The USMR Smelter: Impact on Carteret, New Jersey Residential Soils

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German & Rubenstein, LLP

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By

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Summary of Opinions

Based on my review and analysis of the case file, my experience as a professional geologist, soil data collected by the United States Metals Refining Company (USMR) and Plaintiff, I conclude the following to a reasonable degree of scientific certainty:

1. **The entire proposed Class Area was contaminated by copper, arsenic, and lead emitted from the USMR smelter complex over its 80+ years of operation. Many lines of evidence support this conclusion, including: 1) the history of air pollution violations, leading to the plant's closure; 2) soil samples taken by USMR in the Area of Concern (AOC) that confirm soil contamination extending downward from the surface to over 7 feet deep; 3) contaminated soil samples taken along transects by USMR and the Plaintiff extending into Carteret from the AOC; 4) historical aerial photographs showing plant emissions blowing over Carteret; 5) the operational history of the plant as a primary and secondary smelter; 6) the fact that all pyrometallurgical smelters, like the USMR copper smelter, generate heavy metal plumes of contaminated soil, extending over large areas adjacent to the smelter complex, and 7) air dispersion modeling by Sullivan (2019) that predicts a contamination plume consistent with USMR as the primary source of heavy metal contamination in Carteret soils. Contamination from the USMR smelter will persist in Carteret residential soils unless remediation occurs.**

2. **The USMR smelter complex has contaminated the proposed Class Area residential soils with copper, arsenic, and lead over approximately 80 years, both as a primary copper smelter (~1906-1952) and a secondary copper smelter (~1953-1986). During the first period of its operation, the plant smelted polymetallic ore concentrates, containing arsenic and lead as elements in lead sulfide (galena), iron sulfide (pyrite) and sulfosalts (e.g., enargite) associated with copper sulfide ore deposits. Contamination was transported into Carteret by wind as fugitive dust, particulate matter, and gaseous emissions, derived from the cupola and other furnaces, that cooled, condensed, and settled to the ground, blanketing the proposed Class Area. There is no doubt that contamination moved offsite, and USMR has recognized this fact due to its sampling and extensive remediation in the Area of Concern (AOC). Furthermore, the definition of the AOC as delineated by USMR is both arbitrary and inadequate for addressing the need for soil remediation in the proposed Class Area.**

3. **As would be expected in an area immediately adjacent to a base-metal smelter, heavy metal contamination in the AOC is extreme. Soil metal anomalies in plumes surrounding smelters have been documented in numerous remedial investigations (USEPA, 1998); the Meadowbrook zinc smelter (West Virginia) and the infamous**

Ruston copper smelter (Washington State) are notable examples. Contamination has been documented miles from these smelters, but USMR asserts that their responsibility for offsite remediation ends essentially at the Essex St./Roosevelt Blvd. boundary, a distance of roughly 0.6 miles from the furnace complex. They contend that, although a contribution from the smelter may be present in areas beyond the streets mentioned above, copper, arsenic, and lead pollution in other areas of Carteret is mainly due to other sources.

4. **The McVehil air model (McVehil-Monnett, 2018) is generally consistent with USMR's position regarding the area contaminated by smelter operations. The plume dimensions within the 50 g/m^2 deposition isopleth measure approximately 1.4 by 2 miles in the NW-SE and NE-SW directions, respectively. In my opinion, the plume from the McVehil air model significantly underestimates the extreme contamination observed in the AOC, so its predictive capacity is dubious. In addition, this "petite" smelter plume is too small to provide a reasonable assessment of the overall impact of the USMR smelter on the proposed Class Area residential neighborhoods over 80 years of smelter operations.**

5. **Transect sampling beyond the AOC indicates that copper, arsenic, and lead contamination is present in Carteret neighborhoods beyond Roosevelt Blvd. Although USMR has suggested that the smelter contribution in this area is minor, the strong positive rank correlations observed among the metals, both in the AOC and transects, indicate that a single, major source is responsible for the contamination. Other minor sources may have contributed locally, but it was the major source, the smelter, emitting tons of heavy metals into the environment over 80 years of operations that is responsible for the widespread pattern of contamination observed in the proposed Class Area. Numerous individual sources would give rise to a more highly random, localized pattern of contamination that is not observed in the thousands of samples taken in Carteret. In addition, USMR's contention that soil background loadings in Carteret are elevated above NJDEP SSL's is discredited by the fact that samples taken at the periphery of the proposed Class Area, far from the AOC decrease, occasionally falling below screening levels. This is consistent with air deposition and a decrease in soil contamination with distance from the smelter.**

6. **USMR has not, as yet, fully delineated the impact of the smelter, specifically lead and arsenic contamination, on soils in the proposed Class Area. Because USMR and Plaintiff sampling efforts along transects away from the AOC have detected soil exceedances, further remediation of residential soils is required. It is impossible to discount the smelter as the primary source, let alone attempt to make remediation**

decisions based on a line arbitrarily drawn on a map. The USMR transects attempted to find a "cleaner edge," but the effort failed because exceedances were still found at the ends of those transects. It is irrational to believe that smelter impacts vanish or become insignificant over a distance of 600 – 700 feet from outer boundary of the AOC, or 0.6 – 0.7 miles from the furnace complex.

Statement of Qualifications

Education. -- My education is in environmental chemistry, geochemistry, environmental engineering, environmental geology, and most aspects of the geological sciences. I hold a B. S. degree from the University of South Alabama in Mobile (1975) with honors; an M. A. degree in geology from the University of California, Berkeley (1977); a Ph.D. in geology with a specialty in theoretical geochemistry from the University of California, Berkeley (1979); a post-doctoral fellowship in the Department of Chemistry at the University of California, Berkeley (1980); and an M. S. E. degree in civil and environmental engineering from Tulane University (1995). Over the years, I have endeavored to enhance my skillset through continuing education, which is required along with ethics training, to maintain my registration as a licensed professional.

Experience. -- I have worked in both the academic and public arenas since being hired by Lawrence Berkeley Laboratory in 1980 as a post-doctoral researcher in collaboration with Professor Kenneth Pitzer of Berkeley's Chemistry Department. Over the years, I have taught many courses focused on the environment, including: Groundwater Hydrology, Soil and Water Pollution, Weather and Climate, Extreme Weather, Geographic Information Systems, Geochemistry, Earth as a Living Planet, Geostatistics, Geospatial Analysis, Oceanography, among others. I have served as the Director of the Environmental Studies Program, Chairman of the Geology Department, Director of the Coordinated Instrumentation Facility, Director of the Uptown Vivarium, and Project Director of a Louisiana Systemic Initiatives Program (LaSIP) long-term grant. For my LaSIP Project, which utilized environmental science as a vehicle for reforming middle and high school science education, I received the Governor's Award for Excellence in Science Education and the Society of Exploration Paleontologists and Mineralogists (SEPM) Outstanding Educator Reward.

My consulting practice focuses on the environment, and I am frequently retained as an expert witness in pollution cases involving contaminant fate and transport on land and under water. I have also participated in a number of "water cases" in Louisiana where land ownership and mineral rights were in question. In particular, I have been accepted by courts as an expert on the impact of historical, base-metal (e.g., copper and zinc) smelter operations on soils and indoor dust; specifically, cases in Oklahoma and West Virginia that have been adjudicated through appeal or settled prior to trial. In total, I have over 25 years of experience consulting on geological and environmental projects, which I use as source material when permissible in teaching.

__Certifications.__ -- I was "grandfathered in" as a licensed Professional Geoscientist (#35) in the State of Louisiana when it decided to embrace geoscientists as licensed professionals subject to State regulation in order to protect the public good. I am also certified by the State of Alabama as a Professional Geologist (#1397) because I received a high pass on both the Fundamental and Professional portions of the ASBOG examination given by the National Association of State Boards of Geology and possessed over 25 years of experience as an independent, consulting geologist.

Purpose of Report

I was retained by Steven German, a principal in the law firm of German & Rubenstein LLP, to examine data for soil copper (Cu), arsenic (As), and lead (Pb) collected in the residential area of Carteret and Port Reading, and render an expert opinion on whether or not residential soil contamination in the area was caused by releases from the USMR smelter that operated during the period ~1906-1986 as a primary and secondary copper smelter. I am rendering opinions concerning this matter in the case Duarte, *et al*., v. United States Metals Refining Company, *et al*., (United States District Court; Case #2:2017cv01624) to a reasonable degree of scientific certainty using well-established calculations and methodologies consistent with peer-reviewed scientific literature.

The report is organized as follows: 1) a general review of copper ores and heavy metal contamination contained therein; 2) the copper smelting process and associated emissions; 3) soil contamination associated with base-metal smelter plumes based on previous studies; 4) evolution of metal refining processes at the USMR complex over time; 5) analysis of the USMR Area of Concern (AOC) and associated transects extending further into the Borough of Carteret; and 6) evaluation of the Defendant's hypothesis that heavy metal contamination in Carteret beyond the AOC is not related to USMR smelter complex, but is the result of a myriad of alternate sources.

Introduction

Copper is an economically important, nonferrous, base metal because it is widely used in manufacturing, and its price is a strong indicator of the health of the world economy. The metal is manufactured by smelting of copper ore minerals (primary smelting) and/or recycling of copper-rich scrap and waste (secondary smelting). The oldest artifacts made from native copper, the naturally occurring elemental form, date from about 10,000 B.C., but refining of copper by smelting probably dates from about 5,000 B.C. (Copper.org, 2019).

Most major copper deposits assay out with low (<1%) copper concentrations, so processing at the mine involves crushing and beneficiation of the ore by froth flotation, which physically separates sulfides from gangue minerals (e.g., quartz and feldspar) and generates a copper concentrate that can be sold for smelting and refining. Smelting involves roasting of sulfide copper concentrates (~20-40 % copper) to drive off sulfur and produce matte and slag. The copper-rich matte is then heated in a reducing environment created by the combustion of fuel in the form of coal or coke to form relatively pure copper liquid in a converter, which is tapped to form blister copper. Blister copper is named for bubbles in the metal caused by SO_2 escaping from the molten metal. This material is melted and cast into anodes, which are used to generate high-purity copper through electrolysis in a tank house filled with sulphate solutions that transfer copper from the anode (impure) to the cathode (very pure) via an electric current (i.e., copper refining). In contrast, copper oxide concentrates can be directly refined by acid leaching and electrolysis, but most copper is produced from sulfide ores or recycling of copper-containing scrap (Hoffman, 2000). Copper smelters usually began operations processing copper minerals (primary smelting), but some over time transitioned to copper recycling using smelting to recover copper from waste streams, including insulated wire, car radiators, pipe, bearings, and miscellaneous copper-bearing materials (USEPA, 1980).

This report focuses on the history of the USMR smelter previously located in the Borough of Carteret, New Jersey, which operated both as a primary and secondary copper smelter from about 1906 to 1986 (Brunner, 2018). Under supervision of the New Jersey Department of Environmental Protection (NJDEP), the USMR plant was demolished, and the site was remediated by 1995. The chosen remedy included: 1) contaminated soil removal at selected sites; 2) encapsulation of polluted materials, presumably smelter slag; and 3) construction of warehouses and parking lots (Brunner, 2012). In addition, the company sampled an Area of Concern (AOC) in the residential area of the Carteret, has begun performing limited soil remediation, and ran three sampling transects from the AOC further out into the residential area. Presently, the Responsible Party (RP) is still delineating the extent of its off-site contamination and remediating soils in the originally-defined AOC.

Study Area

As mentioned above, the Study Area is located in the Borough of Carteret, New Jersey, a relatively small municipality with a population of approximately 27,000 people located between the New Jersey Turnpike and the Arthur Kill, a waterway the forms the boundary with the State of New York (Fig. 1). The USMR Smelter was located roughly south of the town on the Arthur Kill and represented a major industrial facility that predated incorporation of the Carteret by approximately 20 years.

Geologically, soils in the area are developed on rocks classified by the New Jersey Geological and Water Survey (2014) as part of the Urban Piedmont with an onlap of the Cretaceous Raritan Formation (a New Jersey Coastal Plain formation). Formations found in the Carteret area include (from oldest to youngest): 1) Upper Triassic to Lower Jurassic Passaic Formation (**JTrp** in Fig. 2); 2) Triassic Locatong Formation (**Trl**); 3) Jurassic Palisades Diabase Sill (**Jd**); and 4) Cretaceous Raritan Formation (**Kr**) With the exception of the diabase, all of the formations in the study area are sedimentary; the Palisades are a basaltic sill (~ 200 million years B.P.) that was intruded in the Newark Basin as part of the rifting of North America from Africa (~220 million years B.P.). Soils in the Carteret area were developed by weathering of rocks of the Urban Piedmont, which were sampled, analyzed, and reported on by BEM Associates (1997). The onlap of the coastal plain, a different physiographic province in the Study Area with low natural background metal loadings (Fig 2), is not considered in determining background Soil Screening Levels (SSL's) in this report.

Copper Ores Used in Primary Copper Smelters

Copper is a chalcophilic (sulfur-loving) trace element in the Earth's crust (~ 0.0068% or 68 ppm abundance), occurring typically in sulfide minerals, such as chalcopyrite ($CuFeS_2$), chalcocite (Cu_2S), covellite (CuS), and bornite (Cu_5FeS_4), among others. The largest deposits are porphyry copper deposits of volcanogenic origin that often contain copper at low concentrations. The major ore mineral mined for copper is chalcopyrite (~50%); other sulfides and sulfosalts (e.g., enargite; Cu_3AsS_4), oxides (cuprite; Cu_2O), carbonates (malachite and azurite), and silicates (chrysocolla) can also be used to manufacture copper metal. Examples of porphyry copper deposits include the Chucquicamata and Escondido deposits in Chile and the Grasberg deposit in Papua-New Guinea. These deposits also contain significant concentrations of precious metals (gold and silver); in fact, the Grasberg deposit mentioned above is the largest gold mine in the world with copper production being secondary. With the exception of native copper deposits (e.g., deposits on the Keeweenaw Peninsula, Michigan), ores must be smelted and/or otherwise metallurgically refined to generate high-purity copper.

Sulfide concentrates generated from low-grade ore often contain a diverse collection of sulfide minerals (i.e., polymetallic sulfide deposits). Sulfide particles in crushed ore separated by froth flotation are skimmed off to produce a concentrate that can contain up to ~ 40% copper; obviously, the higher the copper content of ore minerals, the higher is the copper content of the concentrate sent to the smelter. The concentrate can also contain other sulfides, such as sphalerite (ZnS), galena (PbS), sulfosalts like arsenopyrite ($FeAsS$), and pyrite (FeS_2). In addition to arsenic-bearing sulfosalts, like enargite and arsenopyrite, arsenic can substitute for sulfur in pyrite up to 10% by weight (Abraitis, *et al*., 2004).

Primary Copper Smelting

Of the various unit processes used in a copper smelter, pyrometallurgical (thermal) refining has the greatest potential for contaminant releases into the local environment, depending on the efficacy of air pollution control devices employed to limit dispersion of pollutants via air transport and deposition. Copper smelters use a variety of furnaces to produce copper from ore concentrates (primary smelter), or extract copper during recycling (secondary smelter) from any type of copper-bearing scrap. Sometimes smelters will use sulfides (green ore) directly, which can liberate significant amounts of SO_2 and SO_3 into the atmosphere. In a modern smelter, these gases are captured and routed to a plant to produce sulfuric acid using a variety of chemical processes. A typical reaction for the reduction of a sulfide mineral and production of blister copper (98-99% pure) is given below:

$$\mathbf{2\,CuFeS_2 + 2\,SiO_2 \rightarrow CuS_2 + FeSiO_3 + 3\,SO_2} \qquad \mathbf{(1)}$$

$$\mathbf{Cu_2S + O_2 \rightarrow Cu + SO_2} \qquad \mathbf{(2)}$$

In these furnace reactions, sulfur is oxidized (loses electrons) and copper is reduced (gains electrons) due to the presence of carbon monoxide (CO) generated by fuel (coke) combustion in a reducing (very low oxygen) environment. The iron silicate on the left-hand side of Eq. (1)

reports to the slag, which has a lower density than copper liquid, so it floats on the molten metal. It is important to note that many oxidation-reduction reactions occur in the furnace due to varying sulfide stoichiometries in the feed stock, which is a function of the source of the copper concentrate.

One important furnace used in these smelters is the cupola furnace, which has existed for several thousand years to produce copper from ore minerals. The design of the cupola furnace consists of a cylindrical steel body with a chimney at the top for exhaust and doors on the bottom or side to remove molten metal (matte) and slag (Fig. 3). Along the sides of the cupola are inlets (tuyeres) where gases (e.g., oxygen) and fluxes may be introduced into the charge (ore/scrap plus fuel), depending on the desired effect on the final metal. Although usually made of steel, the inside is lined with refractory bricks to limit the effect of heat produced in the furnace. Because other metals “run” with copper, a variety of other furnaces may be used in a copper smelting, such as: 1) reverberatory furnaces where the ore/scrap is isolated from the fuel, unlike the cupola furnace, but reducing exhaust gases and heat smelt the charge; 2) Dore’ furnaces for extracting precious metals from electrochemical slimes generated during electro-refining of anode copper, and 3) blast furnaces where air is forced into the furnace from above at higher than atmospheric pressure.

A “cupola campaign” involves charging the cupola with fuel (coke or coal) and ore, either green (with sulfur) or calcine (without). The furnace temperature is increased through fuel combustion with introduction of fluxes and air (oxygen) to raise the temperature above the stability field of the ore mineral in the charge (~ 1250° C depending on the decomposition temperature of the ore mineral). Conditions in the furnace are reducing because carbon monoxide (CO) is produced during fuel combustion, which assures copper will remain in the zero valence (native or elemental) molten state. Prior to crystallization, residual sulfurous gases form bubbles in the copper, resulting in blister copper that must be further refined by electro-refining to remove impurities; the final product is copper that is in excess of 99.9% pure.

Secondary Copper Smelting

Secondary copper smelting, not unlike aluminum and iron recycling, utilizes virtually any type of scrap material with a sufficiently high metal content to make its use economical. Because copper in these materials is often in a refined state or copper alloy (e.g., brass or bronze), it is necessary to separate the copper by melting in a furnace after any preprocessing of scrap. Scrap used in secondary smelting is very diverse, including: 1) electrical wiring; 2) telephones; 3) copper alloys like brass and bronze; 4) electrical and electronic material; 5) car radiators; and 6) construction debris, including copper pipes, among others. Virtually all types of copper-bearing scrap can be smelted provided the costs associated with preparatory steps are not prohibitive. The process involves loading scrap and coke into a cupola furnace to produce “black copper,” which can contain between 75-88% copper. It is then processed in a converter furnace where the copper content is raised to ~99% and further refined electrolytically to high-purity cathode copper (USEPA, 1980). Because the market for copper-bearing scrap is very competitive, there is a direct link between copper price per pound and general economic conditions. As a result, the secondary smelter business can be very volatile (USEPA, 1980).

Base-Metal Smelter Emissions and Plume Characteristics

General Comments. -- Many nonferrous, base-metal smelters in the U. S. have followed a similar pattern in terms of their evolution and fate: 1) primary smelting operations began in the last half of the 19th to the early part of the 20th centuries when air pollution control was nonexistent; 2) heightened concern by the smelter industry after air pollution was identified as a national environmental problem in the Air Pollution Control Act of 1955, which publicized the issue after the Donora, PA disaster of 1948; 3) in some cases, a transition to secondary smelters after onset of point-source emission standards because of passage of the Clean Air Act (CLA; passed in 1963, amended in 1965, 1967, 1970, 1977 and 1990); 4) shuttering of some plants after 1970 because smelters had difficulty meeting air pollution control standards (primarily particulates emissions, opacity, and sulfur emissions) imposed by USEPA; and 5) demolition and remediation of smelter sites if a responsible party was extant, or assignment to the National Priorities List (NPL) for cleanup under the Comprehensive Environmental Response, Conservation, and Liability Act (CERCLA) or Superfund Act of 1980 (USEPA, 2019). Because base-metal smelters create large, heavy metal anomalies in soils (plumes), it follows that contamination would probably extend into nearby residential areas like Carteret. According to the USEPA (1998), smelters are a major point source of soil lead contamination in the United States. In this regard, NJDEP has required that USMR sample soils along transects further into Carteret to assess the degree of soil contamination and determine whether or not further remediation is warranted outside the AOC.

Chemical Characteristics of Smelter Emissions. -- Okanigbe, *et al.* (2017) characterized dust from the electrostatic precipitator attached to a reverberatory furnace used to smelt copper ore in South Africa. Most of the particulates (80%) were less than 53 um (1 um = 10^{-6} m) in size with most falling between 5 and 50 um (silt-sized) as previously reported by others (Okanigbe, *et al.* (2017); the second most abundant fraction (12.4%) was coarse material (sand sized) greater than 300 um. Compositionally, it contained heavy metals, as expected, copper (144,000 ppm), lead (1,114 ppm), and zinc (2,169 ppm); arsenic and other trace elements were not reported. Morphologically, the material formed from condensation of flue gases (Okanigbe, *et al.*, 2017), resembling spherulitic particles. The USEPA (1986) in its assessment of emissions from copper smelters states that particulates from materials handling (fugitive dust) and flue gases from furnaces, containing copper, lead, arsenic, antimony, cadmium, mercury, and zinc, are emission sources. Montenegro, *et al.* (2013) found that arsenic is the main concern in Chilean copper smelters in that most of the arsenic (~60%) condenses from the gas phase as flue dust. In general, smelters have been identified as major emitters of air pollution (Glass, 2003), particularly given the fact that air pollution control devices (e.g., baghouses) capture enough condensation dust that can be re-smelted to recover product. A brief summary of emissions from two well-studied smelters is given below.

Meadowbrook (Spelter) Smelter. -- The Meadowbrook smelter was built near the company town of Spelter, West Virginia in 1911, and used manually charged, horizontal retorts to extract zinc via reduction with coke from calcine (ZnO) and other oxide ores. It introduced a more advanced process, vertical retorts, which increased production significantly in 1931, making it the largest slab zinc (spelter) producer in the U.S. (Bliewas and DiFrancesco, 2010).

Bear and Morgan (1919a,b) noted the pernicious effect of the smelter on plants and animals from airborne emissions (zinc and lead) deposited ***several miles*** from the Meadowbrook smelter. Specifically, they indicated that primary smelter operations, without the benefit of emission controls early in the 20th century, distributed heavy metal contamination widely, resulting in injury to farm animals who ate flue dust on grass; they also mapped the distribution of plant blight from acid rain generated by sulfurous emissions from the smelter. Their experiments on plant blight were based on emission estimates and assumed the following: 1) application rate of 5600 lbs. of flue dust per day over a 30 square mile area; 2) average application of 100 lbs. per acre; and 3) higher rates ranging up to 20X the average (Bear and Morgan, 1919b). They noted that acute injury to humans was absent with the only complaint from residents, ironically, being a need to dust daily (Bear and Morgan, 1919a). We now know that chronic exposure to heavy metals can cause health effects in humans long after cessation of industrial activity. The Bear and Morgan (1919a,b) report probably represents the first in-depth investigation of the wide-spread negative impact of base-metal smelter operations on plants and animals prior to the advent of air pollution regulation and control.

The plant had an extensive history of air pollution violations after 1968 due to smoke from the furnace and burning slag on the waste pile (Bliewas and DiFrancesco, 2010). By 1972, it transitioned to a secondary zinc smelter, producing zinc, cadmium, and zinc dust from high-zinc scrap, such as dross (solidified scum skimmed off the top of liquid metal from other smelters) (Bliewas and DiFrancesco, 2010). The plant closed in 2001 and du Pont de Nemours, under supervision from the WVDEP, demolished furnaces and buildings, encapsulated the slag pile, and finished remediating the site by 2005. Chemical data from Goldfaber, *et al.* (2004) indicates that smelter emissions were deposited in Hinkel Reservoir bottom sediments located approximately 6 miles from the Meadowbrook smelter complex during most of the 20th century.

Ruston ASARCO Copper Smelter. -- The American Smelting and Refining Company (ASARCO) copper smelter located in Ruston, Washington adjacent to Tacoma began as a lead smelter in 1888, but it was converted to a copper smelter in 1912 after several changes in ownership (HistoryLink.org, 2019). It closed in 1986 due to economics, as well as difficulty meeting stringent pollution controls imposed by USEPA and the State of Washington. Ultimately, ASARCO was acquired by Grupo Mexico, but went bankrupt in 2005, in no small part, due to its environmental liabilities from some 20 Superfund sites.

The heavy metal plume (~ 450 sq. mi.) from the Ruston smelter consists mainly of elevated soil lead and arsenic concentrations due to atmospheric emissions from the plant over 70+ years (Fig. 4) (Washington Department of Ecology, 2019). The plume is very long (~40+ miles) and wide near the source (~11 miles) if one considers the State cleanup level for arsenic is any parcel within the 20 ppm arsenic contour. Initially, USEPA required sampling and soil remediation within 1 mile of the plant, but Ecology, the Washington State environmental department, discovered that arsenic pollution from the smelter was widespread, covering the central Puget Sound and portions of King and Pierce Counties (Glass, 2003). In addition, Gawel, *et al.* (2014) discovered elevated arsenic and lead loadings in bottom sediments of 26 lakes within 20 miles of the Ruston smelter. Using Pb^{210} dating of sediment cores, they found that elevated metal loadings were temporally correlated with smelting at the Ruston plant. It should be noted that the feed stock for this smelter was high enough in lead and arsenic to recover both elements as byproducts of copper smelting (Glass, 2003).

Brief History of the Carteret Smelter

The following summary of the history of the USMR smelter is based, in large part, on the accounts given by Rolle (1952) and Hoffman (2000), which probably represent the most authoritative sources apart from any company records that might exist. The evolution of the smelter complex can be divided into three time periods: 1) refiner of blister copper purchased from other sources using electrolytic metallurgy and precious metal recovery by Dore' smelting of electrolytic slimes from the tank houses (1902-06); 2) a primary smelter and metal refinery/recycler utilizing ore concentrates and copper/lead-bearing scrap, producing primarily copper, but also precious metals, lead, aluminum, white metal (alloys of zinc, tin, antimony, cadmium, bismuth), among others (1907-59); and 3) a secondary smelter of copper scrap and other metal scrap as a diversified metal refiner, including more exotic metals derived from scrap like selenium, tellurium, platinum, palladium, germanium, among others (1960-1986) (Rolle, 1952; Hoffman, 2000). Not unlike smelters discussed above, it closed in a period of increasing regulatory pressure to reduce air pollution beginning in 1955; specifically, it closed because of uncontrollable, ambient lead pollution in the air (CH2MHILL, 2008).

Founding and Early Copper Refinery. **--** The USMR complex began as the De Lamar Copper Refining Co. at the beginning of the 20th century (~1902-1904) when the Borough of Carteret did not exist (Rolle, 1952). J. R. De Lamar and L. Vogelstein formed a partnership to establish a copper refinery in what was then known as the Chrome area of New Jersey adjacent to the Arthur Kill. They primarily processed copper anode in electrolytic tanks to produce high-grade copper cathodes by removing impurities, and they recovered precious metals. De Lamar soon lost interest in running the company (~ 1905), and sold his interest to the U. S. Smelting, Refining, and Mining Co. (1906). The new owners decided to infuse capital and expertise to diversify into the copper smelting business by building a new primary cupola smelter to process sulfide concentrates and produce blister copper, which could be refined onsite with existing tank houses.

Primary Copper Smelter and Metals Refinery. **--** The first primary smelter was "blown in" in late 1907, and it produced 3,353 tons of blister copper by the end of the year (Rolle, 1952); the following year production of blister copper increased to 10,885 tons. An important priority was identification of a consistent and economical source for copper concentrate to increase the production of the primary smelter. Rolle (1952) mentions arrival of the first shipment of concentrates from the Matahambre mine (polymetallic copper deposit) used in feed stock for the copper smelter as early as 1912; concentrates from other sources were also refined over the years. Cyclones and a baghouse system were added (~1920) to collect metal condensates from flue gases, which could be reprocessed by smelting to enhance production (McVehil, 2018). Although these systems would reduce air pollution to an some extent, a primary motive for installation may have been economic because air emission regulation was nonexistent at the time.

Over the years, new process circuits were added to recover other metals in the smelter/refinery complex, including: 1) copper scrap plant; 2) zinc leaching and COPAX plants (low oxygen, high conductivity copper); 3) white metal (alloys of zinc, tin, bismuth, antimony, and cadmium) plant; 4) lead scrap recycling and refining (1931; dismantled, 1951); 5) aluminum recycling plant; 5) copper powder circuit; 6) radiator sweating with superheated steam plant for copper recovery; and 7) gold and silver recovery, among others. As of 1952, Rolle (1952) states that the smelter capacity had risen to 72,000 tons/y with a refinery capacity of up to 180,000 tons/yr.

Secondary Copper Smelting and Further Diversification. -- Hoffman's (2000) chronology starts during the transition from primary smelter to a metal recycling plant that depended on metal-rich scrap solely as feedstock. It should be noted that scrap smelting occurred throughout most of the plant's history, but concentrate feedstock was dropped in favor of scrap metal sometime around 1960. Specifically, Hoffman (2000) states that prior to 1960 Cuban green concentrates (i.e., sulfur bearing) were the main feedstock to the reverberatory furnace (fuel and combustion isolated from charge, but heat and gases (reductants) cause reactions in the charge). Possibly, the Cuban revolution cutoff the supply of Matahambre concentrates, forcing transition to a secondary smelting and metal refining company. This makes sense because Castro immediately nationalized most industry and marketed commodities within the Communist Bloc.

Feedstock for the cupola furnace (fuel and charge together) in this period included copper wire (bare and insulated), radiators, telephones and motors, alloys (e.g., brass and bronze), electronics, jewelry, and copper tubing, among others (Hoffman, 2000). In addition to products listed above, the diverse composition of the feedstock allowed recovery of more exotic metals that enhanced profitability (Hoffman, 2000). Over time, the complex added several different types of furnaces with a number of chemical process circuits designed to remove product impurities and eliminate problematic metals (e.g., antimony), as well as enlarged tank houses dedicated to electrochemical refining of copper anode, the original business of De Lamar Copper Refining Co. According to Hoffman (2000), the plant turned a profit throughout its existence, in part, due to its production of a diverse suit of refined metal products and metal salts (the plant can be seen in an aerial photo from 1949 in Fig. 5). A generalized map showing major processing and storage areas of the USMR complex in 1985 just prior to its closing in 1986 is shown in Fig. 6 (AMAX, 1988).

Offsite Remedial Activities

With the advent of the Clean Air Act of 1963 and its revisions in succeeding years (1970, 1990), smelting operations were monitored by regulators. Smoke and odors emanating from the plant when the wind blew from the east southeast to south, the so-called critical wind zone (Fig. 7; Plaintiff Exhibit 44, USMR 00755192), would blanket Carteret. It is important to note that "critical" in this context probably meant that residential complaints followed by inspections were most common when the wind carried point-source emissions over the Borough of Carteret. Air emission violations accumulated over the years of nascent air quality monitoring by NJDEP (see Plaintiff Exhibit 2, USMR 00002818-USMR 00003906). By 1986, increasing environmental regulation (point-source air quality permits and resulting pollution abatement costs) and lawsuits resulted in the shutdown of what was known by then as the United States Metal Refining Co. NJDEP required a remedial investigation of the site and remedial action, which converted the former smelter site to a complex of warehouses and parking lots (Fig. 1) after demolition/soil remediation of the smelter complex, which had operated for nearly 82 years (Hoffman, 2000). In 1988, the State of New Jersey ordered USMR and its predecessors to "fully determine the horizontal and vertical extent of at and/or emanating from the site," thereby requiring them to evaluate fully the extent of contamination from the smelter in the surrounding off-site area (Plaintiff Exhibit 54, USMR 000017674). After site remediation, offsite investigations of soil pollution were initiated and an Area of Concern (AOC) located immediately adjacent to the site was defined. Eventually, limited transects were extended from the AOC further into the Carteret residential area, but despite the presence of soil exceedances on residential properties USMR declined further delineation and remediation. To date, USMR has failed to comply with the State's 1988 Order.

<u>Background Soil Loadings and Soil Screening Levels (SSL's).</u> -- Generally, industry is not required to cleanup below the background levels of soil constituents. The most readily defined background is one based on the natural distribution of metals in geological materials, which have been studied in great detail by geochemists. The influence of anthropogenic activities can often be eliminated as a causal mechanism for observed metal loadings in soils (i.e., natural background). Risk-based criteria (RBC) usually exceed natural background levels for metals with the exception of arsenic, which has a very low ingestion-dermal, health-based criterion

(~ 0.4 ppm) because of its high toxicity (Hughes, *et al.*, 2011). Cleanup goals evolve over time as more information becomes available on health effects (e.g., behavioral effects linked to lead exposure -- see Needleman, *et al.* (1996)). Recently, USEPA (2017) issued a Record of Decision (ROD) for the Mateo & Sons Superfund site (former battery recycling site), reducing the cleanup goal for lead from 400 to 200 ppm in the upper 2 feet of soil based on the recognition that blood lead levels in children as low as 5 ug/dl (micrograms per deciliter) can have detrimental effects. Perhaps it should be noted that the copper cleanup goal is very high (3,100 ppm) because copper is an essential nutrient unlike arsenic and lead. However, it is usually a contaminant in the Study Area at soil loadings above the Upper Confidence Limit (UCL) of the mean (~ 36 ppm) in the Urban Piedmont of New Jersey where Carteret is located (BEM Associates, 1997). It is important to note that this value is below the copper loading of the average shale in Table 1, a value based on many analyses of shale (the most abundant sedimentary rock). As such, soils with copper loadings in excess of the average shale value, as is nearly always observed in Carteret soils, indicate pollution by anthropogenic sources.

	CRUST[1]	AVE. SOIL[1]	AVE. SHALE[1]	LCL[2]	UCL[2]	NJDEP RESIDENTIAL SSL'S[3]
Arsenic	**1.6**	**11**	**13**	**5.8**	**8.4**	**19**
Copper	**39**	**23**	**45**	**26.6**	**36.2**	**3100**
Lead	**17**	**26**	**20**	**88.5**	**128**	**400 (200[4])**

[1] **Values given by ERDA.org (2019); numbers in the table are ppm dry weight.**

[2] **Values given by BEM Systems (1997) for soils in the urban piedmont of New Jersey.**

[3] **Residential Soil Screening Levels (SSL's) given by NJDEP (2017).**

[4] **Lead SSL used in Record of Decision (ROD) by USEPA in the Mateo & Sons site (USEPA, 2017)**

Table 1. Arsenic, copper, and lead loadings in the continental crust, soils, and shales. The Lower (LCL) and Upper (UCL) confidence limits for mean background loadings of Urban Piedmont soils in New Jersey are given.

In this report, the following screening values will be used: 1) the Upper Confidence Limit (UCL) given by BEM Systems (1997) for detecting soil enrichment relative to natural background for metals; and 2) New Jersey soil cleanup goals, including the 200 ppm SSL for lead in the upper 2 feet of residential yards used by USEPA (2017) in the Matteo & Sons decision. Notably, California has determined that further limits on exposure to lead are warranted based on their conclusion that the incremental lead concentration in soil responsible for increasing blood lead by 1ug/dL was only 77 ppm based on their risk analysis for children (California Department of Toxic Substances Control (DTSC), 2007; DTSC Lead Risk Assessment Spreadsheet). California revised its SSL for lead to 80 ppm from a previous value of 150 in 2009 (Carlise, 2009) because any increase in children's blood lead due to contaminated soil exposure is deemed unacceptable.

In this report, the location of the average source region for atmospheric emissions from the smelter complex (Fig. 8) was calculated from UTM coordinates provided by McViehl-Monnett (Letter from John Gilpin to J. Stanton Curry (5/17/12); Deposition of George E. McVehil, Plaintiff Exhibit 355) for emission sources (i.e., cupola, converter, and reverberatory furnaces and fugitive dust) used in the their model of the smelter plume. Data sources for the analysis include the following: 1) USMR Area of Concern (AOC) soil sample loadings, excluding field duplicates, for lead, copper, and arsenic as a function of depth; 2) USMR soil sample loadings for the same metals as a function of depth along transects extended into the residential area of Carteret; 3) additional transect samples taken by the Plaintiff in the residential area beyond the USMR transects; and 4) samples taken by the Plaintiff away from the transect samples in the periphery of the proposed Class Area.

***Area of Concern (AOC).* --** The AOC evolved from soil sampling by USMR to detect a zone of declining heavy metal loadings from the smelter, the Initial Soil Decline Analysis (ISDA), where a number of heavy metals loadings were determined as a function of depth. According to Mr. Joseph A. Brunner's deposition (Brunner, 2018), the purpose of the AOC, in consultation with NJDEP and the Licensed Site Remediation Professional (LSRP; Mr. Michael McNally, ELM Group), is as follows:

> "***USMR has committed to clean up properties within the AOC where the three constituents, copper, lead, or arsenic, are present in excess of the cleanup standards consistent with our remedial action work plan, which, again, has been approved by the LSRP.*"** (Deposition of Joseph A. Brunner: p. 140, lines 9-13)

	COPPER (ppm)	**ARSENIC (ppm)**	**LEAD (ppm)**
N	**34270**	**34270**	**34270**
MIN	**<1**	**<1**	**<1**
MAX	**27600**	**4060**	**41400**
AVERAGE	**405**	**24**	**465**
STD. DEV.	**987**	**49**	**1041**
5th	**9.9**	**4.1**	**11**
50th	**155**	**13.8**	**169**
95th	**1360**	**68**	**1710**
EXCEEDANCES	**642**	**13117**	**10197[1] (15845[2])**
PERCENT	**2**	**38**	**30[1] (46[2])**

[1] 400 ppm criterion
[2] 200 ppm criterion

Table 2. Descriptive statistics and exceedances of cleanup criteria in the the AOC (all depths).

	COPPER (ppm)	ARSENIC (ppm)	LEAD (ppm)
N	**21043**	**21043**	**21043**
MIN	**<1**	**<1**	**<1**
MAX	**27600**	**4060**	**41400**
AVE.	**508**	**27**	**559**
STD. DEV.	**1143**	**53**	**1139**
5th	**17**	**4**	**15**
50th	**228**	**16**	**249**
95th	**1670**	**71**	**1919**
EXCEEDANCES	**527**	**9222**	**7693[1] (11823)[2]**
PERCENT	**3**	**44**	**37[1] (56)[2]**

[1] 400 ppm criterion
[2] 200 ppm criterion

Table 3. Descriptive statistics and exceedances of cleanup criteria in the 0-2 foot depth interval in the AOC.

As can be seen in Fig. 8, USMR sampled extensively in the AOC and copper enrichment occurs throughout the sampled area, as do about 2% (642 of 34,270 samples) exceedances of the cleanup criterion (3,100 ppm) were found in the AOC (Fig. 9; Table 2). It can be seen in Fig. 10 that copper enrichment and exceedances occur at all depths sampled as deep as 90 inches measured depth below the ground surface. In the upper 2-foot interval, a depth sometimes specified for contaminant removal and replacement in residential yards, copper enrichment (average enrichment is ~ 11X the average shale) and 527 or 3% exceedances were detected (Table 3). However, copper is not a significant driver of risk in residential yards located in the AOC, and it would not be expected to drive risk in residential neighborhoods located further out in the proposed Class Area.

Although some trace constituents in soils like copper, arsenic, and lead occur as lognormal distributions in nature (Limpert, *et al.,* 2001), PROUCL 5.1 (USEPA, 2015), software used to calculate UCL values for the mean, indicates that the AOC copper data cannot be fit to any distribution considered, and it defaulted to the Chebyshev 95% UCL estimates for copper, arsenic, and lead of 429, 26, and 489 ppm in the AOC, respectively. It should be noted that these UCL estimates are consistent with current USEPA guidance, but there is debate as to their accuracy (Daniel, 2015). Regardless, it should be emphasized that these distributions are decidedly not normal (Fig. 11), and the assumption of normality is invalid. Particular concern is warranted when a small number of samples are used to determine whether or not to remediate a given residential parcel. If the number of samples is small (i.e., <30), a more conservative approach from a human health perspective may be to determine whether to remediate or not based on the maximum observed loading and the number and spatial distribution of exceedances in a parcel.

Copper loadings in soil, as expected for emissions from a point source, decrease with distance from the source, but considerable variation is observed in the data (Fig. 12). Other trace metals associated within the plume show a similar functional relationship with distance from the source. For example, arsenic, potentially the most toxic of the metals present, varies throughout the soils of the AOC; it, too, is decidedly non-normal in its distribution as indicated by ProUCL. Exceedances are widespread (Fig. 13; Tables 2 and 3), and arsenic loadings decrease with distance from the source, but with significant depth variation (Fig. 14) and distance from the source (Fig. 15A, B) like copper. The number of exceedances is approximately 20X the number of copper exceedances (Table 2) and extreme values are observed in close proximity to the USMR property within the AOC (4,060 ppm). Because the AOC has been extensively sampled, it is possible to use contour maps to discern patterns in the spatial distribution of arsenic in the AOC (Fig. 16). Clearly, arsenic enrichment in AOC soils is derived from the main smelter complex, as well as the general area of the lead plant. In particular, there are a number of "hot spots" observed in the vicinity of the former plant boundary. For example, a linear feature is observed adjacent to the parking lot in Fig. 16 with arsenic loadings present in excess of 100 ppm (Table 4); another, smaller feature associated with the parking lot can be seen on its western side with similar arsenic loadings. In the area away from the plant, arsenic levels vary, but the intensive sampling done in the AOC allows for adequate delineation and remediation decisions. Similar spatial distributions are observed for copper and lead because all three metals are highly rank correlated (see below). In other words, copper increases are concomitant with increases in lead and arsenic in Carteret soils due to emissions from the USMR smelter complex.

	COPPER (ppm)	ARSENIC (ppm)	LEAD (ppm)
N	327	327	327
MIN	6.2	2.6	5.7
MAX	19100	605	21300
AVERAGE	3750	135	3436
STD.DEV.	3852	144	4079
5TH	18	5.5	13.7
50TH	2360	73	1870
95TH	10870	443	11700
EXCEEDANCES	149	272	246[1] (263)[2]
PERCENT	46	83	75[1] (81)[2]

[1] 400 ppm criterion
[2] 200 ppm criterion

Table 4. Descriptive statistics for soil samples taken from 0-2 foot depth interval in the linear "hot spot" seen in Fig. 16.

In a similar manner, soil lead contamination in the AOC is linked back to the USMR complex; there is also evidence that the USMR lead plant contributed lead to the AOC (CH2MHILL, 2008). Lead exceedances in soils from the AOC for the 400 and 200 ppm soil screening levels are shown in Figs. 17 and 18, respectively. There are exceedances for lead at all depths sampled (Table 1 and Fig. 19), which is consistent with a copper smelter with a long history of primary smelting of copper ore concentrates that usually contain lead due to the presence of polymetallic sulfides. Applying the 200 ppm criterion used by USEPA in the Mateo & Sons ROD to set the permissible threshold of lead contamination in residential areas, 46% (15845) of soil samples taken in the AOC exceed this SSL. Lead loadings in excess of 200 ppm increase to 56% of samples taken in the upper 2 feet of the AOC (Table 3). Lead, like arsenic and copper, decreases with distance from the source (Figs. 20A and 20B), and the contour map in Fig. 21 indicates that lead contamination is more widespread than arsenic contamination with "hot spots" associated with the parking lot confirmed by coincident lead-arsenic anomalies. In general, soil samples taken in the AOC are contaminated above one or more SSL's (Fig. 22) with the maximum lead loading of in excess of 4% by weight in soil (Table 3).

In summary, analysis of the AOC dataset leads me to conclude to a reasonable degree of scientific certainty: 1) the USMR smelter complex is the predominant source of contamination in the AOC; 2) metal contamination decreases as a function of distance consistent with the presence of a single, large point source of heavy metal contamination; 3) contamination in Carteret is a problem beyond the AOC given the extreme levels of contamination observed in it; and 4) the boundaries of the AOC conform with streets, which did not exist when the smelter began operations early in the 20th century; 5) it is nonsense to even assume the impact zone of a smelter plume would be bounded by streets; 6) significant numbers of soil exceedances above NJDEP SSL's for copper, arsenic, and lead are present in the AOC at all depths sampled to date; and 7) other potential sources (lead paint, inorganic pesticides, fill, etc.) cannot explain the widespread, sympathetic variation of copper, arsenic and lead contamination observed in the AOC.

***Transect Sampling*. --** Sampling and analysis in the AOC indicate that USMR has not, as yet, found a clean edge to the soil contamination plume in Carteret and Port Reading, New Jersey as required by the 1988 Order. Under guidance from NJDEP and the LSRP, three transects totaling 760 samples were extended further into the Carteret residential area from the AOC. The longest transect started ~0.6 mi and ended ~1 mi from the source (Transect B); the two other transects (A and C) were similar in length (Fig. 23). Soil samples were taken on parcels along each transect to a total depth of 1 foot with a 6 inch sampling interval using the same USEPA analytical methods (i.e., 6010 mainly and 6020) as in the AOC. Plaintiffs extended transect sampling for a total of 836 transect samples in an attempt to find a "clean edge" below SSL's endorsed by NJDEP. It can be seen in Table 5 that contamination is present in these samples at levels that can exceed the cleanup criteria required by NJDEP and embraced by USMR in the AOC. Note that exceedances are found all along Transects A, B, and C (Fig. 24) with lead and arsenic exceedances consistent with observed soil contamination in the AOC. In addition, most

	COPPER (ppm)	ARSENIC (ppm)	LEAD (ppm)
N	836	836	836
MIN	10	5	10
MAX	6550	512	10700
AVERAGE	243	26	498
STD. DEV.	307	29	749
5TH	51	8	39
50TH	198	22	301
95TH	529	46	1415
EXCEEDANCES	2	506	320[1] (541)[2]
PERCENT	0.2	61	38[1] (65)[2]

[1] 400 ppm criterion
[2] 200 ppm criterion

Table 5. Descriptive statistics and exceedances of cleanup criteria for all samples in the upper foot of Transects A, B, C.

of the samples (97%) show enrichment (> 36 ppm) in copper, the major heavy metal manufactured by the USMR smelter complex for nearly eight decades. Furthermore, copper exceedances occur in two samples with one "hot spot" located at a depth (6-12") with extremely high arsenic and lead loadings (Sample 7337-B01-03-BG-G0020; Cu = 6550 ppm; As = 512 ppm; Pb = 3470 ppm).

Peripheral Sampling. -- Additional sampling by the Plaintiffs in residential Carteret confirms that soil contamination is present beyond the transects. It is important to note that samples taken along transects, including extended sampling by the Plaintiff, is consistent with decay of the smelter contamination signal with increasing distance from the source. Evidence for decay of the signal can also be seen in peripheral samples taken by the Plaintiff near the

	COPPER (ppm)	ARSENIC (ppm)	LEAD (ppm)
N	52	52	52
MIN	12	2	11
MAX	380	43	760
AVERAGE	103	14	133
STD. DEV.	84	9	141
5TH	18	2	15
50TH	78	11	69
95TH	259	30	384
EXCEEDANCES	0	13	2[1] (13)[2]
PERCENT	0	25	4[1] (25)[2]

[1] 400 ppm criterion
[2] 200 ppm criterion

Table 6. Descriptive statistics and exceedances of cleanup criteria for all samples in the upper foot of peripheral samples near the western boundary of the proposed Class Area.

proposed Class Area western boundary. Although these samples are contaminated, the observed levels are lower than the transects and AOC, a finding that is expected and consistent with airborne deposition from the USMR major point source decaying at greater distances (~1.5 miles; see Table 6). These samples continue to indicate that the "clean edge" has not, as yet, been found in the proposed Class Area, and additional sampling by USMR is warranted to fully delineate the smelter plume. USMR asserts that significant smelter contamination in Carteret neighborhoods does not extend beyond the AOC and that other sources account predominantly for contamination observed beyond Essex St. and Roosevelt Blvd. It is highly unlikely that contamination from a smelter plume would end at a manmade feature, such as a road, fence, or any arbitrary line drawn on a map. Additional soil testing is needed in the proposed Class Area as part of the requirement to remediate that area.

Discussion

It is clear that heavy metal contamination in the AOC is due to the operation of the USMR smelter for a period of over 80 years. The next question in this case is whether or not heavy metal contamination extends further into the residential area of Carteret than the original AOC. Mr. McNally, the LSRP, states in his deposition the probable importance of airborne emissions from smelter complex as an important source of contamination offsite as follows (Deposition of Robert McNally (2018): p.53, lines 2-6):

> ***"Yeah, I mean, to the extent that I sort of -- in that case, mentally, it's their -- it's the operations primarily. If you're talking about outside the main property, I would say it's -- they're primarily airborne deposition."***

Smelters have a zone of extreme contamination in communities located adjacent to the fence line of the plant, but airborne deposition usually extends further away from the site, resulting in contaminated yards and house dust miles from the plant. USEPA (1998) concluded the following based on a literature review on lead soil contamination, including smelter point sources of lead:

> ***"The isopleths, which show increasing soil-lead concentrations in the vicinity of the smelters, "support the conclusion that the smelters are the primary sources of lead contamination in the area." In addition, the Heavy Metal Exposure Study [60] found that "there was a general trend toward increasing levels of environmental metal burdens with proximity to the smelter." The evidence for the emitter being the contributing source of the lead, therefore, stems from increasing soil-lead concentrations with decreasing distance from the emitter."***

The State of New York sued USMR based over violations of air quality regulations because Staten Island, New York is located just across the Arthur Kill near the USMR plant. The relevant part of the complaint against AMAX reads as follows (USMR 00005782 – USMR00005783):

> ***"Third, USMR has a long history of noncompliance with state and federal air pollution laws. New Jersey has issued USMR many notices of violation and threats of prosecution for air pollution."***

In the complaint, New York lists fifteen incidences where New Jersey issued citations to USMR (USMR 00005783 – USMR 00005784) besides the Consent Order between New Jersey and AMAX that triggered the suit. Michael Surgan, an environmental scientist retained by the State of New York, analyzed the technical aspects of the Consent Order and concluded (USMR 00005815):

> ***"In summary, the Consent Order negotiated by USMR and NJDEP is technically vague and inadequate. One cannot evaluate the effectiveness of any remedial measures which might arise from this agreement given the lack of detail. The impact of these remedial measures on New York is not considered. The process for the ultimate determination of compliance is inadequate. The Consent Order is not responsive to the issues raised in New York's complaint."***

Given the life cycle of smelters in the United States born in an age of industrialization over a hundred years ago, evolving over time with new products, processes, and increasing profitability, and eventually increased scrutiny over emissions post 1970, it is no wonder the smelting business model became problematic. Some smelters were able to remain viable as long as commodity prices remained high enough; regulatory fines probably had little to do with their demise because they were effectively part of the operational overhead. In this case, USMR, like most smelters, was identified as a chronic air polluter, and shut the plant down in 1986, which was followed by onsite remediation. Decades later, USMR conducted soil sampling offsite and discovered that the AOC was heavily polluted with copper, arsenic, and lead; offsite remediation was, therefore, required in residential neighborhoods adjacent to the plant in Carteret. As mentioned above, at the behest of the LSRP and NJDEP, USMR sampled parcels beyond the AOC in transects (Fig. 23), and found that pollution extended further into the residential area of Carteret (see Fig. 24). They stopped sampling about 1 mile from the source because pollution removed that far from the plant was not consistent in their Conceptual Site Model (CSM), a tool for guiding the offsite Remedial Investigation (RI). Regardless, the soil loadings in parcels along transects indicated that copper enrichment and SSL exceedances for arsenic and lead were present, but USMR decided the smelter's contribution had diminished in importance along the transects and no longer was a risk driver. I do not agree with this conclusion, and I find it hard to justify scientifically. Soil samples taken thus far by USMR indicate that the smelter contributed to soil contamination above 400 and 200 ppm lead beyond 1 mile from the source further into the Borough of Carteret.

<u>USMR Conceptual Site Model (CSM)</u>**--**Based on the site remedial investigation, Arcadis (2016) identified heavy metals, specifically copper, arsenic, and lead, as Constituents of Concern (COC) in the first phase of the offsite RI. Arcadis (2016; p. 8) agrees with the LSRP that air deposition is the primary pathway for contamination of residential soils as follows:

> ***"Given the duration of the historical operations and the results of previous on-site soil investigations, the potential exists for soil metals concentrations outside of the USMR property boundary to have been increased by past site operations. The most common off-site transport mechanism for metals associated with copper smelting operations is air deposition."***

This conclusion requires some idea of the size of the smelter plume generated by air deposition in order to determine where a "clean edge" ***might*** be located. USMR asked McVehil-Monnett (2018) to generate an air model (AIRMOD) for the plant based on known emission sources (furnaces, fugitive emissions, etc.) and production history of the plant (primary and secondary smelter). McVehil-Monnett (2018) identified four main emission sources: 1) cupola furnace (original and late); 2) converter (original and late); 3) converter fugitives; 4) sinter fugitives; and 5) cupola/reverbatory fugitives. Using emission factors given in AP-42 (USEPA, 1986) and two operating scenarios, McVehil-Monnett (Plaintiff Exhibit 355) generated plume models shown in Figs. 25 and 26. Scenario 1(Fig. 25) and Scenario 2 (Fig. 26) are differentiated as follows: 1) stack heights for cupola and converter emissions of 100 feet; and 2) stack heights of 225 feet for the same emitters. As expected, total lead deposition in the models is linked to stack height and production history as follows: 1) the model for Scenario 1 predicts a maximum lead deposition of 750 g/m^2 near the western shore of the Arthur Kill with the 50 g/m^2 isopleth extending past the northern boundary of the AOC (Fig. 25); and 2) the second model has a lesser maxima (350 g/m^2) located essentially in the same place with the 50 g/m^2 isopleth covering the eastern portion of the AOC (Fig. 26). Several observations can be made about the modeling effort: 1) the results required sampling offsite in the eastern and western parts of the AOC south of Essex St. for model validation; 2) most of the lead is predicted to be deposited onsite, in the Arthur Kill, and on Staten Island; and 3) numerous assumptions are built into the model. McVehil in his deposition states the following (Deposition of George McVehil (2018); p. 21, lines 5-8):

> ***"I would say it was in between. It certainly wasn't a rigorous model because we didn't have all the information we'd like, but it was more a conceptual model. It was a quantitative estimate."***

The primary use of the modeling effort seems to have been as a guide to areas that had been impacted by historical smelter operations and, therefore, required sampling, particularly for lead loadings in soils. McVehil goes on to say (Deposition of George McVehil (2018); p. 21, lines 14-17):

> ***"That was my understanding initially, that they were more interested in -- in the pattern and the gradient of deposition was distance, as opposed to the absolute magnitude of the numbers."***

The qualitative character of the model can be illustrated by a simple calculation wherein 100g Pb/m^2 is distributed uniformly in the upper 2 feet of a soil ped with a volume of 21.52 ft^3 and specific gravity of 2.7. The resulting concentration would be ~164 ppm, which is well below the average lead content of soils in the upper 2 feet of the AOC (559 ppm; Table 3). Clearly, the McVehil model underestimates lead deposition in the AOC by ~3X, which suggests that the plume extends well beyond Essex St. Soil sampling by USMR and Plaintiffs along transects (A-C) confirms this fact in that the average lead loading in the upper foot along transects is 498 ppm (Table 5). Perhaps it should be mentioned in this regard that air models, no matter how simple or sophisticated, require validation before they can be used to develop a CSM for sampling and potential remediation.

Generally, the CSM specifies a mechanism for contaminant fate and transport, and then the company acquires samples to verify the mechanism and seeks a "clean edge" marking the outer boundary of an AOC. A "clean edge" is sometimes defined in the CSM as a regulatory SSL or Risk-Based Criterion (RBC), depending on jurisdiction and natural background. As mentioned above, contamination from airborne metals, whether as condensed gaseous emissions or fugitive dust, can be distributed far (miles) from the smelter. In addition to the very large ASARCO and Meadowbrook plumes mentioned above, Rossi, *et al.* (2017) found lead-zinc-cadmium contamination preserved in lake sediments seven miles from the infamous Donora smelter in Pennsylvania; sediment cores were calibrated using ^{210}Pb dating to correlate contamination in sediment cores with the advent and duration of plant operations. If we conclude that the McVehil air model is too conservative in delineating the footprint of the USMR smelter plume, then additional sampling is clearly necessary. Soil samples taken thus far indicate that the smelter contributed to soil contamination beyond 1.5 miles from the source further into the Borough of Carteret.

As mentioned above, frequency distributions of heavy metals in soils in the study area are not parametric distributions (e.g., normal, lognormal, gamma), so nonparametric statistics should be employed in any statistical analysis. For example, we can use the nonparametric Spearman Rank Correlation (r_s) to calculate a similarity matrix for contaminants in the study area (Tables 7 and 8). This statistic can be used to determine the degree to which variables are monotonic and vary sympathetically, as opposed to the Pearson coefficient, which assesses linearity in a dataset. It can be seen in Table 7 that all COC in the study area are increasing monotonic at a high level (strong, positive correlation with $r_s = 0.8 - 0.9$); specifically, copper, arsenic, and lead increase monotonically at a statistically significant level ($p << 0.0001$). In other words, as copper loadings increase in Carteret soils, so do lead and arsenic loadings**.** In my opinion, the sympathetic variation observed among these metals indicates a common source in an urban setting. This does not mean that other sources did not contribute to varying degrees, but the predominant source of metal pollution in Carteret was the USMR smelter. This makes sense given the long production history of the smelter, the numerous air pollution violations, the total tonnage of metal products produced over 80+ years by the plant from feedstock that contained tons of arsenic and lead, and early primary smelter operations (1907-1920) with nonexistent air pollution control. Samples taken by the Plaintiff indicate that lead and arsenic are strongly and significantly associated with increasing copper contamination in soils (Table 8) in both transect extensions and peripheral areas of the proposed Class Area.

	Cu	As	Pb
Cu	1	0.86	0.89
As	0.86	1	0.79
Pb	0.89	0.79	1

Table 7. Spearman nonparametric correlation coefficient matrix for heavy metal loadings in soil samples taken by USMR and the Plaintiff in Carteret. Statistical significance of strong, rank correlation coefficients is very high ($p<0.0001$); it is, therefore, very unlikely that the observed association of arsenic and lead increases with copper increases in soil is due to chance.

	Cu	As	Pb
Cu	1	0.87	0.86
As	0.87	1	0.81
Pb	0.86	0.81	1

Table 8. Spearman nonparametric correlation coefficient matrix for heavy metal loadings in soil samples taken by the Plaintiff in Carteret. Statistical significance of rank correlation coefficients is very high ($p<0.0001$); it is, therefore, very unlikely that the observed association of arsenic and lead increases with copper increases in soil is due to chance.

Sources of Soil Contamination--In cases like this one, smelter emissions are often treated metaphorically as "the elephant in the room," a difficult and obvious problem that nobody wants to discuss. It is instructive to review what can be definitively said about the USMR smelter, and its contribution to soil heavy metal contamination in Carteret. The smelter operated on a daily basis processing sulfide ore (primary smelter) and as a recycler (secondary smelter). Both of these incarnations processed millions of tons of feedstock over time to generate primarily copper metal and other metals. During its early history, it began processing ore concentrates that contained lead sulfide and arsenic-bearing sulfosalts, including pyrite that often contains significant arsenic. We can definitively conclude that all three COC's were present in the feedstock of the smelter early on in its history as a primary smelter. As mentioned above, lead contamination in the AOC is high, but it is underestimated by the McVehil air model, indicating that the plume has impacted an area in excess of the AOC. Soil samples along transects extended further into Carteret are also contaminated, but USMR concluded that the contribution of the smelter was attributable to other sources despite the fact that the line of demarcation appears to be a road, Essex St.; the gap between the AOC and company transects is evident in Figs. 12, 15A,B, and 20A,B. In my opinion, the most reasonable conclusion based on metal associations over distance is that there is one, dominant point source for metals in soil, the USMR smelter, rather than a myriad of uncorrelated, independent sources.

From a practical perspective, what can be done to apportion the contribution of the smelter if remediation is required? Selective remediation of a portion of a contaminated soil mass to reduce the loadings below regulatory criteria is impractical. One can also imagine that background contamination levels, if sufficiently high, could be elevated by smelter emissions to the point of regulatory concern. There is no doubt that the Defense will proffer a myriad of alternate sources for soil contamination to minimize the role played by the smelter in creating the problem. Sometimes a company clings to the dubious idea that contamination never left the immediate vicinity of the smelter despite all evidence to the contrary. In this case, USMR seems to have taken a different approach by acknowledging that contamination left the site, but based on a semi-quantitative, air model and the ISDA targeted the residential area (AOC) immediately adjacent to the smelter complex to sample and remediate as necessary. The company is correct that other sources ***may*** have contributed to soil loadings beyond the AOC, but there is no alternate source with a large feedstock laced with copper, lead, and arsenic processed at very high temperatures that is known to emit significant particulate and gaseous emissions that transports heavy metals far away (**miles**) from the site -- this is by far the overwhelming source of metals in the proposed Class Area. USMR has effectively stipulated that it is responsible for soil contamination in the AOC, but, although it may have contributed to some degree, it is not responsible for remediation of soils further into Carteret. Strangely, the boundary seems to fortuitously coincide with streets, mainly Essex St. and County Road 604 (Roosevelt Ave.) rather than isopleths of soil loadings. It is my opinion that the most significant and consistent contribution to heavy metal loadings in soils in Carteret was the operation of the USMR smelter.

Other Possibilities

Some of the possibilities being considered as alternate sources for heavy metal contamination beyond the AOC were given by Jeffrey Kurtz, Ph.D. in his deposition as follows (Deposition of Jeffrey Kurtz (2018): p. 101-102; Line 25 (101); Lines 1-7 (102)):

> ***"Well, I mean, if you saw the recent LSRP presentation, copper sulfate utilized on crops was pretty prevalent especially out in the transect area where it was historic orchards and so on. There was copper arsenate that was used as an herbicide/pesticide. There was copper pipes. There's copper brake pads. There's copper used in printing."***

With the exception of agricultural application of copper and lead arsenicals, most alternate sources were probably localized and do not account for strong correlations among the three metals along transects. Again, compared to the heavy metal anomaly created by a copper smelter these sources (***if present***) are minor at best, and distributed randomly across the proposed Class Area. Application of copper arsenites (e.g., Paris Green; $Cu(C_2H_3O_2)_2 \cdot 3Cu(AsO_2)_2$) was fraught with uncertainty because the high copper content made it phytotoxic; it burned trees and grass if the orchard/field was over sprayed, but it was used with lead arsenate. It is clear that USMR needs to explain away copper contamination in Carteret soils because it is inexorably linked to their primary business, copper smelting.

Pesticides. -- USMR has suggested that there was an orchard, which required application of insecticide, in the Carteret residential area north of the AOC boundary. Although focusing on the application of inorganic copper arsenite, lead arsenate is another possibility. Lead arsenate or acid lead arsenate ($PbHAsO_4$) is a white powder that was dissolved in water and sprayed on orchards, particularly apple orchards, to control pests. It was introduced in the late 19th century as an alternative to copper arsenites, and its use continued until it was banned in 1988. Typically, two pounds of pesticide powder were dissolved in 50 gallons of water to yield a solution containing ~660 and ~10000 ppm arsenic and lead, respectively (Schooley, *et al.*, 2008). Trees were sprayed three times during the year as follows: 1) dormant spray in the spring and fall; 2) summer spray of fruit and foliage; and 3) petal fall spray to prevent pests from entering the fruit (Schooley, *et al.*, 2008).

Accumulation of lead and arsenic in former orchards has been documented in New Jersey by NJDEP (1999). Over the past 120 years, most of the fruit production in the state has come from Burlington, Monmouth, Salem, Cumberland, Hunterdon, and Gloucester Counties with Burlington, Gloucester, and Monmouth being the largest fruit producers in New Jersey during the 20th century. The most infamous example of soil contamination from the application of pesticides was in Burlington County where a residential neighborhood developed on an old orchard was found to be contaminated with arsenic above the regulatory soil cleanup level. NJDEP ordered community outreach, soil testing, and remediation in order to reduce soil loadings below cleanup levels. As a result, the State formed a task force to investigate the prevalence of soil contamination from lead arsenate pesticides (NJDEP, 1999). They noted that arsenic exceedances were common (~38%) in agricultural areas of New Jersey, but lead exceedances (400 ppm criterion) were rare (~1%). Overall, they concluded that approximately 5% of New Jersey had been impacted by the application of arsenical pesticides, but they did not

	Copper	**Arsenic**	**Lead**
Copper	**1**	**0.79**	**0.76**
Arsenic	**0.79**	**1**	**0.65**
Lead	**0.76**	**0.65**	**1**

Table 9. Spearman nonparametric correlation coefficient matrix for heavy metal loadings in soil samples taken by USMR and Plaintiff along transects in Carteret. Statistical significance of rank correlation coefficients is very high ($p<0.0001$).

include testing in the Carteret area. Again, the fact that all three COC's increase monotonically, especially along transects (Table 9) indicates the presence of a single, major source for contamination, the USMR smelter.

Furthermore, the pattern of farming (versus development in Carteret) is directly contrary to the pattern of heavy metal contamination observed. According to documents, farming may have occurred throughout Carteret, but as the residential area developed, farming was pushed to the west away from the USMR industrial area. This suggests that inorganic pesticide use would have been greatest along the western boundary of the proposed Class Area and its impacts on soil metal loadings would be greatest there. Instead, the opposite pattern is observed with the lowest copper loadings observed in samples taken along the western boundary of the proposed Class Area.

<u>Other Sources</u>*--**The Defense has suggested that copper, arsenic, and lead contamination in Carteret beyond the AOC ***might be the result of the following: 1) metal scrap (e.g., pipes, brake pads) dumped or buried in Carteret; 2) historic fill placed in and around Carteret; 3) treated lumber; 4) metal typeface from a print shop, among others. As mentioned above, all of these potential sources would tend to create localized metal anomalies if they dissolved to a significant degree. The solubility of heavy metals is limited under neutral to mildly alkaline conditions in the soil. Highly acid soils are found in New Jersey when metal sulfides weather and generate sulfuric acid that enhances the solubility of buried metal. New Jersey has produced maps showing the occurrence of acidic soils, and soils in the Carteret area have a low potential for acidity.

Historic fill is mainly used to create land by filling in waterbodies. A map of the Cateret area shows that portions of the Arthur Kill were filled near Carteret, but there is no indication of widespread use of fill in Carteret proper, especially where sampled by USMR. Again, localized filling may have occurred, and its heavy metal loadings are unknown. Fill cannot, therefore, explain the widespread contamination that blankets the proposed Class Area. Treated lumber (i.e., CCA-treated wood) contains chromium, copper, and arsenic; it preserves by inhibiting fungi growth and wood-eating insects from degrading wood exposed to the elements. CCA may be a localized source of copper and arsenic, but its use cannot explain the widespread contamination observed in samples taken by USMR.

Metal typeface was cast from lead alloys either as individual letters or continuous lines of letters. Improper disposal of used typeface ***might*** have created a localized metal anomaly in the vicinity of a print shop. This would require dissolution and redistribution of metal over a wide area to account for the contamination observed in the proposed Class Area. For the reasons mentioned above, distribution is favored by acidic conditions in soils, which have not been documented in the Carteret area. Exposure on the surface would not dissolve enough metal, particularly lead, to account for the widespread lead contamination.

Other possibilities include leaded paint, leaded gasoline, and other industry in the Carteret area. Although it is impossible to exclude a minor (i.e., relative to the smelter) contribution to soil contamination in Carteret, all tend to be problematic when compared to the pollution profile observed in Carteret soils. For example, leaded paint and gasoline are not asociated with copper or arsenic anomalies in soils, especially at the elevated levels observed in the AOC. Why isn't leaded paint and gasoline the cause of contamination in the AOC, but it is considered a possible source a few hundred feet from the AOC boundary? Arsenic is not usually present in lead paint (compounds like $PbCrO_4$, PbO, $PbCO_3$, or Pb_3O_4 used as pigment) or leaded gasoline, which contained an organo-metallic compound, tetraethyl lead ($(CH_3CH_2)_4Pb$). These compounds do not contain copper or arsenic, which are important elements of the contamination plume observed in Carteret. One can only conclude that the myriad of alternate sources proffered by USMR to explain soil contamination outside the AOC cannot explain the sympathetic variation of concentration observed as a function of distance from the smelter complex; contamination falls off with distance, and samples taken near the periphery of the Proposed Class area are significantly less contaminated as expected in a smelter plume. Besides, the smelter dwarfs all other sources of heavy metal contamination in the Carteret area, and its long history of ambient air pollution in Carteret is consistent with this fact.

Ultimately, high temperature processes that generate gaseous and particulate emissions followed by atmospheric deposition are the most efficient in distributing contamination over a wide area. In nature, there is a drive (entropy) to eliminate concentration gradients over time, and disorder, which is related to entropy, increases with increasing temperature. In the smelter, there is a high concentration of metal and high temperature processes that drive contamination away from the smelter to eliminate a large concentration gradient. In addition, the tonnage of material smelted and associated airborne contamination dwarfs all smaller, localized sources over the ~80 year operating history of the USMR smelter. The smelter early in its history (pre-1920) probably contributed most significantly to the heavy metal loadings observed in Carteret residential soils because air pollution controls were nonexistent. As pollution control devices were added, the impacts were reduced, but it was not until last two decades of operation that emissions control was required by law and regulated, requiring addition of more effective air pollution control devices that were regularly maintained and inspected.

Conclusion

All of the evidence I examined leads me to conclude to a reasonable degree of scientific certainty that the USMR complex is the major source of soil contamination in the proposed Class Area. USMR has suggested alternate explanations for soil contamination in Carteret, but these explanations probably would leave a more chaotic, random distribution of contamination than is observed. It is difficult to believe that heavy metal contamination from the smelter is found only in the AOC, which USMR asserts. They conclude that other random sources dominate the contaminant loadings in soils outside the AOC. In my opinion, the smelter plume extends over Carteret and blankets the proposed Class Area covering Carteret and a portion of Port Reading. Because the Urban Piedmont background UCL of the mean for lead is approached at the periphery of the proposed Class Area, USMR's contention that remediation only to the 400 ppm SSL is unwarranted. The more protective SSL (200 ppm) is the appropriate level for screening soils and making decisions whether or not remediation is required in the Carteret and Port Reading neighborhoods. It should be emphasized that my conclusions are consistent with the critical wind direction defined by USMR (Fig. 7), which indicates that smelter emissions were blown over the entire proposed Class Area. This conclusion is consistent with air modeling (Fig. 27) performed by Sullivan (2019) to estimate true area where additional work must be done to fully assess the impact of smelter operations on Carteret residential soils. My opinions are also consistent with the area impacted by the USMR smelter delineated as the proposed Class Area in Fig. 28.

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Appendix A: Plaintiff Data

ADDRESS	X	Y	SAMPLE	Cu	As	Pb
156 Carteret Avenue	567771	635312	1A	240	27	460
156 Carteret Avenue	567771	635312	1B	140	7*	89
156 Carteret Avenue	567806	635306	2A	210	24	320
156 Carteret Avenue	567806	635306	2B	60	4.6*	45
156 Carteret Avenue	567847	635355	3A	350	32	770
156 Carteret Avenue	567847	635355	3B	130	23	95
177 Carteret Avenue	567463	635392	1A	91	16	78
177 Carteret Avenue	567463	635392	1B	240	51	130
177 Carteret Avenue	567485	635384	2A	240	32	300
177 Carteret Avenue	567485	635384	2B	220	28	130
177 Carteret Avenue	567475	635363	3A	110	18	80
177 Carteret Avenue	567475	635363	3B	33	4.8*	25
44 Cypress Street	567262	634865	1A	70	4.8*	22
44 Cypress Street	567262	634865	1B	86	11	52
44 Cypress Street	567241	634840	2A	58	4.7*	29
44 Cypress Street	567241	634840	2B	39	4.7*	25
44 Cypress Street	567276	634796	3A	750	40	570
44 Cypress Street	567276	634796	3B	1700	69	1000
164 Emerson Street	569687	636110	1A	380	46	760
164 Emerson Street	569687	636110	1B	180	17	280
164 Emerson Street	569686	636082	2A	300	40	590
164 Emerson Street	569686	636082	2B	210	23	160
164 Emerson Street	569759	636041	3A	260	32	420
164 Emerson Street	569759	636041	3B	290	39	220
54 Linden Street	567905	635354	1A	320	52	400
54 Linden Street	567905	635354	1B	130	26	350
54 Linden Street	567923	635375	2A	680	49	650
54 Linden Street	567923	635375	2B	210	11	50
57 Linden Street	567904	635441	1A	590	46	390
57 Linden Street	567904	635441	1B	180	18	180
57 Linden Street	567920	635472	2A	120	12	96
57 Linden Street	567920	635472	2B	83	17	77
57 Linden Street	567839	635492	3A	98	9.6	130
57 Linden Street	567839	635492	3B	120	20	120

* Less than PQL

Table A1. Soil sample locations and analyses for copper (Cu), arsenic (As), and lead (Pb) in ppm taken in the proposed Class Area. Sample coordinates are georeferenced using the NAD83 New Jersey State Plane coordinate system. Samples enriched in copper relative Urban Piedmont soils are highlighted in blue. Samples that equal or exceed NJDEP SSL's of 19 and 400 ppm for arsenic and lead, respectively, are highlighted in yellow; samples that fall between 200 and 400 ppm lead are highlighted in green. Samples taken on the periphery of the proposed Class Area are highlighted in grey.

Appendix A: Plaintiff Data

ADDRESS	X	Y	SAMPLE	Cu	As	Pb
60 Linden Street	567942	635404	1A	260	29	360
60 Linden Street	567942	635404	1B	54	23	53
60 Linden Street	567930	635383	2A	510	65	700
60 Linden Street	567930	635383	2B	1200	200	2200
60 Linden Street	567999	635345	3A	290	33	320
60 Linden Street	567999	635345	3B	200	15	120
65 Linden Street	567961	635523	1A	240	26	290
65 Linden Street	567961	635523	1B	25	7.9	29
65 Linden Street	567961	635573	2A	250	40	310
65 Linden Street	567961	635573	2B	38	13	31
65 Linden Street	567899	635580	3A	450	41	680
65 Linden Street	567899	635580	3B	77	12	92
133 Lowell Street	569257	636081	1A	340	40	720
133 Lowell Street	569257	636081	1B	270	27	550
133 Lowell Street	569248	636124	2A	230	43	560
133 Lowell Street	569248	636124	2B	200	32	240
133 Lowell Street	569190	636145	3A	270	28	490
133 Lowell Street	569190	636145	3B	330	46	820
136 Lowell Street	569367	636136	1A	120	17	150
136 Lowell Street	569367	636136	1B	150	26	100
136 Lowell Street	569376	636158	2A	200	26	200
136 Lowell Street	569376	636158	2B	60	15	52
136 Lowell Street	569449	636078	3A	520	39	950
136 Lowell Street	569449	636078	3B	290	35	600
149 Lowell Street	569462	636365	1A	140	14	440
149 Lowell Street	569462	636365	1B	200	23	310
149 Lowell Street	569416	636355	2A	350	51	240
149 Lowell Street	569416	636355	2B	10	5.1	11
149 Lowell Street	569383	636398	3A	84	10	130
149 Lowell Street	569383	636398	3B	100	20	150
37 Coolidge Avenue	566939	635120	1A	370	27	230
37 Coolidge Avenue	566939	635120	1B	800	30	400
37 Coolidge Avenue	566944	635097	2A	300	37	230
37 Coolidge Avenue	566944	635097	2B	270	18	190
37 Coolidge Avenue	566859	635095	3A	700	28	340
37 Coolidge Avenue	566859	635095	3B	420	33	230

* Less than PQL

Table A1 (continued). Soil sample locations and analyses for copper (Cu), arsenic (As), and lead (Pb) in ppm taken in the proposed Class Area. Sample coordinates are georeferenced using the NAD83 New Jersey State Plane coordinate system. Samples enriched in copper relative Urban Piedmont soils are highlighted in blue. Samples that equal or exceed NJDEP SSL's of 19 and 400 ppm for arsenic and lead, respectively, are highlighted in yellow; samples that fall between 200 and 400 ppm lead are highlighted in green. Samples taken on the periphery of the proposed Class Area are highlighted in grey.

Appendix A: Plaintiff Data

ADDRESS	X	Y	SAMPLE	Cu	As	Pb
73 Arthur Avenue	566956	634869	1A	210	27	150
73 Arthur Avenue	566956	634869	1B	29	6	22
73 Arthur Avenue	566961	634850	2A	310	27	200
73 Arthur Avenue	566961	634850	2B	130	23	100
73 Arthur Avenue	566897	634860	3A	160	19	120
73 Arthur Avenue	566897	634860	3B	250	32	190
6 Hermann Avenue	563689	641338	1A	240	21	260
6 Hermann Avenue	563689	641338	1B	190	19	200
6 Hermann Avenue	563687	641315	2A	340	24	420
6 Hermann Avenue	563687	641315	2B	170	18	120
6 Hermann Avenue	563783	641317	3A	130	21	260
6 Hermann Avenue	563783	641317	3B	200	33	320
30 W. 5th Street	562941	633023	1A	35	5.3	40
30 W. 5th Street	562941	633023	1B	29	5.3	24
30 W. 5th Street	562911	633029	2A	32	2.5*	27
30 W. 5th Street	562911	633029	2B	45	7.1	44
30 W. 5th Street	562886	632990	3A	110	10	270
30 W. 5th Street	562886	632990	3B	83	8.6	200
29 Sunset Drive	563023	633346	1A	43	11	44
29 Sunset Drive	563023	633346	1B	12	2.4*	11
29 Sunset Drive	563053	633330	2A	150	13	54
29 Sunset Drive	563053	633330	2B	15	5	14
29 Sunset Drive	563068	633417	3A	19	8.9	15
29 Sunset Drive	563068	633417	3B	17	2.4*	13
32 Mary Street	567595	637863	1A	79	17	320
32 Mary Street	567595	637863	1B	33	6.4	46
32 Mary Street	567625	637873	2A	99	8.8	260
32 Mary Street	567625	637873	2B	170	13	430
32 Mary Street	567627	637905	3A	120	13	250
32 Mary Street	567627	637905	3B	51	7.9	67
12 Kurdyla Avenue	564989	636457	1A	62	23	71
12 Kurdyla Avenue	564989	636457	1B	34	8.5	23
12 Kurdyla Avenue	564968	636422	2A	140	35	210
12 Kurdyla Avenue	564968	636422	2B	220	43	220
12 Kurdyla Avenue	565070	636415	3A	58	19	61
12 Kurdyla Avenue	565070	636415	3B	71	11	46

* less than PQL

Table A1 (continued). Soil sample locations and analyses for copper (Cu), arsenic (As), and lead (Pb) in ppm taken in the proposed Class Area. Sample coordinates are georeferenced using the NAD83 New Jersey State Plane coordinate system. Samples enriched in copper relative Urban Piedmont soils are highlighted in blue. Samples that equal or exceed NJDEP SSL's of 19 and 400 ppm for arsenic and lead, respectively, are highlighted in yellow; samples that fall between 200 and 400 ppm lead are highlighted in green. Samples taken on the periphery of the proposed Class Area are highlighted in grey.

Appendix A: Plaintiff Data

ADDRESS	X	Y	SAMPLE	Cu	As	Pb
11 Kurdyla Avenue	564935	636462	1A	56	9.7	100
11 Kurdyla Avenue	564935	636462	1B	89	14	94
11 Kurdyla Avenue	564908	636439	2A	110	16	60
11 Kurdyla Avenue	564908	636439	2B	30	2.4*	20
11 Kurdyla Avenue	564882	636514	3A	140	23	150
11 Kurdyla Avenue	564882	636514	3B	160	30	180
110 Wortylko Street	564947	636563	1A	44	7.9	35
110 Wortylko Street	564947	636563	1B	64	11	55
110 Wortylko Street	564889	636571	2A	49	8.9	53
110 Wortylko Street	564889	636571	2B	24	2.4*	23
110 Wortylko Street	564962	636636	3A	76	12	35
110 Wortylko Street	564962	636636	3B	38	6.9	67
73 W. 5th Street	562961	633132	1A	110	8.8	230
73 W. 5th Street	562961	633132	1B	160	21	200
73 W. 5th Street	562947	633073	2A	200	17	370
73 W. 5th Street	562947	633073	2B	81	9	170
73 W. 5th Street	563030	633053	3A	250	28	760
73 W. 5th Street	563030	633053	3B	190	24	400
29 Chestnut Street	564812	637378	1A	120	18	120
29 Chestnut Street	564812	637378	1B	250	13	140
29 Chestnut Street	564782	637383	2A	270	21	220
29 Chestnut Street	564782	637383	2B	380	14	100
29 Chestnut Street	564734	637332	3A	360	24	280
29 Chestnut Street	564734	637332	3B	61	5.6	32
4 Colgan Avenue	565321	636565	1A	180	16	170
4 Colgan Avenue	565321	636565	1B	26	6.2	16
4 Colgan Avenue	565354	636597	2A	120	21	96
4 Colgan Avenue	565354	636597	2B	63	8.1	41
4 Colgan Avenue	565385	636530	3A	130	30	110
4 Colgan Avenue	565385	636530	3B	160	20	80

Table A1 (continued). Soil sample locations and analyses for copper (Cu), arsenic (As), and lead (Pb) in ppm taken in the proposed Class Area. Sample coordinates are georeferenced using the NAD83 New Jersey State Plane coordinate system. Samples that are enriched in copper relative to the UCL of the mean for Urban Piedmont soils are highlighted in blue. Samples that equal or exceed NJDEP SSL's of 19 and 400 ppm for arsenic and lead, respectively, are highlighted in yellow; samples that fall between 200 and 400 ppm lead are highlighted in green.

Appendix B: Figures

Figure 1. Survey Google Earth aerial photo (2017) showing the Borough of Carteret, which is located in New Jersey between the New Jersey Turnpike and Arthur Kill, which is the boundary between New Jersey and New York (i.e., Staten Island). The former USMR site was located to the southeast of Carteret on the Arthur Kill.

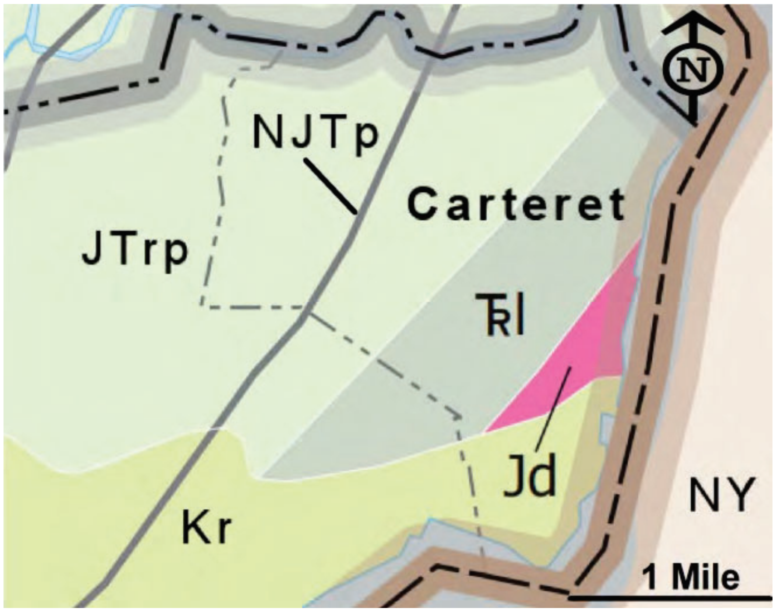


Figure 2. Geologic map of the study area showing rock units found beneath soils in Carteret—see text (New Jersey Geological and Water Survey, 2014).

Figure 3. Photograph of a turn-key cupola furnace (EC&S, 2019). The large cylindrical structure above the base is the cupola with tuyeres on its sides. Refined metal flows from the archway at the base down the ramp.

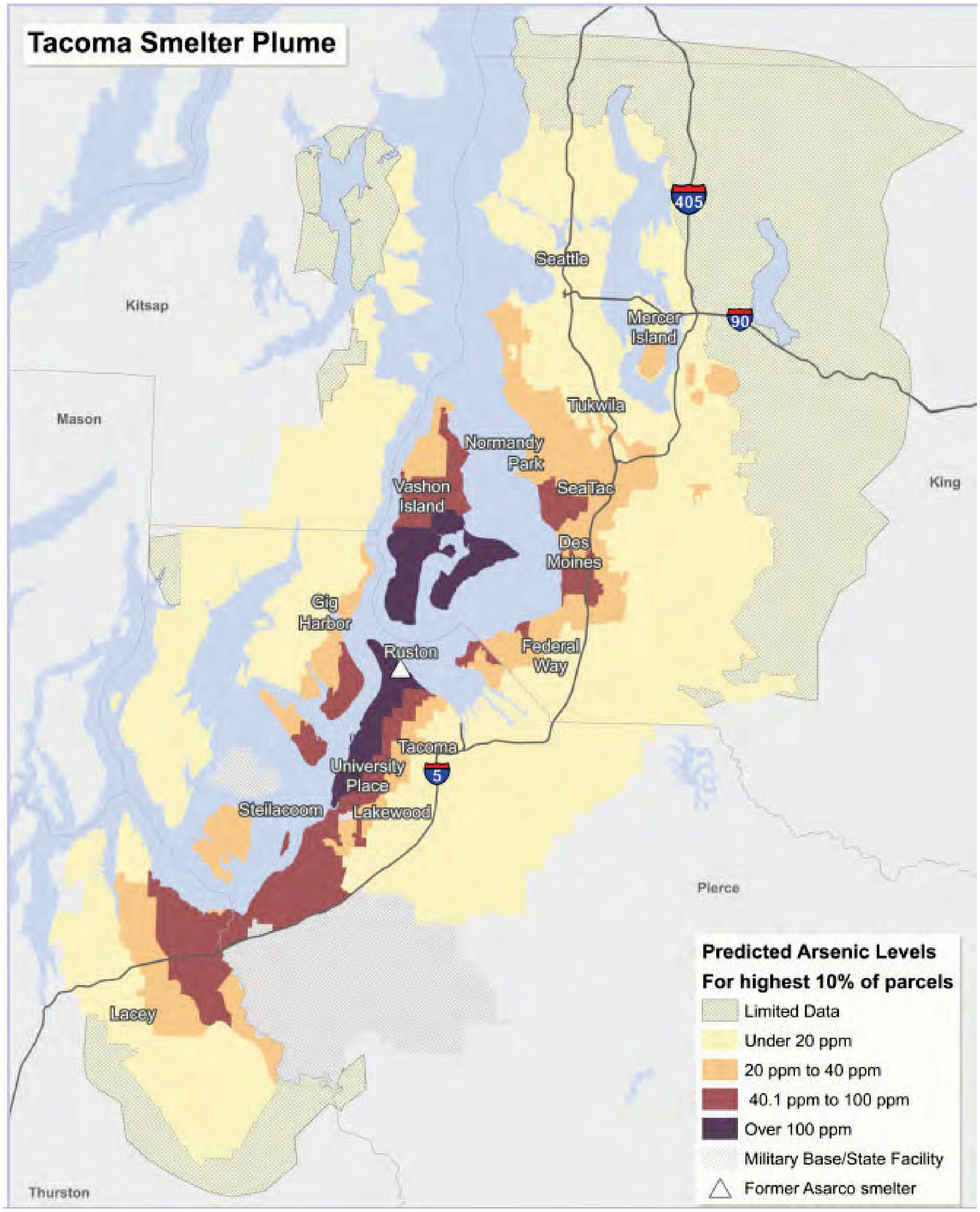


Figure 4. Map of the arsenic plume from the Ruston/Tacoma smelter generated by the Washington State Department of Ecology (2019).

Figure 5. Aerial photo of the USMR complex in 1949 (Deposition of John A. Fenn, 2018; same photo as Plaintiff Exhibits 10 and 397).

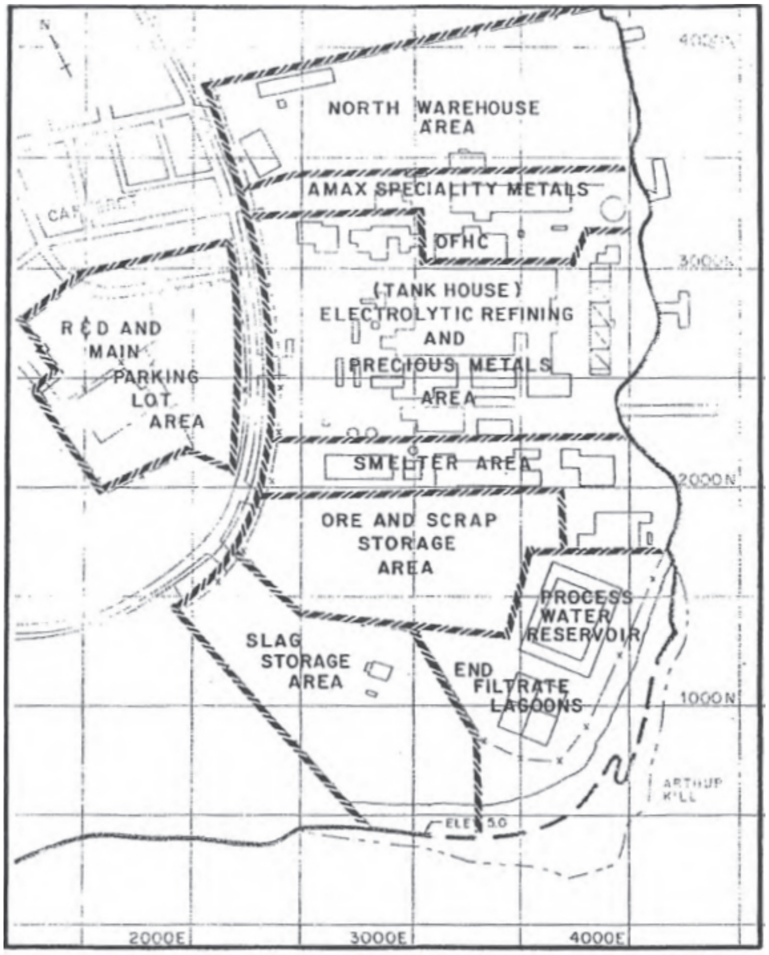
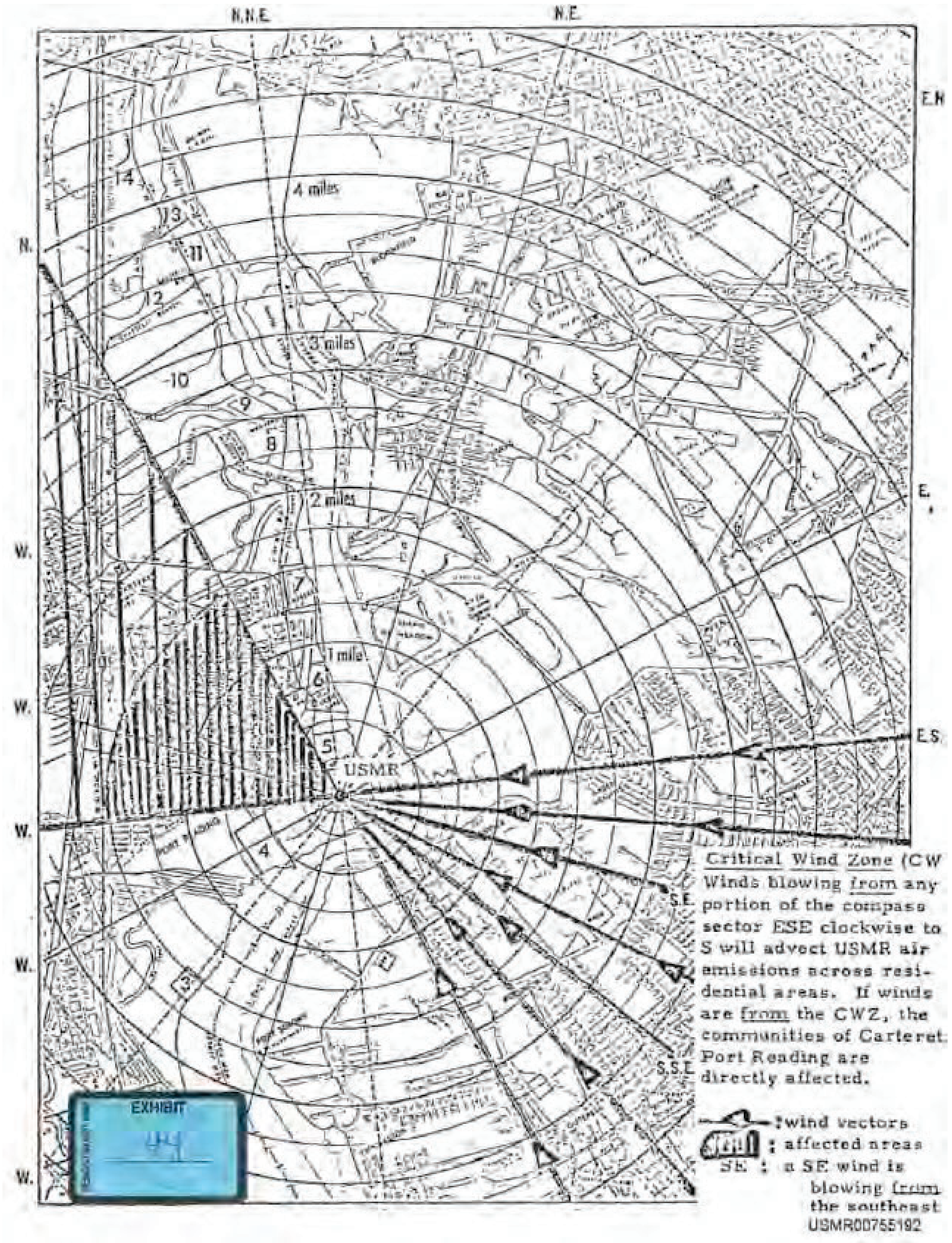


Figure 6. Generalized schematic of the USMR plant in 1985 (AMAX, 1988).



Critical Wind Zone (CW
Winds blowing from any
portion of the compass
sector ESE clockwise to
S will advect USMR air
emissions across residential areas. If winds
are from the CWZ, the
communities of Carteret
Port Reading are
directly affected.

: wind vectors
: affected areas
SE : a SE wind is
blowing from
the southeast

USMR00755192

Figure 7. **Critical wind directions defined by USMR for exposure of Carteret residential neighborhoods to USMR smelter emissions (Plaintiff Exhibit 44; USMR00755192).**

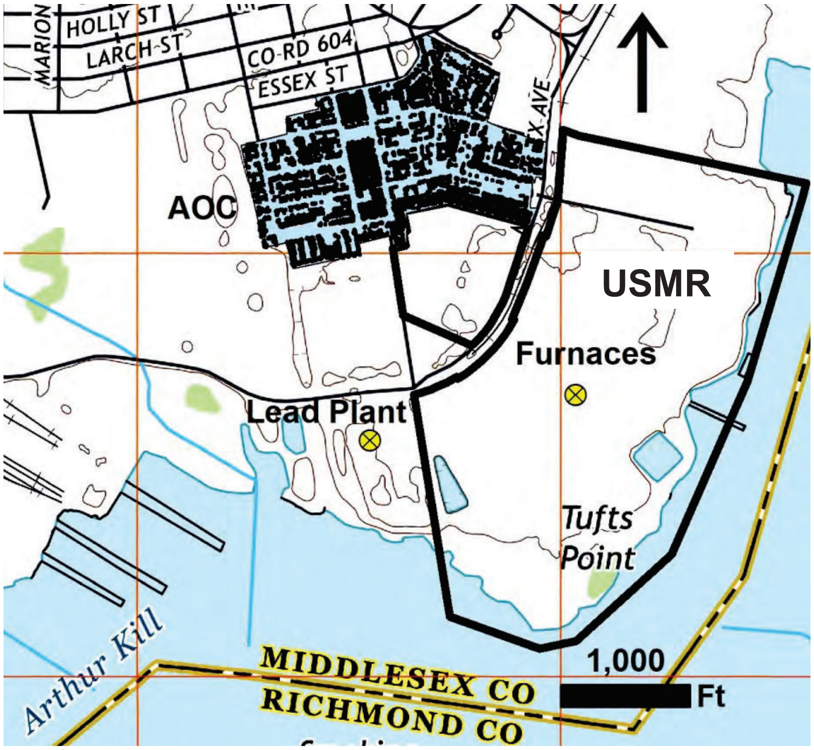


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Fig. 8. Map showing average location of smelter atmospheric sources used in this report based on locations for emission sources used by McViehl-Monnett (2012) in the calculation of the smelter stack-emission plume. Location for the lead plant determined from a 1947 aerial photo.

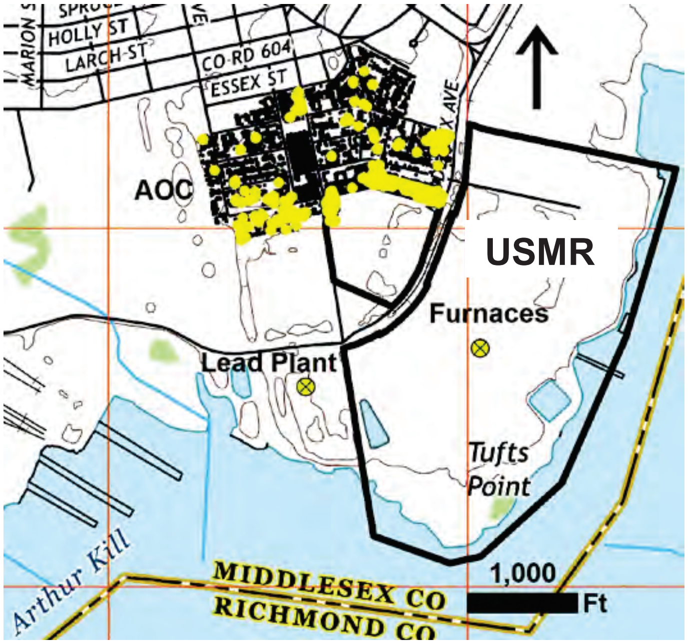


Figure 9. Occurrence of copper exceedances in soil samples taken by USMR in the AOC. Soil samples with metal loadings in excess of 3,100 ppm are selected.

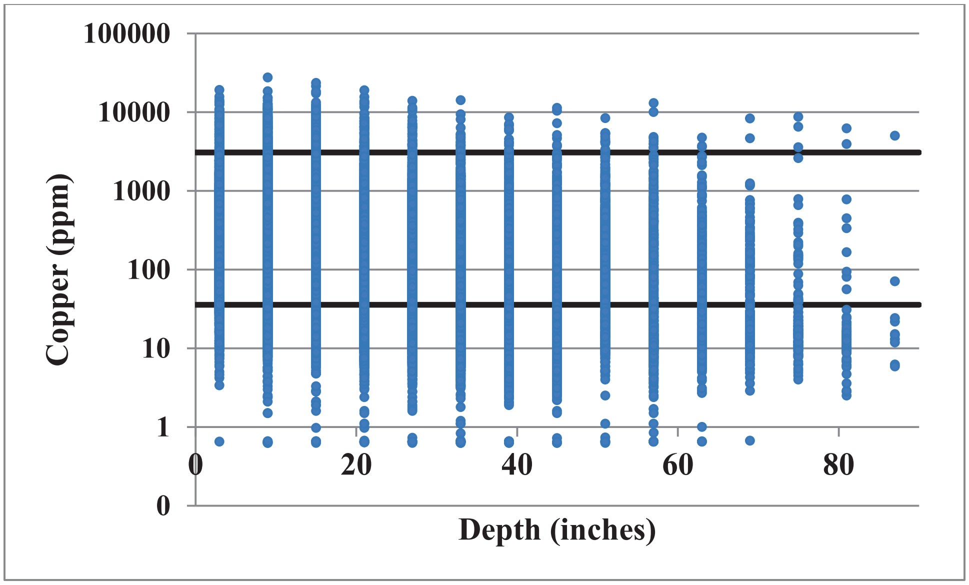


Figure 10. Distribution of copper as a function of depth in the AOC. The upper line is the NJDEP SSL (3100 ppm), and the lower line is the UCL of the mean background for copper (36 ppm) in urban Piedmont soils of New Jersey.

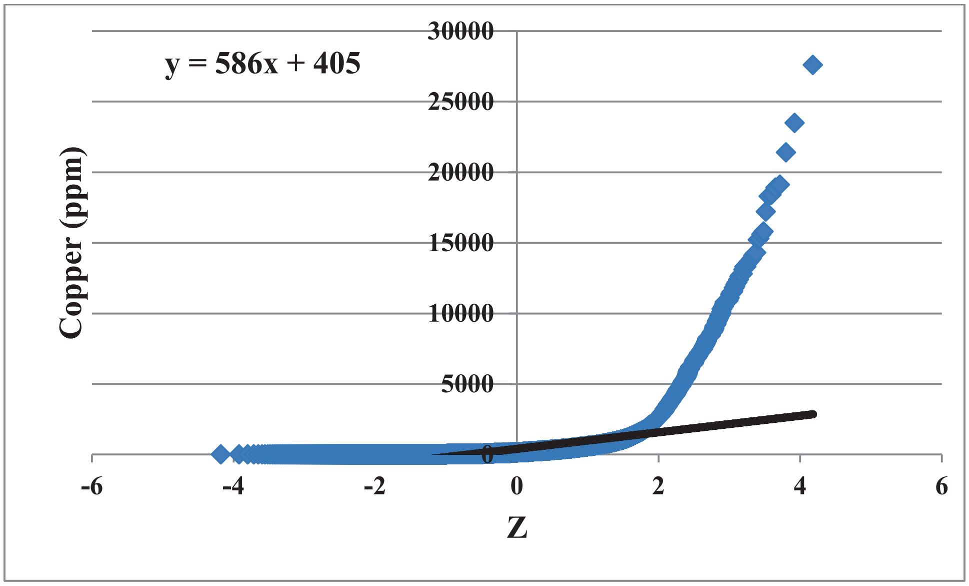


Figure 11. X-Z plot for copper loadings in AOC soils. The solid line corresponds to the X-Z plot for a normal distribution.

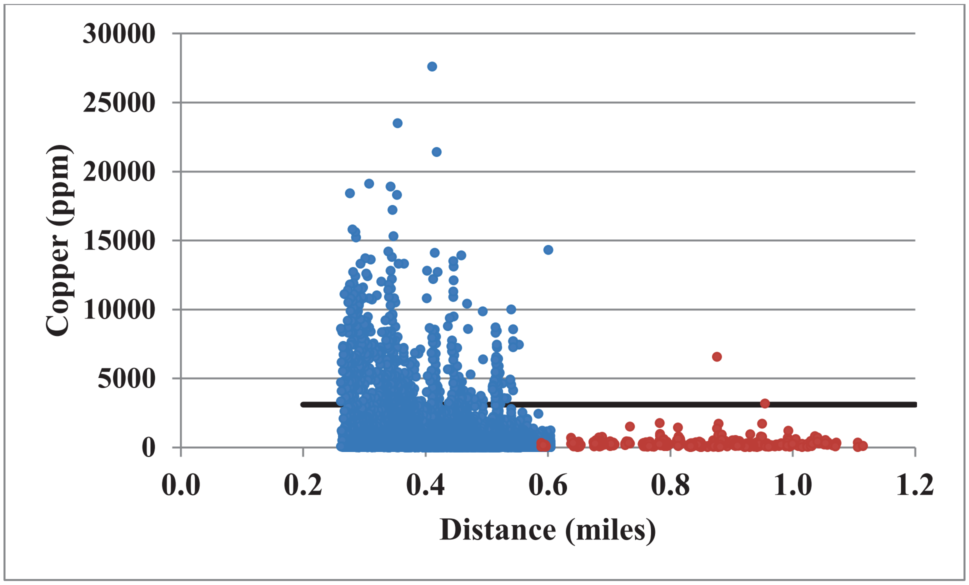
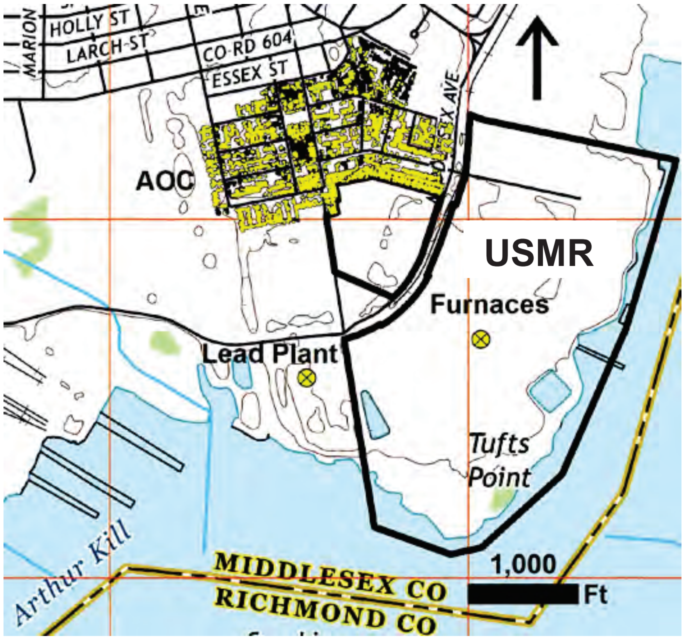


Figure 12. Variation of copper loadings in soil samples taken by USMR and the Plaintiff, including data in the AOC and transects. The horizontal line is the NJDEP cleanup criterion of 3,100 ppm. Transect samples are shown as red dots.



Fgure 13. Occurrence of arsenic exceedances in soil samples taken by USMR in the AOC. Soil samples with metal loadings in excess of 19 ppm are selected.

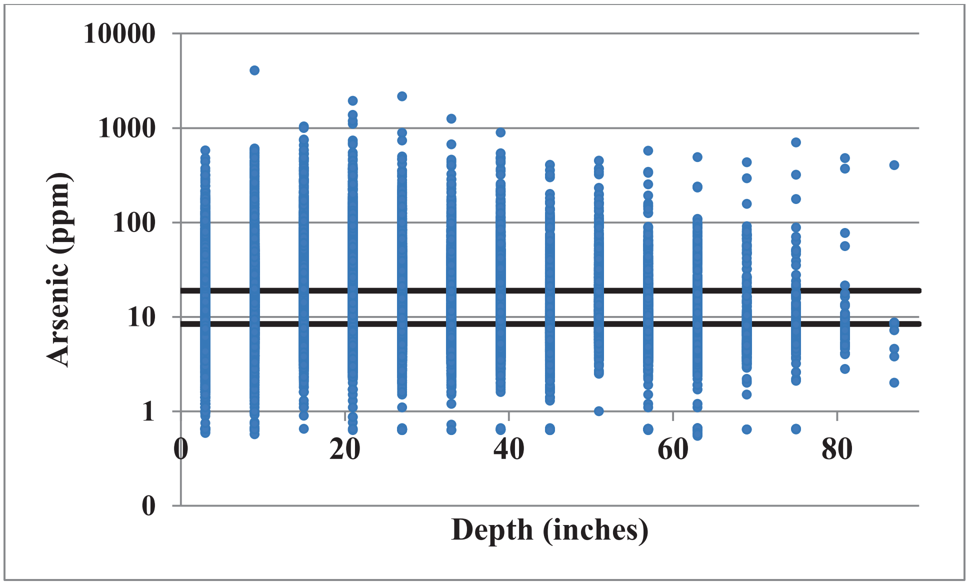
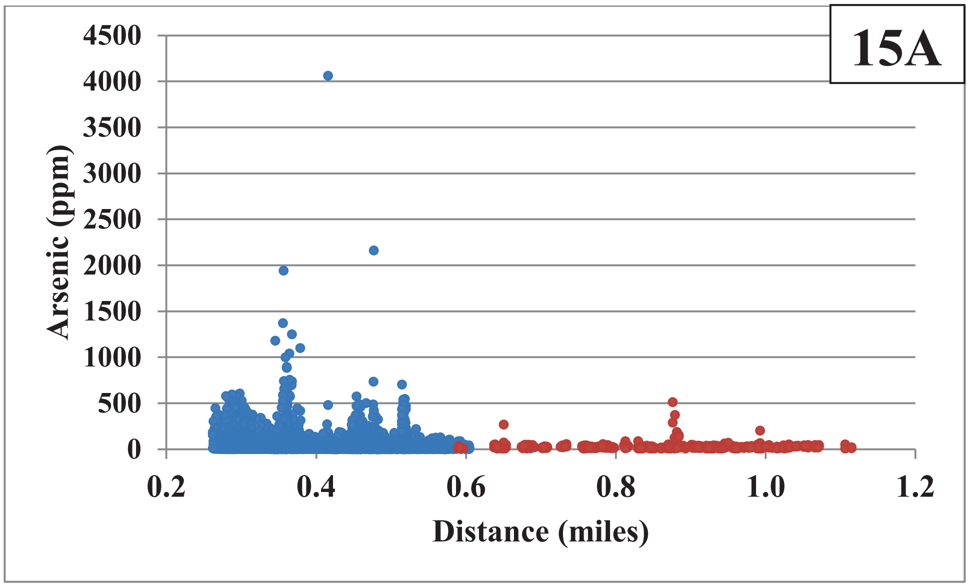


Figure 14. Distribution of arsenic as a function of depth in the AOC. The upper line is the NJDEP SSL (19 ppm), and the lower line is the UCL of the mean background for arsenic (8.4 ppm) in urban Piedmont soils of New Jersey.



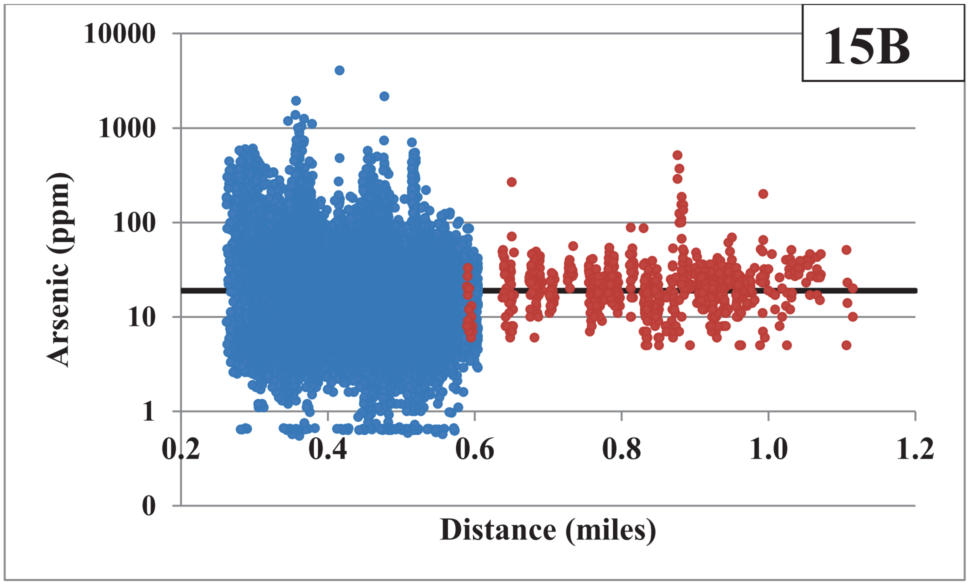


Figure 15. Variation of arsenic loadings in soil samples taken by USMR and the Plaintiff, including data in the AOC and transects. The horizontal line is the NJDEP cleanup criterion of 19 ppm. Transect samples are shown as red dots.

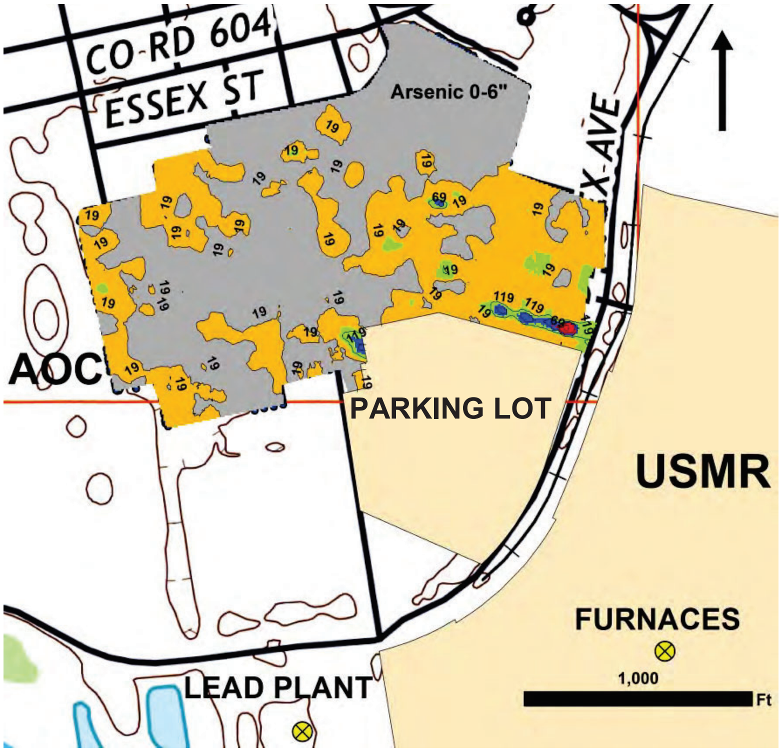


Figure 16. Contour map of the AOC showing the spatial variation of arsenic loadings in soil samples near the surface (0-6”). Note the linear hot spot adjacent to the NE edge of the parking lot.

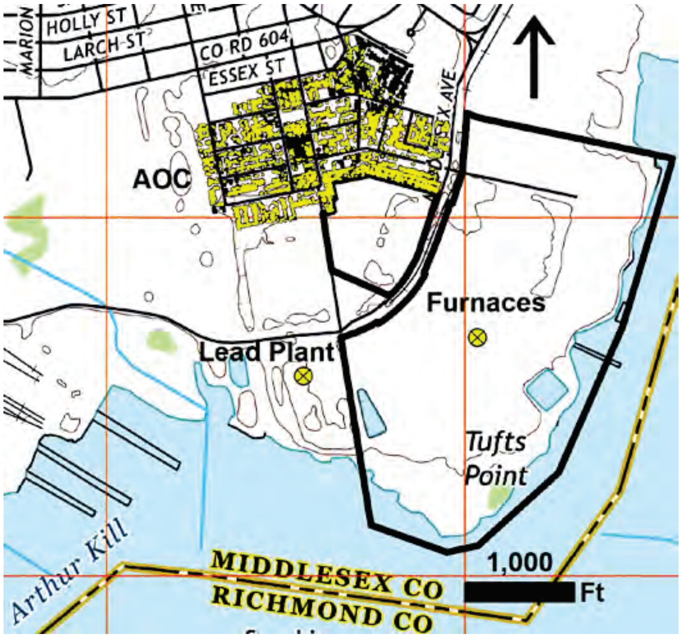


Figure 17. Occurrence of lead exceedances in soil samples taken by USMR in the AOC.   Soil samples with metal loadings in excess of 400 ppm are are selected.

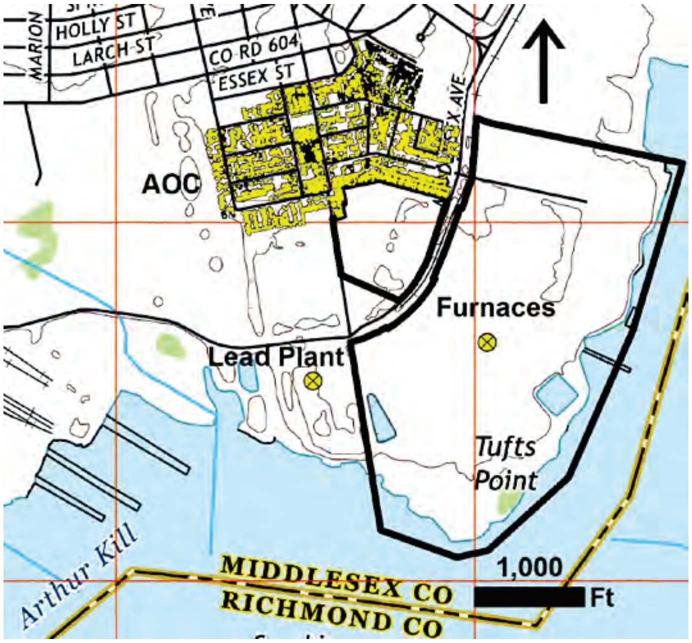


Figure 18. Occurrence of lead exceedances in soil samples taken by USMR in the AOC.   Soil samples with lead loadings in excess of 200 ppm are selected.

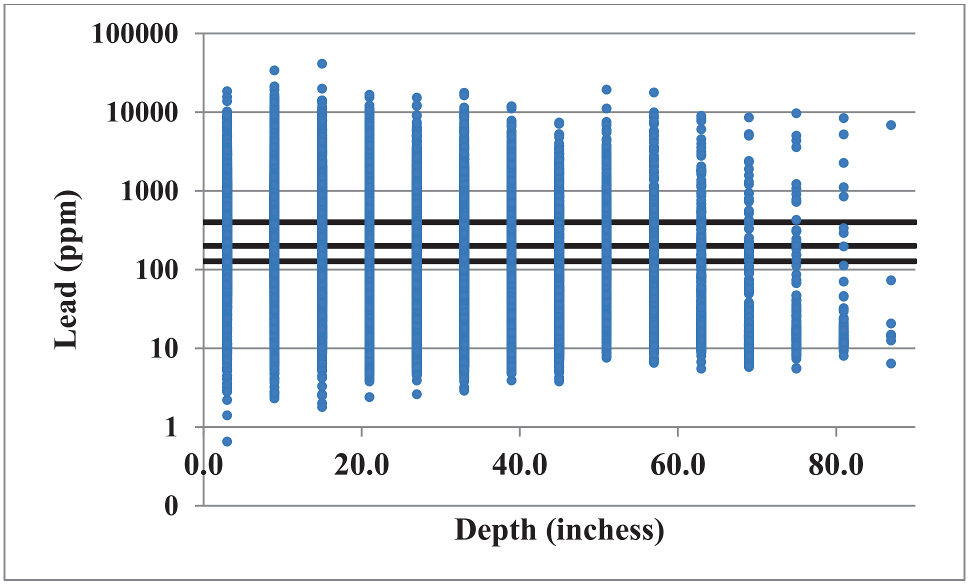
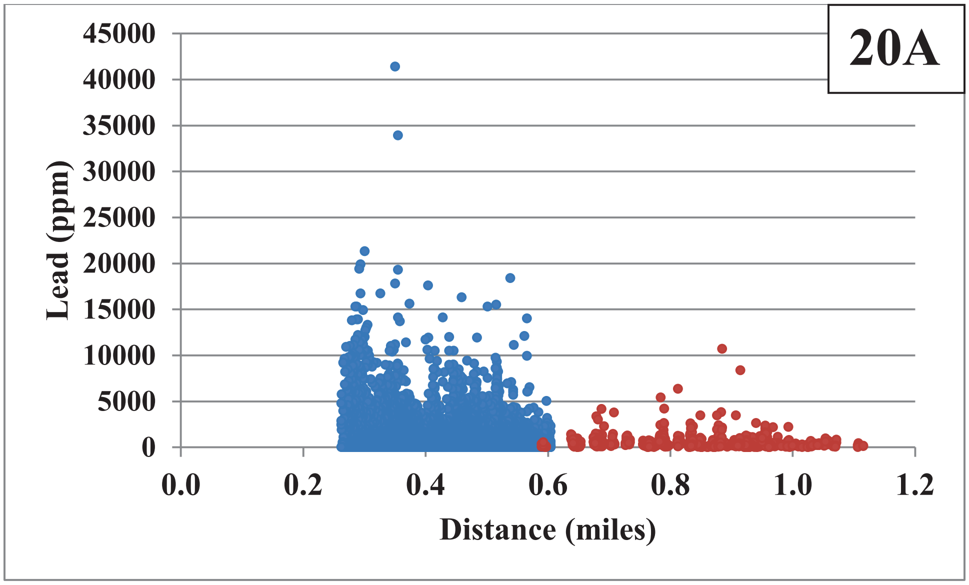


Figure 19. **Distribution of lead as a function of depth in the AOC. The upper and middle lines are SSL's (NJDEP 400 ppm and USEPA 200 ppm), and the lowest line is the UCL of the mean background (128 ppm) for lead in Urban Piedmont soils of New Jersey.**



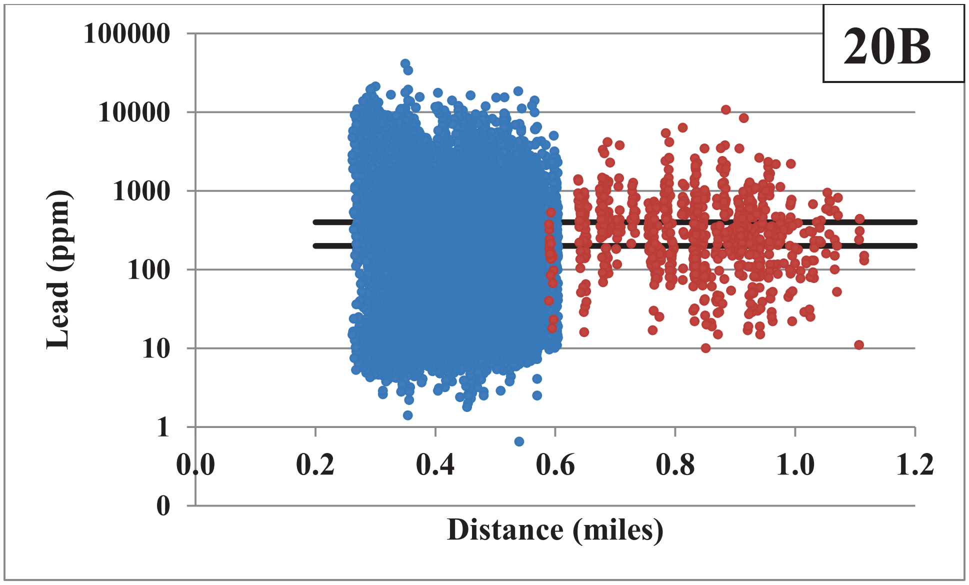


Figure 20. Variation of lead loadings in soil samples taken by USMR and the Plaintiff, including data in the AOC and transects. The horizontal lines are the NJDEP cleanup criteria of 400 and 200 ppm. Transect samples are shown as red dots.

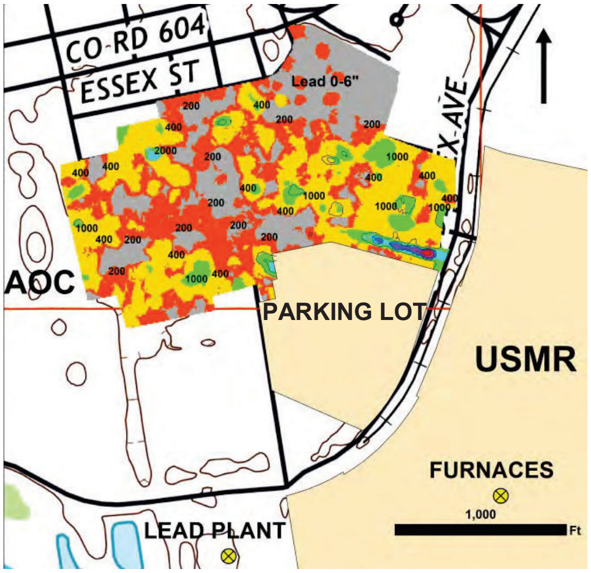


Figure 21. Contour map of the AOC showing the spatial variation of lead loadings in soil samples near the surface (0 – 6”). Note the presence of the hot spot adjacent to the NE edge of the parking lot.

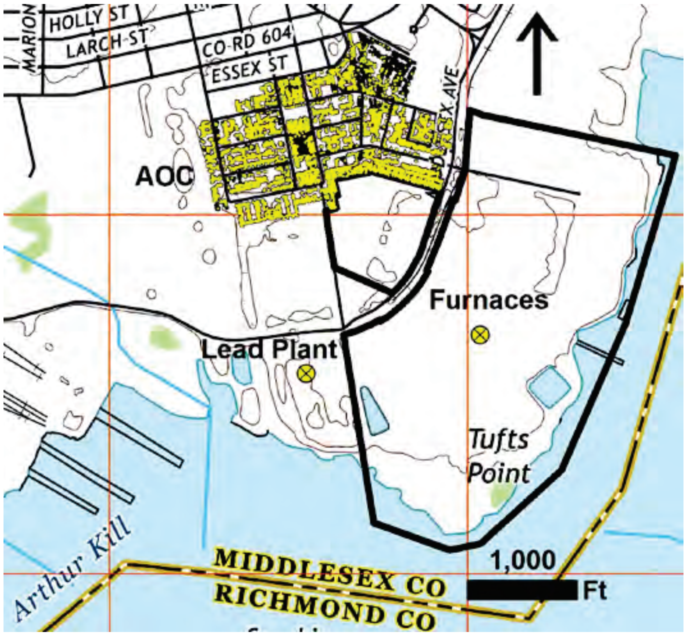


Figure 22. Occurrence of any exceedance in soil samples taken by USMR in the AOC. Soil samples with metal loadings in excess of any SSL given in Table 1 are selected.

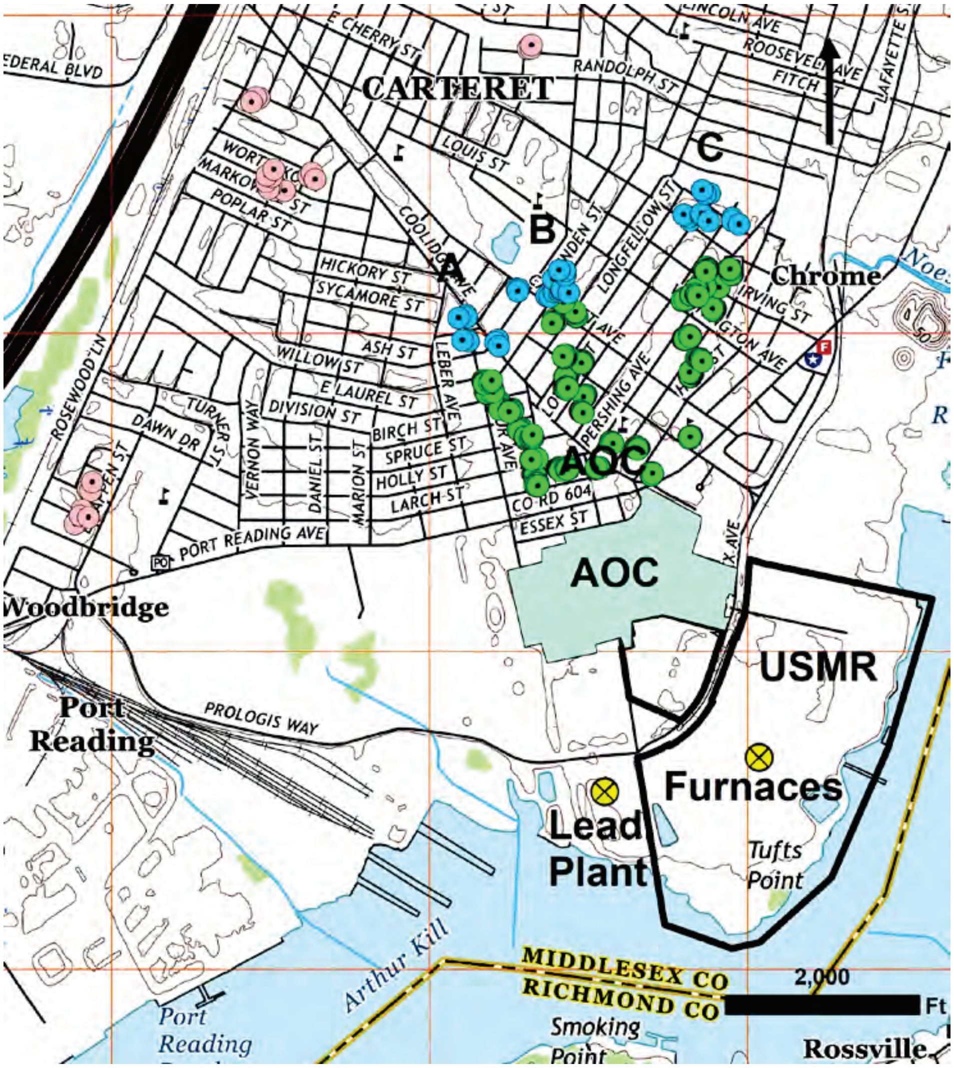


Figure 23. Location map showing Transects A, B, and C, extending outward from the area of intensive sampling and remediation, the AOC. USMR transect samples are shown in green, Plaintiff transect samples are shown in blue, and Plaintiff peripheral samples are shown in pink.

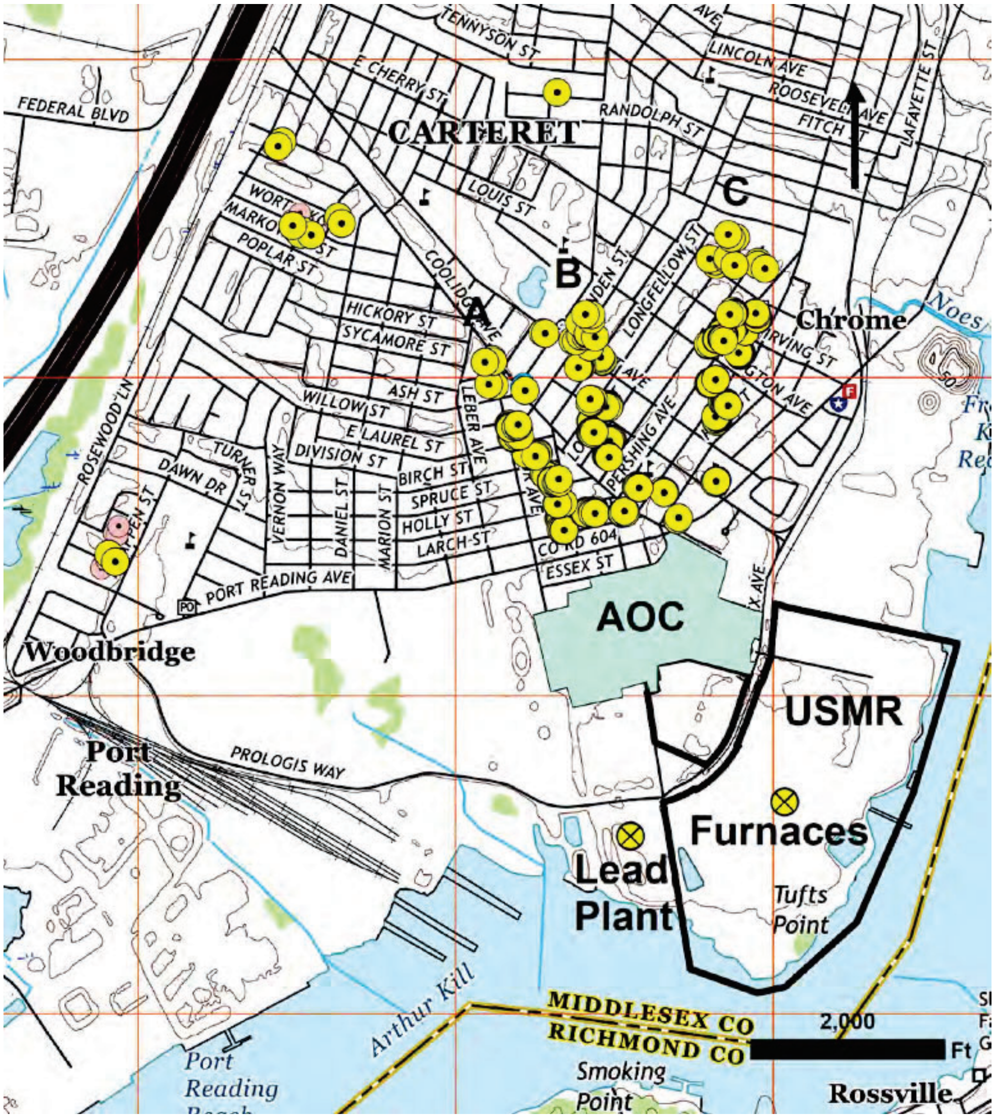


Figure 24. Location map showing any exceedance along Transects A, B, and C (yellow dots), extending outward from the area of intensive sampling and remediation, the AOC. All transect soil samples (USMR and Plaintiff) were considered in the selection. In addition, some peripheral samples from the proposed Class Area are selected.

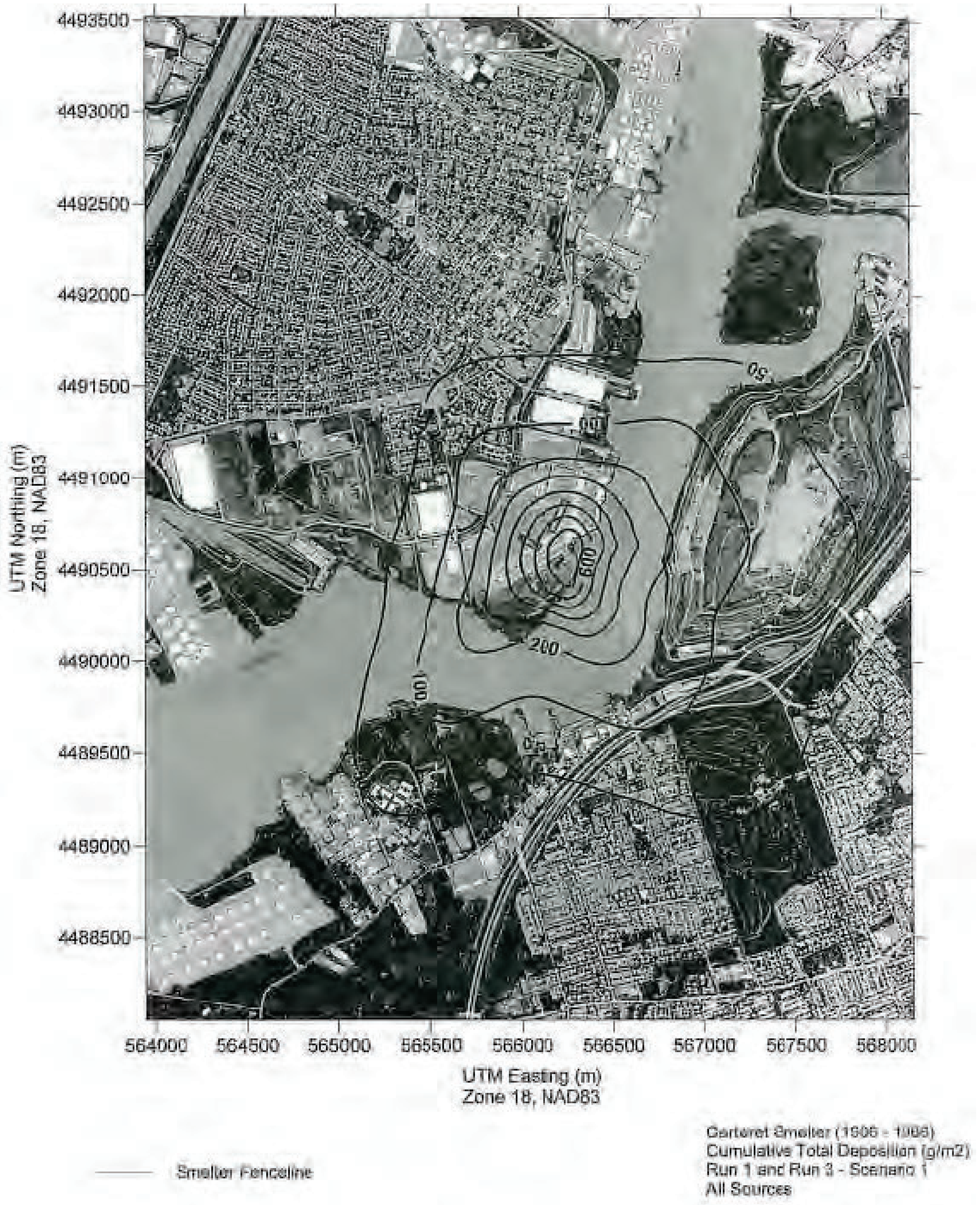


Figure 25. Smelter plume air model (Scenario 1) showing total deposition (g/m^2) due to smelter operations from 1906 to closure in 1986 (McVehil-Monnett, 2018).

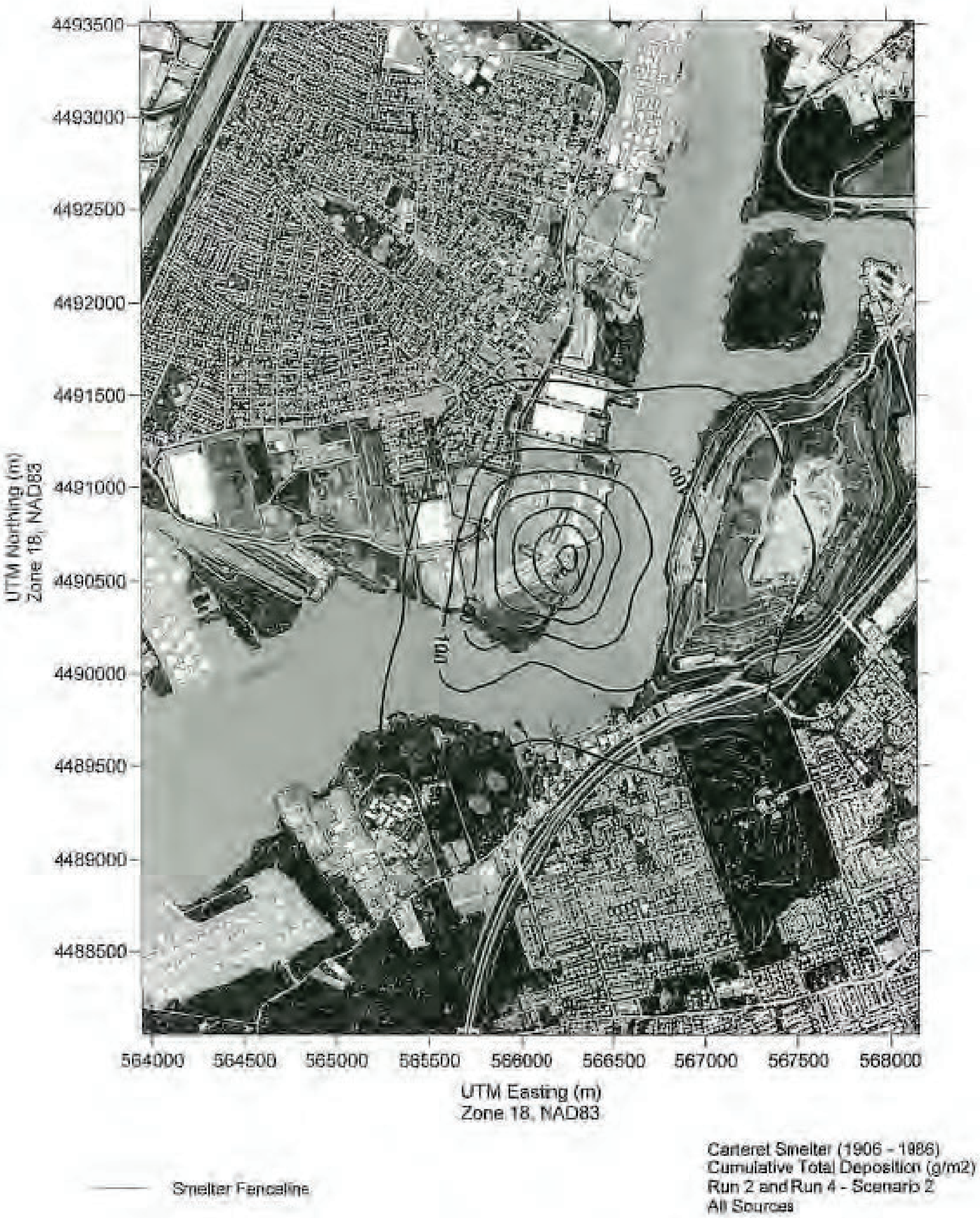


Figure 26. Smelter plume air model (Scenario 2) showing total deposition (g/m^2) due to smelter operations from 1906 to closure in 1986 (McVehil-Monnett, 2018).

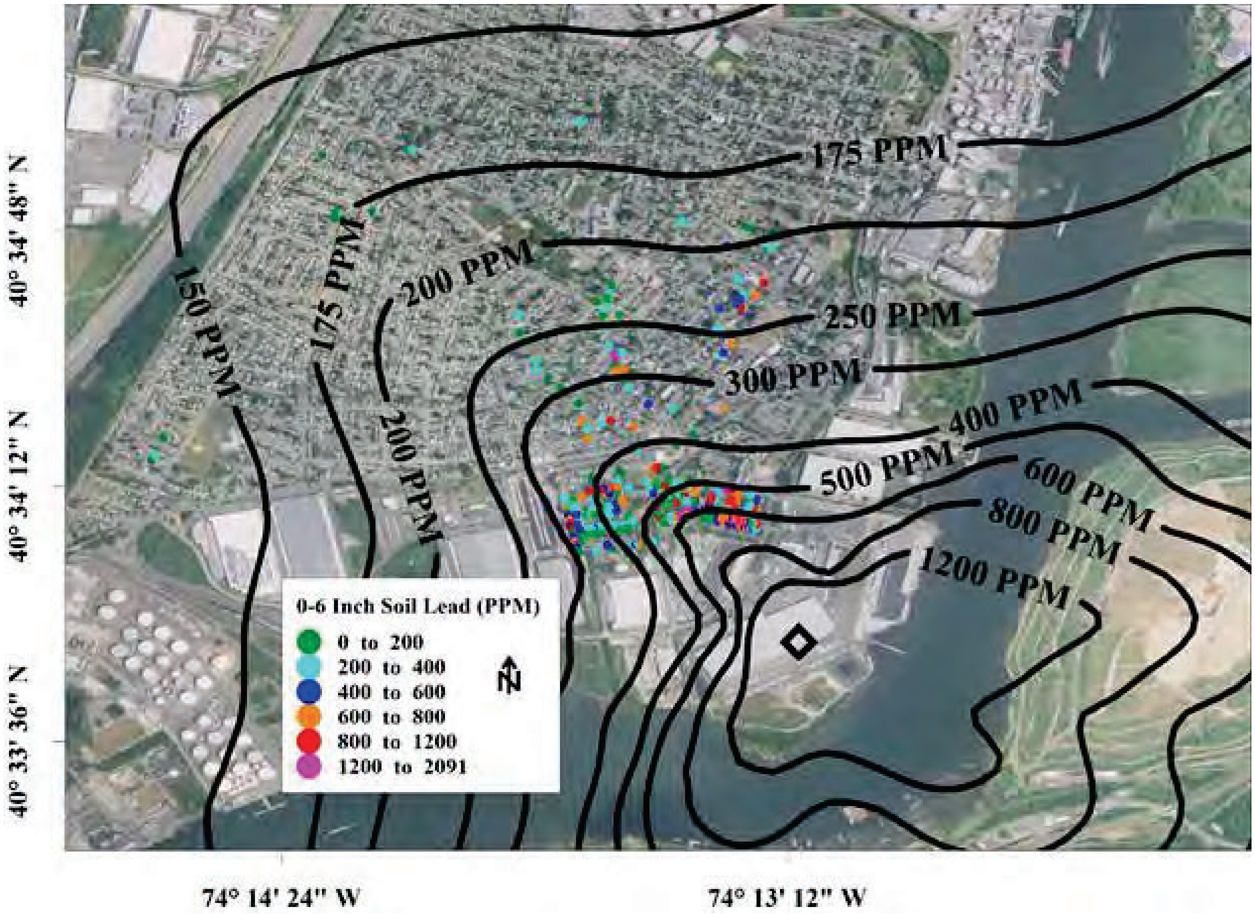


Figure 27. Map showing isopleths of lead loading (ppm) in the upper 6” of soil based air modeling by Sullivan (2019) for Scenario 1.

Figure 28. Proposed Class Area.