Summary of Mine Related Fugitive Dust Studies

Red Dog Mine Site

March 14, 2005

Teck Cominco Alaska Incorporated
3105 Lakeshore Drive
Building A, Suite 101
Anchorage, Alaska 99517

Contents

List of Figures

Figures are provided at the end of the main text.

List of Tables

1 Introduction

The purpose of this technical report is to provide a general overview of historic and existing fugitive dust at the Red Dog Mine. It pertains only to the mine and mill sites (collectively referred to as Mine Site in this report). It does not include information related to the Delong Mountain Transportation System (DMTS) port road and port site**.**

2 Background

2.1 General Overview

Tundra sampling was initiated in 2003 and continued into 2004. The purpose of the program was to determine the extent of fugitive dust impacts immediate to the Mine Site. The data set is comprised of approximately 478 soil and 73 moss samples. The tundra sampling focused on the top 2 centimeters immediately below the live vegetative cover. This sample horizon was chosen in order to estimate the amount of metal deposition from fugitive dust with a minimum amount of concentration or dilution from the native soil at the sample site. The type of soil collected at an individual site varied by plant community and location. The media sampled in the 2003 and 2004 program ranged from vegetative litter to organic soil to mineral soil. This horizon has been termed “tundra soil” for this report. It is not equivalent to conventional soil and, therefore, the results are not directly comparable to the State cleanup standards. The sampling program has identified areas with elevated metals concentration on the surface. The metals concentrations are generally limited to the immediate surface and decline dramatically with depth consistent with the deposition of fugitive dust. The highest tundra soil concentrations were observed in a 12 ha (29.7 ac) area west of the accommodations complex and north of the tailings dam. Zinc and lead concentration ratios in this area appear to indicate zinc is more readily leached than lead, which is supported by sample data that demonstrates that unlike the lead concentrations the zinc concentrations do not decline dramatically with soil depth. It is hypothesized that the distribution of this soluble metal in the vegetative mat could be responsible for specific areas of vegetation showing signs of extreme stress.

Historic and ongoing ambient air monitoring programs have been used to measure fugitive dust concentrations and to assess operational improvements. Several methods have been employed to evaluate and trend fugitive dust impacts at the Mine Site. The methods include dustfall collection jars, ambient air monitoring using hi-vol and tapered element oscillating microbalance (TEOM) samplers, and snow sampling. Dustfall results at the Mine Site indicate the primary areas of fugitive dust deposition are near the pit, ore and waste stockpiles, the concentrate storage building (CSB), and the tailings beaches. The deposition pattern identified by dustfall results is similar to observed metals concentration patterns in tundra soils. Ambient air monitoring over time indicates a general decline in dust concentrations, however, the monitoring data is not directly comparable, due to changes in monitoring locations. The air monitoring further demonstrates a cyclical pattern in dust concentrations with highest concentrations in the winter months and lowest concentrations in the summer months. This suggests higher dust emissions in the winter than the summer.

Current air quality monitoring at the Mine Site verifies full compliance with Federal standards at the ambient air boundary. No Mine Site related impacts to air quality have been measured in Noatak or Kivalina, the two closest villages. Employee and local resident's blood testing, for lead, confirms the health and safety of people have been protected.

Snow sampling was conducted annually beginning in 2001 on a hillside immediately west of the tailings impoundment. The sampling indicates a general decline in fugitive dust deposition from 2001 to 2003 with a slight increase in 2004 from the previous year. Variations in snow accumulation, due to precipitation and wind patterns for a given season, may explain some of the variability.

2.2 Particulate Sources

Based on empirical observations the major Mine Site particulate sources have been:

- Open pit mining activity
- Stockpiling and crushing of ore
- Coarse ore stockpile (China Hat) emission
- Dumping material on waste stockpiles
- Wind erosion of the tailings beach
- Wind erosion of other mineralized surfaces (yards, stockpiles and pit benches)
- The concentrate storage building (CSB) and related facilities
- Dust from access road, yard and mill site traffic.

Improvements have been made that have eliminated or greatly reduced some particulate sources; see Appendix-1 for further details. Each source has the potential to contribute differently to the total fugitive release associated with the Mine Site because each source has varying degrees of metal content. Table-1 is the 2003 average lead and zinc concentration for the major Mine Site particulate sources. During the life of the mine the metal concentration in the sources has varied depending on ore grade, metal price and operational efficiency.

Table 1

Red Dog Mine 2003 Average Grade		
	Lead	**Zinc**
Ore	5.6 %	20.7 %
Waste	1.2 %	1.2 %
Tailings	1.7 %	3.8 %
Lead Concentrate	54.5 %	13.0 %
Zinc Concentrate	3.2 %	55.5 %

2.3 Ambient Air Quality Standards

The EPA defines an ambient air boundary as an area "owned or controlled by the source to which access by the public is precluded by a fence or other physical barriers". The ambient air boundary is the point at which the public has the potential to be exposed to facility emissions and the compliance point for the National Ambient Air Quality Standards (NAAQS). The area inside the boundary is subject to industrial air standards, regulated, in the mining industry, by the Mine Health and Safety Administration (MSHA). The Mine Site Title V air permit requires that the "public" be excluded from the facility to ensure that a person(s) could not be unintentionally exposed to an ambient air concentration that could be potentially harmful.

The Alaska Department of Environmental Conservation (ADEC) regulates air quality and issues permits, based in part on the NAAQS, to operators who have emissions to the atmosphere. The ADEC designated ambient air boundary for the Mine Site is depicted in Figure-1. The ambient air boundary is identical to the facility boundary developed for the Mine Site's solid waste permit. Areas within the facility boundary are part of the active mine. Closure requirements, including the mitigation of fugitive dust impacts, for all areas, within the facility boundary, affected by mining activity will be included in the solid waste permit.

The current NAAQS for particulate matter focuses on inhalable particles. Inhalable particles are defined as particles less than 10 microns in diameter (PM_{10}). Particles larger than 10 microns are normally filtered out by the upper respiratory tract (nose and throat) and do not reach the lungs. The 24-hour PM_{10} (primary and secondary) standard is 150 $\mu g/m^3$ and the annual standard is 50 $\mu g/m^3$.

The NAAQS for lead have essentially remained unchanged since the early 1970's. The primary and secondary standard for lead is 1.5 $\mu g/m^3$ (quarterly average). The standard is based on samples collected using the total suspended particulate (TSP) method rather than the PM_{10} method.

The standards for PM_{10} and lead are summarized below in Table-2. Actual historic monitoring data for the Mine Site is discussed in Section 3 of this report.

Table-2

Particulate Standards			
Component	**Averaging Period**	**Standard**	**Comments**
Particulate Matter < 10 microns (PM_{10})	24-Hour	150 µg/m^3	Primary Standard (Heath Based)
	12-Month	50 µg/m^3	
Lead	Quarterly	1.5 µg/m^3	Primary & Secondary Standard

2.4 Site Cleanup Standards

The Site Cleanup Standards contained in the Alaska Oil and Hazardous Substances Pollution Control Regulations list cleanup levels for hazardous substances. The regulations require that anyone discharging a hazardous substance to land or waters must report the action to the State of Alaska, and the discharge must be cleaned up to ADEC satisfaction.

Areas that qualify as contaminated sites are addressed through the ADEC Site Cleanup Rules. These rules set the processes and standards to determine the necessity for, and the degree of cleanup, required to protect human health and the environment at sites where hazardous substances are located.

The main hazardous substances that are associated with Mine Site fugitive dust are zinc, lead, and cadmium. The associated State of Alaska cleanup levels for those substances, which are health based standards, are 41,000, 1,000, and 140 ppm respectively. These "default" cleanup levels are not necessarily comparable to results from the Mine Site moss and tundra soil sampling because the methodology of sample collection and the characteristics of the moss and tundra media. Instead, State of Alaska regulation allows for alternate or "site-specific" cleanup standards. These site-specific standards can be determined by conducting a formal risk assessment.

2.5 Regulatory History Related to Fugitive Dust

Teck Cominco Alaska, Incorporated (TCAK) has been under two enforcement actions pertaining to fugitive dust at the Mine Site. The first involved Notices of Violation

(NOV) issued in May 1991, and again in December 1991, by ADEC for alleged exceedances in 1990 and 1991 air permit conditions at the Mine Site (and port). This matter was resolved under a Compliance Order By Consent (COBC) that was issued in June 1992. Fugitive dust control measures taken at the Mine Site in response to this action included:

- Addition of the truck loading drive through on the mine concentrate storage building (CSB).
- Construction of an enclosure around the coarse ore stockpile
- Intensification of dust control on roads and yards
- Installation of controls on the CSB air vents.

In October 1993, ADEC issued a Notice of Completion for this COBC.

The second enforcement action was a May 2001 NOV for allegations that certain mine (and port) operations were not in compliance with conditions in the air permit. The measures taken in this matter that pertain to fugitive dust included:

- Completion and implementation of an ISO 14001 conformant Environmental Management System
- Adoption of haul road procedures to minimize the risk of future concentrate truck spills
- Conducting ambient air monitoring for one year in Noatak and Kivalina
- Implementation of operational procedures and controls to avoid future permit violations.

2.6 Improvement Chronology

The initial design of the facility did not adequately address dust control. Major improvements to control fugitives were made in response to the 1992 COBC, the 2001 National Park Service moss survey, and a general greater operational awareness. Appendix 1 contains a detailed chronology of facility improvements, and Appendix 2 has some selected before and after facility improvement photographs.

2.7 Contaminated Sites

In 2002, responding to public concern over the findings of the National Park Service moss study, ADEC made a determination that the DMTS (port facility and associated road) was a contaminated site, and therefore was subject to Alaska contaminated sites regulations and oversight.

To address this TCAK is currently conducting an ecological and human heath risk assessment for the impacts associated with fugitive dust in the DMTS and the area peripheral to the Mine Site's air boundary. The Mine Site area was excluded from the risk assessment. The risk assessment is scheduled to be completed as a draft for delivery to DEC in late March 2005. Approval of the risk assessment by ADEC is scheduled for October 2005. It should be reasonable to assume that many of the conclusions and findings contained in the DMTS risk assessment would apply at the Mine Site.

3 Monitoring Programs and Results

3.1 Exploration Mineral Soil Samples

A routine part of Teck Cominco's exploration programs includes mineral soil sampling and the Red Dog area was no exception. Exploration samples are generally taken from the mineral soil horizon below the organic layer. In the vicinity of Red Dog the top of the mineral soils can occur from the surface (on rocky hill sides) to a 30 cm down in tundra in low lying areas. Normally the top of the mineral soil is about 15-18 cm deep. The lead values in Figure-2 are from a set of mineral soil samples collected from 1977 to 1979 prior to mining. Note the very high levels over the area of the current open pit and the Qanqiyuq deposit. High values near the present-day fish weir are from samples on the alluvial plain of Red Dog Creek. The high values are caused by transported cobbles and boulders of the Red Dog deposit. Exploration mineral soil values from the western side of the tailings pond are less than 100 ppm lead and most are less than 50 ppm. This is the same area where recent samples of the top 2 cm of tundra soil have yielded greater than one thousand of ppm lead from fugitive dust.

3.2 Roads and Yards (road material sampling)

The Mine Site roads and yards have been sampled multiple times. ADEC conducted a road sampling program in 1991 from the exit of the CSB to the airport. TCAK conducted a sample program in 2003 and 2004. In the TCAK program, the Mine Site roads and yards were sampled in 2003 and a subset of the sites re-sampled in 2004 using identical sample methods. Refer to Figure-3 for the sample locations and results. The sample sites are subject to frequent grading and resurfacing at irregular intervals. Therefore, only annual samples can be compared to monitor contaminate tracking and no long term trending information can be obtained from this sampling method.

3.3 2003 Tundra Soil Sampling

In 2003 a reconnaissance program of tundra sampling was conducted, which focused on lead and zinc concentrations on the surface of the tundra soil. A detailed description of tundra soil is provided in Section 2.1. Sample locations were selected along easterly to westerly transects, encompassing a large area within and around the Mine Site. The sample interval was from the surface down to 2 cm. The intent of the sampling program was to identify areas for further focus. Forty-three sites were sampled in 2003 and analyzed using a contract laboratory.

Twelve sample sites were vertically sampled to determine the extent of metal migration. For these twelve samples, profile intervals were divided into the initial 2 cm from the surface and then 4 cm intervals down to 18 cm or until the mineral soil was intercepted. Generally, mineral soil was encountered by the 12 cm interval. Refer to Figure-4 for the average profile results. At a subset of the sites, a moss sample was also collected (see Section 3.12).

Further details, including data and spatial plots, can be reviewed in the December 2004 TCAK submittal to ADEC entitled "*2003 and 2004 Tundra Soil Sampling for Lead and Zinc.*"

3.4 2004 Tundra Soil Sampling

The intent of the 2004 program was to follow up on the 2003 program. Two distinct studies were conducted in 2004. The first study evaluated metal concentrations within a 12 ha (29.7 ac) triangle shaped area immediately west of the accommodations complex and north of the tailings impoundment, (referred to as the "Triangle"). The other study was a continuation of the 2003 surface program into areas west, north, and east of the Mine Site facilities. A total of 478 samples were collected from 260 locations in the two 2004 studies. In this program, the samples were analyzed in house using a portable x-ray fluorescence (XRF) instrument.

Initial work conducted in 2003 identified a substantial metal concentration related to fugitive dust deposition on the tundra soil within the Triangle. In 2004, the Triangle was re-examined using in-situ XRF methods to determine the extent of metal concentrations. For this sampling the XRF was placed directly on the ground and readings were taken. The measurement represents a very thin (several millimeters) surface layer. The sampling is neither accurate nor precise. In-situ readings should only be considered as a screening tool to assess metal concentrations and distribution. To reduce variability three replicate readings were taken within a one meter area. In-situ readings are also affected by the moisture content of the material being tested, which can be a significant source of error if moistures are more than 20%. It is not uncommon for tundra soils to have 50% moisture. Significant moisture levels will result in a lower reading than if the sample were dry.

The typical Red Dog ore has a zinc to lead ratio of 3 to 1 or greater. The zinc to lead ratios in the Triangle were found to be near 1 to 1. This low ratio suggests zinc depletion and a relative lead enrichment of the surface samples. Zinc mobility is also suggested by the soil profiles, since the ratio of zinc to lead increases with depth. In addition, water samples collected within the Triangle had a disproportionably high zinc and cadmium concentration when compared to the lead and iron concentration, indicating zinc leaching. The vegetation within the Triangle is displaying signs of stress, perhaps as a result of the exposure to mobile zinc and cadmium, low pH, or high sulfate ion concentration. See Figures 4, 5, 6 and 7 for sample information from the triangle.

In August and September of 2004, 212 tundra soil samples were collected from 192 sites outside the Triangle and analyzed via ex-situ XRF for lead, zinc, and cadmium. A detailed description of tundra soil is provided in Section 2.1. Ex-situ sampling involved the collection of three grab samples from the top 2 cm of the tundra soil horizon within one meter of the sample site. The three grab samples were homogenized, dried and split. The sample splits were then analyzed in house for metal concentration using a handheld XRF instrument. Samples were collected from grids extending approximately 2 kilometers (1.2 miles) to the west, north, and east from grid center. Outlying areas to the west of the Mine Site contained tundra soils with consistently elevated levels of metals over the largest area. Tundra soil concentrations north of the Mine Site are poorly defined and slightly elevated metal levels persisted to the edge of the current sample grid (more sampling is required in this area). To the northeast and northwest, the tundra soil concentrations drop dramatically. See Figure-5 for plots of lead concentrations and Figure-6 for plots of zinc concentrations.

Further details, including data and spatial plots, can be reviewed in the December 2004 TCAK submittal to ADEC entitled "*2003 and 2004 Tundra Soil Sampling for Lead and Zinc.*"

3.5 Meteorological Monitoring

The Bons meteorological station was established in April 1996 and remains in operation. The station is located near the airport runway approximately 5 kilometers (3 miles) south of the mill. The site monitors and/or calculates wind speed and direction, sigma theta, air temperature, temperature differential, relative humidity, precipitation, solar radiation, and barometric pressure. Figure-8 depicts the 2003 annual, summer (May – October), and winter (November – April) wind direction (as wind roses). The summer wind pattern has a bi-directional predominance. During the period, 15% of the winds were from the northeast and 11 % of the winds were from the southwest. The winter pattern has a predominant wind direction from the northeast (30% northeast, 15 % north-northeast, 15% east-northeast, and 12% east). The annual wind direction is predominantly from the northeast (22% northeast, 12% north-northeast, 11% east-northeast, and 10% east). Weather is characteristically cold and dry in the winter. A summation of monthly temperatures, precipitation and humidity from 1996 to 2003 are provided below in Table-3.

Table-3

Bons Meteorological Station Summary						
MONTH	**Temp Max (°C)**	**Temp Min (°C)**	**Temp Avg (°C)**	**Average Precipitation (cm)**	**Average Relative Humidity (%)**	**Average Specific Humidity (g/kg)**
January	-5.1	-26.6	-12.3	1.46	72.5	0.98
February	-1.5	-26.2	-12.4	1.28	72.5	0.97
March	-1.1	-23.4	-11.6	1.51	64.3	0.93
April	2.1	-20.5	-7.7	2.17	70.2	1.43
May	13.5	-12.0	0.6	2.82	70.3	2.88
June	19.9	-1.8	7.9	3.43	65.8	4.50
July	20.3	1.0	9.5	7.72	76.3	5.82
August	16.5	-1.2	6.8	13.36	77.5	4.92
September	12.1	-6.1	2.9	6.70	79.5	3.84
October	2.4	-16.0	-6.6	3.22	78.7	1.77
November	1.5	-21.4	-9.3	1.94	74.1	1.31
December	-0.5	-26.2	-14.1	1.23	71.2	0.82

The mill tower meteorological station was established in November 2002 and is currently in operation. The station is located near the accommodations complex approximately 100 meters northeast of the mill. The site monitors wind speed, wind direction, and sigma theta at a point 36.6 meters above the ground surface to reduce influence of local structures. Figure-9 depicts the 2003 annual, summer (May – October), and winter (November – April) wind direction (as wind roses). The summer wind pattern has a bi-directional predominance. During the period 11% of the winds were from the east-northeast, 9% from the northeast, and 10 % of the winds were from the south-southwest. The winter pattern has a predominant wind direction from the east-northeast (17% east-northeast, 10% northeast, and 10 % east). The predominant annual wind direction is from the east-northeast (14% east-northeast and 9% northeast).

The site wind direction is heavily influenced by site topography. The topography causes the predominant winds that come over the pit and mill areas (from the east-northeast) to shift (to the north-northeast) as they exit the valley.

During the winter months (October – April), the site experiences extremely low specific humidity. There are four months (December – March) that average below 1 gram of water per kilogram of air. During this period, conventional dust control and application methods cannot be used do to the freezing conditions and low specific humidity (i.e. road watering or hygroscopic palliatives).

3.6 Dustfall Jar Particulate Deposition

Dustfall jars are passive accumulators of fallen dust that are sensitive to wind scouring and the presence or absence of rain and or snow. Three different dustfall programs have been conducted at the Mine Site. Each of the programs utilized an ASTM standard test method (D1739) consisting of 150 mm (6 inch) diameter jars placed approximately 2.5 meters (8.2 feet) from the ground. The sample period for each program was different and not all jars were operated concurrently. The data collected, therefore, can be variable and difficult to correlate.

From January 1999 to June of 2003 ten jars were placed in quadrants within the Mine Site basin with two jars within each quadrant and a reference jar. These jars were placed in an attempt to measure fugitive dust deposition around the Mine Site. The typical dust collection period was 30 days but some sample periods were as long as 7 months. The sampling program experienced several changes over the years with the jars being run dry, or with an alcohol/water or glycol/water mix (to prevent freezing and wind erosion). The collected dust was analyzed for metals at Red Dog or at a third party laboratory.

In another program, eight jars were installed west of the tailings pond and data was collected from October 2001 through June 2003. The purpose of this program was to measure the distribution of dust from a tailings beach, which was exposed during the winter of 2001 and 2002. Sampling intervals were nominally 30 days. Jars were run both dry and with de-ionized water. The metal analysis was done by a third party laboratory.

The present dustfall program consists of twenty-five jars spread throughout the mine site. Twenty-two of the jars were installed in July 2003 and three jars were installed in August 2004. Jars are run dry and each jar is equipped with an aerodynamic ring to reduce the potential loss of collected particulate matter during windy conditions. The collected dust is analyzed for metals at Red Dog.

The data expressed in Figure-10 represents the lead deposition rate recorded by the dustfall jars and shows a similar pattern to the tundra soil results. The results are displayed as the average lead accumulation rate per day for each jar for the entire sampling interval for that jar. Each set of jars was in place for at least a full weather season. The interpretation of results is compromised because of variable techniques. The data indicates that in the areas of the pit, ore stockpiles, CSB/mill facilities, and tailings beach the dust deposition is the greatest. Increased dust deposition occurs westward and to a lesser extent southwestward and northwestward from the higher depositional area.

3.7 Total Suspended Particulates (TSP) – Ambient Air Monitoring

TSP monitoring programs were conducted from January 1992 to August 1994 as a component of the COBC and consisted of a single site, the PAC-Hi-Vol TSP. The current program, which was initiated in October 2003, is intended for operational understanding. The current program has two monitoring sites, the Tailings Dam TEOM TSP and the

Overburden TEOM TSP. Refer to Figure-11 for site locations. In January 2004 the Overburden TEOM TSP was relocated to the original site of the PAC Hi-Vol TSP, in order to improve data comparability. No results from this monitoring location are available for this report.

The monitoring indicates a cyclical pattern in TSP concentration with highest concentrations in the winter months and lowest concentrations in the summer months. The data set was collected at multiple locations utilizing two methods. When comparing past concentration levels to current concentration levels the most comparable data sets are the PAC Hi-Vol TSP and the Tailings Dam TEOM TSP. The sites are 975 meters (3,200 feet) apart with the Tailings Dam site downwind of the PAC Hi-Vol site. A direct comparison of the sites shows a significant reduction in concentrations over time. A portion of the decrease may be attributable to the location of the two sites. The Tailings Dam TEOM TSP site is further away from potential sources allowing for dilution of the emissions and deposition of particles before sample collection. See Figure-12 for the complete monthly average TSP concentrations.

3.8 PM_{10} – Ambient Air Monitoring

A program to monitor ambient air particulate matter less than 10 microns (PM_{10}) was conducted from September 1992 to August 1994 as a component of the COBC. From June 2001 to August 2002 similar monitoring was done at the ambient air boundary.

The 1992-94 program consisted of a single site, the PAC Hi-Vol PM_{10}. This monitor was located next to the PAC Hi-Vol TSP monitor. The data collected demonstrated compliance with the current NAAQS for PM_{10}, within the ambient air boundary (by regulation the standard must be met at the boundary and beyond). The maximum observed daily concentration was 53 $\mu g/m^3$ and the highest monthly average was 18 $\mu g/m^3$. See Figure-11 for the site locations.

The 2001-02 program consisted of a single site labeled MS-13, which was located near the intersection of the DMTS road and the ambient air boundary (roughly south of the airport runway). The data demonstrates compliance with both the daily and annual NAAQS for PM_{10}. The maximum observed daily concentration was 61.2 $\mu g/m^3$ and the highest monthly average was 28.2 $\mu g/m^3$.

3.9 Total Suspended Particulate Lead– Ambient Air Monitoring

TSP lead monitoring programs were conducted from 1992 to 1994 as a component of the COBC and in the current program, which began October 2003. The 1992-94 program consisted of a single site, the PAC Hi-Vol TSP. The current program has two sample sites, the Tailings Dam TEOM TSP and the Overburden TEOM TSP (subsequently, the Overburden TEOM has been relocated as noted in Section 3.7). The data indicates lead concentrations are consistently higher in the winter than in the summer. Comparison of past to current concentrations is subject to the same limitations as the TSP monitoring (different sites). Table-4 contains the annual average lead concentration for the PAC Hi-Vol TSP, Overburden TEOM, and Tailings Dam TEOM. Table-5 is the average percentage of lead in the TSP. See Figure-13 for a graph of the monthly average TSP lead concentrations.

A review of the PAC Hi-Vol demonstrates a 29% reduction (2.21 μg/m^3 to 1.56 μg/m^3) in total lead concentration and a corresponding 23% decrease (4.8% to 3.7%) for lead contained in the TSP from 1992 to 1994.

Table-4

Red Dog Mine Annual Average TSP-Lead Concentration			
Year	**PAC Hi-Vol**	**Tailing Dam TEOM**	**Overburden TEOM**
1992	2.21 μg/m^3	--	--
1993	1.44 μg/m^3	--	--
1994	1.56 μg/m^3	--	--
Oct 03 – Oct 04	--	0.28 μg/m^3	0.04 μg/m^{3*}

* Overburden sampled from December 2003 to July 2004

Table-5

Red Dog Mine Annual Average Percentage of Lead in TSP			
Year	**PAC Hi-Vol**	**Tailing Dam TEOM**	**Overburden TEOM**
1992	4.8%	--	--
1993	4.0%	--	--
1994	3.7%	--	--
Oct 03 – Oct 04	--	1.3%	0.4%*

* Overburden sampled from December 2003 to July 2004

3.10 Village Ambient Air Monitoring – Total Suspended Particulate Lead

The ambient air in Noatak and Kivalina was monitored to fulfill the requirements of a settlement agreement with the Alaska Department of Environmental Conservation (ADEC), and to address concerns by village residents. The program involved one year of monitoring to determine the levels of lead in the airborne dust at each village. Results for both communities indicate lead levels are approximately 200 times below the National Ambient Air Quality Standard (NAAQS) of 1.5 micrograms of lead per cubic meter of air (μg/m^3). Tables 6 and 7 contain the quarterly average lead concentration for Noatak and Kivalina.

Table-6

Noatak Village TSP-Lead Concentration Quarterly Average	
	Average TSP-Lead
April – June 2003	0.0078 $\mu g/m^3$
July – September 2003	0.0072 $\mu g/m^3$
October – December 2003	0.0039 $\mu g/m^3$
January – May 2004	0.0042 $\mu g/m^3$

Table-7

Kivalina Village TSP-Lead Concentration Quarterly Average	
	Average TSP-Lead
September 2003	0.0052 $\mu g/m^3$
October – December 2003	0.0050 $\mu g/m^3$
January – March 2004	0.0039 $\mu g/m^3$
April – May 2004	0.0062 $\mu g/m^3$

3.11 Snow Sampling

A snow-sampling program was initiated in 2001 to monitor wind-generated dust off a tailings beach that existed at the time (current practice is to keep the beach submerged). On the northwest side of the tailings pond, 22 snow samples were collected and analyzed onsite for zinc, lead, and cadmium. The program was repeated in 2002, 2003 and 2004. The increase in 2004 is attributable to the timing of the sample. The sample was taken late in the year after the spring melt had begun. This resulted in minimal sample volume at several stations and the exclusion of four stations due to lack of snow. Therefore, the 2004 sample results are suspect. See Figure-14 for the snow transect location and average yearly result.

3.12 Moss Sampling

Moss studies have been conducted since 1999 by the National Park Service (NPS) and TCAK. Figure-15 provides the combined results of the NPS and TCAK moss studies (lead only). In 1999, the NPS conducted spot moss sampling in Cape Krusenstern National Monument adjacent to the road. Elevated lead values prompted the collection of moss and soil samples along six transects perpendicular to the road in the summer of 2000. J. Ford and L. Hasselbach provide details on this program in the 2001 National Park Services report titled *Heavy metals in mosses and soils on six transects along the Red Dog Mine Haul Road, Alaska*. In 2001, the NPS returned to conduct a regional study that included sampling as much as 45 miles north and south of the road. Details of this program are provided in the 2004 National Park Service report titled *Spatial patterns of cadmium and lead deposition on and adjacent to National Park Service lands in the vicinity of the Red Dog Mine, Alaska* by L. Hasselbach, et al.

In 2001, TCAK conducted a program along seven transects perpendicular to the road and outside of the Monument boundary. In addition, spot sampling was conducted at historic concentrate truck spill sites and around the port facility. In 2002, additional sampling was performed around the Mine Site. All studies analyzed the previous three years of moss growth. The TCAK moss samples were analyzed for aluminum, arsenic, cadmium, calcium, iron, lead, magnesium, and zinc.

3.13 Vegetation Monitoring

Vegetation monitoring was conducted in 1992, 1993, 1997 and 2003. In the 1992 program, four sample areas were established in the four cardinal directions approximately 2 miles from the center of the Mine Site with an additional reference area that was established southeast of the Mine Site. At each sample area, four plots were established for a total of twenty sample plots in five locations. The specific plot locations were based on vegetative community. In each sample plot the vegetative health and vitality, species richness, dominance and distribution and the concentration of lead and zinc in the soil were sampled. In 1993 and 1997 all the plots were resampled using the1992 methods. In 2003, only vegetation plot W3 was resampled as a requirement of the Mine Site air permit. During the monitoring period, the vegetative cover did not show signs of stress associated with the mining activities. The minor changes in species richness and dominance were associated with the timing of the various surveys and the variability in the short growing seasons of arctic species.

In 1992, 1993 and 1997 soil samples were taken from the soil in the root zone (or the bare mineral soil if no plant cover was present). Soil sampling was not a component of the 2003 program. The median metal concentrations of the root zone soil increased at all sites except the south quadrant. The increase in the median concentrations maybe attributed to the small sample size and inherent sample variability associated with soil sampling. The 95% confidence interval for each plot indicates that there has not been a significant change in soil lead concentrations from 1992 to 1997. Figure-16 provides the median lead concentration of the sample areas.

3.14 Village Blood Lead Monitoring

In October 2001, the Alaska Division of Public Health (ADPH) issued the *"Public Health Evaluation of Exposure of Kivalina and Noatak Residents to Heavy Metals from Red Dog Mine."* The evaluation included a review of blood lead testing conducted in

1990. The report also reviewed results of existing soil, sediment, fish, caribou, sourdock, and salmonberry studies. In addition, drinking water studies for the village of Kivalina were reviewed. Overall, the study found that there is very little threat to human health posed by drinking water, soil, sediment, fish, caribou, and salmonberries. Blood lead tests for the residents of Kivalina and Noatak indicted no elevated lead levels. The report concluded that local residents of Kivalina, Noatak, and Point Hope could continue to safely eat traditional subsistence foods and drink the water.

In November 2004, ADPH collaborated with the Maniilaq Health Corporation and conducted additional blood lead studies in the villages of Noatak and Kivalina. This was done to follow up on the blood lead study conducted in 1990. The January 7, 2005 report, titled "*Public Health Evaluation and Assessment Biomonitoring of Residents of Kivalina and Noatak Lead and Cadmium Results"* found that blood lead levels were not elevated in any individual participating in the study. Results of the study also demonstrated lower lead levels in 32 of 33 individuals that were also tested in 1990.

3.15 Red Dog Employee Blood Lead Monitoring

Red Dog conducts blood lead and cadmium monitoring to ensure the safety of the workforce. Coupled with an extensive preventive dust hygiene program, exposures are well managed.

For Red Dog employees the October 2001 ADPH report found recent regional new hires (15 from Noorvik and 20 from Kivalina) had geometric mean blood lead concentrations of 3.4 and 3.7 µg/dL respectively. 10,685 blood tests taken from 1,805 TCAK employees and contract workers had lead geometric mean levels of 9.02 µg/dL and ranged from 1 to 74 µg/dL. One percent of the employees had lead levels greater than 40 µg/dL, which is the Occupational Safety and Heath Administration initial action level that requires an increase in blood lead testing to every six months.

Teck Cominco's blood lead program frequency is more conservative than OSHA's and requires employees with blood lead levels greater than 36 µg/dL to be tested monthly and counseled in lead exposure prevention. Employees with blood lead levels greater than 50 µg/dL require mandatory removal from the work environment, monthly testing, and counseling. Only one individual has exceeded 50 µg/dL (his result was 51µg/dL) since January, 1 2000.

4 Further Work

4.1 Study Plans

A number of engineering and operational improvements to the Mine Site's fugitive dust control systems have been completed. Monitoring programs to determine the effectiveness of the current dust control systems are already in place. More extensive work is required to better understand the nature of mining related fugitive dust. The ultimate goal is continuous improvement, consistent with Red Dog's Environmental Management System, to further reduce fugitive dust levels.

Teck Cominco Alaska's plans for further study to assess the fugitive dust from the Red Dog Mine are as follows:

<u>Source Contribution Evaluation</u>

- Develop a study to determine the contribution from the various sources (source apportionment). This study may include:
  - a systematic evaluation of all potential past and current emissions
  - the ranking of existing source contributions
  - factoring in changes in the operation (including production rate and grade)
  - utilization of an appropriate air dispersion and deposition model which could possibly be confirmed with monitoring information.

<u>Identify Opportunities for Additional Source Control</u>

- Conduct a literature search to determine feasible control measures.
- Develop a program to reduce emissions by changing operational practices and modifying facilities.

<u>Design Monitoring Programs</u>

- Assess past and current monitoring and develop future requirements. This includes:
  - evaluation of future needs for compliance and operational monitoring
  - determining the type and location of monitoring stations
  - identifying the frequency and methodology for future site assessments (i.e. soils and vegetation studies).

<u>Continued Site Assessment</u>

- Expand the "tundra soils" grid established in 2003 and 2004 to delineate all areas with significant metals levels. What is considered to be a significant level will be determined prior to completing the assessment. The assessment will use the ex-situ method that has been developed and will include wet chemical analysis on 10% of the samples.
- Determine the analytical parameters prior to initiating the sample program. At a minimum lead, zinc and pH will be measured.
- Assess whether this information should be collected from prior sample sites
- Conduct soil sampling at the vegetation sites using identical techniques used in the past.
- Develop and implement a sample program to assess driving surfaces.
- Develop and implement a means to assess the localized lee side/snow-drift deposition effect. This may include:
  - snow drift mapping
  - selection of a background site
  - conducting a detailed assessment (soils and vegetation) of several drift areas.

Vegetation Studies

- Develop and implement a vegetation study as related to the Mine Site dust issue. Aspects that may be addressed include:
    - an assessment of stressed vegetation (distribution and characterization)
    - evaluation of effects
    - research on cause of effects
    - determining an understanding of the history of the impacts
    - a prediction for future effects
    - identification of the metals uptake process
    - an evaluation of possible restoration and revegetation methods
    - conducting a literature search.

Explore Deposition Rates

- Develop and implement research to estimate the past, present and future rate of dust deposition. Existing and possibly new monitoring information will be utilized. Modeling will be conduct for past periods that reflect known variations in dust generation.
- A study will be defined to better understand the weathering of the fugitive dust and information obtained will be used to qualify to what extent the deposition is historical and the fate of dust in the environment. Possible areas that will be pursued include:
    - determining the degree of chemical and physical breakdown of dust particulates
    - identifying the method of weathering
    - conducting tests to simulate and quantify the rate of weathering (e.g. humidity cells)
    - evaluating the history of deposition with historical photographs of the site (including satellite imagery).
- A program to identify the characteristics of dust will be developed which may include:
    - size fractionation
    - mineralogy
    - composition.

Studies will be further defined to include start and end dates, periodic review opportunities and an identification of deliverables. Information will be shared periodically as it is becomes available.

Summary of Mine Related Fugitive Dust Studies

Red Dog Mine Site

List of Figures

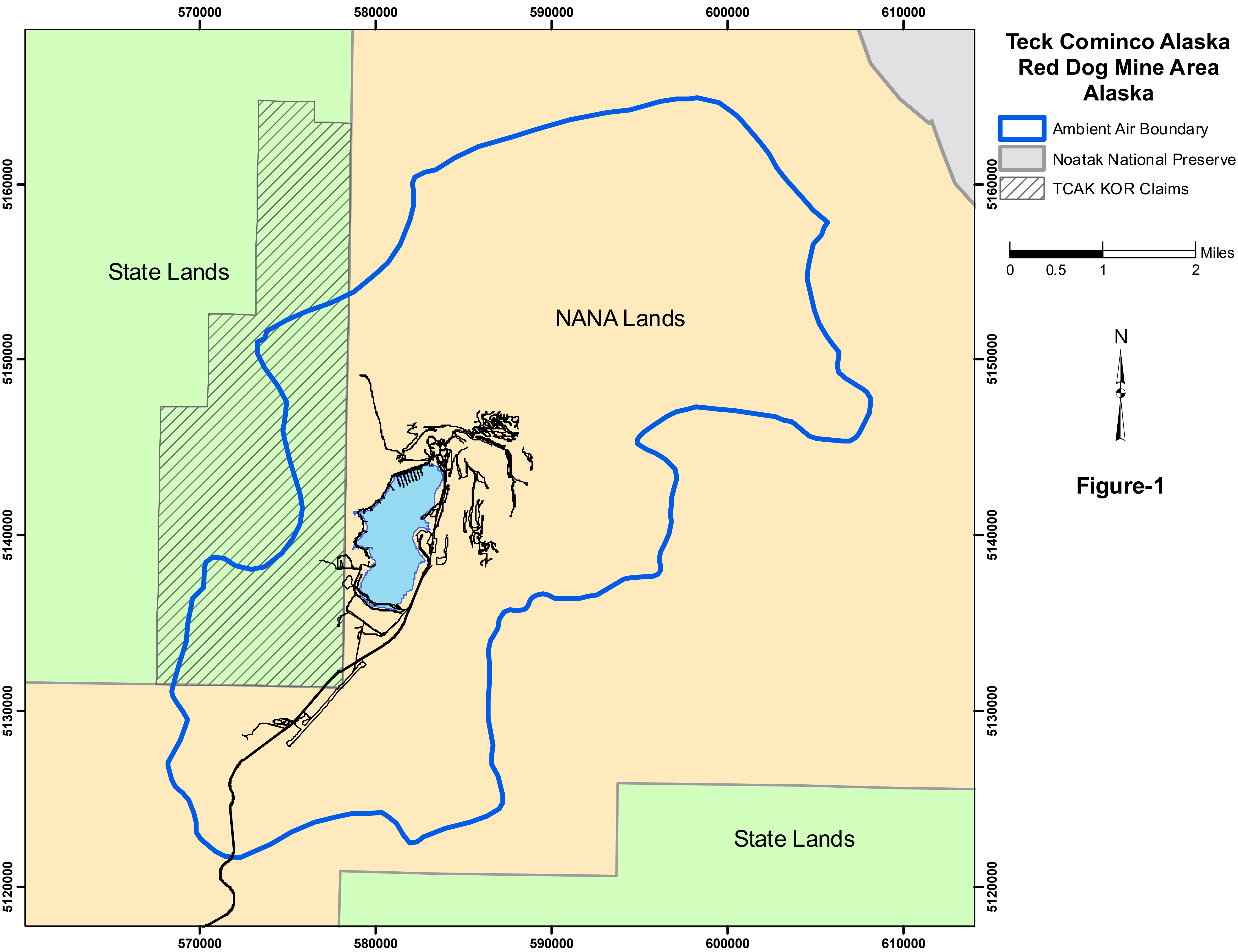

Teck Cominco Alaska
Red Dog Mine Area
Alaska
Ambient Air Boundary
Noatak National Preserve
TCAK KOR Claims
0
0.5
1
2
Miles
N
State Lands
NANA Lands
State Lands
570000
580000
590000
600000
610000
5160000
5150000
5140000
5130000
5120000

Figure-1

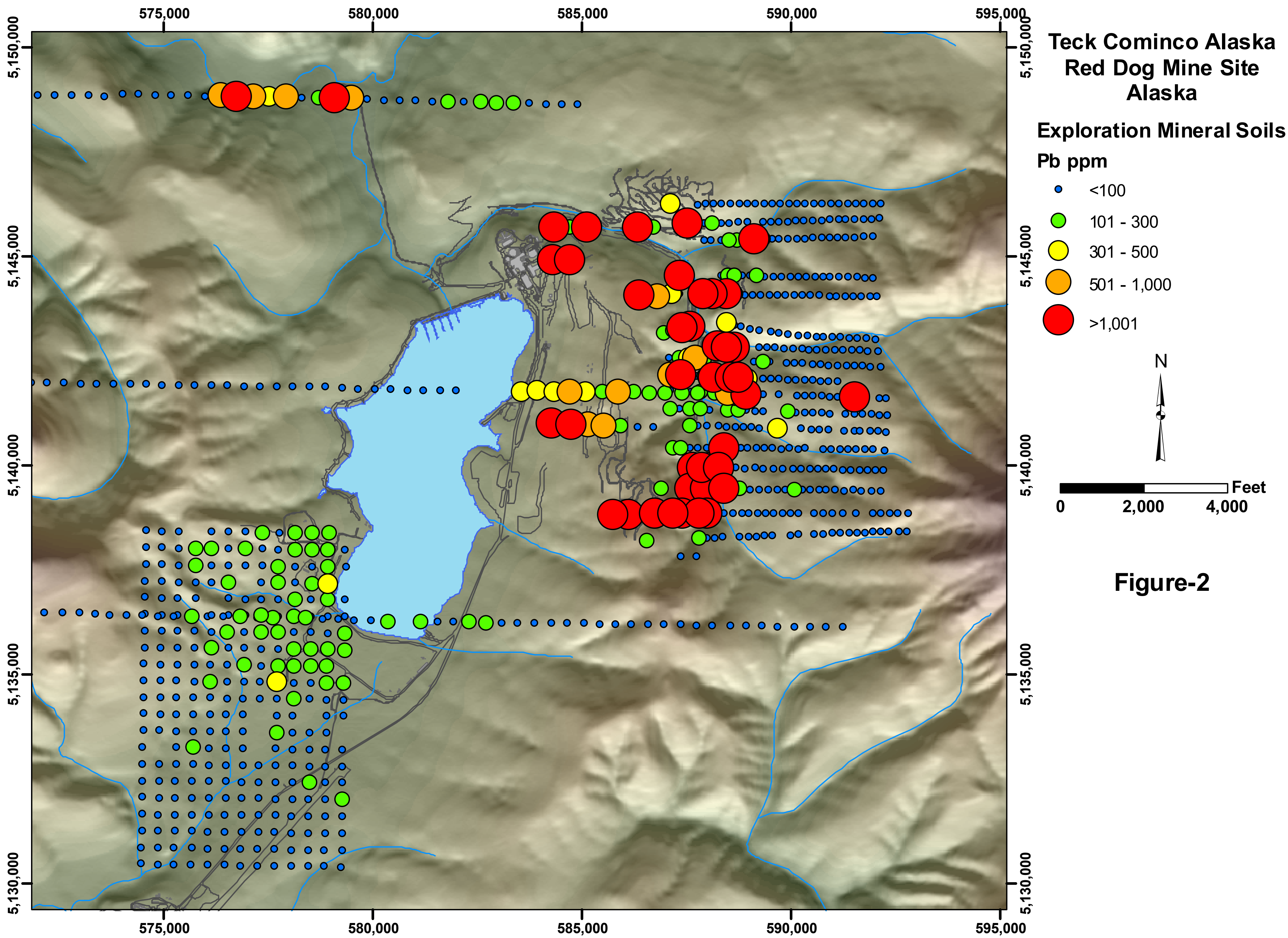

575,000
580,000
585,000
590,000
595,000
5,150,000
5,145,000
5,140,000
5,135,000
5,130,000
Teck Cominco Alaska
Red Dog Mine Site
Alaska
Exploration Mineral Soils
Pb ppm
<100
101 - 300
301 - 500
501 - 1,000
>1,001
N
Feet
0
2,000
4,000

Figure-2

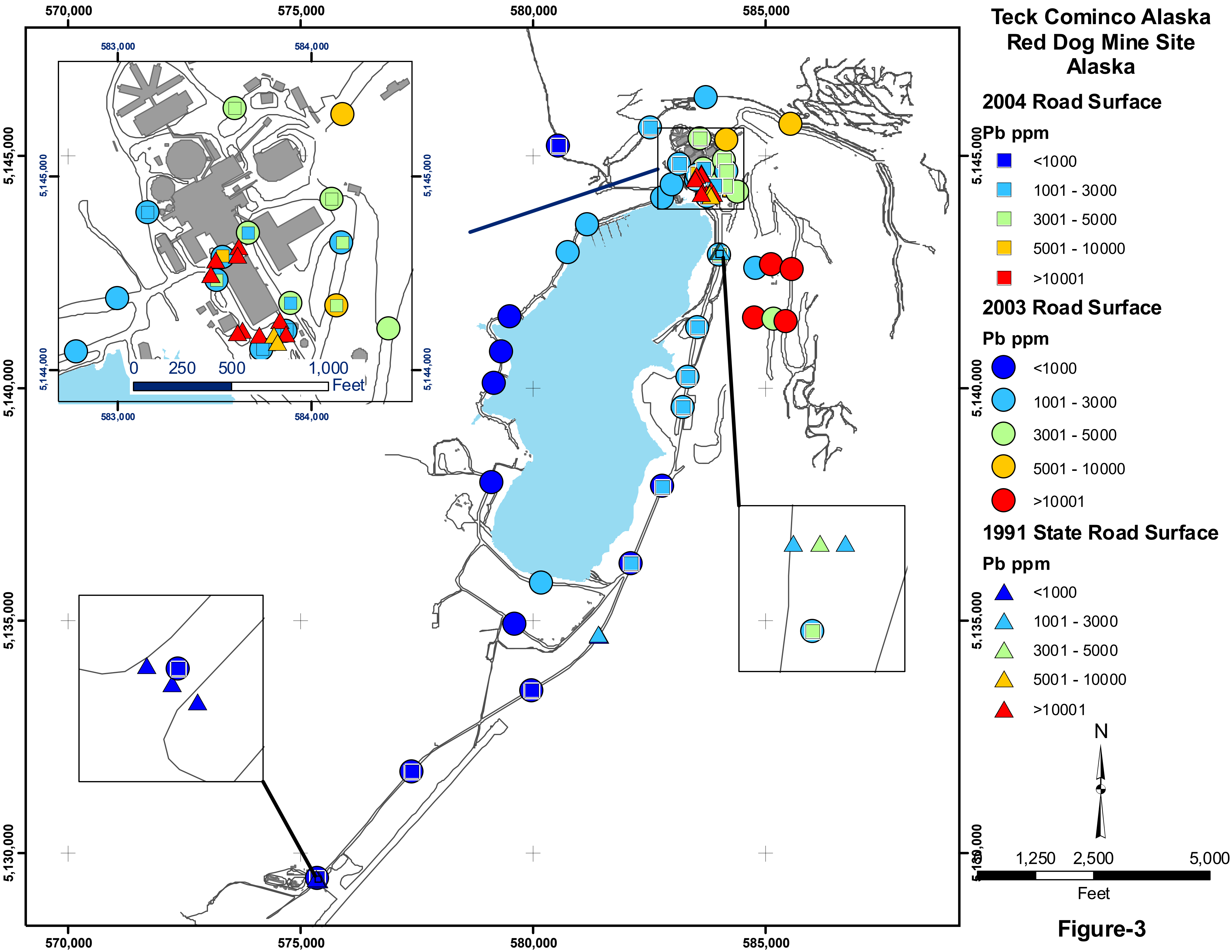
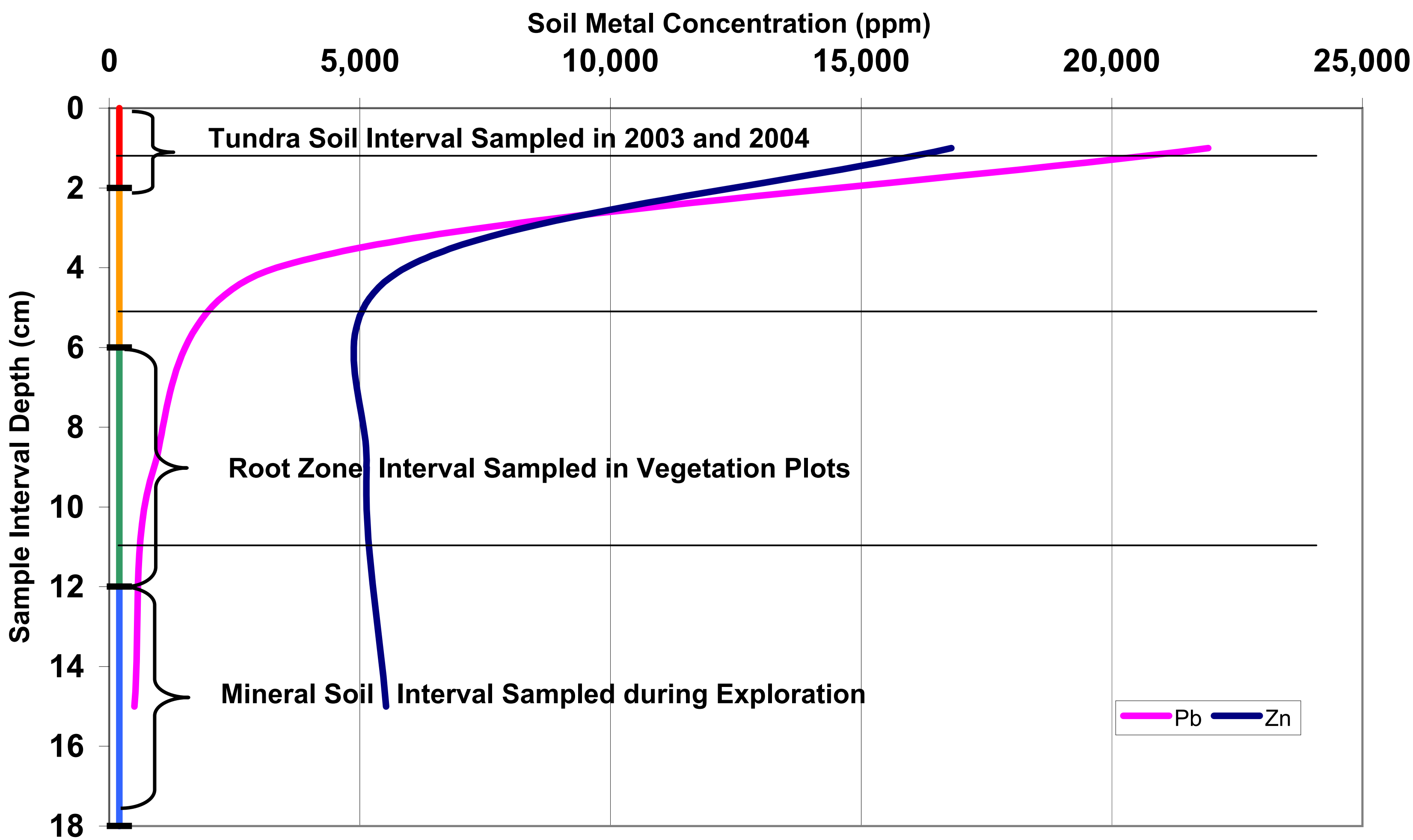
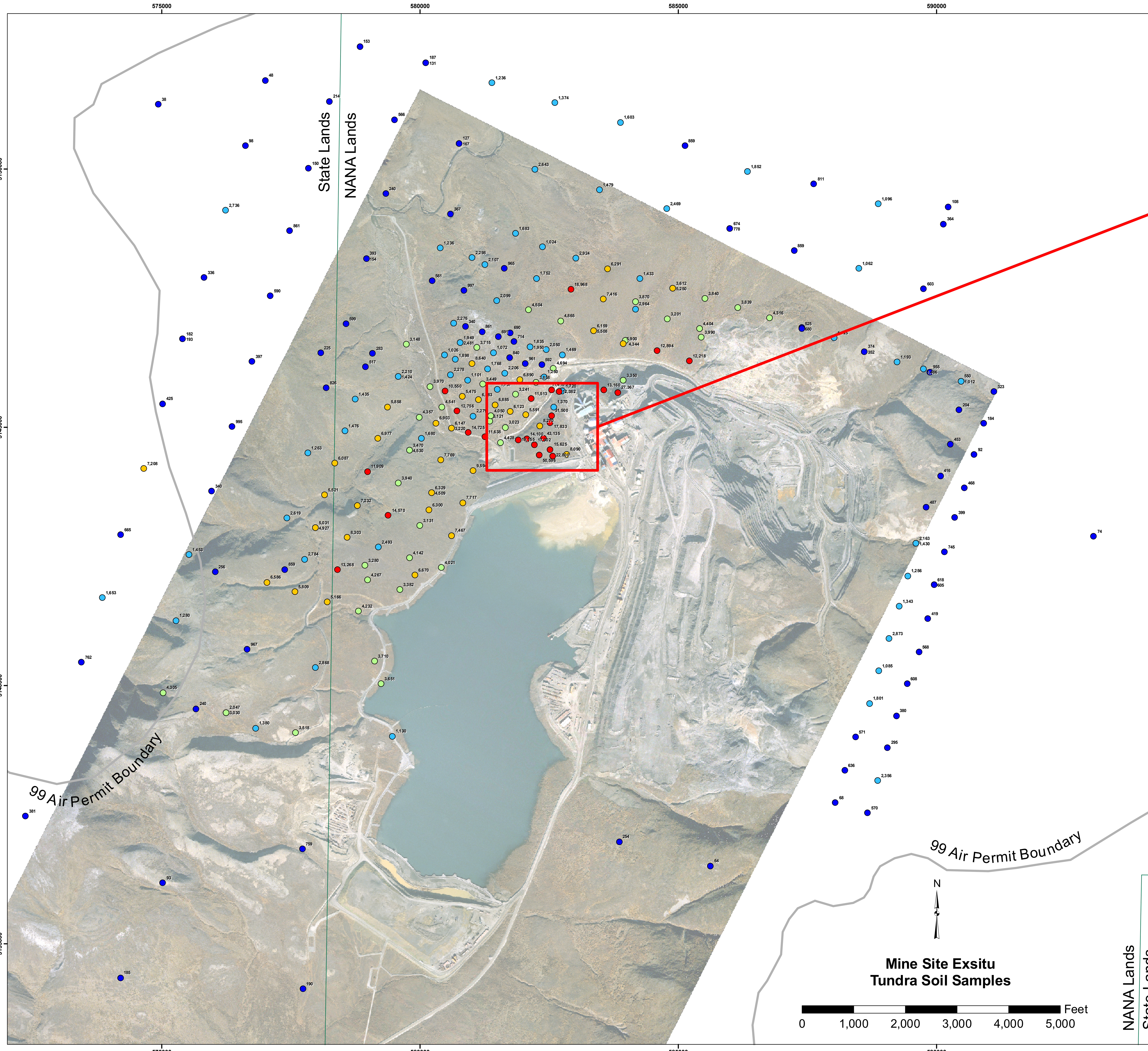
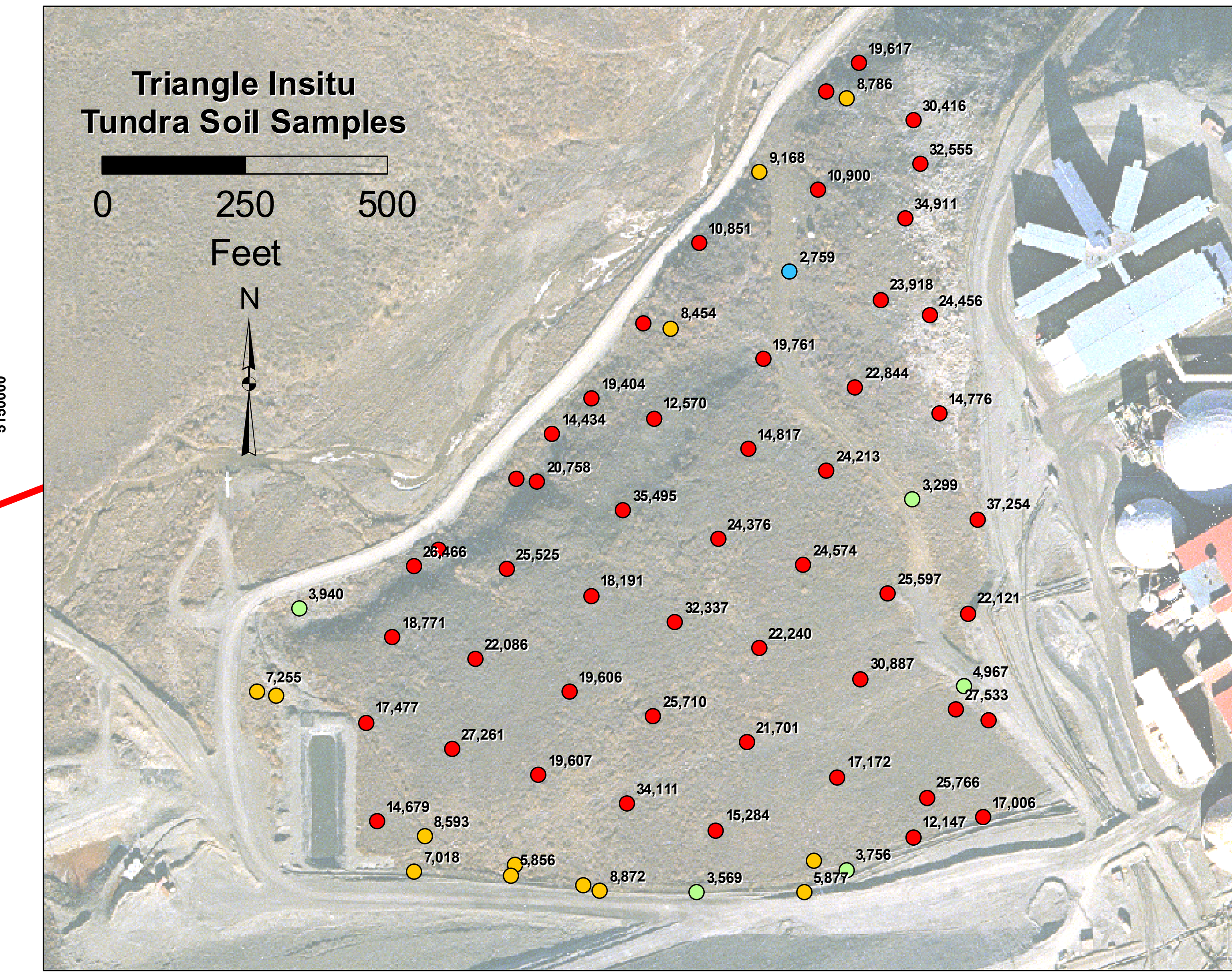

570,000
575,000
580,000
585,000
5,145,000
5,140,000
5,135,000
5,130,000
583,000
584,000
5,144,000
0 250 500 1,000 Feet
Teck Cominco Alaska
Red Dog Mine Site
Alaska
2004 Road Surface
Pb ppm
<1000
1001 - 3000
3001 - 5000
5001 - 10000
>10001
2003 Road Surface
Pb ppm
<1000
1001 - 3000
3001 - 5000
5001 - 10000
>10001
1991 State Road Surface
Pb ppm
<1000
1001 - 3000
3001 - 5000
5001 - 10000
>10001
N
1,250 2,500 5,000
Feet

Figure-3

Figure-4
Average Soil Depth Profile Triangle Area







Teck Cominco Alaska
Red Dog Mine Site
Alaska

2003 & 2004 Tundra Soil Samples

Lead ppm

- <1000
- 1001 - 3000
- 3001 - 5000
- 5001 - 10000
- >10001

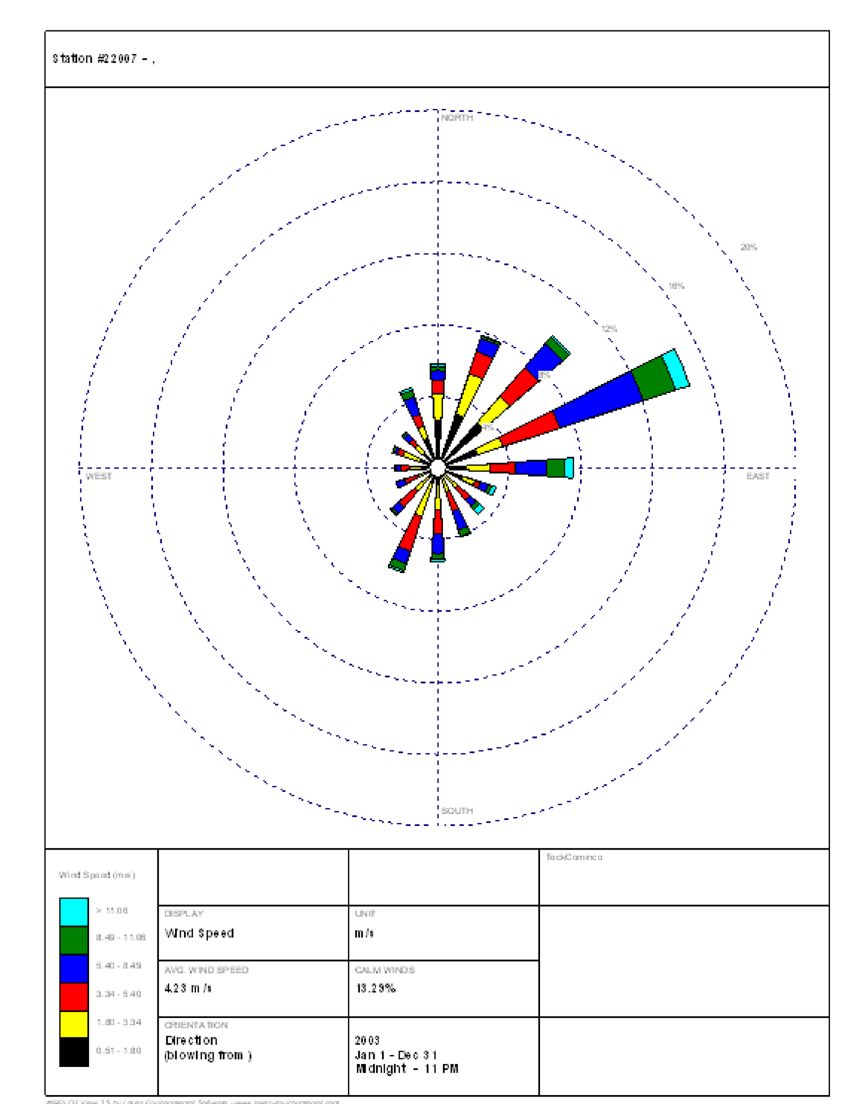
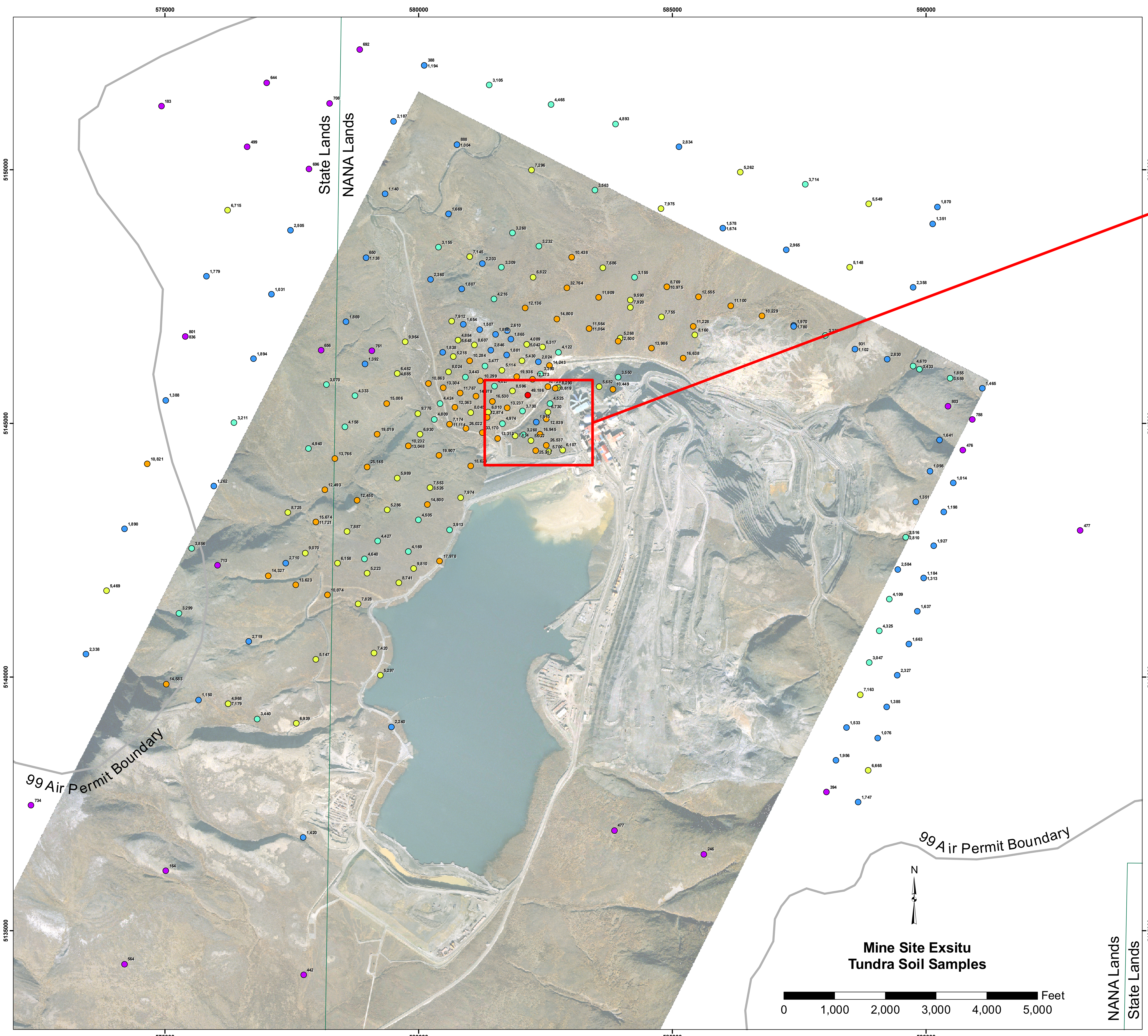
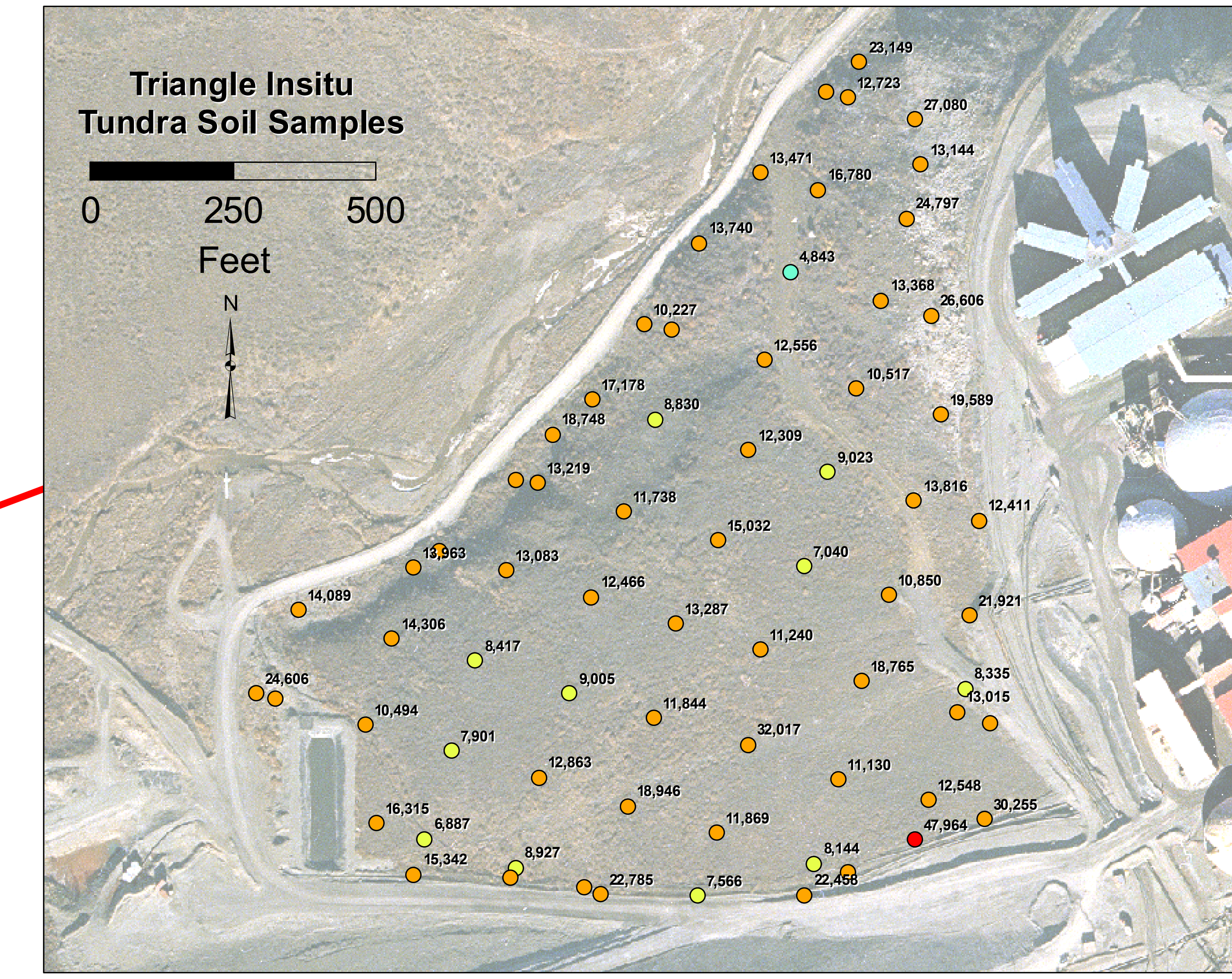


Figure-5

Map by JL Clark November 2, 2004





Teck Cominco Alaska
Red Dog Mine Site
Alaska

2003 & 2004 Tundra Soil Samples

Zinc ppm

- <1,000
- 1,001 - 3,000
- 3,001 - 5,000
- 5,001 - 10,000
- 10,001 - 41,000
- >41,001

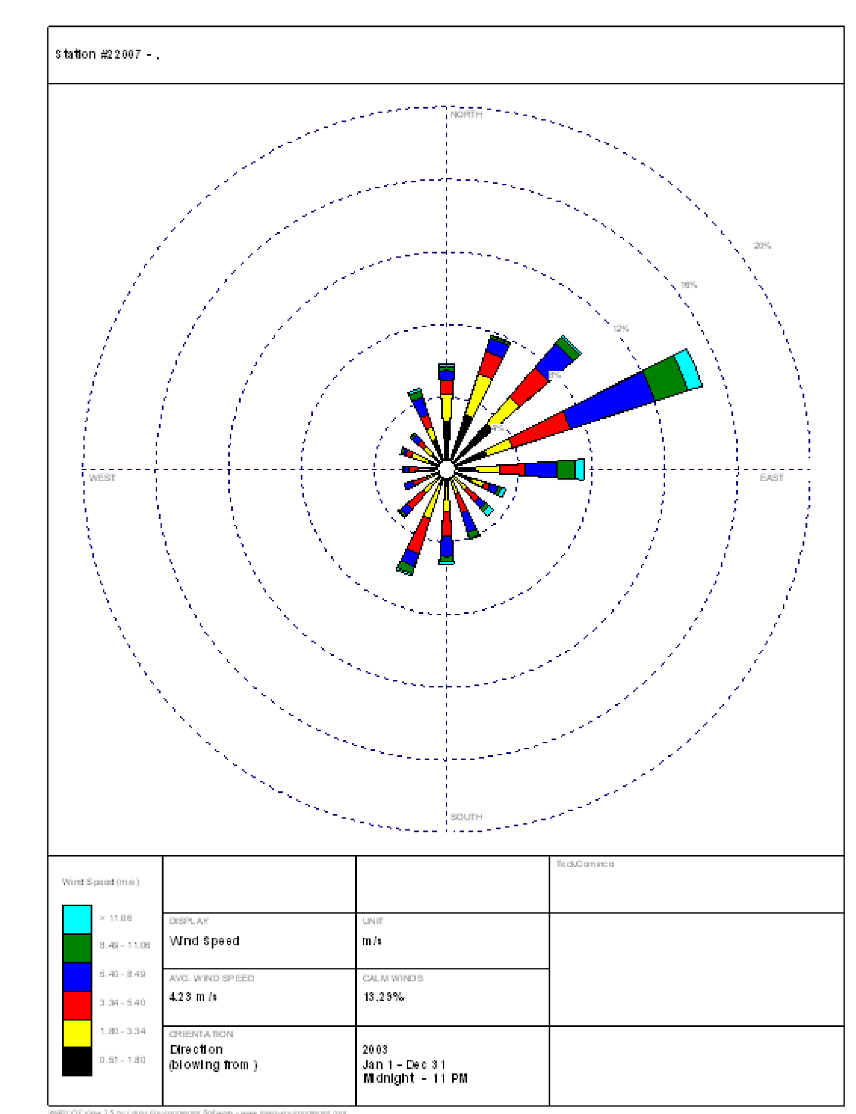
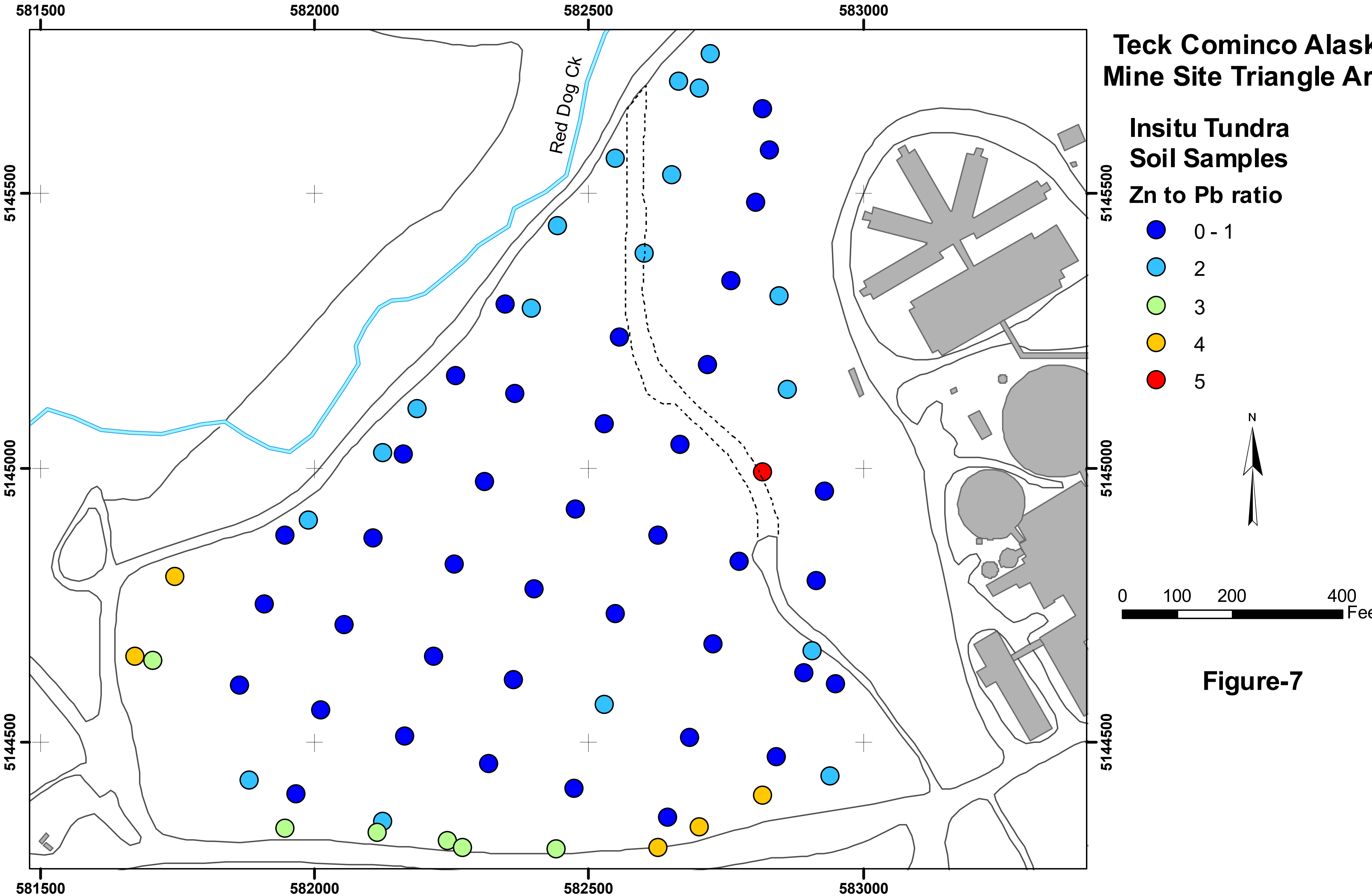


Figure-6

Map by JL Clark November 2, 2004

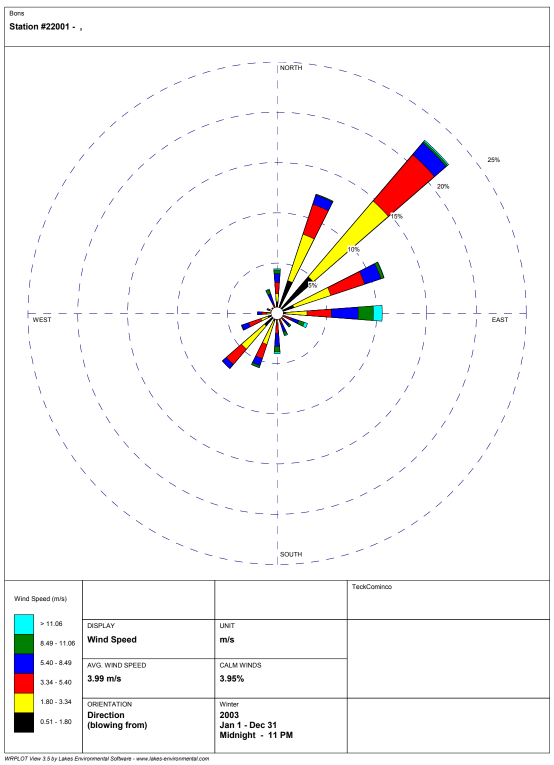


Teck Cominco Alaska
Mine Site Triangle Area

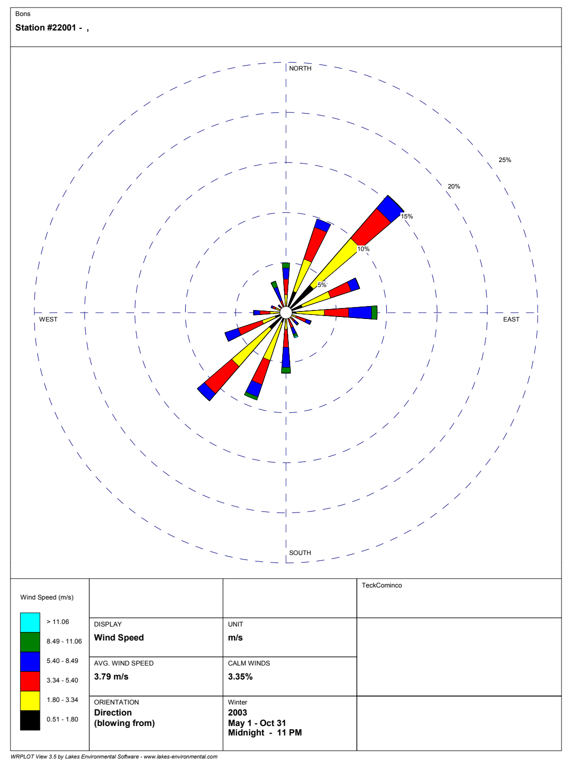
Figure-7

Figure-8
2003 Bons Meteorological Station
Wind Roses

Annual



May thru October



November thru April

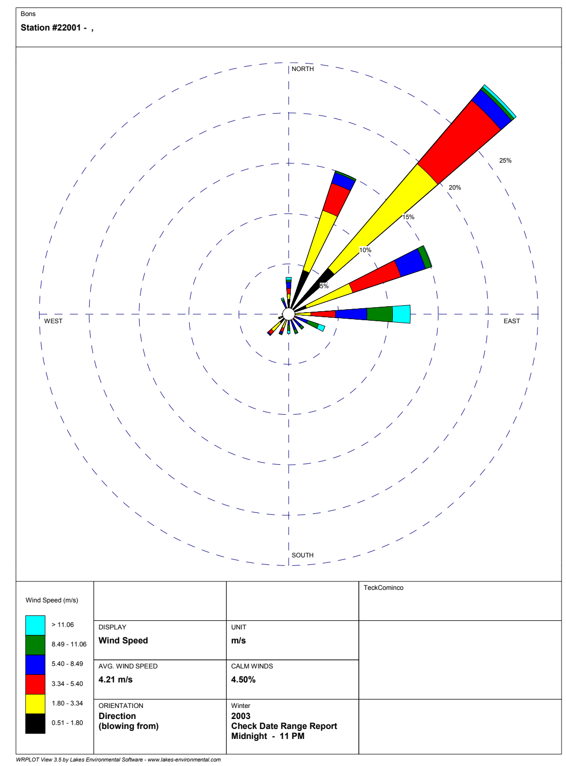
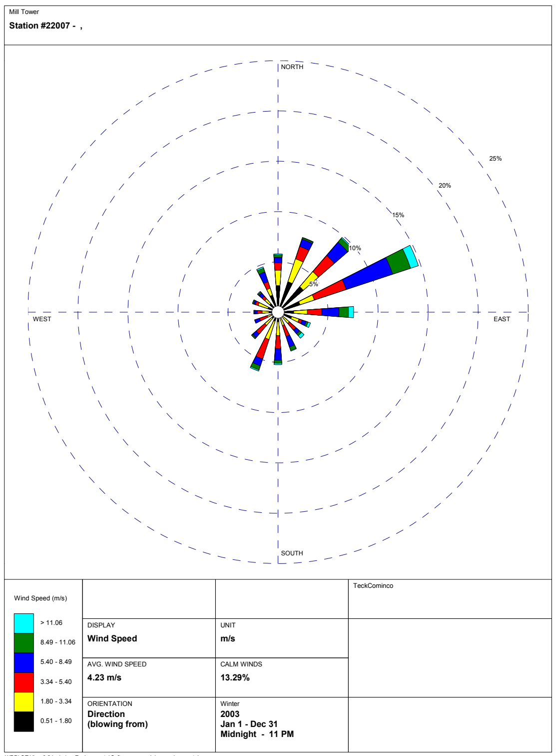
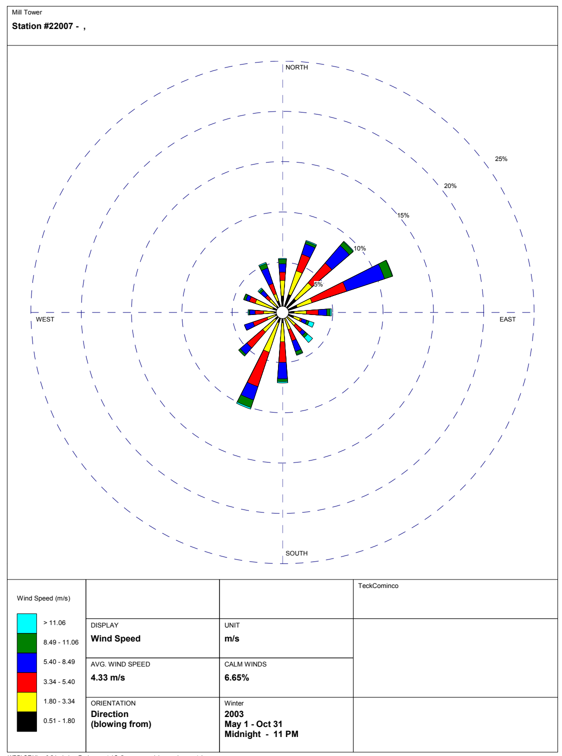


Figure-9
2003 Mill Tower Meteorological Station
Wind Roses

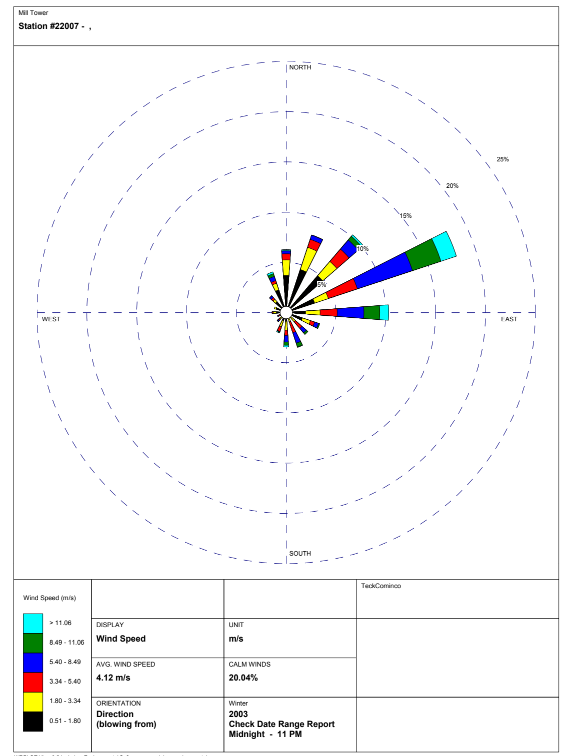
Annual

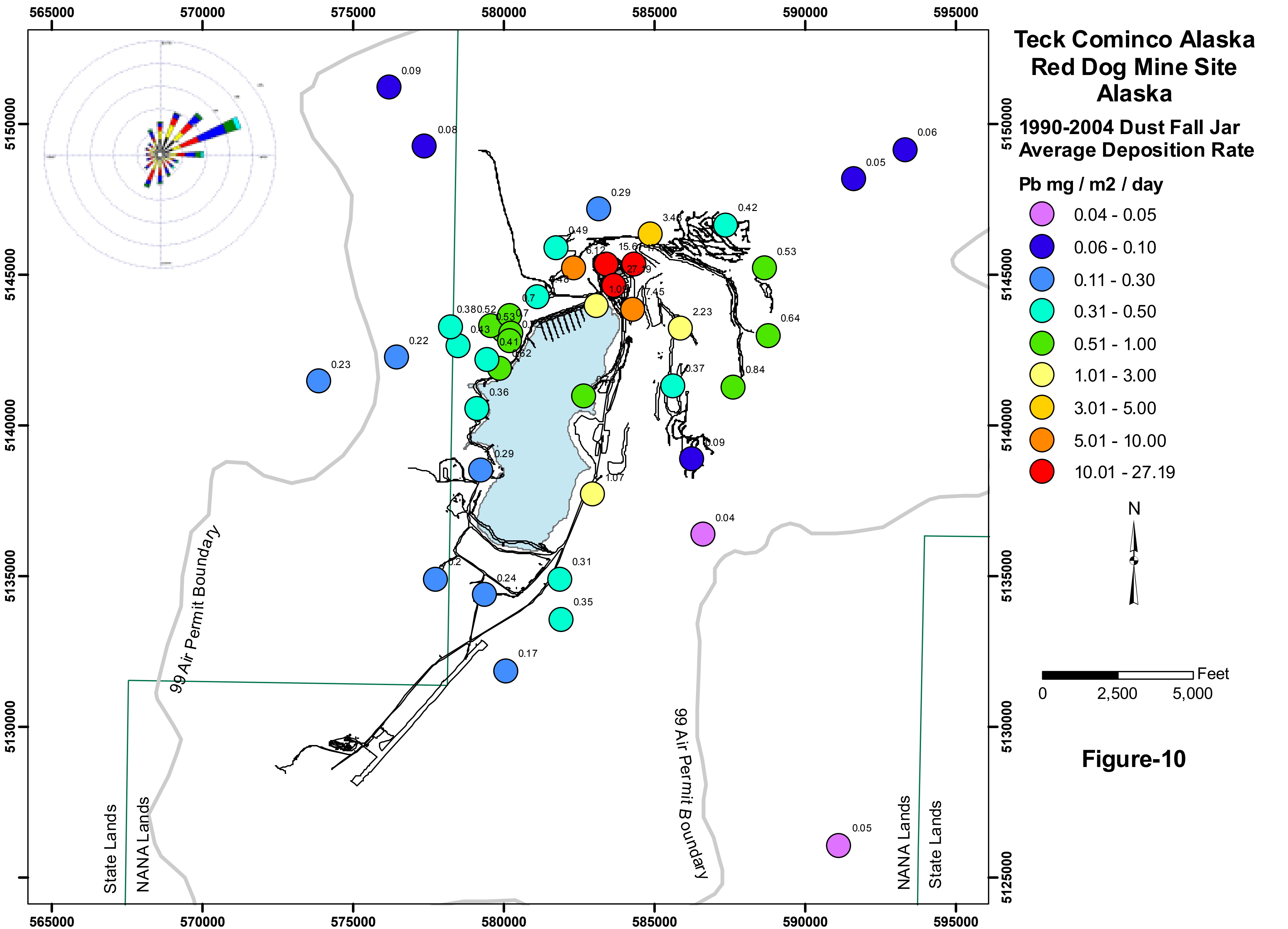


May thru October



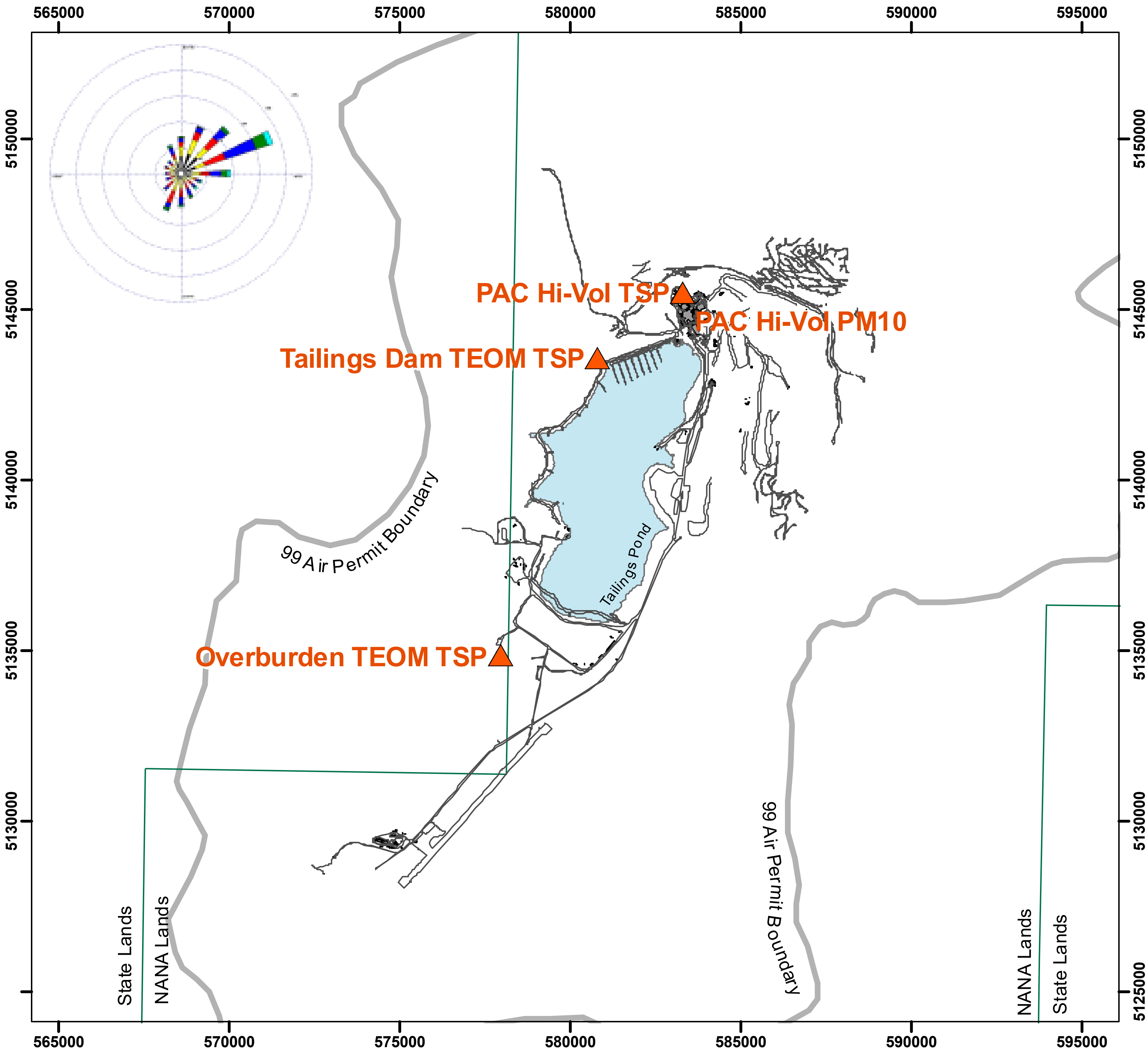
November thru April





Teck Cominco Alaska
Red Dog Mine Site
Alaska
1990-2004 Dust Fall Jar
Average Deposition Rate
Pb mg / m2 / day
0.04 - 0.05
0.06 - 0.10
0.11 - 0.30
0.31 - 0.50
0.51 - 1.00
1.01 - 3.00
3.01 - 5.00
5.01 - 10.00
10.01 - 27.19
N
Feet
0
2,500
5,000
99 Air Permit Boundary
99 Air Permit Boundary
State Lands
NANA Lands
NANA Lands
State Lands

Figure-10



Teck Cominco Alaska Red Dog Mine Site Alaska

Figure-11

Figure-12
Red Dog Mine
Monthly Average Total Suspended Particulates
(January 1992 to December 2004)

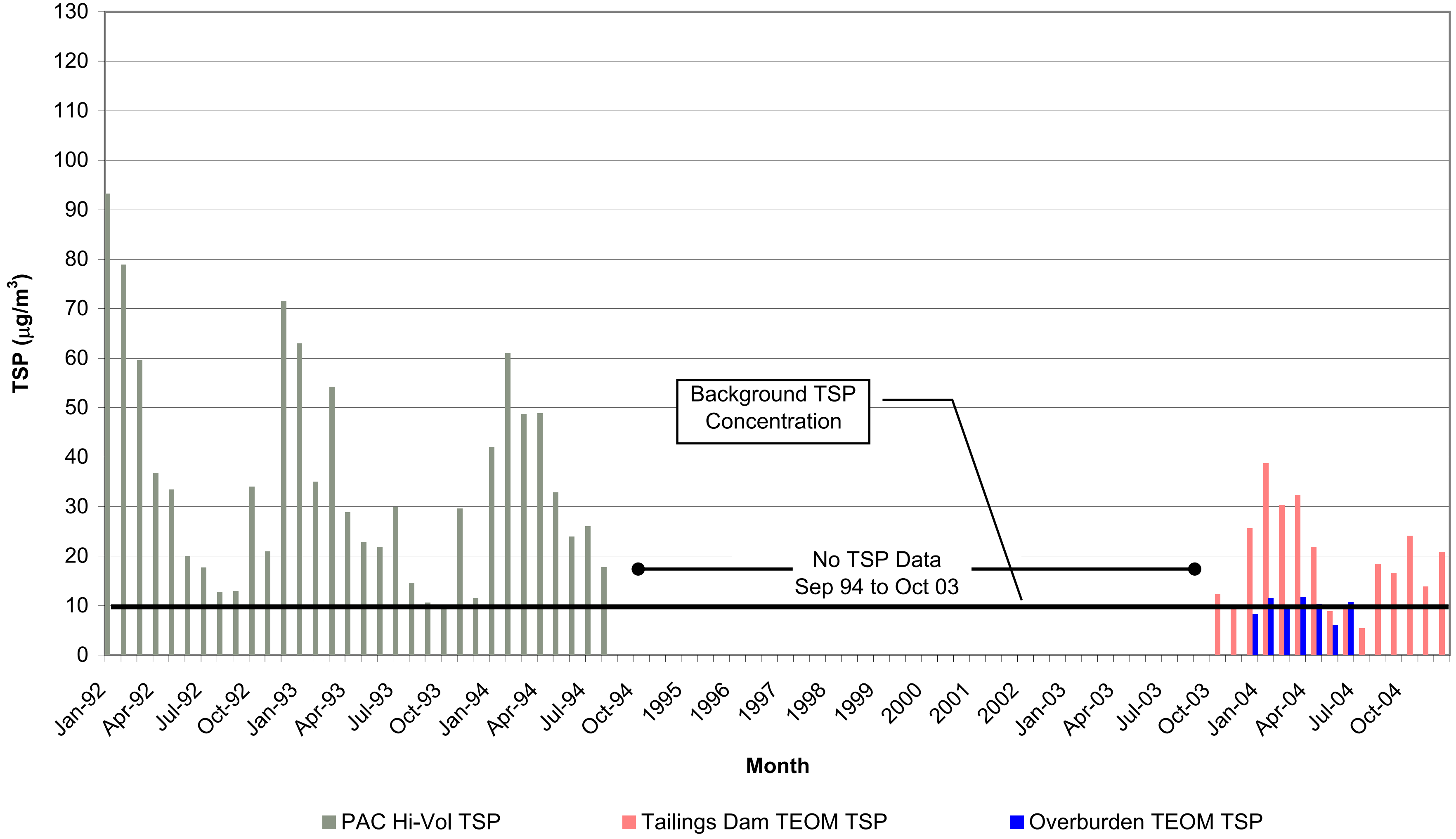


Figure-13
Red Dog Mine
Monthly Average Total Suspended Particulate-Lead
(January 1992 to December 2004)

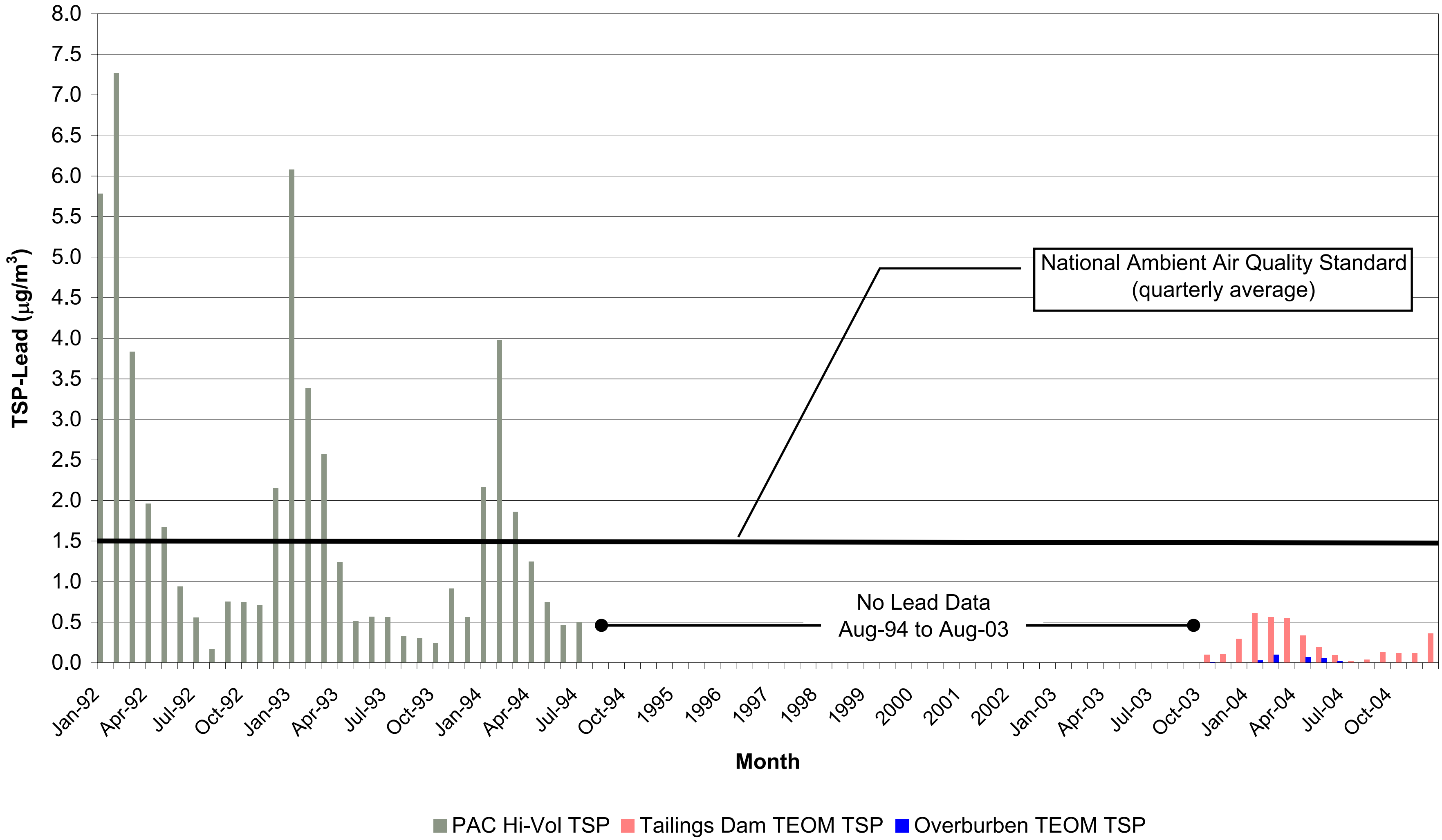
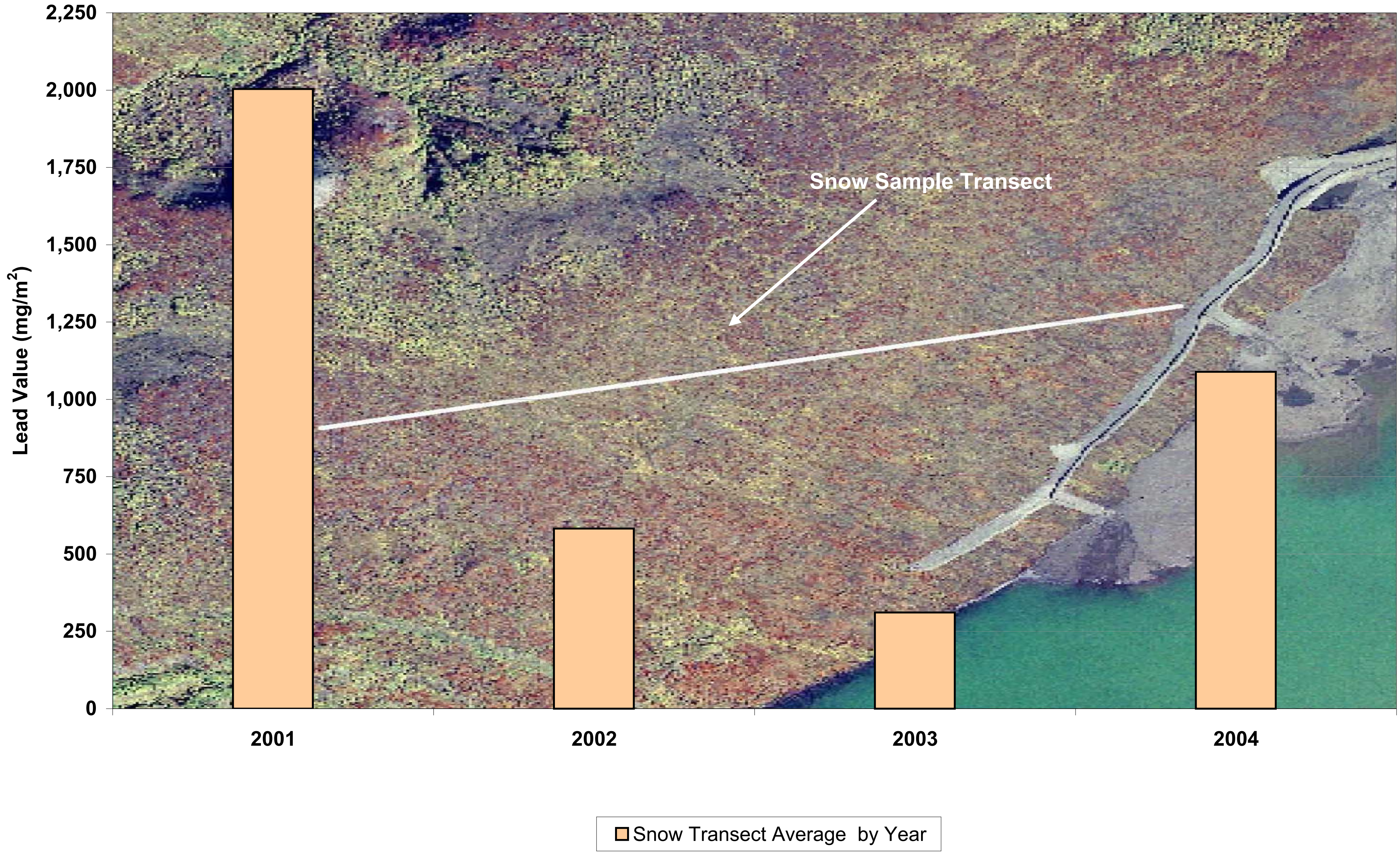


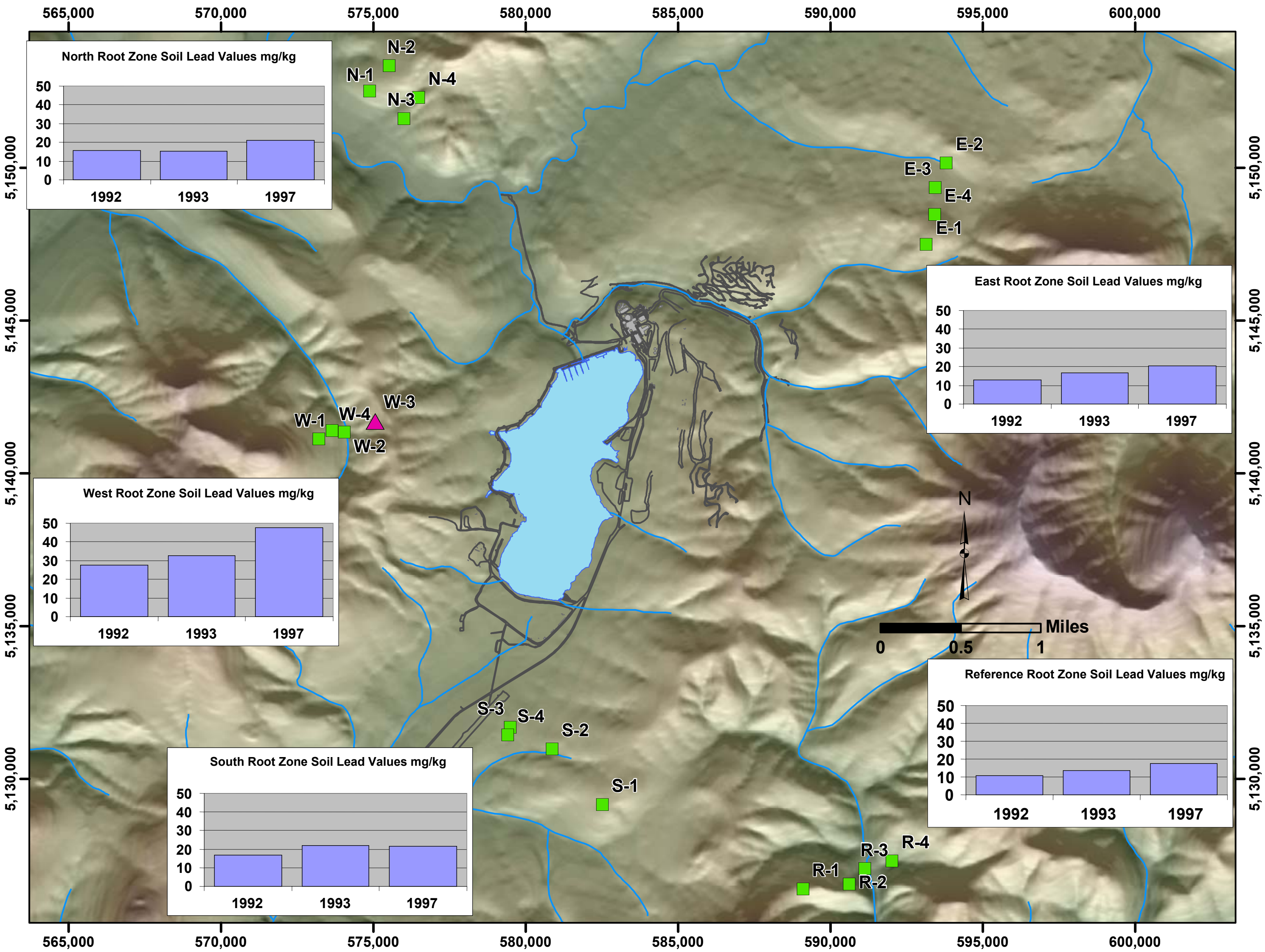
Figure-14
Red Dog Mine
Lead Snow Surveys



Teck Cominco Alaska
Red Dog Mine
Moss Sample
Locations
Pb mg/kg
<49
50 - 99
100 - 249
250 - 499
500 - 999
=>1000
Federal Lands (Areas)
Federal Managing Group
National Park Service
DMTS Road
0
5
10
Miles
N
164°30'0"W
164°0'0"W
163°30'0"W
163°0'0"W
68°0'0"N
67°45'0"N
Red Dog Mine
DMTS Road
Kivalina
DMTS
Port
Noatak
Noatak Wilderness
Noatak National Preserve
Cape Krusenstern National Monument
Tutak Creek
Wulik River
Imikruk Creek
Imikruk Lagoon
Ipiavik Lagoon
Kivalina River
Kiyak Creek
Kuchorak Creek
Kitchak Creek
Noatak River
Eli River
Rabbit Creek
Omikviorok River
Singoalik River
Ikalukrok Creek
January 27, 2005
copyright Earth Satellite Corporation

Figure-15

Figure-16
Red Dog Mine
Median Root Zone Soil Lead Concentrations
at Vegetation Monitoring Sites



Summary of Mine Related Fugitive Dust Studies

Red Dog Mine Site

Appendix I – Improvement Chronology

Mine Improvement Chronology

January 1991 to August 1992

- Tarping installed, repaired and improved in various ways to enclose the coarse ore stockpile to contain fugitive dust.

April 1992

- Calcium chloride applications intensified for all mill site roads and lay-down areas.

June 1992

- Hoppers installed at the mill site conveyor take-up pulleys and temporary curtains hung around the take up pulley towers.

June 1992 – October 1992

- Some crusher feed stockpiles were maintained in the mine pit instead of on the crusher feed stockpile pad.

July 1992

- 18,000 gallon water truck purchased and arrives onsite. Intensified watering of site initiated.
- Water spray bar installed and in use for the coarse ore stockpile conveying system until coarse ore stockpile receives hard sided enclosure.

August 1992

- Coarse Ore Stockpile hard sided enclosure completed.
- Mine CSB vents are covered over.

September 1992

- Mine CSB vents are retrofitted to hold passive filter cartridges as alternative to covering them up.

October 1992

- Mine CSB truck loading bay fully enclosed
- Mill site ore conveyor take-up pulleys are relocated to inside of mill, excluding the mine CSB take-up pulley.

May 1993 – Fall 1993

- Water sprays installed and utilized on Jaw Crusher drop box.
- Below freezing temperatures result in system being abandoned.

January – November 1995

- Nine of fifteen stockpiles built during this time period were built and maintained within the pit. This represents approximately 60 percent of all crusher feed for the period.

December 1995

- Existing 5,000 cfm baghouse for Jaw Crusher dust control replaced with a new 7,000 cfm baghouse.

Winter 2000/2001

- Eight "windrows" are constructed using waste rock on tailings beach perpendicular to the tailings dam. The windrows are approximately six feet high, sixteen feet wide and 150 feet long.

Summer 2001

- Soil-Sement® palliative applied to a portion of the tailings beach.

July 2001

- Fabricate and begin use of concentrate truck wash system at mine site (non-freezing periods only).

November 2001

- Installed stilling curtains in the concentrate truck loading stations.

March 2002

- Installation of gyratory crusher drop box dust control stilling curtains

Summer 2003

- Tailings water level raised to keep tailings beach covered

February 2003

- Door installed on gyratory crusher maintenance bay opening

October 2003

- Relocated the mine CSB take-up pulley to inside of the mill to eliminate potential spillage.

April 2004

- Installed steel grating in the CSB truck drive through floor to allow improved spotting of trucks for loading, and thereby reduce concentrate spillage onto truck and drive through floor, where it could be picked up on the tires.

July 2004

- Dust control system installation completed for the mine CSB truck loading bay. The system is comprised of a stilling shed and curtains to contain any entrained dust during loading operations and fans to draw the entrained dust back into the mine CSB, and away from the concentrate trucks and trailers.

November 2004

- Re-introduced in-pit stockpiling of ore.

December 2004

- Separated the concentrate truck traffic from the general mine equipment traffic and resurfaced the segregated truck road.

Summary of Mine Related Fugitive Dust Studies

Red Dog Mine Site

Appendix II – Photographs of Selective Improvements

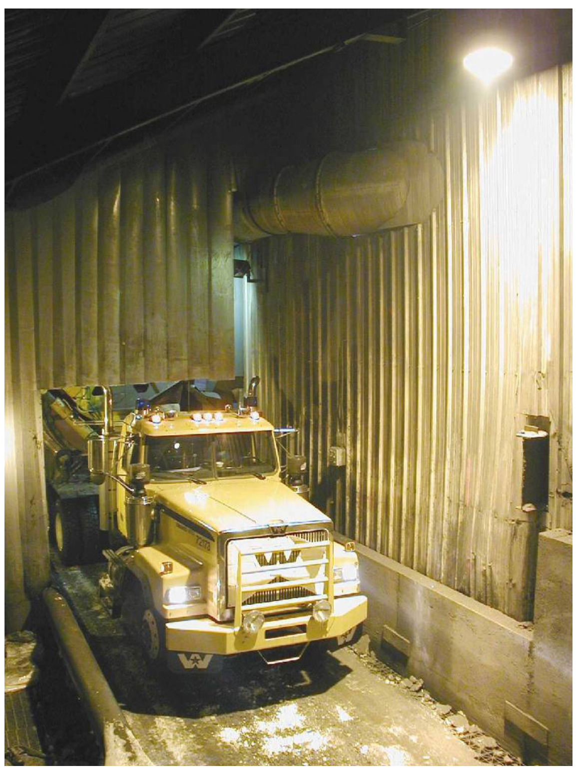
Below is the original configuration of the coarse ore stockpile building. The open design allowed for the generation of fugitive dust. From January 1991 to August 1992, tarps were installed on the sides of the stockpile in an effort to control fugitive dust while the design for a hard sided structure was finalized.

Below is the enclosed configuration of the coarse ore stockpile building. In August 1992, the stockpile was completely enclosed limiting fugitive dust emissions from this source.

Below is the original configuration of the concentrate storage building. In this configuration, the concentrate haul truck would enter the concentrate storage portion of the building to be loaded. This resulted in the tracking of concentrate out of the building.

In October 1992, an enclosed drive thru loading bay was added to the concentrate storage building. The drive thru bay separates the concentrate haul trucks form the concentrate stockpile area, thus, reducing the potential of tracking of concentrate out of the building.

Below are recent two views of the inside of the concentrate truck loading bay. To limit the amount of airborne concentrate settling on the truck during the loading process stilling curtains and a fan system were installed in July 2004. The system draws concentrate that becomes airborne during the loading process back into the concentrate storage portion of the building.



Below is an air photo of the Mine Site taken in fall 2001. At this time, a large area of tailings is exposed in an area near the tailing dam. The exposed area was a source of fugitive dust emissions during winter when the freeze drying conditions are common.

Below is an air photo of the Mine Site taken in fall 2004. In summer 2003, the water level in the pond was raised to cover all exposed tailings to eliminate fugitive dust emissions from this source. The large white area near the mill facility is underwater. The color change is a result of discharge into the tailings pond from the water treatment plant.