

A MODELING TECHNIQUE TO EVALUATE COMMUNITY AND OCCUPATIONAL
AIRBORNE LEAD EXPOSURE IN AND AROUND A PRIMARY LEAD SMELTER

A report to: The National Institute of Occupational
Safety and Health,
R.A. Taft Laboratory,
Cincinnati, Ohio
Request #82-20 DHHS PHS CDC NIOSH.

Project officer: Dr. Phillip Landrigan

Prepared by: Ian H. von Lindern, P.E., Ph.D.
Route 3
Buhl, Idaho 83316

June 30, 1982

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1.0 EXECUTIVE SUMMARY

In this study, a previously developed air quality modeling system was used to evaluate the emissions reductions necessary to simultaneously meet the National Ambient Air Quality Standard for lead (NAAQS) and the Occupational Safety and Health Administration's (OSHA) industrial lead exposure standard at the Bunker Hill Company Lead Smelter in Kellogg, Idaho. That system employs computer-assisted cartographic modeling to empirically relate observed ambient lead and cadmium particulate levels to known emissions estimates. The technique has proved especially effective in evaluating the impacts of fugitive emissions. Fugitive emissions are the primary source of excess lead levels within the smelting complex and have a significant impact on ambient air lead levels in the immediate vicinity of the smelter.

Of the two standards the NAAQS is the more stringent. This is true in both the number of sources that must be addressed and in the level of control that must be instituted to achieve compliance. A Department of Labor study, frequently referred to in this report, found that the majority of excess worker exposures in this plant could be brought into compliance through the institution of certain administrative procedures and available engineering controls. They did, however, find that two plant areas, the Highline (ore preparation plant) and the Blast Furnace, could not achieve compliance without significant process modifications. The primary reason cited in both areas was uncontrolled fugitive emissions.

With respect to the NAAQS there are two overriding factors that influence lead levels in the community. They are severe meteorological conditions and severe emissions excursions. The former are due to complex terrain induced winds and thermal capping phenomena, periods of extended

high pressure, and windblown soils. The combination of the seasonality of these conditions and the NAAQS's quarterly averaging period results in a most stringent standard. The summer control strategy requires reducing low-level smelter emissions and active (storage piles and roadways) and passive (windblown) fugitive emissions outside the complex. The winter control strategy concentrates on mid-level or blast furnace emissions. The net result is that nearly all sources must be reduced significantly at one time or another. Those control measures that will be required for meeting the NAAQS are: 1) elimination of outdoor sinter product storage, 2) institution of road sanitation practices and stabilization of bare contaminated surface soils in some areas, 3) 80-90% reduction in low-level and mid-level point source emissions, 4) a comprehensive control program to minimize upset conditions due to malfunction or startup/shutdown procedures, and 5) 80-85% reduction in Highline Area and Blast Furnace upset uncontrolled fugitive emissions.

Items 1 through 3 can likely be addressed through installation of available control technology. The cost will be significant but would likely be feasible for the smelter during profitable operation periods. Items 4 and 5, however, will require an investment substantially greater than any anticipated for this industry in the foreseeable future. These two sources are the same ones found to make compliance with occupational standards impossible and are the focus of this study in Section 7.

The Blast Furnace upsets must be controlled to have any hope of compliance with either standard. The level of control necessary could be from 60-100% depending on the level of control achieved in the Highline area. The problem in the Highline area is complicated. Add-on technology sufficient to achieve the NAAQS probably exists. However, that would do little to reduce occupational exposures in this area.

The most efficient strategy to achieve compliance with both standards seems to be replacement of the Highline process with modern equipment that effectively eliminates fugitive emissions in this area. This would effect occupational compliance and reduce the blast furnace emission reduction required to around 60%.

There is some uncertainty in the results of this study. The emissions records utilized are outdated and a new inventory collected in 1981 has never been released. Moreover, the smelter is now shut down. Given current metals prices, interest rates, and expenditures discussed in this report it may remain closed.

However, the value of this technique should not be discounted. It has been known for some time that meeting the NAAQS would involve emissions reductions in several source categories and the possible purchase of adjacent property to extend plant boundaries. Considering the NAAQS alone, the most efficient strategy would have been to effect 80% reductions in Blast Furnace emissions, 50-60% in Highline emissions and offset further reductions through property acquisition. By simultaneously considering OSHA requirements, this study shows that the property acquisition and 20% of the blast furnace source reduction would have been superfluous after required industrial exposure reductions were accomplished. The cost would have been significant and would have provided a less efficient solution to the problem. The methodology could be applied to any number of factors having interdependent effects. For example, in the environmental area, hazardous materials risks associated with other metals in the air and contaminated soils could be evaluated in the same context as this study. Other factors such as process efficiency and production increases could be included. Such simultaneous evaluation of environmental concerns

has great promise in finding the most effective solutions and making the most efficient expenditures to correct pollution control problems.

2.0 INTRODUCTION

Lead pollution has been an important environmental issue in the United States for the last decade. A great deal of research was conducted concerning lead in the home, in foodstuffs, the community and the workplace. Evidence of the harmful effects of low levels of lead in children and pregnant women has continued to accumulate. Health problems in workers exposed to high levels of lead has also been documented. Major regulatory programs were enacted in response to this new information. Standards were adopted for the lead content of paints, consumer goods, industrial wastes, gasoline, public air and waters, and in the workplace.

These new regulations have affected the lead industry from the mine to the consumer to the land fill and sewage treatment plant. Among those most severely impacted are the primary producers. The price of complying with new air and water quality and occupational rules will add to production costs. At the same time, manufacturers and consumers are looking for alternatives to lead in their products. This, and current economic problems, has led to a decrease in demand for lead.

Recently, Gulf Resources and Chemical Company of Houston, Texas cited these economic difficulties in announcing the intended closure of the Bunker Hill Company lead/zinc smelter in Kellogg, Idaho. That controversial facility was the principal source of the nation's most severe epidemic of environmental lead poisoning in the mid 1970's. Since that time, the community and the smelter have been the subject of several special studies and the focus of considerable public and political attention.

In an attempt to keep the smelter operating, the administrators of the Environmental Protection Agency (EPA) and the Occupational Safety and

Health Administration (OSHA) issued a joint agreement to suspend any lead related compliance requirements for this facility for five years.

Regional officials of both agencies disclaim any knowledge of the mechanisms or interim measures that might be employed in executing this moratorium. However, Idaho's congressional delegation has assured the public that all health rules will be complied with by the end of the five years. This suggests that, should the smelter restart, some long term compliance schedules will be adopted.

In that event, considerable benefits could accrue if this company were able to concurrently consider public and occupational health expenditures. Many of those sources responsible for excess lead levels in the community environment have also been cited as hazardous in the workplace. Elimination of those sources could benefit both workers and the local populace. This is true, as well, for other primary smelters in this country. The major cause of industrial and community exposures in the near vicinity are in-plant dusting problems caused by fugitive emissions and upset conditions. These sources will have to be corrected to solve either problem. Knowledge of their simultaneous impact and projected necessary exposure reductions, with respect to both standards, can only improve the efficiency of compliance schedules.

However, projecting impacts and exposure reductions for fugitive sources and upsets is extremely difficult. Their erratic and unpredictable strength and behavior makes modeling analyses especially undependable. Moreover, the Silver Valley area surrounding the Bunker Hill Company has several peculiarities that make it a particularly complex modeling problem. Recognizing this, the State of Idaho and the EPA

sponsored a special two year modeling study of lead air pollution in the Silver Valley.

Working at Yale University, Dr. Ian von Lindern, developed and applied a novel analysis technique to this area. Through the use of cartographic modeling and empirically analyzing two years of detailed data, those factors most important in determining lead levels in the area were identified. An empirical dispersion model was then developed and applied to all the lead sources in the Silver Valley. Possible source reduction scenarios for attaining the National Ambient Air Quality Standard (NAAQS) were identified and quantified. Some success was had in modeling and quantifying the long term effects of fugitive emissions and upset conditions. In this study, that model is used to evaluate possible source reduction schemes simultaneously in terms of both the NAAQS and OSHA's occupational standards for primary smelters. The object of this analysis is to determine how much community benefit might be enjoyed by eliminating occupationally hazardous dust problems in the plant and how much that might reduce emission reduction requirements for other sources.

3.0 BACKGROUND

3.1 THE BUNKER HILL COMPANY

The company was first incorporated in 1887 as the Bunker Hill and Sullivan Mining and Concentrating Company. The present name was adopted in 1956. The corporate headquarters and major operations are located in Kellogg, Idaho. The company was locally owned and operated until 1968 when all outstanding stock was acquired by the Gulf Resources and Chemical Company of Houston, Texas. Since that time it has been a wholly owned subsidiary of the Texas conglomerate. For several years the smelting complex was the chief source of revenue for Gulf Resources. The parent company has acquired several other mining and coal interests and the Lithium Company of America, a Virginia based metal producer.

The Bunker Hill Company currently controls or has interest in six mines that produce lead, silver and zinc. The Kellogg complex includes the mines, a mill and concentrator, the lead smelter, electrolytic zinc plant, and a dry chemical fertilizer plant. The Bunker Hill and Sullivan was originally involved only in the mining and concentrating of lead and silver ores from the Bunker Hill Mine. The first concentrator was constructed in 1886. The present concentrator was built in 1912 and has been modernized through the years. Construction of the lead smelter commenced in 1916 and the first blast furnace was put on line July 5, 1917. Prior to that time, local concentrates were sent to the Tacoma smelter in Tacoma, Washington.

The lead smelting process remained essentially the same through 1970 when the down-draft ore roasting operation was replaced by the updraft sintering process and associated sulfuric acid recovery plant. At about the same time the blast furnace was extended to accommodate increased

production rates. In 1977 a 710 foot stack was added to the complex to facilitate pollutant dispersion.

The Bunker Hill Electrolytic Zinc Plant began production in November of 1928. Known then as the Sullivan Mining Company Zinc Plant, it was the first commercial refinery in this country to produce 99.99+% purity zinc. The plant initially had a capacity of 50 tons per day. It was enlarged to 120 tons/day in 1937 and 160 tons/day in 1948. An additional unit was added in 1963 and the plant was finally enlarged to the current 310 tons/day in 1967. Sulfuric acid plants were added to the zinc complex in the early 1950's and 1960's to convert process sulfur dioxide to high grade sulfuric acid for use in the electrolytic process. A 600 foot stack was also added to this plant in 1977.

The total work force of the complex is about 1500 steelworkers, 200 AFL-CIO workers, and 350 salaried personnel. The company operates three shifts per day, seven days per week. Actual production occupies about 300 days per year. The major products are lead, zinc, zinc oxide, cadmium, zinc alloys, silver, antimonial lead, gold doré, copper matte, cobalt, sulfuric acid, nickel, phosphorous acid, and four grades of fertilizer. Approximately 300 workers are currently employed in caretaker positions during the plant closure.

3.2 THE LEAD SMELTER PROCESS

Ores and lead concentrate are imported from around the world. All concentrates are weighed and sampled as they arrive. Lead content is about 65 percent by weight with varying amounts of trace metals, including zinc, cadmium, copper, silver, gold, arsenic, antimony, and bismuth. Table 3.1 contains representative metals content analyses for smelter feed products and concentrates. Figure 3.1 is a materials flow chart for the

Table 3.1

TYPICAL ASSAYS OF LEAD CONCENTRATES AND ORES (*source the Bunker Hill Company)

Material	Source	% Pb	Au oz/T	Ag oz/T	% Cu	% Zn	% Sb	% Cd	% S
Concentrates	B.H. Mine	63.33	.010	43.80	.72	5.93	.43	.03	17.39
Jig Tailings	B.H. Mill	2.50	--	1.36	.03	.85	.04	.01	1.51
Flotation Tailings	B.H. Mill	.83	--	.67	.03	.87	.03	.01	1.99
Zinc Residue	B.H. Zinc Plant	9.88	.094	20.10	.60	17.86	.10	.33	6.40
Zinc Dross	B.H. Zinc Plant	74.51	.008	163.55	.13	1.04	.61	.004	2.14
Scrap Lead	B.H. Zinc Plant	85.00	--	--	--	--	--	--	--
Concentrates	Washington	58.74	.004	1.00	.02	1.68	.02	.01	18.74
"	Mullan, ID	68.57	.045	94.18	1.03	5.47	1.07	.04	14.66
"	Burke, ID	64.20	.003	29.16	.19	10.73	.18	.07	17.10
"	Wallace, ID	64.09	.016	64.03	.66	5.06	.55	.03	14.43
"	Brit. Colum.	60.84	.002	12.88	.01	10.76	.04	.11	19.07
"	Peru	62.55	.185	43.67	.82	5.86	.67	.04	17.00
"	N.W. Terr.	76.25	.007	.08	--	1.99	.03	.01	15.24
"	Nevada	59.02	.005	85.90	.06	8.00	.09	.03	17.14
"	Colorado	47.02	.066	551.65	.43	5.00	.25	.05	14.33
"	Utah	58.46	.007	31.12	.17	13.46	.21	.20	19.39
"	Missouri	74.87	.001	1.52	.88	1.51	.02	.02	15.01

MATERIALS HANDLING AND RECEIVING

CRUDE ORES
LIME ROCK
BY PRODUCTS
RETURN SINTER
SILICEOUS FINE
SHELL AND DUMP SLAG
LEAD CONC.
ZINC PLANT RES.
GRANULATED SLAG

CRUSHER CONE
ADD FINE MILL

STORAGE AND
PROPORTIONING BINS

BEDDING PLANT

PELLETIZING
PLANT

SINTER
PLANT
AREA

SINTER MACH.

RETURN SINTER
TO CHARGE

SIZING
PLANT

BLAST AND
FUMING
FURNACE
AREA

BAGHOUSE

COOLING
TOWER

WASTE
HEAT
BOILER

STEAM TO
PLANT

GRANULATED
SLAG TO STORAGE

SLAG
GRANULATOR

SLAG
FUMING
FURNACE

PULVERIZED
COAL

STRONG
GAS STREAM

SPRAY
CHAMBER
& BAGHOUSE

SULFURIC
ACID
PLANT

ACID TO
FERTILIZER
PLANT

MAIN BAGHOUSE
AND ACID PLANT
AREA

MAIN
BAGHOUSE

GAS TO
ATMOS.

WHEEL
TRATOR

CADMIUM
PLANT

CADMIUM
SPONGE
TO ZINC
PLANT

ELECTRIC
FURNACE

REFINING
AND
CASTING

HARD LEAD
TO MARKET

COKE

B.F. FEED
SYSTEM

BLAST
FURNACE

FUME

SILICA
COAL

Cu DROSS
TO STOR.

BY PRODUCT
REVERB
FURNACE

Cu byproduct
to market

DROSS
KETTLES

SULFUR

SOFTENING
FURNACE

AIR

GOLD
KETTLE

ZINC

SILVER
KETTLE

ZINC
SLAGS

ZINC II

CAUSTIC DROSS
TO CHARGE

VACUUM
DE-ZINC

CAUSTIC
SODA

REFINING K.

SOFT LEAD
TO MARKET

CASTING

REFINERY
AREA

GOLD DORE
TO MARKET

HEATER
FURNACE

CUPEL

PRESS

FINE SILVER
TO MARKET

MONARCH
FURNACE

CUPEL

PRESS

RETORT

ORE
PREPERATION
AREA

ZNO TO
MARKET

Fig. 3.1 Lead Smelter Process Flow Chart

smelter. Figure 3.2 is a map of the study area. It shows monitor locations and the smelter complex. Details of the facility can be found in computer map form in Appendix A. For the purposes of this study, the lead smelter can be divided into six main process areas:

1. Mill and Concentrate Handling
2. Ore Preparation Plant (Highline)
3. Sinter Plant
4. Blast Furnace and Fuming Furnace
5. Lead and Silver Refineries
6. Main Baghouse and Acid Plant

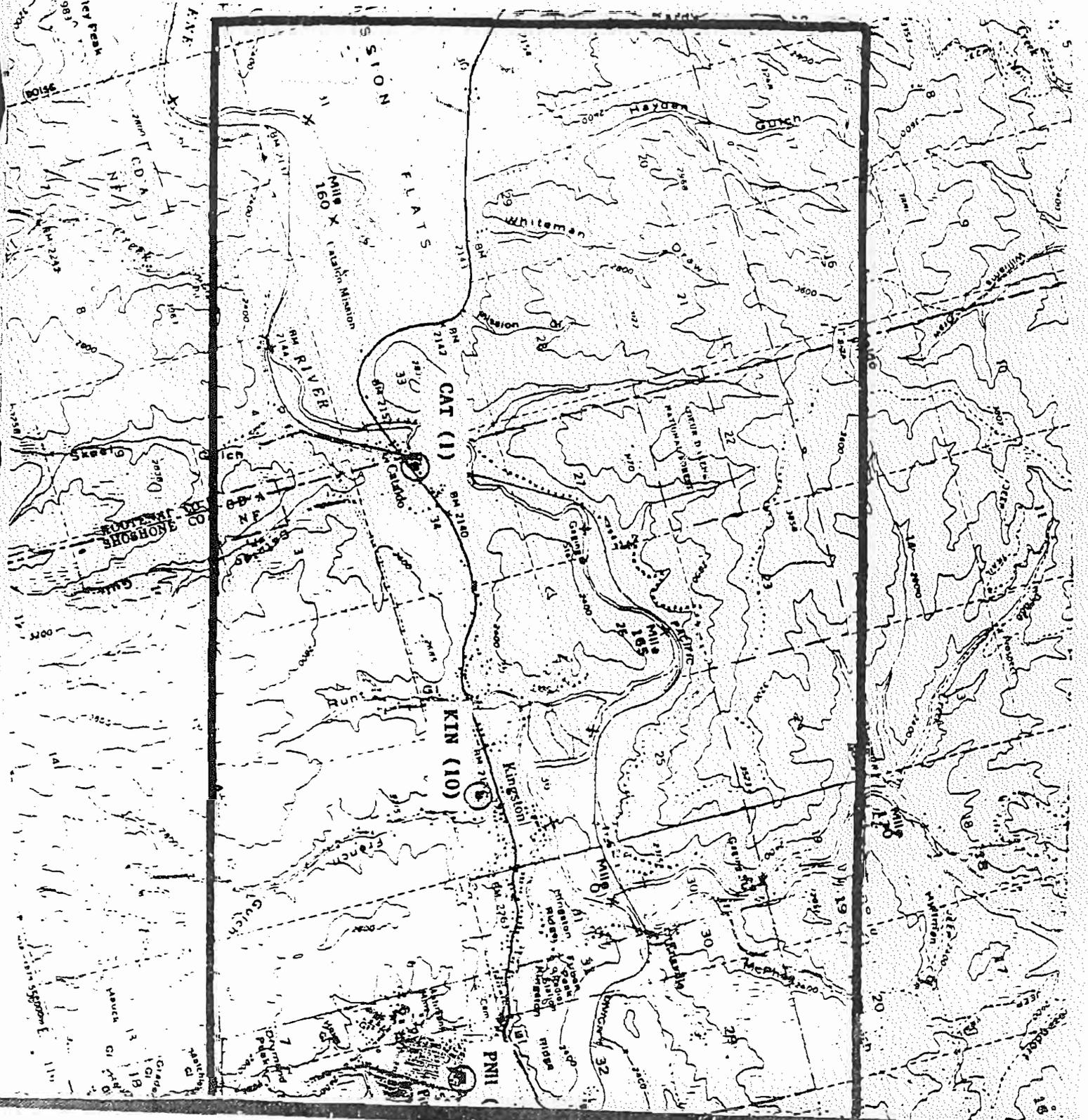
3.2.1 Mill and Concentrate Handling

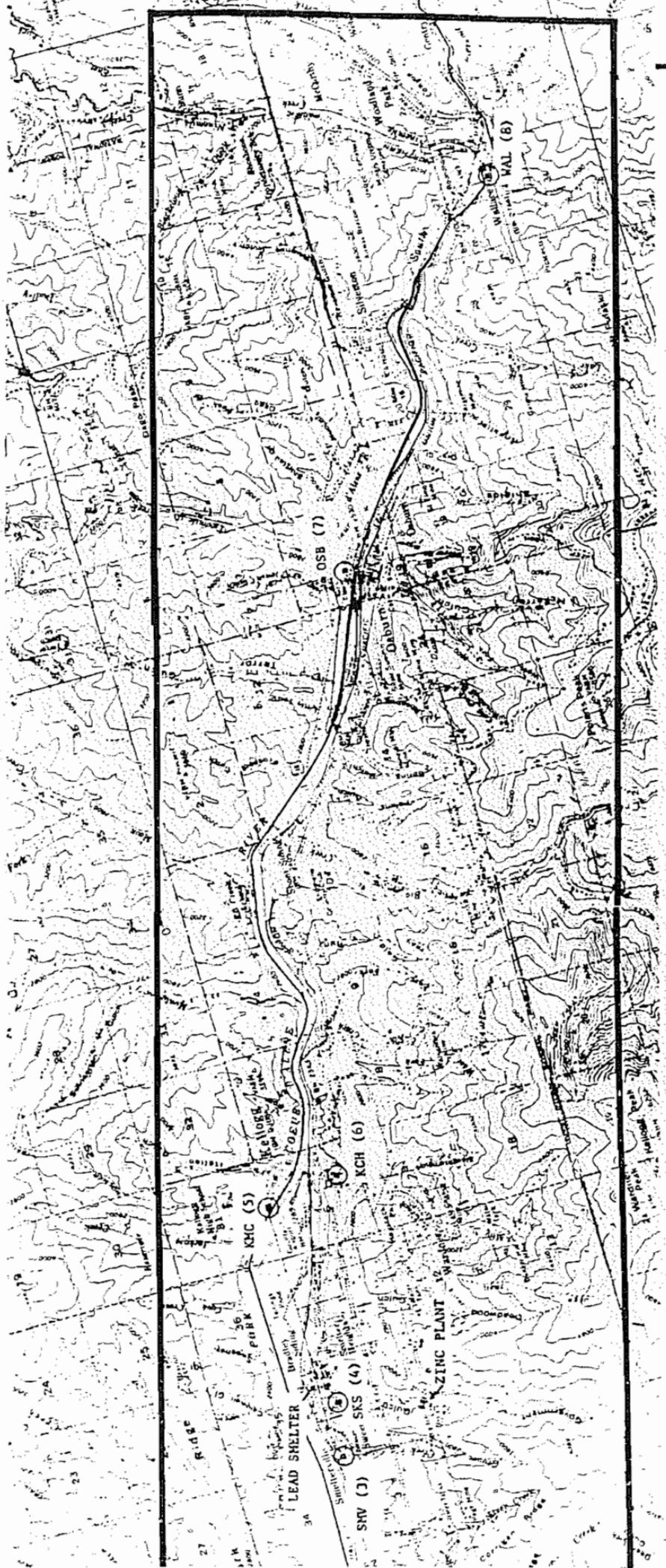
Ores from the mining operation are stored in bins at the crushing plant. They are drawn from storage and crushed in two stages, reducing the material from as large as 12 inches to less than 1 inch. The crushed ore is stored in large bins, where it is drawn from and transported by conveyors to the ball mills. The ball mills contain water and 40 tons of steel balls. They rotate constantly and the crushed ore is pulverized by the tumbling action of the balls to about the size of fine sugar. This material is discharged to a classifier where oversized material is separated from the properly ground ores and is returned to the ball mills. Soda ash, zinc sulfate, sodium cyanide, and sodium isopropyl zanthate are added in the ball mills to condition the ores for flotation. The fine material, 60% minus 200 mesh and 50% solids, is then pumped to the flotation cells.

The material is constantly stirred in the flotation cells by large propellers and air is bubbled through the pulp. The lead bearing materials separate from the remainder and are skimmed off the surface of

Figure 3.2 Map of the Study Area Showing Monitor Locations

<u>Monitor</u>	<u>Symbol</u>	<u>Number</u>
Cataldo	CAT	1
Kingston	KIN	10
Pinehurst	PNH	2
Smeltonville	SMV	3
Silver King School	SKS	4
Kellogg Medical Center	KMC	5
Kellogg City Hall	KCH	6
Osburn	OSB	7
Wallace	WAL	8





the tank as a froth. The remaining solution is further conditioned by adding copper sulfate and lime, and is pumped to the zinc flotation cells where the zinc bearing minerals are removed in a similar process.

Both concentrates are then thickened by settling and the slurry is sent to vacuum filters where the moisture content is reduced to about 7% and 12% in the lead and zinc concentrates, respectively. The concentrated process upgrades ores typically ranging from 5 to 7% lead to about 65% lead, 6% zinc, and 40 ounces/ton of silver in the lead concentrate; and 54% zinc, 1.5% lead, 6 ounces/ton silver in the zinc concentrate.

3.2.2 Ore Preparation Plant (Highline)

Crude ores, limerock, siliceous fluxes, and recycled downstream products are stored together with the concentrates in bins at the ore preparation plant. The concentrates, crusher products, zinc plant residues and granulated slag are proportionately combined and thoroughly mixed mechanically on the floor of the bedding plant. This mixture is then pelletized and carried by conveyor belt to the sinter plant. These silt-like materials are readily suspendable and the Highline Area is a significant source of fugitive emissions. Materials handling transfer points and building fans are the chief sources of background particulates in the general plant area and indoor lead levels in the ore preparation plant are serious occupational exposures. The pellet drying operation is a significant point source of particulate pollution. Emissions from this area are generally about 30% lead in a sulfide form.

3.2.3 Sinter Plant

Pyrometallurgical treatment begins at the sinter plant. The pelletized mixture is fed to the sinter machine as a continuous bed on a large metal conveyor. After igniting the bed with natural gas the sulfur

in the ore burns off in a high temperature, self-sustained combustion reaction. After all the sulfur is consumed the sinter product continuously falls off the end of the sinter machine conveyor. This material, called sinter, is transported to the sizing building where the fines are collected and returned to the crushing plant. The sinter resembles furnace clinkers and are formed into an agglomerated porous mass necessary for proper blast furnace operation. Chemically, most of the lead has been transformed from lead sulfide to lead oxide. Sinter is about 60% lead by weight.

Sinter is stored in bins inside the plant and in large piles outside the plant. This is a brittle and abrasive material. Fines production and particulate emissions are associated with the combustion process. Handling the return fines has, in the past, been a severe source of both indoor and general plant exposures. Although there has been considerable improvement in the sinter plant over the last few years, background lead levels remain high.

3.2.4. Blast Furnace and Fuming Furnace

The blast furnace is a large water-jacketed chimney. Sinter and metallurgical coke are continuously fed into the top of the column. Oxygen enriched air is blasted through tuyers, or ports, located near the bottom. This air supplies the oxygen necessary to burn the coke that, in turn, melts the sinter and also provides the carbon to reduce the lead oxide to metallic lead. The molten lead flows to the bottom of the furnace where it is continuously tapped off as bullion. The lighter slag floats to the top and is intermittently tapped and stored in large pots. This slag is rich in zinc that is recovered in the zinc fuming furnace. The large pots of still molten slag are periodically charged with air and

coal to the fuming furnace. The high temperature volatilizes the zinc and the vapor is oxidized in the top part of the furnace. This fume is then rapidly cooled and the condensed zinc oxide is captured in a baghouse and sold as a by-product.

The blast furnace-fuming furnace area is a large source of fugitive particulate emissions. The smelter's worst single source is, undoubtedly, the blast furnace upset. Often times the molten sinter mass agglomerates in the blast furnace and seals off the column. Gases accumulate under this mass and finally burst through with explosive force. This situation is called a "blowhole" and resembles a volcanic eruption. The gases carry particulate matter and metallic fume out of the top of the furnace around the containment hooding and into the building and out the roof vents. "Blowholes" occur sporadically and result in severe air lead levels in both the plant and the community. There are also significant fugitive emissions associated with feeding the blast furnace and charging the fuming furnace. Blast furnace emissions are about 60% lead in an oxide form. Fuming furnace emissions have a low lead content (<5%).

3.2.5. Refineries

The molten bullion is transferred to the lead refinery by an overhead crane. It is cooled to partially remove impurities such as sulfur, arsenic, zinc, antimony, nickel and other elements as a surface dross. Copper is then removed by adding sulfur and skimming the rising dross. These drosses are then smelted in the reverberatory furnace and the matte is sold to copper refineries. The lead bullion is then pumped through a continuous softening process where antimony and arsenic are oxidized and removed as a surface skim. This skim is stored for an annual campaign of electric furnace treatment to produce antimonial or hard lead.

Zinc metal is then added to the lead in two steps: first for the removal of gold and second for silver. Both are collected as cooling dross and sent to the silver refinery for recovery. There the zinc is removed by retorting and the lead by cupelation. The silver is cast and sold as 99.99% pure. The gold is captured in a silver-gold alloy called doré metal that is sold to refineries.

The lead bullion is subjected to a vacuum dezincing process where residual zinc is evaporated from the lead and redeposited in metallic form on a condenser. Finally, sodium hydroxide is added to remove the last traces of impurities and corroding lead (99.98% pure) is cast for marketing in 100 pound pigs, 25 pound sectioned ingots and one ton blocks.

In comparison to the Highline Area, the Blast Furnace, and the Sinter Plant, the Refineries have little fugitive emissions that impact the community. Certain job titles have significant occupational exposures but none as great as some other plant areas.

3.2.6. Main Baghouse and Acid Plant

The majority of process off-gases produced in the plant are routed to those two facilities. Combustion gases from the sinter machine are collected in two streams. The strong gas sinter stream is collected from the area of the sinter machine where most of the sulfur is burned. This stream is rich in SO_2 . The stream is cleaned of extraneous particulate matter in a baghouse and then sent to the Acid Plant where the SO_2 is catalytically converted to sulfuric acid. This acid is utilized in a commercial fertilizer plant. The weak stream from the sinter machine is sent to the main baghouse along with several off gas streams from the blast furnace and refinery areas. These gases are filtered of particulate

matter at the baghouse and are exhausted to the atmosphere. The particulate matter collected is rich in metals and is returned to the process in the Highline Area. Little fugitive emissions are associated with these facilities under normal operations. However, because most of the pollution gas streams are routed to the main baghouse, upsets in this area can result in enormous particulate emissions.

4.0 SOURCE IDENTIFICATION AND EMISSIONS EVALUATION

4.1 GENERAL

There are several sources of lead to the atmosphere in the Silver Valley. These sources vary in magnitude, frequency, chemical constituency, and configuration. Some categorization scheme is necessary for purposes of discussion and analysis. Developing reasonable source categories requires certain knowledge of the different sources' behavior and the responsible environmental and industrial processes. The mill and smelter processes and their associated air pollution problems were discussed in detail in Section 3. There are, however, sources of lead from outside the smelter that were considered in the model formulation.

Lead/zinc ores have been mined in several locations in the Silver Valley for nearly one hundred years. All currently active mines are east of the smelting complex. Galena (PbS) is the predominant lead ore. The ore is concentrated by wet-chemical milling processes near the mines. Both lead and zinc concentrates are produced in flotation processes similar to that described for the Bunker Hill Company. Concentrates are typically 60% metal in the sulfide form and are the consistency of coffee grounds. They are transported to their respective smelters by rail in wet form.

Direct air pollution from these activities is insignificant. The milling operations are wet and the material is transported before it dries. Concentrates spilled on the roadways constitute an active source of heavy metal particulate after drying. Other residual aspects of the milling operations can have certain air quality effects. Large quantities of tailings containing significant amounts of heavy metals are produced by the milling operations. Currently these tailings are stored in large ponds. The dikes of these ponds are usually made of dried tailings.

These metal-laden, low pH, fine sandy materials are not conducive to vegetation, and the dikes and abandoned ponds can be significant sources of reentrained fugitive dusts.

In the first eighty years of mining, tailings were discharged directly into the river or dumped at convenient locations. Periodically, the river would flood and deposit the waste material on the valley flood plain. These silts are also a source of particulate reentrainment. Tailoring sands are typically 1 to 4% lead by weight. Also, years of sulfur dioxide abuse resulting from smelting activities have denuded most of the hillsides in the vicinity of Kellogg. At the same time, huge quantities of air transported metals have been deposited on these same soils. Levels as high as 2.5% lead are observed in some barren areas. Reentrainment of these materials is a significant atmospheric lead source.

All of these sources and all known industrial in-plant and off site air lead emissions are considered in the model development discussed in Section 5 of this report. Those sources known to impact the ambient air in the community are discussed and characterized in Section 4.2. The community impact aspects of occupational environment are discussed in Section 4.3.

4.2 ENVIRONMENTAL AIR LEAD SOURCES

Community directed air pollution sources are first separated into the gross regulatory categories, point sources and fugitive sources. Point sources are defined as controlled sources that emanate from stacks or equivalent devices. Fugitive sources are all those sources that are not classified as point sources. Four sub-categories of fugitive sources, based on the source's suspension energy, have been developed for these analyses. They are (1) process fugitive sources that are attendant to and

derive their suspension energy from industrial processes, (2) active fugitive sources associated with gross materials handling in industrial areas, (3) active emissions arising from transportation activities, and (4) passive fugitive emissions that are reentrained by the wind. All of the sources in the valley were located on computerized maps prepared especially for these analyses. These maps are presented and discussed in Appendix A. References to the appropriate maps are made in this section.

4.2.1 Point Sources

All point sources in the valley are inventoried by the NEDS classification system designation number. Table 4.1 shows the source characteristic information available for the 32 point sources identified. The variables in that table are as follows:

NEDS--The National Emission Data System identification number

UNIT--identifies the associated industrial process unit (i.e., 1 crushing plant, 5 sinter or Lurgi operation)

PBFR, CDFR--percent lead and cadmium, respectively, in the particulate emission

EXITVEL--exit velocity of the stack emission (m/s)

STHGHT--physical stack height above ground (m)

STDIAM--physical stack diameter (m)

EXITTEMP--stack gas exit temperature ($^{\circ}$ K)

VOLFLOW--stack gas volumetric flow rate (m^3/s)

YROPCT--percent of annual operation time

NAME--emission point name

PSNUM--point source identification number

With the exception of the last variable, these data were gathered from previous reports of PEDCo (1975), Valentine and Fisher (1975), PES (1978), and EPA (1975a,c). The last variable, PSNUM, is a categorization variable

Table 4.1 Point Source Inventory Information

OBS	UNIT	NEDS	PDFR	CDFR	EXITVEL	STIGHT	STDIAH	EXITTEMP	VOLFLOW	YPROPCT	NAME	PSNUM
1	1	2	31	0							Crushpl Dryer	1
2	1	3	31	1						50	Crushpl Collect	1
3	1	4	31	1						50	Crushpl Rodmill	1
4	1	5	31	1		3.1		289	6.63	50	Crushpl Baghouse	1
5	2	6	31	1		9.8		291	3.70	80	Oreprep Baghouse	2
6	3	7	31	1		24.8		310	9.93	75	Pellet Dryer	3
7	5	8	45	1	5.20	6.1	1.07	294	4.72	75	Lurgi D Scrubber	4
8	5	9	45	1		3.0		297	1.66	100	Lurgi N Rotoclon	4
9	5	10	45	1	10.50	6.1	1.07	294	9.45	75	Lurgi B Scrubber	4
10	5	12	45	1	10.90	6.1	3.14	312	84.46	85	Lurgi A Scrubber	4
11	5	11	45	1	10.50	6.1	1.07	294	9.45	75	Lurgi C Scrubber	4
12	7	16	5	1	10.90	53.4	3.14	312	84.46	85	ZN Fume Main St.	5
13	7	17	5	1	10.90	24.4	0.91	344	7.08	85	ZN Fuming Gran	6
14	8	32								85	Pbreein Scrubber	7
15	8	1				9.1		292	4.32	75	Reverb Baghouse	7
16	9	15				19.8		323	1926.00	11	EF Gran Scrubber	7
17	11	1	55	7	14.30	217.9	4.15	327	193.10	100	Smelter Main St.	8
18	20	18	10	1	9.00	186.0	1.83	311	23.62	50	Zinc Main Stack	9
19	21	33	10	1							Concent Dryer	10
20	21	19	10	1							Concent Silo	10
21	22	22	20	1							Rosconv Scrubber	11
22	23	25	10	1							Meltdrs Scrubber	11
23	23	23	10	1							Rodross Baghouse	11
24	23	20	20	1	2.07	18.3	0.76	472	0.94		#1Wedge Scrubber	11
25	24	21	10	1							Residue Dryer	12
26	25	28	5	1							Scrap Furnace	12
27	25	26	5	1	17.90	6.1	0.46	30	1.32	0	#3Melt Scrubber	12
28	25	27	5	1							#2Melt Scrubber	12
29	26	24	5	1							ZN Pure Baghouse	12
30	31	30	0	0	20.60	13.4	0.91	347	14.17		AHP Reactor	13
31	32	29	0	0							AHP Dryer	13
32	33	31	0	0							Doyle Reactor	13

* variables defined on page 26

developed for the purposes of this study. It is explained in a later section of the report. Point sources are located on the Map PTSOURCE in Appendix A.

4.2.2 Process Fugitive Sources

These are pollutants that escape to the atmosphere from industrial processes. They may be leaks, vents, and overflows from production and pollution control equipment or buildings. They may escape from uncontrolled portions of processes exposed to the atmosphere, such as conveyor belts or by-product dumps. Many of these fugitive sources are attendant to the processes and exhibit regularity in their location and strength (e.g., building fans). Others, particularly leaks and overflows associated with process upset conditions and malfunctions, are erratic in both frequency and magnitude.

Process fugitive particulate sources were identified and mean emission rates were estimated in previous studies (PEDCo, 1975c; Valentine and Fisher, 1975; PES, 1978; PEDCo, 1979). Those sources have been identified in Table 4.2, together with percentage lead and cadmium components measured in the same surveys.

All industrial process-related lead sources were combined in categories for later analyses. Those sources and mean emission rate estimates and rankings can be found in Table 4.3. This table represents the best estimates for comparing industrial sources that could be developed with the available data. It was developed from information collected between late 1974 and early 1979 and some updating may be required.

Table 4.2 Process Fugitive Sources Ordered by Lead Source Strength

Name	EMR	PBFR	CDFR	PBEMR	CDEMR
Blast furnace	30.00	61	9	18.3000	2.7000
OPP exhaust fans	34.00	31	1	10.5400	0.3400
ORE con exhaust fans	25.00	34	1	8.5000	0.2500
Cast roof fans	12.40	31	1	3.8440	0.1240
PB ref roof vent	6.70	37	1	2.4790	0.0670
Elec Fur roof	4.30	10	0	0.4300	0.0000
Sinter prod dump	0.54	31	1	0.1674	0.0054

EMR--total particulate emission rate, lb/hr; PBFR--percentage lead in emission; CDFR--percentage cadmium in emission; PBEMR--lead emission rate, lb/hr; CDEMR--cadmium emission rate, lb/hr.

4.2.3 Active Fugitive Sources

These sources are varying and intermittent pollutant sources whose suspension energy is provided by agents other than steady state industrial processes. They may be industrial sources related to activities such as stockpiling, truck and train loading and unloading, or materials handling. They may be related to land use such as ground working, construction, or surface mining. Or they may be related to transportation sources such as reentrainment by vehicular traffic, from open carriers, or mobile source combustion emissions. They are distinguished from the previous category in that their frequency and magnitude are not attendant to industrial processes in the steady state time frame, and from the following category in that their suspension energy is independent of kinetic meteorological factors.

Table 4.3 Point Source Category Components and Lead Emission Rates (EMR)

I. Smelter Low-Level Sources				
NEDS	Name	Mean Lead EMR lb./hr.	% of Category	EMR Rank
2	Crushing Plant Dryer	3.4	6	6
3	Crushing Plant Collector	.4	1	12
4	Crushing Plant Rodmill	.4	1	13
5	Crushing Plant Baghouse	.4	1	14
6	Oreprep Baghouse	.3	1	16
8	Lurgi D Scrubber	1.4	2	10
9	Lurgi N Rotoclon	16.0	28	1
10	Lurgi B Scrubber	4.1	7	4
11	Lurgi A Scrubber	3.4	6	5
12	Lurgi C Scrubber	2.7	5	7
17	Zinc Fume Granulator	1.8	3	9
32	PB Refinery Scrubber	---	0	--
15	Electric Furnace Scrubber	---	0	--
FUG	Oreprep Exhaust Fans	10.5	18	2
FUG	Ore Conc Exhaust Fans	8.5	15	3
FUG	PB Refinery Roof Vent	2.5	4	8
FUG	BF Roof Vents	.9	2	11
FUG	Electric Furnace Roof	.4	1	15
FUG	Sinter Product Dump	.2	1	17
Total Low Smelter PB EMR		57.3		

II. Smelter Mid-Level Sources				
NEDS	Name	Mean Lead EMR lb./hr.	% of Category	EMR Rank
7	Pellet Dryer	8.0	24	2
16	Zinc Fume Main Stack	2.3	7	4
FUG	Blast Furnace	18.3	54	1
FUG	Casting Roof Fans	3.8	11	3
FUG	Fuming Furnace Roof	1.3	4	5
Total Mid Smelter PB EMR		33.7		

Table 4.3 Continued

III. Smelter High Level Sources

NEDS	Name	Mean Lead EMR lb./hr.	% of Category	EMR Rank
1	Smelter Main Stack	43.0	100	1

IV. Zinc Plant Low-Level Sources

NEDS	Name	Mean Lead EMR lb./hr.	% of Category	EMR Rank
33	Concentrate Dryer	.02	1	5
19	Concentrate Silo	0	0	--
22	Rosconv Scrubber	0	0	--
25	Melt DRS Scrubber	.07	3	4
23	Rodross Baghouse	.02	1	6
20	#1 Wedge Scrubber	1.36	67	1
21	Residue Dryer	0	1	7
28	Scrap Furnace	.07	3	4
26	#3 Melt.	.37	18	2
27	#2 Melt.	.11	5	3
24	ZN Pure. Baghouse	0	0	--
Total ZN Plant Low Level		2.02		

V. Zinc Plant High Level Sources

NEDS	Name	Mean Lead EMR lb./hr.	% of Category	EMR Rank
18	Zinc Plant Main Stack	2.28	100	1

VI. Ammonium-Phosphate Plant Sources

NEDS	Name	Mean Lead EMR lb./hr.	% of Category	EMR Rank
31	AMP Reactor	0	---	--
32	AMP Dryer	0	---	--
33	Doyle Reactor	0	---	--

Active Sources (Industrial)--Particulate fugitive sources were identified in the same surveys cited in the process fugitive discussion. Similarly, mean emission rates and chemical constituencies were estimated in those studies. These sources are identified in Table 4.4. They can be located on Map ACTIVES in Appendix A.

Table 4.4. Active Fugitive Source Characteristics

Name	MapID	EMR	PBRF	CDFR	PBEMR	CDEMR
Silica slag pile	73	17.8	5	0	0.890	0.000
Sinter storage	45	1.6	42	1	0.672	0.016
Slag storage	33	20.2	2	0	0.404	0.000
State highway piles	74	30.3	1	0	0.303	0.000
Sinter storage	49	0.4	42	1	0.168	0.004
Coke storage	45	0.6	0	0	0.000	0.000

EMR--total particulate emission rate, lb/hr; PBRF--percentage lead in emission; CDFR--percentage cadmium in emission; PBEMR--lead emission rate, lb/hr; CDEMR--cadmium emission rate, lb/hr.

Active Sources (Transportation)

Each of the roads identified in this study was characterized as paved, unpaved, or dusty paved. Annual vehicle miles traveled (VMT) for each road were obtained from previous reports and traffic studies (PEDCo, 1975c; PES, 1978; State of Idaho, 1974a). Emission Rate Factors developed by the EPA as described in PEDCo (1975c) were then applied to get per unit distance emission rates for these roads. Both road dust and gasoline combustion factors were included. All roads included in this study can be found in Appendix A map ROADS.

Active Sources (Urban)--Urban active fugitive source strengths were considered to be proportional to the traffic volume on city streets. The total VMT estimates for each city were obtained and proportionately allocated over the area of the community. No absolute estimates of emission rates were determined for the last two sub-categories as they were treated proportionately in later regression analysis correlating these estimates to observed concentrations. The details may be found in von Lindern 1980b. However, these sources are located on the Maps TOWNS and ROADS in Appendix A.

4.2.4 Passive Fugitive Sources

These sources are reentrained by the wind. They include open areas of bare soil and exposed industrial areas. Their magnitude depends on wind speed and direction and surface conditions. The air quality aspects of these sources have attracted significant attention in recent years due to the need for predicting urban air pollution levels, and in the nuclear industry where resuspension of spilled nuclear materials is a possible health hazard. Like roadway sources, passive source strengths are greatly dependent on surface conditions. Soil particle size distribution, surface roughness, orientation, cover, and moisture conditions are the principal surface variables. Those factors that contribute most to wind suspension have been investigated for many years in relation to soil erosion. Those studies have been modified to develop air pollution impact estimates (PEDCo, 1973; Wilson, 1975).

All of the available data for passive sources have been accumulated from three studies conducted in the Silver Valley (PEDCo, 1975, PES, 1978; State of Idaho, 1978). The sources can be found in Table 4.5 and located on Maps found in Appendix A, by using the value VAL as described in Part E

Table 4.5 Passive Fugitive Source Characteristics

ID -- are the code numbers from the original studies referenced in the text.

PBFRAC, CDFRAC -- are the ppm lead and cadmium levels in the fines fraction of the soils samples where available.

VAL -- is a number used to key the map input information.

CHARNOTE, PBNOTE, CDNOTE -- The note denotes the source of the data for the variables above. The value E refers to the PES report, P to the Pedco reports, V to estimates by author, H to Health and Welfare Department reports, S & Z to estimates from similar samples.

ERODE, ROUGH, LENGTH, VEG -- are the source development factors for the Windblown Dust Equation as defined by Chepin.

PBPPM, CDPHM -- are the lead and cadmium ppm soil levels

ID	VAL	ERODE	ROUGH	LENGTH	VEG	PBPPM	CDPPM	PBFRAC	CDFRAC	CHARNOTE	PBNOTE	CDNOTE	DESCRIPT
11	1	1	1	1	1	146	84.3	1497	106.0	E	H	H	CIA SOUTH ROAD
12	1	1	1	1	1	100	139.2	15673	76.0	E	H	H	CIA SOUTH DIKE
13	1	1	1	1	1	100	103.0			E	H	H	SOUTH CIA CYPSPM
14	1	1	1	1	1	100	103.0			E	H	H	CYPSPM DIRT
15	1	1	1	1	1	100	103.0			E	H	H	CYPSPM POND
16	1	1	1	1	1	100	103.0			E	H	H	OLD MUMSITES
17	1	1	1	1	1	100	103.0	24000	190.0	E	H	H	PARK EDT S CONC
18	1	1	1	1	1	100	103.0			E	H	H	COKE PILE
19	1	1	1	1	1	100	103.0			E	H	H	WALD PILE
20	1	1	1	1	1	100	103.0			E	H	H	WALD ONE GRIND
21	1	1	1	1	1	100	103.0			E	H	H	WALD ONE GRIND
22	1	1	1	1	1	100	103.0			E	H	H	NEAR SHOSH APIS
23	1	1	1	1	1	100	103.0			E	H	H	ROSS OIL AREA
24	1	1	1	1	1	100	103.0	36053	80.0	E	H	H	MILLISE A ROSS
25	1	1	1	1	1	100	103.0	17897	319.0	E	H	H	CIA AN END A
26	1	1	1	1	1	100	103.0			E	H	H	CIA AN END A
27	1	1	1	1	1	100	103.0			E	H	H	OLD TOWN SITE
28	1	1	1	1	1	100	103.0			E	H	H	OLD TOWN SITE
29	1	1	1	1	1	100	103.0			E	H	H	SUNSHINE POND
30	1	1	1	1	1	100	103.0			E	H	H	OLD RIV CH MOUN
31	1	1	1	1	1	100	103.0			E	H	H	HWAY GRAVEL ST
32	1	1	1	1	1	100	103.0			E	H	H	WEST OF ASPH PLY
33	1	1	1	1	1	100	103.0			E	H	H	TERRACED MILLSIO
34	1	1	1	1	1	100	103.0			E	H	H	S OF FREWAY 823
35	1	1	1	1	1	100	103.0			E	H	H	MOVIE THEATRE
36	1	1	1	1	1	100	103.0	17062	61.5	E	H	H	RIV CH M ZANNETT
37	1	1	1	1	1	100	103.0			E	H	H	PINE CR CUT
38	1	1	1	1	1	100	103.0			E	H	H	ROCK & CHAN PWH
39	1	1	1	1	1	100	103.0			E	H	H	SHY PLAYGROUND
40	1	1	1	1	1	100	103.0			E	H	H	TAI INC AREA
41	1	1	1	1	1	100	103.0			E	H	H	WATERM BASIN
42	1	1	1	1	1	100	103.0			E	H	H	ORE STORAGE AREA
43	1	1	1	1	1	100	103.0			E	H	H	HWAY FILL
44	1	1	1	1	1	100	103.0			E	H	H	ATHLETIC FIELD
45	1	1	1	1	1	100	103.0			E	H	H	GRAVEL AREA
46	1	1	1	1	1	100	103.0			E	H	H	GRAVEL STORAGE
47	1	1	1	1	1	100	103.0			E	H	H	CRADLE AREA
48	1	1	1	1	1	100	103.0			E	H	H	REGRAD T&B BED
49	1	1	1	1	1	100	103.0			E	H	H	TAILING POND OSB
50	1	1	1	1	1	100	103.0			E	H	H	STRAIN PEG
51	1	1	1	1	1	100	103.0			E	H	H	STRAIN PIT
52	1	1	1	1	1	100	103.0			E	H	H	STRAIN PEG
53	1	1	1	1	1	100	103.0			E	H	H	EQUIP STOR AREA
54	1	1	1	1	1	100	103.0			E	H	H	MINE SPOILS
55	1	1	1	1	1	100	103.0			E	H	H	MILL CUT FILL
56	1	1	1	1	1	100	103.0			E	H	H	MILL CUT FILL
57	1	1	1	1	1	100	103.0			E	H	H	MILL CUT FILL
58	1	1	1	1	1	100	103.0			E	H	H	MILL CUT FILL
59	1	1	1	1	1	100	103.0			E	H	H	MILL CUT FILL
60	1	1	1	1	1	100	103.0			E	H	H	MILL CUT FILL
61	1	1	1	1	1	100	103.0			E	H	H	MILL CUT FILL
62	1	1	1	1	1	100	103.0			E	H	H	MILL CUT FILL
63	1	1	1	1	1	100	103.0			E	H	H	MILL CUT FILL
64	1	1	1	1	1	100	103.0			E	H	H	MILL CUT FILL
65	1	1	1	1	1	100	103.0			E	H	H	MILL CUT FILL
66	1	1	1	1	1	100	103.0			E	H	H	MILL CUT FILL
67	1	1	1	1	1	100	103.0			E	H	H	MILL CUT FILL
68	1	1	1	1	1	100	103.0			E	H	H	MILL CUT FILL
69	1	1	1	1	1	100	103.0			E	H	H	MILL CUT FILL
70	1	1	1	1	1	100	103.0			E	H	H	MILL CUT FILL
71	1	1	1	1	1	100	103.0			E	H	H	MILL CUT FILL
72	1	1	1	1	1	100	103.0			E	H	H	MILL CUT FILL
73	1	1	1	1	1	100	103.0			E	H	H	MILL CUT FILL
74	1	1	1	1	1	100	103.0			E	H	H	MILL CUT FILL
75	1	1	1	1	1	100	103.0			E	H	H	MILL CUT FILL
76	1	1	1	1	1	100	103.0			E	H	H	MILL CUT FILL
77	1	1	1	1	1	100	103.0			E	H	H	MILL CUT FILL
78	1	1	1	1	1	100	103.0			E	H	H	MILL CUT FILL
79	1	1	1	1	1	100	103.0			E	H	H	MILL CUT FILL
80	1	1	1	1	1	100	103.0			E	H	H	MILL CUT FILL
81	1	1	1	1	1	100	103.0			E	H	H	MILL CUT FILL
82	1	1	1	1	1	100	103.0			E	H	H	MILL CUT FILL
83	1	1	1	1	1	100	103.0			E	H	H	MILL CUT FILL
84	1	1	1	1	1	100	103.0			E	H	H	MILL CUT FILL
85	1	1	1	1	1	100	103.0			E	H	H	MILL CUT FILL
86	1	1	1	1	1	100	103.0			E	H	H	MILL CUT FILL
87	1	1	1	1	1	100	103.0			E	H	H	MILL CUT FILL
88	1	1	1	1	1	100	103.0			E	H	H	MILL CUT FILL
89	1	1	1	1	1	100	103.0			E	H	H	MILL CUT FILL
90	1	1	1	1	1	100	103.0			E	H	H	MILL CUT FILL
91	1	1	1	1	1	100	103.0			E	H	H	MILL CUT FILL
92	1	1	1	1	1	100	103.0			E	H	H	MILL CUT FILL
93	1	1	1	1	1	100	103.0			E	H	H	MILL CUT FILL
94	1	1	1	1	1	100	103.0			E	H	H	MILL CUT FILL
95	1	1	1	1	1	100	103.0			E	H	H	MILL CUT FILL
96	1	1	1	1	1	100	103.0			E	H	H	MILL CUT FILL
97	1	1	1	1	1	100	103.0			E	H	H	MILL CUT FILL
98	1	1	1	1	1	100	103.0			E	H	H	MILL CUT FILL
99	1	1	1	1	1	100	103.0			E	H	H	MILL CUT FILL
100	1	1	1	1	1	100	103.0			E	H	H	MILL CUT FILL

of that Appendix. No absolute emission rate estimates were prepared for these sources because of the nature of the later analyses as detailed in von Lindern 1980b.

4.3 The Occupational Environment

4.3.1. General

There are considerable differences in developing emissions profiles for community environmental analyses and occupational exposures. Ambient air monitoring is conducted continuously for twenty four hours and represents a daily average. Occupational exposures are an eight-hour time weighted average and reflect the several activities a worker may encounter on a shift. Translating occupational exposure observations to daily averages that are useful in relation to ambient concentrations is difficult and inexact. Significant uncertainty exists not only in the measurements themselves but also because the bulk of the particulate matter exposing a worker, in most instances, never reaches the community environment. Transport barriers restrict pollutant dispersion and most large particles will settle out near the sources.

For this analysis a summary discussion of OSHA findings in each plant area is presented. A general discussion follows and sets of three exposure estimates are developed for each critical plant area. This estimate represents the general or background component of industrial exposure in each area that might impact the community through diffusion and reentrainment phenomena. The minimum estimate represents expected component exposures for optimal operations. The mean level is the representative or expected value to be used in any model comparisons and the maximum value is the peak exposure that might be encountered under upset conditions. These estimates are expected to have an uncertainty

of +100%. Due to the erratic nature of both smelter operations and air lead exposures, greater accuracy is unobtainable without expanded and expensive monitoring. As the smelter is currently inoperative, improved estimates are not available.

4.3.2. Data Source

The occupational environment in the lead smelter was most recently analyzed by the Radian Corporation under a Department of Labor contract (Dunton, 1981). The report was developed to assess the potential of achieving compliance with OSHA lead-in-air standards for job classifications cited in a 1980 OSHA complaint. The analyses considered:

1. Administrative, work practice and engineering controls that could bring specific job classifications into compliance with the 200 $\mu\text{g}/\text{m}^3$ lead standard.
2. Approximate costs to implement the proposed controls.
3. An estimate of the expected results of proposed controls.

Exposure characterizations for the Radian study were developed from data collected from three sources: the 1975 NIOSH study, OSHA inspections, and Bunker Hill Company self monitoring. That report and the support evidence collected for the 1980 OSHA citations (OSHA, 1980) are used to estimate in plant exposures for use in this analysis.

The Radian study has been extremely useful in the preparation of this report. It is presented in a straightforward and concise manner that is useful to both regulatory personnel and those who are considering the continued operation of the Bunker Hill lead smelter. Before proceeding with characterizing in-plant exposures, however, there are some important points that should be reiterated and some exceptions to be taken with this report.

Radian notes that "like other smelters... exposures at Bunker Hill typically range over orders of magnitude. The wide range of exposures is due to upset conditions, inconsistent operating conditions, individual work practices, and other factors which cannot be completely eliminated." With respect to both occupational and community exposures, this point cannot be overstated. Compliance with either set of standards will not be accomplished without technical or administrative controls for upset conditions.

The Radian study considers only retrofit techniques. Controls that require new processes or operations were not included. Radian cited excess costs, poor lead markets, uncertain EPA and OSHA lead regulations, and high unemployment as rendering new processes impractical. However, it is likely that in some smelter areas, upsets will never be controlled nor will compliance be achieved without significant process modifications. Modernization, replacement, and modification of processes must be considered in any long term strategies that project final compliance with the ambient standard. Many of the percent emission reduction schemes presented later in this report are infeasible with retrofit controls. Both the scope and the costs projected in the Radian report must be expanded to address the needs of concurrently considering the off property impacts of these sources.

4.3.3 Exposure Estimates for General Plant Areas

Mill and Concentrate Handling. OSHA found no excess occupational exposures in this area of the smelter. Milling and concentrating are principally wet processes and have little direct contribution to airborne exposures for workers or the community.

Highline Area. Ore Preparation Plant (OPP). The Highline Area has the greatest incidence of excess occupational exposures in the smelter. Sixteen job classifications were cited for excess exposure to airborne lead in the 1980 OSHA complaint. Eight hour exposures ranged from 60 ug/m³ for the area bayhouse operator to 9530 ug/m³ for the Highline lancer. Those working for extended periods in the bedding plant, i.e. OPP tripper, belt operator, laborer, and helper had exposures from 1320 ug/m³ to 6210 ug/m³. Maintenance mechanics in this area recorded exposures of 2750 ug/m³ and 4640 ug/m³.

Four job classifications were considered in the Radian study. They were OPP tripper, belt operator, helper, and lancer. The same conclusion was drawn for all four classifications. Compliance with the 200 ug/m³ 8-hour TWA standard is infeasible without major process modifications. General exposure estimates developed for this area are:

Minimum	20 - 300 ug/m ³	24 hour aver.
Mean	690 - 1330 ug/m ³	" "
Peak	2200 - 3700 ug/m ³	" "

Most of the Highline area exposures occur indoors and community effects are manifest from building ventilation and bulk handling of materials moving in or out of this area. Estimates for general exposures are difficult to predict, hence the wide ranges noted above.

Table 4.6 OSHA CITATIONS IN THE HIGHLINE AREA

Job Title	Exposure 8 hr TWA ug/m ³ Pb	% Attributed to Background or General Area	% Attributed to Direct Job Activity
OPP Tripper	1010	30	70
Belt Operator	6210	30	70
" "	5270	30	70
Helper	1330	/2	/2
"	1320	/2	/2
Highline Lancer	9530	20	80
" "	7370	20	80
OPP Belt Laborer	1020	/3	/3
Maint. Mechanic	2750	/2	/2
" "	4640	/2	/2
Crane Operator	280/1	/3	/3
" "	1150	/3	/3
Crusher Operator	1070	/3	/3
Mill Operator	670	/3	/3
Switchman	180	/3	/3
Baghouse Serv. Leader	60	/3	/3
Baghouse Operator	60	/3	/3

/1. Inside Cab

/2. Too varied to determine

/3. Not addressed

Sinter Plant Area

Seven job classifications were cited for excess lead exposure in the sinter plant area. Concentrations ranged from 240 $\mu\text{g}/\text{m}^3$ in the tool room area to 12,950 $\mu\text{g}/\text{m}^3$ for the pellet plant helper. The operator and assistant operator recorded exposures of 1380 $\mu\text{g}/\text{m}^3$ and 3770 $\mu\text{g}/\text{m}^3$, respectively. The maintenance mechanic had an exposure of 2150 $\mu\text{g}/\text{m}^3$. The control room recorded an 8 hr TWA of 405 $\mu\text{g}/\text{m}^3$. OSHA citations can be found in Table 4.7.

The Radian report considered only two of these job classifications. The tool room and maintenance mechanic exposures were addressed. The report suggested the tool room be moved and that the mechanic's exposure was too varied to analyze. The following estimates were developed for use in this report:

Minimum	200 $\mu\text{g}/\text{m}^3$
Mean	500 $\mu\text{g}/\text{m}^3$
Peak	4000 $\mu\text{g}/\text{m}^3$

As opposed to the highline area, excessive plant exposures in the sinter plant area often occur outdoors and could likely impact the near community as fugitive emissions.

Blast Furnace-Fuming Furnace Area

Eighteen excess exposure citations were issued in the Blast Furnace-Fuming Furnace Area. Lead exposures ranged from 68 $\mu\text{g}/\text{m}^3$ 8 hr TWA in the overhead crane cab to 1800 $\mu\text{g}/\text{m}^3$ for the Blast Furnace operator. In general, exposures for workers throughout the area ranged between 400 and 800 $\mu\text{g}/\text{m}^3$. Radian analyzed five job classifications in this area. Compliance in the crane cabs has been achieved in the last year through an

Table 4.7 OSHA CITATIONS IN THE SINTER PLANT

Job Title	Exposure 8 hr TWA ug/m ³ Pb	% Attributed to Background or General Area	% Attributed to Direct Job Activity
Tool Room	240	50	50
Maint. Mech	2150	/1	/1
Control Room	405	100	-
Asst. Operator	3770	/2	/2
Pellet Plant Helper	7140	/2	/2
" " "	12950	/2	/2
Operator	1380	/2	/2

/1. Too varied to analyze
/2. Not addressed

air tract system. Similarly, tapping positions have achieved acceptable levels through improvements in hooding and tapping practices. However, as Radian notes, compliance for other job classifications in the Blast Furnace area is impossible because of upset conditions that occur on about 25-35% of the shifts. Radian did not address classifications in the Fuming Furnace area. Exposure estimates were developed as follows.

Minimum	300 ug/m ³
Mean	500 ug/m ³
Peak	7000 ug/m ³

These numbers essentially reflect blast furnace upsets. By some estimates, the blast furnace is upset at least four minutes every hour on a daily basis. Other studies have cited upsets as frequent as 35% of the time. In terms of community impact, this is the largest single source of lead dust in the smelter.

Table 4.8 OSHA CITATIONS IN THE BLAST FURNACE-FUMING FURNACE AREA

Job Title	Exposure 8 hr TWA ug/m ³ Pb	% Attributed to Background or General Area	% Attributed to Direct Job Activity
<u>Blast Furnace</u>			
Operator	1800	15	85
Slag Tapper	410	/2	/2
" "	520	/2	/2
" "	430	/2	/2
Crane Operator	220	/2	/2
" "	68/1	/2	/2
Pipe Fitter	440	/4	/4
Feederman	690	/3	/3
<u>Fuming Furnace</u>			
Crane Operator	130/1	/4	/4
" "	180/1	/4	/4
Operator	770	/4	/4
Car Loader	710	/4	/4
Side Lancer	550	/4	/4
Top Lancer	530	/4	/4
Helper	190	/4	/4
Baghouse Operator	580	/4	/4
Baghouse Helper	710	/4	/4

- /1. Inside Cab
- /2. Corrected in 1981
- /3. Dependent on upsets
- /4. Not addressed

Refineries. OSHA cited thirteen job classifications as having excess exposures in the Refinery areas. Six job titles were cited in the lead refinery with levels ranging from 160 ug/m³ for kettle operators to 2850 ug/m³ for the softener operator. In the silver refinery three positions were cited; leadman 550 ug/m³, retort operator 1660 ug/m³, and cupel operator 1550 ug/m³. In the casting and loading area four jobs were cited ranging from 93 ug/m³ for the fork lift operator to 136 ug/m³ for the skimmer helper. OSHA citations can be found in Table 4.9.

Radian's analysis considered five job titles in the lead refinery. No consideration was given to the high temperature fume exposures in the silver refinery or to the relatively low exposures in the casting and loading area. All of the lead refinery exposures with the exception of the reverb operator, have been corrected by improvements installed in 1981. Exposure at the reverb is upset dependent and considered uncorrectable.

Estimates for exposures in the context of this analysis are

Minimum	50 ug/m ³
Mean	100 ug/m ³
Peak	700 ug/m ³

These are relatively low values and impact the community through roof venting of the casting area.

Baghouse Area. OSHA conducted only one compliance evaluation in this area. The control room exposure was 92 ug/m³ 8 hour average. Insufficient data were available to project background levels for this area.

Table 4.9 OSHA CITATIONS IN THE REFINERY AREA

Job Title	Exposure 8 hr TWA ug/m ³ Pb	% Attributed to Background or General Area	% Attributed to Direct Job Activity-
<u>Lead Refinery</u>			
Dross Operator	2100	20	80
Kettle Operator	1100	/1	/1
" "	160	/1	/1
Reverb Operator	700	10/2	90/2
Crane Operator	580	5/2	95/2
Softener Operator	2850	10	90
<u>Silver Refinery</u>			
Leadman	550	/3	/3
Retort Operator	1660	/3	/3
Cupel Operator	1550	/3	/3
<u>Casting and Loading</u>			
Skimmer Helper	120	/3	/3
" "	136	/3	/3
" "	160	/3	/3
Fork Lift Operator	93	/3	/3

- /1. Eliminated 1981
 /2. Upset Dependent
 /3. Not Addressed

5.0 MODEL DEVELOPMENT AND AMBIENT ANALYSIS

5.1 GENERAL

The heavy-metal contamination problem in the Silver Valley is extremely complex. The air pollution component is especially difficult. Considerable care must be exercised in any analysis of the support data and the particulars of the analytical procedures. In any type of modeling study where mathematical expressions are used to represent physical phenomena, certain assumptions have to be made to accommodate the analysis. The adequacy of those assumptions most often determines the quality of the results and conclusions. The types of assumptions that are inherent to simulation diffusion models (at the practiced state-of-art) could possibly make such analyses unreliable for the Silver Valley situation. However, given the wealth of data available, an empirical application in this situation could result in a more reliable analysis. Literature citations and a support argument for this position can be found in von Lindern (1980b).

This is not to say, however, that there are no problems in an empirical analysis. Analyses where observed pollutant concentrations are related to atmospheric and emissions indices, in the ignorance of the physical phenomena involved, are particularly prone to erroneous conclusions. Great care must be exercised in the design of the model and the interpretation of results. In any modeling analysis, it is important to understand the physical and anthropogenic factors involved. This background information is

necessary to select and to evaluate the assumptions discussed above. Most of this background material has been summarized in earlier sections. However, there are three areas of specific difficulty that should be discussed. The problems are presented in detail in von Lindern (1980b). However, they are important enough to repeat briefly in this presentation. They are:

1. Meteorological factors associated with complex terrain.
2. Spatial and temporal variation in source strength and multiple source configurations.
3. Interdependency of source strength and configuration with meteorological variables.

Two atmospheric phenomena common to complex terrain literature are especially important in the Silver Valley: the frequent formation of surface based nocturnal inversions and the mountain-valley drainage wind. Radiative cooling of the slopes of the valley causes air temperature to decrease near the surface. As it cools, it becomes more dense and flows downslope to the valley floor and subsequently down valley. Extreme diurnal shear and low level isothermal structures can result from this drainage. This capping phenomena inhibits pollutant diffusion and enhances terrain channelling. After sunrise the slopes of the valley heat more rapidly than the floor. This results in the descent of the inversion layer as insolation proceeds and fumigation phenomena can return residual pollutants trapped aloft overnight to the ground. Following this period flow up the valley predominates. This flow is typically associated with the prevailing synoptic winds augmented by upslope winds resulting from differential heating. The valley narrows and deepens considerably in this direction. As a result, significant terrain channelling is expected with up-valley winds, even in the absence of stable layers aloft.

Conventional modeling analysis dealing with long-term effects requires some degree of uniformity and homogeneity in both atmospheric and source behavior. The second difficulty in analyzing the Silver Valley via modeling concerns the spatial and temporal irregularities in source behavior. Source descriptions were provided in the last section. Point sources are generally uniform in their behavior. Industrial processes are designed to operate at particular rates and capacities. Control equipment is correspondingly designed and emission rates are consistent. When dealing with process fugitive sources, emission rates become irregular, depending on process fluctuations and outside stimuli. These two categories are also subject to upsets and malfunctions that can result in orders of magnitude changes in emission rates for short periods of time. Active fugitive sources are sporadic and their emission rates depend on the frequency of their parent mechanical activity and local meteorological conditions. Passive fugitive source emission rates are wholly dependent on meteorological factors and vary not only in magnitude and frequency but in configuration as well. Wind speed, wind direction, and surface conditions dictate these sources' contribution to atmospheric levels.

This last factor, the interdependency of source strength and configuration with meteorological variables is, perhaps, the most confounding factor in applying modeling techniques to this problem. Ironically, it is this same dependence that allowed solution of this problem through the techniques employed. As an excellent meteorological data base was available through the Bunker Hill Company's Supplementary Control System (SCS) monitoring network, source behavior could be quantified through meteorological indices. However, doing so in an empirical format utilizing over thirty variables

and two years of data from hundreds of sources was a tremendous computational demand. In this study, the problem was addressed by using the geographic information system described in von Lindern (1980b).

5.2 THE MODELING PROCEDURES AND ASSUMPTIONS

5.2.1 The Basic Source-Receptor Model. The objective of this modeling analysis is to quantify those factors most important in air lead contamination in the Silver Valley and to ascertain the relative contribution of different sources to excess atmospheric concentrations. Considering the wealth of data available and the particular difficulties of applying standard diffusion models, an empirical approach was selected. The first step in the solution strategy was to develop the basic source-receptor model describing the fundamental relationship between a receptor and any source of exposure. The design of that model should account for those particular topographical emissions, and meteorological phenomena suspected of confounding air pollution impact analysis in this area. The most important of these considerations have just been discussed. cursory examination of the wind spectra in the Silver Valley suggests that the mountain-valley drainage/nocturnal inversion scenario dominates the local meteorology on the majority of days. The model developed sought to quantify the basic source-receptor relationship in a quasi-Gaussian fashion by accounting for the peculiar flows associated with this diurnal phenomenon. It is also known that certain meteorological conditions can void or considerably modify the basic relationship. The Bunker Hill Company SCS has identified those critical meteorological situations. Their data are used to modify the basic relationship where appropriate by dummy variable additions to the regression procedure.

5.2.2. Variable Construction. A derivation of the modeling equations and construction of the variables and regression analyses are not contained in this report but can be found in von Lindern (1980b). It is most important in this report to point out and discuss the assumptions inherent to the modeling strategy and how those assumptions affect the quality of the results and limit the conclusions that may be drawn from these techniques.

The basic modeling equation was the simple Gaussian plume model

$$x = Q \cdot \frac{1}{2\pi u} \cdot \frac{1}{\sigma_y \sigma_z} \cdot \exp\left(\frac{-y^2}{2\sigma_y^2}\right) \cdot \exp\left(\frac{-H^2}{2\sigma_z^2}\right)$$

where

x = the pollutant concentration at the receptor

Q = the initial pollutant source strength

u = the wind speed in the x direction

σ_y and σ_z = the standard deviations in pollutant concentration
in the y and z directions

x, y, z = the Cartesian coordinates

H = the difference in elevation between source and receptor

No provision is made for differential plume rise or particulate settling. This model was derived in a surrogate form to accommodate those variables that were available from the emissions, meteorological, and geographic data bases. Three basic requirements were involved in the surrogate derivations: (1) the equation had to be derived using variables that were both available from the emissions and meteorological inventories and that were amenable to

manipulation in the geographic information system, (2) the model had to be capable of empirical parameterization via linear regression, and (3) the model, to the maximum extent possible, should reflect the concepts of accepted air pollution meteorology. Simultaneously accommodating these constraints involved making several assumptions and adjustments to the solution strategy. Those basic assumptions are discussed below.

OBSERVATION TIME PERIOD BASIS. The dependent variable in the equation is the mean 24-hour pollutant concentration observed at the various stations. These data were obtained from the State's hi-vo1 network shown on page 20. These data are believed to be of excellent quality and were used as is. However, this daily periodicity defines the base time unit for the dependent variables.

ADEQUACY OF EMISSION DATA. This represents what could be called the weakest data base in the procedure. Only single observations were available for many of the sources. Quarterly, self-reported, emission rates were available for some smelter sources, but the reliability of these data is unknown. These estimates were reduced to 24-hour emission rates. It is suspected that many of these sources can vary more than an order of magnitude on a daily basis, especially when malfunctions and upsets are considered. Two elements of strategy were developed to deal with this deficiency. The first mitigative factor was to introduce on-off criteria as described in the parent document. Many sources were known to be inoperative on particular days for either operations or meteorological reasons. Zero emission rates were assigned to the appropriate sources for these days. The second mitigative element

concerns the basic philosophy of the entire project. The source contributions and rollbacks eventually developed are discussed in relative rather than absolute terms. Pseudo-dummy variable analysis, as described by Draper and Smith, is utilized throughout. This technique is especially useful in determining the relative significance of different variables in regression analysis.

Source estimates were eventually grouped into eight categories for final analysis. The grouping was based on the spatial configuration of the sources. The basic assumption is that significant particulate lead sources emanate from eight predominant locations in the valley. By appropriately characterizing the emissions (by rate estimates and on-off criteria) and the atmosphere (by wind and stability indices), relative contributions could be ascertained by regression analysis.

THE VIEWFIELD ASSUMPTION. Downwind concentration dilution in the traditional Gaussian formula is inversely proportional to the wind speed. Doubling the wind speed doubles the space between particles and halves observed concentrations. However, this assumes a constant wind direction and speed. In the Silver Valley wind direction and speed change continuously and usually reverse themselves daily in association with the mountain-valley drainage phenomenon. In order to compensate for this difficulty in the daily time basis, two wind flow directions were assumed in conjunction with the mountain-valley drainage phenomenon. Up-valley and down-valley winds were defined. The mean daily wind speed, direction, duration, and standard deviation in wind direction were calculated for each flow. Each receptor's face was turned into the wind and its upstream "view" was considered. This is the

VIEWFIELD assumption. How many sources a receptor can see depends on its "viewfield" or a narrow upwind sector that contains those sources that could possibly impact that receptor. The depth of view depends on wind speed and duration of the wind flow from that direction. The width of the sector depends on the variation in wind direction. An expression was derived to express the number of hours per day that a receptor was exposed to a source and the assumption was made that the downwind component of dilution was proportional to that duration of exposure and inversely proportional to wind speed and the width of the view-sector. These terms are all calculable in the geographic information system and could be easily accomplished for each receptor location. In this way, both a proportioning factor and an additional on-off criteria were developed. If, because of wind speed or direction, a receptor is not exposed to a source during the day the exposure reduces to zero. If the wind blows consistently all day from source to receptor the downwind dilution becomes the $1/u$ term in the traditional equation. This variable is not meant to simulate wind flow in the valley. It is an index meant to represent downwind dilution from sources in the up- and down-valley directions and is designed for use in a regression equation.

THE STABILITY ASSUMPTION. The surrogate term for the $\frac{1}{\sigma_y \sigma_z}$ term in the Gaussian model equation was designed so that the Gifford-Pasquill form of these variables could be recovered from the eventual regression coefficients. First the traditional form of the Gifford-Pasquill plots were derived in a system of linear equations developed through logarithmic transformations. It was then assumed that the linear coefficients for this system were a function of atmospheric stability and would be specific for this situation.

Next the potential temperature gradient at Spokane International Airport was selected as the daily indicator of atmospheric stability. This has been found, through the Company's SCS, to be the most appropriate stability index available. It was then assumed that the linear coefficients were first degree functions of the potential temperature gradient. This assumption is consistent with the form of the Gifford-Pasquill charts and results in a convenient form of the expression for both parameterization and geographic manipulation.

THE PLUME MEANDER ASSUMPTION. The term $\exp\left(\frac{-y^2}{2\sigma_y^2}\right)$ in the Gaussian plume analogy represents the dilution effect of being remote from the mean wind vector. In the Gaussian formulation, a uniform wind direction is assumed and the degree of lateral dilution is a function of atmospheric stability. In the Silver Valley, wind direction fluctuates continuously and straight line flow is not expected. Thus, it was assumed that exposure reductions associated with being remote from the mean wind vector are more a function of variation in the mean wind vector than of the stability criteria per se. Two lines of reasoning justify this assumption. The variation in the mean wind vector (plume meander) is likely a function of stability itself. And the maintenance of a crosswind Gaussian distribution in the Silver Valley is unlikely. Plume meander, when considered on a daily basis, would predominate any such distribution. As a result the standard deviation in wind direction was selected as a measure of crosswind remoteness and dilution was assumed to be a function of the number of standard deviations a receptor was from the mean wind vector.

THE VERTICAL DISTRIBUTION ASSUMPTION. Differential plume rise, particulate settling, and plume depletion are all ignored in this model. A constant plume rise and constant plume elevation are assumed. The main reason for ignoring differential plume rise was the insufficiency of the data base for developing appropriate variables. In order to account for plume rise, an equation utilizing the atmospheric surface temperature and wind velocity would have to be included in the source height factor. These measurements are used in other independent variables in the modeling equation. Including them in another term would increase the possibility of undesirable effects associated with inter-variable correlation. Moreover, from a practical point of view, these are low temperature plumes and only a single morning surface temperature was available. The benefit of using that single observation in predicting an effective daily plume rise was considered not worth the confounding effects of adding a possibly redundant variable. Considering plume depletion, no data were available for developing settling estimates. Making unnecessary assumptions in the development of regression variables should be avoided. Practically, plume depletion must be significant with respect to certain sources. Fugitive sources in particular contain large particle emissions subject to considerable fallout. Point sources, on the other hand, are fine particle emissions that may approximate gaseous behavior. As explained later, cadmium emissions are used to parameterize the basic source receptor model. Cadmium emissions are predominantly fine particulate. Ignoring settling phenomena is, likely, permissible in defining parameters for the model. Later, when developing source estimates for lead and particulates, depletion from fugitive sources must be considered important. However, in the division of source categories, active and passive sources appear in

separate independent variables. When linear regression analyses are applied to those variables it can be inherently assumed that some constant amount of plume depletion is accounted for in assigning the regression coefficients. In practical terms, the assumption is that a particular percentage of fugitive emissions fall out between the source and nearest receptor and that gaseous behavior is observed beyond. This assumption is adequate for the empirical format of the study.

THE EMPIRICAL MODIFIERS. The Bunker Hill Company meteorologists operating the Supplementary Control System (SCS) have long recognized those difficult meteorological factors discussed earlier in this section. They have, through years of experience, developed semi-quantitative indices to represent the onset of certain meteorological and operational conditions. For the most part, these variables identify the onset of non-routine conditions where "normal" assumptions do not apply. As such they are quite appropriate for use in regression analysis as dummy variables to account for the effects of special conditions where the base model may not apply. These variables were transformed to act as empirical modifiers in the regression analyses. Details of the variables and transformations can be found in the parent document.

5.2.3 Finding the Model Parameters. The model was assigned parameters through a stepwise regression procedure that forced inclusion of the variables developed as the initial surrogate model. The several empirical modifiers developed from the SCS were also offered for forward selection. There are several assumptions inherent to regression analysis that are not

necessary to include. However, there are two assumptions made in solving the regression equation that are important to discuss here.

The first is the use of cadmium data to find the model parameters. The number of sources and the difficulties with defining configurations make it impossible to solve the modeling equation for lead or total particulates. Cadmium emissions, however, seem to predominately arise from within the lead smelter or, more to the point, from the same geographic location. This considerably reduces the complexity of the modeling equation for cadmium. Because cadmium emissions do emanate from three distinct source heights, one unknown function still precludes solution of the equation. An assumptive constraint has to be added to the regression matrix. That constraint was developed by assuming that the ratio between σ_y and σ_z at neutral stabilities at 0.1 miles from the source will be the same as the ratio found under these conditions in the traditional Gifford-Pasquill charts.

5.3 THE IMPORTANT SYSTEM VARIABLES

Using these two assumptions, the equation was solved and the selected model is shown below. An extensive discussion of the results is found in von Lindern(1980b).

The regression statistics for this model indicate that pollutant dispersion can be successfully quantified by this model form. Seventy-three percent of the variability in observed concentrations is explained at strong significance levels. The initial model seems particularly strong ($R^2 = .71$ at $p = .0001$). This is especially encouraging considering the difficulties with cadmium source estimates discussed earlier.

Table 5.1 Regression Statistics for Selected Stepwise Model

$$\text{Initial Model: } \text{DEPZ} = \beta_0 + \beta_2 \text{LNVWF} + \beta_3 \text{POTEHP} + \beta_4 \ln X + \beta_5 \text{POTEHP} \ln X + \beta_6 \text{NSDSQ}$$

Model Statistics by Step					
Step	Variable Added	Sum of Squares Model	F-Model (P>F)	F-Variable on Entry (P>F)	R ² Model
0	(Initial Model)	7749.4	673.3(.0001)	(all .0001)	.712
1	MD50LNx	7836.9	583.3(.0001)	39.0(.0001)	.720
2	REGVAR	7870.1	507.3(.0001)	15.0(.0001)	.724
3	BFDOWN	7892.5	448.2(.0001)	10.2(.0015)	.726
4	MD36	7914.2	402.1(.0001)	10.0(.0016)	.728
5	W15	7930.8	364.4(.0001)	7.6(.0059)	.729
Total SS = 10877.5					
Parameter Statistics on Final Step					
Source	Parameter Estimate	Sum of Squares	F (P>F)		
INTERCEPT	2.31	(SAS Type II)			
LNVWF	.17	31.0	14.2(.0002)		
POTEHP	.65	1511.5	694.5(.0001)		
LNx	1.51	1999.4	918.7(.0001)		
POTEHP*LNx	.15	898.2	412.7(.0001)		
NSDSQ	-.04	91.8	42.2(.0001)		
MD50LNx	.16	33.0	15.2(.0001)		
REGVAR	.20	33.2	15.3(.0001)		
BFDOWN	.75	40.9	18.8(.0001)		
MD36	2.06	25.4	11.7(.0006)		
W15	.084	16.5	7.6(.006)		
SS (Model)		7930.8	F-Model = 36.4		
SS (Error)		2446.7	R ² Model = .729		
SS (Total)		10877.5			

* variable descriptions can be found in Table 5.3

Table 5.2 Regression Statistics for Final Logarithmic Model

$$\begin{aligned} \text{DEPZ} = & \beta_0 + \beta_2 \text{LNVWF} + \beta_3 \text{POTEMP} + \beta_4 \text{LNX} \\ & + \beta_5 \text{POTEMP} * \text{LNX} + \beta_6 \text{NSDSQ} + \beta_7 \text{BFDOWN} \\ & + \beta_8 \text{MD36} + \beta_9 \text{MD50LNX} + \beta_{10} \text{W15} + \beta_{11} \text{REGVAR} \end{aligned}$$

Source	DF	Sum of Squares (SAS Type IV)	F-Value (PR>F)
LNVWF	1	40.4	22.0(.0001)
POTEMP	1	1327.9	720.8(.0001)
LNX	1	2016.8	1094.6(.0001)
POTEMP*LNX	1	784.4	425.7(.0001)
NSDSQ	1	80.7	43.8(.0001)
BFDOWN	1	23.4	13.0(.0003)
MD36	1	18.4	10.0(.0016)
MD50LNX	1	22.2	12.0(.0005)
W15	1	17.4	9.4(.0022)
REGVAR	1	36.4	19.8(.0001)
Model	10	7499.4	407.0(.0001)
Error	1428	2631.0	
Total	1438	10130.4	R ² = .740

Parameter	Estimate	T-Value (PR>T)	Std. Error
B ₀	2.26	6.50(.0001)	.347
B ₂	.192	4.69(.0001)	.040
B ₃	-.612	-6.62(.0001)	.023
B ₄	-1.48	-26.85(.0001)	.045
B ₅	.138	-33.08(.0001)	.007
B ₆	-.039	-6.62(.0001)	.006
B ₇	-.569	-3.61(.0003)	.157
B ₈	1.75	3.16(.0016)	.554
B ₉	-.124	-3.47(.0005)	.036
B ₁₀	.085	3.07(.0022)	.027
B ₁₁	.205	4.45(.0001)	.046

* variable descriptions can be found in Table 5.3

As in von Lindern (1980b) the best way to discuss these model results is in terms of the regression coefficients. Parts of those discussions are included here.

Ten variables were selected as important in predicting observed cadmium levels. The first five variables comprise the initial surrogate model. Five of the empirical modifiers offered were found to be significant. Briefly, they are:

BFDOWN--the on-off indicator of blast furnace operation.

MD36--an on-off indicator of the most severe limitation in mixing depth.

MD50LNX--the on-off variable for situation of uninhibited mixing depth times the logarithm of distance.

W15--an indicator of suppressed wind speeds in the middle atmospheric layers of the valley.

REGVAR--the severity code indicating adverse dispersal conditions associated with peculiar synoptic situations.

The model as taken from von Lindern (1980b) is as follows:

$$\begin{aligned} \ln(x_T) = & \beta_0 + \beta_1 \ln QHF + \beta_2 \ln VWF + \beta_3 \text{NSDSQ} + \beta_4 \text{POTEMP} \\ & + \beta_5 \text{LNX} + \beta_6 \text{POTEMP} * \text{LNX} + \beta_7 \text{BFDOWN} + \beta_8 \text{MD36} \\ & + \beta_9 \text{MD50LNX} + \beta_{10} \text{W15} + \beta_{11} \text{REGVAR} \end{aligned}$$

The parameters, their associated independent variable, and the parameter values are shown in Table 5.3.

Table 5.3 Parameter Values for the Logarithmic Model

Parameter	Independent Variable	Factor Description	Parameter Value
β_0	Intercept	Initial dispersion	2.26
β_1	$\ln(QHF)$	Source height function	1.00
β_2	$\ln(VWF)$	Receptor View function	.192
β_3	NSDSQ	Lateral position factor	-.039
β_4	POTEMP	(Stability)	-.612
β_5	LN _X	(and)	-1.48
β_6	POTEMP*LN _X	(distance factors)	.138
β_7	BFDOWN	Operations factor	-.569
β_8	MD36	Limited mixing depth factor	1.75
β_9	MD50LN _X	Uninhibited mixing depth factor	-.124
β_{10}	W15	Inhibited mid-level winds factor	.085
β_{11}	REGVAR	Severe synoptic factor	.204

* for a detailed description and derivation of these variables please see von Lindern 1980b

These parameters and associated variables can be grouped for discussion relative to their contribution to quantifying pollutant dispersion in this valley.

β_0 , β_4 , β_5 , and β_6 are the dispersion parameters for the plume centerline dilution effect associated with the mean wind as derived from the traditional Gaussian form. These parameters were used to derive the familiar σ_y - σ_z plots of Gifford (1961) and direct comparisons of the dispersal conditions in this situation are made relative to the standard modeling assumptions.

β_1 is the unit coefficient for $\ln QHF$ or the source strength-source height term. This term reflects the initial source strength reduced by a factor dependent on the relative source-receptor height. The latter is developed from the same basic component parameters as β_0 , β_4 , β_5 , and β_6 above.

β_2 and β_3 are associated with the terms $\ln(VWF)$ and $NSDSQ$. These two variables, as they were developed, serve to mitigate the standard model predictions with respect to the topographically induced wind conditions. VWF is an exposure factor that accounts for the reduced receptor "view" of the source associated with up- and down-valley wind shifts. $NSDSQ$ is associated with the lateral variance in the mean wind and accommodates reduced exposures associated with the cross-valley wind shifts. In the form offered in the modeling analysis, they become empirical modifiers of the more traditional dispersion equation characterized by the above parameters and variables.

β_7 is the parameter for BFDOWN and is a direct empirical modifier associated with shutdown of the largest single cadmium source. The β estimate for this term is (-.569). When the blast furnace is down (BFDOWN = 1), the predicted effect is $\exp(-.569 * 1) = .57$ times the model prediction. This suggests that when the blast furnace is nonoperative at least 16 hours per day, ambient cadmium levels are reduced 43%.

β_8 and β_9 are associated with extreme mixing depths. β_9 is the parameter for MD50LN_X. This variable allows for greater dispersion under uninhibited vertical dispersion conditions. Because a limited mixing depth associated with nocturnal inversion is the "normal" situation in this valley, the standard diffusion parameters ($\beta_0, \beta_4, \beta_5, \beta_6$) are calculated under that circumstance. The value of β_9 is 0.125. The significance of this variable is as follows: when mixing depth is great (i.e., MD50 = 1, MD50LN_X = $\ln(x)$) the value of the coefficient of $\ln(x)$ or $p + q = -(1.48 + .125) = -1.61$. This is nearly the value supposed in the traditional Gifford-Pasquill form as discussed in von Lindern (1980b). This supports the idea that the "normal" situation in the Silver Valley has an associated limit to vertical dispersion probably related to the surface based nocturnal inversions. Uninhibited vertical dispersion is an "abnormal" situation. Similarly, when mixing depth is severely inhibited, an opposite "abnormal" effect is present. The variable MD36 has a value of 1 when mixing depth is most shallow and 0 at other times. The β value for this variable is 1.75. This suggests that when the lowest level inversion structure exists, the model predictions are increased

by $\exp(1.75) = 5.75$ times. This represents a severe condition treated here by a simple empirical modifier.

β_{10} and β_{11} are empirical modifiers associated with special synoptic situations. $\beta_{10} \cdot W15$ accounts for reduced wind speeds in the mid-level valley atmosphere. β_{11} is associated with REGVAR, an indicator of severe synoptic conditions. The W15 variable has greatest effect when the mean wind value is less than 1 mph. At that value the model estimate may be increased as much as $\exp(.08 \cdot 5) = 1.5$ times. This situation implies extreme calm or shear in the middle atmospheric levels. REGVAR is a severity code associated with some peculiar synoptic conditions. Two conditions are especially important. They are the valley drainage wind (=3) and stagnation (=5) that are both associated with high pressure areas in the mountain range vicinity. The former can increase model estimates by $\exp(3 \cdot .20) = 1.8$ times and the latter by $\exp(5 \cdot .20) = 2.7$ times.

The strength of the initial model indicates that the mountain valley drainage phenomena dominate pollutant dispersion in the Silver Valley. The two mixing depth variables selected in the stepwise process suggest that nocturnal inversions are also part of the "normal" dispersion picture for the valley. Four levels of mixing depth were offered in the stepwise procedure. The non-significance of the two middle levels indicates that they are accounted for in the remainder of the model. In practical terms this means that the basic source-receptor model reflects a diurnal capping inversion between 3600 and 4800 feet. Special modifiers to the basic model are required only when greater or lesser mixing depths are present.

It also means that the dispersion parameters derived from the regression coefficients for this situation reflect this diurnal phenomenon. Some important aspects of the montane air pollution meteorology for this area can be explained by comparing these derived dispersion coefficient estimates with the standard Gifford-Pasquill parameters.

Figures 5.1 a and b show the derived dispersion parameters for this situation plotted as solid lines. The dotted lines are the corresponding plots taken from the subroutine distributed by EPA (1976b) to estimate Gifford-Pasquill dispersion parameters. (The units have been converted as indicated in the axes labels.)

In discussing the differences in these two sets of curves, it is important to remember that the standard curves represent the expected standard deviations in the horizontal and vertical distributions of pollutants calculated for different stability criteria and downwind distances. Both sets assume a normal distribution around a plume centerline defined by the mean wind vector and have been developed from field observations over flat terrain for relatively short averaging periods (<30 min).

The curves offered in this study are derived in a totally different manner. The Gaussian form is present, but much modified in an effort to accommodate the majority of wind fluctuations in the NSDSQ and VWF terms. These two terms account for, respectively, the daily cross-valley variation in wind direction and the variation in wind speed and flow up and down the valley. In a sense they normalize the dispersion curves by accounting for the gross fluctuations related to the local wind phenomena.

The dependent variable in this model development was a twenty-four hour average. As a result, all independent variables were constructed on a

Figure 5.1a Comparison of Standard and Derived
Horizontal Dispersion Parameter Estimates

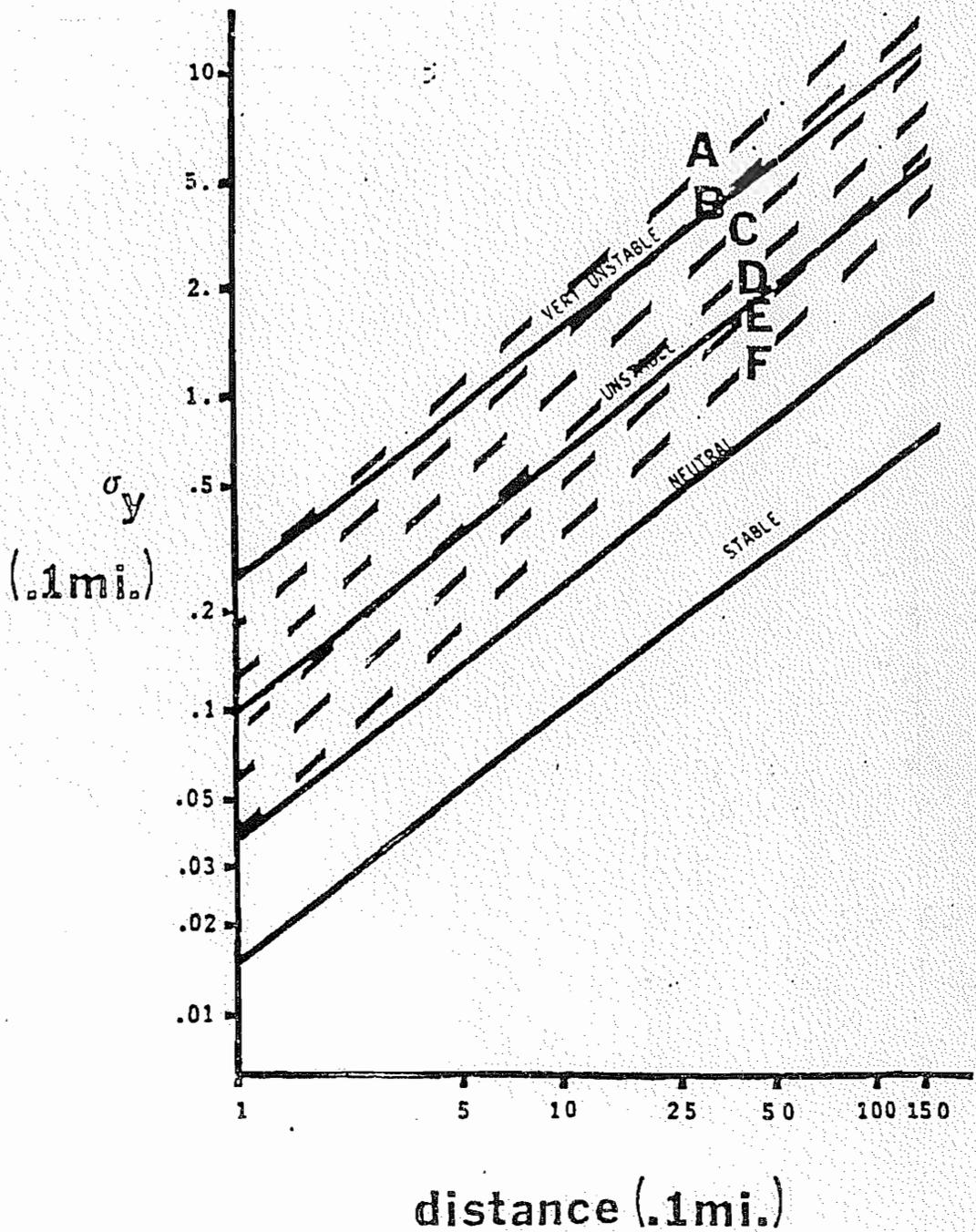
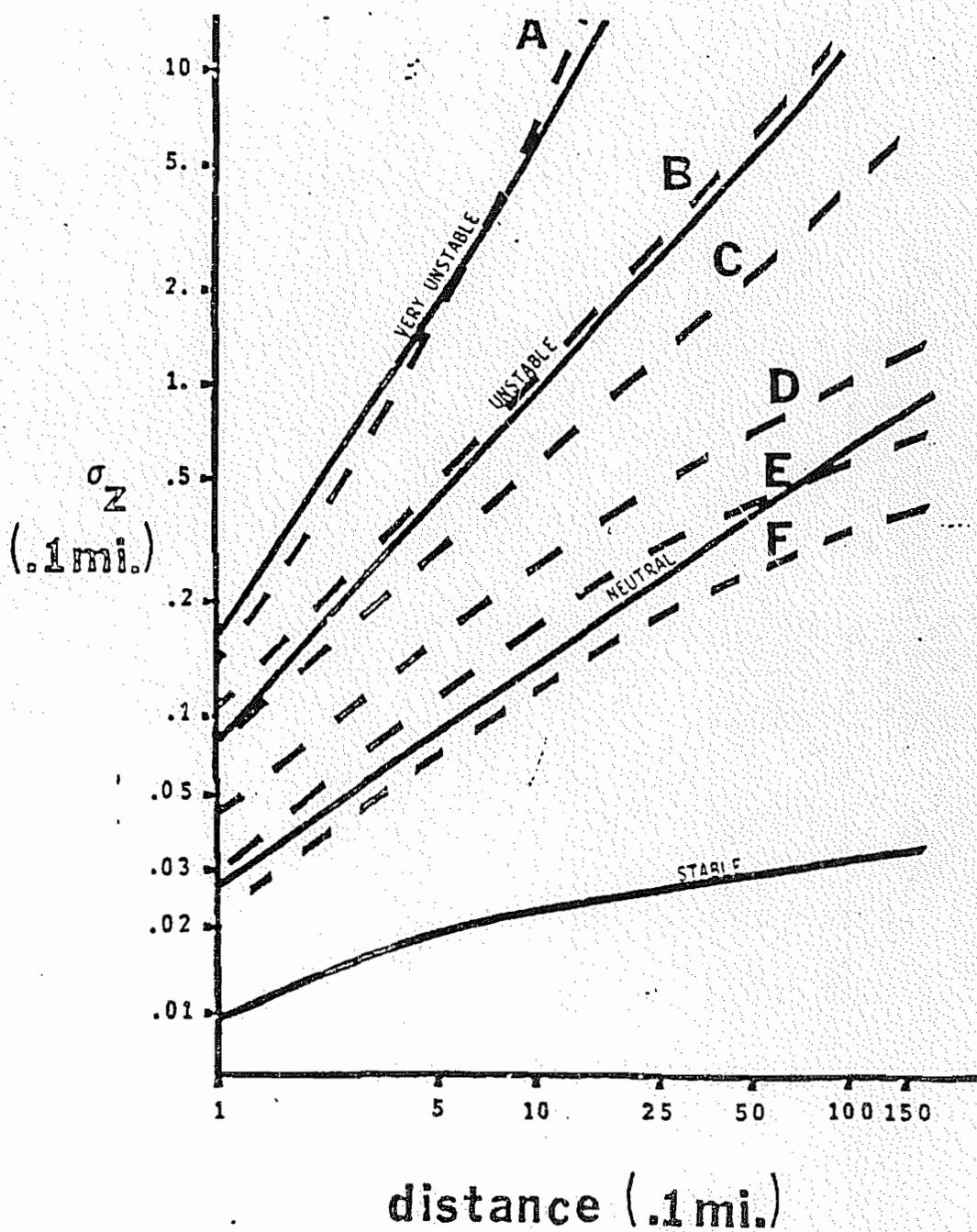


Figure 5.1b Comparison of Standard and Derived
Vertical Dispersion Parameter Estimates



twenty-four hour basis. This represented no great inconvenience because the mountain-valley drainage wind is a diurnal phenomenon. However, it is not obvious what the σ_y and σ_z terms in the above derivations and charts represent. Examination of Table 5.2 shows that a certain amount of the variance in pollutant concentrations is explained by the gross wind variation terms, NSDSQ and VWF. Other empirical factors related to operations and "abnormal" meteorology explain a small percentage. However, the greatest portion of the sums of squares is explained in the three terms from which the σ_y and σ_z charts are derived. Those terms most likely represent the downwind pollutant distribution for the component wind period, averaged over twenty-four hours. The component averaging period is the one-hour mean wind. It is suspected that the σ_y and σ_z values derived are the expected standard deviations in downwind pollutant concentrations for one hour for a given stability category. However, that value necessarily reflects an average for all the hours of the day. This is a most important point to remember in discussing the differences in these and the standard curves.

Turner (1979) pointed out that any modeling effort has to consider the pertinent averaging period with respect to both the prevalent meteorological phenomena and the ambient standard in question. The same logic prevails here. These charts and the other significant model variables can illustrate many of the difficulties encountered in applying Gaussian form models to complex terrain, provided the pertinent averaging time is considered.

There are three obvious differences in the form of these two sets of curves. The first difference is that the estimates are similar for unstable conditions but considerably less dilution occurs as neutral

conditions are approached, and that effect is exacerbated toward stable conditions. The second inconsistency is that the slopes of the curves in the horizontal dispersion chart are notably less than their standard counterparts. The third difference is that under very stable conditions a nearly uniform distribution in the vertical with downwind distance is predicted in this study's σ_z chart.

The mitigation of terrain effects under unstable conditions has been noted by several researchers (Hinds, 1970; Fosberg et al., 1976; Reid, 1979). It is likely that when unstable conditions prevail, no capping phenomena are present and uninhibited vertical dispersion would persist. Similarly, the tendency to develop calm and stable layers aloft is reduced over the twenty-four hour period. As a result, the only inhibition to normal diffusion present would be terrain channeling. Under unstable conditions terrain channeling would likely exercise its influence in the horizontal, but not for some distance downwind. The effect of terrain channeling on the horizontal dispersion parameter may be seen in the reduced slopes noted above. Other complex terrain researchers have made similar findings as reviewed by Miller (1979). However, the result in these cases is usually curved σ_y lines starting out at or near standard slopes and decreasing in slope with distance. This is, perhaps, a more appropriate form than that presented in this study, as the effect of terrain channeling would become more pronounced with plume growth relative to the valley width. Unfortunately, this model form can only accommodate straight lines in the horizontal.

Essentially the mitigative effects of instability on complex terrain dispersion may be accounted for in the absence of those phenomena that produce the confounding situations. As neutral conditions are approached the

nocturnal inversion and drainage wind phenomena become routine. Over a twenty-four hour period, a considerable period of time is spent under an inverted temperature structure, downslope winds develop, and at least two directional changes in valley flow occur. In addition, during inversion breakup a double dosage of pollutants can occur. As stable conditions develop these phenomena become more intense with increased duration. These hours or, more appropriately, the dispersion observed in these hours is included in the "average" that produces the above charts.

As very stable situations are encountered, calm conditions, intense inversions aloft, and severe limitations in mixing depth are likely. Most air quality models of the Gaussian form have recognized that, under limited mixing depths, uniform vertical distribution may develop some distance downwind. That observation may be seen in the σ_z curves at stable conditions.

Several researchers have noted that it is stable conditions that are difficult to simulate in complex terrain situations. In this case, the frequency and duration of particular phenomena (that become more frequent as stability increases) are ultimately responsible. It seems that with the inclusion of mitigating or normalizing variables that account for those phenomena, and with proper consideration of the averaging period, the complex terrain situation may be discussed in an empirical Gaussian format.

5.4 APPLYING THE BASIC SOURCE RECEPTOR RELATIONSHIP

5.4.1 Methodology. Thus far, the modeling procedure has concentrated on defining the basic relationship between a receptor and a source. Having developed a satisfactory model, the next step was to apply it to all the source-receptor combinations in the valley. In practice this was a

mammoth task. However, it was greatly facilitated by employing the Geographic Information System. The details of this application are complex and can be found in von Lindern (1980b).

As the relationship was applied to each source, the impact estimates were accumulated by source category at each of the valley's nine monitoring locations. These categorical estimates were then regressed against observed ambient concentrations. This was accomplished for each day of the two-year study and done simultaneously for lead, cadmium, and TSP. The result is a calibrated model that reflects the most significant particulate sources and weights the relative impacts of the various categories. This, again, was an exhaustive and complex procedure that is detailed in von Lindern (1980b). Over 4300 observations were analyzed. The regression statistics are shown below.

The eight source categories are SMLWEST (low-level smelter sources), SMMIDEST (mid-level smelter sources), SMHIEST (smelter tall stack), ZPLOWEST (zinc plant tall stack), AMP (ammonium phosphate plant), ACTEST (active fugitive sources), and PASEST (passive fugitive sources). They are described in detail in von Lindern (1980b) and the emissions inventory section of this report. Four of these source categories were found to be significant in predicting particulate concentrations in the Silvery Valley. They are low- and mid-level smelter sources, and both active and passive fugitive sources. The other source categories likely do contribute, but are insignificant in magnitude when combined with these sources. Final prediction statistics can be found in Tables 5.4a and b. BKGROUND refers to TSP background levels (BKGROUND = 0 for lead and cadmium).

Table 5.4a Regression Statistics for the Model:

$$\begin{aligned} \text{TPOL} = & \beta_1 \text{SMLOWEST} + \beta_2 \text{SMMIDEST} + \beta_3 \text{SMHIHEST} \\ & + \beta_4 \text{ZPLOWEST} + \beta_5 \text{ZPHIHEST} + \beta_6 \text{AMP} \\ & + \beta_7 \text{PASEST} + \beta_8 \text{ACTEST} + \beta_9 \text{BKGROUND} \end{aligned}$$

Source	DF	Sum of Squares (SAS Type IV)	F-Value (PR>F)
SMLOWEST	1	136963	379.9(.0001)
SMMIDEST	1	27801	77.1(.0001)
SMHIHEST	1	696	1.9(.1646)
ZPLOWEST	1	971	2.7(.1008)
ZPHIHEST	1	993	2.8(.0970)
AMP	1	1196	3.3(.0685)
PASEST	1	52130	144.6(.0001)
ACTEST	1	5246	14.6(.0001)
BKGROUND	1	576519	1598.9(.1646)
Model		3771996	1162.4(.0001)
Error		1527706	
Total		5299703	R ² = .712

Parameter	Estimate	T-Value (PR> T)	Std. Error
β_1	.425	19.5(.0001)	.021
β_2	4.62	8.8(.0001)	.53
β_3	27.	-1.4(.1646)	5.14
β_4	27.8	-1.6(.1008)	17.0
β_5	-109.1	-1.7(.0970)	65.7
β_6	-7.16	-1.8(.0685)	3.93
β_7	19.9	12.0(.0001)	2.43
β_8	9.28	3.8(.0001)	1.65
β_9	35.5	40.0(.0001)	.887

TPOL Total ambient particulate concentration
 SMLOWEST Low-level smelter sources estimated ambient impact
 SMMIDEST Mid-level smelter sources estimated ambient impact
 SMHIHEST Smelter tall stack estimated impact
 ZPLOWEST Low-level zinc plant sources estimated impact
 ZPHIHEST Zinc plant tall stack estimated impact
 AMP Ammonium phosphate plant estimated impact
 PASEST Passive fugitive sources estimated impact
 ACTEST Active fugitive sources estimated impact
 BKGROUND TSP estimated background concentration

Table 5.4b. Regression Statistics for the Final Relative
Source Impact Model:

$$\text{TPOL} = \beta_1 \text{SMLOWEST} + \beta_2 \text{SMMIDEST} + \beta_3 \text{PASEST} \\ + \beta_4 \text{ACTEST} + \beta_5 \text{BKGROUND}$$

Source	DF	Sum of Squares (SAS Type IV)	F-Value (PR>F)
SMLOWEST	1	144129	402. (.0001)
SMMIDEST	1	33016	92. (.0001)
PASEST	1	45310	126. (.0001)
ACTEST	1	7458	21. (.0001)
BKGROUND	1	774061	2159. (.0001)

Model	5	3793243	2116. (.0001)
Error	4310	1545150	
Total	4315	5338393	R ² = .711

Parameter	Estimate	T-Value (PR> T)	Std. Error
β_1	.423	20.1 (.0001)	.021
β_2	4.20	9.6 (.0001)	.437
β_3	17.9	11.2 (.0001)	1.59
β_4	10.9	4.6 (.0001)	2.39
β_5	35.2	46.5 (.0001)	.757

This model in Table 5.4b was used to predict ambient concentrations for each quarter in the study period. Those predictions can be found in Appendix D and a quarterly summary is presented in Table 5.5. Those predictions are used to evaluate relative source contributions to ambient lead concentrations and to estimate required source reductions for achieving the NAAQS. The individual source results and a "residuals" analysis can be found in von Lindern (1980b). An observed/predicted concentrations summary follows.

Model predictions for quarterly lead means range from .26 to 7.2 $\mu\text{g}/\text{m}^3$ over the entire study area. Actual observed concentrations range from .25 to 12.5 $\mu\text{g}/\text{m}^3$. These results are summarized in Table 5.5 along with the ratio of predicted to observed values. This ratio on an annual basis consistently falls between .5 and 2.0 (a kind of unofficial measure of model quality). Moreover, on a quarterly basis the model does well in predicting means for most of the stations. This is especially true in consideration of the range of values and the fact that predictions are based on quarterly mean emissions averages.

However, the model does characteristically underpredict in certain situations. The most important are those where a few extremely high individual readings inflate the observed mean. Many of these outlying values do not seem to be meteorologically based, but do occur at different stations on the same day and always downwind from the smelter. It is most likely that these extreme values are the result of severe emissions excursions at the smelter. It is important to note that the model does not effectively predict the impact these days have on the quarterly means. This is important both in terms of utilizing the model output and developing an attainment

Table 5.5 Summary of Mean Quarterly Ambient Air Lead Impact Estimates, Predicted Values, and Observed/predicted Ratios

SITE	REV E OBSERVED (RATIO) $\mu\text{g Pb}/\text{m}^3$									
	QUARTER 3-77	4-77	1-78	2-78	3-78	4-78	1-79	2-79	3-79	4-79
C	.47 (-1.5)	.06 (1.3)	.57 (1.8)	.37 (1.3)	.20 (1.2)	.54 (1.0)	.60 (1.6)	.21 (1.2)		
(2) A	.91	.67	.76	1.22	.89	.56	1.01	1.13		
P	2.33 (1.2)	4.02 (3.6)	2.75 (1.6)	.99 (.7)	.85 (.5)	2.81 (1.6)	2.38 (.8)	.77 (.4)		
(2) M	1.94	1.19	1.73	1.50	1.82	1.75	3.08	1.88		
S	6.9 (2.0)	6.7 (2.2)	7.7 (1.8)	3.8 (1.2)	2.4 (.8)	6.1 (1.9)	6.8 (1.1)	2.6 (.8)		
(3) M	3.6	3.8	4.2	2.8	2.9	2.3	4.2	3.1		
S	12.5 (2.9)	12.3 (1.7)	11.6 (3.9)	6.2 (2.1)	3.6 (1.0)	6.0 (.9)	5.5 (1.0)	3.7 (.6)		
(4) K	4.6	7.2	3.0	3.0	3.6	5.5	5.7	6.2		
S	6.5 (2.2)	7.1 (2.2)	6.3 (1.5)	2.4 (1.0)	1.9 (.7)	5.2 (1.4)	4.5 (.7)	2.5 (.5)		
(5) M	2.9	3.2	3.2	2.5	2.7	3.7	6.3	5.4		
C	4.1 (1.5)	6.9 (2.1)	6.3 (1.8)	2.9 (1.3)	1.4 (.6)	5.6 (1.6)	4.6 (.8)	2.4 (.6)		
(6) C	2.7	3.2	4.0	2.4	2.5	3.6	6.0	3.8		
H	1.5 (2.5)	3.5 (6.4)	1.9 (2.2)	.7 (1.0)	.4 (1.0)	1.2 (1.8)	1.9 (2.1)	.4 (.8)		
(7) S	.8	.6	.9	.5	.4	.7	.9	.5		
B	.9 (1.9)	1.8 (1.5)	.9 (1.6)	.5 (1.0)	.3 (.8)	.6 (2.1)	1.0 (2.7)	.3 (1.0)		
(8) A	.5	.3	.6	.5	.6	.3	.4	.3		
L	-----	-----	-----	-----	-----	-----	-----	-----		
(10) K	-----	-----	.65 (1.5)	.31 (.5)	.21 (.3)	1.12 (1.0)	.70 (.5)	.31 (.3)		
R	-----	-----	1.33 (1.5)	.77 (.5)	.80 (.3)	1.35 (1.0)	1.3 (.5)	.93 (.3)		

strategy. The effect of these days is great enough that they deserve special treatment in attainment considerations; and they are separately discussed in the next section. What is important to remember, at this point, is that the model predictions are based on average emission rates. The resultant predictions are then "average predictions" and any attainment strategy based on the model applies reductions to average emission rates. These reductions will not guarantee compliance with the ambient standard in and of themselves. Simultaneous control of the severe excursions must be accomplished as well.

5.4.2 Model Results by Source Category. There is little effect of stack height associated with low-level smelter emissions. As a result they exert their predominant effect close to the smelter and decrease rapidly with distance. Mid-level sources, on the other hand, have little effect within one-half mile of the smelter. As distance increased the relative impact of the mid-level sources increases markedly. Figure 5.2 shows the relative impact of low and mid-level sources, by station, on an annual basis. Figure 5.3 shows the actual estimate components at each station on an annual basis.

Active sources exert small effects on estimates at several stations. They seem to be important, in terms of attainment strategy, only during summer quarters at Silver King School, Kellogg Medical Center, and Smeltonville. At these locations the active impacts can be traced to transportation activities around the smelter and McKinley Avenue area, and sinter product handling in areas peripheral to the smelter.

Passive sources exert significant impact at several monitors. In terms of percentage impact, Cataldo is most affected as a result of high lead alluvium deposited across the flood plain and the Mission Flats.

Figure 5.2 Percent Relative Impact Estimates for Ambient Lead
by Source Category at each Monitoring Location

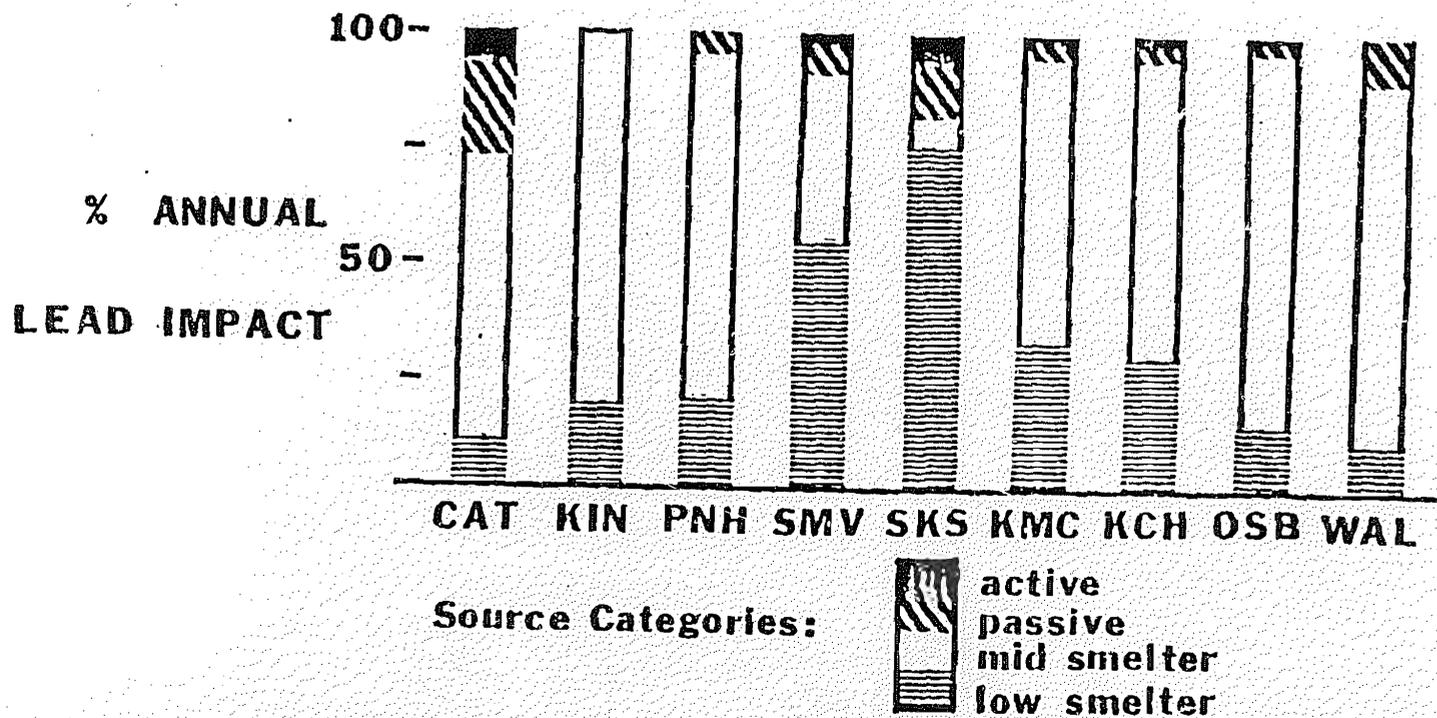
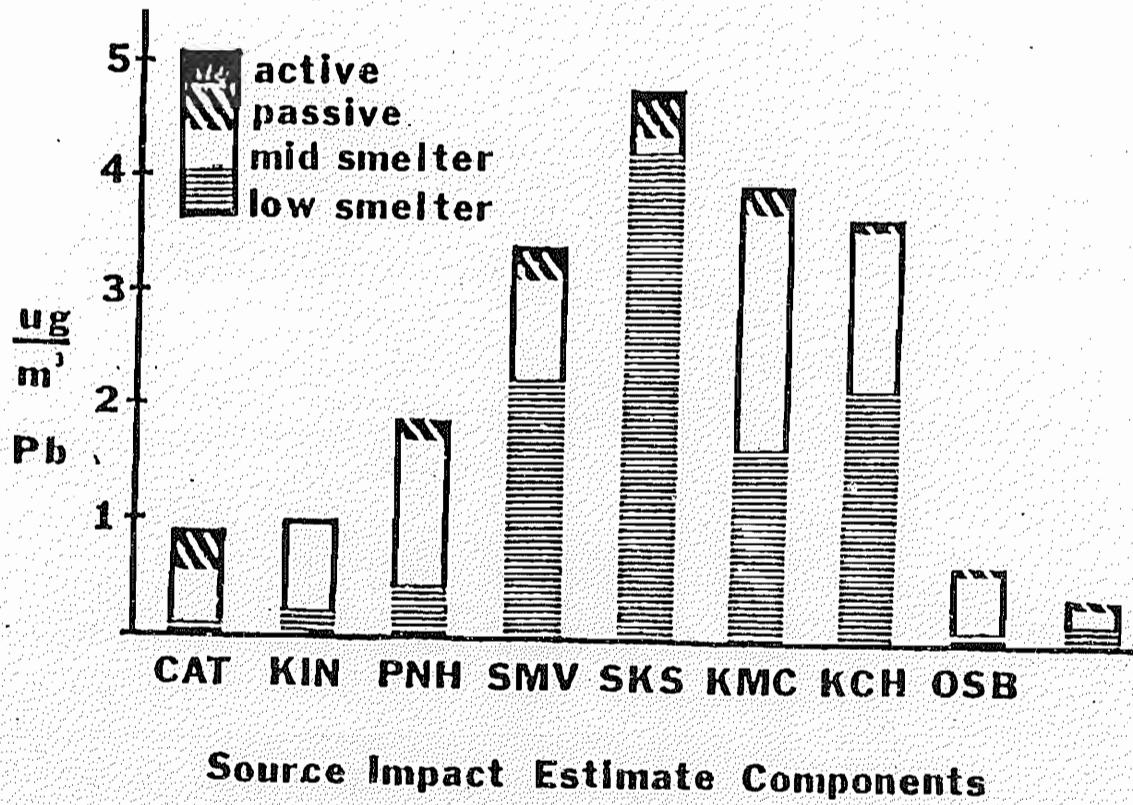


Figure 5.3 Predicted Ambient Lead Impact Estimates by Source Category at each Monitoring Location



In concert with other sources, however, consideration of the passive sources is most important at Silver King School, Smeltonville, and Kellogg Medical Center. Both Smeltonville and Silver King are surrounded by numerous high lead passive sources, especially in the immediate vicinity of the smelter. Kellogg Medical Center is exposed in the predominant wind direction to the airport area and the massive tailings pond impoundment area.

5.5 DISCUSSION OF MODELING RESULTS

Perhaps the most important way to discuss the modeling results is in terms of seasonal impacts of the different source categories. In analyzing the basic source receptor relationship earlier, it was evident that certain meteorological conditions are critical in determining dispersal conditions and ambient concentrations in the Silver Valley. Because these conditions vary with season and because the NAAQS is a quarterly standard this becomes an extremely important consideration. Table 5.6 shows the major components, critical season, and impact area and ambient impact estimate for each significant source category. It is evident that the critical seasons for the several source categories do not coincide. Low- and mid- level smelter sources have their maximum impact under stable conditions exacerbated by light winds and high pressure synoptic patterns that inhibit dispersion. These conditions prevail in the late fall and winter. Active fugitive sources, on the other hand, have their maximum impact under unstable conditions with light winds in the absence of moisture. This type of weather occurs in the spring and early summer. Finally, passive fugitive sources are active at neutral conditions with dry surface conditions and high winds. This weather occurs in the summer and early fall.

Table 5.6 Source Categories' Critical Seasons and Impact Areas

Source category	Largest component sources		Critical season (quarter)	Critical impact area	Maximum ambient estimate $\mu\text{g Pb/m}^3$ quarterly mean
Low-level smelter	Lurgi	50%	Fall, winter (4,1)	< 1 mi.	7.0 $\mu\text{g/m}^3$
	OrePrep	35%		Silver King, Smeltonville	SKS
	Crushing	10%			
Mid-level smelter	Blast furnace	55%	Winter (1)	2-4 mi.	3.5 $\mu\text{g/m}^3$
	Pellet dryer	25%		Kellogg,	KMC, KCH
	Building vents	10%		Pinehurst	2.5 $\mu\text{g/m}^3$ PNH
Active fugitive	Smelter roads		Spring, summer (2,3)	< 1 mi.	.6 $\mu\text{g/m}^3$ SKS
	McKinley Avenue			NW Kellogg	.4 $\mu\text{g/m}^3$ KMC
	Sinter handling			Silver King	
Passive fugitive	Airport		Summer, fall (3,4)	< 1 mi.	.6 $\mu\text{g/m}^3$ SKS
	Smelter property			Smeltonville, Silver King, NW Kellogg	.4 $\mu\text{g/m}^3$ SMU
	Fairgrounds-lumberyard				.75 $\mu\text{g/m}^3$ KMC

This situation has a tremendous impact on any strategy developed to meet the NAAQS. Table 5.7 examines the model estimates for the several non-attainment monitor locations. It can quickly be seen that the worst case situation for each of these locations occurs in the late fall and winter. Further, it is evident that the impacts during this period are nearly exclusively due to low- and mid- level smelter sources. Active and passive fugitive sources are, for all practical purposes, absent during this season.

There are some important conclusions that can be drawn at this point:

1. As the critical impact season for the non-attainment area occurs in the winter when active and passive sources are practically absent, the control strategy for this season must be aimed at the smelter sources.
2. As the primary impact areas for low- and mid- level smelter sources do not coincide, both must be reduced significantly in meeting the NAAQS.
3. A significant questions remains as to the combined effect of smelter sources and passive and active fugitive sources in the summer months. Will the smelter source reductions required to meet the NAAQS in the winter be sufficient to guarantee the standard in the summer when combined with the active and passive source contributions? This difficult question is addressed in the next Section of this report.

Table 5.7 Critical Quarters and Principal Sources for Non-Attainment Monitors

Location	Maximum ambient conc. $\mu\text{g Pb}/\text{m}^3$ quarterly mean	Critical season (quarter)	Component sources		Ambient impact (% max. impact)	
			Low-level	Mid-level	Active	Passive
Pinehurst	3.1 $\mu\text{g}/\text{m}^3$	Winter	.9 $\mu\text{g}/\text{m}^3$	2.2 $\mu\text{g}/\text{m}^3$	0	0
		(1)	(18%)	(82%)	---	---
Smeltonville	4.2 $\mu\text{g}/\text{m}^3$	Winter	2.9 $\mu\text{g}/\text{m}^3$	1.2 $\mu\text{g}/\text{m}^3$	<.1 $\mu\text{g}/\text{m}^3$	<.1 $\mu\text{g}/\text{m}^3$
		(1)	(69%)	(29%)	(1%)	(1%)
Silver King	7.2 $\mu\text{g}/\text{m}^3$	Fall	6.9 $\mu\text{g}/\text{m}^3$.1 $\mu\text{g}/\text{m}^3$.1 $\mu\text{g}/\text{m}^3$.1 $\mu\text{g}/\text{m}^3$
		(4)	(94%)	(2%)	(2%)	(2%)
Kellogg Medical Center	6.3 $\mu\text{g}/\text{m}^3$	Winter	2.6 $\mu\text{g}/\text{m}^3$	3.5 $\mu\text{g}/\text{m}^3$.1 $\mu\text{g}/\text{m}^3$	<.1 $\mu\text{g}/\text{m}^3$
		(1)	(23%)	(75%)	(1%)	(1%)
Kellogg City Hall	6.0 $\mu\text{g}/\text{m}^3$	Winter	2.1 $\mu\text{g}/\text{m}^3$	3.4 $\mu\text{g}/\text{m}^3$	0	0
		(1)	(24%)	(76%)	---	---

6.0 STRATEGIES FOR ATTAINING THE NAAQS

6.1 ATTAINMENT CURVES

In this modeled representation, the primary sources of lead impact have been grouped into four categories. Even with this considerable simplification, development of a sufficient attainment strategy will be difficult. Each of the four main source categories can make a significant contribution to ambient levels when applied to the $1.5 \mu\text{g}/\text{m}^3$ proposed standard. Moreover, those meteorological situations that cause the greatest source impact for one category are not necessarily the most significant in other categories. As a result, great care must be exercised in selecting the proper conditions under which to evaluate an attainment strategy.

In order to determine those combinations of source reductions that will result in attainment of the $1.5 \mu\text{g}/\text{m}^3$ standard, the concept of the "limiting situation" must be introduced. The "limiting situation" is that period (quarter) and location (monitor) that requires the greatest source reduction to meet the proposed standard. The "limiting situation" for any source category is determined not only by the absolute magnitude of that source estimate, but also the relative magnitudes of the other source categories in that same period.

Achieving the proposed standard under the modeled representation requires that the following constraints be true under the "limiting situation" for each source.

$$(1 - C_{LOW}) * (SMLOWEST) + (1 - C_{MID}) * (SMMIDEST)$$

$$+ (1 - C_{PAS}) * (PAEST) + (1 - C_{ACT}) * (ACTEST) \leq 15.$$

SMLOWEST = quarterly impact estimate of low smelter sources

SMMIDEST = quarterly impact estimate of mid smelter sources

PAEST = quarterly impact estimate of passive sources

ACTEST = quarterly impact estimate of active sources

C_{LOW} = fractional reduction of low smelter sources

C_{MID} = fractional reduction of mid smelter sources

C_{PAS} = fractional reduction of passive sources

C_{ACT} = fractional reduction of active sources

It follows that constraints for each source category can be developed as shown:

$$(1 - C_{LOW})(SMLOWEST) \leq 1.5 - (1 - C_{MID})(SMMIDEST)$$

$$- (1 - C_{PAS})(PAEST) - (1 - C_{ACT})(ACTEST) \text{ or}$$

$$C_{LOW} \geq 1 - \frac{(1.5)}{(SMLOWEST)} + (1 - C_{MID}) \frac{(SMMIDEST)}{(SMLOWEST)}$$

$$+ (1 - C_{PAS}) \frac{(PAEST)}{(SMLOWEST)} + (1 - C_{ACT}) \frac{(ACTEST)}{(SMLOWEST)} \text{ and,}$$

$$C_{MID} \geq 1 - \frac{(1.5)}{(SMMIDEST)} + (1 - C_{LOW}) \frac{(SMLOWEST)}{(SMMIDEST)}$$

$$+ (1 - C_{PAS}) \frac{(PAEST)}{(SMMIDEST)} + (1 - C_{ACT}) \frac{(ACTEST)}{(SMMIDEST)}$$

$$\begin{aligned}
 C_{PAS} &\geq 1 - \frac{(1.5)}{(PASEST)} + (1 - C_{LOW}) \frac{(SMLOWEST)}{(PASEST)} \\
 &\quad + (1 - C_{MID}) \frac{(SMMIDEST)}{(PASEST)} + (1 - C_{ACT}) \frac{(ACTEST)}{(PASEST)} \\
 C_{ACT} &\geq 1 - \frac{(1.5)}{(ACTEST)} + (1 - C_{LOW}) \frac{(SMLOWEST)}{(ACTEST)} \\
 &\quad + (1 - C_{MID}) \frac{(SMMIDEST)}{(ACTEST)} + (1 - C_{PAS}) \frac{(PASEST)}{(ACTEST)}
 \end{aligned}$$

These equations can be used to determine the required control for any source category by defining a control regime for the other three categories. Given a proposed control regime for three of the sources, the appropriate equation is solved for each of the monitors for each quarter in the study. The maximum value of C for the fourth source as determined by this method then represents the "limiting situation" for that control strategy. If that maximum value exceeds 1.0, then attainment of the ambient standard is impossible, and further controls must be imposed on at least one of the other sources. By iterating this process for all interesting control strategies under all possible situations, attainment curves can be developed that illustrate those combinations of source reductions capable of achieving the proposed standard.

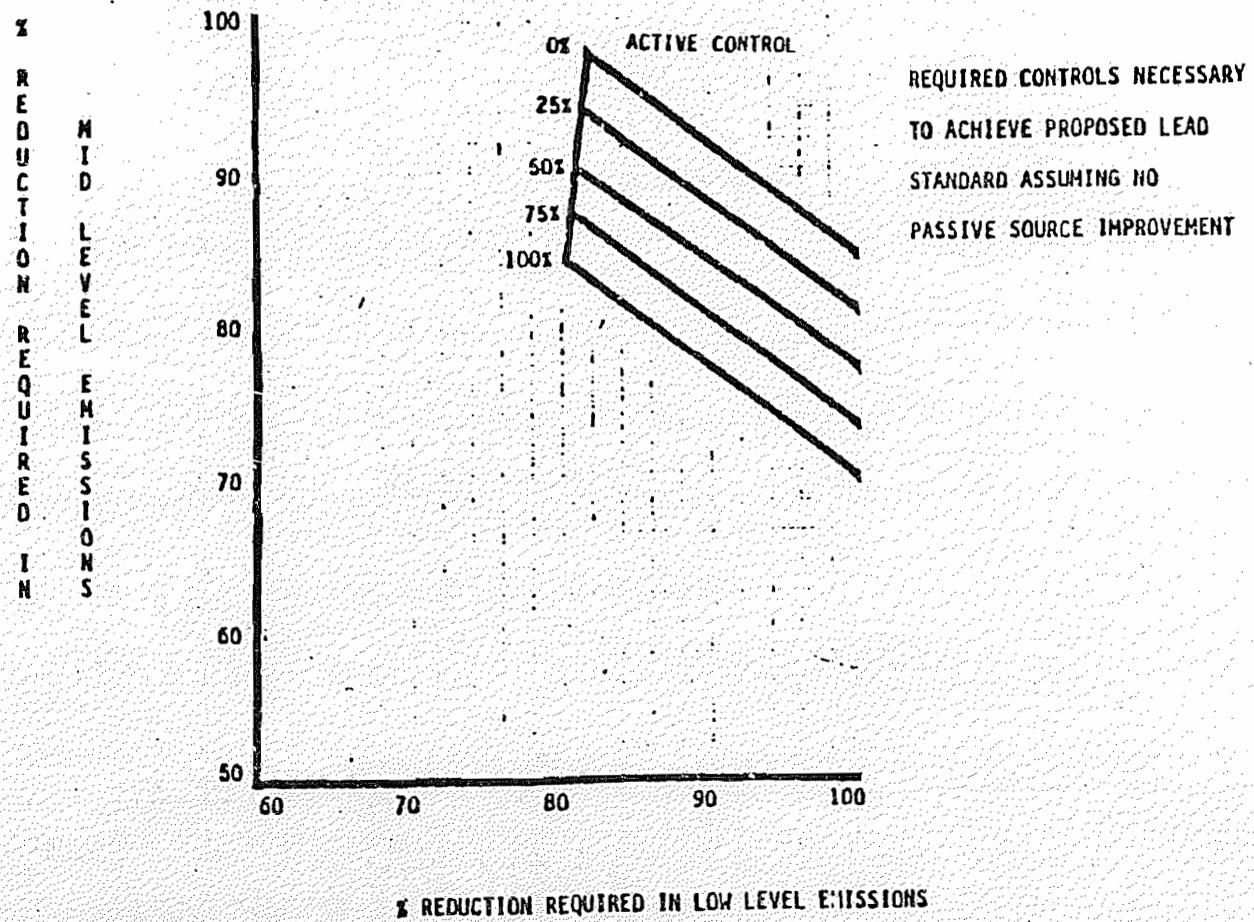
A primary concern of this study has been to evaluate the "background" contribution to ambient lead levels at various locations in the valley and how those "background" contributions can affect an attainment strategy for the area. First, a definition of background is in order. If "background" means lead levels in the absence of industrial activity, then they are probably best represented by passive source category. Active sources,

although they are akin to industrial activity, are not easily addressed in an attainment strategy. The primary active source contributors to lead levels are materials handling of smelter by-products and intermediates in areas outside the smelter proper, and dusts raised by transportation activities in the vicinity of the smelter. The exact regulatory mechanism to be employed in reduction of these sources is unclear.

It is likely that the eventual definition of "background" will be the passive source contribution plus some fraction of the active source contribution. Figure 6.1 shows the results of solving the constraint equations for the limiting situations assuming no control in passive sources and 0, 25, 50, 75, and 100% control of active sources. The abscissal and ordinal values on this graph indicate the minimum combinations of low- and mid-level source reductions required. For example, given no passive control and 50% active control, possible minimal control requirements are found along the 50% line on the graph (e.g., LOW = 90, MID = 84; LOW = 82, MID = 90). Combinations of low- and mid-level control above and to the right of the solution line will achieve the standard; those to the left and below the line will not.

The vertical line in Figure 6.1 shows that no matter how much control is exercised in the active and mid-level source categories, at least 80% low-level control is necessary. This is figured assuming no passive control. However, even if 100% passive control is assumed, solving the C_{LOW} equation for the "limiting situation" yields a control requirement of 78%. The "limiting situation" in this case is the second quarter of 1978 at Silver King School. Knowing that at least 78% control of low-level sources will be required regardless of other source reductions, the constraint

Figure 6.1. Attainment Curve for No Improvement in the Passive Source Contribution



equations are solved assuming 80, 85, 90, 95, and 100% low-level control. One set of attainment curves was then developed for each of these low-level control strategies. That family of curves is shown in Figures 6.2a through 6.2e. In these figures mid-level control requirements are plotted against a supposed passive source reduction; the lines themselves represent a constant level of active source reduction. As with Figure 6.1, values above and to the right of a subject line will result in compliance; those to the left and below will not.

Any combination of source reductions in the four categories can be evaluated by these curves. For example, suppose no additional control on active or passive sources is contemplated, and 90% control of low-level sources is proposed. From Figure 6.2c, it is determined that 91% control of mid-level sources will be necessary. Or suppose 50% active and 25% passive control were feasible but only 80% low-level control were proposed. Under this proposal Figure 6.2a shows that 84% mid-level control would be required.

6.2 EXTREME EXCURSIONS

The inability of this model to predict extreme values at all stations has been discussed. Although that inability is not thought to affect the relative impact calculations for mean emissions, these particular days must be considered in an attainment strategy because of their effect on the quarterly arithmetic means. These days were identified and examined separately. The results of that examination can be found in Table 6.1. The data for each extreme day were qualitatively examined and each day was assigned to one of five categories. Those categories were determined by four factors found common to several of these excursions. The first

Figure 6.2a. Attainment Curve for 80% Improvement in
Low-level Smelter Emissions

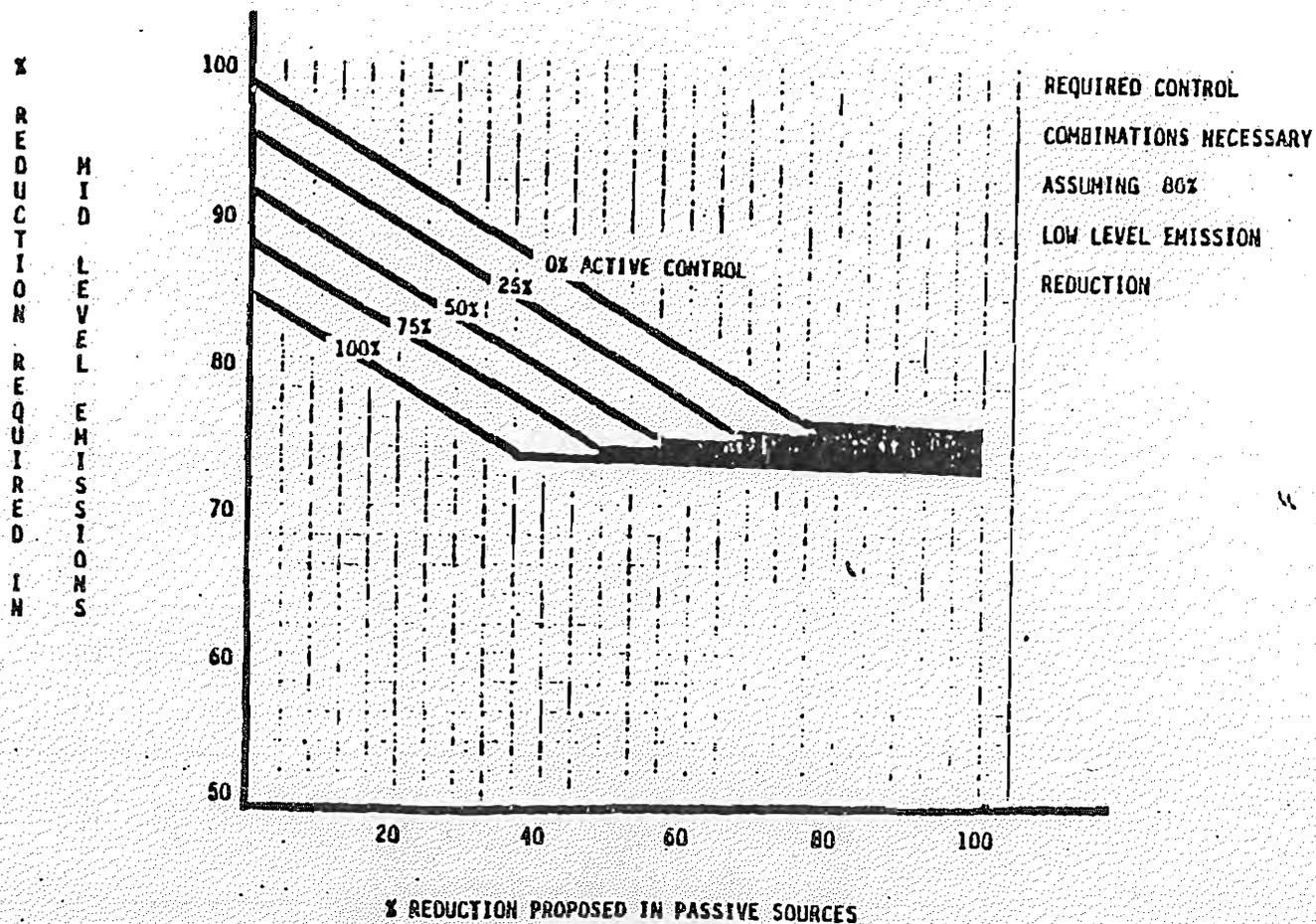


Figure 6.2b. Attainment Curve for 85% Improvement in Low-level Smelter Emissions

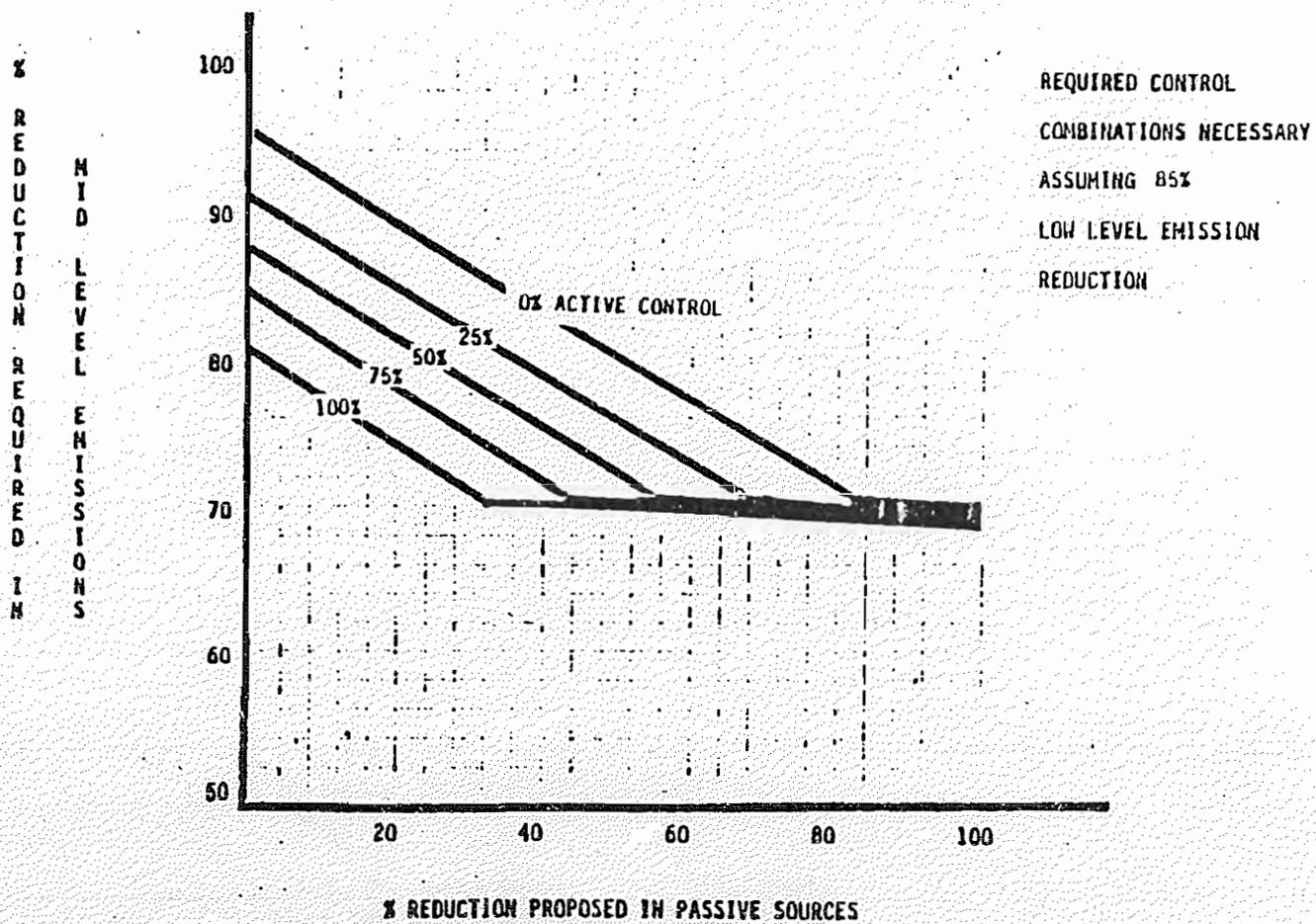


Figure 6.2c. Attainment Curve for 90% Improvement in Low-level Smelter Emissions

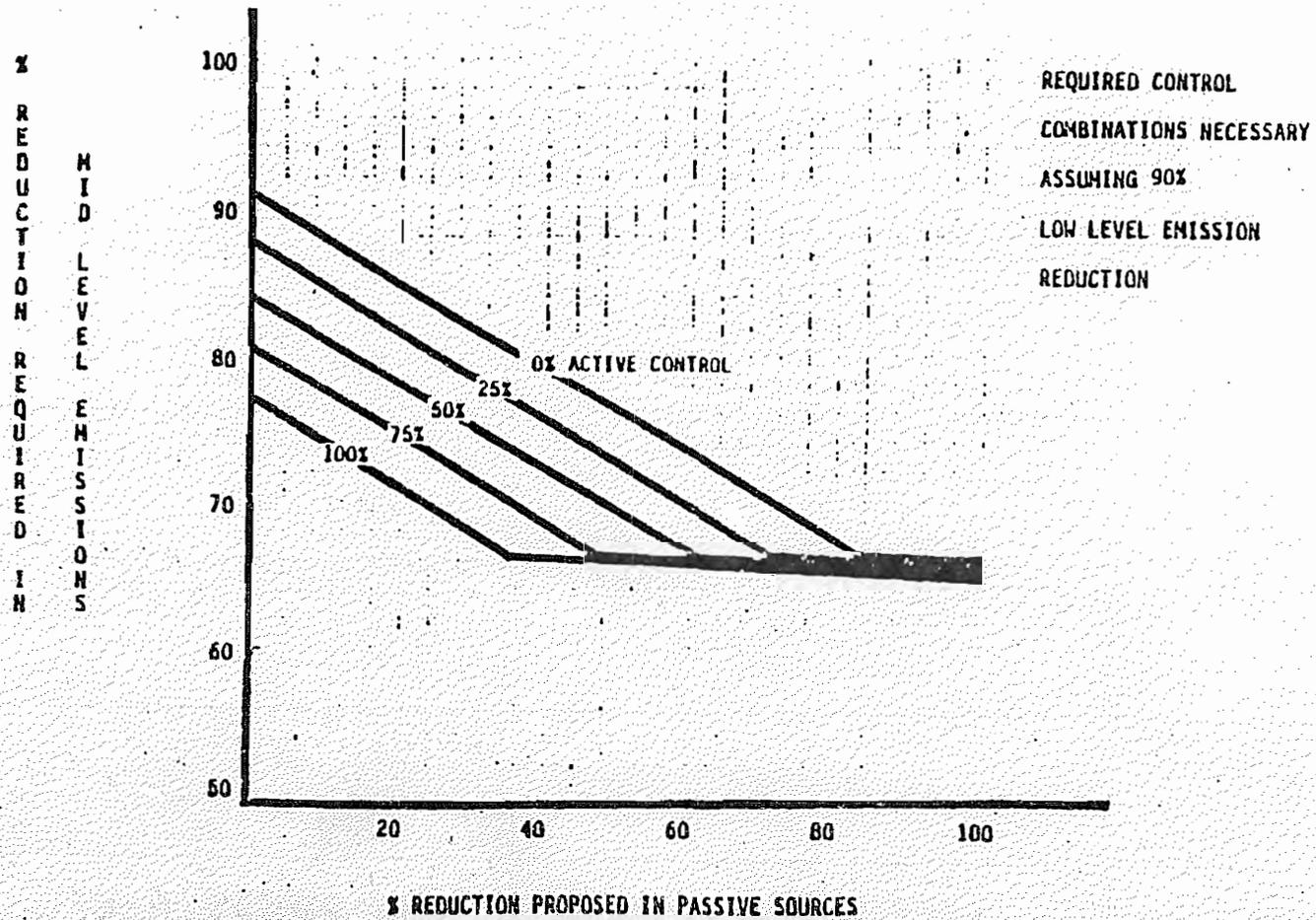


Figure 6.2d. Attainment Curve for 95% Improvement in Low-level Smelter Emissions

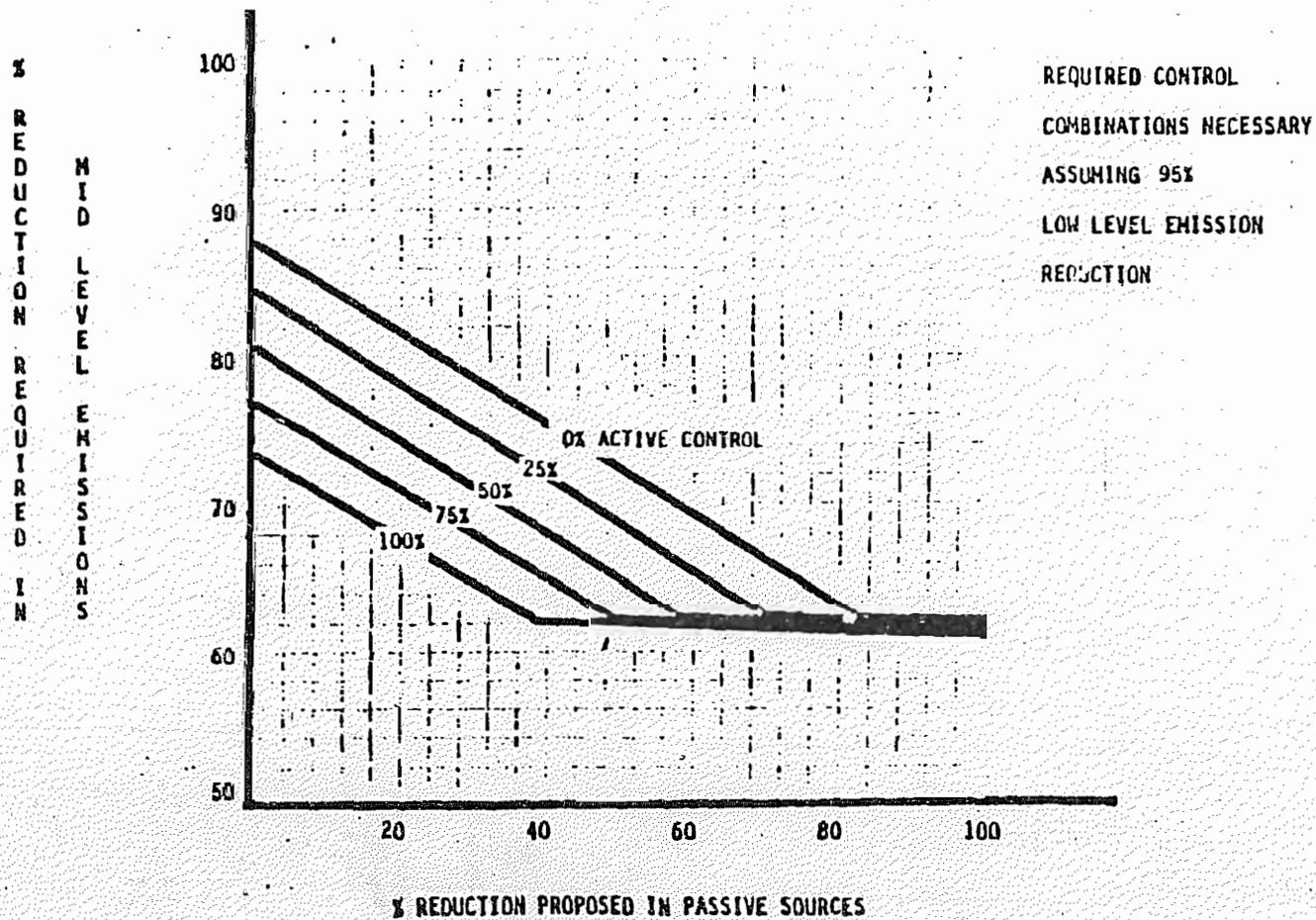


Figure 6.2e. Attainment Curves for Total Elimination
of Low-level Smelter Emissions

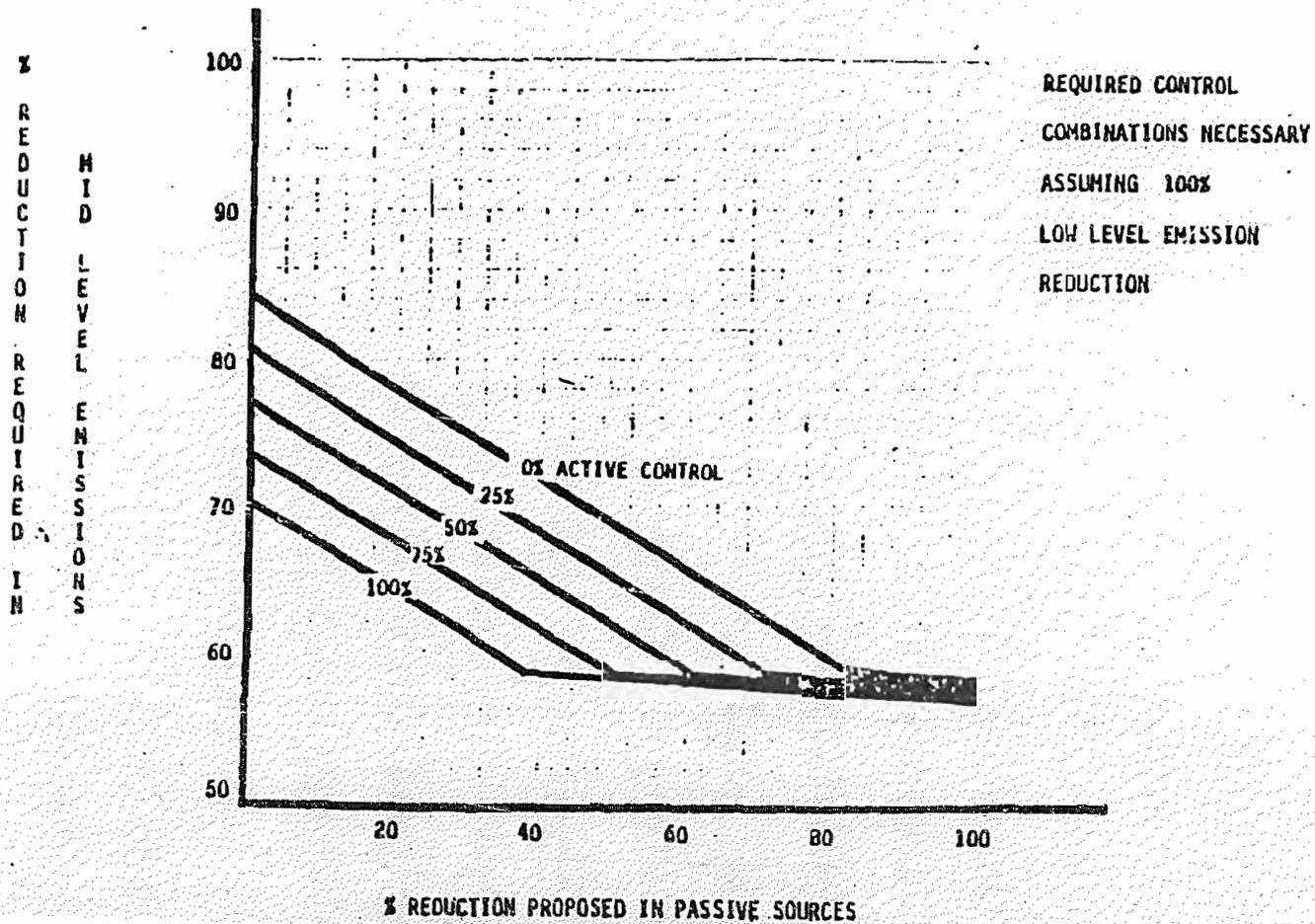


Table 6.1. Tabulation of Possible Causes for Extreme Air Quality Excursions

SUSPECT CAUSE	STATION											
	CAT	KIN	PHH	SHV	SKS	KAC	KCH	OSB	WAL	EAST	WEST	TOTAL
DRAINAGE WINDS	0	0	1	3	2	0	0	0	0	0	6	6
STAGNATION	2	3	7	7	6	4	3	2	2	11	25	36
LOW WIND SPEEDS	2	0	1	2	4	1	1	2	1	5	7	12
STRIKE/STARTUP	1	0	8	6	3	1	2	1	0	4	18	22
UNACCOUNTED	1	2	8	6	6	11	6	9	9	35	23	58
# DAYS	4	5	25	24	21	17	12	14	12	55	79	134
SUM	11.4	20.9	163.4	369.8	485.1	233.1	211.5	100.3	42.1	587	1050.6	1626.2
MEAN	2.9	4.2	6.5	15.4	23.1	13.7	17.2	7.2	3.5	10.7	13.3	12.1
# DAYS	165	140	150	169	167	164	145	172	161	642	791	1433
SUM	74.7	76.1	273.7	805.3	1093.3	659.6	614.2	222.0	111.6	1607	2323	3930
MEAN	.45	.54	1.8	4.8	6.6	4.0	4.2	1.3	.7	2.5	2.9	2.7

condition was several days of extreme readings during the strike of 1977, and the startup period following for which no meteorological data were recorded. The second factor included days of extreme atmospheric stability or stagnation. The third situation was severe synoptic drainage winds affecting stations to the west of the smelter, and the last included periods of low wind speeds in the middle atmospheric levels. No meteorological or operational factor could be found to explain the extreme values on the remainder of the excursion days.

Three of these factors are accounted for to some degree in the model. The stagnation and drainage wind regimes and low wind speeds in the middle atmospheric levels were empirical qualifiers in the regression equation. Passive source estimates predict significant impacts with drainage wind, and extreme stability is treated by nearly a constant dispersion parameter. These factors, however, do not predict as high an impact as was observed. Perhaps the remaining two categories can suggest why. During the strike the smelter was operated intermittently by salaried personnel and considerable construction of pollution control facilities was carried on by outside contractors. Following resolution of the labor difficulties, new pollution control facilities were in use. It may be possible that less than efficient operation was practiced during these periods resulting in exaggerated emission rates. Furthermore, those days for which no meteorological explanation of the high values can be found are likely caused by abnormal emissions. Additional investigation of company operation records and upset reports may be worthwhile in establishing this point.

The remainder of the discussion here will contend with the impact, rather than the cause, of these days. The top part of Table 6.1 shows the

number of extreme days in each category for each station, for each direction, and total tabulation. It can be noted that to the west of the smelter about 8% of the severe days can be attributed to drainage winds, 32% to stagnation and extreme stability, 9% to low wind speeds, 23% to the strike/startup period, and 33% are unknown. In the easterly direction drainage winds have no effect as the monitors are upwind of the smelter. A similar percentage of extremes were attributed to low wind speeds and extreme stabilities. The strike period, however, did not seem to affect eastern stations to the degree that occurred to the west. This may be attributable to less than twenty-four operations of the smelter and the wind direction associated with the operation shift. The suspected cause of over 60% of the extreme concentrations east of the smelter is unknown.

The lower part of Table 6.1 shows the effect of these days on the total impact measured at each station. The number of extreme days at each monitor is shown together with the mean and total lead impact. These values are compared to those for all days. This shows that, at non-attainment stations, from 8 to 17% of the days account for 35 to 60% of the total impact. These days have about 4 times more impact on the quarterly mean than does an average day.

Any attainment strategy must consider these days and their extraordinary impact. Deductive reasoning concludes that those severe excursions whose cause cannot be found in the meteorology are likely due to excess smelter emissions. These excess emissions are, in turn, likely due to upsets, malfunctions, and startup/shutdown conditions. Further work in this area and the development of an effective program for preventing or minimizing upsets is requisite to formulation of a viable attainment strategy.

6.3 DISCUSSION

There are numerous combinations of source reduction scenarios that will achieve the national standard according to results of this study. However, there are certain minimum requirements and generalizations that can be made. In order for any attainment strategy to be successful, the extreme excursions suspected resultant from process upsets, malfunctions, and startup/shutdowns must be addressed. Either additional studies should be undertaken to confirm the cause of these high concentrations, or a comprehensive program and accompanying regulation controlling these situations should be established.

Given that severe excursions are successfully addressed, the attainment curves can be used to ascertain further requirements. Under any circumstances at least 78% reduction in low-level emissions will be necessary. Assuming an 85% reduction in low-level emissions, significant improvements in ambient concentrations can be achieved by reducing the active and passive components. Remembering that Kellogg Medical Center is the limiting situation regarding passive and active sources, improvements in those sources affecting this monitor may be worthwhile. Those sources are sinter product handling outside the smelter, McKinley Avenue, the airport area, the fairgrounds/lumberyard area, and the tailings pond embankment area. With significant improvement in these areas and 85% reduction of low-level sources, perhaps an 80 to 85% control in mid-level sources would be necessary.

Examination of Table 4.3 shows that blast furnace upsets are the dominant source in mid-level emissions. This same source is suspected as being the largest contributor to the startup-upset extreme excursions. If these upsets were eliminated, achievement of the standard would likely be much easier.

One additional point should be considered in developing an attainment strategy. All the attainment curves are based on at least a 78% low-level emission reduction required at Silver King School. Were the smelter owner to purchase all property between the Smeltonville monitor and the plant, this requirement might be significantly reduced.

All these factors deserve consideration. However, in general, given the current conditions, meeting the national standard will require:

1. A comprehensive control program for upset, malfunction, and startup/shutdown situations.
2. Eighty to 85% reduction in low-level and mid-level emissions through elimination or rerouting discharges to the tall stack.
3. Moderate effort to reduce active emission arising from by-product handling outside the smelter, company roads, and McKinley Avenue.
4. Stabilization, covering, or revegetation of bare soils around Linfor Lumber, Smeltonville fairgrounds, the airport, and the smelter tailings pond embankments.

7.0 CONCURRENT CONSIDERATION OF NAAQS AND OSHA SOURCE REDUCTION STRATEGIES

7.1 Data Quality and the Reliability of Results

There is considerable disparity in the quality of the data utilized in the several preceding elements of this study. The environmental data (i.e. weather, air contamination, soil lead content etc.) are of excellent quality for this type of analysis. As a result great confidence can be placed in those conclusions regarding the meteorological factors that influence this air pollution problem. Those weather conditions that have the most severe impact have been identified and the seasonal effects have been characterized. The source categories' relative contributions have been quantified and their required percentage emission reductions have been estimated by meteorological analyses. In a corollary sense, those items that have been identified as being independent of meteorological considerations can be trusted. Specifically, the weight and importance of upsets and malfunctions in contributing to excess ambient lead concentrations cannot be discounted.

On the other hand, the emissions data are relatively sparse and the emissions themselves are subject to considerable variation. Additionally, the source inventory developed in Section 4 spans a five-year period (1975-80) during which considerable changes occurred in the emissions spectra. As a result the source inventory used in this study may not accurately reflect the facility's emissions characteristics at the time of its last operation. It was originally planned to use a new emissions inventory developed in 1981. However, because of several legal objections and the subsequent shutdown that survey was never released.

The problem of uncertain emissions measurements was recognized early in the model development. This was the primary reason for using the empirical approach of relating ambient readings to emissions estimates in a categorical inventory. In that way, the results could be expressed in percentages or relative terms whose confidence levels were based on meteorologically derived variables. As a result the attainment curves presented in Section 6 and those appearing in Section 7.3 can be relied upon to indicate the percentage reductions necessary to achieve NAAQS under the prescribed conditions.

However, when relating those requirements to the actual emissions inventoried in Table 4.3, considerably more uncertainty is introduced. If these attainment curves are indeed ever used in developing a compliance strategy, a new source inventory should be obtained. Because of the particular design of this study a new inventory could be accommodated with a minimum of effort. Unfortunately, in this analysis the only available inventory must be used. For that reason and because of the smelter's uncertain future there is little advantage in relying on other than the general conclusions of Chapter 6.

Were the new source inventory available more intense modeling would be called for and more specific recommendations might be made. For example, with detailed operations data, specific reference could be made to New Source Performance Standards, Best Available Control Technology, and Economic Benefits Criteria. In the remainder of this section only general conclusions will be drawn as to the mutual benefits of simultaneously considering OSHA and NAAQS at this facility.

7.2 Source Reductions Necessary to Meet Each Standard

The problems discussed above do not diminish the reliance that can be placed on the conclusions that follow or detract from what might be learned regarding the feasibility of continued and compliant operation of this plant. The basic premise of this study is to use the Cartographic Modeling System to simultaneously evaluate community and occupational exposure from the lead smelter. The objective is to determine the degree to which these exposures have common sources and if there is advantage in concurrently considering control strategies for OSHA and NAAQS compliance.

A fairly comprehensive understanding of the emissions reductions necessary to meet both standards can be developed from this study and the Radian report. The occupational aspects can be summarized in this context as follows:

1. Compliance can or has been achieved in the majority of plant areas through the use of administrative procedures, change in work practice, or installation of available engineering controls.
2. Upsets, malfunctions, and uncontrolled fugitive emissions play a major role in excess occupational exposures. Given the current processes employed at this facility, compliance is impossible in two areas. They are the Highline area, due to routine uncontrolled fugitive dusting, and the Blast Furnace area, due to the blast furnace upset.

Compliance with the NAAQS is considerably more complex because of the much smaller standard, the intense meteorological and terrain effects, and the number and behavior of sources within and outside of the complex capable of affecting the community. However, the general conclusions of Chapter 6 can be restated here as being necessary to NAAQS compliance.

1. Some active and passive fugitive dust control measures will have to be instituted outside of the complex. They likely will require eliminating the outdoor storage of sinter product, implementation of roadway sanitation practices, and stabilization of bare contaminated soils in key locations.
2. Significant reduction in low-level and mid-level smelter emissions will be required. As will be discussed in the following sub-section, these reductions could vary from 60% to 100% in either category with a grouped average of between 80% and 85% being required.
3. A comprehensive program for controlling excess emissions resultant from upsets, malfunctions, and startup/shutdown procedures must be implemented.

The order of presentation here does not reflect a reordering of priorities from Section 6. Elimination of upsets is and remains the number one concern for this facility. The first item above is so listed because these measures will likely be required independent of actions taken inside the complex and are not of especial occupational concern. The last two items are pertinent to consideration of occupational compliance and are discussed in detail in the next section as they apply to excess exposures both in the work place and the community.

7.3 Modeling Analyses of Simultaneous Effects of Sources

Inside and Outside the Smelter

It is clear from the previous discussion and the results of Section 6 that meeting the NAAQS will require source reductions in each of the four source categories: Active fugitive sources, Passive fugitive sources, Low-level and Mid-level smelter emissions. The last two of those

categories have impacts on occupational exposures as well. In this subsection the Cartographic Modeling System is employed to examine what percentage of reduction options are feasible for these two categories. Two alternative scenarios are modeled. In both it is assumed that a 50% reduction has been achieved in each of the Active and Passive source contributions. The first scenario considers the current real property configuration. The second situation assumes that the smelter acquire all the land within one-mile of the smelters main stack, thus, extending the area immune from NAAQS requirements.

The results are summarized for each scenario in Figures 7a and 7b, respectively. Both show those combinations of source category reductions that would result in NAAQS compliance given the assumptions above. In Figure 7a, which effectively represents compliance at the Silver King School, low-level emission controls range from a required 80% to 100%. Concurrently, mid-level reduction requirements are from a high of 78% at the minimum low level reduction requirement down to a low of 62% were low-level emissions completely eliminated.

Figure 7a. Low-level and Mid-level Smelter Source Reductions

Requirements Assuming Current Property Configuration

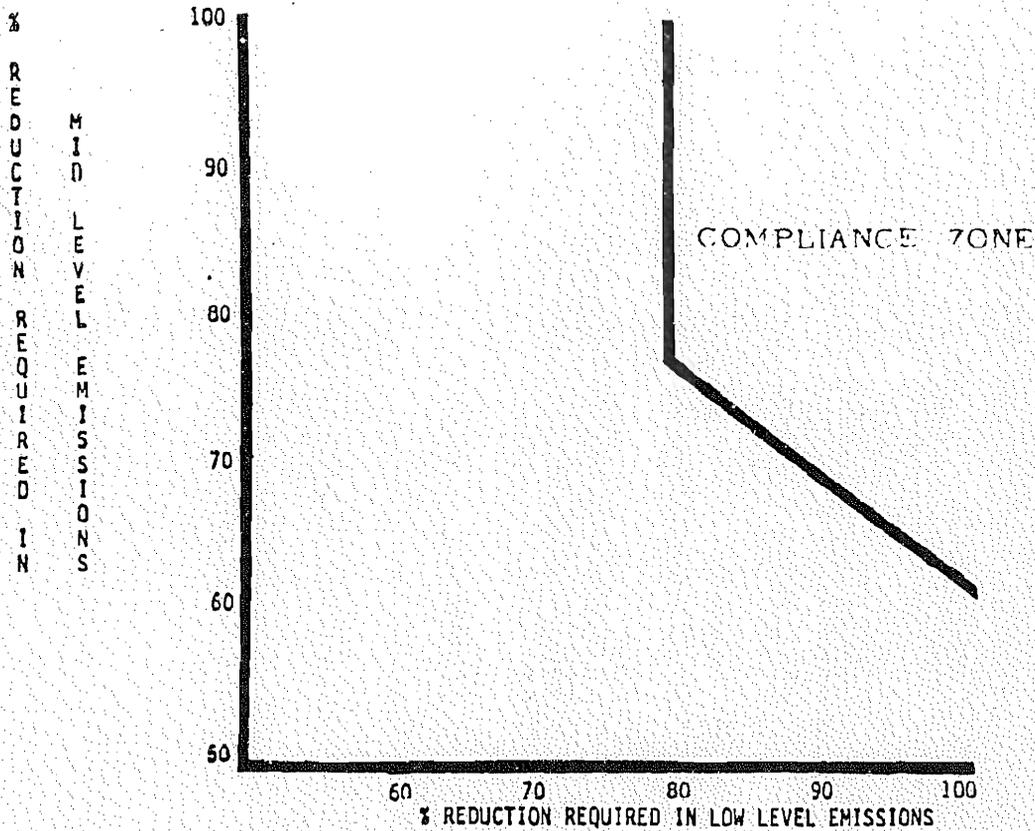
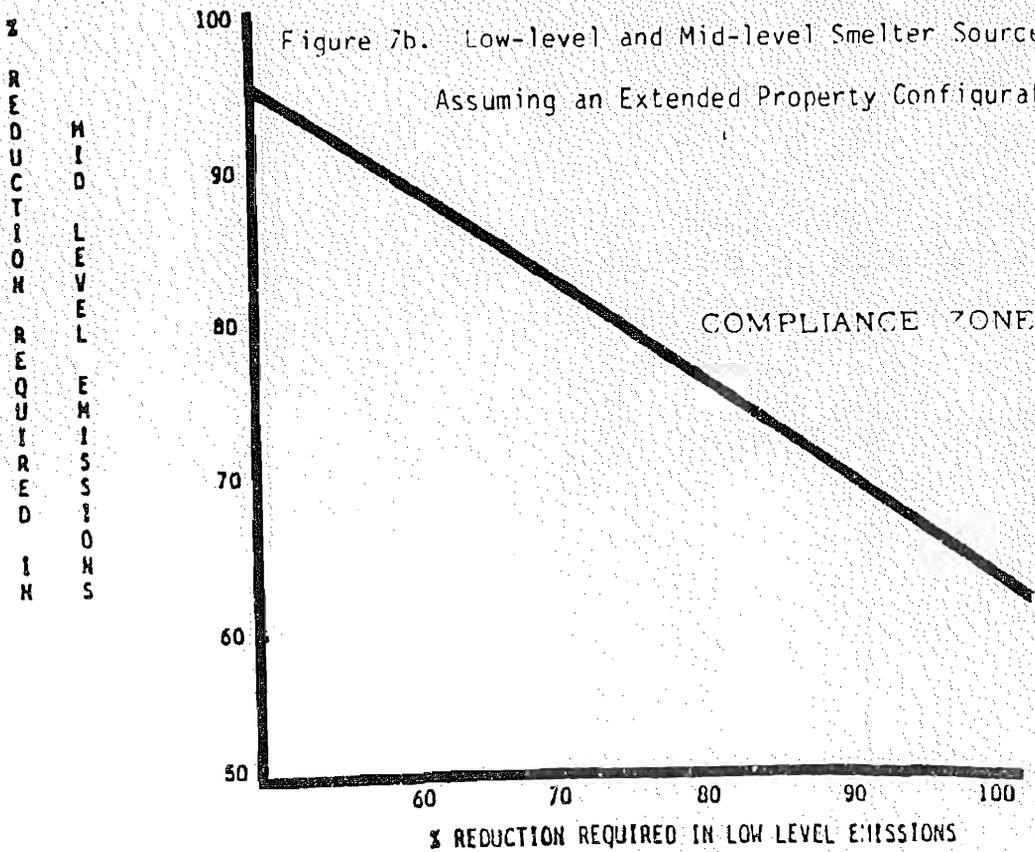


Figure 7b. Low-level and Mid-level Smelter Source Requirements

Assuming an Extended Property Configuration



The predominance of low-level sources' effects at monitors located near the smelter is clear. Significant decreases must be achieved in this category regardless of other emission reductions. This supports the common belief that ground level fugitive dust releases around lead smelters are a major source of excess lead levels in the nearby community.

Figure 7b shows the same results assuming the smelter property line were extended one mile distant. Now the option of reducing low level emissions extends as low as 50% with a concurrent mid-level reduction requirement of 96%. A total elimination of low-level sources would reduce the mid-level reduction requirement to 57%. The latter is not much lower than the 62% required under the present property boundaries. That is significant in the sense that property acquisitions could be used to offset low-level emission reductions that, in turn, decrease the required mid-level emission reductions. However, this strategy is effective only to extend the low-level option below the 80% reduction requirement. How advantageous this might prove depends on the ease with which low-level emission reductions are achieved. If, for instance, 65% of the emissions could be relatively easily eliminated, a property extension and slightly higher mid-level reductions might be more efficient than attacking the remaining 35% of low-level emissions. Consideration of such options requires specific knowledge of the current emissions and how difficult they will be to control. That discussion is reserved for the following Section of this report.

7.4 Concurrent Compliance Strategies for the NAAQS and OSHA Requirements

Discussion of the results of the analysis of the previous sub-section is presented in a new sub-section because of the problems alluded to in Section 7.1. Use of the actual emissions that make up the source

categories begins. The analyses now moves from relative to absolute considerations and projections. From this point on, there is added uncertainty associated with the quality of the available emissions inventory.

Low-level emissions: This category's emissions are principally from two types of sources of about equal contribution. About half are from the Lurgi sinter plant area and are predominantly point sources. A similar amount are from the Highline area and are the result of uncontrolled fugitive emissions. This is a convenient division for discussion of these sources. Point sources are not as important to industrial exposures and are more easily addressed than the fugitive sources. It is likely that sufficient controls for NAAQS compliance needs are currently available and economically feasible for these sources. Control of these sources could effect as much as a 40% reduction in low-level emissions. The uncontrolled fugitive sources in the Highline area are much more difficult. The Radian study concluded that these were impossible to control to the extent necessary to achieve occupational compliance. Many of these sources are manifest to the outside environment through building ventilation and there seems to be a significant difference in the sources that workers and the community are exposed to from this area.

Mid-level emissions: These sources are due almost entirely to one of two sources. Point source in the pelletizing area make up about 30% of this category. The remainder is due directly or indirectly to blast furnace upsets. As with the low-level sources it is likely that a significant reduction in point sources could be achieved through application of available add-on technologies. However, blast

furnace upsets are the primary concern with respect to both community and occupational exposures and are doubtless the most difficulty emissions to control in the entire complex. Numerous attempts have been made in the last ten years to control this source. None have succeeded. If NAAQS or OSHA requirements are ever to be achieved, the blast furnace upset condition will have to be substantially reduced. It is unlikely that this could be accomplished with the current plant configuration. New process designs and a dedicated control device may be necessary.

If the goal of the smelter is to comply with both standards in a compatible time frame, then, based on these emission data, the preferred control strategy is obvious. There are two absolute requirements that cannot be avoided. In order to achieve compliance with OSHA standards in the Highline area at least 75% of the uncontrolled fugitive emissions must be eliminated. In order to achieve compliance with either standard in the Blast Furnace area, at the very least, 65% of these emissions will have to be addressed.

Given these prerequisites, property acquisitions would not be productive in meeting both the standards. Achieving the reductions required for OSHA compliance in the Highline area coupled with best available control technology for the Lurgi area would result in approximately 80% reduction in low-level sources. That, together with a similar reduction required for the blast furnace upset, should result in compliance for both these areas with respect to both standards.

7.5 Economic Discussion

Although no economic analysis is required by this contract and is beyond the current resources of this modeling technique, the current status of the complex requires that this report be summarized in an economic context. Given the goal of simultaneous occupational and environmental compliance for lead emissions the following major control activities are required:

1. Institution of available management practices and engineering control suggested in the Radian report;
2. Elimination of outside storage of sinter produce and maintenance of road sanitation practices;
3. Stabilization of contaminated soils in certain locations.
4. Installation of available control technologies for point sources and certain fugitive sources in the complex.
5. Substantial elimination of uncontrolled fugitive emissions in the Highline area and upset conditions in the Blast Furnace area.

Each of the first four items probably carries a price tag of around a million dollars and could be a reasonable expenditure for this operation during profitable tiems. The last item, however, will require substantial process alterations and replacements in both areas. These costs will be measured in tens of millions of dollars exclusive of the lost production time, demolition, and site preparation expenses. That type of investment, because of current and projected metals prices and interest rates, will not be made in the foreseeable future.

If and when this smelting complex reopens, a large initial investment will be required to reestablish a work force, recruit professional staff, purchase reliable raw material contracts, and refurbish and replace

weathered equipment. It is also likely that such a serious investor will be interested in assuring substantial compliance with health regulations. The Highline area of the smelter is antiquated. It needs to be replaced with up-to-date processes, not only for health reasons, but for operational efficiency and business competitiveness. The blast furnace upset must simply be eliminated for any hope of compliance. A future investor may well make these commitments were a restart to become reality. Perhaps, the most prudent business decision that could be made at this time may be to proceed with demolition of those parts of the complex incongruent with a modern lead smelter. Those demolition and maybe site preparation costs could be used to off-set federal taxes as "discontinued operations losses" and provide a basis for some future industrial use of this facility.

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APPENDIX A

REFERENCED MAP DISPLAYS

Figure A: TOWNS, RIVER, VALLEY, MONITORS

Figure B: ELEVATION, ROADS, VALLEY

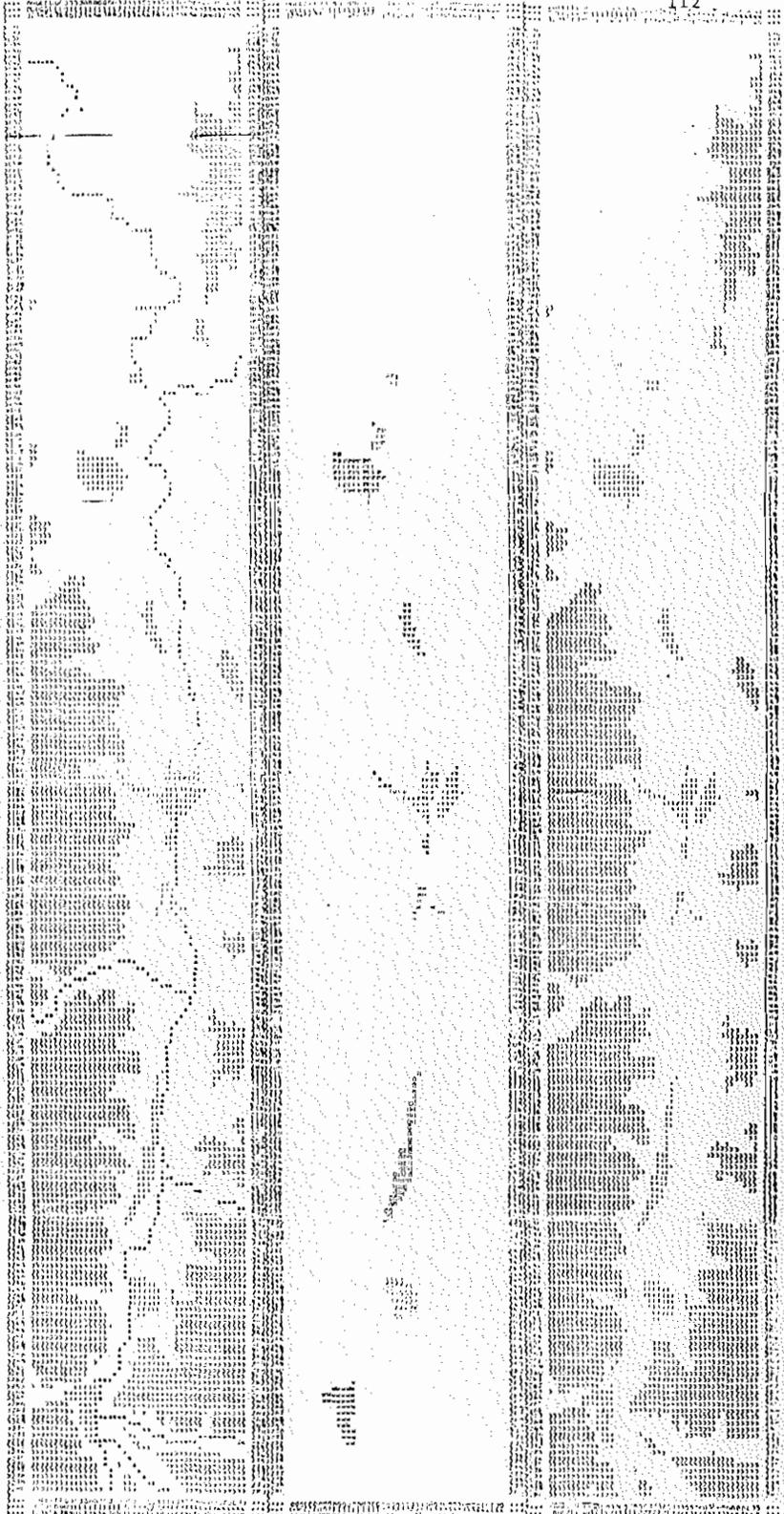
Figure C: ACTIVES, PTSOURCE, SPECSITE

Figure D: SOILPB, SOILCD

Figure E: DOEPASS, PEDCOPAS, PESPASS,
COVERMAP, PASSIVES

Notes for Figure A

The first map demonstrates the map VALLEY overlaid by the river and urban locations. The second map depicts the urban locations through the map TOWNS. The third map superimposes the monitor locations from the map MONITORS.



TABLE

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TABLE

NO.	DESCRIPTION	UNIT	QUANTITY	AMOUNT
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Notes for Figure B

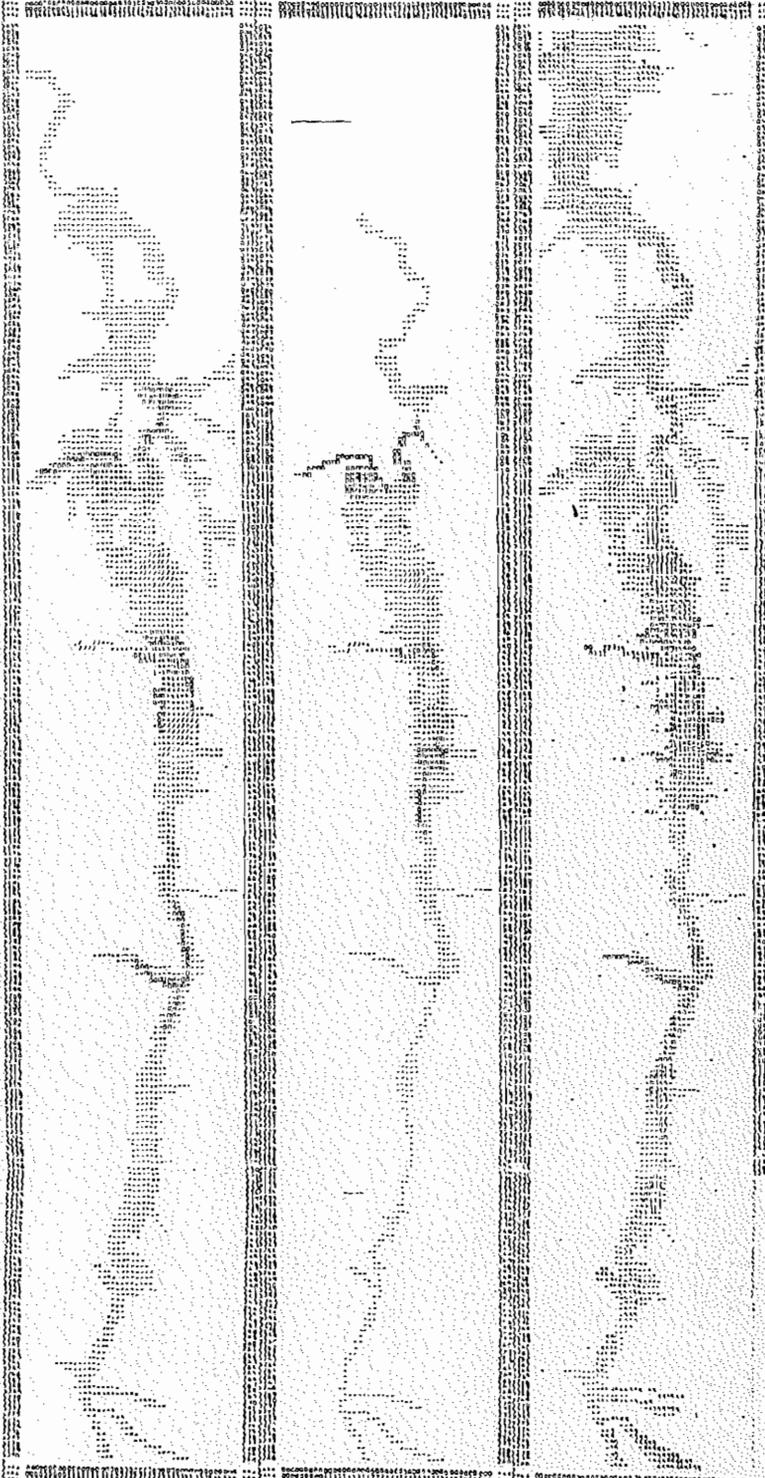
These three maps are first the sliced version of the ELEVATION maps. It is divided into twenty levels representing 100-foot intervals from 2000 to 4000 feet in elevation. The next map shows the ROADS in the valley and in the third map values above 3200 feet elevation are masked out for VALLEY to illustrate the relative location of the roads.

Notes for Figure C

These three maps show the locations of the Active and Point Source locations, and the sites deserving special source considerations in the passive analyses. The point source labels are by process unit as defined in Chapter VIII. ACTIVES, PTSOURCE, and SPECSITE are described in Chapter VI of the parent document.

Notes for Figure D

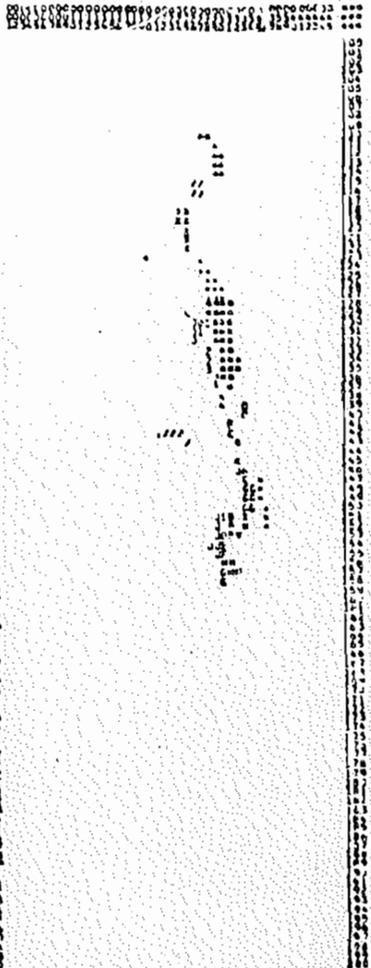
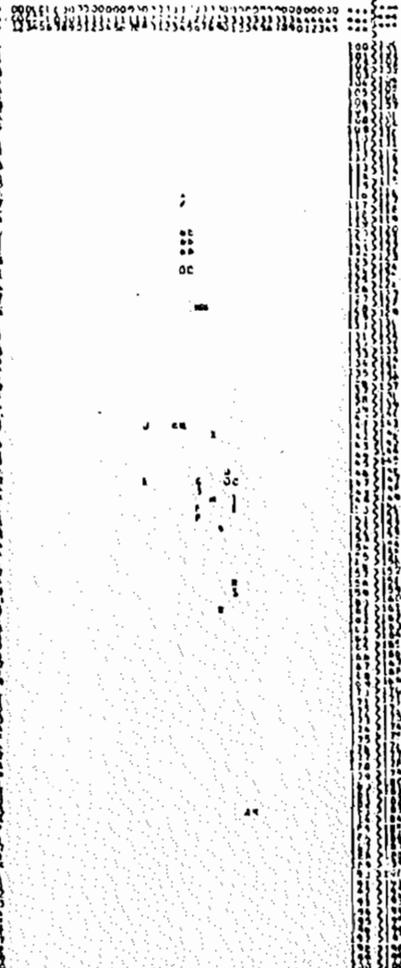
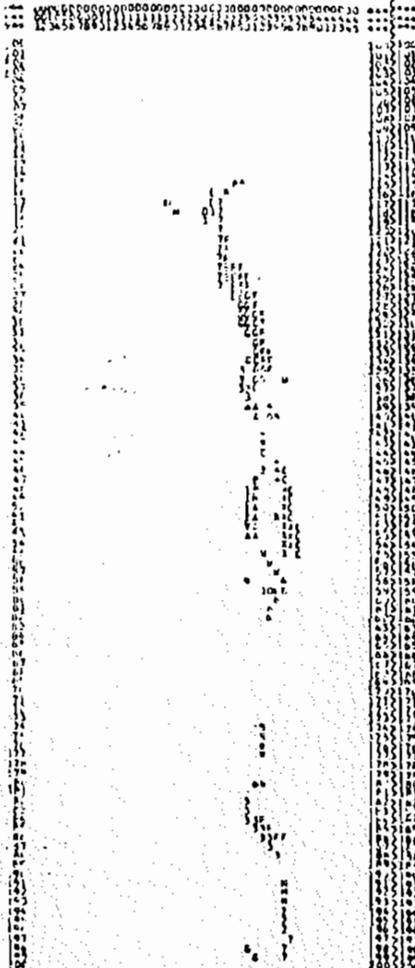
This series of maps illustrates a part of the development of the soil contamination maps SOILPB and SOILCD. The first two maps are the soil lead and cadmium estimates developed by the regression models in the report text. They are displayed here using the "slice" technique in which the different levels signified at the top of the legend are displayed via corresponding symbols below. The levels are in ppm metals. The third map is the soil contamination map synthesized from the several soil studies referenced in the report text. It shows soil lead estimates in ppm for the valley sites (river + 200 feet).



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Notes for Figures E1 and E2

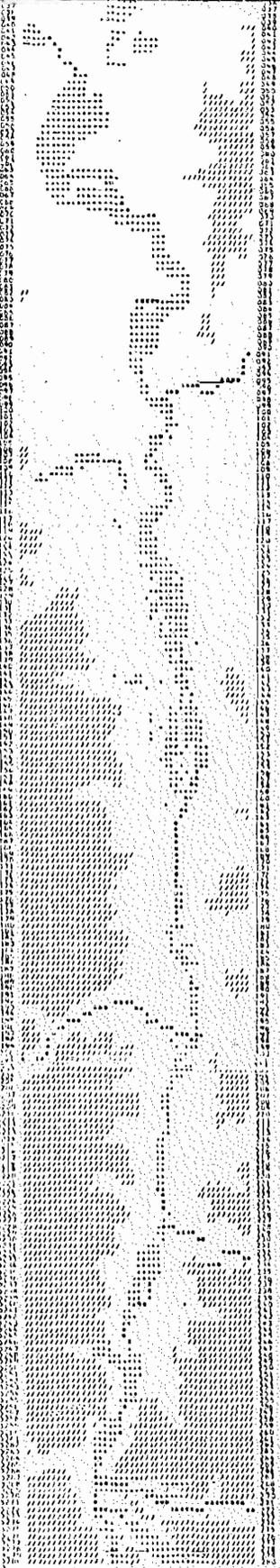
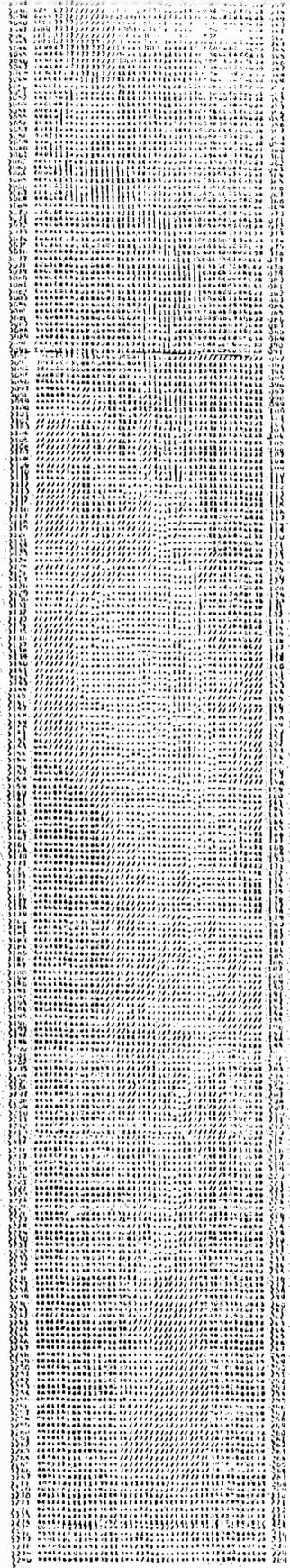
The first three maps are the PASSIVE source locations from three studies referenced in the text. The list at the bottom of the maps refers to those in Table 2 as indicated by the variable VAL for PESPASS, (VAL - 100) for PEDCOPAS, and (VAL - 200) for DOEPASS. The next map is the vegetation COVERMAP that depicts the vegetation cover levels for the valley. Some of the areas from this map are used together with the previous three maps to produce the last in this series. That map referred to as Fig. E2 - X shows all the special passive source areas considered in the valley, and the river.



CELLS	DESCRIPTION	CELLS
1	BRIDGE AREA PUM	1 CELLS
2	ROCK & GRAB PUM	1 CELLS
3	SWY PLAYGROUND	1 CELLS
4	TAILINGS AREA	1 CELLS
5	SLURRY BASIN	1 CELLS
6	DIC STORAGE AREA	1 CELLS
7	MINER PILL	6 CELLS
8	ATHLETIC FIELD	1 CELLS
9	CEMENT	1 CELLS
10	BRUIP STOR AREA	2 CELLS
11	WINE SPELDS	1 CELLS
12	MELLCUT W/ SHREY	2 CELLS
13	MELLCUT STORAG	1 CELLS
14	SHLEPER STORAG	1 CELLS
15	MELLCUT STORAG	2 CELLS
16	MELLCUT PILL	1 CELLS
17	MELLCUT PILL	2 CELLS
18	LUMPER HAND STR	2 CELLS
19	W END W STP	2 CELLS
20	REGRADE AREA	1 CELLS
21	REGRADE AREA	1 CELLS
22	BRIDGE AREA PUM	1 CELLS
23	ROCK & GRAB PUM	1 CELLS
24	SWY PLAYGROUND	1 CELLS
25	TAILINGS AREA	1 CELLS
26	SLURRY BASIN	1 CELLS
27	DIC STORAGE AREA	1 CELLS
28	MINER PILL	6 CELLS
29	ATHLETIC FIELD	1 CELLS
30	CEMENT	1 CELLS
31	BRUIP STOR AREA	2 CELLS
32	WINE SPELDS	1 CELLS
33	MELLCUT W/ SHREY	2 CELLS
34	MELLCUT STORAG	1 CELLS
35	SHLEPER STORAG	1 CELLS
36	MELLCUT STORAG	2 CELLS
37	MELLCUT PILL	1 CELLS
38	MELLCUT PILL	2 CELLS
39	LUMPER HAND STR	2 CELLS
40	W END W STP	2 CELLS
41	REGRADE AREA	1 CELLS
42	REGRADE AREA	1 CELLS
43	BRIDGE AREA PUM	1 CELLS
44	ROCK & GRAB PUM	1 CELLS
45	SWY PLAYGROUND	1 CELLS
46	TAILINGS AREA	1 CELLS
47	SLURRY BASIN	1 CELLS
48	DIC STORAGE AREA	1 CELLS
49	MINER PILL	6 CELLS
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56	SHLEPER STORAG	1 CELLS
57	MELLCUT STORAG	2 CELLS
58	MELLCUT PILL	1 CELLS
59	MELLCUT PILL	2 CELLS
60	LUMPER HAND STR	2 CELLS
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64	BRIDGE AREA PUM	1 CELLS
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66	SWY PLAYGROUND	1 CELLS
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77	SHLEPER STORAG	1 CELLS
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89	SLURRY BASIN	1 CELLS
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98	SHLEPER STORAG	1 CELLS
99	MELLCUT STORAG	2 CELLS
100	MELLCUT PILL	1 CELLS
101	MELLCUT PILL	2 CELLS
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105	REGRADE AREA	1 CELLS
106	BRIDGE AREA PUM	1 CELLS
107	ROCK & GRAB PUM	1 CELLS
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109	TAILINGS AREA	1 CELLS
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111	DIC STORAGE AREA	1 CELLS
112	MINER PILL	6 CELLS
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114	CEMENT	1 CELLS
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116	WINE SPELDS	1 CELLS
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118	MELLCUT STORAG	1 CELLS
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147	REGRADE AREA	1 CELLS
148	BRIDGE AREA PUM	1 CELLS
149	ROCK & GRAB PUM	1 CELLS
150	SWY PLAYGROUND	1 CELLS

CELLS	DESCRIPTION	CELLS
0	BRIDGE AREA PUM	1 CELLS
1	ROCK & GRAB PUM	1 CELLS
2	SWY PLAYGROUND	1 CELLS
3	TAILINGS AREA	1 CELLS
4	SLURRY BASIN	1 CELLS
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6	MINER PILL	6 CELLS
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49	ATHLETIC FIELD	1 CELLS
50	CEMENT	1 CELLS
51	BRUIP STOR AREA	2 CELLS
52	WINE SPELDS	1 CELLS
53	MELLCUT W/ SHREY	2 CELLS
54	MELLCUT STORAG	1 CELLS
55	SHLEPER STORAG	1 CELLS
56	MELLCUT STORAG	2 CELLS
57	MELLCUT PILL	1 CELLS
58	MELLCUT PILL	2 CELLS
59	LUMPER HAND STR	2 CELLS
60	W END W STP	2 CELLS
61	REGRADE AREA	1 CELLS
62	REGRADE AREA	1 CELLS
63	BRIDGE AREA PUM	1 CELLS
64	ROCK & GRAB PUM	1 CELLS
65	SWY PLAYGROUND	1 CELLS
66	TAILINGS AREA	1 CELLS
67	SLURRY BASIN	1 CELLS
68	DIC STORAGE AREA	1 CELLS
69	MINER PILL	6 CELLS
70	ATHLETIC FIELD	1 CELLS
71	CEMENT	1 CELLS
72	BRUIP STOR AREA	2 CELLS
73	WINE SPELDS	1 CELLS
74	MELLCUT W/ SHREY	2 CELLS
75	MELLCUT STORAG	1 CELLS
76	SHLEPER STORAG	1 CELLS
77	MELLCUT STORAG	2 CELLS
78	MELLCUT PILL	1 CELLS
79	MELLCUT PILL	2 CELLS
80	LUMPER HAND STR	2 CELLS
81	W END W STP	2 CELLS
82	REGRADE AREA	1 CELLS
83	REGRADE AREA	1 CELLS
84	BRIDGE AREA PUM	1 CELLS
85	ROCK & GRAB PUM	1 CELLS
86	SWY PLAYGROUND	1 CELLS
87	TAILINGS AREA	1 CELLS
88	SLURRY BASIN	1 CELLS
89	DIC STORAGE AREA	1 CELLS
90	MINER PILL	6 CELLS
91	ATHLETIC FIELD	1 CELLS
92	CEMENT	1 CELLS
93	BRUIP STOR AREA	2 CELLS
94	WINE SPELDS	1 CELLS
95	MELLCUT W/ SHREY	2 CELLS
96	MELLCUT STORAG	1 CELLS
97	SHLEPER STORAG	1 CELLS
98	MELLCUT STORAG	2 CELLS
99	MELLCUT PILL	1 CELLS
100	MELLCUT PILL	2 CELLS
101	LUMPER HAND STR	2 CELLS
102	W END W STP	2 CELLS
103	REGRADE AREA	1 CELLS
104	REGRADE AREA	1 CELLS
105	BRIDGE AREA PUM	1 CELLS
106	ROCK & GRAB PUM	1 CELLS
107	SWY PLAYGROUND	1 CELLS
108	TAILINGS AREA	1 CELLS
109	SLURRY BASIN	1 CELLS
110	DIC STORAGE AREA	1 CELLS
111	MINER PILL	6 CELLS
112	ATHLETIC FIELD	1 CELLS
113	CEMENT	1 CELLS
114	BRUIP STOR AREA	2 CELLS
115	WINE SPELDS	1 CELLS
116	MELLCUT W/ SHREY	2 CELLS
117	MELLCUT STORAG	1 CELLS
118	SHLEPER STORAG	1 CELLS
119	MELLCUT STORAG	2 CELLS
120	MELLCUT PILL	1 CELLS
121	MELLCUT PILL	2 CELLS
122	LUMPER HAND STR	2 CELLS
123	W END W STP	2 CELLS
124	REGRADE AREA	1 CELLS
125	REGRADE AREA	1 CELLS
126	BRIDGE AREA PUM	1 CELLS
127	ROCK & GRAB PUM	1 CELLS
128	SWY PLAYGROUND	1 CELLS
129	TAILINGS AREA	1 CELLS
130	SLURRY BASIN	1 CELLS
131	DIC STORAGE AREA	1 CELLS
132	MINER PILL	6 CELLS
133	ATHLETIC FIELD	1 CELLS
134	CEMENT	1 CELLS
135	BRUIP STOR AREA	2 CELLS
136	WINE SPELDS	1 CELLS
137	MELLCUT W/ SHREY	2 CELLS
138	MELLCUT STORAG	1 CELLS
139	SHLEPER STORAG	1 CELLS
140	MELLCUT STORAG	2 CELLS
141	MELLCUT PILL	1 CELLS
142	MELLCUT PILL	2 CELLS
143	LUMPER HAND STR	2 CELLS
144	W END W STP	2 CELLS
145	REGRADE AREA	1 CELLS
146	REGRADE AREA	1 CELLS
147	BRIDGE AREA PUM	1 CELLS
148	ROCK & GRAB PUM	1 CELLS
149	SWY PLAYGROUND	1 CELLS
150	TAILINGS AREA	1 CELLS

CELLS	DESCRIPTION	CELLS	COVERAGE
0	BRIDGE AREA PUM	1 CELLS	0.1% COVERAGE
1	ROCK & GRAB PUM	1 CELLS	0.1% COVERAGE
2	SWY PLAYGROUND	1 CELLS	0.1% COVERAGE
3	TAILINGS AREA	1 CELLS	0.1% COVERAGE
4	SLURRY BASIN	1 CELLS	0.1% COVERAGE
5	DIC STORAGE AREA	1 CELLS	0.1% COVERAGE
6	MINER PILL	6 CELLS	0.1% COVERAGE
7	ATHLETIC FIELD	1 CELLS	0.1% COVERAGE
8	CEMENT	1 CELLS	0.1% COVERAGE
9	BRUIP STOR AREA	2 CELLS	0.1% COVERAGE
10	WINE SPELDS	1 CELLS	0.1% COVERAGE
11	MELLCUT W/ SHREY	2 CELLS	0.1% COVERAGE
12	MELLCUT STORAG	1 CELLS	0.1% COVERAGE
13	SHLEPER STORAG	1 CELLS	0.1% COVERAGE
14	MELLCUT STORAG	2 CELLS	0.1% COVERAGE
15	MELLCUT PILL	1 CELLS	0.1% COVERAGE
16	MELLCUT PILL	2 CELLS	0.1% COVERAGE
17	LUMPER HAND STR	2 CELLS	0.1% COVERAGE
18	W END W STP	2 CELLS	0.1% COVERAGE
19	REGRADE AREA	1 CELLS	0.1% COVERAGE
20	REGRADE AREA	1 CELLS	0.1% COVERAGE
21	BRIDGE AREA PUM	1 CELLS	0.1% COVERAGE
22	ROCK & GRAB PUM	1 CELLS	0.1% COVERAGE
23	SWY PLAYGROUND	1 CELLS	0.1% COVERAGE
24	TAILINGS AREA	1 CELLS	0.1% COVERAGE
25	SLURRY BASIN	1 CELLS	0.1% COVERAGE
26	DIC STORAGE AREA	1 CELLS	0.1% COVERAGE
27	MINER PILL	6 CELLS	0.1% COVERAGE
28	ATHLETIC FIELD	1 CELLS	0.1% COVERAGE
29	CEMENT	1 CELLS	0.1% COVERAGE
30	BRUIP STOR AREA	2 CELLS	0.1% COVERAGE
31	WINE SPELDS	1 CELLS	0.1% COVERAGE
32	MELLCUT W/ SHREY	2 CELLS	0.1% COVERAGE
33	MELLCUT STORAG	1 CELLS	0.1% COVERAGE
34	SHLEPER STORAG	1 CELLS	0.1% COVERAGE
35	MELLCUT STORAG	2 CELLS	0.1% COVERAGE
36	MELLCUT PILL	1 CELLS	0.1% COVERAGE
37	MELLCUT PILL	2 CELLS	0.1% COVERAGE
38	LUMPER HAND STR	2 CELLS	0.1% COVERAGE
39	W END W STP	2 CELLS	0.1% COVERAGE
40	REGRADE AREA	1 CELLS	0.1% COVERAGE
41	REGRADE AREA	1 CELLS	0.1% COVERAGE
42	BRIDGE AREA PUM	1 CELLS	0.1% COVERAGE
43	ROCK & GRAB PUM	1 CELLS	0.1% COVERAGE
44	SWY PLAYGROUND	1 CELLS	0.1% COVERAGE
45	TAILINGS AREA	1 CELLS	0.1% COVERAGE
46	SLURRY BASIN	1 CELLS	0.1% COVERAGE
47	DIC STORAGE AREA	1 CELLS	0.1% COVERAGE
48	MINER PILL	6 CELLS	0.1% COVERAGE
49	ATHLETIC FIELD	1 CELLS	0.1% COVERAGE
50	CEMENT	1 CELLS	0.1% COVERAGE
51	BRUIP STOR AREA	2 CELLS	0.1% COVERAGE
52	WINE SPELDS	1 CELLS	0.1% COVERAGE
53	MELLCUT W/ SHREY	2 CELLS	0.1% COVERAGE
54	MELLCUT STORAG	1 CELLS	0.1% COVERAGE
55	SHLEPER STORAG	1 CELLS	0.1% COVERAGE
56	MELLCUT STORAG	2 CELLS	0.1% COVERAGE
57	MELLCUT PILL	1 CELLS	0.1% COVERAGE
58	MELLCUT PILL	2 CELLS	0.1% COVERAGE
59	LUMPER HAND STR	2 CELLS	0.1% COVERAGE
60	W END W STP	2 CELLS	0.1% COVERAGE
61	REGRADE AREA	1 CELLS	0.1% COVERAGE
62	REGRADE AREA	1 CELLS	0.1% COVERAGE
63	BRIDGE AREA PUM	1 CELLS	0.1% COVERAGE
64	ROCK & GRAB PUM	1 CELLS	0.1% COVERAGE
65	SWY PLAYGROUND	1 CELLS	0.1% COVERAGE
66	TAILINGS AREA	1 CELLS	0.1% COVERAGE
67	SLURRY BASIN	1 CELLS	0.1% COVERAGE
68	DIC STORAGE AREA	1 CELLS	0.1% COVERAGE



LINE MAP

1	10-10E COAST	488 CELLS	3.38 COVERAGE
2	10-10E COAST	1311 CELLS	12.78 COVERAGE
3	ALL-STATE INTERIOR	688 CELLS	10.48 COVERAGE
4	40-10W COAST	682 CELLS	10.47 COVERAGE
5	0-10E COAST	772 CELLS	11.18 COVERAGE
6	50-50E COAST	1719 CELLS	15.68 COVERAGE
7	HAIRY HILLS	812 CELLS	3.78 COVERAGE
8	HAIRY HILLS AREA	79 CELLS	0.99 COVERAGE
9	40-10E COAST	1008 CELLS	15.38 COVERAGE

4	40-10E COAST	812 CELLS	9.08
5	0-10E COAST	194 CELLS	1.88
6	50-50E COAST	3558 CELLS	31.38
7	HAIRY HILLS	1008 CELLS	9.18

APPENDIX B

NATIONAL EMISSION DATA SYSTEM

(NEDS) Designation for Bunker Hill

Company Point Sources

(Taken From PES, 1978)

TABLE 1. SMELTER STACKS

Process Units	Process and/or Control	NEDS	Name
S1	11. Crushing Plant Dryer - Scrubber	02	Crushing Plant
	12. Crushing Plant Dust Collector - Receiving Bins	03	
	13. Crushing Plant Rod Mill Scrubber	04	
	14. Crushing Plant Conveyor - Baghouse	05	
S2	15. OPP Ore Preparation Plant Baghouse	06	Ore Preparation Plant
S3	16. Pelletizing Dryer - Scrubber	07	
	17. Return Sinter Storage	08	
	18. Pelletizing Plant Conv. } "D" Scrubber		
S4	1. Lurgi-Strong Gas } Smelter Acid Plant } 2. Lurgi-Weak Gas }	01	Lurgi Sinter Machine
S5	19. Lurgi "N" Rotoclone - Sinter Discharge	09	Sizing Building
	20. Lurgi "B" Scrubber - Sizing Building	10	
	21. Lurgi "C" Scrubber - Sizing Building	11	
	22. Lurgi "A" Scrubber - Sinter Rolls - Retrofit Drum	12	
S6	3. Lead Blast Furnace 10. Lead Blast Furnace Feed (Sinter Tunnel)	01	Blast Furnace
S7	26. Zinc Fuming Plant Main Stack - Baghouse	16	Zinc Fuming Plant
	27. Zinc Fuming Plant Granulator - Scrubber	17	

S8	28. Lead Refinery - Dross Kettles - Scrubber	32	Roof Vent Lead Refinery and Reverb. Furn.
	5. Reverb Norblo Flue to Main Stack	01	
	24. Reverb Granulator Scrubber	17	
	23. Reverb Speiss Discharge - Baghouse	13	
S9	6. Electric Furnace (Copper Dross) Norblo to	01	
	25. Electric Furnace Granulator - Scrubber	15	
S10	Silver Refinery Duct		Silvery Refinery
	7. Retort Room	01	
	8. Cupels	01	
	9. Monarchs	01	

NEDS 01 Main Stack

Table 1. ZINC PLANT STACKS

Process Units	Process and/or Control	NEDS	Name
Z1	32. Concentrate Dryer - SO2 Monitor	33 (New)	(Concentrate Dryer)
	33. Concentrate Silo - (No Control) from Rail Car	19	
Z2 After H/H Scrubber & ESP	Zinc Plant Acid Plant #1 } #1 RSTR.-27 #2 RSTR.-28 #3 RSTR.-29 #4 RSTR.-30 #5 RSTR.-31	18	(Zn Roasting Plant - 5 Roasters)
After B/H Scrubber & ESP	Zinc Plant Acid Plant #2 }	18	

	36. Roasting Department Conveyor Scrubber	22	#5 Roaster = 3 Roasters 1-4 Each Acid Plant 3.5 Roasters
Z3	34. #1 Wedge Roaster-Scrubber	20	Zinc Dross Processing
	39. Melting Department Dross-Baghouse	25	
	37. Roaster Dross-Baghouse	23	
Z4	35. Residue Dryer - No Cont.-Temp.	21	Residue Dryer
Z5	Scrap Furnace Sky Vent	()	
	42. Scrap Furnace Scrubber - Not Hooked Up	28	
	40. #2 Melting Furnace Scrubber	27	
	41. #3 Melting Furnace Scrubber	26	
	41A. #3 Melting Furnace Vents	()	
	42A. Alloy Furnace	()	
Z6	38. Purification Zinc Baghouse (Zinc Dust Prep.)	24	Purification Department
Z7			

Table 1. PHOSPHATE PLANT STACKS

Process Units	Process and/or Control	NEDS	Name
P.1	44. Aerotec Ammonium Phosphate Reactor	30	Separate PWR
P.2	43. Dryer S.F. - Ammonium Phosphate	29	Separate PWR
P.3	45. Doy'e Reactor - Phosphoric Acid Reactor	31	Separate PWR