Fugitive Dust Risk Management Plan
2015 Annual Report

Red Dog Operations
Teck Alaska Incorporated
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Teck

Contents

Figures and Tables are presented immediately following the text.

Acronyms and Abbreviations

CAKR	Cape Krusenstern National Monument
CSB	Concentrate Storage Building
CSP	DEC Contaminated Sites Program
DEC	Alaska Department of Environmental Conservation
DFG	Alaska Department of Fish and Game
DMTS	DeLong Mountain Transportation System
ITW	Ikayuqtit Team Technical Workgroup
MSHA	Mine Safety and Health Administration
NANA	NANA Regional Corporation
OSHA	Occupational Safety and Health Administration
PAC	Personnel Accommodations Complex
RMP	Fugitive Dust Risk Management Plan
TDam	Main Tailings Dam
TEOM	tapered element oscillating microbalance
TSP	total suspended particulates
VEE	visible emissions evaluation
XRF	x-ray fluorescence analyzer

Summary

This document presents the Fugitive Dust Risk Management Plan (RMP) Annual Report for 2015. A history of RMP activities was provided in the first (2011) Annual Report (Teck 2012) and will not be repeated here. This report is not intended to give the reader a complete background of the RMP or the RMP Implementation Plans; if background is needed, the reader is encouraged to review the RMP, Implementation Plans, and previous Annual Reports available at www.RedDogAlaska.com.

Included in this report are results from efforts related to each of the risk management implementation plans, including the Communication Plan, Dust Emissions Reduction Plan, Remediation Plan, Worker Dust Protection Plan, Uncertainty Reduction Plan, and Monitoring Plan. Activities related to these implementation plans are summarized below.

The Communication Plan contains a description of Red Dog's efforts to maintain clear communication with all interested parties and local communities about current fugitive dust risk management efforts underway at the mine. Communication activities during 2015 included regularly scheduled village visits, meetings with NANA, the Subsistence Committee, and other stakeholders and organizations who expressed an interest in mine operations. A variety of other outreach, engagement, and educational efforts were undertaken in 2015.

The Dust Emissions Reduction Plan describes current dust reduction efforts underway at the mine. Dust emissions reduction activities during 2015 included purchase of a new dust suppression product for the tailings impoundment that was applied via helicopter in September 2015, and port road dust suppression using chlorides was completed in the summer months.

The Remediation Plan is designed to facilitate the identification and selection of metals or ore concentrate affected areas for implementation of remediation and/or reclamation, to reduce the potential for human and ecological exposure. Remediation and reclamation activities in 2015 included restoration activities at two zinc concentrate spills along the port road (Mile 3 and Mile 13). Also, immediate cleanup was provided at a zinc concentrate spill that occurred on October 3, 2015. Additional reclamation work will occur in 2016, to revegetate the site, after snow melt.

Continued monitoring of the cleanup to verify that zinc was adequately recovered will occur in throughout summer 2016.

The Worker Dust Protection Plan details those programs in place to monitor and minimize workers' exposure to dust while at Red Dog, and to facilitate comprehensive communication about these programs, policies, and practices. In 2015, worker health monitoring continued through regular blood lead level testing, results of which are reported directly to the State of Alaska by the testing laboratory, and by environmental monitoring performed by the on-site Safety & Health department. Strictly enforced policies remain in place to ensure that worker health is protected and that all work environments are safe. Teck takes employee health extremely seriously and noncompliance with health and safety policies is not tolerated.

The Uncertainty Reduction Plan is intended to identify and implement research or studies to reduce uncertainties related to the assessment and management of risk to humans and the environment. In 2014 a study was planned to evaluate bone and bone marrow consumption. Part of the study incorporates a cooking competition so that individuals from Kivalina and Noatak can prepare dishes that include caribou bone, and lead concentrations will be measured in those dishes. The detailed phase one study plan will be issued for review by the Ikayuqtit Review Team in 2016. Following stakeholder review, the detailed phase one study plan will be updated as needed and then posted to www.RedDogAlaska.com. Sampling of caribou and implementation of the first phase of the study is anticipated for 2017, with development of the detailed phase two study plan (the community-based cooking study) to follow later in 2018.

The Monitoring Plan is intended to provide the necessary operational and environmental monitoring data to facilitate continued reduction of fugitive metals emissions and dust emissions, verify the continued safety of caribou and other subsistence foods and water, as well as the health of ecological environments and habitats in the vicinity of the mine, road, and port. In 2015, monitoring activities described in the Monitoring Plan proceeded on schedule and statistical analyses were performed on multi-year data to identify and evaluate any trends and patterns; specific results are presented in the Monitoring Plan section. In 2015, the following monitoring programs were implemented:

- Visual emissions evaluations, source monitoring at the mine and port with real time air samplers, real-time alarm system monitoring for dust at the mine, road surface monitoring to assess tracking of metals, and dustfall jar monitoring at the mine, road, and port.

Results from the monitoring programs largely indicate that concentration trends are flat (i.e., no increasing or decreasing trend). Overall, environmental media concentrations remain similar to or lower than those evaluated in the DMTS risk assessment (Exponent 2007).

Introduction

In accordance with the risk management plan (Exponent 2008),[1] the purpose of this report is to provide a summary of risk management activities conducted at the Red Dog operation in the prior calendar year.

Background

The Red Dog Mine is approximately 50 miles inland of the Chukchi Sea, in the western end of the Brooks Range of Northern Alaska. The mine is located on land owned by NANA and operated by Teck Alaska Incorporated (Teck). Base metal mineralization occurs naturally throughout much of the western Brooks Range, and strongly elevated zinc, lead and silver concentrations have been identified in many areas (Exponent 2007). The Red Dog Mine has been in operation since 1989.

At the mine, ore containing lead sulfide and zinc sulfide is mined and milled to produce lead and zinc concentrates in a powder form. These concentrates are hauled year-round from the mine via the DMTS road to concentrate storage buildings (CSBs) at the port, where they are stored until being loaded onto ships during the summer months. The storage capacity allows mine operations to continue year-round. During the shipping season, the concentrates from the storage buildings are loaded into an enclosed conveyor system and transferred to the shiploader, and then into barges. The barges have built-in and enclosed conveyors that are used to transfer the concentrates to the holds of deepwater ships. The DMTS road passes through the Cape Krusenstern National Monument (CAKR), which is managed by the National Park Service (NPS). A study conducted by NPS in 2000 found elevated levels of metals in moss near the DMTS road, declining with distance from the road (Ford and Hasselbach 2001).

Teck conducted studies to characterize the dust issue throughout the mine, road, and port areas, and subsequently conducted a human health and ecological risk assessment (Exponent 2007) to estimate possible risks to human and ecological receptors[2] posed by exposure to metals in soil, water, sediments, and plants and animals in areas surrounding the DMTS, and in areas surrounding the Red Dog Mine ambient air/solid waste permit boundary and port site. The

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[1] Exponent (2008) is a draft plan. Publication of a revised risk management plan for DEC approval is anticipated in 2015.
[2] Plants and animals

human health risk assessment evaluated potential exposure to DMTS-related metals through incidental soil ingestion, water ingestion, and subsistence food consumption under three scenarios: 1) child subsistence use, 2) adult subsistence use, and 3) combined worker/subsistence use.

The human health risk assessment, which included subsistence foods evaluations, found that it is safe to continue harvesting of subsistence foods from all areas surrounding the DMTS and mine, including in unrestricted areas near the DMTS, without restrictions. Although harvesting remains off limits within the DMTS, human health risks were not elevated even when data from restricted areas was included in the risk estimates.

The ecological risk assessment evaluated potential risks to ecological receptors inhabiting terrestrial, freshwater stream and pond, coastal lagoon, and marine environments from exposure to DMTS-related metals. The ecological risk assessment found that:

- In the tundra environment, changes in plant community composition (for example, decreased lichen cover) were observed near the road, port, and mine, although it was not clear to what extent those effects may have resulted from metals in fugitive dust, or from other chemical and physical effects typical of dust from gravel roads in Alaska.
- The likelihood of risk to populations of animals was considered low, with the exception of possible risks related to lead for ptarmigan living closest to the port and mine.
- No harmful effects were observed or predicted in the marine, coastal lagoon, freshwater stream, and tundra pond environments, although the potential for effects to invertebrates and plants could not be ruled out for some small, shallow ponds found close to facilities within the port site. However, no effects were observed in these port site ponds during field sampling.

Subsequent to completion of the risk assessment, Teck prepared a Risk Management Plan (RMP) designed to minimize the potential for effects to human health and the environment over the remaining mine life and beyond (Exponent 2008).

Risk Management Plan Overview

Based on the results of the risk assessment, and stakeholder input on risk management objectives, a risk management plan (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 over the life of the mine. Specifically, the overarching risk management goal is to: "*Minimize risk to human health and the environment surrounding the DMTS and outside the Red Dog Mine boundary over the life of the mine*."[3]

Although human health risks were not found to be elevated, and potential ecological risks were found to be limited, conditions may change over time, and this possibility was also considered in the design of the RMP. Future changes in conditions and in potential human and ecological exposures over the life of the operation can be addressed through implementation of risk management, dust emissions control, and monitoring activities. More specifically, the RMP established a set of seven risk management objectives (Exponent 2008), which formed the basis for preparation of six implementation plans. Each of the six implementation plans addresses one or several of the overall objectives of the RMP (Figure 1), and includes the planned scope of work to achieve the objectives.

This annual report assumes that the reader has some familiarity with the Fugitive Dust Risk Management program, and is therefore not intended to be a thorough discussion of that program, nor is it intended to provide complete background on either the risk management program or risk assessment that lead to the development of the RMP. To develop a more thorough understanding of the risk management programs, interested parties are encouraged to review the human health and ecological risk assessment documents (Exponent 2007), as well as the RMP (Exponent 2008) and its component implementation plans:

- Communication Plan (Exponent 2010)
- Dust Emissions Reduction Plan (Exponent 2011a)
- Remediation Plan (Exponent 2011b)
- Worker Dust Protection Plan (Exponent 2011c)
- Monitoring Plan (Exponent 2014a)
- Uncertainty Reduction Plan (Exponent 2012)

These plans are available for review at www.RedDogAlaska.com.

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[3] Note that the mine closure and reclamation plan addresses risk management within the mine solid waste permit boundary (collocated with the ambient air boundary, see Figure 3).

Data Collection and Reporting Objectives

The risk management program includes collection of a large amount of data for various implementation plans (discussed below) that are intended for either operational or regulatory purposes. Data collected for operational purposes are intended to provide Teck with information on the effectiveness of dust emissions control and reduction efforts. Data collected for regulatory purposes are intended to provide Alaska Department of Environmental Conservation (DEC) with the necessary information to verify that conditions are protective of human health and the environment.

The soil monitoring and marine sediment monitoring programs (described in the section below regarding the summary of monitoring results) are intended to satisfy a number of requirements, including the regulatory requirements under DEC Contaminated Sites Program (CSP), pursuant to 18 AAC 75.360. These two programs are intended to provide DEC with a means to continue oversight and implement enforcement actions as needed. As such, the results of these programs are formally documented in separate reports to DEC after each monitoring event. These monitoring programs are discussed in the "Monitoring Programs for DEC Oversight" section below, within the "Monitoring Actions" section.

Please note that in 2015, soil and marine sediment monitoring was not conducted because it is scheduled every three and two years, respectively. The next marine sediment monitoring event is scheduled for summer 2016, and the next soil monitoring event is scheduled for summer 2017.

Report Organization

The annual report summarizes work that was conducted during the 2015 calendar year related to each of the implementation plans that are part of the overall RMP. Sections are provided that document the communication, dust emissions reduction, remediation, worker dust protection, uncertainty reduction, and monitoring actions taken in 2015.

Risk Management Actions Taken in 2015

The following sections of this 2015 annual report summarize each implementation plan, the corresponding risk management objectives, and the actions taken during the 2015 calendar year toward achieving these objectives.

Communication Actions

The Communication Plan follows from Risk Management 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 this objective, the Communication Plan was developed with the goal: "To establish consistent methods for communication and collaboration among stakeholders regarding efforts related to dust emission issues." The plan identified multiple types of communication actions, within three categories: communication, collaboration, and education and outreach. A number of methods from these three categories have been implemented as part of the various risk management programs within the RMP. Those actions that were taken in 2015 are outlined below.

The following actions were taken in 2015 in order to increase communication and participation, and to ensure that information is being communicated to all stakeholders and communities of interest in an effective manner:

- **Community Meetings.** Red Dog continued to hold annual community visits/meetings in the surrounding communities. The community meetings provide an opportunity for Red Dog to give the communities updated information on operations, including environmental matters. It also provides an opportunity for community members to raise any concerns.
- **Subsistence Committee Meetings.** Red Dog holds quarterly meetings with the Red Dog Subsistence Committee. This provides a key opportunity to obtain input from knowledge holders and elders from Kivalina and Noatak. In 2015, Red Dog shared information about shipping season, dredging, water management, water discharge, and the tailings storage facility.
- **Quarterly Meetings with the Kivalina IRA.** Red Dog meets, at a minimum, quarterly with the Kivalina IRA Council. Topics of discussion have included human health assessment, tailings dam safety, water quality, and the loss of traditional land use areas.

- **Outreach and Education.** Red Dog continues to look for opportunities to provide stakeholders and communities of interest with greater understanding of Red Dog operations.
  - The Red Dog Environmental Observer program was implemented to encourage community members to accompany Red Dog environmental technicians in the field during sampling events. In 2015, the environmental observer program focused on providing additional opportunities for community members to develop a greater understanding of health and environmental monitoring efforts.
  - Red Dog continued working in collaboration with the Alaska Plant Materials Center to develop a native seed collection program in the village of Noatak, with the intent to use the seed for Red Dog reclamation activities including historic spill sites. The pilot study will serve to establish a fair price/unit for native seeds so that stakeholders who wish to collect native plant seeds for remediation/reclamation can operate as independent business owners.

Dust Emissions Reduction Actions

The Dust Emissions Reduction Plan is intended to achieve Risk Management Objective #1: *Continue reducing fugitive metals emissions and dust emissions*. In order to achieve this objective, the Dust Emissions Reduction Plan was developed with the goal: "To reduce the amount of fugitive dust released into the environment near the DMTS and Red Dog Mine to protect human health and the environment."

In 2015, a new dust suppression product was used on the tailings beaches. The product, Envirotac II, is non-toxic, non-hazardous, and environmentally safe dust control and soil stabilization product. It was applied by helicopter in early September to all exposed tailings.

Every spring and summer, during the warmer months when snow and ice are no longer present, water trucks spread water on the port and mine site roads. Also, calcium chloride is applied to the gravel roads as a dust suppressant because it retains moisture for prolonged periods. This holds down dust and stabilizes unpaved road surfaces.

In 2015, a new dust suppression product, Enssolutions Pitch Emulsion, was tested in the laboratory and showed favorable results for use at Red Dog Operations. Road trials on the port road are scheduled for summer 2016 to see if the product works better than calcium chloride for suppressing dust. The results of these efforts will be reported in the next annual report.

Remediation Actions

The Remediation Plan is intended to facilitate the achievement of the Risk Management Objective #2: *Continue remediation or reclamation of selected areas to reduce human and ecological exposure.* In order to achieve this objective, the Remediation Plan was developed with the goal: “To define a consistent method for identifying and selecting affected areas and implementing remediation and/or reclamation” (for metals or ore concentrate affected areas). Specific requirements for remediation are set forth in various permits and approved documents such as the Reclamation and Closure Plan (Teck 2011), and are referenced in the Remediation Plan.

In 2015, two sites where zinc concentrate spills occurred in 2014 (Mile 3 and Mile 13) were reclaimed. On October 3, 2015, when traveling down a grade on the port road with several corners, a contract driver had an accident where the rear went off the shoulder of the port road, turned on its side, and spilled the contents onto the tundra and across a flowing intermittent drainage. The tractor and first trailer stayed upright, and the driver was not injured. The total weight of concentrate spilled to the environment was 144,000 pounds (65,500kg). The driver reported the incident to his supervisor, the scene was secured, and agencies and stakeholders were notified of the spill as required. A major recovery effort was undertaken to collect the concentrate that was piled on the tundra. Areas with elevated zinc levels were excavated by hand and removed from the site. Soil samples were taken after the cleanup for laboratory analysis. Additional monitoring will occur in 2016 when the site is no longer frozen. Further cleanup activity, if needed, will occur in spring 2016.

Worker Dust Protection Actions

The Worker Dust Protection Plan was developed in response to Risk Management Objective #7: *Protect worker health*. In order to achieve this objective, the Worker Dust Protection Plan was developed with the goal: “To minimize worker exposure to fugitive dust, provide ongoing monitoring of exposure, and ensure a comprehensive communication system.”

Teck considers safety a core value and is committed to providing leadership and resources for managing safety and health. Accordingly, the company has developed Environment, Health, Safety and Community Management Standards applicable to their operations worldwide. In addition, Teck has developed a comprehensive Occupational Safety and Health Program tailored specifically to Red Dog Operations to protect worker health. The program complements the corporate standards and is designed to manage all aspects of workplace safety and health, including worker dust protection. The Worker Dust Protection Plan ties in closely with the existing health and safety programs at the mine, which are overseen by the Safety & Health and Medical Departments.

Worksite blood lead monitoring was conducted in 2015 by the Safety & Health and Medical Department. Blood lead level testing is performed for all employees on a regular basis and the State of Alaska receives copies of all laboratory results directly from the third-party laboratory. In 2015, blood lead monitoring results indicated exposures were below both the MSHA/OSHA standards (summarized below). Five people exhibited blood lead levels that were slightly greater than the more stringent Red Dog standards, ranging from 25.4 to 33.3 µg/dL (summarized below). Therefore, those individuals received counseling and had additional blood lead monitoring. No workers were removed from the job due to blood lead levels in 2015.

	MSHA/OSHA Standard	Red Dog Policy
Monitoring every 6 months	< 40 µg/dL	< 25 µg/dL
Blood Lead—26 to 35 µg/dL	Monitor every 6 months	Monitor every 3 months
Blood Lead—36 to 40 µg/dL	Monitor every 6 months	Monitor monthly, training & counseling
Blood Lead—41 to 50 µg/dL	Monitor every 6 months	Monitor monthly, training & counseling
Blood Lead—> 50 µg/dL	Removal from job duties	Removal from job duties, training, counseling, continued medical monitoring
Pregnant workers	Monitor every 6 months	Monitor every 3–4 weeks
Pregnant workers removed from job duties	>30 µg/dL	>10 µg/dL

Uncertainty Reduction Actions

The Uncertainty Reduction Plan follows from Risk Management Objective #5: *Conduct research or studies to reduce uncertainties in the assessment of effects to humans and the environment*. In order to achieve this objective, the Uncertainty Reduction Plan was developed with the goal: "To identify and prioritize prospective research or studies to reduce uncertainties in the assessment of effects of fugitive dust to humans and the environment."

The results of the risk assessment (Exponent 2007) indicated that overall human health risks were low, including potential risks associated with consumption of metals in caribou tissue. Consumption of caribou muscle (meat), liver, and kidney was evaluated in the risk assessment, but bone and bone marrow were not directly evaluated. Community members expressed concern that they could be exposed to lead stored in caribou bone, therefore an additional study is planned to evaluate bone and bone marrow consumption. The primary objective of the study is to conduct an analysis to determine typical bone lead levels in caribou and transfer of lead from bone to food during cooking. In addition, a cooking competition will be incorporated into the study so that individuals from Kivalina and Noatak can prepare dishes that include caribou bone, and lead concentrations will be measured in those dishes. The scientific questions that this study seeks to address include the following:

1. What are the lead concentrations in bone and bone marrow in caribou harvested near Red Dog?
2. Are lead concentrations in marrow and bone from caribou harvested near Red Dog different from those in reference caribou harvested elsewhere?
3. How much lead does marrow/bone contribute to food cooked by the local community with those ingredients?
4. How do lead concentrations in marrow/bone from other meats (e.g., beef) compare to caribou?

A detailed phase one study plan (the laboratory-based cooking study) was in development in 2015. Presently, the detailed phase one study plan will be issued for review by the Ikayuqtit Review Team in 2016. Following stakeholder review, the detailed phase one study plan will be updated as needed and then posted to www.RedDogAlaska.com. Sampling of caribou and implementation of the first phase of the study is anticipated for 2017, with development of the detailed phase two study plan (the community-based cooking study) to follow later in 2018.

Monitoring Actions

The Monitoring Plan (Exponent 2014a) is intended to facilitate the achievement of the following risk management objectives:

- Objective 1: Continue reducing fugitive metals emission and dust emissions [this objective is indirectly addressed through monitoring, to verify effectiveness of operational dust control measures]
- 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 (Exponent 2014a) was developed with the 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."

Actions included in the Monitoring Plan were developed from priority actions identified during development of the Risk Management Plan, with input from local stakeholders, technical experts, and State and Federal regulatory agencies. This section presents the results of the Monitoring Plan actions implemented during 2015. An overview of the components of the monitoring program with frequencies of monitoring is shown in Figure 2. A map-based illustration of monitoring program components and monitoring stations and sites is shown in Figure 3.

Monitoring Programs for DEC Oversight

The marine sediment and soil monitoring programs are ongoing for DEC oversight, and results are also used for trend analysis at Red Dog Operations. Marine sediment sampling and soil monitoring was not conducted in 2015, but is planned again for 2016 and 2017, respectively.

Operational Monitoring

U.S. EPA Method 22 – Visible Emissions Evaluation

Visible Emissions Evaluations (VEE) were conducted as required for the Title V air permit at the mine. Monitoring occurs at multiple locations within the mine boundary and at the port. Along the DMTS road, VEE observations are conducted daily when road surfaces are dry but not frozen. Typical VEE monitoring locations are shown on Figure 3, though the locations depicted are not all-inclusive, as the locations may vary. All VEE readings that are required under the Title V permit have been performed and are submitted twice a year to ADEC within the Title V Facility Operating Report.

In addition, when operational changes are made for which additional VEE readings are used to evaluate before/after results, these results are reported in the Annual Report. No such changes occurred in 2015; therefore there is no additional VEE monitoring to report for 2015.

TEOM Source Monitoring

Tapered element oscillating microbalance (TEOM) samplers are used for air quality monitoring at four locations near sources within the mine and port (Figure 3). Mine TEOMs are located downwind of the pit and crusher at the Personnel Accommodations Complex (PAC), and at the main tailings dam (Tdam) downwind of the tailings beach, mill, and other facilities (Figure 4). Port TEOMs are located downwind of the Concentrate Storage Buildings (CSBs) and in the lagoon area downwind of the concentrate conveyor (Figure 5).

The TEOMs produce real-time measurements of dust in air, and collect discrete samples which are then analyzed to provide airborne metals concentrations. Measurements are reported as Total Suspended Particulates (TSP), and zinc and lead concentrations are reported as TSP-Zn and TSP-Pb, respectively. TEOMs are operated continuously[4] to measure real-time TSP. Filters are used to collect TSP over 24-hour periods every third day at the mine and every sixth day at the port to be analyzed for TSP-Zn and TSP-Pb.

The calculated monthly averages of 2011, 2012, 2013, 2014, and 2015 TSP-Pb and TSP-Zn concentrations are shown on Figure 6a for all four mine and port TEOM locations. The concentrations of lead and zinc at the mine area are typically higher than those at the port area (Figure 6a).

- **Mine TEOM Results.** At the mine, (Figure 6b), lead and zinc concentrations were typically lowest in summer months (the months with higher humidity and more road watering for dust control), and highest in winter months (the coldest, driest, and lowest humidity months, when road watering is not possible because of freezing conditions).

- **Port TEOM Results.** At the port (Figure 6c), lagoon TEOM lead and zinc concentrations are highest from July through November, corresponding with the peak shipping season.

Statistical Trend Analysis for TEOM Data. Statistical testing methods were used to evaluate whether TEOM datasets have statistically significant temporal trends in metals concentrations. The Seasonal Mann-Kendall (SMK) trend test is a nonparametric method to investigate temporal trends in time series containing substantial seasonal variability. In this case, TEOM data were summarized on a monthly basis. Seasonal trend tests were conducted using monthly means and monthly 95th percentile concentrations to evaluate both average conditions and a measure of the upper limit. Seasonal trend tests require valid data within each month for at least three years within the time frame considered.

Results of the statistical trend tests for TEOM data (lead and zinc concentrations) in four locations (Mine PAC, Mine Tdam, Port CSB, and Port Lagoon) are summarized in Table 1. Port

[4] Occasional system upsets do occur as a result of weather or equipment failure. TEOM readings are monitored frequently so that system upsets are noted and corrected as soon as possible. Missing or unusable data are noted in the raw data files, and are not used in statistical trend evaluations.

CSB and Lagoon results were also analyzed as a combined data set. This combined analysis is supported by the proximity of the two port locations and the similarities in monthly average concentrations for both lead and zinc (Figures 7a and 7b).

For the most recent four-year period (2012-2015), statistical analysis indicates that Port area and Mine area have been relatively stable in lead and zinc concentrations, both in mean and 95th percentile concentrations (Table 1, Figures 7a and 7b).

TEOM Real Time Alarm System Monitoring

Real-time TEOM data is used internally to monitor for high dust events so that mine activities can be modified (where possible) to reduce dust levels. When air quality measurements exceeded a warning level or an alarm level, the alarm status was displayed on the Red Dog weather intranet web page to notify personnel within the Mine Operations and Environmental departments to take corrective action. Examples of these corrective actions include ordering water on the roads or stock-piles, or shutting down loading operations during windy conditions.

Road Surface Monitoring

Loose fine materials subject to airborne transport into the surrounding environment are sampled from the road surface at eight locations every two months. From the mine site to the port, the eight road surface monitoring station locations are:

- Mine CSB (near exit from truck loading portion of CSB)
- The Y (near the back dam, between the CSB and the Airport)
- Airport
- MS-13 (former material site where road crosses the mine boundary)
- MS-9 (material site between the mine and CAKR)
- R-Boundary (northern boundary of CAKR)
- MS-2 (material site just inside the northern boundary of the port)
- Port CSB Track (road near exit from truck unloading building at the port CSBs)

Samples were analyzed onsite using a portable XRF (x-ray fluorescence) analyzer to determine lead, zinc, and cadmium concentrations within road surface materials. The “Mine CSB” and

"The Y" stations (inside the mine boundary) often exceed the cleanup levels, and are managed so as to reduce tracking of metals concentrates toward the port. Final remediation of the mine areas will occur after mine closure according to the methods outlined in the Red Dog Mine Waste Management, Reclamation and Closure Monitoring Plan (Teck 2011).

Results for stations outside the mine boundary do not exceed Arctic Zone Industrial Cleanup Levels for lead, zinc, or cadmium over the time period 2011-2015 (Figures 8a, 8b, and 8c). The exception is at the Port CSB Track, where lead concentrations exceedd the cleanup levels three times in a row in 2015 (Figure 8a)

If sample results at stations outside the mine boundary exceed Arctic Zone Industrial Cleanup Levels for lead, zinc, or cadmium (800, 41,100 and 110 mg/kg respectively[5]) for more than two consecutive sampling periods, that road section is to be remediated and resurfaced as described in the Remediation Plan (Exponent 2011). Based on results from 2015, road remediation and resurfacing is scheduled to occur at the port site in 2016.

Dustfall Jar Monitoring

Dustfall jars are passive continuous collectors for measuring dust deposition; samples are collected every two months at all locations. Approximately 86 dustfall stations are located around the mine, port, and DMTS road, as follows:

- At the mine, approximately 34 jars are placed in locations around the facilities (Figure 3).
- Along the DMTS road, 12 dustfall jars are located at three stations, each with four dustfall jars, two on either side of the road. The DMTS road stations are collocated with road surface sampling stations near the port boundary, the CAKR northern boundary, and midway between CAKR and the mine. The dustfall jars are located approximately 100 m from the shoulder of the DMTS, with 100 m between them, oriented parallel to the road (Figure 3).

[5] Cleanup levels according to 18 AAC 75.341, as revised in 2008 (available on the internet at https://dec.alaska.gov/spar/csp/docs/75mas_art3.pdf). Note that the cadmium and zinc cleanup level would be lower, at 79 and 30,400 mg/kg, if the zone were considered to be the "Under 40 inch Zone" by DEC, which is a function of the definitions at 18 AAC 75.990.

- At the port, 38 jars are placed roughly in a rectangular grid throughout the area (Figure 3).
- An additional two jars are considered reference stations, one upwind of the road near Evaingiknuk Creek, and another near the Wulik River, to the north of the operation (Figure 3).

Statistical Trend Analysis for Dustfall Jar Data. Temporal trends in deposition rates or metals concentrations in dustfall jars data were evaluated using the same statistical methods used for the TEOM analyses, using seasonal trend tests conducted with monthly mean and 95th percentiles (discussed above in TEOM section).

- **Lead.** For lead, dustfall deposition rates and concentrations have been stable over the most recent four-year period. No statistically-significant trends were identified at any location over the most recent four-year period, either in average or upper limits (Table 2). Time series plots of lead dustfall deposition rates and concentrations are presented in Figures 9 and 12, respectively.

- **Zinc.** For zinc, the mean dustfall deposition rates and concentrations have been stable in all areas except for the port, which has shown a significant increasing trend for deposition rates during the most recent four-year period (Table 2). Meanwhile, the upper limits of deposition rates and concentrations have been stable in all areas over the same time period (Table 2). Time series plots of zinc dustfall deposition rates and concentrations are shown in Figures 10 and 13, respectively.

- **Total Solids.** For total solids, the deposition rates have been stable. No statistically-significant trends were identified at any location over the most recent four-year period, either in average or upper limits (Table 2). Time series plots of total solids dustfall rates are presented in Figure 11.

Caribou Tissue Monitoring

Red Dog Mine is located within the normal annual range of the Western Arctic Herd. Surveys of caribou have been conducted periodically since 1984 by the Department of Fish and Game, and have provided baseline information against which more current studies may be compared. Caribou tissue monitoring for dust-related constituents under the RMP program was scheduled to occur in 2015, but due to lack of caribou overwintering near the road, it was postponed until 2016.

Summary of Monitoring Results

Dust monitoring data from the TEOM air samplers and the dustfall jars was statistically evaluated to assess the current trends over the most recent four-year period. Statistical analysis of the data indicates that the measured concentrations and deposition rates at the mine, port and road areas are stable and not significantly increasing. The one exception is for the port, where dustfall jars indicate a significant increase in zinc concentrations, but only for average concentrations, not for upper limits.

A summary of statistical trend analysis results for TEOM and dustfall jar monitoring programs is presented in Table 3. This table provides an at-a-glance overview of results of dust monitoring programs. Results from the monitoring programs largely indicate that concentration trends are flat (i.e., no increasing or decreasing trend). Overall, environmental media concentrations remain similar to or lower than those evaluated in the DMTS risk assessment (Exponent 2007).

References

ABR, 2007. Revegetation plan for the Red Dog Mine, Alaska.Final Report. Prepared for Teck Cominco Alaska, Inc. ABR, Inc.-Environmental Research and Services, Fairbanks, AK.Available at: http://dnr.alaska.gov/mlw/mining/largemine/reddog/publicnotice/pdf/sdf3.pdf.

Bretz, F., Hothorn, T., and Westfall, P. 2010. *Multiple Comparisons Using R*, CRC Press, Boca Raton.

Chambers, J. M. and Hastie, T. J. 1992. *Statistical Models in S*, Wadsworth & Brooks/Cole.

Cedar Creek Associates, Inc., 2011. Red Dog Mine 2010 vegetation monitoring, in accordance with the Solid Waste Permit. Prepared for Teck Alaska Incorporated. February 2011.

Exponent, 2007. DMTS fugitive dust risk assessment. Prepared for Teck Cominco Alaska Incorporated. November 2007.

Exponent, 2008. RMP Exponent. 2008. Fugitive dust risk management plan. Red Dog Operations, Alaska. Prepared for Teck Cominco Alaska. Draft. August 2008.

Exponent, 2010. Fugitive Dust Risk Management Communication Plan. Prepared for Teck Alaska Incorporated. February 2010.

Exponent, 2014a. Fugitive Dust Risk Management Monitoring Plan. Prepared for Teck Alaska Incorporated. May 2014.

Exponent, 2014b. DRAFT 2014 Marine Sediment Monitoring Report. Prepared for Teck Alaska Incorporated. December 2014.

Exponent, 2014c. DRAFT 2014 Soil Monitoring Report. Prepared for Teck Alaska Incorporated. December 2014.

Exponent, 2011a. Fugitive Dust Risk Management Dust Emissions Reduction Plan. Prepared for Teck Alaska Incorporated. December 2011.

Exponent, 2011b. Fugitive Dust Risk Management Remediation Plan. Prepared for Teck Alaska Incorporated. June 2011.

Exponent, 2011c. Fugitive Dust Risk Management Worker Dust Protection Plan. Prepared for Teck Alaska Incorporated. October 2011.

Exponent, 2012. Fugitive Dust Risk Management Uncertainty Reduction Plan. Prepared for Teck Alaska Incorporated. October 2012.

Exponent, 2014. Fugitive Dust Risk Management Monitoring Plan. Prepared for Teck Alaska Incorporated. May 2014.

Ford, S., and L. Hasselbach, 2001. Heavy metals in mosses and soils on six transects along the Red Dog Mine haul road, Alaska. NPS/AR/NRTR-2001/38. National Park Service, Western Arctic National Parklands.

Meyers-Smith, I.H., et al. 2015. Climate sensitivity of shrub growth across the tundra biome. Nature Climate Change. Published online 06 July 2015. doi:10.1038/nclimate2697.

Rare Earth Science, 2009. 2008 Moss Sampling Event, Red Dog Mine Moss Study. Draft Report. July 13, 2009.

Seitz, 2012. Dispersal Patterns and Summer Ocean Distribution of Adult Dolly Varden from the Wulik River, Alaska, Evaluated Using Satellite Telemetry; Annual CMI Review Meeting, Dec 20, Fairbanks, AK.

Sheskin, D.J. 2003. Handbook of Parametric and Nonparametric Statistical Procedures, 3rd ed. CRC Press, Boca Raton.

Teck, 2011. Red Dog Mine Waste Management, Reclamation and Closure Monitoring Plan. April, 2011.

Teck, 2012. Fugitive Dust Risk Management Plan 2011 Annual Report. March 2012.

Teck, 2013. Fugitive Dust Risk Management Plan 2012 Annual Report. March 2013.

Weisstein, Eric W. "Bonferroni Correction." From MathWorld--A Wolfram Web Resource. Available at: http://mathworld.wolfram.com/BonferroniCorrection.html. Accessed on October 10, 2014.

Fugitive Dust Risk Management Plan

RISK MANAGEMENT OBJECTIVES	Communication Plan	Dust Emission Reduction Plan	Remediation/ Reclamation Plan	Monitoring Plan	Uncertainty Reduction Plan	Worker Dust Protection Plan
1. Continue reducing fugitive metals emissions and dust emissions	□	■	□	■	□	
2. Conduct remediation or reclamation in selected areas	□		■	□	□	
3. Verify continued safety of caribou, other representative subsistence foods, and water	□			■	□	
4. Monitor conditions in various ecological environments and habitats, and implement corrective measures when action levels are triggered	□			■	□	
5. Conduct research or studies to reduce uncertainties in the assessment of effects to humans and the environment	□			□	■	□
6. Improve communication and collaboration among all stakeholders	■	□	□	□	□	□
7. Protect worker health	□	□	□	□	□	■

■ Implementation plan directly addresses objective

□ Implementation plan indirectly addresses objective

Figure 1. Risk management objectives and associated implementation plans

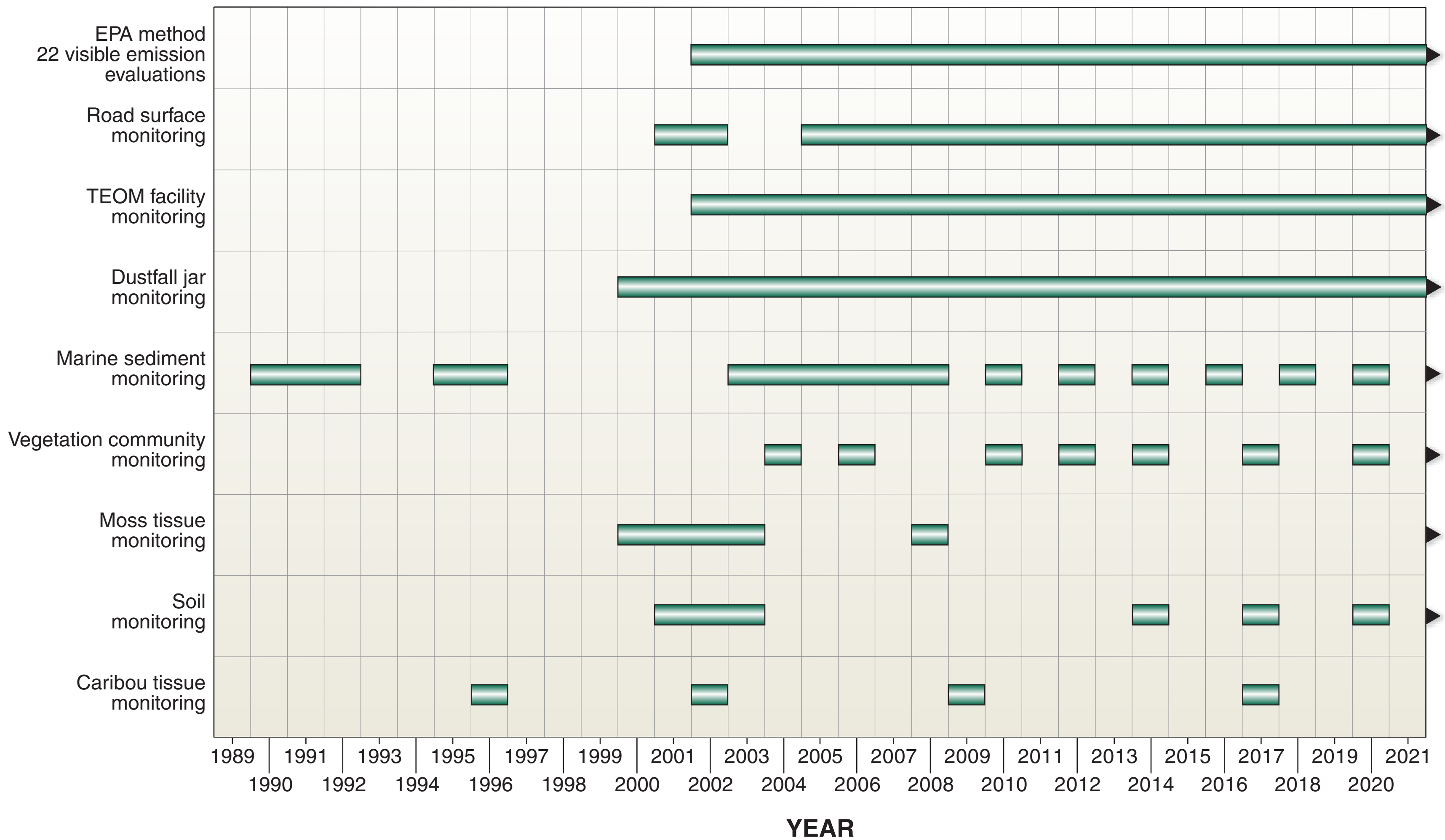


Figure 2. Monitoring timeline with program frequencies

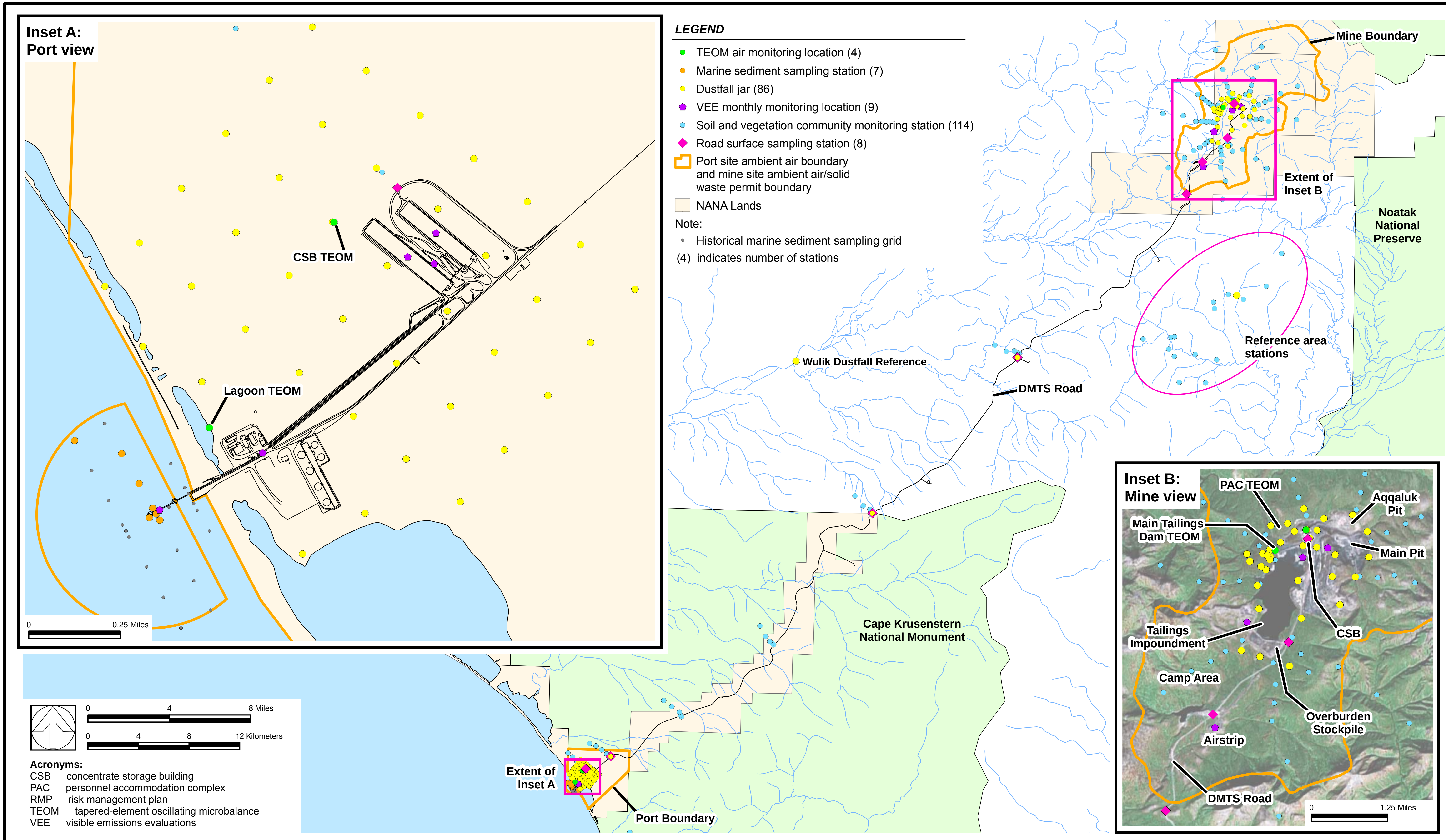


Figure 3. Overview of risk management monitoring programs

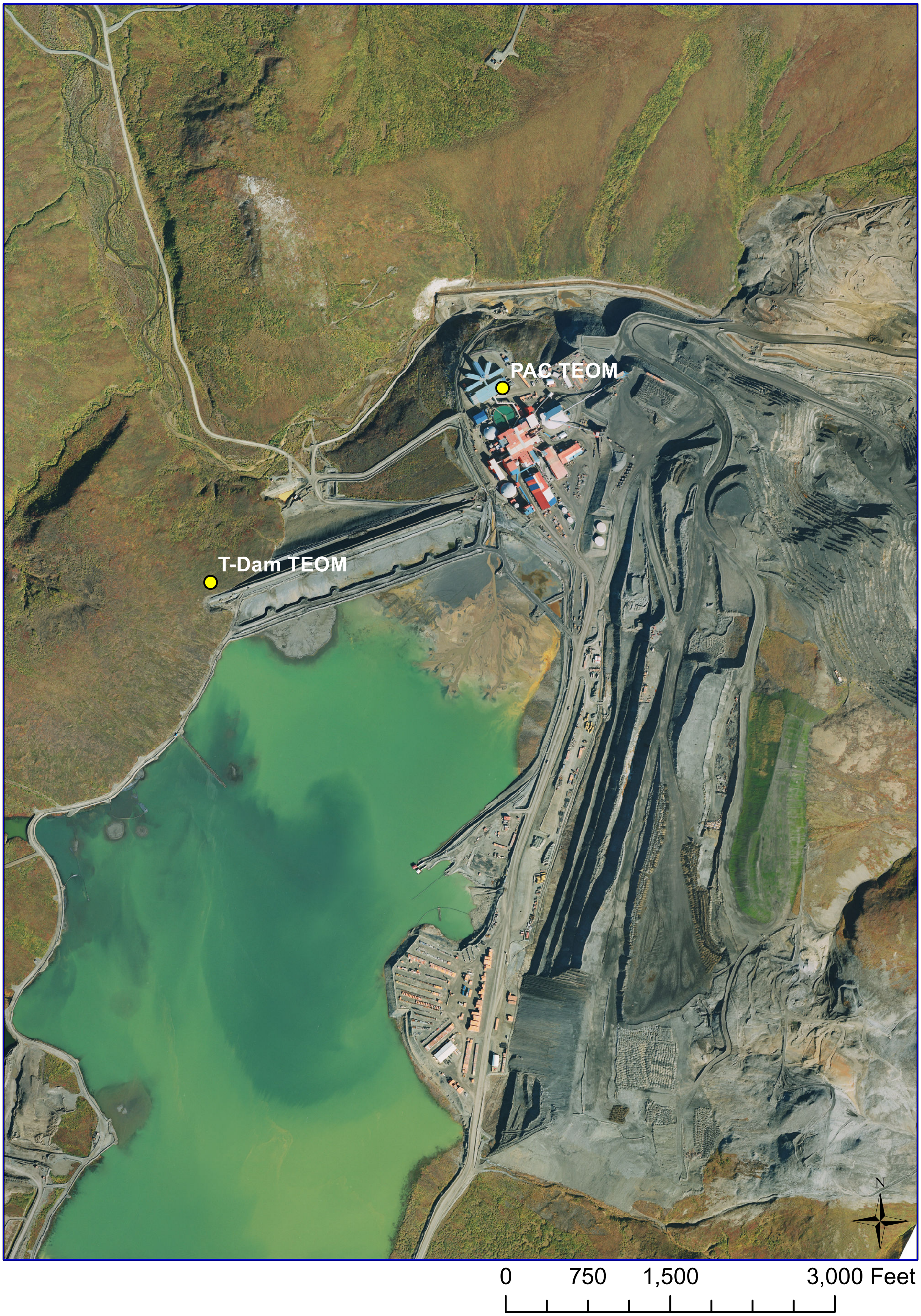
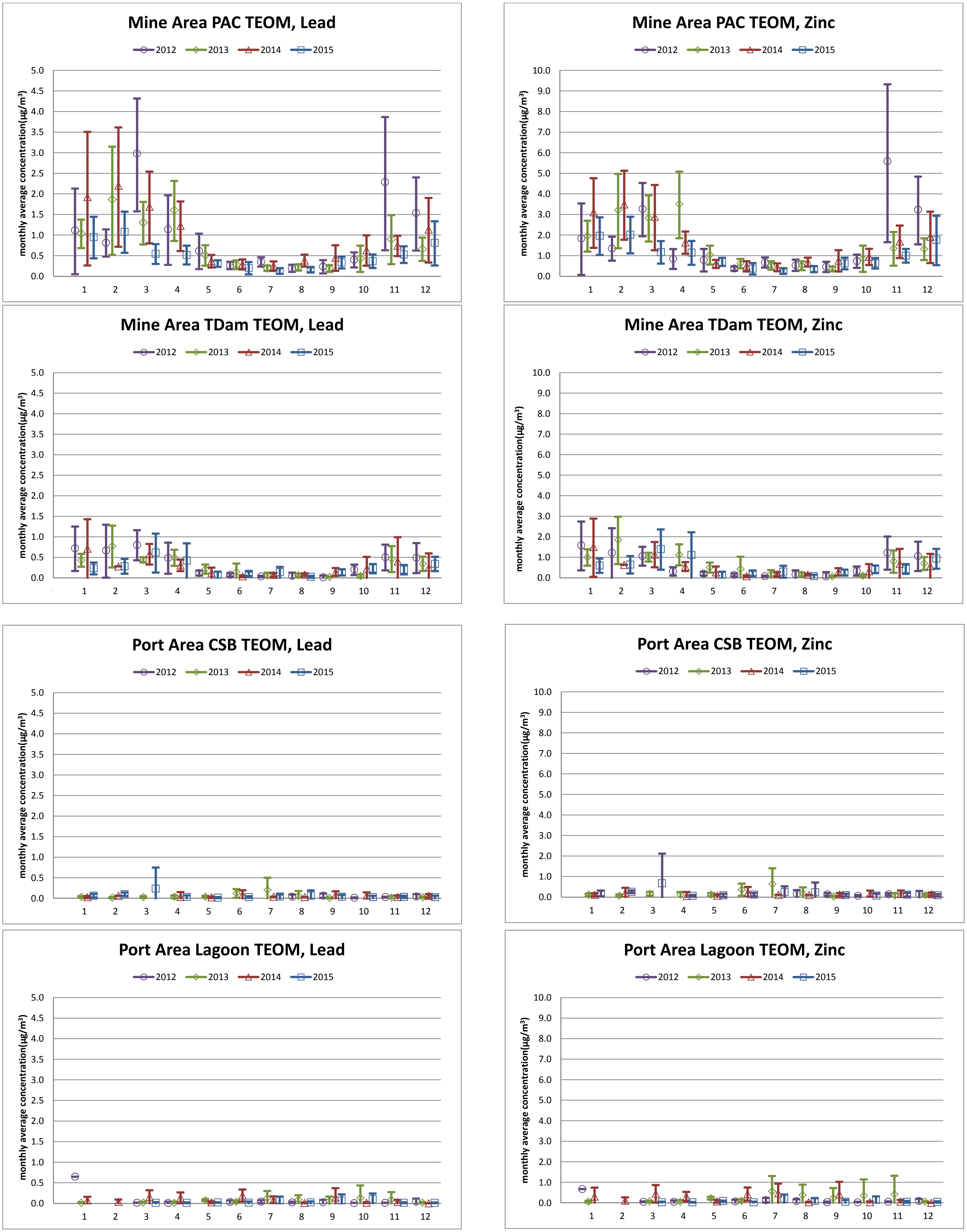


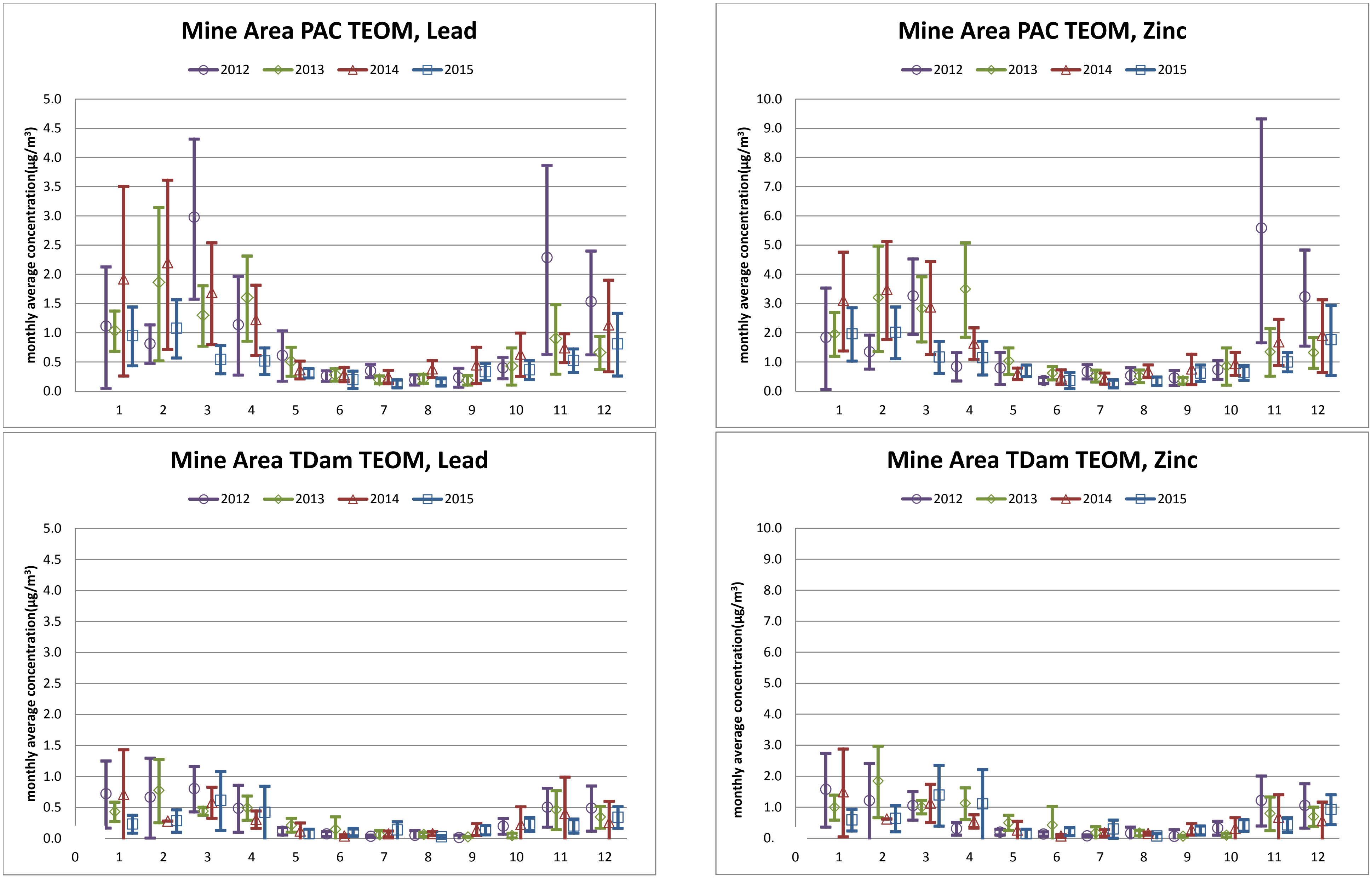
Figure 4. Mine TEOM locations

Figure 5. Port TEOM locations



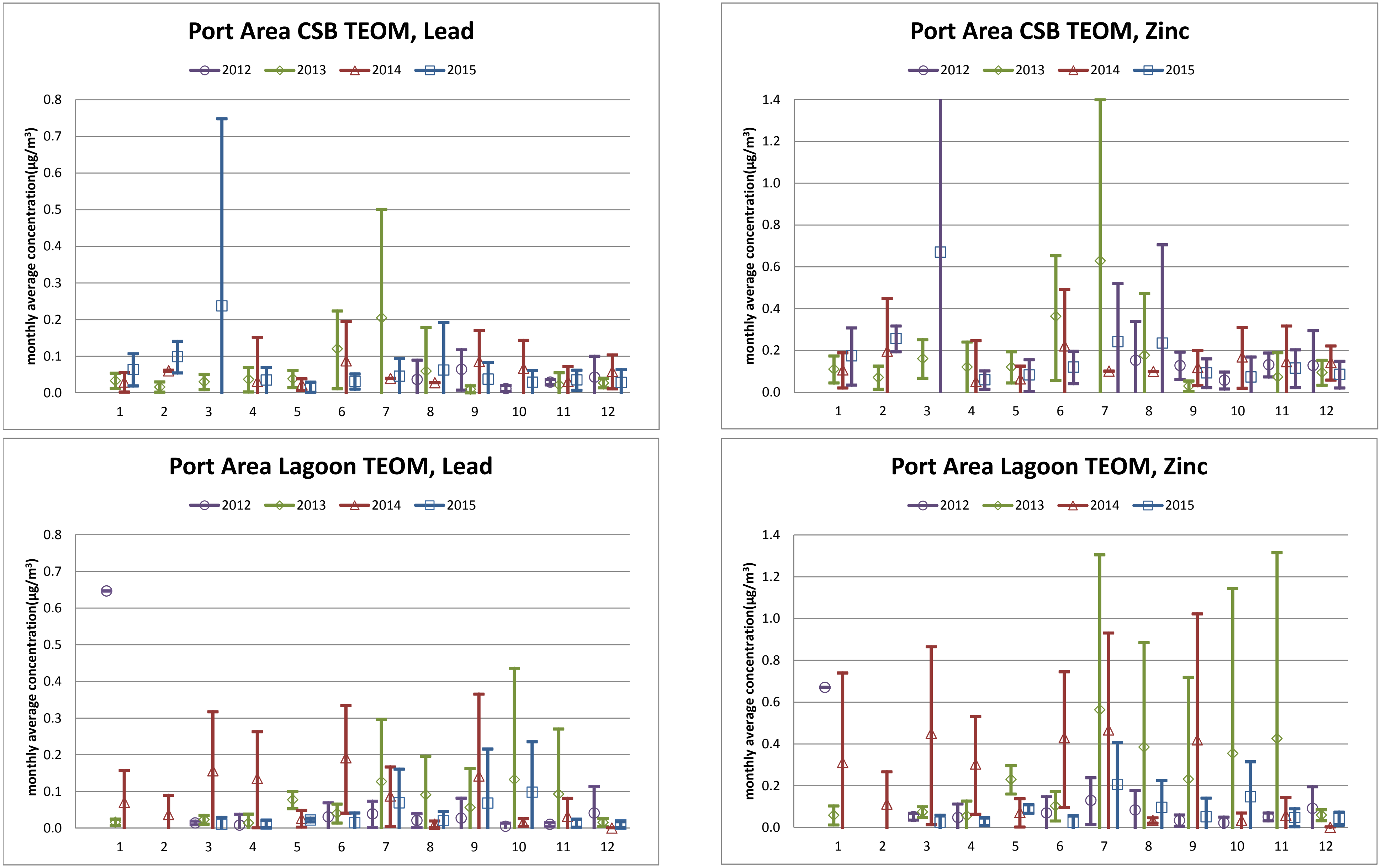
Note: Different vertical axis scales are used for lead and zinc, and for Mine and Port TEOMs.

Figure 6a. TEOM monthly monitoring data comparison, 2012-2015



Note: Different vertical axis scales are used for lead and zinc, and for Mine and Port TEOMs.

Figure 6b. Mine area TEOM monthly monitoring data comparison, 2012-2015



Note: Different vertical axis scales are used for lead and zinc, and for Mine and Port TEOMs.

Figure 6c. Port area TEOM monthly monitoring data comparison, 2012-2015

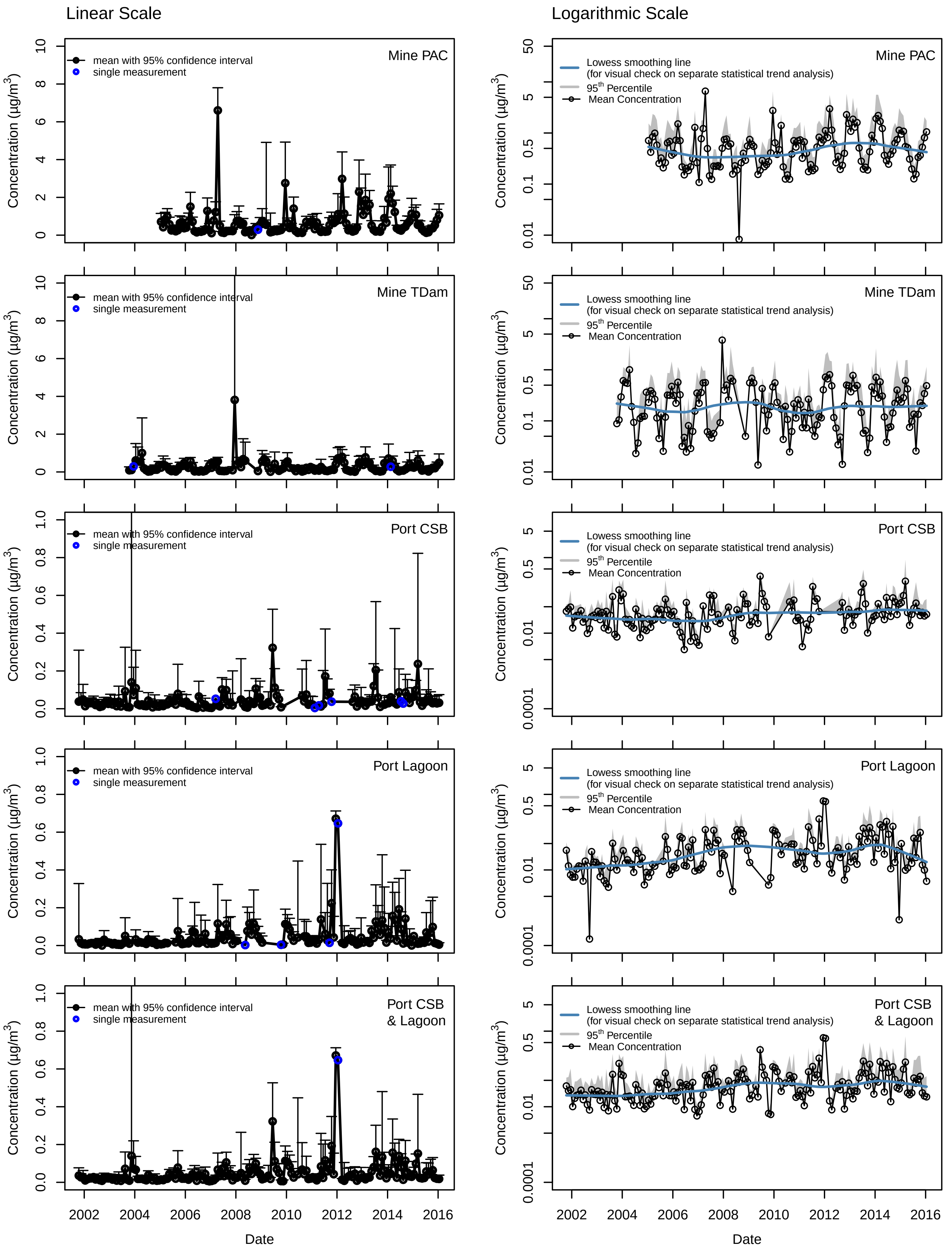


Figure 7a. TEOM Lead Concentration plots (all years)

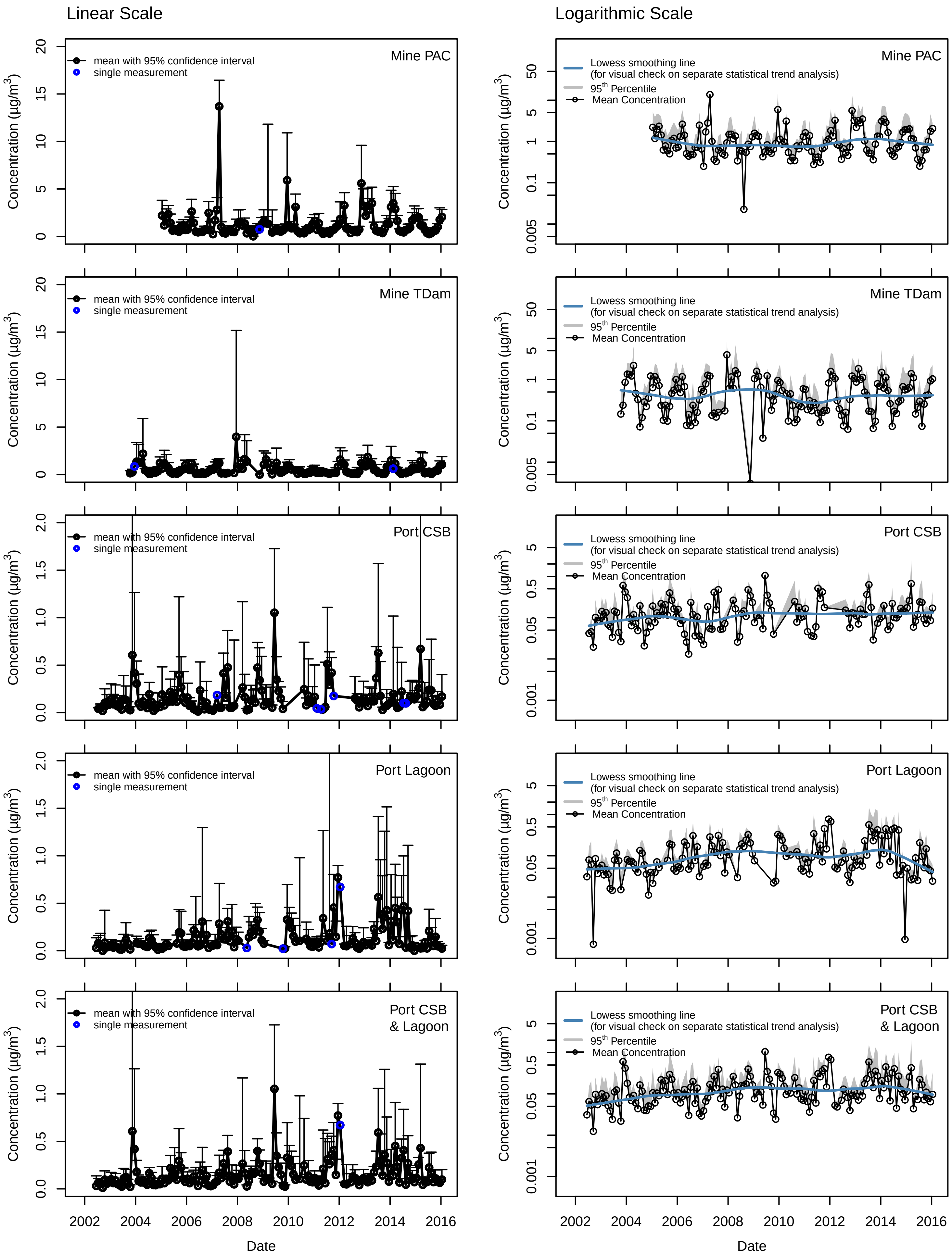


Figure 7b. TEOM Zinc Concentration plots (all years)

Lead

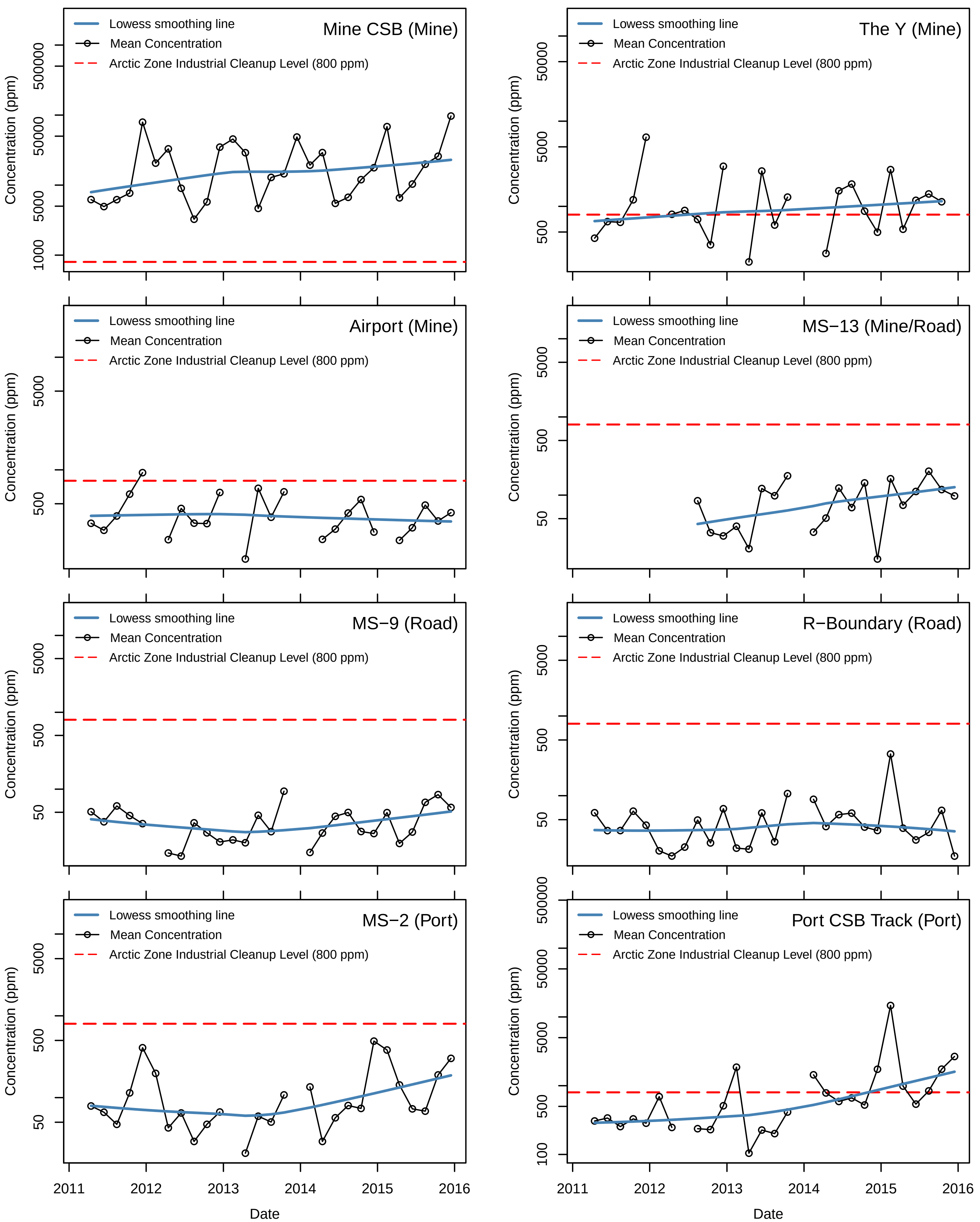


Figure 8a. Road Surface Lead Concentration plots (all years)

Zinc

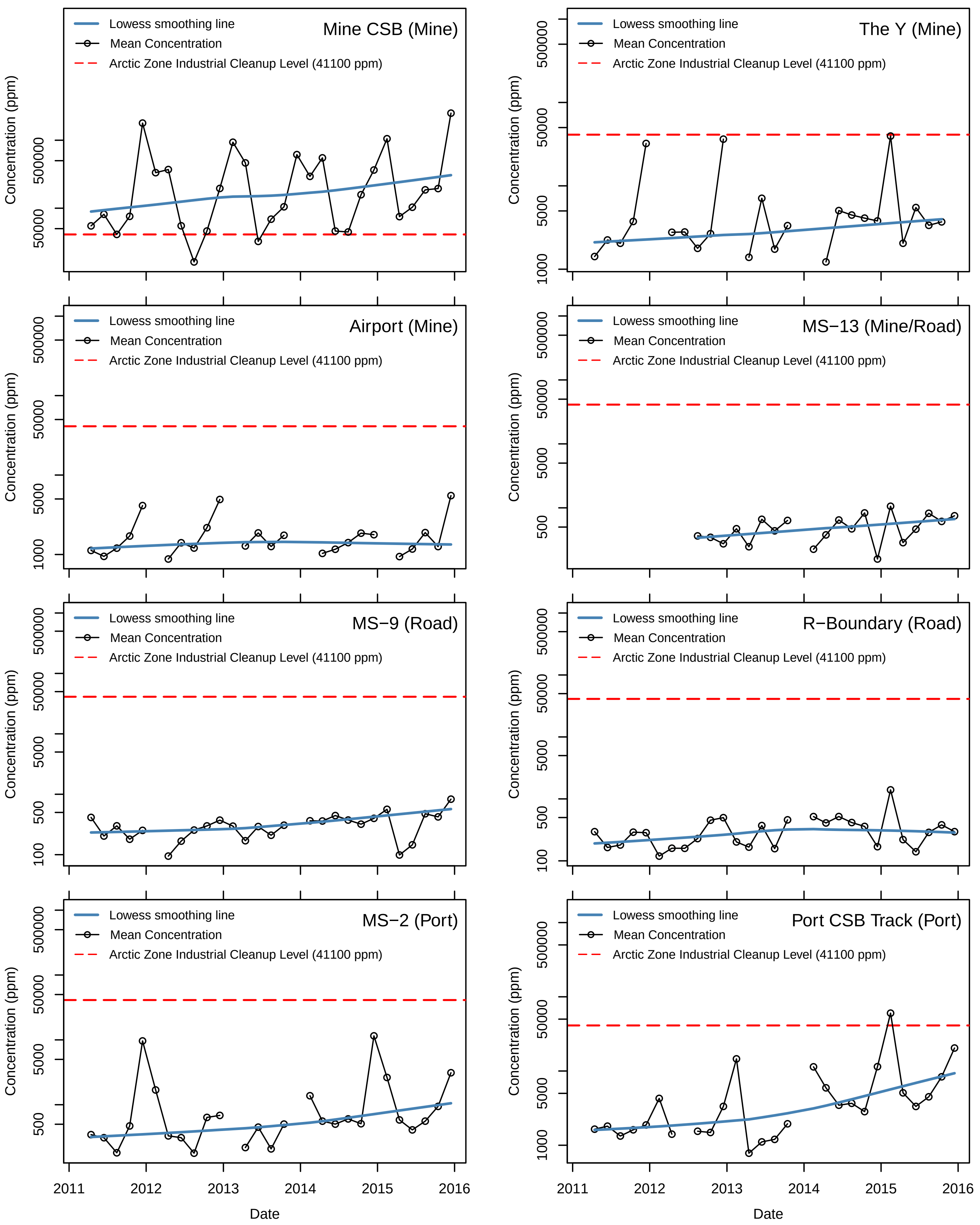


Figure 8b. Road Surface Zinc Concentration plots (all years)

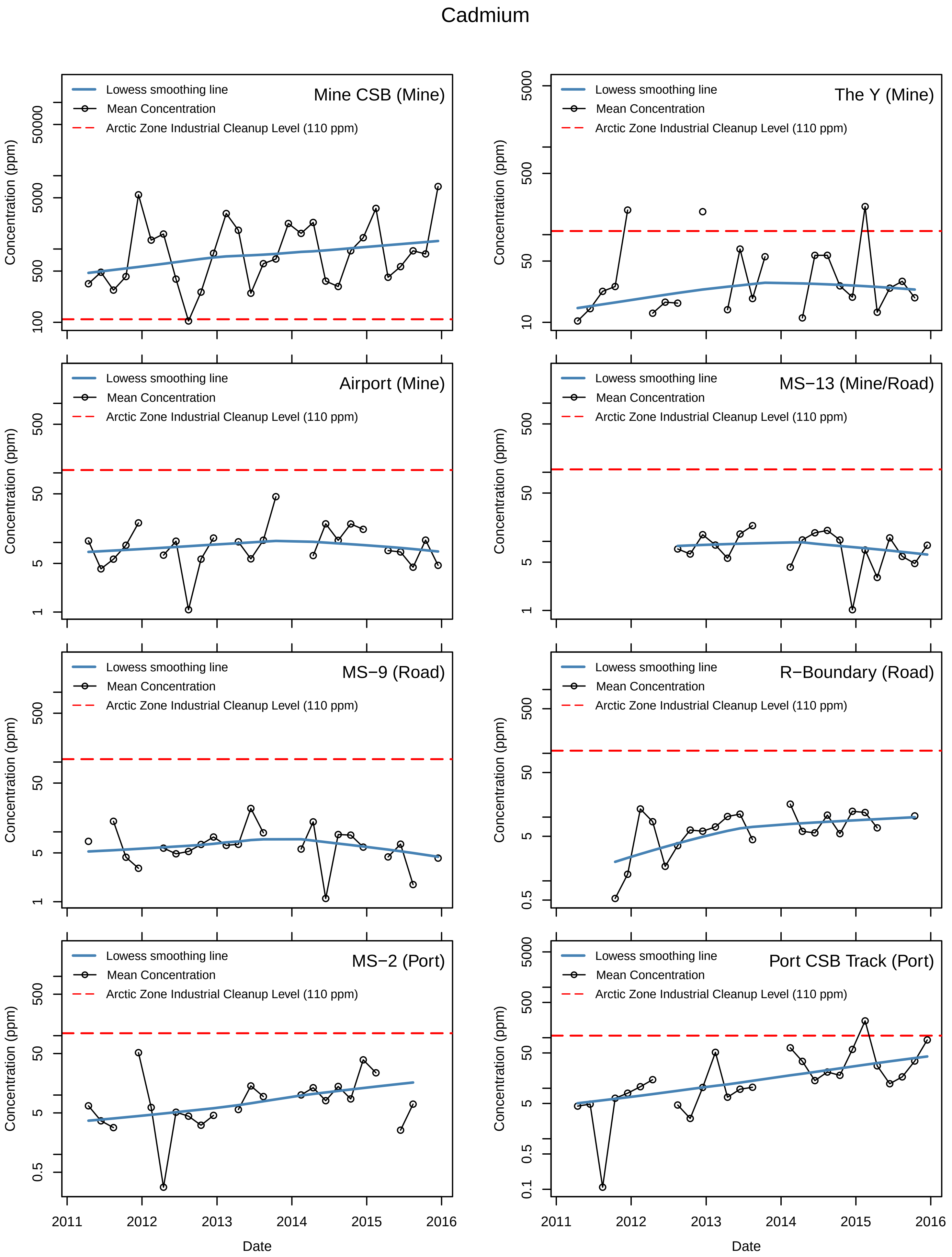


Figure 8c. Road Surface Cadmium Concentration plots (all years)

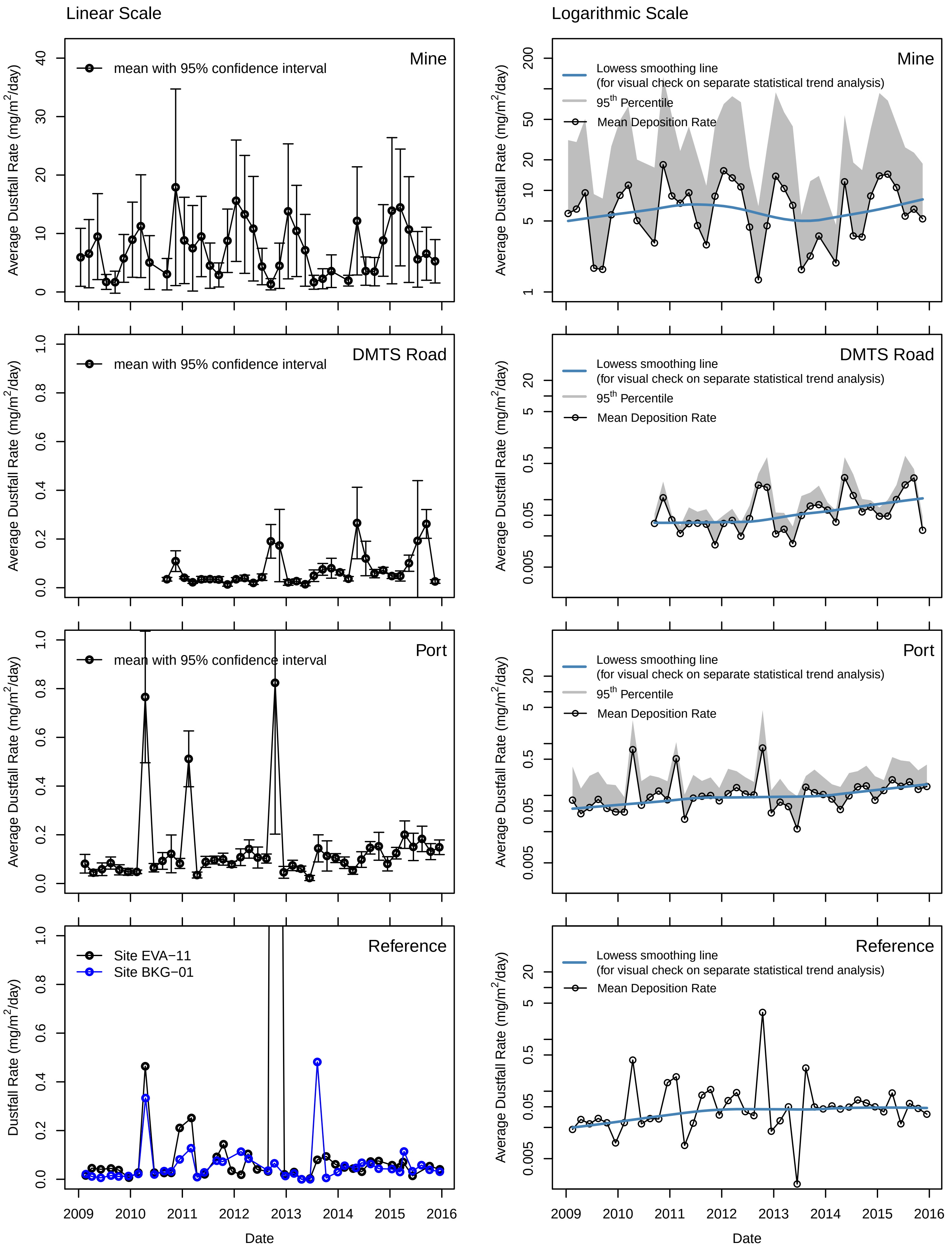


Figure 9. Dustfall Jars Lead Deposition Rate plots (all years)

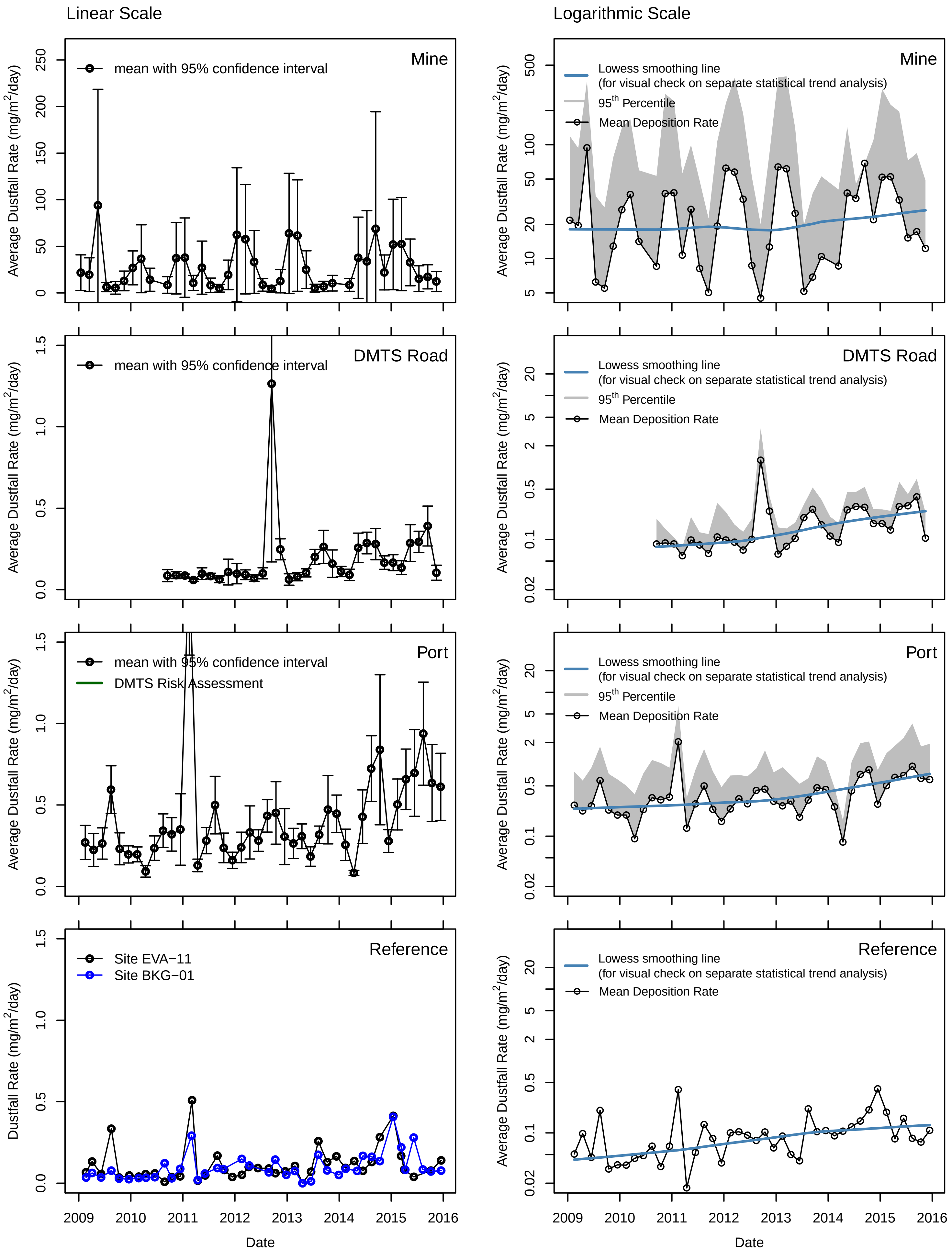


Figure 10. Dustfall Jars Zinc Deposition Rate plots (all years)

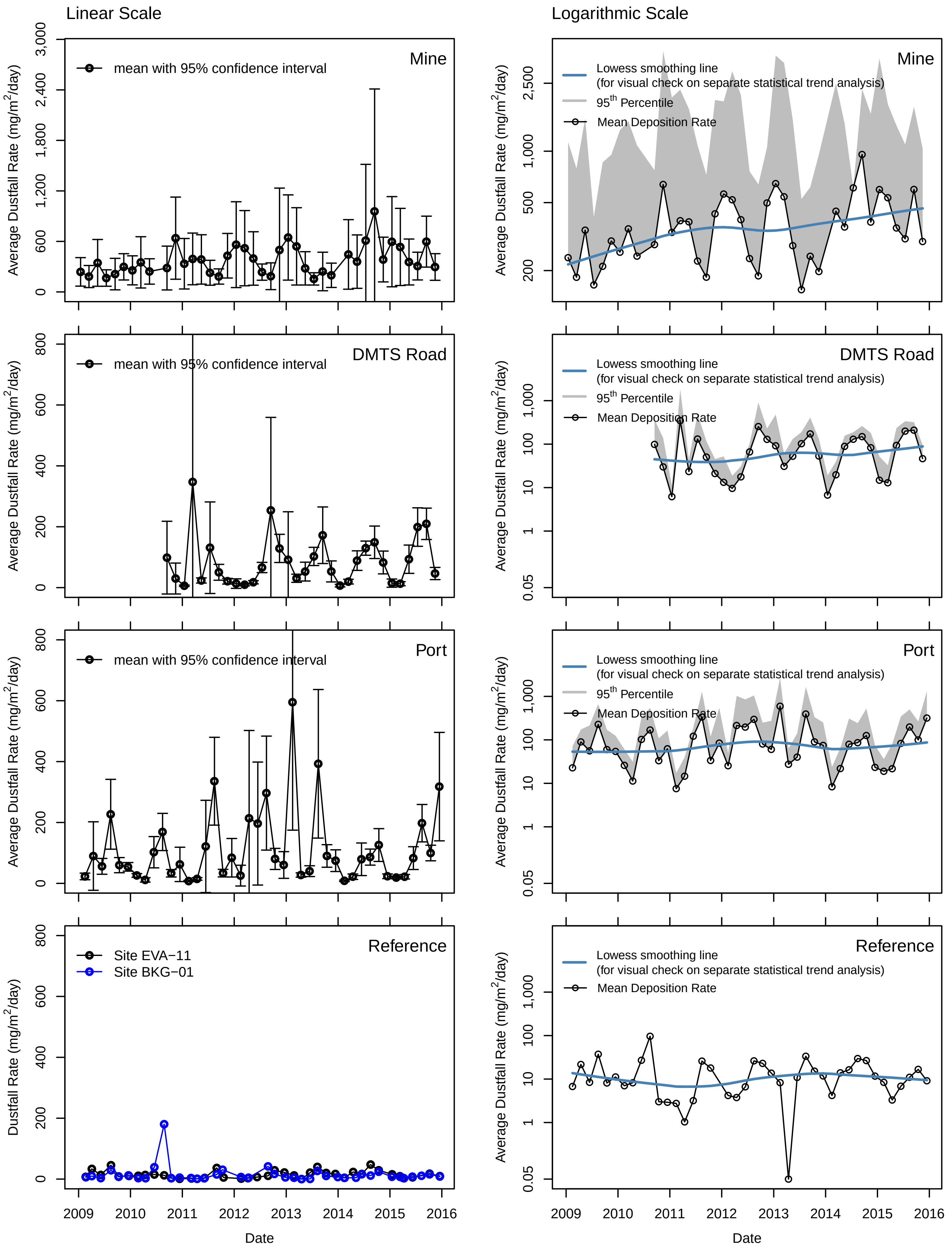


Figure 11. Dustfall Jars Solids Deposition Rate plots (all years)

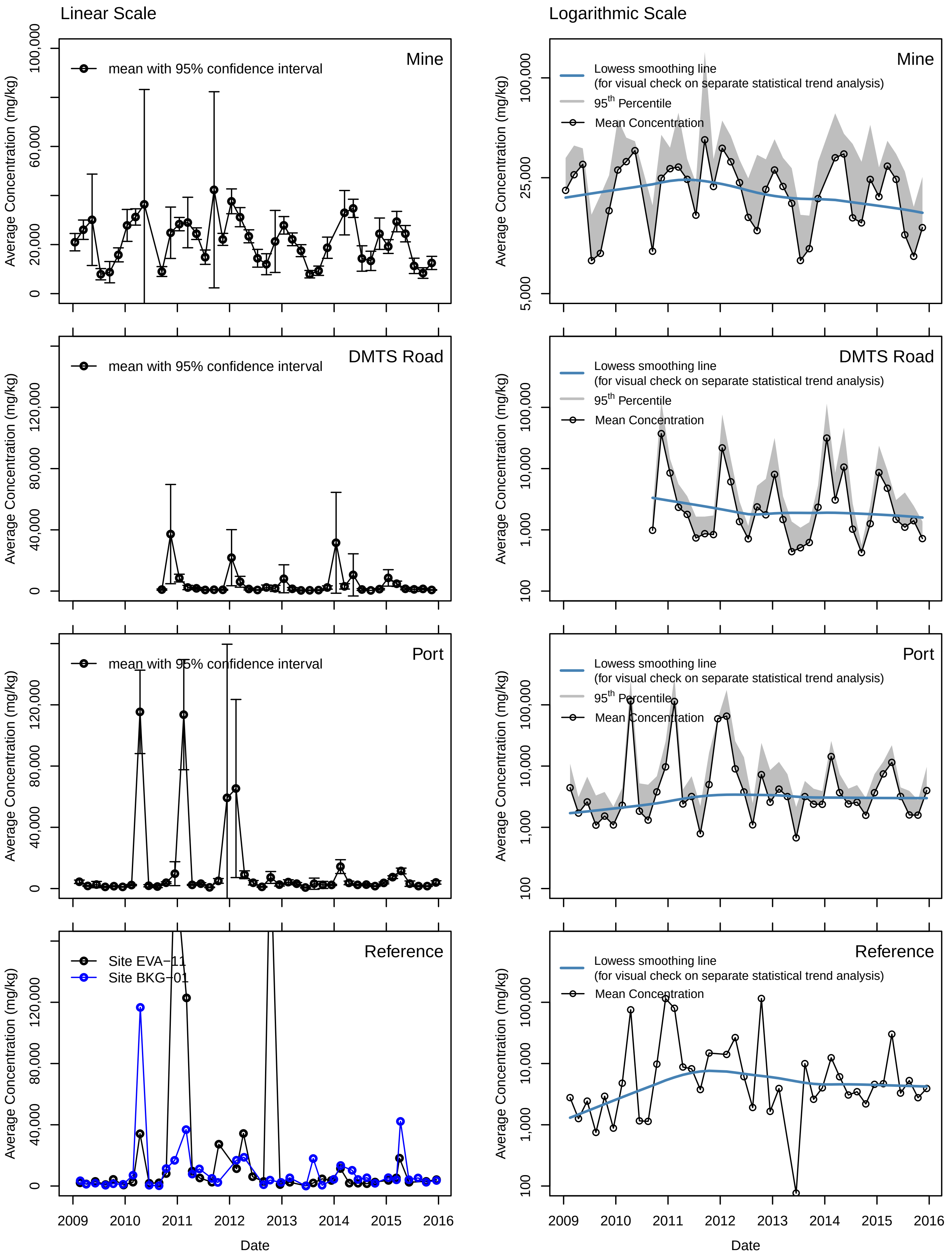


Figure 12. Dustfall Jars Lead Concentration plots (all years)

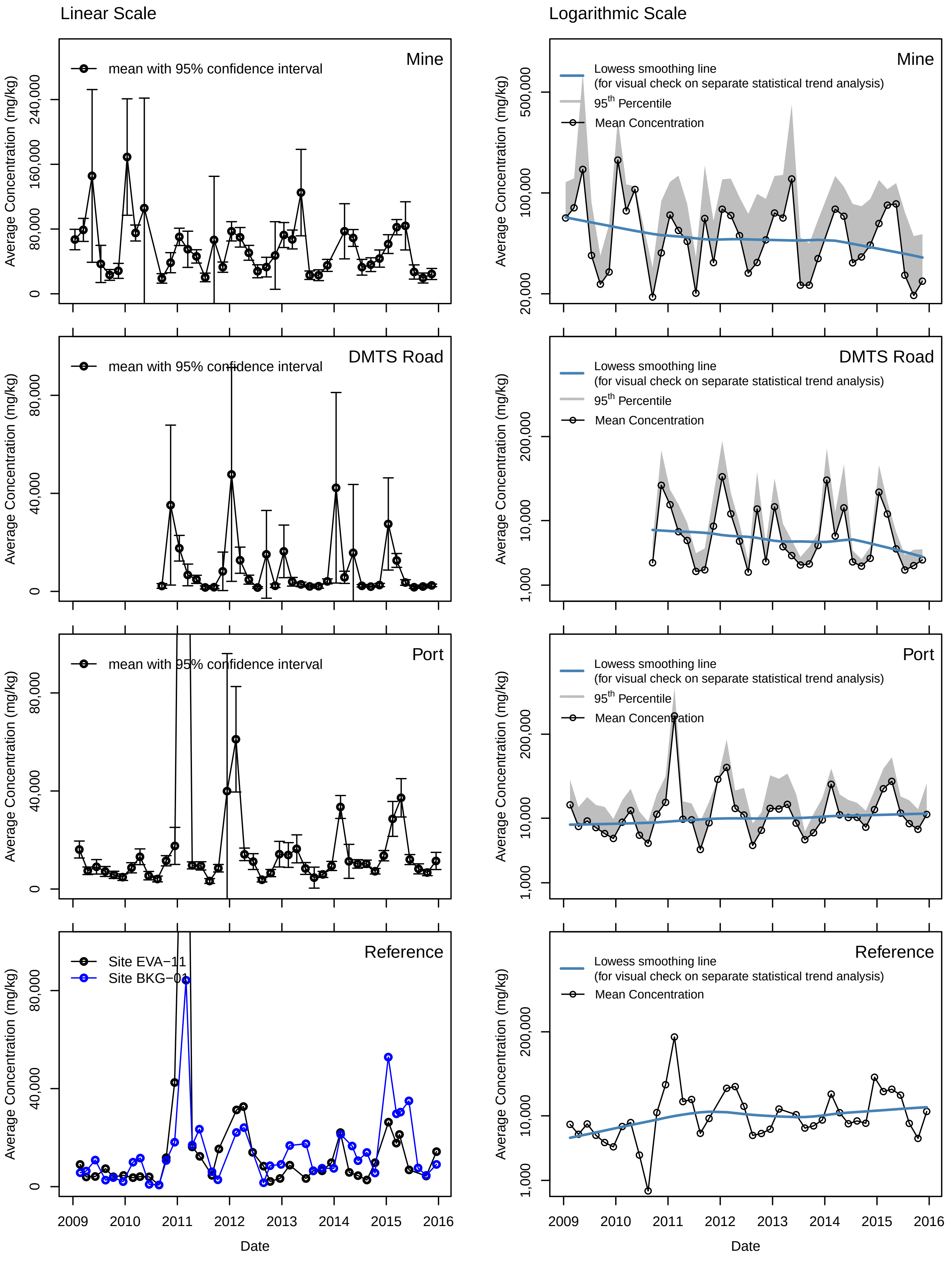


Figure 13. Dustfall Jars Zinc Concentration plots (all years)

Table 1. TEOM concentration statistical trend analysis (seasonal Mann Kendall trend test)

For 1/2012 - 12/2015; Mean concentration:

LEAD	Concentration ($\mu g/m^3$)		
	tau statistic	p value	significant trend?[a]
Mine PAC	-0.306	0.031	no
Mine TDam	-0.083	0.556	no
Port CSB[b]	0.067	0.699	no
Port Lagoon[c]	-0.048	0.752	no
Port CSB & Lagoon	0.061	0.680	no

ZINC	Concentration ($\mu g/m^3$)		
	tau statistic	p value	significant trend?[a]
Mine PAC	-0.222	0.117	no
Mine TDam	-0.056	0.695	no
Port CSB[b]	-0.067	0.699	no
Port Lagoon[c]	-0.111	0.461	no
Port CSB & Lagoon	-0.030	0.837	no

[a] Significant at p<0.05/2 (i.e., p<0.025 with Bonferroni adjustment because multiple [2] related hypotheses are tested).

[b] Excluded March data (see text for explanation)

[c] Excluded February data (see text for explanation)

For 1/2012 - 12/2015; Top 95% concentration:

LEAD	Concentration ($\mu g/m^3$)		
	tau statistic	p value	significant trend?[a]
Mine PAC	-0.222	0.117	no
Mine TDam	-0.056	0.695	no
Port CSB[b]	0.111	0.520	no
Port Lagoon[c]	-0.048	0.752	no
Port CSB & Lagoon	0.182	0.216	no

ZINC	Concentration ($\mu g/m^3$)		
	tau statistic	p value	significant trend?[a]
Mine PAC	-0.250	0.078	no
Mine TDam	0.083	0.556	no
Port CSB[b]	-0.156	0.367	no
Port Lagoon[c]	-0.111	0.461	no
Port CSB & Lagoon	0.121	0.409	no

[a] Significant at p<0.05/2 (i.e., p<0.025 with Bonferroni adjustment because multiple [2] related hypotheses are tested).

[b] Excluded March data (see text for explanation)

[c] Excluded February data (see text for explanation)

Table 2. Dustfall rate and concentration statistical trend analysis (seasonal Mann Kendall trend test)

For 1/2012 - 12/2015; Mean Deposition Rate and Concentration:

LEAD	Dustfall Desposition Rate ($mg/m^2/day$)			Concentration (mg/kg-total solid)		
	tau statistic	p value	significant trend?[a]	tau statistic	p value	significant trend?[a]
Mine	0.273	0.189	no	-0.212	0.307	no
Road	0.167	0.405	no	0.000	1.000	no
Port	0.333	0.096	no	0.000	1.000	no
Reference	-0.111	0.579	no	0.030	0.884	no

ZINC	Dustfall Desposition Rate ($mg/m^2/day$)			Concentration (mg/kg-total solid)		
	tau statistic	p value	significant trend?[a]	tau statistic	p value	significant trend?[a]
Mine	0.091	0.662	no	-0.091	0.662	no
Road	0.389	0.052	no	-0.111	0.579	no
Port	0.500	0.013	yes; increasing	0.167	0.405	no
Reference	0.278	0.166	no	0.212	0.307	no

TOTAL SOLIDS	Dustfall Desposition Rate ($mg/m^2/day$)		
	tau statistic	p value	significant trend?[a]
Mine	0.091	0.662	no
Road	0.167	0.405	no
Port	-0.111	0.579	no
Reference	-0.056	0.782	no

[a]Significant at p<0.05/3 (i.e., p<0.017 with Bonferroni adjustment because multiple [3] related hypotheses are tested).

For 1/2012 - 12/2015; Top 95% Deposition Rate and Concentration:

LEAD	Dustfall Desposition Rate ($mg/m^2/day$)			Concentration (mg/kg-total solid)		
	tau statistic	p value	significant trend?[a]	tau statistic	p value	significant trend?[a]
Mine	0.212	0.307	no	-0.091	0.662	no
Road	0.222	0.267	no	-0.111	0.579	no
Port	0.278	0.166	no	-0.167	0.405	no

ZINC	Dustfall Desposition Rate ($mg/m^2/day$)			Concentration (mg/kg-total solid)		
	tau statistic	p value	significant trend?[a]	tau statistic	p value	significant trend?[a]
Mine	0.212	0.307	no	-0.152	0.466	no
Road	0.278	0.166	no	-0.167	0.405	no
Port	0.444	0.027	no	0.167	0.405	no

TOTAL SOLIDS	Dustfall Desposition Rate ($mg/m^2/day$)		
	tau statistic	p value	significant trend?[a]
Mine	-0.152	0.466	no
Road	0.000	1.000	no
Port	-0.056	0.782	no

[a]Significant at p<0.05/3 (i.e., p<0.017 with Bonferroni adjustment because multiple [3] related hypotheses are tested).

Table 3. Summary of dust monitoring trends

For 1/2012 - 12/2015

Location and Measure	TEOM (Air Concentrations) Mean Concentration		95th Percentile	
	Pb	Zn	Pb	Zn
Mine Tdam (Conc.)	—	—	—	—
Mine PAC (Conc.)	—	—	—	—
Port CSB (Conc.) [b]	—	—	—	—
Port Lagoon (Conc.) [c]	—	—	—	—
Port CSB & Lagoon (Conc.)	—	—	—	—

Location and Measure	Dustfall Jars (concentration and deposition rate) Mean Concentration			95th Percentile		
	Pb	Zn	Solids	Pb	Zn	Solids
Mine (Conc.)	—	—	a	—	—	a
Mine (Rate)	—	—	—	—	—	—
Road (Conc.)	—	—	a	—	—	a
Road (Rate)	—	—	—	—	—	—
Port (Conc.)	—	—	a	—	—	a
Port (Rate)	—	↗	—	—	—	—
Reference (Conc.)	—	—	a			
Reference (Rate)	—	—	—			

[a] Concentration is not evaluated for solids, because total solids is the entire sample mass.
[b] Excluded March data (see text for explanation)
[c] Excluded February data (see text for explanation)

Notes:

—	Indicates no statistically significant change over time period tested (trend is FLAT).
↗	Indicates a statistically significant increase over time period tested (trend is UP). Slope is proportional to the strength of the trend.
↘	Indicates a statistically significant decrease over time period tested (trend is DOWN). Slope is proportional to the strength of the trend.

TEOM = tapered element oscillating microbalance (air sampling device)
Conc = air concentration (TEOM air sampling) or concentration in dustfall (dustfall jars)
Rate = dustfall deposition rate based on dustfall jar measurements
Tdam = mine tailings dam
PAC = personnel accommodations complex
CSB = concentrate storage building

1. Results are summarized from statistical test results in Tables 1 and 2 for air concentrations, concentrations in dustfall, and dustfall rates, respectively.
2. Results are presented for statistical testing using data from the past four years.