TACOMA SMELTER PLUME SITE

PIERCE COUNTY FOOTPRINT STUDY:

Soil Arsenic and Lead Contamination
in
Western Pierce County

FINAL REPORT
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prepared by

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for

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and
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EXECUTIVE SUMMARY

The ASARCO Tacoma Copper Smelter operated for more than 90 years, closing in 1986. The Washington State Department of Ecology (Ecology), in cooperation with local health departments, has been investigating the regional-scale magnitude and extent of soil contamination in areas surrounding the Tacoma Smelter since 1999. The Pierce County Footprint Study continues a series of such soil characterization studies for Ecology's Tacoma Smelter Plume Site under the state's Model Toxics Control Act (MTCA). Previous studies included sampling over all of Vashon-Maury Island and approximately 200 square miles of the King County Mainland.

The Pierce County Footprint Study was funded through an Ecology grant to the Tacoma-Pierce County Health Department (TPCHD). Ecology and TPCHD coordinated in developing a study design and acted cooperatively through completion of the study.

The primary study objective was to systematically define the magnitude and extent of smelter-related soil contamination in western Pierce County. Numerous smaller historic studies had documented but not satisfactorily characterized the effects of smelter emissions on Pierce County soils. An additional objective was to complete at least initial sampling to the western Pierce County boundary lines, providing complete coverage for that area and preliminary information related to possible Tacoma Smelter Plume Site boundaries. Collection of information on trace element concentrations was also included in the study to support source identification evaluations.

The Pierce County study area of approximately 200 square miles included all portions of the county west and north of I-5, extending to the boundaries with adjacent counties. Samples were collected from a total of 194 properties, including 105 residential (disturbed soils) and 89 forested (undisturbed soils) properties. Undisturbed forest locations are preferred for initial soil characterization and were used exclusively in the two previous footprint studies. Sampling at residential properties was required in this study to obtain adequate spatial coverage in the extensive urbanized parts of Pierce County within the study area. The study design varied sampling density by type of property (residential or forested) and location with respect to the Tacoma Smelter (anticipated magnitude and variability of soil concentrations). Samples were collected from 0-2 inch and 2-6 inch depth intervals at all locations; additional samples from 6-12 inch depths were collected at selected locations to further investigate contaminant depth profiles. Multiple borings (two to four) within a sampling location were sampled for 182 of 194 properties, providing information on local-scale variability. In all, 1,409 soil samples were collected and analyzed.

All samples were collected by TPCHD staff between March and October 2002. Samples were analyzed for arsenic and lead, using ICP-MS methods, at Severn Trent Laboratory in Tacoma, Washington. An independent data validation of all results was performed by EcoChem, Inc. of Seattle, Washington. No data were rejected through data validation and all results were quantified (i.e., there were no not-detected results) based on the low Practical Quantitation

Limits associated with ICP-MS analyses. All data in this report are provided for samples sieved to <2mm and reported on a dry weight basis.

After initial arsenic and lead results were available, selected samples were sent to the Battelle Marine Lab at Sequim, Washington for additional trace element analyses to support source evaluations. The trace element results are being reported separately (report in preparation).

Data evaluations support the following conclusions:

- Magnitude of contamination. A broad range of concentrations was found, from at or near background levels (less than 10 ppm) to maximum values of 1,050 ppm for arsenic and 6,670 ppm for lead. Many locations had values exceeding MTCA unrestricted land use (residential) soil cleanup standards of 20 ppm arsenic and 250 ppm lead; such exceedances were more widespread for arsenic than for lead.

- Spatial pattern. The regional-scale patterns of soil contamination showed gradients of decreasing concentrations with increasing distances from the smelter and decreasing wind frequencies. This "bulls-eye" pattern, elongated in the primary downwind directions, is strong evidence that Tacoma Smelter emissions are a primary source for the observed soil contamination. The arsenic spatial pattern was particularly evident, indicating a lack of other large arsenic sources. The lead pattern showed some effects from additional non-smelter sources of lead (e.g., leaded gasoline emissions, weathering of leaded paint). The extension of sampling to the county line in some low-frequency downwind directions (e.g., the Key Peninsula to the west and northwest) provided data showing consistent maximum concentrations below MTCA cleanup standards, and therefore provides a preliminary indication of partial MTCA site boundaries.

- Correlation of arsenic and lead. Undisturbed forested sampling locations had a very strong (R-squared value of 87 percent), statistically highly significant correlation between maximum arsenic and lead concentrations. The characteristic ratios of maximum lead:arsenic concentrations for forested locations were similar to those reported for the King County footprint studies. The correlation for residential sampling locations was much lower, although still statistically significant. A number of high-lead, low-arsenic results for residential sampling locations reduces the correlation and reflects additional sources for lead in urban areas (and possibly, in some cases, residual contamination from the early years of lead smelting at the Tacoma Smelter).

- Depth profiles. At undisturbed forested locations, the 0-2 inch arsenic and lead concentrations typically exceeded those at 2-6 inches. (This contrasts somewhat with the pattern found at forested locations on Vashon-Maury Island, where higher arsenic concentrations occurred about equally often at these two depth intervals). The depth profiles for residential sampling locations were more complex, with many more "inverted" profiles showing higher concentrations at

the 2-6 inch depth interval. The difference is very likely caused by the increased soil disturbance associated with development and maintenance of residential properties. Maximum concentrations were occasionally reported for the 6-12 inch depth interval, primarily at residential locations. For both forested and residential locations, arsenic generally exhibited a greater downward mobility compared to lead.

- Variability. Within local regions of the study area, maximum contaminant concentrations at nearby properties (separated by several thousand feet or more) can differ substantially. The results from one property therefore should not be extended uncritically to nearby unsampled properties. Similarly, the results from one boring to another within a single property (separated by no more than a few hundred feet) can differ substantially. One, or a few, borings at a property therefore may not adequately characterize the magnitude of soil contamination. Small-scale spatial variability in soil contamination likely reflects a combination of aerial deposition effects and post-deposition soil disturbances.

  At residential properties no systematic difference in maximum concentrations was found between front and back yard borings. The difference in maximum concentrations between front and back yards was typically within a factor of two, although higher for a small proportion of residential properties.

  For 62 residential properties within 4 miles of the smelter, the age of the home was not strongly correlated with the maximum arsenic concentration. Maximum lead concentrations, however, did show a significant increase as age increased.

- Further study designs. The prominent large-scale spatial gradients revealed by the Pierce County Footprint Study, especially in terms of bounding curves for exponential decay functions for concentrations versus distances by wind directions, are useful for designing further Tacoma Smelter Plume studies. They have been used to focus on high-priority areas for sampling of Child-Use Areas and for establishing additional study areas to determine Tacoma Smelter Plume Site boundaries in Pierce County and adjacent counties.

- Consistency. The Pierce County Footprint Study results are very consistent with the previous King County footprint results and extend the understanding of regional-scale contamination from Tacoma Smelter emissions to include both dominant downwind directions. Through inclusion of sampling at many residential properties, this study also affords an opportunity to compare soil contamination patterns and magnitudes at disturbed and undisturbed sampling locations.

1.0 PROJECT DESCRIPTION

The Pierce County Footprint Study continues a series of investigations by the Washington State Department of Ecology and local health departments to define the magnitude and spatial extent of soil contamination in the region surrounding the former ASARCO Tacoma Copper Smelter. The Pierce County study was consistent in design with previous investigations on Vashon-Maury Island and the King County Mainland. This report describes and presents the results of the Pierce County study, and also provides a summary of the cumulative results to date for both King County and Pierce County.

1.1 OVERVIEW OF TACOMA SMELTER PLUME STUDIES

The Tacoma Smelter operated from 1890 to 1986, initially as a lead smelter and then for most of its history as a primary copper smelter. The smelter was located in Ruston, Washington (Pierce County), along the Commencement Bay shoreline northwest of downtown Tacoma. It specialized in the toll smelting of complex (e.g., high arsenic) ores. After ASARCO acquired both the smelter in Ruston and one in Everett, Washington to the north, in the early 1900s, it shut down the first arsenic recovery plant in the United States at Everett and installed one at the Tacoma Smelter. Throughout its subsequent operating history, the Tacoma Smelter was a major domestic producer of arsenic; for many years, it was the only domestic source for arsenic. Arsenic production rates approached and at times exceeded 10,000 tons per year.

Tacoma Smelter operations resulted in releases of arsenic, lead, and other metals occurring in smelter feedstocks. Air emissions included both tall stack and low-level, fugitive emissions. Since the early 1970s, many studies have been performed to evaluate the environmental impacts of Tacoma Smelter operations, including among other impacts soil contamination. An early compilation of studies through 1981 was made by the Puget Sound Air Pollution Control Agency (PSAPCA), since renamed the Puget Sound Clean Air Agency, as it reviewed applications by ASARCO for variances from the agency's air pollution control regulations to allow continued smelter operation.

The Tacoma Smelter and surrounding areas were included as part of the designated Commencement Bay Superfund site in the early 1980s. After smelter closure in 1986, the U.S. Environmental Protection Agency (EPA) reviewed available information and completed extensive investigations of the smelter property and nearby residential neighborhoods. In the early 1990s, EPA issued Records of Decision for cleanup actions at the smelter property and in the surrounding Ruston/North Tacoma areas within about one mile of the smelter. Cleanup activities at both of these Operable Units are continuing. Near-surface soil contamination was identified as the primary concern in the residential neighborhoods.

Soil contamination, at concentrations exceeding Ecology's Model Toxics Control Act (MTCA) cleanup standards for unrestricted land use, was reported in several of the historic studies in areas beyond the EPA's Ruston/North Tacoma cleanup area. The historic studies, however, used a variety of inconsistent study designs, provided limited spatial coverage and sampling densities, and because of their age were questionable for defining current conditions more than a decade after smelter closure. During 1998/1999, soil sampling and analysis at locations about 6 miles northeast (Maury Island, King County) and south-southwest (University Place, Pierce County) of the Tacoma Smelter documented arsenic and lead concentrations substantially above the MTCA cleanup standards. Both of these study locations were known to be in the dominant downwind directions from the Tacoma Smelter based on annual wind roses compiled by PSAPCA.

Ecology responded to these findings by initiating studies to better define the current magnitude and spatial extent of soil contamination in the region surrounding the former Tacoma Smelter. Ecology designated the regional-scale area of soil contamination - principally defined by arsenic concentrations - as the Tacoma Smelter Plume Site under MTCA.

Tacoma Smelter Plume studies have been designed and performed through the cooperative efforts of Ecology and local health departments. The studies have largely been funded through Site Hazard Assessment grants from Ecology to the health departments. For one of the investigations, Ecology directly procured a contractor to perform the sampling; in all other cases, local health department staff collected the samples.

A systematic and phased approach to soil investigations was adopted beginning in 1999. Two sequential study phases, termed "footprint" and "child-use area" sampling, were carried out in a series of defined geographic subregions. Footprint sampling, always performed first, focused on relatively undisturbed forested areas to develop information on the likely upper bounds for soil contaminant concentrations. In undisturbed soils arsenic, lead, and other smelter-related contaminants are found to accumulate primarily in the uppermost soils (approximately top foot) resulting in comparatively simple contaminant depth profiles. Child-use area sampling focused on developed areas such as schools, parks, and child care facilities to develop information on soil contamination in locations where exposures to young children are most likely. The soil disturbance that accompanies property development may often diminish the maximum soil contaminant concentrations that would otherwise be present, because of mixing, dilution, and removal of near-surface soils; contaminant depth profiles may similarly be altered substantially (e.g., by placement of fill). For the most part, child-use area sampling focused on the top 6 inches as representative of potential soil exposures under existing conditions (i.e., absent further site development activities that could re-expose deeper and potentially more contaminated soils). The results of previous studies in this series were used to help design subsequent studies; footprint study results, in particular, were used to identify zones within which child-use properties would be considered for sampling.

Three geographic subregions have been defined and sampled to date, including both

footprint and child-use area studies. Footprint studies have included all of Vashon-Maury Island (and also including a small number of pilot study samples along the King County Mainland shoreline; see PHSKC and Glass 2000); an approximately 200 square mile area on the King County Mainland, extending north to the I-90 corridor and east of the Duwamish/Green River valley (see Washington State Department of Ecology 2002); and an approximately 200 square mile area of western Pierce County, including all areas north and west of I-5 (this report). Child-use area studies included all of Vashon-Maury Island and selected portions of the King County Mainland and Pierce County study areas where footprint study results indicated Ecology's interim action levels for soil arsenic contamination could potentially be exceeded (see Section 4.5 below). The child-use area study results for each geographic subregion are reported separately from the footprint study results. The completion of two sequential study designs in each of three defined geographic subregions has thus produced six studies to date for the Tacoma Smelter Plume Site. The combined data set from all three footprint studies includes results for 430 properties and 2,402 samples.

An extended footprint study covering as-yet unsampled portions of King, Pierce, Kitsap, and Thurston counties has been designed to further define the spatial extent of soil contamination and explore possible Tacoma Smelter Plume Site boundaries based on the MTCA unrestricted land use soil arsenic cleanup standard of 20 parts per million (ppm; see Landau Associates, Inc. 2003). That fourth footprint study should be completed in 2004.

The Tacoma Smelter Plume studies have focused on arsenic and lead as the primary contaminants of concern for human exposures. (The initial footprint study on Vashon-Maury Island also included analysis of selected samples for cadmium, which was dropped in subsequent studies based on the reported results from Vashon-Maury Island). As a component of several studies, selected samples in each of the first three defined geographic subregions were analyzed for a set of additional trace elements (e.g., antimony, bismuth, and indium) to support source identification evaluations. The results of those additional trace element analyses are also reported separately (the initial report covering Vashon-Maury Island and King County Mainland results; an addendum report for Pierce County results in preparation). Finally, a separate report (Credible Evidence Report) has been prepared that reviews various types of information identifying the Tacoma Smelter as the primary source for the documented regional-scale soil arsenic contamination in surrounding areas.

1.2 PIERCE COUNTY FOOTPRINT STUDY DESIGN

A Sampling Design Work Group held a series of meetings to develop the study design, as was done in all previous Tacoma Smelter Plume studies. Participants in the Work Group included representatives of Ecology and the Tacoma-Pierce County Health Department; Gregory L. Glass, an independent environmental consultant, facilitated the Work Group meetings and documented the resulting Pierce County Footprint Study Design (see TPCHD 2002a). A brief summary of some of the key study design elements is provided here; for details, refer to the

study design report (TPCHD 2002a).

At the start of the design process, the Work Group compiled and reviewed available data in Pierce County from historic Tacoma Smelter investigations and other related studies. This information was considered as one basis for decisions on design elements such as study area boundaries and sampling densities.

The Work Group identified three primary objectives for the study:

- defining the regional-scale magnitude and extent of soil contamination from Tacoma Smelter emissions within Pierce County
- completing sampling throughout western Pierce County to provide early, if imprecise and incomplete, indications of some Tacoma Smelter Plume Site boundaries
- identifying the likely contribution of the Tacoma Smelter as a source for soil arsenic and lead contamination.

The study design was developed using a hierarchic process to address a series of study design elements, including: defining a Study Area; identifying Candidate Sampling Areas; determining Sampling Zones (i.e., stratification of the Study Area); selecting properties to be sampled; and determining the number and location of borings per property as well as the depth intervals to be sampled. Various exclusion and preference criteria for locations to be sampled were identified and used in structuring the study to best meet the listed objectives within available resource constraints. Exclusion and preference criteria were applied on both a large-scale and localized basis.

While the Pierce County Footprint Study was designed to be consistent with the earlier footprint studies on Vashon-Maury Island and the King County Mainland, two important differences are noteworthy: 1) the study included sampling of residential (i.e., disturbed) properties in heavily urbanized areas in Pierce County, where forested properties were largely absent, to provide spatial coverage for mapping the magnitude and extent of soil contamination, and 2) sampling was extended to complete at least pilot-scale sampling to the western boundaries of Pierce County, with the expectation that this would - for the first time within footprint studies - include sizable areas with maximum arsenic concentrations too low for inclusion as part of the Tacoma Smelter Plume Site, thus providing some information relevant to site boundaries (see the second objective listed above).

The study area within Pierce County was defined as all areas north and west of I-5, extending to the adjacent county lines (for King, Kitsap, and Thurston Counties). This area included approximately 200 square miles of western Pierce County. Some portions of this study area were excluded from sampling based on characteristics that made them unavailable (e.g.,

restricted areas at Fort Lewis and on McNeil Island) or unrepresentative (e.g., floodplains and the highly developed downtown and tideflats industrial areas) of the spatial pattern of Tacoma Smelter impacts (see TPCHD 2002a for a discussion of specific excluded areas). Areas in Ruston and North Tacoma already being addressed by intensive property-by-property sampling under EPA's Superfund cleanup program, as well as several other Superfund sites (e.g., South Tacoma Field and Former DuPont Works Sites), were also excluded. Those parts of the study area not excluded constituted candidate sampling areas for this study.

The land uses in candidate sampling areas ranged from rural, mostly forested areas to heavily urbanized areas where forest cover, except for a few steep slopes, was all but absent. A significant portion of the candidate study areas, from Tacoma south to Steilacoom, consisted of dense residential developments. The Work Group determined that sampling in those residential areas was required to achieve the necessary spatial coverage for the footprint study. Sampling of residential properties focused on older homes, assuming that soil contamination from cumulative deposition of airborne particulates would generally be most seriously disrupted at the time of construction. Older homes would therefore represent longer post-construction periods for accumulation of deposited contaminants from smelter emissions. The few available forested properties within the densely developed residential areas were also targeted for sampling; such relatively undisturbed areas were considered most likely to provide information on the highest local concentrations of soil contaminants.

The conceptual model for soil contamination from smelter emissions, as well as a review of previous study results, indicated that the overall range of values (i.e., the local variability) decreased with increasing distance from the smelter. The mixing, dilution, burial, and partial removal of contaminated soils resulting from property development actions was similarly understood to potentially increase within-property variability, compared to relatively undisturbed forested areas. The sampling design incorporated an allocation of sampling efforts, considering these variability characteristics and the available study resources, to better estimate maximum contaminant concentrations for mapping purposes. The basic allocation principle was to collect more information where variability was anticipated to be greater.

For sample allocation, the study area in Pierce County was subdivided into six zones based on distance from the smelter and the dominant land cover. Three largely residential urbanized zones, called Developed Zones (D1/D2/D3) , and three zones with extensive forest cover, called Undeveloped Zones (U1/U2/U3), were identified. (For both types of land cover, the distances from the smelter generally increased from Zone 1 to Zone 3. Figure 1a, reproduced from the Study Design Report [TPCHD 2002a], shows these six sampling zones and the initial sampling location grids). Forested and residential properties were identified as Undisturbed and Disturbed, respectively. Sampling of undisturbed properties was preferred for the footprint study. Undisturbed properties provided adequate spatial coverage within the three Undeveloped Zones; therefore, only forested properties were sampled there. In the three Developed Zones, most sample locations were residential properties, with a small number of undisturbed properties also identified for sampling on an opportunistic basis.

The allocation of sampling effort involved varying the densities of sampling locations (i.e., grid sizes; see Figure 1a), the number of (clustered) sample borings per sample location, and the depth intervals sampled by sampling zone. Within each zone a sampling grid was used to establish most sampling locations; some targeted sampling locations were added (e.g., to obtain samples at undisturbed properties within Developed Zones or at additional locations meeting preference criteria for elevation and slope aspect in Undeveloped Zones) after sampling grids were established. The final sampling design included the following allocation decisions:

- sampling grids of 2000, 3250, and 4500 feet at Developed Zones D1/D2/D3, respectively and 3000, 6000, and 8000 feet at Undeveloped Zones U1/U2/U3, respectively.

- sampling at 4 locations (borings) for each residential property in one of the Developed Zones D1/D2/D3, with 2 borings each in front and back yards where possible; sampling at 3 borings for any added undisturbed (forested) properties in D1/D2/D3; and sampling at 3, 2, and 1 boring at Undeveloped Zones U1/U2/U3, respectively. The multiple borings per property at undisturbed properties provide information on variability at small spatial scales (and are referred to as "spatial scale" sampling).

- in addition to standard 0-2 and 2-6 inch depth samples at all sampling locations, collecting additional 6-12 inch depth interval samples at 40%, 30%, and 20% of Developed Zone D1/D2/D3 properties, respectively and at 25% of Undeveloped Zone U1 properties. No additional depth interval samples were collected for Undeveloped Zones U2/U3. (At properties selected for 6-12 inch sampling, all borings were intended to have additional 6-12 inch depth intervals sampled). The added depth sampling focused on disturbed properties and zones where higher contaminant concentrations were anticipated, to provide more depth profile information. Maximum concentrations had previously been found to occur below 6 inches more frequently at residential (disturbed) properties. Contaminant mobility and vertical extent were also better characterized by deeper profiling.

These allocation principles resulted in a study design with almost 300 sampling locations and over 2100 soil samples (Table 1, reproduced from the study design report [TPCHD 2002a]). The three Developed Zones, with only about 27 percent of the study area, included almost 72 percent of the total design sample count. This reflects the allocation decisions to sample more intensively closer to the smelter and at residential versus forested properties. Some reduction in the actual numbers of sampled properties and samples were expected because of access denials or non-responses and the application of localized exclusion criteria. The study design incorporated a tolerance for moderate reductions in sample counts while still meeting the primary study objectives. (The actual sample counts by zone are provided in Table 2; a comparison of Tables 1 and 2 thus shows how the final data set differs from the study design).

The designation of Sampling Zones was used only for developing the sample allocation scheme; apart from that use, the zones have no consequences for data evaluations. The spatial patterns in contamination are evaluated on the continuous dimensions of distance and direction from the smelter, taking into account the binary classification of sampling locations as undisturbed or disturbed.

All Pierce County Footprint Study samples were analyzed for arsenic and lead. Arsenic is the primary smelter-related contaminant that determines the extent of the Tacoma Smelter Plume Site and has been the focus for human health risk evaluations. Other sources contributing to arsenic contamination of soils near the smelter are believed to be of much less importance for regional-scale patterns. Lead is also known to have been released by the smelter in substantial quantities and has been evaluated as a second important contaminant for human health risk evaluations. While other sources contributing to lead in soils (e.g., historic leaded gasoline emissions and weathering of lead-based paints) are likely to be important downwind from the smelter, particularly in urbanized areas, the Work Group decided to include lead analyses for all samples as was done in the King County footprint studies. (The distinct patterns in results for arsenic versus lead, by type of property sampled, are discussed in Section 4.0). All of the arsenic and lead results are addressed in this report.

The study design also included analysis of additional trace elements for selected Pierce County Footprint Study samples, to support source identification evaluations. The selection of samples for trace element analyses was made to provide for spatial coverage of the study area, inclusion of a broad range of arsenic and lead results, inclusion of varying lead-to-arsenic ratios, and other factors. Trace element samples were thus selected only after initial arsenic and lead results were known. The study design targeted about 10 percent of all Pierce County footprint samples for trace element analyses; about 12.5 percent of all samples were ultimately included. This component of the study design extended previous trace element analyses in King County soil samples. The same three primary trace elements - antimony, bismuth, and indium - were used in both King County and Pierce County studies. The results for King County samples have already been evaluated and reported (see Glass 2003). An additional report on the Pierce County results is in preparation.

2.0 SAMPLE COLLECTION

All field sampling activities were performed by a two-person sampling team from TPCHD. The protocols for field sampling activities were documented by TPCHD sampling personnel in a Field Sampling Plan (TPCHD 2002b) completed before sample collection started. That Field Sampling Plan also included specific grid layouts for each Sampling Zone. Field sampling staff participated in the Study Design Work Group meetings and were therefore well-versed in the study design principles to be applied in field decisionmaking. They also completed field training with sampling equipment and reviewed all field documentation, database management, and sample handling protocols before sample collection started.

Sample collection took place, without significant delays because of weather conditions, between March 22 and October 21, 2002. Field sampling was preceded by public information activities to increase local awareness of the study and support efforts to secure access agreements. Those activities included a meeting with local officials and press coverage of the impending study during January 2002.

Access agreements with property owners were completed for all properties to be sampled. The TPCHD field sampling staff identified multiple candidate properties for each planned sampling grid node, with a bias for undisturbed properties and the oldest homes, and sent out requests for access. The selection of those candidate properties was supported by information from Pierce County geographic databases (e.g., age of homes, property ownership records). In some cases, properties whose owners had requested sampling after becoming aware of the study and which fit into the study design (e.g., by location and age of the home) were included. Followup contacts were often required when the first mailed notice seeking an access agreement did not produce a timely response. Multiple access agreements were sent out to increase study efficiency, assuming some percentage of access requests would not be successfully completed, and thereby shorten the time to study completion. Where multiple agreements were obtained for one grid node, only one property (generally the first responding property) was sampled. Where no access agreements were obtained for a grid node, additional property owners were contacted or sampling was deferred pending a decision on whether or not adequate coverage had been achieved without sampling at that grid node. The TPCHD staff worked to maintain an inventory of completed access agreements in advance of field sampling activities. There was no overall spatial sequencing to sample collection; daily field activities focused on sampling at a cluster of properties with completed access agreements within a small portion of the study area, with the location of such clusters varying over time more or less randomly.

In a few cases, property owners or their representatives accompanied the TPCHD staff during field sampling activities. There were no requests for split samples.

A utility locator service was used to clear proposed sampling locations at residential properties. This was deemed unnecessary at undisturbed, forested sampling locations.

The TPCHD field staff selected specific boring locations in the field. The selection process focused on obtaining representative soil samples, considering various exclusion and preference criteria (see TPCHD 2002b). At undisturbed properties, any signs of likely disturbance of near-surface soils (e.g., paths in the forest or hummocky terrain indicative of uprooted trees) were noted and those areas avoided. At residential properties, setbacks from roads and painted structures were used and boring locations were selected to be spatially representative of primary lawn areas (avoiding garden beds, sand boxes, and other more obviously disturbed areas). The field sampling team also selected properties where additional 6-12 inch depth samples would be collected on the percentage bases specified in the study design, with broad spatial coverage within the relevant Sampling Zones. In Sampling Zones U1 and U2, as well as at undisturbed properties in the Developed Sampling Zones, clusters of "spatial scale" samples were also laid out in the field using random directions (see TPCHD 2002b).

Most samples were collected using a series of stainless steel drive tubes. This sampling equipment differed from previous Tacoma Smelter Plume footprint studies; the drive tube method had been used by Ecology in a study of residential properties in University Place, Pierce County (an area also included in this footprint study). The drive tubes had a flat top and were driven into the ground using a small sledgehammer. They had diameters of 2 to 3 inches and tube lengths corresponding to the increments used for sampling - 2, 6, and 12 inches. By successively driving these tubes into the same boring, soil samples for 0-2, 2-6, and 6-12 inch intervals were collected. The soils were removed from the drive tubes by tapping their sides, with soils collected into a stainless steel mixing bowl or onto aluminum foil and then placed into sample jars. In those cases when soils were not retained in the drive tube, a stainless steel spoon was used to remove soils from the boring hole marked by advancing the drive tube. Care was taken to avoid having soils from upper levels fall down into a deeper collection interval.

Field QA samples included periodic field duplicate samples and rinsate blank samples. Field duplicate samples were prepared by placing soils from one depth interval sample into a stainless steel mixing bowl, homogenizing them using a stainless steel spoon, and then dividing the sampled materials equally into two sample jars. A similar procedure for homogenization and subsampling was used when the amount of collected sample exceeded the capacity of the sample jar.

The soil samples collected in the field were bulk samples; other than removing large stones or woody materials, no sample preparation measures (e.g., sieving) were taken in the field. The forest duff layer was removed before sample collection at undisturbed properties. The surface grass/root layer from residential lawns was collected in the first drive tube; fine soils within this root mass were then shaken loose and included in the soil sample, discarding the organic grass/root mass. All samples were keep with blue ice packs in a cooler in the field. They were then either delivered to the analytical lab the same day or kept in a locked refrigerator

at 4 degrees C at TPCHD until delivered to the lab (with storage at TPCHD lasting no more than a few days). Chain-of-custody forms were prepared and accompanied the samples from the field. (Additional chain-of-custody forms were later used for shipment of the selected trace element samples from the initial analytical lab to the Battelle Sequim lab). Glass sample jars were provided by the analytical lab, Severn Trent Laboratory (STL) in Tacoma.

The field sampling team recorded various types of information relevant to each sample in a field notebook at the time of sample collection. The field personnel, property address, sample identification, date/time/weather conditions, and similar identifying information was entered, as well as information on such characteristics as elevation, slope magnitude and slope aspect, soil description, and vegetation, among others. The field team entered this field log information on a weekly basis into a project database designed by TPCHD. The TPCHD database included all fields required for submittal of the study results in Ecology's Environmental Information Management (EIM) database format, as well as additional fields.

Unique sample codes were assigned to identify all samples. Those sample codes were used on sample jar labels, chain-of-custody forms, and in all subsequent data management activities. The format for sample codes was as follows:

Zone/Property - Property Type - Boring/Depth - Sample Type - Residential Location

where the designations used are

Zone/Property:	"hundred series" numbering used to distinguish Sampling Zones, with unique numbers for each location: Zone D1: **101-299** Zone U1: **501-599** Zone D2: **301-399** Zone U2: **601-699** and **801-899** Zone D3: **401-499** Zone U3: **701-799**
Property Type:	**1** for disturbed property **2** for undisturbed property
Boring/Depth:	a two-digit series with the first number for boring, the second number for depth interval: borings numbered **1, 2, 3, or 4** depths numbered **1 (0-2"), 2 (2-6"), or 3 (6-12")**
Sample Type:	**4** for regular soil sample **5** for field duplicate soil sample **6** for rinsate blank sample
Residential Location:	where at a residential property a sample was collected: **1** for front yard

2 for back yard
0 if not applicable (e.g., at undisturbed property)

For example, sample **145-1-32-4-2** represents a regular soil sample collected in Sampling Zone D1, property number 45 in that zone, a residential (disturbed) property, from boring number 3, depth interval 2 (2-6"), located in the back yard. Similarly, sample **697-2-11-5-0** represents a field duplicate sample collected in Sampling Zone U2, property number 97 in that zone, a forested (undisturbed) property (and therefore a front/back yard location is not applicable), from boring number 1, depth interval 1 (0-2").

The original grid layouts used sequential property numbering within each zone. However, added opportunistic samples were frequently given non-sequential property numbers, and some of the original grid cells were not sampled (e.g., because no access agreement was completed or no appropriate sampling locations could be identified). As a result, the final data listing deviates from a strictly sequential property numbering scheme in each Sampling Zone.

A map of the locations sampled, with the Zone/Property codes identified at each location, is provided as Figure 1b. Table 2 presents a summary of the samples collected and analyzed for the Pierce County Footprint Study (excluding QA samples). The final data set includes results for 194 sampling locations (i.e., properties), 619 borings, and 1,409 soil samples. Residential (disturbed) results account for 105 locations (54 percent) and 974 samples (69 percent). Forested (undisturbed) results account for 89 locations (46 percent) and 435 samples (31 percent). Of these totals for forested locations, 13 locations and 92 samples occurred within the three Developed Sampling Zones (i.e., were collected as targeted/opportunistic samples).

Overall the 1,409 samples collected and analyzed represent slightly less than 70 percent of the maximum sample count identified in the study design (see Tables 1 and 2). The decrease in sample count reflects loss of samples because of local exclusion criteria and the lack of access agreements. The coverage provided by the collected samples collected was judged adequate to meet the study objectives; the relatively small areas where sampling density was low do not affect the ability to evaluate the regional-scale pattern of soil contamination. Sample collection proceeded in accordance with the design principles, with only a few minor exceptions. At two locations (numbers 411 and 418) an additional 6-12 inch depth interval was sampled at only 1 of 3 borings (see Table 2), instead of all 3 borings as called for in the study design. One residential property (number 383) was very small and had only 3 borings instead of the planned 4. At 16 of the 105 residential properties, samples were collected only in a front yard or a back yard because of the property layout.

3.0 RESULTS

3.1 LABORATORY ANALYSES

All laboratory analyses for arsenic and lead were performed by Severn Trent Laboratory (STL) of Tacoma, Washington under contract to TPCHD. The laboratory protocols are fully described in a Quality Assurance Project Plan (QAPP) (TPCHD 2002c). All collected samples were analyzed; none were archived without analysis.

The bulk soil samples received from the field were sieved by STL, with analyses performed on the <2mm fraction. Percent moisture analyses were also performed and analytical results were reported on a dry weight basis. These measures are consistent with Ecology's Model Toxics Control Act (MTCA) requirements for evaluating soil contamination and with previous Tacoma Smelter Plume Site studies.

Soil samples were prepared for analysis using a microwave digestion procedure (Method 3051A). Arsenic and lead analyses were performed by ICP-MS (Method 6020). This analytical method offered low detection and quantification limits; the nominal Practical Quantitation Limits (PQLs) for arsenic and lead in soils were 1.0 and 0.5 ppm, respectively. The low PQL values proved adequate to quantify all arsenic and lead results; no values were reported as not detected or below quantification limits.

Laboratory analyses were performed on and reported for groups of up to 20 samples, called Sample Delivery Groups (SDGs). The analyses for each SDG included a set of lab QA analyses such as lab duplicates, blanks, matrix spike/matrix spike duplicates, and lab control samples (standard reference materials) (see TPCHD 2002c). Instrument calibrations were also maintained and checked throughout the analytical program. Field duplicate and rinsate blank samples prepared during field sampling were also analyzed and provided additional QA information. As SDG analyses were completed, STL reported the sample and QA results to EcoChem, Inc. with sufficient backup information to support independent data validation reviews (see Section 3.2 below).

Once the arsenic and lead analyses were completed, STL stored the remaining sample materials pending decisions on the selection of samples for additional trace element analyses at a second analytical lab, Battelle Sequim. STL shipped the selected samples to the Battelle Sequim lab in several sample groups as they were identified by TPCHD. Once all trace element analyses had been completed, TPCHD instructed STL and Battelle Sequim to discard all remaining archived samples. Therefore, there are no remaining archived sample materials from the Pierce County Footprint Study.

3.2 DATA VALIDATION

An independent data validation of all arsenic and lead results was performed by EcoChem, Inc. of Seattle, Washington following the procedures established in EPA's *National Functional Guidelines for Inorganic Data Review*. The first SDG and 10 percent of remaining SDGs received full validation (Level IV); the remaining 90 percent of SDGs received summary validation (Level III).

The steps included in data validation reviews are identified in the QAPP (TPCHD 2002c). No data were rejected; the completeness for analytical results was thus 100 percent.[1] EcoChem assigned an "estimated" data quality flag (J flag) to a small proportion of the results, indicating the potential for lesser accuracy or precision in those results compared to unflagged values. All of the J-flagged results were used, as quantified by STL, in data evaluations. EcoChem's data validation reviews did not result in any recommendations for corrective actions at the analytical laboratory during this study.

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[1]After the results of trace element analyses by Battelle were received, it was noted that there was an apparent reversal in one set of 0-2 inch versus 2-6 inch samples between the two labs. The physical descriptions of the two depth intervals from location 247 as recorded in the field notebook did not match the observed characteristics of the samples in jars at Battelle; moreover, the strongly differing arsenic results for the two depths were also reversed between the two labs. Sample jars were not relabeled when sent from STL to Battelle. The exact cause of the apparent reversal was not determined. As a precaution, the trace element results for the two location 247 samples were excluded from data evaluations in the trace element report. The investigation of this apparent sample reversal was not completed before data evaluations for this report were performed. The STL results for the location 247 samples were included, although for consistency with the approach taken in the trace element results data evaluations they might have been excluded. Given the large size of the Pierce County Footprint Study data set, inclusion of the results for location 247 has de minimis effects on the data evaluations and conclusions.

As data validation reviews were completed on SDGs, EcoChem prepared and submitted electronic data delivery packages to TPCHD. Those data were then loaded into TPCHD's data management database, which became the single official data repository for study results. All data entry into the TPCHD database was verified before those data were released or evaluated. The major results from the project were also downloaded from TPCHD to Ecology's Environmental Information Management System database; that download included only selected fields from the extensive TPCHD database.

3.3 ANALYTICAL RESULTS

All data evaluations of the Pierce County Footprint Study results are based on data listings obtained from the TPCHD database. A complete listing of arsenic and lead results for all 1,409 samples is provided as Attachment A. The results in Attachment A are ordered by the three-digit property number (Sampling Zone plus sequence), boring number, and depth. The listing of results also provides information on the distance and direction of sampling locations (see also Figure 1b) from the Tacoma Smelter's tall stack, which has been demolished as part of Superfund cleanup actions at the smelter site. Regional-scale soil contamination around the Tacoma Smelter is primarily the result of cumulative tall stack emissions over the smelter's operational history.

The overall ranges for arsenic and lead concentrations (dry weight basis, samples sieved to <2mm fraction for analysis), over all sampling locations, depths, and property types, are as follows:

arsenic:	1.66 ppm to 1,050 ppm
lead:	1.81 ppm to 6,670 ppm

4.0 DATA EVALUATIONS

The Pierce County Footprint Study data set includes arsenic and lead results for 1,409 soil samples (see Table 2). These soil samples are organized into a hierarchic design; that is, samples for multiple depth intervals were collected from borings which were clustered within sampling locations which occurred within Sampling Zones. Two dissimilar types of sampling locations - residential (disturbed) and forest (undisturbed) - were also included in the study. Under this design, data evaluations can focus at different hierarchic levels. For example, results can be evaluated at the level of individual samples or sampling locations. Soil contaminant patterns were also expected to differ in important ways for residential and forest properties; the data set was therefore often sorted to support separate evaluations by sampling location type.

The Sampling Zones were defined during study design primarily as a means of making sample allocation decisions (see Section 1.2). Sampling Zones offer a convenient stratification of the study area for summarizing some of the spatial aspects of the data set. The boundaries between Sampling Zones do not, however, reflect any marked distinctions in soil contaminant patterns, which show a gradational rather than a sharply differentiated spatial pattern.

The Quality Assurance Project Plan (TPCHD 2002c) describes the flow of information from the analytical laboratory to the data validation contractor to TPCHD. Validated results were compiled in a project database designed and maintained by TPCHD. Validation results were uploaded (via electronic data deliverables) from EcoChem, Inc. The TPCHD field sampling staff entered additional information from the field notebooks by hand. Database entries were QA reviewed before any data evaluations were performed. All data evaluations reported here are based on a download of information from the TPCHD database.

The TPCHD database includes numerous types of information. Selected data fields were used for the data evaluations reported here; information on other variables (e.g., soil descriptions, slope, elevation) is retained in the database for possible later evaluation. Distance and direction values, at the level of sampled properties, were derived by TPCHD from coordinates of the Tacoma Smelter tall stack and location information (e.g., GPS coordinates) measured in the field. Recoded variables (e.g., the maximum concentration at any depth for each boring, the maximum concentrations from the front and back yards of residential properties, or the maximum concentration from any sample at a sampled property) were also derived from the results for individual samples.

The downloaded data were provided by TPCHD in the form of Excel spreadsheets, which were used as input files to the Statgraphics™ software package that was used for data plotting and statistical analyses. The complete data sets used for data evaluations are provided as attachments to this report: Attachment A provides a listing of results by sample, and Attachment B provides a listing of summary data by sampling location. (See explanatory notes at the end of

the data listings in the Attachments). Sample ID codes are explained in Section 2.0. All of the arsenic and lead results are quantified values; there are no not-detected results to be considered within the data evaluations.

Mapping of study results was performed by both TPCHD and Ecology using GIS software.

4.1 MAGNITUDE AND SPATIAL PATTERN

The ranges of concentrations for both arsenic and lead extend over about three orders of magnitude. The maximum concentrations of 1,050 ppm and 6,670 ppm for arsenic and lead, respectively, are much higher than the MTCA cleanup standards for unrestricted (residential) land use of 20 ppm and 250 ppm for arsenic and lead, respectively.

The maximum contaminant concentrations for each sampling location provide the best information on the upper bounds for soil contamination, mapped across the Pierce County study area. The study design Sampling Zones, which reflect smaller subregions of the overall study area generally based on distances and directions from the Tacoma Smelter tall stack, are useful for summarizing the data and suggesting the spatial patterns for soil contamination. For these purposes, the data for maximum concentrations were separated by the six defined Sampling Zones, with a further separation for residential and forest sampling locations within zones D1, D2, and D3. The number of forest sampling locations in each of these heavily developed zones was small. Only forest properties were sampled within the three undeveloped zones U1, U2, and U3.

Maximum arsenic and lead concentrations at the 194 sampling locations, sorted by Sampling Zone and property type, are summarized in Table 3. The information in each block of Table 3 includes the total number of sampling locations; the number of those locations with a maximum concentration exceeding the MTCA cleanup standards, noted above; the percentage of locations for that block whose maximum concentration exceeds the standard; and the range of maximum concentrations for all sampling locations in that block. Examination of these tabled entries shows that where both residential and forest locations are sampled in a zone, the frequency (percentage) of locations exceeding MTCA standards for either arsenic or lead is higher in the forested (undisturbed) locations. This agrees with the conceptual model of the effects of property development on (peak) contaminant concentrations in soils. Trends in the frequencies of exceedance and the highest maximum concentrations are also notable, from zone D1 to zone U3. The width of the range for maximum concentrations is also seen to be greater for zones closer to the smelter, for each sampling location type. The exceedances of MTCA standards are more frequent for arsenic than for lead; arsenic is thus the contaminant of greatest concern for defining site boundaries and focusing protective/remedial measures.

A somewhat more detailed summary of the data distributions for the nine categories of

Sampling Zone/Location Type is provided in Table 4. The numbers of locations, and corresponding percentages, within specified concentration ranges (arbitrarily selected, including ranges both below and above the MTCA standards) are listed for each of the nine categories. The distributions of maximum concentrations shift downward toward lower levels, for each property type, as distances from the smelter increase. (The inclusion of residential Northeast Tacoma areas within zone D2, in a direction not otherwise included for zones D1/D2/D3, influences the results for that zone and accounts for the slight deviations from the general trend).

Tables 2 and 3 show that in Zone U3, located in the northwest corner of the county in directions with low wind frequencies from the smelter, all 12 sampled locations have maximum arsenic and lead concentrations below the MTCA standards. The data collected in this footprint study for that zone thus confirm the expectation that sampling to the county line extended beyond the probable MTCA boundary for the Tacoma Smelter Plume Site in this region. All of the other Sampling Zones include locations whose maximum concentrations exceed the MTCA standards.

The maximum concentrations of arsenic and lead for each sampling location are mapped on Figures 2 and 3, respectively. These "dot maps" use color coded symbols representing specified concentration ranges to help visualize the spatial patterns of contamination. Clear spatial gradients with distance and direction from the smelter are revealed on the arsenic map (Figure 2). The lead map (Figure 3) has a similar appearance, but with some additional high-lead regions in the urbanized portion of the study area.

The regional-scale spatial pattern for soil contamination in relation to distance from the smelter is also shown by creating scatterplots of the maximum concentrations (LOG-scaled, in ppm) versus distance from the tall stack (linear-scaled, in miles). Summary plots, including data for all 194 sampling locations regardless of direction from the stack, are provided in Figures 4 and 5 for arsenic and lead, respectively. Different symbols are used to distinguish residential and forest sampling locations on these figures. (Note: exponential decay bounding curves for concentration versus distance will plot as straight lines on these LOG-linear scatterplots; see Section 4.5). Given the very broad ranges and skewed distributions for contaminant concentrations, linear scaling for the concentration axis compresses much of the data toward the bottom of a scatterplot making it harder to visualize the data.

The scatterplots for both arsenic and lead show that concentrations decrease as distance from the smelter increases; the decreases appear consistent with an exponential decay function. The plots also show a substantial degree of variability in maximum concentrations within small distance intervals. Some of this variability is resolved if the data from all 194 sampling locations are plotted separately according to wind sectors (see the discussion in Section 4.5). However, significant variability among nearby sampling locations in maximum concentrations still occurs even on these wind sector plots, as evidenced by the spread of the plotted values well below the uppermost bounding curve. This has been found to be characteristic in all of the Tacoma

Smelter Plume footprint studies. As revealed in the data summaries in Tables 2 and 3, the ranges of maximum concentrations grow narrower as distance from the smelter (and the overall degree of soil contamination) decreases.

In summary, on a regional scale soil arsenic and lead concentrations show exponential decay gradients with distance from the smelter and an association with wind frequencies (i.e., distances along the concentration gradients to given values extend farther as the wind frequencies increase). Smaller scale spatial patterns are discussed in Section 4.4 below.

4.2 CORRELATION BETWEEN ARSENIC AND LEAD

The arsenic and lead concentrations in the footprint study samples show statistically significant correlations; as will be seen, this association between arsenic and lead is much stronger for undisturbed (forested) than for disturbed (residential) sampling locations.

The data distributions for arsenic and lead are right-skewed; therefore, correlation and regression analyses used LOG-transformed data (to reduce the influence of a small number of values from the upper tails of the distributions and produce approximately normally-distributed variables). Linear regression applied to LOG-LOG data plots results in best-fit equations (in original units) of the form

$$\text{lead} = \text{constant} \times \text{arsenic}^{(\text{exponent})}$$

where the exponent is equal to the slope of the regression line on the LOG-LOG data plot. This equation can then be used to calculate characteristic lead-to-arsenic ratios, which vary along the regression line (i.e., for different assumed arsenic concentrations).

Correlation/regression analyses can be carried out for data sets at different levels of the study design. The analyses can reflect individual samples, the maximum values (at any sampled depth interval) for each boring, or the maximum values (for any boring or depth interval) for each sampled location. This sequence of evaluations reflects decreasing sample sizes but increasing control for the potentially different vertical mobilities of arsenic versus lead and the effects of localized (within-property) variability. Multiple correlation/regression analyses (e.g., separate analyses for 0-2 inch and 2-6 inch samples) can also illustrate other features of the soil contamination (e.g., comparatively greater vertical mobility for arsenic versus lead). Because of the differences between undisturbed and disturbed properties, one of the most useful approaches is to perform separate analyses for forested and residential properties.

The primary correlation/regression analyses were carried out using the maximum values for each sampling location (n=194, including 105 residential and 89 forested locations). The effects of differential contaminant mobility and localized spatial variability are reduced at this level of analysis, which generally produced the strongest statistical results. A scatterplot of the maximum lead versus maximum arsenic results by location (note LOG-scales on the axes) is

provided in Figure 6 (see Attachment B for a data listing). The results for residential and forested sampling locations are shown using different symbols in Figure 6.

Considering the results for all 194 locations together, the correlation between arsenic and lead is 0.62 (R-squared value 38.25 percent) and is statistically significant ($p<0.00001$ for regression slope). The different patterns for residential and forested locations, however, are obvious on Figure 6. Residential locations show greater variability and include a number of high-lead, low-arsenic outliers; most of the increased variability for residential locations is seen to be in the direction of higher lead-to-arsenic ratios. The arsenic:lead correlation for 89 forested locations is 0.93 (R-squared value 86.65 percent, $p<0.00001$), while for 105 residential locations the correlation is only 0.26 (R-squared value 7.02 percent, $p=0.006$). The association between arsenic and lead is thus much clearer for undisturbed forested locations. This is interpreted to be the result of additional lead sources (e.g., leaded gasoline, leaded paints) and soil disturbance in urbanized residential regions; in some cases, it may also reflect the dominance of lead emissions from the early years of operation of the Tacoma Smelter as a lead smelter. Note, however, that a statistically significant association between arsenic and lead is still found for the 105 residential sampling locations.

The regression equation for results from the 89 forested locations is

$$\text{lead}_{max} = 4.42 \times \text{arsenic}_{max}^{0.882}$$

which results in characteristic lead-to-arsenic ratios from 3.37 to 1.96 for arsenic ranging from 10 to 1000 ppm. This is consistent with the ratios found in King County areas downwind of the Tacoma Smelter.

Analyses carried out at the level of borings and individual samples had similar, if slightly more variable, results. For example, based on the maximum values per boring, forested locations had an arsenic:lead correlation of 0.91 ($n=200$, R-squared value 81.99 percent); for individual sample results, forested locations had a correlation of 0.88 ($n=435$, R-squared value 76.74 percent). Both results were still highly statistically significant ($p<0.00001$).

When separate analyses are performed for 0-2 inch and 2-6 inch results from all borings at forested locations ($n=200$ in both cases), the regression results provide an interesting perspective on comparative mobilities for arsenic versus lead. Arsenic and lead show a pattern of strong association at both depths. For 0-2 inches, the correlation is 0.90 (R-squared value of 81.38 percent, $p<0.00001$); for 2-6 inches, the correlation is only slightly less at 0.86 (R-squared value 73.33 percent, $p<0.00001$). The characteristic lead-to-arsenic ratios for arsenic between 10 and 1000 ppm, however, decrease from 3.02 - 1.36 at 0-2 inches to 2.10 - 0.72 at 2-6 inches. This is consistent with a comparatively greater vertical mobility for arsenic versus lead in near-surface soils. Contaminant depth profiles are discussed further in Section 4.3 below.

The lead-to-arsenic ratios, based on maximum values per sampling location, were also

examined as a function of distance from the Tacoma Smelter. Untransformed data were used for this analysis, which focused on forested properties which are less affected by non-smelter artifacts. For the 89 forested sampling locations, a modest association of this contaminant ratio with distance was found, although with considerable variability. The correlation was 0.37 (R-squared value 13.76 percent) with a regression equation (p=0.0003 for slope) of

$$\text{ratio} = 0.13 \times \text{Distance (in miles)} + 2.08$$

indicating that lead-to-arsenic ratios increased with increasing distance from the smelter. (Increasing distances from the smelter in the Pierce County study area are generally associated with an urban-to-rural gradient, which is typically found to have decreasing lead concentrations. Any statistically significant increasing lead-to-arsenic ratios would thus seem unlikely to be caused by non-smelter "urban plume" lead contamination, unless the urban plume effects extended to greater distances than Tacoma Smelter impacts. Higher lead-to-arsenic ratios typical of background soils, mostly sampled at larger distances from the smelter in less frequent wind directions, may be contributing to the statistical result of increasing ratios with increasing distance). However, when the analysis was repeated for only those undisturbed sampling locations in the primary downwind directions in Pierce County (S, SSW, and SW), the results were no longer statistically significant (n=34, correlation of 0.13, R-squared value of 1.60 percent, ratio = 0.037 x Distance + 2.47, and p=0.48). This suggests that the lead-to-arsenic ratios are not strongly associated with distance from the Tacoma Smelter, consistent with the results of similar analyses for Vashon-Maury Island and King County Mainland data sets.

4.3 DEPTH PROFILES

Samples in this study were collected and analyzed separately for several depth intervals in near-surface soils. These results provide information for evaluating patterns in contaminant depth profiles and the comparative mobilities of arsenic and lead. Some characteristic differences between undisturbed (forest) and disturbed (residential) patterns are revealed by performing evaluations for these data subsets separately.

For all 619 borings (200 forest, 419 residential) there are matched 0-2 inch and 2-6 inch results. As described in Section 1.2 (see also Table 2), an additional 6-12 inch depth interval was sampled for selected borings. Results for 6-12 inch samples are available for 171 borings (35 forest, 136 residential) from 47 of the 194 properties sampled (13 forest, 34 residential; see Figure 1b for locations). Contaminant depth profiles are evaluated through comparisons of the matched results within each boring (rather than summary statistics by depth interval sampled).

Graphical data presentations are effective in illustrating the depth profile patterns. They include results from all sampling locations and provide information on both the frequency and magnitude of various patterns in contaminant depth profiles. Two types of scatterplots are used to graph the results by depth, one for evaluating patterns for a single contaminant and a second

for evaluating and comparing the patterns for arsenic versus lead. These two types of scatterplots are briefly described in the following paragraphs, and are illustrated in Figures 7 through 12.

The scatterplots for single contaminants assign each axis a different sampled depth interval; for example, the X axis represents 0-2 inch data and the Y axis represents 2-6 inch data. The paired results for any one boring can then be plotted as a point on this scatterplot. Plotting the results across all borings in this way then provides a visualization of the entire data set. The "decoding" of this graphical information is helped through referencing the X=Y line showing where contaminant concentrations at the two selected depth intervals are equal. A point on one side of the line reflects a higher concentration at the depth interval represented by the closer axis. The proportions of points on either side of the X=Y line thus reflect the frequencies of different depth profile patterns. The distance of a point from the X=Y line indicates how far the ratio of concentrations at the two depth intervals differs from 1.00 (i.e., the relative magnitudes at different depths).[2]

The second type of scatterplot assigns each axis a ratio of concentrations for two depth intervals, with different contaminants represented on the X and Y axes. For example, the X axis can represent the ratio of 0-2 inch to 2-6 inch results for arsenic, and the Y axis a similar ratio for lead. The ratio for a single contaminant, of course, is just an indicator of the depth profile for a given boring; a ratio of 1.00 means equal concentrations at the two depths, a ratio less than 1.00 means the concentration at 2-6 inches is larger, and a ratio greater than 1.00 means the concentration at 0-2 inches is larger. The results for arsenic and lead at any one boring are used to calculate the two required ratios, and those ratios are then used to plot a point on the "comparison of ratios" scatterplot. (Example: a boring with 0-2 inch and 2-6 inch results of 150 ppm and 214 ppm for arsenic and 420 ppm and 300 ppm for lead, respectively, would have 0-2 inch/2-6 inch ratios of 150/214 = 0.7 for arsenic and 420/300 = 1.4 for lead. With the axes defined as above, these results would plot as the point [0.7,1.4]). The X=Y line on the scatterplot is again a useful reference for "decoding" the graphical information. A point on one side of the line reflects a higher ratio for the contaminant on the closer axis; that is, it reflects

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[2]Note that with LOG-scaled axes, a constant distance from the X=Y line (i.e., a line parallel to the X=Y line) represents a constant change in ratio but a varying change in absolute magnitude. A distance in the lower left corner of the plot, for example, represents a far smaller absolute change than one in the upper right corner. Absolute and relative magnitudes are thus both reflected in the plots, but in different ways.

comparatively greater retention of the contaminant at the 0-2 inch depth interval, and therefore comparatively less downward mobility. The patterns of comparative mobilities for arsenic versus lead are thus revealed by the proportions of plotted points on either side of the X=Y line, and the magnitude of those differences in mobility are indicated by the distances from the X=Y line.[3]

The arsenic results at 0-2 inches versus 2-6 inches for borings at forested and residential sampling locations are plotted in Figures 7 and 8, respectively. In Figure 7, most borings at forested locations are seen to reflect higher concentrations at the 0-2 inch depth interval; this is true across the entire range of concentrations. Moreover, for borings where the 2-6 inch concentration exceeds the 0-2 inch result, most points plot very close to the X=Y line, indicating the exceedance is small in magnitude. The results for borings at residential sampling locations, shown in Figure 8, are essentially shifted up compared to the results for forested properties. In a much larger proportion of borings, the 2-6 inch concentration exceeds the 0-2 inch result, and often by a greater magnitude. Residential properties as a group therefore have a pattern of more frequent "inverted" depth profiles (increasing concentrations with depth) for arsenic than forested properties. Both soil disturbance (including placement of fill) and lawn maintenance (e.g., frequent watering, application of phosphate fertilizers) may contribute to this difference in depth profile patterns.

The 0-2 inch versus 2-6 inch lead results for borings at forested and residential sampling locations are plotted in Figures 9 and 10, respectively. The general depth profile patterns for forested and residential locations, and the contrast between those two types of sampling locations, are quite similar to the patterns for arsenic. Comparing matched scatterplots for the two contaminants, lead appears to have somewhat greater retention than arsenic in the 0-2 inch depth interval (e.g., compare Figures 7 and 9). The comparative mobilities for arsenic and lead are examined more directly at the end of this section.

Similar scatterplots comparing arsenic and lead results at 6-12 inches to those at 0-2 and 2-6 inches were prepared and examined (figures not provided here). Residential properties as a group continued to show more frequent inverted depth profiles and relatively more contamination at depth than forested properties. Soil disturbance at residential (developed) properties could have affected contaminant depth profiles below the maximum 12 inch sampling depth in this study. At a few of the child-use properties sampled on Vashon-Maury Island, the maximum contaminant concentrations were found at 18-22 inches, the deepest of 5 depth intervals sampled.

The depths at which maximum contaminant concentrations occurred can be summarized at the level of borings (n=619) and sampling locations (n=194). For borings, the resulting counts are as follows:

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[3]See footnote 2.

	Arsenic		Lead	
	residential	forested	residential	forested
0-2"	187 (44.6%)	162 (81.0%)	278 (66.4%)	176 (88.0%)
below 0-2"	232 (55.4%)	38 (19.0%)	141 (33.7%)	24 (12.0%)

Summarized at the level of sampling locations, the results are:

	Arsenic		Lead	
	residential	forested	residential	forested
0-2"	50	72	66	82
2-6"	49	16	37	7
6-12"	6	1	2	0
number sampled at 6-12"	34	13	34	13

These tabled counts confirm the more frequent inverted profiles at residential properties and the somewhat greater retention of lead versus arsenic within the 0-2 inch depth interval. Overall, when the maximum concentration in a boring occurred below the top 2 inches, it exceeded the 0-2 inch value by more than 50 percent about one-fourth of the time (for arsenic, 57/232 = 24.6 percent at residential properties and 8/38 = 21.1 percent at forested properties; for lead, 39/141 = 27.7 percent at residential properties and 9/24 = 37.5 percent at forested properties).

The occurrence of a maximum concentration at 6-12 inches does not in and of itself indicate that the concentration is markedly elevated above typical (background) values. The pattern of a maximum concentration at 6-12 inches could occur even if all depths had concentrations well below MTCA cleanup standards, for example. The cases where maximum values were reported at 6-12 inches, however, include some substantially elevated contaminant concentrations: for arsenic, 171 ppm (location 518, forested) and 115 ppm (location 148, residential); for lead, 305 ppm (location 159, residential) and 272 ppm (location 163, residential).

The comparative mobilities of arsenic and lead were examined using the "comparison of ratios" scatterplot approach. The results for borings at forested and residential sampling locations are shown in Figures 11 and 12, respectively. Note that the X axis is for arsenic ratios and the Y axis for lead ratios (both calculated as 0-2 inch result divided by 2-6 inch result). For both forested and residential sampling locations, the figures show a very strong pattern of higher ratios for lead than for arsenic over most borings. Moreover, this pattern occurs over a broad range of ratios, indicating that the comparatively greater downward mobility for arsenic versus lead applies regardless of the depth profile pattern for individual contaminants. That is, whether in a given boring a higher lead concentration occurs at 0-2 inches or 2-6 inches, and whatever the ratio of those two results is for lead, the arsenic results generally show smaller ratios indicating comparatively greater movement from 0-2 to 2-6 inches.

4.4 SPATIAL VARIABILITY

Local Spatial Variability

At the spatial scale of the study area included in the Pierce County Footprint Study (approximately 200 square miles), soil contamination shows a strong pattern of spatial gradients with distance and direction from the Tacoma Smelter, as noted in Section 4.1. Within many local regions of the study area, results were found to vary substantially from one sampling location to another (see Figures 2 and 3). The study design resulted in distances between adjacent sampling locations of several thousand feet (the nominal grid distances were 2000 to 8000 feet; see Section 1.2). The variability in results for nearby sampling locations is well illustrated on concentration versus distance scatterplots, especially when separate scatterplots are developed by wind sector (see the discussion in Section 4.5 below). The maximum concentrations for arsenic or lead for individual sampling locations within a wind sector are spread out broadly below a bounding (exponential decay) curve. In the primary downwind directions, over a relatively small distance interval, those maximum concentrations often vary by one to two orders of magnitude. Thus, the results from one sampling location may not be a particularly good indication of results at nearby properties.

The property-by-property differences in soil contamination within the Tacoma Smelter Plume area are likely some combination of differences in deposition (e.g., caused by factors such as episodic smelter releases, elevation, slope, and surface cover) and soil disturbance (especially property development history, but also including erosion and other natural phenomena). Absent contributions from other significant anthropogenic sources (e.g., lead from gasoline or leaded paints), the property-by-property variability generally decreases along the regional contamination gradients until the comparatively low levels of background soil variability are encountered.

Variability Associated With Age of Home

Information on the age of homes (defined as the date of smelter closure [1986] minus the

year of home construction) at residential sampling locations was compiled in this study to explore the extent to which this factor helped explain property-by-property differences. A simplifying assumption is that the most important soil disturbance occurs at the time of initial construction of a home, and that the number of years of smelter operation (and deposition of smelter emissions) post-construction could therefore be a useful indicator for the magnitude of soil contamination on a property-by-property basis.

Residential sampling locations with age information occurred at distances from about 1 to 10 miles from the smelter. The TPCHD database provides age data for 97 of the 105 residential sampling locations (see Attachment B). The distribution of ages is not uniform but bimodal, with most ages in the less than 40 years or more than 70 years ranges. The distribution by distance is also not uniform, with most of the residential sampling locations occurring within a distance of 4 miles. A statistically significant relationship between age and distance from the smelter was found, with age decreasing as distance increased (n=97, p=0.003, R-squared 9.03%). Since distance is one of the major factors influencing airborne contaminant deposition and the magnitude of soil contamination, the covariation of age with distance is a potential confounding factor in the analysis of soil contamination versus age. When the data set is restricted to the approximately two-thirds of residential sampling locations at distances of 4 miles or less, the relationship of age and distance is no longer significant (n=62, p=0.41, R-squared 1.12%) and the distribution across distance is more nearly uniform. Initial evaluations of the relationship of age and soil contamination were therefore restricted to the reduced data set within a distance of 4 miles.

Regression analyses of the maximum arsenic and lead concentrations at these 62 residential locations versus the home's age were performed. Since the maximum concentration data sets were skewed, LOG-transformed values were used (but similar results are obtained using untransformed data). For arsenic, maximum concentrations decreased with age (concentration = 61.1 x ($e^{-0.0076 \text{ x age}}$) ppm) and the results approached statistical significance (n=62, p=0.08, low R-squared of 5.02%). Lead, on the other hand, showed a statistically significant increase in concentration with age (concentration = 54.5 x ($e^{0.0254 \text{ x age}}$) ppm); n=62, p<0.0001, R-squared 38.02%). The decrease of arsenic concentration with age is contrary to the simplistic conceptual model based on duration of post-construction smelter operations. The different slope directions for arsenic and lead suggest the importance of additional lead sources (e.g., leaded paints) for trends with age. The age parameter used here may be too simple an indicator variable to capture the history of soil disturbance over time. More complex data evaluations would be required to start to address various confounding factors. The initial evaluation of age versus maximum arsenic concentration provides scant explanation for property-by-property differences at distances within 4 miles of the smelter.

Within-Property Variability

The sampling design included collection of soil samples from multiple borings at most sampling locations, with separations between borings of no more than a few hundred feet. The small-scale, within-sampling-location variability can be evaluated using the results from such

boring clusters. All sampling locations except those in sampling zone U3 had more than one boring per location (see Section 1.2). Residential properties generally had four borings, two each in front and back yards. Forested properties had either two or three borings depending on sampling zone. Out of 194 sampled properties, 182 (all 105 residential, 77 of 89 forested) have results from more than one boring.

The within-property variability of soil contamination is an indication of how different the results would be if one boring rather than another was sampled. The maximum concentration from any sampled depth interval is used here as a summary parameter for the results at a boring. For each boring, the maximum concentration (from any sampled depth) was recorded. At each property with two or more borings, the "maximum" [Max] and "minimum maximum" [MinMax] values are defined as the largest and smallest maximum concentrations, respectively, from all of the borings at that property. These values for each sampling location are included in the summary data listing in Attachment B. The Max and MinMax values reflect how much difference there would have been in the reported maximum concentration at a property if only one boring was sampled.

A comparison of Max and MinMax values lends itself to a graphical data presentation, in a manner similar to that used for showing depth profiles in Section 4.3. Assigning the X axis to represent Max values, and the Y axis MinMax values, the paired results for any one of the 182 locations where two or more borings were sampled will plot as a point. A scatterplot of the results across sampling locations includes all individual property results and illustrates the patterns and magnitudes of within-property variability. LOG-scaled axes are used because of the non-normal (right-skewed) data distributions and broad ranges of values.

This visualization of within-property variability data is most easily "decoded" with reference to the X=Y line where Max equals MinMax (i.e., where there is no variation in maximum contaminant concentrations across borings). For all properties sampled in this study, there was some degree of variation across borings (albeit small in some cases) and all points plot below the X=Y line. The magnitude of the variation is represented by the (vertical) distance of a point below the X=Y line.[4]

A series of four variability scatterplots is used to present the results for arsenic and lead at residential and forested properties separately. Figures 13 and 14 provide the arsenic results for forested and residential properties, respectively; Figures 15 and 16 provide comparable results for lead. Several patterns can be discerned in these scatterplots. The Max and MinMax values are seen to be positively correlated; this is particularly apparent for undisturbed properties. Thus, as the degree of maximum contamination increases, all borings generally show higher levels to some degree (with infrequent exceptions most notable at residential properties).

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[4]See footnote 2 regarding the different manner in which absolute and relative magnitudes are represented in LOG-scaled plots.

The scatterplots do not show strong patterning (distances below X=Y line) as a function of maximum concentrations (X axis). This indicates that the Max/MinMax ratios are not a function of maximum concentration, but that the absolute magnitudes of differences between Max and MinMax values are a function of maximum magnitudes. A moment's reflections shows that this is quite reasonable; differences of 100 ppm can only occur where the maximum concentration is at least 100 ppm, and so on. Said another way, the bounding curves on maximum concentration versus distance plots for different sampling locations also define the possible variability, in absolute (ppm) terms, for different borings within properties. Thus, while relative within-property variability (ratios) may show little regional spatial pattern, the absolute variability (ppm) corresponds closely with the regional spatial gradients. The positive correlations evident in Figures 13 through 16 indicate that within-property variability is less than it would be if most properties included some areas at or near background concentrations. That is, contaminated properties mostly appear to reflect various degrees of contamination rather than a mixture of contamination and no contamination (although the latter pattern is more evident at a percentage of residential properties).

Additional information is revealed by tabulating counts of sampled locations with specified degrees of relative or absolute variability, using the Max and MinMax values to measure within-property variability. For relative variability (i.e., Max/MinMax ratio), the results are as follows:

	Arsenic		Lead	
ratio	Residential (n=105)	Forested (n=77)	Residential (n=105)	Forested (n=77)
<2	50 (47.6%)	59 (76.6%)	32 (30.5%)	39 (50.7%)
≥2	55 (52.4%)	18 (23.4%)	73 (69.5%)	38 (49.4%)
≥4	16 (15.2%)	4 (5.2%)	23 (21.9%)	4 (5.2%)
≥6	7 (6.7%)	1 (1.3%)	13 (12.4%)	3 (3.9%)

These results show that relative variability within properties is greater for lead than for arsenic. It also is greater for residential versus forested properties; this is judged likely to reflect the different property histories and soil disturbances at these two types of sampling locations, but it may also be (at least partly) confounded by the larger number of borings at residential properties and their location closer to the smelter. Relative variabilities can at times exceed a factor of 5.

Using the difference (in ppm) between Max and MinMax values for a property as an absolute measure of within-property variability produces another tabulation, as follows:

	Arsenic			Lead	
difference	Residential (n=105)	Forested (n=77)	difference	Residential (n=105)	Forested (n=77)
<50 ppm	84 (80.0%)	64 (83.1%)	<200 ppm	78 (74.3%)	67 (87.0%)
≥50 ppm	21 (20.0%)	13 (16.9%)	≥200 ppm	27 (25.7%)	10 (13.0%)
≥100 ppm	4 (3.8%)	5 (6.5%)	≥400 ppm	14 (15.3%)	4 (5.2%)

These results show rather similar patterns of absolute variability for residential and forested properties, instead of the contrasts shown for relative variability. The most notable result is the greater absolute variability for lead at residential versus forested properties. The largest differences between Max and MinMax values within a property were substantial: for arsenic, 311 ppm and 411 ppm at residential and forested properties, respectively; for lead, 6581 ppm and 2630 ppm at residential and forested properties, respectively.

The results from multiple borings at sampled Pierce County locations thus continue to demonstrate that the small-scale variability from boring to boring (at the spatial scale of a single property) can be substantial, measured as either relative or absolute variability. One, or a few, borings at a property may not adequately characterize the magnitude of soil contamination.

Variability for Front Yard versus Back Yard at Residential Properties

Finally, the maximum concentrations from front and back yards at sampled residential properties were compared, for arsenic and lead. The maximum concentration for the property was approximately equally likely to occur in either front or back yard samples. Figure 17 shows a scatterplot of the maximum arsenic results by yard location. The front and back yard maximum arsenic results show positive correlation. Most pairs are within a factor of 2 of each other, while a small proportion show greater variability.

4.5 DEFINING CHILD-USE STUDY AREA BOUNDARIES

The Pierce County Footprint Study results established the basic regional-scale patterns for the magnitude and extent of soil contamination by arsenic and lead around the Tacoma Smelter (see Section 4.1). In the second phase of Pierce County soil investigations, Ecology and TPCHD were interested in the potential soil exposures of young children at locations such as schools, parks and playgrounds, and child care centers; such locations were termed child-use areas. Interim Action criteria, previously selected by Ecology, and the Pierce County Footprint Study results were used to define the boundaries for child-use area sampling in Pierce County. Child-use area study boundaries for Pierce County and the King County Mainland were

developed at the same time in a single study design process; the same methodology for defining study area boundaries was used in both areas. That methodology is described in the child-use areas study design report (see Washington State Department of Ecology et al. 2002) and is summarized here.

Ecology had already established Interim Action criteria for arsenic and lead contamination at child-use areas. (They were established as the first child-use areas study on Vashon-Maury Island was being performed in 2000). The Interim Action criteria identified soil contamination levels at which early actions to reduce exposures should be considered. This reflected a "worst first" approach to managing risks from smelter-related soil contamination in recognition of the scale of contamination and the long timeframe that indicated for addressing the entire site. Based on the selected Interim Action criteria, arsenic was the contaminant of primary concern. Interim Action levels varied depending on the type of location, reflecting assumptions about the potential for soil exposures (e.g., frequencies of soil contact). The strictest criterion for arsenic was 100 ppm.

The results of the Pierce County Footprint Study showed that soil contaminant concentrations decreased according to an approximate exponential decay function with increasing distance from the smelter, and with magnitudes that correlated with wind frequencies. The general approach to defining child-use area study boundaries was therefore to estimate the bounding exponential decay function for each wind sector from the footprint study results and then to determine the distance at which soil arsenic concentrations fell below 100 ppm according to that bounding function. The child-use areas to be considered for sampling (due to resource limitations, only a sample of all candidate child-use areas could be sampled) were those located within those bounding distances. It is important to note that a bounding function (all data points on or below the curve) and not a best-fit function (roughly half the points above and half below the curve) is used for these evaluations. The derived distances are conservative because bounding functions are used, because they are developed from plots of maximum results for single samples and not locally averaged values, and because soil contamination at developed properties is often reduced from nearby undisturbed areas as a result of soil disturbance associated with development. These conservative factors are partly balanced by the limited number of samples in the footprint study and the possibility that unsampled locations would have produced even higher soil arsenic concentrations (which could raise the bounding exponential function).

The bounding exponential function will plot as a straight line when soil arsenic concentrations are plotted as LOG values (Y-axis) versus the linear distance from the smelter tall stack (X-axis) (see Washington State Department of Ecology et al. 2002). The evaluations of bounding functions proceeded as follows: 1) for Pierce County Footprint Study results, a database of maximum concentrations by property, with the associated distance and direction from the smelter, was compiled; 2) those data were partitioned by wind sectors corresponding to annual wind rose data (each wind sector being 22.5 degrees wide, centered on one of 16 compass directions such as SSW); 3) maximum concentration versus distance scatterplots for each wind

sector were prepared, using LOG concentration and linear distance scaling; 4) relevant historic data and results from the King County Footprint Study were added to the scatterplots where appropriate; 5) the points to be used for drawing a bounding line were selected; and 5) a bounding line was drawn by hand. The distances to 100 ppm arsenic for each wind sector were determined from those bounding lines.

Only a single data point was available for one Pierce County wind sector (NNW). Noting the strong correlations between wind frequencies and contaminant patterns, an estimated distance was derived for that wind sector by interpolation from estimated distances for the two adjacent sectors, using wind frequencies for the three sectors. The selection of data points for defining bounding lines took account of possible high outliers reflecting contaminant sources other than tall stack emissions and the effects of extending sampling into areas of minimal smelter impact (i.e., background regions). In a few instances, historic soil arsenic results plotted above the bounding line from Pierce County Footprint Study data and were therefore used to define the final bounding line for a wind sector.

The estimated bounding distances to 100 ppm arsenic by wind sector, derived from soils data, showed a strong association with annual wind frequencies. The SSW wind sector had the greatest estimated distance within Pierce County, almost 15 miles (see Washington State Department of Ecology et al. 2002 for all results).

The combined Pierce County and King County footprint study results were evaluated in a similar manner, but using the MTCA soil cleanup level of 20 ppm arsenic instead of the Interim Action level of 100 ppm as a target concentration, to support establishing study area boundaries for the 2003-2005 Extended Footprint Study (see Landau 2003). The selected study areas include additional parts of Pierce County south and east of I-5, as well as areas in Thurston, Kitsap, and King Counties.

5.0 CONCLUSIONS

The Pierce County Footprint Study, combined with two previous footprint studies in King County, results in a cumulative data set for 430 sampling locations covering an area of about 450 square miles in the region surrounding the former Tacoma Smelter. Sampling locations include all compass directions from the smelter. This cumulative data set provides a regional-scale overview of the spatial patterns of soil arsenic and lead contamination. The maximum arsenic and lead concentrations at each footprint study sampling location in King and Pierce Counties are mapped in Figures 18 and 19, respectively. The large-scale spatial pattern revealed on these maps shows contaminant concentration gradients with distance and direction, closely associated with the annual wind rose frequencies. Of particular note, these gradients are seen to exist in both prominent downwind directions (roughly northeast in King County and south-southwest in Pierce County).

In Section 4.1 scatterplots of maximum concentrations for arsenic and lead versus distance from the smelter were presented (see Figures 4 and 5, respectively). The regional-scale gradients shown in Figures 18 and 19 for the cumulative data set can also be demonstrated by extending the Section 4.1 figures to include data from both King and Pierce Counties. Figure 20 presents results for arsenic for the two primary downwind directions: between bearings of 12.25 and 57.25 degrees (NNE and NE), and between bearings of 192.25 and 237.25 degrees (SSW and SW). (This figure, and a similar one for lead, were included in the Credible Evidence Report). Figure 20 includes maximum arsenic concentrations for 173 of the total of 430 sampling locations to date (one additional location is omitted; see below). As a graphing convention, the Pierce County results are assigned negative distances so that they plot on the left; King County results plot on the right. The smelter tall stack location is at distance zero. In contrast to the Section 4.1 figures, Figure 20 uses linear scaling for arsenic concentration on the Y axis; to better show the spatial gradients, the largest maximum arsenic result of 1,050 ppm in Pierce County is omitted. Different symbols are also used on Figure 20 for residential versus forest sampling locations.

The very similar exponential decay patterns of maximum arsenic concentrations in both dominant downwind directions are clearly revealed in Figure 20. Other downwind directions also show exponential decay gradients, with comparatively lower upper-bound curves correlated with wind frequencies. The 2003-2005 Extended Footprint Study will continue to characterize these regional-scale spatial patterns over an even larger study area.

The Pierce County Footprint Study results are very consistent with the previous King County footprint results and extend the understanding of regional-scale contamination from Tacoma Smelter emissions. (The largest difference noted in the data evaluations - the differences among study areas in 0-2 inch versus 2-6 inch arsenic depth profiles for forested sampling locations, with a substantially lower frequency of maximum arsenic values at the 2-6

inch depth in the Pierce County study - is so systematic that it may be attributable to differences between studies in sampling equipment or field sampling methods, such as the removal of forest duff layers before sample collection). Through inclusion of sampling at many residential properties, this study also affords an opportunity to compare soil contamination patterns and magnitudes at disturbed and undisturbed sampling locations.

Evaluations of the Pierce County Footprint Study results support the following conclusions:

- ❑ Magnitude of contamination. A broad range of concentrations was found, from at or near background levels (less than 10 ppm) to maximum values of 1,050 ppm for arsenic and 6,670 ppm for lead. Many locations had values exceeding MTCA unrestricted land use (residential) soil cleanup standards of 20 ppm arsenic and 250 ppm lead; such exceedances were more widespread for arsenic than for lead.

- ❑ Spatial pattern. The regional-scale patterns of soil contamination showed gradients of decreasing concentrations with increasing distances from the smelter and decreasing wind frequencies. This "bulls-eye" pattern, elongated in the primary downwind directions, is strong evidence that Tacoma Smelter emissions are a primary source for the observed soil contamination. The arsenic spatial pattern was particularly evident, indicating a lack of other large arsenic sources. The lead pattern showed some effects from additional non-smelter sources of lead (e.g., leaded gasoline emissions, weathering of leaded paint). The extension of sampling to the county line in some low-frequency downwind directions (e.g., the Key Peninsula to the west and northwest) provided data showing consistent maximum concentrations below MTCA cleanup standards, and therefore provides a preliminary indication of partial MTCA site boundaries.

- ❑ Correlation of arsenic and lead. Undisturbed forested sampling locations had a very strong (R-squared value of 87 percent), statistically highly significant correlation between maximum arsenic and lead concentrations. The characteristic ratios of maximum lead:arsenic concentrations for forested locations were similar to those reported for the King County footprint studies. The correlation for residential sampling locations was much lower, although still statistically significant. A number of high-lead, low-arsenic results for residential sampling locations reduces the correlation and reflects additional sources for lead in urban areas (and possibly, in some cases, residual contamination from the early years of lead smelting at the Tacoma Smelter).

- ❑ Depth profiles. At undisturbed forested locations, the 0-2 inch arsenic and lead concentrations typically exceeded those at 2-6 inches. (This contrasts somewhat with the pattern found at forested locations on Vashon-Maury Island, where higher arsenic concentrations occurred about equally often at these two depth

intervals). The depth profiles for residential sampling locations were more complex, with many more "inverted" profiles showing higher concentrations at the 2-6 inch depth interval. The difference is very likely caused by the increased soil disturbance associated with development and maintenance of residential properties. Maximum concentrations were occasionally reported for the 6-12 inch depth interval, primarily at residential locations. For both forested and residential locations, arsenic generally exhibited a greater downward mobility compared to lead.

- ❑ Variability. Within local regions of the study area, maximum contaminant concentrations at nearby properties (separated by several thousand feet or more) can differ substantially. The results from one property therefore should not be extended uncritically to nearby unsampled properties. Similarly, the results from one boring to another within a single property (separated by no more than a few hundred feet) can differ substantially. One, or a few, borings at a property therefore may not adequately characterize the magnitude of soil contamination. Small-scale spatial variability in soil contamination likely reflects a combination of aerial deposition effects and post-deposition soil disturbances.

  At residential properties no systematic difference in maximum concentrations was found between front and back yard borings. The differences in maximum concentrations between front and back yards was typically within a factor of two, although higher for a small proportion of residential properties.

  For 62 residential properties within 4 miles of the smelter, the age of the home was not strongly correlated with the maximum arsenic concentration. Maximum lead concentrations, however, did show a significant increase as age increased.

- ❑ Further study designs. The prominent large-scale spatial gradients revealed by the Pierce County Footprint Study, especially in terms of bounding curves for exponential decay functions for concentrations versus distances by wind directions, are useful for designing further Tacoma Smelter Plume studies. They have been used to focus on high-priority areas for sampling of Child-Use Areas and for establishing additional study areas to determine Tacoma Smelter Plume Site boundaries in Pierce County and adjacent counties.

6.0 REFERENCES

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TABLES

FIGURES

ATTACHMENT A

Pierce County Arsenic and Lead Results by Sample

ATTACHMENT B

Summary of Pierce County Arsenic and Lead Results by Sampling Location

Table 1
Tacoma Smelter Plume Site
Pierce County Footprint Study
Summary of Study Design

Sampling Design Summary
Sample Location Arrays by Study Area Zones

Zone	Description	Area (sq. miles)	Grid Size (feet)	Number of Locations (estimate)	Borings per Location	Frequency of 6-12 inch samples	Samples per Location (average)	Number of Samples (estimate)
Developed Areas								
D1	North Tacoma	11.7	2000	82	4	40%	9.6	787
D2	University Place	15.4	3250	41	4	30%	9.2	377
	Browns Point	6.8	3250	18	4	30%	9.2	166
D3	Lakewood	17.4	4500	24	4	20%	8.8	211
Undeveloped Areas								
U1	Point Defiance	0.9	3000	3	3	25%	6.75	20
	Lower E. Gig Harbor/E. Fox Island	15.4	3000	48	3	25%	6.75	324
U2	Lower W. Gig Harbor/W. Fox Island	14.9	6000	12	2	0%	4	48
	S. Key Peninsula/McNeil, Anderson	37.1	6000	29	2	0%	4	116
	Steilacoom/DuPont	15.1	6000	12	2	0%	4	48
U3	Upper Gig Harbor/N. Key Peninsula	53.3	8000	23	1	0%	2	46
Totals:		188		292				2143

Notes:

1. Areas in square miles are approximate and likely upper bounds (some exclusion areas not considered yet).
2. Number of locations and number of samples are estimates (not considering irregularly shaped zones and grid layout).
3. Total sample count does not include QA samples and does not consider results of access requests.
4. Samples per location reflects average values per zone, based on number of borings per location and depth intervals sampled.

Table 2
Tacoma Smelter Plume Site
Pierce County Footprint Study
Summary of Sample Collection

Zone	Location Type	Number of Locations Sampled	Number of Locations with: (counts for borings and depths sampled)						Boring Counts:		Sample Counts:	
			Borings:	**1**	**2**	**3**	**3**	**4**	**4**	**residential**	**forest**	**residential**	**forest**
			Depths: (a)	**2**	**2**	**2**	**3**	**2**	**3**				
D1	residential	65						39	26	260		624	
	forest	3				2	1				9		21
D2	residential	27				1		20	6	107		238	
	forest	7				5	2				21		48
D3	residential	13						11	2	52		112	
	forest	3				2 (b)	1				9		23
U1	forest	21				14	7				63		147
U2	forest	43			43						86		172
U3	forest	12		12							12		24
Total locations sampled:		**194**											
Total boring count:		**619**								419	200		
Total sample count:		**1,409**										974	435

NOTES:

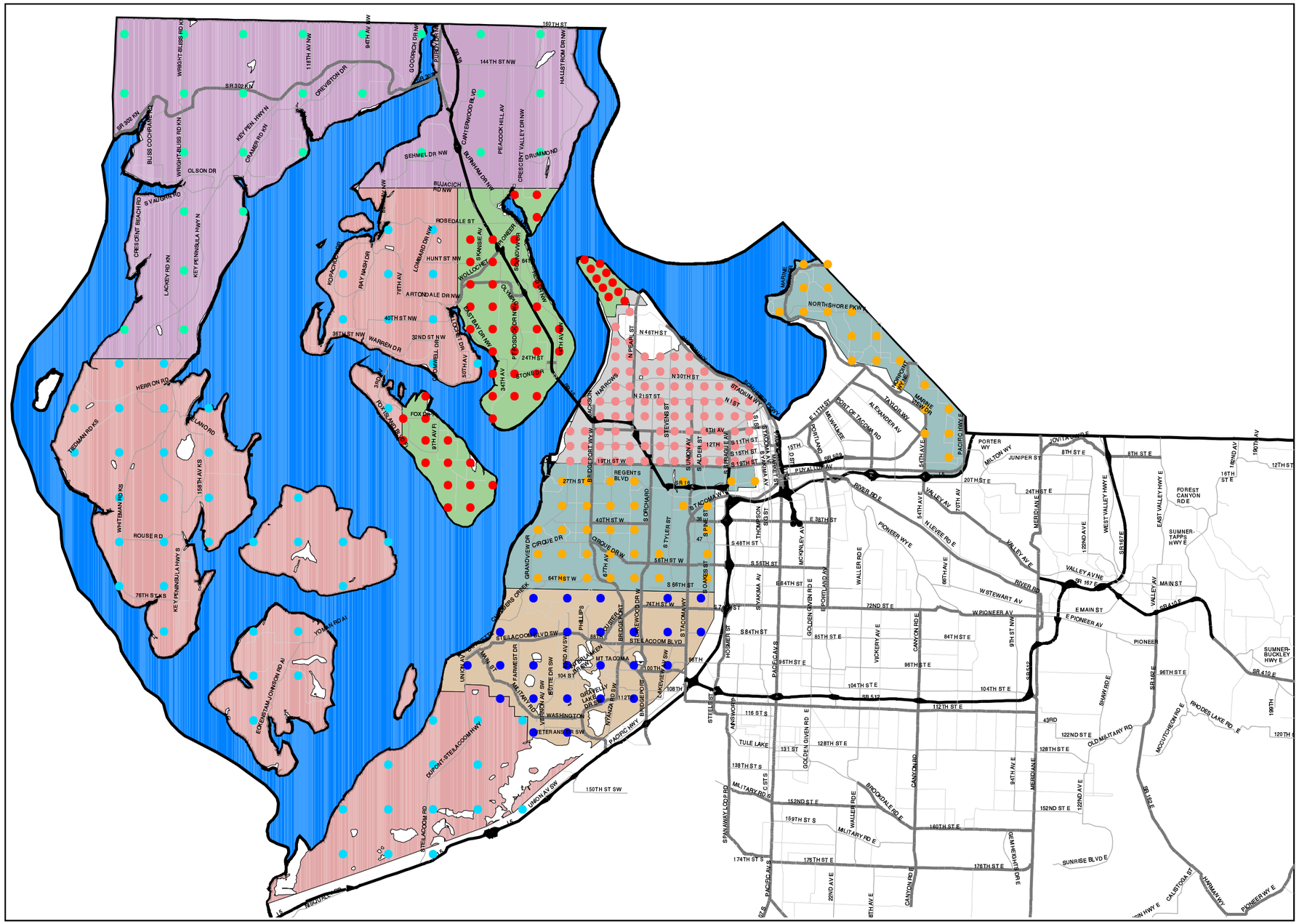
Data format example: In Zone D1, 65 residential locations were sampled.
At 39 of those 65 locations, samples were collected from 2 depths in each of 4 borings.
At 26 of those 65 locations, samples were collected from 3 depths at each of 4 borings.

(a) depth intervals sampled were 0-2" and 2-6" (all locations) and 6-12" (selected locations).
(b) one boring out of three at each of these two locations was sampled at a third depth interval.

Table 3						
Tacoma Smelter Plume Site						
Pierce County Footprint Summary						
Maximum Concentrations by Sampling Location: Data Summary						
		Arsenic Max			**Lead Max**	
		(in ppm, DW)			**(in ppm, DW)**	
	Zone	**Residential**	**Forest**		**Residential**	**Forest**
	D1	(n=65)	(n=3)		(n=65)	(n=3)
		48	3		33	3
		73.9%	100.0%		50.8%	100.0%
		10 - 440	104 - 1050		26 - 6670	402 - 3990
	D2	(n=27)	(n=7)		(n=27)	(n=7)
		14	7		4	4
		51.9%	100.0%		14.8%	57.1%
		7.45 - 88	30.6 - 223		37.5 - 443	80.3 - 474
	D3	(n=13)	(n=3)		(n=13)	(n=3)
		8	3		1	1
		61.5%	100.0%		7.7%	33.3%
		10.9 - 69.1	36.7 - 90.1		53.8 - 333	91.2 - 268
	U1		(n=21)			(n=21)
			20			7
			95.2%			33.3%
			12.8 - 182			22.3 - 577
	U2		(n=43)			(n=43)
			20			2
			46.5%			4.7%
			3.76 - 99.2			13.5 - 390
	U3		(n=12)			(n=12)
			0			0
			0.0%			0.0%
			2.99 - 19.5			8.9 - 67.5
	NOTES:					
	Formats for data blocks are:					
		(n=65)	number of locations by zone and type			
		48	number of locations exceeding MTCA standards:			
			20 ppm for arsenic			
			250 ppm for lead			
		73.90%	percentage of locations exceeding MTCA standard			
		10 - 440	range of maximum concentrations (in ppm, DW)			

Table 4										
Tacoma Smelter Plume Site										
Pierce County Footprint Study										
Distributions of Maximum Concentrations by Sampling Location: Summary										
			Number of Locations by Concentration Ranges:							
			Arsenic Max				**Lead Max**			
			(in ppm, DW)				**(in ppm, DW)**			
	Zone	**Type**	**0 - 20**	**20 - 100**	**> 100**		**0 - 100**	**100 - 250**	**250 - 500**	**> 500**
	D1	residential	17	34	14		10	22	17	16
		(n=65)	26.2%	52.3%	21.5%		15.4%	33.9%	26.2%	24.6%
		forest	0	0	3		0	0	1	2
		(n=3)	0.0%	0.0%	100.0%		0.0%	0.0%	33.3%	66.7%
	D2	residential	13	14	0		17	6	4	0
		(n=27)	48.2%	51.9%	0.0%		63.0%	22.2%	14.8%	0.0%
		forest	0	4	3		1	2	4	0
		(n=7)	0.0%	57.1%	42.9%		14.3%	28.6%	57.1%	0.0%
	D3	residential	5	8	0		6	6	1	0
		(n=13)	38.5%	61.5%	0.0%		46.2%	46.2%	7.7%	0.0%
		forest	0	3	0		1	1	1	0
		(n=3)	0.0%	100.0%	0.0%		33.3%	33.3%	33.3%	0.0%
	U1	forest	1	14	6		5	9	6	1
		(n=21)	4.8%	66.7%	28.6%		23.8%	42.9%	28.6%	4.8%
	U2	forest	23	20	0		32	9	2	0
		(n=43)	53.5%	46.5%	0.0%		74.4%	20.9%	4.7%	0.0%
	U3	forest	12	0	0		12	0	0	0
		(n=12)	100.0%	0.0%	0.0%		100.0%	0.0%	0.0%	0.0%

Tacoma Smelter Plume Sampling Area and Sampling Grid



MAP LEGEND

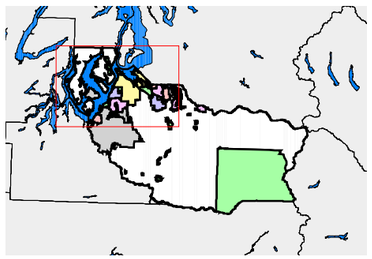
Sample grid points
- D1
- D2
- D3
- U1
- U2
- U3

Arterials*
- Limited Access
- Principle Road
- Major Road
- Collector Road

Arsenic study area
- D1
- D2
- D3
- U1
- U2
- U3

April 2002

Scale 1:178110



N

All geographic information on this map should be cosidered under revision and each user should recognize the limitations on use of this data.

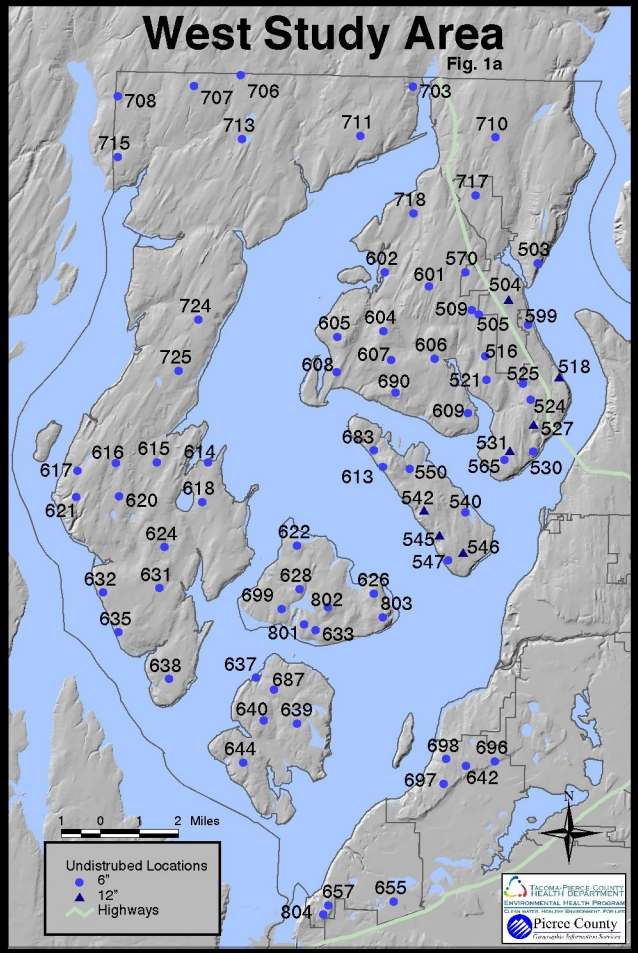
TACOMA-PIERCE COUNTY HEALTH DEPARTMENT

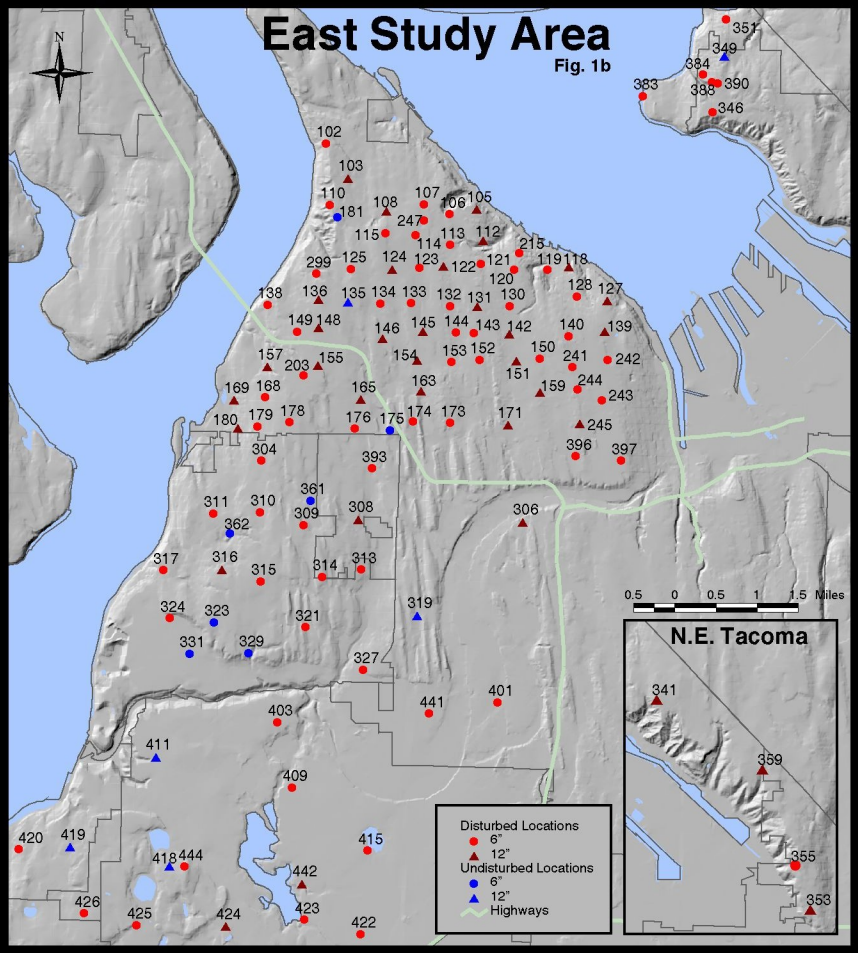
ENVIRONMENTAL HEALTH PROGRAM

CLEAN WATER. HEALTHY ENVIRONMENT. FOR LIFE.

Pierce County

Geographic Information Services


West Study Area
Fig. 1a
1 0 1 2 Miles
Undistrubed Locations
6"
12"
Highways
Tacoma-Pierce County Health Department
Environmental Health Program
Pierce County
Geographic Information Services


East Study Area
Fig. 1b
N
0.5 0 0.5 1 1.5 Miles
N.E. Tacoma
Disturbed Locations
6"
12"
Undisturbed Locations
6"
12"
Highways

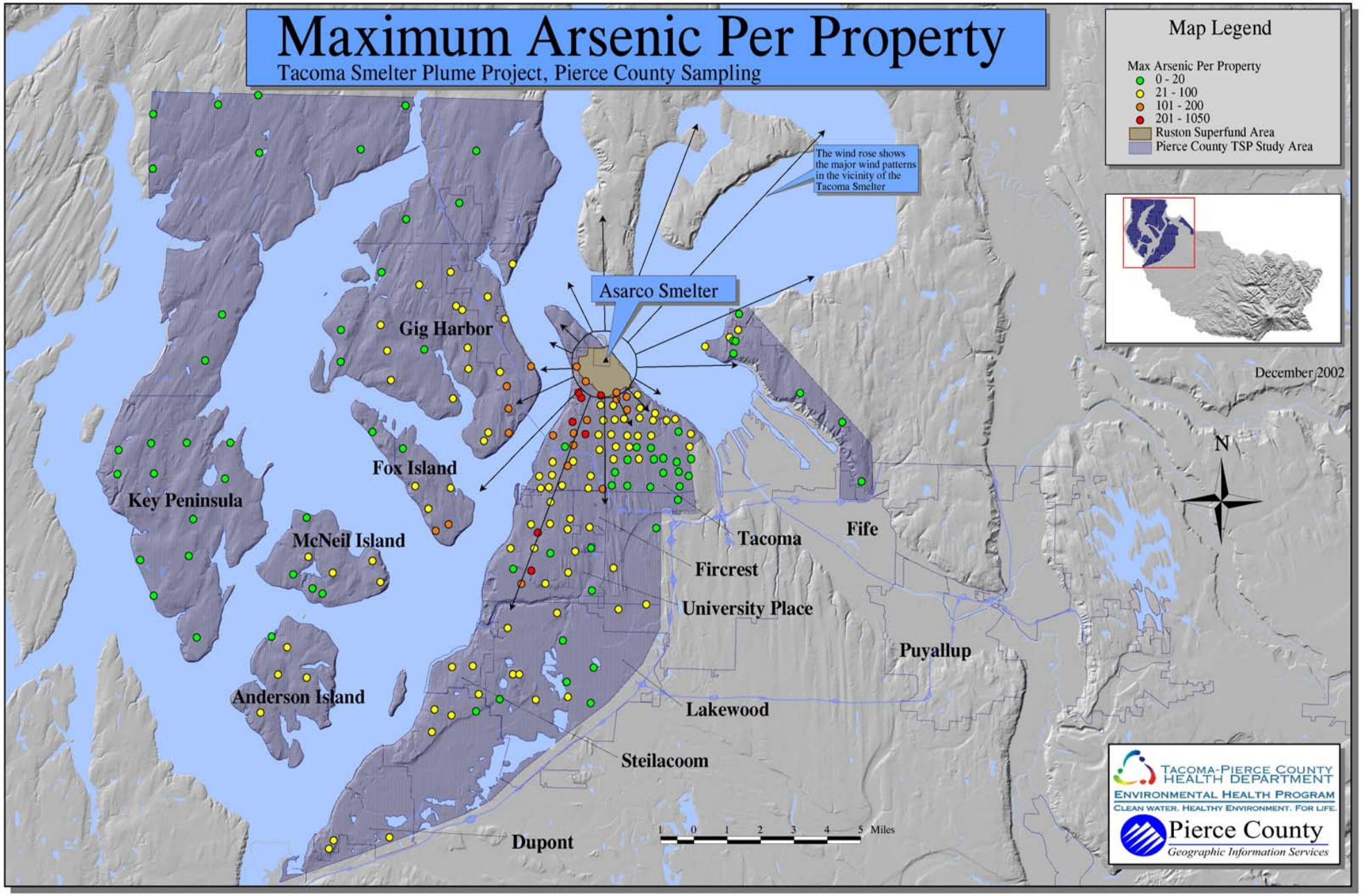


FIGURE 2: Maximum Arsenic Concentrations by Sampling Location: Pierce County

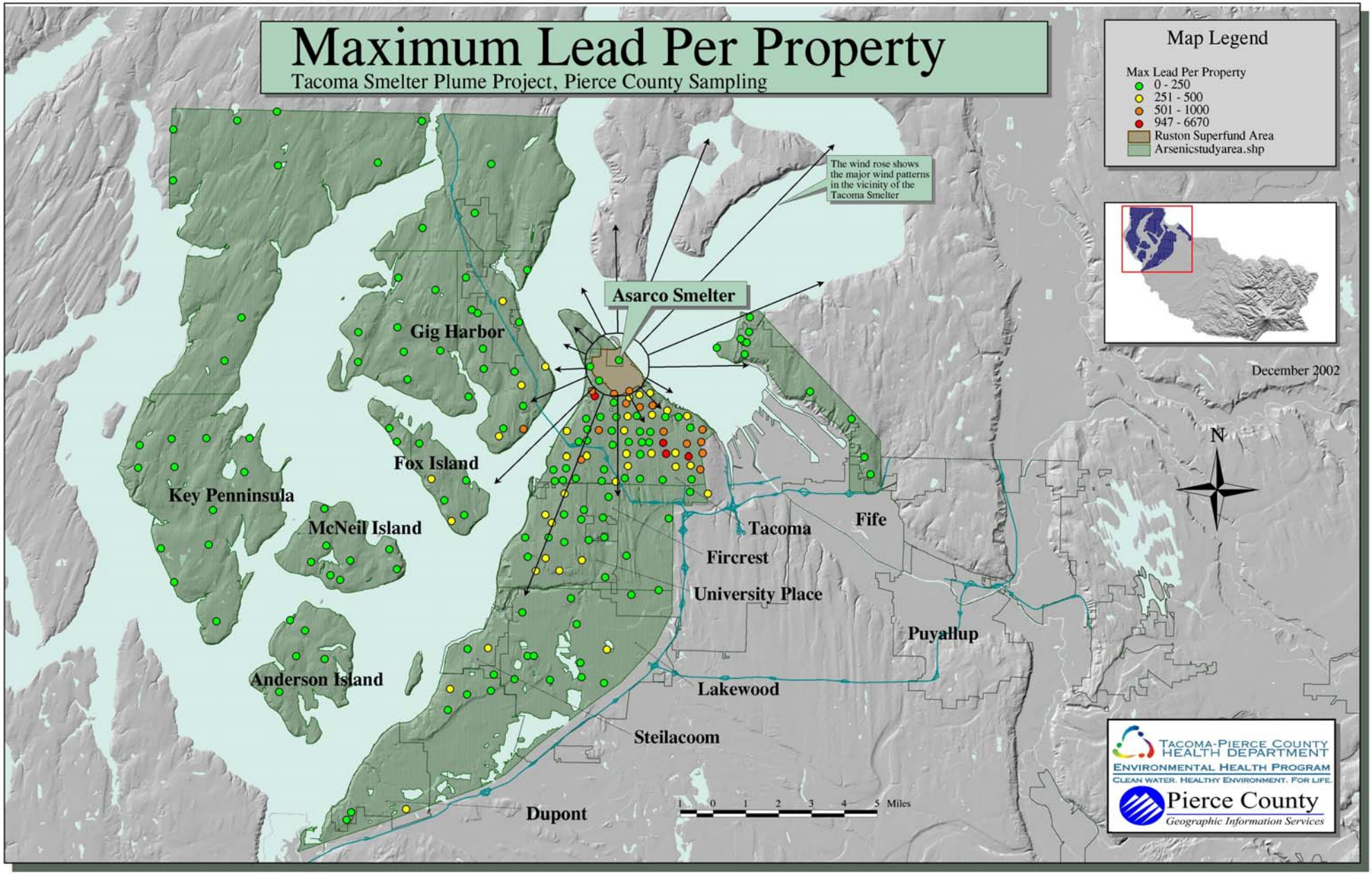
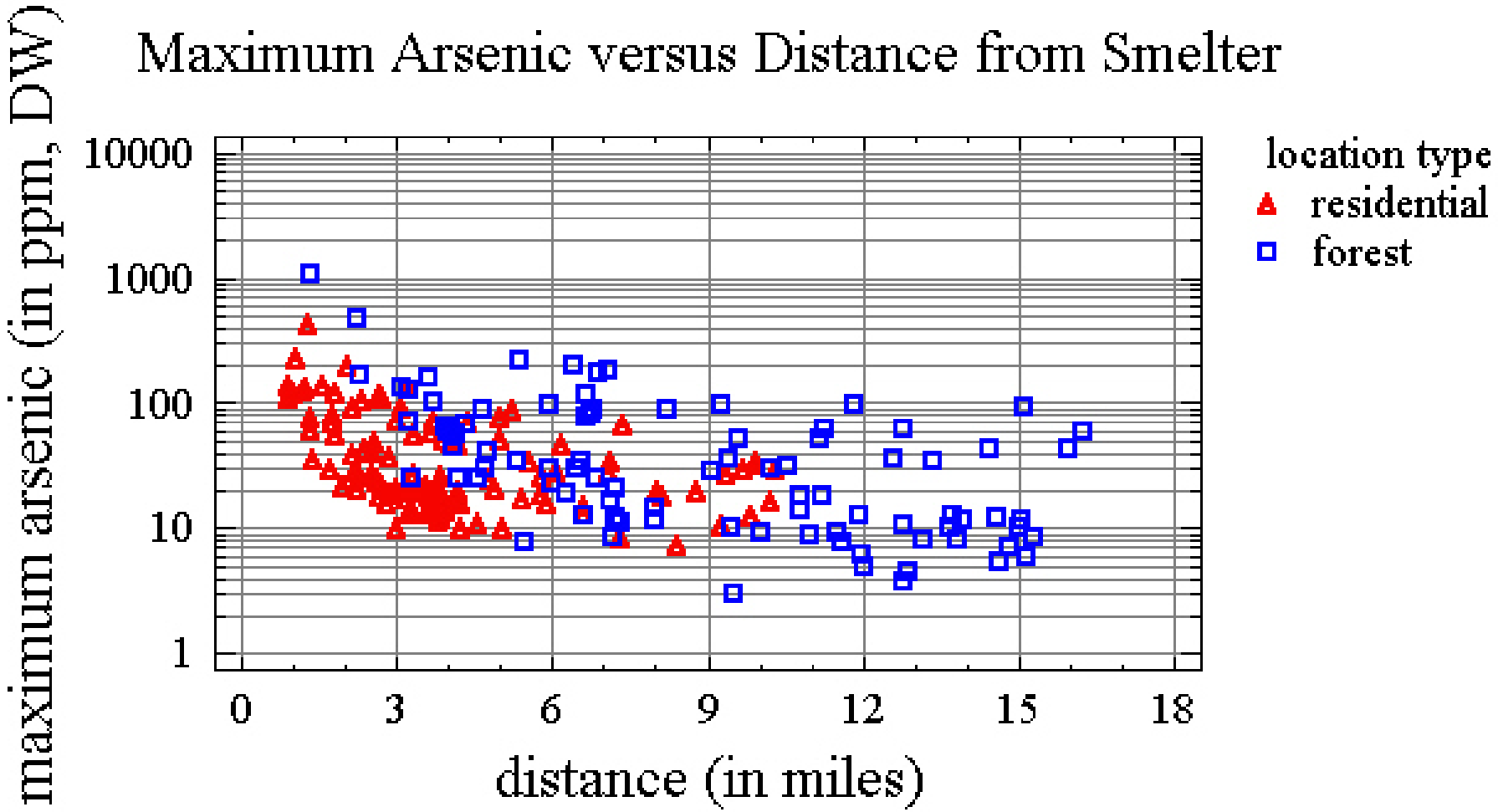
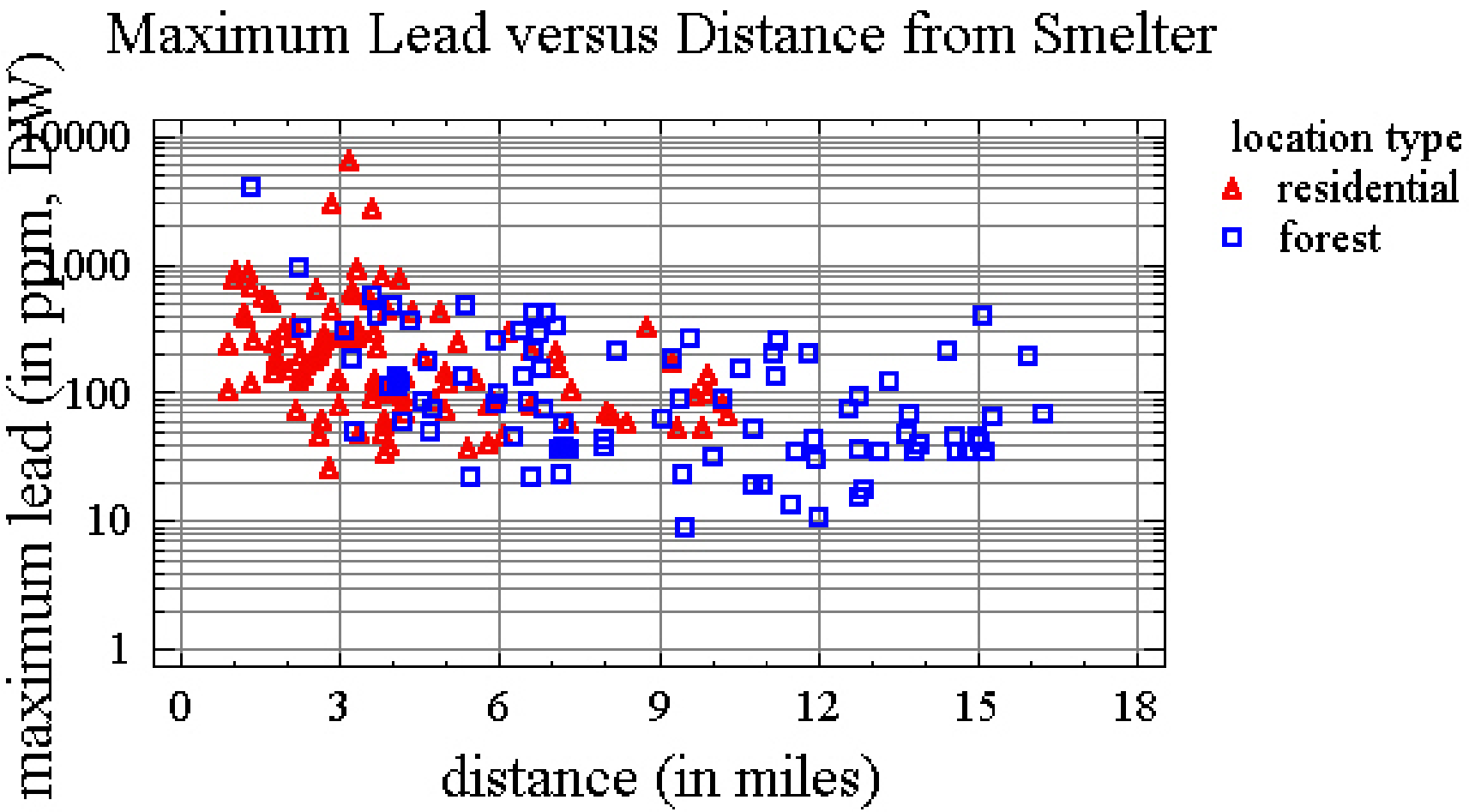
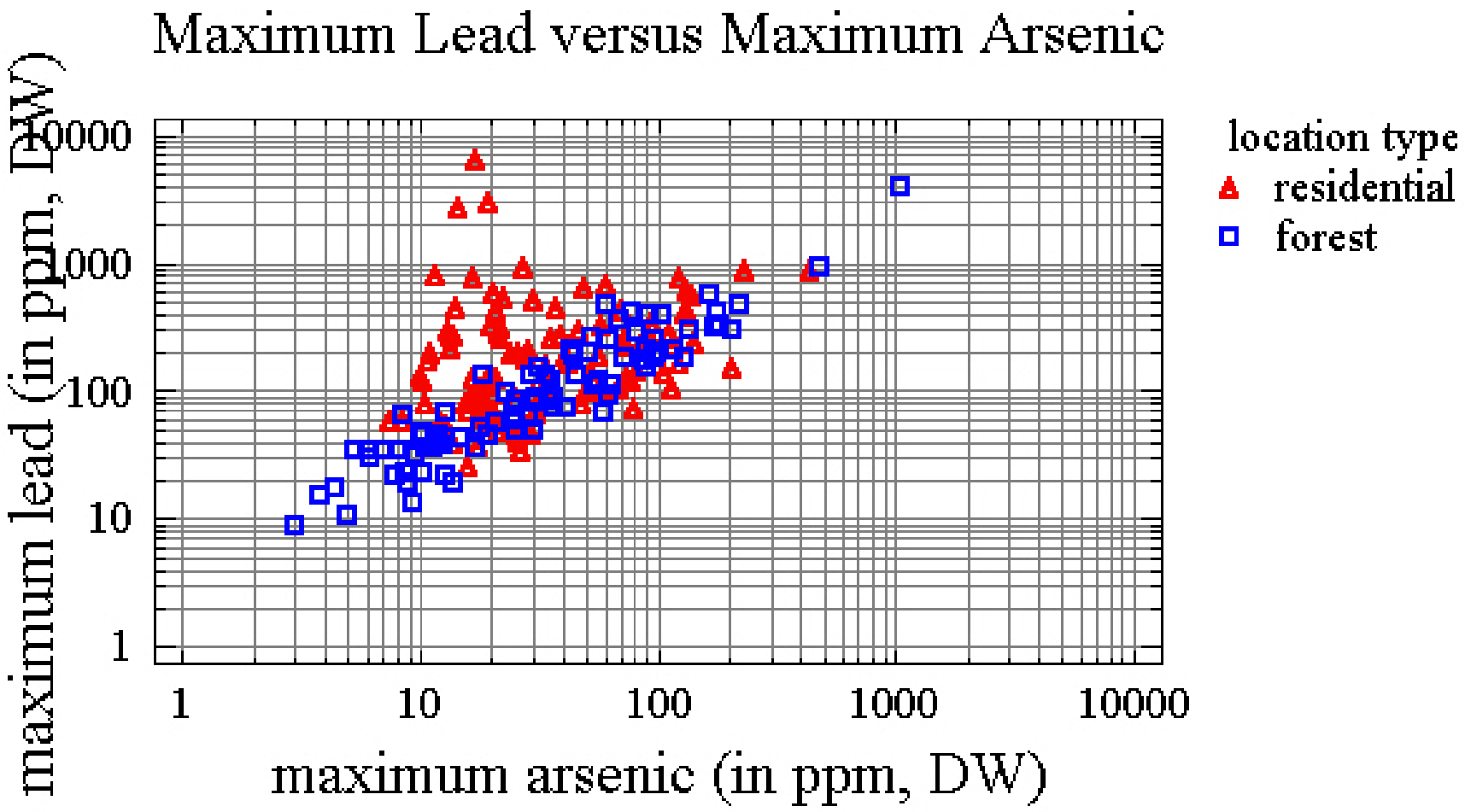
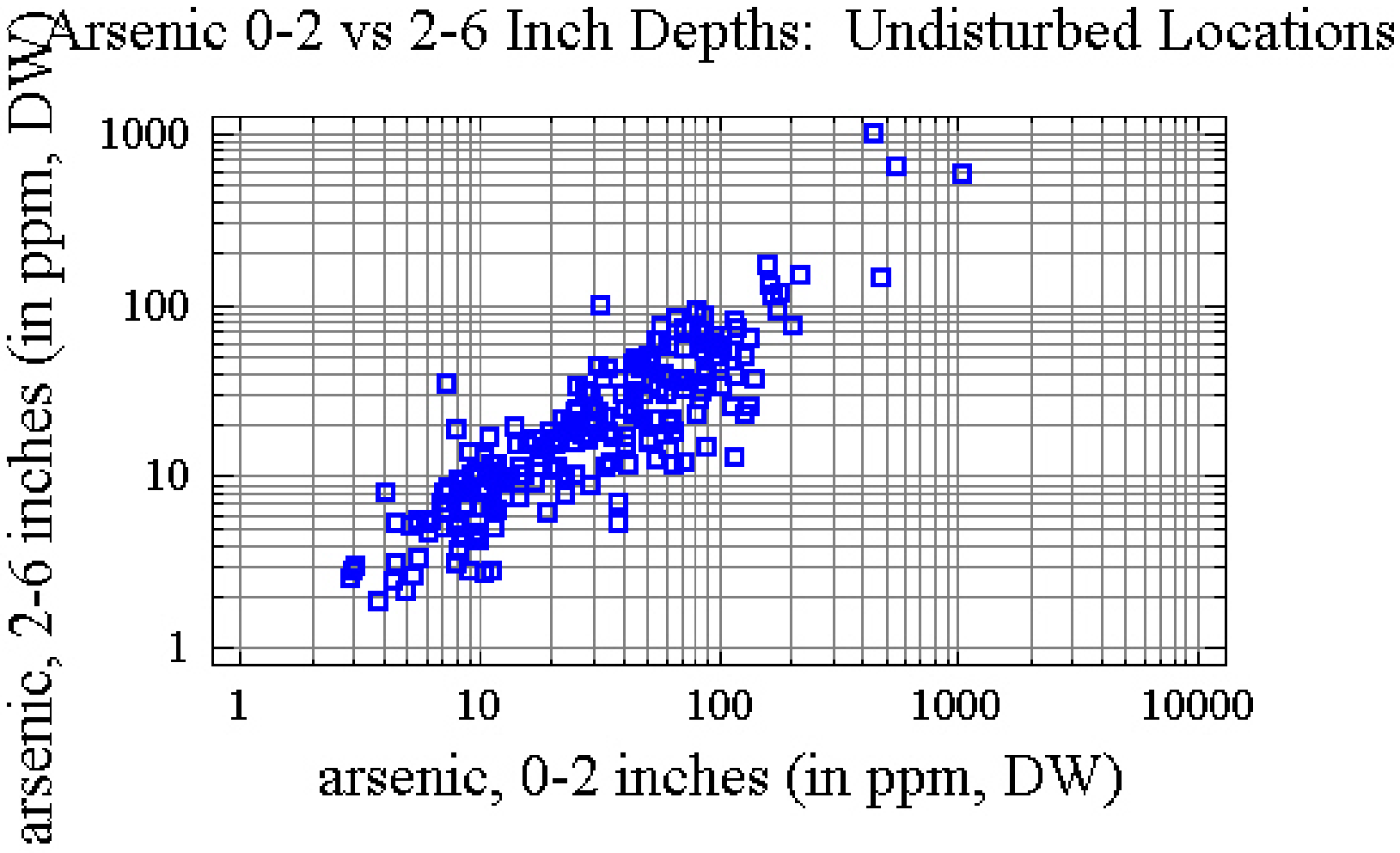


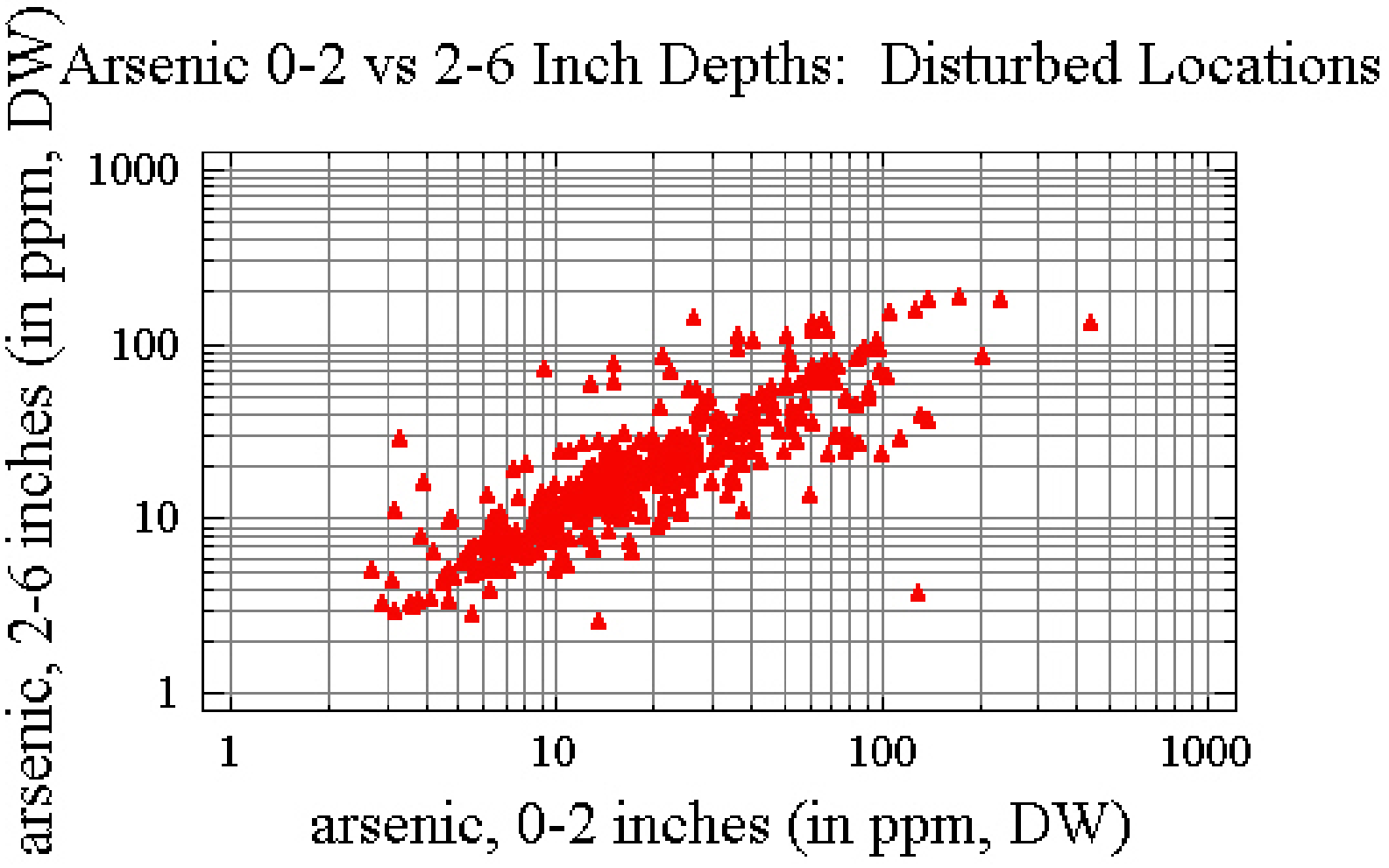
FIGURE 3: Maximum Lead Concentrations by Sampling Location: Pierce County

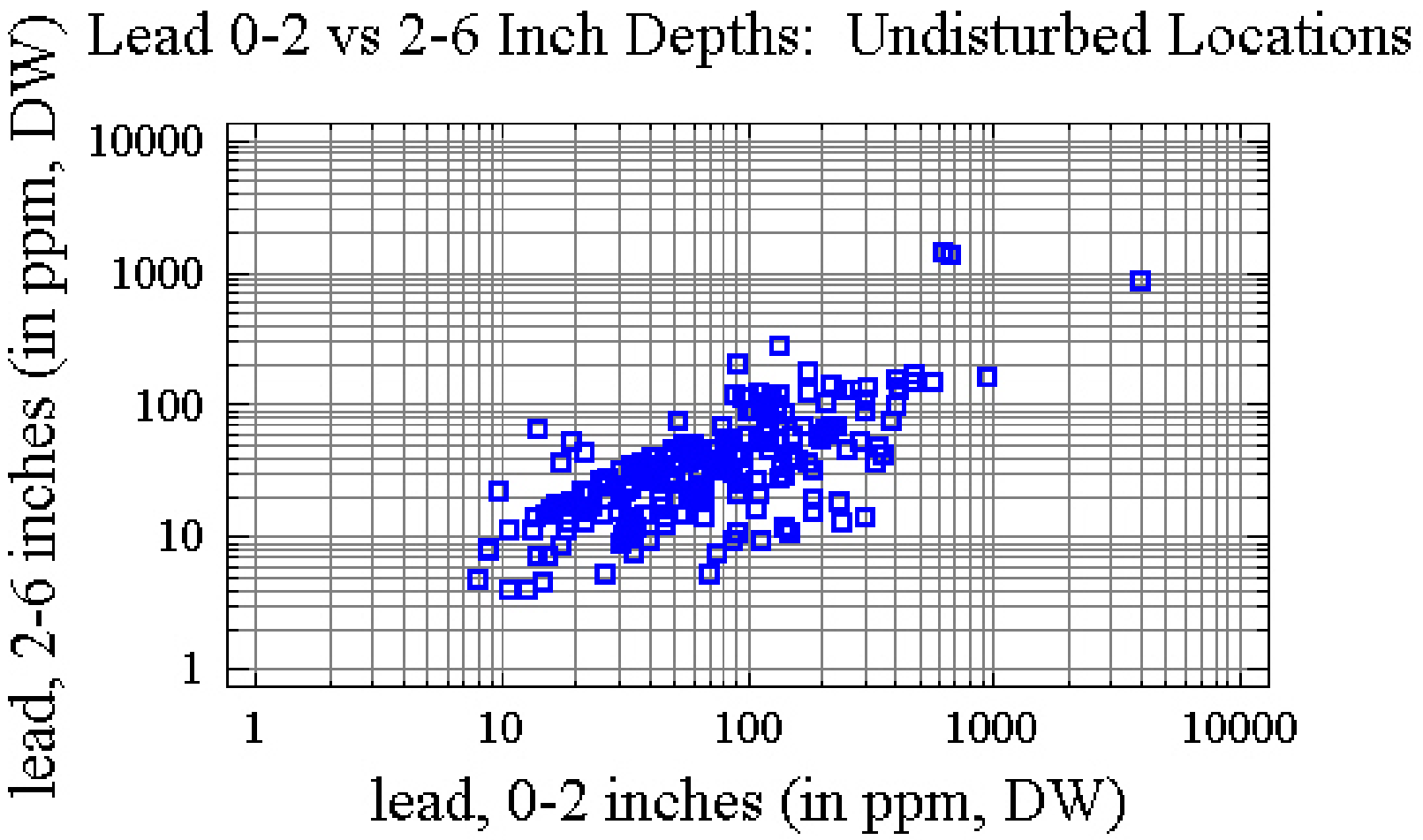

Maximum Arsenic versus Distance from Smelter
maximum arsenic (in ppm, DW)
10000
1000
100
10
1
0
3
6
9
12
15
18
distance (in miles)
location type
residential
forest

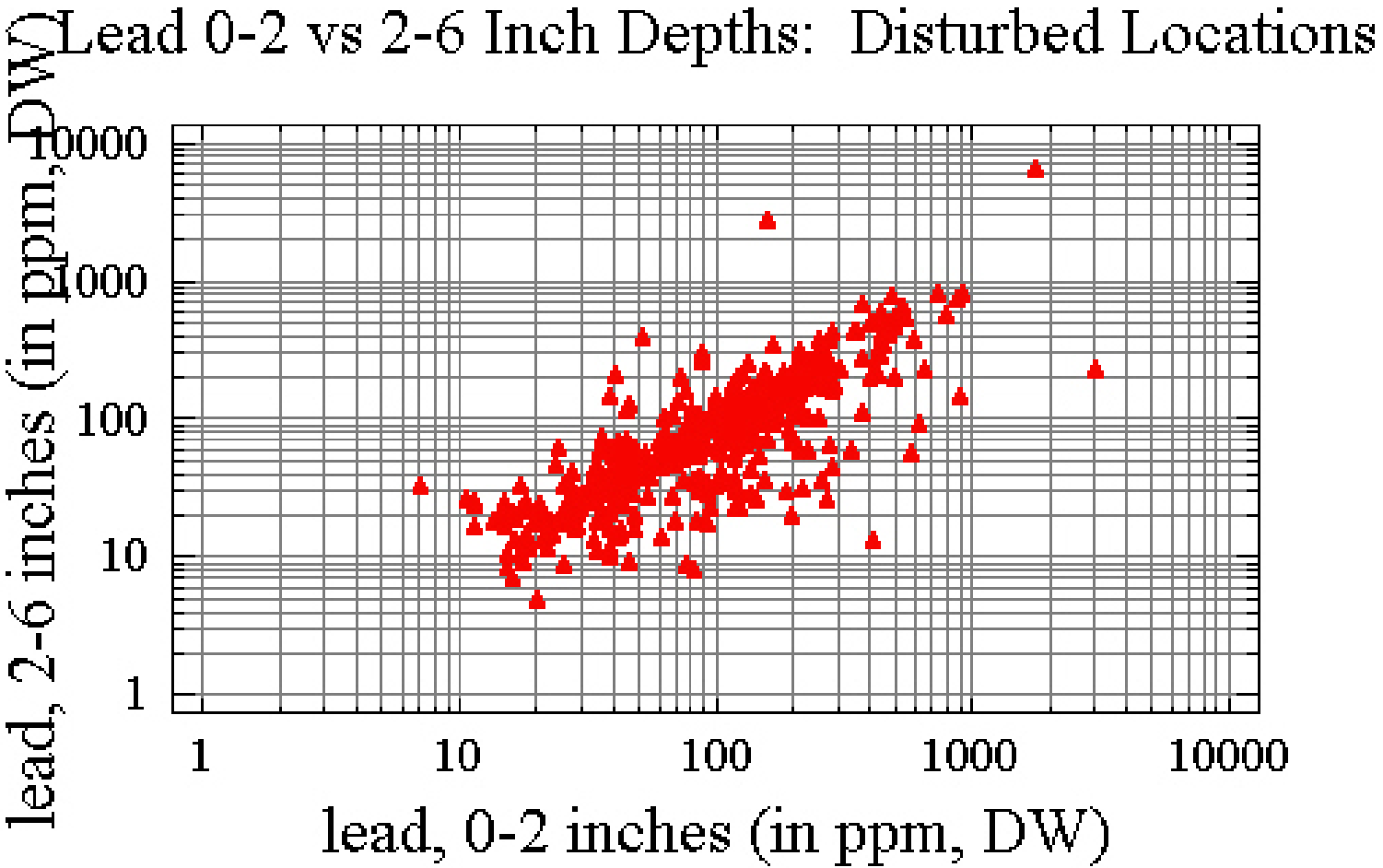

Maximum Lead versus Distance from Smelter
maximum lead (in ppm, DW)
10000
1000
100
10
1
0
3
6
9
12
15
18
distance (in miles)
location type
residential
forest

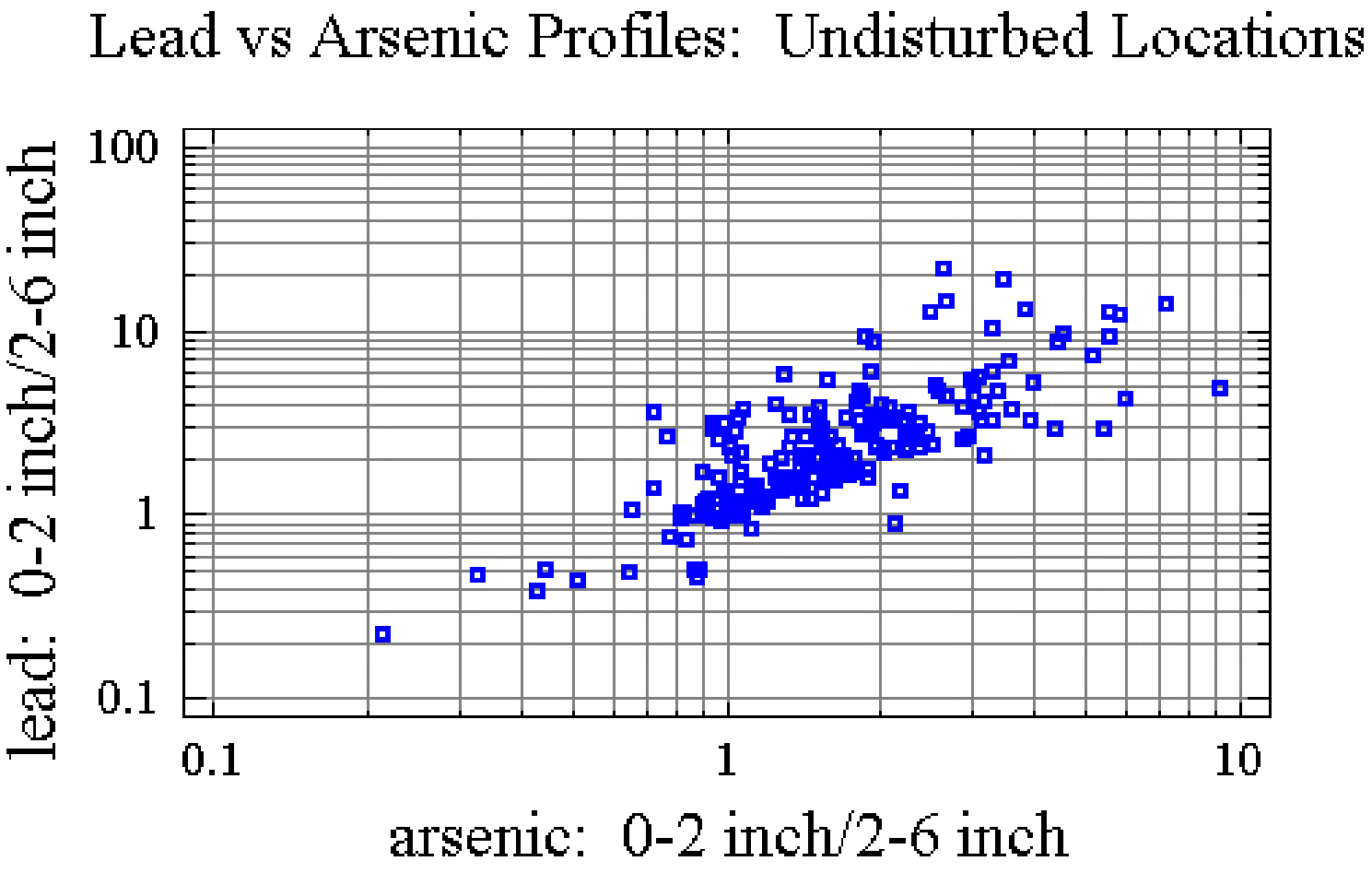

Maximum Lead versus Maximum Arsenic
maximum lead (in ppm, DW)
10000
1000
100
10
1
1
10
100
1000
10000
maximum arsenic (in ppm, DW)
location type
residential
forest

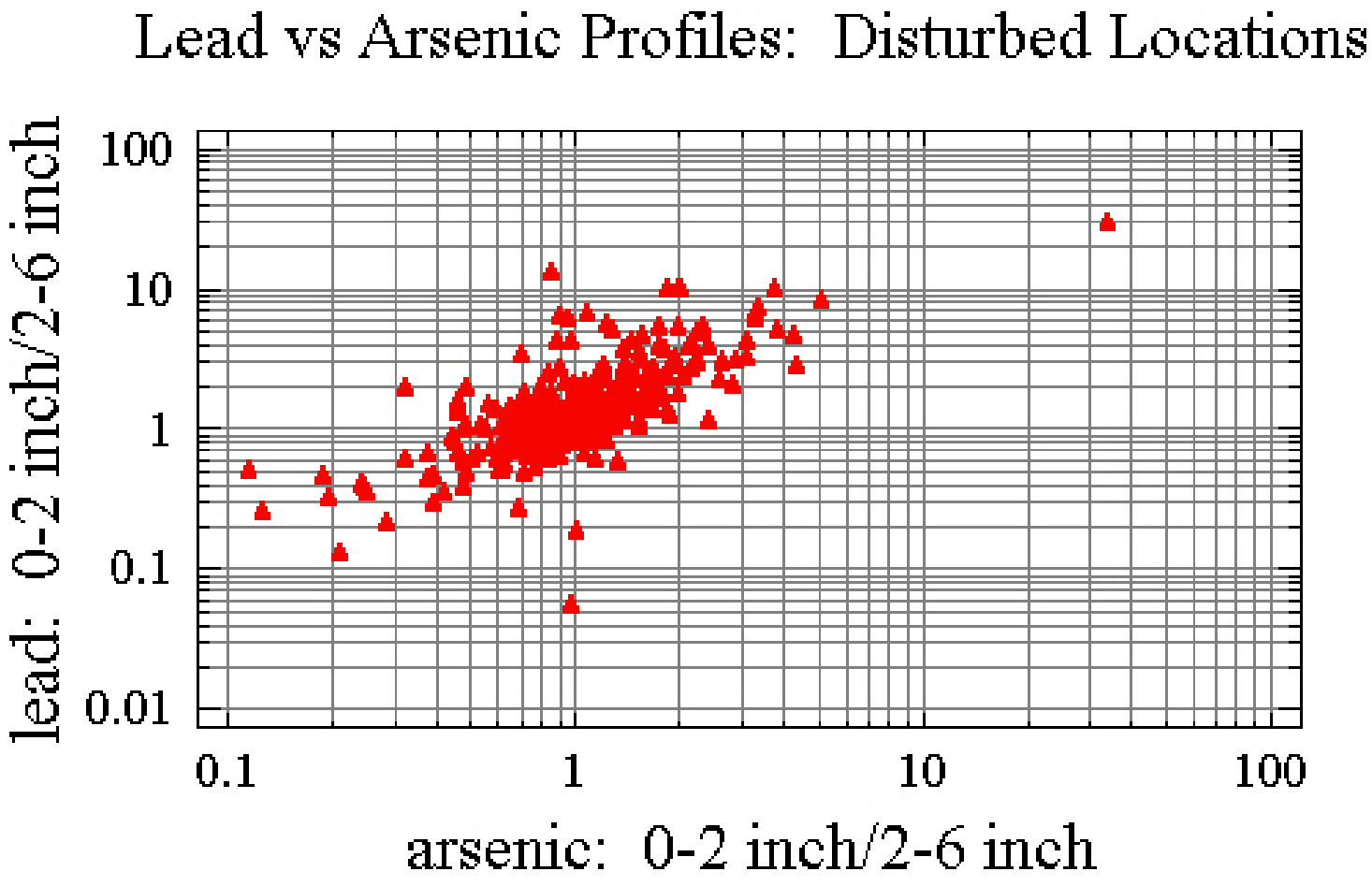

Arsenic 0-2 vs 2-6 Inch Depths: Undisturbed Locations
arsenic, 2-6 inches (in ppm, DW)
1000
100
10
1
1
10
100
1000
10000
arsenic, 0-2 inches (in ppm, DW)


Arsenic 0-2 vs 2-6 Inch Depths: Disturbed Locations
arsenic, 2-6 inches (in ppm, DW)
1000
100
10
1
1
10
100
1000
arsenic, 0-2 inches (in ppm, DW)

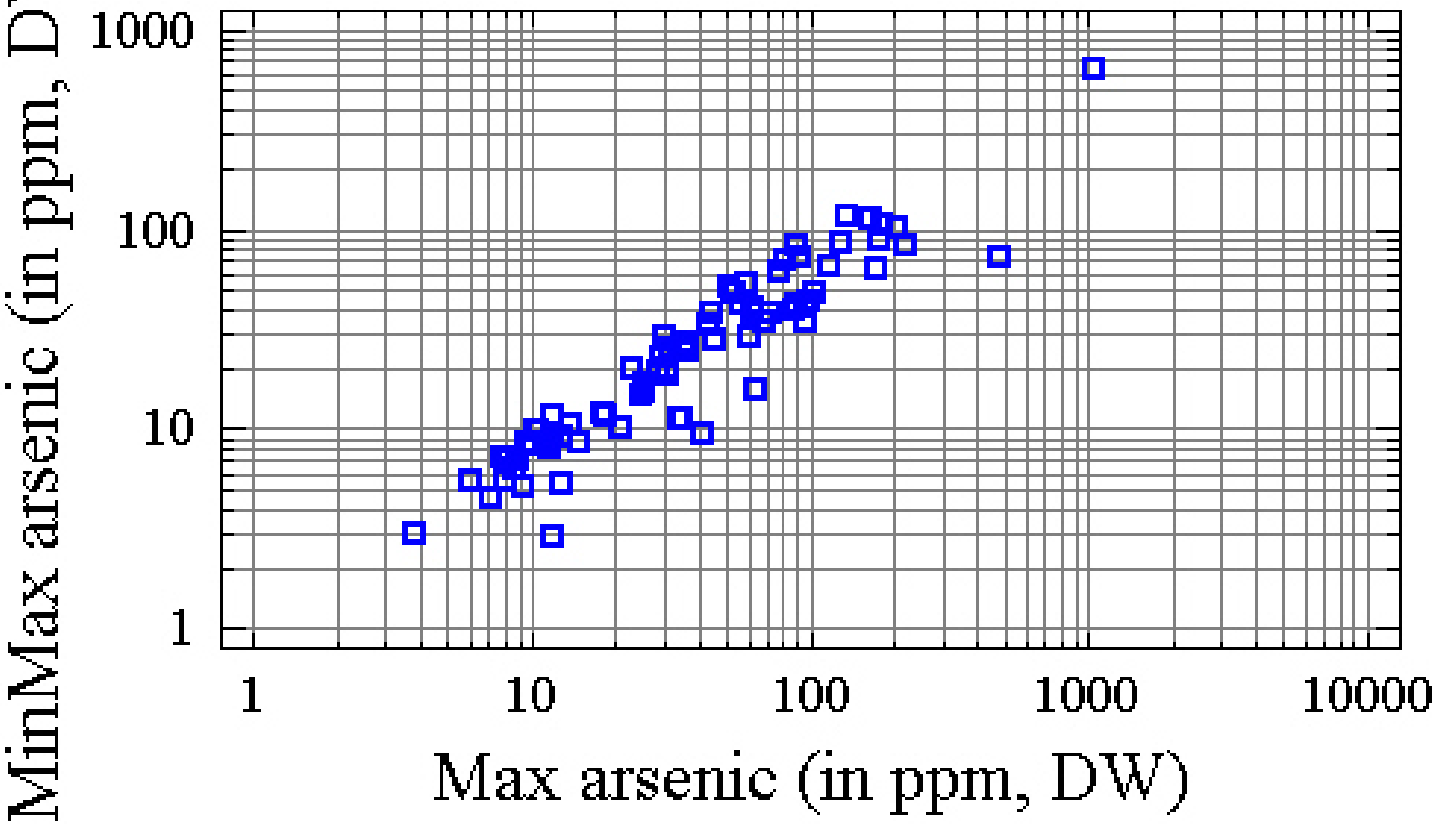

Lead 0-2 vs 2-6 Inch Depths: Undisturbed Locations
lead, 2-6 inches (in ppm, DW)
10000
1000
100
10
1
1
10
100
1000
10000
lead, 0-2 inches (in ppm, DW)

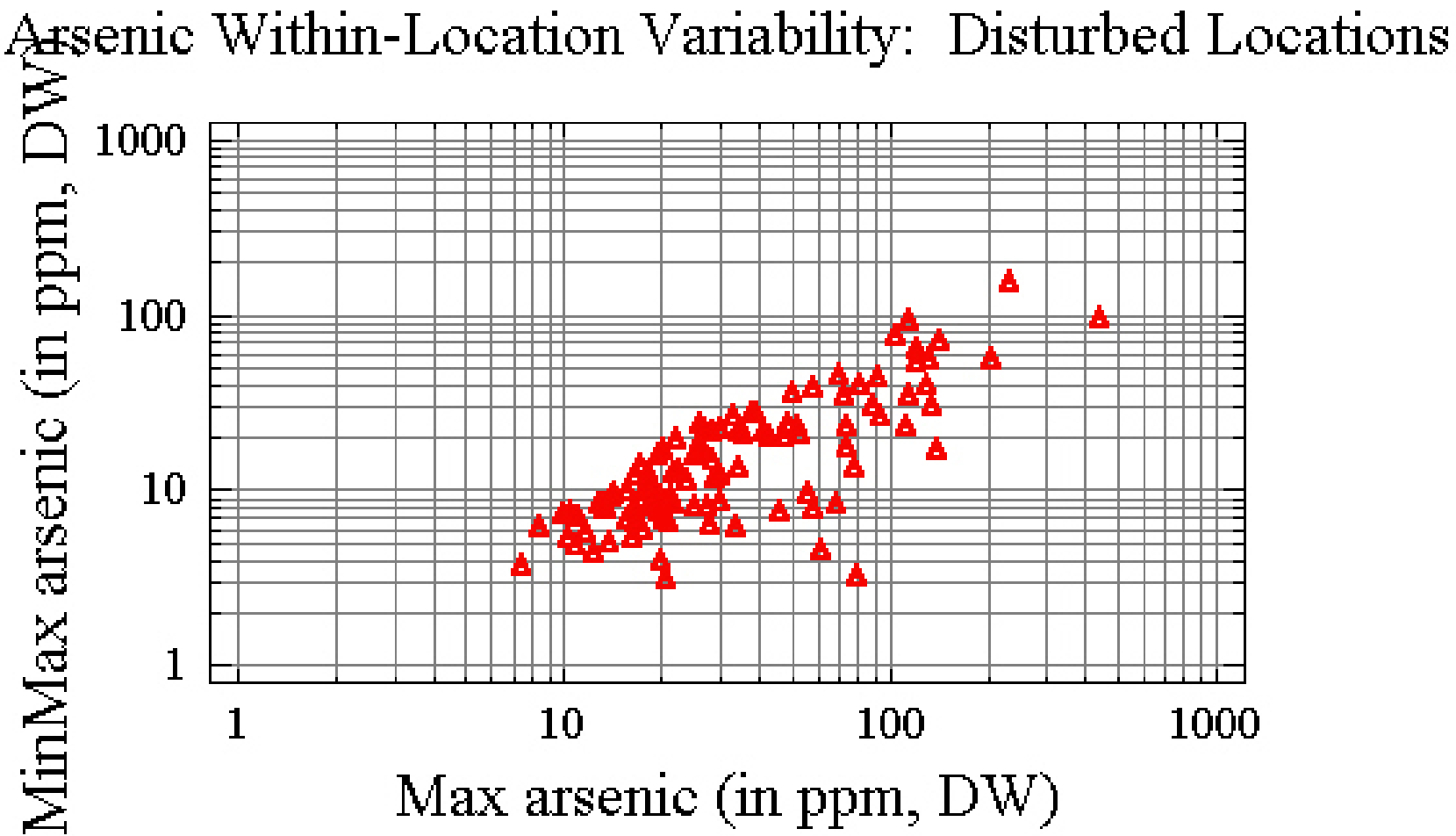

Lead 0-2 vs 2-6 Inch Depths: Disturbed Locations
lead, 2-6 inches (in ppm, DW)
10000
1000
100
10
1
1
10
100
1000
10000
lead, 0-2 inches (in ppm, DW)

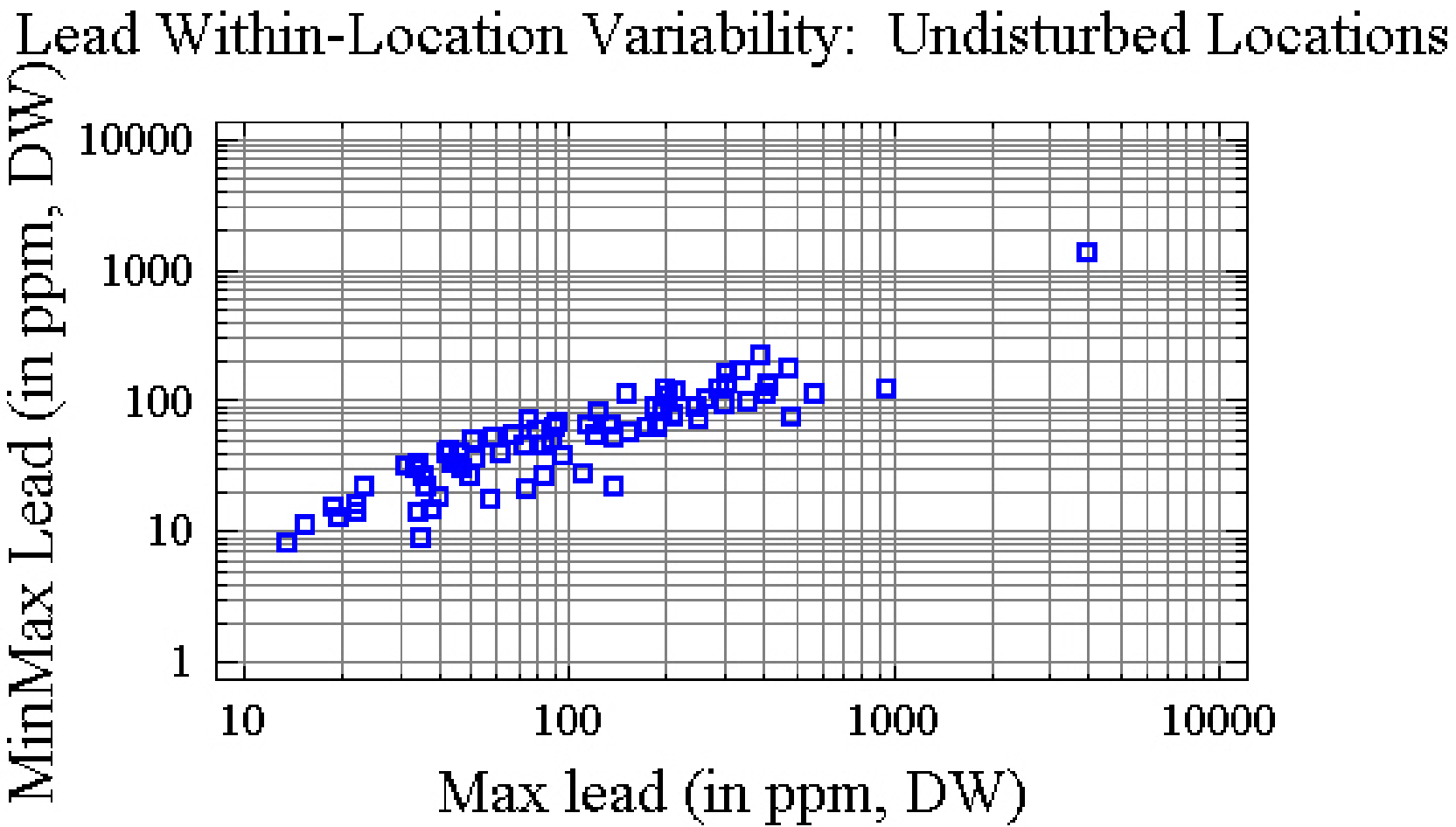

Lead vs Arsenic Profiles: Undisturbed Locations
lead: 0-2 inch/2-6 inch
100
10
1
0.1
0.1
1
10
arsenic: 0-2 inch/2-6 inch

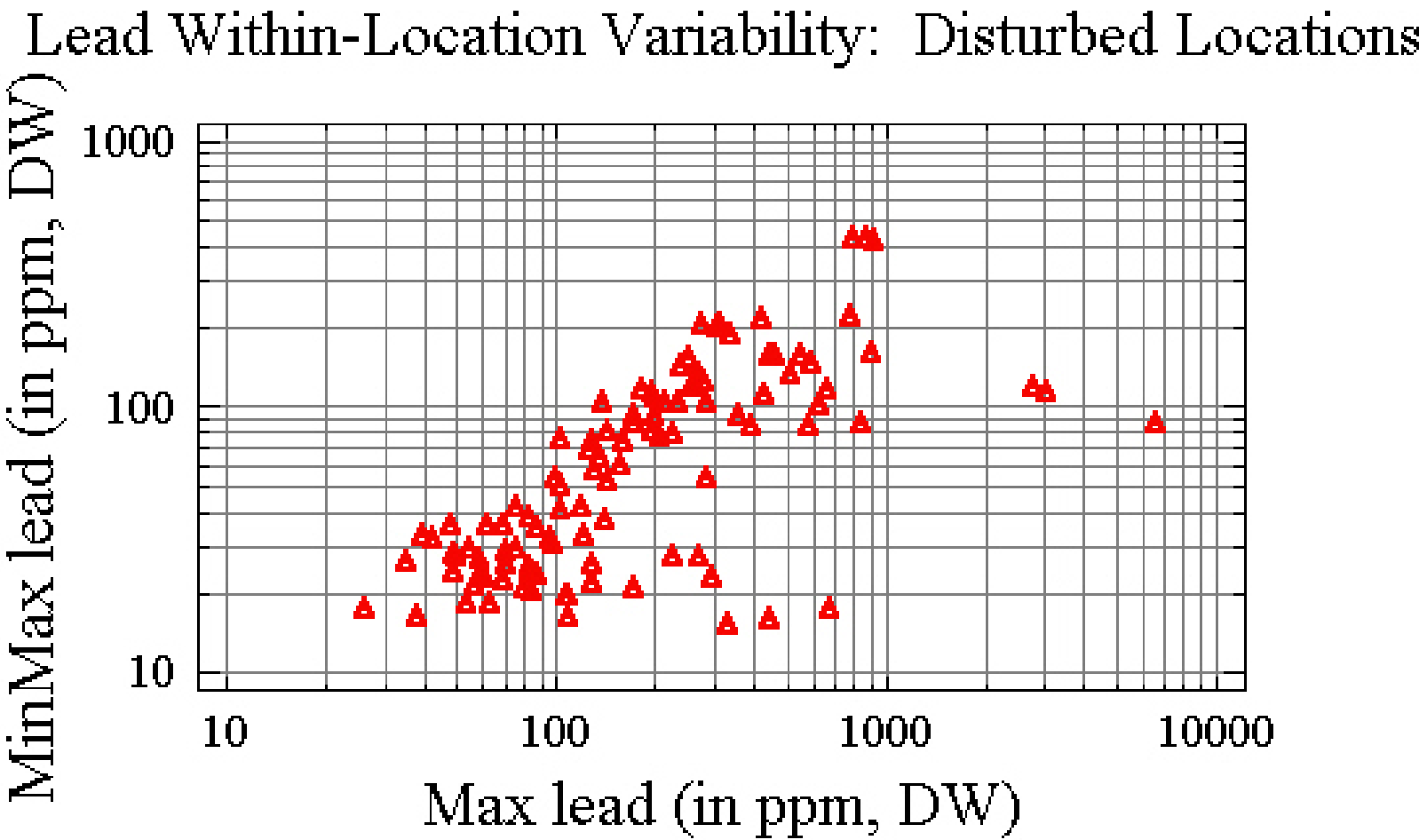

Lead vs Arsenic Profiles: Disturbed Locations
lead: 0-2 inch/2-6 inch
100
10
1
0.1
0.01
0.1
1
10
100
arsenic: 0-2 inch/2-6 inch

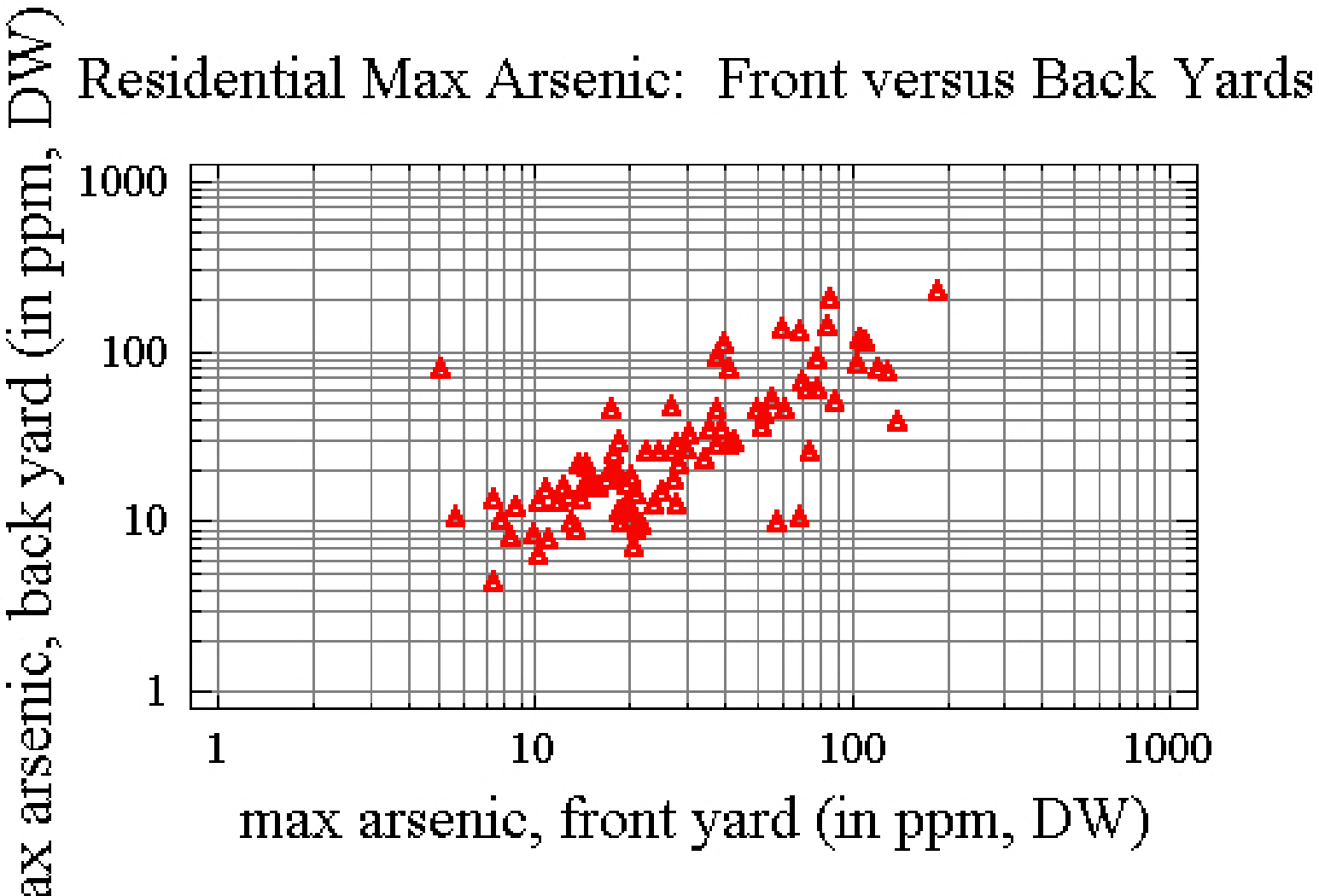
Arsenic Within-Location Variability: Undisturbed Locations



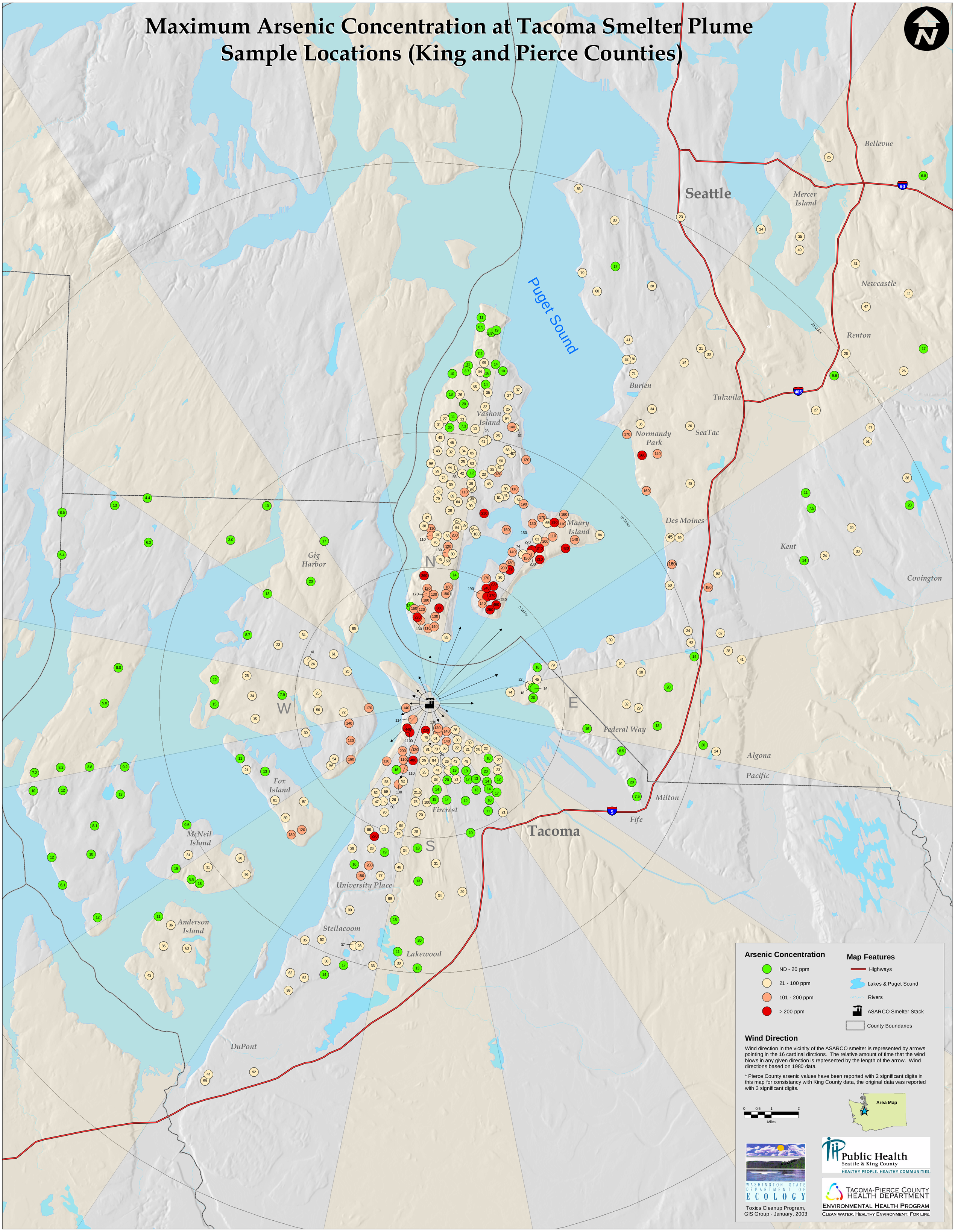

Arsenic Within-Location Variability: Disturbed Locations
MinMax arsenic (in ppm, DW)
1000
100
10
1
1
10
100
1000
Max arsenic (in ppm, DW)


Lead Within-Location Variability: Undisturbed Locations
MinMax Lead (in ppm, DW)
10000
1000
100
10
1
10
100
1000
10000
Max lead (in ppm, DW)

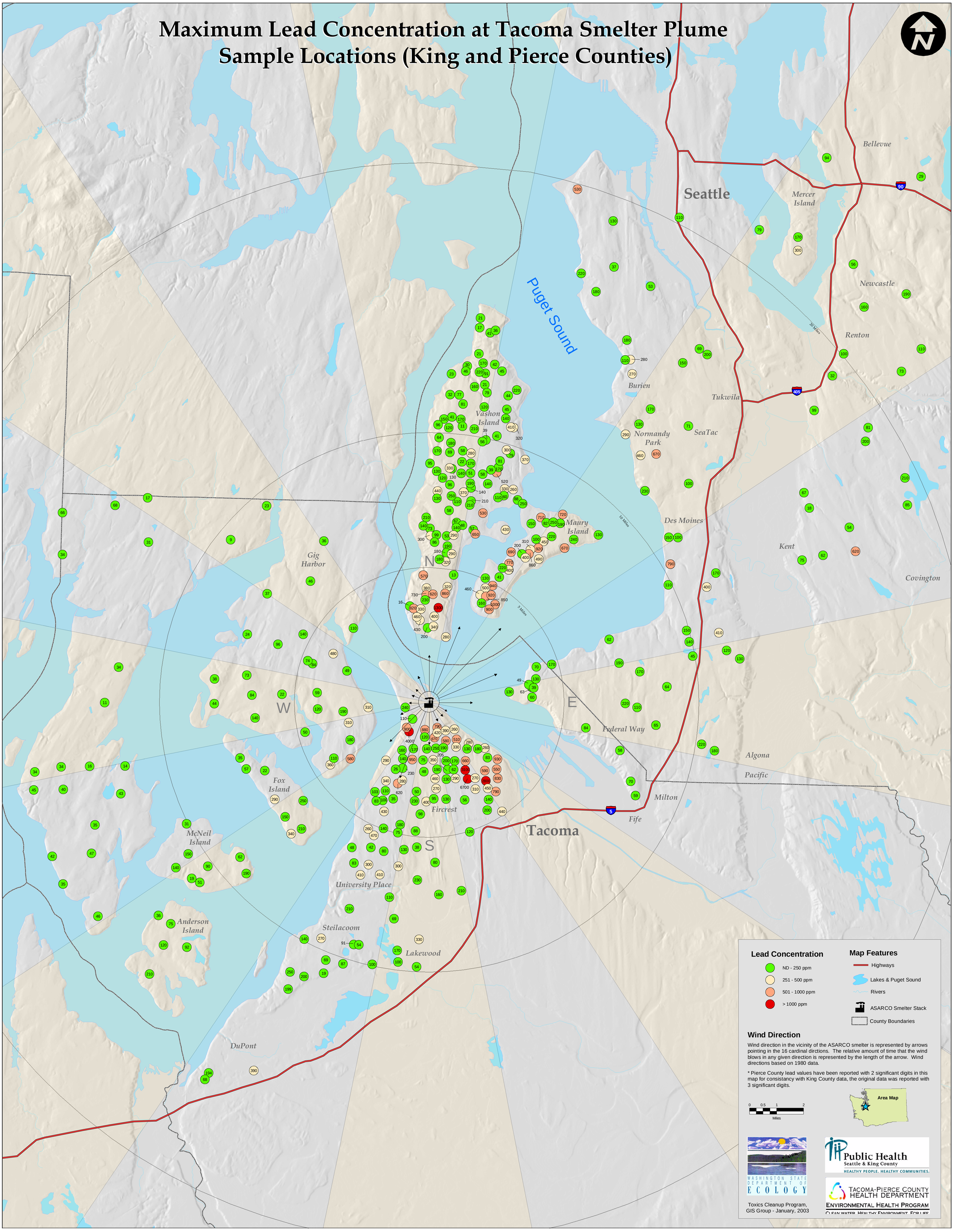

Lead Within-Location Variability: Disturbed Locations
MinMax lead (in ppm, DW)
1000
100
10
10
100
1000
10000
Max lead (in ppm, DW)

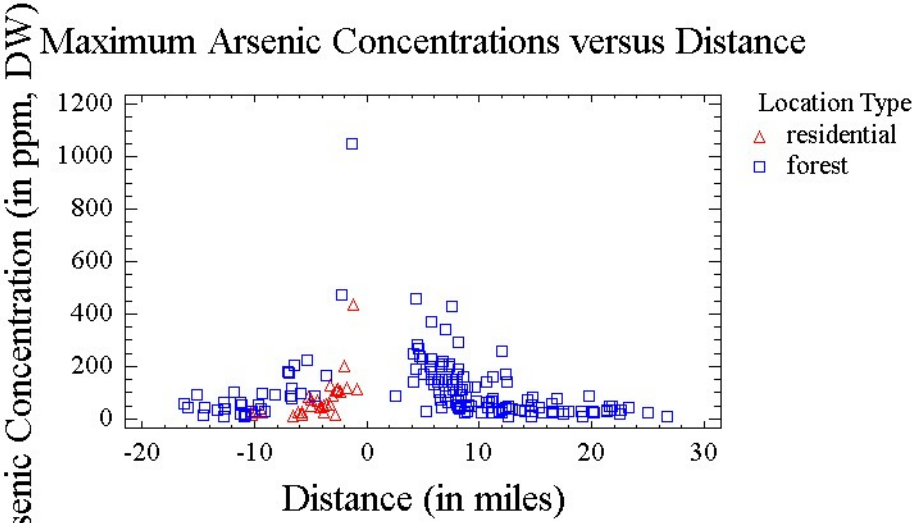

Residential Max Arsenic: Front versus Back Yards
max arsenic, back yard (in ppm, DW)
1000
100
10
1
1
10
100
1000
max arsenic, front yard (in ppm, DW)

Maximum Arsenic Concentration at Tacoma Smelter Plume Sample Locations (King and Pierce Counties)



Maximum Lead Concentration at Tacoma Smelter Plume Sample Locations (King and Pierce Counties)




Maximum Arsenic Concentrations versus Distance
Arsenic Concentration (in ppm, DW)
1200
1000
800
600
400
200
0
-20
-10
0
10
20
30
Distance (in miles)
Location Type
residential
forest

Attachment A							
Tacoma Smelter Plume Site							
Pierce County Footprint Study							
Listing of Results by Sample							
Sample Code	Sampling		Arsenic	Lead		Distance	Direction
	Zone		(ppm, DW)	(ppm,DW)		(miles)	(degrees)
102-1-11-4-1	D1		9.23	39.1		0.89	257.68
102-1-12-4-1	D1		72.7	145		0.89	257.68
102-1-21-4-1	D1		84.4	209		0.89	257.68
102-1-22-4-1	D1		82.2	106		0.89	257.68
102-1-31-4-2	D1		26.8	78.2		0.89	257.68
102-1-32-4-2	D1		142	163		0.89	257.68
102-1-41-4-2	D1		68	240		0.89	257.68
102-1-42-4-2	D1		79.1	178		0.89	257.68
103-1-11-4-1	D1		35.4	20.1		0.87	224.53
103-1-12-4-1	D1		16.6	5.02		0.87	224.53
103-1-13-4-1	D1		1.66	1.81		0.87	224.53
103-1-21-4-1	D1		27	31.8		0.87	224.53
103-1-22-4-1	D1		39.8	25.6		0.87	224.53
103-1-23-4-1	D1		3.62	3.75		0.87	224.53
103-1-31-4-2	D1		114	92.2		0.87	224.53
103-1-32-4-2	D1		29.5	18.1		0.87	224.53
103-1-33-4-2	D1		16.1	19.5		0.87	224.53
103-1-41-4-2	D1		77.4	107		0.87	224.53
103-1-42-4-2	D1		47.7	41.9		0.87	224.53
103-1-43-4-2	D1		9.62	6.69		0.87	224.53
105-1-11-4-1	D1		35.5	124		1.38	136.51
105-1-12-4-1	D1		34.8	95.9		1.38	136.51
105-1-13-4-1	D1		33.9	78.5		1.38	136.51
105-1-21-4-1	D1		21.6	150		1.38	136.51
105-1-22-4-1	D1		12.8	54.2		1.38	136.51
105-1-23-4-1	D1		17.6	168		1.38	136.51
105-1-31-4-2	D1		27.7	235		1.38	136.51
105-1-32-4-2	D1		35.5	262		1.38	136.51
105-1-33-4-2	D1		16.6	80		1.38	136.51
105-1-41-4-2	D1		26.2	148		1.38	136.51
105-1-42-4-2	D1		19.3	122		1.38	136.51
105-1-43-4-2	D1		32.7	249		1.38	136.51
106-1-11-4-1	D1		31.3	155		1.22	149.34
106-1-12-4-1	D1		38	196		1.22	149.34
106-1-21-4-1	D1		12.7	52.1		1.22	149.34
106-1-22-4-1	D1		60	390		1.22	149.34
106-1-31-4-2	D1		65.7	282		1.22	149.34
106-1-32-4-2	D1		136	267		1.22	149.34
106-1-41-4-2	D1		31.5	86.4		1.22	149.34
106-1-42-4-2	D1		22.7	62.3		1.22	149.34
107-1-11-4-1	D1		40.2	253		0.99	161.58
107-1-12-4-1	D1		106	373		0.99	161.58

Attachment A							
Tacoma Smelter Plume Site							
Pierce County Footprint Study							
Listing of Results by Sample							
Sample Code	Sampling		Arsenic	Lead		Distance	Direction
	Zone		(ppm, DW)	(ppm,DW)		(miles)	(degrees)
107-1-21-4-1	D1		25.5	156		0.99	161.58
107-1-22-4-1	D1		55	224		0.99	161.58
107-1-31-4-2	D1		98.3	510		0.99	161.58
107-1-32-4-2	D1		70.3	206		0.99	161.58
107-1-41-4-2	D1		61.4	492		0.99	161.58
107-1-42-4-2	D1		122	787		0.99	161.58
108-1-11-4-2	D1		233	444		1.03	188.26
108-1-12-4-2	D1		179	415		1.03	188.26
108-1-13-4-2	D1		151	392		1.03	188.26
108-1-21-4-2	D1		140	401		1.03	188.26
108-1-22-4-2	D1		183	498		1.03	188.26
108-1-23-4-2	D1		148	397		1.03	188.26
108-1-31-4-1	D1		128	602		1.03	188.26
108-1-32-4-1	D1		158	384		1.03	188.26
108-1-33-4-1	D1		86.9	132		1.03	188.26
108-1-41-4-1	D1		175	875		1.03	188.26
108-1-42-4-1	D1		189	752		1.03	188.26
108-1-43-4-1	D1		120	220		1.03	188.26
110-1-11-4-2	D1		98.9	176		1.25	221.41
110-1-12-4-2	D1		95.8	103		1.25	221.41
110-1-21-4-2	D1		440	900		1.25	221.41
110-1-22-4-2	D1		132	146		1.25	221.41
110-1-31-4-2	D1		107	376		1.25	221.41
110-1-32-4-2	D1		152	111		1.25	221.41
110-1-41-4-2	D1		61.7	163		1.25	221.41
110-1-42-4-2	D1		135	103		1.25	221.41
112-1-11-4-2	D1		10.2	74.6		1.72	143.31
112-1-12-4-2	D1		24.3	202		1.72	143.31
112-1-13-4-2	D1		19.7	81.9		1.72	143.31
112-1-21-4-2	D1		22.5	172		1.72	143.31
112-1-22-4-2	D1		26.9	149		1.72	143.31
112-1-23-4-2	D1		9.29	41.2		1.72	143.31
112-1-31-4-1	D1		14.5	71.5		1.72	143.31
112-1-32-4-1	D1		23.3	136		1.72	143.31
112-1-33-4-1	D1		18.4	61.3		1.72	143.31
112-1-41-4-1	D1		20	509		1.72	143.31
112-1-42-4-1	D1		30.2	470		1.72	143.31
112-1-43-4-1	D1		21.4	82.7		1.72	143.31
113-1-11-4-1	D1		15.8	86.8		1.56	156.21
113-1-12-4-1	D1		17.4	30.8		1.56	156.21
113-1-21-4-1	D1		140	578		1.56	156.21
113-1-22-4-1	D1		37.2	57.4		1.56	156.21

Attachment A							
Tacoma Smelter Plume Site							
Pierce County Footprint Study							
Listing of Results by Sample							
Sample Code	Sampling		Arsenic	Lead		Distance	Direction
	Zone		(ppm, DW)	(ppm,DW)		(miles)	(degrees)
113-1-31-4-2	D1		40	202		1.56	156.21
113-1-32-4-2	D1		24.2	78.1		1.56	156.21
113-1-41-4-2	D1		32.4	264		1.56	156.21
113-1-42-4-2	D1		26	307		1.56	156.21
114-1-11-4-1	D1		4.67	17.9		1.33	170.72
114-1-12-4-1	D1		3.46	9.23		1.33	170.72
114-1-21-4-1	D1		61.3	162		1.33	170.72
114-1-22-4-1	D1		35.6	71.9		1.33	170.72
114-1-31-4-2	D1		29.1	381		1.33	170.72
114-1-32-4-2	D1		46.6	673		1.33	170.72
114-1-41-4-2	D1		14.2	134		1.33	170.72
114-1-42-4-2	D1		23.6	254		1.33	170.72
115-1-11-4-1	D1		78.3	94.6		1.30	186.91
115-1-12-4-1	D1		24.9	29		1.30	186.91
115-1-21-4-1	D1		72.4	120		1.30	186.91
115-1-22-4-1	D1		30.1	30.4		1.30	186.91
115-1-31-4-2	D1		60.5	43		1.30	186.91
115-1-32-4-2	D1		13.9	14.6		1.30	186.91
115-1-41-4-2	D1		13.6	77		1.30	186.91
115-1-42-4-2	D1		2.65	8.97		1.30	186.91
118-1-11-4-1	D1		21.8	259		2.68	129.21
118-1-12-4-1	D1		17.5	197		2.68	129.21
118-1-13-4-1	D1		4.33	41.9		2.68	129.21
118-1-21-4-1	D1		20.3	167		2.68	129.21
118-1-22-4-1	D1		17.3	124		2.68	129.21
118-1-23-4-1	D1		10.9	95.4		2.68	129.21
118-1-31-4-2	D1		3.59	29.6		2.68	129.21
118-1-32-4-2	D1		3.34	16.7		2.68	129.21
118-1-33-4-2	D1		8.62	129		2.68	129.21
118-1-41-4-2	D1		7.58	111		2.68	129.21
118-1-42-4-2	D1		6.44	92.7		2.68	129.21
118-1-43-4-2	D1		9.99	127		2.68	129.21
119-1-11-4-1	D1		19.9	120		2.51	133.58
119-1-12-4-1	D1		27.7	140		2.51	133.58
119-1-21-4-2	D1		8.29	104		2.51	133.58
119-1-22-4-2	D1		6.83	119		2.51	133.58
119-1-31-4-2	D1		14.4	148		2.51	133.58
119-1-32-4-2	D1		18.2	181		2.51	133.58
119-1-41-4-2	D1		8.41	115		2.51	133.58
119-1-42-4-2	D1		8.13	144		2.51	133.58
120-1-11-4-1	D1		17.9	88.5		2.23	140.73
120-1-12-4-1	D1		17.1	76.5		2.23	140.73

Attachment A							
Tacoma Smelter Plume Site							
Pierce County Footprint Study							
Listing of Results by Sample							
Sample Code	Sampling		Arsenic	Lead		Distance	Direction
	Zone		(ppm, DW)	(ppm,DW)		(miles)	(degrees)
120-1-21-4-1	D1		17	126		2.23	140.73
120-1-22-4-1	D1		21	129		2.23	140.73
120-1-31-4-2	D1		12.3	76.9		2.23	140.73
120-1-32-4-2	D1		14.9	88.4		2.23	140.73
120-1-41-4-2	D1		6.21	17.5		2.23	140.73
120-1-42-4-2	D1		6.77	22.4		2.23	140.73
121-1-11-4-2	D1		17.5	208		1.94	148.77
121-1-12-4-2	D1		22.1	229		1.94	148.77
121-1-21-4-2	D1		16.1	160		1.94	148.77
121-1-22-4-2	D1		21.8	208		1.94	148.77
121-1-31-4-2	D1		8.07	90.6		1.94	148.77
121-1-32-4-2	D1		20.6	297		1.94	148.77
121-1-41-4-2	D1		15.6	214		1.94	148.77
121-1-42-4-2	D1		20	316		1.94	148.77
122-1-11-4-1	D1		16.2	80.4		1.77	162.11
122-1-12-4-1	D1		30.8	119		1.77	162.11
122-1-13-4-1	D1		14.3	46.9		1.77	162.11
122-1-21-4-1	D1		27	194		1.77	162.11
122-1-22-4-1	D1		56.1	193		1.77	162.11
122-1-23-4-1	D1		12.9	73.6		1.77	162.11
122-1-31-4-2	D1		53.4	148		1.77	162.11
122-1-32-4-2	D1		32.4	95.2		1.77	162.11
122-1-33-4-2	D1		17.7	62		1.77	162.11
122-1-41-4-2	D1		4.66	45.8		1.77	162.11
122-1-42-4-2	D1		9.71	117		1.77	162.11
122-1-43-4-2	D1		8.35	101		1.77	162.11
123-1-11-4-1	D1		65	146		1.73	171.40
123-1-12-4-1	D1		61.3	154		1.73	171.40
123-1-21-4-1	D1		72.7	182		1.73	171.40
123-1-22-4-1	D1		61.7	163		1.73	171.40
123-1-31-4-2	D1		50.9	238		1.73	171.40
123-1-32-4-2	D1		62	254		1.73	171.40
123-1-41-4-2	D1		36	216		1.73	171.40
123-1-42-4-2	D1		20.9	122		1.73	171.40
124-1-11-4-1	D1		41.1	89.4		1.73	182.63
124-1-12-4-1	D1		37.6	70.7		1.73	182.63
124-1-13-4-1	D1		26.7	39.1		1.73	182.63
124-1-21-4-1	D1		40.2	82.8		1.73	182.63
124-1-22-4-1	D1		32.8	35.5		1.73	182.63
124-1-23-4-1	D1		38	74.2		1.73	182.63
124-1-31-4-2	D1		53.4	110		1.73	182.63
124-1-32-4-2	D1		43	75.3		1.73	182.63

Attachment A							
Tacoma Smelter Plume Site							
Pierce County Footprint Study							
Listing of Results by Sample							
Sample Code	Sampling		Arsenic	Lead		Distance	Direction
	Zone		(ppm, DW)	(ppm,DW)		(miles)	(degrees)
124-1-33-4-2	D1		39.7	62		1.73	182.63
124-1-41-4-2	D1		72.8	144		1.73	182.63
124-1-42-4-2	D1		81.1	124		1.73	182.63
124-1-43-4-2	D1		37.9	84.3		1.73	182.63
125-1-11-4-1	D1		68.1	171		1.81	198.45
125-1-12-4-1	D1		122	113		1.81	198.45
125-1-21-4-1	D1		100	139		1.81	198.45
125-1-22-4-1	D1		23.4	29.4		1.81	198.45
125-1-31-4-2	D1		65.3	88.8		1.81	198.45
125-1-32-4-2	D1		64.9	66		1.81	198.45
125-1-41-4-2	D1		80.1	109		1.81	198.45
125-1-42-4-2	D1		30	34.3		1.81	198.45
127-1-11-4-1	D1		27.1	432		3.30	129.74
127-1-12-4-1	D1		25.1	293		3.30	129.74
127-1-13-4-1	D1		7.72	68		3.30	129.74
127-1-21-4-1	D1		20.4	500		3.30	129.74
127-1-22-4-1	D1		22.6	551		3.30	129.74
127-1-23-4-1	D1		7.07	96.9		3.30	129.74
127-1-31-4-2	D1		24.8	928		3.30	129.74
127-1-32-4-2	D1		26.1	811		3.30	129.74
127-1-33-4-2	D1		19	322		3.30	129.74
127-1-41-4-2	D1		20.3	478		3.30	129.74
127-1-42-4-2	D1		25.5	411		3.30	129.74
127-1-43-4-2	D1		9.31	121		3.30	129.74
128-1-11-4-1	D1		6.05	17.7		2.99	133.32
128-1-12-4-1	D1		7.85	33.1		2.99	133.32
128-1-21-4-1	D1		6.18	18.4		2.99	133.32
128-1-22-4-1	D1		7.74	25.1		2.99	133.32
128-1-31-4-2	D1		9.16	82.5		2.99	133.32
128-1-32-4-2	D1		9.97	83.3		2.99	133.32
128-1-41-4-2	D1		9.22	45.2		2.99	133.32
128-1-42-4-2	D1		10.4	70		2.99	133.32
130-1-11-4-1	D1		27.3	119		2.56	147.98
130-1-12-4-1	D1		24.9	101		2.56	147.98
130-1-21-4-1	D1		24.9	662		2.56	147.98
130-1-22-4-1	D1		20.6	226		2.56	147.98
130-1-31-4-2	D1		48.8	235		2.56	147.98
130-1-32-4-2	D1		31.9	197		2.56	147.98
130-1-41-4-2	D1		25.2	313		2.56	147.98
130-1-42-4-2	D1		27.2	231		2.56	147.98
131-1-11-4-1	D1		27.7	94.8		2.38	156.31
131-1-12-4-1	D1		20.9	62.7		2.38	156.31

Attachment A							
Tacoma Smelter Plume Site							
Pierce County Footprint Study							
Listing of Results by Sample							
Sample Code	Sampling		Arsenic	Lead		Distance	Direction
	Zone		(ppm, DW)	(ppm,DW)		(miles)	(degrees)
131-1-13-4-1	D1		6.08	11.6		2.38	156.31
131-1-21-4-1	D1		42.6	170		2.38	156.31
131-1-22-4-1	D1		21.6	93.5		2.38	156.31
131-1-23-4-1	D1		6.93	27.8		2.38	156.31
131-1-31-4-2	D1		30.5	145		2.38	156.31
131-1-32-4-2	D1		30.4	127		2.38	156.31
131-1-33-4-2	D1		20.8	86.4		2.38	156.31
131-1-41-4-2	D1		18.1	142		2.38	156.31
131-1-42-4-2	D1		20.7	157		2.38	156.31
131-1-43-4-2	D1		20.3	150		2.38	156.31
132-1-11-4-1	D1		15.3	95		2.26	163.69
132-1-12-4-1	D1		24.7	89.2		2.26	163.69
132-1-21-4-1	D1		13	87.5		2.26	163.69
132-1-22-4-1	D1		20.2	105		2.26	163.69
132-1-31-4-2	D1		23.4	184		2.26	163.69
132-1-32-4-2	D1		26.1	196		2.26	163.69
132-1-41-4-2	D1		16.2	124		2.26	163.69
132-1-42-4-2	D1		19.1	197		2.26	163.69
133-1-11-4-1	D1		34.1	94.8		2.14	175.72
133-1-12-4-1	D1		24.6	34.9		2.14	175.72
133-1-21-4-1	D1		37.7	200		2.14	175.72
133-1-22-4-1	D1		20.6	19.7		2.14	175.72
133-1-31-4-2	D1		36.4	167		2.14	175.72
133-1-32-4-2	D1		93.6	353		2.14	175.72
133-1-41-4-2	D1		19.3	122		2.14	175.72
133-1-42-4-2	D1		27.6	79.3		2.14	175.72
134-1-11-4-1	D1		13.6	36.6		2.15	185.76
134-1-12-4-1	D1		28.1	75.2		2.15	185.76
134-1-21-4-1	D1		11	35.3		2.15	185.76
134-1-22-4-1	D1		24.5	42.5		2.15	185.76
134-1-31-4-2	D1		3.31	24.2		2.15	185.76
134-1-32-4-2	D1		28.8	47.6		2.15	185.76
134-1-41-4-2	D1		19.7	54.7		2.15	185.76
134-1-42-4-2	D1		22.3	52.7		2.15	185.76
135-2-11-4-0	D1		167	222		2.21	196.08
135-2-12-4-0	D1		112	142		2.21	196.08
135-2-13-4-0	D1		17.9	16.4		2.21	196.08
135-2-21-4-0	D1		72	111		2.21	196.08
135-2-22-4-0	D1		73.3	121		2.21	196.08
135-2-23-4-0	D1		60.6	105		2.21	196.08
135-2-31-4-0	D1		475	947		2.21	196.08
135-2-32-4-0	D1		144	162		2.21	196.08

Attachment A							
Tacoma Smelter Plume Site							
Pierce County Footprint Study							
Listing of Results by Sample							
Sample Code	Sampling		Arsenic	Lead		Distance	Direction
	Zone		(ppm, DW)	(ppm,DW)		(miles)	(degrees)
135-2-33-4-0	D1		34.4	52.8		2.21	196.08
136-1-11-4-1	D1		105	130		2.31	204.77
136-1-12-4-1	D1		65.7	78.7		2.31	204.77
136-1-13-4-1	D1		42.1	63.7		2.31	204.77
136-1-21-4-1	D1		77.3	119		2.31	204.77
136-1-22-4-1	D1		29.6	50.8		2.31	204.77
136-1-23-4-1	D1		66	128		2.31	204.77
136-1-31-4-2	D1		84.7	105		2.31	204.77
136-1-32-4-2	D1		45.7	75.8		2.31	204.77
136-1-33-4-2	D1		10.1	18		2.31	204.77
136-1-41-4-2	D1		77.5	138		2.31	204.77
136-1-42-4-2	D1		49.5	43.1		2.31	204.77
136-1-43-4-2	D1		41.2	72.8		2.31	204.77
138-1-11-4-1	D1		37.7	286		2.68	216.40
138-1-12-4-1	D1		39.7	46.1		2.68	216.40
138-1-21-4-1	D1		16.9	105		2.68	216.40
138-1-22-4-1	D1		23.7	56.9		2.68	216.40
138-1-31-4-2	D1		34	41.1		2.68	216.40
138-1-32-4-2	D1		33.7	209		2.68	216.40
138-1-41-4-2	D1		36.4	147		2.68	216.40
138-1-42-4-2	D1		112	72		2.68	216.40
139-1-11-4-1	D1		12	207		3.53	134.74
139-1-12-4-1	D1		13.9	110		3.53	134.74
139-1-13-4-1	D1		8.39	51.1		3.53	134.74
139-1-21-4-1	D1		9.61	158		3.53	134.74
139-1-22-4-1	D1		13.5	141		3.53	134.74
139-1-23-4-1	D1		11.5	110		3.53	134.74
139-1-31-4-2	D1		21.9	439		3.53	134.74
139-1-32-4-2	D1		22.5	332		3.53	134.74
139-1-33-4-2	D1		11.5	179		3.53	134.74
139-1-41-4-2	D1		13.6	551		3.53	134.74
139-1-42-4-2	D1		14.6	549		3.53	134.74
139-1-43-4-2	D1		15.3	470		3.53	134.74
140-1-11-4-1	D1		16.9	149		3.28	140.79
140-1-12-4-1	D1		17.4	139		3.28	140.79
140-1-21-4-1	D1		16.7	219		3.28	140.79
140-1-22-4-1	D1		20.1	238		3.28	140.79
140-1-31-4-2	D1		14.4	445		3.28	140.79
140-1-32-4-2	D1		18.3	594		3.28	140.79
140-1-41-4-2	D1		18.8	288		3.28	140.79
140-1-42-4-2	D1		17.7	243		3.28	140.79
142-1-11-4-1	D1		18.5	190		2.85	151.82

Attachment A							
Tacoma Smelter Plume Site							
Pierce County Footprint Study							
Listing of Results by Sample							
Sample Code	Sampling		Arsenic	Lead		Distance	Direction
	Zone		(ppm, DW)	(ppm,DW)		(miles)	(degrees)
142-1-12-4-1	D1		19.4	136		2.85	151.82
142-1-13-4-1	D1		11.7	77.3		2.85	151.82
142-1-21-4-1	D1		18.9	116		2.85	151.82
142-1-22-4-1	D1		19.2	86.9		2.85	151.82
142-1-23-4-1	D1		10.3	44.1		2.85	151.82
142-1-31-4-2	D1		12.6	429		2.85	151.82
142-1-32-4-2	D1		16.2	228		2.85	151.82
142-1-33-4-2	D1		5.81	47		2.85	151.82
142-1-41-4-2	D1		12.3	3050		2.85	151.82
142-1-42-4-2	D1		14.4	230		2.85	151.82
142-1-43-4-2	D1		17	227		2.85	151.82
143-1-11-4-1	D1		12.3	40.8		2.66	159.76
143-1-12-4-1	D1		12.4	39.4		2.66	159.76
143-1-21-4-1	D1		13.7	39.7		2.66	159.76
143-1-22-4-1	D1		18.7	62.1		2.66	159.76
143-1-31-4-2	D1		8.58	36.6		2.66	159.76
143-1-32-4-2	D1		10.1	34.1		2.66	159.76
143-1-41-4-2	D1		8.31	48		2.66	159.76
143-1-42-4-2	D1		8.32	36.1		2.66	159.76
144-1-11-4-1	D1		22.3	136		2.59	164.32
144-1-12-4-1	D1		20.8	84.9		2.59	164.32
144-1-21-4-1	D1		22.3	205		2.59	164.32
144-1-22-4-1	D1		23.9	173		2.59	164.32
144-1-31-4-2	D1		11.7	78.9		2.59	164.32
144-1-32-4-2	D1		11.8	79.4		2.59	164.32
144-1-41-4-2	D1		12.5	99.5		2.59	164.32
144-1-42-4-2	D1		13.1	112		2.59	164.32
145-1-11-4-1	D1		22.5	97.4		2.50	173.17
145-1-12-4-1	D1		23.7	87.5		2.50	173.17
145-1-13-4-1	D1		15.6	115		2.50	173.17
145-1-21-4-1	D1		40.9	194		2.50	173.17
145-1-22-4-1	D1		28.5	87.1		2.50	173.17
145-1-23-4-1	D1		30.3	76.6		2.50	173.17
145-1-31-4-2	D1		22.3	83.3		2.50	173.17
145-1-32-4-2	D1		22.1	71.8		2.50	173.17
145-1-33-4-2	D1		16.4	55		2.50	173.17
145-1-41-4-2	D1		24.7	145		2.50	173.17
145-1-42-4-2	D1		26	142		2.50	173.17
145-1-43-4-2	D1		28.8	172		2.50	173.17
146-1-11-4-2	D1		25	47.9		2.58	184.22
146-1-12-4-2	D1		16.9	28.7		2.58	184.22
146-1-13-4-2	D1		13.3	24.2		2.58	184.22

Attachment A							
Tacoma Smelter Plume Site							
Pierce County Footprint Study							
Listing of Results by Sample							
Sample Code	Sampling		Arsenic	Lead		Distance	Direction
	Zone		(ppm, DW)	(ppm,DW)		(miles)	(degrees)
146-1-21-4-2	D1		23.7	44.1		2.58	184.22
146-1-22-4-2	D1		13.4	24.4		2.58	184.22
146-1-23-4-2	D1		10.4	20.2		2.58	184.22
146-1-31-4-1	D1		16.5	36.8		2.58	184.22
146-1-32-4-1	D1		11	22.5		2.58	184.22
146-1-33-4-1	D1		5.03	9.93		2.58	184.22
146-1-41-4-1	D1		17.8	39.3		2.58	184.22
146-1-42-4-1	D1		13	21.4		2.58	184.22
146-1-43-4-1	D1		7.07	11.5		2.58	184.22
148-1-11-4-1	D1		50.9	213		2.63	201.73
148-1-12-4-1	D1		111	157		2.63	201.73
148-1-13-4-1	D1		17.3	19.4		2.63	201.73
148-1-21-4-2	D1		88.7	136		2.63	201.73
148-1-22-4-2	D1		94.3	99.7		2.63	201.73
148-1-23-4-2	D1		55	56		2.63	201.73
148-1-31-4-2	D1		92.7	107		2.63	201.73
148-1-32-4-2	D1		55.3	77.1		2.63	201.73
148-1-33-4-2	D1		115	102		2.63	201.73
148-1-41-4-2	D1		97.1	233		2.63	201.73
148-1-42-4-2	D1		104	104		2.63	201.73
148-1-43-4-2	D1		77.5	93.7		2.63	201.73
149-1-11-4-1	D1		3.9	10.8		2.77	206.35
149-1-12-4-1	D1		16.1	26		2.77	206.35
149-1-21-4-1	D1		6.39	16.4		2.77	206.35
149-1-22-4-1	D1		10.2	21		2.77	206.35
149-1-31-4-1	D1		5.5	17.7		2.77	206.35
149-1-32-4-1	D1		4.8	10.9		2.77	206.35
149-1-41-4-1	D1		6.12	16.7		2.77	206.35
149-1-42-4-1	D1		13.8	18.8		2.77	206.35
150-1-11-4-1	D1		10.3	136		3.29	148.52
150-1-12-4-1	D1		8.51	115		3.29	148.52
150-1-21-4-1	D1		7.52	195		3.29	148.52
150-1-22-4-1	D1		7.91	189		3.29	148.52
150-1-31-4-2	D1		13	252		3.29	148.52
150-1-32-4-2	D1		13.3	241		3.29	148.52
150-1-41-4-2	D1		9.84	273		3.29	148.52
150-1-42-4-2	D1		9.69	264		3.29	148.52
151-1-11-4-1	D1		12.7	74.8		3.18	153.14
151-1-12-4-1	D1		7.88	51.4		3.18	153.14
151-1-13-4-1	D1		14.2	89.1		3.18	153.14
151-1-21-4-1	D1		17.2	127		3.18	153.14
151-1-22-4-1	D1		17.3	150		3.18	153.14

Attachment A							
Tacoma Smelter Plume Site							
Pierce County Footprint Study							
Listing of Results by Sample							
Sample Code	Sampling		Arsenic	Lead		Distance	Direction
	Zone		(ppm, DW)	(ppm,DW)		(miles)	(degrees)
151-1-23-4-1	D1		13	156		3.18	153.14
151-1-31-4-1	D1		11	1810		3.18	153.14
151-1-32-4-1	D1		15.9	6670		3.18	153.14
151-1-33-4-1	D1		10	460		3.18	153.14
151-1-41-4-1	D1		14.7	359		3.18	153.14
151-1-42-4-1	D1		16.9	427		3.18	153.14
151-1-43-4-1	D1		11	167		3.18	153.14
152-1-11-4-1	D1		21.1	288		3.00	160.64
152-1-12-4-1	D1		19.8	160		3.00	160.64
152-1-21-4-1	D1		17.4	265		3.00	160.64
152-1-22-4-1	D1		20	167		3.00	160.64
152-1-31-4-2	D1		8.94	119		3.00	160.64
152-1-32-4-2	D1		9.06	57.6		3.00	160.64
152-1-41-4-2	D1		7.02	55.1		3.00	160.64
152-1-42-4-2	D1		8.86	27.3		3.00	160.64
153-1-11-4-1	D1		14.5	131		2.92	167.15
153-1-12-4-1	D1		10.8	64.1		2.92	167.15
153-1-21-4-1	D1		19.4	115		2.92	167.15
153-1-22-4-1	D1		19.5	95.5		2.92	167.15
153-1-31-4-2	D1		12.3	116		2.92	167.15
153-1-32-4-2	D1		12.7	69.1		2.92	167.15
153-1-41-4-2	D1		7.03	38.9		2.92	167.15
153-1-42-4-2	D1		7.82	59.4		2.92	167.15
154-1-11-4-1	D1		37.6	264		2.85	175.43
154-1-12-4-1	D1		11.2	36.1		2.85	175.43
154-1-13-4-1	D1		10.5	46.7		2.85	175.43
154-1-21-4-1	D1		31.1	199		2.85	175.43
154-1-22-4-1	D1		22.3	69.4		2.85	175.43
154-1-23-4-1	D1		11.6	34		2.85	175.43
154-1-31-4-2	D1		26.8	158		2.85	175.43
154-1-32-4-2	D1		28.6	153		2.85	175.43
154-1-33-4-2	D1		16.4	98.5		2.85	175.43
154-1-41-4-2	D1		26.9	461		2.85	175.43
154-1-42-4-2	D1		28.3	409		2.85	175.43
154-1-43-4-2	D1		28.4	260		2.85	175.43
155-1-11-4-1	D1		44.6	279		3.06	198.72
155-1-12-4-1	D1		45.9	64		3.06	198.72
155-1-13-4-1	D1		24.8	66.5		3.06	198.72
155-1-21-4-1	D1		52.8	188		3.06	198.72
155-1-22-4-1	D1		78.5	131		3.06	198.72
155-1-23-4-1	D1		42.5	78.2		3.06	198.72
155-1-31-4-2	D1		85.4	127		3.06	198.72

Attachment A							
Tacoma Smelter Plume Site							
Pierce County Footprint Study							
Listing of Results by Sample							
Sample Code	Sampling		Arsenic	Lead		Distance	Direction
	Zone		(ppm, DW)	(ppm,DW)		(miles)	(degrees)
155-1-32-4-2	D1		27.2	29.3		3.06	198.72
155-1-33-4-2	D1		4.8	7.74		3.06	198.72
155-1-41-4-2	D1		92.1	231		3.06	198.72
155-1-42-4-2	D1		50.7	60.7		3.06	198.72
155-1-43-4-2	D1		5.3	9.48		3.06	198.72
157-1-11-4-1	D1		40.7	190		3.32	208.68
157-1-12-4-1	D1		44.7	29.6		3.32	208.68
157-1-13-4-1	D1		7.46	6.06		3.32	208.68
157-1-21-4-1	D1		55.3	272		3.32	208.68
157-1-22-4-1	D1		27.7	26.4		3.32	208.68
157-1-23-4-1	D1		9.83	8.92		3.32	208.68
157-1-31-4-1	D1		58	338		3.32	208.68
157-1-32-4-1	D1		46.8	58.8		3.32	208.68
157-1-33-4-1	D1		11.2	16.8		3.32	208.68
157-1-41-4-1	D1		38.8	219		3.32	208.68
157-1-42-4-1	D1		35.6	31.6		3.32	208.68
157-1-43-4-1	D1		18.1	31.4		3.32	208.68
159-1-11-4-1	D1		6.84	207		3.65	151.87
159-1-12-4-1	D1		6.86	226		3.65	151.87
159-1-13-4-1	D1		8.64	169		3.65	151.87
159-1-21-4-1	D1		7.6	182		3.65	151.87
159-1-22-4-1	D1		8.02	201		3.65	151.87
159-1-23-4-1	D1		13.1	271		3.65	151.87
159-1-31-4-2	D1		6.74	164		3.65	151.87
159-1-32-4-2	D1		5.83	145		3.65	151.87
159-1-33-4-2	D1		10	203		3.65	151.87
159-1-41-4-2	D1		6.73	129		3.65	151.87
159-1-42-4-2	D1		7.14	141		3.65	151.87
159-1-43-4-2	D1		9.47	305		3.65	151.87
163-1-11-4-1	D1		9.91	27.7		3.21	175.14
163-1-12-4-1	D1		10.2	27		3.21	175.14
163-1-13-4-1	D1		9.28	20.2		3.21	175.14
163-1-21-4-1	D1		13.2	48.9		3.21	175.14
163-1-22-4-1	D1		13.6	49.3		3.21	175.14
163-1-23-4-1	D1		11.7	37		3.21	175.14
163-1-31-4-2	D1		7.89	56.9		3.21	175.14
163-1-32-4-2	D1		6.49	37.9		3.21	175.14
163-1-33-4-2	D1		9.05	272		3.21	175.14
163-1-41-4-2	D1		8.15	35.1		3.21	175.14
163-1-42-4-2	D1		6.13	18		3.21	175.14
163-1-43-4-2	D1		5.91	31.7		3.21	175.14
165-1-11-4-1	D1		9.57	27.8		3.34	187.81

Attachment A							
Tacoma Smelter Plume Site							
Pierce County Footprint Study							
Listing of Results by Sample							
Sample Code	Sampling		Arsenic	Lead		Distance	Direction
	Zone		(ppm, DW)	(ppm,DW)		(miles)	(degrees)
165-1-12-4-1	D1		7.51	17.7		3.34	187.81
165-1-13-4-1	D1		5.54	11.5		3.34	187.81
165-1-21-4-1	D1		14.6	49.6		3.34	187.81
165-1-22-4-1	D1		12.9	41.2		3.34	187.81
165-1-23-4-1	D1		5.79	13		3.34	187.81
165-1-31-4-2	D1		21.5	43.3		3.34	187.81
165-1-32-4-2	D1		9.91	15.9		3.34	187.81
165-1-33-4-2	D1		2.54	5.06		3.34	187.81
165-1-41-4-2	D1		15.4	30.6		3.34	187.81
165-1-42-4-2	D1		15.2	28		3.34	187.81
165-1-43-4-2	D1		2.52	5.88		3.34	187.81
168-1-11-4-1	D1		56.6	106		3.66	206.22
168-1-12-4-1	D1		58.5	98.7		3.66	206.22
168-1-21-4-1	D1		46.4	108		3.66	206.22
168-1-22-4-1	D1		48.8	88		3.66	206.22
168-1-31-4-2	D1		4.74	11.5		3.66	206.22
168-1-32-4-2	D1		10.2	16.7		3.66	206.22
168-1-41-4-2	D1		3.86	15.2		3.66	206.22
168-1-42-4-2	D1		8.04	25.4		3.66	206.22
169-1-11-4-1	D1		22.3	40.7		3.87	211.05
169-1-12-4-1	D1		24.1	42.2		3.87	211.05
169-1-13-4-1	D1		21.4	39		3.87	211.05
169-1-21-4-1	D1		29.9	63.1		3.87	211.05
169-1-22-4-1	D1		50.1	103		3.87	211.05
169-1-23-4-1	D1		52.2	89.9		3.87	211.05
169-1-31-4-2	D1		31.3	65.5		3.87	211.05
169-1-32-4-2	D1		36.5	73.5		3.87	211.05
169-1-33-4-2	D1		12.4	19.2		3.87	211.05
169-1-41-4-2	D1		24.2	95.5		3.87	211.05
169-1-42-4-2	D1		11.2	22.7		3.87	211.05
169-1-43-4-2	D1		6.72	4.72		3.87	211.05
171-1-11-4-1	D1		3.16	20.2		3.86	159.85
171-1-12-4-1	D1		4.56	21.6		3.86	159.85
171-1-13-4-1	D1		4.18	16.8		3.86	159.85
171-1-21-4-1	D1		6.59	21		3.86	159.85
171-1-22-4-1	D1		8.65	23.9		3.86	159.85
171-1-23-4-1	D1		6.16	21		3.86	159.85
171-1-31-4-2	D1		12.3	54.1		3.86	159.85
171-1-32-4-2	D1		10.2	56		3.86	159.85
171-1-33-4-2	D1		4.74	18.7		3.86	159.85
171-1-41-4-2	D1		12.3	43.2		3.86	159.85
171-1-42-4-2	D1		8.06	40.4		3.86	159.85

Attachment A							
Tacoma Smelter Plume Site							
Pierce County Footprint Study							
Listing of Results by Sample							
Sample Code	Sampling		Arsenic	Lead		Distance	Direction
	Zone		(ppm, DW)	(ppm,DW)		(miles)	(degrees)
171-1-43-4-2	D1		8.82	51.3		3.86	159.85
173-1-11-4-1	D1		8.33	26.2		3.65	169.97
173-1-12-4-1	D1		8.05	20		3.65	169.97
173-1-21-4-1	D1		12.4	26.2		3.65	169.97
173-1-22-4-1	D1		11.2	32.6		3.65	169.97
173-1-31-4-2	D1		6.44	44.4		3.65	169.97
173-1-32-4-2	D1		8.73	41.6		3.65	169.97
173-1-41-4-2	D1		15.2	127		3.65	169.97
173-1-42-4-2	D1		16.6	125		3.65	169.97
174-1-11-4-1	D1		18.5	94.8		3.58	177.16
174-1-12-4-1	D1		10.5	17.5		3.58	177.16
174-1-21-4-1	D1		16	85.5		3.58	177.16
174-1-22-4-1	D1		10.2	18.3		3.58	177.16
174-1-31-4-2	D1		11.2	32.9		3.58	177.16
174-1-32-4-2	D1		11.6	31.5		3.58	177.16
174-1-41-4-2	D1		8.78	40.7		3.58	177.16
174-1-42-4-2	D1		10.5	31.4		3.58	177.16
175-2-11-4-0	D1		48.2	111		3.68	181.55
175-2-12-4-0	D1		21.5	50.9		3.68	181.55
175-2-21-4-0	D1		104	402		3.68	181.55
175-2-22-4-0	D1		57.7	98.1		3.68	181.55
175-2-31-4-0	D1		92	306		3.68	181.55
175-2-32-4-0	D1		60	105		3.68	181.55
176-1-11-4-1	D1		73.8	227		3.70	188.14
176-1-12-4-1	D1		74.5	173		3.70	188.14
176-1-21-4-1	D1		61.3	166		3.70	188.14
176-1-22-4-1	D1		61.6	129		3.70	188.14
176-1-31-4-2	D1		23.6	82		3.70	188.14
176-1-32-4-2	D1		22	82.3		3.70	188.14
176-1-41-4-2	D1		25.9	80.4		3.70	188.14
176-1-42-4-2	D1		25.8	79.9		3.70	188.14
178-1-11-4-2	D1		25.6	26.5		3.82	200.19
178-1-12-4-2	D1		17.2	17.5		3.82	200.19
178-1-21-4-2	D1		24.6	33.9		3.82	200.19
178-1-22-4-2	D1		17	13.2		3.82	200.19
178-1-31-4-2	D1		24.3	35.1		3.82	200.19
178-1-32-4-2	D1		10.8	11.1		3.82	200.19
178-1-41-4-2	D1		26.3	28.3		3.82	200.19
178-1-42-4-2	D1		15	15.9		3.82	200.19
179-1-11-4-1	D1		50	83.8		4.02	205.19
179-1-12-4-1	D1		24.4	34.7		4.02	205.19
179-1-21-4-1	D1		37.8	86.8		4.02	205.19

Attachment A							
Tacoma Smelter Plume Site							
Pierce County Footprint Study							
Listing of Results by Sample							
Sample Code	Sampling		Arsenic	Lead		Distance	Direction
	Zone		(ppm, DW)	(ppm,DW)		(miles)	(degrees)
179-1-22-4-1	D1		25.2	37.5		4.02	205.19
179-1-31-4-2	D1		32.3	63.1		4.02	205.19
179-1-32-4-2	D1		36.3	77.8		4.02	205.19
179-1-41-4-2	D1		37.9	103		4.02	205.19
179-1-42-4-2	D1		46.6	97.1		4.02	205.19
180-1-11-4-1	D1		20.8	39.5		4.15	208.09
180-1-12-4-1	D1		15.8	29.4		4.15	208.09
180-1-13-4-1	D1		11.8	32.2		4.15	208.09
180-1-21-4-1	D1		25.7	49.2		4.15	208.09
180-1-22-4-1	D1		24.1	52.6		4.15	208.09
180-1-23-4-1	D1		22.3	42.9		4.15	208.09
180-1-31-4-1	D1		37.3	80.9		4.15	208.09
180-1-32-4-1	D1		31.9	64.9		4.15	208.09
180-1-33-4-1	D1		25.1	50.7		4.15	208.09
180-1-41-4-2	D1		39.1	77.8		4.15	208.09
180-1-42-4-2	D1		47.4	83.3		4.15	208.09
180-1-43-4-2	D1		45.8	79.5		4.15	208.09
181-2-11-4-0	D1		445	673		1.32	213.94
181-2-12-4-0	D1		997	1360		1.32	213.94
181-2-21-4-0	D1		1050	3990		1.32	213.94
181-2-22-4-0	D1		574	860		1.32	213.94
181-2-31-4-0	D1		559	636		1.32	213.94
181-2-32-4-0	D1		639	1410		1.32	213.94
203-1-11-4-1	D1		45.7	104		3.23	200.91
203-1-12-4-1	D1		57.4	59.5		3.23	200.91
203-1-21-4-1	D1		68.9	119		3.23	200.91
203-1-22-4-1	D1		23.6	38.2		3.23	200.91
203-1-31-4-2	D1		133	622		3.23	200.91
203-1-32-4-2	D1		40	91.7		3.23	200.91
203-1-41-4-2	D1		85.7	114		3.23	200.91
203-1-42-4-2	D1		86.1	99.8		3.23	200.91
215-1-11-4-1	D1		28.8	276		2.12	136.03
215-1-12-4-1	D1		39	196		2.12	136.03
215-1-21-4-1	D1		33.4	207		2.12	136.03
215-1-22-4-1	D1		33.7	193		2.12	136.03
215-1-31-4-2	D1		20.3	258		2.12	136.03
215-1-32-4-2	D1		28.5	186		2.12	136.03
215-1-41-4-2	D1		32.9	221		2.12	136.03
215-1-42-4-2	D1		35.9	172		2.12	136.03
241-1-11-4-1	D1		9.98	128		3.60	143.97
241-1-12-4-1	D1		12.7	210		3.60	143.97
241-1-21-4-1	D1		10.4	115		3.60	143.97

Attachment A							
Tacoma Smelter Plume Site							
Pierce County Footprint Study							
Listing of Results by Sample							
Sample Code	Sampling		Arsenic	Lead		Distance	Direction
	Zone		(ppm, DW)	(ppm,DW)		(miles)	(degrees)
241-1-22-4-1	D1		12.8	121		3.60	143.97
241-1-31-4-2	D1		9.54	159		3.60	143.97
241-1-32-4-2	D1		9.72	2820		3.60	143.97
241-1-41-4-2	D1		11.3	283		3.60	143.97
241-1-42-4-2	D1		14.4	383		3.60	143.97
242-1-11-4-1	D1		8.79	454		3.80	137.93
242-1-12-4-1	D1		8.49	350		3.80	137.93
242-1-21-4-1	D1		11.6	747		3.80	137.93
242-1-22-4-1	D1		11.7	833		3.80	137.93
242-1-31-4-1	D1		5.82	204		3.80	137.93
242-1-32-4-1	D1		5.19	131		3.80	137.93
242-1-41-4-1	D1		6.2	87.6		3.80	137.93
242-1-42-4-1	D1		5.96	54.4		3.80	137.93
243-1-11-4-1	D1		13.6	549		4.14	143.18
243-1-12-4-1	D1		13.8	647		4.14	143.18
243-1-21-4-1	D1		12.6	449		4.14	143.18
243-1-22-4-1	D1		14.2	488		4.14	143.18
243-1-31-4-2	D1		16.6	438		4.14	143.18
243-1-32-4-2	D1		14.8	215		4.14	143.18
243-1-41-4-2	D1		12.5	792		4.14	143.18
243-1-42-4-2	D1		12	576		4.14	143.18
244-1-11-4-1	D1		12.3	158		3.86	145.58
244-1-12-4-1	D1		13.2	158		3.86	145.58
244-1-21-4-1	D1		14.1	192		3.86	145.58
244-1-22-4-1	D1		11.7	165		3.86	145.58
244-1-31-4-2	D1		9.36	445		3.86	145.58
244-1-32-4-2	D1		8.05	287		3.86	145.58
244-1-41-4-2	D1		10.7	381		3.86	145.58
244-1-42-4-2	D1		13.8	279		3.86	145.58
245-1-11-4-1	D1		10	81.2		4.23	148.51
245-1-12-4-1	D1		8.34	57.1		4.23	148.51
245-1-13-4-1	D1		5.26	29		4.23	148.51
245-1-21-4-1	D1		7.51	65.2		4.23	148.51
245-1-22-4-1	D1		7.77	55.1		4.23	148.51
245-1-23-4-1	D1		6.47	33.9		4.23	148.51
245-1-31-4-2	D1		7.49	95.7		4.23	148.51
245-1-32-4-2	D1		8.47	97.8		4.23	148.51
245-1-33-4-2	D1		5.45	45.8		4.23	148.51
245-1-41-4-2	D1		6.18	131		4.23	148.51
245-1-42-4-2	D1		7.37	136		4.23	148.51
245-1-43-4-2	D1		5.39	101		4.23	148.51
247-1-11-4-1	D1		129	417		1.17	164.47

Attachment A							
Tacoma Smelter Plume Site							
Pierce County Footprint Study							
Listing of Results by Sample							
Sample Code	Sampling		Arsenic	Lead		Distance	Direction
	Zone		(ppm, DW)	(ppm,DW)		(miles)	(degrees)
247-1-12-4-1	D1		3.77	13.7		1.17	164.47
247-1-21-4-1	D1		27.7	187		1.17	164.47
247-1-22-4-1	D1		41.2	217		1.17	164.47
247-1-31-4-2	D1		20.8	401		1.17	164.47
247-1-32-4-2	D1		43.1	199		1.17	164.47
247-1-41-4-2	D1		15.1	89.1		1.17	164.47
247-1-42-4-2	D1		77.5	264		1.17	164.47
299-1-11-4-1	D1		21.4	45.9		2.04	209.33
299-1-12-4-1	D1		85.5	126		2.04	209.33
299-1-21-4-1	D1		15.1	24.8		2.04	209.33
299-1-22-4-1	D1		61.3	62.1		2.04	209.33
299-1-31-4-2	D1		51.2	156		2.04	209.33
299-1-32-4-2	D1		57.3	35.6		2.04	209.33
299-1-41-4-2	D1		204	145		2.04	209.33
299-1-42-4-2	D1		86.8	26.9		2.04	209.33
304-1-11-4-1	D2		66.9	134		4.38	202.31
304-1-12-4-1	D2		70.1	137		4.38	202.31
304-1-21-4-1	D2		46.8	114		4.38	202.31
304-1-22-4-1	D2		44.3	75.9		4.38	202.31
304-1-31-4-2	D2		67.8	290		4.38	202.31
304-1-32-4-2	D2		63.9	425		4.38	202.31
304-1-41-4-2	D2		60.4	136		4.38	202.31
304-1-42-4-2	D2		66.7	144		4.38	202.31
306-1-11-4-1	D2		5.52	23.2		5.03	162.52
306-1-12-4-1	D2		2.94	18.1		5.03	162.52
306-1-13-4-1	D2		4.94	33.3		5.03	162.52
306-1-21-4-1	D2		10.3	122		5.03	162.52
306-1-22-4-1	D2		7.83	63.1		5.03	162.52
306-1-23-4-1	D2		7.17	66.9		5.03	162.52
306-1-31-4-2	D2		5.72	104		5.03	162.52
306-1-32-4-2	D2		4.93	96.6		5.03	162.52
306-1-33-4-2	D2		3.11	32.6		5.03	162.52
306-1-41-4-2	D2		4.24	52.1		5.03	162.52
306-1-42-4-2	D2		6.48	53		5.03	162.52
306-1-43-4-2	D2		5.71	29.7		5.03	162.52
308-1-11-4-1	D2		15.7	52.8		4.80	185.87
308-1-12-4-1	D2		14.5	43.4		4.80	185.87
308-1-13-4-1	D2		13.1	37.4		4.80	185.87
308-1-21-4-1	D2		25	88		4.80	185.87
308-1-22-4-1	D2		17.9	60.3		4.80	185.87
308-1-23-4-1	D2		10.5	32.1		4.80	185.87
308-1-31-4-2	D2		8.23	23.8		4.80	185.87

Attachment A							
Tacoma Smelter Plume Site							
Pierce County Footprint Study							
Listing of Results by Sample							
Sample Code	Sampling		Arsenic	Lead		Distance	Direction
	Zone		(ppm, DW)	(ppm,DW)		(miles)	(degrees)
308-1-32-4-2	D2		6.33	17.4		4.80	185.87
308-1-33-4-2	D2		4.18	11.1		4.80	185.87
308-1-41-4-2	D2		15.3	35.2		4.80	185.87
308-1-42-4-2	D2		11.5	58.5		4.80	185.87
308-1-43-4-2	D2		8.45	46.2		4.80	185.87
309-1-11-4-1	D2		2.73	32.2		4.97	193.39
309-1-12-4-1	D2		5.08	30.4		4.97	193.39
309-1-21-4-1	D2		2.94	29.7		4.97	193.39
309-1-22-4-1	D2		3.36	23.2		4.97	193.39
309-1-31-4-2	D2		36.9	69.1		4.97	193.39
309-1-32-4-2	D2		31.6	53.4		4.97	193.39
309-1-41-4-2	D2		79	75		4.97	193.39
309-1-42-4-2	D2		27.5	36.1		4.97	193.39
310-1-11-4-1	D2		21.1	53.2		4.97	199.75
310-1-12-4-1	D2		15.6	40.1		4.97	199.75
310-1-21-4-1	D2		52.9	100		4.97	199.75
310-1-22-4-1	D2		38.3	86.3		4.97	199.75
310-1-31-4-2	D2		28.1	102		4.97	199.75
310-1-32-4-2	D2		43.1	144		4.97	199.75
310-1-41-4-2	D2		38.6	62.8		4.97	199.75
310-1-42-4-2	D2		38.2	61.2		4.97	199.75
311-1-11-4-1	D2		57.4	215		5.20	205.61
311-1-12-4-1	D2		37.6	59.5		5.20	205.61
311-1-21-4-1	D2		51.9	250		5.20	205.61
311-1-22-4-1	D2		88	176		5.20	205.61
311-1-31-4-2	D2		42.8	257		5.20	205.61
311-1-32-4-2	D2		51.3	101		5.20	205.61
311-1-41-4-2	D2		31.5	120		5.20	205.61
311-1-42-4-2	D2		24.6	23.5		5.20	205.61
313-1-11-4-1	D2		6.3	18.5		5.39	184.75
313-1-12-4-1	D2		7.72	14.9		5.39	184.75
313-1-21-4-1	D2		6.18	16.7		5.39	184.75
313-1-22-4-1	D2		5.09	13.5		5.39	184.75
313-1-31-4-1	D2		5.41	15		5.39	184.75
313-1-32-4-1	D2		6.5	17.1		5.39	184.75
313-1-41-4-1	D2		12.8	34.2		5.39	184.75
313-1-42-4-1	D2		17.5	37.5		5.39	184.75
314-1-11-4-1	D2		15.3	70.5		5.54	189.58
314-1-12-4-1	D2		22.3	63.5		5.54	189.58
314-1-21-4-1	D2		34.4	126		5.54	189.58
314-1-22-4-1	D2		17.2	22.9		5.54	189.58
314-1-31-4-2	D2		24.1	70.8		5.54	189.58

Attachment A							
Tacoma Smelter Plume Site							
Pierce County Footprint Study							
Listing of Results by Sample							
Sample Code	Sampling		Arsenic	Lead		Distance	Direction
	Zone		(ppm, DW)	(ppm,DW)		(miles)	(degrees)
314-1-32-4-2	D2		20.6	46.7		5.54	189.58
314-1-41-4-2	D2		21.4	78.3		5.54	189.58
314-1-42-4-2	D2		22.5	79.1		5.54	189.58
315-1-11-4-1	D2		18.2	80.4		5.77	196.85
315-1-12-4-1	D2		18	80.2		5.77	196.85
315-1-21-4-1	D2		18.6	48.2		5.77	196.85
315-1-22-4-1	D2		16.9	41.9		5.77	196.85
315-1-31-4-2	D2		9.78	21.1		5.77	196.85
315-1-32-4-2	D2		7.71	13.3		5.77	196.85
315-1-41-4-2	D2		17.6	40.3		5.77	196.85
315-1-42-4-2	D2		19	40.5		5.77	196.85
316-1-11-4-1	D2		17.3	42.1		5.79	201.76
316-1-12-4-1	D2		6.54	14.2		5.79	201.76
316-1-13-4-1	D2		2.69	3.8		5.79	201.76
316-1-21-4-1	D2		22.5	41.6		5.79	201.76
316-1-22-4-1	D2		22	31.4		5.79	201.76
316-1-23-4-1	D2		3.17	4.72		5.79	201.76
316-1-31-4-2	D2		7.37	11.7		5.79	201.76
316-1-32-4-2	D2		19.4	25.4		5.79	201.76
316-1-33-4-2	D2		14.8	32.7		5.79	201.76
316-1-41-4-2	D2		25.9	36.3		5.79	201.76
316-1-42-4-2	D2		23.3	28.5		5.79	201.76
316-1-43-4-2	D2		15.7	22.9		5.79	201.76
317-1-11-4-2	D2		15.2	38		6.09	207.98
317-1-12-4-2	D2		27.5	37.3		6.09	207.98
317-1-21-4-2	D2		22.7	43.2		6.09	207.98
317-1-22-4-2	D2		29.1	48.3		6.09	207.98
317-1-31-4-2	D2		8.79	11.7		6.09	207.98
317-1-32-4-2	D2		12.2	24.1		6.09	207.98
317-1-41-4-2	D2		23.1	40.8		6.09	207.98
317-1-42-4-2	D2		15.9	24.3		6.09	207.98
319-2-11-4-0	D2		22.3	80.2		5.94	177.79
319-2-12-4-0	D2		21.1	69.3		5.94	177.79
319-2-13-4-0	D2		10.7	34.5		5.94	177.79
319-2-21-4-0	D2		18.8	59.1		5.94	177.79
319-2-22-4-0	D2		14.8	44.4		5.94	177.79
319-2-23-4-0	D2		7.59	18.9		5.94	177.79
319-2-31-4-0	D2		28	80.3		5.94	177.79
319-2-32-4-0	D2		30.6	68.6		5.94	177.79
319-2-33-4-0	D2		10.6	23.7		5.94	177.79
321-1-11-4-1	D2		14.2	298		6.18	190.54
321-1-12-4-1	D2		17.4	175		6.18	190.54

Attachment A							
Tacoma Smelter Plume Site							
Pierce County Footprint Study							
Listing of Results by Sample							
Sample Code	Sampling		Arsenic	Lead		Distance	Direction
	Zone		(ppm, DW)	(ppm,DW)		(miles)	(degrees)
321-1-21-4-1	D2		10.4	25.2		6.18	190.54
321-1-22-4-1	D2		6.61	17.7		6.18	190.54
321-1-31-4-2	D2		6.65	23.2		6.18	190.54
321-1-32-4-2	D2		7.64	18.3		6.18	190.54
321-1-41-4-2	D2		46.4	160		6.18	190.54
321-1-42-4-2	D2		37.6	107		6.18	190.54
323-2-11-4-0	D2		103	91.5		6.42	200.42
323-2-12-4-0	D2		33	25.5		6.42	200.42
323-2-21-4-0	D2		119	96.1		6.42	200.42
323-2-22-4-0	D2		71.9	41.2		6.42	200.42
323-2-31-4-0	D2		204	301		6.42	200.42
323-2-32-4-0	D2		76.2	14.2		6.42	200.42
324-1-11-4-1	D2		10	39.1		6.58	204.97
324-1-12-4-1	D2		5.17	11.8		6.58	204.97
324-1-21-4-1	D2		10.9	82.7		6.58	204.97
324-1-22-4-1	D2		5.44	8.16		6.58	204.97
324-1-31-4-2	D2		6.82	25.4		6.58	204.97
324-1-32-4-2	D2		10.5	17.2		6.58	204.97
324-1-41-4-2	D2		11.7	27.6		6.58	204.97
324-1-42-4-2	D2		15.6	41.9		6.58	204.97
327-1-11-4-1	D2		3.22	7.11		6.60	183.68
327-1-12-4-1	D2		11.3	32.4		6.60	183.68
327-1-21-4-1	D2		11.9	41.5		6.60	183.68
327-1-22-4-1	D2		9.72	30.2		6.60	183.68
327-1-31-4-2	D2		11.2	225		6.60	183.68
327-1-32-4-2	D2		13.4	167		6.60	183.68
327-1-41-4-2	D2		8.53	27.8		6.60	183.68
327-1-42-4-2	D2		8.02	22.3		6.60	183.68
329-2-11-4-0	D2		55.4	126		6.65	195.90
329-2-12-4-0	D2		61.1	111		6.65	195.90
329-2-21-4-0	D2		76.8	230		6.65	195.90
329-2-22-4-0	D2		73.1	69.6		6.65	195.90
329-2-31-4-0	D2		57.5	410		6.65	195.90
329-2-32-4-0	D2		74.8	157		6.65	195.90
331-2-11-4-0	D2		177	411		6.88	201.65
331-2-12-4-0	D2		91.6	128		6.88	201.65
331-2-21-4-0	D2		89.2	137		6.88	201.65
331-2-22-4-0	D2		37.6	53.7		6.88	201.65
331-2-31-4-0	D2		134	344		6.88	201.65
331-2-32-4-0	D2		25.8	46.8		6.88	201.65
341-1-11-4-1	D2		16	45.9		5.90	99.30
341-1-12-4-1	D2		13.7	36.4		5.90	99.30

Attachment A							
Tacoma Smelter Plume Site							
Pierce County Footprint Study							
Listing of Results by Sample							
Sample Code	Sampling		Arsenic	Lead		Distance	Direction
	Zone		(ppm, DW)	(ppm,DW)		(miles)	(degrees)
341-1-13-4-1	D2		6.99	19		5.90	99.30
341-1-21-4-1	D2		12.2	39		5.90	99.30
341-1-22-4-1	D2		12.2	32.4		5.90	99.30
341-1-23-4-1	D2		6.62	27.4		5.90	99.30
341-1-31-4-2	D2		16.4	84		5.90	99.30
341-1-32-4-2	D2		12.9	53.7		5.90	99.30
341-1-33-4-2	D2		7.72	20.1		5.90	99.30
341-1-41-4-2	D2		6.82	20.9		5.90	99.30
341-1-42-4-2	D2		6.78	17.2		5.90	99.30
341-1-43-4-2	D2		3.84	7.73		5.90	99.30
346-1-11-4-2	D2		14.4	41.1		3.83	87.26
346-1-12-4-2	D2		19.8	42.4		3.83	87.26
346-1-21-4-2	D2		12.5	43.2		3.83	87.26
346-1-22-4-2	D2		19.6	60.2		3.83	87.26
346-1-31-4-1	D2		9.63	23.5		3.83	87.26
346-1-32-4-1	D2		8.7	14.9		3.83	87.26
346-1-41-4-1	D2		16.1	40.3		3.83	87.26
346-1-42-4-1	D2		17.6	36.8		3.83	87.26
349-2-11-4-0	D2		27	75.6		4.06	77.74
349-2-12-4-0	D2		17.5	33.4		4.06	77.74
349-2-13-4-0	D2		28.5	84.4		4.06	77.74
349-2-21-4-0	D2		29.2	64.8		4.06	77.74
349-2-22-4-0	D2		30	41.5		4.06	77.74
349-2-23-4-0	D2		2.88	4.47		4.06	77.74
349-2-31-4-0	D2		44.5	132		4.06	77.74
349-2-32-4-0	D2		44.9	98.8		4.06	77.74
349-2-33-4-0	D2		19.8	36.6		4.06	77.74
351-1-11-4-2	D2		15.8	36.7		4.20	71.78
351-1-12-4-2	D2		15.3	31		4.20	71.78
351-1-21-4-2	D2		7.09	69.8		4.20	71.78
351-1-22-4-2	D2		5.18	18.4		4.20	71.78
351-1-31-4-2	D2		12.5	28.9		4.20	71.78
351-1-32-4-2	D2		13.1	20.8		4.20	71.78
351-1-41-4-2	D2		14.9	34.1		4.20	71.78
351-1-42-4-2	D2		10.6	29.4		4.20	71.78
353-1-11-4-1	D2		5.43	20.9		8.41	114.32
353-1-12-4-1	D2		6.88	23.7		8.41	114.32
353-1-13-4-1	D2		5.13	15.2		8.41	114.32
353-1-21-4-1	D2		7.45	39.5		8.41	114.32
353-1-22-4-1	D2		7.28	38.9		8.41	114.32
353-1-23-4-1	D2		5.54	24.4		8.41	114.32
353-1-31-4-2	D2		4.56	58.6		8.41	114.32

Attachment A							
Tacoma Smelter Plume Site							
Pierce County Footprint Study							
Listing of Results by Sample							
Sample Code	Sampling		Arsenic	Lead		Distance	Direction
	Zone		(ppm, DW)	(ppm,DW)		(miles)	(degrees)
353-1-32-4-2	D2		4.34	52.5		8.41	114.32
353-1-33-4-2	D2		3.71	35.6		8.41	114.32
353-1-41-4-2	D2		3.76	47.5		8.41	114.32
353-1-42-4-2	D2		3.45	35.4		8.41	114.32
353-1-43-4-2	D2		3.01	31.3		8.41	114.32
355-1-11-4-1	D2		20.1	69.8		8.03	111.42
355-1-12-4-1	D2		19.6	67.9		8.03	111.42
355-1-21-4-1	D2		13.4	49		8.03	111.42
355-1-22-4-1	D2		14.4	47.3		8.03	111.42
355-1-31-4-2	D2		8.95	26.3		8.03	111.42
355-1-32-4-2	D2		8.44	24.6		8.03	111.42
355-1-41-4-2	D2		12	32.1		8.03	111.42
355-1-42-4-2	D2		11.4	30.2		8.03	111.42
359-1-11-4-2	D2		6.21	33.9		7.30	104.12
359-1-12-4-2	D2		8.42	43.5		7.30	104.12
359-1-13-4-2	D2		6.48	22.5		7.30	104.12
359-1-21-4-2	D2		6.15	48.5		7.30	104.12
359-1-22-4-2	D2		7.39	58.3		7.30	104.12
359-1-23-4-2	D2		6.93	48.4		7.30	104.12
359-1-31-4-1	D2		6.26	36.9		7.30	104.12
359-1-32-4-1	D2		3.91	20.5		7.30	104.12
359-1-33-4-1	D2		3.66	13.9		7.30	104.12
359-1-41-4-1	D2		5.57	19.9		7.30	104.12
359-1-42-4-1	D2		5.77	18.1		7.30	104.12
359-1-43-4-1	D2		8.47	27.1		7.30	104.12
361-2-11-4-0	D2		88.3	176		4.66	193.24
361-2-12-4-0	D2		68.1	121		4.66	193.24
361-2-21-4-0	D2		39.7	61		4.66	193.24
361-2-22-4-0	D2		29.6	44		4.66	193.24
361-2-31-4-0	D2		64.2	144		4.66	193.24
361-2-32-4-0	D2		36.3	85.2		4.66	193.24
362-2-11-4-0	D2		223	474		5.34	202.49
362-2-12-4-0	D2		146	150		5.34	202.49
362-2-21-4-0	D2		159	419		5.34	202.49
362-2-22-4-0	D2		168	135		5.34	202.49
362-2-31-4-0	D2		67.2	176		5.34	202.49
362-2-32-4-0	D2		82.2	173		5.34	202.49
383-1-11-4-1	D2		37.6	129		3.00	82.67
383-1-12-4-1	D2		38.3	125		3.00	82.67
383-1-21-4-1	D2		17.6	75		3.00	82.67
383-1-22-4-1	D2		18.3	59.7		3.00	82.67
383-1-31-4-1	D2		61.2	97.1		3.00	82.67

Attachment A							
Tacoma Smelter Plume Site							
Pierce County Footprint Study							
Listing of Results by Sample							
Sample Code	Sampling		Arsenic	Lead		Distance	Direction
	Zone		(ppm, DW)	(ppm,DW)		(miles)	(degrees)
383-1-32-4-1	D2		74.1	105		3.00	82.67
384-1-11-4-1	D2		9.13	28.6		3.77	80.08
384-1-12-4-1	D2		14.5	26.2		3.77	80.08
384-1-21-4-1	D2		9.15	31.9		3.77	80.08
384-1-22-4-1	D2		13	27.6		3.77	80.08
384-1-31-4-2	D2		21.9	48.2		3.77	80.08
384-1-32-4-2	D2		11.6	16.4		3.77	80.08
384-1-41-4-2	D2		15.1	49.1		3.77	80.08
384-1-42-4-2	D2		12.4	19.8		3.77	80.08
388-1-11-4-1	D2		16.8	46.8		3.86	81.77
388-1-12-4-1	D2		7.51	9.38		3.86	81.77
388-1-21-4-1	D2		13.1	25.7		3.86	81.77
388-1-22-4-1	D2		6.85	9.09		3.86	81.77
388-1-31-4-2	D2		7.74	13.7		3.86	81.77
388-1-32-4-2	D2		13.4	18.7		3.86	81.77
388-1-41-4-2	D2		18.2	62.6		3.86	81.77
388-1-42-4-2	D2		12.6	14.1		3.86	81.77
390-1-11-4-1	D2		6.05	33.2		3.92	82.15
390-1-12-4-1	D2		7.37	25.7		3.92	82.15
390-1-21-4-1	D2		4.65	33.4		3.92	82.15
390-1-22-4-1	D2		5.22	32		3.92	82.15
390-1-31-4-2	D2		11.8	38.4		3.92	82.15
390-1-32-4-2	D2		11.8	30.8		3.92	82.15
390-1-41-4-2	D2		13.8	39.4		3.92	82.15
390-1-42-4-2	D2		11.8	15.9		3.92	82.15
393-1-11-4-1	D2		13.4	86.3		4.16	184.41
393-1-12-4-1	D2		14.4	98.1		4.16	184.41
393-1-21-4-1	D2		19.1	53.5		4.16	184.41
393-1-22-4-1	D2		20.3	47.6		4.16	184.41
393-1-31-4-2	D2		9.28	28		4.16	184.41
393-1-32-4-2	D2		10.6	31.4		4.16	184.41
393-1-41-4-2	D2		5.66	32.8		4.16	184.41
393-1-42-4-2	D2		6.89	34.5		4.16	184.41
396-1-11-4-1	D2		9.5	104		4.54	151.59
396-1-12-4-1	D2		8.75	111		4.54	151.59
396-1-21-4-1	D2		9.32	142		4.54	151.59
396-1-22-4-1	D2		11.1	165		4.54	151.59
396-1-31-4-2	D2		7.31	139		4.54	151.59
396-1-32-4-2	D2		6.24	125		4.54	151.59
396-1-41-4-2	D2		6.97	157		4.54	151.59
396-1-42-4-2	D2		7.93	200		4.54	151.59
397-1-11-4-1	D2		12.3	354		4.87	146.23

Attachment A							
Tacoma Smelter Plume Site							
Pierce County Footprint Study							
Listing of Results by Sample							
Sample Code	Sampling		Arsenic	Lead		Distance	Direction
	Zone		(ppm, DW)	(ppm,DW)		(miles)	(degrees)
397-1-12-4-1	D2		13	443		4.87	146.23
397-1-21-4-1	D2		20.7	236		4.87	146.23
397-1-22-4-1	D2		20.2	212		4.87	146.23
397-1-31-4-2	D2		3.19	16.3		4.87	146.23
397-1-32-4-2	D2		3.01	7.27		4.87	146.23
397-1-41-4-2	D2		6.9	117		4.87	146.23
397-1-42-4-2	D2		7.15	117		4.87	146.23
401-1-11-4-1	D3		25.3	205		7.09	170.19
401-1-12-4-1	D3		28.5	149		7.09	170.19
401-1-21-4-1	D3		14.6	107		7.09	170.19
401-1-22-4-1	D3		15.5	110		7.09	170.19
401-1-31-4-2	D3		22.4	106		7.09	170.19
401-1-32-4-2	D3		18.8	85.8		7.09	170.19
401-1-41-4-2	D3		17.2	214		7.09	170.19
401-1-42-4-2	D3		14.7	165		7.09	170.19
403-1-11-4-1	D3		22.7	68.4		7.38	191.46
403-1-12-4-1	D3		69.1	108		7.38	191.46
403-1-21-4-1	D3		10.2	39.6		7.38	191.46
403-1-22-4-1	D3		5.82	10.2		7.38	191.46
403-1-31-4-2	D3		11	22.6		7.38	191.46
403-1-32-4-2	D3		7.67	11.7		7.38	191.46
403-1-41-4-2	D3		6.25	14.8		7.38	191.46
403-1-42-4-2	D3		8.7	19.7		7.38	191.46
409-1-11-4-1	D3		13.2	60.2		8.13	189.14
409-1-12-4-1	D3		14.7	68.8		8.13	189.14
409-1-21-4-1	D3		10.6	36.8		8.13	189.14
409-1-22-4-1	D3		11	34.5		8.13	189.14
409-1-31-4-2	D3		12.4	47.2		8.13	189.14
409-1-32-4-2	D3		11.7	38		8.13	189.14
409-1-41-4-2	D3		16.4	62		8.13	189.14
409-1-42-4-2	D3		18.2	44.5		8.13	189.14
411-2-11-4-0	D3		34.8	52.6		8.21	201.07
411-2-12-4-0	D3		41.6	73.7		8.21	201.07
411-2-21-4-0	D3		58.9	107		8.21	201.07
411-2-22-4-0	D3		40	88.1		8.21	201.07
411-2-31-4-0	D3		90.1	209		8.21	201.07
411-2-32-4-0	D3		40.3	66		8.21	201.07
411-2-33-4-0	D3		6.21	9.37		8.21	201.07
415-1-11-4-2	D3		4.13	15.6		8.80	182.42
415-1-12-4-2	D3		3.51	8.5		8.80	182.42
415-1-21-4-2	D3		4.87	15.6		8.80	182.42
415-1-22-4-2	D3		4.74	10.7		8.80	182.42

Attachment A							
Tacoma Smelter Plume Site							
Pierce County Footprint Study							
Listing of Results by Sample							
Sample Code	Sampling		Arsenic	Lead		Distance	Direction
	Zone		(ppm, DW)	(ppm,DW)		(miles)	(degrees)
415-1-31-4-2	D3		17	264		8.80	182.42
415-1-32-4-2	D3		19.8	333		8.80	182.42
415-1-41-4-2	D3		14.3	86.2		8.80	182.42
415-1-42-4-2	D3		15.5	95.5		8.80	182.42
418-2-11-4-0	D3		24.2	61.3		9.40	197.25
418-2-12-4-0	D3		20.6	48.9		9.40	197.25
418-2-13-4-0	D3		8.63	21.4		9.40	197.25
418-2-21-4-0	D3		32.9	81.1		9.40	197.25
418-2-22-4-0	D3		36.7	47.2		9.40	197.25
418-2-31-4-0	D3		26.2	91.2		9.40	197.25
418-2-32-4-0	D3		24.6	42.7		9.40	197.25
419-2-11-4-0	D3		51.9	101		9.62	204.50
419-2-12-4-0	D3		45.7	87.7		9.62	204.50
419-2-13-4-0	D3		10.4	17.9		9.62	204.50
419-2-21-4-0	D3		45.3	114		9.62	204.50
419-2-22-4-0	D3		48.8	94.3		9.62	204.50
419-2-23-4-0	D3		34.5	47.4		9.62	204.50
419-2-31-4-0	D3		50.9	268		9.62	204.50
419-2-32-4-0	D3		49.6	128		9.62	204.50
419-2-33-4-0	D3		16.4	45.5		9.62	204.50
420-1-11-4-2	D3		17.1	47.8		9.92	207.74
420-1-12-4-2	D3		16.6	43.8		9.92	207.74
420-1-21-4-2	D3		14.4	49.3		9.92	207.74
420-1-22-4-2	D3		19	61.4		9.92	207.74
420-1-31-4-2	D3		12.4	36.6		9.92	207.74
420-1-32-4-2	D3		14	38.5		9.92	207.74
420-1-41-4-2	D3		34.5	141		9.92	207.74
420-1-42-4-2	D3		27	71.9		9.92	207.74
422-1-11-4-1	D3		10.1	37.2		9.82	182.65
422-1-12-4-1	D3		10.3	31.2		9.82	182.65
422-1-21-4-1	D3		11.4	32.9		9.82	182.65
422-1-22-4-1	D3		11.1	25		9.82	182.65
422-1-31-4-1	D3		12.9	54.3		9.82	182.65
422-1-32-4-1	D3		12.9	38.6		9.82	182.65
422-1-41-4-1	D3		8.57	29.9		9.82	182.65
422-1-42-4-1	D3		8.48	28.1		9.82	182.65
423-1-11-4-1	D3		9.98	50		9.70	186.75
423-1-12-4-1	D3		16	55.1		9.70	186.75
423-1-21-4-1	D3		12.6	73.9		9.70	186.75
423-1-22-4-1	D3		11.8	65.1		9.70	186.75
423-1-31-4-1	D3		20.6	100		9.70	186.75
423-1-32-4-1	D3		9.17	32.4		9.70	186.75

Attachment A							
Tacoma Smelter Plume Site							
Pierce County Footprint Study							
Listing of Results by Sample							
Sample Code	Sampling		Arsenic	Lead		Distance	Direction
	Zone		(ppm, DW)	(ppm,DW)		(miles)	(degrees)
423-1-41-4-1	D3		30	89.1		9.70	186.75
423-1-42-4-1	D3		21.7	35.9		9.70	186.75
424-1-11-4-1	D3		25	51.2		9.94	192.21
424-1-12-4-1	D3		28.9	43.7		9.94	192.21
424-1-13-4-1	D3		30.8	30.8		9.94	192.21
424-1-21-4-1	D3		27.1	102		9.94	192.21
424-1-22-4-1	D3		26.7	89.2		9.94	192.21
424-1-23-4-1	D3		12.9	34		9.94	192.21
424-1-31-4-2	D3		23	55.7		9.94	192.21
424-1-32-4-2	D3		29	45.8		9.94	192.21
424-1-33-4-2	D3		33.4	43.5		9.94	192.21
424-1-41-4-2	D3		23.8	77.9		9.94	192.21
424-1-42-4-2	D3		30.4	65.4		9.94	192.21
424-1-43-4-2	D3		8.2	14.7		9.94	192.21
425-1-11-4-1	D3		10.9	35.9		10.21	198.16
425-1-12-4-1	D3		10.9	33.6		10.21	198.16
425-1-21-4-1	D3		15.5	51.3		10.21	198.16
425-1-22-4-1	D3		14.6	44.5		10.21	198.16
425-1-31-4-2	D3		12.8	80		10.21	198.16
425-1-32-4-2	D3		17.1	86.9		10.21	198.16
425-1-41-4-2	D3		6.56	44.8		10.21	198.16
425-1-42-4-2	D3		9.11	52.3		10.21	198.16
426-1-11-4-1	D3		8.85	22.6		10.29	201.79
426-1-12-4-1	D3		6.55	13.9		10.29	201.79
426-1-21-4-1	D3		18.4	37.3		10.29	201.79
426-1-22-4-1	D3		16.6	35.3		10.29	201.79
426-1-31-4-2	D3		14.5	28.5		10.29	201.79
426-1-32-4-2	D3		8.44	17.1		10.29	201.79
426-1-41-4-2	D3		30.4	68.7		10.29	201.79
426-1-42-4-2	D3		16.5	28.2		10.29	201.79
441-1-11-4-2	D3		14.3	111		7.13	177.00
441-1-12-4-2	D3		24.7	80.1		7.13	177.00
441-1-21-4-2	D3		6.3	75.3		7.13	177.00
441-1-22-4-2	D3		5.51	59.4		7.13	177.00
441-1-31-4-2	D3		33.9	159		7.13	177.00
441-1-32-4-2	D3		14	138		7.13	177.00
441-1-41-4-2	D3		12.2	147		7.13	177.00
441-1-42-4-2	D3		26.7	97.4		7.13	177.00
442-1-11-4-1	D3		4.53	25.9		9.27	187.28
442-1-12-4-1	D3		4.6	22		9.27	187.28
442-1-13-4-1	D3		4.92	25.8		9.27	187.28
442-1-21-4-1	D3		5.14	21.2		9.27	187.28

Attachment A							
Tacoma Smelter Plume Site							
Pierce County Footprint Study							
Listing of Results by Sample							
Sample Code	Sampling		Arsenic	Lead		Distance	Direction
	Zone		(ppm, DW)	(ppm,DW)		(miles)	(degrees)
442-1-22-4-1	D3		5.68	19.2		9.27	187.28
442-1-23-4-1	D3		5	18.9		9.27	187.28
442-1-31-4-2	D3		6.74	116		9.27	187.28
442-1-32-4-2	D3		10.8	172		9.27	187.28
442-1-33-4-2	D3		10.9	111		9.27	187.28
442-1-41-4-2	D3		3.66	42.3		9.27	187.28
442-1-42-4-2	D3		3.2	66.6		9.27	187.28
442-1-43-4-2	D3		6.37	150		9.27	187.28
444-1-11-4-1	D3		11.3	30.7		9.35	196.11
444-1-12-4-1	D3		12.4	29.3		9.35	196.11
444-1-21-4-1	D3		18.2	40.5		9.35	196.11
444-1-22-4-1	D3		27.9	53.8		9.35	196.11
444-1-31-4-2	D3		12.8	44.7		9.35	196.11
444-1-32-4-2	D3		13.1	32.8		9.35	196.11
444-1-41-4-2	D3		6.6	18.7		9.35	196.11
444-1-42-4-2	D3		5.09	11.8		9.35	196.11
503-2-11-4-0	U1		64.5	111		3.92	314.43
503-2-12-4-0	U1		21.4	20.7		3.92	314.43
503-2-21-4-0	U1		25.4	32.4		3.92	314.43
503-2-22-4-0	U1		18.5	22.1		3.92	314.43
503-2-31-4-0	U1		15.9	27.5		3.92	314.43
503-2-32-4-0	U1		15.2	28.1		3.92	314.43
504-2-11-4-0	U1		57.6	482		3.98	296.95
504-2-12-4-0	U1		60.7	165		3.98	296.95
504-2-13-4-0	U1		27.2	24.3		3.98	296.95
504-2-21-4-0	U1		29.4	76		3.98	296.95
504-2-22-4-0	U1		8.89	7.45		3.98	296.95
504-2-23-4-0	U1		6.23	10.8		3.98	296.95
504-2-31-4-0	U1		55.2	92.1		3.98	296.95
504-2-32-4-0	U1		12.5	10.8		3.98	296.95
504-2-33-4-0	U1		8.43	5.93		3.98	296.95
505-2-11-4-0	U1		25.5	83.6		4.54	288.36
505-2-12-4-0	U1		15.9	32.3		4.54	288.36
505-2-21-4-0	U1		17.2	52.4		4.54	288.36
505-2-22-4-0	U1		9.31	19.5		4.54	288.36
505-2-31-4-0	U1		15.7	45.2		4.54	288.36
505-2-32-4-0	U1		10.2	35		4.54	288.36
509-2-11-4-0	U1		21.2	48.9		4.74	288.91
509-2-12-4-0	U1		11.2	28.3		4.74	288.91
509-2-21-4-0	U1		9.51	21.1		4.74	288.91
509-2-22-4-0	U1		4.35	15.6		4.74	288.91
509-2-31-4-0	U1		40.7	74.3		4.74	288.91

Attachment A							
Tacoma Smelter Plume Site							
Pierce County Footprint Study							
Listing of Results by Sample							
Sample Code	Sampling		Arsenic	Lead		Distance	Direction
	Zone		(ppm, DW)	(ppm,DW)		(miles)	(degrees)
509-2-32-4-0	U1		17.1	32.3		4.74	288.91
516-2-11-4-0	U1		25.1	58.6		4.16	274.86
516-2-12-4-0	U1		17.8	39.9		4.16	274.86
516-2-21-4-0	U1		17.1	55.1		4.16	274.86
516-2-22-4-0	U1		16.1	48.7		4.16	274.86
516-2-31-4-0	U1		8.14	19.5		4.16	274.86
516-2-32-4-0	U1		18.9	51.1		4.16	274.86
518-2-11-4-0	U1		87.2	310		2.25	265.19
518-2-12-4-0	U1		85.3	134		2.25	265.19
518-2-13-4-0	U1		15.2	10.4		2.25	265.19
518-2-21-4-0	U1		80.4	136		2.25	265.19
518-2-22-4-0	U1		93	274		2.25	265.19
518-2-23-4-0	U1		171	78.1		2.25	265.19
518-2-31-4-0	U1		62.8	134		2.25	265.19
518-2-32-4-0	U1		56.4	115		2.25	265.19
518-2-33-4-0	U1		38	54.8		2.25	265.19
521-2-11-4-0	U1		42.4	54.1		4.13	266.41
521-2-12-4-0	U1		11.8	14.8		4.13	266.41
521-2-21-4-0	U1		56	122		4.13	266.41
521-2-22-4-0	U1		32.6	66.3		4.13	266.41
521-2-31-4-0	U1		49.3	119		4.13	266.41
521-2-32-4-0	U1		30.1	76.9		4.13	266.41
524-2-11-4-0	U1		128	177		3.07	255.72
524-2-12-4-0	U1		50	35.9		3.07	255.72
524-2-21-4-0	U1		117	161		3.07	255.72
524-2-22-4-0	U1		38.5	37.5		3.07	255.72
524-2-31-4-0	U1		135	306		3.07	255.72
524-2-32-4-0	U1		63.7	90.6		3.07	255.72
525-2-11-4-0	U1		65.9	187		3.20	263.78
525-2-12-4-0	U1		11.8	15.2		3.20	263.78
525-2-21-4-0	U1		38.4	62.9		3.20	263.78
525-2-22-4-0	U1		7.02	21.6		3.20	263.78
525-2-31-4-0	U1		71.8	143		3.20	263.78
525-2-32-4-0	U1		12.2	11.9		3.20	263.78
527-2-11-4-0	U1		114	184		3.23	244.46
527-2-12-4-0	U1		25.1	19.2		3.23	244.46
527-2-13-4-0	U1		6.52	9.52		3.23	244.46
527-2-21-4-0	U1		128	87.9		3.23	244.46
527-2-22-4-0	U1		22.9	9.54		3.23	244.46
527-2-23-4-0	U1		5.44	8.66		3.23	244.46
527-2-31-4-0	U1		85.2	149		3.23	244.46
527-2-32-4-0	U1		31.5	10.5		3.23	244.46

Attachment A							
Tacoma Smelter Plume Site							
Pierce County Footprint Study							
Listing of Results by Sample							
Sample Code	Sampling		Arsenic	Lead		Distance	Direction
	Zone		(ppm, DW)	(ppm,DW)		(miles)	(degrees)
527-2-33-4-0	U1		5.4	6.92		3.23	244.46
530-2-11-4-0	U1		163	577		3.58	234.26
530-2-12-4-0	U1		130	147		3.58	234.26
530-2-21-4-0	U1		118	142		3.58	234.26
530-2-22-4-0	U1		12.8	29.4		3.58	234.26
530-2-31-4-0	U1		113	101		3.58	234.26
530-2-32-4-0	U1		52.9	114		3.58	234.26
531-2-11-4-0	U1		47.6	96		4.09	239.48
531-2-12-4-0	U1		42.5	114		4.09	239.48
531-2-13-4-0	U1		4.51	9.99		4.09	239.48
531-2-21-4-0	U1		53.7	79.7		4.09	239.48
531-2-22-4-0	U1		21.2	33.3		4.09	239.48
531-2-23-4-0	U1		3.33	4.91		4.09	239.48
531-2-31-4-0	U1		51.1	63.8		4.09	239.48
531-2-32-4-0	U1		15.9	30.7		4.09	239.48
531-2-33-4-0	U1		43.8	39.5		4.09	239.48
540-2-11-4-0	U1		97	200		5.91	231.91
540-2-12-4-0	U1		66.4	58.2		5.91	231.91
540-2-21-4-0	U1		41.1	88.2		5.91	231.91
540-2-22-4-0	U1		24.9	51.1		5.91	231.91
540-2-31-4-0	U1		87.9	248		5.91	231.91
540-2-32-4-0	U1		53.2	129		5.91	231.91
542-2-11-4-0	U1		71.7	121		6.76	237.81
542-2-12-4-0	U1		36.6	51.5		6.76	237.81
542-2-13-4-0	U1		13.8	8.01		6.76	237.81
542-2-21-4-0	U1		71.2	290		6.76	237.81
542-2-22-4-0	U1		54.9	51.5		6.76	237.81
542-2-23-4-0	U1		3.6	5.55		6.76	237.81
542-2-31-4-0	U1		80.8	241		6.76	237.81
542-2-32-4-0	U1		23.2	13		6.76	237.81
542-2-33-4-0	U1		7.52	9.61		6.76	237.81
545-2-11-4-0	U1		87.4	114		6.81	231.43
545-2-12-4-0	U1		35	9.15		6.81	231.43
545-2-13-4-0	U1		6.24	3.95		6.81	231.43
545-2-21-4-0	U1		82.4	152		6.81	231.43
545-2-22-4-0	U1		28.5	39.3		6.81	231.43
545-2-23-4-0	U1		9.59	7.61		6.81	231.43
545-2-31-4-0	U1		88.9	139		6.81	231.43
545-2-32-4-0	U1		14.7	32.9		6.81	231.43
545-2-33-4-0	U1		2.9	5.38		6.81	231.43
546-2-11-4-0	U1		102	76.7		6.66	225.17
546-2-12-4-0	U1		45	33.1		6.66	225.17

Attachment A							
Tacoma Smelter Plume Site							
Pierce County Footprint Study							
Listing of Results by Sample							
Sample Code	Sampling		Arsenic	Lead		Distance	Direction
	Zone		(ppm, DW)	(ppm,DW)		(miles)	(degrees)
546-2-13-4-0	U1		7.35	5.84		6.66	225.17
546-2-21-4-0	U1		117	208		6.66	225.17
546-2-22-4-0	U1		81.4	101		6.66	225.17
546-2-23-4-0	U1		13.8	13.6		6.66	225.17
546-2-31-4-0	U1		65.2	108		6.66	225.17
546-2-32-4-0	U1		18.2	15.7		6.66	225.17
546-2-33-4-0	U1		4.79	8.29		6.66	225.17
547-2-11-4-0	U1		182	167		7.06	226.30
547-2-12-4-0	U1		118	69.6		7.06	226.30
547-2-21-4-0	U1		104	336		7.06	226.30
547-2-22-4-0	U1		55.5	36.3		7.06	226.30
547-2-31-4-0	U1		141	237		7.06	226.30
547-2-32-4-0	U1		36.9	18.3		7.06	226.30
550-2-11-4-0	U1		4.5	15.8		6.59	247.39
550-2-12-4-0	U1		5.41	15.7		6.59	247.39
550-2-21-4-0	U1		8.59	16.9		6.59	247.39
550-2-22-4-0	U1		9.03	17.9		6.59	247.39
550-2-31-4-0	U1		10.5	21.2		6.59	247.39
550-2-32-4-0	U1		12.8	22.3		6.59	247.39
565-2-11-4-0	U1		69.2	358		4.33	237.69
565-2-12-4-0	U1		35.7	41.9		4.33	237.69
565-2-21-4-0	U1		34.2	100		4.33	237.69
565-2-22-4-0	U1		22	57.9		4.33	237.69
565-2-31-4-0	U1		61.4	148		4.33	237.69
565-2-32-4-0	U1		30.5	37.5		4.33	237.69
570-2-11-4-0	U1		11.4	21.9		5.30	298.39
570-2-12-4-0	U1		7.1	12.9		5.30	298.39
570-2-21-4-0	U1		34	137		5.30	298.39
570-2-22-4-0	U1		11.1	27.6		5.30	298.39
570-2-31-4-0	U1		11.3	26.5		5.30	298.39
570-2-32-4-0	U1		2.84	5.12		5.30	298.39
599-2-11-4-0	U1		14.6	25.3		3.25	290.95
599-2-12-4-0	U1		15.3	26.5		3.25	290.95
599-2-21-4-0	U1		19.7	41.4		3.25	290.95
599-2-22-4-0	U1		18.1	40.2		3.25	290.95
599-2-31-4-0	U1		25.1	49.4		3.25	290.95
599-2-32-4-0	U1		24.1	44.3		3.25	290.95
601-2-11-4-0	U2		20.1	96.3		5.99	290.96
601-2-12-4-0	U2		11	30.2		5.99	290.96
601-2-21-4-0	U2		23.2	38.5		5.99	290.96
601-2-22-4-0	U2		7.8	14.6		5.99	290.96
602-2-11-4-0	U2		6.26	22.5		7.18	290.47

Attachment A							
Tacoma Smelter Plume Site							
Pierce County Footprint Study							
Listing of Results by Sample							
Sample Code	Sampling		Arsenic	Lead		Distance	Direction
	Zone		(ppm, DW)	(ppm,DW)		(miles)	(degrees)
602-2-12-4-0	U2		5.61	17.1		7.18	290.47
602-2-21-4-0	U2		8.72	23.5		7.18	290.47
602-2-22-4-0	U2		6.7	16.7		7.18	290.47
604-2-11-4-0	U2		24.9	73		6.83	278.43
604-2-12-4-0	U2		19.9	46.3		6.83	278.43
604-2-21-4-0	U2		14.9	44.6		6.83	278.43
604-2-22-4-0	U2		11.2	19.5		6.83	278.43
605-2-11-4-0	U2		9.16	14.7		7.99	276.16
605-2-12-4-0	U2		2.77	4.53		7.99	276.16
605-2-21-4-0	U2		11.4	37.7		7.99	276.16
605-2-22-4-0	U2		11.8	35.9		7.99	276.16
606-2-11-4-0	U2		7.36	13.8		5.46	273.08
606-2-12-4-0	U2		6.92	13.9		5.46	273.08
606-2-21-4-0	U2		4.09	9.68		5.46	273.08
606-2-22-4-0	U2		7.9	22.2		5.46	273.08
607-2-11-4-0	U2		34.3	84		6.56	272.28
607-2-12-4-0	U2		18	53.3		6.56	272.28
607-2-21-4-0	U2		11.4	25.9		6.56	272.28
607-2-22-4-0	U2		6.72	14.9		6.56	272.28
608-2-11-4-0	U2		7.56	21.7		7.96	269.63
608-2-12-4-0	U2		8.5	43.6		7.96	269.63
608-2-21-4-0	U2		14.7	33.1		7.96	269.63
608-2-22-4-0	U2		7.5	14.2		7.96	269.63
609-2-11-4-0	U2		29.7	49.8		4.72	256.42
609-2-12-4-0	U2		25.3	45.3		4.72	256.42
609-2-21-4-0	U2		28.6	50.2		4.72	256.42
609-2-22-4-0	U2		17.5	32.5		4.72	256.42
613-2-11-4-0	U2		9.35	17.4		7.21	249.89
613-2-12-4-0	U2		10.3	17.5		7.21	249.89
613-2-21-4-0	U2		20.7	57.2		7.21	249.89
613-2-22-4-0	U2		15.5	36.3		7.21	249.89
614-2-11-4-0	U2		5.17	13.5		11.51	258.12
614-2-12-4-0	U2		5.11	11		11.51	258.12
614-2-21-4-0	U2		9.24	8.11		11.51	258.12
614-2-22-4-0	U2		8.65	4.84		11.51	258.12
615-2-11-4-0	U2		3.05	10.9		12.79	259.32
615-2-12-4-0	U2		3.04	11		12.79	259.32
615-2-21-4-0	U2		3.76	15.5		12.79	259.32
615-2-22-4-0	U2		1.85	7.12		12.79	259.32
616-2-11-4-0	U2		8.21	32.4		13.84	260.06
616-2-12-4-0	U2		5.39	9.68		13.84	260.06
616-2-21-4-0	U2		7.06	34.2		13.84	260.06

Attachment A							
Tacoma Smelter Plume Site							
Pierce County Footprint Study							
Listing of Results by Sample							
Sample Code	Sampling		Arsenic	Lead		Distance	Direction
	Zone		(ppm, DW)	(ppm,DW)		(miles)	(degrees)
616-2-22-4-0	U2		4.94	12.9		13.84	260.06
617-2-11-4-0	U2		4.5	30		14.84	259.97
617-2-12-4-0	U2		3.09	15.3		14.84	259.97
617-2-21-4-0	U2		7.18	33.9		14.84	259.97
617-2-22-4-0	U2		6.31	23.5		14.84	259.97
618-2-11-4-0	U2		12.9	41.5		11.91	253.48
618-2-12-4-0	U2		9.43	26.3		11.91	253.48
618-2-21-4-0	U2		9.03	43		11.91	253.48
618-2-22-4-0	U2		8.41	28.3		11.91	253.48
620-2-11-4-0	U2		8.03	18.4		13.93	256.57
620-2-12-4-0	U2		5.07	11.1		13.93	256.57
620-2-21-4-0	U2		11.5	40		13.93	256.57
620-2-22-4-0	U2		6.21	9.26		13.93	256.57
621-2-11-4-0	U2		8.26	45.3		15.01	257.47
621-2-12-4-0	U2		3.67	16.7		15.01	257.47
621-2-21-4-0	U2		10.1	32.5		15.01	257.47
621-2-22-4-0	U2		4.22	10.5		15.01	257.47
622-2-11-4-0	U2		8.63	31.3		10.04	243.36
622-2-12-4-0	U2		4.42	10		10.04	243.36
622-2-21-4-0	U2		8.24	30.5		10.04	243.36
622-2-22-4-0	U2		9.53	31.2		10.04	243.36
624-2-11-4-0	U2		8.08	34.7		13.18	249.84
624-2-12-4-0	U2		3.12	7.52		13.18	249.84
624-2-21-4-0	U2		5.57	14.2		13.18	249.84
624-2-22-4-0	U2		3.27	6.97		13.18	249.84
626-2-11-4-0	U2		14.1	38.9		9.05	230.66
626-2-12-4-0	U2		19.4	28.3		9.05	230.66
626-2-21-4-0	U2		28.4	61.5		9.05	230.66
626-2-22-4-0	U2		16.4	37.6		9.05	230.66
628-2-11-4-0	U2		31.4	153		10.55	237.77
628-2-12-4-0	U2		23.4	57.8		10.55	237.77
628-2-21-4-0	U2		25.3	57.6		10.55	237.77
628-2-22-4-0	U2		10.2	20.4		10.55	237.77
631-2-11-4-0	U2		9.93	46.9		13.71	245.88
631-2-12-4-0	U2		4.74	12.5		13.71	245.88
631-2-21-4-0	U2		10.3	30.6		13.71	245.88
631-2-22-4-0	U2		6.44	19.4		13.71	245.88
632-2-11-4-0	U2		2.88	41.9		15.09	247.75
632-2-12-4-0	U2		2.51	29.5		15.09	247.75
632-2-21-4-0	U2		11.8	39.9		15.09	247.75
632-2-22-4-0	U2		9.31	27.4		15.09	247.75
633-2-11-4-0	U2		11.9	35.4		10.80	231.86

Attachment A							
Tacoma Smelter Plume Site							
Pierce County Footprint Study							
Listing of Results by Sample							
Sample Code	Sampling		Arsenic	Lead		Distance	Direction
	Zone		(ppm, DW)	(ppm,DW)		(miles)	(degrees)
633-2-12-4-0	U2		11.5	31.7		10.80	231.86
633-2-21-4-0	U2		18.1	51.1		10.80	231.86
633-2-22-4-0	U2		13	29.2		10.80	231.86
635-2-11-4-0	U2		5.54	35.2		15.14	243.58
635-2-12-4-0	U2		5.56	11.5		15.14	243.58
635-2-21-4-0	U2		6.06	8.83		15.14	243.58
635-2-22-4-0	U2		5.37	7.64		15.14	243.58
637-2-11-4-0	U2		9.94	36.2		12.76	231.76
637-2-12-4-0	U2		9.67	33.8		12.76	231.76
637-2-21-4-0	U2		9.79	22.5		12.76	231.76
637-2-22-4-0	U2		10.6	21.3		12.76	231.76
638-2-11-4-0	U2		12	40.5		14.61	237.11
638-2-12-4-0	U2		6.28	14.8		14.61	237.11
638-2-21-4-0	U2		11.6	45.9		14.61	237.11
638-2-22-4-0	U2		9.56	39		14.61	237.11
639-2-11-4-0	U2		40.7	91.8		12.76	224.66
639-2-12-4-0	U2		15.1	21.3		12.76	224.66
639-2-21-4-0	U2		62.5	66.6		12.76	224.66
639-2-22-4-0	U2		14.3	23.2		12.76	224.66
640-2-11-4-0	U2		27	123		13.33	227.56
640-2-12-4-0	U2		17.7	46		13.33	227.56
640-2-21-4-0	U2		35.3	81.1		13.33	227.56
640-2-22-4-0	U2		12.1	31.7		13.33	227.56
642-2-11-4-0	U2		51	202		11.17	204.51
642-2-12-4-0	U2		47.4	54.5		11.17	204.51
642-2-21-4-0	U2		51.7	108		11.17	204.51
642-2-22-4-0	U2		16.2	26.7		11.17	204.51
644-2-11-4-0	U2		31.3	213		14.45	225.79
644-2-12-4-0	U2		43.1	60.8		14.45	225.79
644-2-21-4-0	U2		26.1	89		14.45	225.79
644-2-22-4-0	U2		33.5	119		14.45	225.79
655-2-11-4-0	U2		71.7	220		15.11	205.44
655-2-12-4-0	U2		32.5	68.6		15.11	205.44
655-2-21-4-0	U2		91.6	390		15.11	205.44
655-2-22-4-0	U2		58.3	73		15.11	205.44
657-2-11-4-0	U2		43.8	194		15.99	210.73
657-2-12-4-0	U2		22.8	55.6		15.99	210.73
657-2-21-4-0	U2		38.3	86.8		15.99	210.73
657-2-22-4-0	U2		36.7	30.5		15.99	210.73
683-2-11-4-0	U2		8.67	26.7		7.30	253.57
683-2-12-4-0	U2		8.25	24.3		7.30	253.57
683-2-21-4-0	U2		11.3	35.4		7.30	253.57

Attachment A							
Tacoma Smelter Plume Site							
Pierce County Footprint Study							
Listing of Results by Sample							
Sample Code	Sampling		Arsenic	Lead		Distance	Direction
	Zone		(ppm, DW)	(ppm,DW)		(miles)	(degrees)
683-2-22-4-0	U2		10.6	34.3		7.30	253.57
687-2-11-4-0	U2		36.2	71.5		12.61	229.34
687-2-12-4-0	U2		17.1	31.7		12.61	229.34
687-2-21-4-0	U2		25	75.3		12.61	229.34
687-2-22-4-0	U2		17.8	37.8		12.61	229.34
690-2-11-4-0	U2		28.6	136		6.47	264.84
690-2-12-4-0	U2		29.6	53.2		6.47	264.84
690-2-21-4-0	U2		22.8	66.1		6.47	264.84
690-2-22-4-0	U2		10	18.5		6.47	264.84
696-2-11-4-0	U2		9.12	19.4		10.77	201.21
696-2-12-4-0	U2		13.9	18.6		10.77	201.21
696-2-21-4-0	U2		10.6	12.7		10.77	201.21
696-2-22-4-0	U2		2.7	3.94		10.77	201.21
697-2-11-4-0	U2		32.5	92.6		11.84	206.16
697-2-12-4-0	U2		99.2	199		11.84	206.16
697-2-21-4-0	U2		43.8	123		11.84	206.16
697-2-22-4-0	U2		30.9	103		11.84	206.16
698-2-11-4-0	U2		62.1	254		11.24	207.24
698-2-12-4-0	U2		19.9	46.2		11.24	207.24
698-2-21-4-0	U2		38.3	70.5		11.24	207.24
698-2-22-4-0	U2		5.32	5.17		11.24	207.24
699-2-11-4-0	U2		18.6	137		11.20	236.84
699-2-12-4-0	U2		14.5	69		11.20	236.84
699-2-21-4-0	U2		11.5	52.5		11.20	236.84
699-2-22-4-0	U2		5.04	19.1		11.20	236.84
703-2-11-4-0	U3		9.97	23		9.44	320.46
703-2-12-4-0	U3		10.3	21.9		9.44	320.46
706-2-11-4-0	U3		4.43	17.4		12.89	305.99
706-2-12-4-0	U3		2.48	8.59		12.89	305.99
707-2-11-4-0	U3		12.8	67.5		13.73	302.11
707-2-12-4-0	U3		7.41	20.5		13.73	302.11
708-2-11-4-0	U3		8.53	65.8		15.29	297.37
708-2-12-4-0	U3		4.55	24.6		15.29	297.37
710-2-11-4-0	U3		11	17.6		7.13	326.94
710-2-12-4-0	U3		17	36.2		7.13	326.94
711-2-11-4-0	U3		2.99	8.9		9.50	309.32
711-2-12-4-0	U3		2.81	8.15		9.50	309.32
713-2-11-4-0	U3		6.23	30.6		11.97	299.70
713-2-12-4-0	U3		4.68	8.92		11.97	299.70
715-2-11-4-0	U3		5.35	33.9		14.65	291.94
715-2-12-4-0	U3		2.59	10.4		14.65	291.94
717-2-11-4-0	U3		19.5	46.3		6.28	315.59

Attachment A							
Tacoma Smelter Plume Site							
Pierce County Footprint Study							
Listing of Results by Sample							
Sample Code	Sampling		Arsenic	Lead		Distance	Direction
	Zone		(ppm, DW)	(ppm,DW)		(miles)	(degrees)
717-2-12-4-0	U3		6.19	14.3		6.28	315.59
718-2-11-4-0	U3		12.5	37.4		7.22	303.89
718-2-12-4-0	U3		9.78	28.1		7.22	303.89
724-2-11-4-0	U3		7.18	33.5		11.58	276.43
724-2-12-4-0	U3		7.96	33.9		11.58	276.43
725-2-11-4-0	U3		4.98	10.8		12.02	269.92
725-2-12-4-0	U3		2.14	3.9		12.02	269.92
801-2-11-4-0	U2		8.83	18.8		10.95	233.42
801-2-12-4-0	U2		6.64	13		10.95	233.42
801-2-21-4-0	U2		7.04	15		10.95	233.42
801-2-22-4-0	U2		6.9	14.6		10.95	233.42
802-2-11-4-0	U2		30.6	89.7		10.20	233.42
802-2-12-4-0	U2		19.4	42.4		10.20	233.42
802-2-21-4-0	U2		20.1	49		10.20	233.42
802-2-22-4-0	U2		16.4	26		10.20	233.42
803-2-11-4-0	U2		7.29	14.2		9.28	226.84
803-2-12-4-0	U2		34.2	63.8		9.28	226.84
803-2-21-4-0	U2		96.1	188		9.28	226.84
803-2-22-4-0	U2		50.2	31.5		9.28	226.84
804-2-11-4-0	U2		52.6	55.5		16.26	210.72
804-2-12-4-0	U2		34.6	14.6		16.26	210.72
804-2-21-4-0	U2		59.4	67.6		16.26	210.72
804-2-22-4-0	U2		17.5	14.3		16.26	210.72
NOTES:							
Sample Code:	Code formats are Zone/Property - Property Type - Boring/Depth -						
	Sample Type - Residential Location (see text)						
Distance:	Distance of sampling location from Tacoma Smelter tall stack, in miles						
Direction:	Direction of sampling location from Tacoma Smelter tall stack, in						
	bearing degrees (clockwise from due north)						
	Distance and Direction are assigned at the level of the sampled property						
	and are therefore the same for all borings at a sampled property						

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S
1	**Attachment B**																		
2	**Tacoma Smelter Plume Site**																		
3	**Pierce County Footprint Study**																		
4	**Summary of Results by Location**																		
5																Maximum Residential Results:			
6							Max Arsenic:			Max Lead:			Min Max Values:			Arsenic		Lead	
7	Location	Type	Home Age	Distance	Direction		Concentration	Depth		Concentration	Depth		Arsenic	Lead		Front	Back	Front	Back
8			(years <1986)	(miles)	(degrees)		(ppm, DW)			(ppm, DW)									
9																			
10	102	1	44	0.89	257.68		142.00	2		240.00	1		72.70	145.00		84.40	142.00	209	240
11	103	1	18	0.87	224.53		114.00	1		107.00	1		35.40	20.10		39.80	114.00	31.8	107
12	105	1	83	1.38	136.51		35.50	1		262.00	2		21.60	124.00		35.50	35.50	168	262
13	106	1	70	1.22	149.34		136.00	2		390.00	2		31.50	86.40		60.00	136.00	390	282
14	107	1	76	0.99	161.58		122.00	2		787.00	2		55.00	224.00		106.00	122.00	373	787
15	108	1	77	1.03	188.26		233.00	1		875.00	1		158.00	444.00		189.00	233.00	875	498
16	110	1	27	1.25	221.41		440.00	1		900.00	1		98.90	163.00			440.00		900
17	112	1	78	1.72	143.31		30.20	2		509.00	1		23.30	136.00		30.20	26.90	509	202
18	113	1		1.56	156.21		140.00	1		578.00	1		17.40	86.80		140.00	40.00	578	307
19	114	1	77	1.33	170.72		61.30	1		673.00	2		4.67	17.90		61.30	46.60	162	673
20	115	1		1.30	186.91		78.30	1		120.00	1		13.60	43.00		78.30	60.50	120	77
21	118	1	86	2.68	129.21		21.80	1		259.00	1		8.62	127.00		21.80	9.99	259	129
22	119	1	96	2.51	133.58		27.70	2		181.00	2		8.29	119.00		27.70	18.20	140	181
23	120	1	61	2.23	140.73		21.00	2		129.00	2		6.77	22.40		21.00	14.90	129	88.4
24	121	1	78	1.94	148.77		22.10	2		316.00	2		20.00	208.00			22.10		316
25	122	1	72	1.77	162.11		56.10	2		194.00	1		9.71	117.00		56.10	53.40	194	148
26	123	1	76	1.73	171.40		72.70	1		254.00	2		36.00	154.00		72.70	62.00	182	254
27	124	1	35	1.73	182.63		81.10	2		144.00	1		40.20	82.80		41.10	81.10	89.4	144
28	125	1	25	1.81	198.45		122.00	2		171.00	1		65.30	88.80		122.00	80.10	171	109
29	127	1	90	3.30	129.74		27.10	1		928.00	1		22.60	432.00		27.10	26.10	551	928
30	128	1	57	2.99	133.32		10.40	2		83.30	2		7.74	25.10		7.85	10.40	33.1	83.3
31	130	1	61	2.56	147.98		48.80	1		662.00	1		24.90	119.00		27.30	48.80	662	313
32	131	1	79	2.38	156.31		42.60	1		170.00	1		20.70	94.80		42.60	30.50	170	157
33	132	1	81	2.26	163.69		26.10	2		197.00	2		19.10	95.00		24.70	26.10	105	197
34	133	1	38	2.14	175.72		93.60	2		353.00	2		27.60	94.80		37.70	93.60	200	353
35	134	1	32	2.15	185.76		28.80	2		75.20	2		22.30	42.50		28.10	28.80	75.2	54.7
36	135	2		2.21	196.08		475.00	1		947.00	1		73.30	121.00					
37	136	1	20	2.31	204.77		105.00	1		138.00	1		77.30	105.00		105.00	84.70	130	138
38	138	1	27	2.68	216.40		112.00	2		286.00	1		23.70	105.00		39.70	112.00	286	209
39	139	1	96	3.53	134.74		22.50	2		551.00	1		13.50	158.00		13.90	22.50	207	551
40	140	1	103	3.28	140.79		20.10	2		594.00	2		17.40	149.00		20.10	18.80	238	594
41	142	1	91	2.85	151.82		19.40	2		3050.00	1		16.20	116.00		19.40	17.00	190	3050
42	143	1		2.66	159.76		18.70	2		62.10	2		8.32	36.60		18.70	10.10	62.1	48
43	144	1	78	2.59	164.32		23.90	2		205.00	1		11.80	79.40		23.90	13.10	205	112
44	145	1	77	2.50	173.17		40.90	1		194.00	1		22.30	83.30		40.90	28.80	194	172
45	146	1	19	2.58	184.22		25.00	1		47.90	1		16.50	36.80		17.80	25.00	39.3	47.9
46	148	1	31	2.63	201.73		115.00	3		233.00	1		94.30	107.00		111.00	115.00	213	233
47	149	1	33	2.77	206.35		16.10	2		26.00	2		5.50	17.70		16.10		26	
48	150	1	96	3.29	148.52		13.30	2		273.00	1		7.91	136.00		10.30	13.30	195	273
49	151	1	91	3.18	153.14		17.30	2		6670.00	2		14.20	89.10		17.30		6670	
50	152	1	75	3.00	160.64		21.10	1		288.00	1		8.86	55.10		21.10	9.06	288	119
51	153	1	57	2.92	167.15		19.50	2		131.00	1		7.82	59.40		19.50	12.70	131	116
52	154	1	62	2.85	175.43		37.60	1		461.00	1		28.40	158.00		37.60	28.60	264	461
53	155	1	44	3.06	198.72		92.10	1		279.00	1		45.90	127.00		78.50	92.10	279	231

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S
54	157	1	31	3.32	208.68		58.00	1		338.00	1		38.80	190.00		58.00		338	
55	159	1	81	3.65	151.87		13.10	3		305.00	3		8.64	203.00		13.10	10.00	271	305
56	163	1	31	3.21	175.14		13.60	2		272.00	3		8.15	27.70		13.60	9.05	49.3	272
57	165	1	24	3.34	187.81		21.50	1		49.60	1		9.57	27.80		14.60	21.50	49.6	43.3
58	168	1	38	3.66	206.22		58.50	2		108.00	1		8.04	16.70		58.50	10.20	108	25.4
59	169	1	51	3.87	211.05		52.20	3		103.00	2		24.10	42.20		52.20	36.50	103	95.5
60	171	1	39	3.86	159.85		12.30	1		56.00	2		4.56	21.60		8.65	12.30	23.9	56
61	173	1	40	3.65	169.97		16.60	2		127.00	1		8.33	26.20		12.40	16.60	32.6	127
62	174	1	28	3.58	177.16		18.50	1		94.80	1		10.50	32.90		18.50	11.60	94.8	40.7
63	175	2		3.68	181.55		104.00	1		402.00	1		48.20	111.00					
64	176	1	74	3.70	188.14		74.50	2		227.00	1		23.60	80.40		74.50	25.90	227	82.3
65	178	1	17	3.82	200.19		26.30	1		35.10	1		24.30	26.50			26.30		35.1
66	179	1	31	4.02	205.19		50.00	1		103.00	1		36.30	77.80		50.00	46.60	86.8	103
67	180	1		4.15	208.09		47.40	2		83.30	2		20.80	39.50		37.30	47.40	80.9	83.3
68	181	2		1.32	213.94		1050.00	1		3990.00	1		639.00	1360.00					
69	203	1	44	3.23	200.91		133.00	1		622.00	1		57.40	104.00		68.90	133.00	119	622
70	215	1	77	2.12	136.03		39.00	2		276.00	1		28.50	207.00		39.00	35.90	276	258
71	241	1	86	3.60	143.97		14.40	2		2820.00	2		9.72	121.00		12.80	14.40	210	2820
72	242	1		3.80	137.93		11.70	2		833.00	2		5.82	87.60		11.70		833	
73	243	1	91	4.14	143.18		16.60	1		792.00	1		12.50	438.00		14.20	16.60	647	792
74	244	1	78	3.86	145.58		14.10	1		445.00	1		9.36	158.00		14.10	13.80	192	445
75	245	1	40	4.23	148.51		10.00	1		136.00	2		7.37	65.20		10.00	8.47	81.2	136
76	247	1	76	1.17	164.47		129.00	1		417.00	1		41.20	217.00		129.00	77.50	417	401
77	299	1	19	2.04	209.33		204.00	1		156.00	1		57.30	62.10		85.50	204.00	126	156
78	304	1	41	4.38	202.31		70.10	2		425.00	2		46.80	114.00		70.10	67.80	137	425
79	306	1	43	5.03	162.52		10.30	1		122.00	1		5.52	33.30		10.30	6.48	122	104
80	308	1	34	4.80	185.87		25.00	1		88.00	1		8.23	23.80		25.00	15.30	88	58.5
81	309	1	28	4.97	193.39		79.00	1		75.00	1		3.36	29.70		5.08	79.00	32.2	75
82	310	1	41	4.97	199.75		52.90	1		144.00	2		21.10	53.20		52.90	43.10	100	144
83	311	1	39	5.20	205.61		88.00	2		257.00	1		31.50	120.00		88.00	51.30	250	257
84	313	1	24	5.39	184.75		17.50	2		37.50	2		6.18	16.70		17.50		37.5	
85	314	1	20	5.54	189.58		34.40	1		126.00	1		22.30	70.50		34.40	24.10	126	79.1
86	315	1	24	5.77	196.85		19.00	2		80.40	1		9.78	21.10		18.60	19.00	80.4	40.5
87	316	1	26	5.79	201.76		25.90	1		42.10	1		17.30	32.70		22.50	25.90	42.1	36.3
88	317	1	31	6.09	207.98		29.10	2		48.30	2		12.20	24.10			29.10		48.3
89	319	2		5.94	177.79		30.60	2		80.30	1		18.80	59.10					
90	321	1	18	6.18	190.54		46.40	1		298.00	1		7.64	23.20		17.40	46.40	298	160
91	323	2		6.42	200.42		204.00	1		301.00	1		103.00	91.50					
92	324	1	18	6.58	204.97		15.60	2		82.70	1		10.00	25.40		10.90	15.60	82.7	41.9
93	327	1	47	6.60	183.68		13.40	2		225.00	1		8.53	27.80		11.90	13.40	41.5	225
94	329	2		6.65	195.90		76.80	1		410.00	1		61.10	126.00					
95	331	2		6.88	201.65		177.00	1		411.00	1		89.20	137.00					
96	341	1	66	5.90	99.30		16.40	1		84.00	1		6.82	20.90		16.00	16.40	45.9	84
97	346	1	24	3.83	87.26		19.80	2		60.20	2		9.63	23.50		17.60	19.80	40.3	60.2
98	349	2		4.06	77.74		44.90	2		132.00	1		28.50	64.80					
99	351	1	65	4.20	71.78		15.80	1		69.80	1		7.09	28.90			15.80		69.8
100	353	1		8.41	114.32		7.45	1		58.60	1		3.76	23.70		7.45	4.56	39.5	58.6
101	355	1	31	8.03	111.42		20.10	1		69.80	1		8.95	26.30		20.10	12.00	69.8	32.1
102	359	1	18	7.30	104.12		8.47	3		58.30	2		6.26	27.10		8.47	8.42	36.9	58.3
103	361	2		4.66	193.24		88.30	1		176.00	1		39.70	61.00					
104	362	2		5.34	202.49		223.00	1		474.00	1		82.20	176.00					
105	383	1	71	3.00	82.67		74.10	2		129.00	1		18.30	75.00		74.10		129	
106	384	1	23	3.77	80.08		21.90	1		49.10	1		13.00	28.60		14.50	21.90	31.9	49.1

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S
107	388	1	22	3.86	81.77		18.20	1		62.60	1		13.10	18.70		16.80	18.20	46.8	62.6
108	390	1	30	3.92	82.15		13.80	1		39.40	1		5.22	33.20		7.37	13.80	33.4	39.4
109	393	1	23	4.16	184.41		20.30	2		98.10	2		6.89	31.40		20.30	10.60	98.1	34.5
110	396	1	76	4.54	151.59		11.10	2		200.00	2		7.31	111.00		11.10	7.93	165	200
111	397	1	96	4.87	146.23		20.70	1		443.00	2		3.19	16.30		20.70	7.15	443	117
112	401	1	77	7.09	170.19		28.50	2		214.00	1		15.50	106.00		28.50	22.40	205	214
113	403	1	19	7.38	191.46		69.10	2		108.00	2		8.70	19.70		69.10	11.00	108	22.6
114	409	1	86	8.13	189.14		18.20	2		68.80	2		11.00	36.80		14.70	18.20	68.8	62
115	411	2		8.21	201.07		90.10	1		209.00	1		41.60	73.70					
116	415	1	35	8.80	182.42		19.80	2		333.00	2		4.13	15.60			19.80		333
117	418	2		9.40	197.25		36.70	2		91.20	1		24.20	61.30					
118	419	2		9.62	204.50		51.90	1		268.00	1		48.80	101.00					
119	420	1		9.92	207.74		34.50	1		141.00	1		14.00	38.50			34.50		141
120	422	1		9.82	182.65		12.90	1		54.30	1		8.57	29.90		12.90		54.3	
121	423	1	48	9.70	186.75		30.00	1		100.00	1		12.60	55.10		30.00		100	
122	424	1	32	9.94	192.21		33.40	3		102.00	1		27.10	51.20		30.80	33.40	102	77.9
123	425	1	25	10.21	198.16		17.10	2		86.90	2		9.11	35.90		15.50	17.10	51.3	86.9
124	426	1	19	10.29	201.79		30.40	1		68.70	1		8.85	22.60		18.40	30.40	37.3	68.7
125	441	1	43	7.13	177.00		33.90	1		159.00	1		6.30	75.30			33.90		159
126	442	1	69	9.27	187.28		10.90	3		172.00	2		4.92	21.20		5.68	10.90	25.9	172
127	444	1	27	9.35	196.11		27.90	2		53.80	2		6.60	18.70		27.90	13.10	53.8	44.7
128	503	2		3.92	314.43		64.50	1		111.00	1		15.90	28.10					
129	504	2		3.98	296.95		60.70	2		482.00	1		29.40	76.00					
130	505	2		4.54	288.36		25.50	1		83.60	1		15.70	45.20					
131	509	2		4.74	288.91		40.70	1		74.30	1		9.51	21.10					
132	516	2		4.16	274.86		25.10	1		58.60	1		17.10	51.10					
133	518	2		2.25	265.19		171.00	3		310.00	1		62.80	134.00					
134	521	2		4.13	266.41		56.00	1		122.00	1		42.40	54.10					
135	524	2		3.07	255.72		135.00	1		306.00	1		117.00	161.00					
136	525	2		3.20	263.78		71.80	1		187.00	1		38.40	62.90					
137	527	2		3.23	244.46		128.00	1		184.00	1		85.20	87.90					
138	530	2		3.58	234.26		163.00	1		577.00	1		113.00	114.00					
139	531	2		4.09	239.48		53.70	1		114.00	2		47.60	63.80					
140	540	2		5.91	231.91		97.00	1		248.00	1		41.10	88.20					
141	542	2		6.76	237.81		80.80	1		290.00	1		71.20	121.00					
142	545	2		6.81	231.43		88.90	1		152.00	1		82.40	114.00					
143	546	2		6.66	225.17		117.00	1		208.00	1		65.20	76.70					
144	547	2		7.06	226.30		182.00	1		336.00	1		104.00	167.00					
145	550	2		6.59	247.39		12.80	2		22.30	2		5.41	15.80					
146	565	2		4.33	237.69		69.20	1		358.00	1		34.20	100.00					
147	570	2		5.30	298.39		34.00	1		137.00	1		11.30	21.90					
148	599	2		3.25	290.95		25.10	1		49.40	1		15.30	26.50					
149	601	2		5.99	290.96		23.20	1		96.30	1		20.10	38.50					
150	602	2		7.18	290.47		8.72	1		23.50	1		6.26	22.50					
151	604	2		6.83	278.43		24.90	1		73.00	1		14.90	44.60					
152	605	2		7.99	276.16		11.80	2		37.70	1		9.16	14.70					
153	606	2		5.46	273.08		7.90	2		22.20	2		7.36	13.90					
154	607	2		6.56	272.28		34.30	1		84.00	1		11.40	25.90					
155	608	2		7.96	269.63		14.70	1		43.60	2		8.50	33.10					
156	609	2		4.72	256.42		29.70	1		50.20	1		28.60	49.80					
157	613	2		7.21	249.89		20.70	1		57.20	1		10.30	17.50					
158	614	2		11.51	258.12		9.24	1		13.50	1		5.17	8.11					
159	615	2		12.79	259.32		3.76	1		15.50	1		3.05	11.00					

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S
160	616	2		13.84	260.06		8.21	1		34.20	1		7.06	32.40					
161	617	2		14.84	259.97		7.18	1		33.90	1		4.50	30.00					
162	618	2		11.91	253.48		12.90	1		43.00	1		9.03	41.50					
163	620	2		13.93	256.57		11.50	1		40.00	1		8.03	18.40					
164	621	2		15.01	257.47		10.10	1		45.30	1		8.26	32.50					
165	622	2		10.04	243.36		9.53	2		31.30	1		8.63	31.20					
166	624	2		13.18	249.84		8.08	1		34.70	1		5.57	14.20					
167	626	2		9.05	230.66		28.40	1		61.50	1		19.40	38.90					
168	628	2		10.55	237.77		31.40	1		153.00	1		25.30	57.60					
169	631	2		13.71	245.88		10.30	1		46.90	1		9.93	30.60					
170	632	2		15.09	247.75		11.80	1		41.90	1		2.88	39.90					
171	633	2		10.80	231.86		18.10	1		51.10	1		11.90	35.40					
172	635	2		15.14	243.58		6.06	1		35.20	1		5.56	8.83					
173	637	2	56	12.76	231.76		10.60	2		36.20	1		9.94	22.50					
174	638	2		14.61	237.11		12.00	1		45.90	1		11.60	40.50					
175	639	2		12.76	224.66		62.50	1		91.80	1		40.70	66.60					
176	640	2		13.33	227.56		35.30	1		123.00	1		27.00	81.10					
177	642	2		11.17	204.51		51.70	1		202.00	1		51.00	108.00					
178	644	2		14.45	225.79		43.10	2		213.00	1		33.50	119.00					
179	655	2		15.11	205.44		91.60	1		390.00	1		71.70	220.00					
180	657	2		15.99	210.73		43.80	1		194.00	1		38.30	86.80					
181	683	2	13	7.30	253.57		11.30	1		35.40	1		8.67	26.70					
182	687	2		12.61	229.34		36.20	1		75.30	1		25.00	71.50					
183	690	2		6.47	264.84		29.60	2		136.00	1		22.80	66.10					
184	696	2		10.77	201.21		13.90	2		19.40	1		10.60	12.70					
185	697	2		11.84	206.16		99.20	2		199.00	2		43.80	123.00					
186	698	2		11.24	207.24		62.10	1		254.00	1		38.30	70.50					
187	699	2		11.20	236.84		18.60	1		137.00	1		11.50	52.50					
188	703	2		9.44	320.46		10.30	2		23.00	1		10.30	23.00					
189	706	2		12.89	305.99		4.43	1		17.40	1		4.43	17.40					
190	707	2		13.73	302.11		12.80	1		67.50	1		12.80	67.50					
191	708	2		15.29	297.37		8.53	1		65.80	1		8.53	65.80					
192	710	2		7.13	326.94		17.00	2		36.20	2		17.00	36.20					
193	711	2		9.50	309.32		2.99	1		8.90	1		2.99	8.90					
194	713	2	62	11.97	299.70		6.23	1		30.60	1		6.23	30.60					
195	715	2		14.65	291.94		5.35	1		33.90	1		5.35	33.90					
196	717	2		6.28	315.59		19.50	1		46.30	1		19.50	46.30					
197	718	2		7.22	303.89		12.50	1		37.40	1		12.50	37.40					
198	724	2		11.58	276.43		7.96	2		33.90	2		7.96	33.90					
199	725	2		12.02	269.92		4.98	1		10.80	1		4.98	10.80					
200	801	2		10.95	233.42		8.83	1		18.80	1		7.04	15.00					
201	802	2		10.20	233.42		30.60	1		89.70	1		20.10	49.00					
202	803	2		9.28	226.84		96.10	1		188.00	1		34.20	63.80					
203	804	2		16.26	210.72		59.40	1		67.60	1		52.60	55.50					
204																			
205	**NOTES:**																		
206																			
207	Location:	Sampling location number																	
208	Type:	Sampling Location Type 1 = residential (disturbed), 2 = forested (undisturbed)																	
209	Home Age:	For residential properties, age of house calculated as years prior to smelter closure in 1986																	
210	Distance:	Distance of sampling location from Tacoma Smelter tall stack, in miles																	
211	Direction:	Direction of sampling location from Tacoma Smelter tall stack, in bearing degrees (clockwise from due north)																	
212	Max Values:	Maximum arsenic and lead concentrations for any single sample at a sampling location																	

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S
213	Depth:	The sampled depth interval for max concentrations: 1 = 0-2 inch, 2 = 2-6 inch, 3 = 6-12 inch																	
214		Only selected borings and properties had samples collected at depth 3 = 6-12 inches																	
215	Min Max Values: Smallest of max values for any boring at a sampled location (same as max value for locations in Zone U3 with only 1 boring)																		
216	Max Residential results, Front and Back: Max concentrations for arsenic and lead at any single sample in front versus back yard borings																		
217					Applies only to Type 1 (residential) locations. At 16 of 105 such locations the property layout did not														
218					provide samples for both front and back yards														