Fugitive Dust Risk Management Plan
2013 Annual Report

Red Dog Mine
Teck Alaska Incorporated
November 2014

Teck

Contents

Figures, Tables, and Attachments 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 2013. 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 2013 included regularly scheduled village visits, meetings with NANA, the Subsistence Committee, and other stakeholders and organizations who expressed an interest in mine operations. A review of Ikayuqtit Team (IT) technical workgroup membership and activity was undertaken, and outreach efforts made to confirm workgroup members' continued interest in participation, or to identify a replacement representative to the group if needed. Additionally, the Red Dog Alaska website was updated to include a report on the 2013 berry and water study (Exponent 2013) and the 2012 Annual Report (Teck 2013), which were issued during the year. A variety of other outreach, engagement, and educational efforts were undertaken in 2013, including the addition of a local observer during the berry and water sampling effort, and IT workgroup reviews of several documents.

The Dust Emissions Reduction Plan describes current dust reduction efforts underway at the mine. Dust emissions reduction activities during 2013 included purchase of a polymer dust control agent for use on exposed tailings beaches, use of a new helicopter-based dispersal system for application of dust control agents, and identification of a replacement dust control

agent for use in future years, as the polymer product purchased in 2013 will no longer be offered by the manufacturer. In addition, research and review of new dust control methods and technologies is ongoing.

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 2013 included follow-up remediation activities at a zinc concentrate spill site at Mile 34.5 on the DMTS road, monitoring of revegetation at Material Site 10, and monitoring of revegetation methods being tested on the oxide stockpile within the mine boundary.

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 2013, 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. Uncertainty reduction studies implemented in 2013 included sampling of berries to address uncertainty about the timing and proximity to rain events of previous berry sampling in 2004, and also to evaluate temporal differences between 2004 and 2013; and sampling of water from Umayutsiak Creek to the south of the port site to confirm safety for subsistence use during hunting and harvesting activities.

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 2013, 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 2013, the following monitoring programs were implemented:

- **Monitoring Programs for DEC Oversight.** Preparations were made for monitoring scheduled in 2014, in particular, marine sediment monitoring and soil monitoring.

- **Operational Monitoring.** Operational monitoring implemented in 2013 included 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, dustfall jar monitoring at the mine, road, and port, and vegetation community monitoring.

Results from the monitoring programs largely indicate that concentration trends are flat (i.e., no increasing or decreasing trend). Historical data for a few of the programs showed an increasing trend, however, data from the last three years (2010-2013) indicate that trends are flat. In one measure, lead concentration in mine area dustfall jars, the trend is downward in the last three years. 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, and to summarize current conditions and current understanding of risks, with reference to the baseline conditions in the fugitive dust risk assessment (Exponent 2007).

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)

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

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 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.

[2] Plants and animals

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)

[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).

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

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

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 the two programs that require DEC oversight, and as such, the results of these programs will be formally documented in separate reports to DEC after each monitoring event. These two programs will provide DEC with the opportunity to continue oversight and implement enforcement actions as needed. In addition, these two monitoring programs 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 monitoring programs that are to be reviewed by DEC CSP are identified in the "Monitoring Programs for DEC Oversight" section below, within the "Monitoring Actions" section.

Report Organization

The annual report summarizes work that was conducted during the 2013 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 2013.

Risk Management Actions Taken in 2013

The following sections of this 2013 annual report summarize each implementation plan, the corresponding risk management objectives, and the actions taken during the 2013 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 2013 are outlined below.

Communication Actions in 2013. The following actions were taken in 2013 in order to increase communication and participation, and to ensure that information is being communicated to all stakeholders in the most effective manner:

- **Community Meetings.** Continuation of regularly scheduled village visits and quarterly meetings with the Subsistence Committee. Verbal suggestions and comments received during village visits are documented and tracked to ensure that appropriate responses are provided to the interested parties and that suggestions are incorporated into risk management activities where appropriate.
- **Review of the ITW Membership.** The Ikayuqtit Team, in particular the Ikayuqtit Technical Workgroup (ITW), has provided invaluable assistance in the development and review of the RMP and the associated Implementation Plans. Teck anticipates that the group will continue to provide assistance in the development, review, and implementation of upcoming monitoring, uncertainty reduction, and other RMP related tasks. In 2013, the Ikayuqtit Technical Workgroup membership was reviewed, and attempts were made to reconfirm members' interest in continued participation. Those members wishing to discontinue participation were encouraged to nominate a

replacement to ensure that all interested stakeholder groups are represented.[4] This engagement with members will be implemented yearly, as part of an ongoing effort to ensure effective participation and engagement.

- **ITW Review of Caribou Cooking Study Plan Outline.** Members of the ITW were notified on October 23, 2013 of a study outline for a caribou study related to uncertainties regarding metals exposure through bone marrow consumption. Their review of the study outline was solicited, and associated comments were requested. A detailed work plan for the study is anticipated in 2015, and is discussed in the later section titled "Uncertainty Reduction Actions".
- **ITW Review of Berry and Water Sampling Plan.** Members of the ITW were invited to review and comment on the draft version of the Berry and Water Sampling Plan on July 12, 2013. This study was completed in August 2013 and is described in the section titled "Summary of the Uncertainty Reduction Program".
- **Outreach and Education.** Outreach and education actions are focused on providing additional opportunities for stakeholders to gain more understanding of and participation in Red Dog operations as a whole, and health and environmental efforts in particular. The following education and outreach actions occurred during 2013:
  - A local resident named Dawn Schaeffer was included as a third party observer during the berry and water sampling studies that were conducted in August 2013.
  - In-kind funding was provided to Alaska Department of Fish and Game (DFG) for their fish monitoring studies.
  - The 2012 Risk Management Plan Annual Report was announced in the Arctic Sounder.

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

[4] Stakeholder groups in the Ikayuqtit Team include AIDEA, consultants, federal agencies, local and regional governments and authorities (Kivalina, Kotzebue, Noatak, Maniilaq), NANA, environmental non-governmental organizations, Red Dog Subsistence Committee, Alaska state agencies, and Teck Alaska Incorporated. Additional discussion of stakeholder engagement can be found in the risk management plan and communication plan (Exponent 2008, 2010).

amount of fugitive dust released into the environment near the DMTS and Red Dog Mine to protect human health and the environment."

Dust Emissions Reduction Actions in 2013. Dust reduction actions taken in 2013 included the following:

- **Purchase of New Dust Control Agent.** In 2013, a polymer dust control product (LSP-1000C manufactured by 3M) that was tested in 2012 was purchased and applied to areas needing dust control (e.g., exposed tailings beaches within the tailings impoundment).
- **Dust Control Planning.** A new dust suppression product made using guar gum (Earthbound Scientific made by Terra Novo, Inc.) was evaluated and selected to replace the previous polymer product that was discontinued by 3M (LSP-1000C). Dust suppression applications to the tailings beach areas are scheduled to take place in 2014 using the helicopter-based spray dispersal system.

Dust control and reduction efforts as well as research into new methods and technologies are ongoing. 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.

Remediation and/or Reclamation Actions in 2013. There were no concentrate spills in 2013. However, other remediation and reclamation activities occurred in 2013, including the following:

- **Mile 34.5 Zinc Concentrate Spill Follow-up.** On March 15, 2011, a zinc concentrate spill occurred at Mile 34.5 on the DMTS road. The majority of the contaminated material was removed in the fourth quarter of 2012. Several efforts were required to achieve the state industrial cleanup levels for zinc, lead and cadmium in fall 2013. Additional backfilling and reclamation is planned for this area in the near future.

- **Monitoring of Reclamation at Material Site 10.** Seedlings are filling in the site, however, there were some signs that gravel from road was washing into the site and slowing down revegetation efforts. In 2014 there may be some site maintenance work performed to reduce erosion and encourage more seedling growth at the site.
- **Monitoring of Revegetation Methods Testing on the Oxide Stockpile.** In 2013, the oxide stockpile at the Red Dog Mine was revegetated as an initial effort to test the utility of Kivalina shale overburden material as cover growth media, and to document a successful seed mix and best revegetation techniques to be used for disturbed land surrounding the mine. In 2012 the first post-revegetation evaluation was conducted. The site was monitored in 2013, and although plants were doing well, there is some erosion occurring on the east slope. Teck is considering adding armored channels to the east slope to prevent additional erosion.

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.

Worker Dust Protection Actions in 2013. Worksite blood lead monitoring was conducted in 2013 by the Safety & Health and Medical departments. 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 2013, all blood lead monitoring results indicated exposures were below both the MSHA/OSHA standards and the more stringent Red Dog standards (summarized below).

	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."

Uncertainty Reduction Actions in 2013

Work was conducted on the following uncertainty reduction studies in 2013:

- **Salmonberry Sampling**. During the summer of 2013, salmonberries were collected as part of an ongoing effort to reduce uncertainties regarding the assessment of the effects of fugitive dust on humans and the environment. The berry sampling was a one-time event conducted to address uncertainty about the timing and proximity to rain events of previous berry sampling in 2004, and also to evaluate temporal differences between 2004 and 2013. Results indicated that metals concentrations in the salmonberries collected in 2013 were the same as or significantly less than reference concentrations. There were no significant differences between concentrations in unwashed and washed berry samples, consistent with sampling completed in 2004. Results of the study confirm that continued subsistence harvesting of berries remains safe (Exponent 2013). Additionally, it should be noted that because access restrictions remain in place prohibiting harvesting in areas within the port and road ambient air boundaries, berries were not sampled in those areas. The full report is available at www.RedDogAlaska.com.

- **Umayutsiak Creek Water Sampling Study**. Water data used in the human health risk assessment was for samples from creeks that cross the DMTS road, which is the water that is potentially most affected by dust or runoff from the DMTS. Results of the risk assessment showed that water provides a relatively small contribution to overall metals exposure for humans and wildlife. The use of these data was considered to be protective of other drinking water sources. However, in August 2013, water quality at Umayutsiak Creek, to the south of the port site, was assessed to provide increased confidence in the results and protectiveness of the risk assessment related to water consumed during subsistence harvesting activities. The results of the 2013 sampling confirm previous findings that metals concentrations in water are low. Risks calculated using stream water from Umayutsiak Creek as a drinking water source are indistinguishable from (or less than) the very low risks calculated in the DMTS risk assessment. The full report is available at www.RedDogAlaska.com.

- **Caribou Cooking Study Outline**. 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 draft outline of the study plan was developed in 2013. A detailed study plan is anticipated to be issued for review by stakeholders in 2014, and will be posted to www.RedDogAlaska.com.

Monitoring Actions

The Monitoring Plan (recently revised, see Exponent 2014) 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 2014) 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 2013. 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

Marine Sediment Monitoring

No marine sediment monitoring was conducted in 2013. The next marine sediment monitoring event is scheduled for 2014 (Figure 2). The purpose of the marine sediment sampling program is to measure and track over time the concentration and distribution of metals in marine sediments in the vicinity of the port shiploader (Figure 3). According to the monitoring plan sampling protocol (Exponent 2014), because cadmium, lead and zinc concentrations did not exceed the ER-Ls at more than one station for more than two annual monitoring events in a row in 2010 and 2012, monitoring continues on a biennial basis, with the next marine sediment monitoring sampling event scheduled for 2014.

Soil Monitoring

No soil monitoring was conducted in 2013. Based on discussions with DEC in 2013, soil monitoring was added as new monitoring program for risk management purposes. In 2013, sampling protocol development began, and was published in the revised monitoring plan (Exponent 2014). Soil monitoring will occur for the first time in summer 2014, and will occur once every three years, at the same frequency (Figure 2) and locations (Figure 3) as vegetation monitoring.

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 2013; therefore there is no additional VEE monitoring to report for 2013.

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[5] 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. Calculated monthly averages of 2011, 2012, and 2013 TSP-Pb and TSP-Zn concentrations are shown for each TEOM location on Figure 6. Observations regarding the concentration plots are described below, followed by statistical analysis to assess possible trends.

- **Mine TEOM Results.** Lead and zinc concentrations were 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.** Lagoon TEOM lead and zinc concentrations were highest from July through November, corresponding with the peak shipping season. CSB TEOM lead and zinc concentrations were highest in June, July, and August. Compared with the CSB TEOM results, Lagoon TEOM results may reflect greater vehicular activity in the areas near the Port offices and accommodations buildings, as well as shipping container and bulk fuel storage areas.

Statistical Trend Analysis for TEOM Data. Statistical testing methods were used to evaluate whether TEOM datasets have statistically significant temporal trends in metals concentrations.[6]

[5] 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.

[6] Seasonal Mann Kendall tau testing was used to evaluate TEOM monthly averages of lead, zinc, and total solids concentrations, with consideration of the seasonality of data. The testing was used to assess whether a statistically significant monotonic trend was present. A "monotonic trend" is a trend that is consistent in direction, either increasing or decreasing (accounting for seasonality in this case). The significance level was evaluated using the Bonferroni correction for multiple hypothesis testing (Weisstein 2014). The specific p-values used are presented in the tabular results.

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. Test results are presented both for “all years of available data” and for the most recent three years.

Statistical analysis of longer-term data indicates that the Port Lagoon TEOM has historically had a significant increasing trend.in both lead and zinc concentrations (Table 1), which is visually observable in earlier years plotted on Figures 7 and 8. However, for the most recent three year period (2011 through 2013), Figures 7 and 8 show relatively stable concentrations, and statistical analysis found no significant trend in lead or zinc concentrations at any of the four TEOM locations during that period (Table 1).

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.

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. Results for stations outside the mine boundary do not exceed Arctic Zone Industrial Cleanup Levels for lead, zinc, or cadmium over the time period 2011-2013 (Figures 9, 10, and 11).

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[7]) for more than two consecutive sampling periods, that road section is to be remediated and resurfaced as described in the Remediation Plan (Exponent 2011). 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).

Dustfall Jar Monitoring

Dustfall jars have been in use at the mine since 1999 as passive continuous collectors for measuring dust deposition. Samples are collected every two months. Approximately 86 dustfall stations are located around the mine, port, and DMTS road (Figure 3), as follows:

- At the mine, approximately 34 jars are placed in locations around the facilities.
- 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.
- At the port, 38 jars are placed roughly in a rectangular grid throughout the area.
- 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 (see Figure 3).

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[7] 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.

Dustfall deposition rates (total solids, lead, and zinc in Figures 12, 13, and 14, and Figure 15, 16, and 17) and dustfall metals concentrations (lead and zinc in Figures 18 and 19) suggest that dustfall rates and concentrations have remained in a similar range from year to year, with a few exceptions discussed below in the presentation of statistical trend test analyses.

Lead concentrations in dustfall typically range from 5-40 mg/kg in the mine area dustfall jars, 0-10 mg/kg along the road, 0-20 mg/kg at the port, and 0-20 at the reference site, with a few outliers in each area (Figure 15). Zinc concentrations in dustfall typically range from 20-150 mg/kg in the mine area dustfall jars, to approximately 0-20 mg/kg along the road, 0-20 mg/kg at the port, and 0-20 at the reference site, with a few outliers in each area (Figure 16).

Statistical Trend Analysis for Dustfall Jar Data. Statistical testing methods were used to evaluate whether dustfall datasets have statistically significant temporal trends in deposition rates or metals concentrations.[8]

Results of the statistical trend tests are summarized in Table 2 for dustfall rate (lead, zinc, and total dustfall) and dustfall concentrations (lead and zinc), in four areas (mine, road, port, and reference). Test results are presented both for “all years of available data” and for the most recent three years.

Lead. For lead, both dustfall rate and concentrations in dustfall have been stable (no increasing or decreasing trend) in all areas, except for the mine area, where in the most recent three years, concentrations of lead in dustfall are in a significant downtrend. Time series plots of lead dustfall rates and concentrations (Figures 15 and 18) were visually evaluated and found to be consistent with the statistical test results.

[8] Seasonal Mann Kendall tau testing was used to evaluate monthly averages of lead, zinc, and total solids dustfall rates and concentrations, with consideration of the seasonality of data. The testing was used to assess whether a statistically significant monotonic trend was present. A “monotonic trend” is a trend that is consistent in direction, either increasing or decreasing (accounting for seasonality in this case). The significance level was evaluated using the Bonferroni correction for multiple hypothesis testing (Weisstein 2014). The specific p-values used are presented in the tabular results.

Zinc. For zinc, a significant increasing trend in dustfall rate is indicated at road and reference locations over the full time period evaluated, but no significant trend was identified for the three most recent years. Other areas were statistically unchanged for zinc dustfall rate, and there were no significant trends identified for zinc concentration in dustfall. Time series plots of zinc dustfall rates and concentrations (Figures 16 and 19) were visually evaluated and found to be consistent with the statistical test results. Figure 16 suggests that the zinc deposition rate has been increasing since the 2010-2011 time frame. The shape of the curve on the log scale plot is similar to that for zinc deposition rate in the road area. This similarity may be indicative of some degree of road area influence on reference dustfall measurements. However, there is significant variability in the data, and currently there are only two jars in the reference data set, one jar at each of two locations (see Figure 1). These apparent trends will be further evaluated following the installation of additional dustfall jars in the reference area in 2015, and subsequent monitoring data collection.

Total Solids. For total solids, no statistically significant trends in dustfall rate were identified for either the full time-frame evaluated, or for the most recent three years, in any of the four areas evaluated. Time series plots of total solids dustfall rates (Figure 17) were visually evaluated and found to be consistent with the statistical test results.

Vegetation Community Monitoring

One way in which the environment surrounding the mine, road, and port facilities is monitored for potential effects of fugitive dust deposition is through vegetation community monitoring. An array of established community survey sites located around the mine, road, and port (see Figure 3) are monitored periodically according to the schedule in Figure 2. No monitoring actions were implemented in 2013 for this program. The last monitoring event occurred in 2012, and the next is scheduled for 2014.

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 is next scheduled to occur in 2015.

Summary of Monitoring Results

Dust monitoring data from the TEOM air samplers and the dustfall jars was statistically evaluated to assess trends over time. Longer-term results from the monitoring programs (using all years of available data) identified significant increases in lead and zinc concentrations at the port lagoon TEOM. In addition, statistically significant increases in dustfall deposition rate were observed for zinc in the road and reference areas in the longer-term data sets. However, these longer-term results are largely influenced by monitoring results earlier in the historical record.

Statistical analyses of results from the most recent three year period (2011-2013) found largely stable conditions in areas surrounding the port, mine, and DMTS road, with no statistically significant trends in TEOM concentration data, dustfall deposition rates, or metals concentrations in dustfall. The one exception was in the mine area, where there was a significant decrease in lead concentrations in dustfall during that period.

A summary of statistical trend analysis results for TEOM and dustfall jar monitoring programs is presented in Table 3. This figure provides an at-a-glance overview of results.

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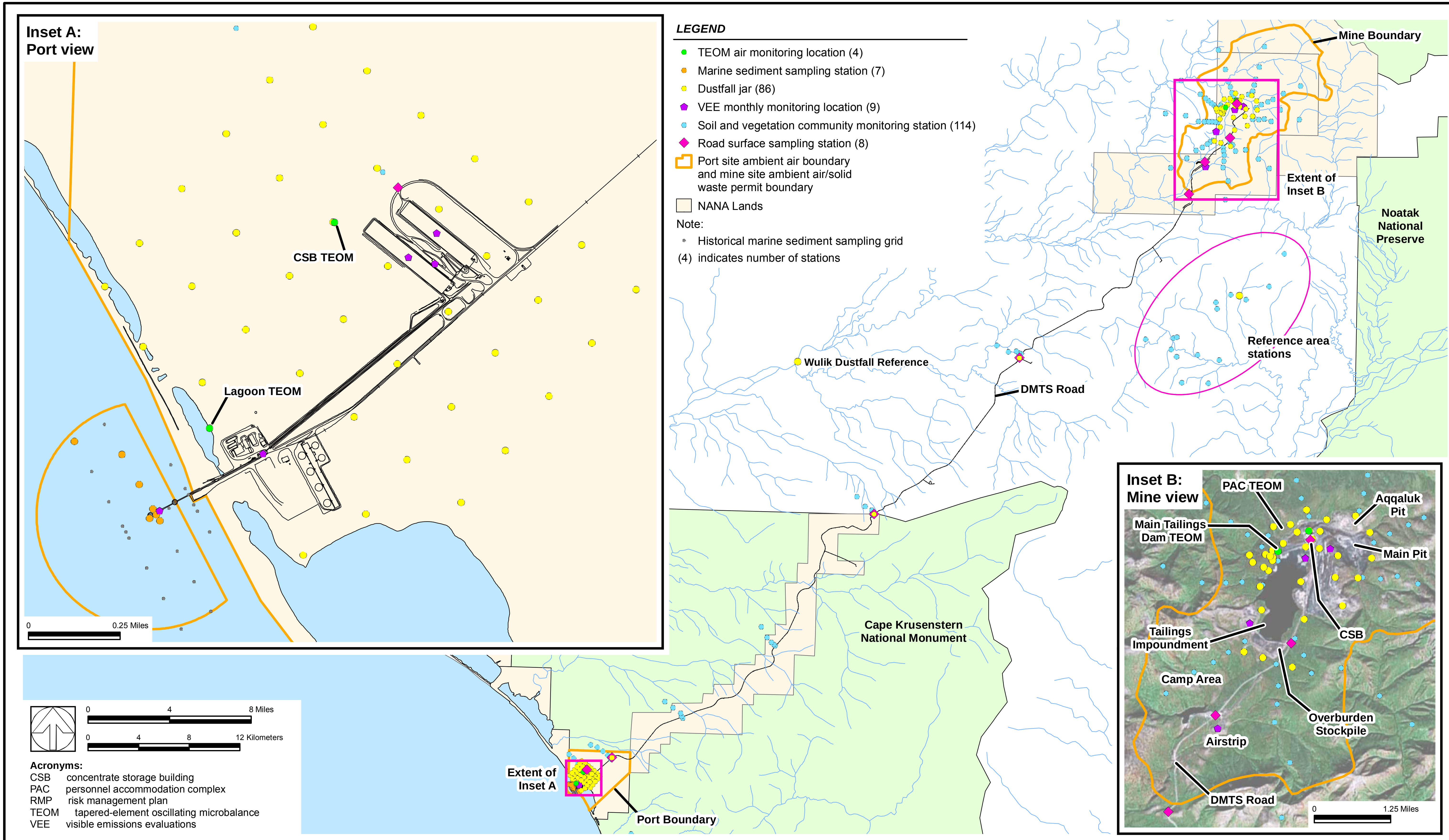


Figure 1. Overview of risk management monitoring programs

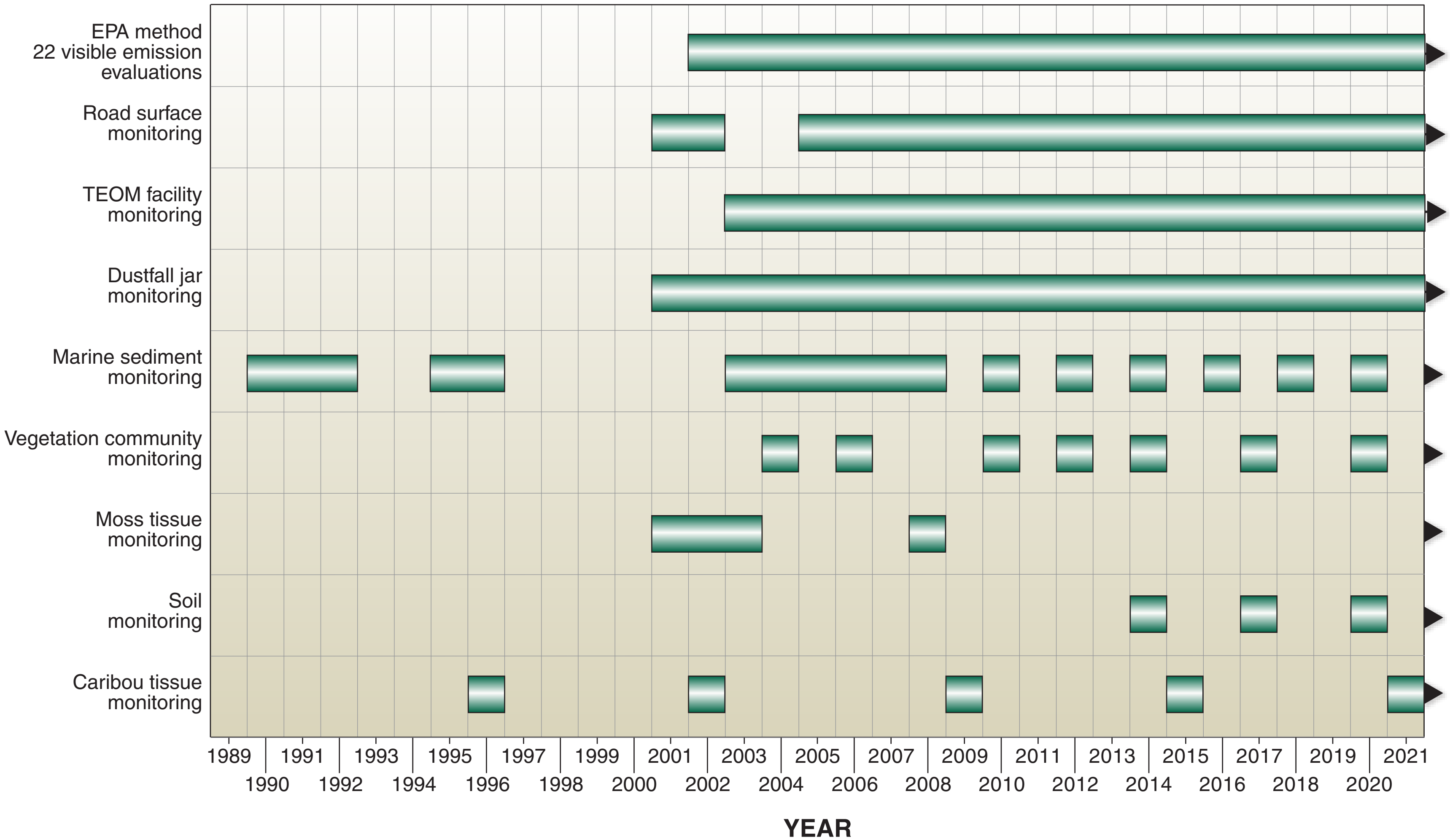


Figure 2. Monitoring timeline with program frequencies

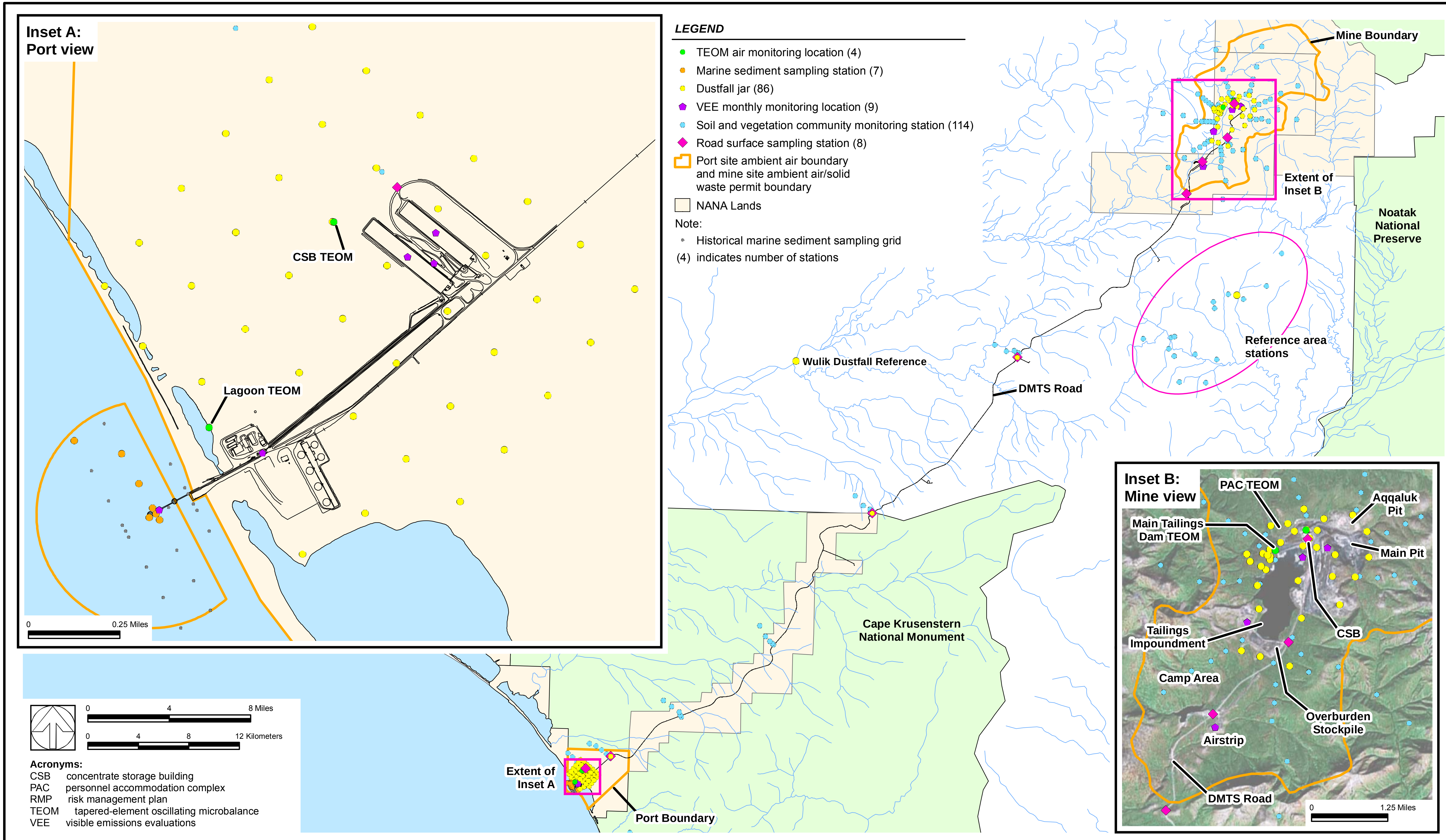


Figure 3. Overview of risk management monitoring programs

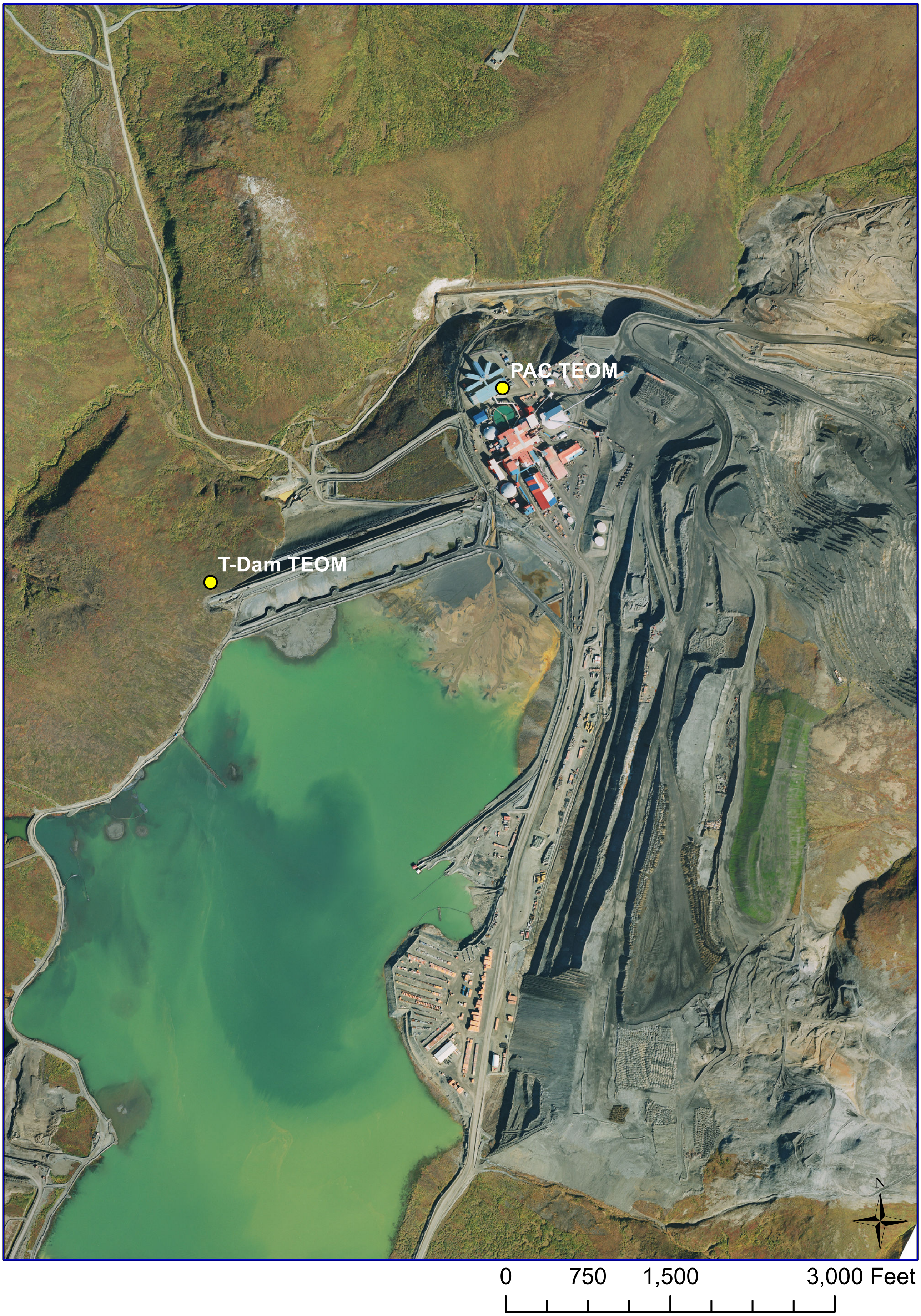
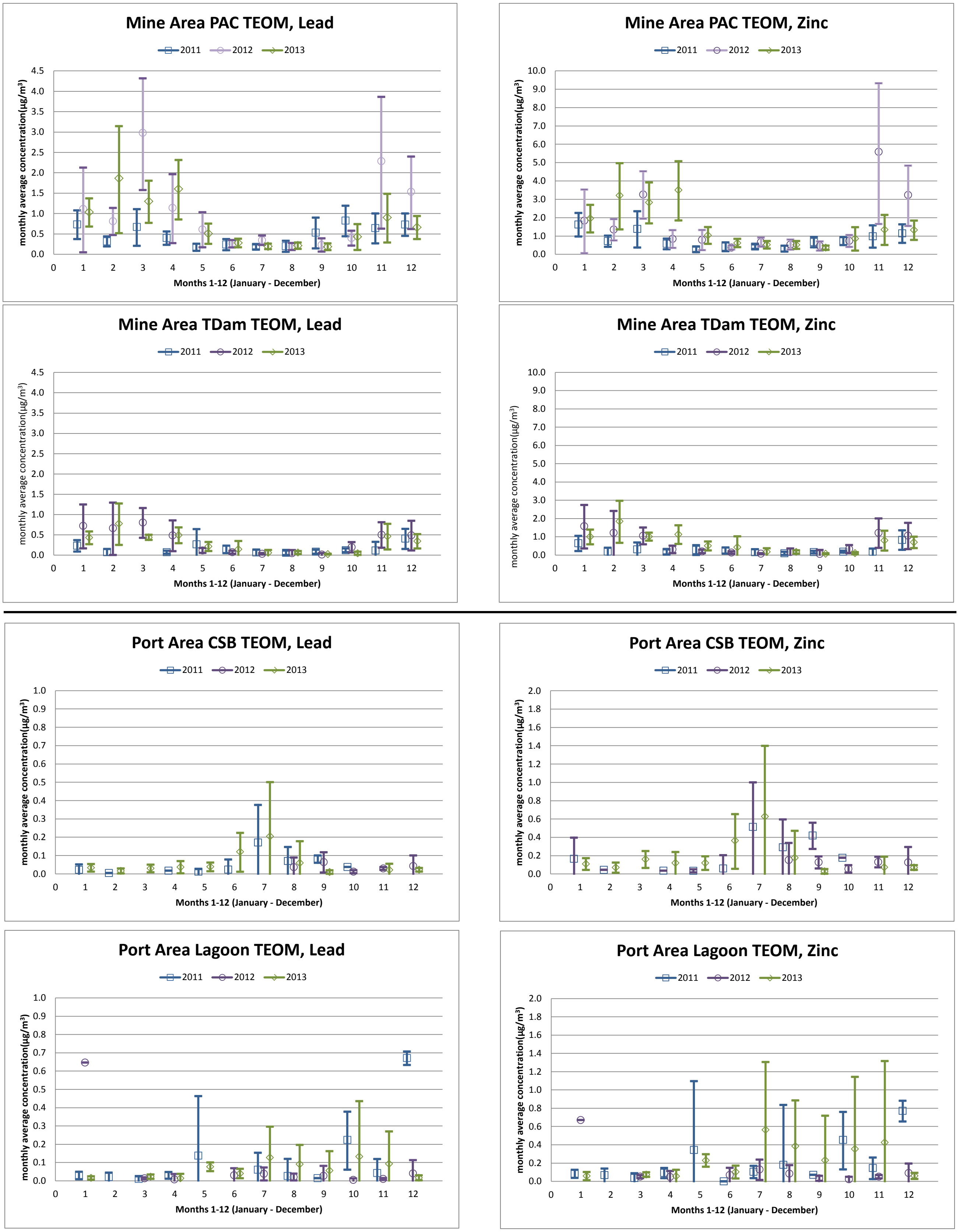


Figure 4. Mine TEOM locations

Figure 5. Port TEOM locations



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

Figure 6. TEOM monthly monitoring data comparison 2011-2013

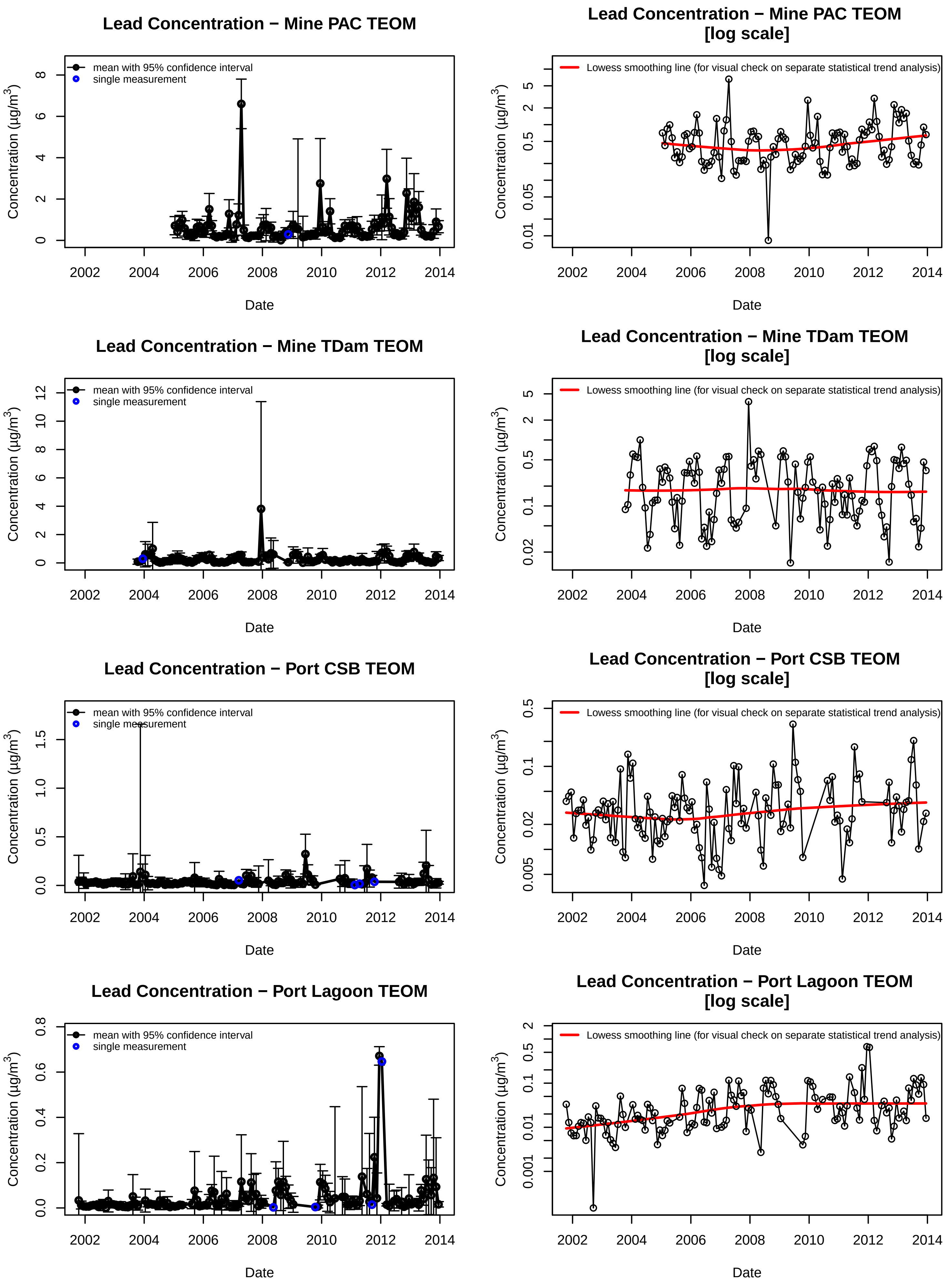


Figure 7. TEOM lead concentration plots (all years)

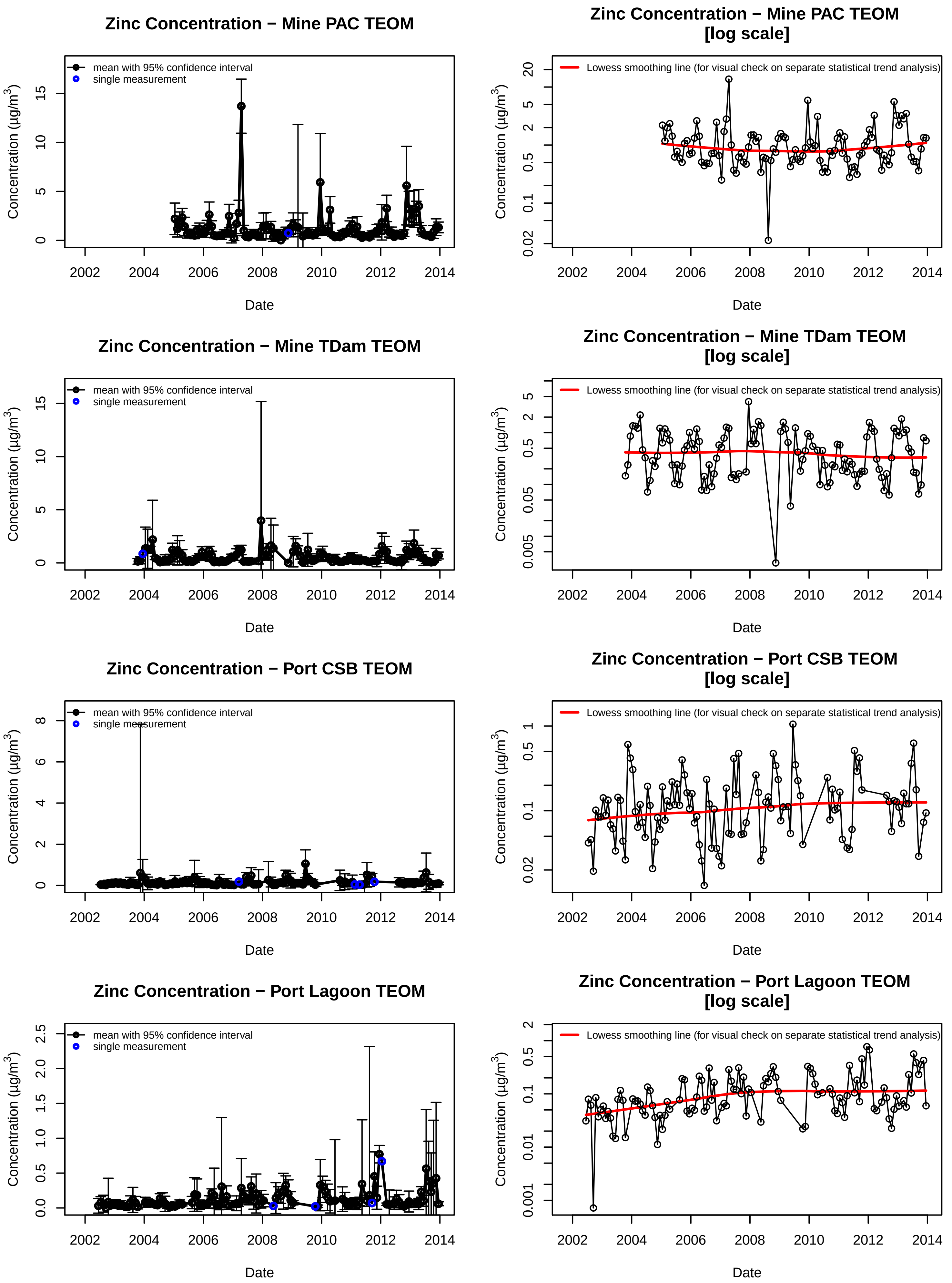


Figure 8. TEOM zinc concentration plots (all years)

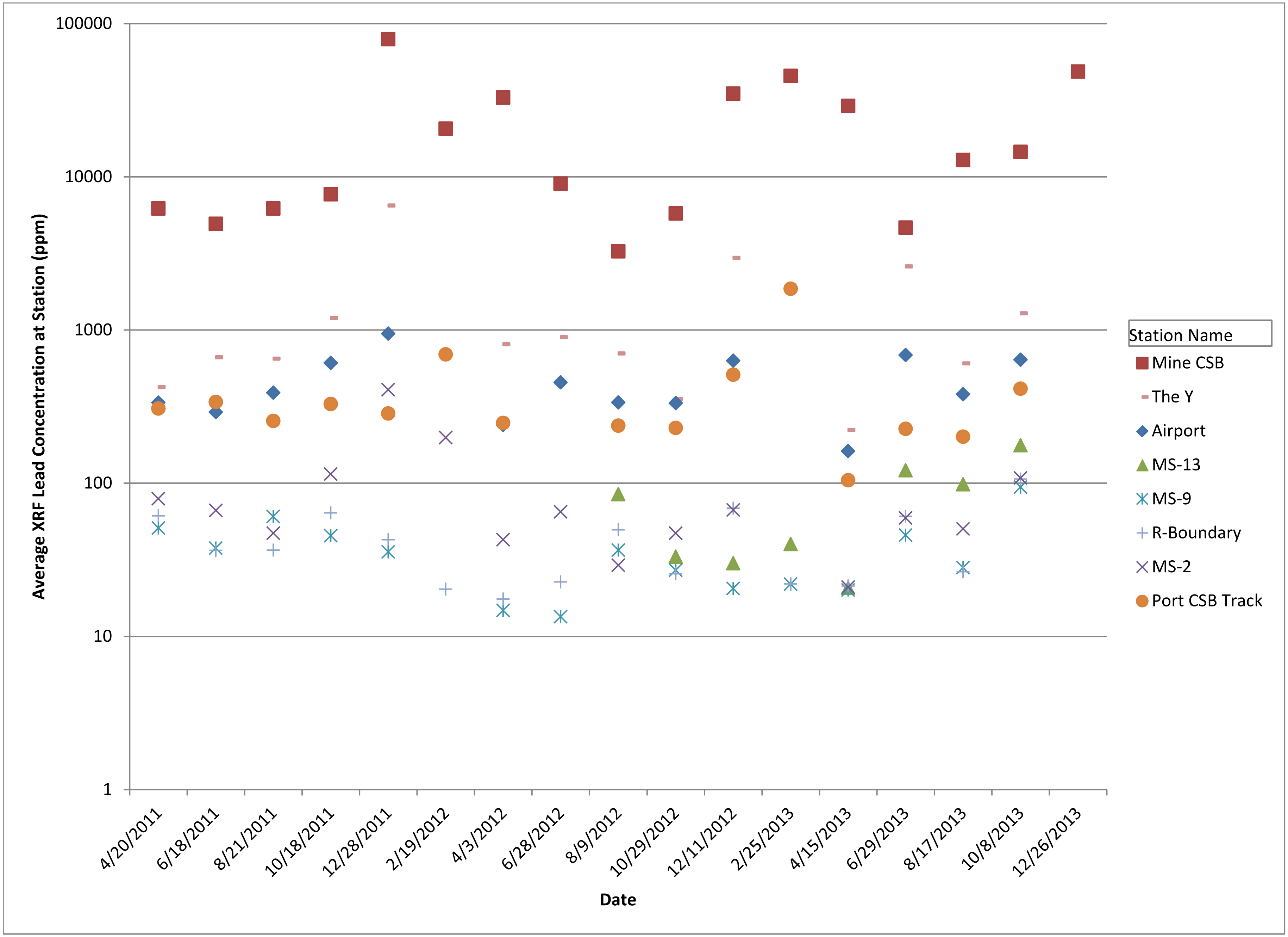


Figure 9. Road surface soil lead monitoring results 2011-2013 (Arctic Zone Cleanup Level = 800 ppm)

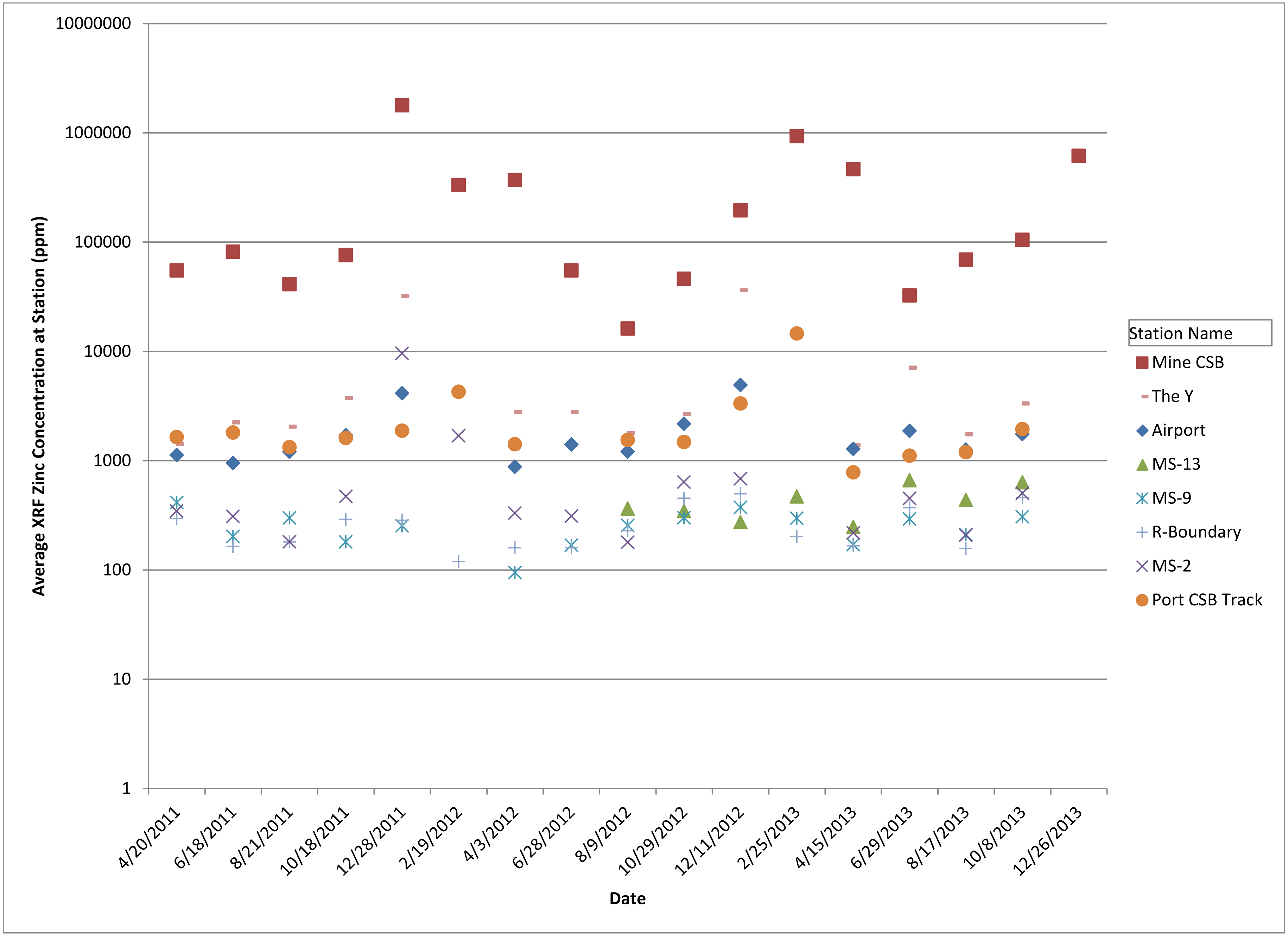


Figure 10. Road surface soil zinc monitoring results 2011-2013 (Arctic Zone Cleanup Level = 41,100 ppm)

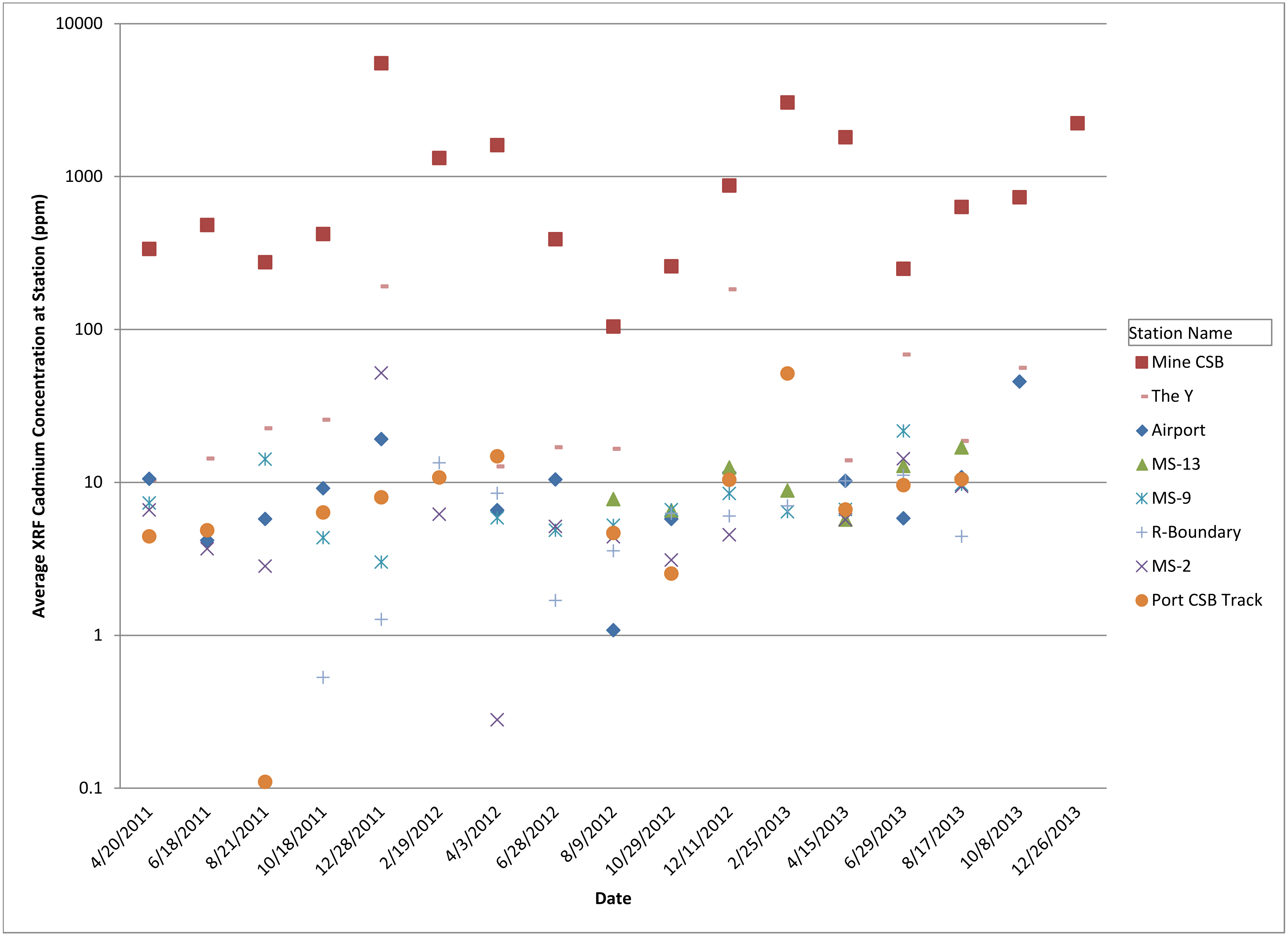


Figure 11. Road surface soil cadmium monitoring results 2011-2013 (Arctic Zone Cleanup Level = 110 ppm)

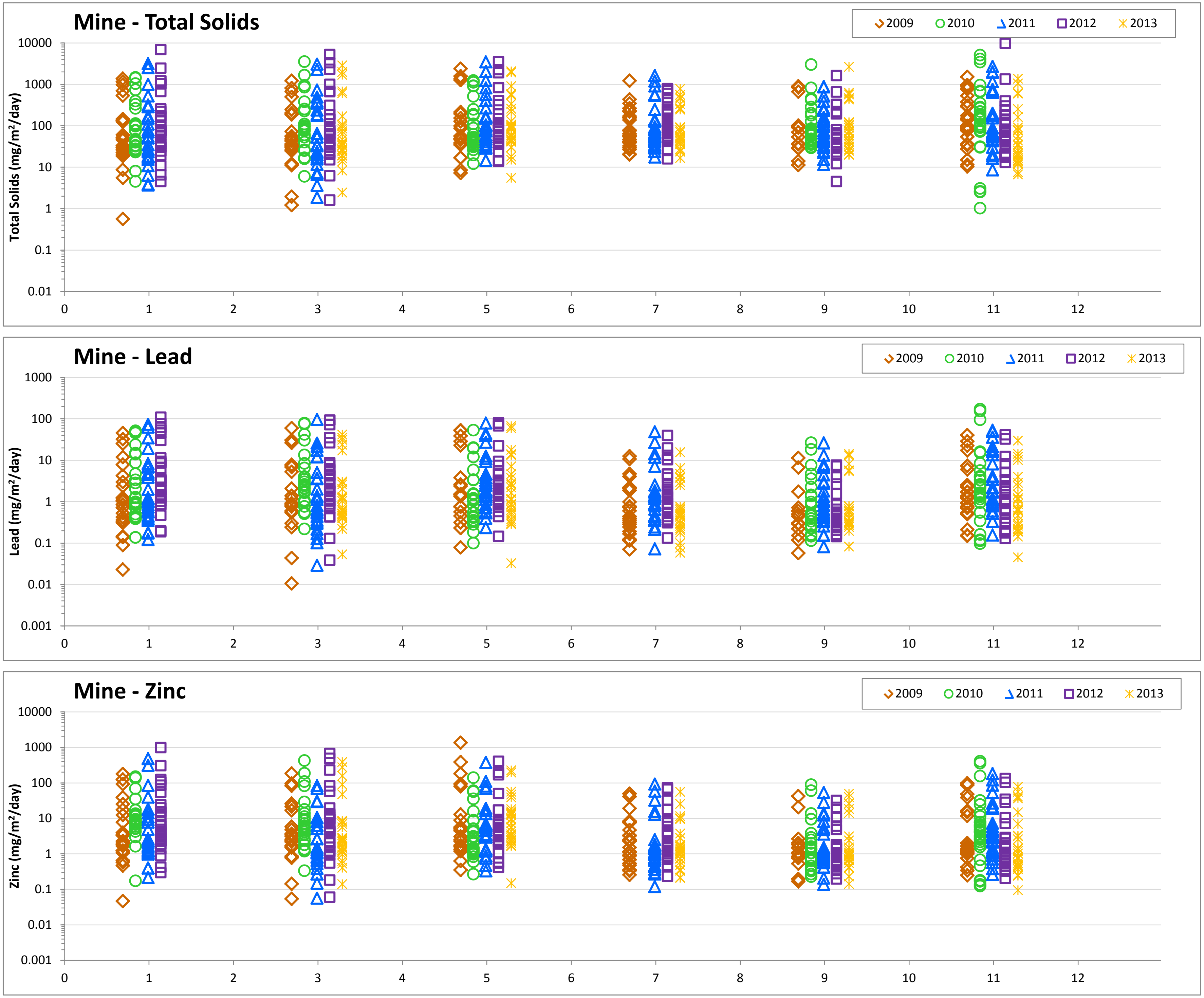


Figure 12. Mine dustfall rate data for total solids, lead, and zinc (results for all jars, collected bimonthly, 2009-2013)

Figure 13. Road dustfall rate data for total solids, lead, and zinc (results for all jars, collected bimonthly, 2009-2013)

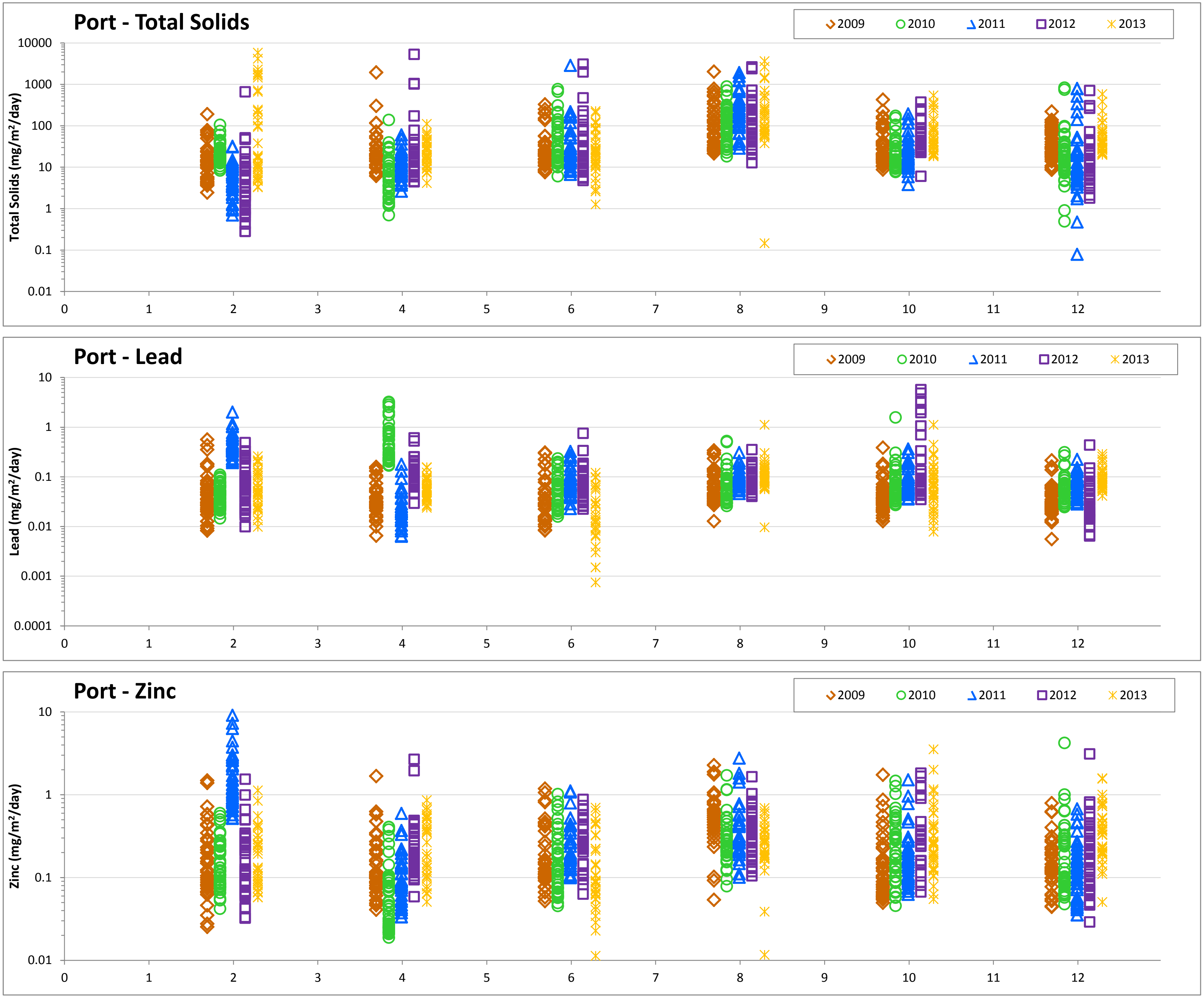


Figure 14. Port dustfall rate data for total solids, lead, and zinc (results for all jars, collected bimonthly, 2009-2013)

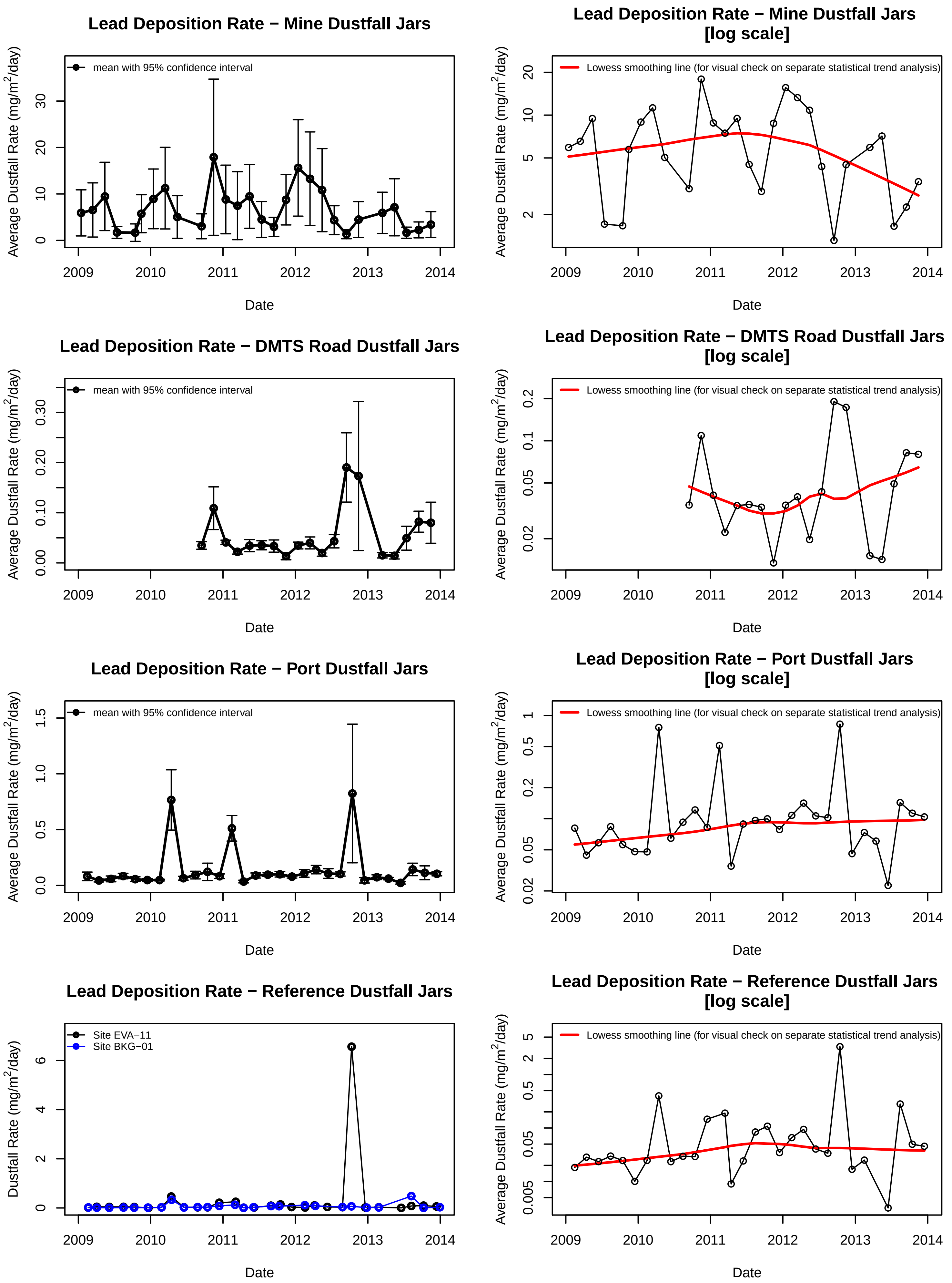


Figure 15. Dustfall deposition rate time series plots (lead)

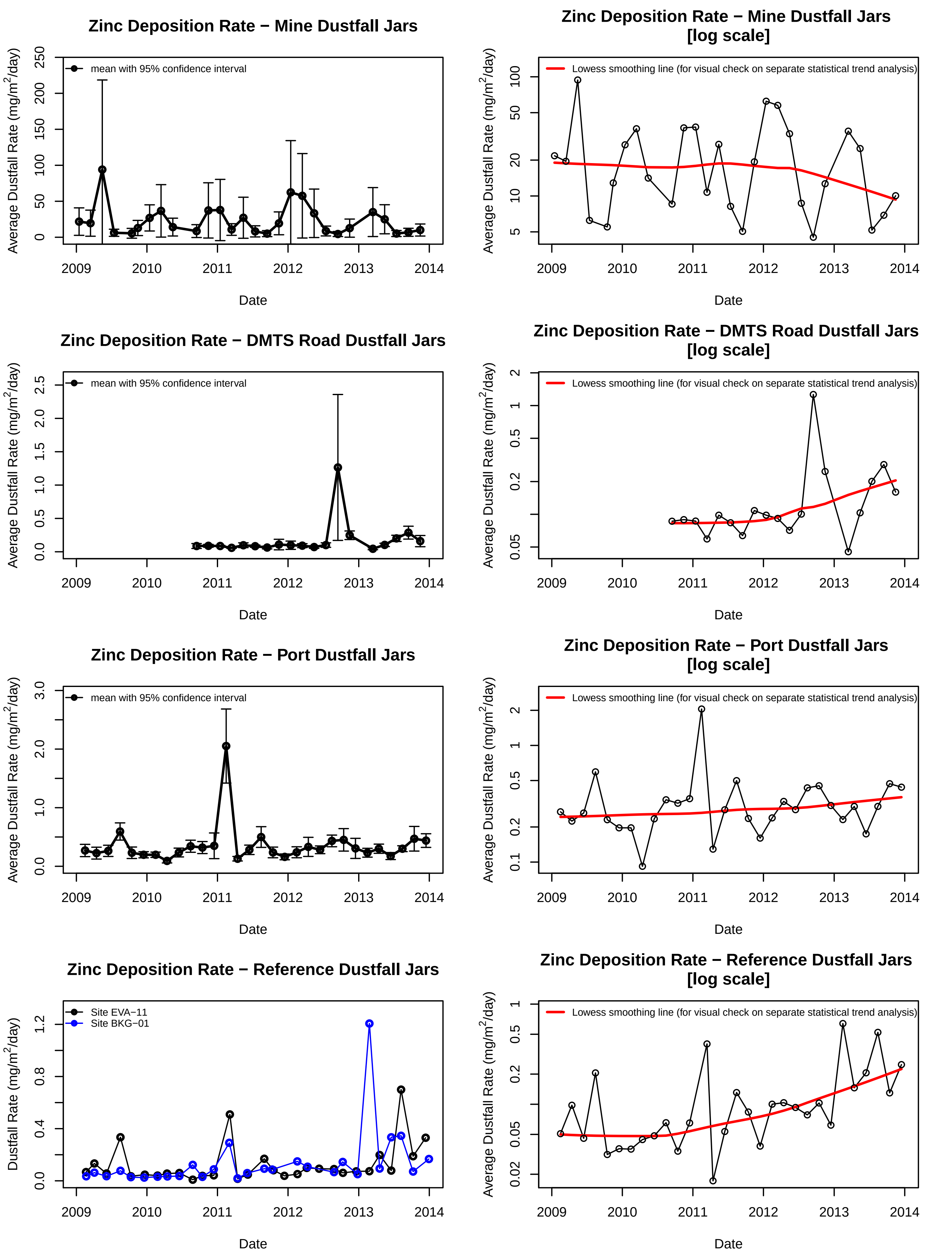


Figure 16. Dustfall deposition rate time series plots (zinc)

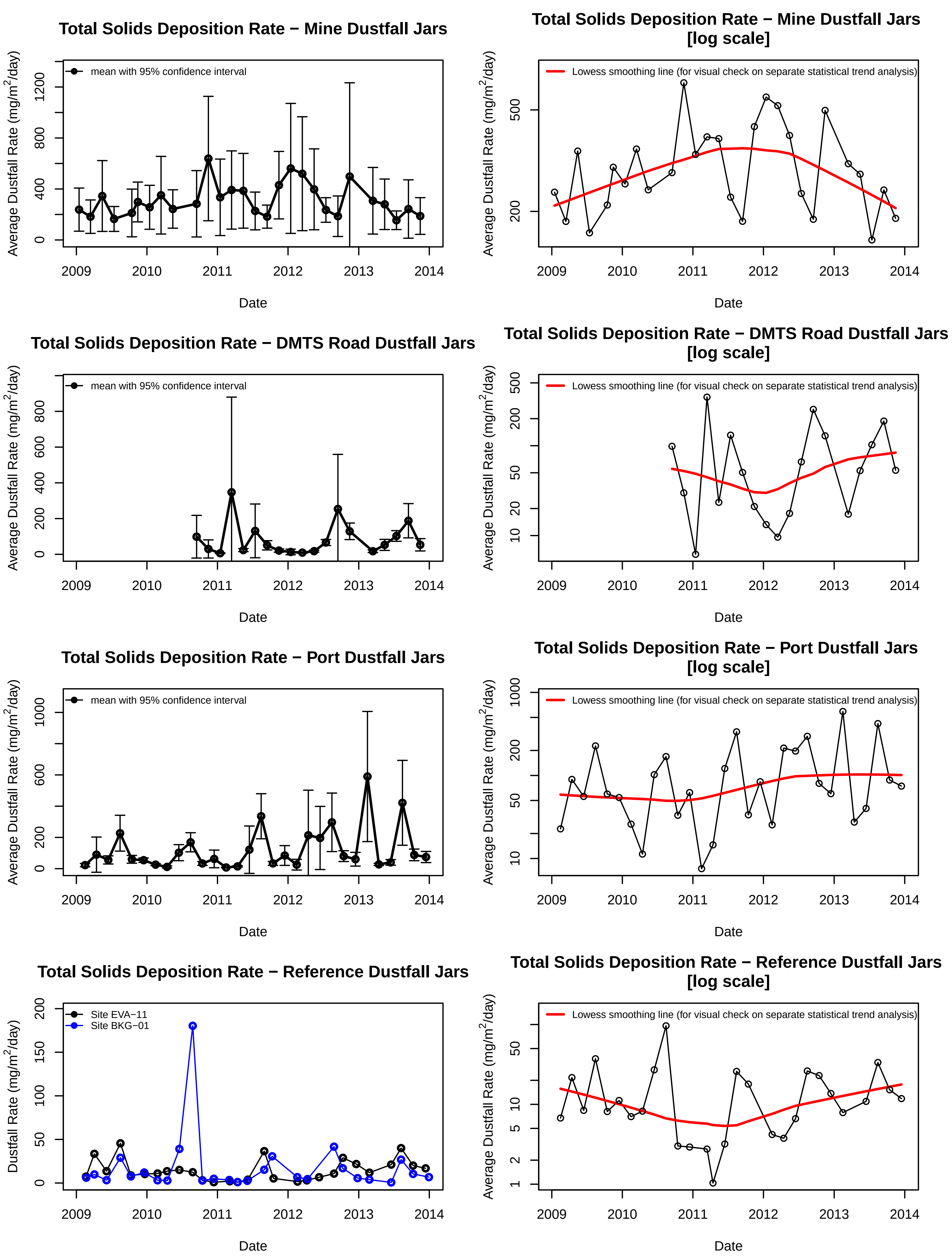


Figure 17. Dustfall deposition rate time series plots (total solids)

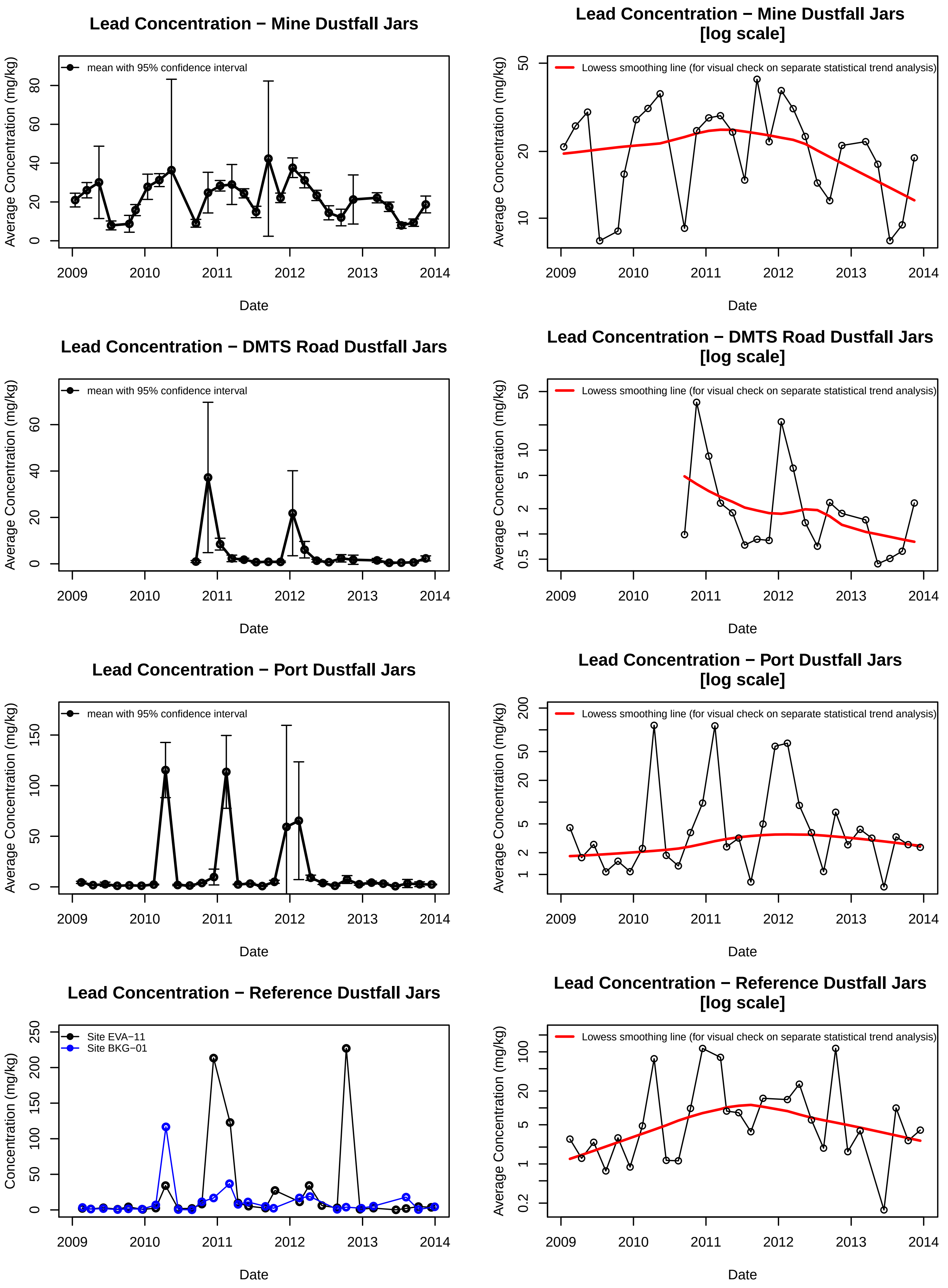


Figure 18. Dustfall concentration time series plots (lead)

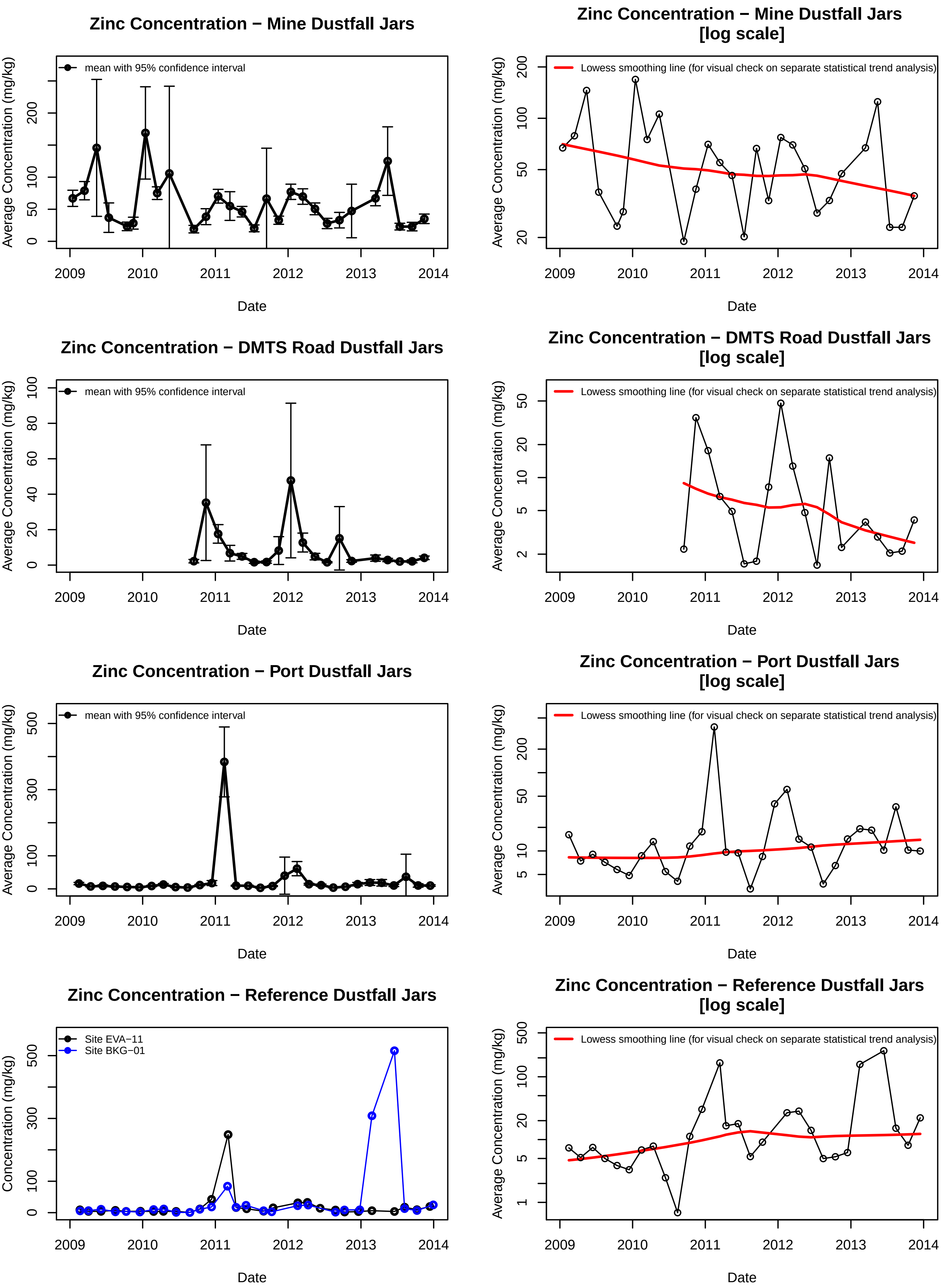


Figure 19. Dustfall concentration time series plots (zinc)

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

For all years of available data:

LEAD	Years of data available	Concentration (μg/m^3)		
		tau statistic	p value	significant trend?[a]
Mine PAC	1/2005 - 12/2013	0.087	0.186	no
Mine TDam	10/2003 - 12/2013	-0.009	0.886	no
Port CSB	10/2001 - 12/2013	0.091	0.136	no
Port Lagoon	10/2001 - 12/2013	0.311	0.0000003	yes; increasing

ZINC	Years of data available	Concentration (μg/m^3)		
		tau statistic	p value	significant trend?[a]
Mine PAC	1/2005 - 12/2013	-0.002	0.976	no
Mine TDam	10/2003 - 12/2013	-0.065	0.305	no
Port CSB	7/2002 - 12/2013	0.123	0.053	no
Port Lagoon	6/2002 - 12/2013	0.271	0.00002	yes; increasing

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

For 1/2011 - 12/2013:

LEAD		Concentration (μg/m^3)		
		tau statistic	p value	significant trend?[a]
Mine PAC	Only for years 2011 - 2013	0.073	0.531	no
Mine TDam		0.003	0.978	no
Port CSB		0.107	0.455	no
Port Lagoon		0.087	0.486	no

ZINC		Concentration (μg/m^3)		
		tau statistic	p value	significant trend?[a]
Mine PAC	Only for years 2011 - 2013	0.124	0.288	no
Mine TDam		0.048	0.683	no
Port CSB		-0.007	0.963	no
Port Lagoon		0.105	0.399	no

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

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

For all years of available data:

LEAD	Years of data available	Dustfall Deposition Rate (mg/m2/day)			Concentration (mg/kg-total solid)		
		tau statistic	p value	significant trend?[a]	tau statistic	p value	significant trend?[a]
Mine	1/2009 - 11/2013	-0.132	0.323	no	-0.143	0.286	no
Road	9/2010 - 11/2013	0.123	0.463	no	-0.310	0.064	no
Port	2/2009 - 12/2013	0.209	0.104	no	0.044	0.735	no
Reference	2/2009 - 12/2013	0.197	0.133	no	0.132	0.323	no

ZINC	Years of data available	Dustfall Deposition Rate (mg/m2/day)			Concentration (mg/kg-total solid)		
		tau statistic	p value	significant trend?[a]	tau statistic	p value	significant trend?[a]
Mine	1/2009 - 11/2013	-0.122	0.363	no	-0.180	0.179	no
Road	9/2010 - 11/2013	0.404	0.016	yes; increasing	-0.228	0.172	no
Port	2/2009 - 12/2013	0.191	0.139	no	0.191	0.139	no
Reference	2/2009 - 12/2013	0.430	0.001	yes; increasing	0.312	0.020	no

TOTAL SOLIDS	Years of data available	Dustfall Deposition Rate (mg/m2/day)		
		tau statistic	p value	significant trend?[a]
Mine	1/2009 - 11/2013	0.053	0.693	no
Road	9/2010 - 11/2013	0.111	0.506	no
Port	2/2009 - 12/2013	0.186	0.148	no
Reference	2/2009 - 12/2013	0.058	0.664	no

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

For 1/2011 - 12/2013:

LEAD		Dustfall Desposition Rate (mg/m2/day)			Concentration (mg/kg-total solid)		
		tau statistic	p value	significant trend?[a]	tau statistic	p value	significant trend?[a]
Mine	Only for years 2011 - 2013	-0.338	0.058	no	-0.471	0.008	yes; decreasing
Road		0.235	0.187	no	-0.294	0.099	no
Port		0.020	0.910	no	-0.281	0.103	no
Reference		-0.059	0.742	no	-0.317	0.087	no

ZINC		Dustfall Desposition Rate (mg/m2/day)			Concentration (mg/kg-total solid)		
		tau statistic	p value	significant trend?[a]	tau statistic	p value	significant trend?[a]
Mine	Only for years 2011 - 2013	-0.191	0.284	no	-0.147	0.410	no
Road		0.412	0.021	no	-0.235	0.187	no
Port		0.124	0.472	no	0.020	0.910	no
Reference		0.373	0.031	no	-0.017	0.928	no

TOTAL SOLIDS		Dustfall Desposition Rate (mg/m2/day)		
		tau statistic	p value	significant trend?[a]
Mine	Only for years 2011 - 2013	-0.235	0.187	no
Road		0.162	0.365	no
Port		0.190	0.272	no
Reference		0.383	0.038	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 (historical and last three years)

Location and Measure	TEOM (Air Concentrations)			
	Historical (All Years)		Recent (Last 3 Years)	
	Pb	Zn	Pb	Zn
Mine Tdam (Conc.)	—	—	—	—
Mine PAC (Conc.)	—	—	—	—
Port CSB (Conc.)	—	—	—	—
Port Lagoon (Conc.)	↗	↗	—	—

Location and Measure	Dustfall Jars (concentration and deposition rate)					
	Historical (All Years)			Recent (Last 3 Years)		
	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	—	—	a
Reference (Rate)	—	↗	—	—	—	—

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).
↘	Indicates a statistically significant decrease over time period tested (trend is DOWN).

Shading is used for emphasis of recent results.

[a] Concentration is not evaluated for solids, because total solids is the entire sample mass.

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