1,2-Dichlorobenzene

1,2-Dichlorobenzene (1,2-DCB) is used as an intermediate chemical in chemical manufacturing, metal polishing agents, and industrial odor control. When ingested, approximately 100% of the 1,2-DCB will be absorbed by the body. Approximately 30% will be absorbed if the 1,2-DCB is inhaled.

Acute and long-term exposures of humans and animals to 1,2-DCB result in central nervous system (CNS) depression, blood dyscrasias, and lung, kidney, and liver damage. No available data suggest that 1,2-DCB is carcinogenic to humans or animals.

1,4-Dichlorobenzene

1,4-Dichlorobenzene, or p-DCB, is a colorless solid with a characteristic penetrating odor. It is transformed to is vapor state when exposed to air. p-DCB is used as an insecticide and a deodorant and disinfectant in restrooms.

p-DCB is released to the air, surface, and groundwater during its manufacture and use. It can enter the body through the lungs or skin and will be absorbed into the bloodstream relatively quickly when ingested. Exposure to high levels of p-DCB are sometimes associated with headaches and dizziness. Death could result from exposure to very high levels, but such levels are associated with an intense, possibly intolerable odor that serves as a danger warning.

After long-term inhalation or ingestion, p-DCB has been observed to cause toxic effects in the liver and kidneys of laboratory animals. Although there is no evidence that p-DCB can cause cancer in humans, increased incidence of cancer has been observed in laboratory animals treated with p-DCB in lifetime studies. At present, p-DCB is classified as a Group C possible human carcinogen. Some evidence also exists from animal studies that birth defects can result from p-DCB exposure.

1,1-Dichloroethane (1,1-DCA)

1,1-DCA is a synthetic organic chemical which is used industrially as a solvent and in the formation of other chemicals. Human exposure to 1,1-DCA can result from breathing contaminated air or eating or drinking contaminated food or water. 1,1-DCA is expected to rapidly enter the body following exposure by these routes. Relatively little information is available on the health effects of 1,1-DCA in humans or animals. 1,1-DCA was once used as an anesthetic gas, although this use was discontinued when it was discovered that cardiac arrhythmias were induced at anesthetic doses (105,000 mg/m^3). Exposure of pregnant rats to 7,067 mg/m^3 for ten days in air resulted in birth defects in the offspring.

No MRLs for adverse effects for the oral or inhalation routes of exposure have been calculated.

1,2-Dichloroethane (1,2-DCA)

1,2-DCA is a synthetic organic chemical used primarily in the synthesis of other solvents--particularly those that remove grease, glue, and dirt. It is also found in commercial and household cleaning agents. Humans are exposed to 1,2-DCA primarily by breathing air containing its vapors or by drinking contaminated water. 1,2-DCA can also enter the body through the skin. The lungs, liver, and kidneys are the organs primarily affected in humans and animals exposed to 1,2-DCA. It has caused cancer in laboratory animals when administered in high doses in the diet or on the skin and is classified as a Group B2 probable human carcinogen.

A short-term exposure MRL of 0.025 ppm in air or 0.026 ppm in water has been derived based on animal studies. Exposure to air concentrations above this level may result in an increased susceptibility to infection and liver, kidney, and/or blood disorders. The long-term MRL of 0.021 ppm in air or 0.5 ppm in food was also derived from animal studies. Effects seen at concentrations greater than the MRL included liver, kidney, and/or heart disease, and death. The MRLs were derived based on potential noncarcinogenic effects and does not consider the presence, absence or level of risk of cancer.

1,1-Dichloroethene

1,1-Dichloroethene (1,1-DCE) is a man-made chemical that does not occur naturally in the environment. It is a clear, colorless liquid that has a mild, sweet, chloroform-like odor. 1,1-DCE is used to make plastic products such as Saranwrap and flame-retardant fabrics.

1,1-DCE usually enters the body via inhalation and/or ingestion. It may also enter the body through the skin. The human health effects resulting from exposure to 1,1-DCE are unknown. In animal studies, brief exposures to high concentrations of 1,1-DCE have caused liver, kidney, heart and lung damage, nervous system disturbances, and death. Prolonged exposure to lower concentrations of 1,1-DCE has also produced liver damage. An increased risk for cancer was observed in animals exposed to 1,1-DCE, as were birth defects in the offspring of exposed pregnant animals. Based upon animal studies, 1,1-DCE is classified as a Group C possible human carcinogen. MRLs for short- and long-term exposures (also based upon animal studies) are, respectively, 0.1 and 0.004 ppm in air and 4 and 10 ppm in food and/or water.

1,2-Dichloroethene (1,2-DCE)

1,2-DCE is a synthetic organic chemical which is primarily used in the production of solvents and as an additive to dyes, lacquer solutions, perfumes, and thermoplastics. There are two forms of 1,2-DCE--cis-1,2-DCE and trans-1,2-DCE, which may occur separately or as a mixture. 1,2-DCE can enter the body through drinking water, eating food, or breathing air which contains 1,2-DCE. Inhalation of high levels of 1,2-DCE can cause nausea, drowsiness, and may result in death. Liver, heart, and lung damage were observed in laboratory animals after short- or long-term exposure to 1,2-DCE in air or food. Humans exposed to 1,2-DCE vapors reported nausea, fatigue, dizziness, and intracranial pressure at vapor concentrations greater than 4.8 ppm. The relative potencies of the cis- and trans- isomers have not been adequately characterized to allow conclusions as to their individual potential to cause adverse health effects.

MRLs have not been derived for 1,2-DCE.

1,2-Dichloropropane

1,2-Dichloropropane is a man-made colorless liquid that has a chloroform-like odor and evaporates quickly at room temperature. Prior to the early 1980s, 1,2-Dichloropropane was used in farming as a soil fumigant and was found in some paint strippers, varnishes, and furniture finish removers. Its only current uses in the United States are in research and industrial applications.

1,2-Dichloropropane enters the body primarily through eating, drinking, or inhalation. The amount able to enter the body following skin contact is unknown. Ingestion of high levels of 1,2-Dichloropropane can produce poisoning, with effects including dizziness, headache, nausea, damage to liver and kidneys, anemia, coma, and, ultimately, death. Inhalation of high levels of the substance produces similar effects. The health effects of both short- and long-term low-level exposure to 1,2-Dichloropropane are unknown, as are the dosages that could result in adverse effects in humans.

The MRLs (derived from animal data) for short- and long-term exposure, respectively, are 50 and 7 ppb in air and 3.6 and 2.5 ppb in food or drinking water.

Based on increased cancer rates seen in long-term oral-ingestion studies in animals, 1,2-Dichloropropane is classified as a Group B2 probable human carcinogen.

Manganese

Manganese is a naturally-occurring element used in the steel industry, metallurgical processing, and as a component of dry cell batteries. Manganese is an essential element and is a co-factor for a number of enzymatic reactions. A World Health Organization committee concluded that an intake of 2-3 mg/day was adequate for adults. Absorption of manganese from the gastrointestinal tract is controlled by homeostatic mechanisms. Following inhalation exposure, manganese absorption into the bloodstream occurs only if particles are sufficiently small to be able to penetrate deep into the lungs. In humans, manganese dusts and compounds have relatively low oral and dermal toxicity, but may cause a variety of toxic effects if inhaled. Chronically inhaled manganese dust may result in a psychiatric disorder characterized by irritability, difficulty in walking, and speech disturbances. Acute inhalation exposure has been associated with respiratory disease. Ambient air concentrations associated with toxicity in miners ranged from 0.5 to 46 mg/m^3 and exposure ranged from 9 months to 16 years.

Methylene Chloride (Dichloromethane, MC)

MC is an organic solvent that is widely used as an industrial solvent and as a paint stripper. Absorption into the body occurs readily following exposure by breathing vapors or accidental ingestion. Occupational worker exposure to MC in air resulted in effects including drowsiness, fatigue, lack of appetite, and lightheadedness. The lowest ambient air concentration identified in the literature associated with adverse effects is 33.57 ppm (69.3 mg/m^3). Effects included impaired performance of time-sharing tasks and increased magnitudes of finger tremors. Chronic exposure of laboratory animals to MC by inhalation resulted in an increased incidence of kidney tumors in male mice but not in female mice or male and female rats. Methylene chloride is classified as a Group B2 probable human carcinogen. MRLs for noncarcinogenic effects have not been derived.

Naphthalene

Naphthalene is used as a chemical intermediate in the synthesis of a number of compounds (e.g., dyes and resins) and as a component of mothballs. Naphthalene can enter the body when breathing air and by eating or drinking food or water contaminated with naphthalene, or through contact with skin. Hemolytic anemia (a condition involving the breakdown of red blood cells) is the primary health concern for humans exposed to naphthalene for either short or long exposure periods. Other effects associated with exposure to naphthalene include nausea, diarrhea, vomiting, and kidney and liver damage. Cataracts have been reported to occur in the eyes of some exposed humans. Cancer has not been seen in humans or animals exposed to naphthalene.

Insufficient studies are available on the naphthalene concentrations which produce adverse health effects in humans or animals to derive MRLs. Ambient air concentrations greater than 20 parts per billion (ppb) were reported as resulting in anemia, nausea, and abdominal pain in humans. Ingestion of napthalene at concentrations greater than 2,000 ppm was lethal to laboratory animals.

Phenol

Phenol is found in nature but is primarily a man-made chemical with a sickeningly sweet and irritating odor. When pure, it is a colorless or white solid. However, it is usually used in liquid form, primarily by the plastics industry. It is also used as a disinfectant and an ingredient in some cough medications.

The health effects resulting from short- and long-term exposure of humans to phenol in air, food, and water are unknown. On the skin, however, phenol produces irritation, burns, and blisters. Death can result following exposure of more than 25% of the body surface to even weak solutions of phenol. The MRL (based upon animal studies) is 100 ppm in food or water.

1,1,2,2-Tetrachloroethane

1,1,2,2-Tetrachloroethane is a man-made, colorless, dense liquid with a penetrating, sweet, chloroform-like odor. In the past, it was used in large amounts as a chemical intermediate and as an industrial solvent. It was also used to clean and degrease metals and as an ingredient in paints and other substances. Present use of 1,1,2,2-Tetrachloroethane appears to be limited, but information regarding this use is unavailable.

1,1,2,2-Tetrachloroethane can enter the body through ingestion, inhalation, or skin contact. Exposure to large amounts by ingestion, inhalation, or dermal contact can cause fatigue, vomiting, dizziness, and possibly unconsciousness. The concentrations required to produce effects via inhalation are high enough that the sickeningly sweet smell would be noticeable. Most people will recover from these effects after exposure ends. The human health effects from long-term exposure to small amounts of the chemical are not known. 1,1,2,2-tetrachloroethane was found to cause liver cancer in mice but not in rats. It is classifed as a Group C possible human carcinogen.

Tetrachloroethene (Perchloroethene, PCE)

PCE is a synthetic organic chemical which is widely used for dry cleaning fabrics, for metal-degreasing operations, and in the manufacture of other chemicals. Humans may be exposed to PCE by breathing air or ingesting food or water which have been contaminated with it. Exposure to high concentrations in air, particularly in confined areas, can cause central nervous system effects which may be expressed as dizziness, headache, sleepiness, confusion, nausea, and possibly unconsciousness and death. Animal studies, conducted with concentrations much higher than those usually encountered in the environment, suggest that PCE can cause liver and kidney damage, developmental effects on fetuses, toxicity to pregnant animals, liver cancer, and leukemia. Based on the evidence from animal studies, PCE is classified as a Group B2 probable human carcinogen.

MRLs have been derived based on noncarcinogenic effects for short-term and long-term inhalation exposure, and long-term oral exposure. The MRLs for short-term and long-term exposure by inhalation are 1.0 ppm and 0.0125 ppm in air, respectively. Concentrations above the MRL may result in effects such as liver and kidney toxicity, dizziness, headache, and sleepiness. The MRL for long-term oral exposure is 0.125 mg/kg/day. At concentrations above the MRL, liver and kidney toxicity and shortened life span may occur based on effects observed in laboratory animal studies.

Toluene

Toluene is used as a solvent in the production of a variety of products and as a constituent in the formulation of automotive and aviation fuels. Toluene can affect the body if it is inhaled, comes in contact with the eyes or skin, or is swallowed. It may also enter the body through the skin. Toluene may cause irritation of the eyes, respiratory tract, and skin, fatigue, weakness, confusion, headache, dizziness, and drowsiness. These symptoms have been reported in association with occupational exposure to airborne concentrations of toluene ranging from 50 ppm (189 mg/m^3) to 1,500 ppm (5,660 mg/m^3). These symptoms generally increase in severity with increases in toluene concentration.

The MRL for short-term exposure to toluene in air is 1.0 ppm. The MRL for long-term exposure to toluene in air is 0.3 ppm (1.1 mg/m^3). The MRL for oral exposure to toluene is 460 and 84 ppm for short- and long-term exposures, respectively.

1,1,1-Trichloroethane (1,1,1-TCA)

1,1,1-TCA is a man-made chemical which has many industrial and household uses. For example, it is used as a cleaning solvent to remove oil or grease from manufactured metal parts, and as a solvent to dissolve other substances such as glue and paint. 1,1,1-TCA is readily absorbed into the body following exposure by inhalation of air containing the vapor and ingestion of water or food containing 1,1,1-TCA. It also readily leaves the body with exhaled air. Inhalation of high levels of 1,1,1-TCA for a short time by humans resulted in effects such as dizziness, lightheadedness, and loss of balance and coordination.

The MRL derived for short-term exposure to 1,1,1-TCA in air is 0.255 ppm. Studies in animals have shown that mild liver effects result from long-term exposure. The long-term effects of exposure in humans has not been established. A long-term exposure MRL has not been derived.

Trichloroethene (TCE)

TCE is used as a cleaning agent and solvent for degreasing operations. TCE may cause adverse health effects following exposure via inhalation, ingestion, or skin or eye contact. TCE may cause drowsiness, dizziness, headache, blurred vision, lack of coordination, mental confusion, flushed skin, tremors, nausea, vomiting, fatigue, and heart arrhythmia. Exposure of laboratory animals to TCE has been associated with an increased incidence of a variety of tumors and TCE is considered a Group B2 probable human carcinogen. MRLs for noncarcinogenic effects have been derived for oral and inhalation exposure.

The MRL for TCE in air is 0.1 ppm for both short- and long-term exposures. The MRL for ingestion of TCE is 0.125 ppm for short-term and 0.1 ppm for long-term exposures.

Vinyl Chloride (VC)

VC is primarily used in the chemical manufacturing industry in the production of polymeric chemicals which are in turn used to manufacture a variety of plastic and vinyl products. VC may cause adverse health effects following exposure by inhalation, ingestion, or by dermal or eye contact. VC has been shown to cause liver and lung cancer in rats, and liver cancer was reported in workers occupationally exposed to air concentrations in the range of less than 25 ppm to greater than 200 ppm. Based on this evidence, VC is classified as a Group A human carcinogen. Air standards as low as 1 ppm are specified for occupational exposure to

Based on this evidence, VC is classified as a Group A human carcinogen. Air standards as low as 1 ppm are specified for occupational exposure to VC in many countries.

Noncarcinogenic effects associated with exposure include hepatitis-like changes in the liver, thyroid depression, alteration in blood chemistries, and dermatitis. MRLs for VC have not been derived.

Xylenes

Xylenes are natural components of coal tar and petroleum. The majority of xylenes used commercially are man-made. There are three isomers of xylene (ortho-, meta-, and para-xylene), which can occur as a mixture and are referred to herein as xylenes. Xylenes are used in solvent mixtures and cleaning agents, and as an ingredient in airplane fuel and gasoline. Exposure to xylene may occur by breathing xylene fumes, or eating or drinking xylene-contaminated food or water. Xylene is rapidly absorbed following inhalation or ingestion. Short-term exposure of humans to high levels of xylene (100-299 ppm) causes irritation of the skin, eyes, nose and throat, increased reaction time to a visual stimulus, impaired memory, stomach discomfort, and possible changes in the liver and kidneys. Long-term exposure of laboratory animals to xylene in air (12-800 ppm) resulted in changes in the cardiovascular system, changes in liver weights, and hearing loss.

No studies were located regarding the long-term effects of inhalation or ingestion of xylene by humans. Xylene may be fatal if large enough concentrations are inhaled or ingested. Ingestion of 5,000 ppm of xylene in food by laboratory rats resulted in impaired visual function. Decreased body weight and increased numbers of birth defects in unborn rats were observed at higher concentrations. MRLs have not been derived for the oral or inhalation exposure routes.

5.4.3 QUANTITATIVE INDICES OF TOXICITY

Quantitative indices of toxicity were compiled for the dose-response assessment to be used to estimate the relationship between the extent of exposure to a contaminant and the potential increased likelihood and/or severity of adverse effects. The methods for deriving indices of toxicity and to estimate potential adverse effects are presented below. The indices of toxicity for the chemicals of concern are presented at the end of the section.

5.4.3.1 Categorization of Chemicals as Carcinogens or Noncarcinogens

For the purpose of this risk assessment, the chemicals of concern were divided into two groups: potential carcinogens and noncarcinogens. The risks posed by these two types of compounds are assessed differently because noncarcinogens generally exhibit a threshold dose below which no adverse effects occur, while no such threshold can be proven to exist for carcinogens.

As used here, the term carcinogen means any chemical for which there is sufficient evidence that exposure may result in continuing uncontrolled cell division (cancer) in humans and/or animals. Conversely, the term noncarcinogen means any chemical for which the carcinogenic evidence is negative or insufficient. These definitions are dynamic; compounds may be reclassified any time additional evidence becomes available which shifts the weight-of-evidence one way or the other.

Chemicals of concern have been classified as carcinogens or noncarcinogens based on weight-of-evidence criteria contained in the EPA Carcinogenicity Evaluation Guidelines (1986b). Table 5-26 summarizes the five EPA weight-of-evidence categories. According to these EPA guidelines, chemicals in the first two groups--A and B (B1 or B2)--are considered human carcinogens or probable human carcinogens based on sufficient evidence and should be the subject of nonthreshold carcinogenic risk estimation procedures. Depending upon the quality of the data, Group C chemicals may also be subjected to these procedures. The remaining chemicals--in Groups D and E--are defined as noncarcinogens and should be subjected to threshold-based toxicological risk estimation procedures.

5.4.3.2 Assessment of Noncarcinogens

Risks associated with noncarcinogenic effects (e.g., organ damage, immunological effects, birth defects, skin irritation) are usually assessed by comparing the estimated average exposure to the acceptable

Table 5-26

FIVE EPA WEIGHT-OF-EVIDENCE CATEGORIES FOR CHEMICAL CARCINOGENICITY

Group	Description
A	Human Carcinogen - sufficient evidence from epidemiological studies
B	Probable Human Carcinogen -
B1	o At least limited evidence of carcinogenicity to humans
B2	o Usually a combination of sufficient evidence for animals and inadequate data for humans
C	Possible Human Carcinogen - limited evidence of carcinogenicity in animals in the absence of human data
D	Not Classified - inadequate animal evidence of carcinogenicity
E	No Evidence of Carcinogenicity for Humans - no evidence of carcinogenicity in at least two adequate animal tests in different species or in both epidemiological and animal studies

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Source: EPA 1986b.

daily dose, now called the "reference dose" (RfD) by EPA. The RfD is selected by identifying the lowest reliable no observed or lowest observed adverse effect level (NOAEL or LOAEL) in the scientific literature, then applying a suitable uncertainty factor (usually ranging from 10 to 1,000) to allow for differences between the study conditions and the human exposure situation to which the acceptable daily dose is to be applied. NOAELs and LOAELs are usually based on laboratory experiments on animals in which relatively high doses are used. Consequently, uncertainty or safety factors are required when deriving RfDs to compensate for data limitations in the experiments and the lack of precision in extrapolating from high doses in animals to lower doses in humans. The five uncertainty factors commonly used are summarized in Table 5-27. Modifying factors are additional adjustment factors based on professional judgment and are incorporated in order to compensate for factors other than the usual uncertainty adjustments.

RfDs are generally calculated using the formula:

$$\text{RfD (in mg/kg/day)} = \frac{\text{NOAEL or LOAEL (in mg/kg/day)}}{\text{(Uncertainty Factor)} \times \text{(Modifying Factor)}}$$

If the estimated exposure exceeds the estimated acceptable intake, some adverse effects are presumed to be possible and that exposure level may be of potential concern. Conversely, if the estimated exposure is less than the estimated acceptable intake, no adverse affects would be expected and the exposure level is considered acceptable. Noncarcinogenic risks are usually assessed by calculating a hazard index which is the ratio of the estimated exposure to the RfD as follows:

$$HI = \frac{ADI}{RfD}$$

where

HI = Hazard Index

ADI = Average Daily Intake (exposure)

RfD = Reference Dose (acceptable daily intake).

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Table 5-27

UNCERTAINTY FACTORS (MARGINS OF SAFETY) USED IN THE DERIVATION OF REFERENCE DOSES

Uncertainty Factor	Condition of Use
10	A 10-fold uncertainty factor is used with valid experimental results on appropriate durations of exposures of humans.
100	A 100-fold uncertainty factor is used when human data are not available and extrapolation is made from valid results of long-term animal studies.
1,000	A 1,000-fold uncertainty factor is used when human data are not available and extrapolation is made from animal studies of less than chronic exposure.
1-10	An additional uncertainty factor from 1 to 10 when using a lowest observed adverse effect level (LOAEL) instead of a no observed adverse effect level (NOAEL).
Intermediate uncertainty factor	Other uncertainty factors used, according to scientific judgment, when justified.

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Source: EPA 1986a.

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A hazard index greater than 1 indicates that adverse effects may be possible while a value less than 1 means that adverse effects would not be expected. The higher the hazard index is above 1, the more likely that adverse effects would occur.

EPA is in the process of developing subchronic RfDs based on potential noncarcinogenic effects associated with exposures ranging from a few weeks to seven years. Short-term exposures can occur when an activity resulting in exposure is performed for a limited period of time or when a chemical degrades or disperses to negligible concentrations within a short period. The hazard index for subchronic exposure is obtained by dividing the estimated average daily dose by the subchronic RfDs.

Chronic and subchronic RfDs for the oral and inhalation exposure routes are presented in Table 5-28. Other entries in the table that have not been previously discussed are as follows. The **CONFIDENCE LEVEL** indicates the degree of confidence that should be placed in the RfD value and is usually obtained from the Integrated Risk Information System (IRIS) entry for a chemical. The **CRITICAL EFFECT** is the effect or target organ affected by the smallest dose of the chemical that produces any adverse effect and which serves as the basis for the RfD. The **RfD SOURCE** is the source or reference for the RfD. The preferred source is EPA's IRIS data base, which contains confirmed values reflecting the consensus judgment of the agency. The second choice is the EPA's Health Effects Assessment Summary Tables (HEAST), which contain information taken from final documents prepared by the EPA Office of Health and Environmental Assessment. The third choice are values from other EPA documents, and the fourth choice would be values derived directly from the general literature. The **RfD BASIS** is the vehicle in which the chemical was administered or the medium of exposure in the study(ies) that served as the basis for the RfD.

5.4.3.3 Assessment of Carcinogens

In contrast to noncarcinogenic effects, for which thresholds are thought to exist, scientists have been unable to demonstrate experimentally a threshold for carcinogenic effects. This has led to the assumption by federal regulatory agencies (e.g., EPA, Food and Drug Administration (FDA), and Occupational Safety and Health Administration (OSHA))

Table 5-28

TOXICITY VALUES FOR POTENTIAL NONCARCINOGENIC EFFECTS

Chemical	Reference Dose (RfD) Route	Type	Value (mg/kg-day)	Confidence Level	Critical Effects	RfD Basis/ Source	Uncertainty (UF) and Modifying (MF) Factors
Antimony	Oral	Chronic	4×10^{-4}	Low	Reduced lifespan, altered blood chemistry	Drinking water/ IRIS	UF=1,000 MF=1
		Subchronic	4×10^{-4}	Low	Reduced lifespan, altered blood chemistry	Drinking water/ IRIS	UF=1,000 MF=1
	Inhalation	Chronic	4×10^{-4}	—	—	Extrapolated from oral value	—
		Subchronic	4×10^{-4}	—	—	Extrapolated from oral value	—
Arsenic	Oral	Chronic	1×10^{-3}	NS	Keratosis and Hyperpigmentation	Human/HEAST	UF=1
		Subchronic	1×10^{-3}	NS	Keratosis and Hyperpigmentation	Human/HEAST	UF=1
	Inhalation	Chronic	1×10^{-3}	—	—	Extrapolated from oral value	—
		Subchronic	1×10^{-3}	—	—	Extrapolated from oral value	—
Barium	Oral	Chronic	7×10^{-2}	Medium	Increased blood pressure	Drinking water/ IRIS	UF=3 MF=1
		Subchronic	7×10^{-2}	Medium	Increased blood pressure	Drinking water/ IRIS	UF=3 MF=1
	Inhalation	Chronic	1×10^{-4}	NS	Fetotoxicity	Inhalation/HEAST	UF=1,000
		Subchronic	1×10^{-3}	NS	Fetotoxicity	Inhalation/HEAST	UF=100

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Key at end of table.

Table 5-28 (Cont.)

Chemical	Route	Type	Reference Dose (RfD) Value (mg/kg-day)	Confidence Level	Critical Effects	RfD Basis/ Source	Uncertainty (UF) and Modifying (MF) Factors
Benzoic acid	Oral	Chronic	4	Medium	Irritation, malaise	Oral/IRIS	UF=1 MF=1
		Subchronic	4	NS	Irritation, malaise	Oral/HEAST	UF=1
	Inhalation	Chronic	4	—	—	Extrapolated from oral value	—
		Subchronic	4	—	—	Extrapolated from oral value	—
Beryllium	Oral	Chronic	5×10^{-3}	NS	None observed	Rat-Gavage/Heast	UF=100
		Subchronic	5×10^{-3}	NS	None observed	Rat-Gavage/Heast	UF=100
	Inhalation	Chronic	5×10^{-3}	—	—	Extrapolated from oral value	—
		Subchronic	5×10^{-3}	—	—	Extrapolated from oral value	—
Chlorobenzene	Oral	Chronic	2×10^{-2}	Medium	Liver and kidney effects	Oral/IRIS	UF=1,000 MF=1
		Subchronic	2×10^{-1}	NS	Liver and kidney effects	Oral/HEAST	UF=1,000
	Inhalation	Chronic	5×10^{-3}	NS	Liver and kidney effects	Inhalation/HEAST	UF=10,000
		Subchronic	5×10^{-2}	NS	Liver and kidney effects	Inhalation/HEAST	UF=1,000

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Key at end of table.

Table 5-28 (Cont.)

Chemical	Reference Dose (RfD) Route	Type	Value (mg/kg-day)	Confidence Level	Critical Effects	RfD Basis/ Source	Uncertainty (UF) and Modifying (MF) Factors
Chromium (III)	Oral	Chronic	1 x 10	Low	Hepatotoxicity	Diet/IRIS	UF=100
		Subchronic	$1 \times 10^{+1}$	Low	Hepatotoxicity	Diet/IRIS	MF=10
	Inhalation	Chronic	6×10^{-7}	NS	Nasal mucosa atrophy	Human inhalation/ HEAST	UF=300
		Subchronic	6×10^{-6}	NS	Nasal mucosa atrophy	Human inhalation/ HEAST	UF=30
p-Cresol	Oral	Chronic	5×10^{-2}	Medium	Reduced body weight gain, neurotoxicity	Oral/IRIS	UF=1,000 MF=1
		Subchronic	5×10^{-1}	NS	Reduced body weight gain, neurotoxicity	Oral/HEAST	UF=100
	Inhalation	Chronic	5×10^{-2}	—	—	Extrapolated from oral value	—
		Subchronic	5×10^{-1}	—	—	Extrapolated from oral value	—
1,2-Dichlorobenzene	Oral	Chronic	9×10^{-2}	Low	Liver effects	Oral/IRIS	UF=1,000 MF=1
		Subchronic	9×10^{-1}	NS	Liver effects	Oral/HEAST	UF=100
	Inhalation	Chronic	4×10^{-2}	NS	Decreased body weight gain	Inhalation/HEAST	UF=1,000
		Subchronic	4×10^{-1}	NS	Decreased body weight gain	Inhalation/HEAST	UF=100
1,4-Dichlorobenzene	Oral	Chronic	2×10^{-1}	—	—	Extrapolated from inhalation value	—
		Subchronic	2×10^{-1}	—	—	Extrapolated from inhalation value	—

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Key at end of table.

Table 5-28 (Cont.)

Chemical	Reference Dose (RfD) Route	Type	Value (mg/kg-day)	Confidence Level	Critical Effects	RfD Basis/ Source	Uncertainty (UF) and Modifying (MF) Factors
1,4-Dichlorobenzene (Cont.)	Inhalation	Chronic	2×10^{-1}	NS	Liver and kidney effects	Inhalation/HEAST	UF=100
		Subchronic	2×10^{-1}	NS	Liver and kidney effects	Inhalation/HEAST	UF=100
1,1-Dichloroethane	Oral	Chronic	1×10^{-1}	NS	None	Oral/HEAST	UF=1,000
		Subchronic	1	NS	None	Oral/HEAST	UF=100
	Inhalation	Chronic	1×10^{-1}	NS	Kidney damage	Inhalation/HEAST	UF=1,000
		Subchronic	1	NS	Kidney damage	Inhalation/HEAST	UF=100
1,1-Dichloroethene	Oral	Chronic	9×10^{-3}	Medium	Hepatic lesions	Drinking water/ IRIS	UF=1,000 MF=1
		Subchronic	9×10^{-3}	NS	Hepatic lesions	Drinking water/ HEAST	UF=1,000
	Inhalation	Chronic	9×10^{-3}	—	—	Extrapolated from oral value	—
		Subchronic	9×10^{-3}	—	—	Extrapolated from oral value	—
1,2-Dichloroethene	Oral	Chronic	2×10^{-2}	NS	Decreased hematocrit and hemoglobin	Gavage/HEAST	UF=3,000
		Subchronic	2×10^{-1}	NS	Decreased hematocrit and hemoglobin	Gavage/HEAST	UF=300
	Inhalation	Chronic	2×10^{-2}	—	—	Extrapolated from oral value	—
		Subchronic	2×10^{-1}	—	—	Extrapolated from oral value	—

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Table 5-28 (Cont.)

Chemical	Reference Dose (RfD) Route	Type	Value (mg/kg-day)	Confidence Level	Critical Effects	RfD Basis/ Source	Uncertainty (UF) and Modifying (MF) Factors
Dichloromethane	Oral	Chronic	6×10^{-2}	Medium	Liver toxicity	Drinking water/ IRIS	UF=100 MF=1
		Subchronic	6×10^{-2}	NS	Liver toxicity	Drinking water/ HEAST	UF=100
	Inhalation	Chronic	8.57×10^{-1}	NS	NS	Inhalation/HEAST	UF=100
		Subchronic	8.57×10^{-1}	NS	NS	Inhalation/HEAST	UF=100
Diethyl phthalate	Oral	Chronic	8×10^{-1}	NS	Reduced terminal body weight	Diet/HEAST	UF=1,000
		Subchronic	8	NS	Reduced terminal body weight	Diet/HEAST	UF=100
	Inhalation	Chronic	8×10^{-1}	--	--	Extrapolated from oral value	--
		Subchronic	8	--	--	Extrapolated from oral value	--
bis(2-Ethylhexyl)-phthalate	Oral	Chronic	2×10^{-2}	Medium	Increased relative liver weight	G. Pig-Diet/IRIS	UF=1,000, MF=1
		Subchronic	2×10^{-2}	Medium	Increased relative liver weight	G. Pig-Diet/IRIS	UF=1,000, MF=1
	Inhalation	Chronic	2×10^{-2}	--	--	Extrapolated from oral value	--
		Subchronic	2×10^{-2}	--	--	Extrapolated from oral value	--

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Table 5-28 (Cont.)

Chemical	Reference Dose (RfD) Route	Type	Value (mg/kg-day)	Confidence Level	Critical Effects	RfD Basis/ Source	Uncertainty (UF) and Modifying (MF) Factors
Manganese	Oral	Chronic	1×10^{-1}	Medium	No effect	Diet/IRIS	UF=1 MF=1
		Subchronic	1×10^{-1}	NS	No effect	Diet/HEAST	UF=1
	Inhalation	Chronic	1.14×10^{-4}	Medium	Respiratory symptoms, psychomotor disturbances	Occupational air/ IRIS	UF=300 MF=3
		Subchronic	1.14×10^{-4}	NS	Respiratory symptoms, psychomotor disturbances	Occupational/ HEAST	UF=900
Mercury (Inorganic)	Oral	Chronic	3×10^{-4}	NS	Neurotoxicity; kidney effects	Occupational; oral/HEAST	UF=1,000
		Subchronic	3×10^{-4}	NS	Neurotoxicity; kidney effects	Occupational; oral/HEAST	UF=1,000
	Inhalation	Chronic	3×10^{-4}	NS	Neurotoxicity; kidney effects	Occupational; oral/HEAST	UF=1,000 UF=1,000
		Subchronic	3×10^{-4}	NS	Neurotoxicity; kidney effects	Occupational; oral/HEAST	UF=1,000
Naphthalene	Oral	Chronic	4×10^{-3}	NS	Decreased body weight gain	Diet/HEAST	UF=10,000
		Subchronic	4×10^{-2}	NS	Decreased body weight gain	Diet/HEAST	UF=1,000
	Inhalation	Chronic	4×10^{-3}	—	—	Extrapolated from oral value	—
		Subchronic	4×10^{-2}	—	—	Extrapolated from oral value	—

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Table 5-28 (Cont.)

Chemical	Reference Dose (RfD) Route	Type	Value (mg/kg-day)	Confidence Level	Critical Effects	RfD Basis/ Source	Uncertainty (UF) and Modifying (MF) Factors
Nickel (Soluble salts)	Oral	Chronic	2×10^{-2}	Medium	Reduced body weight and organ weight	Diet/IRIS	UF=100 MF=3
		Subchronic	2×10^{-2}	Medium	Reduced body weight and organ weight	Diet/IRIS	UF=100 MF=3
	Inhalation	Chronic	2×10^{-2}	—	—	Extrapolated from oral value	—
		Subchronic	2×10^{-2}	—	—	Extrapolated from oral value	—
Phenol	Oral	Chronic	6×10^{-1}	Low	Reduced fetal body weight	Gavage/IRIS	UF=100 MF=1
		Subchronic	6×10^{-1}	NS	Reduced fetal body weight	Gavage/HEAST	UF=100
	Inhalation	Chronic	6×10^{-1}	—	—	Extrapolated from oral value	—
		Subchronic	6×10^{-1}	—	—	Extrapolated from oral value	—
Tetrachloroethene	Oral	Chronic	1×10^{-2}	Medium	Hepatotoxicity	Oral/IRIS	UF=1,000 MF=1
		Subchronic	1×10^{-1}	NS	Hepatotoxicity	Oral/HEAST	UF=100
	Inhalation	Chronic	1×10^{-2}	—	—	Extrapolated from oral value	—
		Subchronic	1×10^{-1}	—	—	Extrapolated from oral value	—
Toluene	Oral	Chronic	2×10^{-1}	Medium	Changes in liver and kidney weights	Gavage/IRIS	UF=1,000 MF=1
		Subchronic	2	NS	Changes in liver and kidney weights	Gavage/HEAST	UF=100

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Table 5-28 (Cont.)

Chemical	Route	Type	Value (mg/kg-day)	Confidence Level	Critical Effects	RfD Basis/ Source	Uncertainty (UF) and Modifying (MF) Factors
	Reference Dose (RfD)						
Toluene (Cont.)	Inhalation	Chronic	5.71×10^{-1}	NS	CNS effects, eye and nose irritation	Inhalation/HEAST	UF=100
		Subchronic	5.71×10^{-1}	NS	CNS effects, eye and nose irritation	Inhalation/HEAST	UF=100
1,1,1-Trichloroethane	Oral	Chronic	9×10^{-2}	Medium	Hepatotoxicity	Oral/IRIS	UF=1,000 MF=1
		Subchronic	9×10^{-1}	NS	Hepatotoxicity	Oral/HEAST	UF=100
	Inhalation	Chronic	3×10^{-1}	NS	Hepatotoxicity	Inhalation/HEAST	UF=1,000
		Subchronic	3	NS	Hepatotoxicity	Inhalation/HEAST	UF=100
Trichlorofluoromethane	Oral	Chronic	3×10^{-1}	NS	Mortality	Gavage/HEAST	UF=1,000
		Subchronic	7×10^{-1}	NS	Mortality	Gavage/HEAST	UF=1,000
	Inhalation	Chronic	2×10^{-1}	NS	Elevated BUN, lung lesions	Inhalation/HEAST	UF=10,000
		Subchronic	2	NS	Elevated BUN, lung lesions	Inhalation/HEAST	UF=1,000
Xylenes (total)	Oral	Chronic	2	NS	None observed	Gavage/HEAST	UF=100
		Subchronic	4	NS	None observed	Gavage/HEAST	UF=100
	Inhalation	Chronic	8.57×10^{-2}	NS	CNS effects, nose and throat irri- tation	Inhalation/HEAST	UF=100
		Subchronic	8.57×10^{-2}	NS	CNS effects, nose and throat irri- tation	Inhalation/HEAST	UF=100

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Key:

NS = Not specified
IRIS = EPA's Integrated Risk Information System
HEAST = EPA's Health Effects Assessment Summary Tables

Compiled by: Ecology and Environment, Inc. 1991.

that any exposure to a carcinogen theoretically entails some finite risk of cancer. However, depending on the potency of a specific carcinogen, and the level of exposure, such a risk could be vanishingly small.

Scientists have developed several mathematical models to estimate low-dose carcinogenic risks from observed high-dose risks. Consistent with current theories of carcinogenesis, EPA has selected the linearized multistage model based on prudent public health policy (EPA 1986b). In addition to using the linearized multistage model, EPA uses the upper 95% confidence limit for doses or concentrations in animal or human studies to estimate low-dose slope factors (SFs). By using these procedures, the regulatory agencies are unlikely to underestimate the actual slope factors (formally called carcinogenic potency factors) for humans.

Using SFs, lifetime excess cancer risks can be estimated by:

$$\text{Risk} = \Sigma \, \text{LADD}_j \times \text{SF}_j$$

where

LADD_j = exposure route-specific lifetime average daily dose

SF_j = route-specific slope factor.

Using the multistage model, the carcinogenic risks for the oral, dermal, and inhalation routes of exposure are calculated as follows:

$$\text{Risk} = \text{LADD}_o\text{SF}_o + \text{LADD}_d\text{SF}_o + \text{LADD}_i\text{SF}_i$$

where subscript "o" indicates the oral route, subscript "d" the dermal route and subscript "i" the inhalation route. SFs for the chemicals of concern for the oral and inhalation exposure routes are presented in Table 5-29. EPA's weight-of-evidence classification for the chemical and the type of cancer which may be associated with exposure to the chemical are also included on Table 5-29.

Once substances have been absorbed via the oral or dermal routes, their distribution, metabolism, and elimination patterns (biokinetics) are usually similar. For this reason, and because dermal route RfDs and SFs are usually not available, oral route RfDs and SFs are commonly used

Table 5-29

TOXICITY VALUES: POTENTIAL CARCINOGENIC EFFECTS CONFIDENCE IN CLASSIFICATION AND IN SLOPE FACTOR (SF)

Chemical	Slope Factor (SF) $(mg/kg\text{-}day)^{-1}$	Weight-of-Evidence Classification	Type of Cancer	SF Basis/SF Source
Oral Route				
Arsenic	1.75	A	Skin	Human drinking water/IRIS
Benzene	2.9×10^{-2}	A	Leukemia	Occupational air/IRIS
Beryllium	4.3	B2	Total tumors	Occupational, drinking water/IRIS
p-Cresol	Not established	C	NS	Dermal/IRIS
1,4-Dichlorobenzene	2.4×10^{-2}	C	Liver	Gavage/HEAST
1,1-Dichloroethane	9.1×10^{-2}	C	Hemangiosarcoma	Extrapolated from 1,2-Dichloroethane
1,2-Dichloroethane	9.1×10^{-2}	B2	Circulatory system	Gavage/IRIS
1,1-Dichloroethene	6×10^{-1}	C	Adrenal	Gavage/IRIS
Dichloromethane	7.5×10^{-3}	B2	Liver	Drinking water/IRIS
1,2-Dichloropropane	6.8×10^{-2}	B2	Liver	Gavage/HEAST
bis(2-Ethylhexyl)phthalate	1.4×10^{-2}	B2	Hepatocellular Carcinoma and Adenoma	Diet/IRIS
1,1,2,2-Tetrachloroethane	2×10^{-1}	C	Liver	Gavage/IRIS
Tetrachloroethene	5.1×10^{-2}	B2	Liver	Gavage/HEAST
Trichloroethene	1.1×10^{-2}	B2	Liver	Gavage/HEAST
Vinyl chloride	1.9	A	Lung	Diet/HEAST

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Key at end of table.

Table 5-29 (Cont.)

Chemical	Slope Factor (SF) $(mg/kg\text{-}day)^{-1}$	Weight-of-Evidence Classification	Type of Cancer	SF Basis/SF Source
Inhalation Route				
Arsenic	5.0×10^{1}	A	Lung	Occupational air/IRIS
Benzene	2.9×10^{-2}	A	Leukemia	Occupational air/IRIS
Beryllium	8.4	B2	Lung	Occupational air/IRIS
p-Cresol	Not established	C	NS	Extrapolated from oral information
1,4-Dichlorobenzene	2.4×10^{-2}	C	—	Extrapolated from oral value
1,1-Dichloroethane	9.1×10^{-2}	C	—	Extrapolated from 1,2-Dichloroethane
1,2-Dichloroethane	9.1×10^{-2}	B2	Circulatory system	Gavage/IRIS
1,1-Dichloroethene	1.2	C	Kidney	Inhalation/HEAST
Dichloromethane	1.4×10^{-2}	B2	Lung, liver	Inhalation/HEAST
1,2-Dichloropropane	6.8×10^{-2}	B2	—	Extrapolated from oral value
bis(2-Ethylhexyl)phthalate	1.4×10^{-2}	B2	—	Extrapolated from oral value
1,1,2,2-Tetrachloroethane	2×10^{-1}	C	Liver	Gavage/HEAST
Tetrachloroethene	1.8×10^{-2}	B2	Leukemia, liver	Inhalation/HEAST
Trichloroethene	1.7×10^{-2}	B2	Lung	Inhalation/HEAST
Vinyl chloride	2.9×10^{-1}	A	Liver	Inhalation/HEAST

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Key:

NS = Not specified
IRIS = EPA's Integrated Risk Information System
HEAST = EPA's Health Effects Assessment Summary Tables

Compiled by: Ecology and Environment, Inc. 1991.

to evaluate exposures to substances by both the oral and dermal routes. This approach is not appropriate and is not used if the adverse effect occurs at the point of exposure. Examples would be skin irritation or skin cancer resulting from dermal exposure. Although inhalation route biokinetics differ more from oral route kinetics than do the dermal route kinetics, oral RfDs and SFs may also be used to evaluate inhalation exposures (except in the case of exposure point effects) if inhalation route RfDs and SFs are not available, and vice versa.

Exposure to some chemicals may result in both carcinogenic and noncarcinogenic effects. In these cases, both the carcinogenic and noncarcinogenic effects were evaluated and considered in the risk assessment process.

Since no "safe" exposure is believed to exist for carcinogens, the task becomes one of determining what level of risk will be deemed acceptable. In general, regulatory agencies in the United States (EPA, FDA, and OSHA) have not established a uniform cancer risk level for distinguishing between risks which are deemed acceptable and those which may be of concern. The agencies have generally considered risks in the range of one in ten thousand (1×10^{-4}) to one in ten million (1×10^{-7}) to be acceptable. EPA has recently adopted the policy that acceptable exposures are generally those that represent an excess upper bound lifetime cancer risk to an individual of between 10^{-4} and 10^{-6}. In addition, EPA will use the 10^{-6} risk level as the point of departure for determining remediation goals for NPL sites (EPA 1990b).

5.4.5 UNCERTAINTIES RELATED TO THE TOXICITY ASSESSMENT

5.4.5.1 Introduction

In order to evaluate the meaning of any risk assessment, one must consider the uncertainties in the assumptions made, the impact of changing the magnitude of those assumptions on the risk estimates, and the relevance of the findings to real world exposures and risks. Due to the number of assumptions, data points, and calculations, a degree of uncertainty is necessarily associated with the numerical toxicity values in any risk assessment.

This section begins with a discussion of the assumptions used to estimate carcinogenic risks, continues with a discussion of noncarcinogenic risk estimates, and concludes with a discussion of the other major assumptions used in developing the exposure scenarios.

5.4.5.2 Evaluation of Carcinogenic Toxicity Assessment Assumptions

The chemicals of concern have been evaluated by EPA using its weight-of-evidence carcinogenicity evaluation criteria and have been placed in Group A, human carcinogens, or Group B, probable human carcinogens, based on sufficient data in humans or sufficient data in animals and insufficient data in humans, respectively (EPA 1986b).

Rodent bioassay and epidemiological studies, such as those performed for the chemicals of concern, would require tens of thousands of animals or humans in order to determine whether or not a chemical may be carcinogenic at low doses. As the relationship between tumor location, time to appearance, and the proportion of animals with cancer determines the estimated carcinogenic SF, animal bioassay or human epidemiological data are not routinely sufficient for directly estimating SF at low doses. Therefore, by necessity, agencies such as EPA use carcinogenic extrapolation models for estimating low doses SFs. Based upon policy grounds, these agencies assume that there is no threshold dose below which carcinogenic risks will not occur. This is equivalent to the assumption that every dose above zero, no matter how low, carries with it a small but finite risk of cancer. They also assume that the dose-response relationship is linear at low doses. This is contrary to approaches used for other toxic effects, for which thresholds are assumed to exist.

The current model favored by EPA and certain other federal regulatory agencies is the linearized multistage model. The agency then uses the statistically derived upper 95% confidence bounds, rather than a maximum likelihood value for SF. The agency has concluded, based on theoretical grounds consistent with human epidemiological and animal data, that cancer follows a series of discrete stages (i.e., initiation, promotion, and progression) which ultimately can result in the uncontrolled cell proliferation known as cancer. Consistent with this conclusion, the use of the linearized multistage model permits an estimation of SF which is not likely to be exceeded if the real slope could be measured. However, compelling scientific arguments can be made for several other extrapolative models which, if used, could result in significantly reduced values for SFs, some tens of millions of times lower than those estimated using the linearized multistage model. The one hit model used to estimate risks due to exposures above the linear range of the multistage model is one such model. Thus, the current EPA SFs calculated in this fashion represent upper-bound values based on animal data which should not be interpreted as necessarily equivalent to actual human cancer potencies. It is this conservative value, nevertheless, that is used in this risk assessment on policy grounds for the protection of public health.

5.4.5.3 Evaluation of Noncarcinogenic Toxicity Assessment Assumptions

Key assumptions used in assessing the likelihood of noncarcinogenic effects are that threshold doses exist below which various noncarcinogenic effects do not occur and that the occurrence or absence of noncarcinogenic effects can be extrapolated between species and occasionally between routes of exposure and over varying exposure durations. The threshold assumption appears to be sound for most noncarcinogens based on reasonably good fits of experimental data to the usual dose response curves. One possible exception to this is lead, which may not have a threshold base for its noncarcinogenic effects (EPA 1988b). However, lead was not a compound of concern at the Strasburg Landfill site.

The other assumption generally appears to be true to varying degrees. The effects observed in one species or by one route of exposure may not occur in another species or by another route, or they may occur at a higher or lower dose due to differences in the biokinetics (uptake, distribution, metabolism, and elimination) of a compound in different species or by different routes of exposure. The uncertainty in these assumptions is taken into account in the development of RfDs through the use of safety or uncertainty factors. The uncertainty factors used by EPA are conservative (health protective) in nature in that they tend to overestimate the uncertainties so that the RfDs obtained are unlikely to be too high. Use of the resulting RfDs tends to overestimate the potential for noncarcinogenic effects occurring at a given exposure level. Section 5.4.3.2 discusses uncertainty factors used to derive the RfDs for chemicals of concern at the Strasburg Landfill site.

Uncertainty factors used to derive RfDs are presented in Table 5-28 for each chemical of concern. For example, an uncertainty factor of 100 was used to derive the RfD for xylenes: 10 for species-to-species extrapolation and 10 to protect sensitive individuals. In addition to uncertainty factors, a modifying factor is applied to reflect a qualitative professional assessment of additional uncertainties in the critical study and in the entire data base for the chemical not explicitly addressed by the preceding uncertainty factors. The modifying factor ranges from >0 to 10 with a default value of 1 (EPA 1989a).

For example, confidence in the oral RfD for xylenes as defined in IRIS is medium, based on a well-designed study in which adequately sized groups of two species were tested over a substantial portion of their lifespan. Comprehensive histology was performed and a NOAEL was defined; clinical chemistries, blood enzymes, and urinalysis were not performed. The data base was given a medium confidence level because, although supporting data exist for mice, and teratogenicity and tetotoxicity data are available with positive results at high oral doses, a LOEL for chronic oral exposure has not been defined. Medium confidence in the RfD follows. Confidence levels for verified RfDs are included in Table 5-28.

5.4.5.4 Discussion of Confidence in the SF

The degree of confidence presented in Table 5-29 reflects the EPA Carcinogen Risk Assessment Verification Endeavor (CRAVE) work groups' judgments about the ability of the risk measures derived from dose-response assessment to estimate the risks of that chemical to humans. Verification involves consideration of factors that increase or decrease confidence in the numerical risk estimate. The following criteria are considered:

- o Appropriateness of data to estimation of human carcinogenic risks;
- o Quality of study design;

- o Strength of study results;
- o Appropriateness of model application to the data; and
- o Support of risk estimate from collateral studies.

5.4.5.5 Summary of Toxicity Assessment Uncertainties

The basic uncertainties underlying the assessment of the toxicity of a chemical include:

- o Uncertainties arising from the design, execution or relevance of the scientific studies that form the basis of the assessment; and
- o Uncertainties involved in extrapolating from the underlying scientific studies to the exposure situation being evaluated, including variable responses to chemical exposures within human and animal populations, between species, and between routes of exposure.

These basic uncertainties could result in a toxicity estimate, based directly on the underlying studies, that either under- or overestimates the true toxicity of a chemical in the circumstances of interest.

The toxicity assessment process compensates for these basic uncertainties through the use of safety factors (uncertainty factors) and modifying factors, when assessing noncarcinogens, and the use of the upper 95% confidence limit from the linearized multistage model for the SF when assessing carcinogens. The use of the safety factors and the upper 95% confidence limit in deriving the RfDs and SFs ensures that the toxicity values used in the risk estimation process are very unlikely to underestimate, and thus, almost always overestimate, the true toxicity of a chemical.

5.5 RISK CHARACTERIZATION

5.5.1 Introduction

This section combines the information developed in the exposure and toxicity assessment sections to obtain estimates of the risks posed by the Strasburg Landfill site contaminants to human health. The process by which this is done is as follows:

Risks due to carcinogenic and noncarcinogenic contaminants are assessed differently, as discussed in Sections 5.4.3.2 and 5.4.3.3.

Briefly, carcinogenic risks are assessed by multiplying the estimated chronic daily intake (CDI) of a carcinogen by its estimated slope factor (SF) to obtain the estimated risk, expressed as the probability of that exposure resulting in an excess incidence of cancer (i.e., more cancers than would normally be expected in that population).

The potential for adverse effects resulting from exposure to noncarcinogens is assessed by comparing the CDI or subchronic daily intake (SDI) of a substance to its chronic or subchronic RfD. This comparison is performed by calculating the ratio of the estimated CDI or SDI to the corresponding RfD, which is called a hazard quotient or hazard index. If the hazard index is less than 1, no adverse effects would be expected; however, if it is greater than 1, adverse effects could be possible.

The excess cancer risk or the hazard quotient for exposure to each chemical by each route of exposure, exposure pathway, category of receptor (i.e., adult or child), and exposure case (RME) are initially estimated separately. The separate cancer risk estimates are then summed across chemicals and across all exposure routes and pathways applicable to the same population to obtain the total excess cancer risk for that population. Hazard quotients for noncarcinogens are summed across chemicals that produce the same type of adverse effect (such as liver damage) but are kept separate if their effects are different. Hazard quotients for subchronic and chronic effects are separately summed across all chemicals, exposure routes, and pathways applicable to the same population to obtain hazard indices for that population.

Section 5.5.2 presents a number of tables that contain the detailed risk estimates just described. Section 5.5.3 discusses uncertainties associated with the risk estimates. Section 5.5.4 summarizes the risk estimation results and identifies the chemicals, pathways, and receptors that account for the most significant risks at the Strasburg Landfill site.

5.5.2 Risk Estimates

This section presents a number of tables that contain exposure and risk estimates. The toxicity estimates (slope factors and reference doses) used in calculating the risk estimates, along with key information qualifying the toxicity estimates, were presented in Tables 5-28 and 5-29.

Because of the number of exposure pathways, receptors, exposure cases, and chemicals that needed to be evaluated, a large number of tables are necessary to summarize the results. A directory (see Table 5-30) has been included to assist the reader in locating the exposure and risk estimates for specific exposure pathways, etc. Tables 5-31 through 5-49, containing the directory and the exposure and risk estimate results, are included at the end of Section 5.5.

5.5.3 Risk Characterization Uncertainties

The risk characterization combines and integrates the information developed in the exposure and toxicity assessments; therefore, uncertainties associated with these assessments also affect the degree of confidence that can be placed in risk characterization results. The reader is referred to Sections 5.3.4 and 5.4.4 for full discussions of the factors causing uncertainty in the exposure and toxicity assessments, respectively. The primary factors contributing to exposure and toxicity uncertainties are briefly reviewed here.

For the exposure assessment, factors that would likely cause overestimation of the true exposures were:

- The directed nature of the sampling program;
- The use of upper 95th percent confidence limits or the maximum observed value for the source concentrations;
- The use of many 90th-percentile values in the exposure estimation calculations; and
- The use of the steady state assumption for source concentration estimates.

One factor could lead to underestimation of the exposures:

- The use of sample quantitation limits that could result in missing low concentrations of some compounds that might pose significant risks.

Table 5-30

DIRECTORY OF EXPOSURE AND RISK
ESTIMATE SUMMARY TABLES

Exposure Pathway	Location	Case	Receptor	Table Number
Residential Groundwater	Zarzycki Area	Historical RME	Adults	5-31
			Children 1-6 Yrs.	5-32
		Current RME	Adults	5-33
			Children 1-6 Yrs.	5-34
	Wheatland Dr. Area	Potential RME	Adults	5-35
			Children 1-6 Yrs.	5-36
Inhalation of Airborne Contaminants	Zarzycki Area	RME	Adults	5-37
			Comp. Child/Adult	5-38
	Wheatland Dr. Area	RME	Adults	5-39
			Comp. Child/Adult	5-40
	On-site	RME	Adult	5-41
			Children 6-12 Yrs.	5-42
			Children 12-18 Yrs.	5-43
Accidental Contact with Seep Areas	East Seep Area	RME	Adult	5-44
			Children 6-12 Yrs.	5-45
			Children 12-18 Yrs.	5-46
	Southeast Seep Area	RME	Adult	5-47
			Children 6-12 Yrs.	5-48
			Children 12-18 Yrs.	5-49

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NOTE: In Tables 5-31 through 5-49, the estimated exposure point concentrations, absorbed doses, cancer risks, and hazard indices are given in exponential notation (E format). The relationship between standard decimal notation, scientific notation, and exponential notation is illustrated below:

Decimal	Scientific	Exponential
6,300	6.3×10^{3}	6.3 E+3
6.3	6.3×10^{0}	6.3 E+0
0.0063	6.3×10^{-3}	6.3 E-3

Table 5-31

CANCER RISK AND NONCANCER HAZARD INDEX ESTIMATES
FOR RESIDENTIAL GROUNDWATER USAGE
Location: Zarzycki Area
Receptor: Adult
Case: Historical RME

Chemical	Exposure Point Water Concentration (mg/L)	Carcinogenic Effects: Absorbed Dose (mg/kg/day)	Carcinogenic Effects: Cancer Risk	Non-Carcinogenic Effects: Absorbed Dose (mg/kg/day)	Non-Carcinogenic Effects: Hazard Index
Exposure Route: Ingestion of Drinking Water					
Barium	2.07E-12	—	—	5.91E-14	8.44E-13
Benzene	3.80E-04	4.65E-06	1.35E-07	—	—
Chlorobenzene	1.80E-04	—	—	5.14E-06	2.57E-04
Chloroethane	3.80E-04	—	—	—	—
1,1-Dichloroethane	9.87E-03	1.21E-04	1.10E-05	2.82E-04	2.82E-03
1,2-Dichloroethane	9.50E-04	1.16E-05	1.06E-06	—	—
1,1-Dichloroethene	1.20E-04	1.47E-06	8.82E-07	3.43E-06	3.81E-04
1,2-Dichloroethene (total)	2.64E-02	—	—	7.54E-04	3.77E-02
Dichloromethane	4.27E-03	5.23E-05	3.92E-07	1.22E-04	2.03E-03
1,2-Dichloropropane	9.10E-04	1.11E-05	7.55E-07	—	—
1,1,2,2-Tetrachloroethane	2.68E-03	3.28E-05	6.56E-06	—	—
Tetrachloroethene	1.56E-02	1.91E-04	9.74E-06	4.46E-04	4.46E-02
1,1,1-Trichloroethane	1.66E-03	—	—	4.74E-05	5.27E-04
Trichloroethene	1.44E-02	1.76E-04	1.94E-06	—	—
Trichlorofluoromethane	5.10E-04	—	—	1.46E-05	4.87E-05
Vinyl Chloride	1.07E-03	1.31E-05	2.49E-05	—	—
Ingestion Route Subtotal:			5.74E-05		8.83E-02

02[UZ]ZD5071:D3222/5960/19

Table 5-31 (Cont.)

Chemical	Exposure Point Water Concentration (mg/L)	Carcinogenic Effects: Absorbed Dose (mg/kg/day)	Carcinogenic Effects: Cancer Risk	Non-Carcinogenic Effects: Absorbed Dose (mg/kg/day)	Non-Carcinogenic Effects: Hazard Index
Exposure Route: Dermal Contact with Water in shower					
Barium	2.07E-12	—	—	1.06E-16	1.51E-15
Benzene	3.80E-04	8.38E-09	2.43E-10	—	—
Chlorobenzene	1.80E-04	—	—	9.26E-09	4.63E-07
Chloroethane	3.80E-04	—	—	—	—
1,1-Dichloroethane	9.87E-03	2.18E-07	1.98E-08	5.08E-07	5.08E-06
1,2-Dichloroethane	9.50E-04	2.09E-08	1.90E-09	—	—
1,1-Dichloroethene	1.20E-04	2.64E-09	1.58E-09	6.17E-09	6.86E-07
1,2-Dichloroethene (total)	2.64E-02	—	—	1.36E-06	6.80E-05
Dichloromethane	4.27E-03	9.41E-08	7.06E-10	2.20E-07	3.67E-06
1,2-Dichloropropane	9.10E-04	2.01E-08	1.37E-09	—	—
1,1,2,2-Tetrachloroethane	2.68E-03	5.91E-08	1.18E-08	—	—
Tetrachloroethene	1.56E-02	3.44E-07	1.75E-08	8.02E-07	8.02E-05
1,1,1-Trichloroethane	1.66E-03	—	—	8.54E-08	9.49E-07
Trichloroethene	1.44E-02	3.17E-07	3.49E-09	—	—
Trichlorofluoromethane	5.10E-04	—	—	2.62E-08	8.73E-08
Vinyl Chloride	1.07E-03	2.36E-08	4.48E-08	—	—
Dermal Route Subtotal:			1.03E-07		1.59E-04

02[UZ]ZD5071:D3222/5960/19

Table 5-31 (Cont.)

Chemical	Exposure Point Air Concentration (mg/m3)	Carcinogenic Effects		Non-Carcinogenic Effects	
		Absorbed Dose (mg/kg/day)	Cancer Risk	Absorbed Dose (mg/kg/day)	Hazard Index
Exposure Route: Inhalation of Vapors in Shower					
Barium	0.00E+00	—	—	0.00E+00	—
Benzene	5.88E-03	4.32E-06	1.25E-07	—	—
Chlorobenzene	2.33E-03	—	—	3.99E-06	7.98E-04
Chloroethane	6.52E-03	—	—	—	—
1,1-Dichloroethane	1.37E-01	1.01E-04	9.19E-06	2.35E-04	2.35E-03
1,2-Dichloroethane	1.14E-02	8.38E-06	7.63E-07	—	—
1,1-Dichloroethene	1.76E-03	1.29E-06	1.55E-06	3.02E-06	3.36E-04
1,2-Dichloroethene (total)	3.77E-01	—	—	6.46E-04	3.23E-02
Dichloromethane	6.00E-02	4.41E-05	6.17E-07	1.03E-04	1.20E-04
1,2-Dichloropropane	1.16E-02	8.52E-06	5.79E-07	—	—
1,1,2,2-Tetrachloroethane	5.48E-03	4.03E-06	8.06E-07	—	—
Tetrachloroethene	1.77E-01	1.30E-04	2.37E-07	3.03E-04	3.03E-02
1,1,1-Trichloroethane	2.08E-02	—	—	3.57E-05	1.19E-04
Trichloroethene	1.81E-01	1.33E-04	2.26E-06	—	—
Trichlorofluoromethane	6.40E-03	—	—	1.10E-05	5.50E-05
Vinyl Chloride	1.90E-02	1.40E-05	4.12E-06	—	—
Inhalation Route Subtotal:			2.03E-05		6.64E-02
Receptor Total:			7.78E-05		1.55E-01

02[UZ]ZD5071:D3222/5960/19

Source: Ecology and Environment, Inc. 1991.

Table 5-32

CANCER RISK AND NONCANCER HAZARD INDEX ESTIMATES FOR RESIDENTIAL GROUNDWATER USAGE
Location: Zarzycki Area
Receptor: Children 1-6 Yrs
Case: Historical RME

Chemical	Exposure Point Water Concentration (mg/L)	Carcinogenic Effects: Absorbed Dose (mg/kg/day)	Carcinogenic Effects: Cancer Risk	Non-Carcinogenic Effects: Absorbed Dose (mg/kg/day)	Non-Carcinogenic Effects: Hazard Index
Exposure Route: Ingestion of Drinking Water					
Barium	2.07E-12	—	—	6.47E-14	9.24E-13
Benzene	3.80E-04	8.48E-07	2.46E-08	—	—
Chlorobenzene	1.80E-04	—	—	5.63E-06	2.82E-05
Chloroethane	3.80E-04	—	—	—	—
1,1-Dichloroethane	9.87E-03	2.20E-05	2.00E-06	3.08E-04	3.08E-04
1,2-Dichloroethane	9.50E-04	2.12E-06	1.93E-07	—	—
1,1-Dichloroethene	1.20E-04	2.68E-07	1.61E-07	3.75E-06	4.17E-04
1,2-Dichloroethene (total)	2.64E-02	—	—	8.25E-04	4.13E-03
Dichloromethane	4.27E-03	9.53E-06	7.15E-08	1.33E-04	2.22E-03
1,2-Dichloropropane	9.10E-04	2.03E-06	1.38E-07	—	—
1,1,2,2-Tetrachloroethane	2.68E-03	5.98E-06	1.20E-06	—	—
Tetrachloroethene	1.56E-02	3.48E-05	1.77E-06	4.88E-04	4.88E-03
1,1,1-Trichloroethane	1.66E-03	—	—	5.19E-05	5.77E-05
Trichloroethene	1.44E-02	3.21E-05	3.53E-07	—	—
Trichlorofluoromethane	5.10E-04	—	—	1.59E-05	2.27E-05
Vinyl Chloride	1.07E-03	2.39E-06	4.54E-06	—	—
Ingestion Route Subtotal:			1.04E-05		1.21E-02

02[UZ]ZD5071:D3222/5960/19

Table 5-32 (Cont.)

Chemical	Exposure Point Water Concentration (mg/L)	Carcinogenic Effects: Absorbed Dose (mg/kg/day)	Carcinogenic Effects: Cancer Risk	Non-Carcinogenic Effects: Absorbed Dose (mg/kg/day)	Non-Carcinogenic Effects: Hazard Index
Exposure Route: Dermal Contact with Water in shower					
Barium	2.07E-12	—	—	1.86E-16	2.66E-15
Benzene	3.80E-04	2.44E-09	7.08E-11	—	—
Chlorobenzene	1.80E-04	—	—	1.62E-08	8.10E-08
Chloroethane	3.80E-04	—	—	—	—
1,1-Dichloroethane	9.87E-03	6.35E-08	5.78E-09	8.88E-07	8.88E-07
1,2-Dichloroethane	9.50E-04	6.11E-09	5.56E-10	—	—
1,1-Dichloroethene	1.20E-04	7.71E-10	4.63E-10	1.08E-08	1.20E-06
1,2-Dichloroethene (total)	2.64E-02	—	—	2.38E-06	1.19E-05
Dichloromethane	4.27E-03	2.75E-08	2.06E-10	3.84E-07	6.40E-06
1,2-Dichloropropane	9.10E-04	5.85E-09	3.98E-10	—	—
1,1,2,2-Tetrachloroethane	2.68E-03	1.72E-08	3.44E-09	—	—
Tetrachloroethene	1.56E-02	1.00E-07	5.10E-09	1.40E-06	1.40E-05
1,1,1-Trichloroethane	1.66E-03	—	—	1.49E-07	1.66E-07
Trichloroethene	1.44E-02	9.26E-08	1.02E-09	—	—
Trichlorofluoromethane	5.10E-04	—	—	4.59E-08	6.56E-08
Vinyl Chloride	1.07E-03	6.88E-09	1.31E-08	—	—
Dermal Route Subtotal:			3.01E-08		3.48E-05

02[UZ]ZD5071:D3222/5960/19

Table 5-32 (Cont.)

Chemical	Exposure Point Air Concentration (mg/m3)	Carcinogenic Effects: Absorbed Dose (mg/kg/day)	Carcinogenic Effects: Cancer Risk	Non-Carcinogenic Effects: Absorbed Dose (mg/kg/day)	Non-Carcinogenic Effects: Hazard Index
Exposure Route: Inhalation of Vapors in Shower					
Barium	0.00E+00	—	—	0.00E+00	—
Benzene	5.88E-03	3.15E-06	9.14E-08	—	—
Chlorobenzene	2.33E-03	—	—	1.75E-05	3.50E-04
Chloroethane	6.52E-03	—	—	—	—
1,1-Dichloroethane	1.37E-01	7.34E-05	6.68E-06	1.03E-03	1.03E-03
1,2-Dichloroethane	1.14E-02	6.11E-06	5.56E-07	—	—
1,1-Dichloroethene	1.76E-03	9.43E-07	1.13E-06	1.32E-05	1.47E-03
1,2-Dichloroethene (total)	3.77E-01	—	—	2.83E-03	1.42E-02
Dichloromethane	6.00E-02	3.21E-05	4.49E-07	4.50E-04	5.25E-04
1,2-Dichloropropane	1.16E-02	6.21E-06	4.22E-07	—	—
1,1,2,2-Tetrachloroethane	5.48E-03	2.94E-06	5.88E-07	—	—
Tetrachloroethene	1.77E-01	9.48E-05	1.73E-07	1.33E-03	1.33E-02
1,1,1-Trichloroethane	2.08E-02	—	—	1.56E-04	5.20E-05
Trichloroethene	1.81E-01	9.70E-05	1.65E-06	—	—
Trichlorofluoromethane	6.40E-03	—	—	4.80E-05	2.40E-05
Vinyl Chloride	1.90E-02	1.02E-05	3.00E-06	—	—
Inhalation Route Subtotal:			1.48E-05		3.10E-02
Receptor Total:			2.52E-05		4.31E-02

02[UZ]ZD5071:D3222/5960/19

Source: Ecology and Environment, Inc. 1991.

Table 5-33

CANCER RISK AND NONCANCER HAZARD INDEX ESTIMATES
FOR RESIDENTIAL GROUNDWATER USAGE
Location: Zarzycki Area
Receptor: Adult
Case: Current RME

Chemical	Exposure Point Water Concentration (mg/L)	Carcinogenic Effects: Absorbed Dose (mg/kg/day)	Carcinogenic Effects: Cancer Risk	Non-Carcinogenic Effects: Absorbed Dose (mg/kg/day)	Non-Carcinogenic Effects: Hazard Index
Exposure Route: Ingestion of Drinking Water					
Benzene	7.40E-04	9.06E-06	2.63E-07	—	—
1,1-Dichloroethane	6.20E-03	7.59E-05	6.91E-06	1.77E-04	1.77E-03
1,2-Dichloroethene (total)	1.30E-02	—	—	3.71E-04	1.86E-02
Dichloromethane	2.60E-04	3.18E-06	2.39E-08	7.43E-06	1.24E-04
1,2-Dichloropropane	4.20E-04	5.14E-06	3.50E-07	—	—
1,1,2,2-Tetrachloroethane	2.90E-04	3.55E-06	7.10E-07	—	—
Tetrachloroethene	8.37E-03	1.02E-04	5.20E-06	2.39E-04	2.39E-02
1,1,1-Trichloroethane	1.90E-04	—	—	5.43E-06	6.03E-05
Trichloroethene	9.44E-03	1.16E-04	1.28E-06	—	—
Vinyl Chloride	1.40E-03	1.71E-05	3.25E-05	—	—
Ingestion Route Subtotal:			4.73E-05		4.45E-02

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Table 5-33 (Cont.)

Chemical	Exposure Point Water Concentration (mg/L)	Carcinogenic Effects: Absorbed Dose (mg/kg/day)	Carcinogenic Effects: Cancer Risk	Non-Carcinogenic Effects: Absorbed Dose (mg/kg/day)	Non-Carcinogenic Effects: Hazard Index
Exposure Route: Dermal Contact with Water in shower					
Benzene	7.40E-04	1.63E-08	4.73E-10	—	—
1,1-Dichloroethane	6.20E-03	1.37E-07	1.25E-08	3.19E-07	3.19E-06
1,2-Dichloroethene (total)	1.30E-02	—	—	6.69E-07	3.35E-05
Dichloromethane	2.60E-04	5.73E-09	4.30E-11	1.34E-08	2.23E-07
1,2-Dichloropropane	4.20E-04	9.26E-09	6.30E-10	—	—
1,1,2,2-Tetrachloroethane	2.90E-04	6.39E-09	1.28E-09	—	—
Tetrachloroethene	8.37E-03	1.84E-07	9.38E-09	4.30E-07	4.30E-05
1,1,1-Trichloroethane	1.90E-04	—	—	9.77E-09	1.09E-07
Trichloroethene	9.44E-03	2.08E-07	2.29E-09	—	—
Vinyl Chloride	1.40E-03	3.09E-08	5.87E-08	—	—
Dermal Route Subtotal:			8.53E-08		8.00E-05

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Table 5-33 (Cont.)

Chemical	Exposure Point Air Concentration (mg/m3)	Carcinogenic Effects: Absorbed Dose (mg/kg/day)	Carcinogenic Effects: Cancer Risk	Non-Carcinogenic Effects: Absorbed Dose (mg/kg/day)	Non-Carcinogenic Effects: Hazard Index
Exposure Route: Inhalation of Vapors in Shower					
Benzene	1.14E-02	8.38E-06	2.43E-07	—	—
1,1-Dichloroethane	8.60E-02	6.32E-05	5.75E-06	1.47E-04	1.47E-03
1,2-Dichloroethene (total)	1.86E-01	—	—	3.19E-04	1.60E-02
Dichloromethane	3.66E-03	2.69E-06	3.77E-08	6.27E-06	7.32E-06
1,2-Dichloropropane	5.32E-03	3.91E-06	2.66E-07	—	—
1,1,2,2-Tetrachloroethane	5.92E-04	4.35E-07	8.70E-08	—	—
Tetrachloroethene	9.56E-02	7.02E-05	1.28E-07	1.64E-04	1.64E-02
1,1,1-Trichloroethane	2.39E-03	—	—	4.10E-06	1.37E-05
Trichloroethene	1.19E-01	8.74E-05	1.49E-06	—	—
Vinyl Chloride	2.48E-02	1.82E-05	5.35E-06	—	—
Inhalation Route Subtotal:			1.34E-05		3.39E-02
Receptor Total:			6.08E-05		7.85E-02

02[UZ]ZD5071:D3222/5960/19

Source: Ecology and Environment, Inc. 1991.

Table 5-34

CANCER RISK AND NONCANCER HAZARD INDEX ESTIMATES
FOR RESIDENTIAL GROUNDWATER USAGE
Location: Zarzycki Area
Receptor: Children 1-6 Yrs
Case: Current RME

Chemical	Exposure Point Water Concentration (mg/L)	Carcinogenic Effects: Absorbed Dose (mg/kg/day)	Carcinogenic Effects: Cancer Risk	Non-Carcinogenic Effects: Absorbed Dose (mg/kg/day)	Non-Carcinogenic Effects: Hazard Index
Exposure Route: Ingestion of Drinking Water					
Benzene	7.40E-04	1.65E-06	4.78E-08	—	—
1,1-Dichloroethane	6.20E-03	1.38E-05	1.26E-06	1.94E-04	1.94E-04
1,2-Dichloroethene (total)	1.30E-02	—	—	4.06E-04	2.03E-03
Dichloromethane	2.60E-04	5.80E-07	4.35E-09	8.13E-06	1.36E-04
1,2-Dichloropropane	4.20E-04	9.38E-07	6.38E-08	—	—
1,1,2,2-Tetrachloroethane	2.90E-04	6.47E-07	1.29E-07	—	—
Tetrachloroethene	8.37E-03	1.87E-05	9.54E-07	2.62E-04	2.62E-03
1,1,1-Trichloroethane	1.90E-04	—	—	5.94E-06	6.60E-06
Trichloroethene	9.44E-03	2.11E-05	2.32E-07	—	—
Vinyl Chloride	1.40E-03	3.13E-06	5.95E-06	—	—
Ingestion Route Subtotal:			8.63E-06		4.99E-03

02[UZ]ZD5071:D3222/5960/19

Table 5-34 (Cont.)

Chemical	Exposure Point Water Concentration (mg/L)	Carcinogenic Effects: Absorbed Dose (mg/kg/day)	Carcinogenic Effects: Cancer Risk	Non-Carcinogenic Effects: Absorbed Dose (mg/kg/day)	Non-Carcinogenic Effects: Hazard Index
Exposure Route: Dermal Contact with Water in shower					
Benzene	7.40E-04	4.76E-09	1.38E-10	—	—
1,1-Dichloroethane	6.20E-03	3.99E-08	3.63E-09	5.58E-07	5.58E-07
1,2-Dichloroethene (total)	1.30E-02	—	—	1.17E-06	5.85E-06
Dichloromethane	2.60E-04	1.67E-09	1.25E-11	2.34E-08	3.90E-07
1,2-Dichloropropane	4.20E-04	2.70E-09	1.84E-10	—	—
1,1,2,2-Tetrachloroethane	2.90E-04	1.86E-09	3.72E-10	—	—
Tetrachloroethene	8.37E-03	5.38E-08	2.74E-09	7.53E-07	7.53E-06
1,1,1-Trichloroethane	1.90E-04	—	—	1.71E-08	1.90E-08
Trichloroethene	9.44E-03	6.07E-08	6.68E-10	—	—
Vinyl Chloride	1.40E-03	9.00E-09	1.71E-08	—	—
Dermal Route Subtotal:			2.48E-08		1.43E-05

02[UZ]ZD5071:D3222/5960/19

Table 5-34 (Cont.)

Chemical	Exposure Point Air Concentration (mg/m3)	Carcinogenic Effects: Absorbed Dose (mg/kg/day)	Carcinogenic Effects: Cancer Risk	Non-Carcinogenic Effects: Absorbed Dose (mg/kg/day)	Non-Carcinogenic Effects: Hazard Index
Exposure Route: Inhalation of Vapors in Shower					
Benzene	1.14E-02	6.11E-06	1.77E-07	—	—
1,1-Dichloroethane	8.60E-02	4.61E-05	4.20E-06	6.45E-04	6.45E-04
1,2-Dichloroethene (total)	1.86E-01	—	—	1.40E-03	7.00E-03
Dichloromethane	3.66E-03	1.96E-06	2.74E-08	2.75E-05	3.21E-05
1,2-Dichloropropane	5.32E-03	2.85E-06	1.94E-07	—	—
1,1,2,2-Tetrachloroethane	5.92E-04	3.17E-07	6.34E-08	—	—
Tetrachloroethene	9.56E-02	5.12E-05	9.32E-08	7.17E-04	7.17E-03
1,1,1-Trichloroethane	2.39E-03	—	—	1.79E-05	5.97E-06
Trichloroethene	1.19E-01	6.37E-05	1.08E-06	—	—
Vinyl Chloride	2.48E-02	1.33E-05	3.91E-06	—	—
Inhalation Route Subtotal:			9.74E-06		1.49E-02
Receptor Total:			1.84E-05		1.99E-02

02[UZ]ZD5071:D3222/5960/19

Source: Ecology and Environment, Inc. 1991.

Table 5-35

CANCER RISK AND NONCANCER HAZARD INDEX ESTIMATES
FOR RESIDENTIAL GROUNDWATER USAGE
Location: Wheatland Area
Receptor: Adult
Case: Potential RME

Chemical	Exposure Point Water Concentration (mg/L)	Carcinogenic Effects		Non-Carcinogenic Effects	
		Absorbed Dose (mg/kg/day)	Cancer Risk	Absorbed Dose (mg/kg/day)	Hazard Index
Exposure Route: Ingestion of Drinking Water					
1,1-Dichloroethane	1.60E-03	1.96E-05	1.78E-06	4.57E-05	4.57E-04
1,2-Dichloroethane	1.70E-03	2.08E-05	1.89E-06	—	—
1,2-Dichloroethene (total)	1.07E-02	—	—	3.06E-04	1.53E-02
Tetrachloroethene	8.00E-03	9.80E-05	5.00E-06	2.29E-04	2.29E-02
Trichloroethene	7.60E-03	9.31E-05	1.02E-06	—	—
Ingestion Route Subtotal:			9.69E-06		3.87E-02

02[UZ]ZD5071:D3222/5960/19

Table 5-35 (Cont.)

Chemical	Exposure Point Water Concentration (mg/L)	Carcinogenic Effects: Absorbed Dose (mg/kg/day)	Carcinogenic Effects: Cancer Risk	Non-Carcinogenic Effects: Absorbed Dose (mg/kg/day)	Non-Carcinogenic Effects: Hazard Index
Exposure Route: Dermal Contact with Water in shower					
1,1-Dichloroethane	1.60E-03	3.53E-08	3.21E-09	8.23E-08	8.23E-07
1,2-Dichloroethane	1.70E-03	3.75E-08	3.41E-09	—	—
1,2-Dichloroethene (total)	1.07E-02	—	—	5.50E-07	2.75E-05
Tetrachloroethene	8.00E-03	1.76E-07	8.98E-09	4.11E-07	4.11E-05
Trichloroethene	7.60E-03	1.68E-07	1.85E-09	—	—
Dermal Route Subtotal:			1.75E-08		6.94E-05

02[UZ]ZD5071:D3222/5960/19

Table 5-35 (Cont.)

Chemical	Exposure Point Air Concentration (mg/m3)	Carcinogenic Effects: Absorbed Dose (mg/kg/day)	Carcinogenic Effects: Cancer Risk	Non-Carcinogenic Effects: Absorbed Dose (mg/kg/day)	Non-Carcinogenic Effects: Hazard Index
Exposure Route: Inhalation of Vapors in Shower					
1,1-Dichloroethane	2.22E-02	1.63E-05	1.48E-06	3.81E-05	3.81E-04
1,2-Dichloroethane	2.03E-02	1.49E-05	1.36E-06	—	—
1,2-Dichloroethene (total)	1.53E-01	—	—	2.62E-04	1.31E-02
Tetrachloroethene	9.08E-02	6.67E-05	1.21E-07	1.56E-04	1.56E-02
Trichloroethene	9.56E-02	7.02E-05	1.19E-06	—	—
Inhalation Route Subtotal:			4.15E-06		2.91E-02
Receptor Total:			1.39E-05		6.79E-02

02[UZ]ZD5071:D3222/5960/19

Source: Ecology and Environment, Inc. 1991.

Table 5-36

CANCER RISK AND NONCANCER HAZARD INDEX ESTIMATES FOR RESIDENTIAL GROUNDWATER USAGE
Location: Wheatland Area
Receptor: Children 1-6 Yrs
Case: Potential RME

Chemical	Exposure Point Water Concentration (mg/L)	Carcinogenic Effects: Absorbed Dose (mg/kg/day)	Carcinogenic Effects: Cancer Risk	Non-Carcinogenic Effects: Absorbed Dose (mg/kg/day)	Non-Carcinogenic Effects: Hazard Index
Exposure Route: Ingestion of Drinking Water					
1,1-Dichloroethane	1.60E-03	3.57E-06	3.25E-07	5.00E-05	5.00E-05
1,2-Dichloroethane	1.70E-03	3.79E-06	3.45E-07	—	—
1,2-Dichloroethene (total)	1.07E-02	—	—	3.34E-04	1.67E-03
Tetrachloroethene	8.00E-03	1.79E-05	9.13E-07	2.50E-04	2.50E-03
Trichloroethene	7.60E-03	1.70E-05	1.87E-07	—	—
Ingestion Route Subtotal:			1.77E-06		4.22E-03

02[UZ]ZD5071:D3222/5960/19

Table 5-36 (Cont.)

Chemical	Exposure Point Water Concentration (mg/L)	Carcinogenic Effects: Absorbed Dose (mg/kg/day)	Carcinogenic Effects: Cancer Risk	Non-Carcinogenic Effects: Absorbed Dose (mg/kg/day)	Non-Carcinogenic Effects: Hazard Index
Exposure Route: Dermal Contact with Water in shower					
1,1-Dichloroethane	1.60E-03	1.03E-08	9.37E-10	1.44E-07	1.44E-07
1,2-Dichloroethane	1.70E-03	1.09E-08	9.92E-10	—	—
1,2-Dichloroethene (total)	1.07E-02	—	—	9.63E-07	4.82E-06
Tetrachloroethene	8.00E-03	5.14E-08	2.62E-09	7.20E-07	7.20E-06
Trichloroethene	7.60E-03	4.89E-08	5.38E-10	—	—
Dermal Route Subtotal:			5.09E-09		1.22E-05

02[UZ]ZD5071:D3222/5960/19

Table 5-36 (Cont.)

Chemical	Exposure Point Air Concentration (mg/m3)	Carcinogenic Effects		Non-Carcinogenic Effects	
		Absorbed Dose (mg/kg/day)	Cancer Risk	Absorbed Dose (mg/kg/day)	Hazard Index
Exposure Route: Inhalation of Vapors in Shower					
1,1-Dichloroethane	2.22E-02	1.19E-05	1.08E-06	1.67E-04	1.67E-04
1,2-Dichloroethane	2.03E-02	1.09E-05	9.92E-07	—	—
1,2-Dichloroethene (total)	1.53E-01	—	—	1.15E-03	5.75E-03
Tetrachloroethene	9.08E-02	4.86E-05	8.85E-08	6.81E-04	6.81E-03
Trichloroethene	9.56E-02	5.12E-05	8.70E-07	—	—
Inhalation Route Subtotal:			3.03E-06		1.27E-02
Receptor Total:			4.81E-06		1.69E-02

02[UZ]ZD5071:D3222/5960/19

Source: Ecology and Environment, Inc. 1991.

Table 5-37

CANCER RISK AND NONCANCER HAZARD INDEX ESTIMATES FOR INHALATION OF AIRBORNE CONTAMINANTS
Location: Zarzycki Area
Receptor: Adult
Case: Reasonable Maximum Exposure

Chemical	Exposure Point Air Concentration (mg/m3)	Carcinogenic Effects: Absorbed Dose (mg/kg/day)	Carcinogenic Effects: Cancer Risk	Non-Carcinogenic Effects: Absorbed Dose (mg/kg/day)	Non-Carcinogenic Effects: Hazard Index
Exposure Route: Inhalation of Vapors					
Benzene	5.91E-06	5.76E-07	1.67E-08	—	—
1,1-Dichloroethene	1.26E-06	1.23E-07	1.48E-07	2.86E-07	3.18E-05
1,2-Dichloroethene (total)	1.81E-10	—	—	4.11E-11	2.06E-09
Tetrachloroethene	4.87E-06	4.74E-07	8.63E-10	1.11E-06	1.11E-04
Trichloroethene	8.08E-06	7.87E-07	1.34E-08	—	—
Vinyl Chloride	9.79E-06	9.54E-07	2.80E-07	—	—
Inhalation Route Subtotal:			4.59E-07		1.43E-04
Receptor Total:			4.59E-07		1.43E-04

02[UZ]ZD5071:D3222/5960/19

Source: Ecology and Environment, Inc. 1991.

Table 5-38

CANCER RISK AND NONCANCER HAZARD INDEX ESTIMATES FOR INHALATION OF AIRBORNE CONTAMINANTS
Location: Zarzycki Area
Receptor: Composite Child/Adult
Case: Reasonable Maximum Exposure

Chemical	Exposure Point Air Concentration (mg/m3)	Carcinogenic Effects: Absorbed Dose (mg/kg/day)	Carcinogenic Effects: Cancer Risk	Non-Carcinogenic Effects: Absorbed Dose (mg/kg/day)	Non-Carcinogenic Effects: Hazard Index
Exposure Route: Inhalation of Vapors					
Benzene	5.91E-06	1.19E-06	3.45E-08	—	—
1,1-Dichloroethene	1.26E-06	2.53E-07	3.04E-07	1.77E-06	1.97E-04
1,2-Dichloroethene (total)	1.81E-10	—	—	2.55E-10	1.28E-08
Tetrachloroethene	4.87E-06	9.79E-07	1.78E-09	6.85E-06	6.85E-04
Trichloroethene	8.08E-06	1.62E-06	2.75E-08	—	—
Vinyl Chloride	9.79E-06	1.97E-06	5.79E-07	—	—
Inhalation Route Subtotal:			9.48E-07		8.82E-04
Receptor Total:			9.48E-07		8.82E-04

02[UZ]ZD5071:D3222/5960/19

Source: Ecology and Environment, Inc. 1991.

Table 5-39

CANCER RISK AND NONCANCER HAZARD INDEX ESTIMATES FOR INHALATION OF AIRBORNE CONTAMINANTS
Location: Wheatland Area
Receptor: Adult
Case: Reasonable Maximum Exposure

Chemical	Exposure Point Air Concentration (mg/m3)	Carcinogenic Effects: Absorbed Dose (mg/kg/day)	Carcinogenic Effects: Cancer Risk	Non-Carcinogenic Effects: Absorbed Dose (mg/kg/day)	Non-Carcinogenic Effects: Hazard Index
Exposure Route: Inhalation of Vapors					
Benzene	1.13E-06	1.10E-07	3.19E-09	—	—
1,1-Dichloroethene	3.82E-07	3.72E-08	4.46E-08	8.68E-08	9.64E-06
1,2-Dichloroethene (total)	3.41E-10	—	—	7.75E-11	3.88E-09
Tetrachloroethene	9.37E-07	9.13E-08	1.66E-10	2.13E-07	2.13E-05
Trichloroethene	1.27E-06	1.24E-07	2.11E-09	—	—
Vinyl Chloride	1.80E-06	1.75E-07	5.15E-08	—	—
Inhalation Route Subtotal:			1.02E-07		3.09E-05
Receptor Total:			1.02E-07		3.09E-05

02[UZ]ZD5071:D3222/5960/19

Source: Ecology and Environment, Inc. 1991.

Table 5-40

CANCER RISK AND NONCANCER HAZARD INDEX ESTIMATES FOR INHALATION OF AIRBORNE CONTAMINANTS
Location: Wheatland Area
Receptor: Composite Child/Adult
Case: Reasonable Maximum Exposure

Chemical	Exposure Point Air Concentration (mg/m3)	Carcinogenic Effects: Absorbed Dose (mg/kg/day)	Carcinogenic Effects: Cancer Risk	Non-Carcinogenic Effects: Absorbed Dose (mg/kg/day)	Non-Carcinogenic Effects: Hazard Index
Exposure Route: Inhalation of Vapors					
Benzene	1.13E-06	2.27E-07	6.58E-09	—	—
1,1-Dichloroethene	3.82E-07	7.68E-08	9.22E-08	5.37E-07	5.97E-05
1,2-Dichloroethene (total)	3.41E-10	—	—	4.80E-10	2.40E-08
Tetrachloroethene	9.37E-07	1.88E-07	3.42E-10	1.32E-06	1.32E-04
Trichloroethene	1.27E-06	2.55E-07	4.34E-09	—	—
Vinyl Chloride	1.80E-06	3.62E-07	1.06E-07	—	—
Inhalation Route Subtotal:			2.09E-07		1.92E-04
Receptor Total:			2.09E-07		1.92E-04

02[UZ]ZD5071:D3222/5960/19

Source: Ecology and Environment, Inc. 1991.

Table 5-41

**CANCER RISK AND NONCANCER HAZARD INDEX ESTIMATES
FOR INHALATION OF AIRBORNE CONTAMINANTS
Location: Near Landfill
Receptor: Adult
Case: Reasonable Maximum Exposure**

Chemical	Exposure Point Air Concentration (mg/m3)	Carcinogenic Effects		Non-Carcinogenic Effects	
		Absorbed Dose (mg/kg/day)	Cancer Risk	Absorbed Dose (mg/kg/day)	Hazard Index
Exposure Route: Inhalation of Vapors					
Benzene	2.41E-04	6.06E-07	1.76E-08	—	—
1,1-Dichloroethene	7.97E-05	2.01E-07	2.41E-07	4.68E-07	5.20E-05
1,2-Dichloroethene (total)	7.25E-08	—	—	4.26E-10	2.13E-08
Tetrachloroethene	2.00E-04	5.03E-07	9.15E-10	1.17E-06	1.17E-04
Trichloroethene	2.69E-04	6.77E-07	1.15E-08	—	—
Vinyl Chloride	3.83E-04	9.64E-07	2.83E-07	—	—
Inhalation Route Subtotal:			5.55E-07		1.69E-04
Receptor Total:			5.55E-07		1.69E-04

02[UZ]ZD5071:D3222/5960/19

Source: Ecology and Environment, Inc. 1991.

Table 5-42

CANCER RISK AND NONCANCER HAZARD INDEX ESTIMATES FOR INHALATION OF AIRBORNE CONTAMINANTS
Location: Near Landfill
Receptor: Children 6-12 Yrs
Case: Reasonable Maximum Exposure

		Carcinogenic Effects		Non-Carcinogenic Effects	
Chemical	Exposure Point Air Concentration (mg/m3)	Absorbed Dose (mg/kg/day)	Cancer Risk	Absorbed Dose (mg/kg/day)	Hazard Index
Exposure Route: Inhalation of Vapors					
Benzene	2.41E-04	2.74E-07	7.95E-09	—	—
1,1-Dichloroethene	7.97E-05	9.06E-08	1.09E-07	1.06E-06	1.18E-04
1,2-Dichloroethene (total)	7.25E-08	—	—	9.61E-10	4.81E-09
Tetrachloroethene	2.00E-04	2.27E-07	4.13E-10	2.65E-06	2.65E-05
Trichloroethene	2.69E-04	3.06E-07	5.20E-09	—	—
Vinyl Chloride	3.83E-04	4.35E-07	1.28E-07	—	—
Inhalation Route Subtotal:			2.50E-07		1.45E-04
Receptor Total:			2.50E-07		1.45E-04

02[UZ]ZD5071:D3222/5960/19

Source: Ecology and Environment, Inc. 1991.

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Table 5-43

CANCER RISK AND NONCANCER HAZARD INDEX ESTIMATES
FOR INHALATION OF AIRBORNE CONTAMINANTS
Location: Near Landfill
Receptor: Children 12-18 Yrs
Case: Reasonable Maximum Exposure

Chemical	Exposure Point Air Concentration (mg/m3)	Carcinogenic Effects: Absorbed Dose (mg/kg/day)	Carcinogenic Effects: Cancer Risk	Non-Carcinogenic Effects: Absorbed Dose (mg/kg/day)	Non-Carcinogenic Effects: Hazard Index
Exposure Route: Inhalation of Vapors					
Benzene	2.41E-04	1.46E-07	4.23E-09	—	—
1,1-Dichloroethene	7.97E-05	4.84E-08	5.81E-08	5.65E-07	6.28E-05
1,2-Dichloroethene (total)	7.25E-08	—	—	5.14E-10	2.57E-09
Tetrachloroethene	2.00E-04	1.21E-07	2.20E-10	1.42E-06	1.42E-05
Trichloroethene	2.69E-04	1.63E-07	2.77E-09	—	—
Vinyl Chloride	3.83E-04	2.33E-07	6.85E-08	—	—
Inhalation Route Subtotal:			1.34E-07		7.70E-05
Receptor Total:			1.34E-07		7.70E-05

02[UZ]ZD5071:D3222/5960/19

Source: Ecology and Environment, Inc. 1991.

Table 5-44

CANCER RISK AND NONCANCER HAZARD INDEX ESTIMATES FOR ACCIDENTAL CONTACT WITH SEEP AREAS
Location: Seep Area
Receptor: Adult
Case: Reasonable Maximum Exposure

Chemical	Exposure Point Water Concentration (mg/L)	Carcinogenic Effects: Absorbed Dose (mg/kg/day)	Carcinogenic Effects: Cancer Risk	Non-Carcinogenic Effects: Absorbed Dose (mg/kg/day)	Non-Carcinogenic Effects: Hazard Index
Exposure Route: Dermal Contact with Water and Sediment					
Antimony	1.56E+01	—	—	2.33E-07	5.83E-04
Arsenic	1.59E+01	1.02E-07	1.79E-07	2.38E-07	2.38E-04
Barium	2.57E+02	—	—	3.84E-06	5.49E-05
Benzene	6.10E-03	3.91E-09	1.13E-10	—	—
Beryllium	1.31E+00	8.39E-09	3.61E-08	1.96E-08	3.92E-05
Bis(2-ethylhexyl)phthalate	2.80E-01	1.79E-07	2.51E-09	4.19E-07	2.10E-05
Chlorobenzene	2.08E-02	—	—	3.11E-08	1.56E-06
Chloroethane	4.85E-03	—	—	—	—
Chromium III	6.69E+01	—	—	1.00E-06	1.00E-06
1,2-Dichlorobenzene	3.98E-03	—	—	5.95E-09	6.61E-08
1,4-Dichlorobenzene	1.60E-02	1.03E-08	2.47E-10	2.39E-08	1.20E-07
1,1-Dichloroethane	2.48E-02	1.59E-08	1.45E-09	3.71E-08	3.71E-07
1,2-Dichloroethane	2.94E-03	1.88E-09	1.71E-10	—	—
1,2-Dichloroethene (total)	2.22E-02	—	—	3.32E-08	1.66E-06
1,2-Dichloropropane	4.43E-03	2.84E-09	1.93E-10	—	—
Ethylbenzene	3.95E-02	—	—	5.91E-08	5.91E-07
Mercury - Inorganic Compounds	4.75E-04	—	—	7.10E-12	2.37E-08
Naphthalene	3.89E-02	—	—	5.82E-08	1.46E-05
Nickel	2.06E+01	—	—	3.08E-07	1.54E-05
Toluene	1.40E-03	—	—	2.09E-09	1.05E-08
Trichloroethene	4.97E-03	3.18E-09	3.50E-11	—	—
Vinyl Chloride	1.91E-02	1.22E-08	2.32E-08	—	—
Xylenes (total)	1.04E-01	—	—	1.55E-07	7.75E-08
Dermal Route Subtotal:			2.42E-07		9.72E-04

02[UZ]ZD5071:D3222/5960/19

Source: Ecology and Environment, Inc. 1991.

Table 5-44 (Cont.)

Chemical	Exposure Point Soil Concentration (mg/kg)	Carcinogenic Effects		Non-Carcinogenic Effects	
		Absorbed Dose (mg/kg/day)	Cancer Risk	Absorbed Dose (mg/kg/day)	Hazard Index
Exposure Route: Ingestion of Chemicals in Water and Sediment					
Antimony	1.56E+01	—	—	1.22E-08	3.05E-05
Arsenic	1.59E+01	1.01E-07	1.77E-07	2.36E-07	2.36E-04
Barium	2.57E+02	—	—	2.01E-07	2.87E-06
Benzene	6.10E-03	4.09E-11	1.19E-12	—	—
Beryllium	1.31E+00	8.79E-10	3.78E-09	2.05E-09	4.10E-06
Bis(2-ethylhexyl)phthalate	2.80E-01	1.88E-09	2.63E-11	4.38E-09	2.19E-07
Chlorobenzene	2.08E-02	—	—	3.26E-10	1.63E-08
Chloroethane	4.85E-03	—	—	—	—
Chromium III	6.69E+01	—	—	5.24E-07	5.24E-07
1,2-Dichlorobenzene	3.98E-03	—	—	6.23E-11	6.92E-10
1,4-Dichlorobenzene	1.60E-02	1.07E-10	2.57E-12	2.50E-10	1.25E-09
1,1-Dichloroethane	2.48E-02	1.66E-10	1.51E-11	3.88E-10	3.88E-09
1,2-Dichloroethane	2.94E-03	1.97E-11	1.79E-12	—	—
1,2-Dichloroethene (total)	2.22E-02	—	—	3.48E-10	1.74E-08
1,2-Dichloropropane	4.43E-03	2.97E-11	2.02E-12	—	—
Ethylbenzene	3.95E-02	—	—	6.18E-10	6.18E-09
Mercury - Inorganic Compounds	4.75E-04	—	—	1.12E-12	3.73E-09
Naphthalene	3.89E-02	—	—	3.05E-10	7.63E-08
Nickel	2.06E+01	—	—	3.23E-08	1.62E-06
Toluene	1.40E-03	—	—	2.19E-11	1.10E-10
Trichloroethene	4.97E-03	3.33E-11	3.66E-13	—	—
Vinyl Chloride	1.91E-02	1.28E-10	2.43E-10	—	—
Xylenes (total)	1.04E-01	—	—	1.63E-09	8.15E-10
Ingestion Route Subtotal:			1.81E-07		2.77E-04

02[UZ]ZD5071:D3222/5960/19

Source: Ecology and Environment, Inc. 1991.

Table 5-44 (Cont.)

Chemical	Exposure Point Air Concentration (mg/m3)	Carcinogenic Effects: Absorbed Dose (mg/kg/day)	Carcinogenic Effects: Cancer Risk	Non-Carcinogenic Effects: Absorbed Dose (mg/kg/day)	Non-Carcinogenic Effects: Hazard Index
Exposure Route: Inhalation of Vapors					
Benzene	1.72E-04	1.73E-08	5.02E-10	—	—
Bis(2-ethylhexyl)phthalate	1.35E-03	1.36E-07	1.90E-09	3.17E-07	1.59E-05
Chlorobenzene	5.30E-04	—	—	1.24E-07	2.48E-05
Chloroethane	1.43E-04	—	—	—	—
1,2-Dichlorobenzene	9.37E-05	—	—	2.20E-08	5.50E-07
1,4-Dichlorobenzene	3.82E-04	3.84E-08	9.22E-10	8.97E-08	4.49E-07
1,1-Dichloroethane	6.54E-04	6.58E-08	5.99E-09	1.54E-07	1.54E-06
1,2-Dichloroethane	7.55E-05	7.60E-09	6.92E-10	—	—
1,2-Dichloroethene (total)	5.91E-04	—	—	1.39E-07	6.95E-06
1,2-Dichloropropane	1.13E-04	1.14E-08	7.75E-10	—	—
Ethylbenzene	1.03E-03	—	—	2.42E-07	2.42E-06
Naphthalene	9.11E-04	—	—	2.14E-07	5.35E-05
Toluene	3.78E-05	—	—	8.88E-09	1.56E-08
Trichloroethene	1.23E-04	1.24E-08	2.11E-10	—	—
Vinyl Chloride	5.70E-04	5.74E-08	1.69E-08	—	—
Xylenes (total)	2.71E-03	—	—	6.36E-07	7.42E-06
Inhalation Route Subtotal:			2.79E-08		1.13E-04
Receptor Total:			4.51E-07		1.36E-03

02[UZ]ZD5071:D3222/5960/19

Source: Ecology and Environment, Inc. 1991.

Table 5-45

CANCER RISK AND NONCANCER HAZARD INDEX ESTIMATES FOR ACCIDENTAL CONTACT WITH SEEP AREAS
Location: Seep Area
Receptor: Children 6-12 Yrs
Case: Reasonable Maximum Exposure

Chemical	Exposure Point Water Concentration (mg/L)	Carcinogenic Effects: Absorbed Dose (mg/kg/day)	Carcinogenic Effects: Cancer Risk	Non-Carcinogenic Effects: Absorbed Dose (mg/kg/day)	Non-Carcinogenic Effects: Hazard Index
Exposure Route: Dermal Contact with Water and Sediment					
Antimony	1.56E+01	—	—	3.06E-07	7.65E-04
Arsenic	1.59E+01	2.67E-08	4.67E-08	3.12E-07	3.12E-04
Barium	2.57E+02	—	—	5.04E-06	7.20E-05
Benzene	6.10E-03	1.03E-09	2.99E-11	—	—
Beryllium	1.31E+00	2.20E-09	9.46E-09	2.57E-08	5.14E-06
Bis(2-ethylhexyl)phthalate	2.80E-01	4.71E-08	6.59E-10	5.49E-07	2.75E-05
Chlorobenzene	2.08E-02	—	—	4.08E-08	2.04E-07
Chloroethane	4.85E-03	—	—	—	—
Chromium III	6.69E+01	—	—	1.31E-06	1.31E-07
1,2-Dichlorobenzene	3.98E-03	—	—	7.81E-09	8.68E-09
1,4-Dichlorobenzene	1.60E-02	2.69E-09	6.46E-11	3.14E-08	1.57E-07
1,1-Dichloroethane	2.48E-02	4.17E-09	3.79E-10	4.87E-08	4.87E-08
1,2-Dichloroethane	2.94E-03	4.94E-10	4.50E-11	—	—
1,2-Dichloroethene (total)	2.22E-02	—	—	4.36E-08	2.18E-07
1,2-Dichloropropane	4.43E-03	7.45E-10	5.07E-11	—	—
Ethylbenzene	3.95E-02	—	—	7.75E-08	7.75E-08
Mercury - Inorganic Compounds	4.75E-04	—	—	9.32E-12	3.11E-08
Naphthalene	3.89E-02	—	—	7.63E-08	1.91E-06
Nickel	2.06E+01	—	—	4.04E-07	2.02E-05
Toluene	1.40E-03	—	—	2.75E-09	1.38E-09
Trichloroethene	4.97E-03	8.36E-10	9.20E-12	—	—
Vinyl Chloride	1.91E-02	3.21E-09	6.10E-09	—	—
Xylenes (total)	1.04E-01	—	—	2.04E-07	5.10E-08
Dermal Route Subtotal:			6.36E-08		1.21E-03

02[UZ]ZD5071:D3222/5960/19

Source: Ecology and Environment, Inc. 1991.

Table 5-45 (Cont.)

Chemical	Exposure Point Soil Concentration (mg/kg)	Carcinogenic Effects: Absorbed Dose (mg/kg/day)	Carcinogenic Effects: Cancer Risk	Non-Carcinogenic Effects: Absorbed Dose (mg/kg/day)	Non-Carcinogenic Effects: Hazard Index
Exposure Route: Ingestion of Chemicals in Water and Sediment					
Antimony	1.56E+01	—	—	2.76E-08	6.90E-05
Arsenic	1.59E+01	4.58E-08	8.02E-08	5.34E-07	5.34E-04
Barium	2.57E+02	—	—	4.54E-07	6.49E-06
Benzene	6.10E-03	1.85E-11	5.37E-13	—	—
Beryllium	1.31E+00	3.97E-10	1.71E-09	4.63E-09	9.26E-07
Bis(2-ethylhexyl)phthalate	2.80E-01	8.48E-10	1.19E-11	9.90E-09	4.95E-07
Chlorobenzene	2.08E-02	—	—	7.35E-10	3.68E-09
Chloroethane	4.85E-03	—	—	—	—
Chromium III	6.69E+01	—	—	1.18E-06	1.18E-07
1,2-Dichlorobenzene	3.98E-03	—	—	1.41E-10	1.57E-10
1,4-Dichlorobenzene	1.60E-02	4.85E-11	1.16E-12	5.66E-10	2.83E-09
1,1-Dichloroethane	2.48E-02	7.51E-11	6.83E-12	8.77E-10	8.77E-10
1,2-Dichloroethane	2.94E-03	8.91E-12	8.11E-13	—	—
1,2-Dichloroethene (total)	2.22E-02	—	—	7.85E-10	3.93E-09
1,2-Dichloropropane	4.43E-03	1.34E-11	9.11E-13	—	—
Ethylbenzene	3.95E-02	—	—	1.40E-09	1.40E-09
Mercury - Inorganic Compounds	4.75E-04	—	—	2.52E-12	8.40E-09
Naphthalene	3.89E-02	—	—	6.88E-10	1.72E-08
Nickel	2.06E+01	—	—	7.28E-08	3.64E-06
Toluene	1.40E-03	—	—	4.95E-11	2.48E-11
Trichloroethene	4.97E-03	1.51E-11	1.66E-13	—	—
Vinyl Chloride	1.91E-02	5.79E-11	1.10E-10	—	—
Xylenes (total)	1.04E-01	—	—	3.68E-09	9.20E-10
Ingestion Route Subtotal:			8.20E-08		6.14E-04

02[UZ]ZD5071:D3222/5960/19

Source: Ecology and Environment, Inc. 1991.

Table 5-45 (Cont.)

Chemical	Exposure Point Air Concentration (mg/m3)	Carcinogenic Effects Absorbed Dose (mg/kg/day)	Carcinogenic Effects Cancer Risk	Non-Carcinogenic Effects Absorbed Dose (mg/kg/day)	Non-Carcinogenic Effects Hazard Index
Exposure Route: Inhalation of Vapors					
Benzene	1.72E-04	7.82E-09	2.27E-10	—	—
Bis(2-ethylhexyl)phthalate	1.35E-03	6.14E-08	8.60E-10	7.16E-07	3.58E-05
Chlorobenzene	5.30E-04	—	—	2.81E-07	5.62E-06
Chloroethane	1.43E-04	—	—	—	—
1,2-Dichlorobenzene	9.37E-05	—	—	4.97E-08	1.24E-07
1,4-Dichlorobenzene	3.82E-04	1.74E-08	4.18E-10	2.03E-07	1.02E-06
1,1-Dichloroethane	6.54E-04	2.97E-08	2.70E-09	3.47E-07	3.47E-07
1,2-Dichloroethane	7.55E-05	3.43E-09	3.12E-10	—	—
1,2-Dichloroethene (total)	5.91E-04	—	—	3.13E-07	1.57E-06
1,2-Dichloropropane	1.13E-04	5.14E-09	3.50E-10	—	—
Ethylbenzene	1.03E-03	—	—	5.46E-07	5.46E-07
Naphthalene	9.11E-04	—	—	4.83E-07	1.21E-05
Toluene	3.78E-05	—	—	2.00E-08	3.50E-08
Trichloroethene	1.23E-04	5.59E-09	9.50E-11	—	—
Vinyl Chloride	5.70E-04	2.59E-08	7.61E-09	—	—
Xylenes (total)	2.71E-03	—	—	1.44E-06	1.68E-05
Inhalation Route Subtotal:			1.26E-08		7.38E-05
Receptor Total:			1.58E-07		1.83E-03

02[UZ]ZD5071:D3222/5960/19

Source: Ecology and Environment, Inc. 1991.

Table 5-46

CANCER RISK AND NONCANCER HAZARD INDEX ESTIMATES FOR ACCIDENTAL CONTACT WITH SEEP AREAS
Location: Seep Area
Receptor: Children 12-18 Yrs
Case: Reasonable Maximum Exposure

Chemical	Exposure Point Water Concentration (mg/L)	Carcinogenic Effects: Absorbed Dose (mg/kg/day)	Carcinogenic Effects: Cancer Risk	Non-Carcinogenic Effects: Absorbed Dose (mg/kg/day)	Non-Carcinogenic Effects: Hazard Index
Exposure Route: Dermal Contact with Water and Sediment					
Antimony	1.56E+01	—	—	2.77E-07	6.93E-04
Arsenic	1.59E+01	2.42E-08	4.23E-08	2.82E-07	2.82E-04
Barium	2.57E+02	—	—	4.56E-06	6.51E-05
Benzene	6.10E-03	9.29E-10	2.69E-11	—	—
Beryllium	1.31E+00	1.99E-09	8.56E-09	2.33E-08	4.66E-06
Bis(2-ethylhexyl)phthalate	2.80E-01	4.26E-08	5.96E-10	4.97E-07	2.49E-05
Chlorobenzene	2.08E-02	—	—	3.69E-08	1.85E-07
Chloroethane	4.85E-03	—	—	—	—
Chromium III	6.69E+01	—	—	1.19E-06	1.19E-07
1,2-Dichlorobenzene	3.98E-03	—	—	7.07E-09	7.86E-09
1,4-Dichlorobenzene	1.60E-02	2.44E-09	5.86E-11	2.84E-08	1.42E-07
1,1-Dichloroethane	2.48E-02	3.78E-09	3.44E-10	4.40E-08	4.40E-08
1,2-Dichloroethane	2.94E-03	4.48E-10	4.08E-11	—	—
1,2-Dichloroethene (total)	2.22E-02	—	—	3.94E-08	1.97E-07
1,2-Dichloropropane	4.43E-03	6.74E-10	4.58E-11	—	—
Ethylbenzene	3.95E-02	—	—	7.02E-08	7.02E-08
Mercury - Inorganic Compounds	4.75E-04	—	—	8.44E-12	2.81E-08
Naphthalene	3.89E-02	—	—	6.91E-08	1.73E-06
Nickel	2.06E+01	—	—	3.66E-07	1.83E-05
Toluene	1.40E-03	—	—	2.49E-09	1.25E-09
Trichloroethene	4.97E-03	7.57E-10	8.33E-12	—	—
Vinyl Chloride	1.91E-02	2.91E-09	5.53E-09	—	—
Xylenes (total)	1.04E-01	—	—	1.85E-07	4.63E-08
Dermal Route Subtotal:			5.74E-08		1.08E-03

02[UZ]ZD5071:D3222/5960/19

Source: Ecology and Environment, Inc. 1991.

Table 5-46 (Cont.)

Chemical	Exposure Point Soil Concentration (mg/kg)	Carcinogenic Effects: Absorbed Dose (mg/kg/day)	Carcinogenic Effects: Cancer Risk	Non-Carcinogenic Effects: Absorbed Dose (mg/kg/day)	Non-Carcinogenic Effects: Hazard Index
Exposure Route: Ingestion of Chemicals in Water and Sediment					
Antimony	1.56E+01	—	—	1.47E-08	3.68E-05
Arsenic	1.59E+01	2.45E-08	4.29E-08	2.85E-07	2.85E-04
Barium	2.57E+02	—	—	2.43E-07	3.47E-06
Benzene	6.10E-03	9.88E-12	2.87E-13	—	—
Beryllium	1.31E+00	2.12E-10	9.12E-10	2.48E-09	4.96E-07
Bis(2-ethylhexyl)phthalate	2.80E-01	4.53E-10	6.34E-12	5.29E-09	2.65E-07
Chlorobenzene	2.08E-02	—	—	3.93E-10	1.97E-09
Chloroethane	4.85E-03	—	—	—	—
Chromium III	6.69E+01	—	—	6.32E-07	6.32E-08
1,2-Dichlorobenzene	3.98E-03	—	—	7.52E-11	8.36E-11
1,4-Dichlorobenzene	1.60E-02	2.59E-11	6.22E-13	3.02E-10	1.51E-09
1,1-Dichloroethane	2.48E-02	4.02E-11	3.66E-12	4.69E-10	4.69E-10
1,2-Dichloroethane	2.94E-03	4.76E-12	4.33E-13	—	—
1,2-Dichloroethene (total)	2.22E-02	—	—	4.19E-10	2.10E-09
1,2-Dichloropropane	4.43E-03	7.17E-12	4.88E-13	—	—
Ethylbenzene	3.95E-02	—	—	7.46E-10	7.46E-10
Mercury - Inorganic Compounds	4.75E-04	—	—	1.35E-12	4.50E-09
Naphthalene	3.89E-02	—	—	3.68E-10	9.20E-09
Nickel	2.06E+01	—	—	3.89E-08	1.95E-06
Toluene	1.40E-03	—	—	2.65E-11	1.33E-11
Trichloroethene	4.97E-03	8.05E-12	8.86E-14	—	—
Vinyl Chloride	1.91E-02	3.09E-11	5.87E-11	—	—
Xylenes (total)	1.04E-01	—	—	1.97E-09	4.93E-10
Ingestion Route Subtotal:			4.39E-08		3.27E-04

02[UZ]ZD5071:D3222/5960/19

Source: Ecology and Environment, Inc. 1991.

Tale 5-46 (Cont.)

Chemical	Exposure Point Air Concentration (mg/m3)	Carcinogenic Effects: Absorbed Dose (mg/kg/day)	Carcinogenic Effects: Cancer Risk	Non-Carcinogenic Effects: Absorbed Dose (mg/kg/day)	Non-Carcinogenic Effects: Hazard Index
Exposure Route: Inhalation of Vapors					
Benzene	1.72E-04	4.18E-09	1.21E-10	—	—
Bis(2-ethylhexyl)phthalate	1.35E-03	3.28E-08	4.59E-10	3.83E-07	1.92E-05
Chlorobenzene	5.30E-04	—	—	1.50E-07	3.00E-06
Chloroethane	1.43E-04	—	—	—	—
1,2-Dichlorobenzene	9.37E-05	—	—	2.66E-08	6.65E-08
1,4-Dichlorobenzene	3.82E-04	9.28E-09	2.23E-10	1.08E-07	5.40E-07
1,1-Dichloroethane	6.54E-04	1.59E-08	1.45E-09	1.85E-07	1.85E-07
1,2-Dichloroethane	7.55E-05	1.83E-09	1.67E-10	—	—
1,2-Dichloroethene (total)	5.91E-04	—	—	1.68E-07	8.40E-07
1,2-Dichloropropane	1.13E-04	2.75E-09	1.87E-10	—	—
Ethylbenzene	1.03E-03	—	—	2.92E-07	2.92E-07
Naphthalene	9.11E-04	—	—	2.58E-07	6.45E-06
Toluene	3.78E-05	—	—	1.07E-08	1.87E-08
Trichloroethene	1.23E-04	2.99E-09	5.08E-11	—	—
Vinyl Chloride	5.70E-04	1.38E-08	4.06E-09	—	—
Xylenes (total)	2.71E-03	—	—	7.68E-07	8.96E-06
Inhalation Route Subtotal:			6.72E-09		3.96E-05
Receptor Total:			1.08E-07		1.45E-03

02[UZ]ZD5071:D3222/5960/19

Source: Ecology and Environment, Inc. 1991.

Table 5-47

CANCER RISK AND NONCANCER HAZARD INDEX ESTIMATES FOR ACCIDENTAL CONTACT WITH SEEP AREAS
Location: Southeast Seep Area
Receptor: Adult
Case: Reasonable Maximum Exposure

Chemical	Exposure Point Water Concentration (mg/L)	Carcinogenic Effects: Absorbed Dose (mg/kg/day)	Carcinogenic Effects: Cancer Risk	Non-Carcinogenic Effects: Absorbed Dose (mg/kg/day)	Non-Carcinogenic Effects: Hazard Index
Exposure Route: Dermal Contact with Water and Sediment					
Antimony	1.56E+01	--	--	1.72E-06	4.30E-03
Arsenic	1.59E+01	7.53E-07	1.32E-06	1.76E-06	1.76E-03
Barium	2.57E+02	--	--	2.84E-05	4.06E-04
Benzene	6.10E-03	2.89E-08	8.38E-10	--	--
Beryllium	1.31E+00	6.20E-08	2.67E-07	1.45E-07	2.90E-05
Bis(2-ethylhexyl)phthalate	2.80E-01	1.33E-06	1.86E-08	3.09E-06	1.55E-04
Chlorobenzene	2.08E-02	--	--	2.30E-07	1.15E-05
Chloroethane	4.85E-03	--	--	--	--
Chromium III	6.69E+01	--	--	7.39E-06	7.39E-06
1,2-Dichlorobenzene	3.98E-03	--	--	4.40E-08	4.89E-07
1,4-Dichlorobenzene	1.60E-02	7.58E-08	1.82E-09	1.77E-07	8.85E-07
1,1-Dichloroethane	2.48E-02	1.17E-07	1.06E-08	2.74E-07	2.74E-06
1,2-Dichloroethane	2.94E-03	1.39E-08	1.26E-09	--	--
1,2-Dichloroethene (total)	2.22E-02	--	--	2.45E-07	1.23E-05
1,2-Dichloropropane	4.43E-03	2.10E-08	1.43E-09	--	--
Ethylbenzene	3.95E-02	--	--	4.36E-07	4.36E-06
Mercury - Inorganic Compounds	4.75E-04	--	--	5.25E-11	1.75E-07
Naphthalene	3.89E-02	--	--	4.30E-07	1.08E-04
Nickel	2.06E+01	--	--	2.28E-06	1.14E-04
Toluene	1.40E-03	--	--	1.55E-08	7.75E-08
Trichloroethene	4.97E-03	2.35E-08	2.59E-10	--	--
Vinyl Chloride	1.91E-02	9.04E-08	1.72E-07	--	--
Xylenes (total)	1.04E-01	--	--	1.15E-06	5.75E-07
Dermal Route Subtotal:			1.89E-06		6.70E-03

02[UZ]ZD5071:D3222/6053/18

Table 5-47 (Cont.)

Chemical	Exposure Point Soil Concentration (mg/kg)	Carcinogenic Effects: Absorbed Dose (mg/kg/day)	Carcinogenic Effects: Cancer Risk	Non-Carcinogenic Effects: Absorbed Dose (mg/kg/day)	Non-Carcinogenic Effects: Hazard Index
Exposure Route: Ingestion of Chemicals in Water and Sediment					
Antimony	1.56E+01	—	—	3.05E-06	7.63E-03
Arsenic	1.59E+01	1.33E-06	2.33E-06	3.11E-06	3.11E-03
Barium	2.57E+02	—	—	5.03E-05	7.19E-04
Benzene	6.10E-03	5.12E-10	1.48E-11	—	—
Beryllium	1.31E+00	1.10E-07	4.73E-07	2.56E-07	5.12E-05
Bis(2-ethylhexyl)phthalate	2.80E-01	2.35E-08	3.29E-10	5.48E-08	2.74E-06
Chlorobenzene	2.08E-02	—	—	4.07E-09	2.04E-07
Chloroethane	4.85E-03	—	—	—	—
Chromium III	6.69E+01	—	—	1.31E-05	1.31E-05
1,2-Dichlorobenzene	3.98E-03	—	—	7.79E-10	8.66E-09
1,4-Dichlorobenzene	1.60E-02	1.34E-09	3.22E-11	3.13E-09	1.57E-08
1,1-Dichloroethane	2.48E-02	2.08E-09	1.89E-10	4.85E-09	4.85E-08
1,2-Dichloroethane	2.94E-03	2.47E-10	2.25E-11	—	—
1,2-Dichloroethene (total)	2.22E-02	—	—	4.34E-09	2.17E-07
1,2-Dichloropropane	4.43E-03	3.72E-10	2.53E-11	—	—
Ethylbenzene	3.95E-02	—	—	7.73E-09	7.73E-08
Mercury - Inorganic Compounds	4.75E-04	—	—	9.30E-11	3.10E-07
Naphthalene	3.89E-02	—	—	7.61E-09	1.90E-06
Nickel	2.06E+01	—	—	4.03E-06	2.02E-04
Toluene	1.40E-03	—	—	2.74E-10	1.37E-09
Trichloroethene	4.97E-03	4.17E-10	4.59E-12	—	—
Vinyl Chloride	1.91E-02	1.60E-09	3.04E-09	—	—
Xylenes (total)	1.04E-01	—	—	2.04E-08	1.02E-08
Ingestion Route Subtotal:			2.80E-06		1.17E-02

02[UZ]ZD5071:D3222/6053/18

Table 5-47 (Cont.)

Chemical	Exposure Point Air Concentration (mg/m3)	Carcinogenic Effects: Absorbed Dose (mg/kg/day)	Carcinogenic Effects: Cancer Risk	Non-Carcinogenic Effects: Absorbed Dose (mg/kg/day)	Non-Carcinogenic Effects: Hazard Index
Exposure Route: Inhalation of Vapors					
Benzene	1.72E-04	2.16E-07	6.26E-09	--	--
Bis(2-ethylhexyl)phthalate	1.35E-03	1.70E-06	2.38E-08	3.96E-06	1.98E-04
Chlorobenzene	5.30E-04	--	--	1.56E-06	3.12E-04
Chloroethane	1.43E-04	--	--	--	--
1,2-Dichlorobenzene	9.37E-05	--	--	2.75E-07	6.88E-06
1,4-Dichlorobenzene	3.82E-04	4.81E-07	1.15E-08	1.12E-06	5.60E-06
1,1-Dichloroethane	6.54E-04	8.23E-07	7.49E-08	1.92E-06	1.92E-05
1,2-Dichloroethane	7.55E-05	9.50E-08	8.65E-09	--	--
1,2-Dichloroethene (total)	5.91E-04	--	--	1.73E-06	8.65E-05
1,2-Dichloropropane	1.13E-04	1.42E-07	9.66E-09	--	--
Ethylbenzene	1.03E-03	--	--	3.02E-06	3.02E-05
Naphthalene	9.11E-04	--	--	2.67E-06	6.68E-04
Toluene	3.78E-05	--	--	1.11E-07	1.94E-07
Trichloroethene	1.23E-04	1.55E-07	2.64E-09	--	--
Vinyl Chloride	5.70E-04	7.17E-07	2.11E-07	--	--
Xylenes (total)	2.71E-03	--	--	7.95E-06	9.28E-05
Inhalation Route Subtotal:			3.50E-07		1.42E-03
Receptor Total:			4.95E-06		1.98E-02

02[UZ]ZD5071:D3222/6053/18

Source: Ecology and Environment, Inc. 1991.

Table 5-48

CANCER RISK AND NONCANCER HAZARD INDEX ESTIMATES FOR ACCIDENTAL CONTACT WITH SEEP AREAS
Location: Southeast Seep Area
Receptor: Children 6-12 Yrs.
Case: Reasonable Maximum Exposure

Chemical	Exposure Point Water Concentration (mg/L)	Carcinogenic Effects		Non-Carcinogenic Effects	
		Absorbed Dose (mg/kg/day)	Cancer Risk	Absorbed Dose (mg/kg/day)	Hazard Index
Exposure Route: Dermal Contact with Water and Sediment					
Antimony	1.56E+01	—	—	1.91E-06	4.77E-03
Arsenic	1.59E+01	1.67E-07	2.92E-07	1.95E-06	1.95E-03
Barium	2.57E+02	—	—	3.15E-05	4.50E-04
Benzene	6.10E-03	6.40E-09	1.86E-10	—	—
Beryllium	1.31E+00	1.37E-08	5.89E-08	1.60E-07	3.20E-05
Bis(2-ethylhexyl)phthalate	2.80E-01	2.94E-07	4.12E-09	3.43E-06	1.72E-04
Chlorobenzene	2.08E-02	—	—	2.55E-07	1.28E-06
Chloroethane	4.85E-03	—	—	—	—
Chromium III	6.69E+01	—	—	8.19E-06	8.19E-07
1,2-Dichlorobenzene	3.98E-03	—	—	4.87E-08	5.41E-08
1,4-Dichlorobenzene	1.60E-02	1.68E-08	4.03E-10	1.96E-07	9.80E-07
1,1-Dichloroethane	2.48E-02	2.60E-08	2.37E-09	3.04E-07	3.04E-07
1,2-Dichloroethane	2.94E-03	3.08E-09	2.80E-10	—	—
1,2-Dichloroethene (total)	2.22E-02	—	—	2.72E-07	1.36E-06
1,2-Dichloropropane	4.43E-03	4.65E-09	3.16E-10	—	—
Ethylbenzene	3.95E-02	—	—	4.83E-07	4.83E-07
Mercury - Inorganic Compounds	4.75E-04	—	—	5.81E-11	1.94E-07
Naphthalene	3.89E-02	—	—	4.76E-07	1.19E-05
Nickel	2.06E+01	—	—	2.52E-06	1.26E-04
Toluene	1.40E-03	—	—	1.71E-08	8.55E-09
Trichloroethene	4.97E-03	5.21E-09	5.73E-11	—	—
Vinyl Chloride	1.91E-02	2.00E-08	3.80E-08	—	—
Xylenes (total)	1.04E-01	—	—	1.27E-06	3.18E-07
Dermal Route Subtotal:			3.61E-07		7.23E-03

02[UZ]ZD5071:D3222/6054/18

Source: Ecology and Environment, Inc. 1991.

Table 5-48 (Cont.)

Chemical	Exposure Point Soil Concentration (mg/kg)	Carcinogenic Effects: Absorbed Dose (mg/kg/day)	Carcinogenic Effects: Cancer Risk	Non-Carcinogenic Effects: Absorbed Dose (mg/kg/day)	Non-Carcinogenic Effects: Hazard Index
Exposure Route: Ingestion of Chemicals in Water and Sediment					
Antimony	1.56E+01	—	—	6.89E-06	1.72E-02
Arsenic	1.59E+01	6.02E-07	1.05E-06	7.03E-06	7.03E-03
Barium	2.57E+02	—	—	1.14E-04	1.63E-03
Benzene	6.10E-03	2.31E-10	6.70E-12	—	—
Beryllium	1.31E+00	4.96E-08	2.13E-07	5.79E-07	1.16E-04
Bis(2-ethylhexyl)phthalate	2.80E-01	1.06E-08	1.48E-10	1.24E-07	6.20E-06
Chlorobenzene	2.08E-02	—	—	9.19E-09	4.60E-08
Chloroethane	4.85E-03	—	—	—	—
Chromium III	6.69E+01	—	—	2.96E-05	2.96E-06
1,2-Dichlorobenzene	3.98E-03	—	—	1.76E-09	1.96E-09
1,4-Dichlorobenzene	1.60E-02	6.06E-10	1.45E-11	7.07E-09	3.54E-08
1,1-Dichloroethane	2.48E-02	9.39E-10	8.54E-11	1.10E-08	1.10E-08
1,2-Dichloroethane	2.94E-03	1.11E-10	1.01E-11	—	—
1,2-Dichloroethene (total)	2.22E-02	—	—	9.81E-09	4.91E-08
1,2-Dichloropropane	4.43E-03	1.68E-10	1.14E-11	—	—
Ethylbenzene	3.95E-02	—	—	1.75E-08	1.75E-08
Mercury - Inorganic Compounds	4.75E-04	—	—	2.10E-10	7.00E-07
Naphthalene	3.89E-02	—	—	1.72E-08	4.30E-07
Nickel	2.06E+01	—	—	9.10E-06	4.55E-04
Toluene	1.40E-03	—	—	6.19E-10	3.10E-10
Trichloroethene	4.97E-03	1.88E-10	2.07E-12	—	—
Vinyl Chloride	1.91E-02	7.23E-10	1.37E-09	—	—
Xylenes (total)	1.04E-01	—	—	4.60E-08	1.15E-08
Ingestion Route Subtotal:			1.26E-06		2.64E-02

02[UZ]ZD5071:D3222/6054/18

Source: Ecology and Environment, Inc. 1991.

Table 5-48 (Cont.)

Chemical	Exposure Point Air Concentration (mg/m3)	Carcinogenic Effects: Absorbed Dose (mg/kg/day)	Carcinogenic Effects: Cancer Risk	Non-Carcinogenic Effects: Absorbed Dose (mg/kg/day)	Non-Carcinogenic Effects: Hazard Index
Exposure Route: Inhalation of Vapors					
Benzene	1.72E-04	9.77E-08	2.83E-09	—	—
Bis(2-ethylhexyl)phthalate	1.35E-03	7.67E-07	1.07E-08	8.95E-06	4.48E-04
Chlorobenzene	5.30E-04	—	—	3.51E-06	7.02E-05
Chloroethane	1.43E-04	—	—	—	—
1,2-Dichlorobenzene	9.37E-05	—	—	6.21E-07	1.55E-06
1,4-Dichlorobenzene	3.82E-04	2.17E-07	5.21E-09	2.53E-06	1.27E-05
1,1-Dichloroethane	6.54E-04	3.72E-07	3.39E-08	4.33E-06	4.33E-06
1,2-Dichloroethane	7.55E-05	4.29E-08	3.90E-09	—	—
1,2-Dichloroethene (total)	5.91E-04	—	—	3.92E-06	1.96E-05
1,2-Dichloropropane	1.13E-04	6.42E-08	4.37E-09	—	—
Ethylbenzene	1.03E-03	—	—	6.83E-06	6.83E-06
Naphthalene	9.11E-04	—	—	6.04E-06	1.51E-04
Toluene	3.78E-05	—	—	2.51E-07	4.40E-07
Trichloroethene	1.23E-04	6.99E-08	1.19E-09	—	—
Vinyl Chloride	5.70E-04	3.24E-07	9.53E-08	—	—
Xylenes (total)	2.71E-03	—	—	1.80E-05	2.10E-04
Inhalation Route Subtotal:			1.57E-07		9.25E-04
Receptor Total:			1.81E-06		3.46E-02

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Source: Ecology and Environment, Inc. 1991.

Table 5-49

CANCER RISK AND NONCANCER HAZARD INDEX ESTIMATES
FOR ACCIDENTAL CONTACT WITH SEEP AREAS
Location: Southeast Seep Area
Receptor: Children 12-18 Yrs.
Case: Reasonable Maximum Exposure

Chemical	Exposure Point Water Concentration (mg/L)	Carcinogenic Effects: Absorbed Dose (mg/kg/day)	Carcinogenic Effects: Cancer Risk	Non-Carcinogenic Effects: Absorbed Dose (mg/kg/day)	Non-Carcinogenic Effects: Hazard Index
Exposure Route: Dermal Contact with Water and Sediment					
Antimony	1.56E+01	—	—	1.65E-06	4.13E-03
Arsenic	1.59E+01	1.44E-07	2.52E-07	1.68E-06	1.68E-03
Barium	2.57E+02	—	—	2.71E-05	3.87E-04
Benzene	6.10E-03	5.52E-09	1.60E-10	—	—
Beryllium	1.31E+00	1.19E-08	5.12E-08	1.38E-07	2.76E-05
Bis(2-ethylhexyl)phthalate	2.80E-01	2.53E-07	3.54E-09	2.96E-06	1.48E-04
Chlorobenzene	2.08E-02	—	—	2.20E-07	1.10E-06
Chloroethane	4.85E-03	—	—	—	—
Chromium III	6.69E+01	—	—	7.06E-06	7.06E-07
1,2-Dichlorobenzene	3.98E-03	—	—	4.20E-08	4.67E-08
1,4-Dichlorobenzene	1.60E-02	1.45E-08	3.48E-10	1.69E-07	8.45E-07
1,1-Dichloroethane	2.48E-02	2.24E-08	2.04E-09	2.62E-07	2.62E-07
1,2-Dichloroethane	2.94E-03	2.66E-09	2.42E-10	—	—
1,2-Dichloroethene (total)	2.22E-02	—	—	2.34E-07	1.17E-06
1,2-Dichloropropane	4.43E-03	4.01E-09	2.73E-10	—	—
Ethylbenzene	3.95E-02	—	—	4.17E-07	4.17E-07
Mercury - Inorganic Compounds	4.75E-04	—	—	5.01E-11	1.67E-07
Naphthalene	3.89E-02	—	—	4.11E-07	1.03E-05
Nickel	2.06E+01	—	—	2.17E-06	1.09E-04
Toluene	1.40E-03	—	—	1.48E-08	7.40E-09
Trichloroethene	4.97E-03	4.50E-09	4.95E-11	—	—
Vinyl Chloride	1.91E-02	1.73E-08	3.29E-08	—	—
Xylenes (total)	1.04E-01	—	—	1.10E-06	2.75E-07
Dermal Route Subtotal:			2.83E-07		6.63E-03

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Table 5-49 (Cont.)

Chemical	Exposure Point Soil Concentration (mg/kg)	Carcinogenic Effects Absorbed Dose (mg/kg/day)	Carcinogenic Effects Cancer Risk	Non-Carcinogenic Effects Absorbed Dose (mg/kg/day)	Non-Carcinogenic Effects Hazard Index
Exposure Route: Ingestion of Chemicals in Water and Sediment					
Antimony	1.56E+01	—	—	3.68E-06	9.20E-03
Arsenic	1.59E+01	3.22E-07	5.64E-07	3.76E-06	3.76E-03
Barium	2.57E+02	—	—	6.07E-05	8.67E-04
Benzene	6.10E-03	1.23E-10	3.57E-12	—	—
Beryllium	1.31E+00	2.65E-08	1.14E-07	3.09E-07	6.18E-05
Bis(2-ethylhexyl)phthalate	2.80E-01	5.67E-09	7.94E-11	6.61E-08	3.31E-06
Chlorobenzene	2.08E-02	—	—	4.91E-09	2.46E-08
Chloroethane	4.85E-03	—	—	—	—
Chromium III	6.69E+01	—	—	1.58E-05	1.58E-06
1,2-Dichlorobenzene	3.98E-03	—	—	9.40E-10	1.04E-09
1,4-Dichlorobenzene	1.60E-02	3.24E-10	7.78E-12	3.78E-09	1.89E-08
1,1-Dichloroethane	2.48E-02	5.02E-10	4.57E-11	5.86E-09	5.86E-09
1,2-Dichloroethane	2.94E-03	5.95E-11	5.41E-12	—	—
1,2-Dichloroethene (total)	2.22E-02	—	—	5.24E-09	2.62E-08
1,2-Dichloropropane	4.43E-03	8.97E-11	6.10E-12	—	—
Ethylbenzene	3.95E-02	—	—	9.33E-09	9.33E-09
Mercury - Inorganic Compounds	4.75E-04	—	—	1.12E-10	3.73E-07
Naphthalene	3.89E-02	—	—	9.19E-09	2.30E-07
Nickel	2.06E+01	—	—	4.87E-06	2.44E-04
Toluene	1.40E-03	—	—	3.31E-10	1.66E-10
Trichloroethene	4.97E-03	1.01E-10	1.11E-12	—	—
Vinyl Chloride	1.91E-02	3.87E-10	7.35E-10	—	—
Xylenes (total)	1.04E-01	—	—	2.46E-08	6.15E-09
Ingestion Route Subtotal:			6.79E-07		1.42E-02

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Table 5-49 (Cont.)

Chemical	Exposure Point Air Concentration (mg/m3)	Carcinogenic Effects		Non-Carcinogenic Effects	
		Absorbed Dose (mg/kg/day)	Cancer Risk	Absorbed Dose (mg/kg/day)	Hazard Index
Exposure Route: Inhalation of Vapors					
Benzene	1.72E-04	5.22E-08	1.51E-09	—	—
Bis(2-ethylhexyl)phthalate	1.35E-03	4.10E-07	5.74E-09	4.78E-06	2.39E-04
Chlorobenzene	5.30E-04	—	—	1.88E-06	3.76E-05
Chloroethane	1.43E-04	—	—	—	—
1,2-Dichlorobenzene	9.37E-05	—	—	3.32E-07	8.30E-07
1,4-Dichlorobenzene	3.82E-04	1.16E-07	2.78E-09	1.35E-06	6.75E-06
1,1-Dichloroethane	6.54E-04	1.99E-07	1.81E-08	2.32E-06	2.32E-06
1,2-Dichloroethane	7.55E-05	2.29E-08	2.08E-09	—	—
1,2-Dichloroethene (total)	5.91E-04	—	—	2.09E-06	1.05E-05
1,2-Dichloropropane	1.13E-04	3.43E-08	2.33E-09	—	—
Ethylbenzene	1.03E-03	—	—	3.65E-06	3.65E-06
Naphthalene	9.11E-04	—	—	3.23E-06	8.07E-05
Toluene	3.78E-05	—	—	1.34E-07	2.35E-07
Trichloroethene	1.23E-04	3.74E-08	6.36E-10	—	—
Vinyl Chloride	5.70E-04	1.73E-07	5.09E-08	—	—
Xylenes (total)	2.71E-03	—	—	9.60E-06	1.12E-04
Inhalation Route Subtotal:			8.40E-08		4.95E-04
Receptor Total:			1.11E-06		2.13E-02

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Source: Ecology and Environment, Inc. 1991.

The cumulative effect of all of the exposure uncertainties probably is to overestimate rather than underestimate the true potential exposures.

The basic uncertainties underlying the assessment of the toxicity of a chemical include:

- o Uncertainties arising from the design, execution, or relevance of the scientific studies that form the basis of the assessment; and
- o Uncertainties involved in extrapolating from the underlying scientific studies to the exposure situation being evaluated, including variable responses to chemical exposures within human and animal populations, between species and between routes of exposure.

These basic uncertainties could result in a toxicity estimate, based directly on the underlying studies, that either under- or overestimates the true toxicity of a chemical in the circumstances of interest.

The toxicity assessment process compensates for these basic uncertainties through the use of safety factors (uncertainty factors) and modifying factors, when assessing noncarcinogens, and the use of the upper 95% confidence limit from the linearized multistage model for the SF when assessing carcinogens. The use of the safety factors and the upper 95% confidence limit in deriving the RfDs and SFs ensures that the toxicity values used in the risk estimation process are very unlikely to underestimate, and hence almost always overestimate, the true toxicity of a chemical.

Two additional factors need to be considered when discussing uncertainties associated with the overall risk characterization: the cumulative effect of using conservative assumptions throughout the process, and the likelihood of the exposures postulated and estimated in the exposure assessment actually occurring.

The cumulative effect of using conservative assumptions throughout the risk estimation process is that the resulting estimate will substantially overestimate the true risks. The Risk Assessment Guidance for Superfund manual (EPA 1989a) recommends that individual parameter values be selected so that the overall estimate of exposure represents a "reasonable maximum exposure." In many cases, the statistical distribution of a parameter is unknown and the risk assessor is left to select a value, using best professional judgment, that is sufficiently conservative to avoid underestimating the true risk, yet not so conservative that the resulting risk estimate turns out to be unreasonably high. When in doubt, the risk assessor will usually elect to err in favor of protecting human health and select a value that results in overestimating the true risk.

Conservative estimates are typically used at every stage of the risk assessment process, including:

- o Selection or derivation of source media concentrations;
- o Selection of the parameters used in estimating contaminant migration and receptor exposure;
- o Selection or derivation of the reasonable maximum exposure point concentrations over the exposure duration postulated (steady state assumption is often used); and
- o Derivation of quantitative indices of toxicity (safety factors are used in deriving RfDs, and the upper 95% confidence limit on the multistage model estimate is used as the carcinogenic potency SF).

In the risk estimation process, these estimates and the parameters contributing to the estimates are usually combined by multiplying them together. If two values, each an upper 90th percentile estimate, are multiplied together, the resulting value would be an upper 99th percentile estimate for the product. If three 90th percentile values are multiplied together, the result is an upper 99.9th percentile estimate, and four 90th percentile estimates yield a 99.99th percentile product, which means the estimate has about 1 chance in 10,000 of underestimating the actual value. A risk estimate derived in this way would obviously be extremely conservative and would substantially overestimate the true risks. There are many instances in the risk assessment process in which four or more parameters are multiplied together to obtain a risk estimate.

In summary, the nature of the risk estimation process itself virtually ensures that the true risks will be overestimated, sometimes by large margins. Many conservatively selected factors are multiplied together, inherent uncertainties exist about parameter values, and conscious decisions are made by risk assessors and the regulatory agencies to err on the side of protecting human health.

The last uncertainty factor to consider is the likelihood of the postulated exposures actually occurring. The exposure pathways identified as complete under current land use conditions are all plausible and exposure is either presently occurring by these pathways or such exposure could reasonably be expected. The postulated frequencies of occurrence may overestimate routine occurrence but could certainly reflect the reasonable maximum occurrence.

5.5.4 Summary Discussion of the Risk Characterization

5.5.4.1 Characterization of Contamination Present at the Site

The remedial investigation was designed to characterize the nature, extent, and limits of contamination originating at the Strasburg Landfill and seems to have successfully accomplished that goal. The possible source areas were identified based on a review of past activities at the site and previous sampling activities. All of the potential source areas and migration pathways were then investigated using various field techniques and by collection and laboratory analysis of samples. In this way, the nature of the contamination was characterized and its extent defined.

Given the information available about the site, it seems unlikely that any significant source areas or migration pathways were overlooked. Since samples were collected from a variety of media encompassing all of the likely source areas and migration pathways, and samples from most of the media except soil gas were analyzed for the full TCL plus any non-TCL organics that were found, it is also unlikely that any significant contaminants would have been missed.

5.5.4.2 Magnitude and Sources of Risks Posed by Site Contaminants

EPA has recently adopted the policy that acceptable exposures to known or suspected carcinogens are generally those that represent an excess upper bound lifetime cancer risk to an individual of between 10^{-4} and 10^{-6}. In addition, EPA will use the 10^{-6} risk level as the point of departure for determining remediation goals for NPL sites. For systemic toxicants (noncarcinogens) EPA defines acceptable exposure levels as those to which the human population, including sensitive subgroups, may be exposed without adverse effects during a lifetime or part of a lifetime, incorporating an adequate margin of safety (EPA 1990b). This acceptable exposure level corresponds to a hazard index of 1. If the hazard index is less than 1, no adverse effects would be expected. If the hazard index is greater than 1, adverse effects could be possible.

A review of Tables 5-31 through 5-49 indicates that estimated carcinogenic risks exceeded the 10^{-6} level for several exposure pathways; however, estimated hazard indices for systemic toxicants did not exceed 1 (the largest was 0.15) for any of the pathways. Therefore, the remainder of this discussion will focus on the sources of the potential cancer risks.

Potential risks to nearby residents from exposure to landfill contaminants by the groundwater and air pathways were estimated separately for residents in the Zarzycki and Wheatland Drive areas, the areas likely to experience the greatest exposures by these pathways. In addition, the potential risks to site visitors from exposure to airborne contaminants on site and accidental contact with the seep areas were estimated. Site visitors are assumed to be a subpopulation of nearby residents; thus, risks to site visitors need to be added to the risks accruing in the residential areas to obtain an estimate of the total risks landfill contaminants could pose to nearby residents.

The magnitude of the potential cancer risks posed by site contaminants are summarized in Table 5-50 for Zarzycki area residents and in Table 5-51 for Wheatland Drive residents. Estimates of reasonable maximum exposures and risks to potential residential receptors are based on 30-year exposures, since that is the 90th percentile amount of time an individual lives at a single residence (EPA 1989b). Among 30-year residents, the greatest exposure and risks would accrue to an individual living at a residence from birth through early adulthood, since children tend to experience greater exposure than adults in the same setting. This occurs for two main reasons: children engage in more exploratory behavior than adults, thereby increasing their potential contact with

Table 5-50

SUMMARY OF ESTIMATED EXCESS LIFETIME CANCER RISKS IN THE ZARZYCKI AREA

		Receptors						
			Children					
Pathway	Case	Adults 30-Year Exposure	1 - 6 Years	6 - 12 Years	12 - 18 Years	Composite Child/Adult 1 - 31 Years	Risk Contributions by Exposure Route	Risk Contributions by Chemical
Residential Groundwater Usage	Historical RME	7.8×10^{-5}	2.5×10^{-5}	--	--	8.7×10^{-5}	Ingestion - 62% Inhalation - 35%	VC - 35% 1,1-DCA - 28% PCE - 11% 1,1,2,2-TCA - 9% TCE - 6% 1,1-DCE - 4% 1,2-DCA - 3% 1,2-DCP - 2%
	Current RME	6.1×10^{-5} (90%)	1.8×10^{-5}	--	--	6.9×10^{-5} (90%)	Ingestion - 70% Inhalation - 30%	VC - 60% 1,1-DCA - 23% PCE - 8% TCE - 5%
Inhalation of Airborne Contaminants	RME to Residents at Home	4.6×10^{-7} (1%)	--	--	--	9.5×10^{-7} (1%)	Inhalation - 100%	VC - 61% 1,1-DCE - 32% Benzene - 4% [BTCE - 3%
	RME to Site Visitors	5.6×10^{-7} (1%)	--	2.5×10^{-7}	1.3×10^{-7}	6.4×10^{-7} (1%)	Inhalation - 100%	VC - 51% 1,1-DCE - 44% Benzene - 4% TCE - 3%
Accidental Contact with Seep Areas	RME	5.5×10^{-6} (8%)	--	2.0×10^{-6}	1.2×10^{-6}	6.5×10^{-6} (8%)	Dermal - 33% Ingestion - 59% Inhalation - 8%	Arsenic - 73% VC - 8% Beryllium - 15% 1,1-DCA - 2% BEHP - 1%

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Key at end of table.

Table 5-50 (Cont.)

Pathway	Case	Receptors					Risk Contributions by Exposure Route	Risk Contributions by Chemical
		Adults 30-Year Exposure	Children 1 - 6 Years	Children 6 - 12 Years	Children 12 - 18 Years	Composite Child/Adult 1 - 31 Years		
Total Receptor Risks	Historical RME	7.9×10^{-5}	--	--	--	8.7×10^{-5}		VC - 56% 1,1-DCA - 21% Arsenic - 6% PCE - 7% TCE - 5% Beryllium -1%
	Current RME	6.8×10^{-5}	--	--	--	7.7×10^{-5}		

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Key:

BEHP = Bis(2-ethylhexyl)phthalate
1,1-DCA = 1,1-Dichloroethane
1,2-DCA = 1,2-Dichloroethane
1,1-DCE = 1,1-Dichloroethene
1,2-DCP = 1,2-Dichloropropane
PCE = Tetrachloroethene
TCE = Trichloroethene
VC = Vinyl chloride

Source: Ecology and Environment 1991.

Table 5-51

SUMMARY OF ESTIMATED EXCESS LIFETIME CANCER RISKS IN THE WHEATLAND DRIVE AREA

Pathway	Case	Receptors: Adults 30-Year Exposure	Children 1 - 6 Years	Children 6 - 12 Years	Children 12 - 18 Years	Composite Child/Adult 1 - 31 Years	Risk Contributions by Exposure Route	Risk Contributions by Chemical
Residential Groundwater Usage	Potential RME	1.4×10^{-5} (69%)	4.8×10^{-6}	--	--	1.6×10^{-5} (69%)	Ingestion - 60% Inhalation - 40%	PCE - 32% 1,2-DCA - 25% 1,1-DCA - 25% TCE - 17%
Inhalation of Airborne Contaminants	RME to Residents at Home	1.0×10^{-7} (1%)	--	--	--	2.1×10^{-7} (1%)	Inhalation - 100%	VC - 51% 1,1-DCE - 44% Benzene - 3% TCE - 2%
	RME to Site Visitors	5.6×10^{-7} (3%)	--	2.5×10^{-7}	1.3×10^{-7}	6.4×10^{-7} (3%)	Inhalation - 100%	VC - 51% 1,1-DCE - 44% Benzene - 3% TCE - 2%
Accidental Contact with Seep Areas	RME	5.5×10^{-6} (27%)	--	2.0×10^{-6}	1.2×10^{-6}	6.5×10^{-6} (28%)	Dermal - 33% Ingestion - 59% Inhalation - 8%	Arsenic - 73% VC - 8% Beryllium - 15% 1,1-DCA - 2% BEHP - 1%
Total Receptor Risks	RME	2.0×10^{-5}				2.3×10^{-5}		PCE - 22% Arsenic - 20% 1,1-DCA - 18% 1,2-DCA - 17% TCE - 12% VC - 4% Beryllium - 4% 1,1-DCE - 2%

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Key: 1,1-DCA = 1,1-Dichloroethane PCE = Tetrachloroethene
1,2-DCA = 1,2-Dichloroethane TCE = Trichloroethene
1,1-DCE = 1,1-Dichloroethene VC = Vinyl Chloride

Source: Ecology and Environment, Inc. 1991.

contaminants, and children have greater ingestion-rate-, inhalation-rate-, and skin-area- to body-weight ratios than adults, thus increasing the intensity of their exposure in a given situation. For these reasons, potential risks to a composite child/adult receptor, age 1 to 31 years, were estimated by summing risks for age groups explicitly evaluated.

A composite child/adult receptor was explicitly evaluated for the residential air pathway. For on-site air exposure and accidental contact with seep areas, the risk for children 6 to 12 years old and 12 to 18 years old were combined with adult risks representing 18 years of exposure to complete the 30-year exposure period. Children 1 to 6 years old would be unlikely to wander onto the landfill unaccompanied by an adult; thus, omission of this age group from these pathways would be unlikely to affect the estimated composite risks. For residential water usage, the estimated risks to 1 to 6 year olds were combined with 25 years of adult risks to obtain the composite risks. Omission of age-specific risks for 6 to 18 year olds probably results in slightly underestimating the risk to the composite individual from this pathway.

For residents in the Zarzycki area (Table 5-50) the estimated risks from residential use of groundwater (without treatment to remove contaminants) exceeded 10^{-6} for adults, children 1 to 6 years old, and the composite individual 1 to 31 years old. In addition, the estimated risks to the composite individual from inhalation of airborne contaminants in the Zarzycki area closely approached the 10^{-6} level. When combined with the estimated inhalation risks to site visitors, the total air pathway risk to the composite individual living in the Zarzycki area becomes 1.6×10^{-6}.

For residents in the Wheatland Drive area (Table 5-51), the potential risks estimated for residential groundwater usage also exceeded 10^{-6} for adults, children 1 to 6 years old, and a composite individual 1 to 31 years old. However, it must be emphasized that for the Wheatland Drive residents, the estimated groundwater risks, which account for the bulk of the risks to residents in this area, are only potential risks based on contaminant concentrations found in monitoring wells between the landfill and Wheatland Drive. Contaminants found in these monitoring wells might reach the Wheatland Drive area someday, depending on groundwater migration pathways and contaminant dispersion and degradation patterns; however, as of 1990, no contaminants were being detected in residential wells along Wheatland Drive. Thus, residential groundwater usage in this area currently poses no apparent risks. This differs from the situation in the Zarzycki area in which the estimated groundwater risks are based on contaminant concentrations actually present in the groundwater at that location.

The estimated risks from inhalation of airborne contaminants in the Wheatland Drive area is well below the 10^{-6} level, and even when combined with estimated on-site inhalation risks, only totals 8.5×10^{-7}.

Residential use of groundwater accounts for the bulk of the estimated risks (69% to 90%) for both the Zarzycki and Wheatland Drive areas. In the Zarzycki area, the majority of the total estimated risk is due to vinyl chloride (56%) and 1,1-dichloroethane (21%), with most of the remainder due to other VOCs found in the groundwater. In the Wheatland Drive area, the total estimated risks are due mainly to a number of VOCs in the groundwater, tetrachloroethene (22%), 1,1-dichloroethane (18%), 1,2-dichloroethane (17%), trichloroethene (12%) and several others, as well as to arsenic (20%).

Since the estimated groundwater risks to Wheatland Drive residents are potential future risks that are not occurring at this time and the estimated air and seep contact risks total less than 10^{-6}, it appears that Wheatland Drive residents are not experiencing any significant site-related risks at this time.

In order to assemble and select appropriate remedial responses in the feasibility study, it is necessary to know which source areas and exposure pathways may pose significant risks and which groups of potential receptors may be at risk. Therefore, the cancer risk estimates presented in Tables 5-50 and 5-51 have been reorganized by area, pathway, and receptor and summarized in Table 5-52.

5.5.4.3 Nature of Potential Adverse Health Effects

The only chemicals contributing to potentially significant adverse health effects are vinyl chloride, 1,1-dichloroethane, 1,2-dichloroethane, tetrachloroethene, and trichloroethene. Vinyl chloride is considered a human carcinogen based on epidemiological studies in workers

Table 5-52

SUMMARY OF CANCER RISKS BY AREA PATHWAY AND RECEPTOR

	Area	
	Zarzycki	Wheatland Dr.
Pathway		
Groundwater	6.9×10^{-5}	1.6×10^{-5}
Air	1.6×10^{-6}	8.5×10^{-7}
Seeps	6.5×10^{-6}	6.5×10^{-6}
Receptors		
Residents	7.7×10^{-5}	2.3×10^{-5}
Site Visitors	7.1×10^{-6}	7.1×10^{-6}

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occupationally exposed to this chemical. Vinyl chloride overexposure causes a rather rare form of liver cancer called angiosarcoma. 1,2-Dichloroethane, tetrachloroethene, and trichloroethene are Category B2 carcinogens. They have been shown to be carcinogens in animals and are considered probable human carcinogens based on the animal data. 1,2-Dichloroethane, tetrachloroethene, and trichloroethene cause liver cancer in animals. They also cause noncarcinogenic damage to the liver, including degenerative changes and fat accumulation. 1,1-Dichloroethane is a Category C carcinogen, and since there is only limited evidence that 1,1-dichloroethane is a carcinogen in animals and no evidence from human studies, it is considered only a possible human carcinogen. 1,1-Dichloroethane exposure produced hemangiosarcomas in rats.

Vinyl chloride accounts for the majority (56%) of the estimated site-related cancer risks that could actually occur under existing environmental and land use conditions. Thus, the carcinogenicity weight of evidence for these potential risks is predominantly Category A. The weight of evidence for the remainder of the estimated cancer risk is Category B2 (12%: tetrachloroethene and trichloroethene) and Category C (21%: 1,1-dichloroethane).

5.5.4.4 Level of Confidence/Uncertainty in the Risk Estimates

These matters are discussed fully in earlier Sections (5.3.4, 5.4.4, 5.5.3) of this report; briefly, the level of confidence in the exposure estimates is moderate to good. The level of confidence in the toxicity estimates varies from chemical to chemical as shown in Tables 5-28 and 5-29.

Overall, the level of confidence in the risk estimates is also moderate to good. However, as noted earlier, the nature of the risk assessment process strongly favors overestimation of the true risks.

5.5.4.5 Major Factors Driving the Estimated Site Risks

The primary factors driving site-related risks are the ongoing presence of contaminants in the groundwater in the Zarzycki area (and upgradient between the Zarzycki area and the landfill) and the use of the groundwater as drinking water and for other domestic purposes. Secondary factors are the high concentrations of toxic VOCs in the soil gas around the landfill, the generation of gas in the landfill that drives the VOCs out of the ground, the existence of the seep areas, unrestricted public access to the landfill, and the proximity of adjacent residential areas.

5.5.4.6 Characteristics of the Potentially Exposed Populations

The potential receptors consist of area residents and site visitors, the latter of whom are expected to be a subpopulation of the nearby residents. These residents would be expected to consist of a mixture of children, adults, and the elderly reflecting the general demographic characteristics of the area. No schools, hospitals, nursing homes, or similar institutions are known to be located in the vicinity of the site; therefore, the potential receptor population would not be expected to be enriched in potentially sensitive subpopulations.

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6. ECOLOGICAL ASSESSMENT

6.1 INTRODUCTION

The purpose of the ecological assessment (EA) is to determine if contaminants related to the Strasburg Landfill site are present in nearby surface waters, sediments, and soils in concentrations sufficient to cause adverse ecological impacts. This EA is based on a variety of information sources, including field investigations (April 30 to May 2, 1990), agency contacts (provided as Appendix E to this report), literature searches, and laboratory toxicity bioassays. In addition, risks to the environment were assessed in quantitative terms based on EPA guidance documents (EPA 1989a, 1989b) and generally accepted procedures taken from the technical literature. The results of the assessment can be used to support the development of appropriate cleanup goals for the Strasburg Landfill site.

Earlier sections of this report provide background information on the history of the site and data on the nature and extent of contamination. Results and analyses of toxicity bioassays are provided in Section 4.6.4.6. The ecology of the site is described briefly in Section 2.7. A more detailed ecological characterization of the site is provided below in Section 6.2, Ecological Characterization, which includes identification and description of the major terrestrial vegetation types and wetlands and quantitative surveys of the macroinvertebrate communities of the two principal streams draining the site area. The methods for the site ecological survey are provided in Section 3.10. The ecological characterization (Section 6.2) is followed by Section 6.3, Ecological Risk Assessment. The EA ends with Section 6.4, Conclusions, which synthesizes the available data regarding the potential ecological risks associated with contamination at the site.

6.2 ECOLOGICAL CHARACTERIZATION OF THE STRASBURG LANDFILL SITE

The purpose of this section is to identify and characterize the terrestrial, wetland, and aquatic ecosystems existing at the Strasburg Landfill site. Specific objectives included the following:

- Systematically survey terrestrial and wetland ecosystems at the site and develop a detailed cover-type map of the area;
- Determine whether or not significant ecological resources are potentially affected by site contamination, including jurisdictional wetlands and other sensitive environments; federal or state endangered, threatened, or rare species; and economically or recreationally important fisheries or wildlife;
- Systematically survey and characterize the two streams draining the site area, namely Briar Run and the West Branch of Brandywine Creek, and quantify the species composition of the macroinvertebrate communities upstream and downstream of the site to identify differences that might be related to site contaminants;
- Provide observations of the physiological condition of aquatic and terrestrial fauna and flora that might indicate the effects of site contaminants, including visual or photographic evidence of fish tumors or stressed vegetation; and
- Develop baseline ecological data to be used in support of the ecological risk assessment.

6.2.1 Terrestrial Ecosystems

A total of 15 distinct terrestrial vegetation cover-types were identified that comprise the 400-acre Strasburg Landfill site study area. Figure 6-1 is a map showing the 15 identified cover types and an associated identification number. The following section provides a brief description of each of the types delineated in Figure 6-1 based upon plant composition, form, structure, edaphic characteristics, or land use. Table 6-1 provides a list of plant species identified in the site area, keyed to cover type, while Table 6-2 provides a list of birds observed in the site area. An extensive Pennsylvania Game Commission list of known species from Chester County is included as Appendix E to this report.

Table 6-1

COMMON AND SCIENTIFIC NAMES OF PLANT SPECIES IDENTIFIED IN THE STRASBURG LANDFILL STUDY AREA AND COVER-TYPE(S) IN WHICH SPECIES WERE OBSERVED

Common Name	Scientific Name	Type*
Trees		
Mockernut hickory	Carya tomentosa	1, 5
Black walnut	Juglans nigra	1, 5, 12
White ash	Fraxinus americana	1, 5, 13
Quaking aspen	Populus tremuloides	1, 6
American basswood	Tilia americana	1
Black gum	Nyssa sylvatica	1, C
Red maple	Acer rubrum	1, 3, 4, 9, 11, 12, B, C, E
Flowering dogwood	Cornus florida	1, 4, 11
Black cherry	Prunus serotina	1, 5, 6, 9, 11, 12, 13
Tree-of-heaven	Ailanthus altissima	5
Tulip poplar	Liriodendron tulipifera	1, 11
Sycamore	Platanus occidentalis	1, 9, 12, B, E
Elm	Ulmus spp.	1, E
Red oak	Quercus rubra	1, 12
Sassafras	Sassafras albidum	1
American beech	Fagus grandifolia	1, 10
Ironwood	Carpinus caroliniana	1, 6
Sweet birch	Betula lenta	1
White oak	Quercus alba	1
Black locust	Robinia pseudo acacia	1, 9
Box elder	Acer negundo	1, E
Green ash	Fraxinus pennsylvanica	9, 12, E
Willow	Salix spp.	12, D, E
Eastern hemlock	Tsuga canadensis	2

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Table 6-1 (Cont.)

Common Name	Scientific Name	Type*
Shrubs		
Rose	Rosa spp.	1, 3, 5, 6, 7, 11, 12, 13, E
Spicebush	Lindera benzoin	1, 11, 12, B
Maple-leafed viburnum	Viburnum acerifolia	1
Autumn olive	Elaeagnus umbellata	3, 4, 6, 8, 13, 15
Common blackberry	Rubus allegheniensis	1, 5, 12
Arrowwood	Viburnum dentatum	1, B, C
Blackhaw	Viburnum prunifolium	1, 11, 12
Silky dogwood	Cornus amomum	6, B
Mountain laurel	Kalmia latifolia	7, 11, 12
Rhododendron	Rhododendron spp.	9, 12
Black raspberry	Rubus occidentalis	1, 5, 6, 12
Common witchhazel	Hamamelis virginiana	11, 12
Common greenbriar	Smilax spp.	9, 11, 12, B, C, E
Vines		
Poison ivy	Rhus radicans	1, 11, 12
Grape vine	Vitus spp.	1, 10, 11, C
Japanese honeysuckle	Lonicera japonica	1, 4, B, C
Herbaceous		
Switchgrass	Panicum virgatum	A
Garlic-mustard	Alliaria officinalis	1, E
Purple dead nettle	Lamium purpureum	1, 9,
Wild onion	Allium spp.	1
Bedstraw	Galium aparine	1, 9
Goldenrod	Solidago spp.	4, 6, 7, 15, A
Round-leaved violet	Viola rotundifolia	1
Violet	Viola spp.	6

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Table 6-1 (Cont.)

Common Name	Scientific Name	Type*
Herbaceous (Cont.)		
Broomsedge	Andropogon virginicus	6, 7, 15
Common buttercup	Ranunculus spp.	6
Deertongue	Panicum clandestinum	5, 9
May apple	Podophyllum peltatum	1, 9
False-solomon's seal	Smilacina stellata	1
Bracken fern	Pteridium aquilinum	2, 1, B
Jack-in-the-pulpit	Arisaema triphyllum	1, C
Cattail	Typha spp.	A
White trillium	Trillium grandiflorum	1
Skunk cabbage	Symplocarpus foetidus	B, C, E
Spring beauty	Claytonia virginica	9, B
Bloodroot	Sanguinaria canadensis	9
Trout lily	Erythronium americanum	2, 10
Dwarf ginseng	Panax trifolius	C
Queen Anne's lace	Daucus carota	6, 15
Flannel mullen	Verbascum thapsus	3, 6
Iris	Iris spp.	D
Solomon's seal	Polygonatum biflorum	1
Vetch	Vicia spp.	A
Reed canary grass	Phalaris arundinacea	A

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*Keyed to Figure 6-1: Cover Type Map of Strasburg Landfill Study Area.

Date of survey: April 30 to May 2, 1990.

Source: Ecology and Environment, Inc. 1991.

Table 6-2

BIRD SPECIES OBSERVED IN THE VICINITY OF THE STRASBURG LANDFILL SITE

Common Name	Scientific Name
Canada goose	Branta canadensis
Mallard	Anas platyrhynchos
Mourning dove	Zenaida macroura
Starling	Sturnus vulgaris
Common flicker	Colptes auratus
Downy woodpecker	Picoides pubescens
Least flycatcher	Empidonax minimus
Tree swallow	Iridoproene bicolor
White-breasted nuthatch	Sitta carolinensis
Brown creeper	Certhia familiaris
Grey catbird	Dumetella cardinensis
Robin	Turdis migratorius
Wood thrush	Hylocichla mustelina
Red-eyed vireo	Vireo olivaceus
Slate-colored junco	Junco hyemalis
Yellow warbler	Dendroica petechia
Rufus-sided towhee	Pipilo erythrophthalamus
White-throated sparrow	Zonotrichia albicollis
Crow	Corvus brachyrhychos
Red-winged blackbird	Agelaius phoeniceus
Common grackel	Quiscalus quiscula
Common yellow throat	Geothlypis trichas
Cardinal	Cardinalis cardinalis
Killdeer	Characrius vociferus
Gold finch	Carduelis tristis
Red-tailed hawk	Buteo jamaicensis
Northern mockingbird	Mimus polyglottus
Chipping sparrow	Spizella passerina
Phoebe	Sayanis phoebe

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Table 6-2 (Cont.)

Common Name	Scientific Name
Bluejay	Cyanocitta cristata
Belted kingfisher	Megaceryle alcyon
Brown-headed cowbird	Molothrus ater
Turkey vulture	Cathartes aura
Black-capped chickadee	Parus atricapillus
Rock dove	Columbia livia
Peewee	Contopus virens
Sandpiper	Calidris spp.

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Date of survey: April 30 to May 2, 1990.

Source: Ecology and Environment, Inc. 1991.

No state or federally-designated terrestrial organisms of special concern are known to occur in the study area, with the exception of occasional transient species (Kulp 1990; McKenna 1990; Shiffer 1990; Sitlinger 1990; Smith 1990). According to the Pennsylvania Natural Diversity Inventory (Smith 1990), there are five records of species of special concern for the vicinity within a 1.5-mile radius of the site (see Table 6-3). These species are not recorded from the study area (Smith 1990; McKenna 1990), nor were they observed during the field survey, nor is it known whether they still inhabit the area. In addition, the Brandywine Conservancy Environment Management Center owns (or has conservation easements on) two properties in the vicinity of the site. One of these is an extensive area of approximately 530 acres located west of Brandywine Creek at the confluence of Buck Run and Doe Run; the other is a smaller area located east of the site. Neither of these properties is located in the E & E field survey study area, but both are nature preserves with significant value for wildlife and plants (Herman 1991).

Type 1: Appalachian Mixed Hardwoods

The northern, western, and southern portions of the study area can be predominantly classified as Appalachian mixed hardwood forest. This forest type is frequently found on moist slopes of the Appalachian Mountain range as well as on adjacent portions of the Allegheny and Cumberland Plateaus.

Appalachian mixed hardwood stands are characterized by numerous and varied species. Forests of this type at the site are composed primarily of mature, well-stocked, sawtimber-sized stands. Dominant species identified include tulip poplar (Liriodendron tulipifera), red maple (Acer rubrum), mockernut hickory (Carya tomentosa), and white ash (Fraxinus americana).

The understory within this forest type varies from dense and shrub-dominated to open. Dominant vegetation found in the understory includes seedlings and saplings of the overstory species, especially black cherry, red maple, American beech, and tulip poplar.

Appalachian mixed hardwoods provide excellent habitat for a variety of birds and mammals. The field survey determined that the site is

Table 6-3

SPECIES OF SPECIAL CONCERN
STRASBURG LANDFILL SITE

Common Name	Scientific Name	Federal Status[1]	State Status[2]	Date Last Observed	Habitat*
Indian Wild Rice	*Zizania aquatica*	N	PR	1860	Swamps
Little Ladies' tresses	*Spiranthes tuberosa*	N	TU	1915	Dry sandy soil
Cranefly Orchid	*Tipularia discolor*	N	PR	1983	Woods
White Heath Aster	*Aster ericoides*	N	PR	1983	Dry soil
Black Vulture	*Coragyps atratus*	N	NL	1983	Open lowlands, garbage dumps

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Key:

N = No federal status.

PR = Pennsylvania rare.

TU = Tentatively undetermined.

NL = Not listed.

*Habitats for plants from Britton and Brown (1970); habitat for Black Vulture from Ehrlich *et al.* (1988).

Source: Pennsylvania Natural Diversity Inventory, Smith 1990.

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heavily utilized, and numerous song birds were seen or heard while conducting the study. Deer tracks and browse and unidentified mammal burrows were also observed. Scattered standing snags and den trees throughout the site provide habitat for cavity-nesting birds and mammals.

Type 2: Eastern Hemlock

Cool, moist conditions occurring on north-facing slopes and in ravines create optimal habitat for the development of forest stands dominated by eastern hemlock (Tsuga canadensis). Conditions of this type occur along a steeply-sided ravine in the western end of the site within a matrix of Appalachian mixed hardwoods (Type 1). This stand is composed of sawtimber-sized eastern hemlock forming a canopy over a primarily herbaceous understory consisting of bracken fern (Pteridium aquilinum) and trout lily (Erythronium americanum).

Coniferous stands are valuable to wildlife because they provide year-round cover. Eastern hemlock, in particular, has dense, low foliage when young, which provides winter cover for such wildlife as ruffed grouse, wild turkey, and deer. Hemlock stands also provide preferred nesting sites for several northern bird species. The small winged seeds are an important food source for several bird species as well as rodents such as the red squirrel (Martin et al. 1951).

Type 3: Early Successional Forest A

Early successional forest is located on even to gently sloping terrain in an abandoned farmyard area near the southern boundary of the site. The zone is dominated by large, intertwined rose (Rosa spp.) bushes, autumn olive (Elaeagnus umbellata), and red maple saplings.

The dense brush of this cover-type provides excellent habitat for small and large mammals as well as nesting sites for game birds and songbirds. Many common songbirds were observed in this area during the survey. Wild rose is important as a winter food source for upland game birds, various furbearing mammals, and hoofed browsers. Autumn olive has considerable importance for both birds and mammals, providing protective cover for rabbits and excellent nesting sites for game birds (Allan and Steiner 1972). The importance of red maple for wildlife is discussed below under cover Type 11.

Type 4: Early Successional Forest B

North and east of Type 3, the community composition changes from a stand dominated by rose and red maple saplings to an almost pure stand of autumn olive. This stand averages 6 to 10 feet in height and has a low-density, somewhat broken canopy that has allowed for the development of a varied understory, including Japanese honeysuckle (Lonicera japonica) and several species of goldenrod (Solidago spp.). Scattered throughout this type are flowering dogwood (Cornus florida) and red maple saplings.

Rose and red maple have considerable value to wildlife, as described in Type 3. The added understory of honeysuckle provides winter cover for birds and rabbits, as well as fruit for songbirds, upland gamebirds, and deer. Flowering dogwood fruits and buds are eaten by the wood duck, various upland game birds and songbirds, as well as fur and game mammals and hoofed browsers of the area.

Type 5: Old Hedgerow

This cover type is a narrow, linear zone of mature, widely spaced trees that previously comprised a hedgerow between two active agricultural fields. This old hedgerow is dominated by mature black cherry (Prunus serotina) and tree-of-heaven (Ailanthus altissima), with a dense understory of Allegheny blackberry (Rubus allegheniensis) and rose. Minor components of this cover type include black walnut (Juglans nigra) and mockernut hickory.

This zone is situated between an old field cover type and a borrow pit, thus providing a well-protected travel corridor through these open areas and edge habitat for various wildlife species. Large trees within the hedgerow provide roosting sites for raptors. The black cherry and the blackberry are among the most significant woodland plant species for numerous songbirds, fur-bearing game and small mammals, and hoofed browsers. Blackberry is also valuable as protective cover for birds and small mammals and as a nesting site for small birds.

Type 6: Old Field (10 Years)

Cover type 6 is an early successional community that has developed on previously pastured or cultivated agricultural land. Aerial photo interpretation and field examination of vegetation suggest that these areas have been out of cultivation for at least 10 years. This cover type is primarily herbaceous and dominated by goldenrod, broomsedge (Andropogon virginicus), common buttercup (Ranunculus spp.), and violets (Viola spp.). Scattered throughout this cover type are rose, autumn olive, silky dogwood shrubs, and seedlings and saplings of black cherry, aspen (Populous spp.), and hornbeam (Carpinus caroliniana).

In this relatively open area, the scattered shrubs and trees provide needed protective cover for wildlife. The important food value of black cherry, dogwood, and rose has been described under preceding cover type discussions. The herbaceous dominants of this cover type are seed-producing and valued as a food source by small birds. Broomsedge is especially valuable as a winter food source.

Type 7: Mountain Laurel

Within a parcel of cover type 6, in the northwest portion of the study area, is a small community composed of almost pure mountain laurel (Kalmia latifolia). This cover type is situated on a relatively dry, west-facing hilltop where hydrologic and edaphic conditions are suitable for the dry-site mountain laurel. This stand of mountain laurel is somewhat unusual as this species is more typically found as a forest understory species.

Mountain laurel is utilized heavily by deer and grouse, which feed on the foliage, buds, and twigs. Dense stands of this species are also valuable to wildlife as winter cover.

Type 8: Borrow Pit

Cover-type 8 comprises the vegetative cover that has invaded the highly disturbed area of the site that was previously used to obtain soil cover for the landfill. This area is in a state of primary succession and is virtually devoid of vegetation, with the exception of a few scattered autumn olive shrubs and some tufts of unidentified grasses.

The majority of the soil surface in this zone remains unvegetated and unstabilized and is therefore largely devoid of any special wildlife value.

Type 9: Mesophytic Hardwood Floodplain Forest

Cover-type 9 is a low-lying zone characterized by uneven terrain dissected by several shallow ravines that feed into Briar Run. This relatively moist area supports a forest community dominated by sycamore (*Platanus occidentalis*), green ash (*Fraxinus pennsylvania*), and red maple in the lower areas and black locust (*Robinia pseudoacacia*) and black cherry in the higher areas. Understory herbaceous species include spring ephemerals such as spring beauty, bloodroot, may apple, deer tongue, purple dead nettle, and bedstraw.

Bottomland hardwood forests provide valuable wildlife habitat and are often suitable for uncommon and endangered species. Proximity to a perennial water source, coupled with the protective cover and food resources of woody vegetation, is extremely desirable for most wildlife. The dissected terrain is marked by several depressional areas located primarily on the west side of Briar Run.

The Chester County soil survey (1987) reports that the soils in this area are of the Glenville series, which are described as poorly drained. Several "pocket" wetlands were identified within this zone that meet the criteria for federal wetland designation based on the presence of hydric soils, hydrophytic vegetation, and wetland hydrology. These wetlands are described below in more detail.

Type 10: Mature American Beech Forest

The west-facing slope on the east side of Briar Run is underlain by soils of the well-drained Manor series. Consequently, this zone supports a cover type dominated almost entirely by American beech (*Fagus grandifolia*), which prefers well-drained soils. The stand is mature and composed of well-formed, widely spaced, sawtimber-sized trees. The understory is marked by numerous large oak stumps, indicating a previous selective logging operation in the area, and is generally lacking in tree seedlings and shrub species. The major understory species is the herbaceous trout lily.

Beechnuts are particularly important as a food source for squirrels and chipmunks. Other mammals such as black bear and porcupine, and several songbird species, utilize beechnuts as well. Whitetail deer movement may also be facilitated by the open nature of the understory.

Type 11: Mature Red Maple Forest

Cover-type 11 consists of a mature, sawtimber-sized stand dominated by an overstory composed of almost pure red maple. Much of the zone supports an open understory dominated by mountain laurel and a few black cherry and tulip poplar seedlings and saplings. In some areas, the understory becomes quite dense and dominated by rose, spicebush (Lindera benzoin), and blackhaw (Viburnum prunifolium).

Red maple seeds, twigs, and foliage provide food and nest material for upland gamebirds (i.e., ruffed grouse, bob-white quail, wild turkey) and numerous songbirds. Fur and game mammals (i.e., black bear, beaver, porcupine, and various squirrel species), small mammals (i.e., eastern chipmunk and various mouse species), and whitetail deer use seeds, flowers, bark, twigs, and foliage of red maple trees. Blackhaw and other viburnum species have some use to wildlife as food and protective cover. On the whole, this cover-type is very valuable to wildlife because of its close proximity to water.

Type 12: Mature Mixed Mesophytic Forest

The southeast portion of the study area supports a mature deciduous forest with an extremely dense understory. Red maple dominates this stand, but black cherry, red oak (Quercus rubra), and sycamore are common components. The dense understory is dominated by briar and shrub species, including rose, blackberry, raspberry (Rubus occidentalis), and mountain laurel, and seedlings and saplings of the dominant overstory species. The canopy of this stand along the southern portion of Briar Run becomes open and dominated by widely spaced black walnuts with a dense understory of spicebush, rose, and blackhaw.

This cover-type is highly valuable for wildlife because Briar Run, a perennial stream, runs through this zone. The dense brush understory provides excellent protective cover for small mammals and nesting sites for small birds, and several tree and shrub species provide food sources for numerous wildlife species. The food value of black cherry, rose, blackberry, and raspberry has been discussed under previous cover-type descriptions. Black walnuts are eaten by several squirrel species in the area. Oak acorns are heavily utilized by numerous wildlife species

Type 13: Rose Thicket

The old field south of the landfill is dominated in areas by an extremely dense thicket composed almost entirely of multiflora rose, with a minor component of autumn olive, white ash, and black cherry saplings.

This area provides superior cover for small mammals and songbirds. The food value of roses is discussed under cover-type 3.

Type 14: Agricultural Land

The majority of the land along the northernmost and southernmost border of the site is in active agricultural usage either as row crop, pasture, or hay field. These areas are off the property owned by the Strasburg Landfill but were examined as a part of the overall study area.

Type 15: Landfill

The landfill cap and adjacent disturbed areas are covered with weedy herbaceous growth, including unidentified grasses, broom sedge, and goldenrods along with a few scattered shrubs. Patches of this highly disturbed area are nearly bare, but sufficient vegetative cover exists to provide minimal habitat for wildlife, particularly on the landfill edge. The borrow pit area to the north of the landfill is included in this cover type and supports a greater density of vegetative cover than the borrow pit cover type (Type 8).

6.2.2 Wetland Types

The Coatesville, Pennsylvania USFWS National Wetland Inventory quadrangle map identifies no federally designated wetlands on or in the general vicinity of the Strasburg Landfill study area. However, several wetland ecosystems were identified during the field survey that meet the criteria for designation based on the presence of hydric soils, wetland hydrology, and hydrophytic vegetation. These wetland areas are coded as A, B, C, D, and E on the site cover-type map (Figure 6-1) and are described in detail below.

Wetland A: Seep Emergent Marsh

Overland storm flow and landfill seepage collect in a depression adjacent to the southwest corner of the landfill. This ponded water has formed an approximately 0.2-acre open water/emergent marsh wetland system. This wetland area is not designated by the USFWS National Wetlands Inventory. However, according to procedures detailed in the Federal Manual, the site meets the wetland designation criteria based on the presence of hydric soils, hydrophytic vegetation, and wetland hydrology.

The northern end of this wetland complex appears to be fed primarily by seep water from the landfill and supports a dense stand of herbaceous vegetation (primarily switchgrass [*Panicum virgatum*] and reed canary grass [*Phalaris arundinacea*]). Minor vegetative associates include vetch (*Vicia* spp.), wet-site goldenrods (*Solidago* spp.), and broad-leaved cattail (*Typha latifolia*).

The southern portion of this wetland consists of a small open-water pond surrounded by a fringe of switchgrass and cattail. Although small, this wetland area appears to provide acceptable habitat for waterfowl and shorebirds due to the lack of such similar habitat in the general vicinity. At the time of the survey, a killdeer (*Characrius vociferus*) was observed foraging in the shallow water of this marsh. At other times, mallard ducks and Canada geese have been observed loafing in this marsh. No nesting waterfowl or shorebirds were observed.

Wetland B: Pocket Floodplain Wetlands

The central portion of the Briar Run floodplain widens and is marked by several intermittent drainages and low-lying depressions. These depressions were likely created by meandering of the creek and, through levee formation, developed from sediment deposited during episodic flooding. These depressions trap storm and floodwaters that, in turn, percolate slowly through the underlying poorly-drained Glenville soils. The resulting long hydroperiod has led to the development of hydric soils that support a prevalence of hydrophytic vegetation dominated by an overstory of red maple and sycamore and an understory of skunk cabbage (*Symplocarpus foetidus*), spicebush, and silky dogwood. Approximately 20% (1.2 acres) of cover-type 9 is composed of small pocket wetlands.

These wetlands are valuable for retention and slow release of floodwaters, filtration of sediment-laden stormwater coming off the disturbed soils of the Strasburg Landfill (thus protecting the water quality of Briar Run), and transitional habitat utilized by numerous wildlife species.

Forested wetlands tend to support higher numbers and more diverse species of breeding birds than upland areas due to the better water availability, dense nesting cover, and abundance of insects. Waterfowl, such as black duck, wood duck, mallard, and hooded merganser, require forested wetlands for breeding and brood raising. None of these species was noted during the survey, however. Vernal ponds created by periodic flooding in forested wetlands are critical to the reproduction cycles of many amphibians, including salamanders, toads, wood frogs, and spring peepers. Reptiles, including wood turtles, spotted turtles, eastern ribbon snakes, brown snakes, watersnakes, and garter snakes, utilize forested wetlands. Several unidentified snakes were observed in the wetlands along Briar Run. Forested wetlands also provide habitat for numerous species of mammals, including the whitetail deer, mink, weasel, and raccoon.

Wetland C: Riparian Wetland

Riparian wetlands were identified at the site in association with Briar Run. These wetlands include the riverine system of Briar Run and the palustrine forested system occupying a narrow corridor of low ground adjacent to Briar Run. The underlying soils are of the poorly drained Glenville series and are on the Pennsylvania hydric soils list. Soil pit analysis identified oxidized rhizospheres, mottling, and gleying within 14 inches, thus indicating hydric soil conditions. The riparian corridor is dominated by primarily hydrophytic vegetation, including skunk cabbage, grape vine (Vitus spp.), jack-in-the-pulpit (Arisaema triphyllum), viburnums (Viburnum spp.), black gum (Nyssa sylvatica), and red maple. Downstream, the riparian system narrows as the banks of Briar Run become steeper.

The riparian wetlands differ from the "pocket" wetlands on the adjacent floodplain, as they are formed differently. The hydrology of the pocket wetlands is derived from flood and storm water that is stored in depressions behind levees. The riparian wetlands, however, derive moisture from regular flooding and slow drainage of stored water in the adjacent floodplain.

Wetland D: Emergent-Marsh/Open-Water Wetland

This wetland occurs in an area of active agricultural land on the floodplain of the West Branch of Brandywine Creek. The 0.16-acre wetland is approximately 400 feet west of Briar Run and appears to be hydrologically isolated from both streams.

Entrance to the site was not permitted by the landowner, so it was not possible to evaluate the soils. However, the Chester County soil survey reports that the soils underlying the site are of the poorly drained Hatboro series, which are contained in the most recent federal list of hydric soils (U.S. Soil Conservation Service 1987).

Vegetation and wetland hydrology were evaluated by observation from the railroad right-of-way directly adjacent to the wetlands. The wetland is characterized as primarily shallow, open water surrounded by a fringe of unidentified iris (Iris spp.) and developmentally immature grasses that could not be positively identified. Scattered willow (Salix spp.) are located on higher ground surrounding the site.

Emergent-marsh/open-water systems are extremely valuable for wildlife, particularly waterfowl and shorebirds. A pair of mallard ducks was observed utilizing this wetland.

Wetland E: Floodplain Swamp Forest

The southwestern-most corner of the study area, on the West Branch of the Brandywine Creek floodplain, is dominated by an approximately 11-acre palustrine forested swamp. Vegetation in this wetland is composed of mature sawtimber-sized trees dominated by sycamore, box elder, green ash, and red maple. The understory is open and dominated by scattered rose, green brier (Smilax spp.), and an herb layer of garlic-mustard (Alliaria officinalis). This area is underlain by several poorly drained soils, including those of the Hatboro, Comus, and Codorus series (U.S. Soil Conservation Service 1987). Functions and values of floodplain forested wetlands are described above in the discussion for Wetland B.

Pennsylvania Game Commission Survey

The Pennsylvania Game Commission Bureau of Land Management conducted a field assessment of the site and reported the results to E & E on September 11, 1990 (Sitlinger 1990). The brief account of this walkover survey is provided in Appendix E of this report. Wildlife or wildlife signs included common species such as white-tailed deer, raccoon, woodchuck, cottontail rabbit, gray squirrel, eastern chipmunk, mourning dove, robin, killdeer, crow, and blue jay (Sitlinger 1990).

6.2.3 Aquatic Ecosystems

Two aquatic ecosystems, Briar Run and Brandywine Creek, are located within the study area. Briar Run is a headwater stream with relatively little upstream drainage. South of the landfill, this stream flows into the West Branch of Brandywine Creek, which is a small tributary of the Delaware River. Both Briar Run and the West Branch Brandywine Creek are classified WWF-MF (warmwater fishery, migratory fish) by the Pennsylvania Bureau of Water Quality Management (Schubert 1991). The following subsections provide a detailed description of the sampling locations on these two creeks. Table 6-4 provides a summary of physical stream characteristics for all of the sampling points.

Briar Run

The upstream Briar Run sampling station, approximately 0.3 mile from the landfill (sample location BR-1, Figure 3-1), was located at a 1- to 3-foot-wide section bordered by nearly level banks. At the time of the survey (April 30 to May 2, 1990), the stream was 2 to 6 inches deep. The substrate is composed primarily of silt, sand, and pebbles with sporadic cobbles. Gross water chemistry, including water temperature, pH, dissolved oxygen (DO), and conductivity, are presented in Table 6-5. The benthic organisms collected and identified from the upstream Briar Run sampling location are listed in Table 6-6. No fish species were observed.

Bordering Briar Run at the sampling station is a riparian floodplain wetland characterized by saturated soil supporting a community of vegetation. The stream banks support a dense stand of herbaceous and woody vegetation.

Table 6-4

GROSS STREAM CHARACTERISTICS OF BRIAR RUN AND THE WEST BRANCH OF BRANDYWINE CREEK

	Width (ft)	Depth (in)	Approximate Flow (cfs)	Bank Height	Bank Slope
West Branch of Brandywine Creek					
BW-1 (Upstream)	50 - 60	6 - 10	135	Nearly level to gradual slope	15%
BW-3 (Downstream)	50 - 55	12 - 22	200	10 feet north side 60 feet south side	15% north 60% south
Briar Run					
BR-1 (Upstream)	1 - 3	2 - 6	1.5	Nearly level	0
BR-3 (Downstream)	2 - 4	2 - 4	2.5	1 - 3 feet	60% west 3% east

02[UZ]ZD5071:D3222/5984/17

Date of survey: April 30 to May 2, 1990.

Source: Ecology and Environment, Inc. 1991.

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Table 6-5

GROSS WATER CHEMISTRY DATA COLLECTED AT SAMPLING LOCATIONS

	Briar Run		Brandywine Creek	
	Upstream BR-1	Downstream BR-3	Upstream BW-1	Downstream BW-3
Water temperature (°C)	16	14	13	16
DO (ppm)	8.2	10.6	11	10.2
pH	10.1	8.8	8.9	9.2
Conductivity (micromhos/cm^2)	100	220	240	210

02[UZ]ZD5071:D3222/5985/25

Date of survey: April 30 to May 2, 1990.

Source: Ecology and Environment, Inc. 1991.

Table 6-6

BENTHIC INVERTEBRATES
COLLECTED AT UPSTREAM BRIAR RUN SAMPLING STATION

Order	Family	Genus	Common Name	Percent Composition
Replicate #1				
Diptera	Tipulidae	--	Cranefly	14.25
Ephemeroptera	Ephemerellidae	Ephemerella	Mayfly	42.90
Ephemeroptera	Heptageniidae	--	Mayfly	14.25
Ephemeroptera	Siphlonuridae	Isonychia	Mayfly	28.60
Replicate #2				
Ephemeroptera	Ephemerellidae	Ephemerella	Mayfly	12.50
Ephemeroptera	Heptageniidae	--	Mayfly	12.50
Ephemeroptera	Siphlonuridae	Isonychia	Mayfly	25.00
Plecoptera	Perlidae	--	Stonefly	12.50
Trichoptera	Hydropsychidae	Hydropsyche	Caddisfly	12.50
Trichoptera	Psychomyiidae	Neuroclipsis	Caddisfly	25.00
Replicate #3				
Diptera	Chironomidae	--	Midge	11.10
Ephemeroptera	Heptageniidae	--	Mayfly	11.10
Ephemeroptera	Siphlonuridae	Isonychia	Mayfly	44.50
Plecoptera	Perlidae	--	Stonefly	11.10
Trichoptera	Psychomyiidae	Neuroclipis	Caddisfly	11.10
Trichoptera	Rhyacophilidae	Rhyacophila	Caddisfly	11.10

02[UZ]ZD5071:D3222/5986/22

Date of survey: April 30 to May 2, 1990.

Source: Ecology and Environment, Inc. 1991.

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The downstream Briar Run sampling station was located 3,000 feet south of the upstream station, approximately 300 feet from the Briar Run confluence with Brandywine Creek (sample location BR-3, Figure 3-1). This portion of the stream has a sand, silt, cobble, and small boulder substrate and is characterized by sharp meanders. The west bank is nearly vertical, with a 2- to 3-foot-high earthen bank showing exposed roots. Overhanging shrubs and vines shade much of the water surface. The east bank is densely vegetated and slopes gently up to an adjacent pasture. Vegetation consists of immature trees, shrubs, and thick beds of herbaceous vegetation. Some areas contain undercut banks that provide habitat for aquatic organisms.

At the time of the survey (April 30 to May 2, 1990), the stream was 2 to 4 inches deep, with a flow of approximately 2.6 cfs. Temperature, dissolved oxygen, pH, and conductivity data of the water are presented in Table 6-5. The benthic invertebrates collected and identified in this area are shown in Table 6-7. No fish species were collected or observed.

Stream surveys conducted by PADER in 1977 and 1979 on Briar Run identified high water-quality conditions suitable for supporting salmonids. The 1979 study revealed a substantial but unquantified population of brook trout (Salvelinus fontinalis). Natural reproduction of the species was confirmed by the numerous year-classes represented, ranging from fingerlings to adults. Other species found included blacknose dace (Rhinichthys atratulus) and creek chub (Semotilus atromaculatus). The 1979 survey concluded that Briar Run was a valuable fisheries resource.

PADER surveyed Briar Run again in 1983. This survey revealed similarly high water quality as evidenced by a diverse array of aquatic macroinvertebrates and the presence of pollution-sensitive stoneflies, mayflies, and caddisflies. However, excessive sedimentation was also observed. Pool areas of the stream necessary to support trout were heavily sedimented, thus severely reducing trout habitat. The study concluded that sediment, most likely from the active Strasburg Landfill, had resulted in the destruction of aquatic habitat and had adversely affected brook trout populations.

Table 6-7

BENTHIC INVERTEBRATES
COLLECTED AT DOWNSTREAM BRIAR RUN SAMPLING STATION

Order	Family	Genus	Common Name	Percent Composition
Replicate #1				
Diptera	Chironomidae	--	Midge	3.6
Ephemeroptera	Ephemorellidae	Ephemerella	Mayfly	21.4
Ephemeroptera	Heptageniidae	--	Mayfly	25.0
Ephemeroptera	Siphlonuridae	Isonychia	Mayfly	3.6
Plecoptera	Nemouridae	--	Stonefly	17.9
Plecoptera	Perlidae	--	Stonefly	7.1
Trichoptera	Hydropsychidae	Hydropsyche	Caddisfly	21.4
Replicate #2				
Diptera	Chironomidae	--	Midge	8.5
Diptera	Tipulidae	--	Cranefly	4.3
Ephemeroptera	Ephemerellidae	Ephemerella	Mayfly	12.8
Ephemeroptera	Heptageniidae	--	Mayfly	21.3
Ephemeroptera	Siphlonuridae	Isonychia	Mayfly	2.0
Plecoptera	Nemouridae	--	Stonefly	42.6
Trichoptera	Hydropsychidae	Hydropsyche	Caddisfly	8.5
Replicate #3				
Diptera	Chironomidae	--	Midge	24.4
Ephemeroptera	Ephemerellidae	Ephemerella	Mayfly	7.3
Ephemeroptera	Heptageniidae	--	Mayfly	36.6
Ephemeroptera	Siphlonuridae	Isonychia	Mayfly	4.9
Plecoptera	Nemouridae	--	Stonefly	17.1
Trichoptera	Hydropsychidae	Hydropsyche	Caddisfly	7.3
Trichoptera	Psychomyiidae	Neuroclipsis	Caddisfly	2.4

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Date of survey: April 30 to May 2, 1990.

Source: Ecology and Environment, Inc. 1991.

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No state or federally-designated aquatic organisms of special concern are known to inhabit Briar Run (Kulp 1990; McKenna 1990; Shiffer 1990; Sitlinger 1990; Smith 1990).

West Branch of Brandywine Creek

The upstream sampling station on the West Branch of Brandywine Creek was located at a 50- to 60-foot-wide section of the stream, approximately 0.4 mile from the landfill (sample location BW-1, Figure 3-1). At this point, the stream banks are nearly level with the water surface for 10 feet, then gradually slope upward away from the stream for approximately 20 feet. The nearly level portion of the stream banks supports herbaceous and immature woody vegetation composed predominantly of sycamore. At the time of the survey, the stream was 6 to 10 inches deep and flowing at a rate of approximately 134 cfs. The cobble substrate was partially covered with periphyton. Water temperature, dissolved oxygen, pH, and conductivity are presented in Table 6-5.

The downstream sampling on the West Branch of Brandywine Creek took place at a 50- to 55-foot-wide section with a silt, sand, cobble, and small boulder substrate (sample location BW-3, Figure 3-1). The south bank is approximately 60 feet high, nearly vertical, and dominated by large beech, hemlock, and sycamore trees. Understory vegetation is sparse. The north bank is nearly level for 20 feet, then slopes gently for 10 feet into a level pasture. The vegetation along this bank is mainly herbaceous with some alder and willow shrubs and scattered large sycamores. At the time of the survey, the stream was 12 to 22 inches deep and had a flow of approximately 206 cfs (see Table 6-4). Data for water temperature, dissolved oxygen, pH, and conductivity are presented in Table 6-5.

The benthic organisms collected and identified from the sample locations are listed in Tables 6-8 and 6-9. Benthic invertebrates collected in the West Branch of Brandywine Creek upstream of the landfill consisted primarily of caddisflies and mayflies with an occasional midge snail (Physidae) and aquatic worm (Oligochaeta). Downstream in the West Branch of Brandywine Creek, the community was dominated by midges. Mayfly larvae and caddisfly larvae were also present. While suitable substrate (cobbles and boulders) was present at the downstream site for

AR300856

Table 6-8

BENTHIC INVERTEBRATES COLLECTED AT UPSTREAM BRANDYWINE CREEK SAMPLING STATION

Order	Family	Genus	Common Name	Percent Composition
Replicate #1				
Diptera	Chironomidae	--	Midge	4.2
Ephemeroptera	Ephemorellidae	Ephemerella	Mayfly	41.6
Gastropoda	Physidae	--	Snail	4.2
Trichoptera	Hydropsychidae	Hydropsyche	Caddisfly	50.0
Replicate #2				
Diptera	Chironomidae	--	Midge	7.1
Ephemeroptera	Ephemerellidae	Ephemerella	Mayfly	7.1
Oligochaeta	--	--	Worm	14.3
Trichoptera	Hydropsychidae	Hydropsyche	Caddisfly	71.5
Replicate #3				
Trichoptera	Hydropsychidae	Hydropsyche	Caddisfly	100.0

02[UZ]ZD5071:D3222/5989/22

Date of survey: April 30 to May 2, 1990.

Source: Ecology and Environment, Inc. 1991.

Table 6-9

BENTHIC INVERTEBRATES COLLECTED AT DOWNSTREAM BRANDYWINE CREEK SAMPLING STATION

Order	Family	Genus	Common Name	Percent Composition
Replicate #1				
Diptera	Chironomidae	--	Midge	72.7
Ephemeroptera	Ephemerellidae	Ephemerella	Mayfly	13.6
Ephemeroptera	Siphlonuridae	Isonychia	Mayfly	9.1
Trichoptera	Hydropsychidae	Hydropsyche	Caddisfly	4.6
Replicate #2				
Diptera	Chironomidae	--	Midge	76.2
Ephemeroptera	Ephemerellidae	Ephemerella	Mayfly	14.3
Trichoptera	Hydropsychidae	Hydropsyche	Caddisfly	9.5
Replicate #3				
Diptera	Chironomidae	--	Midge	69.7
Ephemeroptera	Ephemerellidae	Ephemerella	Mayfly	21.7
Ephemeroptera	Heptageniidae	--	Mayfly	4.3
Trichoptera	Hydropsychidae	Hydropsyche	Caddisfly	4.3

02[UZ]ZD5071:D3222/5990/22

Date of survey: April 30 to May 2, 1990.

Source: Ecology and Environment, Inc. 1991.

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mayfly, stonefly, and caddisfly larvae colonization, the substrate was not available because of embeddedness. Mayflies and other clinging invertebrates require areas such as the bottoms of unembedded stones on which to retreat from strong currents. Suitable substrate for chironomid larvae (e.g., sand and silt) was available, thus explaining the abundance of these midges and the paucity of mayflies and caddisflies at the downstream site. No fish species were observed or collected.

The Pennsylvania Fish Commission reports that this stretch of the West Branch of Brandywine Creek is primarily a warmwater fishery. Common species reported to inhabit this creek include smallmouth bass (*Micropterus dolomieuii*), bluegill (*Lepomis macrochirus*) and red-breast sunfish (*Lepomis auritus*), white sucker (*Catostomus commersoni*), rock bass (*Ambloplites rupestris*), and brown bullhead (*Ictalurus nebulosus*) (Kaufman 1990).

According to a report by the PADER Bureau of Water Quality Management dated April 1988, the West Branch of Brandywine Creek from Route 30 to Strasburg Road has had deterioration of water quality, though the report did not specify how the water quality was reduced. Of the 8 miles noted in the 1988 Water Quality Assessment report, 6 miles only partially attained designated stream use quality. Causes listed were physical barriers (i.e., a dam), industrial waste and municipal discharges, urban and industrial non-point-source runoff, organic enrichment, metals, and scouring. The 1990 PADER 305(b) Water Quality Assessment notes a fish consumption advisory for the West Branch of Brandywine Creek 4 miles downstream from Coatesville, with PCB and chlordane as parameters of concern.

No state or federally-designated aquatic organisms of special concern are known to inhabit the West Branch of Brandywine Creek (Kulp 1990; McKenna 1990; Shiffer 1990; Sitlinger 1990; Smith 1990). The segment of Brandywine Creek adjacent to the site is not listed on the Nationwide Rivers Inventory List of Rivers, although segments downstream from Chadds Ford are listed (Wood 1991).

6.2.4 Discussion

The ecological survey of the Strasburg Landfill study area revealed a vegetatively diverse landscape characterized by numerous distinct communities and ecosystems. The upland terrestrial ecosystem is composed of vegetative communities ranging from highly disturbed borrow pits in a state of early primary succession, to old fields, to mature forests with well-developed understories. In areas where soils have not been heavily disturbed, vegetative growth is well developed, suggesting high productivity.

These various cover-types and associated ecotones potentially provide excellent and diverse habitat for mammals, birds, herpetiles, and invertebrates. The survey determined that the study area contains high quality old field, scrub forest, and mature forest habitat, with evidence of wildlife utilization. The landscape surrounding the study area has few areas of undeveloped or uncultivated open land in the general vicinity, with the exception of the two areas managed by the Brandywine Conservancy Environment Management Center. Therefore, the occurrence of protected areas and the relative scarcity of other natural areas near the site further increases the habitat value of the site at the local level.

The quality of habitat provided by the upland ecosystem at the site is enhanced by the presence of wetland and stream ecosystems within the study area. Most wildlife species are not limited to one specific habitat; thus, the aquatic ecosystems at the site provide additional food, water, and cover resources.

In addition, several wetland ecosystems were identified within the study area (see Figure 6-1). Wetlands found within the Strasburg Landfill study area include emergent marshes, riparian wetlands, floodplain forested wetlands, and an unnatural marsh/seep wetland adjacent to the landfill.

It is well documented that wetlands provide numerous valuable functions, including flood control, high primary productivity, water purification, habitat for many species of plants and animals, nutrient recycling, groundwater recharge, and toxicant assimilation. All of the wetland areas found in the vicinity of the site presented evidence of wildlife usage, including use by deer, small mammals, waterfowl, songbirds, and herpetiles.

No significant populations of species of special concern, recreational significance, or commercial importance were identified from agency contacts or field investigations. Other than jurisdictional wetlands and the Brandywine Conservancy properties, no wildlife refuges, fish hatcheries, or other significant habitats or resources were located within 1.5 miles of the site. The diversity and high quality of habitats in the study area render them potentially suitable for occasional use by a variety of transient special status species, however, or for colonization by species of special concern identified as occurring in the vicinity (see Table 6-3).

Areas potentially sensitive to impacts by landfill contaminants are the Wetlands A, B, and C. Wetland A is fed by landfill seepage and could be a recipient of landfill contaminants. This man-made emergent marsh has been observed being utilized by waterfowl and shorebirds and has the potential for allowing contaminants to enter the food web. Wetland B is also a recipient of landfill seepage. Within Wetland B, a small pond was excavated to obtain seepage water for chemical analysis and bioassays. Analytical results of bioassays performed using this pond water demonstrated that the water is chronically toxic (LOEC = 6.25% and NOEC = 3%) to the invertebrate *Ceriodaphnia dubia* and, therefore, is potentially chronically toxic to other aquatic invertebrates (results of bioassays performed under SAS 5226 C Task 2; see Section 4).

The ecosystems downstream from this point include riparian wetlands, the aquatic system of Briar Run that drains into Brandywine Creek, bottomland forest (Types 9 and 12), the thicketed area (Type 13), the reverting fields (Type 6), and upland forest (Type 1). All of these areas show vigorous signs of wildlife utilization, and wildlife could be considered potential receptors of contaminants. Because of the apparent high productivity of both the plant and animal components of the area's ecosystems, the potential exists for contaminant incorporation into the food web and possible effects on life cycles of organisms occupying the site.

Although the potential exists for direct impacts to plant and animal populations in the vicinity, little evidence of stressed vegetation or diseased or dead animals was observed. However, the lack of direct damage to biotic communities cannot be conclusively determined without additional analysis.

Physical and chemical water-quality parameter results measured in Brandywine Creek and Briar Run (see Table 6-5) fall within an expected range for first- to third-order streams (Hynes 1970), with the exception of pH, which was high at all sample locations. At the downstream Briar Run sampling site (BR-3), the water is super-saturated with oxygen, which suggests there is minimal input of conservative organic pollutants (e.g., decaying plant or animal material). At the upstream site (BR-1), the water approaches saturation at 8.2 mg/L (compared to 9.56 mg/L O_2 at 16°C saturation). The lower oxygen content of the upstream water could be attributed to this stretch of stream being located in a wetland area where organic carbon content of the water and microbial respiration is likely to be high. In addition, much of the stream is shaded, reducing phytoplankton and algal photosynthesis. Nevertheless, dissolved oxygen was high enough to sustain the forms of aquatic life that may reasonably be expected to inhabit this type of stream.

The high pH (8.8 to 10.1) measured in Brandywine Creek and Briar Run could be considered anomalous (Hynes 1970). However, since the pH was high at all sample locations and the highest value (10.1) was measured upstream of the landfill in Briar Run, high pH does not appear to be related to site contamination. Natural causes such as bedrock geology, soils, or planktonic activity could contribute to high pH, but the available data is not sufficient to explain the elevated pH values observed in both creeks.

Benthic invertebrates collected in Briar Run upstream and downstream of the site consisted primarily of mayflies, caddisflies, and stoneflies (see Tables 6-6 and 6-7). These organisms are generally indicative of uncontaminated conditions and high dissolved oxygen levels. Large populations of midge or cranefly larvae, which may indicate polluted conditions, were not observed at either upstream or downstream locations. The data suggest that conditions downstream of the landfill in Briar Run may be more conducive to mayfly and stonefly habitation, although this cannot be conclusively demonstrated with the available data.

Shannon Diversity Indices were calculated for the benthic invertebrate samples collected at upstream and downstream locations in Briar Run and Brandywine Creek. The index was calculated using the following equation:

$$H' = -\Sigma p_i \log p_i$$

Where:

H' = Shannon Diversity Index

p_i = the proportion of the total number of individuals occurring in species or taxon i.

For Briar Run, species diversity was higher downstream of the landfill (H' downstream = 0.72) than upstream (H' upstream = 0.66). For Brandywine Creek, species diversity was higher downstream of the landfill (H' downstream = 0.35) than upstream (H' upstream = 0.27). Thus, there is no evidence of a decrease in diversity of benthic invertebrates downstream of the landfill in either Briar Run or Brandywine Creek.

As noted previously, differences in species composition of benthic invertebrates at upstream and downstream sample locations in Brandywine Creek can be attributed largely to differences in substrate suitability and are probably not indicative of contaminants related to the Strasburg Landfill. In general, it appears from previous PADER surveys that ecological conditions in Brandywine Creek have been adversely impacted by a variety of sources of pollutants and human disturbance, thus making it difficult to ascribe any observed effects to the Strasburg Landfill site.

6.3 ECOLOGICAL RISK ASSESSMENT

The approach taken to the quantification of risks to the ecological environmental receptors is a five-step process, summarized as follows:

- Step 1 - Identification of potential contaminants of concern;
- Step 2 - Identification of environmental receptors;
- Step 3 - Derivation of environmental exposure concentrations (EECs) and exposure scenarios;
- Step 4 - Derivation of benchmark criteria (BC) and determination of environmental concern levels (ECLs) for potential contaminants of concern; and
- Step 5 - Evaluation of baseline risk.

6.3.1 Identification of Contaminants of Concern

Potential contaminants of concern were identified for soil, air, surface water, and sediment pathways. Elevated parameter levels were detected at sample locations adjacent to or downgradient from the Strasburg Landfill relative to background or reference concentrations described in Section 4. By convention, levels of contaminants less than twice the background concentration were considered tolerable (e.g., CDHS 1983). Furthermore, chemical parameters of potential concern to human health were also considered of potential concern to environmental receptors if the chemicals were found at elevated levels in seep or leachate water samples at the source area. If these chemicals were found only in groundwater or residential wells, however, they were not evaluated any further, since these exposure routes are not relevant to most non-human receptors. Moreover, chemical parameters not considered of potential concern to human health were considered of potential concern to the environmental receptors if: (a) elevated levels were found relative to reference and background levels; (b) adequate toxicological information was available to permit derivation of benchmark criteria and concern levels (see below); and (c) toxicological information indicated that concern levels for environmental biota may be lower than trigger levels for human toxicity.

For soil contaminants, levels of organic and inorganic contaminants were evaluated at four soil sampling locations (SB-1S, SB-2S, SB-3S, and SB-4S) relative to a reference location (SB-5S) and USGS background data (Shacklette and Boerngen 1984) (see Table 4-16 and Figure 3-1 for concentrations and sampling locations). Particular attention was paid to the surface soil layer (0 to 2 feet deep), where most plants are rooted and soil-dwelling organisms reside. As stated in Section 4, there was little evidence of widespread surface inorganic or organic contamination in the soil samples tested. A possible exception was location SB-1S, where surface levels of chromium were roughly 10 times, and levels of nickel four times, the reference level at SB-5S. Soil at this location also had a calcium deficiency and an excess of magnesium, however, which are characteristic of naturally occurring serpentine soils prevalent in southeastern Pennsylvania. These soils are known to contain naturally elevated chromium and nickel (Brooks 1987), as discussed earlier and in Section 4.6.2.

For surface water and sediment samples, levels of organic and inorganic contaminants were evaluated at sampling locations in Brandywine Creek (BW-2, BW-3, BW-4, BW-5), Briar Run (BR-2 and BR-3), landfill seep areas (SA-1 and SA-2), and the landfill leachate seep (LS-10). In addition, two of the sediment pond samples (SP-1 and SP-2) were evaluated for contaminants in surface water and sediments, and one sediment pond sample (SP-3) was evaluated for contaminants only in the surface water. All surface water and sediment samples were evaluated relative to levels of contaminants in an upstream reference location in Briar Run (BR-1). The upstream sample location in Brandywine Creek (BW-1) was not considered a "pristine" reference area because of the influence of the multiple pollutant sources discussed earlier. However, downstream Brandywine Creek samples BW-2 through BW-5 were compared to BW-1 in the screening process.

A number of organic and inorganic parameters were detected at elevated levels in surface water samples. However, with the exception of one organic parameter (cis-1,2-dichloroethene) detected at one sample location (BR-2), elevated levels of the organic parameters were confined to the seep areas and sediment pond (see Tables 4-40 and 4-41). Similarly, with the possible exception of one inorganic parameter (aluminum) detected at sample location BW-4, elevated levels of inorganic parameters also were confined to the seep areas and sediment pond (see Tables 4-44 through 4-47).

For the sediments, a number of inorganic parameters were detected at elevated levels relative to background samples. No organic contaminants were detected at unusually elevated levels in the sediments, however.

For the air pathway, soil-gas target compounds were considered potential contaminants of concern; these include benzene; 1,1-DCE; PCE; TCE; and vinyl chloride.

6.3.2 Identification of Environmental Receptors

Environmental receptors are non-human populations and communities of organisms that could become exposed to contamination. From the ecological characterization of the study area, a subset of receptors was chosen to quantify ecological risk. Particular species, communities, or other elements of the biota were chosen for analysis if they could be classified within one or more of the following categories:

- Environmental receptors of intrinsic economic, recreational, or regulatory importance (e.g., endangered species);
- Receptors with the potential to serve as vectors for human exposure;
- Receptors playing a critical ecological role in the food chain, or whose abundance, physiological condition, presence, or absence is indicative of specific contaminants or alterations in ecosystem processes such as energy flow or nutrient cycling; and
- Receptors representative of the habitats potentially affected by site-specific contamination.

No significant populations of rare, threatened, or endangered species were identified in the survey area (see Section 6.2). The area is utilized as habitat by a diversity of wildlife with recreational or ecological value, although no single species could be singled out as a significant environmental receptor according to the categories given above. In addition, site contamination is confined largely to areas on or immediately adjacent to the landfill. Two small wetland areas, Wetland A and Wetland B, appear to be sensitive environments with the greatest potential for exposure to site-derived contaminants because of their proximity to the landfill and the likelihood, based on field observations, that they receive landfill seep water. Moreover, toxicity bioassay results demonstrated that the landfill seep water has toxic effects (see Section 4). The Type B wetland adjacent to the landfill could also serve as pathways for contaminant migration into Briar Run and associated wetland Type C.

Therefore, for aquatic ecosystems, this assessment focused on the community of freshwater aquatic life, including fish, aquatic plants, zooplankton, and benthos, that could be exposed to site contaminants entering the wetlands and Briar Run from seeps and runoff.

For terrestrial wildlife, small mammals were considered because of their abundance at the site and the potential for exposure from contaminated drinking water and air. The potential for close association of small mammals, such as rodents, with site contaminants on a daily basis through feeding and drinking in potentially contaminated areas makes them a good model for evaluating possible adverse effects on wildlife. Rodents such as field mice and voles are expected to be sensitive indicators of risk because of their large food and water ingestion rates relative to body weight. In addition, rodents and other small mammals are an important food source for predators and scavengers. Therefore, impacts of chemical contamination on small mammals could adversely affect species at higher trophic levels, either through reduction of prey numbers or bioaccumulation of toxins. Since important, special-status raptors and carrion-feeders such as the black vulture (see Table 6-3) could be exposed to contaminants via the ingestion pathway, risks to small mammals have added significance.

The potential for contaminant exposure to terrestrial flora and soil organisms was not evaluated because no evidence of widespread, site-related soil contamination exists.

In summary, the biota of concern for the risk assessment are the community of freshwater aquatic life and small rodents such as field mice and voles.

6.3.3 Derivation of Environmental Exposure Concentrations and Exposure Scenarios

Environmental Exposure Concentrations (EECs) were developed for potential contaminants of concern at the interface with the environmental receptors based on the ambient concentrations of contaminants measured in field samples (presented in Section 4). Realistic exposure scenarios were developed for each of the selected environmental receptors using conservative assumptions (i.e., reasonable worst case).

Aquatic Biota

For aquatic life in the potentially affected Wetlands A and B, Briar Run, and Brandywine Creek, a reasonable worst-case exposure scenario could involve acute or chronic exposure to the estimated levels of contaminants at each location. The seep area samples (SA-1, SA-2), leachate sample (LS-10), and sediment pond samples (SP-1, SP-2) could collectively represent conditions at the interface of the source area and Wetlands A and B. The sediment pond discharge sample (SP-3), which was taken at the sediment pond outfall to Briar Run, was considered separately as representative of conditions at the interface of the landfill and Briar Run. An arbitrary factor of 100 was used to model conservatively the dilution of concentrated leachate and runoff into wetland and Briar Run surface waters (Kingsbury et al. 1980). This model is considered conservative because it assumes only a small degree of biochemical transformation, attenuation, and evaporation of contaminants prior to their reaching surface water. To make this model even more conservative, the highest measured concentration of any sample at the source area was used to estimate the EECs (see Table 6-10).

For certain individual organisms, the chronic or acute exposures to contaminants could be higher or lower depending on the spatial distribution of populations. Therefore, the exposure scenario reflects an approximation of average effects on the aquatic biota rather than definitive effects on specific individuals, populations, or species. Additional exposure could arise from bioaccumulation of some contaminants through the food chain.

It was impossible to conduct a comparable exposure analysis for sediment because the bioavailability of contaminants was not determined. In general, sediment pore water concentration is a better measure than total sediment concentrations for assessing the toxins available for uptake by benthic organisms, but pore water concentrations were not measured.

Therefore, total sediment concentrations of chemicals were compared to background levels or to tentative criteria and guidelines for contaminated sediments to determine if these chemicals were at levels indicative of polluted waters. These comparisons are provided under Step 5, below.

Terrestrial Biota

For small mammals, exposure to contaminants could occur from exposure to contaminated drinking water, soil, food, and air. Potential sources of contaminated drinking water include the landfill source area, wetlands, sediment pond outfall, and stream water locations. Estimation

Table 6-10

ENVIRONMENTAL EXPOSURE CONCENTRATIONS (EECs) FOR EXPOSURES OF AQUATIC BIOTA TO POTENTIAL CONTAMINANTS OF CONCERN IN SURFACE WATER

Location[1]	Chemical	EEC (µg/L)[2]
Wetlands A and B[3] (SA-1, SA-2, LS-10, SP-1, SP-2)	Benzene	0.06
	Chlorobenzene	0.23
	Cyanide	0.15
	1,2-Dichlorobenzene	0.03
	1,4-Dichlorobenzene	0.16
	trans-1,2-Dichloroethene	0.01
	Dichloroethenes (total)	0.54
	1,2-Dichloropropane	0.04
	Ethylbenzene	0.45
	Iron	200
	Naphthalene	0.44
	Toluene	0.02
	Trichloroethene	0.06
Brandywine Creek (BW-2, BW-3, BW-4, BW-5)	None detected	--
Briar Run (BR-2, BR-3)	Dichloroethenes (total)	0.55
Sediment Pond Outfall[3] (SP-3)	Cyanide	1.45

02[UZ]ZD5071:D3222/4642/25

[1]See Figure 3-1 for sample locations; see Figure 6-1 for locations of Wetland Areas A and B.

[2]Exposure concentrations were estimated from the highest measured concentration of any sample at a given location; if duplicate samples were taken, the average was used.

[3]Wetland Areas A and B and Sediment Pond Outfall exposure concentrations were based on landfill source measurements diluted 100 times (see text for explanation).

Source: Ecology and Environment, Inc. 1991.

of EECs for drinking water contaminants at each location generally followed the methods used to calculate EECs for aquatic biota discussed previously, but were converted to dosages based on the approximate water consumption rate of 5 ml/day for a 25 gram mouse (Sax and Lewis 1988). Values are provided in Table 6-11.

The air pathway for small mammals was considered to be insignificant at all locations except the landfill periphery, where soil gas measurements indicated significant areas of contamination.

Two areas were considered for potential exposure of small mammals to air contamination. The landfill soil gas grid survey area corresponds to the soil gas plume observed near the Wetlands B area, from points C-7 to AA-2 (see section 4.6.1.1). The landfill soil gas perimeter survey area corresponds to samples taken near the Wetland A area around the western perimeter of the landfill, from points P-15 to P-23 (see Section 4.6.1.2). The proximity of Wetlands A and B to these sample locations would heighten the risk of exposure for small mammals residing or passing through on a regular basis. In order to estimate EECs, however, it was necessary to model the transport of contaminants from the soil gas to the near-ground breathing zone of a mouse or other small mammal.

Contaminant concentrations in air close to the ground surface were estimated using a two-step modeling procedure. The first step of the model was the calculation of the chemical vapor-phase emission rate, or mass flux, at the ground surface in terms of the measured soil gas concentration of the chemical sampled at an average depth of 2 feet below the soil surface. This calculation was accomplished by applying the model for vapor releases from landfills with internal gas generation, as suggested in the EPA Superfund Exposure Assessment Manual (EPA 1988). This model was selected because the Strasburg Landfill is a co-disposal landfill, and the upward movement, or "convective sweep," of landfill gases would be expected to be a dominant mechanism for vapor release. According to this model, the pressure-driven flow of landfill gas upward toward the soil surface is much greater than concentration-driven vapor diffusional flow. Also, the validity of the use of this model at the Strasburg Landfill site was confirmed by an independent model verification calculation. This verification showed that the model

Table 6-11

ENVIRONMENTAL EXPOSURE CONCENTRATIONS (EECs) FOR EXPOSURES OF SMALL MAMMALS TO POTENTIAL CONTAMINANTS OF CONCERN IN DRINKING WATER

Location[1]	Chemical	Observed Concentration[2] (µg/L)	EEC (mg/kg/day)[3]
Landfill Source Area (SA-1, SA-2, LS-10, SP-1, SP-2)	Barium	367	0.073
	Benzene	5.7	0.001
	Chlorobenzene	22.7	0.005
	Cyanide	15	0.003
	1,4-Dichlorobenzene	16	0.003
	1,1-Dichloroethane	27	0.005
	Dichloroethenes (total)	54.4	0.011
	1,2-Dichloropropane	3.8	0.001
	Ethylbenzene	44.8	0.009
	Naphthalene	44.2	0.009
	Toluene	1.6	0.0003
	Trichloroethene	5.5	0.001
	Vinyl chloride	19	0.004
	Xylenes (total)	118	0.024
Wetlands A and B (SA-1, SA-2, LS-10, SP-1, SP-2)	See Footnote 4		
Brandywine Creek (BW-2, BW-3, BW-4, BW-5)	None detected		
Briar Run (BR-2, BR-3)	Dichloroethenes (total)	0.55	0.0001
Sediment Pond Outfall[4] (SP-3)	Cyanide	1.45	0.0003

02[UZ]ZD5071:D3222/5970/21

[1]See Figure 3-1 for sample locations; see Figure 6-1 for locations of Wetlands A and B.

[2]Observed concentrations were the highest measured concentration of any sample at a given location; if duplicate samples were taken, the average was used.

[3]EECs were calculated based on an assumed approximate water consumption rate for a mouse of 0.2 L/kg/day (Calculated from Sax and Lewis 1988).

[4]Wetlands A and B and sediment pond outfall exposure concentrations were based on landfill source measurements diluted 100 times (see text for explanation). Wetlands A and B chemicals are as listed for landfill source area.

Source: Ecology and Environment, Inc. 1991.

could predict a volatilization flux high enough to yield estimated ambient air concentrations in good agreement with measured ambient air concentrations of TCE and VC at sample location EE-012.

The second step in the air modeling procedure was the calculation of chemical concentrations in air near the ground surface, in terms of the emission rate or flux calculated in the first step above. This calculation was performed by applying the methodology described in Thibodeaux (1981). According to this model, chemical movement into the air near the soil-air interface proceeds through a thin laminar sublayer by diffusion before entering the overlying turbulent air layer. Application of this conservative model shows that no appreciable difference is predicted between the vapor concentration at the ground surface and the concentration at approximately 10 centimeters above the surface. As a result, the ground-level concentrations can be considered representative of concentrations throughout the zone from 0 to 10 cm above the ground surface.

The results of this two-step model are as follows. Ambient air concentrations close to the ground surface can be estimated using the following equation:

$$C_a = K \cdot C_{sg}$$

where:

C_a = ambient air concentration of chemical vapors within 10 cm of the ground surface

C_{sg} = measured soil gas concentration beneath the exposure location of interest

K = a constant that incorporates both the convective flux to the soil surface and diffusion through the overlying diffusive sublayer in the air immediately above the soil surface (dimensionless)

The value of the multiplier K varies slightly with chemical but is roughly constant at about 0.4; that is, near-ground air concentrations can be conservatively estimated to be of the same order of magnitude as the corresponding soil gas concentrations measured beneath each location. Derivation of EECs for air exposure is shown in Table 6-12.

Table 6-12

ENVIRONMENTAL EXPOSURE CONCENTRATIONS (EECs) FOR EXPOSURES OF SMALL MAMMALS TO POTENTIAL CONTAMINANTS OF CONCERN IN AIR

Location[1]	Chemical	Observed Concentration[2] (ppm)	EEC (ppm)[3]
Landfill Soil Gas Perimeter Area (P-15 to P-23)	Benzene	8.15	3.42
	1,1-DCE	0.95	0.34
	PCE	3.65	1.13
	TCE	4.75	1.76
	Vinyl chloride	11	5.83
Landfill Soil Gas Grid Survey Area (C7 to AA-2)	Benzene	0.23	0.1
	1,1-DCE	1.70	0.61
	PCE	0.52	0.16
	TCE	1.3	0.48
	Vinyl chloride	6.8	3.6

02[UZ]ZD5071:D3222/5972/21

[1]See Figure 3-1 for sample locations.
[2]Observed concentrations were the highest measured concentration of any sample at a given location; if duplicate samples were taken, the average was used.
[3]EECs were calculated by multiplying observed concentrations by a constant, K, as described in the text; values of K are: Benzene, K=0.42; 1,1-DCE, K=0.36; PCE, K=0.31; TCE, K=0.37; Vinyl chloride, K=0.53.

Source: Ecology and Environment, Inc. 1991.

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6.3.4 Derivation of Benchmark Criteria and Environmental Concern Levels

The available toxicological literature and regulatory standards were reviewed to determine benchmark toxicity criteria (BC). BCs are toxicological indices of effects generally based on laboratory bioassays of single species exposed to known concentrations or quantities of toxic compounds. Environmental concern levels (ECLs) are derived by multiplying the BCs by appropriate uncertainty factors to account for a variety of data limitations, as shown in Table 6-13.

Aquatic Biota

Threshold concentrations necessary to show significant effects on survival, growth, or reproduction of aquatic biota can be quantified using regulatory standards or guidelines. For example, EPA Ambient Water Quality Criteria (AWQC) for chronic exposure are based on maximum acceptable toxicant concentrations (MATCs) for numerous species of aquatic organisms. The MATC is assumed to lie between the no-observed-effect-level (NOEL) and the lowest-observed-effect-level (LOEL) for a given contaminant and species combination (Suter 1986). The EPA AWQC derived from these MATCs are intended to protect 95% of aquatic species. The EPA AWQC for acute exposures are analogous to criteria for chronic exposure, but they are based on published LC_{50}s (lethal concentrations for 50% of the exposed population) or acute LOELs for many species of aquatic organisms.

For the Strasburg Landfill site, published EPA or analogous PADER criteria for the protection of aquatic life were used as BCs. Most of the values used were Pennsylvania criteria because these were considered more protective than the EPA criteria. The derivation of ECLs from the BCs is provided in Table 6-14. Uncertainty factors of 1.0 were chosen for all contaminants with the exception of total dichloroethenes because uncertainty factors are already incorporated into the national and Pennsylvania criteria for the contaminants listed. An uncertainty factor of 0.1 was chosen for total dichloroethenes to account for the lack of an adequate chronic toxicity criterion.

Table 6-13

UNCERTAINTY FACTORS AND THEIR APPLICATION

Uncertainty Factor	Application to ECLs
0.10 - 1.0	Used when MATC (or NOEL) data are unavailable and LOEL data are used instead. The range of the factor depends on the reliability and appropriateness of the data and the experimental design.
0.010	Used when data for the biota of concern are unavailable but valid long-term studies for other species are used.
0.0010 - 0.010	Used when data for the biota of concern are unavailable and studies of less than chronic exposure are used. The magnitude of the factor depends upon the data and experimental design.
Intermediate Factors	Other uncertainty factors may be used based on scientific judgment.

02[UZ]ZD5071:D3222/5973/24

Source: Dourson and Stara 1983; Barnes and Dourson 1988; EPA 1984.

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Table 6-14

ENVIRONMENTAL CONCERN LEVELS (ECLs) FOR EXPOSURES OF AQUATIC BIOTA TO POTENTIAL CONTAMINANTS OF CONCERN IN SURFACE WATER

Chemical	Selected Benchmark Criteria (μg/L)[1]	Uncertainty Factor[2]	ECL (μg/L)[3]
Benzene	128	1.0	128
Chlorobenzene	236	1.0	236
Cyanide	5	1.0	5
1,2-Dichlorobenzene	164	1.0	164
1,4-Dichlorobenzene	146	1.0	146
trans-1,2-Dichloroethene	1,350	1.0	1,350
Dichloroethenes (total)	11,600[4]	0.1	1,350
1,2-Dichloropropane	2,165	1.0	2,165
Ethylbenzene	580	1.0	580
Iron	1,000[5]	1.0	1,000
Naphthalene	43	1.0	43
Toluene	330	1.0	330
Trichloroethene	450	1.0	450

02[UZ]ZD5071:D3222/5974/22

[1]Values based on Pennsylvania Water Quality Criteria for Toxic Substances, Fish and Aquatic Life Criteria, Continuous Concentrations, unless otherwise indicated.

[2]See Table 6-12 and text for explanation.

[3]ECL = Selected Benchmark Criterion X Uncertainty Factor (see text for explanation).

[4]Value is the LOEL for acute toxicity to freshwater aquatic life (EPA Quality Criteria for Water 1986).

[5]Value is national criterion for chronic toxicity to freshwater aquatic life (EPA Quality Criteria for Water 1986).

Source: Ecology and Environment, Inc. 1991.

Terrestrial Biota

Toxicity data for small mammals were evaluated to determine BCs based on the published sources. For each potential contaminant of concern found in drinking water or air, a data survey was conducted to identify the LOEL or NOEL for the most sensitive species. Acute, subchronic, and chronic cancer and non-cancer end points were screened for inhalation and oral exposure pathways. If sufficient information was available to derive a BC, the ECL was estimated using the appropriate uncertainty factor. The derivation of oral (drinking water) ECLs is provided in Table 6-15. The derivation of inhalation (air) ECLs is provided in Table 6-16.

6.3.5 Evaluation of Baseline Risk

The baseline risk is the risk to environmental receptors that could potentially occur if no remedial actions were taken. The quantitative evaluation of baseline risks to environmental receptors was based on application of the quotient method (Suter 1986). The quotient method is a standard approach for screening sample locations for potentially toxic concentrations of chemicals involving calculation of the ratio of each EEC to the corresponding ECL. The higher the ratio is (greater than 1.0), the higher the probability of significant risk to the receptor population. The ratio of EEC to ECL was calculated for the biota of concern at each location.

Aquatic Biota

The comparisons of ECLs to EECs for each of the potential contaminants of concern is given in Table 6-17. All of the ratios are less than one, indicating surface-water exposures below concern levels in the wetlands adjacent to the Strasburg Landfill and in Briar Run. Only iron, cyanide, and naphthalene were at concentrations high enough to exceed a ratio of 0.001.

Levels of iron were within an order of magnitude of the acceptable risk ratio of 1.0 in Wetlands A and B. Given more conservative assumptions (e.g., a dilution factor of less than 100 and an uncertainty factor of less than 1.0), this contaminant could have been considered to be at toxic levels to aquatic biota. Similarly, cyanide levels were within

Table 6-15

ENVIRONMENTAL CONCERN LEVELS (ECLs) FOR EXPOSURES OF SMALL MAMMALS TO POTENTIAL CONTAMINANTS OF CONCERN IN DRINKING WATER

Chemical	Selected Benchmark Criteria (mg/kg/day)[1]	Uncertainty Factor[2]	ECL[3] (mg/kg/day)
Barium	0.51	0.1	0.051
Benzene	1	1.0	1
Chlorobenzene	60	1.0	60
Cyanide	2.62	0.1	0.262
1,4-Dichlorobenzene	150	0.1	1.5
1,1-Dichloroethane	1,780	0.1	178
Dichloroethenes (total)	1,000	0.1	100
1,2-Dichloropropane	100	0.1	10
Ethylbenzene	4,728	0.1	472.8
Naphthalene	41	1.0	41
Toluene	19.7	1.0	19.7
Trichloroethene	50	0.1	5
Vinyl chloride	0.1	1.0	0.1
Xylenes (total)	200	0.1	20

02[UZ]ZD5071:D3222/5975/25

[1]Values based on best available toxicity data for rats and mice (LOELs or NOELs) taken from Toxicological Profiles published for each chemical by the Agency for Toxic Substances and Disease Registry (ATSDR), or from EPA Drinking Water Criteria Documents.

[2]See Table 6-12 and text for explanation.

[3]ECL = Selected Benchmark Criterion x Uncertainty Factor.

Source: Ecology and Environment, Inc. 1991.

Table 6-16

ENVIRONMENTAL CONCERN LEVELS (ECLs) FOR EXPOSURE OF SMALL MAMMALS TO POTENTIAL CONTAMINANTS OF CONCERN IN AIR

Chemical	Selected Benchmark Criteria (ppm)[1]	Uncertainty Factor[2]	ECL (ppm)[3]
Benzene	10	0.1	1.0
1,1-DCE	4	0.1	0.4
PCE	9	0.1	0.9
TCE	50	0.1	5.0
Vinyl chloride	10	0.1	1.0

02[UZ]ZD5071:D3222/5977/21

[1]Values based on LOELs for rats or mice taken from Toxicological Profiles published for each chemical by the Agency for Toxic Substances and Disease Registry (ATSDR).

[2]See Table 6-12 and text for explanation.

[3]ECL = Selected Benchmark Criterion X Uncertainty Factor (see text for explanation).

Source: Ecology and Environment, Inc. 1991.

Table 6-17

EEC/ECL RATIOS FOR AQUATIC BIOTA, SURFACE WATER PATHWAY

Location	Chemical	EEC (μg/L)[1]	ECL (μg/L)[2]	EEC/ECL Ratio[3]
Wetlands A and B	Benzene	0.06	128	<0.001
	Chlorobenzene	0.23	236	0.001
	Cyanide	0.15	5	0.030
	1,2-Dichlorobenzene	0.03	164	<0.001
	1,4-Dichlorobenzene	0.16	146	0.001
	trans-1,2-Dichloroethene	0.01	1,350	<0.001
	Dichloroethenes (total)	0.54	1,350	<0.001
	1,2-Dichloropropane	0.04	2,165	<0.001
	Ethylbenzene	0.45	580	0.001
	Iron	200	1,000	0.200
	Naphthalene	0.44	43	0.010
	Toluene	0.02	330	<0.001
	Trichloroethene	0.06	450	<0.001
Briar Run	Dichloroethenes (total)	1.1	5,800	<0.001
Sediment Pond Outfall	Cyanide	1.45	5	0.290

02[UZ]ZD5071:D3222/5978/22

[1]EECs are from Table 6-9.

[2]ECLs are from Table 6-13.

[3]Ratio is unitless.

Source: Ecology and Environment, Inc. 1991.

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an order of magnitude of acceptable risk at the sediment pond outfall. Neither iron nor cyanide was detected at significant levels in downstream Briar Run surface water samples, however, indicating little potential for extensive migration and contamination of the environment by the source area. Therefore, on the basis of the quotient method, there does not appear to be a significant risk of adverse effects from surface water contamination affecting aquatic life in the wetlands or streams of the area.

The possible adverse effects of sediment contaminants were assessed using the "sediment quality triad" approach, which involves analysis of three sets of measurements: levels of contaminants in sediments, toxicity of sediments as indicated in bioassays, and evidence of alterations in benthic communities (Long and Chapman 1985).

Elevated levels of contaminants in sediment samples were evaluated relative to background concentrations and tentative EPA Region V guidelines for Great Lakes harbor sediments (Table 6-18). The seep area samples, sediment pond samples, and leachate samples were again taken as representative of levels of contamination at the interface of the landfill and Wetlands A and B. The upstream Briar Run sample (BR-1) was used as background for both Wetlands A and B and Briar Run locations. The upstream Brandywine Creek sample (BW-1) was used as background for Brandywine Creek. Chemicals that exceeded two times background levels and criteria are listed in Table 6-18. Chromium and manganese were found at levels indicative of polluted conditions in both the wetlands and Briar Run. Arsenic, barium, copper, and iron were also found at elevated levels in samples from the wetlands area. However, no dilution factor was used for transport of sediment contamination from the landfill source samples to the wetlands. These reported levels of contamination probably overestimate actual levels in the wetlands.

The results of bioassay toxicity tests with Daphnia magna and Chironomus tentans were reported in detail in Section 4.6.4.6. The results clearly indicate significant chronic toxicity (depression of reproductive potential) of downstream Briar Run sediments (BR-3) relative to upstream sediments (BR-1) for Daphnia magna in solid phase tests but not in elutriate tests. No toxic effects of sediments from downstream Briar Run on Chironomus tentans were reported.

Table 6-18

COMPARISON OF SEDIMENT CONTAMINATION TO
TENTATIVE REGULATORY GUIDELINES AND BACKGROUND CONCENTRATIONS

Location[1]	Chemical	Tentative Criteria[2] (mg/kg)	Background Concentration[3] (mg/kg)	Observed Concentration[4] (mg/kg)
Wetlands A and B (SA-1, SA-2, SP-1, SP-2, LS-10)	Arsenic	3 - 8	1.3[5]	53.1
	Barium	20 - 60	46.1[5]	903
	Chromium	25 - 75	15.6[6]	192[6]
	Copper	25 - 50	--[7]	42.2
	Iron	17,000 - 25,000	16,300	425,000
	Manganese	300 - 500	745	1,860
Briar Run (BR-2, BR-3)	Chromium	25 - 75	15.6[6]	38.7[6]
	Manganese	300 - 500	745	1,510
Brandywine Creek (BW-2, BW-3, BW-4, BW-5)	None above background			

02[UZ]ZD5071:D3222/5979/19

[1]See Figure 3-1 for sample locations; see Figure 6-1 for locations of Wetlands A and B.

[2]Limits define the range for moderately polluted sediments in the Great Lakes; concentrations below the lower limit are considered nonpolluted; concentrations above the upper limit are considered heavily polluted (EPA 1977).

[3]Background concentrations observed at sample site BR-1 (upstream of the Strasburg Landfill) were used for Wetlands A and B and Briar Run locations; background concentrations observed at sample site BW-1 were used for Brandywine Creek.

[4]Observed concentrations were the highest measured concentration of any sample at a given location; if duplicate samples were taken, the average was used.

[5]Quantitation may not be accurate as values approach IDL.

[6]Value may be biased low; actual value expected to be higher.

[7]Parameter not detected substantially above the level reported in laboratory or field blanks.

Source: Ecology and Environment, Inc. 1991.

Finally, the survey of benthic invertebrates indicated the presence of a healthy, normal stream community at upstream and downstream locations in Briar Run (see Section 6.2.3), including abundant stonefly, mayfly, and caddisfly populations. A higher species diversity was calculated downstream from the landfill than upstream from it in both Briar Run and Brandywine Creek.

In summary, the sediment quality triad approach indicates that elevated levels of certain metals may be migrating from the landfill to downstream habitats and that these or other contaminants could be responsible for toxic effects witnessed in bioassays with Daphnia magna. On the other hand, the macrobenthic survey indicates that toxic levels of contaminants have not caused a significant deterioration of downstream aquatic ecosystems.

Terrestrial Biota

The comparison of ECLs to EECs for the drinking water pathway is given in Table 6-19. With the exception of barium at the landfill source area, all ratios are less than one. None of the other ratios approach the acceptable risk ratio of 1.0 to within an order of magnitude. The baseline risk to small mammal populations from exposure to contaminants in drinking water appears to be minimal. There is potential for risk of toxic effects from exposure to barium only at the landfill source (seep areas). It may be assumed that most small mammals would derive their drinking water from a variety of sources, including the relatively uncontaminated Wetlands A and B. Therefore, the risk of exposure to barium is not likely to have a serious adverse impact on populations of small mammals in the area.

The comparison of ECLs to EECs for the inhalation pathway is given in Table 6-20. There appears to be potential for risk of toxic effects from exposure to vinyl chloride at "hot spots" at both the perimeter and grid soil gas survey area locations. In addition, there are potential risks of adverse effects from exposure to PCE and benzene at the perimeter survey area location, and from exposure to 1,1-DCE at the grid survey area location. All other ratios are within an order of magnitude of the acceptable risk ratio of 1.0. Because the contaminant concentrations in soil gas rapidly decrease with distance from the landfill, however, the associated potential for risk is likely to decrease for small

Table 6-19

EEC/ECL RATIOS FOR
SMALL MAMMALS, DRINKING WATER PATHWAY

Location	Chemical	EEC (mg/kg/day)[1]	ECL (mg/kg/day)[2]	EEC/ECL Ratio[3]
Landfill Source Area	Barium	0.073	0.051	1.4
	Benzene	0.001	1	0.001
	Chlorobenzene	0.005	60	<0.001
	Cyanide	0.003	0.262	0.01
	1,4-Dichlorobenzene	0.003	1.5	0.002
	1,1-Dichloroethane	0.005	178	<0.001
	Dichloroethenes (total)	0.011	100	<0.001
	1,2-Dichloropropane	0.001	10	<0.001
	Ethylbenzene	0.009	472.8	<0.001
	Naphthalene	0.009	41	<0.001
	Toluene	0.0003	19.7	<0.001
	Trichloroethene	0.001	5	<0.001
	Vinyl chloride	0.004	0.1	0.04
	Xylenes (total)	0.024	20	0.001
Wetlands A and B	See Footnote 4			
Briar Run	Dichloroethenes (total)	0.0001	100	<0.001
Sediment Pond Outfall	Cyanide	0.0003	0.262	0.001

02[UZ]ZD5071:D3222/5980/17

[1]EECs are from Table 6-10.

[2]ECLs are from Table 6-14.

[3]Ratio is unitless.

[4]Wetlands A and B chemicals are as listed for landfill source area. EEC/ECL ratios are ratios for landfill source area divided by 100.

Source: Ecology and Environment, Inc. 1991.

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Table 6-20

EEC/ECL RATIOS FOR SMALL MAMMALS, INHALATION PATHWAY

Location	Chemical	EEC (ppm)[1]	ECL (ppm)[2]	Ratio[3]
Landfill Soil Gas Perimeter Survey Area	Benzene	3.42	1.0	3.4
	1,1-DCE	0.34	0.4	0.9
	PCE	1.13	0.9	1.3
	TCE	1.76	5.0	0.4
	Vinyl chloride	5.83	1.0	5.8
Landfill Soil Gas Grid Survey Area	Benzene	0.10	1.0	0.1
	1,1,-DCE	0.61	0.4	1.5
	PCE	0.16	0.9	0.2
	TCE	0.48	5.0	0.1
	Vinyl chloride	3.60	1.0	3.6

02[UZ]ZD5071:D3222/5982/26

[1]EECs are from Table 6-11.

[2]ECLs are from Table 6-15.

[3]Ratio is unitless.

Source: Ecology and Environment, Inc. 1991.

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mammals residing in vegetation cover types other than Type 15 on the landfill and periphery or in Wetlands A and B immediately adjacent to the landfill.

Insufficient published information exists to evaluate the potential toxicological effects of vinyl chloride, benzene, 1,1-DCE, or PCE on raptors or other terrestrial predators or scavengers that might utilize small mammals as a food source. Any effects of ingesting contaminated food would be expected to be minor, however, because of the localized extent of contamination relative to the large areas utilized by most predators. In addition, the contaminants of concern all have relatively low tendencies to bioaccumulate. Nevertheless, risks to predators of small mammals cannot be completely ruled out.

6.4 CONCLUSIONS

In the human health risk assessment, four potential exposure pathways were identified. Three of these pathways appear to be complete under existing environmental and land use conditions, based on the information developed in the remedial investigation, and were quantitatively evaluated. The complete exposure pathways are:

- Residential use of contaminated groundwater;
- Inhalation of volatile organic contaminants on site and in nearby residential areas; and
- Accidental contact with seep areas.

The fourth pathway involved contact of recreational users of Briar Run and Brandywine Creek with contaminants in surface water and sediment at these locations. It was not considered complete because little or no site-related contamination was found in either stream.

The potential receptors are residents living near the landfill and individuals using the site for various recreational purposes (walking, jogging, and horseback and ATV riding). These site visitors were assumed to be a subpopulation of the nearby residents.

Residents living in the vicinity of the Zarzycki residence, southwest of the landfill, and along Wheatland Drive, southeast of the landfill, appear to be those most likely to experience the largest potential exposures by both the groundwater and air pathways; therefore, the potential exposures and risks to these residents were estimated. Since the site visitors were assumed to be a subpopulation of the residents living near the site, the estimated risks to these individuals were added to the estimated risks occurring in the nearby residential areas to obtain estimates of the total site-related risks nearby residents might experience.

Systemic toxicants (noncarcinogens) did not pose significant risks by any of the pathways evaluated. The estimated risk of excess cancers was significant (greater than 10^{-6}) for residents living both in the vicinity of the Zarzycki residence (8 to 9 x 10^{-5}) and along Wheatland Drive (2 x 10^{-5}). In both cases, the risks were due primarily (69% to 90%) to the groundwater pathway. For the Zarzycki area residents, the risk estimates were based on contaminant concentrations actually found in residential wells in that area. In contrast, the estimated risks for the Wheatland Drive residents were based on concentrations found in monitoring wells between that area and the landfill because no contaminants are currently being detected in residential wells along Wheatland Drive. However, given the uncertainties about groundwater migration patterns in the area, there is a slight possibility that the contaminants found in the monitoring wells might reach the Wheatland Drive wells sometime in the future.

The estimated risks due to the air pathway, considering both on-site and off-site exposures, were 1.6 x 10^{-6} for Zarzycki area residents and 8.5 x 10^{-7} for Wheatland Drive residents. The estimated risks to site visitors from accidental contact with seep areas were 6.5 x 10^{-6}.

The total risks, including all potential exposure pathways, were estimated to be 8 x 10^{-5} for Zarzycki area residents and 2 x 10^{-5} for Wheatland Drive residents.

Ecological field investigations and risk assessments were conducted in the 400-acre study area surrounding the Strasburg Landfill site to characterize the biological communities and determine if significant ecological resources are potentially affected by site contamination. The ecological site survey and contacts with natural resource trustee personnel indicated the presence of high-quality habitat in the study area. The landfill is surrounded by apparently healthy, diverse terrestrial and aquatic communities, including river, wetland, forest, and open-field ecosystems harboring abundant wildlife populations. Stream surveys of benthic invertebrates indicated no alteration of community structure directly downstream from the site, and there was no other obvious evidence of adverse effects of chemical contamination on the existing populations, communities, or ecosystems. Other than the identified wetlands, no significant sensitive or protected biological resources (such as endangered species) are known to occur in the study area. Several species with special status in the Commonwealth of Pennsylvania have been reported in the vicinity, however, and these or other protected species could conceivably come in contact with the site or establish populations there. The Brandywine Conservancy Management Center manages two nature preserve properties within one mile of the landfill, providing potential source populations of special-status species.

The ecological risk assessment for the Strasburg Landfill site identified elevated levels of contaminants relative to background concentrations and environmental concern levels in seep areas, surface water, sediments, and soil gas. Potential low-level, chronic exposure of aquatic biota to site-related contaminants is considered likely from uncontrolled releases at seep areas and from runoff into surrounding wetlands and streams. No single contaminant appears to be occurring in surface water at levels toxic to aquatic life, but bioassay results demonstrate that seep water is toxic to indicator organisms tested under laboratory conditions. Shannon Diversity Indices were calculated for the benthic invertebrate samples collected at upstream and downstream locations in Briar Run and Brandywine Creek. For both streams, the diversity indices were higher downstream of the landfill than upstream. Thus, there is no evidence of a decrease in diversity of benthic invertebrates downstream of the landfill in either Briar Run or Brandywine Creek.

Although sediment contamination is not sufficient to alter benthic community composition in Briar Run, there is evidence of elevated levels of metals in wetland sediments with the potential to migrate downstream. In addition, bioassays indicated that downstream Briar Run sediments may have toxic effects on some aquatic organisms.

Terrestrial organisms may also be exposed to site-related contaminants, particularly landfill air emissions of volatile organic compounds (VOCs). For example, small mammals such as field mice inhaling air on the landfill perimeter may be exposed to toxic levels of VOCs migrating from soil gas to the near-ground ambient air. Elevated and potentially toxic levels of vinyl chloride occurred in soil gas plume areas on the east and west sides of the landfill, and benzene, PCE, and 1,1-DCE were present at elevated and potentially toxic levels on both sides of the landfill. Small mammals could also be at risk from elevated levels of barium in drinking water at the seeps. The potential risks to small mammals decrease rapidly with distance from the landfill and are likely to be negligible for all populations except those residing on the landfill and its perimeter or in wetlands adjacent to the landfill. Because of the limited spatial distribution of chemical contamination, predators and scavengers that utilize small mammals as prey probably face negligible risks from feeding on a contaminated food source or from reduced abundance of prey populations.

7. CONCLUSIONS AND RECOMMENDATIONS

7.1 CONCLUSIONS

Contaminants of potential concern at the Strasburg Landfill site include the following compounds:

- o Volatile organic compounds: benzene; chlorobenzene; 1,2-dichlorobenzene; 1,4-dichlorobenzene; 1,1-dichloroethane; 1,2-dichloroethane; 1,1-dichloroethene; 1,2-dichloroethene; 1,2-dichloropropane; ethylbenzene; methylene chloride; 1,1,2,2-tetrachloroethane; tetrachloroethene; toluene; 1,1,1-trichloroethane; trichloroethene; trichlorofluoromethane; vinyl chloride; xylenes;
- o Monocyclic aromatic hydrocarbons (chlorinated and unchlorinated);
- o Semivolatile organic compounds: benzoic acid, bis(2-ethylhexyl)phthalate, diethylphthalate, 4-methyl phenol, naphthalene, phenol; and
- o Inorganics: arsenic, barium, beryllium, iron, and manganese.

VOC contamination was detected in ambient air, soil gas, soil, groundwater, surface water, sediment, and seep areas. The distribution of base-neutral and inorganic contamination was more limited. The observed contaminant distribution reflects the differing mobilities of the different compounds, with the widest distribution observed in the most mobile class of compounds, the VOCs.

Disposal of polyvinyl chloride (PVC) wastes, metal sludges, sewage treatment plant sludges, and municipal waste in the Strasburg Landfill provides the source of the observed contamination (see Table 4-1). Identified potential contaminants of concern were compounds that were not naturally occurring or detected at concentrations above natural occurring concentrations at levels that pose a potential risk. Iron and manganese are naturally occurring elements that were detected in soil, groundwater, surface water, sediment, and seep areas. In some areas (e.g., the seep areas), concentrations of these compounds exceeded naturally occurring concentrations. Mechanisms for transport of the organic compounds from the landfill include landfill gas emissions elevating contaminants in the ambient air and leachate generation resulting from precipitation or groundwater entering the landfill. Leachate that enters the groundwater is transported with the groundwater. The contaminant distribution in the soil gas (e.g., the grid area southeast of the landfill) and the groundwater is not a simple radial distribution around the landfill. It appears that fractures in the bedrock are creating preferential flow paths in groundwater. Soil gas seems to protrude from the landfill in a lobate shape in several areas. This is best exhibited in the gridded sampling area in the southeast side of the landfill. Inorganic contaminant distribution appears to be limited primarily to the sediment and water in the seep areas and to the sediment pond. The distribution of the observed contaminants is summarized in the following subsections.

7.1.1 Air

Air emissions from the landfill were measured using SUMMA passivated canisters to collect ambient air from locations on and adjacent to the landfill, and using a stainless steel vessel (flux box) inverted on the landfill surface to trap vapor emissions passing through the landfill cap at selected locations (vapor emissions measured by flux boxes actually measured shallow soil gas). The flux-box samples were analyzed in the field using a Photovac gas chromatograph (GC) for five target VOCs (see Table 4-61).

The results of the air investigation indicated that elevated concentrations of VOCs were detected in the ambient air sample (5.94 ppb total VOCs at EE012; see Table 4-60) located adjacent to areas where elevated concentrations were measured in the flux boxes (809 ppb total VOCs at FB04 and 1,498 ppb at FB07; see Table 4-61). This area of elevated VOC levels is located along the western edge of the landfill (Figure 4-6). The only other ambient air sample with elevated VOC concentrations relative to background levels was located on the northern portion of the landfill (EE007 with 4.63 ppb total VOCs; see Table 4-60). Generally, all flux box samples had concentrations of VOCs greater than measured background levels (20 ppb total VOCs at FB10; see Table 4-61).

7.1.2 Soil Gas

Soil gas samples were collected southeast of the landfill between the landfill and Briar Run, and along the perimeter of the landfill. The soil gas samples were analyzed for five volatile organic target compounds in the field using a Photovac GC. Soil gas concentrations indicated that a northeast-southwest-trending soil gas plume exists east of the landfill. Elevated soil gas concentrations were also detected south, southwest, and west of the landfill perimeter.

The similarity of the soil gas contaminants to the contaminants measured in the flux boxes indicates that landfill air emissions are a primary source for the compounds identified in the soil gas. Potentially, the presence of a partial PVC cap could be forcing landfill gas out of the perimeter of the landfill into the adjacent soil. The highest soil gas VOC concentrations (up to 16,060 ppb total VOCs; see Table 4-11) were detected in the perimeter soil gas samples collected along the southwestern portion of the site (P-13 through P-17B) and western portion of the site (P-18A through P-24) near the elevated VOC concentrations detected in the air sample (EE012) and flux box (FB07). Elevated soil gas VOC concentrations were also detected at the southern end of the landfill (P-5 through P-11, with total VOCs up to 10,540 ppb; see Table 4-11) and in the seep area east of the landfill (grid area sampling, with total VOCs up to 7,020 ppb; see Table 4-10).

7.1.3 Soil

Soil samples were collected at or near the shallow monitoring well locations surrounding the landfill. Generally all samples had inorganic levels within the published United States Geological Survey (USGS) ranges for eastern United States soils (Shacklette and Boerngen 1984) and organic levels below the levels detected at the background samples (background samples collected at MW-5S). Volatile organic contamination was not identified in the soils collected at the monitoring well locations, except for low levels of 1,4-dichlorobenzene (1,4-DCB at 220 µg/kg) detected at the background well location (MW-5S).

7.1.4 Groundwater

Twelve of the 19 volatile organic contaminants of potential concern were detected in water collected from monitoring wells, and four volatile contaminants of concern were detected in water samples collected from residential wells during the November 1990 sampling event (Table 4-62). The highest concentrations of organic contaminants were limited to the monitoring wells located southwest of the landfill along a fracture trace that trends toward the southwest (the highest concentration was 170.5 µg/L total VOCs in MW-3I; see Figure 4-3). Less extensive organic contamination was noted in the monitoring wells east of the landfill. The only residential wells impacted with detectable organic concentrations during RI sampling were located southwest of the landfill, proximal to the above-noted fracture trace. The highest total VOC concentration in any residential well located near this fracture trace was found in the Zarzycki shallow well (120 feet deep). Concentrations up to 80.8 µg/L of total VOCs--primarily TCE and PCE--were detected in this well during January 1990 packer testing of Zone 1. VOCs were also detected in the Zarzycki deep well (300 feet deep), located near this fracture trace. (This water supply is currently treated with carbon.) The highest concentrations were measured in the April 1990 sample analyzed by field GC with 27 µg/L PCE, 3.7 µg/L TCE, and 1.7 µg/L VC detected. The presence of biodegradation daughter-products, especially 1,2-dichloroethene (1,2-DCE), in other monitoring wells along this fracture trace indicates that anaerobic degradation of chlorinated volatile compounds, principally TCE and PCE, has occurred.

Naturally occurring iron and manganese obscure delineation of areas potentially impacted by inorganics in landfill leachate. Elevated levels of iron and manganese in monitoring wells that also have high VOC levels suggest that at these locations landfill leachate may also be contributing to elevated inorganic concentrations (MW-3I and M-5; see Tables 4-34 through 4-37).

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7.1.5 Surface Water and Sediment of Brandywine Creek and Briar Run

A limited number of organic compounds were detected in the surface water of Briar Run and the sediment of Brandywine Creek. The surface water of Briar Run had low concentrations of 1,1-DCA (0.6 μg/L) and cis-1,2-DCE (1.1 μg/L) detected in the sample collected from the sampling location nearest the landfill (SB-BR-2; see Table 4-40). Toluene was the only VOC of potential concern detected in the sediment at any location that was not qualified with a B (see Table 4-42). Toluene was detected at 23 μg/kg in the sediment at Brandywine Creek sediment sampling location SB-BW-2. The only other organic compound of concern detected was 4-methylphenol. This compound was detected (95 J to 380 J) in the sediment at three locations along Brandywine Creek (Table 4-42).

Selected inorganic analyte concentrations in some of the surface water samples collected from Brandywine Creek and Briar Run exceeded water quality criteria. Selected inorganic analyte concentrations in some of the sediment samples collected from Brandywine Creek and Briar Run would be classified as heavily polluted, using EPA Region V guidelines (Great Lakes Water Quality Board 1982) (see Table 4-50). The inorganic concentrations in the surface water and sediment were generally highest at the upgradient Brandywine Creek sampling location (SB-BW-1), indicating that inorganic levels observed in the surface water and sediment in the streams surrounding the site may be unrelated to site activities.

Bioassay tests were performed using sediment and surface water collected from Brandywine Creek and Briar Run. No evidence of acute or chronic toxicity was shown by any species tested for in any sample, except for the downstream sediment sample collected from SB-BR-3. The sediment from that location indicated that *Daphnia magna* exhibited diminished reproduction in comparison to reproduction occurring at the upstream reference site (see Section 4.6.4.6).

7.1.6 Seep Areas and Sediment Pond

Sediment and surface water samples were collected from the sediment pond and seep areas on the Strasburg Landfill site. These samples contained elevated levels of some of the tested organic and inorganic parameters when compared to levels measured in the samples collected from the surface water.

Organic compounds of potential concern were detected in sediment samples collected from the seep areas (85 μg/kg 1,1-DCA; 11 μg/kg 1,2-DCA; and 39 μg/kg 1,2-DCE) and sediment pond (54 μg/kg benzoic acid) (see Table 4-43). The leachate seep on the landfill contained approximately 300 μg/L total detected organic compounds, and the seep areas east of the landfill had more than 100 μg/L total detected organic compounds (see Table 4-41).

Arsenic, barium, beryllium, iron, and manganese were detected in the surface water and/or sediment in the seep areas and sediment pond at elevated levels compared to what was observed in Brandywine Creek and Briar Run. The highest barium concentration (903 mg/kg) and beryllium concentration (3.4 mg/kg) were detected in the leachate seep on the landfill. The highest arsenic (53.1 mg/kg), iron (425,000 mg/kg), and manganese concentrations (2,090 mg/kg) were detected in the sediment of the seep sample (SB-SA-2; see Table 4-49). The seep areas also had elevated concentrations of barium (48.3 to 367 μg/L), iron (6,680 to 20,200 μg/L), and manganese (753 to 14,100 μg/L), and the sediment pond had elevated barium levels (173 to 235 μg/L) in filtered water samples. Unfiltered water samples generally had even higher concentrations (see Tables 4-44 and 4-46).

Bioassay sampling indicated that the seep area sample from the Strasburg Landfill site exhibited evidence of chronic toxicity to the species tested.

The distribution of organic contamination is more widespread than the distribution of inorganic contamination. Organic contaminants were detected primarily in the water and sediment of the seep areas, groundwater, air, and soil gas.

7.2 RISK EVALUATION

In the human health risk assessment, four potential exposure pathways were identified. Three of these pathways appear to be complete under existing environmental and land use conditions, based on the information developed in the remedial investigation, and were quantitatively evaluated. The complete exposure pathways are:

- o Residential use of contaminated groundwater;
- o Inhalation of volatile organic contaminants on site and in nearby residential areas; and
- o Accidental contact with seep areas.

The fourth pathway involved contact of recreational users of Briar Run and Brandywine Creek with contaminants in surface water and sediment at these locations. It was not considered complete because little or no site-related contamination was found in either stream.

The potential receptors are residents living near the landfill and individuals using the site for various recreational purposes (walking, jogging, and horseback and ATV riding). These site visitors were assumed to be a subpopulation of the nearby residents.

Residents living in the vicinity of the Zarzycki residence, southwest of the landfill, and along Wheatland Drive, southeast of the landfill, appear to be those most likely to experience the largest potential exposures by both the groundwater and air pathways; therefore, the potential exposures and risks to these residents were estimated. Since the site visitors were assumed to be a subpopulation of the residents living near the site, the estimated risks to these individuals were added to the estimated risks occurring in the nearby residential areas to obtain estimates of the total site-related risks nearby residents might experience.

Systemic toxicants (noncarcinogens) did not pose significant risks by any of the pathways evaluated. The estimated risk of excess cancers was significant (greater than 10^{-6}) for residents living both in the vicinity of the Zarzycki residence (7 to 9 x 10^{-5}) and along Wheatland Drive (2 x 10^{-5}). In both cases, the risks were due primarily (92% to 98%) to the groundwater pathway. For the Zarzycki area residents, the risk estimates were based on contaminant concentrations actually found in residential wells in that area. In contrast, no contaminants are currently being detected in residential wells along Wheatland Drive. Therefore, the estimated risks for the Wheatland Drive residents were based on concentrations found in monitoring wells between that area and the landfill. It is not known if contaminants in these monitoring wells could migrate to these residential wells, but given the uncertainties about groundwater migration patterns in the area, there is a slight possibility that the contaminants found in the monitoring wells might reach the Wheatland Drive wells sometime in the future.

The total estimated risks due to the air pathway, considering both on-site and off-site exposures, were 1.6×10^{-6} for Zarzycki area residents and 8.5×10^{-7} for Wheatland drive residents. The estimated risks to site visitors from accidental contact with seep areas were 6.5×10^{-6}.

The total risks, including all potential exposure pathways, were estimated to be 8×10^{-5} for Zarzycki area residents and 2×10^{-5} for Wheatland Drive residents.

Ecological field investigations and risk assessments were conducted in the 400-acre study area surrounding the Strasburg Landfill site to characterize the biological communities and determine if significant ecological resources are potentially affected by site contamination. The ecological site survey and contacts with natural resource trustee personnel indicated the presence of high-quality habitat in the study area. The landfill is surrounded by apparently healthy, diverse terrestrial and aquatic communities, including river, wetland, forest, and open-field ecosystems harboring abundant wildlife populations. Stream surveys of benthic invertebrates indicated no alteration of community structure directly downstream from the site, and there was no other obvious evidence of adverse effects of chemical contamination on the existing populations, communities, or ecosystems. Other than the identified wetlands, no significant sensitive or protected biological resources (such as endangered species) are known to occur in the study area. Several species with special status in the Commonwealth of Pennsylvania have been reported in the vicinity, however, and these or other protected species could conceivably come in contact with the site or establish populations there. The Brandywine Conservancy Management Center manages two nature preserve properties within one mile of the landfill, providing potential source populations of special-status species.

The ecological risk assessment for the Strasburg Landfill site identified elevated levels of contaminants relative to background concentrations and environmental concern levels in seep areas, surface water, sediments, and soil gas. Potential low-level, chronic exposure of aquatic biota to site-related contaminants is considered likely from uncontrolled releases at seep areas and from runoff into surrounding wetlands and streams. No single contaminant appears to be occurring in surface water at levels toxic to aquatic life, but bioassay results demonstrate that seep water is toxic to indicator organisms tested under laboratory conditions. Shannon Diversity Indices were calculated for the benthic invertebrate samples collected at upstream and downstream locations in Briar Run and Brandywine Creek. For both streams, the diversity indices were higher downstream of the landfill than upstream. Thus, there is no evidence of a decrease in diversity of benthic invertebrates downstream of the landfill in either Briar Run or Brandywine Creek.

Although sediment contamination is not sufficient to alter benthic community composition in Briar Run, there is evidence of elevated levels of metals in wetland sediments with the potential to migrate downstream. In addition, bioassays indicated that downstream Briar Run sediments may have toxic effects on some aquatic organisms.

Terrestrial organisms may also be exposed to site-related contaminants, particularly landfill air emissions of volatile organic compounds (VOCs). For example, small mammals such as field mice inhaling air on the landfill perimeter may be exposed to toxic levels of VOCs migrating from soil gas to the near-ground ambient air. Elevated and potentially toxic levels of vinyl chloride occurred in soil gas plume areas on the east and west sides of the landfill, and benzene, PCE, and 1,1-DCE were present at elevated and potentially toxic levels on both sides of the landfill. Small mammals could also be at risk from elevated levels of barium in drinking water at the seeps. The potential risks to small mammals decrease rapidly with distance from the landfill and are likely to be negligible for all populations except those residing on the landfill and its perimeter or in wetlands adjacent to the landfill. Because of the limited spatial distribution of chemical contamination, predators and scavengers that utilize small mammals as prey probably face negligible risks from feeding on a contaminated food source or from reduced abundance of prey populations.

7.3 RECOMMENDATIONS

Detection of contaminants in the groundwater, surface water, sediment, and seep areas surrounding the site requires a long-term monitoring program be conducted at the Strasburg Landfill. PADER should continue its quarterly monitoring of the residential wells surrounding the site. Additional sampling of groundwater monitoring wells, surface water, sediment, and seep areas on the site is recommended to develop a data base to further evaluate current conditions, such as possible seasonal variability, and to provide baseline data to measure the effectiveness of remedial measures to be implemented at the site.

A sampling plan should be established that will detail the sampling frequency and the analytical parameters. Quarterly sampling is recommended to evaluate seasonal fluctuations. At least one annual sampling event should include an expanded parameter list to include general water quality parameters, such as biological oxygen demand (BOD), chemical oxygen demand (COD), and fecal coliforms, as well as analyses for anions such as sulfates, SO_4^-, and the nitrates NO_2^- and NO_3^-. The sampling plan should also include the data required for landfill closure monitoring. Stream gauging and water-level measurement of monitoring wells is recommended during sampling of the respective media.

Based on the results of the field investigations performed to date, it is obvious that while groundwater poses a threat to local residents, concentrations of chemicals in groundwater are not sufficient to justify a large-scale remediation of the landfill (i.e., source removal). Remedial alternatives for the site will most likely focus on mitigation and control of continued releases. Assuming that the landfill will not be remediated, long-term monitoring of groundwater must be implemented to further define and quantify the landfill's long-term impact on area groundwater. The monitoring well network should be expanded to further evaluate possible migration pathways and hydraulic characteristics of the aquifer. Specific recommendations are outlined as follows:

- A monitoring well cluster should be installed between Briar Run and Wheatland Drive to determine whether a deeper groundwater flow regime exists between the landfill and the homes along Wheatland Drive. Some of the homes along Wheatland Drive have yielded low-level concentrations (less than 10 μg/L) of VOCs. Long-term monitoring between Wheatland Drive and the landfill would assist in defining the potential for plume movement toward the Wheatland Drive area.

- A monitoring well cluster should be installed on the west side of Brandywine Creek to define groundwater quality and determine if Brandywine Creek receives groundwater discharge from the landfill area. A monitoring well cluster at this location and one located along the fracture trace on which MW-3I is located will aid in the evaluation of Brandywine Creek as a discharge point for the groundwater.

- A deep monitoring well should be installed adjacent to MW-5S to monitor deep groundwater quality upgradient of the landfill. These data are imperative to determine background water quality upgradient of the landfill, especially since a low-level concentration of PCE (2 μg/L) from MW-5S was detected during the last sampling event.

- Monitoring wells should be installed in the groundwater zone nearest the surface in areas of high soil gas concentrations surrounding the landfill. Information from these wells will aid in the evaluation of the soil gas sources.

- Long-term monitoring of soil gas should also be conducted, as concentrations measured around the landfill may pose a potential threat to human health.

Additional data should also be collected from the wells on site to provide information on aquifer characteristics. This includes monitoring the groundwater elevations in the residential wells (Craig, Dilworth, Hughes, and Zarzycki shallow and deep) over a 24-hour period using a transducer to determine drawdown and recharge rates. This information is crucial to evaluate groundwater gradient data collected from the residential wells and the recharge of the aquifer at these locations. Modified pump tests are recommended at the well clusters to determine the communication between monitoring wells at a well cluster (i.e., if pumping at one well has an immediate effect on the other well or wells within a given cluster); this would indicate communication between monitoring wells within the cluster. In the event that groundwater treatment or groundwater control are considered as remedial options at this site, more extensive pump tests should be performed. To optimize remedial design, the pump test should be performed near the anticipated location of any proposed groundwater recovery system. Since the greatest groundwater contamination was detected in the wells along the fracture trace at the southwestern edge of the landfill, that area should be targeted for the pump test. A pump test will also require the installation of piezometers to monitor the response of the aquifer during pumping. If an existing monitoring well cannot be used as the actual pumping well (i.e., M-5), an additional well will need to be constructed for this purpose.

Additional stream gauging and groundwater level measuring events are recommended to gather information on the interaction of the groundwater and surface water. The increasing water volumes noted along Briar Run and Brandywine Creek between the upstream and downstream sampling points (Table 4-5) could be the result of groundwater discharge to the streams. The groundwater gradient map indicates that groundwater is likely discharged to the streams (See Figure 4-1). To evaluate the hydrologic connection between the streams and the groundwater, additional monitoring wells (previously referenced), stream gauging stations, and stream and groundwater gauging events are needed.

Landfill emissions pose a potential human health risk. Before long-term air monitoring can be considered, additional air sampling should be performed. A night-time ambient air sampling event during a relatively dry season is recommended to evaluate emissions during a dry, still period that would be optimal for the collection of emissions. Air sampling using the SUMMA passivated canisters within the landfill (possibly within the vent pipes) is also recommended to further characterize the emission source.

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