DRAFT

RED DOG OPERATIONS ALASKA

# Fugitive Dust Risk Management

## Monitoring Plan

Teck

July 2011

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# Acronyms and Abbreviations

| | |
|---|---|
| ADFG | Alaska Department of Fish and Game |
| ASTM | American Society for Testing and Materials |
| CAKR | Cape Krusenstern |
| CSB | concentrate storage building |
| DEC | Alaska Department of Environmental Conservation |
| DMTS | DeLong Mountain Regional Transportation System |
| EPA | U.S. Environmental Protection Agency |
| ER-L | effects range-low |
| MOU | Memorandum of Understanding |
| NANA | NANA Regional Corporation |
| NPS | National Park Service |
| PAC | Personnel Accommodation Complex |
| RMP | risk management plan |
| RTAS | real-time alarm system |
| SEIS | supplemental environmental impact statement |
| Teck | Teck Alaska Incorporated |
| TEOM | tapered element oscillating microbalance |
| TSP | total suspended particulates |
| VEE | visible emissions evaluation |
| XRF | x-ray fluorescence |

# Executive Summary

In August 2008, a draft risk management plan (RMP) was released as part of a process intended to minimize risks associated with fugitive dust emissions from operations at Red Dog Mine (Exponent 2008). The RMP combines and builds upon prior and ongoing efforts by Teck to reduce dust emissions and incorporates stakeholder input obtained during a 3-day risk management workshop held in Kotzebue, Alaska, in March 2008 (Teck Cominco 2008). The RMP describes seven fundamental risk management objectives that address the overall goal of minimizing risk to human health and the environment, identifies and evaluates risk management options to achieve those objectives, and describes a process for developing implementation plans to achieve the fundamental objectives. Part of that process is the development of six individual risk management implementation plans that describe more specifically how the fundamental objectives will be met. This document presents one of those implementation plans, the Red Dog fugitive dust monitoring plan (monitoring plan).

Preparation of a monitoring plan follows from four risk management objectives:

- Objective 1: Continue reducing fugitive metals emission and dust emissions
- Objective 3: Verify continued safety of caribou, other representative subsistence foods, and water
- Objective 4: Monitor conditions in various ecological environments and habitats, and implement corrective measures when action levels are triggered
- Objective 6: Improve collaboration and communication among all stakeholders to increase the level of awareness and understanding of fugitive dust issues.

In order to achieve these objectives, the monitoring plan was developed with the following goal: *To monitor changes in dust emissions and deposition over time and space, using that information to: 1) assess the effectiveness of operational dust control actions, 2) evaluate the* *effects of the dust emissions on the environment and on human and ecological exposure, and 3) trigger additional actions where necessary.*

This plan includes a thorough review of past, ongoing, and potential future actions, and selection and development of standard monitoring actions specifically chosen to accomplish the goal of the monitoring plan. Each step is described below.

**Review of Past, Ongoing, and Potential Future Actions—**Review of past and ongoing monitoring actions carried out as part of Red Dog environmental operations provides an opportunity to take stock of diverse efforts already taking place, evaluate what actions work well, and identify ways to improve future efforts. The review of potential future actions includes those actions established during the RMP development process, such as additional monitoring actions suggested by various stakeholder groups.

**Selection of Monitoring Actions—**Based on the review, the selected monitoring programs provide coverage of mine, road, and port areas. The monitoring programs were selected to ensure spatial coverage at the source, operational boundary, and regional scales, as well as temporal coverage with short- and long-term monitoring frequencies.

- Source Monitoring
  - U.S. Environmental Protection Agency Method 22-Visible Emissions Evaluation: Emissions from specific sources will be conducted monthly at 9 locations (4 in the mine area, and 5 in the port area), and daily at one randomly chosen location along the DeLong Mountain Regional Transportation System (DMTS) road. For each 15 minute-observation period, the average duration of visible dust emissions per activity or vehicle passage will be calculated. If statistical comparison of pre- and post-improvement durations indicates no significant improvement in dust emissions, additional dust control measures will be implemented.

- Tapered Element Oscillating Microbalance (TEOM) Source Monitoring: The PAC TEOM will continue to be used to monitor the relationship between dust levels and mine operations originating from the crusher pad and ore feed stockpiles. The instrument is linked to a real time alarm system, and if 8- or 24-hour average total suspended particulates (TSP) measurements exceed the specified warning level, follow-up evaluation and corrective actions are implemented. If trends indicate increases over a 2-year period, additional dust control measures will be implemented.

- Road Surface Monitoring: Materials will be collected from 7 locations within mine, port, and along the DMTS once every 2 months. If concentrations are elevated above action levels, the road surface will be reclaimed and resurfaced with clean material.

* Operational Monitoring

  - TEOM Facility Monitoring: TEOMs will be run continuously to measure TSP and airborne lead and zinc concentrations over 24-hour periods every third day at the mine and every sixth day at the port. If monthly averages significantly increase over 2 years, additional dust control measures will be defined in the dust emissions reduction plan.

  - Dustfall Jar Monitoring: Eighty-six dustfall jars will be operated at the mine, port, and along the DMTS road. Jars will be collected and replaced with clean jars once every 2 months, and samples will be analyzed for total mass and lead and zinc concentrations. Both spatial and temporal analyses will be conducted using the data collected, and if statistically significant changes are identified and corroborated by other monitoring data, additional dust control measures will be implemented as defined in the dust emissions reduction plan.

  - Marine Sediment Monitoring: Sediment samples will be collected from seven grid stations near the end of the shipping seasons.

Samples will be analyzed for lead, zinc, and cadmium. Stations will be monitored at least once every 2 years; however, monitoring frequencies may be increased based on the results. If metals concentrations exceed guideline values at more than one station for more than two annual monitoring events in a row, additional dust control measures will be implemented as defined in the dust emissions reduction plan.

– Vegetation Community Monitoring: Once every 3 years, monitoring of moss and lichen cover, and plant community health will be implemented at multiple locations along the DMTS road, port sites, and mine sites using point-intercept surveys. Statistical analysis will be used to evaluate changes in moss and/or lichen cover between sampling years, and if cover in a geographical areas decreases for more than two monitoring periods in a row, additional dust control measures will be evaluated and may be implemented as defined in the dust emission reduction plan.

– Moss Tissue Monitoring: Once every 6 years, lead, zinc, cadmium, iron, and aluminum will be monitored in moss samples collected from four areas: 1) within the mine ambient air boundary, 2) within the DMTS corridor through NANA Regional Corporation and state lands between the mine boundary and the Cape Krusenstern National Monument boundary, 3) along the DMTS corridor through Cape Krusenstern National Monument, and 4) the area within the port site ambient air boundary. If metals concentrations increase significantly over time, monitoring frequencies will be increased. If concentrations are significantly higher for more than two sampling events in a row, additional dust control remedies will be implemented in accordance with the dust emissions reduction plan.

- Regional Monitoring
  - Vegetation Community Monitoring: The vegetation monitoring program described above serves a dual purpose as both operational area monitoring and regional level monitoring.
  - Moss Tissue: The moss monitoring program described above serves a dual purpose as both operational area monitoring and regional level monitoring.
  - Caribou Tissue Monitoring: Caribou tissues will be collected once every 6 years and will be analyzed using protocols developed by the Alaska Department of Fish and Game (ADFG). Results of caribou tissue metals concentrations will be compared with metals concentrations from caribou during previous monitoring events. Based on results, modifications to the caribou monitoring plan and/or additional analyses will be considered following consultation with ADFG and other stakeholders.

Additional details regarding these planned monitoring actions are provided in this document, along with details of plan implementation, communication and collaboration tools to be used, detailed implementation and quality assurance, periodic review and reporting, milestones for completion and review of the plan, and stakeholder involvement in the plan. For a spatial and temporal overview of planned monitoring actions, refer to Figures 1 and 2, provided at the end of the main text.

# 1 Introduction

The fugitive dust monitoring plan is an implementation plan associated with the risk management plan (RMP). The RMP was developed to combine and build upon prior and ongoing efforts by Teck Alaska Incorporated (Teck) to reduce dust emissions and minimize potential effects to human health and the environment. The RMP addresses issues identified by several different studies and programs, including the DeLong Mountain Regional Transportation System (DMTS) risk assessment (Exponent 2007a,b), the mine-area ecological risk evaluation conducted as part of the mine closure and reclamation planning process (Exponent 2007c), the Fugitive Dust Memorandum of Understanding (MOU) between the Alaska Department of Environmental Conservation (DEC) and Teck (DEC 2007), and the draft supplemental environmental impact statement (SEIS) for the Aqqaluk Extension (www.reddogseis.com).

The RMP also incorporates stakeholder input obtained during a 3-day risk management workshop held in Kotzebue, Alaska, in March 2008 (Teck Cominco 2008). The RMP describes seven fundamental risk management objectives that address the overall goal of minimizing risk to human health and the environment surrounding the mine, road, and port, over the life of the mine and post-closure operation. These seven objectives are:

- Objective 1: Continue reducing fugitive metals emissions and dust emissions
- Objective 2: Conduct remediation or reclamation in selected areas
- Objective 3: Verify continued safety of caribou, other representative subsistence foods, and water
- Objective 4: Monitor conditions in various ecological environments and habitats, and implement corrective measures when action levels are triggered
- Objective 5: Conduct research or studies to reduce uncertainties in the assessment of effects to humans and the environment

- Objective 6: Improve collaboration and communication among all stakeholders to increase the level of awareness and understanding of fugitive dust issues[1]
- Objective 7: Protect worker health.

The RMP also identifies and evaluates risk management options to achieve those objectives, and describes a process for developing implementation plans to achieve the seven fundamental objectives. This monitoring plan is one of six individual risk management implementation plans that were identified in the RMP to address these objectives. The other five implementation plans are:

- Communication plan
- Dust emissions reduction plan
- Remediation/Reclamation plan
- Uncertainty reduction plan
- Worker dust protection plan.

This document presents the monitoring plan. The remainder of this document is organized as follows:

- Section 2. Goal of the Monitoring Plan
- Section 3. Summary of Past, Ongoing, and Potential Future Monitoring
- Section 4. Actions to be Implemented
- Section 5. Periodic Review and Reporting
- Section 6. Milestones
- Section 7. Stakeholder Roles
- Section 8. References.

[1] The language of this objective has been clarified from the original language in the draft RMP, which was: "Improve communication and collaboration among all stakeholders."

# 2 Goal of the Monitoring Plan

The RMP includes information on the legal, social, cultural, and environmental context in which the RMP is being developed (the Decision Context). A series of fundamental objectives were developed as part of the RMP to address the overall goal of minimizing risk to human health and environment in the areas adjacent to the Red Dog Mine, DMTS Port, and DMTS road.

The monitoring plan builds upon ongoing efforts by Teck to reduce dust emissions and minimize effects to the environment. The plan addresses dust-related issues identified by the DMTS risk assessment, the mine-area ecological risk evaluation, the MOU between DEC and Teck, and the SEIS for the Aqqaluk Extension. This plan also incorporates initial stakeholder input that was obtained at a 3-day risk management workshop held in Kotzebue, Alaska, in March 2008 (Teck Cominco 2008).

The RMP describes seven fundamental risk management objectives that address the overall goal of minimizing risk to human health and the environment surrounding the mine, road, and port, over the life of the mine, and post-closure operations. The monitoring plan will detail techniques to observe, record, and detect fugitive dust-related changes in the environment and seek to meet the following three of the seven fundamental objectives.

- Objective 1: Continue reducing fugitive metals emissions and dust emissions
- Objective 3: Verify continued safety of caribou, other representative subsistence foods, and water
- Objective 4: Monitor conditions in various ecological environments and habitats, and implement corrective measures when action levels are triggered.

These objectives are built into the monitoring plan goal set out in the RMP, which was stated as follows: *"To monitor changes in dust emissions and deposition over time and space, using that information to: 1) assess the effectiveness of operational dust control actions, 2) evaluate* *the effects of the dust emissions on the environment and on human and ecological exposure, and 3) trigger additional actions where necessary."*

In addition, communication and collaboration between stakeholders is a universally applicable goal related to the monitoring plan, and is encompassed by Objective 6 of the RMP:

- Improve collaboration and communication among all stakeholders to increase the level of awareness and understanding of fugitive dust issues.

Therefore, recommendations and actions from the communication plan (Exponent 2009) are included in the monitoring plan.

# 3 Summary of Past, Ongoing, and Potential Future Monitoring

The following sections review past and ongoing actions, as well as potential actions identified during the risk management planning process. The purpose of this section is to identify all of the possible monitoring actions that may be taken with regard to operations.

## 3.1 Caribou Monitoring

The Red Dog Mine is located within the normal annual range of the Western Arctic Herd. Surveys of caribou were conducted as part of preconstruction baseline studies and post-construction monitoring for the Red Dog Mine Project and DMTS. The surveys conducted in 1984−1986 provided baseline information on distribution and movements of caribou in the vicinity of the Red Dog Mine and the DMTS haul road and port site. Surveys were also conducted during project construction from 1986 through 1989.

### 3.1.1 1996 and 2002 Evaluations of Metals Concentrations in Caribou Tissues

Caribou near the Red Dog Mine have been evaluated for metals concentrations on two occasions, in 1996 as part of a region-wide investigation (O'Hara et al. 2003, discussed below) and again in 2002 as part of the DMTS fugitive dust risk assessment. As part of a subsistence foods evaluation, metals concentrations in caribou muscle, liver, and kidney tissue from the 2002 study were compared to the 1996 data from Red Dog and other areas of northern Alaska, and with metals concentrations identified in Canadian caribou and Scandinavian reindeer (Exponent 2007a [Appendix H]; Garry et al. 2004).

In addition, the 2002 data were used in the DMTS fugitive dust risk assessment. These caribou had over-wintered near the mine. Thus, they were harvested during a period of time when any metals exposure related to the site would have still been reflected in their soft tissues.

By comparison with northern Alaska caribou metals concentrations, there were no statistically significant elevations in tissue metals concentrations in the 1996 or 2002 Red Dog caribou samples. None of the metals were consistently higher or lower in all tissues of the Red Dog caribou relative to caribou or reindeer from Canada, Scandinavia, or elsewhere in northern Alaska.

Although several potential differences were noted between the 2002 Red Dog data and the comparison groups, the biological relevance or importance for human health is unclear. For example, although lead is one of the two primary constituents of the concentrates produced at the mine, muscle lead concentrations in area caribou did not appear to differ from those found in the U.S. meat supply (ATSDR 1999).

The results of the risk assessment, along with the results from the subsistence foods evaluations, indicate it is safe to continue harvesting subsistence foods without changes. In addition, although harvesting remains off limits within the DMTS, human health risks were not elevated even when data from restricted areas were included in the risk estimates (Exponent 2007a).

### 3.1.2 2009 Red Dog Mine Caribou Health Assessment

In March 2009, four Alaska Department of Fish and Game (ADFG) scientists and two hunters from Kivalina harvested 10 caribou from within the Red Dog Mine Valley. Methodology was similar to that used in the 2002 study of metals in caribou as part of the DMTS fugitive dust risk assessment (Exponent 2007a). Tissue samples consisting of hair, muscle, kidney, and liver were collected from the caribou and analyzed for metals. Along with the tissue samples the scientists conducted an animal health and parasite load evaluation. The caribou were identified as over-wintering Teshekpuk Herd animals that had been in the mine area for most of the winter. After the tissue samples were collected the edible portions were donated to residents of Kivalina. Preliminary metals results are similar to the results of the 2002 caribou study. A full report including necropsy analysis from ADFG will be included in the next RMP annual monitoring report, or as soon as it is available.

## 3.2 Vegetation Monitoring

A variety of vegetation monitoring programs have been conducted, including moss tissue studies and vegetation community composition surveys, as described in the following sections.

### 3.2.1 2001 Moss Tissue Study

The objective of the 2001 sampling program (Exponent 2002) was to expand on the geographic scope of the initial moss sampling work conducted by Ford and Hasselbach (2001) that identified elevated metals in moss surrounding the DMTS road. Moss and vegetation samples were collected along transects perpendicular to the haul road and within the port operations area. The target moss species for collection was the stair-step moss (*Hylocomium splendens*). The study also included collocated vegetation sampling stations with road dust fall collection and road surface sampling stations in order to evaluate source/receptor relationships.

### 3.2.2 2002 Moss Tissue Study

In 2002, Teck conducted moss sampling around the mine area and some outlying areas to further expand on past moss sampling programs for more complete spatial coverage (Exponent 2007a).

### 3.2.3 2003 Moss Tissue Study

In 2003, Teck conducted additional moss sampling in the mine area and a reference area in support of the ecological risk assessment for evaluation of potential ecological risks to terrestrial receptors (Exponent 2007a).

Moss data collected during various sampling efforts by the National Park Service (NPS) and Teck, when presented together in the risk assessment (Exponent 2007a), effectively illustrated the primary source areas and deposition patterns in the vicinity of the DMTS corridor and mine. The moss concentration patterns illustrated how the prevailing wind patterns from the southeast toward the northeast result in greatest deposition to the Northwest of DMTS and mine facility areas.

Within the DMTS facility areas, metals concentrations decrease away from facility sources, and vary along the length of the road corridor, with the highest concentrations near the port and the mine, as a result of concentrate tracking that has historically occurred with haul trucks exiting the concentrate storage buildings (CSBs) at the mine and port.

### 3.2.4 2004 Vegetation Community Survey

Terrestrial plant communities in the DMTS road corridor were surveyed systematically by Teck in the summer of 2004 to characterize the vascular plant community composition, and moss and lichen abundance at increasing distances from the road (Exponent 2007a). Representative reference locations for each community type were also identified and surveyed for comparison with the site survey locations.

Plant communities were evaluated in a series of site and reference stations in the terrestrial and coastal lagoon environments. Terrestrial stations were aligned along transects perpendicular to the DMTS road, in order to evaluate communities at various distances from dust sources. Plant community parameters were measured at terrestrial and coastal lagoon sites, including percent cover, frequency of occurrence, and species richness.

Each community type sampled as part of the terrestrial risk assessment was statistically compared to its respective reference station. Correlations with distance from the DMTS road, soil metals concentrations, pH, and total solids were also assessed. Results of the plant community composition study were presented in the DMTS fugitive dust risk assessment (Exponent 2007a).

Results suggested that changes in the vegetation community structure were observable within 100 m of the DMTS road and port facilities. These community shifts appeared to be, in part, a result of physical and chemical influences of the road and their effect on hydrology, soil chemistry, and plant vitality. Also, differences between reference plant communities and plant communities beyond 100 m from the DMTS road, specifically a 2- to 4.5-fold decrease in lichen cover at 1,000 to 2,000 m from the road, appear to be a result of fugitive dust deposition.

### 3.2.5 2006 Mine Vegetation Survey

In July 2006, Teck conducted a vegetation survey to assess vegetation impacts in the mine area (ABR 2007a,b).

Permanent monitoring plots were established along nine 4-km transects radiating out from the mine facilities in all directions, covering areas within and beyond the ambient air boundary. The 50-$m^2$ plots were spaced on each transect at approximately 0 m, 500 m, 1,000 m, 1,500 m, 2,500 m, and 4,000 m intervals. A total of 55 monitoring plots were established.

At each monitoring plot, plant cover was quantitatively measured using the point intercept sample method. Vascular plants were identified to species level, and non-vascular plants (lichens, mosses, and liverworts) were identified to genus level, with species identification where possible.

Following multiple years of surveys, trends in vegetation community composition parameters are expected to be analyzed to evaluate effects from dust deposition, and/or recovery that may occur in response to mine dust control mitigation measures.

### 3.2.6 2008 Moss Tissue Study

In 2008, Teck conducted a moss study using a new, more efficient and statistically robust design for monitoring of fugitive dust deposition in four interest areas including the mine site, DMTS road, Cape Krusenstern (CAKR) portion of the road, and the port site (Rare Earth Sciences 2009). A fifth interest area was included for comparison with historical moss stations. The design of the study employs a multi-incremental sampling approach based on Gy (1992, 1998). Lead, zinc, cadmium, and the crustal elements iron and aluminum were measured for interpretive purposes. *H. splendens* collection methods employed by the field team, and the analysis, generally followed protocols developed by the NPS for previous studies.

Results of the 2008 sampling event were used to evaluate the effectiveness of the study design. General findings included the following:

- Moss sample field replicates (five within each interest area) had low variability in average metals concentrations. These results suggest that the study design produces a robust, replicable characterization of the average metals concentrations within each interest area.
- Results also suggest that the monitoring design will allow detection of meaningful changes in concentrations over time (i.e., relative to past moss monitoring results).
- Statistical comparisons of the average concentrations of metals of concern detected during the 2001 NPS study (Hasselbach et al. 2004) and the concentrations detected during the 2008 study indicate lead, zinc, cadmium concentrations have significantly decreased[2] within Cape Krusenstern. .

## 3.3 Operational Monitoring

The studies and monitoring programs listed below provide an overview of past and ongoing actions related to operational monitoring.

### 3.3.1 U.S. Environmental Protection Agency Method 22—Visible Emissions Evaluation

Visible emissions evaluation (VEE), as outlined under U.S. Environmental Protection Agency (EPA) Method 22, was developed for determination of the frequency and quantity of fugitive emissions from stationary sources (U.S. EPA 2000). Measures are only conclusive if

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2 Statistical comparisons were conducted at a 0.05 significance level using standard t-tests.

observations are conducted both before and after dust reduction modifications. The observer must be knowledgeable with respect to the general procedures for determining the presence of visible emissions. The observer must be trained and knowledgeable regarding the effects of background contrast, ambient lighting, and observer position relative to lighting, wind, and presence of uncombined water on the visibility of emissions.

Method 22 observations are one of the monitoring techniques required for the Title V air permits at Red Dog Mine, and are used to maintain compliance. Method 22 observations are conducted at specific sources, recording the amount of time (in seconds) that dust visibly emanates from each source. Sources consist of locations such as specific sections of road surface, building vents, or activity sectors and also may consist of an event that represents an ongoing process such as truck loading or unloading activities.

Monitoring is conducted monthly at 9 locations; 4 within the mine boundary, and 5 at the port. In addition, when the road surfaces are dry and not frozen an observation is made daily at a single location within the mine area or along the DMTS road.

### 3.3.2 High-Volume Total Suspended Particulates Monitoring

High-volume air monitoring is the approved federal method for determining total suspended particulates (TSP) and TSP-Pb. Results can be directly related to compliance with national ambient air quality standards.

High-volume air sampling has been conducted by Teck on an ongoing basis at the port and mine facilities. Studies conducted in 1992 and 1993 at the Personnel Accommodation Complex (PAC) high-volume location have provided benchmark data for comparison with more recent dust emissions monitoring results in the mine and mill area. High-volume studies were also conducted in the villages of Noatak and Kivalina in 2003−2005, and are summarized in Exponent (2007a).

### 3.3.3 TEOM Air Monitoring

The tapered element oscillating microbalance (TEOM) air monitoring device is used for air quality monitoring at locations within the mine and port. The TEOMs produce real-time total dust measurements with the capability of collecting discrete samples that can be analyzed for metals concentrations. In addition, filters attached to TEOM units collect measurements of airborne lead and zinc concentrations.

Currently, TEOMs run continuously to measure real time TSP. The filters collect TSP-Pb and TSP-Zn concentrations over 24-hour periods every third day at the mine and every sixth day at the port. TSP and TSP-Pb concentrations at the mine and port are compiled into monthly averages.

### 3.3.4 Dustfall Jar Monitoring

Dustfall jars are passive accumulators of windblown dust. Dustfall jars provide a means to monitor large areas year after year and can be used to supplement information collected via other monitoring techniques. Laboratory testing and analysis is performed for physical parameters (e.g., particle size) and inorganic chemical parameters (e.g., metals such as lead and zinc). Dustfall monitoring is based on an American Society for Testing and Materials (ASTM) standard test method (D1739). It should be noted that while dustfall jars provide a means of looking at long term deposition, they do not provide data of adequate precision to quantify air quality or to determine compliance with National Ambient Air Quality Standards (NAAQS). This plan is not intended to determine or illustrate compliance with NAAQS.

Dustfall jar arrays have been established within the mine, port, and road areas. In August 2001, dustfall jars were installed at seven station locations spaced along the length of the DMTS road to assess dust control measures. Each station had four dustfall collectors, two on each side of the road, placed 10 m from the toe of the road shoulder. Results from both sides of the road were summed, and then compared on a monthly basis. In addition, jars were installed at the port site at 40 locations in a 1,000-ft grid pattern. All jars were collected and replaced with clean jars on a monthly schedule. The road stations were monitored for approximately 1 year, and the port stations have been monitored since they were installed.

From January 1999 to June 2003, dustfall jars were placed in quadrants within the mine air boundary, with two jars within each quadrant plus a reference jar. The jar locations were selected to facilitate monitoring of fugitive dust deposition around the mine site. The typical dust collection period was 30 days.

From October 2001 through June 2003, eight dustfall jars were installed west of the tailings pond and monitored to measure the distribution of dust from a tailings beach, which was exposed during the winters of 2001 and 2002. Sampling intervals were nominally 30 days.

In July 2003, 22 jars were installed near the mine facilities with an additional 3 jars installed in August 2004. This array of jars remains in place and the collected dust is analyzed for metals concentrations every 2 months.

Dustfall jar data were used initially to help characterize the deposition patterns around mine, road, and port sources. The data have been evaluated to look for any temporal trends. However, because of changes in method, location, and the natural variability inherent in dustfall jar monitoring, no significant trends were identified.

### 3.3.5 Road Surface Monitoring

Collection of compacted road bed material and loose fine materials from the surface of the road represent the two types of road dust monitoring that have been performed in the past.

Collection of the compacted road bed material has occurred at multiple locations around the mine and port. Generally, 3 to 5 grab samples were collected on transects across the traffic area of the road and composited into one sample, which was dried, sieved, and analyzed via field-portable x-ray fluorescence (XRF) or at an offsite laboratory. Sample depths were generally 0−1 in. All samples were analyzed for lead, zinc, cadmium.

Road surface sample sites are subject to frequent grading and resurfacing at irregular intervals. Information on the condition of the road, for example when grading last occurred and/or the presence of fresh road material, rutting, etc., was recorded in the field logbook.

An alternative method for sampling road surface materials to monitor source controls involves the collection (by sweeping) of loose material laying on the road surface. The samples are used to assess metals concentrations within road surface materials that are subject to airborne transport into the surrounding environment.

### 3.3.6 Snow Sampling Study

In 2005, Teck sampled snow accumulations in five different sites in drift and non-drift areas at the mine site, both upwind and downwind of dust sources (Teck Cominco 2005). At each sampling site, 10 core samples were collected with a snow coring tool, composited into one sample, and placed in a plastic bag. Lead, cadmium, and zinc concentrations, total solids, and total mass per unit area (deposition) were reported for each sample.

Snow drift accumulation rates were notably higher for drift samples than non-drift samples, and the non-drift accumulation rates were higher than nearby dustfall jar accumulation rates.

Metals concentrations were approximately equal in each pair of drift and non-drift samples, in both the upwind and downwind areas. Zinc-to-lead metal ratios in downwind snow samples were similar to the values measured at the PAC and tailings dam TEOM monitors.

### 3.3.7 Marine Sediment Monitoring

Marine sediment metals concentrations have been monitored periodically in the Chukchi Sea around the port site facilities. A grid of stations was originally established around the port site before the onset of shipping operations in 1990. The grid layout was designed to allow evaluation of sediment concentration patterns around the port sources (primarily the ship loader), as well as potential temporal changes in metals concentrations (i.e., by resampling stations from previous studies).

Sampling results indicate that sediment metals concentrations at these grid stations have generally been decreasing over time as various dust control improvements were made, particularly since significant upgrades were made to dust controls on the ship loader conveyor and lightering barges in June 2003.

A marine sediment assessment was conducted in 2003 and 2004 as part of the DMTS fugitive dust risk assessment (Exponent 2007a). A subset of 7 of the 26 original grid stations was used in the assessment, and has been monitored annually since 2003. These station locations were selected based on historical evaluations and offshore current patterns and were designed to allow evaluation of metal concentrations in relation to sources. Reference site samples were also collected from three stations at an area approximately 4 km south of the port facilities.

Samples were analyzed for lead, zinc, and cadmium concentrations and compared with the effects range-low (ER-L) guideline values developed by Long et al. (1995) for marine sediment:

- Cadmium ER-L = 1.2 mg/kg dry
- Lead ER-L = 46.7 mg/kg dry
- Zinc ER-L = 150 mg/kg dry.

The marine assessment demonstrated that marine sediment metals concentrations near the port facilities are very low, particularly since the significant upgrades to the ship loader and lightering barges were completed.

### 3.3.8 Meteorological Monitoring

Meteorological monitoring has been conducted near the airport at the mine site and near the personal accommodation complex at the port site since 1996. An additional wind monitoring tower was constructed in 2002 at the mine near the mill facilities. Considering the influence that meteorological conditions have on the results of monitoring projects and subsequent interpretation, meteorological monitoring will continue to be an integral part to all monitoring and operational aspects at the Red Dog Mine and DMTS port site.

## 3.4 Additional Monitoring Programs

In addition to monitoring programs conducted by Teck, relevant monitoring programs conducted by others are outlined below.

### 3.4.1 Aquatic Biomonitoring

Aquatic biomonitoring is conducted on an ongoing basis by ADFG in support of the Red Dog National Pollutant Discharge Elimination System permit, using the protocols they have developed (ADFG 1998). Operational biomonitoring was initiated with fish tissue sampling in the Red Dog Creek area in 1990 and was expanded to the Bons Creek area in 1994. In 1996, invertebrate and periphyton sampling was added. The programs include a combination of aquatic life and water quality monitoring.

The key elements of the biomonitoring program consist of the following:

- Aquatic life and ambient water quality monitoring within the Bons Creek drainage and Evaingiknuk Creek (referred to as the Bons Creek Biomonitoring Program)
- Aquatic life and ambient water quality monitoring within the Red Dog Creek drainage, Ikalukrok Creek, and Wulik River (referred to as the Mine Drainage Biomonitoring Program)
- Stream flow measurements.

Fish population surveys are also conducted by ADFG as part of the biomonitoring program:

- Chum salmon and Dolly Varden trout population counts are conducted each year by ADFG. Chum salmon are counted from the end of July to mid-August. The count is done by helicopter from approximately the confluence of the Ikalukrok and Wulik rivers upstream to the mouth of Dudd Creek.

- Also conducted under the same ADFG biomonitoring program, Dolly Varden "trout" are counted by helicopter from the mouth of the Wulik River to approximately the mouth of the Ikalukrok River. The count is conducted from mid- to late-September to determine the overwintering population in the Wulik River.

A summary of the aquatic monitoring results will be reported on an annual basis in the annual review of the monitoring plan.

## 3.5 Potential Monitoring Actions Identified in the Risk Management Planning Process

As part of the risk management planning process, a list of potential monitoring activities was developed by all stakeholders present at the Risk Management Workshop (Teck Cominco 2008). The list of potential activities was presented in the RMP (Exponent 2008). Table 1 lists each potential action that scored either a 1 or 2 based on effectiveness, level of effort, and stakeholder preference criteria. Table 1 also shows the fundamental objectives related to each potential action.

# 4 Actions to be Implemented

The overall goal of the RMP is to minimize risks associated with fugitive dust emissions from Red Dog Mine operations. In this section, specific monitoring programs are defined to accomplish the goals of the monitoring plan defined in Section 2.

Possible monitoring actions were identified and evaluated in order to assemble the most appropriate set of actions for a complete and robust monitoring program. A summary of potential actions that were identified by stakeholders during the risk management workshop is provided in Table 1. A compilation of actions or potential actions that have been carried out as part of past or ongoing programs and/or identified at the RMP workshop is provided in Table 2. These potential actions were screened, resulting in a focused list available for use in developing the monitoring plan. Table 3 provides a summary of issues and actions identified during the DMTS risk assessment that were deferred to the RMP. This table also indicates which items are addressed within this monitoring plan.

The monitoring plan includes the following monitoring programs:

- Source Monitoring
  - EPA Method 22–VEE
  - TEOM Source Monitoring
  - Road Surface Monitoring
- Operational Monitoring
  - TEOM Facility Monitoring
  - Dustfall Jar Monitoring
  - Marine Sediment Monitoring
  - Moss Tissue Monitoring

- Vegetation Community Monitoring

- Regional Monitoring
  - Vegetation Community Monitoring
  - Moss Tissue Monitoring
  - Caribou Tissue Monitoring.

The selected monitoring programs ensure spatial coverage at the source, operational boundary, and regional scales, as well as temporal coverage with short- and long-term monitoring frequencies (Table 4). A general overview of the spatial coverage of the monitoring programs is shown in Figure 1. Frequencies for the various monitoring programs are illustrated in Figure 2. These monitoring programs provide spatial coverage of the mine, road, and port areas as outlined in Table 5 and illustrated in Figure 1. In some cases, monitoring programs can be applied at more than one scale, and therefore they are listed in more than one place in the tables.

Endpoints of interest (including receptors of concern) are shown in Table 6 to confirm that these endpoints are addressed. The endpoints of interest include receptors for which concerns were identified in the DMTS risk assessment and the mine area ecological risk assessment, and summarized in the RMP. They include mosses, lichens, small mammals such as voles and shrews, and ptarmigan. In addition, caribou is included as a receptor of interest in Table 6 because of its importance to the regional subsistence lifestyle. The applicability of the selected monitoring programs for addressing operational monitoring objectives is also illustrated in Table 6.

In the monitoring strategy outlined in this document, stair-step moss (*Hylocomium splendens*) is used as a surrogate for other wildlife food and prey items (Table 6). Exposure of wildlife receptors to metals was evaluated in the DMTS risk assessment (Exponent 2007a), and in the mine ecological evaluation (Exponent 2007b). These assessments provided an understanding of baseline conditions and the general correlation between dust concentrations in moss and other food and prey items. Thus, moss tissue serves as a surrogate food item for evaluating changes in human and wildlife exposure. Monitoring moss, which is a medium with broad spatial coverage, provides an understanding of whether exposures are increasing or decreasing for wildlife receptors in the tundra environment, and whether concentrations are increasing or decreasing in subsistence plant foods.

Communication and collaboration actions available at each stage of the monitoring program are summarized in Table 7. The specific actions selected to accomplish the goals of the monitoring plan are summarized in Table 8, along with planned timelines for implementation.

Figure 3 illustrates important milestones in the development of the monitoring plan and associated programs, and provides the specific communication actions to be implemented as part of the monitoring plan.

**Statistical Analysis Methods.** A discussion regarding results interpretation is included in each of the following sections for each monitoring program. Exact statistical tests have not been specified because they will depend on the data. The most powerful statistical methods will be used for each statistical evaluation. These will include parametric methods when the underlying method assumptions can be met by the data, otherwise non-parametric methods will be used. Generally, an overall 0.05 significance (alpha) level (i.e., 95 percent confidence) will be used for statistical analyses.

The following sections describe the components of the monitoring plan.

## 4.1 Source Monitoring

Planned source monitoring programs include the following:

- EPA Method 22–VEE
- TEOM Source Monitoring
- Road Surface Monitoring.

These programs are described in the following sections.

### 4.1.1 U.S. Environmental Protection Agency Method 22–Visible Emission Evaluation

In addition to its use for Title V air permit monitoring, Method 22 (VEE) provides a means to monitor emissions from specific sources on a regular basis and on an as-needed basis (e.g., to evaluate the effectiveness of dust control measures where and when improvements or changes are made). This section describes the application of the VEE method for evaluating dust control measures.

#### 4.1.1.1 Monitoring Design

Teck will continue to use Method 22 (VEE) at appropriate locations throughout the site to meet Title V air permit requirements. Monitoring will be conducted monthly at 9 locations; 4 in the mine area, and 5 in the port area, at the locations shown in Figure 4. In addition, when the road surfaces are dry and not frozen, an observation will be made daily at a single location within the mine area or along the DMTS road.

Under ideal application of the method, the observer stands with the sun or other light source at their back and perpendicular to the observation area. Once a vehicle enters the observation area or the monitored activity begins, the 15-minute VEE observation period begins. For each vehicle or activity event, the duration (in seconds) that dust was observed and the type of vehicle or activity that produced the dust are recorded on a VEE form. The "duration of visible dust" is defined as the time that dust is visibly emanating from the source area (not the length of time the dust is visible as it drifts away from the immediate source area). If the duration of any single dust emission from road surfaces is greater than 2 minutes, or if dust is observed to be blowing from exposed surfaces such as the tailings beaches, then the surface crew, Mine Department, or Environmental Department will be contacted to apply additional water, calcium chloride, or otherwise reduce the dust emission as soon as practicable. Additional detail for conducting VEE observations is provided in U.S. EPA (2000).

A minimum of ten VEE observation periods should be conducted prior to improvements or operational changes to a dust source. After dust control measures have been implemented, another 10 VEE observation periods should be made for comparison with the pre-improvement observations. Pre- and post-improvement observations should be made in as similar weather and operational conditions as possible and from the same location and at the same time of day.

#### 4.1.1.2 Results Interpretation

Although VEE observations are a semi-quantitative method, VEE has proven useful for documenting changes in dust emissions, particularly with the addition of photographs or video.

For each 15-minute observation period, the average duration of visible dust emissions per activity or vehicle passage will be calculated at the 9 locations that are monitored monthly. Pre- and post-improvement average emission durations will be compared statistically to evaluate the effectiveness of dust control measures.

Standard t-tests will be used to compare the average time periods pre- and post-improvement unless the underlying assumptions are not met by the data. In that case, the non-parametric Wilcoxon test will be used. Differences will also be evaluated on a qualitative basis using plots. Significance will be determined using a 0.05 alpha level (95 percent confidence).

If results of the statistical comparison indicate no significant improvement in dust emissions, then additional dust control measures will be implemented, as defined in the dust emissions reduction plan.

#### 4.1.1.3 Reporting

Results of source-specific Method 22 VEE observations from the previous year will be reported in the annual RMP monitoring report.

### 4.1.2 TEOM Source Monitoring

TEOM real-time air monitoring devices have been used effectively in evaluating dust sources. In this section, a source monitoring program using the real-time alarm system (RTAS) in conjunction with the TEOM is described.

#### 4.1.2.1 Monitoring Design

In 2009, a program using the PAC TEOM (see Figure 5) for source monitoring began at the mine. The purpose of the program is to develop a relationship between dust levels and mine operations originating from the crusher pad and ore feed stockpiles. Fugitive dust events defined as periods that exceed the warning or alarm TSP levels are captured by the PAC TEOM RTAS and accompanying dust event log. By communicating real time dust levels to key personnel, corrective actions can be more efficiently deployed by addressing the specific source or activity that triggered the alarm system.

The RTAS involves real-time measurements of TSP via the PAC TEOM. A display of the RTAS has been incorporated into the Red Dog weather intranet web page, which is available to all personnel at Red Dog. The weather web page includes a 24-hour chart of TSP levels that allows operational staff to continually evaluate the effects of weather and/or operational activities on TSP levels. When air quality measurements exceed a warning level or an alarm level (described below), the alarm status is displayed on the weather page.

If either the 8-hour or the 24-hour average TSP measurements exceed a warning level of 75 $\mu g/m^3$, a warning email is issued to the dust notification group that includes personnel within the Mine Operations and Environmental departments. If either the 8-hour or the 24-hour average TSP measurements exceed an alarm level of 150 $\mu g/m^3$, an alarm email is issued to the Dust Notification Group, and the shift supervisors are prompted to log activities in a dust event log for follow-up evaluation, and corrective action.

The dust event log is an Excel® spreadsheet that captures the following information:

- Date and time of alarm condition
- 8-hour and 24-hour average TSP concentrations
- Wind direction and speed
- Temperature
- Operational activity possibly contributing to dust emissions
- Corrective actions taken.

In addition to the dust event log, the RTAS creates an automatic text log of alarm conditions.

#### 4.1.2.2 Results Interpretation

As discussed above, if either the 8-hour or the 24-hour average TSP measurements exceed a warning level of 75 $\mu g/m^3$, a warning email is issued to appropriate personnel, and follow-up evaluation and corrective actions are implemented.

Because of known patterns of seasonal variation, results from sequential years of RTAS monitoring should be compared across years for the same season (e.g., spring 2008 to spring 2009 to spring 2010). Data regarding the number of warning or alarm events will be evaluated along with weather and operational data to assess the effectiveness of operational dust control management practices.

A statistical evaluation will be conducted annually to identify significant trends in the number of warning or alarm events. Trends will be quantified using standard regression analysis when the underlying assumptions are met by the data. When these assumptions are not met the non-parametric sign test may be used. Trends will be evaluated on a qualitative basis using plots. An increasing trend over 2 years will trigger implementation of additional dust control measures, as defined in the dust emissions reduction plan.

If any projects are planned that may influence rates of dust emissions, a separate monitoring plan may be prepared to describe the deployment and use of TEOM units for the project.

#### 4.1.2.3 Reporting

The real-time monitoring results from the TEOM RTAS, and response actions taken to address alarm conditions (as described in Section 4.1.2.1) will be reported semi-annually to the mine operations manager and Red Dog management groups. Summaries of these reports and the dust event log will be included in the annual RMP monitoring report.

### 4.1.3 Road Surface Monitoring

The purpose of road surface monitoring is to determine metals concentrations on road surfaces, which are potential sources of dust to the surrounding environment. This section describes the road surface monitoring program.

#### 4.1.3.1 Monitoring Design

Road surface sampling involves the physical collection of loose materials from the surface of the road. Information on the condition of the road, such as how recently it was graded, and the presence of fresh road material, rutting, etc. are recorded. To collect a sample, a pre-washed plastic-bristled 3-ft broom is used to sweep the loose material from a transect across the traffic area of the road (e.g., shoulder, tire zone, center, tire zone, shoulder). This material is composited, and the resulting sample is then dried, sieved to less than 2 mm, and analyzed using a portable XRF device to measure metals concentrations.

Monitoring will be conducted every 2 months at locations within the mine, port and along the DMTS. The road surface sampling will be conducted at the following seven locations (Figure 6):

- Exit of the mine CSB

- The “Y” in the Haul Road
- The airport
- MS-9
- CAKR Boundary pull-out (approximately mile 24)
- MS-2
- Exit of the port race track.

#### 4.1.3.2 Results Interpretation

If the concentration at a road surface sampling station is elevated above the action level defined in the remediation plan for three consecutive sampling events, the road will be reclaimed and resurfaced with clean material, as defined in the remediation plan.

Affected areas south of the “Y” intersection by the Overburden Stockpile at the mine site will be remediated to meet the Arctic Zone industrial cleanup levels (18 AAC 340). Areas may be remediated by removal and recycling or treatment to minimize further releases of CoPCs to the surrounding environment.

#### 4.1.3.3 Reporting

Results of the road surface monitoring program will be reported on an annual basis in the annual RMP monitoring report.

## 4.2 Operational Area Monitoring

Planned monitoring efforts within the operational boundary include the following monitoring actions:

- TEOM facility monitoring

- Dustfall jar monitoring
- Marine sediment monitoring
- Moss tissue monitoring
- Vegetation community monitoring.

These programs are described in the following sections.

### 4.2.1 TEOM Facility Monitoring

Source-scale air quality monitoring using TEOMs was previously described in Section 4.1.2. Operational-scale air quality monitoring using TEOMs for TSP, TSP-Pb, and TSP-Zn is described in this section.

#### 4.2.1.1 Monitoring Design

TEOMs are currently deployed at two locations at the mine and two locations at the port (Figure 5).

TEOMs will be run continuously to measure TSP. In addition, filters attached to TEOM units collect measurements of airborne lead and zinc concentrations over 24-hour periods every third day at the mine and every sixth day at the port.

TSP, TSP-Pb, and TSP-Zn concentrations will be reported in $\mu g/m^3$.

#### 4.2.1.2 Results Interpretation

A monthly average of TSP, TSP-Pb, and TSP-Zn concentrations will be calculated based on the 24-hour daily averages. The monitoring data will be analyzed in conjunction with data from prior years to evaluate trends.

Because of known patterns of seasonal variation, results from sequential years of TEOM monitoring should be compared across years for the same month (e.g., January 2008 to January 2009 to January 2010), or by comparing consecutive annual averages.

A statistical evaluation will be conducted annually to identify significant trends in concentrations. An increasing trend over 2 years will trigger implementation of additional dust control measures as defined in the dust emissions reduction plan.

#### 4.2.1.3 Reporting

Results of the TEOM air monitoring program will be reported on an annual basis in the annual RMP monitoring report.

### 4.2.2 Dustfall Jar Monitoring

Dustfall jars provide a means to monitor operational scale dust deposition at an annual frequency at multiple locations in the outlying areas around facilities. The dustfall jar monitoring program is described in this section.

#### 4.2.2.1 Monitoring Design

Eighty-six dustfall jars will be operated at the mine, port, and along the DMTS road at locations where dustfall jars are presently or have historically been monitored (Figure 7). Dustfall jars will be placed at three stations along the length of the DMTS road (Figure 7), collocated with road surface sampling stations near the port boundary, CAKR northern boundary, and midway between CAKR and the mine. Each station will have four dustfall jars, two on each side of the road. The dustfall jars will be located approximately 100 m from the shoulder of the DMTS, with 100 m between them, oriented parallel to the road.

Monitoring at the port and mine site will continue at the locations shown on Figure 7. Dustfall jars at the port are placed in a grid format consisting of 40 jars. At the mine, 34 jars will continue to be used for monitoring, and are placed in locations that are downwind of various operations associated with mining operations.

The collection equipment and methods will be based on ASTM D1739, consisting of 150 mm (6-in.) diameter jars placed approximately 2.5 m (8.2 ft) above the ground. The jars will be equipped with aerodynamic collars to help trap collected dust particles and minimize scour (i.e., prevent dust from being blown out of the jars).

All dustfall jars from the port and the DMTS will be collected and replaced with clean jars once every 2 months. The mine dustfall jars will be collected on a 2-month schedule offset 1 month from the port. If possible, all the jars from the port or mine will be changed on the same day.

Dustfall jar samples will be analyzed for total mass and for specific metal concentrations (i.e., lead and zinc).

#### 4.2.2.2 Results Interpretation

Dustfall jars are collected and replaced every 2 months, thus a bimonthly average deposition rate will be calculated for each station, as follows. The mass of each analyte will be divided by the number of days in the sampling period and the cross-sectional area of the collection jar to give a deposition rate in $mg/m^2$-day.

**Temporal Analysis—**Bimonthly dustfall results will be averaged annually by station. The annual station averages within an area (e.g., the port, road, or mine) will be compared against results from prior years. These comparisons will identify any detectable change (increase or decrease) in the annual average concentration at each of the areas monitored.

In the event that annual average dustfall jar monitoring results indicate that an increase in concentrations may be occurring, results will be compared with other monitoring data to corroborate the findings (e.g., comparison with TEOM data at the mine and port, and road surface data along the DMTS road). If statistically significant increases are found and corroborated by other monitoring data, then additional dust control measures will be implemented as defined in the dust emissions reduction plan.

**Spatial Analysis—**Dustfall jars at the port and mine sites may also be used to identify possible sources of fugitive dust, by comparing annual averages of individual dustfall jars or small groups of dustfall jars. If a statistically significant change is identified, an evaluation will be undertaken to assess possible dust sources that may have contributed to results for those stations.

#### 4.2.2.3 Reporting

Results of the dustfall jar monitoring program will be reported on an annual basis in the annual RMP monitoring report.

### 4.2.3 Marine Sediment Monitoring

Marine sediment monitoring provides a means to monitor operational-scale dust deposition in the marine environment surrounding the port ship loader facilities. The marine sediment monitoring program is described in this section.

#### 4.2.3.1 Monitoring Design

Historically, a grid of stations had been established around the port site since before the onset of shipping operations in 1990 (Figure 8). The grid layout was designed to allow evaluation of sediment concentration patterns around the port sources (primarily the ship loader), as well as potential temporal changes in metals concentrations (i.e., by resampling stations from previous studies).

For ongoing marine sediment monitoring, sediment samples will be collected from seven of the historical grid stations previously sampled (Figure 8). These stations were selected primarily on the basis of the historical sediment concentration distribution (i.e., stations historically having highest concentrations). Monitoring data from these stations will allow evaluation of temporal changes in the annual average metal concentrations.

Sediment will be collected once every 2 years near the end of the shipping season (i.e., late September or early October). Samples will be analyzed for lead, zinc, and cadmium, and compared to effects concentrations as discussed below.

#### 4.2.3.2 Results Interpretation

Metals concentrations will be compared with the ER-L guideline values developed by Long et al. (1995) for marine sediment:

- Cadmium ER-L = 1.2 mg/kg dry
- Lead ER-L = 46.7 mg/kg dry
- Zinc ER-L = 150 mg/kg dry.

Monitoring will initially occur once every 2 years, with the next sampling scheduled for 2010. If cadmium, lead, and zinc concentrations are less than the marine ER-L identified above, then monitoring will continue on a 2-year frequency.

However, if the cadmium, lead, or zinc concentrations exceed the ER-Ls at more than one station, then monitoring will be performed annually. If the cadmium, lead, or zinc concentrations exceed the ER-Ls at more than one station for more than 2 annual monitoring events in a row, additional dust control measures will be implemented as defined in the dust emissions reduction plan. Monitoring will continue on an annual basis until cadmium, lead, and zinc concentrations remain below the ER-Ls for two successive years, at which point monitoring will revert to a 2-year frequency.

#### 4.2.3.3 Reporting

Results of the marine sediment monitoring program will be reported on an annual or biennial basis, as applicable, in the annual RMP monitoring report.

### 4.2.4 Vegetation Community Monitoring

Vegetation community monitoring provides a means to monitor community health on an operational-scale in the terrestrial environment surrounding the mine, road, and port facilities. Vegetation community monitoring results provide two key measures: 1) moss and lichen cover, and 2) plant community health as indicated by evaluation of the community parameters. The first measure is considered the most important indicator of dust deposition effects, because moss and lichen have been found to be most sensitive to dust deposition. The vegetation community monitoring program is described in this section.

#### 4.2.4.1 Monitoring Design

Vegetation community monitoring will occur at multiple locations along the DMTS road, and also at the port and mine sites (Figure 9). A point-intercept survey will be used to measure composition, relative cover, frequency of occurrence, and species diversity at each monitoring location. The method, as adapted for use in this program, will be conducted at each monitoring location using a 1-m long "laser point bar," which consists of a bar with 10 specialized low-energy lasers at 10-cm intervals. The bar will be placed parallel to, and approximately 1.5 m vertically above, the ground surface. Sampling is conducted by activating the lasers and recording the items (vegetation or surface) that are intercepted by each of the 10 lasers along the bar.

Readings will be recorded as "hits" in one or more of the following categories: vegetation (identified to genus level, and to species level if possible), litter (including standing dead vegetation), rocks (>5 mm), or bare soil. Each item that is intercepted by a laser beam will be recorded. Where appropriate, the "1st hit" intercept reading will be supplemented with a "2nd hit" intercept reading when multilayered vegetation is present (e.g., where lichens and/or mosses occur below a canopy of vascular vegetation). Total ground cover will be based on "1st hit" data; however, separate analyses and discussion with regard to lichens and mosses will be based on the combination of 1st and 2nd hit data. The combination of 1st and 2nd hit data for lichens and mosses will provide a more complete estimate of lichen and moss ground cover. Appropriate local taxonomic references will be used to identify plants to the genus level and when possible, to the species level of taxonomic classification..

**Mine Site—**Point-intercept monitoring at the mine site will be conducted along nine previously established 4-km transects that radiate away from the mine facilities (Figure 1). Monitoring plots are located on each transect at distances of 0 m, 500 m, 1,000 m, 1,500 m, 2,500 m, and 4,000 m from the transect origin. Plot locations were established based on landscape features (wind shelter, snow bed locations, slope, and aspect) and plant community structure. There are a total of 55 monitoring plots on the nine transects that radiate from the mine facilities (one of the radial transects has 7 plots rather than 6). Each monitoring plot is 50 $m^2$ (10 m × 5 m), and each plot will consist of five 10 m long survey lines spaced 1 m apart. On each survey line, intercept readings will be conducted at one hundred sampling points, yielding 500 intercept points per monitoring plot.

**DMTS Port and Road—**Monitoring at the port site and along the DMTS road will use a different sampling configuration than the mine site. Sampling will occur at four transect locations, two within the port boundary (one at the CSB loop, and one along the road near the port boundary) and two along the road (Figure 9). On each transect, point-intercept sampling will occur along three different 100 m (328 ft) survey lines oriented parallel to the road, located at stations at distances of 100 m, 1,000 m, and 2,000 m from the road (Figure 9). The 100-m stations will be located just beyond the 100-m dustfall jar stations to prevent trampling of the vegetation transect when dustfall jars are collected and replaced.

Each survey line will have 10 segments, each 10 m long. Intercept readings will be conducted at one hundred sampling points along each 10-m segment, resulting in 1,000 intercept points per survey line.

Vegetation community monitoring will occur once every 3 years, with the next sampling scheduled for 2011.

#### 4.2.4.2 Results Interpretation

Vegetation community monitoring results provide two key measures: 1) moss and lichen cover, and 2) plant community health as indicated by evaluation of community parameters such as canopy cover, frequency of occurrence, species richness, and diversity.

Statistical analysis will be conducted to evaluate changes in plant community parameters between sampling years. Where applicable the statistical methods used in the risk assessment will be implemented. Standard paired t-tests will be used to compare the relevant endpoints used to quantify the plant community (i.e., percent moss cover and percent lichen cover) between years unless the underlying assumptions are not met by the data. In that case, the non-parametric Wilcoxon test will be used. Differences will be evaluated on a qualitative basis using plots. If moss or lichen cover in a geographical area (i.e., mine, road, or port) decreases for 2 monitoring periods in a row, additional dust control measures will be evaluated and implemented as defined in the dust emissions reduction plan.

#### 4.2.4.3 Reporting

Results of the vegetation community monitoring program will be reported in the annual RMP monitoring report in years following the monitoring events.

### 4.2.5 Moss Tissue Monitoring

Moss tissue sampling provides a means to monitor operational and regional scale dust deposition in the terrestrial environment surrounding the mine, road, and port facilities. Moss tissue also serves as a surrogate food item for evaluating changes in human and wildlife exposure. Monitoring moss, which is a medium with broad spatial coverage, provides an understanding of whether exposures are increasing or decreasing for wildlife receptors in the tundra environment, and whether concentrations are increasing or decreasing in subsistence plant foods.

The moss tissue monitoring program is described in this section.

#### 4.2.5.1 Monitoring Design

The moss monitoring program is designed to detect long-term temporal trends in average concentrations of metals of concern (lead, zinc, cadmium, iron, and aluminum) in *H. splendens* within four interest areas. The interest areas were defined to produce data for evaluation of temporal changes within each area. The design of the study employs a multi-incremental sampling[3] approach based on Gy (1992, 1998).

Within each interest area, 60 to 80 increment (i.e., subsample) stations are distributed randomly (Figure 10). At each increment station, five replicates are collected. The first replicates from each increment station within an interest area are combined to create a composite sample for that area. This process is repeated for the second through fifth replicate samples from each increment station to create a total of five composite samples for the interest area. The concentration for each interest area will be represented by the average of the results for the five replicate composite samples. The sampling within each interest area is summarized as follows:

- **Sample 1 (representing Interest Area 1–the area within the mine ambient air boundary):** Increment stations were established at 28 historical discrete moss sampling locations concentrated in the southwest part of the interest area, and 32 additional increment stations were distributed throughout the interest area on approximately a 1-mile grid.
- **Sample 2 (representing Interest Area 2–the DMTS corridor through NANA Regional Corporation and state lands between the mine boundary and the CAKR National Monument boundary):** Sixty-four

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[3] A method using composite sampling with subsamples collected throughout areas of interest.

increment stations based on approximately a 1-mile grid and 8 additional increment stations at historical discrete moss sampling locations.

- **Sample 3 (representing Interest Area 3–the DMTS corridor [easement lands] through CAKR National Monument):** Approximately 50 increment stations based on approximately a 1-mile grid and an additional 26 increment stations based on a 1-mile grid offset and fitted to the interest area to capture areas unrepresented by the initial grid.
- **Sample 4 (representing Interest Area 4–the area within the port site ambient air boundary):** Increment stations established at 4 historical discrete moss sampling locations and 45 additional increment stations distributed throughout the interest area on approximately a 0.3-mile grid.

Monitoring will initially occur once every 6 years, with the next sampling scheduled for 2014. Depending on the results, monitoring may be increased in frequency to every 3 years, as described below.

#### 4.2.5.2 Results Interpretation

Statistical analysis will be performed for each set of sample replicates to quantify the variation in the sample population, and assess changes in metals concentrations over time. Standard paired t-tests or analysis of variance will be used for comparisons between years unless the underlying assumptions are not met by the data. In that case, the non-parametric Wilcoxon test will be used. Trends will be quantified using standard regression analysis when the underlying assumptions are met by the data. When these assumptions are not met the non-parametric sign test may be used. Trends and differences between years will be evaluated on a qualitative basis using plots.

If there is a significant increase in lead, zinc, or cadmium concentrations, the monitoring frequency will be increased to once every 3 years.

If cadmium, lead, or zinc concentrations are significantly higher for more than two sampling events in a row, additional dust control remedies will be implemented in accordance with the dust emissions reduction plan.[4]

Monitoring will revert to a 6-year basis once concentrations significantly decrease for two successive sampling events following the event in which the significant increase was identified.

#### 4.2.5.3 Reporting

Results of the moss tissue monitoring program will be reported in the annual RMP monitoring report, in years following the monitoring events.

## 4.3 Regional Monitoring

The regional monitoring includes the following monitoring actions to be implemented:

- Vegetation community monitoring
- Moss tissue monitoring
- Caribou tissue monitoring.

These programs are described in the following sections.

### 4.3.1 Vegetation Community Monitoring

The vegetation community monitoring program described in Section 4.2.4 and illustrated on Figure 1, serves a dual purpose as both operational area monitoring and regional level monitoring.

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[4] However, implementation of additional dust control remedies would be triggered by other types of monitoring conducted more frequently. Moss monitoring provides a landscape-scale confirmation of trends observed in monitoring programs implemented on a more frequent basis (Figure 2).

### 4.3.2 Moss Tissue Monitoring

The moss tissue monitoring program described in Section 4.2.4 and illustrated on Figure 1, serves a dual purpose as both operational area monitoring and regional level monitoring.

### 4.3.3 Caribou Tissue Monitoring

Caribou are an important subsistence food. The primary goal of the caribou monitoring program is to verify the continued safety of caribou as a subsistence resource. The following specific goals have been identified to address the primary goal:

1. Evaluate trends in caribou metals concentrations near the DMTS over time
2. Compare concentrations in caribou harvested near the DMTS to baseline concentrations evaluated in the DMTS human health risk assessment.

Additionally, the caribou monitoring data will be used to evaluate whether metals from the DMTS and Red Dog mine contribute to caribou metals concentrations and to what degree. Thus, additional analyses will be conducted, such as comparison of metals concentrations in caribou harvested near the DMTS to concentrations in caribou from elsewhere in Alaska and Canada.

Periodic collection of caribou will continue in the vicinity of the Red Dog Mine, DMTS road, and port on a 6-year basis. The caribou tissue monitoring program is described in this section.

#### 4.3.3.1 Monitoring Design

Monitoring of metals concentrations will focus on tissue collection with analysis following protocols developed previously by ADFG. Continuing this methodology will ensure comparability of results with both past and future sampling.

ADFG biologists, subsistence committee members, and Red Dog Mine staff will harvest caribou. Whenever possible, local hunters will also be used. Necropsies will be conducted by a state veterinarian whenever possible, with observation allowed by local hunters and other interested stakeholders.

Every effort will be taken to harvest animals with a shot to the head so that no possible contamination from the lead bullets reaches the sampled tissues. If animals are shot in the body, tissues will be sampled at least 12 in. distant from the wound channel for metals analysis. In addition, field logs will provide information about shot location that can be cross-checked if apparent outliers are identified during data analysis.

Caribou muscle, liver, and kidney tissues will be collected and analyzed for lead, zinc, and cadmium. The following samples will be collected:

- 8 ounces of muscle
- 1 entire kidney
- Portion of the liver
- Incisor teeth.

Incisor teeth will be collected to estimate the age of the sampled animal.

All remaining edible portions of the caribou will be donated to the Kotzebue Senior Center, or other community organization, that can make use of it. Arrangements for the donation will be made a few weeks ahead of time if possible so that the meat can remain optimally refrigerated after arrival.

#### 4.3.3.2 Results Interpretation

Results of caribou tissue metals concentrations will be compared with metals concentrations from caribou collected during previous monitoring events. Metals concentrations detected during the current monitoring period will be compared statistically with previously reported concentrations. Standard paired t-tests or analysis of variance will be used for comparisons between years unless the underlying assumptions are not met by the data. In that case, the non-parametric Wilcoxon test will be used. Trends will be quantified using standard regression analysis when the underlying assumptions are met by the data. When these assumptions are not met the non-parametric sign test may be used. Trends and differences between years will be evaluated on a qualitative basis using plots.

Additional analyses will assess whether concentrations are increasing or decreasing over time based on the most recent data combined with the three prior sampling periods. If a trend of increasing concentrations is observed or if measured metals concentrations in caribou from the site area are elevated compared to metals concentrations measured in caribou tissue from elsewhere in Alaska, then modifications to the caribou monitoring plan and/or additional analyses will be considered after consultation with ADFG and other stakeholders.

#### 4.3.3.3 Reporting

Results of the caribou tissue monitoring program will be reported in the annual RMP monitoring report in the years following the monitoring events. Results will include specifics of the statistical evaluations and their results.

## 4.4 Communication and Collaboration

In this section the standard communication guidelines developed in the communication plan (Exponent 2009) are applied to monitoring related activities. As with other programs, the monitoring plan and associated monitoring activities will have planning, implementation, and reporting stages. At each stage, communication actions have been identified that address the three categories of communication-related actions identified in the communication plan: collaboration, communication, and education and outreach. Table 7 provides a matrix summarizing the types of actions identified for the monitoring plan and related activities to address the three communication categories at each stage.

The communication tools identified in Table 7 have been further developed in Table 8 to identify the specific actions expected to be necessary to accomplish the goals of the monitoring plan. This list of actions draws from each of the three communication-related categories (i.e., communication, collaboration, and education/outreach) and provides a set of actions that meet the goal of effectively communicating ongoing issues and efforts related to monitoring efforts. Figure 2 illustrates important milestones in the reporting of results from the monitoring plan or associated study plans, and provides the specific communication actions to be implemented.

### 4.4.1 Technical and Public Review

As described in the communication plan, the Ikayuqtit Technical Review Team has been expanded to incorporate other existing stakeholder representatives/groups and to serve as the technical review committee for fugitive dust-related studies and reports. The expanded Ikayuqtit Team will provide technical review and input to the monitoring plan and related study plans and reports at the planning, review, and reporting stages. Following review by the team, a revised document incorporating team input will be made available for public review and comment.

### 4.4.2 Community Meetings

Teck will continue to provide updates on monitoring-related activities during regularly scheduled community meetings. Face-to-face meetings foster positive working relationships and provide a forum for soliciting local traditional ecological knowledge for incorporation into study planning and design. Strategies for improving adequate and representative participation in community meetings will be incorporated, including: 1) maintaining a regular and predictable schedule of meetings, 2) improving use of community liaisons to identify potential scheduling conflicts, 3) improving awareness of meetings (e.g., use of additional venues for written notices and/or announcements, improved email lists, early advertisement of meetings), 4) facilitating active participation by using appropriate language and terminology, using translators, and providing information and opportunities for input using varied formats (e.g., formal presentations, informal discussions, small workgroups, written materials and questionnaires, etc.), and 5) providing effective, timely follow-up summarizing the input provided and how it will be incorporated and/or addressed.

### 4.4.3 Web Portal and Email Lists

Teck has established an information-sharing portal to provide access and/or links to fugitive dust-related studies, reports, and other information. The purpose of the portal is to facilitate collaborative development, review, and reporting of studies, monitoring programs, and dust control efforts with stakeholders on the expanded Ikayuqtit Team. Thus, the web portal will be used to facilitate and coordinate technical review of monitoring-related plans and reports. When documents are finalized and/or ready for full public review, they will be made available on the open access Red Dog website (www.RedDogAlaska.com). Teck will work with state agencies to ensure accessibility of monitoring-related documents for public access and review, and provide links from the web portal and the Red Dog website where appropriate. Associated with this effort, Teck has expanded and will continue to update email lists and use them to notify stakeholders of additions and/or revisions to the web portal, or when review and input is needed. Overall, this approach builds in several improved information sharing strategies that were identified as part of the RMP stakeholder workshop process.

### 4.4.4 Written Technical Communications

In the annual fugitive dust RMP report, Teck will include a brief summary of the prior year's monitoring-related results, and planned programs for the upcoming year. In addition, where appropriate, other relevant stakeholder groups monitoring activities and accomplishments will be summarized and/or incorporated into the report. A simplified summary will be included at the front of the document to facilitate better understanding of the technical information. If necessary, a separate "fact sheet" summary may be developed.

### 4.4.5 Education and Outreach

Education and outreach actions include those activities that are related to, but outside the immediate scope of, monitoring activities. They are focused toward providing additional opportunities for stakeholders to gain more understanding and participation in Red Dog operations as a whole, and health and environmental efforts in particular. Several education and outreach actions were proposed by stakeholders during the RMP process. The following actions have been identified as achievable for monitoring efforts:

- Hire at least two local hunters to assist with caribou tissue metals monitoring.
- Invite Kivalina and Noatak community residents to observe caribou tissue sample collection. The number of observers may be limited by space and technical considerations.
- Provide updates and information related to caribou monitoring as part of KOTZ radio updates and newsletter articles.

## 4.5 Detailed Implementation and Quality Assurance

Details on field and laboratory quality control practices for the monitoring programs are documented in the Red Dog quality assurance project plan and in additional documents cited herein. Additional details for implementation of the monitoring programs will be in the form of Red Dog standard operating procedures (SOPs), which will be available upon request.

# 5 Periodic Review and Reporting

The monitoring results and effectiveness of the monitoring plan will be evaluated and reported on an annual basis (Figure 2). All data collected from the previous year will be used to determine if the program is working to achieve the three fundamental objectives. Public comment will be invited on an annual basis, and if additional monitoring activities are requested, they will be evaluated and included, if warranted, in an updated monitoring plan. Similarly, if a portion of the monitoring program does not contribute to the information needs, then it will be re-evaluated and either discontinued or replaced by other activities.

Each section of the monitoring report will describe the purpose, methods, statistical analysis, results, recommendations and conclusions for each monitoring program, and for the monitoring program as a whole.

The Monitoring Plan is intended to serve as part of the overall cleanup plan for Red Dog Mine, and will be used to satisfy a number of requirements, including the regulatory requirements under DEC Contaminated Sites Program, pursuant to 18 AAC 75.360. As such, issues to be reviewed by DEC CSP (or those that require DEC approval) have been identified throughout this document and will be clearly identified within the annual monitoring report.

# 6 Milestones

The major milestones for the monitoring plan include:

- Scope and goal of plan: August 2008 (in draft RMP)
- Stakeholder technical review: October 2009
- Public review draft release: July 2011
- Comment period ends for public review draft: October 2011
- Final draft release: November 2011
- Annual report and review: Spring 2012 as part of annual fugitive dust risk management report

# 7 Stakeholder Roles

Red Dog Operations will prepare the draft plan. Review will be invited from all stakeholders. Periodic review, revision, and input on this plan or results produced as a result of this plan will be invited from all stakeholders.

Teck will prepare the annual monitoring report detailing the results of the previous year's monitoring and any identified trends. The report will be provided to the Ikayuqtit technical review workgroup by the end of the first quarter for review and comment prior to release to the general public.

Other stakeholder groups are encouraged to initiate other regional monitoring programs outside the operational boundaries of the mine or port such as:

- Caribou migration monitoring
- Ptarmigan and other subsistence food monitoring
- Berry and other edible plant tissue monitoring
- Seal tissue monitoring
- Vegetation tissue sampling on public land such as CAKR National Monument and Noatak National Preserve.

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# Figures

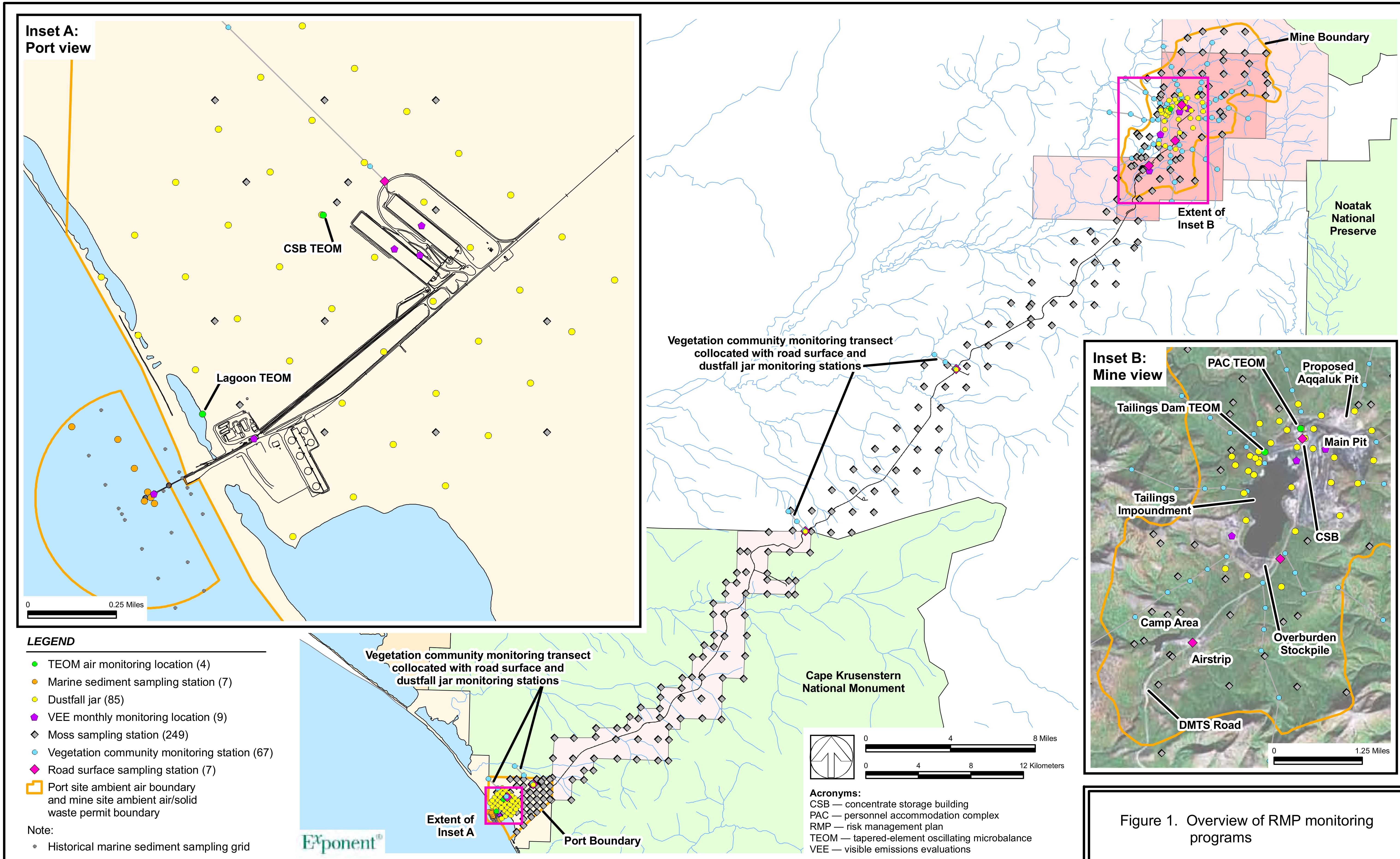



Figure 1. Overview of RMP monitoring programs

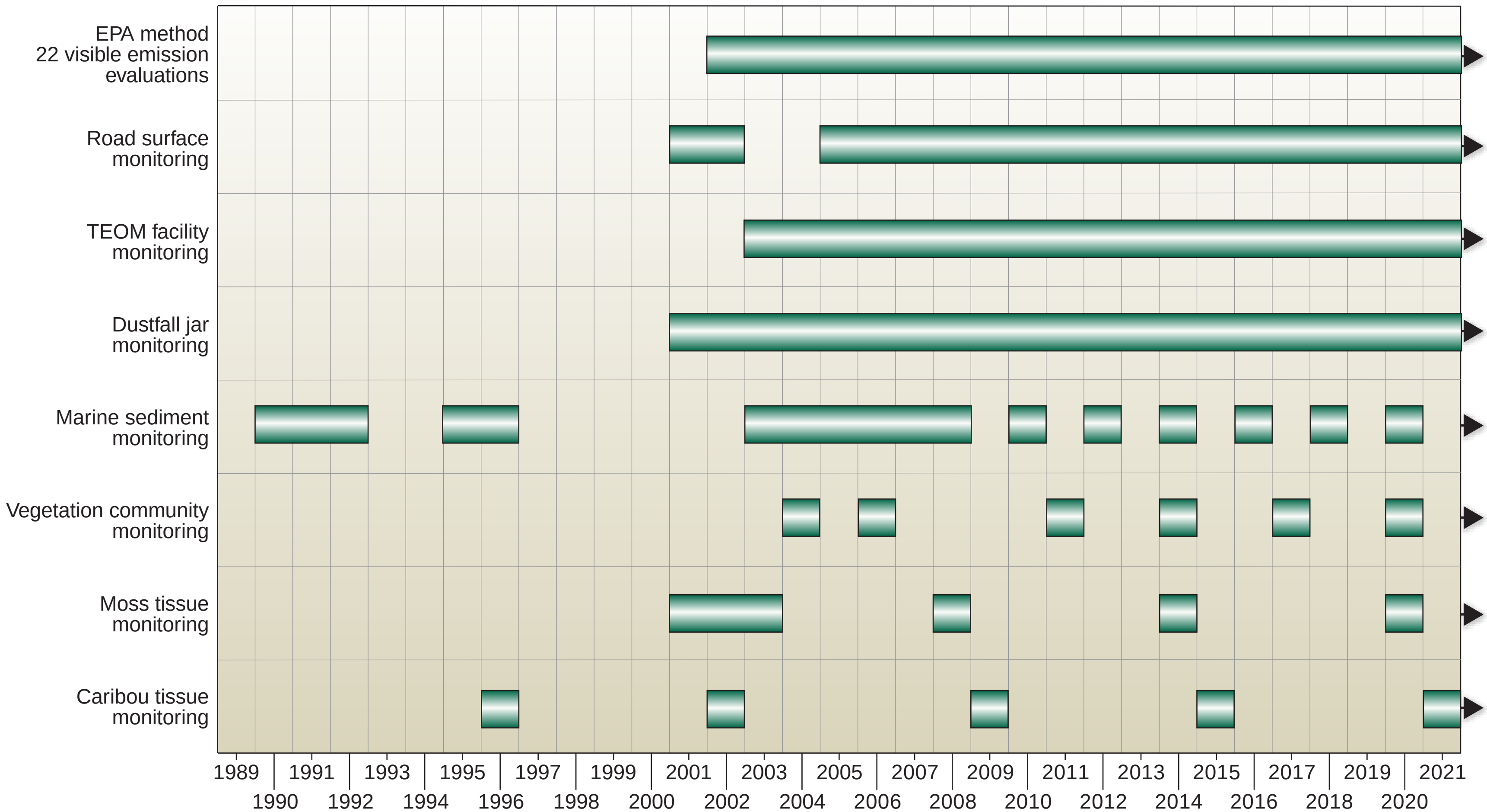
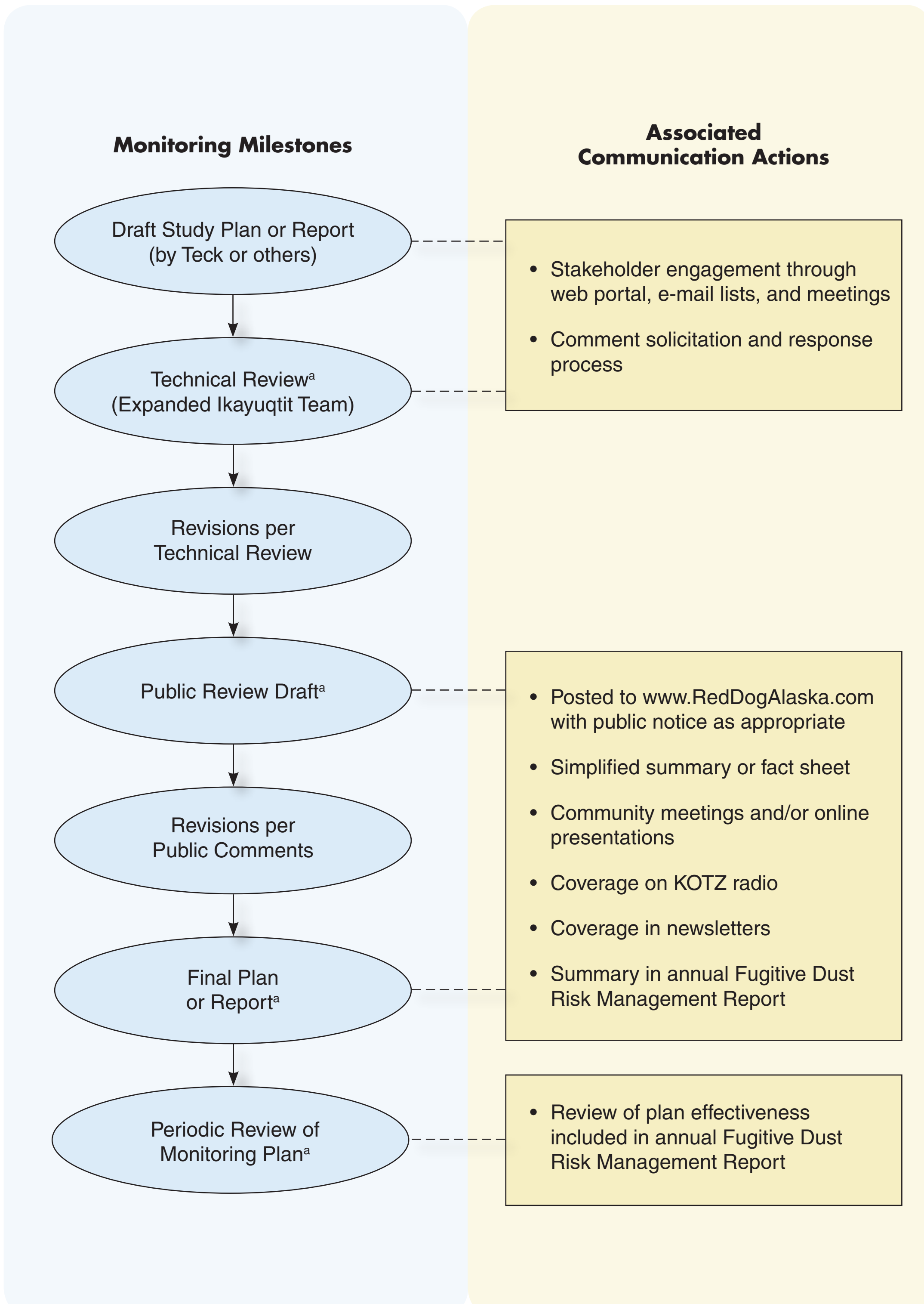



Figure 2. Monitoring timeline with program frequencies




[a] Stages where regulatory input and review will be solicited

Figure 3. Monitoring plan and report development flowchart illustrating associated communication actions

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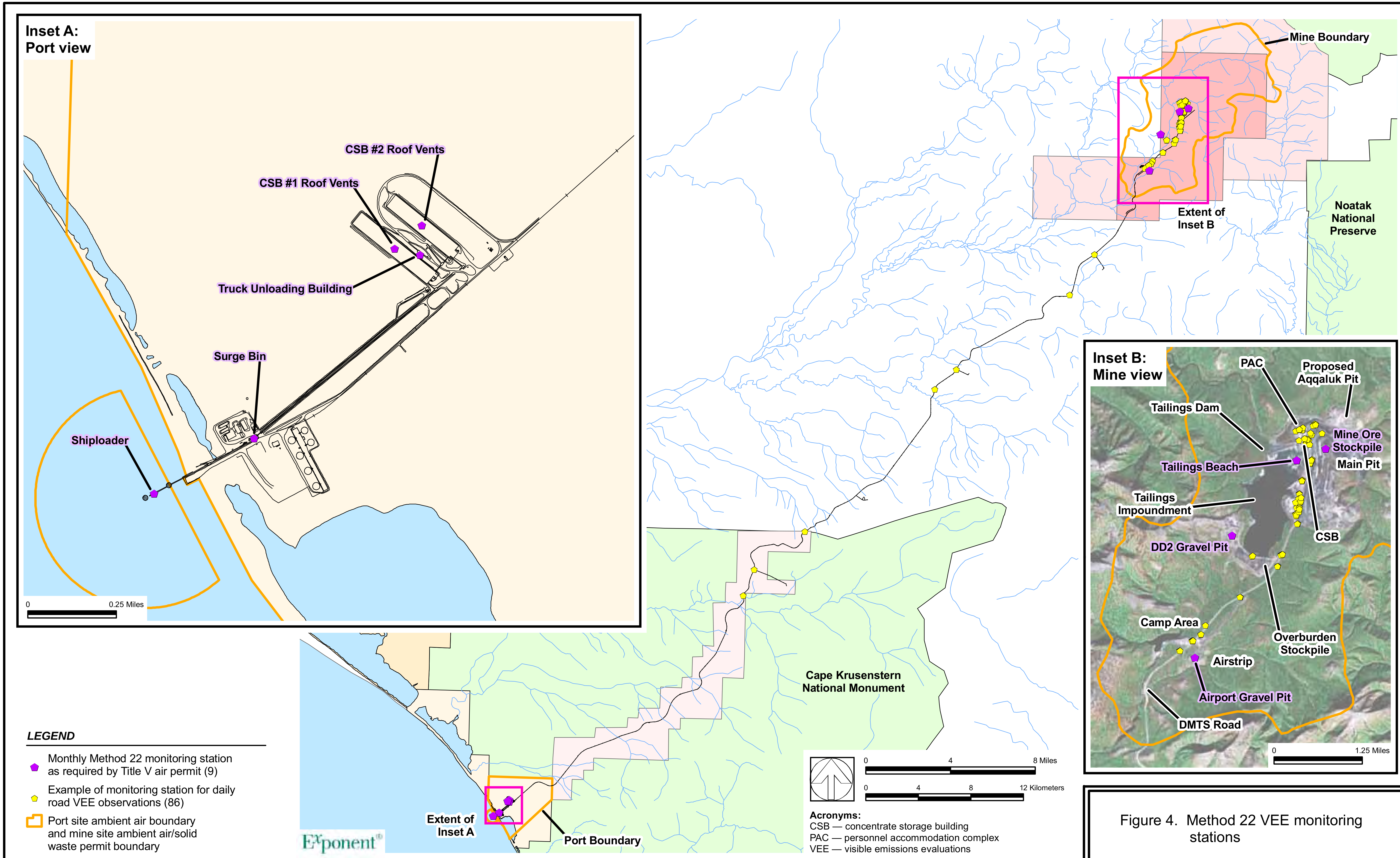



Figure 4. Method 22 VEE monitoring stations

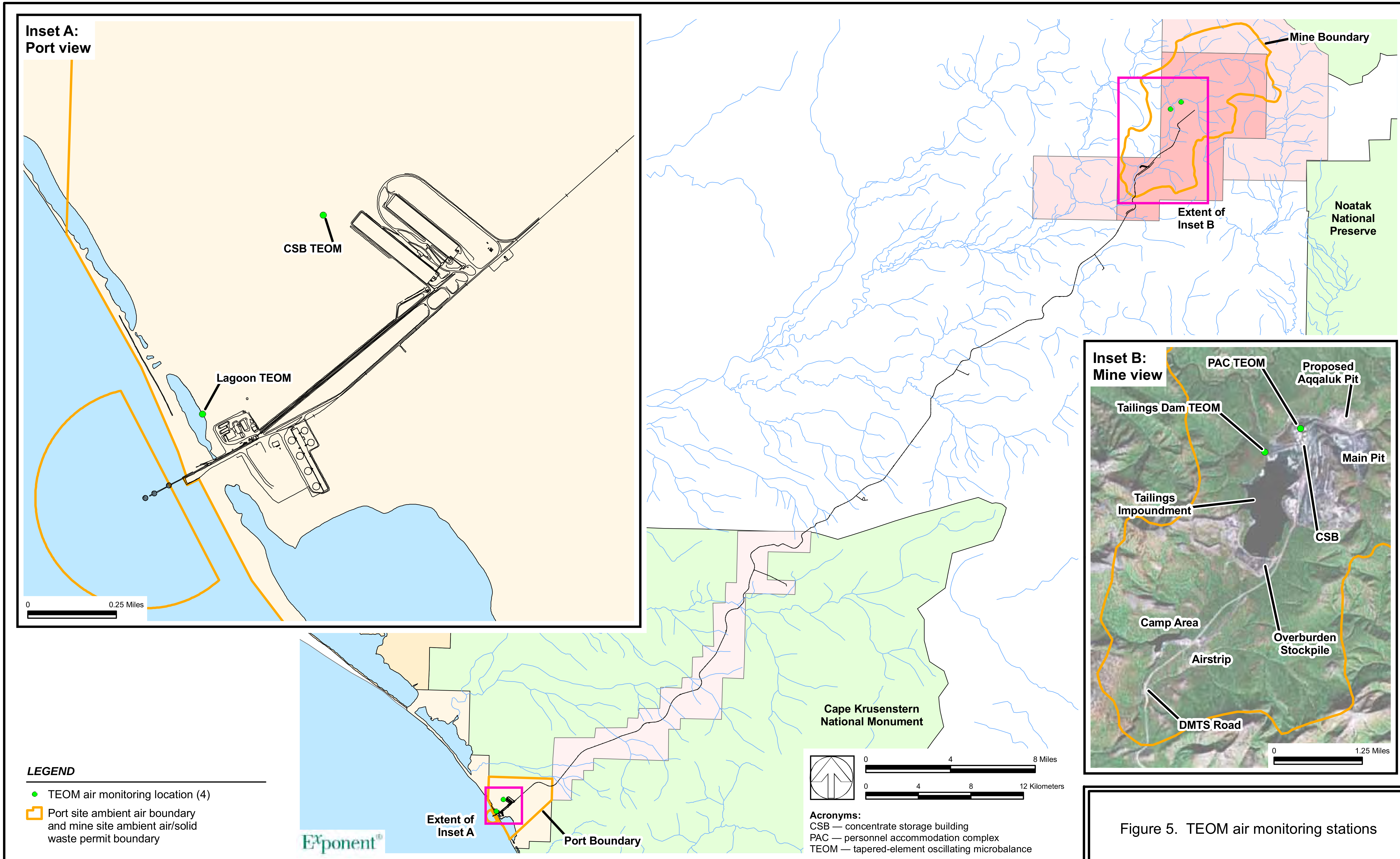
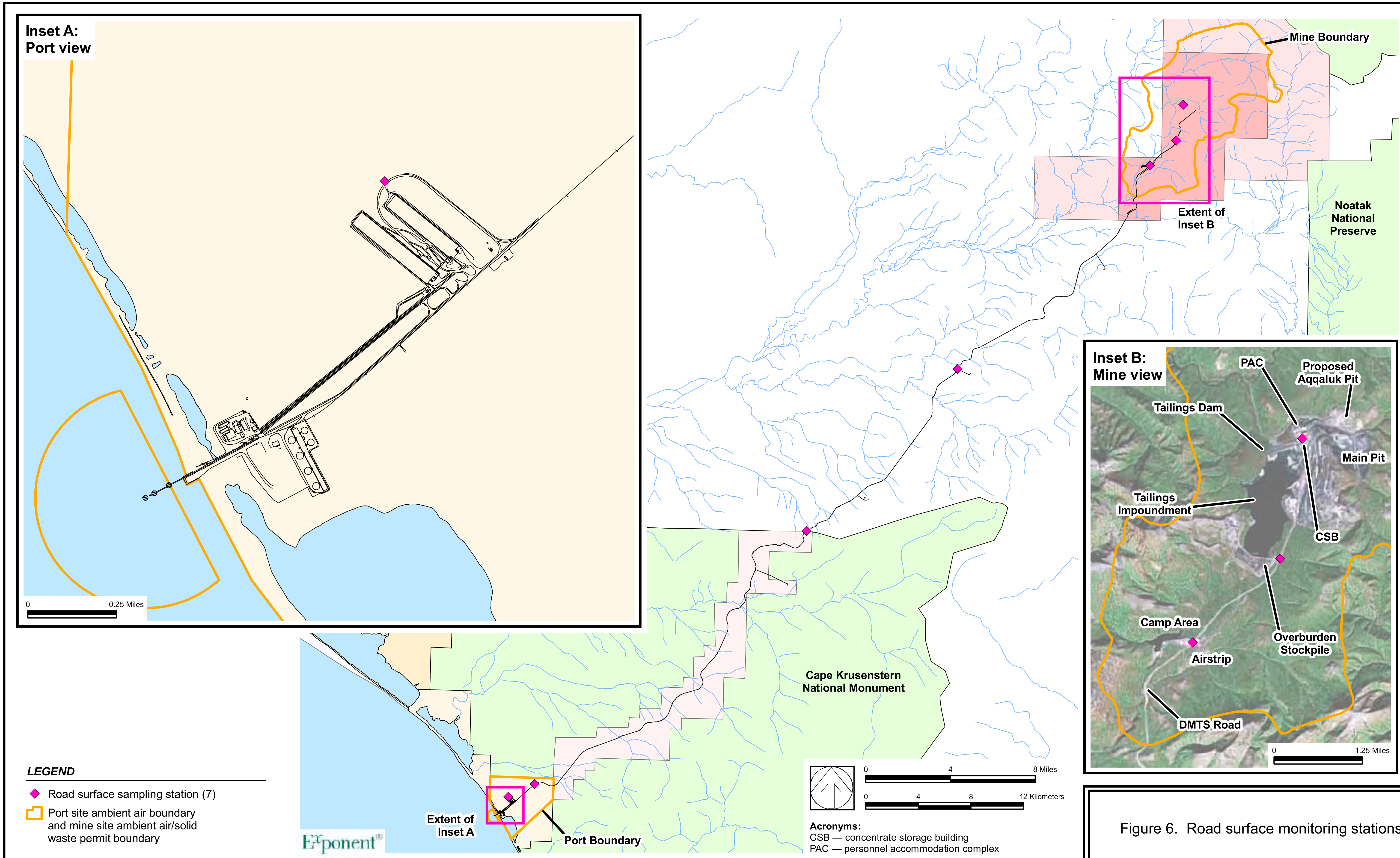
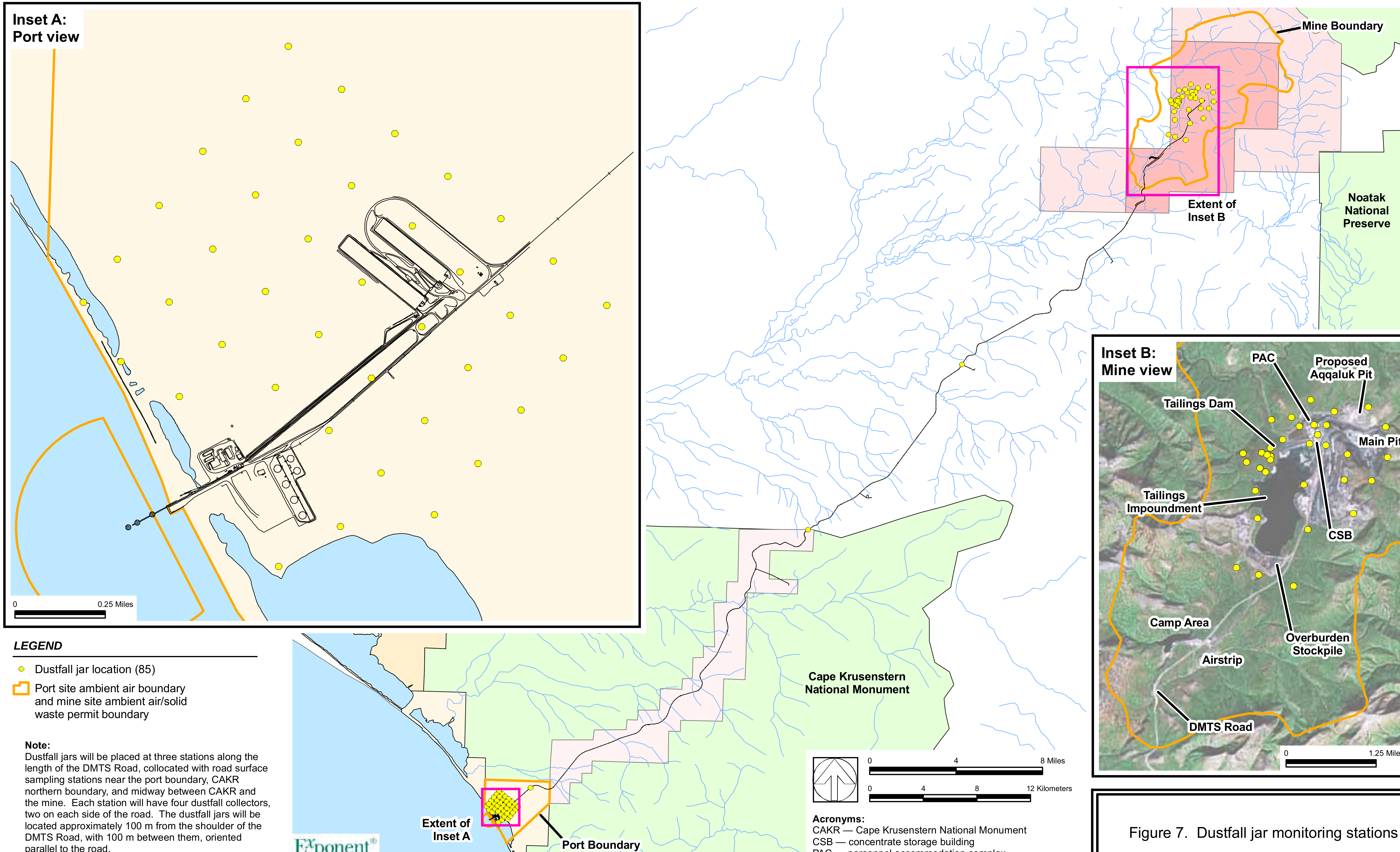



Figure 5. TEOM air monitoring stations




Acronyms:
CSB — concentrate storage building
PAC — personnel accommodation complex

Figure 6. Road surface monitoring stations




*LEGEND*

- Dustfall jar location (85)
- Port site ambient air boundary and mine site ambient air/solid waste permit boundary

**Note:**
Dustfall jars will be placed at three stations along the length of the DMTS Road, collocated with road surface sampling stations near the port boundary, CAKR northern boundary, and midway between CAKR and the mine. Each station will have four dustfall collectors, two on each side of the road. The dustfall jars will be located approximately 100 m from the shoulder of the DMTS Road, with 100 m between them, oriented parallel to the road.

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**Acronyms:**
CAKR — Cape Krusenstern National Monument
CSB — concentrate storage building
PAC — personnel accommodation complex

Figure 7. Dustfall jar monitoring stations

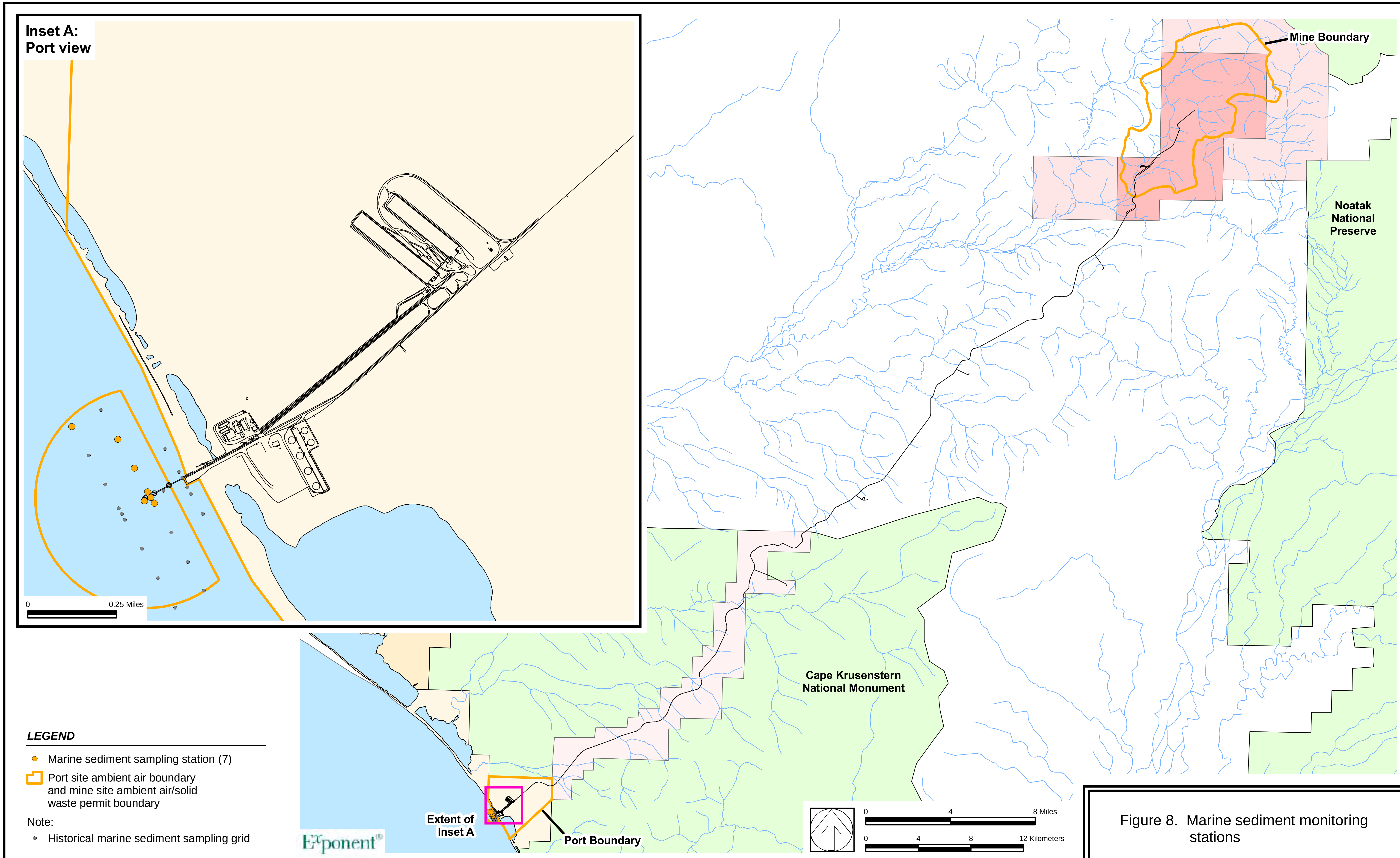
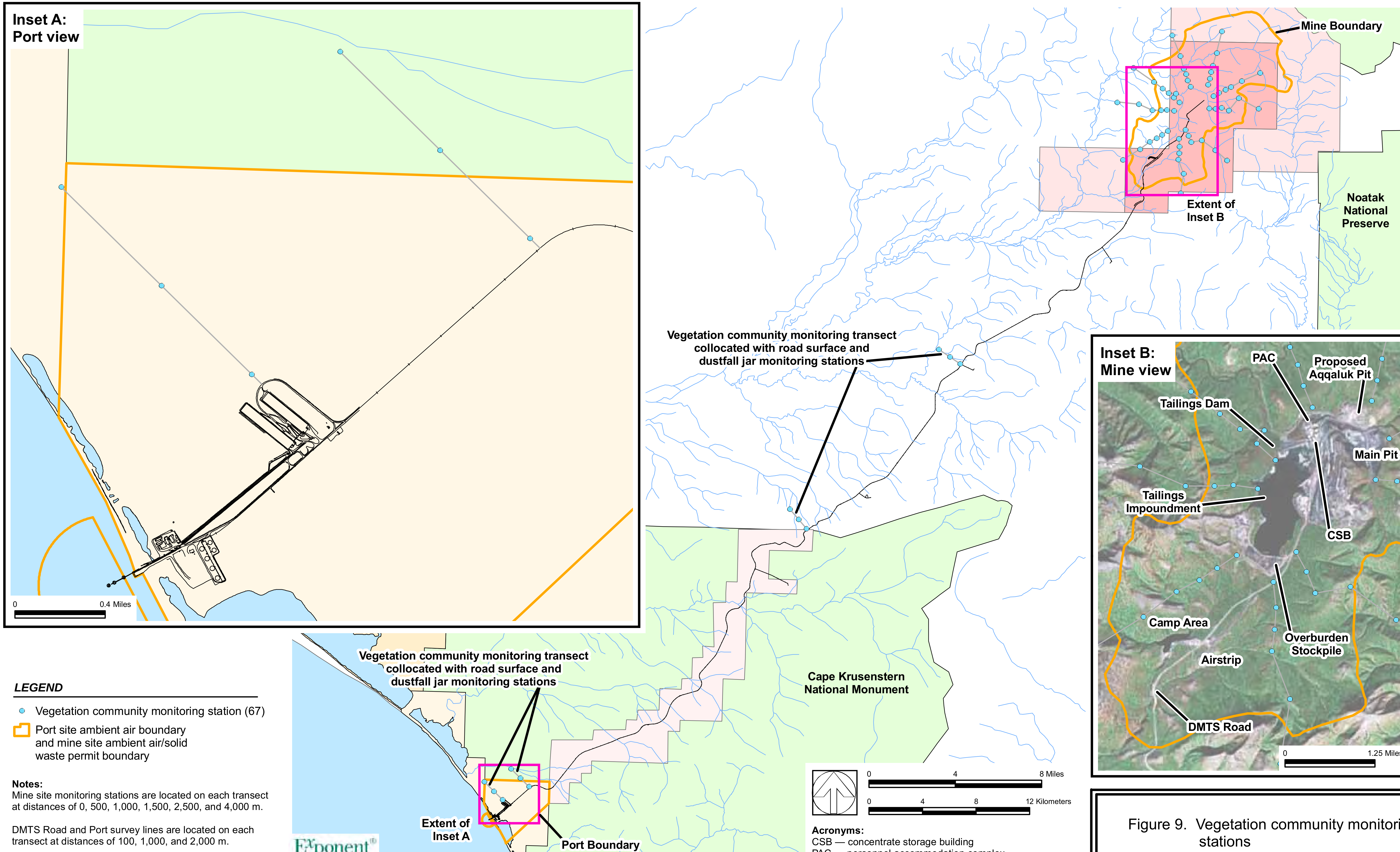



Figure 8. Marine sediment monitoring stations




*LEGEND*

- Vegetation community monitoring station (67)
- Port site ambient air boundary and mine site ambient air/solid waste permit boundary

**Notes:**
Mine site monitoring stations are located on each transect at distances of 0, 500, 1,000, 1,500, 2,500, and 4,000 m.

DMTS Road and Port survey lines are located on each transect at distances of 100, 1,000, and 2,000 m.

Exponent

**Acronyms:**
CSB — concentrate storage building
PAC — personnel accommodation complex

Figure 9. Vegetation community monitoring stations

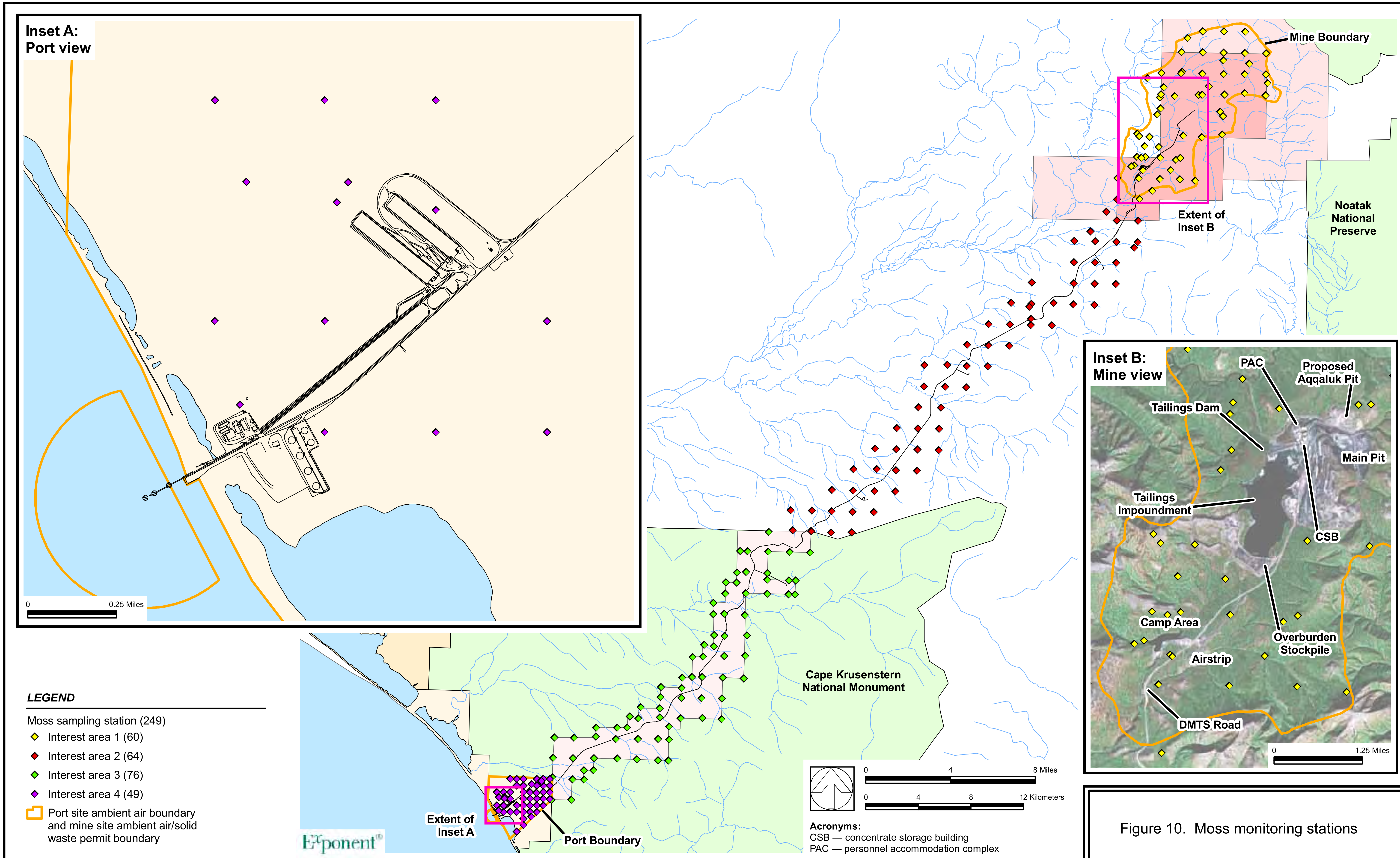



Figure 10. Moss monitoring stations

# Tables

**Table 1. Priority ranking of potential monitoring actions identified in the risk management workshop**

| Potential Actions[a] | Objective[b] | Priority Ranking |
|---|---|---|
| Implement operational monitoring program to evaluate effectiveness of dust control measures (e.g., through short-term [daily, monthly, annual frequencies] methods such as air monitoring [dustfall, TEOM], and water monitoring of streams at road crossings, tundra ponds, and coastal lagoons) | 1 | 1 |
| Monitor tissue concentrations in shrubs or herbaceous plants to track rate of change (1 year frequency) | 1,4 | 1 |
| Monitor tissue concentrations in mosses or lichens to track rate of change (3- to 5-year frequency) | 1,4 | 2 |
| Develop standard methods for sampling, analysis, and reporting | 4 | 1 |
| Hire local people to assist with monitoring | 3,4 | 1 |
| Monitor levels of metals in road-bed surface soil | 4 | 1 |
| Develop appropriate action levels to evaluate potential for effects of metals in tundra, plants, fish and other animals, and people | 4 | 1 |
| Monitor streams for changes in fish spawning, nursery, and foraging habitats | 4 | 1 |
| Monitor (metals, presence of dusts) in special areas such as Noatak National Preserve | 4 | 1 |
| Monitor moss and lichen community composition to evaluate bryophyte community health | 4 | 1 |
| Use traditional knowledge and ecological observations for development of monitoring program | 4 | 1 |
| Evaluate and implement long-term monitoring programs for soil and sediment (5-year frequency) | 4 | 2 |
| Monitor caribou health, movement, and population levels | 4 | 2 |
| Monitor changes in the vertical distribution of metals in surface tundra and underlying soils | 4 | 2 |
| Monitor tracking of metals dust at snow-machine trail crossings | 4 | 2 |
| Monitor health of local populations of animals that tend to be resident in the area (moose, small mammals, musk ox, fish such as slimy sculpins) to determine if there is an indication of mine-related exposures and effects | 4 | 3 |
| Incorporate remote monitoring tools to enhance collection of information (satellite imagery, Doppler radar, meteorological stations) | 4 | 3 |
| Develop monitoring plan for foods and water | 3 | 1 |

[a] Potential actions identified in the risk management workshop were scored based on effectiveness, implementability, level of effort, stakeholder preference for the action category, and stakeholder preference for the potential action. Scores for the five criteria were summed and a priority ranking between 1 and 3 was assigned based on total score. Details are provided in the risk management plan.

[b] Objective 1: Continue reducing fugitive metals emissions and dust emissions
Objective 3: Verify continued safety of caribou, other representative subsistence foods, and water
Objective 4: Monitor conditions in various ecological environments and habitats, and implement corrective measures when action levels are triggered

**Table 2. Examples of monitoring actions**

| Potential Actions | Monitoring Action | Communication Action | Source |
|---|---|---|---|
| Visible emissions evaluation–EPA Method 22 | X | | RDEO |
| Tapered element oscillating microbalance (TEOM) monitoring | X | | RDEO |
| Dustfall jar monitoring | X | | RDEO |
| Road surface monitoring | X | | RDEO |
| High-volume monitoring | X | | RDEO |
| Marine sediment monitoring | X | | RDEO |
| Aquatic biomonitoring | X | | ADNR |
| Snow monitoring | X | | RDEO |
| Meteorological monitoring | X | | RDEO |
| Implement operational monitoring program to evaluate effectiveness of dust control measures (e.g., through short-term [daily, monthly, annual frequencies] methods such as air monitoring [dustfall, TEOM], and water monitoring of streams at road crossings, tundra ponds, and coastal lagoons) | X | | RMP |
| Monitor tissue concentrations in shrubs or herbaceous plants to track rate of change (1 year frequency) | X | | RMP |
| Monitor tissue concentrations in mosses or lichens to track rate of change (3- to 5-year frequency) | X | | RMP |
| Develop standard methods for sampling, analysis, and reporting | X | | RMP |
| Hire local people to assist with monitoring | | X | RMP |
| Monitor levels of metals in road-bed surface soil | X | | RMP |
| Develop appropriate action levels to evaluate potential for effects of metals in tundra, plants, fish and other animals, and people | X | | RMP |
| Monitor streams for changes in fish spawning, nursery, and foraging habitats | X | | RMP |
| Monitor (metals, presence of dusts) in special areas such as Noatak National Preserve | X | | RMP |
| Monitor moss and lichen community composition to evaluate bryophyte community health | X | | RMP |
| Use traditional knowledge and ecological observations for development of monitoring program | | X | RMP |
| Evaluate and implement long-term monitoring programs for soil and sediment (5-year frequency) | X | | RMP |
| Monitor caribou health, movement, and population levels | X | | RMP |
| Monitor changes in the vertical distribution of metals in surface tundra and underlying soils | X | | RMP |
| Monitor tracking of metals dust at snow-machine trail crossings | X | | RMP |
| Monitor health of local populations of animals that tend to be resident in the area (moose, small mammals, musk ox, fish such as slimy sculpins) to determine if there is an indication of mine-related exposures and effects | X | | RMP |
| Incorporate remote monitoring tools to enhance collection of information (satellite imagery, Doppler radar, meteorological stations) | X | | RMP |
| Develop monitoring plan for foods and water | X | | RMP |
| Caribou tissue metals monitoring | X | | RDEO |

**Note:** ADNR - Alaska Department of Natural Resources
RDEO - Red Dog Environmental Operations
RMP - Fugitive Dust Risk Management Plans

**Table 3. Actions retained for the monitoring plan**

| Potential Actions | Retained (Y/N) | Rationale for Not Retaining the Action |
|---|---|---|
| Visible emissions evalution–EPA Method 22 | Yes | |
| Tapered element oscillating microbalance (TEOM) monitoring | Yes | |
| Dustfall jar monitoring | Yes | |
| Road surface monitoring | Yes | |
| High volume monitoring | No | Permit-based use continues, but not needed for RMP program |
| Marine sediment monitoring | Yes | |
| Aquatic biomonitoring | No | Fish population studies are addressed in the monitoring conducted by ADFG as part of the NPDES monitoring, and therefore this action is not included in this plan |
| Snow monitoring | No | Eliminated in favor of more reliable monitoring methods, including road dust, TEOM, dustfall jar, and moss monitoring programs |
| Meteorological monitoring | Yes | |
| Implement operational monitoring program to evaluate effectiveness of dust control measures (e.g., through short-term [daily, monthly, annual frequencies] methods such as air monitoring [dustfall, TEOM], and water monitoring of streams at road crossings, tundra ponds, and coastal lagoons) | | |
| Monitor tissue concentrations in shrubs or herbaceous plants to track rate of change (1-year frequency) | No | Utility of this method will be evaluated in the uncertainty reduction plan |
| Monitor tissue concentrations in mosses or lichens to track rate of change (3- to 5-year frequency) | Yes | |
| Develop standard methods for sampling, analysis, and reporting | Yes | |
| Hire local people to assist with monitoring | Yes | |
| Monitor levels of metals in road-bed surface soil | Yes | |
| Develop appropriate action levels to evaluate potential for effects of metals in tundra, plants, fish and other animals, and people | Yes | Criteria for triggering follow-up actions are built into the monitoring plan |
| Monitor streams for changes in fish spawning, nursery, and foraging habitats | No | Fish population studies are addressed in the monitoring conducted by ADFG as part of the NPDES monitoring, and therefore this action is not included in this plan |
| Monitor (metals, presence of dusts) in special areas such as Noatak National Preserve | No | This operational monitoring plan is designed to measure changes in areas most likely to be exposed to metals and dust; therefore, results from this monitoring plan will dictate whether additional monitoring is needed in Noatak National Preserve |

**Table 3. (cont.)**

| Potential Actions | Retained (Y/N) | Rationale for Not Retaining the Action |
|---|---|---|
| Monitor moss and lichen community composition to evaluate bryophyte community health | Yes | |
| Use traditional knowledge and ecological observations for development of monitoring program | Yes | |
| Evaluate and implement long-term monitoring programs for soil and sediment (5-year frequency) | Yes/No | Sediment monitoring is included in this plan; alternatives to soil collection that are included in this plan are dustfall jar monitoring, road surface monitoring, and moss monitoring |
| Monitor caribou health, movement, and population levels | No | Addressed by ADFG WAH monitoring program, and NANA aerial survey program for the Red Dog area |
| Monitor changes in the vertical distribution of metals in surface tundra and underlying soils | No | Will be evaluated in the uncertainty reduction plan |
| Monitor tracking of metals dust at snow-machine trail crossings | No | This operational plan is designed to measure changes in areas most likely to be exposed to metals and dust; it is possible that some of these areas will intersect with snow machine crossings, however, the objective of this plan is to document changes throughout the potential exposure area |
| Monitor health of local populations of animals that tend to be resident in the area (moose, small mammals, musk ox, fish such as slimy sculpins) to determine if there is an indication of mine-related exposures and effects | No | Exposure monitoring aspects are addressed in this monitoring plan; fish monitoring is included in the ADFG aquatic biomonitoring program; caribou populations and health addressed by the ADFG WAH monitoring program |
| Incorporate remote monitoring tools to enhance collection of information (satellite imagery, Doppler radar, meteorological stations) | No | Meteorological monitoring is addressed in this plan |
| Develop monitoring plan for foods and water | Yes | Caribou tissue monitoring is included in this plan; subsistence foods are monitored indirectly through moss tissue monitoring; water quality monitoring is implemented separately by Teck |
| Caribou tissue metals monitoring | Yes | |

**Note:** ADFG - Alaska Department of Fish and Game
ADNR - Alaska Department of Natural Resources
NPDES - National Pollutant Discharge Elimination System
RDEO - Red Dog Environmental Operations
RMP - Fugitive Dust Risk Management Plans

**Table 4. Frequency of monitoring at the source, operational, and regional scale**

| Spatial and Temporal Scale | Monitoring Frequency: Short-Term (annually or more often) | Monitoring Frequency: Medium- to Long-Term (biennially or less often) |
|---|---|---|
| Source | EPA Method 22–VEE<br>TEOM Source Monitoring with RTAS<br>Road Surface Monitoring | |
| Operational | TEOM Facility Monitoring<br>Dustfall Jar Monitoring | Marine Sediment Monitoring<br>Moss Tissue Monitoring<br>Vegetation Community Monitoring |
| Regional | | Vegetation Community Monitoring<br>Moss Tissue Monitoring<br>Caribou Tissue Monitoring |

**Note:** EPA - U.S. Environmental Protection Agency
RTAS - real-time alarm system
TEOM - tapered element oscillating microbalance
VEE - visible emissions evaluation

**Table 5. Frequency of monitoring in the mine, road, and port areas**

| Monitoring Action | Short-Term (annually or more often) | | | Medium- to Long-Term (biennially or less often) | | |
|---|---|---|---|---|---|---|
| | Mine | Road | Port | Mine | Road | Port |
| EPA Method 22–VEE | x | x | x | | | |
| TEOM Monitoring | x | | x | | | |
| Road Surface Monitoring | x | x | x | | | |
| Dustfall Jar Monitoring | x | x | x | | | |
| Marine Sediment Monitoring | | | | | | x |
| Moss Tissue Monitoring | | | | x | x | x |
| Vegetation Community Monitoring | | | | x | x | x |
| Caribou Tissue Monitoring | | | | x | x | x |

**Note:** EPA - U.S. Environmental Protection Agency
RTAS - real-time alarm system
TEOM - tapered element oscillating microbalance
VEE - visible emissions evaluation

**Table 6. Monitoring program coverage of endpoints of interest and RMP objectives**

| | Endpoints of Interest | | | | | | |
|---|---|---|---|---|---|---|---|
| | Dust Emissions | Caribou | Ptarmigan | Fish | Small Mammals | Moss and Lichen | Vegetation Community |
| RMP Objective: | 1 | 3, 4 | 3, 4 | 3, 4 | 4 | 1, 4 | 1, 4 |
| **Monitoring Program** | | | | | | | |
| **Source Monitoring** | | | | | | | |
| EPA Method 22–Visible Emissions Evaluation | x | | | | | | |
| TEOM Source Monitoring | x | | | | | | |
| Road Surface Monitoring | x | | | | | | |
| **Operational Monitoring** | | | | | | | |
| TEOM Facility Monitoring | x | | | | | | |
| Dustfall Jar Monitoring | x | | | | | | |
| Marine Sediment Monitoring | x | | | x | | | |
| Vegetation Community Monitoring | | | | | | | x |
| Moss Tissue Monitoring | x | x | x | | x | x | |
| **Regional Monitoring** | | | | | | | |
| Vegetation Community Monitoring | | | | | | | x |
| Moss Tissue Monitoring | x | x | x | | x | x | |
| Caribou Tissue Monitoring | | x | | | | | |

**Note:** EPA - U.S. Environmental Protection Agency
RMP - risk management plan
TEOM - tapered element oscillating microbalance

**Table 7. Communication elements and potential actions used in monitoring-related activities**

| | Options Available at Various Program Stages | | |
|---|---|---|---|
| | Planning | Implementation | Review and Reporting |
| **Collaboration (Working together as a team)** | | | |
| Ikayuqtit technical review | X | | X |
| Community meetings | X | | |
| Web portal and Red Dog website | X | | X |
| E-mail list | X | | X |
| Comment solicitation and response process | X | | X |
| Hire and train local residents for program | X | X | X |
| **Communication (Providing information)** | | | |
| Community meetings | | X | X |
| Web portal and Red Dog website | X | X | X |
| E-mail list | X | | X |
| Radio broadcasts and announcements | X | | X |
| Technical reports | | | X |
| Annual summary | | | X |
| Report summaries and fact sheets | | | X |
| **Education and Outreach** | | | |
| Web portal and website | X | | X |
| Hire and train local residents for program | X | X | X |
| Invite local residents to observe | | X | |
| Newsletter articles | | | X |
| Radio broadcasts | | | X |

**Note:** Adapted from the communication plan (Exponent 2009).

**Table 8. Monitoring plan actions**

| Actions | Planned Timeline for Implementation | Purpose and Objectives[a] |
|---|---|---|
| **Monitoring** | | |
| **Source Monitoring** | | |
| EPA Method 22–Visual Emissions Evaluation | Ongoing | Verify dust control effectiveness; Objective 1 |
| TEOM Source Monitoring | Ongoing | |
| Road Surface Monitoring | Ongoing bimonthly | Facilitate control of metals in dust from road; Objective 1 |
| **Operational Area Monitoring** | | |
| TEOM Facility Monitoring | Ongoing | Verify dust control effectiveness; Objective 1 |
| Dustfall Jar Monitoring | Ongoing bimonthly | |
| Marine Sediment Monitoring | Fall 2010 | Verify dust control effectiveness and safety of subsistence and ecological resources; Objectives 1, 3, 4 |
| Moss Tissue Monitoring | Summer 2014 | |
| Vegetation Community Monitoring | Summer 2011 | Verify dust control effectiveness and safety of ecological resources; Objectives 1, 4 |
| **Regional Monitoring** | | |
| Vegetation Community Monitoring | Ongoing bimonthly | Verify dust control effectiveness and safety of ecological resources; Objectives 1, 4 |
| Moss Tissue Monitoring | Summer 2014 | Verify dust control effectiveness and safety of subsistence and ecological resources; Objectives 1, 3, 4 |
| Caribou Tissue Monitoring | Spring 2015 | |
| **Communication and Collaboration** | | |
| **Technical Review** | | |
| 1) Utilize the expanded Ikayuqtit team for technical review of operational monitoring-related plans and reports at planning, reporting, and review stages | | Creates a clear process for technical review using existing structures |
| 2) Implement public review process (illustrated in Figure 2) | | Provides a means to incorporate local traditional ecological knowledge into study planning and design<br>Identifies which stakeholder group technical review is appropriate for which activities |
| **Community Meetings** | | |
| 1) Provide updates on operational monitoring-related activities during regularly scheduled community meetings | | Forum for soliciting local traditional ecological knowledge for incorporation into study planning and design<br>Increases trust and positive working relationships |
| **Web Portal and E-mail Lists** | | |
| 1) Use the newly created e-Project web portal to facilitate and coordinate technical review of operational monitoring-related plans and reports | | Creates a single clearinghouse for access to all Red Dog environmental-related documents, work plans, studies, and data |
| 2) Provide access to operational monitoring-related plans and reports on the Red Dog website when they are finalized and/or ready for full public review. | | Increases knowledge of both the existence of new information and access to that information |

**Table 8. (cont.)**

| Actions | Planned Timeline for Implementation | Purpose and Objectives[a] |
|---|---|---|
| **Written Technical Communications** | | |
| 1) Include a summary of prior-year operational monitoring-related activities/results and planned programs for the upcoming year in the annual report (described in the communication plan)<br>2) Provide a simplified summary or fact sheet for all operational monitoring-related reports to facilitate better comprehension of the technical information | | Summarizes in one place yearly accomplishments and activities and plans for the future<br>Provides sense of continuity and communicates how information gained from past activities is used to develop future actions<br>Facilitates better understanding of technical information, and thus, more stakeholder involvement |
| **Education and Outreach** | | |
| 1) Provide updates and information related to caribou monitoring as part of KOTZ radio updates and newsletter articles (described in communication plan) | | Activities related to, but often outside the immediate scope of, standard Red Dog Environmental Operations<br>Helps ensure collaboration between stakeholders and to use traditional ecological knowledge as part of the monitoring program |

[a] Objective 1: Continue reducing fugitive metals emissions and dust emissions
Objective 3: Verify continued safety of caribou, other representative subsistence foods, and water
Objective 4: Monitor conditions in various ecological environments and habitats, and implement corrective measures when action levels are triggered