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APPENDIX A

1.0 Exposure Assessment of the No-Action Alternative

One criterion in selecting the proper remedial action alternative for the Industri-Plex 128 Site is the level of potential off-site exposure mitigated by the proposed action. In order to establish exposure mitigation, it is necessary to estimate the human exposure that would occur if the current situation were allowed to run its course with no intervention: the No-Action alternative. The purpose of this chapter is to perform a brief exposure assessment of the No-Action alternative. The exposure assessment's goal is to identify the population with a potential for being exposed to the chemical(s) under study, and the concentration of chemical that members of this potentially exposed population might receive.

1.1 Selection of Indicator Substances

In lieu of monitoring and assessing the exposure due to each of the dozens of chemicals present at the Industri-Plex Site, it is a valid approach to select indicator - or representative - chemicals to study. These chemicals are selected because they (i) are the most concentrated in ground-water samples, and (ii) have been shown to be hazardous to health. The participants in the Industri-Plex Site evaluation have selected the following set of indicator substances as the subjects of the exposure assessment;

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- o arsenic
- o lead
- o zinc
- o cyanide
- o benzene
- o toluene
- o bis (2-ethylhexyl) phthalate
- o phenols

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1.2 Potential Exposure

The assessment of potential exposure requires estimation of the routes and levels of possible human exposure, as discussed in the following sections.

1.2.1 Points of Human Exposure

Human exposure to chemicals in the ground water leaving the Industri-Plex Site could occur when that ground water was used as a drinking water source. The hydrogeology studies show that the ground-water flow follows the buried Aberjona Valley southward. Inactive drinking water Wells G and H of the City of Woburn are situated approximately 3,400 ft. and 3,900 ft., respectively, south of Mishawum Road. These wells tap the Aberjona Valley at depths of 88 ft. and 84 ft., respectively, and undoubtedly intercept ground water originating at the Industri-Plex Site. Thus, they represent the nearest potential receptor points at which the levels of human exposure and concentration can be calculated. The wells would produce a total of 1500 gpm if operating at capacity.

1.2.2 Projected Concentrations in Wells G and H

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In order to estimate the projected concentrations that would occur in Wells G and H if the No-Action alternative were followed, it is necessary to estimate the rate of movement of each of the indicator chemicals down the Aberjona Valley aquifer between the Site and the receptor. As with all studies of solute movement in ground water, these estimates require several key assumptions concerning the nature of the underground environment through which the chemicals move; the uncertainties surrounding these assumptions are carried over into the estimated concentrations at the receptor.

In estimating projected concentrations, several processes that occur between the Site and the receptor must be considered: dilution of the solute due its sorption to solid particles, and its dispersion within the aquifer, degradation of solutes by soil bacteria, and non-biological chemical reactions in the soil. (Another possibility, evaporation of organics out of ground water, is considered to make a negligible contribution to human exposure). These key processes will be discussed in separate sections below.

1.2.2.1 Rates of Solute Movement

Different processes govern the rate of solute movement, depending on whether the solute is inorganic or organic. For inorganic cations

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Pb²⁺ and Zn²⁺) the process that retards movement of ions is ion exchange at negatively-charged sites on particle-surfaces. Arsenic probably exists as arsenate (AsO₄), which would exchange at positively-charged surfaces. Cyanide ion, although organic, would also be electrostatically bound at cationic sites. Organics other than cyanide, on the other hand, are characterized by low water solubility and lack of ionic charges. Their movement is retarded by hydrophobic and van der Waals bonding to soil surfaces - almost always to the organic fraction of the soil. The rate of ground-water flow from the Industri-Plex Site to Wells G and H is estimated from hydrogeological considerations to be approximately 1 ft/day. It is now necessary to estimate how much the solutes in this ground water are retarded as they are carried toward the receptor by ground-water flow.

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Inorganic Solutes

The movement of inorganic solutes in ground water has been studied, but no coherent theoretical or empirical framework for predicting the rates of ion movements in ground water is available. This is undoubtedly due to the number of variables that would need to be considered in any modeling project: pH, quantity and quality of ion exchange sites, oxidation-reduction potential, and the ionic composition of the ground water, to name a few. Under these conditions, it is only possible to make some qualitative observations concerning the movement of arsenate, lead ion, zinc ion, and cyanide ion towards Wells G and H.

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(1) The Aberjona Valley is filled with sand and gravel of apparently low clay content. This lack of clay would predict a low ion exchange capacity in the buried valley, and a consequent lack of ability to bind inorganic ions or cyanide.

(2) The pH of Aberjona Valley ground water is measured in the range 5.6-8.4. This neutral water would shift hydrolysis equilibria for Pb^{2+} and Zn^{2+} toward lower solubility, producing some precipitation as the hydroxides. Also, the lack of excess H^+ would prevent the release of bound lead and zinc cations through exchanging with H^+ .

(3) To set a minimum time for the migration of the respective ionic solutes to the nearest receptor, the distance traveled and the estimated ground-water flow rate of 1 ft/day were used. The nearest receptor is Well G. The starting points were the southernmost observation wells containing detectable solute. The results are: arsenic, from OW-20A, 4125 days (11 years); lead, from OW-17, 6900 days (19 years); zinc, from OW-20A, 4125 days (11 years); and cyanide, from OW-17, 6900 days (19 years). Since these migration times are based on the assumption of no retardation of ion movement by the aquifer matrix, any retardation of these ions that did occur would lengthen these migration times significantly. In fact, this retardation may be a significant process, because the history of the Site shows that arsenic and lead have been disposed there for 50-75 years without migration off the site. (Another explanation for this lack of migration might be a low rate of leaching of arsenic and lead from

wastes into ground-water, rather than retardation of dissolved metals. Some evidence for this hypothesis is the fact that observation wells OW-11 and OW-14, which under lie soil with high arsenic and lead contents, show very little contamination with these solutes.)

Organic Solute

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The movement of organic solutes in ground-water is better understood than the movement of inorganics. In particular, it is possible to estimate the retention time of a solute, t_r , if the solute's octanol-water partition coefficient is known along with three physical properties of the aquifer. The relationship is (1,2):

$$t_r = 1 + (0.2) (0.63) (f_{OC}) (K_{OW}) (\rho_{aq}/\epsilon_{aq})$$

where t_r = the time required for the solute to travel between two points in the aquifer relative to the time required for ground water to travel the same distance;

(0.2) = a factor reflecting the estimate (1) that sand has a binding constant of about 20% of that of silts;

(0.63) = an empirical factor relating k_{ow} to t_r ;

f_{OC} = the fraction of organic carbon in the solid matrix;

k_{ow} = the solute's octanol-water partition coefficient; the ratio of the solute's solubility in n-octanol to its solubility in water;

ρ_{aq} = the average bulk density of the aquifer material; and

ϵ_{aq} = the effective porosity of the aquifer. This relationship has been applied to at least one field situation for validation (7). The predicted t_r - values for three organic compounds were in reasonable agreement with their measured retention times.

Table 1-1 summarizes available information on the above parameters.

No literature value was found for k_{ow} of bis (2-ethylhexyl) phthalate. However, k_{ow} can be estimated from an empirical relationship with water solubility (1) using the reported solubility value for bis (2-ethylhexyl) phthalate, 400 μ g/l (6). The relationship is:

$$\log K_{ow} = -0.54 \log S + 0.44 - \log (0.63),$$

where k_{ow} = the octanol-water partition coefficient; and

S = solubility in water, mole fraction.

Converting a water solubility of 400 μ g/l to mole fraction gives 1.83×10^{-8} moles bis (2-ethylhexyl) phthalate per mole H_2O . The equation then yields a value for K_{ow} of 6.6×10^4 .

The value for f_{oc} was judged to be nonzero, but less than the organic fraction of 0.4% in a sandy clay loam described in ref. 6. A value of 0.1% was adopted because (i) it is approximately the lower end of the soil organic content range over K_{ow} is predictably related to t_r (2) and (ii) it is consistent with the observation during well drilling of very little organic material in the core samples from the buried valley.

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Table 1-1. Solute and Aquifer Properties for Use
in Calculation of Solute Retention Times

<u>Property</u>	<u>Benzene</u>	<u>Toluene</u>	<u>DEHP (1)</u>	<u>Phenol (2)</u>	<u>Aquifer</u>
K_{ow}	135 (3)	447 (4)	6.6×10^4 (5)	30 (4)	
f_{oc}					est. 0.001 (5)
ρ_{aq}					est. 2 kg/kg (5)
ϵ_{aq}					est. 0.22 (5)

(1) DEHP: bis (2-ethylhexyl) phthalate

(2) Representing total phenols

(3) Source: ref. 3

(4) Source: ref. 4

(5) See text for estimation method

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The estimated values of ρ_{aq} and ϵ_{aq} were taken from ref. 7. They describe a fine of coarse sand aquifer containing some gravel and clay - similar to the Aberjona Valley core samples.

Using the parameters in Table 1-1, the following values for t_r were calculated: benzene, 1.2; toluene, 1.5; bis (2-ethylhexyl) phthalate, 76; phenol, 1.03. When multiplied by the time required for ground water to travel between the nearest observation well containing the respective chemicals and Wells G and H, these will yield the amount of time required for each organic solute to reach the receptor wells.

The distances between the southernmost contaminated well and the northernmost receptor well (Well G) were estimated from maps as: benzene, from OW-17, 6900 ft; toluene, from OW-17, 6900 ft; bis (2-ethylhexyl) phthalate, from OW-18, 7200 ft; phenol, from OW-17, 6900 ft.

Using the estimated ground-water flow rate of 1 ft/day, and the t_r values calculated above, the following elapsed times are calculated for the movement of organic solutes to Well G: benzene, 8300 days (23 yrs.); toluene, 10,000 days (28 yrs.); bis (2-ethylhexyl) phthalate, 5.5×10^5 days (1.5×10^3 yrs.); phenol, 7100 days (19 yrs.).

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1.2.2.2 Biodegradation of Solutes

Besides retardation by the aquifer matrix, a second key process affecting the solute in ground water is biodegradation. This is the metabolic conversion of solutes into food and energy by soil microorganisms - either aerobic or anaerobic.

Inorganic Solutes

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Inorganic solutes - arsenic, lead and zinc - are not chemically altered by microorganisms. The only impact these organisms might have on the concentrations of inorganic solutes in ground water would be a very small lowering of solute concentration due to uptake and immobilization within the microbial cell.

Organic Solutes

All five of the organic solutes under consideration are potentially subject to depletion due to biodegradation. There are at present too many variables still unknown to predict quantitatively the extent of biodegradation for any of them. Among these variables are aquifer pH farther down the valley, aquifer redox potential, microorganism population characteristics, solute concentrations, presence of other nutrients and potential solute biodegradability (8). Of these, only the last is a property of the solute for which previous studies can be extrapolated to the current situation. Qualitative statements on

the biodegradability of the organic solutes from the Industri-Plex Site are present below.

Benzene is moderately degradable by activated sludge (9) and by mixed soil microorganisms (10), and is therefore likely to be biodegraded by soil microorganisms in the Aberjona Valley ground water.

Toluene, which is chemically almost identical to benzene, is reported to be metabolized by soil microorganisms, also (10, 11). Consistent with this observation is the fact that it is metabolized by both humans and experimental animals (12).

Bis (2-ethylhexyl) phthalate has been well studied and shown to be readily degraded by activated sludge (13,14) and mixed soil microorganism cultures (10).

Phenols have also been well studied, and various members of this family have been shown to be biodegraded by activated sludge (9,13), a natural aquatic microbial community (10,15) and a pure microbial culture (16).

Cyanide is a metabolic poison that inhibits aerobic metabolism. Its presence will retard the aerobic degradation of other organic solutes. No information was available on the anaerobic degradation of cyanide.

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The conclusions of these observations are: (i) any concentrations of benzene, toluene, bis (2-ethylhexyl) phthalate, or phenol estimated at the receptor wells are likely to be maximum values since the effects of solute biodegradation will not have been considered quantitatively; and (ii) aerobic digestion (activated sludge treatment) may be an efficient means of removing organic solutes during a ground-water treatment process.

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1.2.2.3 Maximum 7-Day Average Concentrations Expected at Well G

In order to estimate the solute concentrations expected at Well G, the following assumptions were made:

- o The solute entered ground water as a slug at the observation well showing the highest solute concentration (not necessarily the well used to calculate elapsed migration time in Section 1.2.2.1);

- o For the purposes of estimating dispersion of solute, the volume of the solute slug was estimated for each solute at its maximum concentration site. These estimates are described below:

- Arsenic. The arsenic slug volume was considered to be centered at OW-20A, with a concentration of 106 $\mu\text{g}/\text{l}$. Since observation wells within 60m (200 ft) on either side of OW-20A (namely, OW-7 and OW-8) showed 18 $\mu\text{g}/\text{l}$ and 2 $\mu\text{g}/\text{l}$ arsenic, respectively, the slug appeared to be within a

reasonably small radius of OW-20A. The volume of the slug was estimated to be the volume of a cylinder of radius 5m and a height of 9.15m (the height of the OW-20A well screen). An aquifer porosity of 30% was estimated from core sample characteristics, and was used in this and subsequent calculations. The resulting estimated slug volume for arsenic was 220,000 l (58,000 gal).

- Lead. The maximum lead concentration occurred at OW-13 (120 μ g/l). The only other well showing detectable lead was OW-17 with 70 μ g/l. (An intermediate well, OW-12, shows no lead.) In the absence of further information, it will be assumed that the 120 μ g/l concentration at OW-13 represents a cylinder of radius 5m and a height of 7.6m (25ft, the height of the well screen). The resulting estimated volume of the lead slug was 180,000 l (47,000 gal).

- Zinc. The maximum zinc concentration was measured at OW-19 (47,000 μ g/l). The nearest observation wells, OW-17, OW-19A, and OW-20/20A all showed less than 0.2% of this level. No further data was available on the width of the slug around OW-19. The concentration maximum was considered to be characteristic of a cylinder 5m in radius and with a height of 9.15m (30 ft, the well screen height). The resulting estimated slug volume was 220,000 l (58,000 gal).

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- Cyanide. Cyanide was most concentrated at OW-12 (94 $\mu\text{g}/\text{l}$). This measurement may be part of a plume extending from OW-16 through OW-12 to OW-17 (although OW-18 shows no detectable cyanide). The concentration at OW-12 was considered to be a slug within a plume; its radius was estimated to be 5m, with a height corresponding to the screen height, 12.2m (40 ft). The resulting estimated slug volume was 290,000 l (76,000 gal).

- Benzene. This estimate was based on an evaluation of the terrain at the location of the sampling well with the highest benzene concentration (designated SD-55, and showing 36 ppm benzene) as well as the aquifer properties at that point. SD-55 was located in an alley between two buildings. The area could have either received the runoff from a hypothetical benzene spill on the adjacent paved parking lot, or it could have been the site of illegal dumping in the alley from the back of a truck. In either case, the width of the alley restricts the size of the initial slug to probably less than 2 meters in diameter. The saturated thickness of the aquifer in the area is estimated from geologic cross sections to be approximately 20 ft. The porosity was estimated to be approximately 30%. Assuming that SD-55 represents a cylinder containing 36 ppm benzene, the volume of the cylinder would be obtained by estimating its height to be 6.1m (20 ft), and its radius to be approximately 0.6 meters (2 ft). The estimated volume was

approximately 6.8 m^3 of aquifer, or approximately 2 m^3 (2,000 l; 500 gal) of liquid volume.

- Toluene. The toluene slug was apparently centered at OW-16 (32,000 $\mu\text{g/l}$). Shallow sampling wells within 15 ft of OW-16 showed toluene concentrations of approximately 4,000 $\mu\text{g/l}$, indicating a steep drop-off of concentration. The representative cylinder for the 32,000 $\mu\text{g/l}$ concentration was therefore estimated to be 2m in radius and 6.1m in height (the height of the well screen). The volume of the slug within this cylinder was calculated to be 23,000 l (6,000 gal).

- Bis (2-ethylhexyl) phthalate. (DEHP). The DEHP maximum concentration (2,200 $\mu\text{g/l}$) occurred at OW-18. Observation wells approximately 400 ft away showed lower concentrations (OW-12, 1090 $\mu\text{g/l}$; OW-17, 341 $\mu\text{g/l}$), while the upper screening at the OW-18 location has 352 $\mu\text{g/l}$ (OW-18A). As with cyanide, the OW-18 "slug" was treated as a concentration peak superimposed on a larger plume. The cylinder representing the 2,200 $\mu\text{g/l}$ concentration was considered to be 5m in radius and 12.2m high (the height of the screen). The resulting slug volume was 290,000 l (76,000 gal).

- Phenols. The highest concentration of total phenols occurred at OW-17 (7,840 $\mu\text{g/l}$). The nearest neighboring well, OW-18, showed no detectable phenols. The representative cylinder

around OW-17 was considered to have a radius of 5m and a height of 6.1m (20 ft, the height of the screen). The resulting slug volume used for the purposes of subsequent calculations was 140,000 l (38,000 gal).

The slug volumes estimated above were used as the value of V_0 , the initial slug volume, in the following calculations:

The concentration of each solute at Well G can be approximated by using the equation (17):

$$C_{\max} = \frac{C_0 V_0}{8 (\pi t)^{3/2} \sqrt{D_x D_y D_z}}$$

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Where

C_{\max} = the peak concentration at the center of gravity of the migrated slug;

C_0 = the solute concentration of the initial slug;

V_0 = the volume of the initial slug;

t = the elapsed time of migration; and

D_x , D_y , and D_z = the respective coefficients of dispersion of the solute in the x, y, and z directions.

The values of D_x , D_y , and D_z were estimated from Figure 9.6 of ref. 17, using a flow rate of 3.5×10^{-4} cm/s (1 ft/day). This figure plots data on the relationship between ground-water flow rate and coefficients of dispersion in homogeneous sandstone of porosity = 22%.

These data were the best available for estimating D_x , D_y , and D_z for use in the above equation. The transverse dispersion coefficients were estimated to be $D_y = D_z = 8 \times 10^{-9} \text{ m}^2 / \text{s}$; the longitudinal dispersion coefficient was estimated to be $6 \times 10^{-7} \text{ m}^2 / \text{s}$. Using these values, the maximum concentration expected at Well G upon the arrival of the center of concentration of each solute slug was calculated. The results are shown on Table 1-2. It is important to note that there is a large uncertainty associated with these estimates. With the caveat firmly in mind, these estimated concentrations were used to estimate potential daily lifetime exposure concentrations for the solutes.

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1.2.2.4 Average Daily Lifetime Concentrations Expected at Well G

The average concentrations of solutes in water drawn by Well G over an 80-year period from the time of first solute appearance (Section 1.2.2.1) were estimated from the predicted dispersion of the solute slug in the aquifer. These estimated concentrations are summarized along with the maximum 7 day averages in Table 1-2.

Because of the lack of data on the origination kinetics of solute injection into ground water, it was necessary to make the conservative estimate that the average concentrations over 80 years would be 1/2 of the maximum concentrations. This is particularly conservative for organic solutes because of the possibility of biodegradation during migration. However, other contaminants found in the ground

Table 1-2. Estimation of Solute Concentrations at Well G

	<u>AsO₄³⁻</u>	<u>Pb²⁺</u>	<u>Zn²⁺</u>	<u>CN⁻</u>	<u>Benzene</u>	<u>Toluene</u>	<u>DEHP (1)</u>	<u>Phenols</u>
Location of highest conc.	OW-20A	OW-13	OW-19	OW-12	SD-55	OW-16	OW-18	OW-17
Initial conc., ug/l	106	120	47,000	94	36,000	32,000	2,200	7,840
Distance to Well G, ft	4,125	7,725	5,475	7,500	7,900	8,625	7,200	6,900
Migration time to Well G(2) yrs	11	21	15	20	26	35	1.5X10 ³	19
Max. conc. at Well G, ug/l	13	5	3,600	0.6	10	70	0.2	270
Avg. conc. at Well G over 80 yrs, ug/l	7	2.5	1,800	0.3	5	35	0.1	140

(1) DEHP: bis (2-ethylhexyl) phthalate

(2) Calculated as in Section 1.2.2.1

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water, including all of the metals, are not considered an off-site threat. This evaluation is based on both the results of EP Toxicity Tests run on waste materials at the Site which show them to be non-hazardous and by ground-water monitoring data which indicates that essentially no leaching of metals is occurring from on-site waste materials. Thus, the risk assessment, even though assuming a worst case situation, indicates no off-site impact from metals. For this reason, evaluation of possible remedial action for metals was not undertaken.

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APPENDIX B

APPENDIX B

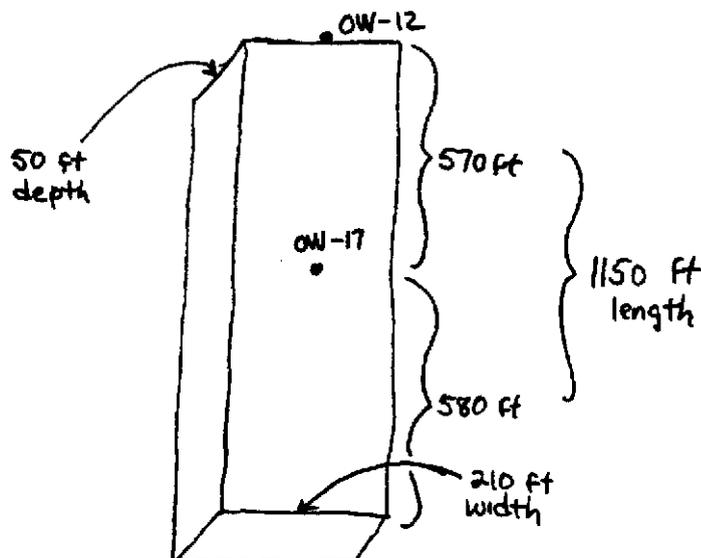
DISPERSION OF RESIDUAL BENZENE PLUME

The purpose of these calculations is to estimate the benzene concentration at Well G due to the benzene allowed to remain in the aquifer downgradient of the proposed pumping point - OW-12. Two steps are involved in these calculations: (i) define the size and concentration of the benzene plume as of the beginning of the removal pumping; and (ii) estimate the dispersion of this benzene slug as it migrates to Well G over a period of several years.

I. Initial Conditions of Benzene Slug

It is postulated that remedial pumping will begin as of September 1985 in the region of OW-12. This time and location will therefore mark the tail end of the remaining benzene plume.

In September 1983, ground-water analyses showed that the benzene plume reached downgradient as far as OW-17. By September 1985, ground-water will have moved 730 ft ($= 365 \text{ ft/yr} \times 2 \text{ yrs}$). Benzene was estimated (Phase II report) to move 20% slower than ground-water, due to retardation by the aquifer. Therefore, benzene will be expected to be $(730 \text{ ft})(0.8)$ or 580 ft below OW-17 by September 1985. The width of the plume has been estimated to be 210 ft (the 100 ppb contour of benzene + toluene). The slug to be modeled will have dimensions as follows in September 1985:



The depth of the slug was estimated to be half way between the depth of the saturated zone at OW-12 (40 ft) and the depth at OW-19 further downgradient (60 ft).

The volume of the initial slug = (210 ft)(1150 ft)(50 ft) = $1.2 \times 10^7 \text{ ft}^3$.

The volume of ground water in this portion of aquifer (assuming 30% porosity) = $(1.2 \times 10^7 \text{ ft}^3)(0.3) = 3.6 \times 10^6 \text{ ft}^3$.

The representative concentration of benzene in the initial slug was estimated as follows:

1. The benzene concentration at OW-12 in September 1983 was 203 ppb.
2. The benzene concentration at OW-17 in September 1983 was 402 ppb. However, OW-17 is screened in only the lower half of the saturated zone at that point. Furthermore, the screen lies in a gravel seam of high permeability, which would be expected to carry a greater proportion of the solute because of its lower resistance to flow. The average concentration of benzene at OW-17, when averaged over the entire aquifer depth, is likely to be much closer to the 200 ppb concentration observed over the entire aquifer depth at OW-12. Therefore, the representative concentration for the entire slug was taken to be 200 ppb.

II. Dispersion of the Benzene Slug

- A. Distance from the center of the benzene slug to Well G.

This distance was estimated from area maps to be 6900 ft.

- B. Migration time from center of slug to Well G.

With an aquifer flow rate of 1 ft/day, it would take ground water 6900 days or 19 years to move Well G. Since benzene is estimated to migrate 20% slower than ground water, its travel time from the center of the slug to Well G would be 8280 days or 23 years.

C. Dispersion of the benzene slug in three dimensions.

While migrating down the ground-water valley toward Well G, the benzene slug will be dispersed in the direction of flow and in both directions (i.e., vertical and horizontal) perpendicular to the direction of flow. The maximum concentration, C_{max} , that will arrive at Well G after 23 years of migration is predicted by the equation (ref. 1):

$$C_{max} = \frac{C_0 V_0}{(\pi)^{3/2} [(rt)(t)]^{3/2} [D_x D_y D_z]^{1/2}}$$

Where C_0 = the initial concentration of benzene at the slug's center of density = 200 ppb;

V_0 = the initial volume of the slug =
 $3.6 \times 10^6 \text{ ft}^3$
 $= 1.0 \times 10^5 \text{ m}^3$

t = the time of migration from the center of the slug to Well G = 8280 days;

D_x = the dispersion coefficient of the aquifer in the direction of flow. A value of $6.5 \text{ m}^2/\text{day}$ was derived from modeling of an aquifer on Long Island similar to the Aberjona Valley;

D_y = the dispersion coefficient for horizontal spreading = $1.3 \text{ m}^2/\text{day}$ (from the same source as D_x);

D_z = the dispersion coefficient for vertical spreading = $1.3 \text{ m}^2/\text{day}$ (the same as D_y).

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$$C_{\max} = \frac{(200 \text{ ppb})(1.0 \times 10^5 \text{ m}^3)}{(8) [(11)(9280 \text{ days})]^{3/2} [(6.5 \text{ m}^2/\text{day})(1.3 \text{ m}^2/\text{day})(1.3 \text{ m}^2/\text{day})]^{1/2}}$$

= 0.2 ppb benzene at Well G.

(Note that these calculations don't account for possible biodegradation of benzene during the 23 years it is migrating toward Well G).

Estimates of aquifer volume between OW-12 and Well G indicate that the likely dilution of the benzene slug would be closer to 100-fold than 1000-fold. Therefore, the latter dilution factor will be used to give a conservative estimate of maximum benzene concentration at Well G of 2 ppb.

Reference

1. Freeze, R.A., and Cherry, J.A., Groundwater, Prentice-Hall, Englewood Cliffs, NJ, 1979.

APPENDIX C

APPENDIX C

Air Emissions Modeling

A) Condition East Hide Pile Existing Emission

EPA/DEQE requested an estimate of existing/prior maximum downwind Woburn gas concentrations be made based on A.D. Little's November 13 and 16, 1981 off site odor survey. Two air modeling consultants, Trinity consultants and Form and Substance, Inc., together with D. Grasick of DEQE's air modeling section were contacted about an estimate based on ADL's 1981 odor survey. All advised no valid estimate could be made at a distance of three miles in wooded terrain without meteorological data. Even with meteorological data a valid estimate probably couldn't be made without tracer studies to determine wind and terrain effects. Therefore, it was assumed a valid estimate of maximum downwind H₂S concentration could not be made based on the 1981 ADL odor surveys.

The maximum downwind concentrations were estimated using the peak combined emission estimates measured in the field observations, barometric pressure fluctuations, etc.

The worst case peak east hide pile emission rate of 80 cfm was assumed based on contributions from the following sources.

- 4 ACFM from sudden collapse of a 6' x 20' x 100' slide slope
- 9 ACFM from a sudden drop of 0.3" Hg in barometric pressure
- 16 ACFM from a two foot change in the water table during 24 hours
- 50 ACFM from infiltration of 0.25" of rain per hour

a) The worst case east hide pile emission estimate is very conservative because of the following assumptions:

- H₂S Mercaptan Concentration - The average emission concentration was assumed to be 5% H₂S and 475 ppm mercaptans. However, the average H₂S concentration during the Phase II gas measurements was 1.4% and the average mercaptan concentration was 180 ppm (1).
- Benzene/Toluene Concentration - The average emission concentration was assumed equivalent 11 ppm benzene and 4 ppm toluene. However, the average benzene concentration was 2.7 ppm and the average toluene concentration was 1 ppm during the Phase II gas measurements (1).
- Gas release from sudden fall of 6' x 20' x 100' section of pile It was assumed large section of the pile would fall away and that the gas release over six hours would be 150% of the entire fallen void space trapped gas. It is believed this could grossly over estimate the actual release. If the atmospheric

(1) Appendix I, Table 2 BH 9,10,11,12 and 13

barometric pressure was in equilibrium with internal pile pressure, then there should be no release of trapped gas.

- Release from 0.3" Hg drop in barometric pressure - The estimated barometric pressure drop is 0.3" Hg over a six hour period. This is at least double the average drop and corresponds to a worst case 5 year occurrence. The Woburn area hourly barometric pressure averages 0.02 to 0.03" Hg change (increase-decrease) with a 0.15" Hg drop three times in 5 years, 0.10 to 0.13" Hg drop 20 times in 5 years and 0.06 to 0.09" Hg drop about 10 times/year. A rare storm of December 6-7, 1983 gave a drop of 1.5" Hg in 24 hours⁽²⁾.

The peak existing east hide pile concentrations were assumed to be the maximum individual concentration analyzed during Stauffer's 1982 and 1983 site studies, i.e, H₂S 5%, benzene 11 ppm, mercaptans 475 ppm and toluene 4 ppm. The estimated wind speeds and atmosphere stability classes during ADL's 1981 surveys were used for the Texas Episodic Model Version 8 (TEM8) air model to predict ground level concentrations of the various pollutants.

b) Screening models such as PTPLU and TEM8 tend to give higher results than refined models using site meteorological data and more sophisticated computer programs. As an example, PTPLU and TEM8 were used with worst case constant wind speeds and directions. However, if refined air models utilizing site meteorological data were used, these same worst case wind speeds and direction should have a low probability of occurring, perhaps never.

A description of the two air models used is as follows:

PTPLU⁽³⁾

PTPLU, an EPA guideline model is an adapted and improved version of PTMAX for quickly analyzing the approximate location of maximum concentrations and the meteorological conditions under which it occurs for a single point source. Most air quality studies will start by analyzing a representative number of stacks with this program to guide the receptor replacement for more extensive modeling.

TEM8⁽⁴⁾

The TEM (Texas Episodic Model) was developed by the Texas Air Control Board to predict air pollution concentrations for periods up to 24 hours. Since then, it has been revised and modified to increase its flexibility and utility. The current version is TEM-3 (Version 8) which is a CPM guideline model. The TEM was developed as an alternative to the EPA models, PTMTP and PAL. In developing the TEM, the Texas Air Control Board incorporated a number of enhancements that provided flexibility and speed in the program operation.

PTMTP and PAL were originally developed to provide a method to compare calculated and observed pollutant concentrations. For this comparison, the user enters receptor points and meteorological data that would correspond to actual conditions. In contrast, the TEM calculates

(2) Communication from R. Lautzenheiser, N.E. Climatic Service, Reading, Mass.

(3) Schultz, op. cit. page 142

(4) Schultz, op. cit. page 147n

concentrations for a program generated grid using meteorological data supplied by the user. By varying the input of meteorological data, the TEM is used primarily to identify worst case conditions over the area covered by the grid. Both PTMTP and PAL could also be used to simulate worst case conditions, but these conditions could only be analyzed for user-specified receptor points.

c) 1. Ambient H₂S TLV, Limit

Massachusetts' DEQE guidelines for calculating acceptable ambient air levels is to divide the H₂S work place TLV of 10 ppm by a 100 safety factor and adjust it for 168 hours of exposure per week vs. 40 hour/week work place exposure. There is no residential area within 700 meters radius of the east hide pile. Therefore, the ambient TLV for 700 meters radius of the east hide pile will be 0.1 ppm. Table III A shows that the after remedial action H₂S concentrations are all below the ambient TLV for a 37.5 and 75 foot² stack, but exceeds the TLV at 100 meters for a ground level emission.

2. Odors

The primary site odor constituent is H₂S, based upon the following:

- November 1981 A.D. Little Off Site Survey
- Sept. - Oct. 1983 A.D. Little Site Evaluation
- Stauffer's Phase I bore hole gas analyses which found non-detectable (N.D.) to 5% H₂S compared to N.D. to 0.05% total other odorous gases
- Stauffer's Phase II bore hole gas analysis found N.D. to 2% H₂S compared to N.D. to 0.04% total other odorous gases

The east hide pile was the source of site H₂S based upon the following:

- The Phase I east hide pile bore hole gas analysis average 2.7% H₂S and 220 ppm other odorous gases. The remaining site bore holes contained N.D. amounts of H₂S or other odorous gases
- The Phase II east hide pile bore hole analysis averages 1.4% compared to a maximum of 0.6% elsewhere in the site
- The measured Phase II bore hole gas emissions were 1.82 CFM from the east hide pile, 0.65 CFM from the west hide pile and non-detectable from the remainder of the site. However, 0.65 CFM from the west hide pile only averaged 55 ppm H₂S

It was assumed downwind H₂S/odor could be correlated based upon ADL's Total Intensity of Aroma² (TIA) findings during the 1983 study. The TIA is a measure of the odor perception in the field. This is significantly different from odor perception achievable under laboratory conditions, since background odors tend to dull odor perception. ADL

advised their trained odor analysts could perceive TIA levels of 0.5 but the public perception level is about 1.0. The range of H₂S concentration vs. TIA levels during the 1983 ADL site survey was .02 - .15 ppm H₂S at TIA = 0.5 and .05 - .25 ppm at TIA = 1.0.

East Hide Pile Bore Hole	H ₂ S Analysis	ADL Dilutions To TIA=1	H ₂ S Level At TIA=1	ADL Dilutions To TIA=0.5	H ₂ S Level At TIA=0.5 (Threshold)
9	5,600 ppm	14,000	0.4 ppm	37,000	0.15 ppm
10	19,500 ppm	430,000	0.05	1,000,000	0.02
11	5,700 ppm	50,000	0.11	140,000	0.04
12	19,000 ppm	230,000	0.08	450,000	0.04
13	20,500 ppm	86,000	0.25	220,000	0.09
Range	5,600 - 20,500	14,000 - 230,000	.05 - .25	37,000 - 1,000,000	.02 - .15
General Public's Odor Perception Level			.05 - .25	Trained ADL Odor Specialists Odor Perception Level .02 - .15	

The remedial action alternative recommended for control of the east hide pile emissions is to cap, provide positive venting, carbon treat, and discharge through a 12 foot stack. No detectable H₂S, benzene, or mercaptan are anticipated.

Table III-A - Downwind Worst Case Concentrations of Air Emissions
From The East Hide Pile (Based on TEM8 Air Model)

Concentration in PPM

<u>Conditions</u>	<u>Property Line 100 meters</u>	<u>Nearest Residential Area 700 meters</u>	<u>1 Km</u>	<u>2 KM</u>	<u>3 Km</u>
A) Existing/Prior					
Hydrogen Sulfide	1.35	0.187	0.139	0.077	0.055
Benzene	0.00035	0.000004	0.000003	0.000002	0.000001
Toulene	0.0001	5×10^{-5}			
Mercaptans	.02	5×10^{-3}			
B) After Carbon Treatment		Non-detectable			
Hydrogen Sulfide					
Benzene					
Toulene					
Mercaptans					

GROUNDWATER STRIPPER EMISSIONS
IMPACT ON AMBIENT AIR

The Malcolm Pirnie air stripper design is as follows: (pg V-23 and 3 pgs after V-27).

Option 1: 75 gpm Hot Spots

Benzene in 9,300 ppb
Toluene in 10,300 ppb
Column diameter
Air to water ratio 60:1
Exit gas volume 600 ft³/min.
Assume stack height 40' & 1' exit diameter
Assume temperature 1°C above ambient
Use air model PTPLU

The maximum benzene and toluene concentrations, see attachment Option 1 are:

$$\underline{\text{Benzene}} = 7.56 \times 10^{-5} \text{ gm/m}^3 \text{ at 80 meters}$$

$$\underline{\text{Toluene}} = \frac{.386}{.345} \times 7.56 \times 10^{-5} = 8.36 \times 10^{-5} \text{ at 80 meters}$$

$$\underline{\text{Benzene}} = 7.56 \times 10^{-5} \frac{\text{gm}}{\text{m}^3} \times \frac{22.41}{\text{gm mole}} \times \frac{\text{m}^3}{1000 \text{ l}} \times \frac{\text{gm mole}}{78.11 \text{ gm}} \text{ benzene} = 21.6 \text{ ppb}$$

$$\underline{\text{Toluene}} = 8.36 \times 10^{-5} \times 22.4 \div 1000 \div 92.13 = 20.3 \text{ ppb}$$

$$\underline{\text{VOC}} = (9,300 + 10,300 \text{ ppb}) \times 75 \text{ gpm} \times 1440 \text{ min/yr} \times 365 \text{ days/yr} \times 8.34 \text{ lbs/gal} = 6440 \text{ lbs/yr}$$

Option 2: 110 gpm Downgradient of Site

Malcolm Pirnie's Design

Benzene in 9300 ppb
Toluene in 10,300 ppb
Column diameter 2'
Air to water ratio 60:1
Exit gas volume 880 ft³/min.
Assumed 90% removal in BOD section, 10' in stripper section
Option 2 involves BOD treatment requiring a building. Assume
Butler building 30' high
GEP stack height = H + 1.5(L) = 2.5H = 75'
Assume 75' stack & 1' diameter
Use PTPLU air model

The maximum benzene and toluene concentrations are:

$$\underline{\text{Benzene}} = 1.50 \times 10^{-6} \text{ gm/m at 167 meters}$$

$$\underline{\text{Toluene}} = \frac{.57 (1.50)}{.51} = 1.67 \times 10^{-6} \text{ gm/m}^3 \text{ at 167 meters}$$

$$\underline{\text{Benzene}} = 1.50 \times 10^{-6} \times 22.4 \div 1000 \div 78.11 = 0.4 \text{ ppb}$$

$$\underline{\text{Toluene}} = 1.67 \times 10^{-6} \times 22.4 \div 1000 \div 92.13 = 0.4 \text{ ppb}$$

$$\underline{\text{VOC}} = 0.1 \times 19.6 \text{ ppm} \times 110 \times 1440 \times 8.34 \times 365 = 945 \text{ lbs/yr}$$

Option 3: 370 gpm Downgradient of the Plume

Malcolm Pirnie's Design

Benzene in 115 ppb

Toluene in 40 ppb

Column diameter 4'

Air to water ratio 60:1

Exit gas volume = 2970 ft³/m

Assume stack height 40' & 1' diameter

Assume temperature 1°C above ambient

Use air model PTPLU

The maximum concentrations are:

$$\underline{\text{Benzene}} = 4.21 \times 10^{-7} \text{ at 206 meters}$$

$$\underline{\text{Toluene}} = \frac{40}{115} 4.21 = 1.46 \times 10^{-7} \text{ at 206 meters}$$

$$\underline{\text{Benzene}} = 4.21 \times 10^{-7} \times 22.4 \div 1000 \div 78.11 = 0.1 \text{ ppb}$$

$$\underline{\text{Toluene}} = 1.46 \times 10^{-7} \times 22.4 \div 1000 \div 92.13 = 0.04 \text{ ppb}$$

$$\underline{\text{VOC}} = 370 \times 155 \text{ ppb} \times 8.34 \times 1440 \times 365 = 251 \text{ lbs/yr}$$

WIND PROFILE EXPONENTS = A:0.07, B:0.07, C:0.10
 D:0.15, E:0.35, F:0.55

Option 1

RECEPTOR HEIGHT = 0.00 (M)

SOURCE

EMISSION RATE = 0.04 (G/SEC)
 STACK HEIGHT = 12.20 (M)
 EXIT TEMP. = 294.00 (K)
 EXIT VELOCITY = 0.28 (M/SEC)
 STACK DIAM. = 0.30 (M)

>>>CALCULATED PARAMETERS<<<

VOLUMETRIC FLOW = 0.02 (M**3/SEC)
 BUOYANCY FLUX PARAMETER = 0.00 (M**4/SEC**3)

WOBURN 75 GPM GROUNDWATER

STACK TOP WINDS (EXTRAPOLATED FROM 10.0 METERS)

STABILITY	WIND SPEED (M/SEC)	MAX CONC (G/CU M)	DIST OF MAX (KM)	PLUME HT (M)
1	0.51	7.0040E-05	0.060	12.1
1	0.81	4.6110E-05	0.059	11.8
1	1.01	3.7544E-05	0.058	11.7
1	1.52	2.5632E-05	0.058	11.6
1	2.03	1.9456E-05	0.057	11.5
1	2.54	1.5678E-05	0.057	11.5
1	3.04	1.3128E-05	0.057	11.4

STACK TOP WINDS (EXTRAPOLATED FROM 10.0 METERS)

STABILITY	WIND SPEED (M/SEC)	MAX CONC (G/CU M)	DIST OF MAX (KM)	PLUME HT (M)
2	0.51	7.5614E-05	0.080	12.1
2	0.81	4.9813E-05	0.078	11.8
2	1.01	4.0569E-05	0.077	11.7
2	1.52	2.7705E-05	0.076	11.6
2	2.03	2.1033E-05	0.076	11.5
2	2.54	1.6950E-05	0.075	11.5
2	3.04	1.4195E-05	0.075	11.4
2	4.06	1.0712E-05	0.075	11.4
2	5.07	8.6011E-06	0.075	11.4

Max Conc

STACK TOP WINDS (EXTRAPOLATED FROM 10.0 METERS)

STABILITY	WIND SPEED (M/SEC)	MAX CONC (G/CU M)	DIST OF MAX (KM)	PLUME HT (M)
3	2.04	2.2798E-05	0.110	11.5
3	2.55	1.8374E-05	0.109	11.5
3	3.06	1.5387E-05	0.109	11.4
3	4.08	1.1612E-05	0.109	11.4
3	5.10	9.3247E-06	0.108	11.4
3	7.14	6.6890E-06	0.108	11.3
3	10.20	4.6974E-06	0.108	11.3
3	12.24	3.9194E-06	0.108	11.3
3	15.30	3.1394E-06	0.108	11.3

****STACK TOP WINDS (EXTRAPOLATED FROM 10.0 METERS)****

STABILITY	WIND SPEED (M/SEC)	MAX CONC (G/CU M)	DIST OF MAX (KM)	PLUME HT (M)
4	0.52	7.4335E-05	0.198	12.1
4	0.82	4.9037E-05	0.193	11.8
4	1.03	3.9955E-05	0.191	11.7
4	1.55	2.7303E-05	0.188	11.6
4	2.06	2.0734E-05	0.187	11.5
4	2.58	1.6713E-05	0.186	11.5
4	3.09	1.3997E-05	0.186	11.4
4	4.12	1.0564E-05	0.185	11.4
4	5.15	8.4836E-06	0.184	11.4
4	7.21	6.0861E-06	0.184	11.3
4	10.30	4.2742E-06	0.184	11.3
4	12.36	3.5663E-06	0.184	11.3
4	15.45	2.8567E-06	0.183	11.3
4	20.61	2.1452E-06	0.183	11.3

****STACK TOP WINDS (EXTRAPOLATED FROM 10.0 METERS)****

STABILITY	WIND SPEED (M/SEC)	MAX CONC (G/CU M)	DIST OF MAX (KM)	PLUME HT (M)
5	2.14	1.5179E-05	0.300	12.8
5	2.68	1.2380E-05	0.299	12.6
5	3.22	1.0468E-05	0.296	12.6
5	4.29	8.2024E-06	0.277	12.3
5	5.36	6.8060E-06	0.274	12.1

****STACK TOP WINDS (EXTRAPOLATED FROM 10.0 METERS)****

STABILITY	WIND SPEED (M/SEC)	MAX CONC (G/CU M)	DIST OF MAX (KM)	PLUME HT (M)
6	2.23	1.3748E-05	0.507	12.5
6	2.79	1.1185E-05	0.502	12.4
6	3.35	9.4397E-06	0.499	12.3
6	4.46	7.2103E-06	0.493	12.2
6	5.58	5.8428E-06	0.489	12.2

- (1) THE DISTANCE TO THE POINT OF MAXIMUM CONCENTRATION IS SO GREAT THAT THE SAME STABILITY IS NOT LIKELY TO PERSIST LONG ENOUGH FOR THE PLUME TO TRAVEL THIS FAR.
- (2) THE PLUME IS CALCULATED TO BE AT A HEIGHT WHERE CARE SHOULD BE USED IN INTERPRETING THE COMPUTATION.
- (3) NO COMPUTATION WAS ATTEMPTED FOR THIS HEIGHT AS THE POINT OF MAXIMUM CONCENTRATION IS GREATER THAN 100 KILOMETERS FROM THE SOURCE.

WOBURN 110 GPM GROUNDWATER

Option 2

OPTIONS

IF = 1, USE OPTION
 = 0, IGNORE OPTION
 T(1) = 1 (GRAD PLUME RISE)
 IUPT(2) = 1 (STACK DOWNWASH)
 IOPT(3) = 1 (BUOY. INDUCED DISP.)

METEOROLOGY

AMBIENT AIR TEMPERATURE = 293.00 (K)
 MIXING HEIGHT = 2000.00 (M)
 ANEMOMETER HEIGHT = 10.00 (M)
 WIND PROFILE EXPONENTS = A:0.07, B:0.07, C:0.10
 D:0.15, E:0.35, F:0.55

RECEPTOR HEIGHT = 0.00 (M)

SOURCE

EMISSION RATE = 0.06 (G/SEC) - Actual x 10¹
 STACK HEIGHT = 22.86 (M)
 EXIT TEMP. = 294.00 (K)
 EXIT VELOCITY = 5.70 (M/SEC)
 STACK DIAM. = 0.30 (M)

>>>CALCULATED PARAMETERS<<<

VOLUMETRIC FLOW = 0.42 (M**3/SEC)
 BUOYANCY FLUX PARAMETER = 0.00 (M**4/SEC**3)

WOBURN 110 GPM GROUNDWATER

****STACK TOP WINDS (EXTRAPOLATED FROM 10.0 METERS)****

STABILITY	WIND SPEED (M/SEC)	MAX CONC (G/CU M)	DIST OF MAX (KM)	PLUME HT (M)
1	0.53	1.5047E-05	0.167	32.7
1	0.85	1.1674E-05	0.149	29.0
1	1.06	1.0113E-05	0.143	27.8
1	1.59	7.5400E-06	0.135	26.1
1	2.12	5.9969E-06	0.131	25.3
1	2.65	4.9742E-06	0.129	24.8
1	3.18	4.2481E-06	0.127	24.5

Max Conc x 10⁻¹

****STACK TOP WINDS (EXTRAPOLATED FROM 10.0 METERS)****

STABILITY	WIND SPEED (M/SEC)	MAX CONC (G/CU M)	DIST OF MAX (KM)	PLUME HT (M)
2	0.53	1.5106E-05	0.232	32.7
2	0.85	1.1858E-05	0.206	29.0
2	1.06	1.0313E-05	0.194	27.8
2	1.59	7.7460E-06	0.183	26.1
2	2.12	6.1844E-06	0.176	25.3
2	2.65	5.1420E-06	0.173	24.8
2	3.18	4.3985E-06	0.170	24.5
2	4.24	3.4368E-06	0.167	24.0
2	5.30	2.8445E-06	0.164	23.6

****STACK TOP WINDS (EXTRAPOLATED FROM 10.0 METERS)****

STABILITY	WIND SPEED (M/SEC)	MAX CONC (G/CU M)	DIST OF MAX (KM)	PLUME HT (M)
3	2.17	6.4472E-06	0.260	25.3
3	2.72	5.3591E-06	0.254	24.8
3	3.26	4.5834E-06	0.251	24.5
3	4.34	3.5869E-06	0.245	23.9
3	5.43	2.9679E-06	0.241	23.5
3	7.60	2.2049E-06	0.236	23.1
3	10.86	1.5904E-06	0.232	22.7
3	13.03	1.3410E-06	0.230	22.6
3	16.29	1.0856E-06	0.229	22.5

****STACK TOP WINDS (EXTRAPOLATED FROM 10.0 METERS)****

STABILITY	WIND SPEED (M/SEC)	MAX CONC (G/CU M)	DIST OF MAX (KM)	PLUME HT (M)
4	0.57	1.2843E-05	0.620	32.1
4	0.91	1.0198E-05	0.542	28.6
4	1.13	8.8953E-06	0.516	27.5
4	1.70	6.6960E-06	0.481	25.9
4	2.26	5.3518E-06	0.464	25.2
4	2.83	4.4523E-06	0.454	24.7
4	3.40	3.8100E-06	0.448	24.4
4	4.53	2.9944E-06	0.435	23.9
4	5.66	2.4796E-06	0.427	23.5
4	7.92	1.8437E-06	0.417	23.0
4	11.32	1.3307E-06	0.409	22.7
4	13.58	1.1223E-06	0.407	22.6
4	16.98	9.0880E-07	0.404	22.5
4	22.64	6.8995E-07	0.402	22.3

****STACK TOP WINDS (EXTRAPOLATED FROM 10.0 METERS)****

STABILITY	WIND SPEED (M/SEC)	MAX CONC (G/CU M)	DIST OF MAX (KM)	PLUME HT (M)
5	2.67	3.5727E-06	0.769	26.4
5	3.34	2.9188E-06	0.760	26.1
5	4.01	2.4820E-06	0.750	25.9
5	5.34	1.9427E-06	0.731	25.4
5	6.68	1.5995E-06	0.719	25.1

****STACK TOP WINDS (EXTRAPOLATED FROM 10.0 METERS)****

STABILITY	WIND SPEED (M/SEC)	MAX CONC (G/CU M)	DIST OF MAX (KM)	PLUME HT (M)
6	3.15	3.0451E-06	1.203	24.5
6	3.94	2.5260E-06	1.174	24.2
6	4.73	2.1850E-06	1.146	23.8
6	6.30	1.7185E-06	1.112	23.3
6	7.88	1.4153E-06	1.091	23.0

(1) THE DISTANCE TO THE POINT OF MAXIMUM CONCENTRATION IS SO GREAT THAT THE SAME STABILITY IS NOT LIKELY TO PERSIST LONG ENOUGH FOR THE PLUME TO TRAVEL THIS FAR.

Option 3

SOURCE
EMISSION RATE = 0.26 (G/SEC)
STACK HEIGHT = 12.20 (M) ^{Actual}
EXIT TEMP. = 294.00 (K) ^{X10²}
EXIT VELOCITY = 19.20 (M/SEC)
STACK DIAM. = 0.30 (M)

1. CALCULATED PARAMETERS<<<

VOLUMETRIC FLOW = 1.40 (M**3/SEC)
BUOYANCY FLUX PARAMETER = 0.01 (M**4/SEC**3)

WOBURN 370 GPM GROUNDWATER

****STACK TOP WINDS (EXTRAPOLATED FROM 10.0 METERS)****

STABILITY	WIND SPEED (M/SEC)	MAX CONC (G/CU M)	DIST OF MAX (KM)	PLUME HT (M)
1	0.51	3.4364E-05	0.223	46.8
1	0.81	3.8509E-05	0.167	33.8
1	1.01	3.9451E-05	0.147	29.5
1	1.52	3.9170E-05	0.121	23.7
1	2.03	3.7241E-05	0.107	20.9
1	2.54	3.4971E-05	0.097	19.1
1	3.04	3.2855E-05	0.091	18.0

****STACK TOP WINDS (EXTRAPOLATED FROM 10.0 METERS)****

STABILITY	WIND SPEED (M/SEC)	MAX CONC (G/CU M)	DIST OF MAX (KM)	PLUME HT (M)
2	0.51	3.3365E-05	0.317	46.8
2	0.81	3.8658E-05	0.231	33.8
2	1.01	4.0105E-05	0.203	29.5
2	1.52	4.0820E-05	0.160	23.7
2	2.03	3.9403E-05	0.141	20.9
2	2.54	3.7323E-05	0.129	19.1
2	3.04	3.5119E-05	0.121	18.0
2	4.06	3.1018E-05	0.111	16.5
2	5.07	2.7569E-05	0.105	15.7

****STACK TOP WINDS (EXTRAPOLATED FROM 10.0 METERS)****

STABILITY	WIND SPEED (M/SEC)	MAX CONC (G/CU M)	DIST OF MAX (KM)	PLUME HT (M)
3	2.04	4.2117E-05	0.206	20.8
3	2.55	3.9977E-05	0.188	19.1
3	3.06	3.7672E-05	0.177	17.9
3	4.08	3.3337E-05	0.162	16.5
3	5.10	2.9665E-05	0.153	15.6
3	7.14	2.4115E-05	0.143	14.7
3	10.20	1.8712E-05	0.135	13.9
3	12.24	1.6256E-05	0.132	13.6
3	15.30	1.3880E-05	0.128	13.2

Max Conc
X10⁻²
=

****STACK TOP WINDS (EXTRAPOLATED FROM 10.0 METERS)****

STABILITY	WIND SPEED (M/SEC)	MAX CONC (G/CU M)	DIST OF MAX (KM)	PLUME HT (M)
4	0.52	2.7700E-05	0.900	46.3
4	0.82	3.3996E-05	0.621	33.5
4	1.03	3.6129E-05	0.531	29.2
4	1.55	3.7826E-05	0.414	23.6
4	2.06	3.7121E-05	0.356	20.7
4	2.58	3.5551E-05	0.323	19.0
4	3.09	3.3717E-05	0.300	17.9
4	4.12	2.9936E-05	0.280	16.5
4	5.15	2.6684E-05	0.264	15.6
4	7.21	2.1735E-05	0.246	14.6
4	10.30	1.6892E-05	0.232	13.9
4	12.36	1.4684E-05	0.227	13.6
4	15.45	1.2568E-05	0.218	13.2
4	20.61	1.0162E-05	0.209	12.7

****STACK TOP WINDS (EXTRAPOLATED FROM 10.0 METERS)****

STABILITY	WIND SPEED (M/SEC)	MAX CONC (G/CU M)	DIST OF MAX (KM)	PLUME HT (M)
5	2.14	3.3363E-05	0.528	20.2
5	2.68	3.1491E-05	0.480	18.8
5	3.22	2.9895E-05	0.446	17.7
5	4.29	2.6712E-05	0.403	16.3
5	5.36	2.3914E-05	0.377	15.5

****STACK TOP WINDS (EXTRAPOLATED FROM 10.0 METERS)****

STABILITY	WIND SPEED (M/SEC)	MAX CONC (G/CU M)	DIST OF MAX (KM)	PLUME HT (M)
6	2.23	3.1405E-05	0.847	19.4
6	2.79	2.8100E-05	0.794	18.5
6	3.35	2.6761E-05	0.733	17.4
6	4.46	2.3910E-05	0.697	16.1
6	5.58	2.1286E-05	0.655	15.3

- (1) THE DISTANCE TO THE POINT OF MAXIMUM CONCENTRATION IS SO GREAT THAT THE SAME STABILITY IS NOT LIKELY TO PERSIST LONG ENOUGH FOR THE PLUME TO TRAVEL THIS FAR.
- (2) THE PLUME IS CALCULATED TO BE AT A HEIGHT WHERE CARE SHOULD BE USED IN INTERPRETING THE COMPUTATION.
- (3) NO COMPUTATION WAS ATTEMPTED FOR THIS HEIGHT AS THE POINT OF MAXIMUM CONCENTRATION IS GREATER THAN 100 KILOMETERS FROM THE SOURCE.

APPENDIX D

ODOR EVALUATIONS OF BORE HOLE GASES
AT THE INDUSTRIplex 128 SITE
WOBURN, MASSACHUSETTS

A Report to
Stauffer Chemical Company
Westport, CT

By
S.E. Ellis
Arthur D. Little, Inc.
Cambridge, MA 02140

November 1983

89992

INTRODUCTION

On six days during the period 23 September through 3 November 1983, a team of trained odor analysts from the Chemical and Food Sciences Section of Arthur D. Little, Inc. conducted odor evaluations at the Woburn (Industriplex 128) site located in Woburn, Massachusetts using sensory evaluation techniques. The purpose of these evaluations was to validate the sensitivity of Stauffer Chemical Company's gas sampling and analyses to odorous chemical compounds found in the gases taken from each of 15 bore holes.

It had been identified during previous site evaluations that the primary odor types at the site were reduced sulfur species, primarily hydrogen sulfide (H_2S). In order to perform sensory evaluations on these highly odorous bore hole gases, an odor sample dynamic dilution system was developed which provided up to one million dilutions of each sample of concentrated bore hole gas. In order to identify other odorous species present in a concentrated H_2S gas sample, an odor adsorption system was used which excluded the H_2S and similar low-boiling compounds. The adsorbed odors were eluted for subsequent odor evaluations.

Throughout this study the odor team used specific chemical names to describe the observed odor when possible to do so. Use of these chemical names does not necessarily indicate the presence of that compound. Rather, it represents compounds with similar odor characteristics.

CONCLUSIONS

During direct analysis of the bore hole gases, the characteristic odor of H_2S was identified as the principal odorant in 7 of the 15 bore

holes evaluated (including bore hole 9, 10, 11, 12, 13, 14, 23). These H₂S sources required 6.4 x 10⁴ to greater than 1 x 10⁶ dilutions with odor-free air to reduce to the recognition odor threshold of the professional odor team. In four of these seven bore holes the H₂S odor was accompanied by odors described as mercaptan, rubbery, sulfide, oniony, animal and fecal. The other three bore holes, all located at the east hide pile, were described as strictly H₂S in direct sensory analysis though other odors were revealed during the evaluation of the adsorbed odors. No H₂S odors were found in the west hide pile.

Non-H₂S-related odors found during direct analysis included oniony, sulfide, cheesy sour, dimethyl sulfide, animal/horsey, phenyl acetic acid, musty, tarry, fecal and naphthalene. The odor strength of these bore hole gases as measured by odor threshold dilutions varied widely from 2 x 10³ to 5 x 10⁵. The most significant of these non-H₂S sources were Bore Hole No. 25 located on the center mound area and Bore Hole No. 16 located in the southeast corner of the site. The odors from both of these sources were described as fermented, cheesy sour.

Odors eluted from the adsorption medium included oniony mercaptan (similar to that of propyl-or butyl-mercaptan), fecal (skatole), rubbery, solventy (naphthalene or p-dichlorobenzene), tarry and musty. These odors were not quantitatively assessed during this program.

APPROACH

During the period of September 28 to October 3, 1983, odorous gases from 15 bore holes located at the Woburn (Industriplex 128) site in Woburn, Massachusetts were evaluated by a team of 3 odor analysts. The approach used during these evaluations was developed for and modified during preliminary on-site evaluations during the week preceding the test period.

The three odor analysts used during these evaluations were trained in Arthur D. Little's Flavor Profile methodology. This objective technique makes use of trained personnel to describe odor in terms of descriptive character notes and to assign a defined intensity rating to the perceived odor. The following seven-point scale was used by the panelists to denote the total intensity of aroma, TIA:

- 0 = not detected
- 0.2 = threshold or barely detectable
- $\frac{1}{2}$ = very slight
- 1 = slight
- $1\frac{1}{2}$ = slight-to-moderate
- 2 = moderate
- $2\frac{1}{2}$ = moderate-to-strong
- 3 = strong

The character notes used by the panelists during their evaluations are descriptive only and are not intended to identify specific chemical species in the gases sampled. Rather, they represent compounds with similar odor characteristics. Certain compounds, such as hydrogen sulfide (H_2S), have unique characteristic odors while others, like methyl mercaptan, have odor characteristics such as mercaptan, sulfidy,

decayed vegetation, cabbagey, etc. Some of these characteristics are shared by other reduced sulfur species.

Direct Analysis of Bore Hole Gases

Odor analysis of each of the 15 bore holes was conducted by the odor team immediately following the bag sampling by a team of Stauffer Chemical personnel. The depth to refusal or ground water was measured by the Stauffer team and a 1/4 in. Teflon sample line was lowered in to the bore hole to a depth of 1 to 2 feet less than the total depth. The final sample depth is included in Table 1. After connecting a small sample pump to the sample line and purging for approximately two minutes, the gas samples were collected for chemical analysis by the Stauffer team.

The Portable Dynamic Dilution System shown in Figure 1 was connected to the Teflon® sample line for odor presentations to the panelist. This dilution system provides a constant flow of odor-free dilution air. The gas samples are metered in through a particulate filter. For this program the exhaust was closed in order to conserve the limited available sample volume.

Beginning at the maximum available dilution (1×10^6) with odor-free air, the sample gas concentrations were increased (dilutions decreased) until the odor was just perceptible by each panelist. The maximum dilution at which all panelists could describe the odor was taken to be the recognition dilutions-to-threshold value for each bore hole. This provides a basis for comparing the relative odor strengths of the bore holes.

The odorant concentrations were increased by a factor of approximately two and again evaluated by each panelist who reported his observation of odor intensity and characteristics when odor was perceived. Due to the highly odorous background air at the Industriplex 128 site, the panelists breathed carbon-treated air between observations to minimize interference from extraneous odors.

The odor intensities were increased over the range of normal sensory acuity to establish the dose-response characteristics for each bore hole gas sample. The odor intensity responses for each dilution were averaged. Using the method of least squares, the best-fit line is established using the general form:

$$\text{Intensity (TIA)} = A \text{ Log Dilutions} + B$$

where A = slope and B = intercept.

Sample Collection and Evaluation

In order to assess the non-H₂S odors found in the gases from each bore hole, odors were collected on sorbent traps prepared at our Cambridge, Massachusetts odor laboratory. The sampling procedure involves passing approximately 500 L of the odorous gases through stainless steel cylinders containing 10 grams of XAD-2 sorbent resin. This material has very limited capacity for sorbing H₂S which aided in the identification of higher boiling species. No attempt was made to quantitatively evaluate these collected samples because the bore holes did not contain adequate volume to prevent dilution of the gases during sample collection.

After collecting the odors on the sorbent, the tubes were reconnected in the dynamic dilution system as shown in Figure 2. The odorous compounds which could be air stripped were presented at a fixed dilution for qualitative odor assessment by the panelists.

The sorbent tubes were taken to a Stauffer's field laboratory located near the site where they were eluted with 10 ml of chromatographically pure, distilled-in-glass pentane. Each panelist conducted qualitative analysis on the odors released from a blotter strip containing the pentane and eluted odorous compounds.

RESULTS

The results of the direct sensory analysis are included in Table 2. Based on dilution-to-threshold, Bore Hole No. 10 on the east hide pile was the most odorous sample, requiring greater than one million dilutions (the equipment limit). The gases from this bore hole were described as "H₂S only". The other two bore holes described as "H₂S only" (Nos. 12 and 13) were also located on the east hide pile - lower level.

H₂S was the most significant odor type found during the analysis, being identified in 7 of 15 samples. With the exception of the three holes discussed above, the H₂S characteristics were normally included with odors described as oniony, mercaptan, sulfide, rubbery, animal and fecal. While a number of chemical compounds could produce these odors the following are offered as possible candidates:

Oniony	=	propyl mercaptan, propylene sulfide
Mercaptan	=	any mercaptan
Sulfide	=	dimethyl sulfide (DMS) or dimethyl disulfide (DMDS)

Rubbery = propyl mercaptan, butyl mercaptan
Animal = nitrogenous compounds, fatty acids such as
caprylic
Fecal = skatole
WWTP = wastewater treatment plant

In most cases the non-H₂S odor sources were more dilute. Two exceptions were found, Bore Holes No. 16 and 25, where the dilutions-to-threshold were 128,000 and 512,000, respectively. The gases from these bore holes were both described as cheesy or fermented sour and were easily recognizable even at near-threshold dilutions. Other odors described in these gases are included below with candidate chemical compounds:

Fermented = decaying protein
Cheesy = fatty acids, butyric and isovaleric
Garbagey = methacrylic acid or similar compounds
Burnt sweet = very dilute skatole or indole

Also included in Table 2 are the results of the dose/response analysis. These results are shown graphically in Figures 3 and 4. A significant point to be gained from these curves is that in those bore holes where H₂S predominated, the slopes are significantly greater than when appearing blended with other odors (see Figure 4, curves 10 and 12). This suggests that impurities in the gases may serve to temper the odor impact of the gases at the supra-threshold level.

The dilutions required to reach a slight odor intensity (TIA = 1) for each of the dose/response curves are included in Table 2 for comparison of the supra-threshold odor strengths of the gases from the bore holes.

This odor intensity has been used during some of our odor pollution programs as an indicator of complaint-intensity odors.

The characteristics of the air and solvent-eluted odors from the sorbent tube samples are included in Table 3. The prevalent odors collected on these tubes were oniony, horsey, animal, fecal, rubbery and dimethyl sulfide (DMS). Less frequently identified characteristics included burnt, and solventy. No attempt was made to quantitate these odors.

TABLE 1

BORE HOLE DATA

INDUSTRIPLEX 128 (WOBURN SITE)

<u>Bore Hole No.</u>	<u>Date Sampled</u>	<u>Sample Depth (ft.)</u>	<u>Bore Hole Location</u>
9	9/28	19	East hide pile - upper level
10	9/28	21	East hide pile - upper level
11	9/28	11	East hide pile - upper level
12	9/30	12.5	East hide pile - lower level
13	9/30	10	East hide pile - lower level
14	9/29	9	Southeast corner of site
16	9/29	9.5	Southeast corner of site
17	9/29	7	Southeast corner of site
19	10/3	15	West hide pile
20	10/3	18.5	West hide pile
21	10/3	13	West hide pile
22	9/29	5	Approximately 100 M north of main gate
23	10/3	9.5	Near chrome pit south of main gate
24	9/29	22	Center mound - upper level
25	9/30	13	Center mound - lower level

TABLE 2

DIRECT SENSORY EVALUATION OF BORE HOLE GASES

Dose/Response Analysis ⁽²⁾

Bore Hole No.	Dilutions to Threshold ⁽¹⁾	-A Slope	B Int.	r Regr. Coef.	Dilutions to TIA = 1	Odor Characteristics
9	64,000	1.23	6.12	0.970	14,000	H ₂ S, X-SH, sour, fatty acid, fecal, oniony-SH, solventy
10	>1 x 10 ⁶	1.40	8.87	0.973	430,000	H ₂ S
11	256,000	1.12	6.29	0.994	50,000	H ₂ S, rubbery, sulfide, oniony
12	512,000	1.66	9.89	0.993	230,000	H ₂ S
13	512,000	1.21	6.99	0.947	86,000	H ₂ S
14	128,000	1.37	7.30	0.994	40,000	H ₂ S, trace fecal, trace sour
16	128,000	0.83	4.49	0.974	15,000	Cheesey sour, dirty sour, burnt sweet, trace fecal (butyric, propionic, and isovaleric acids)
17	8,192	0.73	3.35	0.989	2,000	Animal, sweet fragrance, fecal, DMS, musty, sulfidy (WWTP)
19	4,096	1.16	4.55	0.987	1,400	Sulfidy, sour, oniony-SH, tarry, fecal
20	32,000	0.97	4.53	0.994	4,200	Sour, oniony, SH, vegetable sulfide, rubbery, slightly fecal and H ₂ S, naphthalene (moth balls)
21	4,096	1.04	4.22	0.993	1,200	Oniony, sulfidy, animal, horsey, rubbery, tarry, fecal

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TABLE 2 (Continued)

DIRECT SENSORY EVALUATION OF BORE HOLE GASES

Bore Hole No.	Dilutions to Threshold ⁽¹⁾	Dose/Response Analysis ⁽²⁾			Dilutions to TIA = 1	Odor Characteristics
		-A Slope	B Int.	r Regr. Coef.		
22	2,048	1.07	3.73	0.992	350	Horse, animal, fecal, leathery, sulfide, oniony
23	512,000	0.99	6.06	0.946	135,000	H ₂ S, trace oniony, oniony-SH, rubbery, animal, fecal
24	2,048	0.83	2.93	0.967	200	Fecal, rubbery sulfide, vegetable sulfide, animal, musty, WWTP
25	512,000	0.99	5.71	0.982	55,000	Fermented sour, cheesy, garbagey

(1) Recognized by 100% of the panel participants.

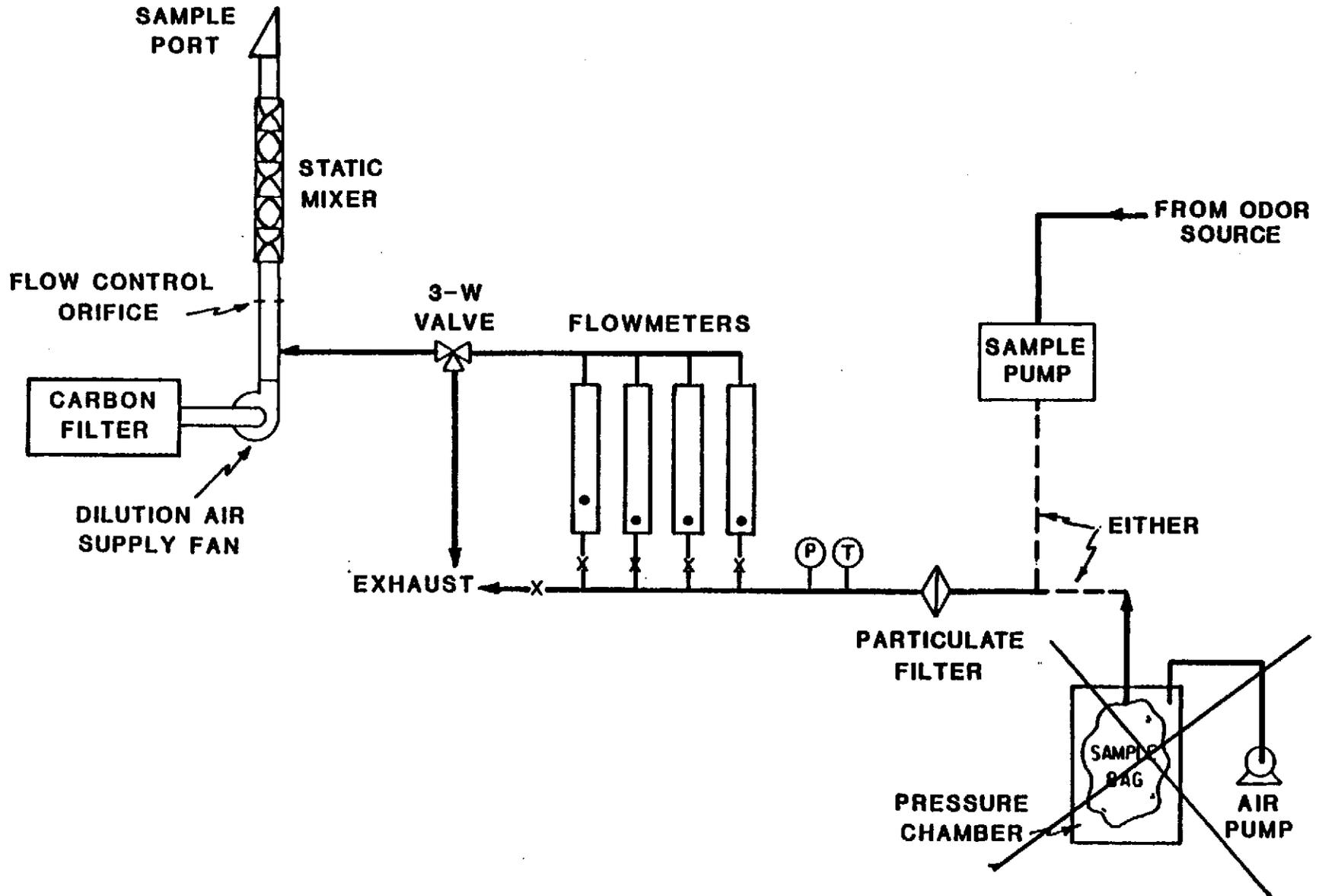
(2) Results of best fit for all data, TIA = A (log Dilutions) + B.

11

TABLE 3
SENSORY EVALUATIONS OF
ADSORBED BORE HOLE ODORS

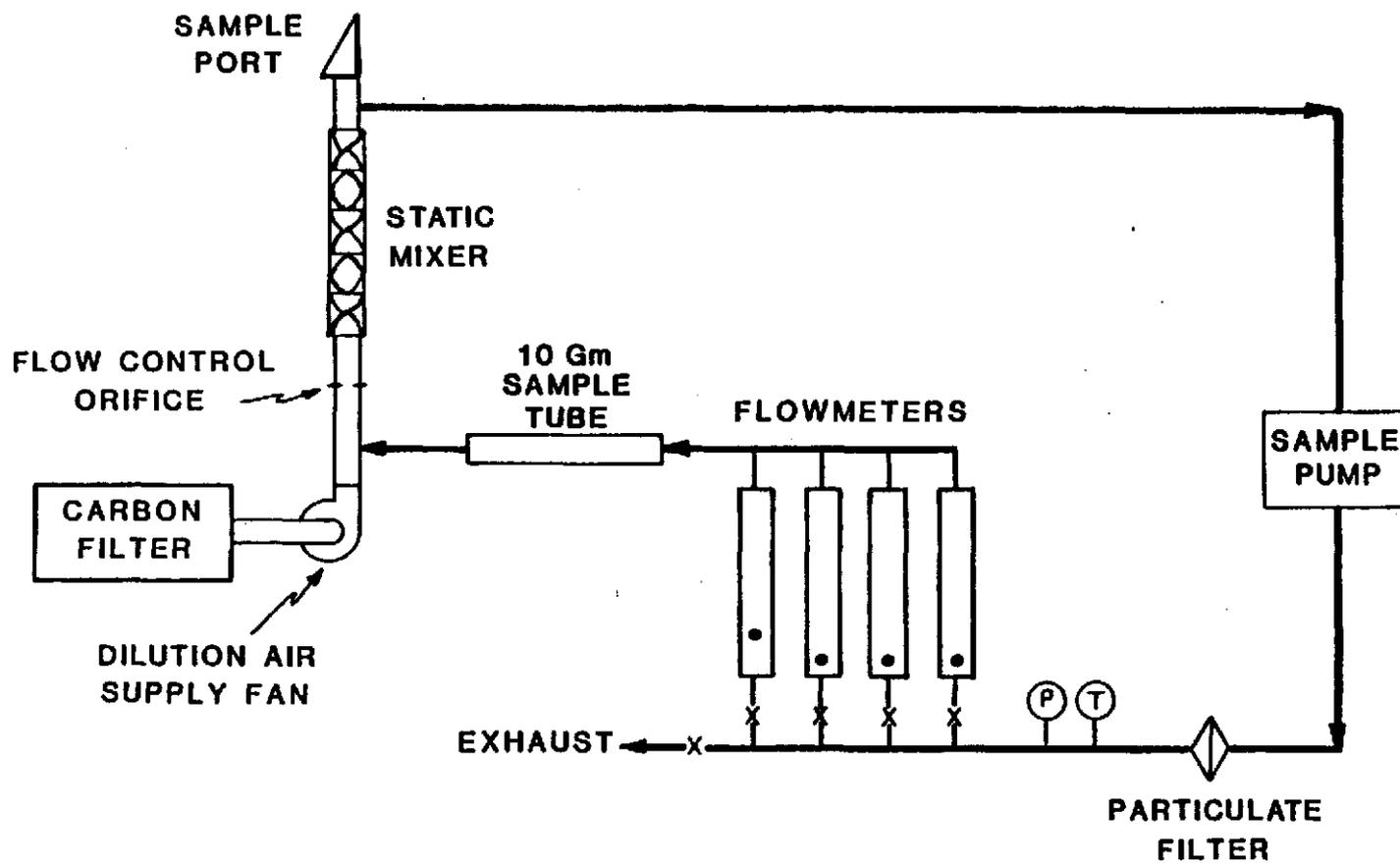
Bore Hole No.	Odor Characteristics	
	Air Eluted	Solvent Eluted
9	Oniony, sour, sulfidy, burnt oniony	Oniony (Pr or allyl-SH) fecal (skatole), solventy naphthalene)
10	Oniony, horsey, animal, fecal	(Me or ET)-SH, Pr-SH, fecal and fatty acid, rubbery
11	Oniony, fecal, rubbery, sulfide, DMS or DMDS	Oniony, (Pr or allyl-SH), fecal, p-dichlorobenzene
12	Oniony, horsey, DMS, animal	Oniony-SH, rubbery-SH (TBM), musty-earthly, horsey, trace skatole
13	Corny (DMS), barny, fecal, vegetable sulfide	-SH (TBM?), musty, animal, fecal, skatole
14	Fecal, burnt sweet, animal	Rubbery-SH or sulfide, musty- earthy, fecal (WWTP)
16	N/A	N/A
17	N/A	N/A
19	Oniony, garlicky, rubbery	-SH (Me or ET), tarry, oniony, WWTP
20	N/A	N/A
21	Trace acetic acid, sulfidy, horsey, animal	Sulfidy, fuel oil, WWTP
22	N/A	N/A
23	Oniony, sour, rubbery, animal, horsey, fecal	-SH, fuel oil WWTP, fecal
24	N/A	N/A
25	Putrid, cheesey, garbagey fermented sour, trace fecal, coffee-like-SH	Cheesey, burnt, animal, fecal (WWTP), benzene-tarry (trace methyl benzene)

FIGURE 1



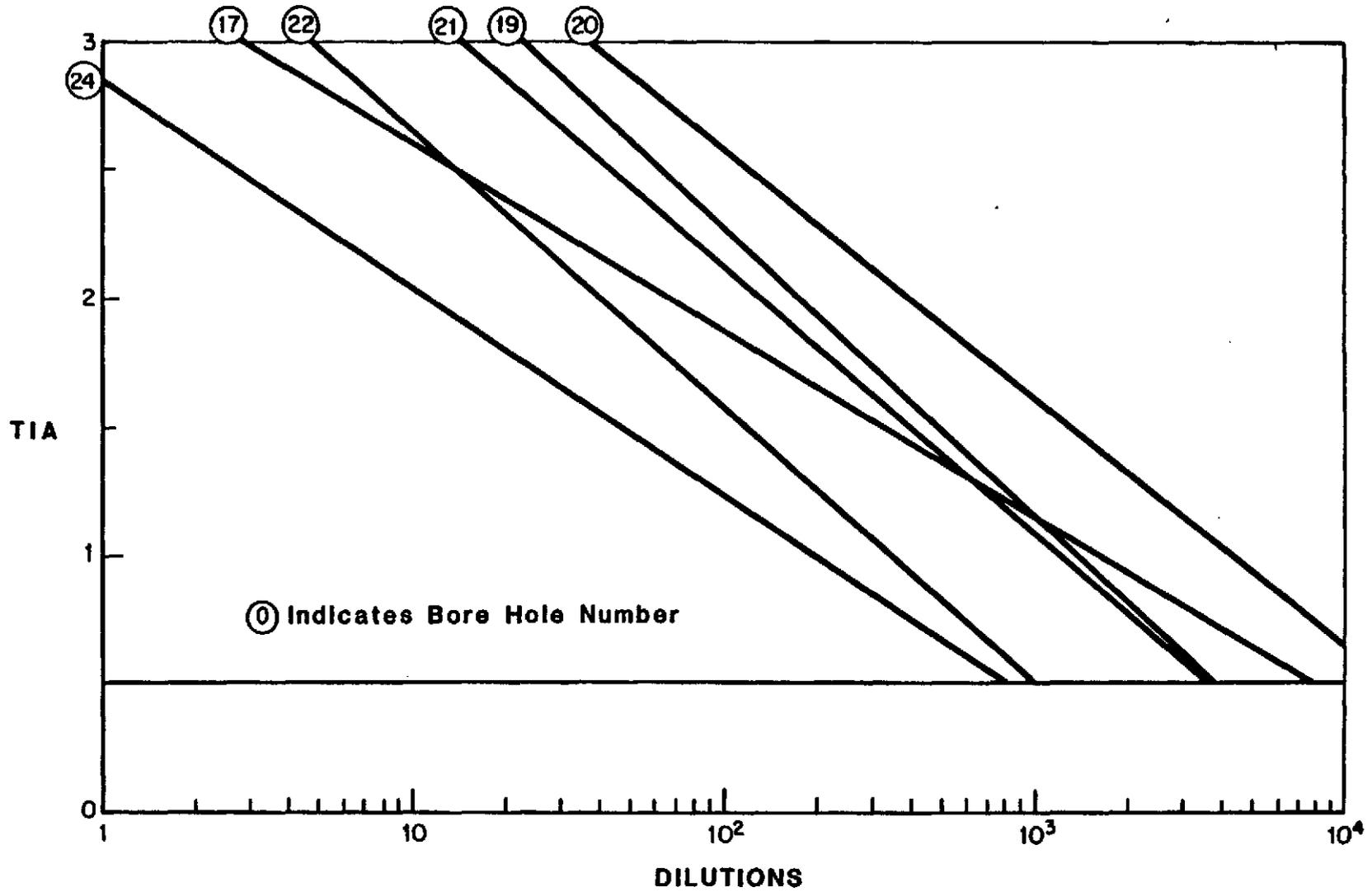
PORTABLE DYNAMIC DILUTION SYSTEM

FIGURE 2



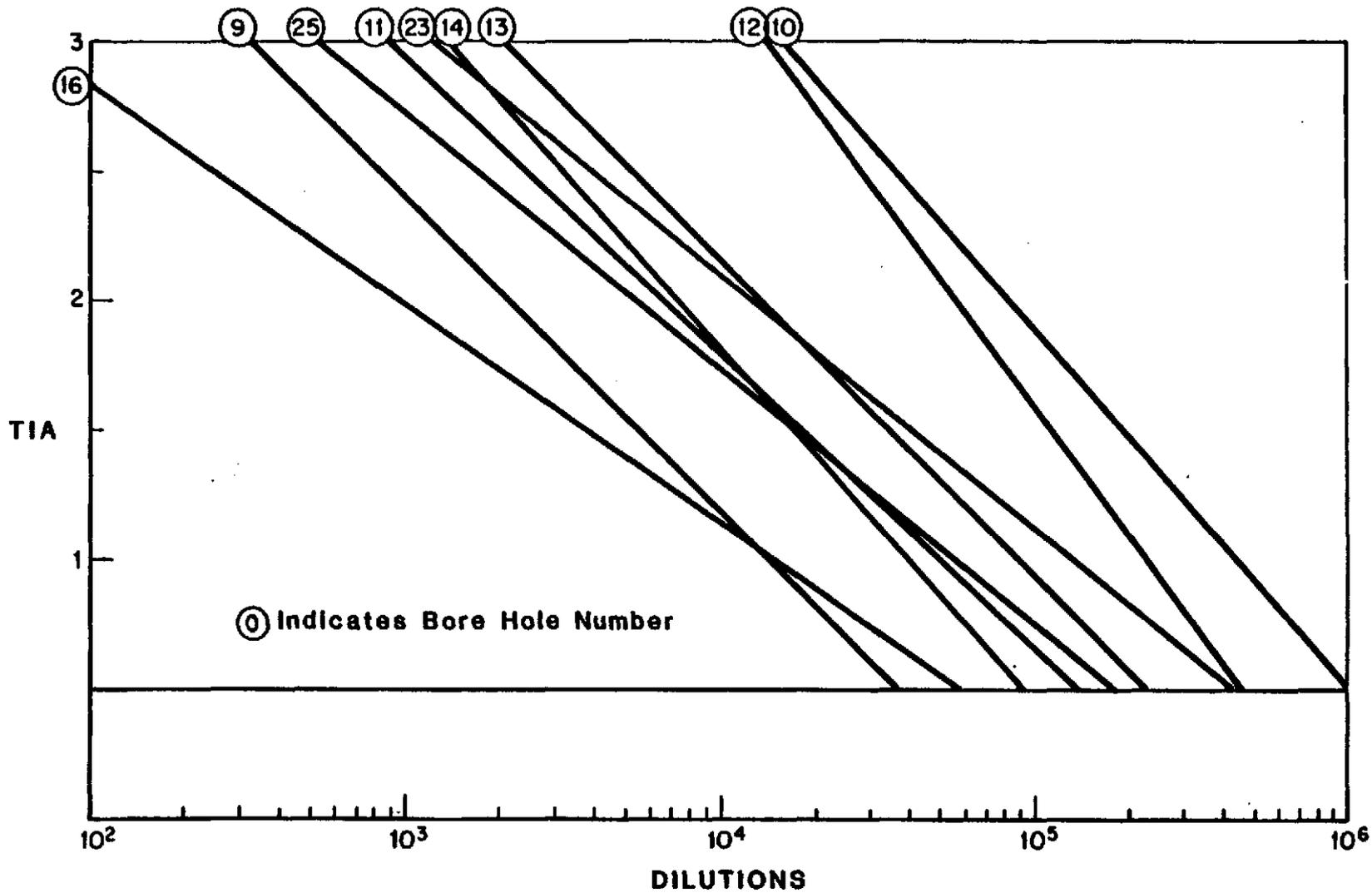
PORTABLE DYNAMIC DILUTION SYSTEM - SAMPLE TUBE EVALUATIONS

FIGURE 3



BORE HOLE DIRECT ANALYSIS DOSE/RESPONSE CURVES

FIGURE 4



BORE HOLE DIRECT ANALYSIS DOSE/RESPONSE CURVES

APPENDIX E

APPENDIX E

As, Cr and Pb Phytotoxicity

The phytotoxicity of a heavy metal is related to the soluble concentration in water supplied to plant roots. Surface vegetation would be influenced by relatively shallow soil contaminants, from 0-2 foot, while deeper rooted scrubs or trees would be unaffected by 0-2 foot contamination because of a deeper root zone. An example is apple orchards when arsenic pesticides were heavily used. Mature apple trees would show no signs of phytotoxicity despite high surface arsenic concentration. However, when orchards were removed, then it was noticed crops planted exhibited growth reduction.

A survey of literature indicated relatively high levels of chromium or lead are not phototoxic to plants^{1,2,5,6,7,8,9}. Chromium levels up to 5000 ppm are reported to support adequate cover vegetation but at a level of 1+% no vegetation grew¹. Lead was added to soil at 1000 ppm with no effect upon corn growth over a two year period³. These findings are well substantiated by Woburn 0-2 foot soil levels of lead and chromium greater than 5000 ppm with abundant vegetation. A conservative estimated phytotoxic level for chromium and lead will be assumed of 1000 ppm.

Arsenic is widely reported to be phytotoxic to plants with most observations based upon former apple orchards where arsenic pesticides were used. Inorganic arsenates have also been widely used as weed killers, primarily non selective soil sterilants³. Many farm crops suffer yield reduction of 50% at 300 ppm soil arsenic with green beans being most sensitive³. However arsenic addition to soil at 188 ppm increased rye yields and at 1131 ppm wheat yields increased³. Soil from lawns and golf courses⁴ was found to contain 130-550 ppm, arsenic with no reported damage⁴. The Phase II Investigation found numerous areas with vegetation at levels of 300 to 600+ ppm arsenic¹⁰.

The preceding arsenic data strongly supports the conclusion that "The effects are usually dose-related but are strongly modified by a host of variables including plant species, geographic region, soil type and climatic conditions"³. The apparently unaffected vegetation on the Woburn site at 300+ ppm arsenic levels contrasts to the reported 50% reduction for many plants at 300 ppm. It will be assumed a 0-2 foot level of 300 ppm arsenic is suitable for vegetation to cap/cover Woburn Wastes.

End Notes

- 1) Land Reclamation and River Pollution Problems in the Croal Valley Caused by Waste from Chromate Manufacture. Breeze, V. C. - Journal of Applied Ecology pg. 513-525, 10(2)1973
- 2) LEAD - Airborne Lead in Perspective, Committee on Biological Effects of Atmospheric Pollutents. Division of Medical Sciences National Research Council, NAIONAL ACADEMY of SCIENCES, Wash. D.C. 1972.
- 3) ARSENIC Committee on Medical and Biological Effects of Environtmental Pollutants, Division of Medical Sciences, Assembly of Life Sciences, National Research Council, NAIONAL ACADEMY OF SCIENCES, Wash D. C. 1977.
- 4) ARSENIC Distribution in Soils and Its Presence in Certain Plants U. S. Department of Agriculture Washington D.C. Technical Bulletin No. 732, July 1940
- 5) Reviews of the Environtmental Effects of Pollutants. III. Chromium, Oak Ridge National Lab, Tenn. U.S. Dept of Commerce PB-282 796 May 78.
- 6) Effect of Land Disposal Application of Municipal Wastes on Crop Yields and Heavy Metal Uptake. National Fertilizer Development Center, Research Bulletin 1090., North Central Regional Regional Research Publication 235, October 1976.
- 7) Application of Sewage Sludge to Cropland: Appraisal of Potential Hazards of the Heavy Metals to Plants and Animals. EPA 430/9 - 75 - 013 November, 1976.
- 8) Application of Sludges and Wastewaters on Agricultural Land Knezek, B. D. and R. H. Miller Ohio Agricultural Research and Development Center Research Bulletin 1090. North Central Regional Research Publication 235, October 1976.
- 9) Application of Sewage Sludge to Cropland: Appraisal of Potential Hazards of the Heavy Metals to Plants and Animals. EPA 430/9-75-013. November 1976.
- 10) Drawing 001 Phase II Woburn Investigation Arsenic Concentration (PPM) from 0-2 feet.

APPENDIX F

APPENDIX F

CALCULATIONS OF MAXIMUM SOIL CONCENTRATIONS THAT WOULD NOT EXCEED SAFE

CHRONIC DOSE LEVELS

Basis:

1. The calculation includes ingestion and dermal exposures. Inhalation exposure is an order of magnitude less and not significant in the calculation.
2. For purposes of assessing the potential for chronic exposure, 12 days of exposure on the site per year are assumed.
3. The average child weighs about 10 Kg and is assumed to be the most sensitive individual.
4. During an exposure day a child might eat 5 grams of dirt and physically handle about 10 pounds of dirt.
5. The ability of most toxicants to be removed from soil by skin contact is probably no greater than 10%.
6. Of all the soil handled by a child, only about 1% of the total amount will actually stick to the skin. Of this amount, about 1% of the metal constituents will penetrate during the ensuing 24 hours.
7. Kehoe's studies, cited in Cassarett and Doull's text book, indicate lead absorption via food ingestion to be 5-10%. Even though binding to soil should be greater, it is assumed that when soil is eaten, about 8% of the metals in the soil will be absorbed in the alimentary track.

Routes of Exposure and Dose Calculations:

Ingestion - By ingesting 5 grams of soil, a child's daily uptake of soil metal contaminants will be dependent on the soil metals concentrations. The calculations showing this dependency follow:

$$(5 \text{ gm/day}) (1/10 \text{ Kg}) (1 \text{ mg}/1000 \text{ ug}) (8\%) (x \text{ ug/gm}) \\ = (0.00004) (x \text{ ug/gm}) \text{ mg/Kg/day}$$

Dermal - By handling 10 pounds of soil, a child's daily uptake of soil metal contaminants by dermal absorption will be dependent on the soil metals concentrations and can be calculated as follows:

$$(10 \text{ lbs/day}) (454 \text{ g/lb}) (1/10 \text{ Kg}) (1\%) (10\%) (1\%) (1 \text{ mg}/1000 \text{ ug}) (x \text{ ug/g}) \\ = (0.0000045) (x \text{ ug/gm}) \text{ mg/Kg/day}$$

Total Dose - The total dose is the sum of the ingestion and dermal dose and equals:

$$(0.00004) (x \text{ ug/g}) + (0.0000045) (x \text{ ug/g}) \\ = (0.0000445) (x \text{ ug/gm}) \text{ mg/Kg/day}$$

Annualized Daily Dose: The annualized daily chronic dose assuming 12 exposure days per year equals 12/365 times the Total Dose, or:

$$(12/365) (0.0000445) (x \text{ ug/gm}) \text{ mg/Kg/day} \\ = (0.0000015) (x \text{ ug/gm}) \text{ mg/Kg/day}$$

Calculated Safe Soil Concentrations:

To calculate the safe soil concentrations, the equation for the annualized chronic dose is set equal to the chronic Limiting Effect Dose* (LED) and the equation is solved for the soil concentration (x). Soil concentrations less than this value will result in chronic exposures less than the respective LEDs.

Lead: $(0.0000015) (x \text{ ug/gm}) = 0.00083 \text{ (LED)}$

$$x = 567 \text{ ug/gm (ppm)}$$

Arsenic: $(0.0000015) (x \text{ ug/gm}) = 0.0017 \text{ (LED)}$

$$x = 1161 \text{ ug/gm (ppm)}$$

Chromium: $(0.0000015) (x \text{ ug/gm}) = 0.0017 \text{ (LED)}$

$$x = 1161 \text{ ug/gm (ppm)}$$

* LED is calculated in the Endangerment Assessment Appendix and defined as exposure below which no adverse effects are expected.

APPENDIX G

This document is a supplement to the Woburn Endangerment Assessment previously submitted to the Environmental Protection Agency Regional Office in Boston Mass. The Engangerment Assessment provided both an acute and chronic quantitative risk assessment of the Woburn site major contaminants via the appropriate routes of exposure. The data base evaluated was comprehensive and in depth.

Concerns raised by the Agency during a December 7, 1984 meeting and a subsequent meeting on January 25, 1985 are discussed herein.

1. Risk assessments associated with short term (acute) exposures and use of the LD₅₀.

The LD₅₀ (LC₅₀ for inhalation) is the basis upon which acute hazards are regulated under the Federal Department of Transportation (DOT) and Environmental Protection Agency (EPA). The actual LD₅₀ value is compared against the relevant health standard. An example of such a system is summarized in the table below.

TABLE 1 - TOXICITY CATEGORY CRITERIA

Hazard Indicators	Category I	Category II	Category III	Category IV
Oral LD ₅₀	Up to and including 50 mg/kg	>50 thru 500 mg/kg	>500 thru 5000 mg/kg	>5000 mg/kg
Dermal LD ₅₀	Up to and including 200 mg/kg	>200 thru 2000 mg/kg	>2000 thru 5000 mg/kg	>5000 mg/kg
Inhalation LC ₅₀ (actual) chamber concentration measured for a 4-hour exposure	Up to and including 0.05 mg/liter	>0.05 thru 0.5 mg/liter	>0.5 thru 5 mg/liter	>5 mg/liter

1. Risk assessments associated with short term (acute) exposures and use of the LD₅₀. (cont'd.)

This table was taken from the Chemical Regulation Reporter (9-28-84) p. 720. It covers precautionary warning statements on pesticide labels. Toxicity category criteria are established based upon the actual LD₅₀ value for the respective hazard indicators (i.e. oral LD₅₀, dermal LD₅₀, inhalation LC₅₀). The actual LD₅₀ values of 50, 500 and 5000 mg/kg are the breakpoints for categorizing label statements. The 50 mg/kg value is also important in DOT labelling standards.

The LD₅₀ values (oral and dermal) are shown in the table below for the significant site contaminants.

TABLE 2

Compound	Oral LD ₅₀ mg/kg	Dermal LD ₅₀ mg/kg
Bis (2-ethylhexyl)phthalate	31,000 (rat)	25,000 (rabbit)
Arsenic and compounds	20-50 (rat)	N/A
Lead	10-50 (human)	N/A
Benzene	4,894 (rats)	N/A
Ethylmercaptan	1,034 (rat)	N/A
*Methylmercaptan	as above	N/A
Sodium or Potassium Cyanide	5 mg/kg (rat)	N/A
Hydrogen Sulfide	est. 132 (rat)	N/A
Nickel	105 (rat)	N/A
Phenol	414 (rat)	850 (rabbit)
Tetrahydrofuran	3,000 (rat)	N/A
Toluene	5,000 (rat)	12,124 (rabbit)
Zinc	30 (mouse)	N/A

*Based upon ethylmercaptan
N/A - Not available

1. Risk assessments associated with short term (acute) exposures and use of the LD₅₀. (cont'd.)

The acute toxicity values span a broad range. Most compounds would not fall into Category I. The more toxic members include lead, arsenic, cyanide and zinc. Of these, the only highly toxic material is cyanide.

The approach in the endangerment assessment is consistent with existing regulations for acute hazards. Perhaps, use of the term limiting effect dose for acute effects has resulted in some concern. The points raised by Agency reviewers are correct in stating that lethality is not the only significant acute effect. In every case, the endangerment assessment shows that substantial margins of safety exist between potential exposure levels and acute toxicity of site contaminants.

2. Acute Effects of Benzene

The endangerment assessment provides a relevant acute toxicologic profile on benzene. This is clearly a case where the rodent toxicity data should be ignored and attention should be focused on human health effects data. Central nervous system (CNS) depression has been observed in humans at levels of 100 ppm benzene. These effects are rapidly reversible following cessation of exposure and do not result in chronic brain damage. The current threshold limit value for benzene is 10 ppm (30 mg/m³). This level does not result in CNS depression and provides a substantial margin of safety from potential acute exposure. The dose in mg/kg from inhaling an atmosphere of 10 ppm (30 mg/m³) converts to 5 mg/kg

Conversion Calculation

meters day air x conc (mg/m³)/kg b.w.

$$10 \text{ m}^3 \times 30 \text{ mg/m}^3 \times 1/60 \text{ kg} = 5 \text{ mg/kg}$$

2. Acute Effects of Benzene (cont'd.)

The acute dose estimated (Woburn site modeling) for benzene is 0.027 mg/kg for an adult and 0.0080 mg/kg for a child. Safety factors associated with these doses are 1,850 and 625 respectively. These convincingly show that benzene is not an acute hazard at the Woburn site. For your information, safety factors have been calculated (Table 3) for other site contaminants.

Another approach to risk estimation from short exposure to benzene is to employ SNARL's. SNARL is an acronym for Suggested No Adverse Response Level. SNARL's have been calculated for a number of selected contaminants in drinking water including benzene. Both EPA and NAS determined that insufficient data exists to determine a one-day SNARL for benzene. However, a 10-day SNARL of 230 ug/L has been established. Assuming 1 L of water is consumed by a 10 kg child then this translates to an actual dose of 23.0 ug/kg/day. The comparable value for an adult is 23 ug/kg/day

$$\times \frac{70 \text{ kg b.w. adult}}{10 \text{ kg b.w. child}} = 161 \text{ ug/kg/day}$$

The acute dose estimated (Woburn site modeling) for benzene is 27 ug/kg for a child and 8.0 ug/kg for an adult. Therefore, potential benzene exposure based upon site modeling is lower than the 10-day SNARL for benzene.

3. Toluene

Toluene is one of the Woburn site contaminants. The original Stauffer endangerment assessment provided key toxicology data including a limited effect dose for acute effects. The evaluation of short-term effects for toluene has been expanded to include the EPA SNARL. The

3. Toluene (Cont'd.)

one-day toluene SNARL is 21.5 mg/kg for an adult and approximately 3 mg/kg for a child. The potential total daily uptake of toluene from the site modeling data is 0.0032 mg/kg for an adult and 0.0095 mg/kg for a child. This negligible exposure when compared to the SNARL reinforces the conclusion that toluene does not constitute a risk from short-term exposure.

4. Arsenic

The Agency furnished references on arsenic (letter of 2/5/85) previously evaluated by Stauffer. These references do not add to our evaluation. The National Research Council has established a maximum allowable concentration for arsenic in drinking water. This value of 50 ug/l provides a sufficient margin of safety to protect from chronic effects of arsenic toxicity. Assuming ingestion of 1 L of H₂O by a 10 kg child or 70 kg adult would result in a dose of 5 ug/kg and 0.7 ug/kg respectively. The potential daily uptake of arsenic based upon site modeling data is 1.3 ug/kg for a child and 0.23 ug/kg for an adult. Both of these values are lower than the arsenic MCL for chronic exposure. Therefore, exposure to arsenic at the Woburn site does not constitute a risk.

5. Lead

The EPA MCL for lead is 50 ug/l. This value is designed to protect individuals from daily ingestion of lead over a lifetime of exposure. An ultra conservative approach would be to use this concentration of 50 ug/l x 1 L of drinking water to calculate a dose of 50 ug/day. Assuming a 10 kg child or 70 kg adult ingests 50 ug, this translates to a dose of 5 ug/kg for the child and 0.7 ug/kg for the adult. The potential exposure

5. Lead (Cont'd.)

to lead, based upon site modeling is 1.2 ug for the adult and 7.1 ug/kg for the child. These values are very close to the dose that protects against toxicity based upon daily ingestion of lead over a lifetime of exposure. This provides further evidence that exposure to these levels does not constitute a hazard from exposure to lead.

6. Rationale for Safety Factors

Safety factors are critical to a scientifically sound endangerment assessment. The safety factor is a measure of the relationship between the no-effect level in the appropriate toxicological study and the anticipated or projected level of exposure. The safety factors provided in the Stauffer endangerment assessment are far more conservative than they appear. For example, the limiting chronic effect dose for bis(2-ethyl hexyl)phthalate is 60 mg/kg/day (endangerment assessment). Assuming that man is 10-100 times more sensitive to this compound than rats, the limiting effect dose for man would be 0.6 to 6 mg/kg/day. When one compares this dose to anticipated chronic exposure to bis(2-ethyl hexyl)phthalate (0.000092 mg/kg/day adult to 0.00056 mg/kg/day child), the margins of safety are in reality greater than 100,000 for a child and greater than 650,000 for an adult. The calculations are shown below for both cases.

$$\begin{array}{r} 60 \text{ mg/kg/day (NOEL)} \\ 0.000092 \text{ mg/kg/day exposure adult} \end{array} = 652,173$$

$$\begin{array}{r} 60 \text{ mg/kg/day (NOEL)} \\ 0.0056 \text{ mg/kg/day exposure child} \end{array} = 107,142$$

6. Rationale for Safety Factors (Cont'd.)

When safety factors are viewed in this context, the substantial margins of safety indicated in the endangerment assessment are but a small fraction of the much larger margin of safety that exists when factoring in anticipated exposure. This further reinforces the conclusions of the endangerment assessment that there are no significant acute or chronic hazards posed by the Woburn site.

TABLE 3

<u>COMPOUND</u>	<u>LD₅₀</u>	<u>MG/KG/DAY DAILY INTAKE</u>		<u>SAFETY FACTOR</u>	
		<u>ADULT</u>	<u>CHILD</u>	<u>ADULT</u>	<u>CHILD</u>
BIS(2-ETHYLHEXYL)PHTHALATE	31,000	0.0028	0.017	>11x10 ⁶	>1.8x10 ⁶
ARSENIC	20	.00023	0.0013	87,000	15,000
LEAD	10	0.0012	0.0071	>8,000	1,500
MERCAPTANS	1,034	0.0016	0.0049	650,000	>211,000
HYDROGEN SULFIDE	132	0.117	0.350	>1,100	377
NICKEL	105	0.00098	0.0059	107,000	17,700
PHENOL	414	0.0033	0.0098	125,000	>42,000
TETRAHYDROFURAN	3,000	0.00032	0.0019	>9.3x10 ⁶	1.5x10 ⁶
TOLUENE	5,000	0.0032	0.0095	>1.5x10 ⁶	>526,000
ZINC	30	0.0015	0.0090	20,000	3,333

ENDANGERMENT ASSESSMENT

I. INTRODUCTION

In order to assess whether the contaminants detected on the Woburn site might present a hazard to the population residing in the vicinity of the site, it was determined that a quantitative endangerment assessment would be required. Such a quantitative assessment would also provide a basis for evaluating the impact of various selected remedial action alternatives. To conduct this assessment all of the Phase I and II analytical findings were reviewed. This review indicated that site contaminants could be categorized into four major areas:

1. Contaminants found in groundwater beneath the site.
2. Volatile contaminants originating from the waste piles.
3. Contaminants found in the site soil.
4. Contaminants found in the site surface water.

After reviewing the levels of the various contaminants found in each of these four major media, those contaminants that might present a potential for endangerment by some anticipated route of exposure were selected for further evaluation. This initial selection was based on the contaminant concentration in the medium and the degree of toxicity of the contaminant. Using these criteria, a total of 13 contaminant substances were selected for further detailed evaluation. These are listed below by source.

1. Groundwater

Arsenic
Lead
Zinc
Benzene
Toluene
Cyanide
Total Phenols

2. Volatiles In Waste Piles

Hydrogen Sulfide
Mercaptans
Benzene
Toluene

3. Soil Contaminants

Arsenic
Lead
Chromium

4. Surface Water

bis (2-ethylhexyl) phthalate

Zinc

Nickel

Tetrahydrofuran

To assess the potential for human endangerment if the surrounding population might be exposed to significant levels of these contaminants, it was first necessary to estimate the human exposure doses for which no observable adverse acute or chronic health effects would be expected (i.e., safe dose), or in the case of contaminants that are recognized as potential human carcinogens the exposure dose above which the risk of developing cancer would be unacceptable. The limiting effects chosen for prevention (or for cancer to prevent an unacceptable risk) were the most sensitive toxic effects produced by acute and chronic exposure to each contaminant. All other less sensitive toxic effects would also be prevented at these dose levels. For each of the 13 contaminant substances these limiting effect doses for acute and chronic health effects have been estimated based on available animal and/or human toxicological data. An overview of the toxicology for each substance has been provided in Attachment 1. The details regarding the estimation of the limiting effect doses are included.

After the safe dose levels for these contaminants were estimated, it was next necessary to estimate the potential for exposure of the surrounding population to the site contaminants. These potential exposure levels could then be compared to the safe dose levels to determine the potential for human endangerment from the site.

In estimating the potential for human exposure to the 13 contaminants selected for evaluation, 6 potential routes of exposures were identified:

1. Drinking groundwater (off site exposure potential)
2. Drinking surface water (on site exposure potential)
3. Breathing volatile organic contaminants (on and off site exposure potential)
4. Breathing airborne particulate contaminants (on and off site exposure potential)
5. Ingesting soil contaminants (on site exposure potential)
6. Dermal absorption of soil contaminants (on site exposure potential)

Incorporating these potential routes of exposure, 3 distinct exposure scenarios were constructed.

1. Incidental On-Site Exposure

It was assumed that incidental users of the property (such as trespassing hunters or children) might potentially be exposed to surface water contaminants, volatile organic contaminants, and soil contaminants (from breathing, ingestion, and dermal absorption).

2. Off-Site Residential Exposure

It was assumed that nearby residents might potentially be exposed to groundwater contaminants and volatile organic contaminants.

3. Exposure During On-Site Construction Activity

It was assumed that during on-site construction activity, construction workers might potentially be exposed to soil contaminants (from breathing and dermal absorption) and that nearby residents might be potentially exposed to airborne particulate contaminants (breathing).

The potential pathways for contaminant exposure within each of these scenarios are summarized in Table I.

For each of these three scenarios the potential for human contaminant exposure under assumed worst case conditions was estimated for the "No Remedial Action" alternative.

After these estimated worst case acute and chronic potential exposures were determined, they were compared to the estimated limiting effect doses. If the estimated potential exposures were less than the respective limiting effect doses, one would not expect to observe any adverse acute or chronic toxic effects, or to produce an unacceptable risk of exposure to a carcinogen. The details of this analysis have been provided in Attachment 2.

When the estimated potential exposures were less than the estimated limiting effect dose levels, margins of safety were calculated. The margins of safety indicate how many times lower the estimated exposure doses are than the limiting effect (i.e., safe) doses. For example, a margin of safety of 10 implies:

1. Even if an actual exposure might be up to ten times greater than the estimated worst case potential exposure, it still would not be expected to produce an adverse toxic effect or unacceptable risk (if the actual safe dose is no lower than the estimated limiting effect dose).

2. Even if an actual safe dose might be up to ten times lower than the estimated limiting effect dose, exposure at the estimated worst case level would still not be expected to produce an adverse toxic effect or unacceptable risk.

Since conservative assumptions and safety factors have been incorporated into the estimated limiting effect doses and the estimated worst case potential exposures, an inherent margin of safety has been incorporated into these estimates. The calculated margins of safety are over and above these inherent margins of safety.

For all of these quantitative endangerment assessments, the exposure to a child has been used as the basis for analysis. Since the child has a lower body weight than an adult, the effect of an equivalent total dose will be greater for the child. Adults will always be at lower risk to the exposures estimated in this assessment, and their respective margins of safety will be greater than those presented.

II. BACKGROUND - USE OF INVESTIGATIVE ANALYTICAL DATA

During Phase I & II investigative activities the nature and extent of the site contaminants were characterized. This contaminant information, along with air dispersion and groundwater transport models, was used in estimating the potential exposure to humans within the specific exposure scenarios.

A review of the soil sampling analyses showed that the level of organic contaminants in the soil was very low and would not present a significant source of exposure to persons who might be exposed to the site soil. Of the inorganic (metal) contaminants arsenic, lead, and chromium were identified as contaminants which required exposure assessments based on their level of contamination and their degree of toxicity. The geometric mean level of approximately 400 soil sample results was used to characterize the average levels of these contaminants across the site. These 400 samples were collected from the top 2 feet of soil and would represent the soil that persons might contact or that might become airborne. Based on these results, it was assumed that the site soil was on the average likely to be composed of 161 ug/g lead, 31 ug/g arsenic, and 82 ug/g total chromium.

Certain smaller areas within the site, such as the phytotoxic arsenic waste, chromium lagoon, and west hide pile areas, were identified as having higher localized soil concentrations of these three metals. A review indicated that in these smaller "hot spot" areas average concentrations of these contaminants might be as high as 620 ug/g lead, 130 ug/g arsenic, and 850 ug/g total chromium.

A review of the surface water samples collected in the Phase I activities indicated that only four substances were present in the on-site surface water at any significant level. These were bis (2-ethyl hexyl) phthalate, nickel, zinc, and tetrahydrofuran. The geometric mean levels of four samples collected on-site were 171 ug/l bis(2-ethyl hexyl) phthalate, 90 ug/l zinc, 59 ug/l nickel, and 19 ug/l tetrahydrofuran. The mean levels for the remaining contaminants identified were less than 15 ug/l. Although it was not felt that the site was actually a source of these contaminants (in light of the fact that contaminant levels measured upstream of the site were similar to those measured downstream of the site), these levels were used for the exposure assessment for potential exposure to surface water contaminants.

During Phase II activities, gas generation rates from the east waste pile were measured, along with the concentrations of contaminants in the gas. Hydrogen sulfide, mercaptans, benzene, and toluene were identified as the significant volatile emissions from the pile. Based on these results a worst case estimate of the maximum short term gas emission rate from the east waste pile was made. This, along with the maximum concentration of contaminants measured in any of the bore holes, was used to estimate the maximum short term emission rates of the four contaminants. Using these rates, air dispersion modeling conducted by M. Beers was used to estimate off-site air concentrations of these contaminants.

Groundwater monitoring identified seven contaminants in the groundwater aquifer that might eventually reach municipal wells G and H after a 10-35 year period of migration. These contaminants are benzene, toluene, total phenols, cyanide, arsenic, lead, and zinc. Groundwater transport models were used by Roux Associates to estimate the average concentrations of these contaminants that might eventually reach these municipal wells if no action to intercede was taken.

These estimated levels of contaminants in the off site ambient air, groundwater, surface water, and on site soil, along with standard risk assessment exposure assumptions, were used to estimate the potential for human exposure in each of the exposure scenarios.

III. ASSESSMENT SUMMARY

Based on the estimated limiting effect doses, the estimated potential for human exposure to contaminants originating from the Woburn site through either on-site incidental exposure, off-site routine residential exposure, or construction activity (during any site development) would not be expected to produce any observable adverse acute or chronic health effects or to produce an unacceptable risk of exposure to a carcinogen under the no-action alternative. The estimated doses for each contaminant in each exposure scenario all provide at least some margin of safety below the estimated limiting effect doses for acute and chronic health effects. Since this risk assessment used conservative worst case assumptions in estimating the potential for human exposure and incorporated safety factors into the estimated limiting effect doses, the actual margins of safety will likely be greater than those calculated.

1. On Site Incidental Exposure

Under the on site incidental exposure scenario, it was assumed that persons might hunt or play on the property no more than 1 or 2 times per month, therefore the risk of acute injury was of primary concern. Other than for hydrogen sulfide, the calculated margins of safety are greater than 10 for each contaminant, and none of these estimated exposures would be expected to cause an acute injury or illness. Although the hydrogen sulfide acute margin of safety is less than 10 (5.7), the total H₂S dose that might be accumulated over an 8 hour period has been treated as if it occurred over a fifteen minute period. Since the maximum recorded short term levels of H₂S measured during periods of active waste pile gassing never approached one-tenth of the known hazardous H₂S short term air concentration (approximately 300 ppm), the potential for acute injury from H₂S exposure on site is nil.

Although the likelihood of once monthly incidental chronic exposure on site is very slight, the analysis indicates that such exposure would not be expected to present an unacceptable chronic hazard. Other than for lead, the calculated chronic margins of safety are greater than 10 for each contaminant. Since the limiting effect chronic dose for lead was selected to minimize incremental chronic exposure in light of other acknowledged environmental sources of lead exposure, a calculated margin of safety of 3.6 should be ample.

The analysis does not indicate that remedial action would be required due to any expected acute or chronic health hazard.

2. Off Site Residential Exposure

Under the off site residential exposure scenario, it was anticipated that because of the low level and the routine nature of the potential for exposure, chronic exposure would be of primary concern. This was verified by the analysis, as all the calculated acute margins of safety were greater than 10, and all but two were greater than 100.

Although several of the calculated chronic margins of safety were less than 10, all of the estimated chronic exposure doses were less than the respective limiting effect doses. For non-carcinogenic substances this indicates that no observable adverse chronic effects would be expected from these estimated worst case potential exposures. For potential human carcinogens, such as benzene, this indicates that an unacceptable risk of developing cancer (greater than 10^{-5}) would not be expected from these estimated worst case potential exposures. Since conservative assumptions were used in modeling the estimated off site ambient air concentrations and the estimated groundwater concentrations that might eventually reach municipal wells G & H, the calculated margins of safety should be adequate in assuring that an unacceptable risk of chronic illness will not occur.

For example, although the calculated chronic margin of safety for H_2S is 1.8, H_2S presents no known chronic health hazard. The limiting effect dose was based on the conservative assumption of limiting exposure to an average of 1 ppm. Although this level of exposure would present an unacceptable odor, it would not be expected to pose a chronic health hazard. The estimated exposure dose was based on the assumptions of continuous maximum emission from the waste pile, modeled off site air concentrations equivalent to those at the nearest residence, and 24 hours a day exposure to a 10 kg child. Thus, although the calculated margin of safety is 1.8, no adverse chronic health effects from off site exposure to H_2S would be expected even under these unlikely conditions.

As with the on site incidental exposure scenario the analysis does not indicate that remedial action would be required.

The estimates of the off site ambient air concentrations of the volatile contaminants originating from the east waste pile were derived from standard air dispersion models using the east waste pile as an area source. The estimated worst case maximum short term emission rate from the pile was used in the model. Although this maximum rate might occur only infrequently and only for short duration when it would, it was assumed to occur continuously for estimating the worst case chronic exposure estimates.

3. On Site Construction Activity

As a special case, the potential for exposure to soil metal contaminants during any future site developmental construction activity was evaluated. As expected, the on site construction worker would receive higher estimated acute exposures to the soil metals than the off site residents. However, none of the soil metals would present an adverse acute health effect to these workers under these exposure conditions. For purposes of estimating these acute exposure potentials, it was assumed that activity would occur in one of the "hot spot" areas of higher average metals concentrations. Even under this assumption, the calculated margins of safety were 300 or greater.

The estimated potential for off site residential chronic exposure was based on the assumption of continuous long-term construction activity on site. Even under these extremely unlikely conditions, the estimated exposures would not present a chronic health hazard to the surrounding residents. The calculated margins of safety ranged from 26 to 270. Since these were calculated for the nearest resident and assuming continuous activity, the actual margins of safety will be much greater.

The calculated acute and chronic margins of safety for the three scenarios (no action alternative) are summarized in Tables II, III and IV.

IV. DISCUSSION

As noted in the Introduction, in estimating the limiting effect (i.e., safe) doses for exposure to the non-carcinogenic substances, the limiting effect chosen for prevention was the most sensitive effect (i.e., that which had the lowest No Observable Effect Level). In addition, this dose level was based on the most sensitive route of exposure tested, whether this route of exposure was appropriate to normal environmental exposure pathways or not. In extrapolating animal dose data to human estimates, appropriate safety factors were used. When human dose data were available they were used.

For certain of the heavy metals, such as lead and total chromium, the approach was even more conservative. The chronic limiting effect doses for these contaminants were based on the drinking water limits, which typically acknowledge other sources of environmental exposure. These limiting effect doses are therefore minimizing incremental exposure to these substances. Exposure doses greater than these limiting effect doses, in the absence of other environmental sources, would not be expected to cause chronic illness by themselves.

Only two of the thirteen substances evaluated, benzene and arsenic, are potential human carcinogens. For benzene, the limiting effect dose for chronic exposure was based on an acceptable level of risk of 10^{-5} for developing cancer. The National Drinking Water Advisory Council has recommended a 10^{-5} risk level as the basis for establishing recommended Maximum Contaminant Levels for carcinogens in drinking water. This is also a level of risk which the EPA has declared acceptable for Superfund sites, especially when smaller populations are at risk. Based on the Harvard School of Public Health Woburn Study Report, approximately 8 to 9 thousand Woburn residents, on average, might receive some of their drinking water from municipal wells G & H if they were re-opened.

The EPA's Carcinogen Assessment Group estimated the benzene dose that would produce a 10^{-5} risk level at 6.7 ug/liter using a linearized multi-stage extrapolation model which used data from human epidemiology studies on workers exposed to benzene vapor on the job. This model is presumed to give a conservative risk estimate. Furthermore, since the EPA has used the upper 95% confidence limit of the observed response in deriving their dose-response model, the best estimate of the 10^{-5} risk level dose based on the mean of the observed response should be approximately 30 ug/liter. This level has been used in deriving the limiting effect chronic dose for benzene, below which an unacceptable risk of developing cancer would not be expected.

The calculated margin of safety below the limiting effect dose for benzene has been based on the exposure dose that a child might receive. Since the excess cancer risk estimated by the EPA is based on exposure to an adult over a 70 year period, it can be seen that our calculated margin of safety would be significantly greater if it were based on exposure to an adult. Even if one were to use the 6.7 ug/liter dose estimate based on the upper 95% confidence limit of the observed response, it can be seen that the estimated concentration of benzene that might reach wells G & H (5.0 ug/l) is less than this concentration.

The current EPA Maximum Contaminant Level for arsenic is 50 ug/liter. Although arsenic has been implicated as a potential human carcinogen from exposure through both inhalation and ingestion, it has not produced cancer in animal tests through any route of exposure. The available human epidemiology studies investigating the relationship between exposure to elevated levels of arsenic in drinking water and the development of adverse chronic health effects, including skin cancer, were reviewed by the Safe Drinking Water Committee of the National Research Council (National Academy of Sciences) in 1983. The Committee concluded that the current drinking water limit provided a sufficient margin of safety. Based on the conclusion of this committee, the EPA MCL of 50 ug/liter has been used to derive the limiting effect chronic dose for arsenic.

When estimating the potential for exposure, the total dose for a contaminant was derived by summing all the individual doses by each route of exposure that were appropriate for the particular exposure scenario. This total combined dose was then compared to the limiting effect dose that was derived from the most sensitive route of exposure. This approach again will likely provide an additional margin of safety above those calculated in Attachment 2.

In determining these estimated potential exposure doses a number of worst case, often highly unlikely, assumptions have been made with regard to volatile site emissions, exposure to surface water, and exposure to soil contaminants:

1. For calculating the modeled exposure to H₂S and benzene in air (on and off site), worst case emission rates from the east waste pile have been assumed. Off site air concentrations were predicted for the nearest residence (about 700 meters from the emission source). Concentrations farther from the source would be lower. Further, it has been assumed that chronic exposure potential would be based on this emission rate on a continuous basis. Based on site experience, this peak emission rate occurs infrequently and for limited duration when it occurs.
2. For estimating the potential exposure to surface water contaminants, it has been assumed that a trespassing child would drink one liter of surface water. While unlikely in itself, it has been further assumed for purposes of estimating annual chronic exposure that the same child would drink one liter of surface water on 12 separate days per year.
3. The concentrations of metal contaminants in the site soil are not distributed evenly across the site. Certain areas of elevated metals concentrations have been identified. These higher concentrations have been used to estimate the potential for acute exposure to soil contaminants from soil ingestion and dermal absorption.

4. For estimating the potential exposure to soil contaminants by ingestion, it has been assumed that a trespassing child would eat 5 grams of soil. While unlikely in itself, it has been further assumed for purposes of estimating annual chronic exposure that the same child would eat 5 grams of soil on 12 separate days per year.
5. For each exposure scenario, it has been assumed that an individual will be exposed to the maximum assumed level of any particular contaminant by each potential route of exposure concurrently.

The ultimate effect of these assumptions is to estimate worst case potential exposures which rarely, if ever, will be approached, especially with regard to the potential for chronic exposure.

TABLE I

POTENTIAL PATHWAYS FOR CONTAMINANT EXPOSURE WITHIN EACH EXPOSURE SCENARIO

	<u>GROUNDWATER CONTAMINANTS</u>	<u>SURFACE WATER CONTAMINANTS</u>	<u>VOLATILE ORGANIC CONTAMINANTS</u>	<u>SOIL CONTAMINANTS</u>
	-Arsenic -Lead -Zinc -Benzene -Toluene -Cyanide -Total Phenols	-bis(2-ethyl hexyl)phthalate -Zinc -Nickel -Tetrahydrofuran	-Hydrogen Sulfide -Benzene -Toluene -Mercaptans	-Lead -Arsenic -Chromium
INCIDENTAL ON - SITE EXPOSURE	No Potential	Yes - drinking	Yes - breathing	Yes-ingestion - dermal absorption - breathing
OFF - SITE RESIDENTIAL EXPOSURE	Yes - drinking	No Potential	Yes - breathing	No Potential
ON/OFF SITE EXPOSURE DURING CONSTRUCTION ACTIVITY	No Potential	No Potential	No Potential	Yes (On-Site) -breathing -dermal absorption Yes (Off-Site) -breathing

TABLE II

ON SITE INCIDENTAL EXPOSURE SCENARIO "NO ACTION" ALTERNATIVE
CALCULATED ACUTE AND CHRONIC MARGINS OF SAFETY

<u>Substance</u>	<u>ACUTE</u> "No Action" Margins of Safety	<u>CHRONIC</u> "No Action" Margins of Safety
bis(2-ethylhexyl)phthalate	1.8×10^4	1.8×10^3
Tetrahydrofuran	5.3×10^4	1.6×10^5
Hydrogen Sulfide	5.7	39
Mercaptans	43	190
Benzene	6.6×10^3	380
Toluene	5.3×10^3	1.9×10^4
Zinc	560	3.3×10^3
Nickel	170	260
Lead	18	3.6
Arsenic	170	40
Chromium	16	14

TABLE III

OFF SITE RESIDENTIAL EXPOSURE SCENARIO "NO ACTION" ALTERNATIVE
CALCULATED ACUTE AND CHRONIC MARGINS OF SAFETY

<u>Substance</u>	<u>ACUTE</u> "No Action" Margins of Safety	<u>CHRONIC</u> "No Action" Margins of Safety
Hydrogen Sulfide	7	1.8
Mercaptans	880	120
Benzene	1.3×10^5	2.4
Toluene	2.0×10^4	2.4×10^3
Zinc	38	7.7
Lead	2.8×10^3	4.6
Arsenic	2.0×10^3	3.5
Cyanides	950	48
Phenol	410	34

TABLE IV

CONSTRUCTION ACTIVITY EXPOSURE SCENARIO "NO ACTION" ALTERNATIVE
CALCULATED ACUTE AND CHRONIC MARGINS OF SAFETY

<u>Substance</u>	<u>ACUTE</u> "No Action" Margins of Safety	<u>CHRONIC</u> "No Action" Margins of Safety
Lead	330	26
Arsenic	3.1×10^3	270
Chromium	300	110

Attachment 1

TOXICOLOGY OVERVIEW FOR BIS(2-ETHYLHEXYL)PHTHALATE, ARSENIC AND COMPOUNDS, LEAD, BENZENE, CHROMIUM, ETHYL MERCAPTAN, METHYL MERCAPTAN, CYANIDES, HYDROGEN SULFIDE, NICKEL, PHENOL, TETRAHYDROFURAN, TOLUENE, AND ZINC

A good deal is known about both the acute and chronic toxicity of these chemicals in both animal and man. As is the case with all animal carcinogens, our ability to interpret the likely risk of very, very low levels of exposure is poor. The following paragraphs discuss the toxicity of the substances noted in the emissions. These were generally taken from the book Documentation of Threshold Limit Values, 4th Edition, published in 1980 by the American Conference of Governmental Industrial Hygienists (ACGIH). This reference text was selected because the TLV committee summarizes all pertinent data on a substance before it establishes guidelines for human exposure in the workplace, i.e., the Threshold Limit Values. It has been augmented for selected chemicals by Patty's Industrial Hygiene and Toxicology, Volumes 2A-2C, published in 1981 and 1982, and Drinking Water and Health, Volumes 1-5, published from 1977 through 1983 by the National Research Council.

Bis(2-ETHYL HEXYL) PHTHALATE (DI-sec-OCTYL PHTHALATE)

According to the ACGIH Documentation of the TLV's:

Bis(2-ethyl hexyl) phthalate (DEHP) is used as a plasticizer for many resins and elastomers.

Krauskopf has reviewed the acute oral toxicity of DEHP and other phthalate esters and has shown DEHP to have an extremely low order of toxicity for small laboratory animals. The oral LD₅₀ determined by various investigators ranged from 26.3 g/kg for the mouse to 33.8 g/kg for the rat. The LD₅₀ value by intraperitoneal injection in the mouse of 14.2 g/kg and over 50 g/kg in the rat, places this agent in the practically nontoxic classification. No irritant response from dermal application or sensitizing potential has been noted in animal or human. The ester is very poorly absorbed through the skin with very large concentrations (approximately 25 mL/kg) being necessary to bring about death in the rabbit.

The chronic toxicity for laboratory animals has been reviewed by Gesler. Oral studies of 90 days to two years in the rat, one year in the guinea pig, and up to one year in the dog, have established a no-effect oral dose of about 60 mg/kg/day. Higher doses were associated with retardation of growth, and increased weights of livers and kidneys. No histologic abnormalities however, were associated with these higher oral intakes, nor were there increased incidences of tumors. A feeding study in four dogs confirmed the low order of chronic toxicity of DEHP.

In testing teratogenicity in pregnant rats in doses of 0.1, 0.2 and 0.33 of the acute LD₅₀ intraperitoneal dose, on the 5th, 10th and 15th day of gestation, DEHP was found to not affect fertility, but to have very slight effects on embryonic and fetal development with skeletal effects more common. Effects were judged slight because of the low solubility in tissue fluids.

Mutagenic effects consisted of significant reductions in live fetuses and implants, and were judged consistent with the finding of a significant level of dominant lethal mutations produced by DEHP. The effects were found in male mice at intravenous doses of 1/3, 1/2, and 2/3 of the acute LD₅₀, scarcely an attainable concentration under industrial working conditions.

In a preliminary study of exposure of 150 to 250 workers to vapors in air mixture of diethyl phthalate, dibutyl phthalate, and di, 2-ethyl hexyl phthalate, 19 personal air samples (collected in breathing zone of employees), four hours duration each, were taken over eight different days at a number of locations in the vicinity of the operations. The results of the air analysis ranged from 1-6 ppm (8-53 mg/m³). In a diagnostic multiphasic testing operation, no phthalates in blood were found before and after the phthalate exposure and no peripheral polyneuritis was observed in the population.

A TLV of 5 and a STEL of 10 mg/m³ are recommended for DEHP, a substance of low toxicity by all routes of exposure.

Key Toxicity Data: Bis (2-ethyl hexyl) phthalate (Di-Sec-Octyl Phthalate)

LD₅₀ (oral): 31,000 mg/kg (Rat)

LD₅₀ (dermal): 25,000 mg/kg (Rabbit)

LC₅₀ (inhalation): Not available

Limit for Water: SNARL (based on TLV) = 2.68 mg/l

Mutagenic Potential: Moderate

Threshold Limit Value: 5 mg/m³

Carcinogenic Hazard: Positive bioassay (NOEL = 60 mg/kg/day)

Reproductive Hazard: Teratogenic at high doses (NOEL=60 mg/kg/day)

Limiting Effect

Dose (acute): Lethality (50%) at 31,000 mg/kg (Rats). Acknowledging the low toxicity of DEHP in all species tested, it is likely that man will be no more than 10 times more sensitive than the rat to its toxic effects. Even though each chemical produces a dose-response curve with its own slope, one can usually estimate that the dose which will produce a 0-1% response is about 10 fold less than that which causes a 50% response (Casarett and Doull, 1982). Therefore,

the predicted safe (i.e., 0-1% response) dose for acute toxicity in man is 1/100th the LD₅₀ in rats.
Assumption: L.E. dose is 310 mg/kg (Human)

Limiting Effect

Dose (chronic): 300 mg/kg dose yielded 5% incidence rate of cancer in rat. NOEL was 60 mg/kg/day. Assuming that man is 10 times more sensitive to these effects, a 10-100 fold safety factor below the NOEL would seem appropriate to protect man.

Assumption: L.E. dose is 1.0 mg/kg/day (Human)

ARSENIC AND COMPOUNDS

According to the ACGIH Documentation of the TLV's:

Elemental or metallic arsenic is employed as an alloying agent for heavy metals, in special solders, and as a doping agent in silicon and germanium solid state products.

In addition to arsenic compounds discussed separately (As₂O₃, AsH₃ and lead arsenate, q.v.) many others find commercial application. The arsenites are important herbicides, calcium and other arsenates are insecticides, sulfides are pigments, rodenticides and used in pyrotechnics, gallium arsenide is in semiconductors; arsenic trichloride, a liquid with a boiling point of 130.5C, is employed in chemical synthesis; the gaseous tri- and pentafluorides apparently have no important commercial uses. Many organic arsenic compounds, however, have been employed in medicine, or as war gases.

Although the epidemiologic evidence is not complete, arsenic is considered by some to be a carcinogen, certainly of the skin, and perhaps of the bronchi. Cancers from exposure to arsenic have followed: 1) the internal use of Fowler's Solution, an aromatic solution of potassium arsenite, 2) inhalation and skin contact with sheep-dust, a mixture of sodium arsenite and sulfur, 3) the combined inhalation of As₂O₃, SO₂ and other particulates from the smelting ores containing arsenic. Experimental cancers in animals have not been produced from As₂O₃ despite several attempts and the conclusion of Vallee et al was that "it is improbable that arsenic (per se) plays a significant role in the generation of cancer". The belief that other occupational factors are necessary for the development of cancer, in addition to arsenic exposure, has been expressed by others.

In its criteria document for inorganic arsenic, NIOSH in 1973 recommended 0.05 mg As/m³ (as a TWA) as a workplace air standard. This was changed in 1975 to 0.002 mg/m³ as a 15 minute ceiling.

According to the 1977 compilation of occupational exposure limits of the International Labour Office, the following countries had adopted the previous TLV of 0.5 mg/m^3 : Australia, Finland, Japan, Holland, Switzerland and Yugoslavia. Czechoslovakia, East Germany, Hungary and Poland specified the USSR MAC of 0.3 mg/m^3 ; Romania 0.2 and Sweden 0.05 mg/m^3 . Only three of 18 countries (West Germany, Italy and Sweden) designated arsenic and compounds as carcinogens, although Belgium and the Netherlands so characterized arsenic trioxide.

It is possible that some arsenic compounds, the trichloride for example, might produce certain toxic effects at concentrations below 0.2 mg/m^3 of arsenic. Data to substantiate this speculation are lacking. The contrary situation, that some compounds, or the metal itself, are chronically less toxic than As_2O_3 , to form for which most information is available, seems more probable in the light of present knowledge. Therefore, a TLV of 0.2 mg As/m^3 for soluble compounds of arsenic is recommended.

The Safe Drinking Water Committee of the National Research Council has reviewed the available epidemiology studies on the effects of exposure to elevated levels of arsenic in drinking water, including the 1968 Tseng study which indicated an association between prolonged exposure to extremely high levels of arsenic in drinking water (400-800 ug/liter) and the development of skin cancer (Drinking Water and Health, Volume 5, (National Academy Press, 1983, pp. 118-123)). The Committee concluded that the current limit of 50 ug/liter of arsenic in drinking water provides a sufficient margin of safety.

Key Toxicity Data: Arsenic and Compounds

LD₅₀ (oral): Usually around 20-50 mg/kg (Rat)

Mutagenic Potential: Yes

Limit for Water: EPA MCL = 0.05 mg/l

Threshold Limit Value: 0.2 mg/m^3 (1984)

Permissible Exposure Limit: 0.010 mg/m^3 (1984)

Carcinogenic Hazard: Slightly positive in human epidemiology studies when workroom air exceeded 0.5 mg/m^3 and workers were exposed for upwards of 30 years. Some human epidemiological evidence (unconfirmed in recent studies) that high arsenic concentrations in drinking water (500-800 ppb) for extended exposure periods are associated with skin cancer. Animals do not seem to be susceptible to the carcinogenic hazard.

Reproductive Hazard: None Reported

Limiting Effect

Dose (acute): Death following exposures of about 50 mg/kg. A dose 1/50th of this should protect man because of the steep dose-response curve.

Assumption: L.E. dose is 1.0 mg/kg (TD_{LO})

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Limiting Effect

Dose (chronic): The National Research Council has concluded that the chronic dose of arsenic obtained from drinking water with an arsenic concentration of 50 ug/liter provides a sufficient margin of safety against the development of adverse health effects. Chronic occupational exposure to arsenic in air at the OSHA Permissible Exposure Limit of 10 ug/m³ (which was derived from the linear extrapolation model) would result in a dose equivalent to that from drinking 2 liters of water at 50 ug/liter of arsenic. A safe dose for arsenic by any route of exposure is therefore estimated at:
(50 ug/l)(2 l/day)(1/60 kg) = 1.67 ug/kg/day
Assumption: L.E. dose is 1.67 ug/kg/day.

LEAD

According to the ACGIH Documentation of the TLV's:

Despite the tremendous importance of lead as an occupational hazard, only a handful of papers in the voluminous literature on lead poisoning present meaningful data relating to the threshold limit value. The chief reason for this situation is probably the fact that most authorities rely primarily, if not exclusively, on other tests for estimation of the degree of lead hazard. Urinary and blood leads, urinary coproporphyrin and delta aminolevulinic acid, as well as blood examination for stippled cells and other abnormalities, are among the preferred procedures.

A limit of 0.5 mg/m³ for lead in air was proposed by Legge in 1912, with the comment that, if adhered to, cases of encephalopathy and paralysis would never, and cases of colic would very rarely, occur. The data of Duckering's experiments on the quantities of lead in the air from various industrial processes are given as evidence. This value (0.5 mg/m³) was quoted by Alice Hamilton in 1925, with a similar comment.

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In 1933, Russell et al, following a U.S. Public Health Service survey of a lead storage battery plant, proposed a limit of 0.15 mg/m³ for lead dust and fume in this industry. Eight years later Dreessen et al published results of a follow-up study and considered that their findings confirmed this value. In 1943 Kehoe and other members of the Committee on Lead Poisoning of the American Public Health Association recommended 0.15 mg/m³ as a time-weighted average limit.

A number of investigators found the 0.15 mg/m³ value difficult to achieve in many industries, and observation of workers, combined with lead urinalysis and similar studies convinced them that this limit was unnecessarily stringent. Winn and Shroyer concluded that maintenance of the average concentration of lead dust and fume at or

below 0.5 mg/m^3 , combined with a medical program, would assure adequate control. Weber considered the 0.15 mg/m^3 too low, but stipulated that 0.3 mg/m^3 should not be exceeded (as time-weighted average). He found that an atmospheric concentration of 0.43 mg/m^3 corresponded to 0.20 mg/L of urine, a level considered by some investigators to represent the upper limit of safety. Elkins assembled the data available on lead in air and lead in urine and concluded that a urinary lead concentration of 0.20 mg/L would, on the average, correspond to an air-lead value of 0.20 mg/m^3 .

On the basis of these reports and unpublished data from several sources, the TLV for lead was increased from 0.15 to 0.20 mg/m^3 in 1957. Some authorities continued to use the previous limit, however, Schrenk implied that the 0.15 mg/m^3 value was to be preferred. The preponderance of American opinion, however, seemed to be that the 0.2 mg/m^3 limit was adequate to prevent episodes of lead intoxication. Thus Kehoe, in a discussion of threshold limit for lead, stated that: "Evidence of validity of the standard (0.2 mg/m^3) has been provided elsewhere and need not be enlarged upon here". He went on to warn that this value is adequate only if ingestion of lead is prevented. Johnstone and Miller referred to the 0.2 mg/m^3 limit as generally accepted.

More recent comparisons of atmospheric and urinary lead concentrations have indicated conflicting results. Berg and Zenz, in a foundry study, found that air-lead concentrations between 0.14 and 0.18 mg/m^3 resulted in urinary lead values below 0.15 mg/L ; 0.28 mg/m^3 was associated with 0.17 mg/L of urine.

Tsuchiya and Harashima concluded that for a 48 to 60-hour work week, an average air-lead concentration of 0.10 mg/m^3 would bring about an average urinary lead level of 0.15 mg/L ; and 0.12 mg/m^3 to 0.20 mg/L . Concentrations of 0.12 to 0.14 mg/m^3 resulted in increased urinary coproporphyrin, some stippling of blood cells and anemia.

Most extensive lead exposure studies have involved lead oxide dust or the fume of metallic lead. Some reports have indicated that the dusts of certain insoluble lead compounds, such as the sulfide and chromate, were less hazardous than more soluble forms of lead. Thus Harrold and associates studied a group of painters exposed to mists of lead chromate in concentrations averaging between 1.2 and 12 mg of lead per cubic meter of air, and found little evidence of lead absorption or intoxication. They also suggested that lead titanate would present relatively little hazard, due to its very low solubility.

On the other hand, Hartogenesis and Zielhuis found blood changes in workers exposed to lead chromate dust at levels above 0.2 mg/m^3 (as lead) and doubtful changes between 0.1 and 0.2 mg/m^3 . They consider that the TLV for lead chromate should be the same as that for other inorganic lead compounds.

Curiously there is evidence that lead fume is less harmful than equal amounts of the dust of relatively soluble lead compounds. This is presumed to be due to a lesser retention of the extremely fine particles present in the fume.

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The International Subcommittee for Occupational Health of the Permanent Commission and International Association of Occupational Health, at a meeting in Amsterdam in November, 1968, recommended a limit of 0.15 mg/m³ for a 40-hour week. This conclusion represented the concensus of 20 experts from 12 nations.

In an extremely thorough study of atmospheric lead exposures and biochemical criteria, Williams et al found among 39 battery workers in England high correlation coefficients between air concentrations and blood lead (r=0.9); urinary lead (r=0.82); urinary coproporphyrins (r=0.82) and urinary dALA (r=0.68). Lower correlations were found for punctate (stippled) basophilic count (r=0.45) and percent hemoglobin (r=0.09). Furthermore, they observed that in every case the upper 95% confidence limit considerably exceeded the safe limits, when the air limit is 0.2 mg/m³, but approximates it when the air limit is 0.15 mg/m³.

In view of these data using improved biochemical indicators of lead exposure, clearly showing that the TLV of 0.2 mg/m³ had little or no margin of safety for some workers, the limit was reduced back to 0.15 mg/m³ in 1971.

In its first criteria document on inorganic lead, published in 1972, NIOSH recommended the 0.15 mg/m³ TLV as a workplace standard, but emphasized that reliance should be placed primarily on biological measurements, especially blood lead, for which the limit of 0.08 mg/100 grams was endorsed. A revised document appeared in 1978, however, in which a lower limit of 0.1 mg/m³, was proposed. The maximum permissible blood lead level was also reduced, to 0.06 from 0.08 mg/100 grams.

Emphasis in the document is placed on findings of adverse effects among workers with blood leads below 0.08 mg/100 grams, but generally above 0.06 mg.

Although the updated document contains 185 additional references (most published since 1971), only five relate directly to atmospheric lead concentrations, and these are all given as support for the amazing statement that "it has been shown that 1 ug lead/m³ in air contributes about 1-2 ug lead/100 grams of blood". Amazing, that is, until examination of the references indicates that four of them deal with continuous exposures of the public, or volunteers, to lead in air levels of the order of 0.01 mg/m³ or less. Only one related to occupational exposure; a mean lead in air concentration in one department of a rubber hose and tire company in Japan of 0.0579 mg/m³ (based on 34 tests) was associated with a mean blood lead level, in 20 workers, of 51.8 ug/100 grams.

In addition, testimony of the Deputy Director of NIOSH at an OSHA hearing refers to an unpublished battery plant study in which average exposures of workers, using personal monitors, were below 0.1 mg/m³ in all departments except pasting and grid casting, where exposures were generally below 0.15 mg/m³. Blood levels in over 90% of the workers were 60 ug/100 grams or less.

The findings of these two reports are hardly adequate to justify the proposed reduction in the limit for lead in workroom air.

The papers on effects associated with blood lead levels below 80 ug/100 grams are also few in number. Findings of changes in urinary ALA and coproporphyrin, erythrocyte protoporphyrin and zinc protoporphyrin in blood, hemoglobin decreased and altered spermatogenesis are reported in conjunction with likely "excessive absorption", as evidenced by blood leads between 40 and 60 ug/100 grams. The proposed standard apparently would not recognize these effects as inconsistent with a satisfactory state of health. Unacceptable lead absorption, with blood leads in excess of 60 ug/100 grams (mostly, but not entirely, below 80 ug) are associated with CNS effects, peripheral neuropathy, gastrointestinal disturbances and anemia, according to one reference. Another paper cited reported evidence of renal damage in six of thirteen workers, one with a blood lead of 98 ug/100 grams, one with 66 ug, and the remainder below 60 ug/100 grams of blood. An unpublished NIOSH report found renal damage and anemia in similarly exposed (blood leads above 60 ug/100 grams, but presumably not over 80 ug) workers, but no details are given.

Perhaps the strongest case for the reduced limit is presented in a paper on nerve conduction velocities, in which decreases (mostly minimal, but in one system significant) were found in workers with maximal blood leads between 50 and 70 ug/100 grams. The authors felt that these findings were more serious than the alterations in heme synthesis, demonstrated by biochemical measurements, since the regenerative capacity of the nervous system is relatively slow.

The Committee is not convinced that the biochemical changes found due to low level lead absorption are incompatible with good health. It has not adopted, or proposed a biologic TLV for lead, nor has it accepted the NIOSH hypothesis that an air TLV must be set at a level at which most workers (i.e., 90-95%) do not exceed a specified biologic TLV.

In view of the notation in the title of the consultant's review of the recent literature in the revised NIOSH document that it is to "support the update" of the criteria document, one wonders if the citations are chosen and their contents summarized without bias.

For the present, the TLV of 0.15 mg/m³ and the STEL of 0.45 mg lead/m³ in air are retained.

The Safety Drinking Water Committee of the National Research Council has reviewed the available health studies on the effects of exposure to elevated levels of lead in drinking water (Drinking Water and Health, Volume 4, (National Academy Press, 1982, pp. 179-183)). The Committee concluded that the present drinking water limit of 50 ug/liter may not, in view of other sources of environmental exposure, provide a sufficient margin of safety, particularly for fetuses and young

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growing children. They suggested that the limit be lowered, but could not suggest a lower standard based on available evidence. In an earlier review by the Committee (1977) they had concluded that a revised limit could not be set with any assurance at a level greater than 25 ug/liter.

Key Toxicity Data: Lead

LD₅₀ (oral): 10-50 mg/kg (For Humans) (For Lead Arsenate)

LC₅₀ (inhalation): Not Available

Mutagenic Potential: None

Limit for Water: EPA MCL = 0.05 mg/l

Threshold Limit Value: 0.15 mg/m³

Permissible Exposure Limit: 0.05 mg/m³

Carcinogenic Hazard: Slight

Reproductive Hazard: Pb per se has produced reproductive effects in man.

Limiting Effect

Dose (acute): Acute systemic toxicity (death) at 10 mg/kg (lead arsenate). Since these data are based on accidental human exposure, a safety factor of 10-20 is probably ample. A factor of 20 is used to assure protection.
Assumption: L.E. dose is estimated at 0.5 mg/kg.

Limiting Effect

Dose (chronic): The National Research Council has concluded that the chronic dose of lead obtained from drinking water with a lead concentration of 50 ug/liter (current EPA MCL) may not provide a sufficient margin of safety, in view of other sources of environmental exposure. They concluded that a specific lower limit could not be suggested based on available evidence. They earlier had indicated that a revised limit should probably not be greater than 25 ug/liter. In order to assure a sufficient margin of safety against adverse chronic health effects from incremental lead exposure, a limiting effect chronic dose obtained from drinking water at a lead concentration of 25 ug/liter should be adequate. Chronic occupational exposure to lead in air at the OSHA PEL of 50 ug/m³ (which was selected to prevent sensitive nervous system effects) would result in a dose 10 times greater than that from drinking 2 liters of water at 25 ug/liter of lead. A safe dose for lead by any route of exposure is therefore estimated at:
(25 ug/l)(2 l/day)(1/60 kg) = 0.83 ug/kg/day
Assumption: L.E. dose is 0.83 ug/kg/day.

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BENZENE

Benzene has been known to have the capacity to affect the blood forming organs since 1930. It has been shown to produce leukemia in man at levels far in excess of ambient air or water levels.

According to the ACGIH Documentation of the TLV's:

"As an acute poison benzene produces narcotic effects comparable to those of toluene; it is a more potent narcotic than the alkanes or naphthenes of similar boiling points. But the effect of chronic exposure to this compound is by far the most serious disease caused by any of the common hydrocarbon solvents. Its action on the bone marrow may result in detectable alterations, and, in some instances, aplastic anemia. The reported LD50 orally in young adult rats is 3.8 mL/kg.

It is unique among hydrocarbons as a myelotoxicant. More than 140 fatal cases of benzene poisoning had been recorded prior to 1959. Vigliani and Saita listed 26 deaths from chronic benzene poisoning in two provinces in Italy between 1960 and 1963. Eleven of these were diagnosed as leukemia, which may develop several years after cessation of exposure to benzene.

Two investigators have studied the effects on rats of exposures at relatively low levels of benzene vapor for extended periods. Deichmann, et al. found that after 5 to 8 weeks of 5 hour/day, 5 days/week exposure at 44 and 47 ppm, rats developed a moderate degree of leukopenia, but that none resulted from 15 to 31 ppm. Nau, et al. found a decrease in the white blood cell counts of rats following 756 hours of exposure at 50 ppm of benzene on a schedule of 8 hours/day, 5 days/week. Reduced amounts of DNA in the white cells, a depression in myelocytic activity, and an increase in the relative numbers of red cells precursors in the bone marrow were also observed.

Epidemiologic studies of workers exposed to measured low concentrations of benzene vapor have yielded negative or inconclusive results. Thorpe after studying the occurrence of leukemia in a population of 38,000 workers in a variety of European petroleum and petrochemical operations, some of whom were exposed at levels of benzene that occasionally reached 20 ppm, over a period of ten years, found that deaths from leukemia "were not abnormal" for the countries involved (18 vs. 23.23 expected)".

The TLV for benzene is 10 ppm. NIOSH has proposed a limit of 1 ppm. An ambient air limit of 0.05 to 0.1 ppm would seem reasonable. Through modeling of the results of a human epidemiologic study of workers exposed to benzene vapors on their jobs, the EPA has identified 0.66 ug/l as the Virtually Safe Dose (10^{-6}) for benzene based on the upper 95% confidence limit of the observed response. The maximum likelihood estimate (best estimate) of the dose which would product a 10^{-6} risk is about 3.0 ug/l. For a number of reasons, the EPA has considered a risk of 1 in 1,000 (10^{-3}) to 10,000 (10^{-4}) as one that is insignificant in situations where large numbers of persons are not routinely exposed. For benzene, the best estimate of the risk of 10^{-3} corresponds to a daily dose of 3000 ug/l or 100 ug/kg/day.

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Key Toxicity Data: Benzene

LD50 (oral): 4894 mg/kg (Rat)

LC50 (inhalation): 10,000 ppm/7 hours (Rat)

Mutagenic Potential: Positive

Threshold Limit Value: 10 ppm or 30 mg/m³

Permissible Exposure Limit: 10 ppm or 30 mg/m³

Carcinogenic Hazard: Positive in human epidemiology studies at 30 ppm (in air) following 20 years of exposure.

Reproductive Hazard: Teratogenic in some animal studies

Limit for Water: SNARL (based on TLV) = 16.1 mg/l

Limiting Effect

Dose (acute): Severe CNS depression at 100 ppm (humans) (8 hr).

Assumption: L.E. dose is 53 mg/kg (humans).

Limiting Effect

Dose (chronic): Low incidence of leukemia following chronic inhalation of 15-30 ppm (NOEL in man is apparently 10 ppm). A dose which produces a risk of 10⁻³ should be acceptable if only small populations are exposed. This has been estimated at 100 ug/kg/day. Assumption: L.E. dose is 100 ug/kg/day (for small populations at risk). The L.E. dose (10⁻⁵) for larger populations at risk is 1.0 ug/kg/day (based on the best estimate of the models).

CHROMIUM (Probably exists as Chromic Sulfate, trivalent Cr)

According to the ACGIH Documentation of the TLV's:

Chromium metal was first isolated in 1798. The chief uses of chromium and chromium compounds are in stainless and alloy steels, refractory products, tanning agents for leather, pigments, electroplating, catalyst and in corrosion resistant products. Chromium is obtained from chromite ores (FeO-Cr₂O₃). Relatively large deposits of chromite ore were found near Baltimore in the United States but no mining has taken place there since 1961.

Chromium can have a valence of 2, 3 or 6, and wide range of chromium alloys and inorganic chromium compounds are encountered in the workplace. These chromium compounds vary greatly in their toxic and carcinogenic effects. For this reason it is necessary to divide chromium and its inorganic compounds into a number of groupings -- each with its specific TLV based on available toxicological and epidemiological evidence. These groupings are:

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1. Chromium metals and alloys

This grouping includes chromium metal, stainless steels and other chromium-containing alloys.

2. Divalent chromium compounds (Cr^{2+}) (Chromous compounds)

This grouping includes chromous chloride (CrCl_2) and chromous sulfate (CrSO_4).

3. Trivalent chromium compounds (Cr^{3+}) (Chromic compounds)

This grouping includes chromic oxide (Cr_2O_3), chromic sulfate ($\text{Cr}_2(\text{SO}_4)_3$), chromic chloride (CrCl_3), chromic potassium sulfate ($\text{KCr}(\text{SO}_4)_2$) and chromite ore (FeOCr_2O_3).

4. Hexavalent chromium compounds (Cr^{6+})

These compounds have a wide variety of toxicities. These will not be reviewed since they are apparently not present at this site and would not have been used in tanning processes.

Because of the low toxicity of the metal and its divalent and trivalent compounds, a TLV of 0.5 mg/m^3 as Cr is recommended. This TLV should be adequate to prevent pulmonary disease or other toxic effect.

Key Toxicity Data: Chromium (as Chromic Sulfate)

LD₅₀ (I.V.): 30 mg/kg (Mouse)

Mutagenic Potential: Cr^{+6} was positive in some test batteries.

Threshold Limit Value: 0.5 mg/m^3 (Trivalent Cr)

Carcinogenic Hazard: Cr^{+6} is only positive via inhalation. The other chromium compounds lack carcinogenic potential.

Limit for Water: EPA MCL = 0.05 mg/l

Limiting Effect

Dose (acute): Systemic toxicity (death) at 30 mg/kg (Mouse). A 50 fold safety factor from the mouse LD₅₀ should be ample to protect man from the acute effects, especially since the LD₅₀ was based on I.V. dosing.
Assumption: L.E. dose is 0.6 mg/kg

Limiting Effect

Dose (chronic): The EPA's MCL for total chromium in drinking water (0.05 mg/l) is only 1/100th of the maximum no-observed-adverse-health effect concentration. (Drinking Water and Health, Volume 1 (National Academy Press, 1977, p. 307)). Chronic poisoning, therefore, should be prevented when doses are less than:
 $(0.05 \text{ mg/l})(2 \text{ l/day})(1/60 \text{ kg}) = 0.0017 \text{ mg/kg/day}$
Assumption: L.E. dose is 0.0017 mg/kg/day.

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ETHYL MERCAPTAN (Ethanethiol)

The primary hazard associated with exposure to ethyl mercaptan (ethanethiol) is moderate skin irritation and severe eye irritation. No chronic hazard is anticipated.

According to the ACGIH Documentation of the TLV's:

It is used as an intermediate and starting material in the manufacture of plastics, insecticides and antioxidants, and as an odorant for natural gas.

All of the acute toxicity data determined in animals, stems from a single study. This study found that single exposure of animals to ethyl mercaptan by various routes showed it to be only slightly toxic; the 4-hour inhalation LC₅₀ values for rats and mice were 2770 and 4420 ppm, respectively. These values are about the same as for butyl mercaptan and show about one-fifth the acute toxicity of hydrogen sulfide, as far as can be judged from available data.

Chronic inhalation studies in which rabbits, rats and mice were exposed for a period of five months at a concentration of 100 mg/m³ (approximately 40 ppm) showed minimal deviations in cardiovascular system regulation, organ weights, etc., and was considered to be the threshold effect concentration.

Human volunteers exposed at 10 mg/m³ (4 ppm) three hours daily during 5-10 days showed minimal effects such as a rise in olfactory threshold and altered taste reaction to bitter and sweet substances. All subjects complained of periodic nausea, irritation of mucous membranes of the lips, mouth and nose and a sensation of fatigue. Exposure at 1 mg/m³ (0.4 ppm) produced no unpleasant symptoms.

Accordingly, a TLV, based on the prevention of discomfort and minor irritation (disagreeable odor) of 0.5 ppm and a STEL of 2.0 ppm are recommended.

In view of the fact that this level exceeds the odor threshold by about 500, it is doubtful that this concentration can be maintained in a workplace without causing a community air pollution problem if appreciable quantities are involved.

Key Toxicity Data: Ethyl Mercaptan

LD₅₀ (oral): 1034 mg/kg (Rat)

LC₅₀ (inhalation): 4420 ppm/4 hr - Rat
2770 ppm/4 hr - Mice

Mutagenic Potential: None

Threshold Limit Value: 0.5 ppm (1 mg/m³)

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Limit for Water: SNARL (based on TLV) = 0.54 mg/l

Toxic Dose Low (chronic) = 100 mg/m³ (40 ppm)

Limiting Effect

Dose (acute): Minor irritation and discomfort via inhalation exposure are prevented at an exposure level of 0.5 ppm (1.25 mg/m³) in air. The absorbed dose due to 8 hours of exposure at 0.5 ppm is (1.25 mg/m³)(10 m³)(1/60 kg) = 0.21 mg/kg
Assumption: L.E. dose is 0.21 mg/kg.

Limiting Effect

Dose (chronic): There appears to be no insidious toxicity associated with chronic exposure to ethyl mercaptan. Based on all available data, chronic effects should certainly be avoided at doses 5-10 times lower than the limiting acute dose.

Assumption: L.E. dose is 0.03 mg/kg/day.

METHYL MERCAPTAN

According to the ACGIH Documentation of the TLV's:

It is used to give odor to natural gas and in the synthesis of methionine. It is also employed as an intermediate in the production of pesticides, fungicides, jet fuel and plastics. In addition, it may be encountered as a by product in the operations of paper and pulp mills.

Methyl mercaptan has been reported to exhibit an acute toxicity similar to, but less than, that of hydrogen sulfide. Others have reported the toxicity of methyl mercaptan and hydrogen sulfide to be of the same magnitude. All investigators agree, however, that methyl mercaptan acts, like hydrogen sulfide, on the respiratory center producing death by respiratory paralysis. At lower, less acute concentrations methyl mercaptan, like its homologues and hydrogen sulfide, produces pulmonary edema.

A death attributed to inhalation of methyl mercaptan was described by Schultz et al. A worker handling tanks used for holding methyl mercaptan was hospitalized because of coma. Acute hemolytic anemia and methemoglobinemia developed.

There is a close toxicologic similarity of methyl mercaptan to hydrogen sulfide, but because of the stronger and more unpleasant odor the limit of 0.5 pm is recommended for the TLV of methyl mercaptan.

Key Toxicity Data: Methyl Mercaptan

LD₅₀ (oral): 1034 mg/kg (Rat) based on ethyl mercaptan

Limit for Water: SNARL (based on TLV) = 0.54 mg/l

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Limiting Effect

Dose (acute): Since methyl mercaptan is thought to produce the same adverse effects as ethyl mercaptan, the bases for the limiting effect doses are identical.
Assumption: L.E. dose is 0.21 mg/kg.

Limiting Effect

Dose (chronic): There appears to be no insidious toxicity associated with chronic exposure to methyl mercaptan. Based on all available data, chronic effects should certainly be avoided at doses 5-10 times lower than the limiting acute dose.
Assumption: L.E. dose is 0.03 mg/kg/day.

CYANIDES (Sodium and Potassium)

Since the presence of cyanide was noted only in the water, it can be expected that it is not due to the gas hydrogen cyanide. Consequently, it is assumed that KCN and NaCN are present.

According to the ACGIH Documentation of the TLVs:

The acute LD₅₀ values of NaCN and KCN for laboratory animals range from 5 to 10 mg/kg, as compounds. Equivalent amounts of cyanide would be inhaled in 30 to 60 minutes from a concentration of slightly over 100 ppm of HCN in the air. Absorption of the alkali cyanides in amounts as low as 50 to 100 mg from a single instantaneous dose may be followed by immediate collapse and cessation of respiration. At lower dosages, the earliest symptoms may be weakness, headache, confusion, and occasionally nausea and vomiting.

Because of their extremely rapid action, the TLV must be based to a large extent on the acute effects of the alkali cyanides. Relatively few reports of chronic cyanide poisoning have been published.

The cyanides of the heavy metals, while generally toxic, usually act less rapidly than those of the alkali metals, since they tend to release HCN much more slowly.

In addition to the asphyxiant action of HCN, (q.v.) inhalation of mists of the alkali cyanides, in concentrations of slightly more than 5 mg/m³, calculated as CN, has been reported to cause nosebleed and nasal ulceration. This has been attributed to the alkalinity of such solutions, as well as their cyanide content per se.

In order to prevent irritation and injury to the respiratory passages, as well as the chronic effects of cyanide, and provide a margin of safety against acute effects, it is recommended that the 5 mg CN/m³ TLV for alkali cyanides and calcium cyanide be retained.

DRAFT

Key Toxicity Data: KCN and NaCN

LD₅₀ (oral): 5 mg/kg (Mouse and Rat)

LD₁₀₀ (oral): 1-2 mg/kg (Humans) (Patty's Industrial Hygiene and Toxicology, Volume 2C, 3rd Revised Ed., 1982)

Threshold Limit Value: 5 mg/m³ (as CN)

Limit for Water: SNARL (based on TLV) = 2.68 mg/l

Carcinogenic Hazard: None

Reproductive Hazard: None

Limiting Effect

Dose (acute): Death following exposure to 2 mg/kg has been predicted for humans. Acute human toxicity should be prevented at 1/50 the oral LD₁₀₀ for humans (0.04 mg/kg) due to the steepness of the dose-response curve. A factor of 100 will be used due to the severity of the adverse effects.

Assumption: L.E. dose is 0.02 mg/kg.

Limiting Effect

Dose (chronic): Low level exposure to cyanide is apparently beneficial, but since this amount is often found in the diet, levels markedly greater than this should be controlled. A chronic dose 10-20 times below the human TD_{LO} (0.02 mg/kg) should provide ample safety. Therefore, a limiting effect dose of (0.02 mg/kg/day)(1/20) = 0.001 mg/kg/day is presumed.

Assumption: L.E. dose is 0.001 mg/kg/day.

HYDROGEN SULFIDE

Hydrogen sulfide is primarily a respiratory irritant. It poses no known chronic hazard to humans.

According to the ACGIH Documentation of the TLVs:

Hydrogen sulfide has been widely employed as a reagent in analytical chemistry, and is used in the manufacture of heavy water. It is a source of elemental sulfur. The majority of occupational exposures to H₂S, however, have resulted from its occurrence in petroleum, natural gas, soil, sewer gas, and as a byproduct of chemical reactions, such as may take place in the viscose rayon and certain leather tanning processes.

In high concentrations (500-1000 ppm) hydrogen sulfide acts primarily as a systemic poison, causing unconsciousness and death through respiratory paralysis. A case of polyneuritis and encephalopathy from one day's exposure to a concentration insufficient to cause loss of consciousness has been reported. In lower concentrations (50-500 ppm) hydrogen sulfide acts primarily as a respiratory irritant. It is reported that pulmonary edema and bronchial pneumonia may follow prolonged exposure at concentrations

of the order of 250-600 ppm. At low concentrations the effects on the eye predominate, with conjunctivitis the most common effect while keratitis frequently occurs. Poda, however, in summarizing the effects of 174 exposures to H₂S in a heavy water plant, stated that eye irritation was relatively uncommon. More common findings were nervousness, cough, nausea, headache and insomnia. The reported LC₅₀, one hour inhalation exposure, for rats was 713 ppm and 673 ppm for mice.

The concentrations at which eye effects occur have been variously reported as 100 ppm, 30 ppm, 20 ppm, 15 ppm, above 10 ppm, 10 ppm or even 5 ppm and 4-15 ppm.

It is recommended that the 10 ppm TLV be retained as a time-weighted average; in addition, a short term exposure limit (STEL) of 15 ppm is proposed.

Key Toxicity Data: H₂S

LD₅₀ (oral): Estimated based on LC₅₀ = $550 \text{ mg/m}^3 \times \frac{1 \text{ m}^3}{10^6 \text{ cc}} \times$

$$\frac{1000 \text{ cc/min} \times 240 \text{ min}}{\text{kg}} = 132 \text{ mg/kg}$$

LC₅₀ (inhalation): 550 mg/m³ (444 ppm) (rat)

Mutagenic Potential: No

Threshold Limit Value: 10 ppm (14 mg/m³)

Limit for Water: SNARL (based on TLV) = 7.5 mg/l

Carcinogenic Hazard: None

Reproductive Hazard: Yes

Limiting Effect

Dose (acute): 300 ppm in air (causes unconsciousness or acute injury following 15 minutes of exposure).

Assumption: L.E. dose is 2.0 mg/kg.

Limiting Effect

Dose (chronic): No known chronic hazard. Exposures to 1 ppm of H₂S in air or 0.5 ppm in water should be acceptable.

Assumption: L.E. dose is 0.47 mg/kg/day.

NICKEL (Perhaps existing as Nickel Chloride)

The presence of Ni was noted only in the water. Since NiCl is soluble and the other forms of nickel are less toxic, the assumption that the Ni is NiCl will provide ample protection.

According to the ACGIH Documentation of the TLVs:

Nickel is used in making numerous high temperature and corrosion-resistant alloys in welding, in electroplating, in the production of catalysts and in storage batteries.

Water insoluble nickel compounds include the oxides, NiO and Ni₂O₃, carbonate and sulfide. Trinickel disulfide, Ni₃S₂ is encountered in the refining of certain nickel ores.

Soluble salts of nickel include the chloride, sulfate and nitrate.

Hueper conducted inhalation exposures with rats and guinea pigs exposed to concentrations of 15 mg/m³ of powdered nickel. He reported pulmonary neoplasms but this could not be interpreted as evidence of carcinogenicity in animals. Kim et al. exposed 4 groups of rats by inhalation to soluble and insoluble nickel dusts in concentration of 1 to 3 mg/m³ (as nickel) and found no real difference in respiratory cancer between exposed and control groups. Ottolenghi et al. reported an excess of lung cancer in rats exposed daily for 14 months to inhalation of nickel sulfide (Ni₃S₂) at a concentration of 1.0 mg/m³. One of the groups of Kim et al. was similarly exposed but no increased incidence of lung cancer was observed.

Wehner et al. exposed hamsters to 53 mg/m³ of nickel oxide (NiO); they found no significant carcinogenic effects but noted "massive pneumoconiosis". Animals exposed to 39 to 50 mg/m³ of nickel and nickel oxide showed pulmonary changes with pneumonia according to Soviet workers.

Rats exposed by inhalation to nickel chloride at concentrations of 0.1 mg/m³ for 12 hours a day for 2 weeks showed evidence of hyperplasia and mild irritation of alveolar cells. Clary exposed rats and guinea pigs daily to 1.0 mg/m³ (as nickel) of nickel chloride for 6 months. Exposed animals showed increased lung weight which was considered to be an indication of mild irritation of the lungs. On the basis of these reports, it was felt that the TLV for soluble nickel compounds should be reduced from that of the metal and insoluble compounds.

Nickel and its organic compounds are not absorbed through the unbroken skin in amounts sufficient to cause intoxication. Nickel and nickel salts; however, are well known for their capability of causing contact dermatitis in some sensitized individuals.

Eye contact does not present any special problem peculiar to nickel although eye irritation in workers exposed to aerosols from nickel electrolysis tanks has been reported. These aerosols contained acidic components as well as nickel. Soluble nickel salts should be considered as mild eye irritants.

Nickel metal is relatively non-toxic on oral ingestion. Insoluble inorganic nickel compounds have a low order of oral toxicity. Monkeys, dogs and cats fed up to 1000 ppm in their diet as nickel metal, nickel soaps and nickel carbonate on a chronic basis showed no deleterious effects. Schroeder et al. concluded that 5 ppm of nickel in drinking water was non-toxic, non-tumorigenic and non-carcinogenic in rats when ingested over a 2 year period. In general, nickel and its inorganic compounds are considered to be of a low order of oral toxicity on both an acute or chronic basis. Nickel salts are highly toxic on intravenous or subcutaneous administration.

With the available knowledge, it is not felt that all forms of nickel are carcinogenic. Therefore, a TLV of 1.0 mg/m³ is recommended for nickel metal and insoluble inorganic nickel compounds. A TLV of 0.1 mg/m³ and a STEL of 0.3 mg/m³ are recommended for soluble nickel compounds.

Key Toxicity Data: Nickel

LD₅₀ (oral): 105 mg/kg (Rat)

Mutagenic Potential: None

Limit for Water: SNARL (based on TLV) = 0.054 mg/l

Theshold Limit Value: 0.1 mg/m³

Carcinogenic Hazard: None via ingestion

Limiting Effect

Dose (acute): Maintain acute dose below 1/100th the LD₅₀ for rats.
Assumption: L.E. dose is 1.0 mg/kg (humans).

Limiting Effect

Dose (chronic): Chronic nickel poisoning should be avoided at doses 1/10th the chronic NOEL for rats exposed for 2 years: (5 ug/ml)(100 ml/kg/day)(1/10) = 0.05 mg/kg/day
Assumption: L.E. dose is 0.05 mg/kg/day.

PHENOL

According to the ACGIH Documentation of the TLVs:

Intermittent industrial exposure (five to ten minutes per hour) inside a conditioning room for phenol-impregnated asbestos resulted in marked irritation of the nose, throat and eyes. The average phenol concentration in the room was 48 ppm, although formaldehyde (8 ppm) also was found. Urine sulfate ratios were 79.4 and 86.7 percent. Workers at the same plant, continuously exposed during winding operations, experienced no respiratory irritation, although the odor of phenol was noticeable. The average concentration found was 4 ppm. Urine sulfate ratios averaged 74 percent.

Due in part to its low volatility, phenol does not frequently constitute a serious respiratory hazard in industry. Formerly its use as an antiseptic in surgery resulted in numerous cases of sub-acute or chronic poisoning among surgeons and their assistants. Urinary excretions of 2 grams per day, by patients, have been reported. Absorption of 2 grams of phenol could result from eight hours' inhalation at about 50 ppm.

According to Thomas and Back, the TLV of 5 ppm provides a sufficiently large factor of safety to prevent systemic poisoning if skin absorption is avoided.

The NIOSH recommendation of 20 mg/m³ as a time-weighted average standard is essentially the same as the TLV of 5 ppm, established in 1952. The NIOSH ceiling of 60 mg/m³ for any 15 minute period is higher than the STEL of 10 ppm (38 mg/m³).

Except for the USSR, which has set an MAC of 1.3 ppm, most of the published hygienic standards (East and West Germany, Sweden, Czechoslovakia) are either 19 or 20 mg/m³, or, for practical purposes, 5 ppm.

Key Toxicity Data: Phenol (Other phenols possess similar toxicity)

LD₅₀ (oral): 414 mg/kg (Rat)

LD₅₀ (dermal): 850 mg/kg (Rabbit)

LC₅₀ (inhalation): 316 mg/m³ (Rat)

Mutagenic Potential: Positive

Threshold Limit Value: 5 ppm (19 mg/m³)

Carcinogenic Hazard: None

Reproductive Hazard: None

Limit for Water: SNARL (based on TLV) = 10.2 mg/l

Limiting Effect

Dose (acute): Death at 400 mg/kg. Maintain acute dose to 1/100th the rat LD₅₀.

Assumption: L.E. dose is 4.0 mg/kg.

Limiting Effect

Dose (chronic): Chronic poisoning due to phenol should be prevented at doses 1/10th of the TLV or (20 mg/m³)(10 m³)(1/10)(1/60 kg) = 0.33 mg/kg/day

Assumption: L.E. dose is 0.33 mg/kg/day.

TETRAHYDROFURAN

Primarily, THF can be an irritant at concentrations above 500 ppm and systemic effects can involve the kidney and liver. Persons exposed to 25,000 ppm for 4 hrs/day showed no adverse effects. The TLV of 200 ppm protects against both the systemic toxicity and the irritation.

According to the ACGIH Documentation of the TLVs:

It is a solvent for natural and synthetic resins, particularly vinyls, in various applications; in lithium aluminum hydride reduction, and polymerization. It is also a chemical intermediate and monomer.

Experimentation has shown that 200 ppm tetrahydrofuran in daily, six-hour exposures produced an observable effect on the pulse pressure of dogs within three or four weeks, but no demonstrable histopathologic changes in the critical organs of the animals

despite an exposure of nine weeks followed by an additional three weeks exposure at nearly twice this level. In contrast to literature reports, tetrahydrofuran was found not to irritate the skin or be a skin sensitizer. Greater validity is believed for these results than those previously reported, because of the greater number of animals tested.

Oette exposed cats, rabbits, rats and mice to tetrahydrofuran at concentrations ranging from 3,400 to 60,000 ppm for periods up to six hours' duration. After ten three-hour to thirty six-hour exposures ranging from 3,400 to 17,000 ppm, there was no evidence of kidney damage and changes in the livers of cats and rabbits. The action of tetrahydrofuran was compared with that of ethyl ether.

The TLV of 200 ppm and the STEL of 250 ppm are recommended to protect against irritative effects and has a wide margin of safety for narcotic and systemic effects.

Key Toxicity Data: THF

LD₁₀ (oral): 3000 mg/kg (Rat)

LD₁₀ (inhalation): 24000 mg/m³/2 hr (Mouse)

TC₁₀ (humans): 25,000 ppm

Limit for Water: SNARL (based on TLV) = 316 mg/l

Mutagenic Potential: Positive

Threshold Limit Value: 200 ppm (590 mg/m³)

Carcinogenic Hazard: None (NTP prechronic test complete)

Reproductive Hazard: None

Limiting Effect

Dose (acute): The LD₅₀ (rats) for THF is about 3000 mg/kg. CNS effects could occur at 2000 mg/kg (rat). If the acute dose to man is 10-20 fold less than the TD₁₀ (2000 mg/kg) for the rat, no acute effects should occur at: (2000 mg/kg)(1/20) = 100 mg/kg.
Assumption: L.E. dose is 100 mg/kg.

Limiting Effect

Dose (chronic): Chronic poisoning should be prevented at doses 1/10th the TLV:
(590 mg/m³)(1/10)(10 m³)/60 kg = 9.8 mg/kg/day
Assumption: L.E. dose is 9.8 mg/kg/day

TOLUENE

Toluene is a systemic toxin whose target organ is the central nervous system. It does not appear to present a chronic hazard to man.

According to the ACGIH Documentation of the TLVs:

From the standpoint of chronic poisoning, toluene does not cause the severe injury to the bone marrow characteristic of benzene poisoning. Gerarde stated that the myelotoxicity of benzene was completely absent in toluene and other alkyl derivatives of benzene. Von Oettingen et al. found that exposure of rats at 2500 to 5000 ppm of toluene caused a temporary decrease in the white-cell count, but no evidence of injury to blood-forming organs or liver. Greenburg and co-workers studied a group of painters exposed to toluene in concentrations ranging from 100 to 1100 ppm. Their findings included enlargement of the liver, macrocytosis, moderate decrease in erythrocyte count and absolute lymphocytosis, but no leukopenia.

Wilson found that among workers exposed at less than 200 ppm of toluene there were some complaints of headache, lassitude and nausea, but physical findings were essentially negative. At concentrations between 200 and 500 ppm impairment of coordination, momentary loss of memory and anorexia were also present. Between 500 and 1500 ppm palpitation, extreme weakness, pronounced loss of coordination and impairment of reaction time were noted. The red cell count fell in many instances, and there were two cases of aplastic anemia, in which recovery followed intensive hospital treatment. A later comment by Wilson, however, suggests that he did not rule out the possibility that some of the above effects were due to a benzene impurity in the toluene used.

Von Oettingen and co-workers found that human subjects exposed at 200 ppm suffered slight but definite changes in muscular coordination. They concluded that such concentrations were unlikely to have any discernible untoward effects on health. Gerarde however, believed that von Oettingen's work did not justify the 200 ppm limit. Ogata et al. found that experimental human subjects exposed at 200 ppm for seven hours showed prolongation of reaction time, decrease in pulse rate and in systolic blood pressure. They consider 200 ppm too high as the MAC. Takeuch exposed rats at 200 ppm and higher concentrations of toluene for 32 weeks and then to benzene for 39 days. On the basis of differences found between the toluene-exposed animals and controls, e.g., changes in weight of adrenal glands, he suggested that the MAC of 200 ppm for toluene should be reconsidered.

Smyth et al. reported an oral LD₅₀, administered to rats, to be 7.53 mL/kg.

On the basis of the above data, a reduction in the TLV for toluene from 200 ppm to 100 ppm is recommended, with a STEL of 150 ppm.

Key Toxicity Data: Toluene

LD₅₀ (oral): 5000 mg/kg (Rat)

LD₅₀ (dermal): 12124 mg/kg (Rabbit)

LC_{L0} (inhalation): 4000 ppm/4 hr (Rat)

Mutagenic Potential: Slight

Threshold Limit Value: 100 ppm (375 mg/m³)

Limit for Water: SNARL (based on TLV) = 200 mg/l

Carcinogenic Hazard: None-NTP chronic inhalation study in progress.

Chronic Toxicity: No effects seen at doses of 590 mg/kg/day for 193 days (rats).

Reproductive Hazard: None reported.

Limiting Effect

Dose (acute): Death due to CNS effects is caused at 5000 mg/kg (rat). If daily doses are kept below 1/100th the rat LD₅₀, acute human effects should be prevented.

Assumption: L.E. dose is 50 mg/kg.

Limiting Effect

Dose (chronic): Chronic liver toxicity is prevented at doses of 600 mg/kg/day (rat). Assuming that man is 100 times more sensitive, a limiting effect dose of 6.0 mg/kg/day is predicted.

Assumption: L.E. dose is 6.0 mg/kg/day (humans).

ZINC

According to Patty's Industrial Hygiene and Toxicity; Vol. IIA, (1983), zinc has the following characteristics:

Aside from their irritant action, inorganic Zn compounds are relatively nontoxic by mouth. Acute oral toxicity in laboratory animals ranges from 250 mg/kg for lowest lethal dose (LD₅₀) for ZnF₂ for the guinea pig to 1190 mg/kg as rat oral LD₅₀ for Zn nitrate hexahydrate, and 2200 mg/kg for the rat oral LD₅₀ for ZnSO₄ 7H₂O, to 2460 mg/kg for Zn acetate dihydrate. By parenteral routes, however, inorganic Zn salts are highly toxic; the intravenous LD₅₀ and LD₁₀ for ZnSO₄ and its heptahydrate are, respectively, 40 and 49 mg/kg, and the LD₁₀ for ZnCl₂ by the same route for the rat is very similar, 30 mg/kg. Oddly, the rat intraperitoneal LD₁₀ for the cyanide is greater, 100 mg/kg.

The acute toxicity by the subcutaneous route appears to be intermediate between intravenous and oral routes; the rat subcutaneous LD₁₀ for ZnSO₄ 7H₂O is 330 mg/kg, and that for ZnF₂ for the guinea pig, 100 mg/kg. Strangely, no experimental acute toxicity data could be found on ZnO, the compound presenting the greatest industrial exposure.

The single piece of acute toxicity data for man relates to the inhalation of ZnCl₂ dust; a 30-min exposure at 4800 mg/m³ constituted the lowest toxic concentration, TC₁₀. When this is parenterally administered, Zn depresses the central nervous system, causing tremors and paralysis in the extremities.

The chronic toxicity of Zinc is very low. To emphasize the low oral toxicity of Zn compounds it is only necessary to refer to Drinker et al.; these investigators gave 175 to 1000 mg of ZnO/day for periods of 3 to 53 weeks to dogs and cats, and it was

tolerated; glycosuria occurred in the dogs, and fibrous degeneration of the pancreas in some of the cats was found at autopsy. No manifest injury occurred in rats from administration of 0.5 to 34.4 mg ZnO/day for periods of 1 month to 1 year. Similar lack of response from ZnCO₃ is reported. On the other hand, Waltner and Waltner reported that feeding the same salt induced anemia and osteoporosis in rats; 2 percent metallic Zn in the diet of rats; however, resulted in no injury. Zinc acetate fed to rats for 4 months in doses of 10 to 15 mg daily and 50 mg of Zn malate fed to cats for 10 days to 2 months caused no intoxication, according to Salant. Sutton and Nelson found that 0.1 percent Zn was tolerated in the diet of rats, but that more than 0.5 percent reduced their capacity to reproduce, and 1 percent inhibited growth and caused severe anemia and death. Zinc salts in the diet are somewhat more toxic to pigs.

Zinc is omnipresent in living organisms and ranks with the most abundant of the trace metals in man. As far as is known, all living things require Zn, and it is a constituent of all cells serving as a cofactor in many essential enzyme systems. For this reasons, Zn has been found in all specimens of all 29 tissues analyzed.

According to the ACGIH Documentation of the TLVs:

According to Fairhall, the toxicity of zinc compounds by mouth is low. Metal fume fever (zinc chills, brass founder's ague, etc.) may result from the inhalation of zinc oxide fume. The symptoms include fever, chills, muscular pain, nausea and vomiting, however complete recovery occurs in 24 to 48 hours. The same effects are produced by the fumes of some other metals, and according to Turner and Thompson can also result from breathing finely divided zinc oxide dust.

Pegues reported concentrations between 12 and 183 mg of ZnO/m³ in the welding of galvanized and zinc silicate coated steel. There were lesser exposures to iron and lead oxides. No mention is made of symptoms among the welders.

Vallee gave the normal human intake of zinc in food as 10 to 15 mg per day, and the average urinary excretion as 0.3 to 0.4 mg per 24 hours. Hamdi reported 24-hour excretions of 0.4 to 0.6 mg among workers who suffered mild gastric symptoms (but not chills) attributed to zinc. Concentrations of 0.6 to 0.7 mg/liter have been found in the urines of workers exposed to zinc oxide fume in concentrations between 3 and 5 mg/m³.

It is recommended that the TLV of 5 mg/m³ be retained. It is believed that if concentrations are kept below this level, the incidence of metal fume fever will be low and any attacks which may occur will be mild. The Committee suggests 10 mg/m³ as a STEL.

Key Toxicity Data: Zinc

LD₅₀ (I.V.): 30 mg/kg (Mouse)

Mutagenic Potential: Yes

Limit for Water: SNARL (based on $ZnCl_2$ TLV) = 0.536 mg/l

Threshold Limit Value: 1 mg/m³ ($ZnCl_2$ has lowest TLV)

Carcinogenic Hazard: None

Reproductive Hazard: None

Limiting Effect

Dose (acute): Acknowledging that nearly all zinc compounds have an LD_{50} (oral) above 100 mg/kg, acute exposures to 1/20th this level, especially in the diet, should provide a wide margin of safety for human exposure.
Assumption: L.E. dose is 5 mg/kg.

Limiting Effect

Dose (chronic): Zinc's chronic toxicity is extremely low. 1000 mg/kg/day has been tolerated for long periods by animals. Since Zinc is essential to man and the safety of animal exposure to 1000 mg/kg/day has been shown, doses of 1-10 mg/kg/day should be very acceptable for humans.
Assumption: L.E. dose is 1.0 mg/kg/day.

WOBURN ENDANGERMENT ASSESSMENT

ESTIMATED POTENTIAL FOR EXPOSURE TO SURFACE
WATER CONTAMINANTS THROUGH PERCUTANEOUS ABSORPTION

Overview:

Dermal exposure to surface water contaminants may be possible if an adult or child might swim or bathe in the surface waters on site.

Background:

The available literature on percutaneous absorption has been reviewed for the U.S. EPA Office of Drinking Water by A. Levin, H. Maibach, and R. Wester. Their April 1984 draft final report "Assessment of Dermal Absorption of Contaminants in Drinking Water" summarizes the existing experimental data on percutaneous permeation rates. Based on this review, the ranges of estimated absorbed doses for organic chemicals and heavy metals, assuming a water concentration of 10 ug/l, 17,000 cm² total body surface area, and a 20 minute exposure, are listed below.

<u>Substance</u>	<u>Absorbed Dose Range</u>
Organic chemicals	0.15-1.0 ug
Heavy metals	0.056 ug

In deriving these absorbed doses they have assumed that the permeation rates are proportional to the water concentration and that the absorbed dose is proportional to the time spent in the water and total body surface area.

Scenario

Assumptions:

1. Persons who swim or bathe in the site surface waters will be immersed in the water for no more than 1 hour per day.
2. A 60 kg adult has a total body surface area of 17,000 cm² and a 10 kg child has a total body surface area of 4,600 cm².
3. The entire body surface area of the adult or child will be covered by water while swimming or bathing.
4. As a conservative estimate, the upper end of the absorbed dose range for organic chemicals will be used to estimate absorption of the surface water organics.
5. The estimated percutaneous absorbed dose for heavy metals will be used to estimate absorption of the surface water metals.

- 6. Total absorbed dose by percutaneous absorption is proportional to body surface area and contact time with the contaminant.
- 7. Percutaneous permeation rates are proportional to contaminant water concentrations.

Given:

Based on the results of the Phase I surface water sampling, surface water on the site can contain on the average 171 ug/l of bis(2-ethylhexyl)phthalate, 90 ug/l zinc, 59 ug/l nickel, 19 ug/l of tetrahydrofuran, and less than 15 ug/l of other less toxic chemicals.

Example Dose Calculations:

bis(2-ethylhexyl)phthalate - for child

$$(1.0 \text{ ug}) \left(\frac{60 \text{ min}}{20 \text{ min}} \right) \left(\frac{4,600 \text{ cm}^2}{17,000 \text{ cm}^2} \right) \left(\frac{171 \text{ ug/l}}{10 \text{ ug/l}} \right)$$

$$= 13.9 \text{ ug}$$

$$(13.9 \text{ ug}) / (10 \text{ kg}) = 1.39 \text{ ug/kg} = 0.0014 \text{ mg/kg}$$

Estimated Acute Exposure Doses:

<u>Substance</u>	<u>Adult (mg/kg)</u>	<u>Child (mg/kg)</u>
bis(2-ethylhexy)phthalate	0.00086	0.0014
Zinc	0.000025	0.000041
Nickel	0.000016	0.000027
Tetrahydrofuran	0.000095	0.00015

Comparison with Safe Dose Levels:

Even when the acute exposure dose estimates are compared with the estimated safe chronic dose levels, margins of safety are ample. The calculated margins of safety for children follow:

bis(2-ethylhexyl)phthalate:	$\frac{1.0 \text{ mg/kg (Chronic L.E.)}}{0.0014 \text{ mg/kg (dose)}} = 714$
Zinc:	$\frac{1.0 \text{ mg/kg (Chronic L.E.)}}{0.000041 \text{ mg/kg (dose)}} = 24,390$
Nickel:	$\frac{0.05 \text{ mg/kg (Chronic L.E.)}}{0.000027 \text{ mg/kg (dose)}} = 1,850$
Tetrahydrofuran:	$\frac{9.8 \text{ mg/kg (Chronic L.E.)}}{0.00015 \text{ mg/kg (dose)}} = 65,300$

Because of the low concentrations of contaminants in the surface water and the limited availability through percutaneous absorption, the margins of safety when compared with even the chronic safe dose levels are at least 700. Thus, dermal exposure to measured surface water contaminants will present no acute or chronic health hazard to persons on site.

MARGINS OF SAFETY
CHRONIC EXPOSURE

<u>Substance</u>	<u>Case 1</u>	<u>Case 2</u>	<u>Case 3</u>
	Incidental On-Site Exposure-No Remedial Action	Off-Site Exposure-No Remedial Action	Construction Activity Exposure- No Remedial Action
bis(2-ethylhexyl)phthalate	1.8 X 10 ³	NSP	NSP
Tetrahydrofuran	1.6 x 10 ⁵	NSP	NSP
Hydrogen Sulfide	39	1.8	NSP
Mercaptans	190	120	NSP
Benzene	380	2.4	NSP
Toluene	1.9 x 10 ⁴	2.4 x 10 ³	NSP
Zinc	3.3 x 10 ³	7.7	NSP
Nickel	260	NSP	NSP
Lead	3.6	4.6	26
Arsenic	40	3.5	270
Chromium	14	NSP	110
Cyanides	NSP	48	NSP
Phenol	NSP	34	NSP

NSP = No Significant Potential for exposure to this substance within the particular exposure scenario.

MARGINS OF SAFETY
ACUTE EXPOSURE

<u>Substance</u>	<u>Case 1</u>	<u>Case 2</u>	<u>Case 3</u>
	Incidental On-Site Exposure-No Remedial Action	Off-Site Exposure-No Remedial Action	Construction Activity Exposure- No Remedial Action
bis(2-ethylhexyl)phthalate	1.8 x 10 ⁴	NSP	NSP
Tetrahydrofuran	5.3 x 10 ⁴	NSP	NSP
Hydrogen Sulfide	5.7	7	NSP
Mercaptans	43	880	NSP
Benzene	6.6 x 10 ³	1.3 x 10 ⁵	NSP
Toluene	5.3 x 10 ³	2.0 x 10 ⁴	NSP
Zinc	560	38	NSP
Nickel	170	NSP	NSP
Lead	18	2.8 x 10 ³	330
Arsenic	170	2.0 x 10 ³	3.1 x 10 ³
Chromium	16	NSP	300
Cyanides	NSP	950	NSP
Phenol	NSP	410	NSP

NSP = No Significant Potential for exposure to this substance within the particular exposure scenario.

Attachment 2

ESTIMATES OF EXPOSURE POTENTIAL AND RISK OF ACUTE AND CHRONIC INJURY

Case 1: Incidental Human Exposure (No Remedial Action)

Exposure Scenario: What is the approximate degree of human exposure to various toxicants during trespassing or hunting situations?

Assumptions:

- a. Persons who incidentally use the land will drink no more than 1 liter of surface water on a given day.
- b. Persons who only occasionally walk through the property will be exposed for only 1 or 2 days per month and therefore the risk of acute injury is of primary concern. For purposes of assessing the potential for chronic injury, 12 days of exposure on the site per year are assumed.
- c. A child who might walk through or play on the property might:
(1) eat 5 grams of dirt, (2) breath 5 m³ of air in 8 hours,
(3) physically handle 10 pounds of dirt.
- d. The average adult weighs about 60 kg and the average child weighs about 10 kg.
- e. The likely daily time weighted average concentration of dust in the air on the site should be no greater than 100 ug/m³ (approximately the national average ambient level).
- f. The ability of most toxicants to be removed from soil by skin contact is probably no greater than 10%.
- g. Of all the soil handled by a child or adult, only about 1% of the total amount will actually stick to the skin (e.g., about 45 grams). Of the soil particles that stick to the skin, only about 10% of the available dose of the organic constituents and about 1% of the inorganic (metal) constituents will penetrate during the ensuing 24 hours.
- h. Kehoe's studies indicate lead absorption via food ingestion to be 5-10%. Even though binding to soil should be greater, it is assumed that when soil is eaten, about 8% of the metals in the soil will be absorbed in the alimentary track.
- i. The potential for acute exposure to heavy metal soil contaminants due to ingestion of soil or dermal absorption has been based on the metals concentrations in certain isolated site areas such as the phytotoxic arsenic waste, chromium lagoon, and west hide pile areas, which had higher chromium, lead, and arsenic soil concentrations than for the overall site average. The potential for chronic exposure to these metals (assumed 12 days per year exposure) has been based on the overall site average soil concentrations.

Potential Routes of Exposure and Estimated Dose

a. Drinking Groundwater

Overview: This group will not be exposed to this water.

b. Drinking Surface Water

Overview: Exposure is possible if a child, pet, or adult hunter would drink the surface water.

Given: Based on the results of the Phase I surface water sampling, surface water on the site can contain on the average 171 ug/l of bis (2-ethylhexyl) phthalate, 90 ug/l of zinc, 59 ug/l of nickel, 19 ug/l of tetrahydrofuran, and less than 15 ug/l of other less toxic chemicals. Children or adults could ingest 1 liter per day of surface water.

Example Dose Calculations: bis (2-ethylhexyl) phthalate

$$(1 \text{ l/day})(1/60 \text{ kg})(171 \text{ ug/l})(1 \text{ mg}/1000 \text{ ug}) = 0.0028 \text{ mg/kg/day}$$

Results (Dose):

	<u>Adult (mg/kg/day)</u>	<u>Child (mg/kg/day)</u>
bis(2-ethylhexyl)phthalate	0.0028	0.017
Zinc	0.0015	0.0090
Nickel	0.00098	0.0059
Tetrahydrofuran	0.00032	0.0019

c. Dust in Ambient Air

Overview: Exposure due to breathing dust in air assuming a time-weighted average concentration of 100 ug/m³.

Given: Based on the results of the Phase II investigative activities, airborne dust and soil is on the average likely to be composed of 161 ug/g lead, 31 ug/g arsenic, and 82 ug/g chromium.

Example Dose Calculation: Lead

$$(10 \text{ m}^3/\text{day})(1/60 \text{ kg})(100 \text{ ug}/\text{m}^3)(1 \text{ g}/10^6 \text{ ug})(161 \text{ ug}/\text{g})(1 \text{ mg}/1000 \text{ ug}) = 0.000027 \text{ mg/kg/day}$$

Results (Dose):

	<u>Adult (mg/kg/day)</u>	<u>Child (mg/kg/day)</u>
Lead	0.0000027	0.0000080
Arsenic	0.00000050	0.0000015
Chromium	0.0000014	0.0000041

d. Breathing Volatile Organics in the Air

Overview: Exposure is possible from breathing airborne volatile organics on site.

Given: Measured breathing zone air concentrations of H₂S in the vicinity of the waste piles typically were at nondetectable levels (lower limit of detection of 0.5 ppm). Although it is unlikely that H₂S air concentrations in the vicinity of the waste piles averaged as high as 0.5 ppm, to evaluate an extreme case an average H₂S concentration of 0.5 ppm (0.7 mg/m³) has been selected. Based on the relative concentration ratios derived from bore hole air measurements, the ambient air directly around the waste piles should contain no more than an average of 5 ppb of total mercaptans and 5 ppb of total aromatic compounds (benzene, toluene).

Example Dose Calculation: Hydrogen Sulfide

$$(10 \text{ m}^3/\text{day})(1/60 \text{ kg})(0.7 \text{ mg}/\text{m}^3) = 0.117 \text{ mg}/\text{kg}/\text{day}$$

Results (Dose):

	<u>Adult (mg/kg/day)</u>	<u>Child (mg/kg/day)</u>
Hydrogen Sulfide	0.117	0.350
Mercaptans	0.0016	0.0049
Benzene	0.0027	0.0080
Toluene	0.0032	0.0095

e. Ingestion of Soil

Overview: A child playing on the site might eat as much as 5 gm/day of the soil.

Given: Based on the results of the Phase II investigative activities, soil on the average is likely to be composed of 161 ug/g lead, 31 ug/g arsenic, and 82 ug/g chromium. Soil metals concentrations may average as high as 620 ug/g lead, 130 ug/g arsenic, and 850 ug/g chromium in a few smaller areas such as the phytotoxic arsenic waste, chromium lagoon, and west hide pile areas. Typical potential for exposure from ingestion of soil is based on the average site concentrations. Maximum potential for exposure is based on the higher average concentrations found in the smaller areas.

Example Dose Calculation: Lead

$$(5 \text{ g}/\text{day})(1/10 \text{ kg})(620 \text{ ug}/\text{g})(1 \text{ mg}/1000 \text{ ug})(8\%) = 0.025 \text{ mg}/\text{kg}/\text{day}$$

Results (Dose):

	<u>Adult (mg/kg/day)</u>	<u>Child (mg/kg/day)</u>
<u>Typical Exposure Potential</u>		
Lead	0.0011	0.0064
Arsenic	0.00021	0.0012
Chromium	0.00055	0.0033
<u>Maximum Exposure Potential</u>		
Lead	0.0041	0.025
Arsenic	0.00087	0.0052
Chromium	0.0057	0.034

f. Dermal Absorption of Toxicants From Soil

Overview: A child playing on the site might handle the soil and absorb through the skin some of the chemicals in the soil matrix.

Given: Soil on the average is likely to be composed of 161 ug/g lead, 31 ug/g arsenic, and 82 ug/g chromium. Soil metals concentrations may average as high as 620 ug/g lead, 130 ug/g arsenic, and 850 ug/g chromium in a few smaller areas such as the phytotoxic arsenic waste, chromium lagoon and west hide pile areas. Typical potential for exposure from dermal absorption of soil toxicants is based on the average site concentration. Maximum potential for exposure is based on the higher average concentrations found in the smaller areas. It is assumed that 1% of the soil handled will stick to skin, 10% of the chemicals in that portion will be desorbed, and 1% of that portion will penetrate the skin.

Example Dose Calculation: Lead

$$(10 \text{ lbs/day})(454 \text{ gm/lb})(1/10 \text{ kg})(620 \text{ ug/g})(1\%)(10\%)(1\%)(1 \text{ mg}/1000 \text{ ug}) = 0.0028 \text{ mg/kg/day}$$

Results (Dose):

	<u>Adult (mg/kg/day)</u>	<u>Child (mg/kg/day)</u>
<u>Typical Exposure Potential</u>		
Lead	0.00012	0.00073
Arsenic	0.000024	0.00014
Chromium	0.000062	0.00037
<u>Maximum Exposure Potential</u>		
Lead	0.00047	0.0028
Arsenic	0.000098	0.00059
Chromium	0.00064	0.0039

g. Total Daily Uptake of Each Contaminant

	<u>Adult (mg/kg/day)</u>	<u>Child (mg/kg/day)</u>
bis(2-ethylhexyl)phthalate	0.0028	0.017
Tetrahydrofuran	0.00032	0.0019
Hydrogen Sulfide	0.117	0.350
Mercaptans	0.0016	0.0049
Benzene	0.0027	0.0080
Toluene	0.0032	0.0095
Zinc	0.0015	0.0090
Nickel	0.00098	0.0059
Lead - Typical	0.0012	0.0071
- Maximum	0.0046	0.028
Arsenic - Typical	0.00023	0.0013
- Maximum	0.00097	0.0058
Chromium - Typical	0.00061	0.0037
- Maximum	0.0063	0.038

h. Annualized Daily Contaminant Uptake (Chronic)

Assuming 12 days per year exposure on the site, the annualized daily chronic doses (12/365 times acute doses) are listed below.

	<u>Adult (mg/kg/day)</u>	<u>Child (mg/kg/day)</u>
bis(2-ethylhexyl)phthalate	0.000092	0.00056
Tetrahydrofuran	0.000010	0.000062
Hydrogen Sulfide	0.0038	0.012
Mercaptans	0.000053	0.00016
Benzene	0.000089	0.00026
Toluene	0.00011	0.00031
Zinc	0.000049	0.00030
Nickel	0.000032	0.00019
Lead	0.000040	0.00023
Arsenic	0.0000076	0.000043
Chromium	0.000020	0.00012

Risk Analysis-Case 1

Acute

Even when reasonably worst case exposure assumptions are used, the maximum anticipated daily dose of any of the chemicals for persons who might walk around or play on the site would not exceed 0.35 mg/kg/day. Based on the acute toxicity of these materials and the low exposures, none should present a hazard to these persons. The following calculations show the margins of safety between the exposures and the doses which should not cause an acute toxic response. A margin of safety of five means that even if exposures were five times as high as the estimated worst case, no risk of injury should be present.

MARGINS OF SAFETY (BASED ON LIMITING EFFECTS FOR ACUTE TOXICITY)-CHILD

bis(2-ethylhexyl)phthalate: $\frac{310 \text{ mg/kg (Acute L.E.)}}{0.017 \text{ mg/kg (dose)}} = 1.8 \times 10^4$

Tetrahydrofuran: $\frac{100 \text{ mg/kg (Acute L.E.)}}{0.0019 \text{ mg/kg (dose)}} = 5.3 \times 10^4$

Hydrogen Sulfide: $\frac{2.0 \text{ mg/kg (Acute L.E.)}}{0.350 \text{ mg/kg (dose)}} = 5.7$

Mercaptans: $\frac{0.21 \text{ mg/kg (Acute L.E.)}}{0.0049 \text{ mg/kg (dose)}} = 43$

Benzene: $\frac{53 \text{ mg/kg (Acute L.E.)}}{0.0080 \text{ mg/kg (dose)}} = 6.6 \times 10^3$

Toluene: $\frac{50 \text{ mg/kg (Acute L.E.)}}{0.0095 \text{ mg/kg (dose)}} = 5.3 \times 10^3$

Zinc: $\frac{5 \text{ mg/kg (Acute L.E.)}}{0.0090 \text{ mg/kg (dose)}} = 560$

Nickel: $\frac{1.0 \text{ mg/kg (Acute L.E.)}}{0.0059 \text{ mg/kg (dose)}} = 170$

Lead: $\frac{0.5 \text{ mg/kg (Acute L.E.)}}{0.028 \text{ mg/kg (dose)}} = 18$

Arsenic: $\frac{1.0 \text{ mg/kg (Acute L.E.)}}{0.0058 \text{ mg/kg (dose)}} = 170$

Chromium: $\frac{0.6 \text{ mg/kg (Acute L.E.)}}{0.038 \text{ mg/kg (dose)}} = 16$

Chronic

The chronic hazard presented to any one person who might be trespassing, hunting, or playing on the site as many as 12 days per year is quite low. The following calculations show the margins of safety between the annualized dose to these persons and the doses which are not expected to cause a chronic toxic response.

MARGINS OF SAFETY (BASED ON LIMITING EFFECT FOR CHRONIC HAZARD)-CHILD

bis(2-ethylhexyl)phthalate: $\frac{1.0 \text{ mg/kg (Chronic L.E.)}}{0.00056 \text{ mg/kg (dose)}} = 1.8 \times 10^3$

Tetrahydrofuran: $\frac{9.8 \text{ mg/kg (Chronic L.E.)}}{0.000062 \text{ mg/kg (dose)}} = 1.6 \times 10^5$

Hydrogen Sulfide $\frac{0.47 \text{ mg/kg (Chronic L.E.)}}{0.012 \text{ mg/kg (dose)}} = 39$

$$\text{Mercaptans: } \frac{0.03 \text{ mg/kg (Chronic L.E.)}}{0.00016 \text{ mg/kg (dose)}} = 190$$

$$\text{Benzene: } \frac{0.100 \text{ mg/kg (Chronic L.E.)}}{0.00026 \text{ mg/kg (dose)}} = 380$$

$$\text{Toluene: } \frac{6.0 \text{ mg/kg (Chronic L.E.)}}{0.00031 \text{ mg/kg (dose)}} = 1.9 \times 10^4$$

$$\text{Zinc: } \frac{1.0 \text{ mg/kg (Chronic L.E.)}}{0.00030 \text{ mg/kg (dose)}} = 3.3 \times 10^3$$

$$\text{Nickel: } \frac{0.05 \text{ mg/kg (Chronic L.E.)}}{0.00019 \text{ mg/kg (dose)}} = 260$$

$$\text{Lead: } \frac{0.00083 \text{ mg/kg (Chronic L.E.)}}{0.00023 \text{ mg/kg (dose)}} = 3.6$$

$$\text{Arsenic: } \frac{0.0017 \text{ mg/kg (Chronic L.E.)}}{0.000043 \text{ mg/kg (dose)}} = 40$$

$$\text{Chromium: } \frac{0.0017 \text{ mg/kg (Chronic L.E.)}}{0.00012 \text{ mg/kg (dose)}} = 14$$

Discussion:

Because it is unlikely that any individual will be exposed on average for more than one day per month to the contaminants on site, the risk of acute injury is of primary concern. All anticipated exposures will produce acute doses which are less than the respective doses for which an acute toxic response would not be expected. Generally, very conservative worst-case assumptions were used in assessing the magnitude of an acute exposure. For the substance with the lowest acute margin of safety, H₂S, we have assumed that persons would be exposed for 8 hours to levels which are rarely attained and which would present an objectionable odor. It is unlikely that persons would remain on the site under these conditions.

Assuming 12 days per year of exposure on the site for any one individual, lead is the only substance for which the estimated dose is not more than 10 fold below the estimated limiting effect dose for man. We feel that even though this margin of safety from our predicted safe level is smaller than for the other substances on site, it is clear that these persons are at no risk of injury due to the safety factors incorporated in our predicted safe levels. In conclusion, even using worst case exposure assumptions, likely chronic exposure to these substances on the site should not present an unacceptable risk to these persons. It is noteworthy that this assessment suggests that no remedial action appears to be necessary to protect the public if only a few persons use the site on a non-routine basis.

Case 2: Off Site Human Exposure (No Remedial Action)

Exposure Scenario: What is the approximate degree of human exposure to various toxicants in the drinking water and ambient air which originate from the site (off site exposure due to developmental construction activity is addressed in a separate case)?

Assumptions:

- a. Adults who might draw their home drinking water from this aquifer would take in 2 liters of water per day and children about 1 liter per day.
- b. The average adult weighs about 60 kg and the average child weighs about 10 kg.
- c. Adults will breath as much as 20 m³ of air and children 10 m³ of air during a typical 24 hour day.
- d. Conservatively, no more than 70% of the level of contaminants in groundwater will be present in the tap water.

Potential Routes of Exposure and Estimated Dose

a. Drinking Groundwater

Overview: Exposure is possible if municipal wells G and H are reopened and contaminants measured in the groundwater aquifer, which may have originated from the site, eventually reach these wells.

Given: Estimates of the average (over an 80 year period) concentrations of measured groundwater contaminants that might reach well G after a 10-35 year period of migration are listed below (taken from Roux Associates report on groundwater contaminant transport).

<u>Contaminant</u>	<u>Concentration (ug/l)</u>
Arsenic	7.0
Lead	2.5
Zinc	1800
Benzene	5.0
Toluene	35
Cyanide	0.3
Total Phenols	140

Example Dose Calculation: Benzene

$$(1 \text{ l/day})(1/10 \text{ kg})(5.0 \text{ ug/l})(70\%)(1 \text{ mg}/1000 \text{ ug}) = 0.00035 \text{ mg/kg/day}$$

Results (Dose):

	<u>Adult (mg/kg/day)</u>	<u>Child (mg/kg/day)</u>
Arsenic	0.00016	0.00049
Lead	0.000058	0.00018
Zinc	0.042	0.13
Benzene	0.00012	0.00035
Toluene	0.00082	0.0024
Cyanide	0.0000070	0.000021
Total Phenols	0.0033	0.0098

b. Drinking Surface Water

Overview: The off-site exposure scenario addresses routine daily exposure potential to contaminants originating from the site. Although surface water on the site runs off site, exposure to contaminants in surface water is addressed in the on-site incidental exposure scenario. It is not anticipated that residents will routinely drink from the surface water off site. In any event, the site is not a contributor to off site surface water contamination, since contaminant levels measured upstream of the site are similar to contaminant levels measured downstream of the site.

c. Dust in Ambient Air

Overview: At an assumed on-site average ambient dust concentration of no more than 100 ug/m³, there would be an insufficient amount of dust to contribute to the off-site ambient dust concentrations.

d. Breathing Volatile Organics in the Air (Residential)

Overview: Exposure to residents in the area surrounding the site is possible from breathing airborne volatile organics originating from the site.

Given: The nearest residential dwelling to the east waste pile is 700 meters away. Based on measurements taken during Phase II activities, a gas emission rate of 80 acfm from the east waste pile is selected as the worst case. Assuming constant peak emissions, the modeled H₂S air concentration downwind at a distance of 700 meters from the east waste pile will be no greater than 187 ppb. The modeled mercaptan air concentrations will be no greater than 120 ppt and the modeled benzene and toluene air concentrations will be no greater than 22 ppt.

Example Dose Calculation: Hydrogen Sulfide

$$(20 \text{ m}^3/\text{day})(1/60 \text{ kg})(0.26 \text{ mg/m}^3) = 0.087 \text{ mg/kg/day}$$

Results (Dose):

	<u>Adult (mg/kg/day)</u>	<u>Child (mg/kg/day)</u>
Hydrogen Sulfide	0.087	0.26
Benzene	0.000023	0.000070
Toluene	0.000028	0.000083
Mercaptans	0.000080	0.00024

e. Ingestion of Soil

Overview: People off site will not be exposed to the soil on the site in this scenario. Incidental exposure to the soil on the site is addressed in the on-site exposure scenario.

f. Dermal Absorption of Toxicants from Soil

Overview: People off site will not be exposed to the soil on the site in this scenario. Incidental exposure to the soil on the site is addressed in the on-site exposure scenario.

g. Total Daily Uptake of Each Contaminant

	<u>Adult (mg/kg/day)</u>	<u>Child (mg/kg/day)</u>
Hydrogen Sulfide	0.087	0.26
Benzene	0.00014	0.00042
Toluene	0.00085	0.0025
Mercaptans	0.00008	0.00024
Arsenic	0.00016	0.00049
Lead	0.000058	0.00018
Zinc	0.042	0.13
Cyanide	0.0000070	0.000021
Total Phenols	0.0033	0.0098

Risk Analysis-Case 2

Acute

Even when reasonably worst case assumptions regarding the east waste pile gas emissions are used, the maximum anticipated exposure of residents to any of the contaminants would not exceed 0.26 mg/kg/day. Based on the acute toxicity of these materials, none of the substances should present a hazard to these persons. The following are calculations showing the margins of safety between the exposures and the doses which should not cause an acute toxic response. The assessment is based on the exposure to children since these represent the higher risk. Risks to adults from equivalent exposures will always be much less due to their greater body weight.

MARGINS OF SAFETY (BASED ON LIMITING EFFECT FOR ACUTE TOXICITY)-CHILD

$$\text{Hydrogen Sulfide: } \frac{2.0 \text{ mg/kg (Acute L.E.)}}{0.26 \text{ mg/kg (dose)}} = 7$$

$$\text{Mercaptans: } \frac{0.21 \text{ mg/kg (Acute L.E.)}}{0.00024 \text{ mg/kg (dose)}} = 880$$

$$\text{Benzene: } \frac{53 \text{ mg/kg (Acute L.E.)}}{0.00042 \text{ mg/kg (dose)}} = 1.3 \times 10^5$$

$$\text{Toluene: } \frac{50 \text{ mg/kg (Acute L.E.)}}{0.0025 \text{ mg/kg (dose)}} = 2.0 \times 10^4$$

$$\text{Zinc: } \frac{5 \text{ mg/kg (Acute L.E.)}}{0.13 \text{ mg/kg (dose)}} = 38$$

$$\text{Lead: } \frac{0.5 \text{ mg/kg (Acute L.E.)}}{0.00018 \text{ mg/kg (dose)}} = 2.8 \times 10^3$$

$$\text{Arsenic: } \frac{1.0 \text{ mg/kg (Acute L.E.)}}{0.00049 \text{ mg/kg (dose)}} = 2.0 \times 10^3$$

$$\text{Cyanide: } \frac{0.02 \text{ mg/kg (Acute L.E.)}}{0.000021 \text{ mg/kg (dose)}} = 950$$

$$\text{Phenol: } \frac{4.0 \text{ mg/kg (Acute L.E.)}}{0.0098 \text{ mg/kg (dose)}} = 410$$

Chronic

The following calculations show the margins of safety between the estimated long-term human exposure to the various contaminants and the highest doses for which chronic toxic responses are not expected. All estimated doses are less than the corresponding estimated safe levels of exposure.

MARGINS OF SAFETY (BASED ON LIMITING EFFECT FOR CHRONIC HAZARD)-CHILD

$$\text{Hydrogen Sulfide: } \frac{0.47 \text{ mg/kg (Chronic L.E.)}}{0.26 \text{ mg/kg (dose)}} = 1.8$$

$$\text{Mercaptans: } \frac{0.03 \text{ mg/kg (Chronic L.E.)}}{0.00024 \text{ mg/kg (dose)}} = 120$$

$$\text{Benzene: } \frac{0.001 \text{ mg/kg (Chronic L.E.)}}{0.00042 \text{ mg/kg (dose)}} = 2.4$$

$$\text{Toluene: } \frac{6.0 \text{ mg/kg (Chronic L.E.)}}{0.0025 \text{ mg/kg (dose)}} = 2.4 \times 10^3$$

$$\text{Zinc: } \frac{1.0 \text{ mg/kg (Chronic L.E.)}}{0.13 \text{ mg/kg (dose)}} = 7.7$$

$$\text{Lead: } \frac{0.00083 \text{ mg/kg (Chronic L.E.)}}{0.00018 \text{ mg/kg (dose)}} = 4.6$$

$$\text{Arsenic: } \frac{0.0017 \text{ mg/kg (Chronic L.E.)}}{0.00049 \text{ mg/kg (dose)}} = 3.5$$

$$\text{Cyanides: } \frac{0.001 \text{ mg/kg (Chronic L.E.)}}{0.000021 \text{ mg/kg (dose)}} = 48$$

$$\text{Phenol: } \frac{0.33 \text{ mg/kg (Chronic L.E.)}}{0.0098 \text{ mg/kg (dose)}} = 34$$

Discussion:

Although the estimated exposure dose for H₂S is only marginally less than the limiting effect chronic dose, the dose was calculated for the nearest residence assuming continuous maximum emission from the east waste pile. Even under these extremely unlikely conditions, the estimated dose would not present either an acute or chronic hazard. Risks to other residents who live farther from the east waste pile would be shown to be vanishingly small.

The insignificance of the risk of chronic injury due to exposure to benzene is made more clear when it is recognized that the limiting effect dose was based on the results of a nearly linear extrapolation model which uses data from human epidemiology studies. In addition, although the chronic effect for benzene is based on long term exposure, the margin of safety has been calculated for the child exposure dose. A significant portion of any long term exposure would be received as an adult, which would result in a smaller mg/kg dose, and a corresponding greater margin of safety.

Although the margins of safety for chronic exposure to arsenic and lead are less than 10, these limiting effect doses already provide a sufficient margin of safety as concluded by the National Research Council.

Case 3: Human Exposure During Construction Activity (No Remedial Action)

Exposure Scenario: What is the approximate degree of human exposure to various toxicants during site developmental construction activity to both construction workers and off site populus?

Assumptions:

- a. The average adult weighs about 60 kg and the average child weighs about 10 kg.
- b. The ability of most toxicants to be removed from soil by skin contact is probably no greater than 10%.
- c. Of all the soil handled by a child or adult, only about 1% of the total amount will actually stick to the skin (e.g., about 45 grams). Of the soil particles that stick to the skin, only about 10% of the available dose of the organic constituents and 1% of the inorganic (metal) constituents will penetrate during the ensuing 24 hours.
- d. Adults will breath as much as 20 m³ of air and children 10 m³ of air during a typical 24 hour day.
- e. The potential for acute exposure to heavy metal soil contaminants for construction workers during on-site activity has been based on the metals concentrations in certain isolated site areas such as the phytotoxic arsenic waste, chromium lagoon, and west hide pile areas. The potential for off-site residential chronic exposures to these metals has been based on the overall site average soil concentrations.

Potential Routes of Exposure and Estimated Dose

a. Drinking Groundwater

Overview: This group will not be exposed to this water.

b. Drinking Surface Water

Overview: It is not anticipated that this group will drink any surface water.

c. Dust in Ambient Air (Worker Exposure)

Overview: Exposure is possible for construction workers to breathing dust in the air assuming that the time-weighted average total particulate concentration is not greater than 10 mg/m³.

Given: Based on Phase II investigative sampling results, airborne dust and soil is on the average likely to be composed of 161 ug/g lead, 31 ug/g arsenic, and 82 ug/g chromium. Soil metals concentrations in certain smaller areas such as the phytotoxic arsenic waste, chromium

lagoon, and west hide pile areas may average as high as 620 ug/g lead, 130 ug/g arsenic, and 850 ug/g chromium. Typical airborne metals exposure potentials are based on average site soil composition. Maximum exposure potentials are based on elevated soil metals concentrations in the smaller areas.

Example Dose Calculation: Lead

$$(10 \text{ m}^3/\text{day})(1/60 \text{ kg})(10 \text{ mg}/\text{m}^3)(161 \text{ ug}/\text{g})(1 \text{ g}/1000 \text{ mg})(1 \text{ mg}/1000 \text{ ug}) =$$

$$= 0.00027 \text{ mg}/\text{kg}/\text{day}$$

Results (Dose):

	<u>Adult (mg/kg/day)</u>
<u>Typical Exposure Potential</u>	
Lead	0.00027
Arsenic	0.000052
Chromium	0.00014
<u>Maximum Exposure Potential</u>	
Lead	0.0010
Arsenic	0.00022
Chromium	0.0014

d. Dust in Ambient Air (Off-Site)

Overview: Exposure is possible to off-site residents from breathing dust in the air generated on-site during construction activities.

Given: It is assumed that the contribution to off-site total dust levels from on-site construction activity will raise off-site air dust concentrations 300 meters from the construction activity to an average level no greater than 200 ug/m³ during the period of construction activity. Soil on the average is likely to be composed of 161 ug/lead, 31 ug/g arsenic, and 82 ug/g chromium. As in (c) above, soil metals concentrations may be as high as 620 ug/g lead, 130 ug/g arsenic, and 850 ug/g chromium. Typical and maximum exposure potentials are based on these site average and maximum average soil metals concentrations, respectively.

Example Dose Calculation: Lead

$$(20 \text{ m}^3/\text{day})(1/60 \text{ kg})(200 \text{ ug}/\text{m}^3)(1 \text{ g}/10^6 \text{ ug})(161 \text{ ug}/\text{g})(1 \text{ mg}/1000 \text{ ug}) =$$

$$0.000011 \text{ mg}/\text{kg}/\text{day}$$

Results (Dose):

	<u>Adult (mg/kg/day)</u>	<u>Child (mg/kg/day)</u>
<u>Typical Exposure Potential</u>		
Lead	0.000011	0.000032
Arsenic	0.0000021	0.0000062
Chromium	0.0000055	0.000016
<u>Maximum Exposure Potential</u>		
Lead	0.000041	0.00012
Arsenic	0.0000087	0.000026
Chromium	0.000057	0.00017

e. Dermal Absorption of Toxicants in Soil

Overview: A construction worker on site might handle the soil and absorb through the skin some of the chemicals in the soil matrix.

Given: About 45 grams of soil might stick to the skin of a construction worker during a typical workday. Soil on the average is likely to be composed of 161 ug/g lead, 31 ug/g arsenic, and 82 ug/g chromium. Maximum potential soil metals concentrations in certain smaller areas may average as high as 620 ug/g lead, 130 ug/g arsenic, and 850 ug/g chromium.

Example Dose Calculation: Lead

$$(45 \text{ g/day})(1/60 \text{ kg})(10\%)(1\%)(161 \text{ ug/g})(1 \text{ mg}/1000 \text{ ug}) = 0.00012 \text{ mg/kg/day}$$

Results (Dose):

	<u>Adult (mg/kg/day)</u>
<u>Typical Exposure Potential</u>	
Lead	0.00012
Arsenic	0.000023
Chromium	0.000062
<u>Maximum Exposure Potential</u>	
Lead	0.00046
Arsenic	0.000098
Chromium	0.00064

f. Total Daily Uptake of Each Contaminant

	<u>Adult (mg/kg/day)</u>	<u>Child (mg/kg/day)</u>
<u>Worker</u>		
Lead - Typical	0.00039	-----
- Maximum	0.0015	-----
Arsenic - Typical	0.000075	-----
- Maximum	0.00032	-----
Chromium - Typical	0.00020	-----
- Maximum	0.0020	-----
 <u>Off-Site</u>		
Lead - Typical	0.000011	0.000032
- Maximum	0.000041	0.00012
Arsenic - Typical	0.0000021	0.0000062
- Maximum	0.0000087	0.000026
Chromium - Typical	0.0000055	0.000016
- Maximum	0.000057	0.00017

Risk Analysis-Case 3

Acute

As expected, during construction activity, the on-site construction worker will receive higher exposures to the contaminants than the off site residents. Based on the acute toxicity of the metals present, none should present an acute hazard to these workers from either inhalation or dermal uptake. The following are calculations showing the margins of safety between the anticipated exposures and the doses which should not cause an acute adverse effect (i.e., safe level).

MARGINS OF SAFETY (BASED ON LIMITING EFFECT FOR ACUTE TOXICITY)-CONSTRUCTION WORKER

$$\text{Lead: } \frac{0.5 \text{ mg/kg (Acute L.E.)}}{0.0015 \text{ mg/kg (dose)}} = 330$$

$$\text{Arsenic: } \frac{1.0 \text{ mg/kg (Acute L.E.)}}{0.00032 \text{ mg/kg (dose)}} = 3.1 \times 10^3$$

$$\text{Chromium: } \frac{0.6 \text{ mg/kg (Acute L.E.)}}{0.0020 \text{ mg/kg (dose)}} = 300$$

Chronic

Even under the unlikely assumption of continuous (60 yrs.) construction activity, the chronic inhaled dose of dust of nearby residents to the metals in the soil is quite low. The following are calculations showing the margins of safety between the anticipated exposures and the doses which should prevent a chronic toxic response.

MARGINS OF SAFETY (BASED ON LIMITING EFFECT FOR CHRONIC HAZARD)-CHILD OFF SITE

$$\text{Lead: } \frac{0.00083 \text{ mg/kg (Chronic L.E.)}}{0.000032 \text{ mg/kg (dose)}} = 26$$

$$\text{Arsenic: } \frac{0.0017 \text{ mg/kg (Chronic L.E.)}}{0.0000062 \text{ mg/kg (dose)}} = 270$$

$$\text{Chromium: } \frac{0.0017 \text{ mg/kg (Chronic L.E.)}}{0.000016 \text{ mg/kg (dose)}} = 110$$

Discussion:

During construction activity it has been assumed that workers will be exposed for 8 hours a day to total particulate at the TLV concentrations of 10 mg/m³. Under these conditions and conservative assumptions regarding dermal exposures, working on the site should not present an unacceptable health risk to these workers. It was assumed that no respiratory protection will be used.

For off-site residents it has been assumed that construction activity (although likely intermittent) will double the background total particulate level adjacent to the site on a continuous basis. Even under these conservative assumptions, this unlikely degree of activity would not pose an unacceptable health risk to these residents.

APPENDIX H

APPENDIX H

UTILITY CONTAMINATION

The utility line layout and estimated potential surrounding waste is based upon the GZA report for Dundee Park Associates dated 1/83 Fig. #A-3499 "Utility Line Assessment, Woburn, Mass."

The GZA report, pg. 13, stated elevated levels and lead and arsenic are confined to discolored and cinderlike fills which underlie an approximately 1800 ft. section between boring GZ-4A & WL-12 along New Boston Street and a 450 foot section between New Boston Street and boring WL-5A in Merrimac Street. (See attached GZA drawing).

GZA reported the maximum observed waste thickness of 10 ft. at boring GZ-1A with an average thickness of about 5 ft. The waste layer along New Boston Street between boring WL-7 and GZ-11 is overlain by a clean granular fill 2-3' thick, estimate 600' section of New Boston Street.

There are four reported utility lines in contact with potential contaminated waste layers. These are as follows:

- 1) 6"/16" Woburn Water lines running 1800 ft. from boring WL-12 to GZ-4 along New Boston Street and 450 ft. from New Boston Street to boring WL-6 on Merrimac Street.
- 2) 15" V.C. Woburn sewer line running 1800 ft. along New Boston Street between borings WL-12 and GZ-4.
- 3) 30" reinforced concrete, MDL sewer line running ~1000 ft. along New Boston Street from GZ-4 to just south of Merrimac Street and then ~1500 ft. south along the Boston & Main R.R. right-of-way.

The estimated total length of utility lines of concern are:

- 2250' of 6" or 16" Woburn Water line
- 1800' of 15" V.C. Woburn sewer line
- 2500' of 30" R.C.MDC sewer line

It is assumed utility repairs/replacement through contaminated site area would be handled as follows:

- 1) Break in utility line or tie-in to adjacent business.
 - Excavate an area 10' X 10', remove 5' thick layer of waste and haul to approved landfill.
- 2) Major repairs to lines would be made by slip lining in place and no excavation required except possible access to each end of the line. Assume (2) 10' X 10' excavation.
- 3) If larger lines are installed then the utility line route would bypass the site by running along the northern and western border.

Estimated waste disposal cost during utility work.

Assume average 2 excavations/year for repairs, business tie-ins or slip lining existing water or sewer lines.

Assume 10' X 10' hole through 5' thick waste layer.

Volume = 10' X 10' x 5' = 500 ft.³ = 18.5 yd.³

Assume 50% contingency for thicker layers, swelling, etc.

Yearly waste volume = 18.5 yd.³ x 15 x 2 = 55.5 yd.³

Assume \$200/yd.³ to excavate, haul and dispose at Model City, N.Y. hazardous waste landfill.

Yearly cost = 55.5 x 200 = \$11,000

Assume excavate 1/3 of total line & replace. Total length of utility lines within site ~ 6500.

Assume excavate 1/3 = ~ 2200 ft.

Assume 5' wide trench & shore sides

Excavation of waste 5' x 5' x 2200' + 27 = 815 yd.³

Assume 50 extra for greater thickness swellup, etc.

Volume = 1200 yd.³

Assume two options:

- 1) Excavate & phase in onsite RCRA landfill
- 2) Excavate & truck to Model City. The 4/30/84 estimate for an onsite non-RCRA landfill was 6,000,000 for 76,000 yd.³ = \$79/yd.³.
Assume \$80/yd.³

Option 1 cost = 1200 x \$80 = \$96,000 ??

Option 2 cost = 1200 x \$200 = \$240,000

APPENDIX I

REMEDIAL ACTION PROGRAM
Woburn, Massachusetts

A/R 3955A004 - Phase III

APPENDIX I

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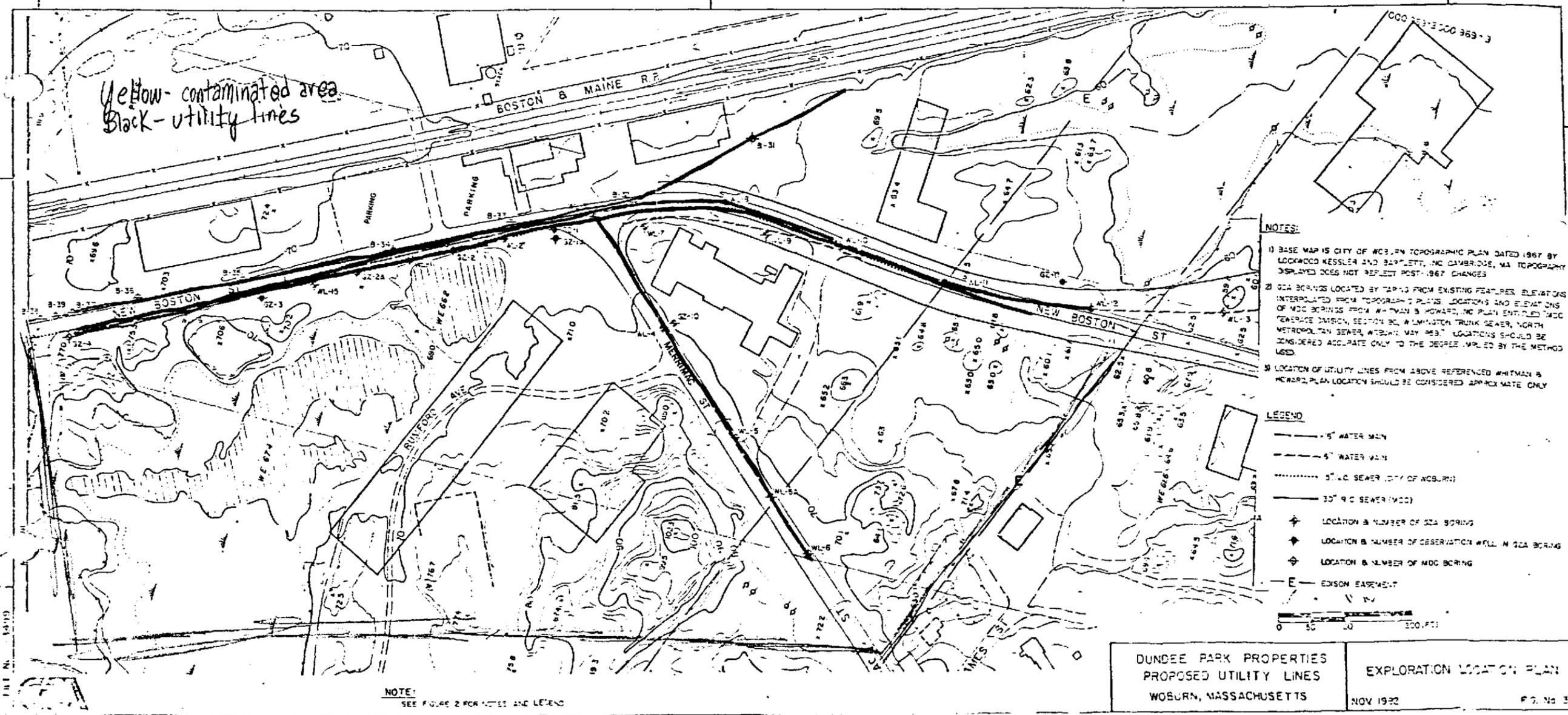
CO-5-004
J. Duffy
4-4-85

REMEDIAL ACTION PROGRAM
WOBURN, MASSACHUSETTS
A/R 3955A004 - PHASE III

COMPARISON OF WASTE OPTIONS
(ALL COSTS IN '85 DOLLARS)

DESCRIPTION OF WORK	OPTION I	OPTION II	OPTION III	OPTION IV	OPTION V	OPTION VI	OPTION VII	OPTION VIII	OPTION IX	OPTION X	OPTION XI	OPTION XII
	24" Clay Barrier, 6" Soil Cover Vegetate	Excavate with Offsite Disposal	20 Mil PVC Liner Sand Beds, 12" Fill, 6" Soil Cover, Vegetate	6" Clay Barrier, 18" Fill, 6" Soil Cover, Vegetate	RCRA Onsite Landfill	24" Fill, 6" Soil Cover, Vegetate	Consolidation w/Back- fill, PVC liner, Sand Beds, 12" Fill, 6" Soil Cover, Vegetate	Ltd. Excavation, 6" Soil Cover, Vegetate	Ltd. Excavation, Fencing, Good Restrictions	Consolidation w/o Backfill, PVC Liner, Sand Beds, 12" Fill, 6" Soil Cover, Vegetate	Cover Contaminated Areas: As >300 PPM Pb >600 PPM Cr >1000 PPM Use Option VI Cover	Cover Contaminated Areas: As >300PPM Pb >600PPM Cr >1000PPM Use Option VIII Cover
AREA												
CONTAMINATED SOIL	\$ 22.65	\$209.68	\$ 11.43	\$ 12.30	\$ 78.98	\$ 8.18	\$ 17.94	\$ 4.05	\$ 2.32	\$ 8.98	\$ 5.27	\$2.98
FX Engineering												
Chromium Lagoons												
Janpet												
Wedge												
Arsenic/Phytotoxic												
Stafford												
East Central Nide Deposit												
West Nide Deposit												
South Nide Deposit												
ODOR CONTROL												
Cover	2.36	35.86	1.86	1.95	13.51	1.69	1.86	1.86	1.86	1.86	1.86	1.86
Gas Treatment*	0.50	-	0.50	0.50	2.00	0.50	0.50	0.50	0.50	0.50	0.50	0.50
TOTAL 15-YEAR MONITORING COSTS (PRESENT WORTH IN 1985 DOLLARS)	0.95	-	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95
OPERATING AND MAINTENANCE COSTS (PRESENT WORTH IN 1985 DOLLARS)	0.30	-	0.30	0.30	0.40	0.30	0.30	0.30	0.30	0.30	0.30	0.30
ODOR CONTROL*												
*IF A FLARE FOR ODOR CONTROL GAS TREATMENT, THEN INCREASE CAPITAL COSTS \$0.14 AND INCREASE O & M COSTS \$0.19 FOR A TOTAL OF \$0.33 FOR EACH OPTION												
			FOR ALL OPTIONS									
			NOT SPOT INTERCEPTOR WELLS		110 GPM INTERCEPTOR WELLS		360 GPM INTERCEPTOR WELLS			SLURRY CUT-OFF WALL		
			CAPITAL COST	\$0.79	CAPITAL COST OF	\$1.25	CAPITAL COST OF	\$1.35		A SLURRY CUT-OFF AT A COST		
			SIX MONTH OPERATING	0.14	VOC STRIPPING		VOC STRIPPING			OF \$240,000 WOULD BE RE-		
			AND MAINTENANCE COST		ODOR REMOVAL		ODOR REMOVAL			QUIRED IF THE NATIVE ROCK		
					800 REMOVAL		800 REMOVAL			ON THE EAST SIDE OF THE		
					15-YEAR OPERATING AND	2.16	15-YEAR OPERATING AND	2.36		EAST NIDE DEPOSIT IS REMOVED		
					MAINTENANCE COSTS		MAINTENANCE COSTS			OR FRACTURED		
					(PRESENT WORTH IN 1985 DOLLARS)		(PRESENT WORTH IN 1985 DOLLARS)					
					CAPITAL COST OF	1.80	CAPITAL COST OF	3.15				
					HEAVY METALS REMOVAL SYSTEM		HEAVY METALS REMOVAL SYSTEM					
					15-YEAR OPERATING AND	2.10	15-YEAR OPERATING AND	4.10				
					MAINTENANCE COSTS		MAINTENANCE COSTS					
					(PRESENT WORTH IN 1985 DOLLARS)		(PRESENT WORTH IN 1985 DOLLARS)					

CO-5-004
J. DUFFY
4-4-85



Yellow - contaminated area
 Black - utility lines

- NOTES:
- 1) BASE MAP IS CITY OF WOBURN TOPOGRAPHIC PLAN DATED 1967 BY LOCKWOOD KESSLER AND BARTLETT, INC. CAMBRIDGE, MA. TOPOGRAPHY DISPLAYED DOES NOT REFLECT POST-1967 CHANGES.
 - 2) SEA SPRINGS LOCATED BY TAPING FROM EXISTING FEATURES. ELEVATIONS INTERPOLATED FROM TOPOGRAPHIC PLANS. LOCATIONS AND ELEVATIONS OF MDC BORINGS FROM WHITMAN & HOWARD, INC. PLAN ENTITLED "MDC TERRACE DIVISION, SECTION 20, WILMINGTON TRUNK SEWER, NORTH METROPOLITAN SEWER, WOBURN" MAY BE "L" LOCATIONS SHOULD BE CONSIDERED ACCURATE ONLY TO THE DEGREE IMPLIED BY THE METHOD USED.
 - 3) LOCATION OF UTILITY LINES FROM ABOVE REFERENCED WHITMAN & HOWARD, INC. PLAN SHOULD BE CONSIDERED APPROXIMATE ONLY.

- LEGEND
- 5" WATER MAIN
 - - - 6" WATER MAIN
 - 8" S.C. SEWER (CITY OF WOBURN)
 - 10" R.C. SEWER (MDC)
 - ◆ LOCATION & NUMBER OF SEA SPRING
 - ◆ LOCATION & NUMBER OF OBSERVATION WELL IN SEA SPRING
 - ◆ LOCATION & NUMBER OF MDC BORING
 - E EDISON EASEMENT
- 0 50 100 200 FT.

NOTE:
 SEE FIGURE 2 FOR NOTES AND LEGEND

DUNDEE PARK PROPERTIES PROPOSED UTILITY LINES WOBURN, MASSACHUSETTS	EXPLORATION LOCATION PLAN NOV 1992 P.O. No. 3
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REMEDIAL ACTION PROGRAM
Woburn, Massachusetts

A/R 3955A004 - Phase III

ESTIMATE SCOPE

Excavation and consolidation quantities are based on assumption that geologist's visual observation will determine waste. If soil analysis is required to determine extent of waste, then costs could increase as much as 30 to 50%. The Phase I study found that quick turnaround X-ray fluorescence was unsuitable and therefore time consuming AA or ICAP testing for soil would be necessary.

Areas contaminated with As, Cr, Pb above 100 PPM in the soil were taken from R. Pease's computer printout, dated February 19, 1985, of 0-2 feet and below 2 feet concentrations.

Several of the areas have clean sections comingled with contaminated sections that will be difficult to separate, therefore the areas of contamination will be increased as follows:

PX Engineering	10%
Wedge Area	10%
Chromium Lagoon	10%
Janpet	20%
Stafford	20%
Arsenic Pit/Phytotoxic	30%

The following costs were evenly divided between the East and West Hide Pile covering costs for all options:

Excavating and Transporting South Hide Materials.

Covering the Former South Hide Pile Area.

Reshaping the Slopes of the East and West Hide Piles
Using the South Pile Materials.

Installing an Underground Pipe to Drain the Wetlands
Between the East and West Hide Piles.

REMEDIAL ACTION PROGRAM
Woburn, Massachusetts

A/R 3955A004 - Phase III

Areas of Waste Deposits

As greater than 300 PPM
Pb greater than 600 PPM
Cr greater than 1000 PPM

A. CONTAMINATED SOILS

PX Engineering	2.59 acres
Chromium Lagoons	5.90
Janpet	9.68
Wedge Area	3.89
Arsenic Pit/Phytotoxic Area	7.40
Stafford Lot	0.94
East Central Hide Deposit	4.86
West Hide Deposit	4.09
South Hide Deposit	2.00
	<hr/>
	41.35 acres

B. ODOR CONTROL

East Hide Deposit	3.75 acres
-------------------	------------

TOTALS 45.10 acres

One Acre = 44,000 SF

**REMEDIAL ACTION PROGRAM
Woburn, Massachusetts**

A/R 3955A004 - Phase III

OPTION I - SUMMARY

Capital Cost

Contaminated Soils	\$22,650,000
Odor Control	
Cover	2,360,000
Gas Treatment	500,000
Total Capital Cost	\$25,510,000
Total 15-Year Monitoring Costs (Present Worth in 1985 Dollars)	950,000
Operating and Maintenance Costs (Present Worth in 1985 Dollars)	300,000
Total Implementation Cost	\$26,760,000

REMEDIAL ACTION PROGRAM
Woburn, Massachusetts

A/R 3955A004 - Phase III

OPTION I

- A. Cover all As, Cr, Pb Waste Deposits with individual concentrations of one or more exceeding 100 PPM, and cover the East Central and the West Hide Deposit.

Cut, fill, regrade the top 12" of the existing surface to develop new contours, eliminate water pockets, promote better drainage, etc.	\$ 707,000
Cover area with a 24" clay barrier constructed in 6" lifts. This clay barrier is composed of Bentonite Clay mixed at a rate of four pounds per square foot with native offsite soil to achieve 10^{-7} permeability.	9,889,000
Cover clay barrier with a 6" layer of top soil and vegetate.	621,000
Relocate the South Hide Pile (include 25% swell up factor) to reshape the West Hide Pile slope (allow for one half of costs).	292,000
Cover former South Hide Area with a 6" layer of top soil and vegetate.	10,000
Reshape the slopes of the West Hide Pile using South Hide materials (allow for one half of costs).	265,000
Drain Wetlands with 60" dia. underground polyethylene pipe to stabilize hide pile slopes (allow for one half of costs).	200,000
Cover area with a 24" clay barrier constructed in 6" lifts. This clay barrier is composed of Bentonite Clay mixed at a rate of four pounds per square foot with native offsite soil to achieve 10^{-7} permeability.	630,000
Cover clay barrier with a 6" layer of top soil and vegetate.	40,000
TOTAL DIRECTS	\$12,654,000

Site Overhead Costs	1,504,000
Surveying and Test Borings	
Dewatering	
Mobilization and Demobilization	
Equipment and Personnel Downtime	
Indirect Costs	2,095,000
Site Facility Costs	
Stauffer Engineering & Research Personnel	
Outside Analytical Contractors	
Sub-Total	\$16,253,000
Contingency and Escalation	6,397,000
CAPITAL COST	\$22,650,000

B. Cover East Hide Pile for odor control.

Relocate the South Hide Pile (include 25% swell up factor) to reshape the East Hide Pile Slope (allow for one half of costs).	\$ 292,000
Cover former South Hide Pile area with a 6" layer of top soil and vegetate.	10,000
Reshape the slopes of the East Hide Pile using South Hide materials (allow for one half of costs).	265,000
Drain wetlands with 60" dia. underground polyethylene pipe to stabilize hide pile slopes (allow for one half of costs).	200,000
Cover area with a 24" clay barrier constructed in 6" lifts. This clay barrier is composed of Bentonite Clay mixed at a rate of four pounds per square foot with native offsite soil to achieve 10^{-7} permeability.	578,000
Cover clay barrier with a 6" layer of top soil and vegetate.	36,000
TOTAL DIRECTS	\$ 1,381,000

Site Overhead Costs		83,000
Surveying and Test Borings		
Dewatering		
Mobilization and Demobilization		
Equipment and Personnel Downtime		
Indirect Costs		220,000
Site Facility Costs		
Stauffer Engineering & Research Personnel		
Outside Analytical Contractors		
	Sub-Total	\$ 1,684,000
Contingency and Escalation		676,000
	CAPITAL COST	\$ 2,360,000

C. Gas Treatment for East Hide Pile Odor Control

Install a 12" layer of gravel with 6" perforated PVC pipe for gas gathering and venting system		\$ 98,000
Install Blower and Control System		50,000
Blower 0-150 Ft ³ 304SS	4,000	
Foundation and Enclosure	8,000	
Piping	8,000	
Electrical	6,000	
Instrumentation	4,000	
Measurements	20,000	
Install a Carbon Adsorption System		86,000
2000 Gal 304SS Vessels	12,000	
Carbon	35,000	
Foundations, Dike	16,000	
Piping	21,000	
Electrical	2,000	
	TOTAL DIRECTS	\$ 234,000
Construction Expense (5 months duration @ \$20,000/mo.)		100,000
Engineering (15% of Total Directs)		35,000
	Sub-Total	\$ 369,000
Contingency and Escalation		\$ 131,000
	CAPITAL COST	\$ 500,000

REMEDIAL ACTION PROGRAM
Woburn, Massachusetts

A/R 3955A004 - Phase III

OPTION II

- A. Remove all As, Cr, Pb Waste Deposits with individual concentrations of one or more exceeding 100 PPM, and remove the East Central, the West, and the South Hide Deposit.

Excavation with offsite disposal (includes 25% swell-up factor). \$138,131,000

Backfill excavated areas with offsite fill (includes 20% compaction factor). 7,957,000

TOTAL DIRECTS \$146,088,000

Site Overhead Costs 1,382,000
 Surveying and Test Borings
 Dewatering
 Mobilization and Demobilization
 Equipment and Personnel Downtime

Indirect Costs 2,302,000
 Site Facility Costs
 Stauffer Engineering & Research Personnel
 Outside Analytical Contractors

Sub-Total \$149,772,000

Contingency and Escalation 59,908,000

CAPITAL COST \$209,680,000

- B. Remove East Hide Pile for Odor Control.

Excavation with offsite disposal (includes 25% swell up factor). \$ 23,625,000

Backfill excavated areas with offsite fill (includes 20% compaction factor). 1,361,000

TOTAL DIRECTS \$ 24,986,000

Site Overhead Costs	\$	236,000
Surveying and Test Borings		
Dewatering		
Mobilization and Demobilization		
Equipment and Personnel Downtime		
Indirect Costs	\$	394,000
Site Facility Costs		
Stauffer Engineering and Research Personnel		
Outside Analytical Contractors		
	Sub-Total	\$ 25,616,000
Contingency and Escalation		10,244,000
	CAPITAL COST	\$ 35,860,000

REMEDIAL ACTION PROGRAM
Woburn, Massachusetts

A/R 3955A004 - Phase III

OPTION III - SUMMARY

Capital Cost

Contaminated Soils	\$11,430,000
Odor Control	
Cover	1,860,000
Gas Treatment	500,000
Total Capital Cost	\$14,290,000

Total 15-Year Monitoring Costs (Present Worth in 1985 Dollars)	950,000
---	---------

Operating and Maintenance Costs (Present Worth in 1985 Dollars)	300,000
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Total Implementation Cost	\$15,540,000
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REMEDIAL ACTION PROGRAM
Woburn, Massachusetts

A/R 3955A004 - Phase III

OPTION III

- A. Cover all As, Cr, Pb Waste Deposits with individual concentrations of one or more exceeding 100 PPM, and cover the East Central and the West Hide Deposit.

Cut, fill, regrade the top 12" of the existing surface to develop new contours, eliminate water pockets, promote better drainage, etc.	\$ 707,000
Cover area with a 6" layer of compacted sand. Install a 20 mil PVC membrane liner. Install a 6" layer of compacted sand over the PVC liner.	2,825,000
Cover liner and sand with a 12" layer of offsite fill (includes 20% compaction factor).	1,131,000
Cover fill with a 6" layer of top soil and vegetate.	621,000
Relocate the South Hide Pile (include 25% swell up factor) to reshape the West Hide Pile slope (allow for one half of costs).	292,000
Cover former South Hide Area with a 6" layer of top soil and vegetate.	10,000
Reshape the slopes of the West Hide Pile using South Hide materials (allow for one half of costs).	265,000
Drain Wetlands with 60" dia. underground polyethylene pipe to stabilize hide pile slopes (allow for one half of costs).	200,000
Cover area with a 6" layer of compacted sand. Install a 20 mil PVC membrane liner. Install a 6" layer of compacted sand over the PVC liner.	180,000
Cover liner and sand with a 12" layer of offsite fill (includes 20% compaction factor).	72,000
Cover fill with a 6" layer of top soil and vegetate.	40,000
TOTAL DIRECTS	\$ 6,343,000

Site Overhead Costs	760,000
Surveying and Test Borings	
Dewatering	
Mobilization and Demobilization	
Equipment and Personnel Downtime	
Indirect Costs	1,066,000
Site Facility Costs	
Stauffer Engineering & Research Personnel	
Outside Analytical Contractors	
Sub-Total	\$ 8,169,000
Contingency and Escalation	3,261,000
CAPITAL COST	\$11,430,000

B. Cover East Hide Pile for odor control.

Relocate the South Hide Pile (include 25% swell up factor) to reshape the East Hide Pile Slope (allow for one half of costs).	\$ 292,000
Cover former South Hide Pile area with a 6" layer of top soil and vegetate.	10,000
Reshape the slopes of the East Hide Pile using South Hide materials (allow for one half of costs).	265,000
Drain wetlands with 60" dia. underground polyethylene pipe to stabilize hide pile slopes (allow for one half of costs).	200,000
Cover area with a 6" layer of compacted sand. Install a 20 mil PVC membrane liner. Install a 6" layer of compacted sand over the PVC liner.	165,000
Cover liner and sand with a 12" layer of offsite fill (includes 20% compaction factor).	66,000
Cover fill with a 6" layer of top soil and vegetate.	36,000
TOTAL DIRECTS	\$ 1,034,000

Site Overhead Costs	124,000
Surveying and Test Borings	
Dewatering	
Mobilization and Demobilization	
Equipment and Personnel Downtime	
Indirect Costs	174,000
Site Facility Costs	
Stauffer Engineering & Research Personnel	
Outside Analytical Contractors	
Sub-Total	\$ 1,332,000
Contingency and Escalation	528,000
CAPITAL COST	\$ 1,860,000

C. Gas Treatment for East Hide Pile Odor Control

Install a 12" layer of gravel with 6" perforated PVC pipe for gas gathering and venting system	\$ 98,000
Install Blower and Control System	50,000
Blower 0-150 Ft ³ 304SS	4,000
Foundation and Enclosure	8,000
Piping	8,000
Electrical	6,000
Instrumentation	4,000
Measurements	20,000
Install a Carbon Adsorption System	86,000
2000 Gal 304SS Vessels	12,000
Carbon	35,000
Foundations, Dike	16,000
Piping	21,000
Electrical	2,000
TOTAL DIRECTS	\$ 234,000
Construction Expense (5 months duration @ \$20,000/mo.)	100,000
Engineering (15% of Total Directs)	35,000
Sub-Total	\$ 369,000
Contingency and Escalation	\$ 131,000
CAPITAL COST	\$ 500,000

**REMEDIAL ACTION PROGRAM
Woburn, Massachusetts**

A/R 3955A004 - Phase III

OPTION IV - SUMMARY

Capital Cost

Contaminated Soils	\$12,300,000
Odor Control	
Cover	1,950,000
Gas Treatment	500,000
Total Capital Cost	\$14,750,000

Total 15-Year Monitoring Costs (Present Worth in 1985 Dollars)	950,000
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Operating and Maintenance Costs (Present Worth in 1985 Dollars)	300,000
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Total Implementation Cost	\$16,000,000
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REMEDIAL ACTION PROGRAM
Woburn, Massachusetts

A/R 3955A004 - Phase III

OPTION IV

- A. Cover all As, Cr, Pb Waste Deposits with individual concentrations of one or more exceeding 100 PPM, and cover the East Central and the West Hide Deposit.

Cut, fill, regrade the top 12" of the existing surface to develop new contours, eliminate water pockets, promote better drainage, etc.	\$ 707,000
Cover area with a 6" clay barrier. This clay barrier is composed of Bentonite Clay mixed at a rate of four pounds per square foot with native soil to achieve 10^{-7} permeability.	2,543,000
Cover clay barrier with an 18" layer of offsite fill (includes 20% compaction factor).	1,695,000
Cover fill a 6" layer of top soil and vegetate. and vegetate.	621,000
Relocate the South Hide Pile (include 25% swell up factor) to reshape the West Hide Pile slope (allow for one half of costs).	292,000
Cover former South Hide Area with a 6" layer of top soil and vegetate.	10,000
Reshape the slopes of the West Hide Pile using South Hide materials (allow for one half of costs).	265,000
Drain Wetlands with 60" dia. underground polyethylene pipe to stabilize hide pile slopes (allow for one half of costs).	200,000
Cover area with a 6" clay barrier. This clay barrier is composed of Bentonite Clay mixed at a rate of four pounds per square foot with native offsite soil to achieve 10^{-7} permeability.	162,000
Cover clay barrier with an 18" layer of offsite fill (includes 20% compaction factor).	108,000
Cover fill with a 6" layer of top soil and vegetate.	40,000
TOTAL DIRECTS	\$ 6,643,000

Site Overhead Costs	998,000
Surveying and Test Borings	
Dewatering	
Mobilization and Demobilization	
Equipment and Personnel Downtime	
Indirect Costs	1,146,000
Site Facility Costs	
Stauffer Engineering & Research Personnel	
Outside Analytical Contractors	
Sub-Total	\$ 8,787,000
Contingency and Escalation	3,513,000
CAPITAL COST	\$12,300,000

B. Cover East Hide Pile for Odor Control.

Relocate the South Hide Pile (include 25% swell up factor) to reshape the East Hide Pile Slope (allow for one half of costs).	\$ 292,000
Cover former South Hide Pile area with a 6" layer of top soil and vegetate.	10,000
Reshape the slopes of the East Hide Pile using South Hide materials (allow for one half of costs).	265,000
Drain wetlands with 60" dia. underground polyethylene pipe to stabilize hide pile slopes (allow for one half of costs).	200,000
Cover area with a 6" clay barrier. This clay barrier is composed of Bentonite Clay mixed at a rate of four pounds per square foot with native offsite soil to achieve 10^{-7} permeability.	149,000
Cover clay barrier with an 18" layer of offsite fill (includes 20% compaction factor).	99,000
Cover fill with 6" of top soil and vegetate.	36,000
TOTAL DIRECTS	\$ 1,051,000

Site Overhead Costs	158,000
Surveying and Test Borings	
Dewatering	
Mobilization and Demobilization	
Equipment and Personnel Downtime	
Indirect Costs	181,000
Site Facility Costs	
Stauffer Engineering & Research Personnel	
Outside Analytical Contractors	
Sub-Total	\$ 1,390,000
Contingency and Escalation	560,000
CAPITAL COST	\$ 1,950,000

C. Gas Treatment for East Hide Pile Odor Control

Install a 12" layer of gravel with 6" perforated PVC pipe for gas gathering and venting system	\$ 98,000
Install Blower and Control System	50,000
Blower 0-150 Ft ³ 304SS	4,000
Foundation and Enclosure	8,000
Piping	8,000
Electrical	6,000
Instrumentation	4,000
Measurements	20,000
Install a Carbon Adsorption System	86,000
2000 Gal 304SS Vessels	12,000
Carbon	35,000
Foundations, Dike	16,000
Piping	21,000
Electrical	2,000
TOTAL DIRECTS	\$ 234,000
Construction Expense (5 months duration @ \$20,000/mo.)	100,000
Engineering (15% of Total Directs)	35,000
Sub-Total	\$ 369,000
Contingency and Escalation	\$ 131,000
CAPITAL COST	\$ 500,000

**REMEDIAL ACTION PROGRAM
Woburn, Massachusetts**

A/R 3955A004 - Phase III

OPTION V - SUMMARY

Capital Cost

Contaminated Soils	\$78,980,000
Odor Control	
Cover	13,510,000
Gas Treatment	2,000,000
Total Capital Cost	\$94,490,000

Total 15-Year Monitoring Costs 950,000
(Present Worth in 1985 Dollars)

Operating and Maintenance Costs 400,000
(Present Worth in 1985 Dollars)

Total Implementation Cost \$95,840,000

Note: Costs associated with excavation of the Janpet Site (contaminated soils) could be considerably higher because of abandoned plant equipment and ruins.

**REMEDIAL ACTION PROGRAM
Woburn, Massachusetts**

A/R 3955A004 - Phase III

OPTION V

- A. Remove all As, Cr, Pb Waste Deposits with individual concentrations of one or more exceeding 100 PPM, and remove the East Central, the West, and the South Hide Deposit.

Construct a RCRA onsite containment facility.	\$ 22,838,000
Remove and replace waste deposits.	13,334,000
TOTAL DIRECTS	\$36,172,000

Site Overhead Costs	4,702,000
Surveying and Test Borings	
Dewatering	
Mobilization and Demobilization	
Equipment and Personnel Downtime	

Indirect Costs	15,554,000
Site Facility Costs	
Stauffer Engineering & Research Personnel	
Outside Analytical Contractors	

Sub-Total	\$56,428,000
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Contingency and Escalation	22,552,000
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CAPITAL COST	\$78,980,000
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- B. Remove the East Hide Deposit for Odor Control.

Construct a RCRA onsite containment facility.	\$ 3,906,000
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Remove and replace waste deposits.	2,281,000
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TOTAL DIRECTS	\$ 6,187,000
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Site Overhead Costs	804,000
Surveying and Test Borings	
Dewatering	
Mobilization and Demobilization	
Equipment and Personnel Downtime	
Indirect Costs	2,660,000
Site Facility Costs	
Stauffer Engineering & Research Personnel	
Outside Analytical Contractors	
Sub-Total	\$ 9,651,000
Contingency and Escalation	3,859,000
CAPITAL COST	\$13,510,000

The gas treatment costs for the RCRA landfill were scaled up from the East Hide Deposit gas treatment costs.

A scale up factor of 4 was used due to the larger quantities of gases that would be generated.

East Hide Deposit Gas Treatment	\$ 500,000
Scale-up Factor	x 4
	<u> </u>
	\$2,000,000

Increase operating and maintenance costs (present worth in 1985 dollars) to \$400,000.

REMEDIAL ACTION PROGRAM
Woburn, Massachusetts

A/R 3955A004 - Phase III

OPTION VI - SUMMARY

Capital Cost

Contaminated Soils	\$ 8,180,000
Odor Control	
Cover	1,690,000
Gas Treatment	500,000
Total Capital Cost	\$10,370,000

Total 15-Year Monitoring Costs (Present Worth in 1985 Dollars)	950,000
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Operating and Maintenance Costs (Present Worth in 1985 Dollars)	300,000
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Total Implementation Cost	\$11,620,000
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REMEDIAL ACTION PROGRAM
Woburn, Massachusetts

A/R 3955A004 - Phase III

OPTION VI

- A. Cover all As, Cr, Pb Waste Deposits with individual concentrations of one or more exceeding 100 PPM, and cover the East Central and the West Hide Deposit.

Cut, fill, regrade the top 12" of the existing surface to develop new contours, eliminate water pockets, promote better drainage, etc.	\$ 707,000
Cover area with a 24" layer of offsite fill (includes 20% compaction factor).	2,261,000
Cover fill with a 6" layer of top soil and vegetate.	621,000
Relocate the South Hide Pile (include 25% swell up factor) to reshape the West Hide Pile slope (allow for one half of costs).	292,000
Cover former South Hide Area with a 6" layer of top soil and vegetate.	10,000
Reshape the slopes of the West Hide Pile using South Hide materials (allow for one half of costs).	265,000
Drain Wetlands with 60" dia. underground polyethylene pipe to stabilize hide pile slopes (allow for one half of costs).	200,000
Cover area with a 24" layer of offsite fill (includes 20% compaction factor).	144,000
Cover fill with a 6" layer of top soil and vegetate.	40,000
TOTAL DIRECTS	\$ 4,540,000

Site Overhead Costs	545,000
Surveying and Test Borings	
Dewatering	
Mobilization and Demobilization	
Equipment and Personnel Downtime	
Indirect Costs	764,000
Site Facility Costs	
Stauffer Engineering & Research Personnel	
Outside Analytical Contractors	
Sub-Total	\$ 5,849,000
Contingency and Escalation	2,331,000
CAPITAL COST	\$ 8,180,000

B. Cover East Hide Pile for Odor Control.

Relocate the South Hide Pile (include 25% swell up factor) to reshape the East Hide Pile Slope (allow for one half of costs).	\$ 292,000
Cover former South Hide Pile area with a 6" layer of top soil and vegetate.	10,000
Reshape the slopes of the East Hide Pile using South Hide materials (allow for one half of costs).	265,000
Drain wetlands with 60" dia. underground poly-ethylene pipe to stabilize hide pile slopes (allow for one half of costs).	200,000
Cover area with a 24" layer of offsite fill (includes 20% compaction factor).	132,000
Cover fill with a 6" layer of top soil and vegetate.	36,000
TOTAL DIRECTS	\$ 935,000

Site Overhead Costs	112,000
Surveying and Test Borings	
Dewatering	
Mobilization and Demobilization	
Equipment and Personnel Downtime	
Indirect Costs	157,000
Site Facility Costs	
Stauffer Engineering & Research Personnel	
Outside Analytical Contractors	
Sub-Total	\$ 1,204,000
Contingency and Escalation	486,000
CAPITAL COST	\$ 1,690,000

C. Gas Treatment for East Hide Pile Odor Control

Install a 12" layer of gravel with 6" perforated PVC pipe for gas gathering and venting system	\$ 98,000
Install Blower and Control System	50,000
Blower 0-150 Ft ³ 304SS	4,000
Foundation and Enclosure	8,000
Piping	8,000
Electrical	6,000
Instrumentation	4,000
Measurements	20,000
Install a Carbon Adsorption System	86,000
2000 Gal 304SS Vessels	12,000
Carbon	35,000
Foundations, Dike	16,000
Piping	21,000
Electrical	2,000
TOTAL DIRECTS	\$ 234,000
Construction Expense (5 months duration @ \$20,000/mo.)	100,000
Engineering (15% of Total Directs)	35,000
Sub-Total	\$ 369,000
Contingency and Escalation	\$ 131,000
CAPITAL COST	\$ 500,000

REMEDIAL ACTION PROGRAM
Woburn, Massachusetts

A/R 3955A004 - Phase III

OPTION VII - SUMMARY

Capital Cost

Contaminated Soils	\$17,940,000
Odor Control	
Cover	1,860,000
Gas Treatment	500,000
Total Capital Cost	\$20,300,000
Total 15-Year Monitoring Costs (Present Worth in 1985 Dollars)	950,000
Operating and Maintenance Costs (Present Worth in 1985 Dollars)	300,000
Total Implementation Cost	\$21,550,000

REMEDIAL ACTION PROGRAM
Woburn, Massachusetts

A/R 3955A004 - Phase III

OPTION VII

- A. Remove all As, Cr, Pb Waste Deposits with individual concentrations of one or more exceeding 100 PPM; consolidate on the East Central/West Hide deposit areas; and cover the East Central and the West Hide Deposit.

Consolidation of 460,000 CY of waste deposits on the approximately 15 acres of the East Central/West Hide Deposit area will raise the elevation by 18 to 20 feet. Therefore, increase surface area by 15% to account for height.

Cut, fill, regrade the top 12" of the existing East Central Hide Pile surface to develop new contours, eliminate water pockets, promote better drainage, etc.	\$ 118,000
Excavate and relocate (includes 25% swell up factor).	2,588,000
Backfill excavated areas (includes 20% compaction factor).	4,968,000
Cover area with a 6" layer of compacted sand. Install a 20 mil PVC membrane liner. Install a 6" layer of compacted sand over the PVC liner.	750,000
Cover liner and sand with a 12" layer of offsite fill (includes a 20% compaction factor).	300,000
Cover fill with a 6" layer of top soil and vegetate.	165,000
Relocate the South Hide Pile (include 25% swell up factor) to reshape the West Hide Pile slope (allow for one half of costs).	292,000
Cover former South Hide Area with a 6" layer of top soil and vegetate.	10,000
Reshape the slopes of the West Hide Pile using South Hide materials (allow for one half of costs).	265,000
Drain Wetlands with 60" dia. underground polyethylene pipe to stabilize hide pile slopes (allow for one half of costs).	200,000

Cover area with a 6" layer of compacted sand. Install a 20 mil PVC membrane liner. Install a 6" layer of compacted sand over the PVC liner.	180,000
Cover liner and sand with a 12" layer of offsite fill (includes 20% compaction factor).	72,000
Cover fill with a 6" layer of top soil and vegetate.	40,000
TOTAL DIRECTS	\$ 9,948,000
Site Overhead Costs	1,194,000
Surveying and Test Borings	
Dewatering	
Mobilization and Demobilization	
Equipment and Personnel Downtime	
Indirect Costs	1,671,000
Site Facility Costs	
Stauffer Engineering & Research Personnel	
Outside Analytical Contractors	
Sub-Total	\$12,813,000
Contingency and Escalation	5,127,000
CAPITAL COST	\$17,940,000

B. Cover East Hide Pile for Odor Control.

Relocate the South Hide Pile (include 25% swell up factor) to reshape the East Hide Pile Slope (allow for one half of costs).	\$ 292,000
Cover former South Hide Pile area with a 6" layer of top soil and vegetate.	10,000
Reshape the slopes of the East Hide Pile using South Hide materials (allow for one half of costs).	265,000
Drain Wetlands with 60" dia. underground poly- ethylene pipe to stabilize hide pile slopes (allow for one half of costs).	200,000
Cover area with a 6" layer of compacted sand. Install a 20 mil PVC membrane liner. Install a 6" layer of compacted sand over the PVC liner.	165,000

Cover liner and sand with a 12" layer of offsite fill (includes 20% compaction factor).	66,000
Cover fill with a 6" layer of top soil and vegetate.	36,000
TOTAL DIRECTS	\$ 1,034,000
Site Overhead Costs	124,000
Surveying and Test Borings	
Dewatering	
Mobilization and Demobilization	
Equipment and Personnel Downtime	
Indirect Costs	174,000
Site Facility Costs	
Stauffer Engineering & Research Personnel	
Outside Analytical Contractors	
Sub-Total	\$ 1,332,000
Contingency and Escalation	528,000
CAPITAL COST	\$ 1,860,000

C. Gas Treatment for East Hide Pile Odor Control

Install a 12" layer of gravel with 6" perforated PVC pipe for gas gathering and venting system		\$	98,000
Install Blower and Control System			50,000
Blower 0-150 Ft ³ 304SS	4,000		
Foundation and Enclosure	8,000		
Piping	8,000		
Electrical	6,000		
Instrumentation	4,000		
Measurements	20,000		
Install a Carbon Adsorption System			86,000
2000 Gal 304SS Vessels	12,000		
Carbon	35,000		
Foundations, Dike	16,000		
Piping	21,000		
Electrical	2,000		
	TOTAL DIRECTS	\$	234,000
Construction Expense (5 months duration @ \$20,000/mo.)			100,000
Engineering (15% of Total Directs)			35,000
	Sub-Total	\$	369,000
Contingency and Escalation		\$	131,000
	CAPITAL COST	\$	500,000

REMEDIAL ACTION PROGRAM
Woburn, Massachusetts

A/R 3955A004 - Phase III

OPTION VIII - SUMMARY

Capital Cost

Contaminated Soils	\$ 4,050,000
Odor Control	
Cover	1,860,000
Gas Treatment	500,000
Total Capital Cost	\$ 6,410,000
Total 15-Year Monitoring Costs (Present Worth in 1985 Dollars)	950,000
Operating and Maintenance Costs (Present Worth in 1985 Dollars)	300,000
Total Implementation Cost	\$ 7,660,000

REMEDIAL ACTION PROGRAM
Woburn, Massachusetts

A/R 3955A004 - Phase III

OPTION VIII

- A. Cover all As, Cr, Pb Waste Deposits with individual concentrations of one or more exceeding 100 PPM, and cover the East Central and the West Hide Deposit.

Limited excavation at the PX Engineering site.

Cut, fill, regrade the top 12" of the existing surface to develop new contours, eliminate water pockets, promote better drainage, etc.	\$ 706,000
Cover area with a 6" layer of top soil and vegetate.	621,000
Relocate the South Hide Pile (include 25% swell up factor) to reshape the West Hide Pile slope (allow for one half of costs).	292,000
Cover former South Hide Area with a 6" layer of top soil and vegetate.	10,000
Reshape the slopes of the West Hide Pile using South Hide materials (allow for one half of costs).	265,000
Drain Wetlands with 60" dia. underground polyethylene pipe to stabilize hide pile slopes (allow for one half of costs).	200,000
Cover area with a 6" layer of top soil and vegetate.	40,000
Excavate limited quantities of waste deposits from the PX engineering site. Transport to East/West Hide Deposit area (includes 25% swell-up factor).	38,000
Backfill excavated areas (includes 20% compaction factor).	77,000
TOTAL DIRECTS	\$ 2,249,000

Site Overhead Costs	270,000
Surveying and Test Borings	
Dewatering	
Mobilization and Demobilization	
Equipment and Personnel Downtime	
Indirect Costs	378,000
Site Facility Costs	
Stauffer Engineering & Research Personnel	
Outside Analytical Contractors	
Sub-Total	\$ 2,897,000
Contingency and Escalation	1,153,000
CAPITAL COST	\$ 4,050,000

B. Cover East Hide Pile for odor control.

Relocate the South Hide Pile (include 25% swell up factor) to reshape the East Hide Pile Slope (allow for one half of costs).	\$ 292,000
Cover former South Hide Pile area with a 6" layer of top soil and vegetate.	10,000
Reshape the slopes of the East Hide Pile using South Hide materials (allow for one half of costs).	265,000
Drain wetlands with 60" dia. underground poly-ethylene pipe to stabilize hide pile slopes (allow for one half of costs).	200,000
Cover area with a 6" layer of compacted sand. Install a 20 mil PVC membrane liner. Install a 6" layer of compacted sand over the PVC liner.	165,000
Cover liner and sand with a 12" layer of offsite fill (includes 20% compaction factor).	66,000
Cover fill with a 6" layer of top soil and vegetate.	36,000
TOTAL DIRECTS	\$ 1,034,000

Site Overhead Costs	124,000
Surveying and Test Borings	
Dewatering	
Mobilization and Demobilization	
Equipment and Personnel Downtime	
Indirect Costs	174,000
Site Facility Costs	
Stauffer Engineering & Research Personnel	
Outside Analytical Contractors	
Sub-Total	\$ 1,332,000
Contingency and Escalation	528,000
CAPITAL COST	\$ 1,860,000

C. Gas Treatment for East Hide Pile Odor Control

Install a 12" layer of gravel with 6" perforated PVC pipe for gas gathering and venting system	\$ 98,000
Install Blower and Control System	50,000
Blower 0-150 Ft ³ 304SS	4,000
Foundation and Enclosure	8,000
Piping	8,000
Electrical	6,000
Instrumentation	4,000
Measurements	20,000
Install a Carbon Adsorption System	86,000
2000 Gal 304SS Vessels	12,000
Carbon	35,000
Foundations, Dike	16,000
Piping	21,000
Electrical	2,000
TOTAL DIRECTS	\$ 234,000
Construction Expense (5 months duration @ \$20,000/mo.)	100,000
Engineering (15% of Total Directs)	35,000
Sub-Total	\$ 369,000
Contingency and Escalation	\$ 131,000
CAPITAL COST	\$ 500,000

REMEDIAL ACTION PROGRAM
Woburn, Massachusetts

A/R 3955A004 - Phase III

OPTION IX - SUMMARY

Capital Cost

Contaminated Soils \$ 2,320,000

Odor Control
Cover 1,860,000
Gas Treatment 500,000

Total Capital Cost \$ 4,680,000

Total 15-Year Monitoring Costs 950,000
(Present Worth in 1985 Dollars)

Operating and Maintenance Costs 300,000
(Present Worth in 1985 Dollars)

Total Implementation Cost \$ 5,930,000

**REMEDIAL ACTION PROGRAM
Woburn, Massachusetts**

A/R 3955A004 - Phase III

OPTION IX

- A. Fence areas of waste deposits, deed restrictions. Limited excavation at PX Engineering site. Cover the East Central and the West Hide Deposit.

Fencing Costs, Deed Restrictions:

<u>Area</u>	<u>Fencing Footage</u>	
PX Engineering	2700 LF	
Chromium Lagoons	1500	
Janpet	-	
Wedge Area	2000	
Arsenic/Phytotoxic Area	3000	
Stafford Lot	900	
	10100 LF	\$ 173,000

- Janpet - Presently fenced, therefore do nothing.
 Chromium Lagoons - Only the triangular shaped area between the mainline railroad right of way and west of the railroad siding is to be fenced.

Excavate limited quantities of waste deposits from the PX engineering site, transport to East/West Hide Deposit area (includes 25% swell up factor).	38,000
Backfill excavated areas (includes 20% compaction factor).	77,000
Cut, fill, regrade the top 12" of the existing East Central Hide Pile surface to develop new contours, eliminate water pockets, promote better drainage, etc.	118,000
Cover fill with a 6" layer of top soil and vegetate.	104,000
Relocate the South Hide Pile (include 25% swell up factor) to reshape the West Hide Pile slope (allow for one half of costs).	292,000
Cover former South Hide Area with a 6" layer of top soil and vegetate.	10,000

Reshape the slopes of the West Hide Pile using South Hide materials (allow for one half of costs).	265,000
Drain Wetlands with 60" dia. underground polyethylene pipe to stabilize hide pile slopes (allow for one half of costs).	200,000
Cover area with a 6" layer of top soil and vegetate.	40,000
TOTAL DIRECTS	\$ 1,317,000
Site Overhead Costs	167,000
Surveying and Test Borings	
Dewatering	
Mobilization and Demobilization	
Equipment and Personnel Downtime	
Indirect Costs	173,000
Site Facility Costs	
Stauffer Engineering & Research Personnel	
Outside Analytical Contractors	
Sub-Total	\$ 1,657,000
Contingency and Escalation	663,000
CAPITAL COST	\$ 2,320,000

B. Cover East Hide Pile for odor control.

Relocate the South Hide Pile (include 25% swell up factor) to reshape the East Hide Pile Slope (allow for one half of costs).	\$ 292,000
Cover former South Hide Pile area with a 6" layer of top soil and vegetate.	10,000
Reshape the slopes of the East Hide Pile using South Hide materials (allow for one half of costs).	265,000
Drain wetlands with 60" dia. underground polyethylene pipe to stabilize hide pile slopes (allow for one half of costs).	200,000
Cover area with a 6" layer of compacted sand. Install a 20 mil PVC membrane liner. Install a 6" layer of compacted sand over the PVC liner.	165,000
Cover liner and sand with a 12" layer of offsite fill (includes 20% compaction factor).	66,000
Cover fill with a 6" layer of top soil and vegetate.	36,000
TOTAL DIRECTS	\$ 1,034,000

Site Overhead Costs	124,000
Surveying and Test Borings	
Dewatering	
Mobilization and Demobilization	
Equipment and Personnel Downtime	
Indirect Costs	174,000
Site Facility Costs	
Stauffer Engineering & Research Personnel	
Outside Analytical Contractors	
Sub-Total	\$ 1,332,000
Contingency and Escalation	528,000
CAPITAL COST	\$ 1,860,000

C. Gas Treatment for East Hide Pile Odor Control

Install a 12" layer of gravel with 6" perforated PVC pipe for gas gathering and venting system	\$ 98,000
Install Blower and Control System	50,000
Blower 0-150 Ft ³ 304SS	4,000
Foundation and Enclosure	8,000
Piping	8,000
Electrical	6,000
Instrumentation	4,000
Measurements	20,000
Install a Carbon Adsorption System	86,000
2000 Gal 304SS Vessels	12,000
Carbon	35,000
Foundations, Dike	16,000
Piping	21,000
Electrical	2,000
TOTAL DIRECTS	\$ 234,000
Construction Expense (5 months duration @ \$20,000/mo.)	100,000
Engineering (15% of Total Directs)	35,000
Sub-Total	\$ 369,000
Contingency and Escalation	\$ 131,000
CAPITAL COST	\$ 500,000

REMEDIAL ACTION PROGRAM
Woburn, Massachusetts

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OPTION X - SUMMARY

Capital Cost

Contaminated Soils	\$ 8,980,000
Odor Control	
Cover	1,860,000
Gas Treatment	500,000
Total Capital Cost	\$11,340,000

Total 15-Year Monitoring Costs (Present Worth in 1985 Dollars)	950,000
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Operating and Maintenance Costs (Present Worth in 1985 Dollars)	300,000
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Total Implementation Cost	\$12,590,000
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REMEDIAL ACTION PROGRAM
Woburn, Massachusetts

A/R 3955A004 - Phase III

OPTION X

- A. Remove all As, Cr, Pb Waste Deposits with individual concentrations of one or more exceeding 100 PPM; consolidate on the East Central/West Hide deposit areas; and cover the East Central and the West Hide Deposit.

Consolidation of 460,000 CY of waste deposits on the approximately 15 acres of the East Central/West Hide Deposit area will raise the elevation by 18 to 20 feet. Therefore, increase surface area by 15% to account for height.

Cut, fill, regrade the top 12" of the existing East Central Hide Pile surface to develop new contours, eliminate water pockets, promote better drainage, etc.	\$ 118,000
Excavate and relocate (includes 25% swell up factor).	2,588,000
Cover area with a 6" layer of compacted sand. Install a 20 mil PVC membrane liner. Install a 6" layer of compacted sand over the PVC liner.	750,000
Cover liner and sand with a 12" layer of offsite fill (includes a 20% compaction factor).	300,000
Cover fill with a 6" layer of top soil and vegetate.	165,000
Relocate the South Hide Pile (include 25% swell up factor) to reshape the West Hide Pile slope (allow for one half of costs).	292,000
Cover former South Hide Area with a 6" layer of top soil and vegetate.	10,000
Reshape the slopes of the West Hide Pile using South Hide materials (allow for one half of costs).	265,000
Drain Wetlands with 60" dia. underground polyethylene pipe to stabilize hide pile slopes (allow for one half of costs).	200,000
Cover area with a 6" layer of compacted sand. Install a 20 mil PVC membrane liner. Install a 6" layer of compacted sand over the PVC liner.	180,000

Cover liner and sand with a 12" layer of offsite fill (includes 20% compaction factor).	72,000
Cover fill with a 6" layer of top soil and vegetate.	40,000
TOTAL DIRECTS	\$ 4,980,000
Site Overhead Costs	598,000
Surveying and Test Borings	
Dewatering	
Mobilization and Demobilization	
Equipment and Personnel Downtime	
Indirect Costs	837,000
Site Facility Costs	
Stauffer Engineering & Research Personnel	
Outside Analytical Contractors	
Sub-Total	\$ 6,415,000
Contingency and Escalation	2,565,000
CAPITAL COST	\$ 8,980,000

B. Cover East Hide Pile for Odor Control.

Relocate the South Hide Pile (include 25% swell up factor) to reshape the East Hide Pile Slope (allow for one half of costs).	\$ 292,000
Cover former South Hide Pile area with a 6" layer of top soil and vegetate.	10,000
Reshape the slopes of the East Hide Pile using South Hide materials (allow for one half of costs).	265,000
Drain wetlands with 60" dia. underground polyethylene pipe to stabilize hide pile slopes (allow for one half of costs).	200,000
Cover area with a 6" layer of compacted sand. Install a 20 mil PVC membrane liner. Install a 6" layer of compacted sand over the PVC liner.	165,000
Cover liner and sand with a 12" layer of offsite fill (includes 20% compaction factor).	66,000
Cover fill with a 6" layer of top soil and vegetate.	36,000
TOTAL DIRECTS	\$ 1,034,000

Site Overhead Costs	124,000
Surveying and Test Borings	
Dewatering	
Mobilization and Demobilization	
Equipment and Personnel Downtime	
Indirect Costs	174,000
Site Facility Costs	
Stauffer Engineering & Research Personnel	
Outside Analytical Contractors	
Sub-Total	\$ 1,332,000
Contingency and Escalation	528,000
CAPITAL COST	\$ 1,860,000

C. Gas Treatment for East Hide Pile Odor Control

Install a 12" layer of gravel with 6" perforated PVC pipe for gas gathering and venting system	\$ 98,000
Install Blower and Control System	50,000
Blower 0-150 Ft ³ 304SS	4,000
Foundation and Enclosure	8,000
Piping	8,000
Electrical	6,000
Instrumentation	4,000
Measurements	20,000
Install a Carbon Adsorption System	86,000
2000 Gal 304SS Vessels	12,000
Carbon	35,000
Foundations, Dike	16,000
Piping	21,000
Electrical	2,000
TOTAL DIRECTS	\$ 234,000
Construction Expense (5 months duration @ \$20,000/mo.)	100,000
Engineering (15% of Total Directs)	35,000
Sub-Total	\$ 369,000
Contingency and Escalation	\$ 131,000
CAPITAL COST	\$ 500,000

REMEDIAL ACTION PROGRAM
Woburn, Massachusetts

A/R 3955A004 - Phase III

Areas and Quantities of As, Cr, Pb Waste Deposits Greater than 100 PPM

A. CONTAMINATED SOILS

PX Engineering	6.07 acres	9,900 CY
Chromium Lagoons	8.23	107,300
Janpet	19.36	173,600
Wedge Area	5.82	37,900
Arsenic Pit/Phytotoxic Area	12.79	125,100
Stafford Lot	1.18	5,800
East Central Hide Deposit	10.75	142,000
West Hide Deposit	4.09	50,000
South Hide Deposit	2.00	85,000
	<u>70.29 acres</u>	<u>736,600 CY</u>

B. ODOR CONTROL

East Hide Deposit	3.75 acres	126,000 CY
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TOTALS	74.02 acres	862,600 CY
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One Acre = 44,000 SF

REMEDIAL ACTION PROGRAM
Woburn, Massachusetts

A/R 3955A004 - Phase III

OPTION XI - SUMMARY

Capital Cost

Contaminated Soils	\$ 5,270,000
Odor Control	
Cover	1,860,000
Gas Treatment	500,000
Total Capital Cost	\$ 7,630,000

Total 15-Year Monitoring Costs (Present Worth in 1985 Dollars)	950,000
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Operating and Maintenance Costs (Present Worth in 1985 Dollars)	300,000
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Total Implementation Cost	\$ 8,880,000
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REMEDIAL ACTION PROGRAM
Woburn, Massachusetts

A/R 3955A004 - Phase III

OPTION XI

- A. Cover all Waste Deposits, As greater than 300 PPM, Pb greater than 600 PPM, Cr greater than 1000 PPM, and cover the East Central and the West Hide Deposit.

Cut, fill, regrade the top 12" of the existing surface to develop new contours, eliminate water pockets, promote better drainage, etc.	\$ 388,000
Cover area with a 24" layer of offsite fill (includes 20% compaction factor).	1,241,000
Cover fill with a 6" layer of top soil and vegetate.	341,000
Relocate the South Hide Pile (include 25% swell up factor) to reshape the West Hide Pile slope (allow for one half of costs).	292,000
Cover former South Hide Area with a 6" layer of top soil and vegetate.	10,000
Reshape the slopes of the West Hide Pile using South Hide materials (allow for one half of costs).	265,000
Drain Wetlands with 60" dia. underground polyethylene pipe to stabilize hide pile slopes (allow for one half of costs).	200,000
Cover area with a 24" layer of offsite fill (includes 20% compaction factor).	144,000
Cover fill with a 5" layer of top soil and vegetate.	40,000
TOTAL DIRECTS	\$ 2,921,000

Site Overhead Costs	350,000
Surveying and Test Borings	
Dewatering	
Mobilization and Demobilization	
Equipment and Personnel Downtime	
Indirect Costs	491,000
Site Facility Costs	
Stauffer Engineering & Research Personnel	
Outside Analytical Contractors	
Sub-Total	\$ 3,762,000
Contingency and Escalation	1,508,000
CAPITAL COST	\$ 5,270,000

B. Cover East Hide Pile for Odor Control.

Relocate the South Hide Pile (include 25% swell up factor) to reshape the East Hide Pile Slope (allow for one half of costs).	\$ 292,000
Cover former South Hide Pile area with a 6" layer of top soil and vegetate.	10,000
Reshape the slopes of the East Hide Pile using South Hide materials (allow for one half of costs).	265,000
Drain wetlands with 60" dia. underground polyethylene pipe to stabilize hide pile slopes (allow for one half of costs).	200,000
Cover area with a 6" layer of compacted sand. Install a 20 mil PVC membrane liner. Install a 6" layer of compacted sand over the PVC liner.	165,000
Cover liner and sand with a 12" layer of offsite fill (includes 20% compaction factor).	66,000
Cover fill with a 6" layer of top soil and vegetate.	36,000
TOTAL DIRECTS	\$ 1,034,000

Site Overhead Costs	124,000
Surveying and Test Borings	
Dewatering	
Mobilization and Demobilization	
Equipment and Personnel Downtime	
Indirect Costs	174,000
Site Facility Costs	
Stauffer Engineering & Research Personnel	
Outside Analytical Contractors	
Sub-Total	\$ 1,332,000
Contingency and Escalation	528,000
CAPITAL COST	\$ 1,860,000

C. Gas Treatment for East Hide Pile Odor Control

Install a 12" layer of gravel with 6" perforated PVC pipe for gas gathering and venting system	\$ 98,000
Install Blower and Control System	50,000
Blower 0-150 Ft ³ 304SS	4,000
Foundation and Enclosure	8,000
Piping	8,000
Electrical	6,000
Instrumentation	4,000
Measurements	20,000
Install a Carbon Adsorption System	86,000
2000 Gal 304SS Vessels	12,000
Carbon	35,000
Foundations, Dike	16,000
Piping	21,000
Electrical	2,000
TOTAL DIRECTS	\$ 234,000
Construction Expense (5 months duration @ \$20,000/mo.)	100,000
Engineering (15% of Total Directs)	35,000
Sub-Total	\$ 369,000
Contingency and Escalation	\$ 131,000
CAPITAL COST	\$ 500,000

**REMEDIAL ACTION PROGRAM
Woburn, Massachusetts**

A/R 3955A004 - Phase III

OPTION XII - SUMMARY

Capital Cost

Contaminated Soils	\$ 2,980,000
Odor Control	
Cover	1,860,000
Gas Treatment	500,000
Total Capital Cost	\$ 5,340,000

Total 15-Year Monitoring Costs (Present Worth in 1985 Dollars)	950,000
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Operating and Maintenance Costs (Present Worth in 1985 Dollars)	300,000
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Total Implementation Cost	\$ 6,590,000
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REMEDIAL ACTION PROGRAM
Woburn, Massachusetts

A/R 3955A004 - Phase III

OPTION XII

- A. Cover all Waste Deposits, As greater than 300 PPM, Pb greater than 600 PPM, Cr greater than 1000 PPM, and cover the East Central and the West Hide Deposit. Limited excavation at the PX Engineering site.

Cut, fill, regrade the top 12" of the existing surface to develop new contours, eliminate water pockets, promote better drainage, etc.	\$ 388,000
Cover fill with a 6" layer of top soil and vegetate.	341,000
Relocate the South Hide Pile (include 25% swell up factor) to reshape the West Hide Pile slope (allow for one half of costs).	292,000
Cover former South Hide Area with a 6" layer of top soil and vegetate.	10,000
Reshape the slopes of the West Hide Pile using South Hide materials (allow for one half of costs).	265,000
Drain Wetlands with 50" dia. underground polyethylene pipe to stabilize hide pile slopes (allow for one half of costs).	200,000
Cover fill with a 6" layer of top soil and vegetate.	40,000
Excavate limited quantities of waste deposits from the PX engineering site. Transport to East/West Hide Deposit area (includes 25% swell-up factor).	38,000
Backfill excavated areas (includes 20% compaction factor).	77,000

TOTAL DIRECTS \$ 1,651,000

Site Overhead Costs	198,000
Surveying and Test Borings	
Dewatering	
Mobilization and Demobilization	
Equipment and Personnel Downtime	
Indirect Costs	277,000
Site Facility Costs	
Stauffer Engineering & Research Personnel	
Outside Analytical Contractors	
Sub-Total	\$ 2,126,000
Contingency and Escalation	854,000
CAPITAL COST	\$ 2,980,000

B. Cover East Hide Pile for Odor Control.

Relocate the South Hide Pile (include 25% swell up factor) to reshape the East Hide Pile Slope (allow for one half of costs).	\$ 292,000
Cover former South Hide Pile area with a 6" layer of top soil and vegetate.	10,000
Reshape the slopes of the East Hide Pile using South Hide materials (allow for one half of costs).	265,000
Drain wetlands with 60" dia. underground polyethylene pipe to stabilize hide pile slopes (allow for one half of costs).	200,000
Cover area with a 6" layer of compacted sand. Install a 20 mil PVC membrane liner. Install a 6" layer of compacted sand over the PVC liner.	165,000
Cover liner and sand with a 12" layer of offsite fill (includes 20% compaction factor).	66,000
Cover fill with a 6" layer of top soil and vegetate.	36,000
TOTAL DIRECTS	\$ 1,034,000

Site Overhead Costs	124,000
Surveying and Test Borings	
Dewatering	
Mobilization and Demobilization	
Equipment and Personnel Downtime	
Indirect Costs	174,000
Site Facility Costs	
Stauffer Engineering & Research Personnel	
Outside Analytical Contractors	
Sub-Total	\$ 1,332,000
Contingency and Escalation	528,000
CAPITAL COST	\$ 1,860,000

C. Gas Treatment for East Hide Pile Odor Control

Install a 12" layer of gravel with 6" perforated PVC pipe for gas gathering and venting system	\$ 98,000
Install Blower and Control System	50,000
Blower 0-150 Ft ³ 304SS	4,000
Foundation and Enclosure	8,000
Piping	8,000
Electrical	6,000
Instrumentation	4,000
Measurements	20,000
Install a Carbon Adsorption System	86,000
2000 Gal 304SS Vessels	12,000
Carbon	35,000
Foundations, Dike	16,000
Piping	21,000
Electrical	2,000
TOTAL DIRECTS	\$ 234,000
Construction Expense (5 months duration @ \$20,000/mo.)	100,000
Engineering (15% of Total Directs)	35,000
Sub-Total	\$ 369,000
Contingency and Escalation	\$ 131,000
CAPITAL COST	\$ 500,000

REMEDIAL ACTION PROGRAM
Woburn, Massachusetts

A/R 3955A004 - Phase III

MONITORING AND MAINTENANCE COSTS

Annual Inspection of Remedial Action Program

53 Acres Contaminated Soil
21 Hide Areas
74 Acres

Allow for visual inspection of .5 Hr/Acre
or 40 Hours

25 Hours Report Writing
65 Hours X \$45 = \$ 2,900
Travel Expenses 800
\$ 3,700

ANNUAL MAINTENANCE COSTS

Mowing costs twice per year @ .50 Hrs/Ac. @ \$50/Hr.
74 x .50 x 2 x \$50 = \$ 3,700

Revegetation costs once per year (Orig. seeding costs
@ \$1800/Ac., for revegetation use 15%)
74 Ac. x \$1800 x .15 = \$20,000

Erosion Control, Drainage Maintenance.
Allow for \$100/Ac. Per Year (EPA Report)
74 Ac. x \$100 = \$ 7,000

Allowance for Shrink/Swell, Freeze/Thaw Repairs \$ 600

Sub-Total \$35,000

CONTINGENCY & ESCALATION 10,000

TOTAL YEARLY COST \$45,000

SEMI ANNUAL SAMPLING AND ANALYSIS COSTS

Purging and Pumping Wells, Collecting and Delivering Samples:

1 Day	Prep	
1	Purge, Pump	
1	Collect, Deliver	
2	Travel	
5 Days x 8 Hrs. x 2 People X \$75/Hr.		\$ 6,000
(ERC \$36/Hr. x 25% Anal. O/H +		
59% ERC O/H) =		X 2
		<u>\$12,000</u>
+ Travel Exp. @ \$100/Day = 5x100x2x2		4,000
		<u>\$16,000</u>

Analysis Costs		
15 Samples Per Trip @ \$600 Ea.		\$ 9,000
		X 2
		<u>\$18,000</u>

	Sub Total	\$34,000
CONTINGENCY		11,000
	TOTAL	<u>\$45,000</u>

ASSUME THAT AIR SAMPLING OF HIDE PILE GAS IS DONE EITHER WHEN WATER SAMPLING IS DONE OR WHEN ANNUAL INSPECTION IS DONE.

	Monitoring Maintenance	\$45,000
	Sampling Analysis	<u>45,000</u>
TOTAL YEARLY MONITORING AND MAINTENANCE COSTS		\$90,000

ALLOW FOR 6% ANNUAL INFLATION PER ANNUM DISCOUNTD AT 12% PER ANNUM FOR 15 YEARS TO DETERMINE TOTAL MONITORING AND MAINTENANCE COSTS (PRESENT WORTH IN 1985 DOLLARS)

<u>YEAR</u>	<u>P.W.+6%</u>	<u>DISCOUNT FACTOR</u>	<u>P.W. DISCOUNTED</u>
1	\$ 90,000	-	\$ 90,000
2	95,400	.893	85,192
3	101,124	.797	80,595
4	107,190	.712	76,320
5	113,623	.635	72,150
6	120,440	.567	68,290
7	127,667	.507	64,727
8	135,327	.452	61,168
9	143,446	.404	57,952
10	152,053	.361	54,891
11	161,176	.322	51,899
12	170,847	.287	49,033
13	181,098	.257	46,542
14	191,963	.229	43,960
15	203,481	.205	<u>41,714</u>
			\$944,433

TOTAL MONITORING AND MAINTENANCE COSTS
(Present Worth in 1985 Dollars)

\$950,000

REMEDIAL ACTION PROGRAM
Woburn, Massachusetts

A/R 3955A004 - Phase III

OPERATING AND MAINTENANCE COSTS VENT GAS HANDLING

<u>Supplies</u>		-
<u>Electricity</u>		\$ 5,000
Blower 5HP	3.7 KW	
Lighting and Instr. Requirements	1.0	
	<u>4.7 KW/HR @ .12/KWH</u>	
<u>Maintenance</u>		3,000
Capital Costs of Blower System is \$50,000		
Assume Maintenance @ 5% (\$60,000 x 5%)		
<u>Operation and Supervision</u>		
Included with Operating Costs of Groundwater Treatment		<u>-</u>
	Sub Total	\$ 8,000
Contingency		<u>2,500</u>
TOTAL OPERATING AND MAINTENANCE COSTS		\$10,500

Allow for 6% annual inflation per annum discounted at 12% per annum for 15 years to determine total operating and maintenance costs (present worth in 1985 dollars).

<u>YEAR</u>	<u>P.W.+6%</u>	<u>DISCOUNT FACTOR</u>	<u>P.W. DISCOUNTED</u>
1	\$10,500	-	\$10,500
2	11,130	.893	9,939
3	11,798	.797	9,403
4	12,506	.712	8,904
5	13,256	.635	8,418
6	14,051	.567	7,967
7	14,894	.507	7,551
8	15,788	.452	7,136
9	16,735	.404	6,761
10	17,339	.361	6,404
11	18,804	.322	6,055
12	19,932	.287	5,720
13	21,128	.257	5,430
14	22,396	.229	5,129
15	23,739	.205	4,867
			\$110,184

TOTAL OPERATING AND MAINTENANCE COSTS **\$110,000**
VENT GAS HANDLING
(Present worth in 1985 Dollars)

REMEDIAL ACTION PROGRAM
Woburn, Massachusetts

A/R 3955A004 - Phase III

OPERATING AND MAINTENANCE COSTS ACTIVATED CARBON SYSTEM

IVP Carbon with Na Ott Onsite Regeneration

<u>Supplies</u>	\$ 6,000
Assume Replacement of Carbon Every Five Years 12,000# @ \$2.70/# = $\frac{\$32,400}{5}$ =	
<u>Regeneration</u>	\$ 4,000
Soak Carbon in Dilute Na Ott for 24 Hours \$600/Day for Truck Rental \$500 for 300 Gal. Na Ott \$300 for Acid 2 Men for 3 Days @ \$25/Hr	
<u>Electricity</u>	-
<u>Maintenance</u>	4,000
Capital Costs of Carbon Adsorption System is \$81,000 Assume Maintenance @ 5% (\$81,000 x 5%)	
<u>Operation and Supervision</u>	
Included with Operating Costs of Groundwater Treatment	-
Sub Total	\$14,000
Contingency	<u>4,000</u>
TOTAL OPERATING AND MAINTENANCE COSTS	\$18,000

Allow for 6% annual inflation per annum discounted at 12% per annum for 15 years to determine total operating and maintenance costs (present worth in 1985 dollars).

<u>YEAR</u>	<u>P.W.+6%</u>	<u>DISCOUNT FACTOR</u>	<u>P.W. DISCOUNTED</u>
1	\$18,000	-	\$18,000
2	19,080	.893	15,130
3	20,225	.797	16,119
4	21,438	.712	15,264
5	22,725	.635	14,430
6	24,088	.567	13,658
7	25,533	.507	12,945
8	27,065	.452	12,233
9	28,689	.404	11,590
10	30,411	.361	10,978
11	32,235	.322	10,380
12	34,169	.287	9,807
13	36,219	.257	9,308
14	38,393	.229	8,792
15	40,696	.205	<u>8,343</u>
			\$186,977

TOTAL OPERATING AND MAINTENANCE COSTS **\$190,000**
ACTIVATED CARBON SYSTEM
(Present worth in 1985 Dollars)

**REMEDIAL ACTION PROGRAM
Woburn, Massachusetts**

A/R 3955A004 - Phase III

CAPITAL COSTS THERMAL OXIDATION

Process Equipment			
Incinerator 150,000 BTU/HR		\$28,000	
Vent Gas Blower 20 ACFM, 304 SS		4,000	
Propane Storage Tank 3,000 Gal.		20,000	
			\$ 52,000
Substructures			7,000
Superstructures			3,000
Rigging			3,000
Piping			36,000
Electrical			12,000
Instrumentation			10,000
Insulation			6,000
Painting			3,000
		TOTAL DIRECTS	\$132,000
Construction Expense			
4 months Duration @ \$20,000/Month			80,000
Premium on Overtime			2,000
Engineering			17,000
Incinerator	\$28,000 @ 5%		
Other	\$104,000 @ 15%		
Punch List			2,000
Spare Parts			3,000
		Sub Total	\$236,000
Contingency and Escalation			74,000
		Capital Cost	\$310,000

Total 15-year Monitoring Costs
(Present worth in 1985 dollars)

Included with Area
Covering Costs

Operating and Maintenance Costs
(Present worth in 1985 dollars)

380,000

TOTAL IMPLEMENTATION COST

\$690,000

REMEDIAL ACTION PROGRAM
Woburn, Massachusetts

A/R 3955A004 - Phase III

OPERATING AND MAINTENANCE COSTS THERMAL OXIDATION

<u>Supplies</u>	\$20,000
1.5 Gal. of Propane per hour @ \$1.90 Gal.	
<u>Electrical</u>	1,000
Assume majority of electric costs will be with Blower System, therefore allow for minor electric costs	
<u>Maintenance</u>	7,000
Use E. Stocker 3/6/85 Flare Estimate of \$132,000 Capital Assume 5% of Capital (\$132,000 x 5%)	
<u>Operation and Supervision</u>	
Included with operating costs of Groundwater Treatment	-
	<u>Sub Total</u>
	\$28,000
Contingency	<u>8,000</u>
TOTAL OPERATING AND MAINTENANCE COSTS	\$36,000

Allow for 6% annual inflation per annum discounted at 12% per annum for 15 years to determine total operating and maintenance costs (present worth in 1985 dollars).

<u>YEAR</u>	<u>P.W.+6%</u>	<u>DISCOUNT FACTOR</u>	<u>P.W. DISCOUNTED</u>
1	\$36,000	-	\$36,000
2	38,160	.893	34,077
3	40,450	.797	32,238
4	42,877	.712	30,528
5	45,450	.635	28,860
6	48,177	.567	27,316
7	51,067.	.507	25,891
8	54,131	.452	24,478
9	57,379	.404	23,181
10	60,822	.361	21,957
11	64,471	.322	20,760
12	68,339	.287	19,613
13	72,440	.257	18,617
14	76,786	.229	18,617
15	81,393	.205	<u>16,686</u>
			\$377,786

TOTAL OPERATING AND MAINTENANCE COSTS **\$380,000**
THERMAL OXIDATION
(Present worth in 1985 Dollars)

REMEDIAL ACTION PROGRAM
Woburn, Massachusetts

A/R 3955A004 - Phase III

Incremental Costs Using Thermal Oxidation for Odor Control Gas
Treatment In Lieu of Activated Carbon

	<u>CAPITAL \$</u>	<u>O. & M. \$</u>
Vent Gas Collection	\$316,000	\$110,000
Thermal Oxidation	310,000	380,000
Vent Gas Collection	316,000	110,000
Activated Carbon	184,000	190,000
	<hr/>	<hr/>
Total Increases	\$126,000	\$190,000

O. & M. Costs are for 15 years
(Present worth in 1985 Dollars)

**REMEDIAL ACTION PROGRAM
Woburn, Massachusetts**

A/R 3955A004 - Phase III

CAPITAL COST INTERCEPTOR WELL SYSTEM - HOT SPOT RECOVERY

DRILL FIVE INTERCEPTOR WELLS	\$	24,000
SUPPLY AND INSTALL FIVE 10-20 GPM SUBMERSIBLE 316SS IMPELLOR PUMPS		5,000
SUPPLY AND INSTALL WELL MANIFOLD AND DISCHARGE LINE		17,000
ELECTRIC SUPPLY FOR PUMPS		1,000
MISCELLANEOUS		2,000
INSTALL EIGHT 2" dia. PIEZOMETER WELLS		10,000
GROUNDWATER CONSULTANTS COSTS		26,000
Interceptor Wells		
Piezometer Wells		
Pumping Test		
Start-up		
Pumping OW-16		
Report Writing and Issue		
SITE IMPROVEMENTS		
.5 Acres of Land	53,000	
30' x 40' Pre-engineered Building	76,000	
40' x 50' Curbed Concrete Slabs	11,000	
50' x 60' Fenced Enclosure	5,000	
Site Lighting, Grounding	4,000	
Furniture, Safety Supplies	1,000	
		150,000
VOC STRIPPING COST		
100 GPM Pump C.I.	3,000	
1000 ACFM Blower FRP	2,000	
Two 48"dia.x35' High Packed Towers 304SS	66,000	
Piping, Valves	9,000	
Electrical	1,000	
Instrumentation	5,000	
Painting	1,000	
		87,000

ODOR REMOVAL

5% Fe Cl ₂ Tank 200 Gal. PPL	1,000
50% H ₂ O ₂ Tank 7000 Gal. Alum.	21,000
Groundwater Tnk 8000 Gal Fiberglass	10,000
Mixer 316 SS	2,000
Metering Pumps (2) 0 to 1.7 GPM	1,000
Pulsefeeders (2) 3 GPH 316SS	1,000
Agitator 1/3 HP 304 SS	1,000
Agitator 5 HP 304 SS	3,000
Piping, Valves	7,000
Electrical	5,000
Instrumentation	-
Insulation	1,000
Paint	1,000

54,000

TOTAL DIRECTS \$ 376,000

CONSTRUCTION EXPENSE

6 Months Duration @ \$20,000/Month 120,000

PREMIUM ON OVERTIME 5,000

ENGINEERING 50,000

Wells \$85,000 @ 5%
Other \$150,000 + 87,000 + 54,000 @ 15%

PUNCH LIST 5,000

SPARE PARTS 8,000

Sub-Total \$ 564,000

CONTINGENCY & ESCALATION 226,000

CAPITAL COST \$ 790,000

Total 15-Year Monitoring Costs (Present Worth in 1985 Dollars) Included with Area Covering Costs

Operating and Maintenance Costs (Present Worth in 1985 Dollars) 140,000

TOTAL IMPLEMENTATION COST \$ 930,000

REMEDIAL ACTION PROGRAM
Woburn, Massachusetts

A/R 3955A004 - Phase III

CAPITAL COST INTERCEPTOR WELL SYSTEM - 110 GPM

COSTS OF FIVE INTERCEPTOR WELL SYSTEMS		\$	85,000
COSTS OF:			
Site Improvements	150,000		
VOC Stripping	87,000		
Odor Control	54,000		
			291,000
	TOTAL DIRECTS	\$	376,000
INDIRECT COSTS			
Construction Expense	120,000		
Premium on Overtime	5,000		
Engineering	50,000		
Punch List	5,000		
Spare Parts	8,000		
			188,000
	Sub-Total	\$	564,000
CONTINGENCY & ESCALATION			226,000
	Sub-Total	\$	790,000
BOD Removal Costs from "Handbook for Remedial Action at Waste Disposal Sites" EPA-625/6-82-006, June 1982, Pg. 229. Package Plant; Activated Sludge; Extended Aeration; 2 Stages; Includes Chlorination and Secondary Clarification.			460,000
	TOTAL CAPITAL COST	\$	1,250,000
Total 15 Year Monitoring Costs (Present Worth in 1985 Dollars)			Included with Waste Area Covering Costs
Operating and Maintenance Costs (Present Worth in 1985 Dollars)			2,360,000
	TOTAL IMPLEMENTATION COST	\$	3,610,000

**REMEDIAL ACTION PROGRAM
Woburn, Massachusetts**

A/R 3955A004 - Phase III

CAPITAL COST INTERCEPTOR WELL SYSTEM - 360 GPM

COSTS OF FIVE INTERCEPTOR WELL SYSTEMS		\$ 110,000
<p>\$85,000. Costs are increased 30% to account for larger diameter wells and installation of two wells in a lake in lieu of dry land.</p>		
COSTS OF:		
Site Improvements	150,000	
VOC Stripping	87,000	
Odor Control	54,000	
Increase Size of Ageing Tank in Odor Control	21,000	
		312,000
	TOTAL DIRECTS	\$ 422,000
CONSTRUCTION EXPENSE		140,000
7 Months @ \$20,000/Month		
PREMIUM ON OVERTIME		5,000
ENGINEERING		53,000
Wells - \$110,000 @ 5%		
Other - \$150,000 + 87,000 + 75,000 @ 15%		
PUNCH LIST		5,000
SPARE PARTS		8,000
	Sub-Total	\$ 633,000
CONTINGENCY & ESCALATION		257,000
	Sub-Total	\$ 890,000
BOD Removal Costs from "Handbook for Remedial Action at Waste Disposal Sites" EPA-625/6-82-006, June 1982, Pg. 229. Package Plant; Activated Sludge; Extended Aeration; 2 Stages; Includes Chlorination and Secondary Clarification.		460,000
	TOTAL CAPITAL COST	\$1,350,000
Total 15 Year Monitoring Costs (Present Worth in 1985 Dollars)		Included with Waste Area Covering Costs
Operating and Maintenance Costs (Present Worth in 1985 Dollars)		2,360,000
	TOTAL IMPLEMENTATION COST	\$3,710,000

REMEDIAL ACTION PROGRAM
Woburn, Massachusetts

A/R 3955A004 - Phase III

OPERATING AND MAINTENANCE COSTS INTERCEPTOR WELLS
HOT SPOT RECOVERY

Operating and Maintenance Costs for minimum six month
Duration is estimated at \$140,000.

**REMEDIAL ACTION PROGRAM
Woburn, Massachusetts**

A/R 3955A004 - Phase III

OPERATING AND MAINTENANCE COSTS INTERCEPTOR WELLS 110 GPM

Supplies		\$14,000
H ₂ O ₂	84#/day @ .45/#	\$13,800
FeCl ₂	Negligible amount per year	200
Electrical		32,000
Well Pumps (5)	7.5 HP	
Stripper Pump (2)	6.	
Blowers (2)	10.	
Metering Pumps (2)	2.	
Agitator (2)	6.	
	<u>31.5 HP or 23.5 KW</u>	
Building and Site Lighting 30'x40'	5.0	
Heat Tracing	1.8	
Assume 5 Watts/LF of Pipe		
100 feet of 2"0 Pipe		
6 mo. Usage Factor		
.6 Utilization Factor		
	<u>30.3 KW/HR @</u>	
	\$.12/KWH	
Heating		5,000
Assume 20 Gal/Day of Propane @ \$1.50/Gal. for Six Months		
Maintenance		19,000
Assume 5% of Capital Cost (\$376,000 x 5%)		
Operation and Supervision		88,000
Assume Eight Hour Shift, 365 Days @ \$30/Hour		
	Sub Total	<u>\$158,000</u>

REMEDIAL ACTION PROGRAM
Woburn, Massachusetts

A/R 3955A004 - Phase III

OPERATING AND MAINTENANCE COSTS BOD REMOVAL SYSTEM

<u>Supplies</u>		-
<u>Electrical</u>		3,000
Rotating Disc Aerator	3 HP	
Blowers	1	
	<hr/>	
	4 HP or 2.98 KW/HR	
	@ \$.12/KWH	
<u>Heating</u>		-
<u>Maintenance</u>		12,000
Assume half of total cost of \$460,000 is equipment. Maintenance costs are 5% (\$230,000 x 5%)		
<u>Operation and Supervision</u>		-
Included with Interceptor Wells		
		<hr/>
	Sub Total	15,000
TOTAL INTERCEPTOR WELLS		\$158,000
BOD REMOVAL		15,000
	Sub Total	\$173,000
Contingency		<u>52,000</u>
	TOTAL OPERATING AND MAINTENANCE COSTS	\$225,000

Allow for 6% annual inflation per annum discounted at 12% per annum for 15 years to determine total operating and maintenance costs (present worth in 1985 dollars).

<u>YEAR</u>	<u>P.W.+6%</u>	<u>DISCOUNT FACTOR</u>	<u>P.W. DISCOUNTED</u>
1	\$225,000	-	\$225,000
2	238,500	.893	212,980
3	252,810	.797	201,490
4	267,978	.712	190,800
5	284,057	.635	180,376
6	301,101	.567	170,724
7	319,167	.507	161,818
8	338,317	.452	152,919
9	358,616	.404	144,881
10	380,133	.361	137,228
11	402,941	.322	129,747
12	427,117	.287	122,583
13	452,744	.257	116,355
14	479,909	.229	109,899
15	508,703	.205	<u>104,284</u>
			\$2,361,084

TOTAL OPERATING AND MAINTENANCE COSTS **\$2,360,000**
INTERCEPTOR WELLS AND BOD REMOVAL SYSTEM
(Present worth in 1985 Dollars)

REMEDIAL ACTION PROGRAM
Woburn, Massachusetts

A/R 3955A004 - Phase III

OPERATING AND MAINTENANCE COSTS INTERCEPTOR WELLS 360 GPM

Total Operating and Maintenance Costs \$2,360,000
(Present worth in 1985 dollars)

Assumed to be the same as 110 GPM

**REMEDIAL ACTION PROGRAM
Woburn, Massachusetts**

A/R 3955A004 - Phase III

CAPITAL COST HEAVY METALS REMOVAL SYSTEM 110 GPM

Process Equipment		
Sulfex TM Process consisting of Single Stage Neutralization followed by 2-Stage Clarification, Filtration and Sludge Dewatering		\$646,000
50% Caustic Storage and Feed System 5,000 Gal.		22,000
Sludge Conveyor		12,000
		\$680,000
Safety and Fire Equipment		4,000
Building		
30'W.x80'L. Pre-engineered, Insulated Building		151,000
Substructures		50,000
Rigging		26,000
Piping		29,000
Electrical		78,000
Instrumentation		22,000
Insulation		3,000
Painting		6,000
	TOTAL DIRECTS	\$1,049,000
Construction Expense		
6 months duration @ \$20,000/month		120,000
Premium on Overtime		5,000
Engineering		100,000
Package	\$600,000 @ 5%	
Other	\$449,000 @ 15%	
Punch List		10,000
Spare Parts		14,000
	Sub Total	\$1,298,000

Contingency and Escalation	392,000
Sub Total	\$1,690,000
Allowance for .5 acre Land Purchase, Site Improvements, Fence	110,000
Capital Cost	\$1,800,000
15-Year Monitoring Costs (Present worth in 1985 dollars)	NONE
Operating and Maintenance Costs (Present worth in 1985 dollars)	\$2,200,000
TOTAL IMPLEMENTATION COST	\$4,000,000

REMEDIAL ACTION PROGRAM
Woburn, Massachusetts

A/R 3955A004 - Phase III

CAPITAL COST HEAVY METALS REMOVAL SYSTEM 360 GPM

Process Equipment	\$1,360,000
Sulfex TM Process for 110 GPM Scaled up to 360 GPM using .6 Scale Up Factor	
Safety and Fire Equipment	4,000
Building	
40'W.x100'L. Pre-engineered Insulated Building	250,000
Substructures	95,000
Rigging	54,000
Piping	54,000
Electrical	163,000
Instrumentation	41,000
Insulation	9,000
Painting	5,000
	TOTAL DIRECTS \$2,035,000
Construction Expense	
6 months duration @ \$20,000/month	120,000
Premium on Overtime	5,000
Engineering	169,000
Package \$1,360,000 @ 5%	
Other \$ 675,000 @ 15%	
Punch List	20,000
Spare Parts	27,000
	Sub Total \$2,376,000

Contingency and Escalation		714,000
	Sub Total	\$3,090,000
Allowance for .5 acre Land Purchase, Site Improvements, Fence		60,000
	Capital Cost	\$3,150,000
15-Year Monitoring Costs (Present worth in 1985 dollars)		NONE
Operating and Maintenance Costs (Present worth in 1985 dollars)		\$4,100,000
	TOTAL IMPLEMENTATION COST	\$7,250,000

**REMEDIAL ACTION PROGRAM
Woburn, Massachusetts**

A/R 3955A004 - Phase III

OPERATING AND MAINTENANCE COSTS HEAVY METALS REMOVAL SYSTEM
110 GPM

<u>Supplies</u>		\$26,000
Total Reagents Cost	\$22,400	
(F. Heinze 11/6/85 memo E/R 1600E423)		
50% caustic 10 Gal/Day, 12.76#/Gal @ .0787#	3,600	
<u>Electrical</u>		53,000
Sulfex System Horsepower		
Assume 50HP or	37.3 KW	
Building and Site Lighting 30'x80'	10.0	
Heat Tracing	2.7	
Assume 5 Watts/LF of Pipe		
150 feet of 2"0 Pipe		
6 mo. Usage Factor		
.6 Utilization Factor		
	<u>50.0 KW/HR @</u>	
	\$.12/KWH	
<u>Heating</u>		14,000
Assume 50 Gal/Day of Propane @ \$1.50/Gal.		
for six months		
<u>Maintenance</u>		52,000
Assume 5% of Capital Cost (\$1,049,000 x 5%)		
<u>Operation and Supervision</u>		
Included with Operating Costs of Interceptor		
Well System		
<u>Disposal Costs</u>		15,000
Sub Total		\$160,000
Contingency		<u>50,000</u>
TOTAL OPERATING AND MAINTENANCE COSTS		\$210,000

Allow for 6% annual inflation per annum discounted at 12% per annum for 15 years to determine total operating and maintenance costs (present worth in 1985 dollars).

<u>YEAR</u>	<u>P.W.+6%</u>	<u>DISCOUNT FACTOR</u>	<u>P.W. DISCOUNTED</u>
1	\$210,000	-	\$210,000
2	222,600	.893	198,782
3	235,956	.797	188,057
4	250,113	.712	178,080
5	265,120	.635	168,351
6	281,027	.567	159,342
7	297,889	.507	151,030
8	315,762	.452	142,724
9	334,708	.404	135,222
10	354,791	.361	128,080
11	376,078	.322	121,097
12	398,643	.287	114,411
13	422,561	.257	108,598
14	447,915	.229	102,573
15	474,790	.205	<u>97,332</u>
			\$2,203,679

TOTAL OPERATING AND MAINTENANCE COSTS **\$2,200,000**
HEAVY METALS REMOVAL SYSTEM 110 GPM
(Present worth in 1985 Dollars)

**REMEDIAL ACTION PROGRAM
Woburn, Massachusetts**

A/R 3955A004 - Phase III

**OPERATING AND MAINTENANCE COSTS HEAVY METALS REMOVAL SYSTEM
360 GPM**

<u>Supplies</u>		\$26,000
Same as 110 GPM		
<u>Electrical</u>		140,000
Power 150 HP or	112 KW	
Lighting	15	
Heat Tracing	5	
	<u>132 KW/HR @ \$.12/KWH</u>	
<u>Heating</u>		20,000
<u>Maintenance</u>		101,000
Assume 5% of Capital Cost (\$2,035,000 x 5%)		
<u>Operation and Supervision</u>		
Same as 110 GPM		
<u>Disposal Costs</u>		
Same as 110 GPM		<u>15,000</u>
	Sub Total	\$302,000
Contingency		<u>88,000</u>
	TOTAL OPERATING AND MAINTENANCE COSTS	\$390,000

Allow for 6% annual inflation per annum discounted at 12% per annum for 15 years to determine total monitoring and maintenance costs (present worth in 1985 dollars).

For 110 GPM System Annual O&M Cost	\$ 210,000
15-year O&M Costs (Present worth)	\$2,200,000

$$\frac{\$2,200,000}{\$210,000} = 10.5$$

Therefore for 360 GPM Annual O&M Cost	\$390,000
	X <u>10.5</u>

TOTAL OPERATING AND MAINTENANCE COSTS HEAVY METALS REMOVAL SYSTEM **\$4,100,000**
360 GPM
(Present worth in 1985 dollars)

REMEDIAL ACTION PROGRAM
Woburn, Massachusetts

A/R 3955A004 - Phase III

CAPITAL COSTS SLURRY CUT-OFF WALL

350 LF x 3 Foot High Slurry Cut-off Wall @ \$7.50/SF for Bentonite Clay/Soil Mixture and/or Grout/Soil Mixture.	\$ 74,000
Allowance for Rock Excavation (1,000 CY).	30,000
Load and Haul Excavated Materials for Onsite Disposal (14,000 CY).	14,000
Trench Shoring (50 LF) Four Uses.	3,000
	<hr/>
Sub-Total	\$121,000
Indirects, Contingency, Escalation @ 100%	119,000
	<hr/>
CAPITAL COST	\$240,000

Note: Slurry wall installation is required if native rock on east side of the East Hide Deposit is fractured or removed.

REMEDIAL ACTION PROGRAM
Woburn, Massachusetts

A/R 3955A004 - Phase III

Costs for limited utility line excavation over a 15-year period would be covered by a \$200,000 provision.

Assume an average of three excavations per year for repairs, new tie-ins, or slip lining of existing sewer and water lines.

Assume 10'W. x 10'L. x 5'T. waste layer = 19 CY
Increase by 15% to cover swell-up,
thicker waste layers, etc.

	3
	<u>22</u> CY
	3
Yearly waste volume	<u>66</u> CY

From Option II, Costs To Excavate, Haul, And Dispose At Model City, N.Y. Hazardous Waste Landfill

66 CY @ \$280/CY = \$19,000 Annual Cost

x10.5 Multiplier

\$200,000 Total Provision
For 15-year Period
For Limited Utility
Excavation

**REMEDIAL ACTION PROGRAM
Woburn, Massachusetts**

A/R 3955A004 - Phase III

UNIT PRICES

Unit prices used in the estimate were taken from the following Woburn estimates:

Arsenic and Lead Containment Facility	CO-4-008	4/30/84
Remedial Action Program-Phase II	CO-4-009	7/03/84
In-Place Remedial Action Program	CO-4-012	12/06/84

MATERIAL Costs

<u>Item</u>	<u>Unit</u>	<u>Unit Cost</u>	<u>Source</u>
60" Dia. Polyethy. Pipe	LF	\$118.00	Spiral Engineered Sys., Norcross, Ga.
6" Dia. PVC Perforated Pipe including Fittings	LF	1.90	Richardson 84/85 Section 2.30
Gravel	CY	11.00	C. J. Mabardy Cambridge, Mass.
Silt	CY	6.00	Roma Stone Co. Woburn, Mass.
Bentonite Clay	Ton	160.00	American Colloid Skokie, Ill.
Soil Cover	CY	4.00	Roma Stone Co. Woburn, Mass.

Note: All material costs are April, 1984.

INSTALLATION Costs

60" Dia. Polyethy. Pipe	LF	\$ 11.00	Richardson 84/85 Section 2.34 Modified
6" Dia. PVC Perforated Pipe including Fittings	LF	0.75	Richardson 84/85 Section 2.3
Spread Gravel	CY	1.97	Richardson 84/85 Section 2.43

Silt/Bentonite Clay Cap	SF	0.39	Richardson 84/85 Sections 2.2, 2.7, 2.48
Soil Cover 12" Thick	SF	0.13	Richardson 84/85
6" Thick	SF	0.06	Section 2.2
Hydraulic Seeding including Mulch	SY	0.37	Means 1984
Hide Pile Excavation	CY	1.13	Richardson 84/85 Section 2.18
Hide Pile Material Loading & Hauling Onsite	CY	3.24	Richardson 84/85 Section 2.23
Rock Excavation and Onsite Disposal	CY	28.00	Richardson 84/85 Section 2.19
Trenching for 60" Pipe Including Excavation and Backfill	LF	36.00	Richardson 84/85 Sections 2.14, 2.21
East/West Hide Pile Re- shaping Costs Using CAT D-8K Bulldozers	CY	4.90	Richardson 84/85 Section 2.4
Swales	LF	8.25	Richardson 84/85 Section 2.24
10' High Cyclone Fence	LF	16.25	Woburn-Phase II Costs Escalated
Re-contouring Costs using CAT-D-8K Bulldozers (Costs vary with depth of soil being moved)	SF	0.10 to 0.28	Richardson 84/85 Section 2.4
4" Dia. 50' Deep Inter- ceptor Wells	LF	90.00	Woburn-Phase II Costs Escalated
Two-Man Survey Party	HR	103.00	Richardson 84/85 Section 1.0

Note: Labor costs are Boston area union scale.

The preceding unit prices were escalated to bring them up to present day costs.

Unit prices used to develop the costs of Options I thru XII.

<u>Item</u>	<u>Unit</u>	<u>Unit Cost</u>
Regrading	SF	\$ 0.25
Clay Barrier 10 ⁻⁷ 24" Thick	SF	3.50
Clay Barrier 10 ⁻⁷ 6" Thick	SF	0.90
6" Top Soil and Vegetate	SF	0.22
Transport Hide Deposits Onsite	CY	5.50
Transport Waste Deposits Offsite	CY	150.00
Reshaping East/West Hide Pile Slopes	CY	5.00
Compacted Backfill Installed	CY	9.00
Compacted Sand Bed Installed 6" Thick	SF	0.30
20 Mil PVC Membrane	SF	0.40
Construct RCRA Onsite Landfill	CY	31.00
Remove Wastes to RCRA Onsite Landfill and Replace with Clean Backfill	CY	18.10
Supply and Install Buried 60" Dia. Polyethylene Pipe	LF	200.00

The cost of imported fill is based on the assumption that the necessary quantities are available within a reasonable travel distance. The unavailability of fill in the area could raise the total cost considerably, but this possibility has not been taken into consideration. The cost of fill could also decrease if advertisements for fill are issued and contractors are encouraged to use the site to spoil their excess clean excavation materials.

**REMEDIAL ACTION PROGRAM
Woburn, Massachusetts**

A/R 3955A004 - PHASE III

ESTIMATED QUANTITIES OF FILL, BENTONITE CLAY, SAND AND TOP SOIL

		<u>CY FILL</u>	<u>TN CLAY</u>	<u>CY SAND</u>	<u>CY TOP SOIL</u>
OPTION I					
Contaminated Soil	68.29A.	278,000	24,000	-	56,000
Odor Control	3.75A.	15,000	1,300	-	4,700
OPTION II					
Contaminated Soil	68.29A.	885,000	-	-	-
Odor Control	3.75A.	151,000	-	-	-
OPTION III					
Contaminated Soil	68.29A.	133,000	-	111,000	-
Odor Control	3.75A.	7,300	-	6,100	4,700
OPTION IV					
Contaminated Soil	68.29A.	278,000	6,000	-	56,000
Odor Control	3.75A.	15,000	300	-	4,700
OPTION V					
Contaminated Soil	68.29A.	Size of RCRA Landfill Not Determined			
Odor Control	3.75A.				
Backfill Contaminated Soil		885,000	-	-	-
Backfill Odor Control		151,000	-	-	-
OPTION VI					
Contaminated Soil	68.29A.	278,000	-	-	56,000
Odor Control	3.75A.	15,000	-	-	4,700
OPTION VII					
Contaminated Soil	68.29A.	34,000	-	28,000	56,000
Odor Control	3.75A.	7,300	-	6,100	4,700
Backfill of Excav. Areas		552,000	-	-	-
OPTION VIII					
Contaminated Soil	68.29A.	-	-	-	56,000
Odor Control	3.75A.	7,000	-	6,100	4,700
Backfill of Excav. Areas		10,000	-	-	-

OPTION IX

Contaminated Soil	68.29A.	-	-	6,100	9,600
Odor Control	3.75A.	7,300	-	-	4,700
Backfill of Excav. Areas		10,000	-	-	-

OPTION X

Contaminated Soil	68.29A.	34,000	-	28,000	56,000
Odor Control	3.75A.	7,300	-	6,100	4,700

OPTION XI

Contaminated Soil	39.35A.	154,000	-	-	32,000
Odor Control	3.75A.	7,300	-	6,100	4,700

OPTION XII

Contaminated Soil	39.35A.	-	-	-	32,000
Odor Control	3.75A.	7,300	-	6,100	4,700
Backfill of Excav. Areas		10,000	-	-	-

NOTES:

- Option I Clay is mixed at rate of 4#/SF for each of four 6" lifts. Fill requirements include 25% compaction factor.
- Option II Backfill requirements include 20% compaction factor.
- Option IV Clay is mixed at rate of rate of 4#/SF. Fill requirements include 25% compaction factor.
- Option V Size of RCRA landfill not determined.
- Option VII Surface area of East Central/West hide area increased by 15% to cover height of relocated wastes. Backfill requirements exclude east central and west hide deposits.
- Option IX Only the east central and the hide deposits are covered with top soil.
- All Options Fill requirements include 20% compaction factor. Top soil requirements for odor control include covering former south hide pile area.

APPENDIX J

APPENDIX J

Yale University New Haven, Connecticut 06510

SCHOOL OF MEDICINE
333 Cedar Street
Department of Laboratory Medicine

October 6, 1982

Dr. Herbert Northrop
Stauffer Chemical Company
Westport, Ct.

Dear Dr. Northrop:

I have microbiologically analyzed the results of the samples you sent to me from Woburn, Massachusetts. This letter represents a summary of my findings. The individual data sheets, containing a detailed description of the processing of the specimens, are in my files and are available to Stauffer upon request.

-Using techniques to isolate both pathogenic and the common soil microbes, your specimens contained no virulent microorganisms. Predominant in the soil samples were fungi of various genera: Mucor, Rhizopus, Penicillium, Aspergillus, Paecilomyces, and Cladosporium. The major genera of bacteria were Azotobacter, Clostridium, Pseudomonas, Acetobacter, and Erwinia. There were other fungi, yeasts, and molds present in small numbers that I did not feel significant.

None of the above mentioned microbes, I feel, were present in sufficient numbers or in relatively high proportions to warrant their being considered a potential hazard for the workers on site.

Sincerely,

Dr. Stephen C. Edberg / dag

Stephen C. Edberg, Ph.D., D.A.B.M.M.
Director, Clinical Microbiology Laboratory
Yale-New Haven Hospital
Associate Professor of Laboratory Medicine
Yale University School of Medicine

SCE:dag

(dictated by Dr. Edberg and signed in his absence)