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FINAL REPORT

ASSESSMENT OF THE POTENTIAL FOR EFFECTS ON WILDLIFE FROM EXPOSURE TO PROCESSED KIMBERLITE AT THE EKATI DIAMOND MINE

Submitted to:

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EXECUTIVE SUMMARY

Introduction

BHP Billiton Diamond Mines Ltd. (BHPB) retained Golder Associates Ltd. (Golder) to conduct an assessment of risk to wildlife health from exposure to processed kimberlite. BHPB's current research to develop an Abandonment and Reclamation Plan for the Long Lake Containment Facility (LLCF) includes growing plants on processed kimberlite. Public concerns have been raised that wildlife such as caribou, muskoxen and hare may be exposed to metals in kimberlite by directly ingesting kimberlite or by indirectly ingesting metals through plants growing on processed kimberlite. In addition, people may be concerned that if they hunt caribou that have been exposed to processed kimberlite, human health could be affected. Therefore, the purpose of the risk assessment is to determine if wildlife may be exposed to metals from the LLCF area that could cause unacceptable health risks and to evaluate the potential human health risks from consuming caribou meat. The results of the risk assessment will be used as input to the Abandonment and Reclamation Plan for the EKATI Diamond Mine.

Risk Assessment Approach

The risk assessment focused on the potential risks to wildlife health due to exposure to kimberlite and plants growing on kimberlite. In addition, ingestion of standing water in the LLCF was evaluated for all wildlife and ingestion of prey was evaluated for carnivores. Risks to human health were also evaluated based on consumption of caribou that could be exposed to processed kimberlite. All applicable and available recent data that have been collected from the revegetation studies conducted by Harvey Martens and Associates were reviewed. Therefore, the risk assessment is based on currently available data.

The following wildlife receptors, (also called valued ecosystem components (VECs)) were evaluated in the risk assessment:

- muskoxen (*Ovibos moschatus*);
- caribou (*Rangifer tarandus*);
- grizzly bears (*Ursus arctos horribilis*);
- wolverine (*Gulo gulo*);

- wolves (*Canis lupus*);
- hare (*Lepus arcticus*); and
- ptarmigan (*Lagopus lagopus*).

Humans are not expected to be directly exposed to metals in the LLCF by incidental ingestion of processed kimberlite or via drinking processed kimberlite effluent. The only valid pathway for the human health assessment is via ingestion of caribou meat from caribou that have been exposed to metals from ingestion of processed kimberlite soil, vegetation and standing water. Therefore, concentrations of metals in caribou meat were estimated, and risks to people eating caribou meat were evaluated.

Potential effects on human and wildlife health can be determined by assessing risk, which is defined by two components, exposure and effect, as follows:

- Exposure: the intake of a metal (e.g., via ingestion) for a particular time period; and
- Effect: the adverse health effect(s) that may result from the exposure.

A health risk assessment is a standard process for determining the exposure to a substance received by a receptor (human or wildlife) and the effects that exposure may have on a receptor's health.

Exposure to metals by wildlife that may inhabit areas near the LLCF and people that may consume caribou meat is estimated by determining the following:

- the concentrations of metals in soil, plants and standing water within the LLCF;
- the types of receptors (i.e., wildlife) that could be in the vicinity of the LLCF or consume organisms that spend time in the area;
- the pathways by which receptors may come in contact with metals (i.e., incidental ingestion of soil, ingestion of food and water);
- the amount of time receptors may spend within the vicinity of the LLCF (i.e., days/year);
- typical soil, water and food ingestion rates and body weights for wildlife receptors;
- typical meat ingestion rates and body weights for human receptors; and

- the quantity of metals that receptors are likely to take into their bodies by each pathway.

In the risk assessment, the effect of metals is estimated by considering the following:

- determining whether the quantity of metals in soil exceeds applicable regulatory guidelines;
- reviewing the toxicity information associated with each metal; and
- determining the total amount of exposure from all applicable pathways that would cause no adverse health effects in receptors (called toxicity benchmarks).

Chemicals that were not essential nutrients, and were present in soil at concentrations greater than guidelines (or for which guidelines were not available), and were present in the LLCF at concentrations greater than concentrations measured in areas without processed kimberlite were identified as Chemicals of Concern (COC) and were evaluated in the risk assessment. The following COCs were evaluated for all receptors and exposure pathways (i.e., soil, food and water ingestion for wildlife and meat ingestion for people) in the risk assessment:

- chromium;
- cobalt;
- manganese;
- molybdenum;
- nickel; and
- strontium.

Receptors may be exposed to metals from the LLCF via several pathways. The following pathways were evaluated in the risk assessment:

- ingestion of soil (all VECs);
- ingestion of plants that have taken up metals from the soil (caribou, muskoxen, hare and ptarmigan);
- ingestion of standing water (all VECs);
- ingestion of prey (wolves, wolverine, grizzly bears); and

- ingestion of caribou meat (humans).

The final step in a risk assessment, referred to as risk characterization, involves comparing the estimated exposure to the toxicity benchmark. If the estimated exposure is less than the toxicity benchmark, no health risks are expected. If the estimated exposure is greater than the toxicity benchmark, then alternatives to the use of plants to stabilize processed kimberlite or mitigation measures that reduce exposure to processed kimberlite may need to be examined. Risk estimates were calculated as the exposure ratio (ER), which is a ratio of the estimated exposure of metals from the LLCF to the toxicity benchmarks, as follows:

$$ER = \frac{\text{Estimated Exposure}}{\text{Toxicity Benchmark}}$$

If the ER is greater than 1, then the amount taken in is greater than the threshold amount for which there are no health effects. Since many conservative assumptions were used throughout the assessment, an ER greater than 1 does not mean that there will be health effects but that further consideration is necessary to reduce uncertainty in the risk assessment (see discussion below on layers of safety). If the ER is less than 1, then we can be certain that no health effects or unacceptable risks would occur, also because of the many layers of safety used throughout the risk assessment.

Layers of Safety

In this risk assessment, exposures and toxicity benchmarks were estimated from available information about how exposure might take place and the potential health effects that could result. There is always uncertainty associated with these estimations, depending on the quality, quantity and variability associated with the available data. When information is uncertain, it is standard practice in a risk assessment to make assumptions that are biased towards safety, so that even if there is uncertainty, human and wildlife health will still be protected.

There are several layers of safety applied in this study. For example, maximum concentrations were used in the risk assessment to estimate exposure. The assumption that all concentrations are at maximum accounts for the potential variability in concentrations in soil, water and vegetation. Conservative assumptions regarding the amount of time that wildlife spent near the LLCF were also applied to the risk assessment. In addition, it was assumed that people ate caribou meat every day (365 days per year) from caribou that were exposed to maximum metals concentrations from the LLCF for 6 months per year.

There is also uncertainty associated with estimating toxicity benchmarks. Extrapolating from animal studies in the laboratory to the possible effects that may result from exposure to metals from the study area is uncertain. For wildlife health, toxicity benchmarks were chosen from studies that were credible and that evaluated subtle health effects such as changes in blood chemistry and growth. For human health risk assessments it is a standard practice to assume that people are more sensitive to the toxic effects of a substance than laboratory animals. Therefore, the toxicity benchmark for human health is set at a much lower level than the animal benchmark (typically 100 to 1,000 times lower). This large margin of safety ensures that doses less than the toxicity benchmarks are safe and that minor exceedances of these benchmarks are extremely unlikely to cause adverse health effects.

All of these layers of safety ensure that risk from exposure to metals at the LLCF has not been underestimated.

Results

Wildlife Health

There is no increased health risk for wildlife exposed to metals in the LLCF via ingestion of soil, water and food. Since none of the VECs would be at risk from ingesting water, soil and food from the LLCF and since the VECs selected for the risk assessment are representative of different levels of the ecosystem, it is concluded that no other species of wildlife that inhabit the LLCF would be exposed to concentrations of metals that could cause a health risk. Conservative assumptions and many layers of safety were applied to the wildlife health risk assessment. This means that there is a high degree of certainty that risks have not been underestimated and that all wildlife would be safe from exposure to metals from the LLCF.

Human Health

For the human health risk assessment, for all of the metals evaluated in the assessment, estimated exposure was less than the toxicity benchmarks. Therefore, there is no risk to health due to the ingestion of caribou meat. Conservative assumptions and many layers of safety were used to estimate exposure and to derive toxicity benchmarks. This means that there is a high degree of certainty that risks have not been underestimated and that all members of a family would be safe from exposure to metals from the Study Area.

What Does This Mean for the Abandonment and Reclamation Plan?

Stabilizing processed kimberlite by revegetating the LLCF as part of the BHPB Abandonment and Reclamation Plan for the EKATI Diamond Mine will not result in human or wildlife health risks due to exposure to metals from processed kimberlite.

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1. INTRODUCTION

BHP Billiton Diamond Mines Ltd. (BHPB) retained Golder Associates Ltd. (Golder) to conduct an assessment of risk to wildlife health from exposure to processed kimberlite. BHPB's current research to develop an Abandonment and Reclamation Plan for the Long Lake Containment Facility (LLCF) includes growing plants on processed kimberlite. Public concerns have been raised that wildlife such as caribou, muskoxen and hare may be exposed to metals in kimberlite by directly ingesting kimberlite or by indirectly ingesting metals through plants growing on processed kimberlite. In addition, people may be concerned that if they hunt caribou that have been exposed to processed kimberlite, human health could be affected. Therefore, the purpose of the risk assessment is to determine if wildlife may be exposed to metals from the LLCF area that could cause unacceptable health risks and to evaluate the potential human health risks from consuming caribou meat. The results of the risk assessment will be used as input to the Abandonment and Reclamation Plan for the EKATI Diamond Mine.

1.1 Background

The use of vegetation to stabilize processed kimberlite was first considered during the closure planning of the Fox Exploration Portal, which was operated by BHPB until 1995. ABR Inc. (ABR) conducted revegetation studies as part of the reclamation and closure plan for the Fox Exploration Portal site. Results indicated that kimberlite with soil added to it ("amended" kimberlite) produced abundant plant growth and good ground cover while kimberlite alone produced less vigorous growth and inadequate ground cover. Different seed mixtures were attempted on different soil amendments. After 5 growing seasons, the seed mix that included tundra bluegrass (*Poa glauca*), alpine bluegrass (*Poa alpine*), alyeska polargrass (*Arctagrotis latifolia*) and arctared fescue (*Festuca rubra*) resulted in the most abundant ground cover. Native forbs including alpine milk-vetch (*Astragalus alpine*), viscid oxytrope (*Oxytropis viscida*) and wormwood (*Artemisia arctica*) and local grasses and shrubs including alpine holygrass (*Hierochloe alpine*), Labrador tea (*Ledum decumbens*) and alpine azalea (*Loiseleuria procumbens*) were less successful. The study evaluated mean percentage plant cover; however, metal concentrations in plant tissue were not analyzed (ABR 2000).

In 2000, research continued as part of a joint venture between Harvey Martens and Associates Inc. (Martens and Associates) and the University of Alberta (U of A) to answer the question: "should processed kimberlite tailings be stabilized with a plant cover or with waste rock as currently proposed in the EKATI Diamond Mine Interim Abandonment and Reclamation Plan (BHPB 1998)?" A summary of the field reclamation from studies 2000, 2001 and 2002 is provided in the following sections below.

1.1.1 Revegetation Studies Conducted in 2000

In June 2000, Martens and Associates in conjunction with the U of A began reclamation research trials at EKATI. Study plots (42 revegetation plots and 4 species trial plots) were set up on processed kimberlite in the LLCF. A revegetation study investigated establishment of plant cover on kimberlite tailings with and without the addition of peat and various nutrient combinations (i.e., rock phosphate, gypsum and calcium. Peat was selected as a suitable soil amendment as it would satisfy most of the limiting soil conditions for plant growth on kimberlite. Perennial and annual species trials were also conducted to evaluate the suitability of seven northern grasses, alyeska polargrass (*Arctagrotis latifolia*), bluejoint reedgrass (*Calamagrotis canadensis*), tundra bluegrass (*Poa glauca*), alpine bluegrass (*Poa alpine*), bering hairgrass (*Deschampsia beringensis*), Norton hairgrass (*Deschampsia caespitosa* var. Norton) and arctared fescue (*Festuca rubra*), to establish cover on kimberlite (Martens and Associates 2000).

A field soil study was also conducted at the EKATI LLCF to evaluate the effects of physical and chemical soil amendments on plant growth and community establishment. Soil amendment plots in the LLCF consisted of processed kimberlite alone, low and high peat combined with processed kimberlite and all three trials with and without the addition of calcium in the form of gypsum and rock phosphate (Reid 2000).

Soil chemistry was assessed for the soil-amended and revegetation study plots. Nutrient and metal concentrations were analyzed for plant tissue from revegetation plots. Chemistry analysis indicated that the metals chromium, nickel, manganese and iron and potassium were taken up into plants from soil. The highest concentrations were found in plants grown in plots with unamended processed kimberlite (Martens and Associates 2000).

The main conclusion from this research was that revegetation on kimberlite is a viable option; however, additional trials to determine if soil-amendments other than peat would enhance plant community establishment were required (Martens and Associates 2000; Reid 2000).

1.1.2 Revegetation Studies Conducted in 2001

In 2001, Martens and Associates and U of A repeated the 2000 research but used additional soil options (i.e., lake sediment and sewage sludge) as possible media for amending processed kimberlite. The research was conducted both in plots established in the LLCF and in greenhouses at U of A. Field research indicated that the incorporation of lake sediment with processed kimberlite produced marginal benefits in terms of plant growth (Martens and Associates 2001). Greenhouse experiments were designed to evaluate the different soil amendments on plant growth. Peat, lake sediment and sewage sludge were added to trials at different rates. Arctared fescue (*Festuca rubra*) was used as a representative perennial species to remove inter-species competition and to compare plant establishment on the different soil amendment treatments. Nutrient amendment rates for gypsum, rock phosphate, calcium carbonate and fertilizer were also tested during these trials (Reid 2001).

Supplementary soil studies were conducted in greenhouses at U of A for soil treatments that could not be conducted outdoors due to time constraints. Amendments and amendment combinations that were tested in the field were also tested in the greenhouse for comparison purposes. Additional amendments that were tested in the greenhouse experiments included sewage sludge, pulp mill waste and Agri-boost, a commercial organic soil conditioner. Metals concentrations were not presented in the report; however, soils analyses (parameters not specified) were reported to have been conducted (Reid 2001).

The main conclusion from the 2001 trials was that amendment and amendment combinations, particularly peat, lake sludge and/or sewage sludge, improved processed kimberlite as a plant growth medium. Tissue analysis was not conducted for revegetation plots at EKATI for the 2001 growing season (Martens and Associates 2001) or for the trials at U of A greenhouses (Reid 2001).

1.1.3 Revegetation Studies Conducted in 2002

In 2002, Martens and Associates and U of A added the following five studies to their research program:

- native seedling study to evaluate the effectiveness of rooted seedlings;
- a rock pile study to assess the effects of wind shelter on the growth and establishment of plants;
- a paper pulp waste study to determine the effectiveness of paper pulp as organic source;
- species trial to test the growth of several new grass species; and
- wet area study to test several methods of establishing plant cover in moist areas.

The studies indicated that plant cover on processed kimberlite is feasible; however, concerns regarding metal uptake by vegetation and ingestion by wildlife and ultimately humans were raised. Martens and Associates (2002) conducted a trace metals study in response to these concerns (herein referred to as the Trace Metals Report). Soil and plant samples were collected from the revegetation study plots detailed above and in three areas not impacted by processed kimberlite (i.e., reference locations). Reference sites included three sample locations at the mine site away from the LLCF, 1 sample location in a wet meadow at the mine site and from three sample locations near the Arnie Exploration site. The mine site and Arnie Exploration site supported an open-shrub tundra community, while the wet meadow supported grasses and sedges.

Three surface soil samples (0 to 15 cm depth) were collected at each site and combined into one composite sample per site. At the reclamation study sites, plant cover was determined and plant tissue samples were collected from the four most successful grass species and from alkali grass (*Puccinellia distans*), a natural invader at the site. Three common shrubs from the open shrub community, dwarf birch (*Betula glandulosa*), blueberry (*Vaccinium uliginosum*) and willow (*Salix sp.*) were collected. In the wet meadow site, two sedges (*Carex aquatilis* and *Eriophorum vaginatum*) and a grass (*Calamagrostis canadensis*) were collected. Soil and vegetation samples from both the LLCF study plots and from reference locations were submitted to a laboratory for analysis of metals (Martens and Associates 2002).

Soils typically found in kimberlite-rich areas have naturally elevated concentrations of chromium, iron, manganese and nickel (Martens and Associates 2002). Plant tissue analysis conducted on samples collected from the revegetation plots at EKATI LLCF after the 2000 and 2002 growing season indicated elevated levels of these metals in plant tissue grown on processed kimberlite. These concentrations are greater than typically found throughout the tundra (Martens and Associates 2002). However, the growth response of annual plants, measured by percent cover and shoot length, did not indicate that trace metals caused a reduction in plant growth success (Martens and Associates 2000). Perennial grass seedlings showed no visible symptoms of metal toxicity or deficiency.

In February 2003, technical workshops were conducted with regulators and community representatives to describe the above monitoring and research activities. Trace metals in vegetation growing on processed kimberlite caused concern among elders regarding wildlife health, in particular, caribou. Elders were also concerned about human health effects from consumption of caribou and other animals that may graze in the area because caribou are a primary staple of the aboriginal diet. Golder was asked to conduct a wildlife and human health risk assessment to address the elders' concerns. The results from the Trace Metals Report conducted by Martens and Associates (2002) were used in this risk assessment.

1.2 Scope of Work

The risk assessment focused on the potential risks to wildlife health due to exposure to kimberlite or plants growing on kimberlite. Risks to human health were also evaluated based on consumption of caribou that could be exposed to processed kimberlite. All applicable and available recent data that have been collected from the revegetation study conducted by Martens and Associates were reviewed.

1.3 Organization of Report

The remainder of the report is structured as follows:

Section 2	Site Description: provides a brief description of the environmental setting.
Section 3	Sources of Data: provides a summary of the data used in the risk assessment. A more detailed summary of the data is presented in Appendix I.

Section 4	Definition of Reference: provides a definition of the source(s) of the reference data used in the risk assessment ("reference" data are data from comparable areas without affects from processed kimberlite).
Section 5	Risk Assessment Approach: provides a brief description of the approach and methods used to determine the potential for adverse effects on people and wildlife. Detailed methods are described in Appendix II.
Section 6	Risk Assessment Results: provides a summary of the results of the human and wildlife health risk assessments.
Section 7	Conclusions: provides a brief summary of the report.

2. SITE DESCRIPTION

2.1 Environmental Setting

The BHPB EKATI Diamond Mine is located near Lac de Gras, approximately 300 km northeast of Yellowknife, Northwest Territories in the southern arctic ecoregion. The land surface is mostly rock outcrops with little or no plant growth. The region also has numerous lakes. Common plants are dwarf birch (*Betula pumila*), willow (*Salix spp.*), and northern Labrador tea (*Dryas spp.* and *Vaccinium spp.*). Characteristic wildlife includes caribou, muskox, grizzly bear, hare, fox, wolf, raptors, shorebirds, and waterfowl.

The closest community is Wekweti, a Dogrib community approximately 180 km southwest of the EKATI Diamond Mine. People from this community, as well as others, have used the area around EKATI as traditional hunting and trapping grounds.

The risk assessment focused on the LLCF, which is planned for revegetation upon closure of the mine. This area is approximately 390 ha. The LLCF receives processed kimberlite from the EKATI Diamond Mine. Processed kimberlite is the finely crushed rock that results from separating rock from diamonds. No chemicals are added to rock during the crushing process. In addition, water from the processed kimberlite effluent will be present in the LLCF.

3. SOURCES OF DATA USED IN THE RISK ASSESSMENT

Risk assessment was used in this study to evaluate the potential for adverse effects on wildlife and people as a result of exposure to metals from the LLCF.

The risk assessment required information on metal concentrations in the following parts of the food chain:

- reference soil and reference native plant species;
- soil-amended processed kimberlite (herein referred to as soil), which will be used as the growing material for plants;
- plants grown on the LLCF;
- water in the LLCF; and
- animal tissue (calculated).

The focus was on metal concentrations because processed kimberlite does not contain other kinds of chemicals that may pose a risk to health. The soil and vegetation data from the 2002 field trials (Martens and Associates 2002) were used in the risk assessment because both the study area and reference samples were collected during the same field season. The previous data from the 2000 and 2001 field trials were not used because data from reference sites were not collected. Uptake of metals is influenced by many factors including climactic variables such as rainfall, temperature and sunlight. Therefore, it was considered more appropriate to use soil and vegetation collected from the both reference sites and the LLCF during the same growing season. In addition, the growth success of the grasses was good and it is likely that the long-term revegetation plan will include primarily a mix of grasses and a smaller component of other plant species (Martens and Associates 2002).

Water metals concentrations are based on processed kimberlite effluent data from BHPB (pers. comm. Millard 2003). These data are from water quality samples collected from the 'end-of-the-pipe' during kimberlite processing before deposition to the LLCF. Wildlife are not likely to consume their daily drinking water from the end of the pipe, but are more likely to consume standing water within the LLCF, which is expected to have lower metals concentrations.

Therefore, use of these undiluted effluent concentrations are conservative (i.e., over-estimation and therefore protective) for the risk assessment.

Animal tissue concentrations (i.e., caribou) were calculated based on uptake from soil, water and vegetation into animal tissue. These calculations are based on uptake factors for each metals reported by researchers in the scientific literature.

More detailed descriptions of the sources of the data, the data, summary statistics and meat tissue calculations are presented in Appendix I.

4. DEFINITION OF REFERENCE

Reference concentrations are an important component of risk assessments. A reference concentration is the amount of a chemical found in an area that is similar to the study area but without the source being studied (in this case, processed kimberlite). In a risk assessment, reference concentrations are one of the screening tools used to evaluate the significance of concentrations of substances found in an area of interest. The use of reference concentrations as a screening tool is consistent with risk assessment protocols developed by Health Canada (2003).

Reference concentrations are required because some substances, particularly metals, are naturally occurring, especially in an area rich in mineral and diamond deposits. Since metals are common and widespread, soil and water always contain some metals. Metals are a major component of the earth's crust; therefore, metals can be measured in all environmental samples (e.g., soil, sediment, water, plants,) no matter where the samples are taken from. Thus, comparisons between the study area concentrations and reference area concentrations were used to check whether or not metals measured in the study area are increased due to deposition of processed kimberlite.

Three reference areas were sampled as part of the Trace Metal Report (Martens and Associates 2002): an area within the mine site that is vegetated with native shrubs; a nearby wet meadow; and the Arnie Exploration Site, which is an open shrub community. At the Mine Site, three plant species, dwarf birch (*Betula glandulosa*), blueberry (*Vaccinium uliginosum*) and willow (*Salix sp.*) were collected. Two sedges, water sedge (*Carex aquatilis*) and cotton grass (*Eriophorum vaginatum*) and bluejoint reedgrass (*Calamagrostis canadensis*) were collected from a wet meadow area. Three samples dwarf birch (*Betula glandulosa*), blueberry (*Vaccinium uliginosum*) and willow (*Salix sp.*) were collected from the Arnie Exploration Site.

As part of the chemical screening step in the risk assessment, maximum metals concentrations measured in soil from the LLCF were compared with mean concentrations measured in each of the reference areas. If the study area concentrations were less than reference concentrations, the chemical was screened out; that is, it was not considered a chemical of concern and not considered further in the risk assessment. In other words, if concentrations are lower in the study area than in the reference areas, the source of metals in the study area is not from processed kimberlite. If the study area concentrations were greater than the reference values, the substance was carried forward to the next step of the screening process. The screening process used in the risk assessment is described in more detail in Appendix II, Section 3.

5. RISK ASSESSMENT APPROACH

This risk assessment was conducted according to established health risk assessment protocols endorsed by Health Canada, the Canadian Council of Ministers of the Environment, Alberta Environment (AENV) and the United States Environmental Protection Agency (Health Canada 1994, 2003; CCME 1996 a,b,c; AENV 2000, U.S. EPA 1998) and risk assessment principles outlined in a report to Health Canada (Health Canada [unpublished] 1995).

Standard risk assessment terminology used in these guidance documents has been modified in this report to convey the information in a less technical manner. Refer to Appendix II for more detailed technical information.

What is Risk Assessment?

Risk assessment is a standard procedure for answering three fundamental questions about an area:

- How safe is it? (Section 5.1)
- How sure are we? (Section 5.2)
- Is it acceptable? (Section 5.3)

These questions must be answered in the context of the overall risk management goal. The overall goal for the reclamation plan for the LLCF at the EKATI Diamond Mine is "No significant risks to wildlife populations using the LLCF as a source of food and no risks to individual humans that consume caribou meat".

5.1 How Safe Is It?

Potential effects on human and wildlife health can be determined by assessing risk, which is defined by two components, exposure and effect, as follows:

- Exposure: the intake of a metal (e.g., via ingestion) for a particular time period; and
- Effect: the adverse health effect(s) that may result from the exposure.

A health risk assessment is a standard process for determining the exposure to a substance received by a receptor (human or wildlife) and the effects that exposure may have on a receptor's health.

Exposure to metals by wildlife that may inhabit areas near the LLCF and people that may consume caribou meat is estimated by determining the following:

- the concentrations of metals in soil, plants and water within the LLCF;
- the types of receptors (i.e., wildlife) that could be in the vicinity of the LLCF or consume organisms that spend time in the area;
- the pathways by which receptors may come in contact with metals (i.e., incidental ingestion of soil, ingestion of food and water);
- the amount of time receptors may spend within the vicinity of the LLCF (i.e., days/year);
- typical soil, water and food ingestion rates and body weights for wildlife receptors;
- typical meat ingestion rates and body weights for human receptors; and
- the quantity of metals that receptors are likely to take into their bodies by each pathway.

In the risk assessment, the effect of metals is estimated by considering the following:

- determining whether the quantity of metals in soil exceeds applicable regulatory guidelines;
- reviewing the toxicity information associated with each metal; and
- determining the total amount of exposure from all applicable pathways that would be unlikely to cause adverse health effects in receptors (called toxicity benchmarks).

The final step in a risk assessment, referred to as risk characterization, involves comparing the estimated exposure to the toxicity benchmark. If the estimated exposure is less than the toxicity benchmark, no health risks are expected. If the estimated exposure is greater than the toxicity benchmark, then alternatives to the use of plants to stabilize processed kimberlite or mitigation measures that reduce exposure to processed kimberlite may need to be examined.

5.1.1 Identifying Chemicals of Concern

The first step of the risk assessment was to identify chemicals that are of concern in the study area, as a result of processed kimberlite deposition. First, maximum concentrations of metals in soil measured in the study area were compared to mean reference concentrations. The assessment focussed on metals concentrations in soil since soil is the primary medium for processed kimberlite deposition (i.e., plants take up metals from soil). Also, regulatory guidelines are not available for plant tissue quality. Chemical concentrations that were less than reference concentrations were not considered further.

Chemicals with concentrations that were greater in the study area than in reference areas were then compared to regulatory guidelines for soil quality. Guidelines applicable to wildlife health are those developed for livestock, which are designed to protect individual animals 100% of the time (CCME 1999). Therefore, the Canadian Council of Ministers of the Environment (CCME) Soil Quality Guidelines for Protection of Agricultural Land Use were used (CCME 1999).

The published guidelines used in this assessment are conservative; that is, they err on the side of safety in order to ensure the protection of the health of the most susceptible individuals in a population under daily exposure conditions. Soil quality guidelines are derived using data for the most sensitive test species and are derived to be protective of all receptors, 100% of the time. Therefore, concentrations less than guidelines can be assumed to be safe. Metals that were present at concentrations less than these guidelines were not evaluated further in the risk assessment.

The final step in determining the list of chemicals of concern was to determine if the chemical is an essential nutrient (e.g., calcium). Chemicals that were not essential nutrients, and were present in soil at concentrations greater than guidelines (or for which guidelines were not available), and were present at concentrations greater than reference values were identified as Chemicals of Concern (COC) and were evaluated in the risk assessment. The screening process is presented in Figure 1. Further details on the screening process are provided in Appendix II, Section 3. The following COCs were evaluated for all receptors and exposure pathways (i.e., soil, food and water ingestion for wildlife and meat ingestion for people) in the risk assessment:

- chromium;
- cobalt;
- manganese;
- molybdenum;
- nickel; and
- strontium.