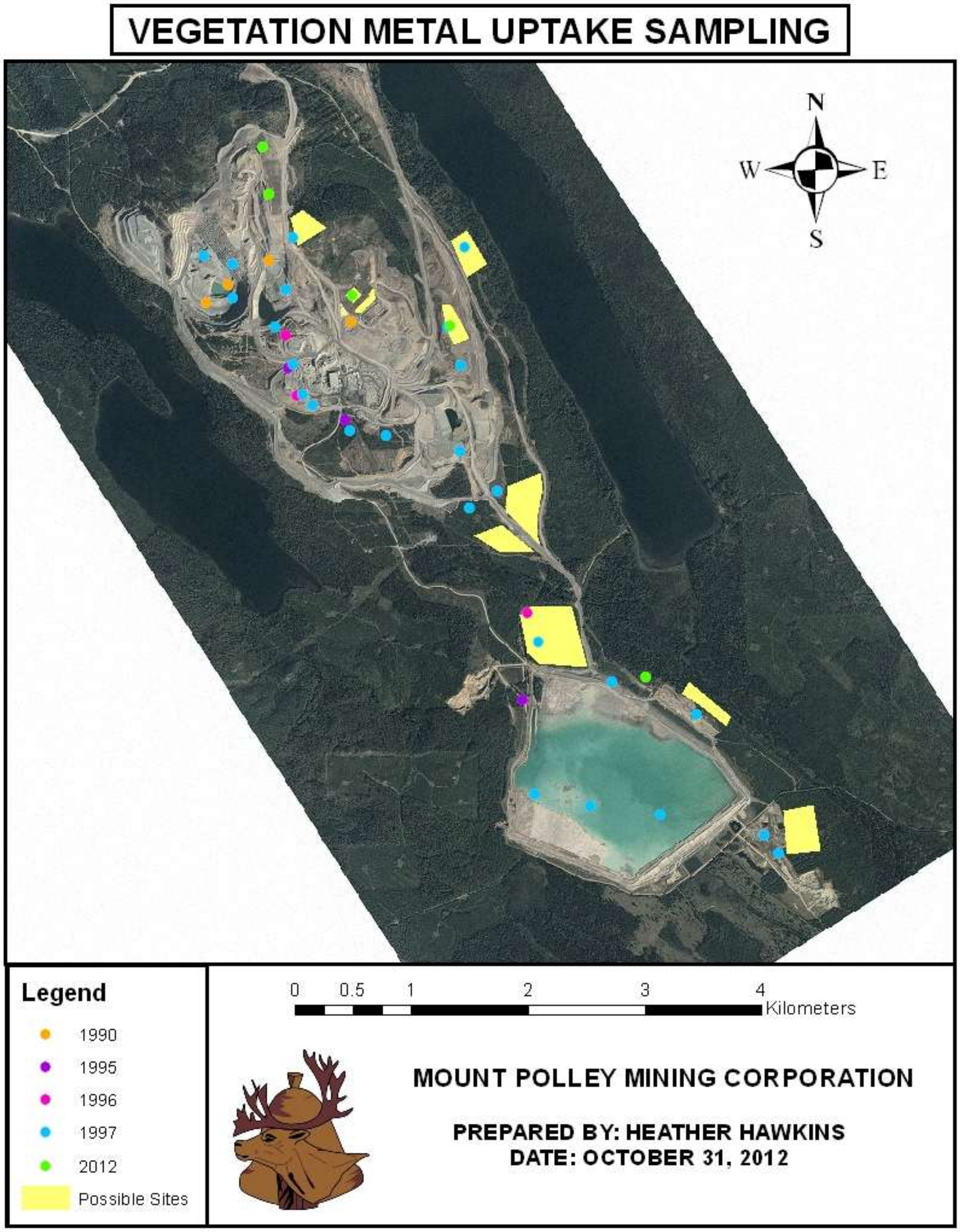
- Composite grab samples of seed heads, young vegetation, and leaves to mimic cattle or ungulate browsing on reclamation sites.
- On the NEZ Dump, separate samples from each native species plot on all three treatment units to assess metal uptake by species.
- A composite grab sample from an unaffected control site in the forest adjacent to the Perimeter Pond.

Samples were collected in paper bags using scissors, with approximately a handful of fresh foliar material as the sample size. The samples were stored in the refrigerator for up to 48 hours before being shipped to ALS Laboratory in Burnaby for analysis. Refer to Table 1 for the metal analysis suite.

Data analysis used the student's t-test to assess if differences between the NEZ Dump individual species samples and baseline individual samples were statistically different (using a 95% confidence interval). Statistical comparisons were not made for comparison of brome species data or comparison of composite samples from the NDB reclamation and control site because the baseline brome data and 2012 control site data both had a sample size of one. Instead, general trends were considered.

Table 1 List of parameters for vegetation metal uptake analysis.

Parameter
Aluminum (Al)-Total
Antimony (Sb)-Total
Arsenic (As)-Total
Barium (Ba)-Total
Beryllium (Be)-Total
Bismuth (Bi)-Total
Boron (B)-Total
Cadmium (Cd)-Total
Calcium (Ca)-Total
Cesium (Cs)-Total
Chromium (Cr)-Total
Cobalt (Co)-Total
Copper (Cu)-Total
Gallium (Ga)-Total
Iron (Fe)-Total
Lead (Pb)-Total
Lithium (Li)-Total
Magnesium (Mg)-Total
Manganese (Mn)-Total
Molybdenum (Mo)-Total
Nickel (Ni)-Total
Phosphorus (P)-Total
Potassium (K)-Total
Rhenium (Re)-Total
Rubidium (Rb)-Total
Selenium (Se)-Total
Sodium (Na)-Total
Strontium (Sr)-Total
Tellurium (Te)-Total
Thallium (Tl)-Total
Thorium (Th)-Total
Tin (Sn)-Total
Titanium (Ti)-Total
Uranium (U)-Total
Vanadium (V)-Total
Yttrium (Y)-Total
Zinc (Zn)-Total
Zirconium (Zr)-Total



1. **Figure 1 Mount Polley Mine site vegetation metal uptake plots (1990 – 2012)**

Results & Discussion

Excerpt from *Mount Polley Mining Corporation Vegetation Metal Study* (Meister, 2007) which provides background for the data analysis approach used in this report:

"There are no established limits of heavy metal content in vegetation for ungulate or herbivore consumption due to the varied nature of the animal diet which may consist of a variety of plants with each plant differing in their absorption capability of heavy metals. Animals move, and large ungulates will spend varying time on any one site but are unlikely to spend a significant amount of time on one spot, and are thus limited to exposure from any one area. The metal content of plants changes with changes in their phenology, therefore plant metal content changes through the growing season. Animals may not get all their heavy metal consumption from vegetation. Other possible sources include water and soil which may be consumed inadvertently when the animal is grazing. Foliar metal content is altered by growing conditions, such as climate and soil variability and rate of defoliation by grazers (C. Hackinen 1987).

A risk assessment approach is used to evaluate the potential risk due to heavy metals in the environment. This report will compare the ambient potential exposure to the potential heavy metal exposure on the reclaimed mine site"

Composite Samples

Historically, composite samples have not been collected, so samples taken from the NBD reclamation area were compared to the control plot T12-01 (in the forest between Hazeltine Creek and the Tailings Storage Facility). Refer to Table 2 for a summary of results. Five samples were taken at both sites P1 and P2 on the NBD, however; because only one control sample was taken, statistical conclusions cannot be made (only general trends can be observed).

Table 2 Comparison of 2012 NBD Reclamation and control plot sample results

Parameter	T12-01 (mg/kg)	NBD-P1 (mg/kg) Average	NBD-P2 (mg/kg) Average
Aluminum (Al)-Total	83.9	31.38	40.86
Antimony (Sb)-Total	<0.010	<0.010	<0.010
Arsenic (As)-Total	<0.060	<0.15	<0.14
Barium (Ba)-Total	15.0	6.688	11.584
Beryllium (Be)-Total	<0.010	<0.010	<0.010
Bismuth (Bi)-Total	<0.010	<0.010	<0.010
Boron (B)-Total	17.7	8.92	7.88
Cadmium (Cd)-Total	0.025	0.0422	0.0706
Calcium (Ca)-Total	9200	4568	5380
Cesium (Cs)-Total	0.0949	0.1772	0.415
Chromium (Cr)-Total	0.205	0.07975	0.0712
Cobalt (Co)-Total	0.084	0.0536	0.0728
Copper (Cu)-Total	8.83	11.08	13.84
Gallium (Ga)-Total	0.032	<0.020	<0.020
Iron (Fe)-Total	210	83.22	102.36
Lead (Pb)-Total	0.057	0.0215	0.0272
Lithium (Li)-Total	<0.20	<0.10	<0.20
Magnesium (Mg)-Total	2470	1476	1686
Manganese (Mn)-Total	63.4	120.2	101.9
Molybdenum (Mo)-Total	1.50	1.422	4.524
Nickel (Ni)-Total	0.331	0.1046	0.2318
Phosphorus (P)-Total	2780	2782	2876
Potassium (K)-Total	16500	18800	16340
Rhenium (Re)-Total	0.038	0.036	0.025
Rubidium (Rb)-Total	46.6	22.3	24.9
Selenium (Se)-Total	<0.10	0.124	0.31
Sodium (Na)-Total	<100	<100	<100
Strontium (Sr)-Total	49.6	18.74	18.82
Tellurium (Te)-Total	<0.020	<0.020	<0.020
Thallium (Tl)-Total	<0.0020	0.007	0.0052
Thorium (Th)-Total	0.013	<0.010	<0.010
Tin (Sn)-Total	<0.020	<0.020	<0.020
Titanium (Ti)-Total	7.23	2.97	3.378
Uranium (U)-Total	0.0035	<0.0020	<0.0020
Vanadium (V)-Total	0.574	0.1846	0.2086
Yttrium (Y)-Total	0.052	0.019	0.0212
Zinc (Zn)-Total	28.0	40.46	41.54
Zirconium (Zr)-Total	<0.20	<0.20	<0.20

Copper

Copper levels on the North Bell Dump range from 10.5 to 15.9 mg/kg, compared to 8.83 mg/kg at the control site. Hackinen (1987) reported a cattle Copper toxicity level of 115 mg/kg. Based on the principle that cattle and ungulates have similar digestive systems, it is assumed that they have similar susceptibility to the effects of copper, thus current Copper foliar levels on the NBD do not appear to pose a hazard to ungulates at Mount Polley.

Molybdenum

Foliar molybdenum levels of the NBD composite samples ranged from 1.0 to 6.1 mg/kg compared to 1.5 mg/kg at the control site. Molybdenum values are variable between plots, indicating soil molybdenum available to plants varies, reflecting variable soil quality. Hackinen (1987) also reported a cattle Molybdenum toxicity level of 6 mg/kg. A replicate at one plot on the NBD exceeded this guideline by 0.1 mg/kg, indicating that Molybdenum levels within Mount Polley may be of concern to wildlife health.

Copper/Molybdenum Ratio

Cu:Mo ratios ranged from 2.6:1 to 10.7:1 on the NBD with a mean value of 5.7:1. The Cu:Mo for the control was 5.9, which is approximately equal to the mean value observed on the NBD.

When the ratio of Copper to Molybdenum drops below 2:1 molybdenosis can be expected unless the Copper concentration exceeds 13-16 ppm (Jones, 1994). Data from the 2012 samples at the NBD and control site meet this standard.

Other Metals

Sample results for both NDB plots and the control were all below MDL for antimony, arsenic, beryllium, bismuth, lithium, sodium, tellurium, tin, and zirconium.

Sample results for were above MDL in the control, but below MDL on both NBD plots for gallium, thorium, and uranium.

Sample results on the NBD were lower than the results from the control for aluminum, barium, boron, calcium, chromium, cobalt, iron, lead, magnesium, nickel, rubidium, strontium, titanium, vanadium, and yttrium.

Sample results on the NBD and control were roughly equivalent for cesium, phosphorus, potassium and rhenium.

The remaining metals or plan micronutrients (cadmium, manganese, selenium, thallium and zinc) show higher levels than the control. While levels deemed toxic to cattle and ungulates are unknown for these parameters, these parameters should be monitored closely in the future.

Individual Species Samples

Table 3 shows the baseline individual species samples available for comparison with the 2012 NEZ Dump samples. Table 4 provides a comparison of average results from these samples. Graphs illustrating changes over time are presented in Figure 2. The baseline studies are composed of an extensive analysis of 30 species, but the analysis was limited to the following metals: Arsenic, Copper, Lead, Iron, Molybdenum, Selenium, and Zinc. Therefore, for comparison to baseline on the seven parameters can be analysed. A discussion of each parameter is provided below. Note that t-test statistical calculations were not completed for Brome, because the 1995 the sample size was only one.

Copper & Molybdenum

Copper levels increased slightly in brome (from 2.80 mg/kg to an average of 4.46 mg/kg), and remained constant in rye, while averages decreased slightly in fireweed (from 9.95 mg/kg to 9.25 mg/km) between baseline and 2012. No results were statistically significant, however all results are well below the cattle guideline of 115 mg/kg.

Molybdenum levels in brome showed a large decrease between 1995 and 2012 from 11.30 mg/kg to an average of 1.18 mg/kg. A significant increase in average concentrations from baseline was observed for rye grass (from 0.40 mg/kg to 3.22 mg/kg), while average concentrations in fireweed decreased from 2.91 mg/kg to 2.23 mg/kg. All samples except for the baseline brome sample were below the cattle toxicity guideline of 6 mg/kg.

When the Cu:Mo drops below 2:1, molybdenosis can be expected unless the copper concentration exceeds 13-16 ppm. 2012 ratios for brome ranged from 3.6:1 to 4.2 to 1, which are well above the baseline of 0.3:1. For fireweed, 5 of 22 baseline samples were below this level, however, the average ratio was 3.4:1. 2012 fireweed ratios ranged from 2.5:1 to 8.6:1. The only 2012 sample not meeting this guideline was of rye grass (1.8:1). The remaining 2012 rye grass samples (2.2:1 and 4.2:1) and baseline rye grass samples (15.5 and 43.6) exceeded the minimum ratio.

Arsenic
Arsenic levels decreased slightly between baseline and 2012 in brome and fireweed, while rye grass showed a large decrease (not statistically significant) between 1996 and 2012.

Lead
In 2012, average lead levels were lower than baseline for all species, with rye grass and fireweed decreases being statistically significant.

Selenium
An increase in selenium concentration was observed for all three species, with the increase in fireweed between baseline and 2012 being statistically significant.

Zinc
An increase in zinc levels was observed between 1995 and 2012 for brome, while concentrations in rye grass and fireweed have decreased over time (not statistically significantly).

Table 3 Baseline vegetation metal uptake species samples available for comparison with 2012 NEZ Dump Samples

Species	1990	1995	1996	1997	2012
Fireweed	-	-	X	-	X
Rye Grass	-	-	X (Wild Rye)	-	X (Blue Wild Rye)
Brome	-	X (Pumelly Brome)		-	X (Mountain Brome)

Table 4 Species specific 2012 NEZ Dump results compared with baseline results

	BROME		RYE GRASS		FIREWEED	
Parameter	**1995**	**2012**	**1996**	**2012**	**1996**	**2012**
Arsenic	0.025	0.033	0.210	0.038	0.114	0.118
Copper	2.80	4.46	7.93	7.96	9.95	9.25
Lead	0.10	0.01	0.18	0.04	0.16	0.03
Molybdenum	11.30	1.18	0.40	3.22	2.91	2.23
Selenium	0.025	0.183	0.125	0.200	0.062	0.270
Zinc	17.5	26.6	33.4	25.1	32.5	29.4
Sample Size	1	3	2	3	22	3

Notes:

1) Samples results from each of the 3 NEZ Dump treatment units were averaged (substrates are consider the same, because the parcel that used biosolids, the biosolids were below the root zone of young plants).

2) Values below MDL are represented as 0.5*MDL.

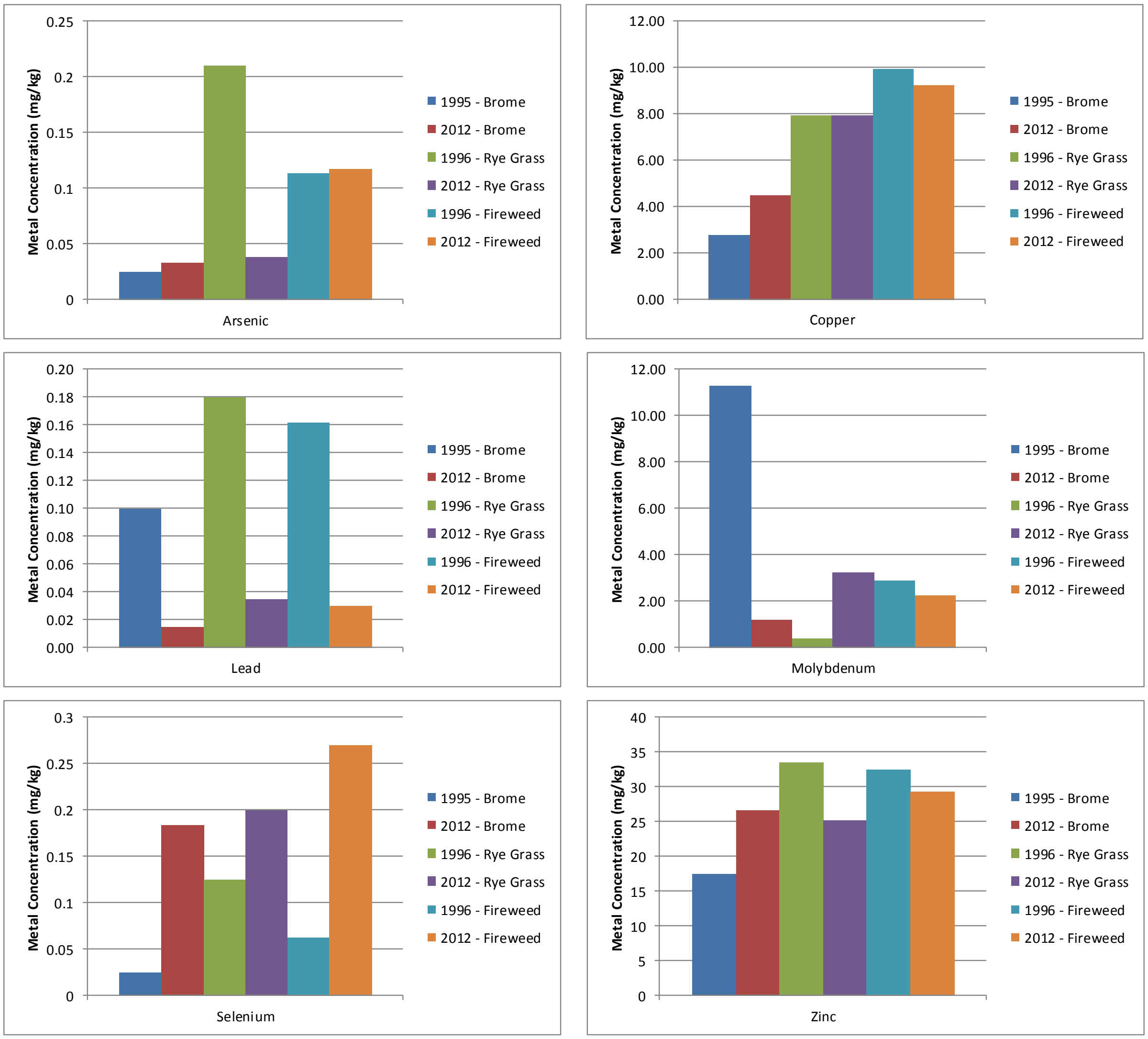


Figure 2 Comparison of 2012 NEZ Dump and baseline individual species metal uptake samples.

Conclusion & Recommendations

Based on results of the 2012 sample program, increases have been observed in some parameters, in some or all data sets. It is expected that soil weathering over time will decrease metal uptake in vegetation and limit possible consequences to animal health, however, the following metals should be closely monitored in the future: cadmium, manganese, molybdenum (and the Cu:Mo), selenium, thallium, and zinc. Currently copper levels and the Cu:Mo are not a concern, however, they should be continued to be analyzed due to their significance for livestock and wildlife health.

Further sampling and methodology recommendations have been made to complete development of a standardized procedure that provides a complete assessment of vegetation metal uptake on site:

1. Prior to sampling new areas, site land cover types should be pre-stratified (for example: level waste rock dumps, sloped waste rock dumps, and tailings beach) and sample sites should be pre-selected to avoid bias (for example: by using transects on a map). Samples should be collected at a density of one 20 m^2 plot per two hectares or to a maximum of ten sites per stratum. Additional samples should be collected in areas where the known mineralization is a concern.

2. Take vegetation metal uptake samples at baseline sites that have not been disturbed (refer to Figure 1 for a map of locations) to monitor trends over time.

3. Establish monitoring locations farther from the mine site that have less potential to be affected by mining activities. Comparisons between data collected on site and data collected at these locations can be made to assess mine influence. A possible site is at the mouth of Hazeltine Creek.

4. At all sites, take composite samples (to mimic animal browsing), as well as species specific samples as available. Based on the availability of baseline data, and species that are in MPMC's reclamation seed mix or are commonly occurring, recommended desirable species are:
   - Fireweed
   - Rye Grass
   - Red Clover (*Trifolium pretense*)

Selection of these species is also supported by the fact that in baseline and 2012 data, metal concentrations in fireweed and rye grass are higher than those in brome. This is expected for fireweed, because legumes tend to show greater foliar elemental uptake than grasses (reference).

5. Continue to monitor vegetation metal uptake at established locations (reclamation, baseline, and control sites) every five years. Ensure enough sample are taken that statistically significant conclusions can be made.

6. Complete foliar analysis of foliage (summer) and stems (winter) of deciduous trees, and coniferous trees (October – December). Recommended species are:
   - Sitka Alder
   - Willows
   - Pine (this will provide information on soil nutrient deficiencies)

Consider completing soil nutrient and heavy metal content research. This will more readily confirm soil contamination and establish a relationship between soil and vegetation heavy metal levels. Use the BC Ministry of Environment *Overview of CSST [Contaminated Sites Soil Task Group] Procedures for the Derivation of Soil Quality Matrix Standards for Contaminated Sites*. This will develop site specific standards of heavy metal content for Mount Polley and contribute to public confidence that mining at

Mount Polley is not detrimental to the environment. The *Canadian Soil Quality Guidelines for Protection of Environmental and Human Health* may also be of use.

References

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