Anvil Range Mine Complex Terrestrial Effects Study Design: Elemental Concentrations in Vegetation, Wildlife and Soils

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1. Abstract

The Anvil Range Mine Complex is located approximately 200 km north-northeast of Whitehorse, Yukon, and includes both the Faro and Vangorda / Grum mine sites. The mine complex operated as an open-pit lead-zinc producer from 1968 to 1998, inclusive of several temporary closures. In 2002 a reconnaissance-level field program focusing on terrestrial vegetation and soils was initiated on and adjacent to the mine complex in support of the environmental assessment of the mine's 2004 – 2008 water license renewal. Results of this study indicated elevated concentrations of elements attributed to airborne contamination originating on site. It was concluded that further work was required to better characterize the potential contamination and provide information for on site care and maintenance activities and for the development of the Final Closure and Reclamation Plan for the mine complex. A commitment was also made to the affected First Nations to ensure that First Nation input was effectively integrated into future work. These commitments formed the basis of the Terrestrial Effects Study. The objectives of the Terrestrial Effects Study are to:

- Further define the spatial distribution of elevated elemental concentrations, including definition of the distance to reference levels;
- Determine whether airborne deposition is currently ongoing or historic;
- Investigate elemental levels in vegetation species of importance to humans and wildlife; and
- Investigate elemental concentrations in wildlife tissue, including species of importance to humans.

This paper will report on the methodological approach used to meet the above objectives.

2. Background

The Anvil Range Mine Complex is located approximately 200 km north-northeast of Whitehorse, Yukon, and includes both the Faro and Vangorda / Grum mine sites (Figure 1). The mine complex operated as an open-pit lead-zinc producer from 1968 to 1998, inclusive of several temporary closures. In 2004, Gartner Lee Limited was retained by Deloitte & Touche Inc. (in its capacity as Interim Receiver of the Anvil Range Mine) to develop and execute a Terrestrial Effects Study for the Anvil Range Mine Complex. This study was initiated under the recommendation of the Environmental Assessment conducted in support of the application for Water Licence Renewal for ongoing care and maintenance activities at the Anvil Range Mine Complex (Deloitte & Touche Inc. and Gartner Lee Limited 2003) and based on the findings of a reconnaissance-level field program that focused on terrestrial vegetation and soils (CE Jones & Associates Limited 2003).

The specific objectives of the Terrestrial Effects Study are to:

- Further define the spatial distribution of elevated elemental concentrations, including definition of the distance to background levels;
- Determine whether airborne deposition is ongoing or historic;
- Investigate elemental levels in vegetation species of importance to humans and wildlife; and
- Investigate elemental concentrations in wildlife tissue, including species of importance to humans.

Meetings these objectives will also provide the field and analytical information necessary for a future human and ecological risk assessment. The findings of the Terrestrial Effects Study and future risk assessments will feed into on site care and maintenance activities and into the development of the Final Closure and Reclamation Plan for the Anvil Range Mine Complex.

This paper will report on the methodological approach used to meet the above objectives.

3. Methods

3.1 Spatial Distribution of Elevated Elemental Concentrations

3.1.1 General Approach

Sampling for the 2004 Terrestrial Effects Study was designed to build on information collected in 2002 (C.E. Jones & Associates Ltd. 2003). Data from 2002 show that elevated elemental concentrations resulting from potential airborne contamination occur in a zone that extends at a minimum of 2 to 3 km in all directions from potential mine-site contaminant dust sources, and that the highest concentrations appear to extend northwest to north of the tailings impoundments and mill complex. Study objectives relating to spatial distribution were:

1. To provide additional information on near-source contamination and improve delineation of contamination patterns; and
2. To determine the extent of potential contamination, or the maximum distance from the mine complex of identifiable effects.

The determination of spatial distribution of potential contamination in the 2004 data collection program is based primarily on sampling of terrestrial lichens and supported through soil sampling. Soil sampling provides confirmation of lichen results (in surface horizons) and also allows for the evaluation of the presence of natural soil mineralization unrelated to mining operations through separate sampling of surface organic, subsurface organic and subsurface mineral samples.

3.1.2 Lichen Sampling

Lichen are entirely dependent on airborne or precipitation sources of nutrients (and metals), and thus are isolated from underlying soil mineralization. A study of the till geochemistry in the area of the Anvil Range Mine Complex (Bond 2001) indicates a dispersal train of mineralized till (subsurface mineral) trending north and west from the Faro deposits towards Next Creek and Rose Creek. This coincides with the primary direction of airborne dispersal indicated by the 2002 vegetation and soils metals study (C.E. Jones & Associates Ltd. 2003). Thus, in the 2004 study, every precaution was taken to ensure that elevated elemental concentrations resulting from natural mineralization are not misattributed to effects of airborne contamination generated by mining operations. To this end it was concluded that the determination of spatial distribution of potential contamination in the 2004 data collection program be based primarily on lichen sampling. Furthermore, lichen are long-lived perennial accumulators i.e., do not annually renew "foliar" tissue, as deciduous species do. As a result, elemental concentrations in lichen tissues represent a cumulative history of airborne deposition.

3.1.2.1 Lichen Sampling Locations

Geostatistical analysis (Kriging) of 2002 lichen data was used to assist in the identification of 2004 sample locations. Where the results of the Kriging exercise showed data gaps (through analysis of confidence in interpolation between 2002 sample points), potential sampling locations were identified. Sample sites were then selected by eye with the objective of filling these identified data gaps. Figure 2 shows the distribution of sampling locations for both the 2004 and 2002 field sessions. This figure shows an increased sample point density within the projected affected areas (e.g., surrounding the tailings impoundments and mill complex), an extension of existing transects (e.g., northwest to north of the tailings impoundments and mill complex and downstream Rose Creek) as well as an increased coverage of all areas surrounding the mine footprint (e.g., Grum / Vangorda mine areas, along the haul road between the Faro and Grum / Vangorda mine areas and between the Town of Faro and the haul road). There are a number of outlying sample locations that have been incorporated into this sampling program in response to specific public input, *e.g.*, at the confluence of Anvil Creek and the Pelly River (Selkirk First Nation Traditional Knowledge Workshop April 2004) and within the Town of Faro (Town of Faro Open House, March 2004).

A primary objective of the 2004 sampling program was to delineate the maximum distance from the mine complex of elevated lichen elemental concentrations. A conservative approach was adopted based on the limited information available from the 2002 results. This approach was informed by two factors:

1. It was hypothesized that lichen elemental concentrations might not decay consistently with distance from the mine complex contaminant sources, but might decrease abruptly from the influence of significant topographic features; and
2. Kriging functions best as an interpolation tool, and is weak as an extrapolation tool.

Based on these factors, 2004 sampling transects were extended 1-2 points past the local significant "heights-of-land" surrounding the Faro tailings impoundment / mill complex (e.g., Rose Mountain and Mount Aho). It was reasoned that this approach would allow abrupt lichen elemental concentration breaks to be captured within the Kriging interpolation zone.

The 2002 lichen data set showed that one of the major zones of elevated elemental concentrations was the Rose Creek drainage downstream of the mine complex. There are a number of potentially confounding contaminant sources within this drainage. In addition to the hypothesized airborne contamination originating from the mine complex, there are potential water- and sediment-borne contamination sources. These latter sources include the historical

Faro tailings dam breach[1] and fluvial transport of native naturally mineralized surficial material. In an attempt to differentiate between these sources in the Rose Creek drainage, sixteen paired sample points were established, with one sample point of each pair located on the current (fluvial) floodplain of Rose Creek, and the corresponding point located on the adjacent (northern) till side slope. Sample points on the till side slope are isolated from fluvial transport of anthropogenic or native sediment.

3.1.2.2 Lichen Sampling Methods

The primary terrestrial lichen species sampled was *Cladina mitis* – this species was collected on all sample points wherever it occurred (Figure 2). Lichen samples were collected using un-powdered nitrile gloves, with new gloves used at each sample site. Non-lichen material was removed from the samples at each sample site, to ensure comparability of samples. Samples were collected in metalized polyester Kapak bags (designed to be trace element-free) and isolated from other potential contaminant sources prior to laboratory analysis.

3.1.2.3 Lichen Laboratory Analysis

Lichen samples were sent to CanTest Laboratories (Burnaby, BC) for analysis of the 33 elements listed in Table 1. Samples were first digested using a nitric acid - hydrogen peroxide digestion procedure based on U.S. Environmental Protection Agency Method 200.3. Analysis of all elements except mercury was performed using ICP-MS (Inductively Coupled Argon Plasma Spectroscopy - Mass Spectrometry). Analysis of mercury was performed using Cold Vapour Atomic Absorption or Fluorescence Spectrophotometry.

3.1.2.4 Lichen Data Analysis

Geostatistical analytical techniques were applied to lichen data to delineate patterns of elevated elemental concentrations surrounding the Anvil Range Mine Complex. Geostatistical analytical techniques allow for the consideration of the gradational natures of the data, i.e., elemental concentrations decreasing with distance from a source. This method effectively controls for the confounding effect of variation within, in this case, potentially mine-effected areas. For example, if a straight comparison was made between potentially mine-effected areas and reference areas, the variation in the data in mine-effected areas would likely be too great to detect any statistically significant difference between the two areas; not because there is no difference but because an inherent source of variation in the data has not been controlled. Therefore to avoid this confounding effect, geostatistical analytical techniques (in this case Getis-Ord G statistical test for non-random spatial distribution and the Kriging technique for spatial surface creation) were employed to separate out this source of variation in the data. Results of the Getis-Ord and Kriging techniques were employed in the analyses throughout (e.g., categorization of groups for statistical comparison of elemental concentrations in vegetation and wildlife).

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[1] A tailings dam breach occurred in 1975 resulted in the deposition of mine waste materials in the Rose Creek drainage.

Therefore, the lichen data set was screened using the Getis-Ord G-statistic (a test of spatial clustering) to investigate the potential occurrence of significant non-random patterns in the distribution of elemental concentrations.

$$G^*_{i,t} = \frac{\sum_j w_{ij,t} v_{j,t} - W^*_{i,t} \bar{v}_t}{s_t \sqrt{\frac{(n_t S^*_{1i,t}) - W^{*2}_{i,t}}{n_t - 1}}}$$

Where

$\bar{v}_t$	sample mean
$W^*_{i,t}$	sum of the weights
s_t	sample standard deviation
n_t	number of objects in the geography at time t
$S^*_{1i,t} = \sum_j w^2_{ij,t}$	the sum of the squared weights

A high General G value indicates that high values are clustered within the study area; a low General G value indicates that low values tend to cluster. Also calculated is the “z score”. The z score represents the statistical significance of the relationship and indicates whether the apparent similarity (or dissimilarity) in values between the feature and its neighbors is greater than one would expect simply by chance. A non-significant result of this test indicates no spatial pattern in elevated elemental concentrations, and thus no statistically identifiable effect of mine-related activities on lichen elemental concentrations. Significant results of this test indicate the occurrence of a non-random pattern in elevated elemental concentrations that could be related to mine-related activities. A geostatistical technique known as Kriging is then employed to spatially represent the pattern of elemental concentrations to determine whether patterns indicate an effect of mine-related activities, e.g., by showing that the location of highest elemental concentrations is centred on the Anvil Range Mine Complex. Kriging technique breaks down the variance in a data set into three components: a general spatial trend, a spatially dependent component, and a stochastic or random component. The technique involves looking at how different sample results are as a function of distance (called a Semivariogram). One then selects a numerical model that describes the spatial component of the variance, and uses that along with the measured points to produce an interpolated surface of values. In addition to producing a surface of predicted concentrations (from which contours can be calculated), the Kriging analysis produces a surface of prediction standard errors. The prediction standard error surface is used to constrain the predicted surface so that contour lines are only produced in areas where there is reasonable confidence in the surface; in this case the prediction is constrained to one third of the total predicted standard error.

Observed elemental concentrations were also compared in the context of published reference levels (Crete *et al.* 1992; Gamberg unpub. data; Kabata-Pendias 2001; Rhoades, 1999; Shaw and Gunn 1981) and those on contaminated sites (Kabata-Pendias 2001).

3.1.3 Soil Sampling

Soils are also perennial accumulators and therefore provide a cumulative history of airborne deposition. However, mineral soils are also subject to confounding influences through natural mineralization and glacial transport. Sampling soils as part of the spatial distribution program therefore enables:

- Confirmation of lichen results (through comparison with surface soil results); and
- Evaluation of the presence of naturally elevated elemental concentrations unrelated to mine operations in local surficial materials.

In order to allow this latter evaluation, soils were sampled separately by horizon / parent material, as follows:

- Surface organic (0-2 cm of F horizon) – obtained directly under live vegetation and its associated litter layer;
- Subsurface organic (lower F / H horizon) – obtained directly over the organic / mineral interface, at a minimum depth of 5 cm from soil surface; and
- Subsurface mineral sample (B horizon).

This stratification by depth and type of soil material provides some interpretative power (e.g., elevated elemental concentrations in surface organics in comparison to sub-surface organics would support the airborne deposition hypothesis, whereas elevated concentrations throughout the organic and mineral profile would suggest mineralization pre-dating mining operations).

3.1.3.1 Soil Sampling Locations

For the purposes of the spatial distribution program, soil samples were collected at a subset of the sampling locations displayed in Figure 2 including the paired sample sites on Rose and Anvil Creeks, all sites on Swim Lakes reference areas and a representative number of sites throughout the study area. Soil samples were also collected on sites where vegetation species of importance to humans and / or wildlife were collected.

3.1.3.2 Soil Sampling Methods

Soil samples were collected using stainless-steel shovels to minimize metal contamination during sampling. Shovels were cleaned with 99% isopropanol prior to sampling at each site. Soil was handled wearing un-powdered nitrile gloves, with new gloves used at each sample site. Living vegetation and rocks were removed from the samples, to ensure comparability of samples. Samples were collected in metalized polyester Kapak bags (designed to be trace element-free) and isolated from other potential contaminant sources prior to laboratory analysis. Soil samples were collected at all three depths described above (where available):

- Surface organic (0-2 cm of F horizon);
- Subsurface organic (lower F / H horizon); and
- Subsurface mineral sample (B horizon).

A small number of collected soil samples did not fit into the categories described above. For instance, a small number of surface mineral samples were collected on the Rose Creek floodplain, as fluvial activity at the sample point has prevented deep surface organic layers from forming, or has removed these layers. Some anomalous materials were also collected, such as samples of White River Ash[2] deposits, typically encountered at the organic / mineral interface.

3.1.3.3 Soil Sub-sampling Methods

A subset of soil samples collected was selected for immediate analyses of elemental concentrations. The remaining soil samples were archived for any future analyses. A further subset of samples was analyzed using a sequential extraction technique, in order to provide information on relative mobility of metals deposited as a result of mining operations. This sample subset was also analyzed for organic matter content, to investigate the effects of organic complexation of metals by evaluating potential correlations between mobility as indicated by sequential extraction and organic matter content. This subset of samples was selected to adequately represent the Swim Lake reference area and the most highly mine-affected areas.

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[2] The White River Ash is a voluminous deposit of Holocene airfall tephra covering an area of 540,000 square kilometers across parts of Alaska and portions of the Yukon and Northwest Territories. The deposit was created as the product of two explosive eruptions of Mount Churchill, approximately 1887 and 1147 years B.P.

Cyanide was analyzed on a further subset of analyzed samples in response to public concerns raised during a community meeting (Selkirk First Nation Faro Mine Remediation Plan Update and Closure Plan Objectives Workshop November 2004) with regards to the absence of cyanide in the list of elements analyzed (Table 2). Although it was suspected that cyanide was unlikely to be an issue in the terrestrial environment, confirmatory sampling was conducted. Soil sample selection focused on areas anticipated to have the greatest potential to be influenced by cyanide, i.e., those areas subject to the tailings dam breach in Rose Creek. Samples collected on Rose Creek floodplain were then compared to CCME guidelines.

3.1.3.4 Soil Laboratory Analysis

The subset of soil samples collected for metals analyses was sent to CanTest Laboratories (Burnaby, BC) for analysis of the 29 elements listed in Table 2 and pH. Soil pH was analyzed based on procedures described in the Manual on Soil Sampling and Methods of Analysis, published by the Canadian Society of Soil Science, 1993. The test was performed using a deionized water leach with measurement by pH meter. Strong acid leachable metals analysis was used to test all elements (except mercury, arsenic and selenium) in soils: analysis was performed using British Columbia Ministry of Environment, Lands and Parks Method, Strong Acid Leachable Metals in Soil, Version 1. (Province of British Columbia 2001). This method involves drying the sample at 60 degrees Celsius, sieving using a 2 mm (10 mesh) sieve and digestion using a mixture of hydrochloric and nitric acids. Analysis was then performed using Inductively Coupled Argon Plasma Spectroscopy (ICAP). The same preparation procedures (i.e., drying, sieving and digestion using a mixture of hydrochloric and nitric acids) were used to prepare arsenic, selenium and mercury for analysis. Arsenic and selenium were analyzed using ICP-MS and mercury was analyzed using Cold Vapour Atomic Fluorescence.

The sequential extraction used was based on that developed by Tessier *et al.* (1979). The first extraction, with hydroxylamine hydrochloride ($NH_2OH{\bullet}HCl$), releases Fe and Mn oxides in addition to soluble and exchangeable metals, metals bound to carbonates and fulvic acids, and possibly amorphous metal sulphides (Zhang *et al.*, 2001). The second extraction, with sodium pyrophosphate ($Na_4P_2O_7$), releases organically bound metals as described in Lavkulich (1981). The final extraction by aqua regia digest SALM method (Province of British Columbia 2001) releases the residual fraction (metals bound to sulphur compounds, some recalcitrant organics, and crystalline structures). All extract solutions were analyzed for metals using ICP-MS. Mercury in extract solutions was determined using a procedure based on the US EPA method 1631 oxidative digestion using bromination, then analyzed by Cold Vapour Atomic Fluorescence Spectroscopy.

Total cyanide analysis was performed using procedures based on those described in British Columbia Environmental Laboratory Manual for the Analysis of Water, Wastewater, Sediment and Biological Materials (Province of British Columbia 1994) and Standard Methods for the Examination of Water and Wastewater (American Public Health Association).

3.1.3.5 Soil Data Analysis

The stratification of samples used in 2004 (surface organic, subsurface organic and subsurface mineral) was designed to allow inferences to be drawn on potential contaminant sources (anthropogenic versus "natural"), and to identify trends in underlying till mineralization. Information from surface organic samples is reflective of recent deposition levels, and is expected to be similar to lichen data. Information from subsurface organic samples is reflective of surface deposition in the period far pre-dating operations at the Anvil Range Mine Complex and information from subsurface mineral samples reflects native mineralization in study-area surficial materials, again independent of recent deposition. If data from subsurface organic and / or subsurface mineral samples show a similar pattern to lichen and surface organic-soil data, it could suggest that the source of apparent contamination is not anthropogenic.

Geostatistical techniques were again used to analyze soil data. As with lichen data, soils data were screened using Getis-Ord methods to detect spatial clustering of elevated elemental levels, then Kriged where appropriate (i.e., where significant results indicated non-random distribution of data). Elemental concentrations were also correlated between surface and subsurface organic soils and subsurface organic and mineral soils to investigate the relationship in patterns of elemental concentrations between soils collected at different depths and parent materials. In soils, these examinations were conducted for lead and zinc only, as these are the two primary contaminants of interest on the Anvil Range site.

In order to isolate effects of airborne contamination from potential effects from fluvial transport of naturally mineralized materials, and from the tailings breach that occurred in 1975, elemental concentrations in soils were compared between samples collected from both the side slope and the floodplain of Rose Creek valley. Samples of White River Ash were submitted for laboratory analyses to investigate potential effects of this deposit on study-area soils. Samples analyzed for cyanide were compared to CCME guidelines.

Soil samples analyzed by sequential extraction technique provided data for comparisons in the relative mobility of elements, in addition to data on total concentrations. The relative mobility of selected elements (lead, zinc, cadmium and copper) could therefore be compared between areas (Swim Lake background versus mine-affected) and soil sample types (surface organic, subsurface organic and subsurface mineral) by measuring the relative amounts of these elements in various forms of complexation:

- Weakly complexed – this extraction (hydroxylamine hydrochloride) releases metals associated with iron and manganese oxides, carbonates and fulvic acids, and amorphous metal sulphides. This extraction step would also include water-soluble and exchangeable metals; however, it is not anticipated that substantial amounts of the analyzed metals exist in these latter forms in the study area. Therefore, results from this extraction process reflect metals complexation by more labile compounds. These metals are not readily mobile, but are relatively readily mobilized as associated compounds decompose or are degraded;

- Strongly complexed – this extraction (sodium pyrophosphate) releases metals complexed by more recalcitrant organic compounds. These compounds are relatively persistent, and will release metals very slowly; and
- Immobile – the last extraction (digestion) procedure used was the *aqua regia* process used to determine total elemental concentrations for the analysis of soils. Results from this step in the sequential extraction process reflect metals that are bound by residual recalcitrant organics, sulphur compounds, and crystalline structures.

3.2 Improve Characterization of Reference Concentrations

3.2.1 General Approach

Selection of reference sampling locations is critical to conducting a retrospective study of mine impacts on soils and vegetation metal concentrations where pre-mining sampling does not exist. Near-surface ore bodies that can be mined by open-pit methods are frequently associated with more widespread mineralization of surficial materials and soils. This mineralization can lead to naturally occurring elevated elemental concentrations in both soils and vegetation in areas surrounding ore deposits. It is important that such concentrations not be mistaken as evidence of contamination resulting from mining operations. For this reason, reference sampling locations for the 2002 study (C.E. Jones & Associates Ltd. 2003) were carefully chosen to be located in areas of natural mineralization that would be free from additional mine site impacts. Geological reports on the Anvil Range area indicated a zone of mineralization trending from northwest of the Faro pit, through the mined deposits and to the southeast as far as the Swim Lakes basin (Bond 2001). This information suggested the Swim Lakes basin as the most representative retrospective reference sampling location.

Following the results of the 2002 study (C.E. Jones & Associates Ltd. 2003), concerns were raised by community members of the Town of Faro that the Swim Lakes reference area was not far enough from the footprint of the Anvil Range Mine Complex to be unaffected by mining activities, i.e., potential airborne contamination (Town of Faro Open House, March 2004). It was therefore suggested that a more extensive search for candidate reference areas be conducted in 2004 (GLL and C.E. Jones & Associates Ltd. 2004). If this search did not yield additional candidate reference areas, a commitment was made to conduct an expanded sampling program on Swim Lakes with the objectives of:

- Expanding the reference data set and ensuring that sampling adequately covered the area of the identified Swim Deposit (Bond 2001); and
- Sample and analyze lichen, soils and moss bags from the Swim Lakes reference areas to determine the suitability of this area as a reference site by testing for evidence of cumulative and / or ongoing deposition related to the activities of the Anvil Range Mine.

3.2.2 Search for Additional Candidate Reference Areas

Location of additional reference areas requires that candidate areas must be free of potential airborne contamination from any source and also possess similar surficial geochemistry to that of the project area. The ideal background location should therefore be far enough removed from the Anvil Range Mine Complex to be free of mine-generated contamination, but within the same deposit type. A study of quaternary geology and till geochemistry of the Anvil district (Bond 2001) reports the following:

> "The Anvil district Zn-Pb-Ag stratiform pyritic massive sulphide deposits occur within a 150-m interval in the pre-Ordovician strata at the contact between Mount Mye and Vangorda formations. Five ore deposits occur in the Anvil District along a southeast curvilinear trend: Faro, Grum, Vangorda, Grizzly, and Swim…. Swim basin is considered to be the most representative area to calculate a regional threshold because of its similar geology, physiography and glacial history to the Vangorda plateau."

The Swim basin was initially selected as the most suitable background location for the study of the potential effects of the Anvil Range Mine Complex on surrounding terrestrial ecosystems, based on information in Bond's study; the Swim basin is the furthest-removed of the similar deposits that occur off-site from the Anvil Range Mine Complex and the Swim basin is situated in the upwind direction for prevailing summer winds (when contaminant sources on the mine site are not frozen or snow-covered). The only other potential candidate site is the Grizzly deposit. This site was rejected; it is situated only 4 km SE of the Vangorda mine site.

A search for appropriate additional reference sites prior to the 2004 field program did not yield any suitable candidates additional to the Swim Lake basin. This search was based on:

- A review of the rationale for the original selection of the Swim basin (predominantly Bond's 2001 report); and
- A review of 2002 lichen data from the Swim location, which indicated no elevation in lead or zinc concentrations in the Swim Lakes area relative to published reference levels.

As a result of this search and review process, and the lack of additional suitable candidate reference locations, the approach taken for the 2004 field program was to expand the sampling grid at the Swim Lakes location in order to expand the reference data set and to ensure that sampling adequately covered the area of the identified Swim Deposit (including areas where Bond's study had previously identified anomalously high lead and zinc concentrations in subsurface till samples). The Swim deposit is located approximately 3 km northwest of the western end of Swim Lake (i.e., at the northern end of the 2002 sampling transect displayed in Figure 2). Anomalously high lead and zinc levels located by Bond were most concentrated in the approximately 5 km x 5 km area directly west of Swim Lake. Both of these areas are covered by the integrated 2002 / 2004 Swim Lake reference location sampling grid.

3.2.3 Sampling and Analysis on Swim Lakes Reference Areas

3.2.3.1 Lichen

A total of 21 sites were selected for sampling in 2004 on Swim Lakes reference area; this increases reference observations to 28 from the seven collected in 2002. *Cladina mitis* were collected wherever these species occurred on the Swim Lakes reference area sample sites (Figure 2). Lichen sampling methods and laboratory analysis follow the procedures outlined above. Maximum elemental concentrations recorded on Swim Lakes reference area were compared to published concentration ranges for vegetation from uncontaminated areas (Crete *et al.* 1992; Gamberg unpub. data; Kabata-Pendias 2001; Rhoades 1999; Shaw and Gunn 1981). For all elements considered to be affected by the operations of the Anvil Range Mine, elemental concentrations in Swim Lakes lichen could be compared to concentrations in other lichen species except thallium; reference lichen data were not available for this element and therefore levels in vascular plants were used for comparison.

3.2.3.2 Soil

Soil samples were collected on all Swim Lakes reference area sample sites (Figure 2). Soil sampling methods and laboratory analysis follow the procedures outlined above. Lead levels in Swim Lakes soils samples were compared to those potentially affected by activities of the Anvil Range Mine. In this comparison, if lead concentration in surface soils of Swim Lakes is similar to that in soils of mine-affected areas, it would suggest that Swim Lakes reference area is not free of potential airborne contamination from the Anvil Range Mine. Furthermore, if lead concentrations in subsurface soils of Swim Lakes are dissimilar to those in mine-affected areas, it would suggest that Swim Lakes reference area does not possess similar surficial geochemistry to mine-affected areas.

3.2.3.3 Moss Bags

Three moss bag sampling locations were defined on the Swim Lakes reference areas (Figure 3). Moss bag sampling methods and laboratory analysis follow the procedures outlined below. Maximum elemental concentrations recorded in unexposed moss were compared to elemental concentrations in moss bags deployed on Swim Lakes reference area.

3.3 Timing of Deposition of Mine-Related Dust

3.3.1 General Approach

The 2002 metals in soils and vegetation reconnaissance study indicated that likely off-site contamination from mine operations exists, but did not provide any information on the likely timing of this contamination. In 2004, one project objective was to determine if ongoing deposition is contributing to the elevated elemental concentrations in vegetation or whether deposition of airborne mine-related dust is historical. Understanding whether ongoing deposition exists at the Anvil Range Mine is critical to determining whether measured contaminant concentrations are at their maxima, or will continue to increase. It will also provide an indication of the level of prioritization needed with respect to removing any current contaminant sources during the closure phase of the Anvil Range Mine Complex.

Moss bags were employed to determine whether airborne deposition is currently ongoing. Establishment and analyses of moss bags is a standard low-technology method for assessing both dry and wet (e.g., dust and precipitation-based) deposition of airborne contaminants (Temple *et al.* 1981; Onianwa 2000). Bags are constructed through acquisition of a standard or uncontaminated source of moss. Moss materials are rinsed, dried and analyzed for pre-exposure elemental concentrations and then placed into polypropylene mesh bags. Bags are held aerially in monitoring locations, and analyzed after determined exposure intervals. Detected increases in element concentrations from pre-exposure concentrations are indicative of airborne deposition.

3.3.2 Moss Bag Sampling

3.3.2.1 Moss Bag Sampling Locations

Moss bag sampling locations were selected from both 2002 and 2004 sample points with the objective of sampling areas: 1) closest to potential dust sources (Faro tailings impoundment / mill complex, Vangorda / Grum pits, the haul road and the connector road between the Town of Faro and the haul road); 2) at Swim Lakes reference locations; 3) on a transect from the immediate vicinity of potential sources (i.e., northwest to north of the tailings impoundments and mill complex) and 4) near the Town of Faro. Figure 3 shows the distribution of moss bag sampling locations.

3.3.2.2 Duration of Moss Bag Deployment

In previous applications of the moss bag sampling technique, authors have attempted to define optimal periods for the duration of moss bag deployment (Little and Martin 1974; Cameron and Nickless, 1977; Temple *et al.* 1981; Onianwa 2000) and have observed that these durations have varied with environmental conditions, e.g., the rate of deposition of trace elements and therefore the extent of potential saturation and weathering as well as the observation of preferential displacement of some metals (Onianwa 2000). Standard optimal periods for the duration of moss bag deployment have varied from 4 - 10 weeks, however these durations have been adopted where levels of deposition were anticipated to be much higher (e.g., near operational smelters (Temple *et al.* 1981)) than for an un-operational mine site such as the Anvil Range Mine Complex. In order to ensure that the period of duration of exposure would be sufficient to detect any changes in elemental concentrations in moss bags from pre-exposure levels, it was decided that moss bags be deployed for increasing durations (10, 20 and 30 weeks) in attempt to detect low levels of deposition. Therefore three bags were deployed at each sampling location and one bag collected after each 10 week interval:

- Week 10: The first moss bag pick up was in early November and sampled a period representative of fall (August 18, 2004 – November 1, 2004);
- Week 20: The second pick up was in mid-January and sampled a period representative of fall and early winter (August 18, 2004 – January 26, 2005); and
- Week 30: The third pick up was in late March and sampled a period representative of fall through to late winter (August 18, 2004 – March 31, 2005).

3.3.2.3 Moss Preparation

Moss was sourced locally from the Ross River area during a 2 day field session in mid-July 2004. Golden fuzzy fen (*Tomenthypnum nitens*) moss was collected using non-powdered nitrile gloves and stored in heavy-duty ziplock bags. It was anticipated that approximately 2,000g (fresh weight) of moss would be required to render roughly 600g (dry weight) of moss (assuming an estimated 70% moisture content). Over 2,000 g (FW) of moss was therefore collected from the Ross River area and transported on ice within 24 hours to Soilcon for preparation and analysis. Moss was soaked overnight in distilled water and then rinsed three times the next day in distilled water (Temple *et al.,* 1981). All moss was spread out to be air dried on laboratory drying racks for 48 hours (Temple *et al.,* 1981). A sub-sample of the prepared moss (i.e., n = 12 (total 36g DW)) was analyzed to obtain pre-exposure metal concentrations and the remainder of the prepared moss was used to create 170 moss bags (3 g dry weight moss per bag). Non-powdered latex or nitrile gloves were worn at all times in the handling and analysis of moss (Temple *et al.,* 1981).

3.3.2.4 Moss Bag Design and Creation

Temple *et al.* (1981) provides a comprehensive summary of accepted moss bag design specifications and methods. These methods were used as the basis for the design of a method of moss bag sampling for the Anvil Range Mine Terrestrial Effects Study. Moss bags were prepared using polypropylene mesh (mesh size 1,680 µm by 1,680µm) purchased from J & K Products, Quebec. This material was pre-cut and folded into 10cm by 10cm bags in Whitehorse and shipped with all other moss bag materials (nylon rope loops and plastic zip ties) to CanTest's Soilcon Laboratories (Richmond, BC). Each moss bag was filled with 3 g dry weight of moss at Soilcon laboratories. Before securing the zip ties, two pieces of nylon rope (~20cm long) were placed under the plastic zip at opposite corners to create loops that later served as a means to suspend the moss bag. Prepared moss bags (n = 170) were then shipped back to Whitehorse in Kapak bags for deployment on the project area.

3.3.2.5 Moss Bag Deployment and Collection Methods

Thirty-four moss bags were deployed on the project area. Moss bags were maintained in Kapak bags until reaching the sampling location and then removed from the Kapak bag and secured onto a tree using the nylon loops described above. Moss bags were deployed and collected using un-powdered nitrile gloves, with new gloves used at each sample site and were collected in metalized polyester Kapak bags (designed to be trace element-free) and isolated from other potential contaminant sources prior to laboratory analysis.

3.3.2.6 Moss Bag Laboratory Analysis

Pre-exposure moss and all post-exposure moss bags sent to CanTest Laboratories (Burnaby, BC) were analyzed for the 33 elements listed in Table 1. Moss samples were prepared for analysis following the methods of Temple *et al.* (1981), i.e., moss is oven dried, reweighed and homogenized in a Wiley mill. Dried, ground moss samples were then digested using a nitric acid-hydrogen peroxide digestion procedure based on U.S. Environmental Protection Agency Method 200.3. Analysis of all elements except mercury was performed using ICP-MS (Inductively Coupled Argon Plasma Spectroscopy - Mass Spectrometry). Analysis of mercury was performed using either Cold Vapour Atomic Absorption Spectrophotometry or Fluorescence Spectrophotometry.

3.3.2.7 Moss Bag Data Analysis

The objective of the moss bag sampling program was to determine whether airborne deposition is currently ongoing or historical. Therefore elemental concentrations in exposed moss bags were compared to those of unexposed moss.

3.4 Elemental Concentrations in Vegetation and Mineral Licks

3.4.1 General Approach

In order to investigate potential elemental uptake by vegetation species of importance to wildlife (*e.g.*, forage species) and / or humans (e.g., species used for medicinal use and / or consumption) selected vegetation species were sampled and analyzed. Soils can also influence wildlife species through direct consumption at mineral lick sites (or through consumption of soil during grazing). Soil samples were therefore collected at known mineral lick sites as well as at sites where vegetation was sampled. These data can then be used to investigate the extent of elevated elemental concentrations in the food chain by feeding into a future terrestrial risk analysis and will also assist in predicting possible current and future impacts on local land-users from elevated elements resulting from care and maintenance operations.

Vascular (i.e., rooting) vegetation can be influenced by both pre-existing mineralization (by rooting in the soil) and by airborne contamination (through deposition on plant materials and uptake through surface soil). Therefore in order to distinguish between sources of observed elevated elemental concentrations, and ensure that elevated concentrations are not erroneously attributed to mine operations if this conclusion is incorrect, results of soils analyses were used to assist in the analysis and interpretation of vegetation data results.

3.4.2 Vegetation and Mineral Lick Sampling

3.4.2.1 Determination of Vegetation Species of Importance to Wildlife and / or Humans

Vegetation species were selected from an expanded list of species documented to occur in the area of the Anvil Range Mine Complex (MEC Ltd. 1976; Weinstein 1992; Staniforth 1998; C.E. Jones & Associates Ltd. 2003; Selkirk First Nation Traditional Knowledge Workshop April 2004; Ross River Dena Council Terrestrial Effects Workshop May 2004). The selection of species aims to sample species that are important to wildlife and / or humans and relied heavily on input from the First Nations community and scientific knowledge regarding local wildlife food habits (Pearson 1976; Weinstein 1992; Schweinsburg 1990; Kuzyk and Farnell 1997; R. Ward, pers. comm., March 2004; Selkirk First Nation Traditional Knowledge Workshop April 2004; Ross River Dena Council Terrestrial Effects Workshop May 2004; McCann in prep.) and input from the First Nations on species of importance for human consumption and use (Selkirk First Nation Traditional Knowledge Workshop April 2004; Ross River Dena Council Terrestrial Effects Workshop May 2004; Ross River Terrestrial Effects Project Update and Traditional Knowledge Data Handling Meeting, August 2004) and community members of the Town of Faro (A. Domes, pers. comm. August 2004).

Table 3 lists vegetation species that were identified for sampling and analysis in 2004. In the selection of vegetation species of importance to humans, where the specific species or genus was identified during community meetings, samples were collected as single species (i.e., not composite samples), e.g., northern rough stemmed mushroom, tree sap from sub-alpine fir (*Abies lasciocarpa*) or White Spruce (*Picea glauca*), bear roots (*Hedysarum alpinium* or *Hedysarum boreale*) and Labrador tea (*Ledum groenlandicum*). All berry species identified during community meetings were collected where available as single species samples to ensure unique samples were collected to represent specific species of importance to humans. Those species not identified to species (e.g., willow and forbs consumed by humans) were sampled as composite samples.

The selection of vegetation species representing wildlife forage aims to sample broad vegetation groups that are representative of the major food types available and of importance to wildlife in the area of the Anvil Range Mine Complex. A number of vegetation species were identified for each broad vegetation group to allow for variation in abundance and occurrence of specific species on the study area. For example, amongst the forb group, five forb species were identified as potential species to sample to represent forbs: *Epilobium angustifolium* (fireweed); *Petasites frigidus* (coltsfoot); *Artemisia spp.* (sage); *Achillea spp.* (yarrow); and *Nuphar spp.* (water lily). Therefore where samples of more than one species of forbs could be collected, samples were collected as composite samples for the purposes of representing wildlife forage (and percent cover of each species documented and represented in the sample accordingly). Composite samples representing wildlife forage were collected for grasses and sedges, forbs, horsetails, berries and willows. Some single species samples representing specific species of importance to humans also represented wildlife forage: Labrador Tea, bear root, northern rough stemmed mushroom and tree sap. Lichen samples collected as single species for the purposes of the spatial distribution program also represented wildlife forage.

3.4.2.2 Vegetation and Mineral Lick Sampling Locations

Samples of vegetation of importance to wildlife and / or humans were collected opportunistically where they were found to occur in sufficient abundance at all sample locations visited (2004 sampling locations in Figure 2). Areas of importance to wildlife and / or humans were also identified by First Nations and Faro community members (Town of Faro Open House, March 2004; Ross River Dena Council Terrestrial Effects Workshop May 2004) and used to determine selected sampling locations. The specific locations of mineral lick sites were identified on working maps during community meetings (Town of Faro Open House, March 2004; Meeting with Anvil Range Mine Site Personnel, March 2004; Ross River Dena Council Terrestrial Effects Workshop May 2004).

The distribution of some plants was not ubiquitous and therefore less suited to the original sampling design, i.e., for the most part opportunistic sampling of species where they occurred on sample sites determined as part of the spatial distribution program. Some sampling locations were determined through input from First Nations and local community members; however, sampling locations closer to the Anvil Range Mine were not typically used for harvesting. Therefore to obtain samples of selected species (i.e., northern rough stemmed mushroom, bear roots and aquatic grasses) future sampling will require additional field preparation (aerial photograph interpretation for habitats containing these species) and a non-random sampling technique that will specifically sample where these species occur.

3.4.2.3 Vegetation and Mineral Lick Sampling Methods

Garden clippers were used to collect leaf and stem samples of grasses, sedges, horsetails and forbs and the tips of willows. Clippers were cleaned with 99% isopropanol prior to sampling at each site. Labrador tea leaves, berries, bear roots and mushrooms were collected by hand using un-powdered nitrile gloves, with new gloves used at each sample site. Dead vegetation and non-vegetation materials were removed from the samples at each sample site, to ensure comparability of samples. Samples were collected in metalized polyester Kapak bags (designed to be trace element-free) and isolated from other potential contaminant sources prior to laboratory analysis. Methods of tree sap collection followed those provided by First Nations (Ross River Terrestrial Effects Project Update and Traditional Knowledge Data Handling Meeting, August 2004).

The timing of collection of species of importance to humans and wildlife aimed to coincide with one of the seasons of use. For example, mushroom and bear roots were sampled during fall (these species are consumed during fall and bear root is also consumed by bears during early spring), berries and Labrador tea were sampled during summer (these species are consumed during summer and some berry species are also consumed by bears as over-wintered berries during early spring), sap of *Abies lasciocarpa* (locally known as balsam fir) and *Picea glauca* (white spruce) was collected in the fall (these species can be harvested throughout the year), willow twigs were sampled during summer (these species are consumed throughout the year), and grasses, sedges, horsetail and forbs were sampled during summer (these species are consumed from emergence in spring up until senescence in fall). The exception is lichen; lichen samples were collected during summer although lichen is consumed during winter. However, the concentration of trace metals in lichen tissues do not appear to vary seasonally (Berryman et al in 2004) although macronutrients (such as potassium, magnesium and calcium) do (Boonpragob et al. 1989), these elements are not related to the activities of the Anvil Range Mine.

Soil samples from mineral lick sites were collected using the same methods described for soils above. Soil samples were taken from the horizon where consumption of soil was evident, i.e., through lick marks and / or pawing. Standard soil samples (surface organic, subsurface organic and subsurface mineral) were taken at a nearby location, a short distance from the lick site to avoid disruption of the site.

3.4.2.4 Vegetation and Mineral Lick Sub-sampling Methods

A subset of vegetation samples collected was selected for immediate analysis of elemental concentrations (the remaining samples were archived for any future analysis). All soil samples from mineral lick sites were sent for analysis.

3.4.2.5 Vegetation and Mineral Lick Laboratory Analysis

Vegetation samples were sent to CanTest Laboratories (Burnaby, BC) for analysis of the 33 elements listed in Table 1. Laboratory procedures follow the procedures outlined above for lichen. Soil samples from mineral lick sites were sent to CanTest Laboratories (Burnaby, B.C.) for analysis of the 29 elements listed in Table 2 and pH. Laboratory procedures follow the procedures outlined above for soil.

3.4.2.6 Vegetation and Mineral Lick Data Analysis

Results of the lichen Getis-ord statistical analyses and Kriging were used to focus comparative analyses of vegetation data between mine-affected and reference areas. Those elements considered to be affected by Anvil Range Mine operations (as determined through lichen Getis-ord analyses) were statistically compared in vegetation tissues between lichen lead zones (determined through lichen Kriging) and also compared to Swim Lakes reference levels and, wherever possible, published reference sources. Lichen lead zones were used to classify vegetation samples for categorical analysis of differences in elemental concentrations by ANOVA (data were log-transformed if necessary to meet assumptions of normal distribution necessary for parametric analysis). For each vegetation species sampled, the ANOVA identifies elements that indicate mine-related effects. Results were also compared to published reference levels (Gamberg unpub. data; Kabata-Pendias 2001; Puls 1994; Shaw and Gunn 1981).

Comparison between elemental levels in vegetation species found in mine-affected areas and Swim Lakes reference areas is considered valid despite the potential confounding effects of subsurface soil concentrations; subsurface mineral and organic soils were found to be similar between Anvil Range Mine Complex and Swim Lakes reference area. Where differences do exist they occur in the subsurface organic and are the result of influence of surface soils, i.e., through translocation of contamination through a thin surface organic veneer into the subsurface organic.

Results of soil analyses from mineral lick sites were compared to subsurface mineral soils on Swim Lakes reference area; with the assumption that Swim Lakes levels in subsurface mineral soils would be representative of a potential mineral lick site in the reference area. It should be noted that it not assumed that Swim Lakes subsurface mineral levels are representative of concentrations of elements that may be selected for consumption by ungulates; it is likely that these elements may be elevated in mineral lick sites. Instead, it is assumed that elements considered to be affected by the operations of the Anvil Range Mine, can be compared between mineral lick sites within potentially mine affected zones and similar soil types (mineral soil) on Swim Lakes reference areas.

3.5 Elemental Concentrations in Wildlife Tissue

3.5.1 General Approach

To investigate potential element uptake by wildlife species and wildlife species of importance to humans (*e.g.,* species used for medicinal use and / or consumption) selected wildlife species were sampled and analyzed. Three main groups of animals have been considered in this evaluation:

- Small mammals such as voles and shrews (given their significance as a food species of many other animals such as marten and foxes);

- Furbearers such as snowshoe hare (*Lepus americanus*) given their significance as a food species of people and wildlife and marten (*Martes americana)* given their position in the food chain as consumers of other animal species; and
- Hunted animals such as moose (*Alces alces*) and willow ptarmigan (*Lagopus lagopus*) given their significance as a food species of people and wildlife.

These data can then be used to investigate the extent of elevated metal concentrations in the food chain by feeding into a future terrestrial risk analysis and will also assist in predicting possible current and future impacts on local land-users from elevated metals resulting from care and maintenance operations.

3.5.2 Permit Applications

An application for a wildlife research permit was submitted to the Department of Environment. This permit allows project staff to trap small mammals for the purposes of the Anvil Range Mine Complex Terrestrial Effects Study and also allows the collection of furbearer and small game carcasses and the collection of liver, kidneys and tissue samples from hunter killed large game within the bounds of a set of listed conditions (*e.g.,* small game can be hunted by Department of Environment staff only and the purchase of organs or tissues from hunter killed large game is not permitted). Originally it was anticipated that trappers active within the project area would submit carcasses of furbearers for the purposes of this study. However, this was only possible for one trapper active on Swim Lakes. Therefore in order to obtain samples of furbearers from on the mine site, the Wildlife Research Permit was amended in March 2005 to allow Department of Environment staff to trap marten for the purposes of the Terrestrial Effects Study. A wildlife act permit was also issued that allows project staff to offer to purchase and purchase carcasses of furbearing animals legally harvested by licensed trappers on their registered Trapping Concessions in accordance with the aforementioned wildlife research permit.

3.5.3 Small Mammal Trapping

3.5.3.1 Small Mammal Trapping Locations and Methods

Small mammal trap lines were laid out in the immediate vicinity of the mine site and in the Swim Lake reference area. A combination of standard snap traps and pit fall traps were placed in areas where small mammals were anticipated to be found, *e.g.,* outside tunnel entrances, under logs and near the base of trees with low, over-hanging branches. Snap traps were used to target mice and voles and pit fall traps were employed to sample shrews (RIC 1998). Small mammal traps were laid out on a 150m long transect with 10 stations placed approximately 15m apart beginning at each sample site. At each station two snap traps were deployed and at three of the ten stations, three pit fall traps were also deployed. Therefore at each transect, 20 snap traps and 9 pit fall traps were deployed. Traps were set for at least one 24-hour period before being removed. Small mammal trapping was conducted in the fall in an attempt to reduce the impact of mortality on the overall population; populations fluctuate annually with low populations occurring in winter and high populations occurring after the breeding season, typically in fall (RIC 1998).

Small mammal carcasses were collected using un-powdered nitrile gloves (with new gloves used for each transect) and stored in ziplock bags and isolated from other potential contaminant sources prior to laboratory analysis. Data collected at each trap site includes: transect and capture station number; UTM coordinates; date traps set and pulled; number of snap and pit fall traps deployed; morphological measurements (including body mass in grams), gender and age estimation; and species of specimen collected. When species could not be identified in hand, additional morphological measurements were taken (including head and body length (mm); tail length (mm), total length (mm), hind foot length (mm), ear size (mm) and notes on pelage, tail and other distinguishing characteristics (*e.g.*, teeth or hairy feet) to aid in species identification; and comments / notes (particularly on habitat type). At the end of each field day carcasses were immediately frozen to at least minus 20 degrees Celsius, and at the end of the field session carcasses were sorted and bulk transported for tissue processing in Whitehorse.

3.5.3.2 Small Mammal Processing and Laboratory Analysis

Samples of muscle, liver and whole kidneys from small mammal carcasses were removed, weighed and recorded by unique sample ID. Liver, kidneys and muscle tissues were processed and stored separately for analysis and transported frozen to CanTest Laboratories Ltd. (Burnaby, B.C.) for ICP-MS analysis of the 33 elements listed in Table 1.

The moisture content of each sample was calculated gravimetrically by heating a pre-weighed portion of the sample at 105 degrees Celsius and measuring the weight loss. In preparation for elemental analysis, samples were digested using a nitric acid - hydrogen peroxide digestion procedure based on U.S. Environmental Protection Agency Method 200.3. Analysis of all elements except mercury was performed using ICP-MS (Inductively Coupled Argon Plasma Spectroscopy - Mass Spectrometry). Analysis of mercury was performed using Cold Vapour Atomic Absorption Spectrophotometry or Fluorescence Spectrophotometry.

Certified standards obtained from the National Research Council were sent to CanTest for analysis and duplicate small mammal samples were sent from CanTest to Elemental Research for analysis for the purposes of QA / QC. All preparation and digestion procedures employed at Elemental Research Inc. were the same as those used at CanTest outlined above. Differences in laboratory analytical technique include the use of ICP-MS at Elemental Research Inc. for the analysis of all elements tested (*i.e.*, including mercury) and a reduced number of elements tested at Elemental Research Inc. (Table 4).

Hair / fur samples (associated with each tissue sample) were also collected and stored to provide data necessary for future investigation of non-lethal methods of element sampling, if required. Hair samples and tissue samples from the same animal can be analyzed to determine whether a correlation exists between element concentration in the muscle tissue / organs and in the hair / fur. If a correlation exists, hair sampling could replace the necessity for killing small mammals when investigating concentrations of elements in small mammals during future monitoring programs.

Effort has been made to ensure that methods of tissue handling and analysis are consistent with those of the Northern Contaminants Monitoring Program. The only deviation from these methods has been in the selection of the laboratory used for the analysis of small mammal samples, *i.e.*, CanTest as opposed to Elemental Research. It should be noted that all samples of furbearer and hunter killed animals (*i.e.*, those more likely to be consumed by humans) will be analyzed by the laboratory used by the Northern Contaminants Monitoring Program (*i.e.*, Elemental Research Inc.).

3.5.3.3 Small Mammal Data Analysis

Following a review of tissue mass of small mammal muscle, kidney and liver, it became apparent that tissue samples from small mammals would require pooling to create sufficient tissue mass (>5.0g FW) for laboratory analysis (between 4 and 15 animals for each set of samples). Given limited sample size and / or body mass of all species other than northern red-backed voles, preparation and analyses were conducted only on northern red-backed vole samples in support of the 2004 / 2005 project report (remaining samples were archived for future analysis). Tissue samples from specimens of northern red-backed voles collected at transects within the same lichen lead zone were therefore pooled for analyses. Attempts were made to maximize the number of replicate tissue samples within each lichen lead zone, therefore samples from one zone were not pooled into one sample but rather into as many samples as possible of at least 5.0g (FW) mass.

Results of the lichen Getis-ord statistical analyses and Kriging were used to focus comparative analyses of small mammal data between mine-affected and reference areas. Those elements considered to be affected by Anvil Range Mine operations (as determined through lichen Getis-ord analyses) were statistically compared in small mammal tissues between lichen lead zones (determined through lichen Kriging) and also compared to Swim Lakes reference levels and, wherever possible, published reference sources (Andrews et al 1989; CE Jones, unpub. report; Hunter et al 1989; Johnson and Roberts 1977; Puls 1994; Pankakoski et al 1994; Shaw and Gunn 1981).

Sufficient sample sizes were available for parametric statistical analyses (ANOVA) of muscle and liver tissues only. Interpretation of kidney tissue results was restricted to a comparison of maximum elemental concentrations between zones; a maximum of one sample for kidney in each zone was available therefore means and standard deviations could not be calculated.

3.5.4 Trapped / Hunted Animal Samples

3.5.4.1 Methods of Collection of Samples from Trapped / Hunted Animals

According to interpretation of range information the following species of furbearers, small game and large mammals could potentially occur within the area of the Anvil Range Mine Complex:

Furbearers	Small Game	Large Game	Others
• Snowshoe hare • Marten • Ermine • Fox • Beaver • Muskrat • Wolverine • Lynx • Wolf	• Hoary marmot • Ground squirrel • Grouse spp. • Ptarmigan spp.	• Moose • Woodland Caribou • Stone Sheep • Mule deer • Grizzly bear • Black bear	• Least weasel • Chipmunk • Red squirrel • Northern flying squirrel • Collared pika • Porcupine

This species list was taken to community meetings in Ross River (Ross River Dena Council Terrestrial Effects Workshop May 2004), Pelly Crossing (Selkirk First Nation Traditional Knowledge Workshop April 2004) and the Town of Faro (Town of Faro Open House, March 2004) and feedback was requested, particularly on the suitability of species selected and sampling logistics, that was then integrated into project design.

Public advertisement of our requests for organ, tissue and carcass submissions from hunter killed animals and trapped furbearers was made through the following means:

- Creation and display of a poster requesting donation of organs and tissues from moose, sheep, caribou, black and grizzly bears. This poster was displayed in various locations (*e.g.,* gas stations, grocery stores, restaurants, post offices, RRDC Band Office and Department of Environment offices) in Faro and Ross River as well as on the mine site at the head of ATV trails leading to Mount Aho (northwest of Faro Tailings impoundment / mill complex);
- Submission of a project update aimed at community members to the Faro community newsletter (Focus on Faro) and to Ross River Dena Council (RRDC) and Selkirk First Nation (SFN) band offices. This project update was also distributed in hard copy around Faro and Ross River;
- Direct contact was made with the most active trappers and hunters in the vicinity of the Anvil Range Mine Complex;
- Direct contact was made with the most active trappers in the area of Swim Lakes; and
- Direct contact was made with community members from the Town of Faro.

Organs (liver and kidneys) and tissue (muscle) samples from hunter killed large mammals and carcasses of trapped animals were collected from First Nation and non-aboriginal hunters and trappers through Department of Environment Staff in Faro and Ross River. Hunters and trappers were requested to provide information on the animal hunted or trapped (*e.g.,* species and gender), on the sample donated (*e.g.,* whole carcass or kidney) and on the location of where the animal was hunted or trapped through the completion of a wildlife submission form. To protect the confidentiality of information on the location of hunted / trapped animals, the location is recorded by grid cell (1 km by 1 km UTM grid) rather than exact location (*e.g.,* GPS coordinates). Assurance was made that the location of where the animal was hunted or trapped would not be displayed on any publicly available maps. Upon submission of each furbearer carcass, a financial reimbursement of $20 was given to the trapper. It should be noted that the wildlife research permit issued for the purposes of this project does not allow the purchase of organs or tissues from hunter killed animals. Instead, hunters who donate organs and tissues in support of this project may enter their name in a draw to win a custom made hunting knife. The wildlife submission form was also completed by Department of Environment staff collecting carcasses of small game.

Upon receipt of carcasses or tissues, samples were immediately frozen to at least minus 20 degrees Celsius. All Department of Environment offices contain a lockable freezer stored in a secure location. Carcasses were regularly bulk transported for tissue processing in Whitehorse.

3.5.4.2 Processing and Laboratory Analysis of Trapped / Hunted Animals

Furbearer and small game carcasses were processed for tissue samples of liver, kidneys and muscle. Samples of muscle, liver and whole kidneys were removed and weighed from the carcasses of furbearers and small game and recorded by unique sample ID. Liver and muscle tissues of large game were subsampled from samples removed by hunters in the field in accordance with the Northern Contaminants Monitoring program methodology. Kidneys were maintained as entire organs. All liver, kidneys and muscle tissue were processed and stored separately for analysis and transported frozen to Elemental Research (Vancouver, BC) for ICP-MS analysis of the 26 elements listed in Table 4. Duplicate samples of selected tissues and certified standards obtained from the National Research Council were submitted for the purposes of QA / QC. In preparation for analysis, kidney samples were thoroughly homogenized. All tissue samples were then digested in a closed Teflon vessel using ultrapure nitric acid. The resulting digestate was then analyzed. Analysis of all elements was performed using ICP-MS.

3.5.4.3 Trapped / Hunted Animals Data Analysis

Only methods of ungulate tissue analyses will be discussed in this paper; methods of analyses of other species will await the collection of a sufficient number of specimens. Data from ungulates sampled in the vicinity of the Anvil Range Mine Complex were compared to tissue samples from the same species submitted as part of the Yukon Hunter Survey Program (Gamberg unpub. data). Hunter Survey data collected between 1992 and 1997 were available for comparison. Hunter

Survey data were screened for suitability of comparison and data outliers prior to the calculation of mean, standard deviation and maximum elemental concentrations for each species (woodland caribou, moose and sheep) and each tissue (muscle, liver and kidney) analyzed. Samples from all moose and sheep collected as part of the Yukon Hunter Survey Program were considered suitable for comparison (feeding strategies of moose and sheep on the Anvil Range Mine Complex are similar to those of moose and sheep across the territory). However, for the comparison of woodland caribou samples, all barren ground caribou samples were omitted from the analyses; barren ground and woodland caribou differ markedly in their feeding strategies. Furthermore, in order to compare woodland caribou samples collected from the Anvil Range Mine to those of similar abiotic and biotic environments, only woodland caribou from the neighbouring herd (Finlayson) were included in the analyses.

Outlying data in the Hunter Survey dataset were those samples considered to be anomalous due to: 1) sample integrity or 2) atypical sampling location. Samples from five Yukon Hunter Survey moose and one woodland caribou were omitted from the analyses due to very high lead levels in their tissues; likely related to the presence of lead shot. All samples omitted had lead concentrations in excess of 11.3ppm dry weight (DW). Samples from one Yukon Hunter Survey moose were omitted from the analysis due to very high cadmium concentrations (1380 ppm DW) in the kidney. This concentration is far greater than all other samples collected as part of the Hunter Survey Program and may have been related to atypical mineralization within the home range of the animal.

Results of the lichen Getis-ord statistical analyses were used to focus comparative analyses of ungulate data between areas potentially affected by activities on the Anvil Range Mine Complex and reference areas (*i.e.*, Yukon Hunter Survey data). Those elements considered to be affected by Anvil Range Mine operations (determined through lichen Getis-ord analyses) were statistically compared to Yukon Hunter Survey data. Maximum elemental concentrations of those elements considered to be unaffected by Anvil Range Mine operations were compared to Yukon Hunter Survey maxima. The age of an animal can have a discernable effect on the concentration of elements in their tissues (Gamberg unpub. data); age was therefore controlled for within the ANOVA computation (with the exception of comparisons of concentration in muscle tissue; Yukon Hunter Survey muscle tissues were pooled from a number of animals with disparate ages).

3.6 Community Participation

3.6.1 Workshops and Open Houses

An integral part of this study is information exchange between members of the local communities of Ross River, Faro and Pelly Crossing and project personnel. Frequent contact not only allows project personnel to provide community members with regular updates on project progress, it also provides an effective forum for input from community members into study design. The following provides a summary of meetings held within the communities during the design and execution phases of this project:

Open House, Town of Faro, March 15, 2004, Faro
A public meeting was held in Faro Council Chambers. Gartner Lee Ltd. provided an update on project design to date. Community members from the Town of Faro provided input into study design, in particular in the identification of vegetation species of importance to humans, the general location of berry gathering areas, the general location of wildlife sightings and the location of sheep mineral lick sites. Names of local trappers were also provided to facilitate the collection of wildlife tissues. General comments and concerns were raised and have since been addressed and where appropriate incorporated into the original project work plan.

Selkirk First Nation Traditional Knowledge Workshop, April 21 – 22, 2004, Pelly Crossing
A traditional knowledge workshop was organized by Selkirk First Nation (SFN) and held in Pelly Crossing. Gartner Lee Ltd. was invited to attend this workshop to receive input into study design. Gartner Lee Ltd. also provided an update on project design to date. A presentation of traditional knowledge collected from SFN Elders formed the medium of input from SFN, supplemented with input from Elders present at the workshop. Information provided was incorporated into the study design, in particular the identification of vegetation species of importance to wildlife and humans and wildlife species of importance as food for other wildlife species and humans. General comments and concerns were raised and have since been addressed and where appropriate incorporated into the original project work plan.

Ross River Terrestrial Effects Workshop, May 5, 2004, Ross River
A workshop was organized by Ross River Dena Council (RRDC) and held in Ross River School Gathering Room. Gartner Lee Ltd. was invited to attend this workshop to provide an update on project design to date and receive comment and input into study design. Information provided was incorporated into the study design, in particular the selection of vegetation species of importance to wildlife and humans, the location of wildlife foraging areas, the location of mineral lick sites and the location of berry and game harvesting areas. General comments and concerns were raised and have since been addressed and where appropriate incorporated into the original project work plan.

Terrestrial Effects Update and Traditional Knowledge Data Handling, August 25, 2004, Ross River
A meeting with RRDC Chief and Council and members was held in Ross River Dena Council Boardroom. Gartner Lee Ltd. provided an update on project design to date and requested input into study design. Information provided was incorporated into study design, in particular the selection of mushroom species of importance to humans and in the methods of sampling required

for tree sap collection. Names of local trappers were also provided to facilitate the collection of wildlife tissues.

Selkirk First Nation Faro Closure Plan Workshop, November 25 and 26, 2004, Pelly Crossing

A workshop was organized by Selkirk First Nation and held in Selkirk Community Hall. Gartner Lee Ltd. was invited to attend this workshop to provide an update on project activities to date and receive comment and input into study design. Information provided was incorporated into the study design, in particular the consideration of cyanide in the analysis of soils.

Community updates and requests for community participation have also been made through the release of project updates through local newsletters and posters and through informal meetings with community members. In addition, field assistants from both of the affected First Nations (RRDC and SFN) were employed and provided invaluable guidance in distinguishing identified vegetation species of importance to humans.

3.6.2 Protection of Information

Information collected from First Nations and community members was used to guide sampling of vegetation species and wildlife species of importance to wildlife and / or humans. During workshops and meetings, discussions were held to ensure a consensus was reached on how these data would be used and presented. A clear understanding was reached on what was required for the purposes of the study and how the data required could be handled and presented to be sensitive to the confidentiality of the data.

For example, in order to guide sampling methods to meet the objectives of this study, it was necessary to obtain information on which vegetation species and plant parts were consumed by humans and at what time of year. This information was necessary to ensure samples collected were representative of what humans and / or wildlife consumed and also to ensure that project results could be compared to reference data collected by other researchers. It was agreed that this information would therefore be documented in project reports. However, additional information would sometimes be provided in the course of conversations (e.g., specific medicinal use of a plant). In order to protect the confidentiality of this information, project staff assured First Nations that the specific use of vegetation (or animal) species would never be documented in any publicly available or internal documents. Furthermore, in order to guide sampling methods, it was necessary to obtain information on the specific location of mineral lick sites and harvesting sites. In order to protect the confidentiality of this information, project staff assured First Nations and local community members that the specific location of mineral lick sites and harvesting sites would not be displayed on any publicly available maps and that the internal use of these data would be considered confidential. It was also necessary to obtain information on how to sample tree sap so that samples collected for analysis would be as similar as possible to what people would typically consume. In order to protect the confidentiality of this information, project staff assured First Nations would not be documented in any publicly available reports and that the internal use of these data would be considered confidential.

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5. Workshops

Anvil Range Mine Site Personnel Meeting, March 2004. Meeting held in the Guesthouse Boardroom in Faro on March 15, 2004.

Ross River Dena Council Terrestrial Effects Workshop May 2004. Workshop held in Ross River School Gathering Room on May 5, 2004.

Ross River Terrestrial Effects Project Update and Traditional Knowledge Data Handling Meeting, August 2004. Meeting held in Ross River Dena Council Boardroom on August 25, 2004.

Selkirk First Nation Traditional Knowledge Workshop April 2004. Workshop held in Pelly Crossing between April 21 – 22, 2004.

Town of Faro Open House, March 2004. Open House held in Faro Council Chambers on March 15, 2004.

Selkirk First Nation Faro Mine Remediation Plan Update and Closure Plan Objectives Workshop November 2004. Workshop held in Pelly Crossing between November 25 – 26, 2004.

6. Personal Communication

A. Domes, pers. comm., August 2004. Resident, Town of Faro.

R. Ward, pers. comm., March 2004. Moose Biologist, Yukon Department of Environment, Whitehorse, Yukon.

Table 1. Analytical Parameters for Tissue and Detection Limits at CanTest Laboratories in ug/g

Element	Reported Detection Limit
Aluminum Al	0.5
Antimony Sb	0.1
Arsenic As	0.1
Barium Ba	0.1
Beryllium Be	0.02
Boron B	2
Cadmium Cd	0.02
Calcium Ca	1
Chromium Cr	0.1
Cobalt Co	0.1
Copper Cu	0.1
Iron Fe	5
Lead Pb	0.1
Magnesium Mg	0.5
Manganese Mn	0.1
Mercury Hg	0.01
Molybdenum Mo	0.1
Nickel Ni	0.1
Phosphorus PO_4	0.5
Potassium K	1
Selenium Se	0.2
Silicon SiO2	10
Silver Ag	0.01
Sodium Na	1
Strontium Sr	0.05
Tellurium Te	0.1
Thallium Tl	0.02
Tin Sn	0.1
Titanium Ti	0.3
Uranium U	0.04
Vanadium V	0.5
Zinc Zn	0.5
Zirconium Zr	3

Table 2. Analytical Parameters for Soil and Detection Limits at CanTest Laboratories in ug/g

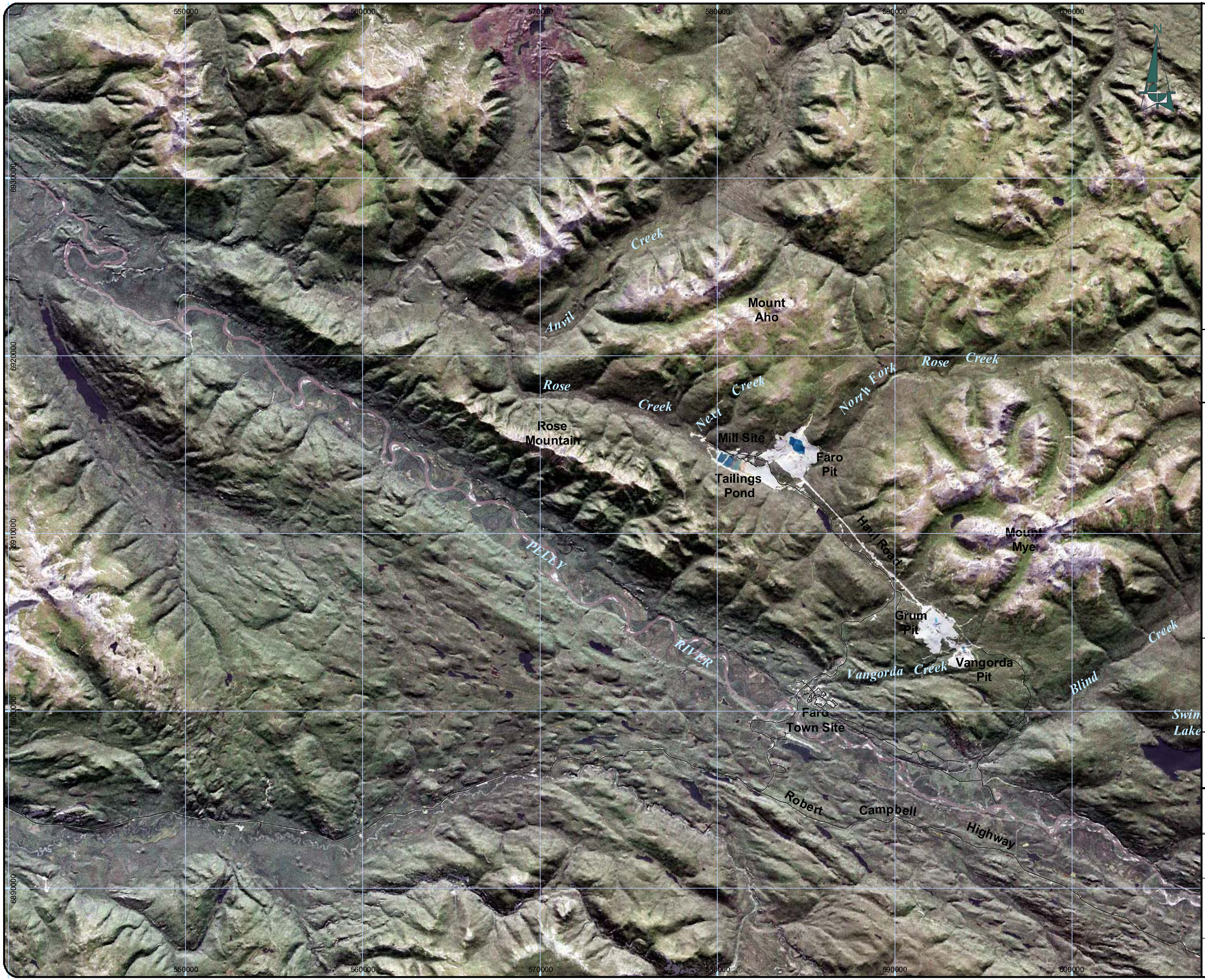
Element	Reported Detection Limit
Aluminum Al	10
Antimony Sb	10
Arsenic As	0.1
Barium Ba	1
Beryllium Be	0.02
Boron B	1
Cadmium Cd	0.5
Calcium Ca	1
Chromium Cr	2
Cobalt Co	1
Copper Cu	1
Iron Fe	2
Lead Pb	5
Magnesium Mg	0.1
Manganese Mn	1
Mercury Hg	0.01
Molybdenum Mo	4
Nickel Ni	2
Phosphorus PO_4	20
Potassium K	10
Selenium Se	0.2
Silver Ag	2
Sodium Na	5
Strontium Sr	1
Tin Sn	5
Titanium Ti	1
Vanadium V	1
Zinc Zn	1
Zirconium Zr	1

Table 3. Vegetation Species and Groups for Collection and Analysis

Species Group	Selected Species	Plant Part	Wildlife Value	Food / Use for Humans
Grasses and Sedges	*Bromus spp; Calamagrostis spp.; Festuca altaica; and Carex spp.*	Leaves	Potential forage species of small mammals, game birds, ungulates and bears	Not documented
Aquatic grasses	*Beckmannia syzigachne*	Leaves	Potential forage for moose, black bear and muskrat	Not documented
Horsetails	*Equisetum spp.*	Stems	Potential forage for bears and ungulates	Not documented
Forbs	*Epilobium angustifolium, Petasites spp.; Artemisia spp.* (sage); *Achillea spp.* (yarrow); and Water lily (*Nuphar spp.*)	Leaves and stems	Potential forage species of small mammals, game birds, ungulates and bears	Yes
Labrador tea	*Ledum groenlandicum*	Leaves	Not documented as forage species	Yes
Berries	*Empetrum nigrum* (crowberry); *Arctostaphylos uva-ursi* (Kinnikinnick); *Arctostaphylos rubra* (red bearberry); *Arctostaphylos alpine* (alpine bearberry); *Shepherdia canadensis* (Soopolallie); *Vaccinium uliginosum* (bog blueberry)*; Vaccinium vitis-idea* (low bush cranberry)*; Rosa acicularis* (Rosehip); *Viburnum edule* (high bush cranberry); *Ribes spp.* (currants and gooseberries); *Rubus chamaemorous* (cloudberry); and *Juniperus spp.* (juniper).	Berries	Potential forage for small mammals, game birds and bears	Yes
Willow	*Salix spp (S. pulchra* or any browsed species)	Tips	Potential winter forage of moose and snowshoe hare and spring forage for bears	Yes
Trees	*Picea glauca* and *Abies lasciocarpa*	Sap	Potential spring food for bears	Yes
Bear root	*Hedysarum alpinium* and *Hedysarum boreale*	Roots	Potential forage for bears	Yes
Mushroom spp.	*Leccinium boreale* and *Agaricus silvicola*	Above ground parts	Potential forage species of small mammals, ungulates and bears	Yes
Lichen	*Cladina mitis*	Branchlets	Potential forage of caribou	Not documented

Table 4. Analytical Parameters for Tissue and Detection Limits at Elemental Research Laboratories in ug/g

Element	Reported Detection Limit
Aluminum Al	0.5
Antimony Sb	0.01
Arsenic As	0.01
Barium Ba	0.01
Beryllium Be	0.01
Boron B	1
Cadmium Cd	0.01
Calcium Ca	1
Chromium Cr	0.2
Cobalt Co	0.01
Copper Cu	0.05
Iron Fe	0.5
Lead Pb	0.01
Magnesium Mg	0.01
Manganese Mn	0.01
Mercury Hg	0.05
Molybdenum Mo	0.01
Nickel Ni	0.05
Selenium Se	0.1
Silver Ag	0.005
Strontium Sr	0.01
Thallium Tl	0.01
Tin Sn	0.01
Uranium U	0.005
Vanadium V	0.05
Zinc Zn	0.1



INSET MAP

Location of Project Area in Yukon

LEGEND

Road

DATA SOURCES AND DISCLAIMERS:

Updated Road Network compiled by Government of Canada, Natural Resources Canada (NRCan).

Shaded relief colour orthorectified image at 15m resolution compiled by Yukon Territorial Government, Dept. of Infrastructure, Yukon Geomatics, from Landsat 7 image 59-16, bands 3, 2, & 1.

Created By: AS
Reviewed By: MG
Date Issued: March 2005
Project Number: 40569
File Name: 40569_overview_map_11x17_09Mar2005v2.mxd
Revision: 1.1
Projection: UTM Zone 8 NAD83

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Kilometres
Scale 1: 200 000

Deloitte.

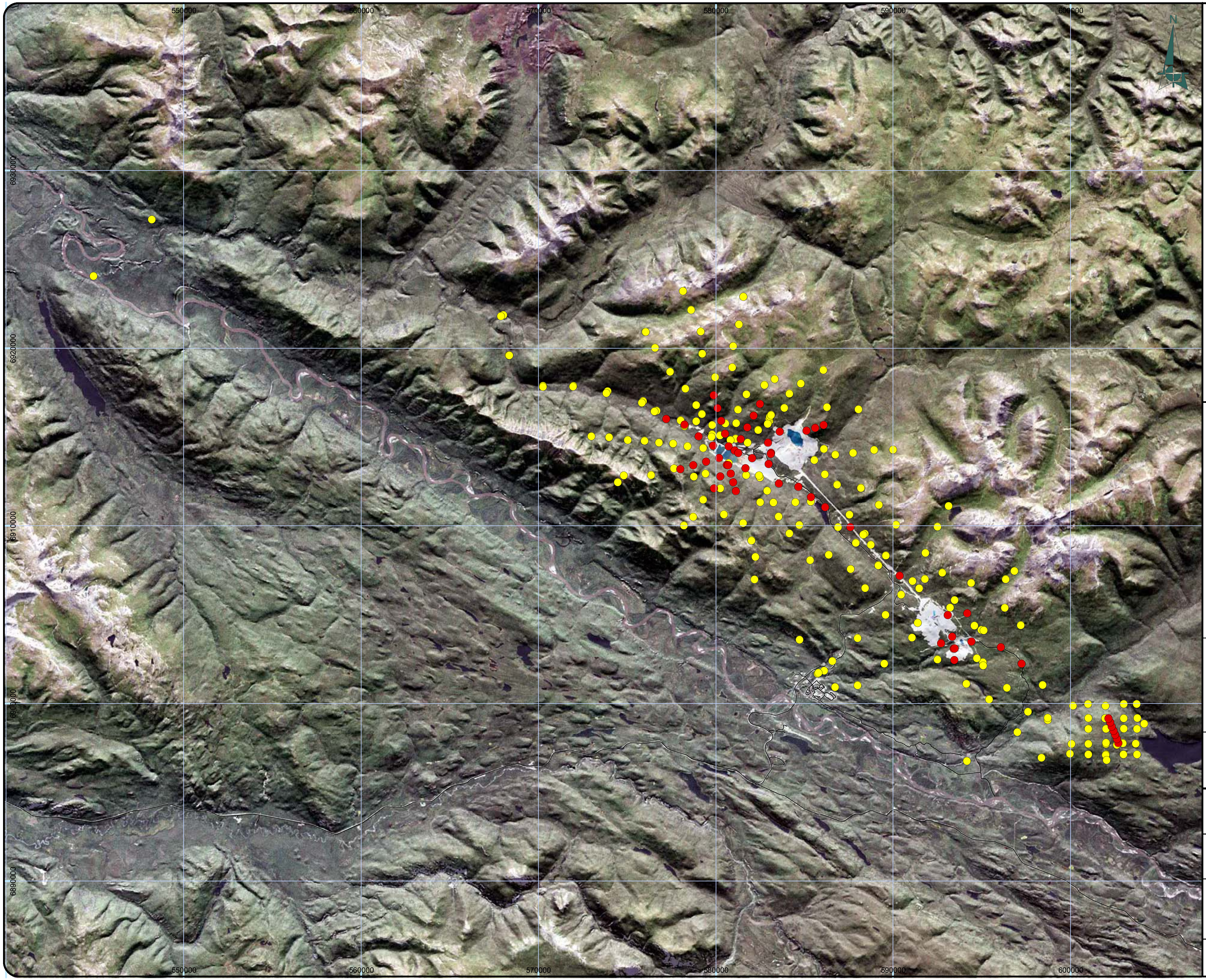
Project: Anvil Range Project 17a Terrestrial Effects
Location: Faro Mine Site, Yukon
Client: Deloitte & Touche Inc.

Overview Map of Project Area

Gartner Lee

Jones

Figure No.
1



LEGEND

- 2002 Sample Locations
- 2004 Sample Locations
- Road

DATA SOURCES AND DISCLAIMERS:

Sample Site Locations determined by field Global Positioning System (GPS). Locations recorded in UTM Zone 8, NAD83. All sample locations recorded by Gartner Lee Ltd. and C.E. Jones & Associates Ltd.

Updated Road Network compiled by Government of Canada, Natural Resources Canada (NRCan).

Shaded relief colour orthorectified image at 15m resolution compiled by Yukon Territorial Government, Dept. of Infrastructure, Yukon Geomatics, from Landsat 7 image 59-16, bands 3, 2, & 1.

Created By: AS

Reviewed By: MG

Date Issued: March 2005

Project Number: 40569

File Name: 40569_distribution_sampling_11x17_09Mar2005v2.mxd

Revision: 1.1

Projection: UTM Zone 8 NAD83

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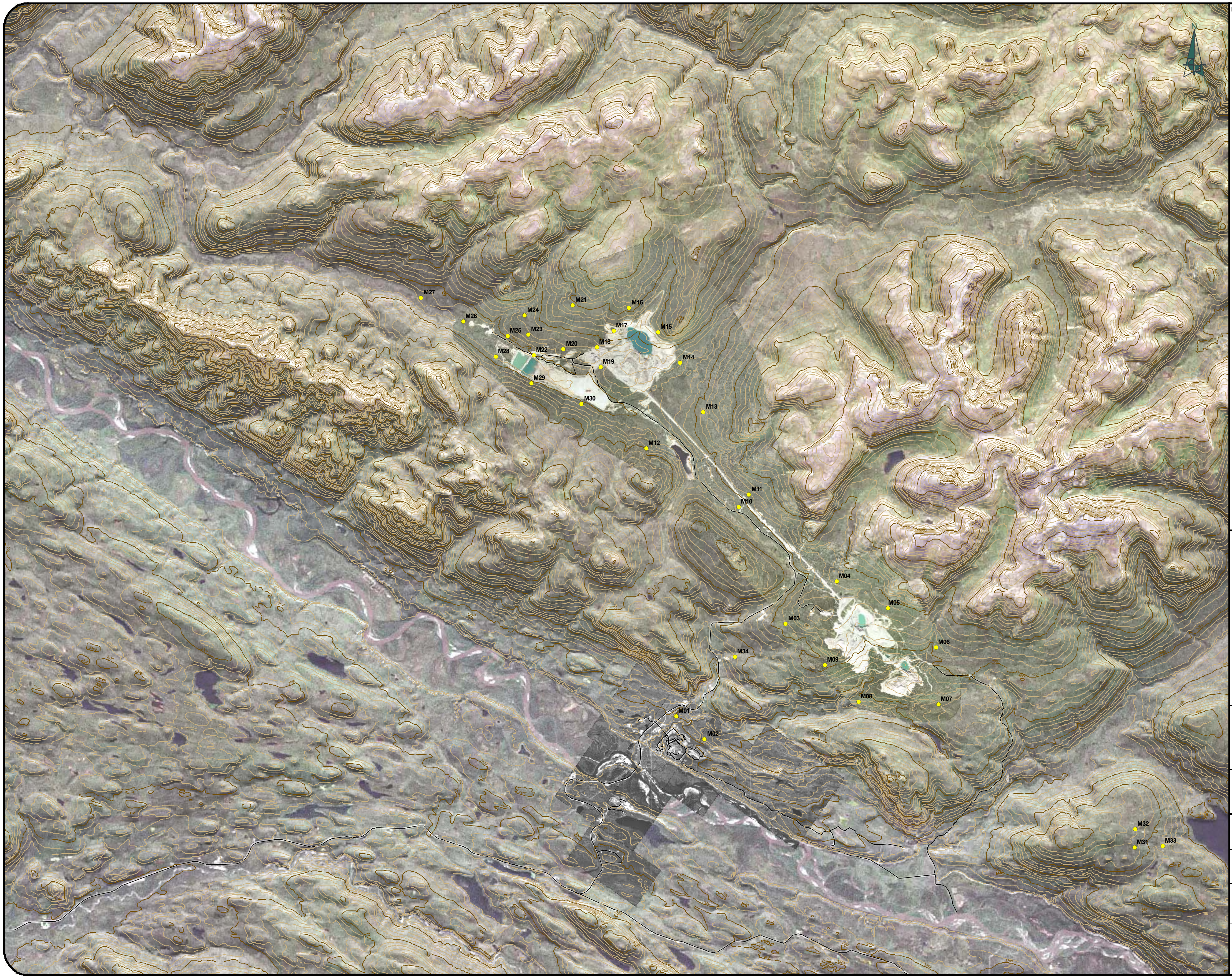
Kilometres
Scale 1: 200 000

Deloitte.

Project: Anvil Range Project 17a Terrestrial Effects
Location: Faro Mine Site, Yukon
Client: Deloitte & Touche Inc.

Distribution of 2002 and 2004 Sampling Locations

Gartner Lee | Jones | Figure No. 2



LEGEND:

2004 Moss Bag Sample Locations

Roads (Updated Road Network)

DATA SOURCES AND DISCLAIMERS:

National Topographic Data Base (NTDB) contours compiled by Government of Canada, Natural Resources Canada (NRCan), at 1:50 000 scale.

Updated road network complied by Government of Canada, Natural Resources Canada (NRCan) at 5m accuracy.

Sample site locations determined by field Global Positioning System (GPS) locations recorded in UTM Zone 8, NAD83. All sample locations recorded by Gartner Lee Ltd. and C.E. Jones and Associates Ltd.

Fused LandSat7 True Colour Image with 30 metre shaded relief prepared by Government of Yukon, Geomatics Yukon, 2003.

Orthophotos flown August 2003.

Created By: AS
Reviewed By: MG
Date Issued: March 2005
Project Number: 40569
File Name: 40569_moss_bag_sample_locations_23Mar2005.mxd
Revision: 1
Projection: UTM Zone 8 NAD83

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Scale 1:125 000
Contour Interval: 100 Feet

Deloitte.

Project: Anvil Range Project 17a Terrestrial Effects
Location: Faro Mine Site, Yukon
Client: Deloitte & Touche Inc.

Distribution of Moss Bag Sampling Locations

Gartner Lee

C.E. Jones and Associates Ltd.

Figure No.
3