
**Risk Assessment for the Transportation of
Hazardous Waste and Hazardous Waste
Components of Low-Level Mixed Waste and
Transuranic Waste for the U.S. Department
of Energy Waste Management Programmatic
Environmental Impact Statement**

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NOTATION

The following is a list of the acronyms, initialisms, and abbreviations (including units of measure) used in this document.

ACRONYMS, INITIALISMS, AND ABBREVIATIONS

AIHA	American Industrial Hygiene Association
ALOHA™	Areal Locations of Hazardous Atmospheres
ANL	Argonne National Laboratory
CEEL	Community Emergency Exposure Level
COT	Committee on Toxicology
DOE	U.S. Department of Energy
DOT	U.S. Department of Transportation
DW	dangerous waste
EHS	extremely hazardous substance
EPA	U.S. Environmental Protection Agency
EPCRA	Emergency Planning and Community Right to Know Act
ERPG	Emergency Response Planning Guideline
HaWRAM	Hazardous Waste Risk Assessment Modeling
HEAST	Health Effects Assessment Summary Tables
HMIRS	Hazardous Materials Information Reporting System
HQ	hazard quotient
HW	hazardous waste
HWDAR	Hazardous Waste Disposal Approval Record
ICRC	increased cancer risk concentration
IDLH	immediately dangerous to life and health
IRIS	Integrated Risk Information System
LC ₅₀	concentration of gas or vapor that causes death in half of the animals tested when administered by continuous inhalation
LC _{LO}	lowest concentration of gas or vapor that has caused death in any exposed species
LLMW	low-level mixed waste
LLNL	Lawrence Livermore National Laboratory
LOC	level of concern
MEI	maximally exposed individual
MRI	Midwest Research Institute
NIOSH	National Institute for Occupational Safety and Health
NOAA	National Oceanic and Atmospheric Administration
PAEC	potential any adverse effect concentration
PEIS	Programmatic Environmental Impact Statement
PIH	poison inhalation hazard
PLC	potentially life-threatening concentration
RfC	reference concentration
RfD	reference dose
RTECS	Registry of Toxic Effects of Chemical Substances
SAM	Station for Atmospheric Measurements
SPEGL	Short-Term Public Exposure Guidance Level

STEL	short-term exposure level
TC _{LO}	lowest concentration causing any adverse human effect
TRUW	transuranic waste
WM	Waste Management
WPPSS	Washington Public Power Supply System

UNITS OF MEASURE

cm	centimeter(s)
cm ²	square centimeter(s)
cm ³	cubic centimeter(s)
d	day(s)
°F	degree(s) Fahrenheit
ft	foot (feet)
g	gram(s)
gal	gallon(s)
h	hour(s)
kg	kilogram(s)
km	kilometer(s)
lb	pound(s)
m	meter(s)
m ³	cubic meter(s)
µg	microgram(s)
mg	milligram(s)
mi	mile(s)
min	minute(s)
ppm	part(s) per million
s	second(s)
wk	week(s)
yr	year(s)

**RISK ASSESSMENT FOR THE TRANSPORTATION
OF HAZARDOUS WASTE AND HAZARDOUS WASTE COMPONENTS
OF LOW-LEVEL MIXED WASTE AND TRANSURANIC WASTE
FOR THE U.S. DEPARTMENT OF ENERGY WASTE MANAGEMENT
PROGRAMMATIC ENVIRONMENTAL IMPACT STATEMENT**

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ABSTRACT

This report, a supplement to Appendix E (Transportation Risk) of the U.S. Department of Energy Waste Management Programmatic Environmental Impact Statement (WM PEIS), provides additional information supporting the accident data for chemical risk assessment and health risk methodology described in that appendix (Part II) and presents the uncertainty analysis and on-site risk calculations. This report focuses on hazardous material truck accident rates, release probabilities, and release quantities; provides the toxicological values derived for each hazardous chemical assessed in the WM PEIS and further details on the derivation of health criteria; describes the method used in the transportation risk assessments to address potential additivity of health effects from simultaneous exposure to several chemicals and the method used to address transportation risks for maximally exposed individuals; presents an expanded discussion of the uncertainty associated with transportation risk calculations; and includes the results of the on-site transportation risk analysis. In addition, two addenda are provided to detail the risk assessments conducted for the hazardous components of low-level mixed waste (Addendum I) and transuranic waste (Addendum II).

1 INTRODUCTION

As a technical support supplement to Appendix E of the U.S. Department of Energy (DOE) Waste Management Programmatic Environmental Impact Statement (WM PEIS) (DOE 1996), this report provides (1) additional information and technical detail to support the accident data and health risk methodology described in that appendix and (2) supplemental information supporting the uncertainty analysis and the on-site risk calculations. This report is not intended to be a comprehensive stand-alone document; rather,

readers who require a more detailed discussion of some of the data and data sources, assumptions, and analysis methods relevant to the hazardous waste (HW) transportation risk calculations can find that information here. In addition, two addenda are provided to detail the risk assessment conducted for the hazardous components of low level mixed waste (LLMW) and transuranic waste (TRUW).

Section 2 discusses data on hazardous material truck accident rates, hazardous material release probabilities, and release quantities (supplementing Section E.16.3 of WM PEIS Appendix E). Section 3, which supplements Section E.16.5 of Appendix E, provides the toxicological values derived for each hazardous chemical assessed in the WM PEIS (DOE 1996) and further details on how health criteria are derived. Section 3 also discusses (1) the method used in the transportation risk assessment to address potential additivity of health effects from simultaneous exposure to several chemicals and (2) the methodology for calculating risk for maximally exposed individuals. Section 4 provides an expanded discussion of the uncertainty associated with transportation risk calculations, supplementing Section E.18 of Appendix E. Finally, the approach, assumptions, model input data, and results of the on-site transportation risk analysis are presented in Section 5.

Additional information provided in this report documents key parameters of the transportation risk equation (Equation 1). This equation is used to quantify both radiological and HW transportation health risks. Equation 1 can be used to estimate the risk to the general public and to on-site workers (i.e., number of individuals potentially experiencing an adverse health effect) from transporting a specific HW through a given population zone. General population risk estimates are given in Appendix E, Part II (DOE 1996); on-site worker risk estimates are included in Section 5 of this document. Total risk for a specific shipment is calculated as:

$$Risk = \sum_i TAR_i \times P(R/A)_i \times C_i \times D_i \times L_i, \quad (1)$$

where

$Risk$ = health effects (individuals potentially affected);

TAR_i = truck accident rate per unit of distance traveled in population zone i (accidents/km; accidents/mi);

$P(R/A)_i$ = conditional probability of an HW release in population zone i , given an accident involving a truck carrying HW;

C_i = health consequence area for population zone i (km²/accident; mi²/accident);

D_i = population density in zone i (individuals/km²; individuals/mi²);
and

L_i = distance traveled in population zone i (i.e., routing data; km; mi).

The notation i in Equation 1 refers to one of three population zones (rural, urban, or suburban) with differing population densities. The risk for each shipment is calculated by summing the risk for each population zone; risks for all shipments are summed to arrive at the risk for each alternative.

2 TRANSPORTATION ACCIDENT AND RELEASE PROBABILITIES

The probability of a hazardous chemical release given an accident is the product of the rate of truck accidents involving hazardous materials and the probability of a release of a hazardous chemical (by cargo type). The truck accident rate and conditional probability are given by the TAR_i and $P(R/A)$ parameters in Equation 1, which are used with consequence and population data to compute the HW transportation risk. Data on the fraction of hazardous chemicals released for those HW containers breached in an accident are used to quantify the source term in the consequence assessment. The risk for each mile is then computed by population density zones and summed for each alternative. The following discussion provides more details on the choice of accident rates, release probabilities, and container breach fractions for HW risk assessment modeling, which are summarized in Section E.1.6.3, Part II, of the WM PEIS Appendix E (DOE 1996).

The assessments for TRUW and LLMW included both truck and rail transportation modes. The container types required for TRUW are Type B, which provide package integrity even in severe accidents. The assumed release rates, rail accident rates and other data for assessment of TRUW and LLMW are provided in Appendix E of the WM PEIS (DOE 1996) and in the addenda to this document, and in the technical support document for LLMW (Monette et al. 1996).

2.1 TRUCK ACCIDENT PROBABILITIES

A study conducted in California (Graf and Archuleta 1985) is the only known source of information that accurately matches accident data and corresponding shipment miles for selected sites statewide to generate accident involvement rates by highway category and truck configuration. These rates are given in Table 1 and can be found in the Midwest Research Institute (MRI) report (Harwood and Russell 1990).

Only the single-unit truck configuration rates in the first row of Table 1 have been used. Truck configuration is not documented on the DOE manifests (Argonne National Laboratory [ANL] HW database); however, the DOE HW is shipped predominantly in consignments of multiple drums with maximum capacities of less than or equal to 55 gal per drum. These types of shipments are conveyed mostly in single-unit trucks.

Furthermore, routing information is categorized by urban freeway, suburban freeway, rural freeway, and rural nonfreeway miles. Suburban freeway accident involvement rates have been estimated by averaging the rural and urban freeway rates to more accurately match the route descriptions.

TABLE 1 California Accident Involvement Rates per Million Miles of Truck Travel by Truck Configuration and Highway Category, 1979-1983

Truck Configuration	Highway Category				
	Rural Freeway	Rural Other	Suburban Freeway ^a	Urban Freeway	Urban Other
Single-Unit	0.56	0.68	0.79	1.01	1.04
Single Comb.	0.94	1.91	1.56	2.18	2.03
Double Comb.	1.18	1.63	1.41	1.63	5.33
All Trucks	0.90	1.49	1.19	1.48	1.64

^a The suburban highway-type numbers are not presented in the MRI Report (Harwood and Russell 1990). The numbers presented here are the average of rural freeway and urban freeway. The suburban freeway accident rates will be matched with corresponding route mileage in the suburban population zone.

2.2 HAZARDOUS WASTE RELEASE PROBABILITIES

A key problem with national data relevant to release probabilities is that procedures for reporting hazardous material accident data at the state level for entry in nationally mandated databases are nonuniform. By contrast, some individual states maintain more comprehensive and better monitored hazardous material accident data for their own recording purposes. For example, Missouri Highway Patrol accident reports contain entries that identify whether the involved vehicles contained hazardous cargo, specify the type of hazardous material, and determine whether a release occurred. This information allows for accurate classification of releasing accidents by cargo type. Furthermore, the Missouri 1985-1986 data are nearest the midpoint of total annual hazardous material movements by road and have therefore been selected as the basis for estimating release probabilities given an accident for the risk assessment. These probabilities are given in Table 2 and can be found in the MRI report (Harwood and Russell 1990).

2.3 RELEASE QUANTITIES

One variable in computing health consequence is the release quantity. In HW risk assessment, it is assumed that in each accident modeled, a fixed percentage of the shipment capacity is released depending on the type of container used. These fixed percentages are presented in Table 3.

The quantity released in an accident is given in Equation 2. The breach fraction for bulk containers is 1 because bulk containers are generally large, single-unit containers like tanker trucks. Although multiple bulk-portable containers can be shipped on one truck, no DOE shipments make use of bulk-portable tanks.

$$Q = nt \times bf \times cc \times fr , \quad (2)$$

where

- Q = quantity released;
 nt = number of containers in transit;
 bf = breach fraction;
 cc = container capacity; and
 fr = fraction released.

All numbers in Table 3, other than the bulk containers breach fraction, were computed by averaging the corresponding breach fractions and container capacity release

TABLE 2 Probability of a Release Given an Accident, by Hazardous Cargo Type

Hazardous Cargo Type (in Bulk)	Probability
Gases	0.072
Solids	0.091
Liquid	0.187

TABLE 3 Container Breach Rates and Release Fractions for Containers Subject to Transport Accidents (Liquid and Gas Shipments)^a

Shipment Type	Breach Fraction	Capacity Release Fraction
Package freight containers		
0 to 2 gal	0.438	0.653
2 to 10 gal	0.451	0.368
10 to 50 gal	0.407	0.271
Greater than 50 gal	0.359	0.199
Bulk containers	1.000	0.162

^a Based on data from 1989 to 1992 in the Hazardous Materials Information Reporting System (HMIRS) database (U.S. Department of Transportation [DOT] 1993a).

fractions in a subset of the accident records found in the HMIRS database (DOT 1993a). The subset of the HMIRS accidents used to compute these numbers includes all accidents that satisfy the following conditions:

- A release of a nonradioactive hazardous waste occurred;
- The release did not result from a loading, unloading, or temporary storage incidents;
- The physical state of the hazardous material was liquid or gas; and
- The mode of travel was highway (excludes rail, water, and air travel).

3 HEALTH RISK CRITERIA

The on-site and off-site shipment of HW, TRUW, and LLMW from generator facilities to treatment facilities imposes a population health risk associated with potential accidents involving the release of toxic chemicals to the atmosphere. These shipments also impose a potential collision health risk to other vehicle drivers and passengers, pedestrians, and the transport truck crew members. The approach developed to quantify the accident chemical exposure and collision risks is described in this section.

Health impacts associated with transporting HW, and hazardous components of TRUW, and LLMW may include impacts under both routine and accident transport conditions. The end point assessed under routine transport conditions is excess latent mortality due to inhalation of vehicle exhaust emissions. Additionally, the probability of injury or fatality for the general public due to vehicle collisions but independent of any release of HW is estimated. For predicting inhalation hazards associated with accidental releases, the Areal Locations of Hazardous Atmospheres (ALOHA™) model can be used to calculate the health consequence area (C_i in Equation 1) by predicting the area of the HW plume produced by an accident. To predict the plume area, concentrations corresponding to appropriate health end points are required. Human health risk end points addressed in this assessment include the potential for life-threatening effects (evaluated by using potentially life-threatening concentration [PLC] values), the potential for any adverse effects (evaluated by using potential any adverse effect concentration [PAEC] values), and the potential for carcinogenic effects (evaluated by using increased cancer risk concentration [ICRC] values). Calculated risks correspond to the end point being assessed (i.e., PLC values are used to estimate the number of individuals in the general population potentially experiencing life-threatening effects; PAEC values are used to estimate the number of individuals in the general population potentially having any adverse effects; and ICRC values are used to estimate the number of individuals potentially having an increased risk of cancer). PLC, PAEC, and ICRC values were derived from toxicological data and risk evaluation methods for emergency planning available from the U.S. Environmental Protection Agency (EPA) and other sources (DOT 1990; Maloney 1990; EPA et al. 1987; EPA 1986; National Resource Council 1993). The development of health criteria used to assess risk with respect to these end points is described in the following subsections.

The goal of the proposed approach for identifying PLC, PAEC, and ICRC values is to estimate the minimum concentration level that could induce the adverse health effect. This minimum level is used in the ALOHA™ model to estimate the plume area with an air concentration at that level or higher. The total population exposed is assumed to be at risk for the health effect. Of the population at risk (i.e., within the plume), those exposed to the highest concentrations will have the greatest likelihood of experiencing the health effect. The method identifies the number of individuals in the general population at risk but does not differentiate the risk for individuals within the plume.

3.1 GENERAL INFORMATION ON CRITERIA DEVELOPMENT FOR ACCIDENTAL RELEASES

The health criteria concentrations required to analyze exposures occurring as a result of accidental chemical releases (e.g., from transportation accidents) must be applicable for single, brief exposures of individuals in the general public. Before the 1984 accidental release of methyl isocyanate in Bhopal, India, which killed more than 2,400 people, chemical risk assessment focused primarily on methods for evaluating risks from chronic, low-level exposures due to environmental contamination. In response to the Bhopal catastrophe and accidental releases in the United States, Title III of the Superfund Amendments and Reauthorization Act of 1986 (also known as the Emergency Planning and Community Right to Know Act or EPCRA) was passed. This act required the EPA to publish a list of extremely hazardous substances (EHSs) and to develop methods for assessing the lethal hazards of these substances (EPA et al. 1987). The EPA complied by identifying more than 500 EHSs and introducing the level of concern (LOC) concept, which is defined as the concentration in air of each EHS above which there may be serious irreversible health effects or death as a result of a single exposure for a relatively short period of time. The EPA published estimated measures of LOC for each EHS on the basis of occupational guideline levels, fractions of lethal concentrations for animals, or modified occupational standards and emphasized that these were preliminary guidelines to be used while more precise measures were being developed (EPA et al. 1987). Documentation of the LOC derivation for each chemical was never published.

A consortium of chemical firms has developed a protocol for developing community Emergency Response Planning Guidelines (ERPGs), which are reviewed and distributed by the American Industrial Hygiene Association (AIHA 1988-1992). The procedure for developing the ERPGs relies on thorough review of both published and unpublished chemical-specific data. ERPGs are available for about 50 chemicals. For a number of chemicals, the NRC has developed Short-Term Public Exposure Guidance Levels (SPEGLs) intended for application to single, unpredicted short-term exposures of the general public (National Research Council 1986).

At the request of the EPA, the NRC Committee on Toxicology (COT) recently prepared a report entitled *Guidelines for Developing Community Emergency Exposure Levels (CEELs) for Hazardous Substances* (National Research Council 1993). This document discusses data sources and appropriate risk assessment methods for deriving emergency response guidelines for the general public; it advocates a chemical-specific approach to developing CEELs like that used in the development of ERPG values. To date, however, CEEL values have not been developed by federal agencies.

The guidance in the NRC CEEL document was implemented whenever possible in developing the health criteria concentrations to be used in the transportation risk assessment for HW and hazardous components of other wastes for the WM PEIS. The large number of chemicals transported by DOE waste generators, however, precluded evaluation of the primary literature for individual chemicals. The proposed approach for deriving criteria concentrations relies on primary toxicity data reported in databases or reference books, and,

as such, must be considered a screening level approach. However, the health criteria values used in this transportation risk assessment constitute an improvement over the EPA LOC values, because their data sources are carefully documented, and because refining features have been implemented (e.g., exposure duration adjustment and the additional health end points of any adverse effects and increased carcinogenic risk).

3.1.1 Potentially Life-Threatening Concentration Values

The potential for life-threatening health effects is assessed for specific HW components designated as "poison inhalation hazards" (PIHs) by the DOT (49 *Code of Federal Regulations* Parts 173.115 and 173.132-133). These substances are assigned protective action distances in the DOT *Emergency Response Guidebook* commonly used by personnel responsible for hazardous materials incident response (DOT 1990). Only liquids and gases are designated as PIH substances. Two criteria must be met for a chemical substance to be designated a PIH: (1) high toxicity, on the basis of animal 50% lethal concentrations (LC_{50}), and (2) for liquids, medium to high volatility. PLC values have been derived for PIH substances shipped by DOE HW waste generators in FY 1992, which is considered the baseline case for the no-action alternative. No PIH chemicals were included in either the TRUW or the LLMW inventories.

PLC values are air concentrations of HW above which exposed persons are at risk of potentially life-threatening health effects when exposed for the associated exposure duration. PLC values are input to the ALOHA™ code to estimate "PLC areas at risk" (i.e., areas that equal or exceed the PLC air concentration). In deriving PLC values, three main issues must be addressed: (1) selection of toxicity values, (2) selection of appropriate uncertainty factors, and (3) exposure duration adjustment. These issues are summarized below.

Toxicity Value Selection. For this screening level assessment, toxicity data were obtained from one of two sources: (1) the Registry of Toxic Effects of Chemical Substances (RTECS) database (National Institute for Occupational Safety and Health [NIOSH] 1992) or (2) *Dangerous Properties of Industrial Materials* (Sax and Lewis 1992). Uncertainty in the toxicity values could be reduced by verifying the toxicity data in the primary literature. Also, the toxicity data should be updated periodically to reflect the most recent data available.

Two possible toxicity values for estimating potential human life-threatening health effects are the LC_{50} and the LC_{LO} . The LC_{50} is defined as that concentration of gas or vapor that causes death in half of the animals tested when administered by continuous inhalation. The LC_{50} is obtained only from animal tests; consequently, results must be extrapolated for application to humans. The LC_{LO} is defined as the lowest concentration of gas or vapor that has caused death in any exposed species. The LC_{LO} values may be obtained from animal tests or from accidental human exposure occurrences. When obtained from the latter, the lethal concentration measurement may not be accurate.

Because of the limitations of both the human LC_{LO} values and the LC_{50} values, a conservative approach was taken in selecting the chemical-specific toxicity values. The lower

of either (1) the lowest available human LC_{LO} value divided by an uncertainty factor of 3 or (2) the LC_{50} value for the most sensitive tested mammalian species divided by an uncertainty factor of 10 was selected as the primary toxicity value for deriving PLCs (uncertainty factor selection is discussed below). Currently, LC_{50} values or human LC_{LO} values are available for 87% of the substances evaluated. For substances for which no LC_{50} or human LC_{LO} value was available, the lowest mammalian LC_{LO} value was substituted for the LC_{50} value. If none of the above were available, a short-term exposure level (STEL) for occupational exposures was multiplied by 15 to derive the PLC value (based on methods used to derive LOC values [EPA et al. 1987]).

Uncertainty Factor Selection. The EPA uses uncertainty factors in deriving reference doses for hazardous chemical substances (EPA 1989a). This EPA precedent has been used to support reduction of human LC_{LO} values by an uncertainty factor of 3 (to correct for variations in susceptibility among individuals in the human population) and LC_{50} or mammalian LC_{LO} values by an uncertainty factor of 10 (3 to correct for interspecies extrapolation and 3 to account for variations in human susceptibility; rounded to 10 for simplicity). When the EPA derives reference doses, additional uncertainty factors are also considered to account for extrapolation of subchronic data to chronic exposure conditions and use of lowest adverse effect data instead of no adverse effect data. However, these two factors are not considered appropriate for deriving PLC values for acute human exposures and have not been incorporated in toxicity value development for this end point.

The default uncertainty factor generally used by the EPA for each category of uncertainty is 10. However, use of an uncertainty factor of 10 for human LC_{LO} data or 100 for LC_{50} data would in general have reduced the estimated human life-threatening level to a concentration that was *not* life threatening to humans (compared with other published criteria). The EPA acknowledges that use of modifying factors of less than 10 is appropriate in certain instances. The EPA prefers the use of an intermediate factor on a logarithmic scale in these instances (EPA 1980). Therefore, an uncertainty factor of 3 (approximate log mean of 1 and 10) was selected.

Exposure Duration Adjustment. The ALOHA™ code used to estimate the "PLC areas at risk" for transportation accidents also provides estimated release duration, ranging from 1 to 60 min. Releases of longer duration are reported as "greater than 60 min." For the HW transportation risk assessment, it was assumed that control and dispersion of the source limits significant exposures to periods of 1 hour or less.

Because toxic dose is a function of both exposure level (e.g., air concentration of chemical) and duration of exposure (Klaassen et al. 1986), reported LC_{LO} and LC_{50} values are associated with experimental exposure times. The release durations estimated by the ALOHA™ code are used to scale LC_{LO} or LC_{50} values in the literature from experimental exposure times to the estimated exposure durations. For simplicity, human PLC values were generated for three exposure durations: 15, 30, and 60 min. The PLC value for the exposure duration closest to but greater than the ALOHA™-estimated release duration is used to generate the area within which exposed persons are at risk of potentially life-threatening

effects (e.g., if the release duration is 20 min, the PLC for a 30-min exposure duration is used to estimate the area at risk).

Either a linear or exponential function was assumed in scaling literature-reported toxicity values to the appropriate exposure durations. The linear scaling procedure is based on Haber's Law (Klaassen et al. 1986), which in equation form is as follows:

$$PLC = \frac{\text{Toxicity Value} \times EET}{ED \times UF}, \quad (3)$$

where

PLC = potentially life-threatening concentration (ppm);

Toxicity Value = literature-reported LC_{LO} or LC₅₀ value (ppm);

EET = experimental exposure time (min);

ED = exposure duration (15, 30, or 60 min); and

UF = uncertainty factor (3 or 10).

The exponential scaling equation is as follows:

$$PLC = \frac{\left[\frac{(\text{Toxicity Value})^n \times EET}{ED} \right]^{1/n}}{UF}. \quad (4)$$

The parameters for Equation 4 are defined in Equation 3. Wilson (1991) discusses the use of this scaling equation and gives the appropriate range of values for *n* as 1.5 to 3.5; a factor of 2 was used in calculations for this assessment. The linear scaling procedure results in a lower estimate of the PLC when scaling from an experimental exposure time shorter than the exposure duration (e.g., scaling from a 15-min experimental exposure time to a 60-min exposure duration). The exponential scaling procedure results in a lower estimate of the PLC when scaling from an experimental exposure time longer than the exposure duration. In the absence of chemical-specific data, the scaling assumption (i.e., linear versus exponential) resulting in the lower PLC value was used.

In calculating accident risks for the potentially life-threatening end point, it is assumed that the entire population residing within the PLC area at risk would experience serious health effects from the exposure. This is a conservative assumption because the PLC values have incorporated uncertainty factors to account for sensitive human subpopulations. The PLC values derived for the HW risk calculations for 15-, 30-, and 60-min exposure

durations are given in Table 4. The literature-reported toxicity value used to derive the PLC for each chemical is also provided.

Table 4 gives two emergency criteria for comparison with PLC values. The ERPG-3 value is defined as "the maximum airborne concentration below which it is believed that nearly all individuals could be exposed for up to 1 hour without experiencing or developing life-threatening health effects" (AIHA 1988-1992). In Table 4, ERPG-3 values should be compared with PLC values for 60-min exposure durations. Where available, ERPG-3 values correspond fairly well to the PLC values; in all cases, the difference was less than an order of magnitude.

Table 4 also provides LOC values developed by the EPA. The LOC values should be compared with 30-min PLC values. Comparison of the values shows no definite correlation. Of the substances with LOC values available, 17% were higher than the corresponding PLC, 45% were within a factor of 10 lower than the PLC, and 38% were more than 10 times lower than the PLC (the factor ranged from 15 to 180 times lower). LOC values were originally derived as one-tenth of immediately dangerous to life and health (IDLH) values (EPA et al. 1987). A lack of correlation of IDLH (and thereby LOC) values with primary toxicity values has also been noted in the literature (Alexeeff et al. 1989) and may be due to the fact that IDLH and LOC values have not been updated to reflect more recent toxicity data since their initial compilation. An additional problem with the use of LOC values is that documentation of the primary toxicity values used to generate the LOCs has not been published.

3.1.2 Potential Any Adverse Effect Concentration Values

To estimate the probability of the occurrence of less severe effects, values were also developed to estimate air concentrations of HW above which exposed persons are potentially at risk of any adverse effect (PAEC values). PAEC values were derived for all PIH substances shipped by DOE HW waste generators in FY 1992 and for HW, TRUW, and LLMW other shipped substances that had inhalation reference doses or concentrations available from the EPA for use as the toxicity value. As in the derivation of PLC values, the derivation of PAEC values requires selection of toxicity values and uncertainty factors and exposure duration adjustment, which are discussed below.

Toxicity Value Selection. Inhalation reference doses and reference concentrations developed by the EPA were selected as the most applicable toxicity values for use in deriving PAEC values. An inhalation reference dose is defined as an estimate (with uncertainty spanning perhaps an order of magnitude) of continuous exposure to the human population (including sensitive subgroups) that is likely to be without appreciable risk of deleterious effects (EPA 1989b). The reference dose in mg/kg/d is derived from the reference

TABLE 4 Potentially Life-Threatening Concentration Values for HW Chemicals Transported by DOE^a

Substance	CAS No.	Molecular Weight	Toxicity Value (ppm)	Time/Species ^b	Concentration (ppm)				
					PLC (15 min)	PLC (30 min)	PLC (60 min)	ERPG-3 ^c (60 min)	LOC ^d (30 min)
Acrolein ^e	107-02-8	56	131	30 min/rat ^f	19	13	6.6	3.0	0.44
Allylamine	107-11-9	57	286	4 h/rat ^g	110	81	57		1.4
Ammonia	7664-41-7	17	5,000	5 min/human/LC ₁₀ ^f	560	280	140	1,000	50
Arsine	7784-42-1	78	79	10 min/mouse ^f	5.2	2.6	1.3		0.60
Boron trifluoride	7637-07-2	68	39	4 h/guinea pig ^f	16	11	8		10
Bromine	7726-95-6	160	750	9 min/mouse ^f	45	23	11	5.0	1.0
Carbon monoxide	630-08-0	28	5,000	5 m/human/LC ₁₀ ^f	560	280	140		
Carboxyl fluoride	353-50-4	66	360	1 h/rat	72	51	36		
Chlorine	7782-50-5	71	137	1 h/mouse ^f	27	19	14	20	2.5
Chloropicrin	76-06-2	164	10	4 h/mouse ^f	3.9	2.8	2.0	3.0	
Cyanogen bromide	506-68-3	106	116	10 min/mouse/LC ₁₀ ^f	7.7	3.9	1.9		10
Cyclohexyl isocyanate ^e	3173-53-3	125	30	1 h/guinea pig	6.0	4.2	3.0		
Dimethyl sulfate	77-78-1	126	9	4 h/rat ^f	3.5	2.5	1.7		1.0
Ethyl chloroformate	541-41-3	109	145	1 h/rat	29	21	15		
Hydrogen fluoride ^e	7783-07-5	81	50	30 min/human/LC ₁₀ ^g	24	17	8	50	2.0
Hydrogen selenide	7783-06-4	34	6.1	1 h/rat/LC ₁₀ ^f	1.2	0.86	0.61		0.20
Hydrogen sulfide	7783-06-4	34	800	5 min/human/LC ₁₀ ^f	89	44	22	100	30
Methylamine	74-89-5	31	1,897	2 h/mouse ^f	540	380	270	500	
Methyl bromide	74-83-9	95	397	2 h/mouse ^f	110	79	56		200
Methyl chloroformate	79-22-1	95	48	2 h/mouse ^f	14	10	7		0.47
Methyl iodide	74-88-4	142	224	4 h/rat ^f	90	63	45	125	
Methyl vinyl ketone	78-94-4	70	3	2 h/mouse ^f	0.79	0.56	0.40		0.024
Nickel carbonyl ^e	13453-39-3	171	10	30 min/mouse ^f	1.4	0.96	0.48		0.050
Nitric acid (fuming)	7697-37-2	63	67	4 h/rat ^f	27	19	13		10
Nitric oxide	10102-43-9	30	872	4 h/rat ^f	350	250	170		25
Nitrogen dioxide	10102-44-0	46	30	1 h/guinea pig ^f	6.0	4.2	3.0		5.0
Nitrosyl chloride ^h	2696-92-6	65	30	1 h/guinea pig	6.0	4.2	3.0		
Phosgene	75-44-5	99	50	5 min/human/LC ₁₀ ^f	5.6	2.8	1.4	1.0	0.20
Phosphine	7803-51-2	34	11	4 h/rat ^f	4.4	3.1	2.2		20
Phosphorous oxychloride	10025-87-3	153	32	4 h/rat ^f	13	9.1	6.4		0.48
Phosphorous trichloride	7719-12-2	137	50	4 h/guinea pig ^f	20	14	10		5.0
Selenium hexafluoride	7783-79-1	193	10	1 h/rat, mouse, guinea pig/LC ₁₀	2.0	1.4	1.0		
Silicon tetrafluoride	7783-61-1	104	16,000	4 h/rat/LC ₁₀	6,400	4,500	3,200		
Sulfur dioxide	7446-09-5	64	3,000	5 min/human/LC ₁₀ ^f	330	170	83	15	10
Sulfur trioxide	7446-11-9	80	9	6 h/guinea pig/LC ₁₀ ^f	4.5	3.2	2.2		0.92
Sulfuric acid (fuming)	7664-93-9	98	80	2 h/mouse ^g	23	16	11	30 mg/m ³	2.0

TABLE 4 (Cont.)

Substance	CAS No.	Molecular Weight	Toxicity Value (ppm)	Time/Species ^b	Concentration Values by Exposure Time (ppm)					
					PLC (15 min)	PLC (30 min)	PLC (60 min)	ERPG-3 ^c (60 min)	LOC ^d (30 min)	
Sulfuryl fluoride	2699-79-8	102	991	4 h/rat	400	280	200			
Tellurium hexafluoride	7783-80-4	242	5	1 h/mouse/LC ₅₀ ^f	1.0	0.71	0.50	100 mg/m ³	0.10	
Thionyl chloride	7719-09-7	119	500	1 h/rat	100	71	50			
Thiophosgene ^j	463-71-8	115	80	2 h/mouse	23	16	11			
Titanium tetrachloride	7550-45-0	190	13	2 h/mouse ^f	3.7	2.6	1.8		0.13	
Toluene diisocyanate	26471-62-5	174	9.7	4 h/mouse	3.9	2.7	1.9			
Trimethylacetyl chloride ^j	3282-30-2	121	137	1 h/mouse	27	19	14			
Tungsten hexafluoride ^k	7783-82-6	298	0.82	15 min/STEL × 15 ^f	20	10	15			

^a Data preference hierarchy and linear versus exponential extrapolation detailed in text. Values rounded to two significant figures. To convert toxicity values to ppm, multiply the concentration (mg/m³) by 24.5 and divide by the molecular weight. Toxicity value scaled linearly or exponentially to result in lowest PLC value. Linear scaled PLC = (Toxicity Value × EET)/(ED × UF); exponential scaled PLC = ((Toxicity Value)² × EET/ED)^{1/2} ÷ UF; UFs: for human LC₅₀, 3; LC₅₀ or mammalian LC₁₀, 10.

^b Toxicity value is LC₅₀ unless otherwise noted.

^c ERPG-3: Emergency Response Planning Guideline-3 (AIHA 1988-1992).

^d EPA et al. (1987).

^e Exponential scaling used for 15-min PLC; linear scaling used for 60-min PLC.

^f Data obtained from RTECS database (NIOSH 1992).

^g Data obtained from Sax and Lewis (1992).

^h Value for nitrogen dioxide used for cyclohexyl isocyanate and nitrosyl chloride; emits toxic fumes of NO_x when heated to decomposition (Sax and Lewis 1992).

ⁱ Value for sulfuric acid used for thiophosgene; emits toxic fumes of SO_x when heated to decomposition (Sax and Lewis 1992).

^j Value for chlorine used for trimethylacetyl chloride; emits Cl⁻ when heated to decomposition (Sax and Lewis 1992).

^k No LC₅₀ or LC₁₀ data available for tungsten hexafluoride; used the 15-min STEL value (10 mg W/m³) converted to ppm (i.e., 10/184 [MW of W] × 24.5). This was multiplied by an uncertainty factor of 15, derived as follows: In deriving LOC values, EPA et al. (1987) suggest that the IDLH value divided by 10 (for sensitive human subpopulations) is an appropriate LOC value (to be used as the PLC in this instance). Further, it is suggested that IDLH = 8-h TWA × 500, and STEL/3 = 8-h TWA. Thus, algebraically, the appropriate adjustment for an STEL is: 15-min PLC = STEL × 500/(10 × 3).

Abbreviations: CAS = Chemical Abstracts Service, EET = experimental exposure time; ED = exposure duration (15-, 30-, or 60-min); IDLH = immediately dangerous to life and health, LOC = level of concern, RTECS = Registry of Toxic Effects of Chemical Substances, STEL = short-term exposure level, TWA = time-weighted average, and UF = uncertainty factor.

concentration (RfC) in mg/m^3 . The EPA Integrated Risk Information System (IRIS) database and Health Effects Assessment Summary Tables (HEAST) have been used to obtain current reference concentration values (EPA 1993a, 1993b).

Many of the PIH substances did not have available RfC values. For these substances, toxicity values were selected in a hierarchical fashion analogous to that used to estimate PLC values. In the absence of an RfC, the lowest human TC_{LO} value (defined as the lowest concentration causing any adverse effect) was selected as the most appropriate toxicity value for PAEC derivation. When human TC_{LO} values were not available, the following toxicity values from the literature were used (in decreasing order of preference): (1) lowest mammalian TC_{LO} values, (2) lowest human LC_{LO} values, (3) lowest LC_{50} values, (4) lowest mammalian LC_{LO} values, and (5) the STEL value.

Uncertainty Factor Selection. For substances with available RfC values, applying uncertainty factors was not necessary because the appropriate factors are already incorporated into the RfC value (EPA 1993a, 1993b). Where use of other toxicity values was necessary, uncertainty factors were selected following the rationale used by the EPA in deriving RfCs (EPA 1989a): (1) human TC_{LO} divided by 10 (for sensitive subpopulations); (2) mammalian TC_{LO} divided by 100 (10 for sensitive subpopulations and 10 for extrapolation from animal data to humans); (3) human LC_{LO} divided by 100 (10 for sensitive human subpopulations and 10 for extrapolation of lethality data to estimate sublethal effects); (4) LC_{50} or mammalian LC_{LO} divided by 1,000 (10 for sensitive human subpopulations, 10 for extrapolation from animal data to humans, and 10 for extrapolation of lethality data to estimate sublethal effects); and (5) the STEL value divided by 3 (for sensitive human subpopulations).

Exposure Duration Adjustments. As in the assessment of potentially life-threatening effects, PAECs were generated only for assumed exposure durations of 15, 30, and 60 min. The PAEC value for the exposure duration closest to but greater than the ALOHA™-estimated release duration was used to generate the area within which exposed persons are at risk of any adverse effects (e.g., for a 20-min ALOHA™-estimated release duration, the 30-min PAEC value is used).

For substances for which RfC values were available, the equation used to estimate PAEC values was based on EPA methods for estimating inhalation exposures and acceptable air concentrations of noncarcinogenic contaminants (EPA 1989a, 1991). To ensure that the derived PAEC values are protective, exposure values for a 6-year-old child at a moderate breathing rate were modeled rather than standard adult values. Appropriate body weight and inhalation rate values for a child were obtained from the EPA's *Exposure Factors Handbook* (EPA 1989a). In addition, because subchronic RfCs were used, the minimum

exposure time of 14 days was used as the averaging time. The equation for deriving PAEC values is as follows:

$$PAEC = \frac{THQ \times RfD \times BW \times AT \times 24.5}{IR \times ET \times MW}, \quad (5)$$

where

PAEC = any adverse effect concentration (ppm);

THQ = target hazard quotient (1), defined as an exposure level over a specified time period divided by a reference dose derived for a similar exposure period;

RfD = reference dose (mg/kg/d); equal to (RfC × 20 m³/d)/70 kg;

BW = body weight for a 6-year-old child (21 kg);

AT = averaging time (14 d);

IR = moderate activity inhalation rate for a 6-year-old child (0.033 m³/min);

ET = exposure time (min; 15, 30, or 60 min);

MW = molecular weight of substance; and

$\frac{24.5}{MW}$ = unit conversion factor (mg/m³ to ppm).

For substances for which no RfC values are available, the exposure duration adjustment is identical to that used in generating PLC values: the exposure duration adjustment (i.e., linear or exponential) resulting in the lowest PAEC value was used in modifying toxicity values for the derivation of PAECs. Toxicity data for these chemicals (e.g., TC_{LO} values) were obtained from either the NIOSH (1992) or Sax and Lewis (1992). The primary literature can be consulted to verify these values and periodically update the PAEC values.

In calculating accident risks for the any adverse effect end point, it is assumed that the entire population residing within the PAEC area at risk would experience some adverse effect from the exposure. Again, this is a conservative assumption because the PAEC values have incorporated uncertainty factors to account for sensitive human subpopulations. The PAEC values derived for the HW, LLMW and TRUW risk calculations for 15-, 30-, and 60-min exposure durations are given in Table 5. The table also gives the toxicity value used to derive the PAEC for each chemical.

Table 5 lists Emergency Response Planning Guideline-1 (ERPG-1) values for comparison with PAEC values. ERPG-1 values are defined as levels "below which exposure

TABLE 5 Potential Any Adverse Effect Concentration Values for HW Chemicals Transported by DOE^a

Substance	CAS No.	Molecular Weight	Subchronic RfC (mg/m ³)	Toxicity Value (ppm)	Time/Species/Effect	Inhalation RfD (mg/kg/d)	PAEC (ppm)			ERPG-1 ^b (ppm) 60 min
							15 min	30 min	60 min	
Acetonitrile	75-5-8	41	0.5	3.0E-01	2 wk-7 yr/human/NOAEL ^c	1.4E-01	50.6	25.3	12.7	
Acrolein ^d	107-02-8	56	0.00002	8.7E-06	2 wk-7 yr/human/NOAEL ^c	5.7E-06	1.5E-03	7.4E-04	3.7E-04	0.1
Acrylic acid	79-10-7	72	0.003	1.0E-03	2 wk-7 yr/human/NOAEL ^c	8.6E-04	0.173	0.087	0.043	
Acrylonitrile ^d	107-13-1	53	0.002	9.2E-04	2 wk-7 yr/human/NOAEL ^c	5.7E-04	0.157	0.078	0.039	
Allyl alcohol	107-18-6	58		1000	1 h/human/LC ₅₀ ^e		20	14	10	
Allylamine	107-11-9	57		2.5	5 min/human/TC ₁₀ /eye, resp irrit ^e		0.08	0.04	0.02	
Ammonia ^d	7664-41-7	17	0.1	1.4E-01	2 wk-7 yr/human/NOAEL ^c	2.7E-02	25	12	6.1	25
Aniline	62-53-3	93.12	0.01	2.6E-03	2 wk-7 yr/human/NOAEL ^c	2.7E-03	0.45	0.22	0.11	
Arsine ^f	7784-42-1	78		25	30 min/human/LC ₁₀ ^e		0.35	0.25	0.13	
Boron trifluoride	7637-07-2	68	0.007	2.5E-03	2 wk-7 yr/human/NOAEL ^c	2.0E-03	0.43	0.21	0.11	
Bromine	7726-95-6	160		750	9 min/mouse/LC ₅₀ ^e	2.7E-03	0.45	0.23	0.11	0.2
Carbon disulfide ^d	75-15-0	76	0.01	3.2E-03	2 wk-7 yr/human/NOAEL ^c		0.55	0.27	0.14	
Carbon monoxide	630-08-0	28		525	10 min/human/TC ₁₀ /headache ^e		35	18	8.8	
Carbon tetrachloride	53-23-5	155	0.06	9.5E-03	2 wk-7 yr/human/NOAEL ^c	1.7E-02	1.61	0.81	0.40	
Carbonyl fluoride	363-50-4	66		360	1 h/rat/LC ₅₀ ^e		0.7	0.5	0.4	
Chlorine	7782-50-5	71		500	5 min/human/LC ₁₀ ^e		1.7	0.83	0.42	1
Chloroform	67-66-3	119	0.04		2 wk-7 yr/human/NOAEL ^c	1.1E-02	1.4	0.70	0.35	
Chloromethane	74-87-3	50	9	298	2.6E+00		741	371	185	
Chloroethane	76-06-2	164			2 wk-7 yr/human/NOAEL ^c		2.0	1.0	0.5	
Cyanogen bromide	506-68-3	106		92	10 min/human/LC ₁₀ ^e		0.61	0.31	0.15	
Dichlorodifluoromethane	75-71-8	121	2	4.1E-01	2 wk-7 yr/human/NOAEL ^c	5.7E-01	69	34	17	
Dichloromethane ^d	75-09-2	85	3	8.7E-01	2 wk-7 yr/human/NOAEL ^c	8.6E-01	146.9	73.4	36.7	
Diethylene glycol monobutyl ether	112-34-5	162	0.2	3.0E-02	2 wk-7 yr/human/NOAEL ^c	5.7E-02	5.1	2.6	1.3	
Dimethyl sulfate	77-78-1	126		97	10 min/human/LC ₁₀ ^e		0.6	0.3	0.2	
Epichlorohydrin	106-89-8	93	0.01	2.6E-03	2 wk-7 yr/human/NOAEL ^c	2.9E-03	0.45	0.22	0.11	
Ethyl chloride ^d	75-00-3	65	10	3.8E+00	2 wk-7 yr/human/NOAEL ^c	2.9E+00	644.4	322.2	161.1	
Ethylene glycol monobutyl ether	111-76-2	118	0.2		2 wk-7 yr/human/NOAEL ^c	5.7E-02	7.0	3.5	1.8	
Hydrofluoric acid	7664-39-3	20		123	1 min/human/TC ₁₀ /cough, irrit ^e		1	0.4	0.2	5
Hydrogen chloride ^d	7647-01-0	36		4.7E-03	2 wk-7 yr/human/NOAEL ^c	2.0E-03	0.8	0.4	0.2	
Hydrogen fluoride	7664-39-3	20	0.007	123	1 min/human/TC ₁₀ /cough, irrit ^e		0.82	0.41	0.20	5
Hydrogen selenide	7783-07-5	81		0.3	8 h/guinea pig/LC ₅₀ ^e		0.0017	0.0012	0.0008	
Methylamine	74-89-5	31		1897	2 h/mouse/LC ₅₀ ^e		5.4	3.8	2.7	
Methyl bromide ^h	74-83-9	95		397	2 h/mouse/LC ₅₀ ^e		1.1	0.8	0.6	
Methyl cyclohexane ^d	108-87-2	112	3	6.5E-01	2 wk-7 yr/human/NOAEL ^c	8.6E-01	111.1	55.5	27.8	
Methylene chloride ^d	75-09-2	85	3	8.7E-01	2 wk-7 yr/human/NOAEL ^c	8.6E-01	150	73	37	
Methyl ethyl ketone ^d	78-93-3	72	1	3.4E-01	2 wk-7 yr/human/NOAEL ^c	2.9E-01	58	29	14	
Methyl iodide	74-88-4	142		224	4 h/rat/LC ₅₀ ^e		0.90	0.63	0.45	25
Methyl isobutyl ketone	108-10-1	100	0.8	2.0E-01	2 wk-7 yr/human/NOAEL ^c	2.3E-01	33.2	16.6	8.3	
Methyl vinyl ketone	78-94-4	70		2.8	2 h/mouse/LC ₅₀ ^e		0.008	0.006	0.004	
Nickel carbonyl	13453-39-3	171		8.6	15 min/rat, hamster/TC ₁₀ /reprod ^e		0.086	0.043	0.021	
Nitric acid (fuming)	7697-37-2	63		67	4 h/rat/LC ₅₀ ^e		0.27	0.19	0.13	

TABLE 5 (Cont.)

Substance	CAS No.	Molecular Weight	Subchronic RfC (mg/m ³)	Toxicity Value (ppm)	Time/Species/Effect	Inhalation RfD (mg/kg/d)	PAEC (ppm)			ERPG-1 ^b (ppm) 60 min
							15 min	30 min	60 min	
Nitric oxide	10102-43-9	30		872	4 h/rat/LC ₅₀ ^e		3.5	2.5	1.7	
Nitrobenzene	98-95-3	123	0.02	4.0E-03	2 wk-7 yr/human/NOAEL ^c	5.7E-03	0.68	0.34	0.17	
Nitrogen dioxide	10102-44-0	46		6.2	10 min/human/TC ₁₀ /pulmonary changes ^e		0.41	0.21	0.10	
Nitrosyl chloride ^d	2696-92-6	65		6.2	10 min/human/TC ₁₀ /pulmonary changes ^e		0.41	0.21	0.10	
Phosgene	503-38-8	198		445	10 min/mouse/LC ₅₀ ^e		0.30	0.15	0.07	
Phosphine	7803-51-2	34	0.0003	2.2E-04	2 wk-7 yr/human/NOAEL ^c	8.6E-05	3.7E-02	1.8E-02	9.2E-03	
Phosphorous oxychloride	10025-87-3	153		32	4 h/rat/LC ₅₀ ^e		0.13	0.09	0.06	
Phosphorous trichloride	7719-12-2	137		50	4 h/guinea pig/LC ₅₀ ^e		0.20	0.14	0.10	
Propylene oxide ^d	75-56-9	58	0.03	1.3E-02	2 wk-7 yr/human/NOAEL ^c	8.6E-03	2.2	1.1	0.54	
Selenium hexafluoride	7783-79-1	193		10	1 h/rat, mouse, guinea pig/LC ₁₀ ^e		0.020	0.014	0.010	
Silicon tetrafluoride	7783-61-1	104		16000	4 h/rat/LC ₁₀ ^e		64	45	32	
Styrene	100-42-5	104	3	7.1E-01	2 wk-7 yr/human/NOAEL ^c	8.6E-01	120	60	30	
Sulfur dioxide	7446-09-5	64		12	1 h/human/TC ₁₀ /resp changes ^e		2.4	1.7	1.2	0.3
Sulfuric acid (fuming) ^j	7664-93-9	98	0.07	NA	All durations - units are mg/m ³ ^e	NA	0.070	0.070	0.070	2 mg/m ³
Sulfur trioxide	7446-11-9	80		9.2	6 h/guinea pig/LC ₁₀ ^e		0.045	0.032	0.022	2 mg/m ³
Sulfuryl fluoride	2699-79-8	102		225	6 h/rat, rabbit/TC ₁₀ /reprod ^e		11.0	7.8	5.5	
Tellurium hexafluoride	7783-80-4	242		5	1 h/mouse/LC ₅₀ ^e		0.010	0.007	0.005	
Thionyl chloride	7719-09-7	119		500	1 h/rat/LC ₅₀ ^e		1.0	0.7	0.5	
Thiophosgene ^k	463-71-8	115	0.07	NA	All durations ^c	NA	0.07	0.07	0.07	
Titanium tetrachloride	7550-45-0	190		13	2 h/mouse/LC ₅₀ ^e		0.037	0.026	0.018	5 mg/m ³
Toluene	108-88-3	92	0.4	1.1E-01	2 wk-7 yr/human/NOAEL ^c	1.1E-01	18	9.0	4.5	
1,2,4-Trichlorobenzene	120-82-1	181	0.09	1.2E-02	2 wk-7 yr/human/NOAEL ^c	2.6E-02	2.1	1.0	0.52	
1,1,1-Trichloroethane ^l	71-55-6	133.42		1	2 wk-7 yr/human/NOAEL ^g	2.9E-01	31	16	7.8	
Trichlorofluoromethane	75-69-4	137	7	1.2E+00	2 wk-7 yr/human/NOAEL ^c	2.0E+00	210	106	53	
1,1,2-Trichloro-1,1,2-trifluoroethane	76-13-1	187	30	3.9E+00	2 wk-7 yr/human/NOAEL ^c	8.6E+00	665.6	332.8	166.4	
Triethylamine ^d	121-44-8	101	0.007	1.7E-03	2 wk-7 yr/human/NOAEL ^c	2.0E-03	0.29	0.14	0.072	
Trimethylacetyl chloride ^l	3282-30-2	121		500	5 min/human/LC ₁₀ ^e		1.67	0.83	0.42	
Tungsten hexafluoride ^m	7783-82-6	298		0.82	15 min/human/TLV-STEL ⁿ		0.27	0.14	0.070	
Vinyl acetate ^d	108-05-4	86	0.2	5.7E-02	2 wk-7 yr/human/NOAEL ^c	5.7E-02	9.7	4.8	2.4	

See footnotes on next page.

TABLE 5 (Cont.)

- ^a The data preference hierarchy and linear versus exponential scaling are detailed in text. For chemicals with RfC values available, inhalation RfD calculated as $RfC \times 20 \text{ m}^3/\text{d} \div 70 \text{ kg}$. PAEC concentrations in ppm calculated as $(RfD \times BW \times AT \times 24.5)/(IR \times MW \times ED)$, where: RfD = inhalation RfD calculated from RfC (mg/kg/d); BW = body weight for 6-year-old child, 21 kg (EPA 1989a); AT = averaging time - 14 days for subchronic exposures; 24.5 = factor for converting to ppm; IR = inhalation rate for 6-yr-old child, 0.033 m³/min (EPA 1989a); MW = molecular weight; ED = exposure duration - 15, 30, or 60 min. For chemicals with no RfC value available, linear scaled PAEC = (Toxicity Value \times EET/ED \times UF; exponential scaled PAEC = $[(\text{Toxicity Value})^2 \times \text{EET}/\text{ED}]^{1/2}/\text{UF}$. The toxicity value was scaled linearly or exponentially to result in lowest PAEC value. UF's: for human TC_{LO}, 10; mammalian TC_{LO}, 100; human LC₅₀, 100; LC₅₀ or mammalian LC_{LO}, 1,000. Values rounded to two significant figures. To convert toxicity values to ppm, multiply the concentration (mg/m³) by 24.5 and divide by the molecular weight.
- ^b ERPG-1; Emergency Response Planning Guideline-1 (IAHA 1988-1992).
- ^c Data obtained from the EPA (1993a or 1993b).
- ^d Indicates that chronic RfC was adopted as subchronic RfC; value may be conservative.
- ^e Data obtained from NIOSH (1992).
- ^f Power function used to scale 15 min estimated NAE dose; linear function used for 1 h NAE dose.
- ^g Data obtained from Dollarhide (1992).
- ^h Human LC_{LO} data for methyl bromide from RTECS and Sax did not match (1 g/m³ vs 1 mg/m³) — reference not obtainable; therefore, LC₅₀ data used.
- ⁱ Value for nitrogen dioxide used for cyclohexyl isocyanate and nitrosyl chloride; emit toxic fumes of NO_x when heated to decomposition (Sax and Lewis 1992).
- ^j HEAST states that portal-of-entry effects for sulfuric acid make it inappropriate to convert to mg/d; Carson et al. (1981) as cited in HEAST (EPA 1993a) give 0.07 mg/m³ as an "acceptable" concentration for sulfuric acid.
- ^k Value for sulfuric acid used for thiophosgene; emits toxic fumes of SO_x when heated to decomposition (Sax and Lewis 1992).
- ^l Value for chlorine used for trimethylacetyl chloride; emits Cl⁻ when heated to decomposition.
- ^m No TC_{LO}, LC₅₀, or LC_{LO} data available for tungsten hexafluoride; used 15-min STEL value (10 mg W/m³) divided by 3, converted to ppm.
- ⁿ Data obtained from Sax and Lewis (1992).
- Abbreviations: CAS = Chemical Abstracts Service, EET = experimental exposure time, ED = exposure duration, HEAST = Health Effects Assessment Summary Tables, IRIS = Integrated Risk Information System, NOAEL = no observed adverse effect level, RfC = reference concentration, RfD = reference dose, RTECS = Registry of Toxicity Effects of Chemical Substances, UF = uncertainty factor.

for up to 1 hr would not result in any but mild, transient adverse health effects" (AIHA 1988-1992). These values are available for only about 10 of the substances for which PAEC values were derived; they are best compared with the 60-min PAEC values. Generally, ERPG-1 values are higher than the PAEC values, which suggests that the PAECs will not underestimate risks.

3.1.3 Increased Cancer Risk Concentration Values

Hazardous chemical waste transported from DOE facilities may also be evaluated for possible increased cancer risk in exposed individuals. Values were developed to estimate the air concentrations of carcinogenic HW components above which exposed persons have an increased carcinogenic risk of one in one million (10^{-6}) or higher (increased cancer risk concentration [ICRC]). The 10^{-6} risk level was selected to represent the level below which increased risk is considered negligible. However, regulatory programs generally specify 10^{-4} to 10^{-6} as an acceptable risk range (EPA 1990a, 1990b). For chemicals showing greater than 10^{-6} risks, it would be informative to supplement results with risks (e.g., number of people affected) at the 10^{-4} level.

For this assessment, an ICRC value was derived for each gaseous or liquid substance transported by DOE HW, TRUW and LLMW generators in FY 1992 that meets the following criteria: (1) the substance is classified as a known, probable, or possible human carcinogen (EPA 1993a, 1993b); (2) the substance has an inhalation unit-risk value available from the EPA; and (3) the substance is volatile enough that there is a significant potential for exposure of the general public. Several inorganic and organic substances were not evaluated because they are solids under ambient conditions or because the potential to volatilize is minimal (e.g., polychlorinated biphenyls, lindane, arsenic, beryllium, cadmium). Only four transported substances classified as carcinogenic did not have inhalation unit-risk values available from IRIS or HEAST. Should inhalation unit-risk values become available for these substances, ICRC values will be derived.

The method used to generate ICRC values is that recommended by the National Research Council (1986, 1993). Because estimating increased cancer risk for exposure periods of less than 1 hour is uncertain, ICRC values were generated only for assumed exposure duration of 1 hour. Exposures were averaged over a 70-year lifetime. In calculating risks for individual accidents, it was assumed that the entire population residing within the ICRC area at risk would experience an increased cancer risk of 10^{-6} or greater. The following equation was used to estimate the ICRC value:

$$ICRC = \frac{R \times AT \times 24.5}{UR \times ET \times MW} \quad (6)$$

where

ICRC = increased carcinogenic risk concentration (ppm);

R = assumed risk level (10^{-6});

AT = averaging time (70 yr \times 365 d/yr \times 24 h/d);

UR = chemical-specific unit risk $[(\text{mg}/\text{m}^3)^{-1}]$;

ET = exposure time (1 h);

MW = molecular weight of substance; and

$\frac{24.5}{MW}$ = unit conversion factor (mg/m^3 to ppm).

ICRC values derived for the HW and LLMW risk calculations are given in Table 6.

3.2 POTENTIAL ADDITIVE EFFECTS OF MULTICHEMICAL EXPOSURES

In many of the shipment accidents assessed, several chemicals are being transported in the same shipment. Therefore, it is possible for a number of chemicals to be released to the atmosphere simultaneously, either if several chemicals are contained in a single breached container or if several containers are breached. The possibility for inhalation of multiple chemicals by an individual downwind of the release must therefore be addressed. To accomplish this, the ALOHA™ code was first run separately for each chemical in a shipment to determine the individual plume footprints at the PLC, PAEC, or ICRC values. By using an iteration method, the "composite" plume footprint for all chemicals evaluated in a single shipment was determined such that the following relationship was reached:

$$\sum_{i=1}^n (C_i/T_i) \cong 1 \quad , \quad (7)$$

where

C_i = concentration at "composite" plume footprint for the *i*th chemical of concern; and

T_i = toxicity value (i.e., PLC, PAEC, or ICRC value)

Use of this method leads to a larger area of influence of the mixture than any one of its chemical components.

TABLE 6 Increased Carcinogenic Risk Concentration Values for HW Chemicals Transported by DOE^a

Chemical Name	CAS No.	Molecular Weight	Carcinogen Class ^b	Inhalation Unit Risk ($\mu\text{g}/\text{m}^3\text{-yr}$) ⁻¹	VSD ^c (mg/m^3)	ICRC (60 min)	
						mg/m^3 ^d	ppm ^e
1,1-Dichloroethylene	75-35-4	97	C	5.0E-05	2.0E-05	1.2E+01	3.1
1,1,2-Trichloroethane	79-00-5	133	C	1.6E-05	6.3E-05	3.8E+01	7.0
1,1,2,2-Tetrachloroethane	79-34-5	168	C	5.8E-05	1.7E-05	1.1E+01	1.5
1,2-Dibromoethane	106-93-4	188	B2	2.2E-04	4.5E-06	2.8E+00	0.36
1,2-Dichloroethane	107-06-2	99	B2	2.6E-05	3.8E-05	2.4E+01	5.8
1,3-Butadiene	106-99-0	54	B2	2.8E-04	3.6E-06	2.2E+00	0.99
Acrylamide	79-06-1	71	B2	1.3E-03	7.7E-07	4.7E-01	0.16
Acrylonitrile	107-13-1	53	B1	6.8E-05	1.5E-05	9.0E+00	4.2
Aldrin	309-00-2	365	B2	4.9E-03	2.0E-07	1.3E-01	0.0084
Benzene	71-43-2	78	A	8.3E-06	1.2E-04	7.4E+01	23
Beryllium	7440-41-7	9	B2	2.4E-03	4.2E-07	2.6E-01	0.70
Bromoform	75-25-2	253	B2	1.1E-06	9.1E-04	5.6E+02	54
Carbon tetrachloride	56-23-5	154	B2	1.5E-05	6.7E-05	4.1E+01	6.5
Chloroform	67-66-3	119	B2	2.3E-05	4.3E-05	2.7E+01	5.5
Chloromethane ^f	74-87-3	50	C	1.8E-06	5.6E-04	3.4E+02	160
Dichloromethane	75-09-2	85	B2	4.7E-07	2.1E-03	1.3E+03	380
Epichlorohydrin	106-89-8	93	B2	1.2E-06	8.3E-04	5.1E+02	130
Ethylene oxide	75-21-8	44	B1	1.0E-04	1.0E-05	6.1E+00	3.4
Formaldehyde	50-00-0	30	B1	1.3E-05	7.7E-05	4.7E+01	38
Heptachlor	76-44-8	373	B2	1.3E-03	7.7E-07	4.7E-01	0.031
Hexachloroethane	67-72-1	237	C	4.0E-06	2.5E-04	1.5E+02	16
Hydrazine/Hydrazine sulfate	302-01-2	32	B2	4.9E-03	2.0E-07	1.3E-01	0.096
N-Nitrosodimethylamine	62-75-9	74	B2	1.4E-02	7.1E-08	4.4E-02	0.015
Propylene oxide	75-56-9	58	B2	3.7E-06	2.7E-04	1.7E+02	70
Tetrachloroethene ^g	127-18-4	166	C-B2	5.8E-07	1.7E-03	1.1E+03	160
Trichloroethene ^g	79-01-6	131	C-B2	1.7E-06	5.9E-04	3.6E+02	67
Vinyl chloride ^f	75-01-4	63	A	8.4E-05	1.2E-05	7.3E+00	2.9

^a ICRC values correspond to concentrations above which exposed persons have an increased carcinogenic risk of 1 in one million (10^{-6}) or higher. Methods for deriving ICRC values detailed in text. Unit-risk values obtained from the EPA (1993b) unless otherwise noted. Values rounded to two significant figures.

^b Carcinogens are grouped as follows: Group A-human carcinogen; Group B1-probable human carcinogen, limited evidence in humans; Group B2-probable human carcinogen, sufficient evidence in animals and inadequate evidence in humans; and Group C-possible human carcinogen.

^c VSD = virtually safe dose = $10^{-6}/(\text{inhalation unit risk} \times 1,000 \mu\text{g}/\text{mg})$.

^d ICRC = $\text{VSD} \times 24 \text{ h}/\text{d} \times 365 \text{ d}/\text{yr} \times 70 \text{ yr}$ (NRC 1986, 1993).

^e ICRC (ppm) = $\text{ICRC} (\text{mg}/\text{m}^3) \times 24.5/\text{molecular weight}$.

^f Data from the EPA (1993a).

^g Data from the Superfund Health Risk Technical Support Center (Dollarhide 1992).

3.3 TRANSPORTATION RISK ASSESSMENT METHODS FOR MAXIMALLY EXPOSED INDIVIDUALS

In the WM PEIS (DOE 1996), Section E.17.3 of Appendix E describes the cargo-related accident transportation risks for the maximally exposed individual (MEI) in the general public. The cargo-related risk is the risk associated with inhalation of accidentally released chemicals. This subsection provides supporting information on methods used to describe risk for the MEI for the potentially life-threatening, any adverse effects, and increased carcinogenic risk end points.

The evaluation of MEIs is intended to address the question of what maximum exposure levels could be and whether health effects would be associated with those levels. To evaluate the MEI for each health end point, the primary factors considered were a combination of chemical potency, quantity released, and dispersion, as reflected by the exposed areas output from the ALOHA™ model. Although many shipments of each chemical may be included in the database for each end point, only the HW, TRUW, and LLMW shipments resulting in the largest exposed areas for each chemical were evaluated for the MEI. For each health end point, the MEI was assumed to be located 30 m (98 ft) from the release point (i.e., the assumed closest distance of a residence from the middle of the roadway).

3.3.1 Potentially Life-Threatening Effects for the MEI

For potentially life-threatening effects, the health end point is so severe (i.e., lethality) that the traditional estimation of exposure to the MEI is not useful. Therefore, for this end point, hazard zones were calculated to indicate the distance from the release point to which a potentially life-threatening chemical plume might extend. For each poison inhalation hazard (PIH) chemical in the database, the shipment resulting in the largest exposed area was identified by modeling with ALOHA™. The hazard zones for these worst-case shipments are reported in Appendix E to the WM PEIS (DOE 1996). The PIH chemicals that were shipped in small quantities and for which spills would not result in a potentially lethal plume were not evaluated.

3.3.2 Any Adverse Effects for the MEI

The ALOHA™ code was used to estimate the chemical concentration and duration of exposure for the MEI with respect to the any adverse effects end point. The PIH chemicals were not included in the exposure assessment for the MEI because the appropriate end point for PIH chemicals is potential lethality (Section 3.3.1).

The exposure duration and chemical concentration in air during the exposure duration, as given by the ALOHA™ code, were used to estimate a chemical-specific intake value for the MEI receptor. To emulate a reasonable upperbound exposure scenario for any adverse effects, the MEI receptor was assumed to be a child engaged in moderately strenuous outdoor activity. Calculated intake values were compared with EPA reference dose values, by generating a hazard quotient (HQ) (i.e., intake/reference dose) for each chemical. An HQ greater than 1 indicates that an adverse effect for the MEI is likely.

Intakes were calculated with the following standard risk equation (EPA 1989b):

$$I = \frac{CA \times IR \times ET \times EF \times ED}{BW \times AT}, \quad (8)$$

where

I = chemical-specific average daily intake (mg/kg/day);

CA = chemical concentration in air (mg/m³), as obtained from ALOHA™ modeling;

IR = inhalation rate for a 6-year-old child, moderate activity (0.033 m³/min [EPA 1989a]);

ET = exposure time (min/day), as obtained from ALOHA™ modeling;

EF = exposure frequency (1 day/year);

ED = exposure duration (1 year);

BW = body weight for a 6-year-old child (21 kg [EPA 1989a]); and

AT = averaging time, 14 days/year × 1 year.

The use of a 14-day averaging time was a departure from the standard 365-day averaging time recommended in EPA guidance (EPA 1989b). A 14-day averaging time is a conservative assumption because it results in a calculated intake approximately 25 times greater than that obtained when 365 days is assumed. However, the 365-day averaging time is generally used in evaluating longer-term, low-level exposures, and was not considered valid for assessing the risks of one-time, higher-level exposures. A 14-day averaging time was selected because that is the lowest exposure duration to which subchronic RfD values are applicable (EPA 1989b).

The hazard quotients were then derived by dividing intakes by the chemical-specific subchronic reference doses obtained from the EPA (1993a). For chemicals with no subchronic reference doses available, chronic reference doses were used (EPA 1993b), which would likely overestimate the hazard quotients by about a factor of 10. The level of concern associated with exposure does not increase linearly as HQ values exceed 1. In other words, HQ values do not represent a probability or a percentage. One may conclude that as the HQ value above 1 increases, there is greater concern about potential adverse effects. However, it is incorrect to assume that an HQ value of 10 indicates that adverse health effects are 10 times more likely to occur than for an HQ value of 1.

3.3.3 Increased Carcinogenic Risk for the MEI

Risks to the MEI were calculated for the carcinogens of greatest concern, on the basis of potency, quantity released, and dispersivity, as reflected by exposed areas output from the ALOHA™ model. All carcinogens ranked as class A (known human carcinogens) were included in the MEI evaluation.

Similar to the MEI evaluation for the any adverse effects end point, carcinogenic risk was estimated by calculating the average daily intake and multiplying that intake by the chemical-specific EPA-derived slope factor value. For carcinogens, it is appropriate to estimate daily intake averaged over a lifetime (EPA 1989b), so the MEI receptor evaluated was an adult. The following equation was used to calculate average daily intake:

$$I = \frac{CA \times IR \times ET \times EF \times ED}{BW \times AT}, \quad (9)$$

where

I = chemical-specific average daily intake (mg/kg/d);

CA = chemical concentration in air (mg/m³), as obtained from ALOHA™ modeling;

IR = inhalation rate for an adult, moderate activity (0.014 m³/min [EPA 1989a]);

ET = exposure time (min/day), as obtained from ALOHA™ modeling;

EF = exposure frequency, 1 d/yr;

ED = exposure duration, 1 yr;

BW = body weight for an adult (70 kg [EPA 1989a]); and

AT = averaging time (365 d/yr × 70 yr).

Increased lifetime carcinogenic risks were then derived by multiplying the average daily intake by the chemical-specific slope factor value. Risks can be compared with a risk range of 10⁻⁴ to 10⁻⁶ generally considered acceptable for increased carcinogenic risk associated with hazardous waste sites. Increased lifetime carcinogenic risks of 10⁻⁴ are often used as the departure point for levels of concern when evaluating risks from short-term, accidental exposures (National Research Council 1993).

4 SUPPLEMENTAL INFORMATION ON UNCERTAINTY ANALYSIS AND DETERMINISTIC APPROACH

The purpose of including the results presented in this section is to place into better perspective the risk numbers obtained in the HW transportation risk appendix, which are the same risk numbers repeated in the WM PEIS main text. The deterministic modeling results referred to are presented in Appendix E for the HW transportation risk calculations. Those calculations analyzed the risk from the HW shipments assuming unchanging (but representative) meteorological conditions during all shipments, assuming a fixed accident scenario (all accidents are of the same severity and occur the same way), and without recognizing any time of day or seasonal bias.

The modeling work presented here, which uses Monte Carlo techniques, focuses on the baseline case for HW in which 63 shipments (i.e., those leading to nonzero risk in the Appendix E deterministic modeling) were studied in detail. It is recognized that there are uncertainties, that is, probability distributions for key input variables, such as the following:

- Meteorological conditions during the time of the postulated accident,
- Release rates for small drums, large drums, and cylinders — with different probability distributions of release amounts for each transportation container,
- Time of day of the accident (affecting meteorological conditions), and
- Month of year affecting the relative accident probabilities.

Although these four variables involve key parameters in the risk assessment, they are not the only ones. Other items of uncertainty include the health criteria values used, the uncertainty due to accuracy of the consequence model used, and uncertainty in that the database used for identifying accidents represents all the chemicals. An attempt will be made to include those latter uncertainties into a broader uncertainty analysis in the future by using Monte Carlo techniques. At this time, however, we restrict our uncertainty study to the variables (a) through (d) listed above and seek to determine the probability distribution of risk due to those four items. This evaluation has led to very interesting supplementary results (to the deterministic findings), even though the Monte Carlo analysis is not all encompassing.

The Monte Carlo analysis has included not only probability distributions for a number of the key variables but also a few proposed improvements to the methodology that is under consideration for the deterministic treatment. Notable among those changes in approach is the recognition that accidents with a truck would likely involve spills of different chemicals within the same or other DOE drums on the truck. The health effects of inhaling a mixture of vapors from different chemicals were included in the Monte Carlo analysis. In addition, a truck with three DOE chemicals was assumed in the Monte Carlo analysis to lead

to a proportionate amount of release of each of the chemicals, with the total release amount obtained from a probability distribution based on data from DOT's HMIRS database.

The details of the Monte Carlo method are beyond the scope of this discussion. The four variables listed above have been set up with probability distributions based on available data. Previous hazardous material accidents were used to develop probability distributions for (a), (c), and (d) variables listed above. For the meteorological data variation, data from 61 cities in the continental United States were used in a database so that an accident on a particular road segment could use the meteorological data from the nearest of the 61 National Weather Service sites.

Figure 1 depicts the components of the Monte Carlo uncertainty analysis. The results of the Monte Carlo modeling of the risk from this no-action scenario that use the health end point of "potentially life-threatening health effects" are presented in Figures 1 and 2. The key findings from that work are briefly summarized as follows.

Figures 2 and 3 show that the cumulative probability distribution of risk (Figure 2) is extremely skewed because there is only slightly greater than a 1% probability of any potentially life-threatening effects occurring in the 20-year period. The large percentage of zero-effect cases results from the about 93% probability of no releases in the 20-year period coupled with the fact that most releases (especially liquids) lead to zero impacts outside of the 30.5-m (100-ft) range. The curve in Figure 3 would dip down to about 93% (for an abscissa value of 0) if impacts within 30.5 m (100 ft) of the road were included in the calculations. Within the remaining 1% probability (99-100% on the cumulative probability; Figure 2), there is a tremendous range of possible effects covering many orders of magnitude in the number of people affected. For example, in considering Figure 2 we see the effects from accidents in which more than 0.01, 1, 100, and 1,000 people who are affected are confined to above the 99.57, 99.93, 99.999, and 99.99995 percentiles, respectively. These cumulative probabilities indicate that for the actual probabilities that at most 0.01, 1, 100, and 1,000 people are affected in 20 years are about 1 in 250; 1 in 1,500; 1 in 100,000; and 1 in 2,000,000, respectively. High numbers of people with life-threatening effects were possible in very few shipments. For example, only three shipments were capable of affecting 1,000 or more people in a single accident. Likewise, only 14 shipments were capable of affecting 100 or more people in a single accident. Eliminating shipments within these groups would dramatically reduce the mean number of affected people and, of course, eliminate the probabilities of catastrophic accidents occurring.

An additional observation concerning the highly skewed nature of the cumulative probability distribution (especially the large percentage of zero-effect cases) is that the mean of 0.0078 people with potentially life-threatening effects lies above the 99.5 percentile. The true skewness of the distribution is apparent here because for a nonskewed distribution (e.g., a Gaussian), the mean is on the 50th percentile. Obviously, the 50th percentile of our

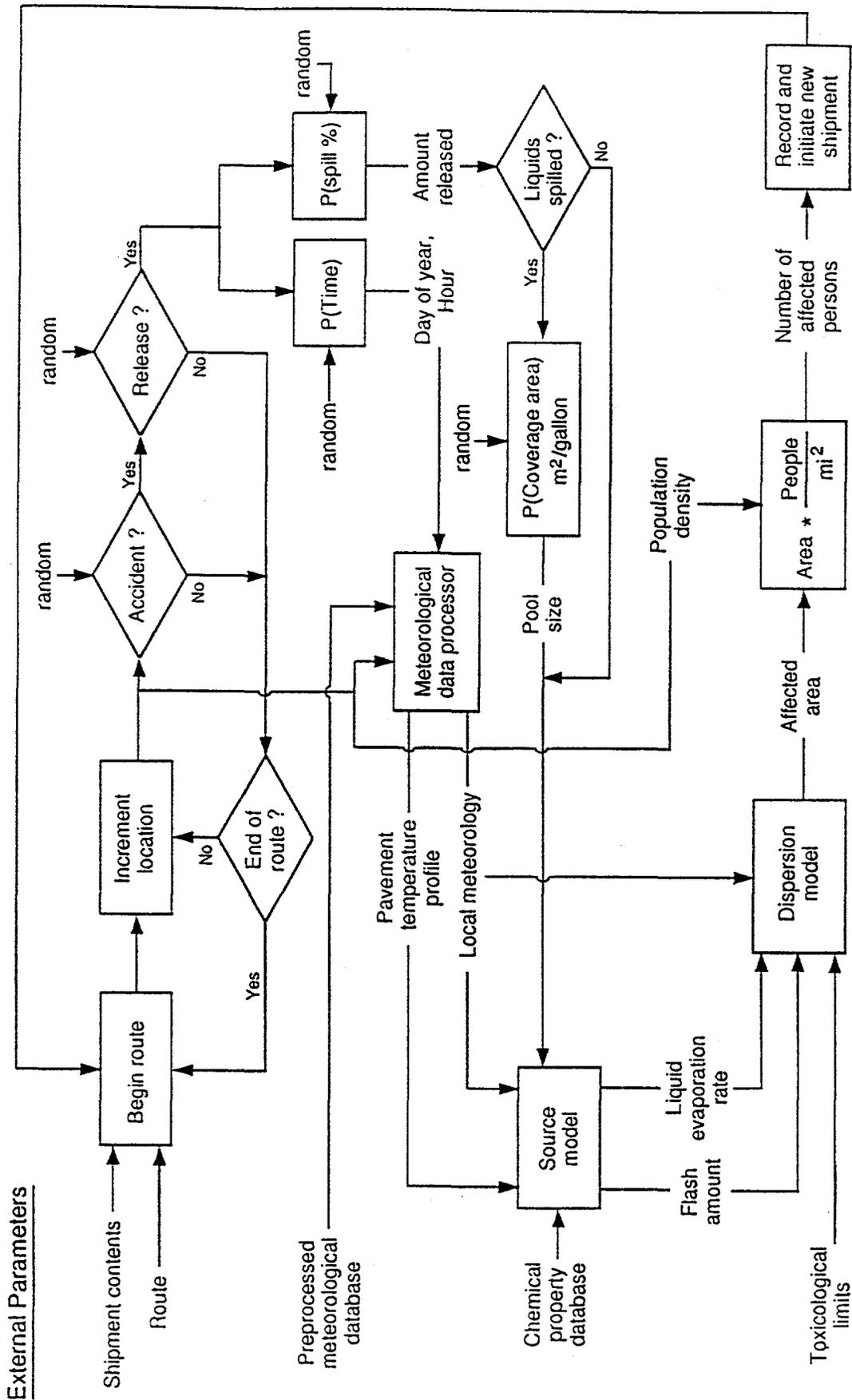


FIGURE 1 Flowchart Illustrating the Operating Procedures of the Monte Carlo Risk Assessment Model (Decision processes and model components that are stochastically treated are marked as having random inputs. For a typical shipment, this process is continued until approximately 100,000 chemical releases are recorded.)

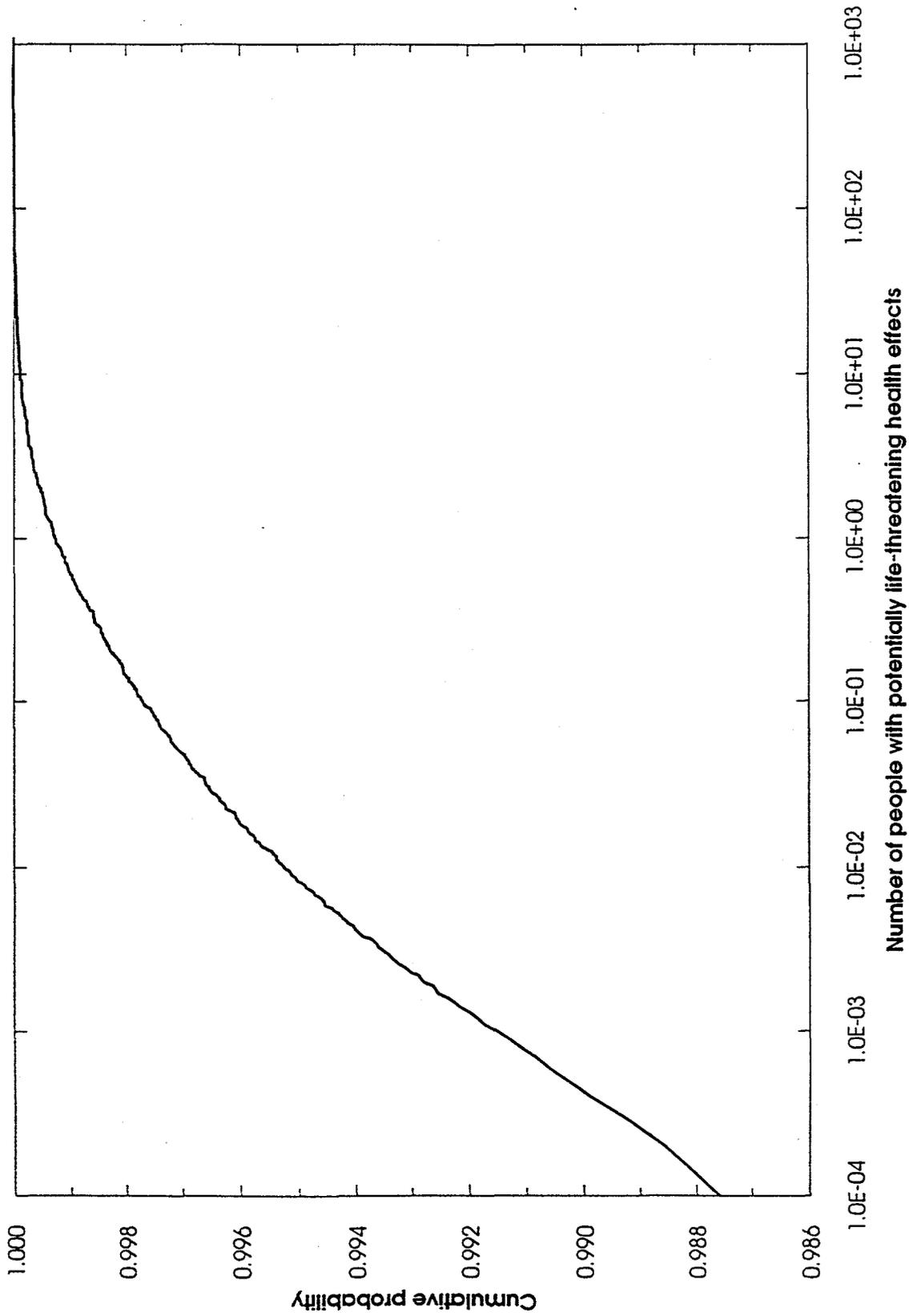


FIGURE 2 Results of Monte Carlo Modeling for the No-Action Alternative — Probability that the Number of People with Potentially Life-Threatening Effects Will Be Greater than N

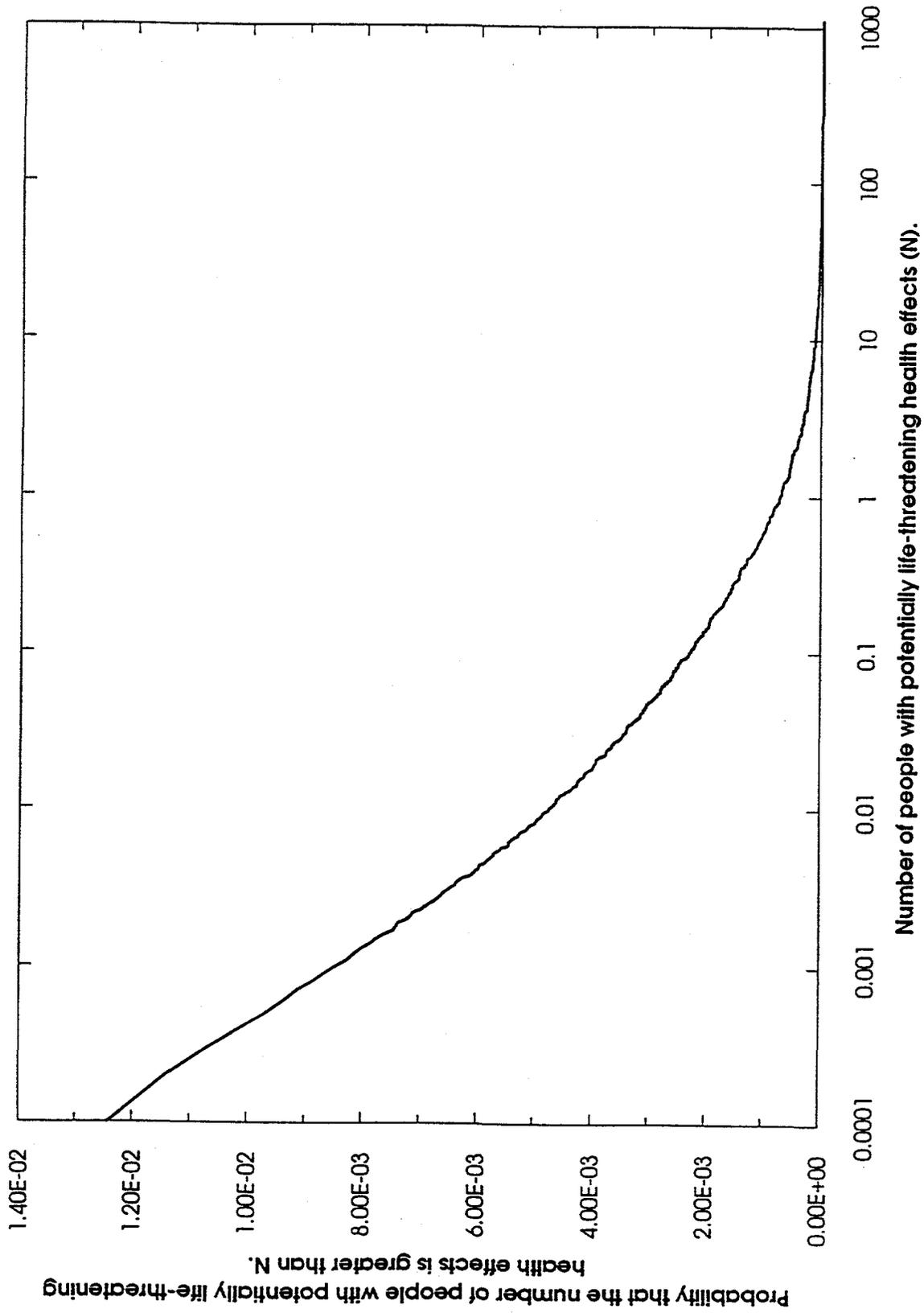


FIGURE 3 Results of Monte Carlo Modeling for the No-Action Alternative — Cumulative Probability of People with Potentially Life-Threatening Health Effects

distribution is 0, as are all percentiles lower than 98.8. This leads to difficulties when comparing the cumulative probability distribution to the result of the deterministic analysis. The deterministic method provided a mean of 0.15 people with potentially life-threatening effects, which lies on the 99.5 percentile. This seems extremely conservative; however, the mean of the distribution itself lies on the 99.5 percentile. From this, all we can say about the difference between the probabilistic method and the deterministic method is that the mean values are a factor of 19 apart.

5 ON-SITE RISKS

This section evaluates on-site HW transportation risk at DOE sites for the various alternatives. It has been shown that HW transportation risk is directly related to the number of miles traveled by the waste to the final destination. Because the number of miles traveled for on-site HW shipments is much less than for off-site movement of waste, it is expected that the on-site transportation risk would be less than the off-site risk. However, this assumption is not always correct because some DOE sites are large and the transport distances within their boundaries are very long; moreover, some of the on-site routes are near to worker populations, which increases the overall uncertainty of associated risks. On-site analyses were not conducted for TRUW and LLMW, because the low risks estimated for off-site transportation indicated that risks from on-site transportation would be negligible.

This section presents the on-site risk assessment for a representative DOE site and compares the results of this analysis to those of off-site transportation risks for the same site. A representative site, rather than all 10 of the major sites, was chosen for the on-site analysis, because the total on-site risks are significantly smaller than the total off-site risks (transportation risk is directly proportional to distance traveled).

5.1 REPRESENTATIVE DOE SITE FOR RISK ASSESSMENT

The Hanford Site (Hanford) was chosen for the on-site HW transportation risk assessment because it was considered typical of large DOE sites. Although Hanford may not be representative of all large DOE HW generators, particularly the Kansas City Plant (which is small in area), it can serve as a surrogate for most large DOE sites that generate and ship HW. Like other large DOE sites, Hanford is expansive and is not located near large population centers. It has a well-developed system of roads and is easily accessed by a regional transportation network. Figure 4 shows the major work areas, principal highways and roads, and the Washington Public Power Supply System (WPPSS) station of Hanford.

The HW storage facility, designated as Building 616, is located between the 200 West and 200 East Areas. The on-site analysis is necessary to assess the risk from HW shipments to people who work at Hanford and commute between its work areas. Westinghouse Hanford also operates work areas located outside the site. These include the 700 Area, located in the city of Richland south of the 1100 Area, and the 3000 Area, located on Stevens Drive immediately east of the 1100 Area (Figure 4). Because of their off-site location, small size, and contribution to risk, these sites are not included in this study.

Although the WM PEIS will consider four alternatives, only current conditions (no action and decentralized alternatives) and the regionalized-1 alternative will be examined in this study. Under the regionalized-1 alternative, the construction of an incinerator at Hanford would take place to thermally treat HW from Hanford and Lawrence Livermore National Laboratory (LLNL). Consequently, the volume of HW transported on-site would

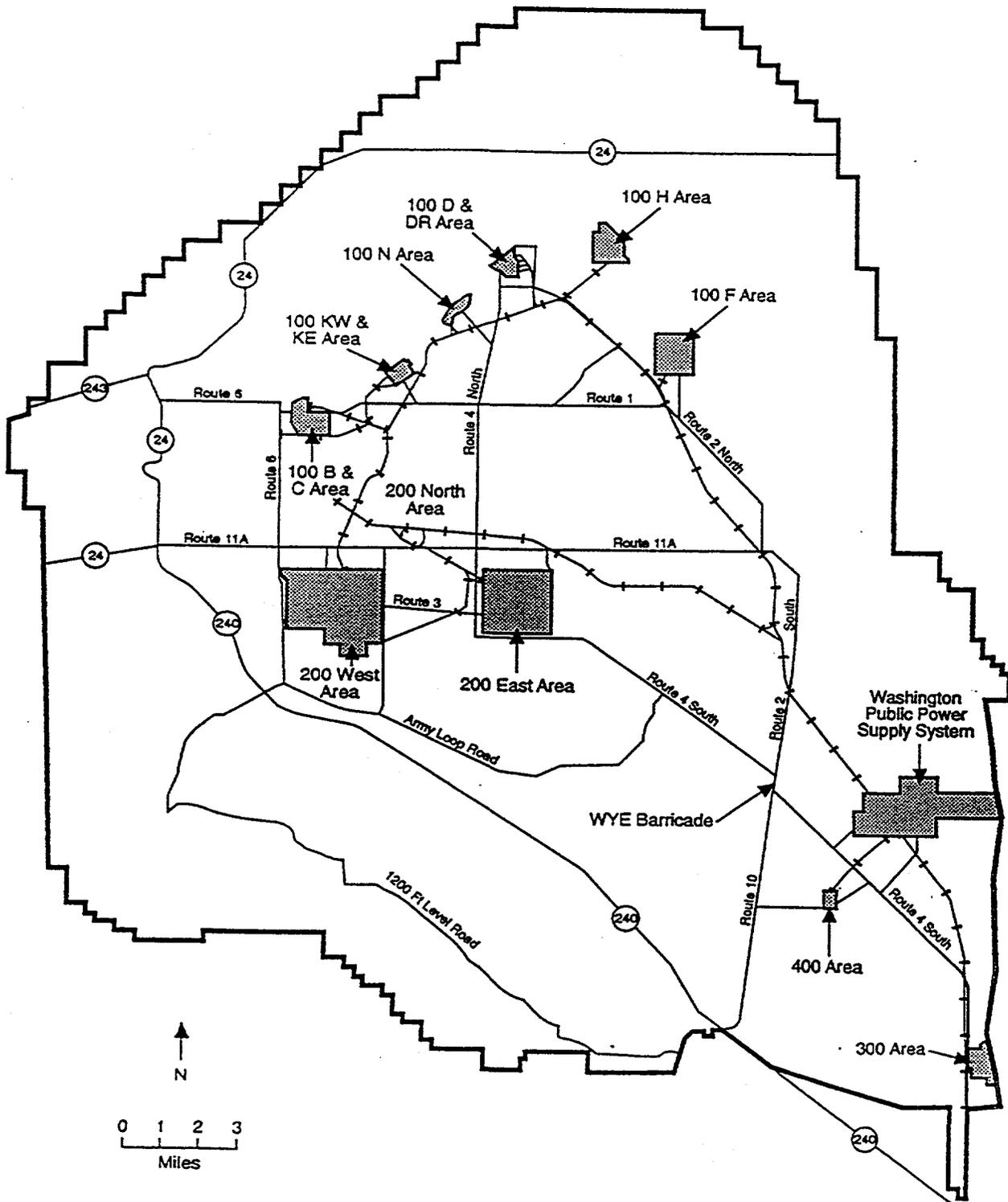


FIGURE 4 Boundaries, Work Areas, and Principal Highways and Roads at the Hanford Site

increase under this alternative. Under the regionalized-2 alternative and current program, volumes of HW transported on-site at Hanford would be the same because the difference in the alternatives occurs off-site.

According to DOT regulations specified in 49 CFR Parts 173, 178, and 179, EPA-designated HW and state-designated dangerous waste (DW) must be packaged before shipment. Furthermore, the EPA and the Washington Department of Ecology regulations must be met. A Hazardous Waste Disposal Approval Record (HWDAR) is a compliance document that is filed for each waste shipment. The HWDAR contains specific instructions for packaging and labeling Hanford's HW (Westinghouse Hanford Company 1993).

The on-site population of Hanford is limited to work areas, facilities (i.e., Building 616 — the HW storage facility), barricades, and the WPPSS station. Members of the public who use those portions of public highways located within Hanford boundaries were not included in this assessment because of relatively low use rates and the assumption that many were workers who use the highways to get to work, where they would already be under consideration for exposure. Table 7 contains population, population density, and land area for all on-site work areas and major facilities.

Generally, all packages, liners, and HW must be compatible. Liquid wastes must be shipped in bung-type drums that are inspected before and after filling. Small amounts of compatible HW and DW are shipped as labpacks. Labpacks must contain wastes of the same DOT hazard class and must be transported by highway only (Westinghouse Hanford Company 1993). Except for certain sublethal liquid wastes (solvents, kerosene, methyl isobutyl ketone) that are transported in bulk via tanker trucks, most of Hanford's HW is shipped in 55-gal steel drums. A small portion of HW is transported in plastic and fiber cylinders.

5.2 ROUTING ANALYSIS

The Hanford Site is served by a rail line owned and operated by DOE and a network of highways that connect it to regional transportation nodes and population centers. Currently, HW is shipped by truck transport only. HW may be shipped by rail in the future, but no decision concerning rail transport has been made or is expected before early 1995. Consequently, this study will assess the risks associated with truck transport of HW only.

Approximately 290 mi of paved highways and roads are located within the confines of Hanford. Of this total, nearly 65 mi are open to the public (Daling et al. 1991). Figure 4 depicts Hanford's principal highways, roads, and work areas. State Highway 24 intersects with State Route 43 north of the Columbia River and runs east to west through the northern portion of Hanford. State Highway 240 runs from State Highway 24 in the western portion of Hanford and continues in a southeasterly direction before terminating in Richland west of the 1100 Area. These two routes form the major perimeter highways at Hanford, and neither runs through any of the site's work areas. Both routes are public access roads. Other

TABLE 7 Population and Area Data for Work Areas at the Hanford Site

Work Area	Area Population ^a	Land Area (mi ²)	Population Density (people/mi ²)
100 B & C	4	0.66	6.0
100 D & DR	4	0.58	6.8
100 H	4	0.27	14.8
100 F	3	NA ^b	NA
100 K	143	0.35	408.5
100 N	397	0.39	1,018.0
200 West	2,008	3.67	547.1
200 East	3,096	3.47	892.2
300	3,253	0.58	5,608.6
400	728	0.81	898.7
600 ^c	547	NA	NA
1100	827	NA	NA
WPPSS	1,744	1.7	1,025.8

^a Blowers (1994); Data for Washington Public Power Supply System (WPPSS) provided by Sommer (1994).

^b NA = not applicable.

^c The 600 Area represents Building 616 and all facilities on-site that are not included in the above areas.

public access routes include Route 10, from the Wye barricade to State Highway 240, and a segment of Route 4 South, from the Wye barricade through the 1100 Area (where its designation becomes Stevens Drive) and into Richland city. Hanford's highways are categorized as rural monitor arterial (Daling et al. 1991). All incoming and outgoing materials are processed through the 1100 Area.

The on-site transport of HW at Hanford is limited to the main arteries, particularly Routes 1, 3, and 4, that access the points of HW generation and the HW storage facility (Building 616). HW is generated and shipped from the 100 N, 100 KW & KE, 200 East and West, 300, and 400 Areas. Occasionally, HW from the 100 Areas is generated and shipped to Building 616 or directly off-site. Such HW is usually associated with remedial activities and consists of small quantities. The 200 Areas account for approximately 90% of all HW generated by Westinghouse Hanford. Almost all of the HW generated in the 300 Area (managed by Pacific National Laboratory) is shipped directly off-site via the lower reaches of Route 4. Therefore, Route 3, which runs between the 200 Areas and past the HW storage facility, and both the north and south segments of Route 4 carry almost 100% of all HW transported on-site. All HW is processed through the 1100 area before it leaves Hanford. Figures 5 and 6 illustrate on-site transport routes for HW generated in the 100 and 200 Areas.

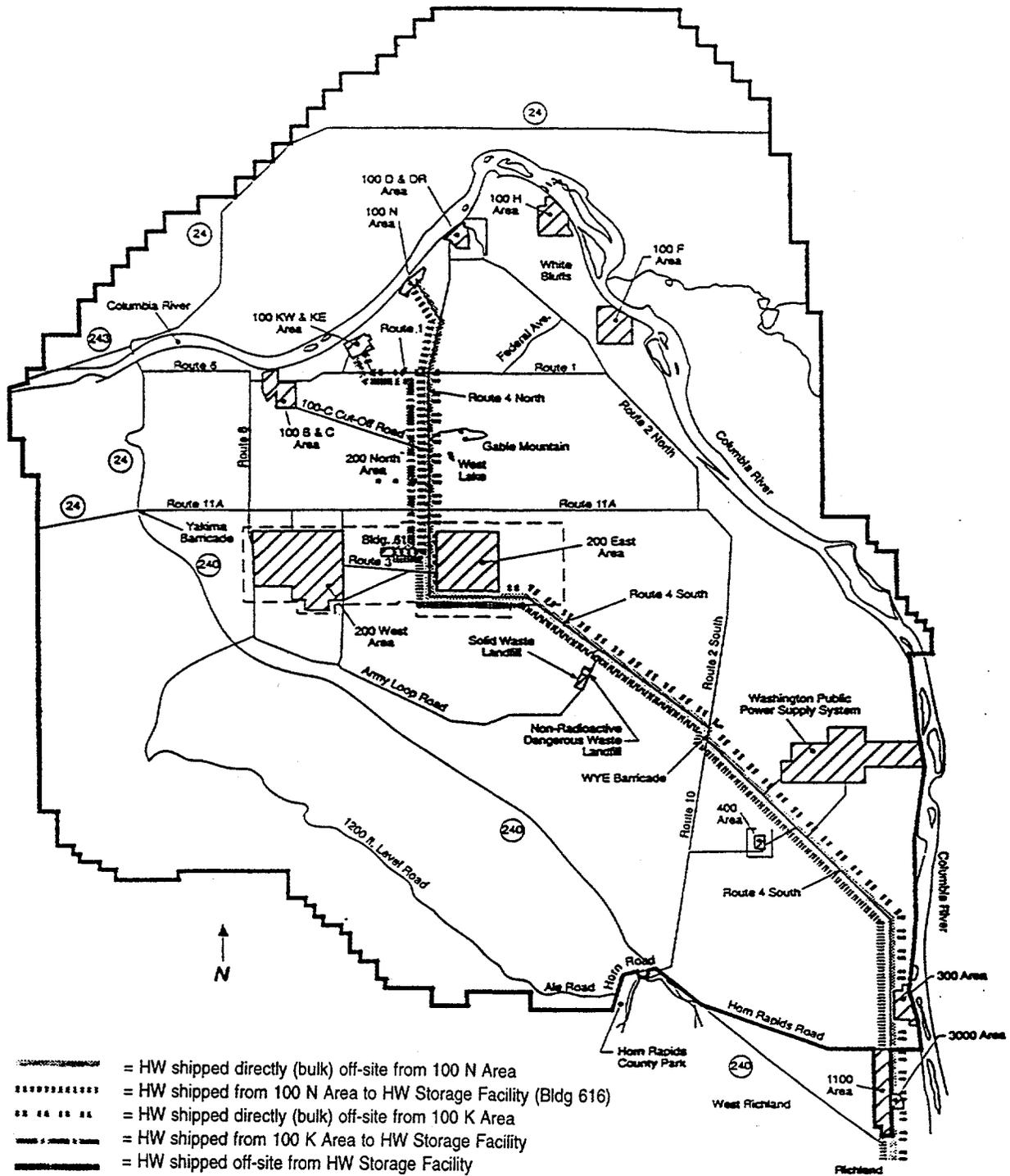


FIGURE 5 Hazardous Waste Routes at 100K and 100N Areas — Hanford Site

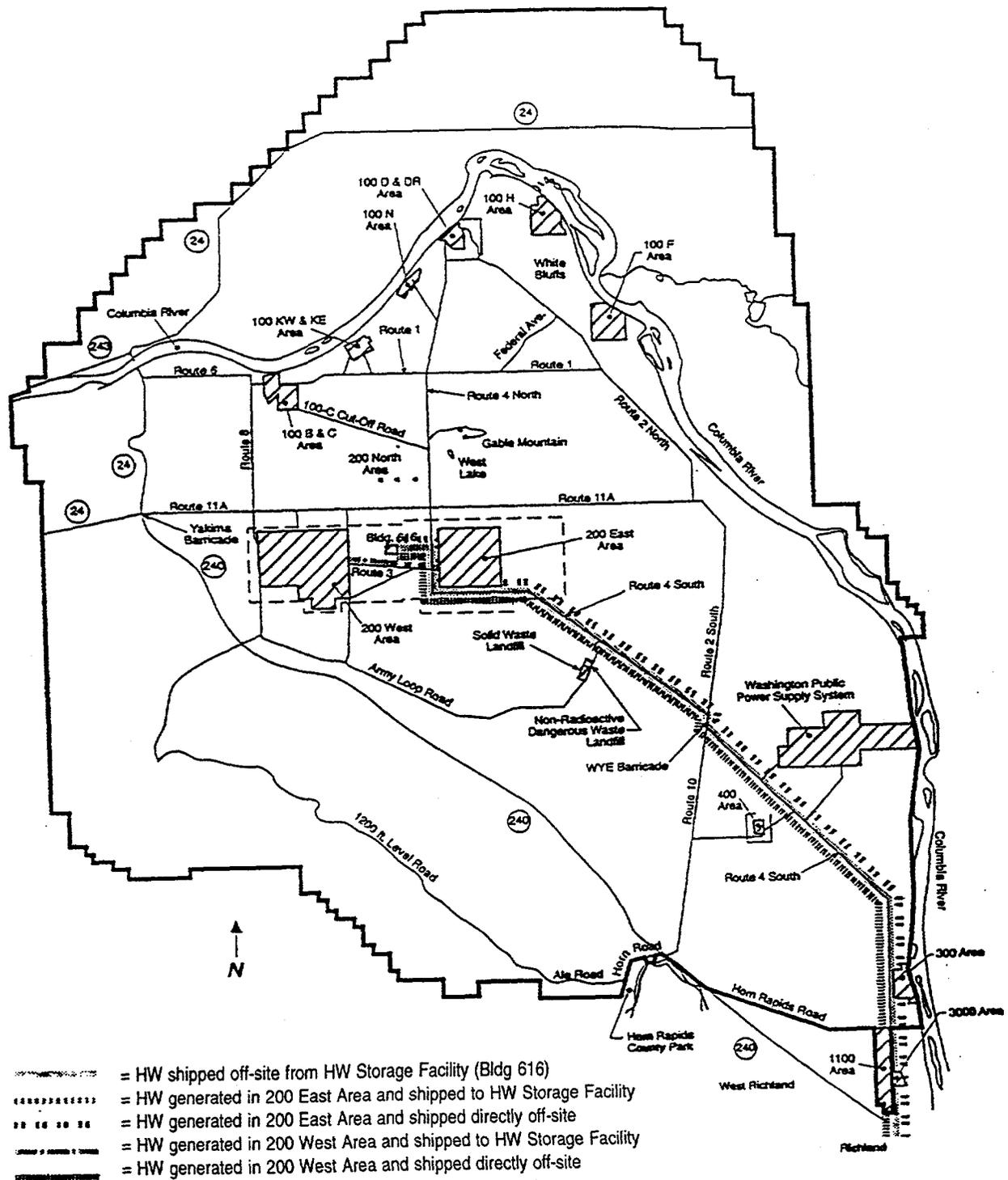


FIGURE 6 Hazardous Waste Routes at 200 Areas — Hanford Site

Under the regionalized-1 alternative described in the WM PEIS, the HW transport routes would be virtually the same as those described under existing conditions. The incinerator would be located on Route 3, between the 200 West Area and the HW storage facility. HW from LLNL would be shipped to the incinerator from the 1100 Area via Routes 4 and 3. After incineration, any residual HW would be shipped off-site along the same routes described for current conditions.

5.3 ON-SITE TRANSPORTATION RISK ASSESSMENT METHOD

General assumptions on health risk assessments for on-site transportation are closely related to those for off-site transportation, so the same methodology was used whenever possible. In general, the assessment for HW includes vehicle-related (independent of the chemical nature of a cargo) and cargo-related impacts, under both routine and accident transport conditions.

Vehicle-related impacts under routine condition are the result of exposure to vehicle exhaust emissions; risks are primarily associated with exposure in an urban environment. Because the routes used for HW transport at Hanford are located in a rural environment, vehicle-related impacts under routine condition are minimal. Compared with mileage traveled off-site, on-site transportation is limited to much shorter distances within the installation itself (i.e., among facilities, work areas, and/or site boundaries). Vehicle-related impacts under accident transport conditions, such as injuries or fatalities due to vehicle collisions, are expected to be insignificant.

Containers used for shipment of HW are approved under the Resource Conservation and Recovery Act and have been assumed to preclude any significant exposure to workers or the general public resulting from potential seepage during routine HW transport. No cargo-related impacts exist associated with transport of HW under routine conditions. Accordingly, health risk assessment for HW is limited to the cargo-related impacts occurring only under accident transport conditions. The primary pathway of concern is inhalation associated with a chemical release of a toxic vapor or gas of HW into the atmosphere. Direct exposure to HW other than through the inhalation pathway, such as ingestion or dermal contact, is possible. However, these pathways are expected to result in much lower exposure than the inhalation pathway.

Both population risks and risks to the maximally exposed individual (MEI) have been evaluated for on-site transportation. Potential receptors identified for population risks are workers adjacent to the transport route and the general public in the vicinity of a gate. The general public is included in the impact assessment because of potential accidents on public access roads within the Hanford site or along on-site routes near the 1100 Area that could affect nearby residents. Potential MEIs are on-site workers at individual facilities or guards at checkpoints along the route. Human health risk end points addressed in this assessment include the potential for life-threatening effects, carcinogenic effects, and nonlethal effects.

5.4 ASSUMPTIONS AND IN/OUT PARAMETERS

Total risk for all chemicals being shipped along all on-site transportation routes was calculated employing Equation 1. The probabilities of a chemical release in an accident are given by cargo type and chemical state (i.e., gas, liquid, solid) in Section 2.

Under accident conditions with a chemical release, exposure to HW results from the release and dispersion of HW into the atmosphere. The ALOHA™ computer software (version 5.1; Reynolds 1992) developed by the EPA and the National Oceanic and Atmospheric Administration (NOAA) is used to estimate the release and dispersion of HW in this assessment. The health impacts of the exposure concentrations were developed by various agencies for emergency planning and health risk assessment (National Research Council 1993; DOT 1993b; Maloney 1990; EPA et al. 1987; EPA 1986).

The ALOHA™ model is able to handle frequently encountered accidental source releases from direct sources (with known release information), tanks, pipes, and puddles. The model has a built-in source-term algorithm that is used to compute the rate, quantity, and type of atmospheric release of a hazardous air pollutant. To aid in computing release rates and trajectories, the model has a chemical database library containing physical and chemical properties for approximately 700 pure chemical substances. Its dispersion algorithm simulates continuous and intermittent releases of passive nonbuoyant vapors and heavy gases. The atmospheric parameters of interest to ALOHA™ are stability class, inversion height, wind speed, wind direction, ambient temperature, ground roughness, cloudiness, and humidity. Atmospheric data can be entered into the ALOHA™ model by user input or by real-time weather data fed directly to the model from a Station for Atmospheric Measurements (SAM). Also, the model simulates dispersion in both rural and urban atmospheres and calculates time-dependent concentration and hazard distances for specified chemical concentrations in air. The ALOHA™ model calculates maximum distance and a footprint (a plan view of the area) in which the concentration exceeds a specified LOC. The footprint is used to estimate the consequences of population exposure along the on-site route. Input parameters used for the ALOHA™ model runs for this analysis are listed in Table 8.

In general, the shapes of footprints from the ALOHA™ model vary according to chemical substance, container size, released quantity, etc. The ALOHA™ model does not calculate the maximum width of a footprint. To estimate the affected area from the footprint, the following assumptions were made:

1. All footprints are assumed to be ellipses. The area can be calculated by

$$S = \pi AB/4 , \quad (10)$$

where

- A = length of major axis (maximum downwind distance of the footprint over the concentration level of concern); and
- B = length of minor axis.

TABLE 8 Input Parameters Used for ALOHA™ Dispersion Model

Site Data

Location *Hanford, Washington^a*
 Building type *Sheltered, single storied*
 Date and time *August 31, 1994, 1200 hours (noon)*

Chemical Data: Case dependent

Meteorology

Stability class *Class D*
 Inversion layer *No*
 Wind speed *4 m/s*
 Wind direction *SW*
 Air temperature *95°F*
 Ground roughness *Open Country ($z_0 = 3$ cm)*
 Cloud cover *Complete Cover*
 Relative humidity *50%*

Source: *Tank*

Tank Size and Orientation: Shipment dependent (Based on given container type and chemical quantity, select one among containers listed below)

Container Type	Diameter (ft)	Height (ft)	Capacity (gal)	Orientation	Hole diameter (in.)
Cylinder (small)	0.83	3.7	15	Vertical	0.5
Cylinder (large)	0.83	7.1	29	Vertical	0.5
1-ton cylinder	2.33	6.0	190	Horizontal	0.87
1-gal jug	0.7	0.35	1	Vertical	0.25
55-gal drum	1.85	2.73	55	Vertical	2.0
470-gal drum	4.0	5.0	470	Vertical	2.0
800-gal drum	4.0	8.5	800	Vertical	2.0
1,400-gal drum	4.0	14.9	1,400	Vertical	2.0
Tanker truck	5.5	36.6	6,500	Horizontal	3.0

Chemical State: Chemical and Shipment dependent (Choose "Liquid" if the boiling temperature of a chemical is above the ambient temperature of 95°F, and choose "Unknown" if not - this option lets ALOHA™ decide)

Chemical Storage Temperature: *95°F*

Chemical; mass or volume: Shipment dependent (currently, 100% of chemical mass in a container is assumed to be released).

TABLE 8 (Cont.)

Area and Type of Leak
<i>Circular Opening</i>
Opening diameter was listed in the previous page
Leak occurs through a <i>Hole</i>
<i>Top</i> and <i>Bottom</i> leaking if stored in gaseous and aqueous states in a container, respectively
Puddle Parameters
<i>Default</i> ground type
<i>Use Air Temperature</i> for ground temperature
<i>Unknown</i> maximum puddle diameter
Computational Preferences: <i>Let model decide</i> (Gaussian or Heavy Gas)
Display
User-specified concentration: chemical dependent
Footprint output option: <i>Plot on grid and auto scale to fit window</i>
Output unit: <i>English</i>

^a Data input to the model are in italics.

- The affected area from the point of spill to 30 m (100 ft) downwind, where no residential areas usually exist, was subtracted by using the integration formula for the arc of an ellipse in the mathematical table (Beyer 1991).
- The regression equations for the ratio of the length of minor axis to that of major axis were derived from more than 20 ALOHA™ test runs each for Gaussian and Heavy Gas Dispersion.
 - Gaussian Dispersion: Ratio $B/A = 0.14$
 - Heavy Gas Dispersion: Ratio $B/A = 7.556/(\log_{10}[A \text{ in yard}])^{5.033} + 0.09$

For calculating on-site transportation risk at Hanford, the demographic region is assumed to be rural nonfreeway, which sets $\text{Pr}(A)^*$ in Equation 1 at 6.8×10^{-7} . Population densities were estimated along every mile of the routes. For the analysis, population density estimates were based on 1-mi² areas because more than 90% of the plume lengths estimated from the ALOHA™ software are less than 1 mi. Sensitivity analysis indicated that total risks based on 1-mi² areas were more conservative (by 35%) than those based on 2-mi² areas.

Under the no-action alternative, most HW generated at Hanford would be shipped to off-site treatment facilities. The same would be true under the decentralized and regionalized-2 alternatives. Detailed on-site transportation routes for each shipment are not available, so three routes are identified as being representative of on-site transportation.

* On the basis of California accident involvement rates per mile from 1979 to 1983; the probabilities of accident per mile are estimated to be 5.6×10^{-7} , 6.8×10^{-7} , 7.9×10^{-7} , and 1.01×10^{-6} for rural freeway, rural nonfreeway, suburban freeway, and urban freeway, respectively (Harwood and Russell 1990).

Center points and the sequential numbers of each 1-mi² area are also shown in Figure 7. Three routes are assumed to run from the 200 E, 200 W, and 100 N Areas to the gate in the 1100 Area via the HW storage facility (Building 616). Population densities along the three routes are estimated in Table 9. As shown in Figure 7, each route is dissected into 1-mi segments and population densities representative of each mile are estimated based on a 1-mi² area.

Assuming an accident could take place at any point within a 1-mi segment, 1-mi² areas are constructed to result in the largest population densities possible. On the basis of 1992 hazardous chemical transportation data at Hanford, percentages of route usage associated with the 200 E, 200 W, and 100 N Areas are assumed to be 45, 45, and 10%, respectively. Total health risks were weighted by multiplying risks estimated along the three routes by percentages of route usage. Combining these assumptions, the above equation can be rewritten to calculate on-site transportation risk at Hanford:

$$Risk = \sum_{Chemical} (2.4 \times 10^{-14}) Pr(R/A)(EA)(WP), \quad (11)$$

where

(2.4×10^{-14}) = the probability of accident per mile (for rural nonhighway) times the conversion factor (ft² to mi²),

EA = exposed hazard area (mi²), and

WP = weighted population per mile along the on-site routes (i.e., population density times miles traveled).

For the no-action alternative, the WP value of 9,472 was estimated.

Under the regionalized-1 alternative, two-thirds of the HW generated at Hanford would be treated at the on-site incinerator, which would be located near Building 616, and the rest would be shipped to off-site treatment facilities; also, about two-thirds of the HW generated at LLNL would be transported to the incinerator at Hanford for treatment. In addition to three routes identified for the no-action alternative, three routes (from mile 28 and up in Figure 7 and Table 9) from the 200 E, 200 W, and 100 N Areas to the on-site incinerator for HW generated at Hanford and one route (from mile 1 to mile 27) from the gate to the incinerator for HW generated at LLNL are included. For health risk calculations due to HW generated at Hanford and LLNL, the WP values in Equation 11 are estimated to be 3,881 and 8,387, respectively. No detailed information (e.g., number of employees, location, site area) on the proposed incinerator facility under the regionalized-1 alternative is currently available. Thus, population related to the incinerator facility is not included for the analysis.

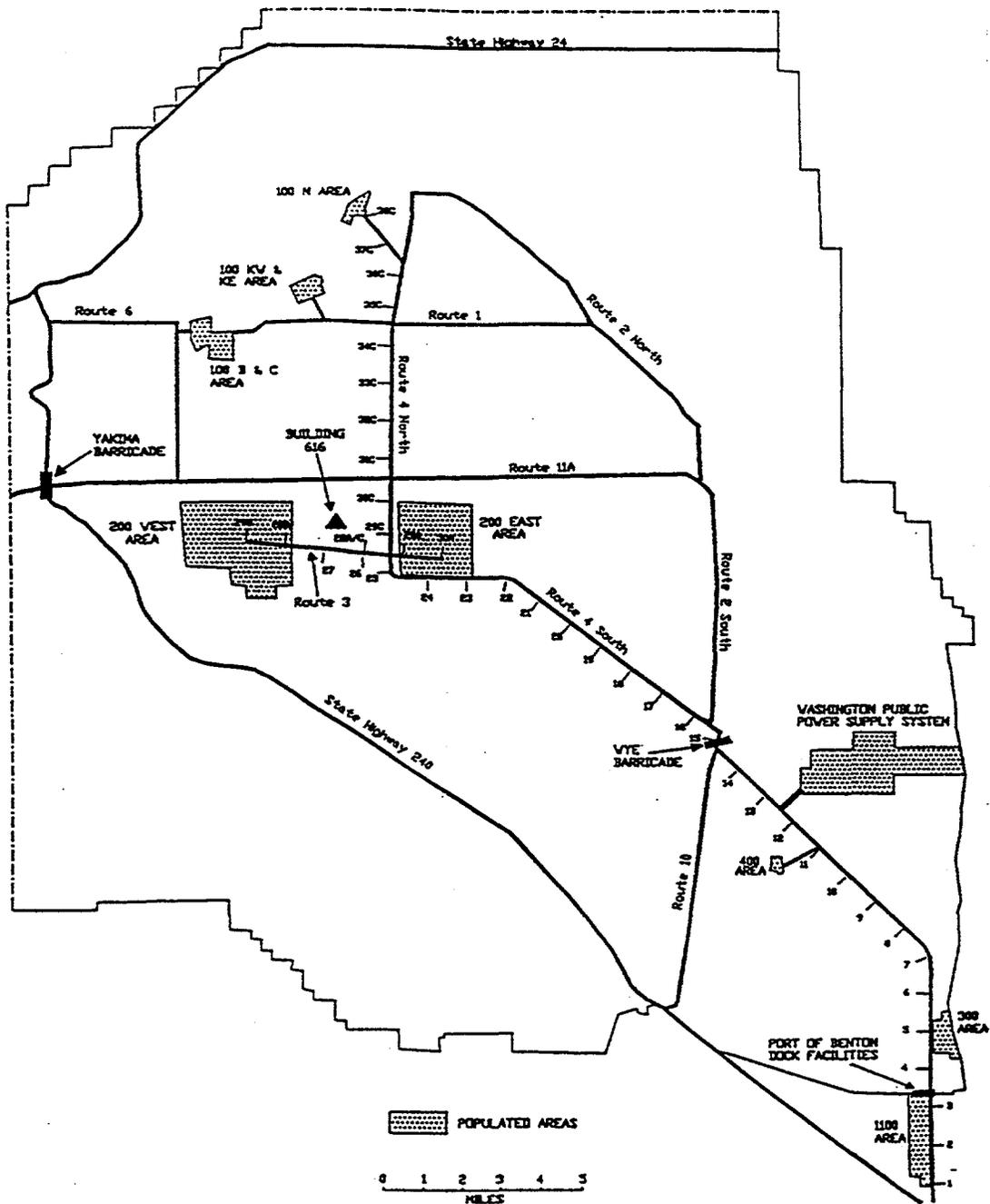


FIGURE 7 One-Mile Segments along Routes of On-Site Transportation — Hanford Site

TABLE 9 Population Densities along the Three Representative Routes at Hanford

Mile ^a	Population/mi ²		
	Route A ^b	Route B ^c	Route C ^d
1	936	936	936
2	1,364	1,364	1,364
3	825	825	825
4	1,033	1,033	1,033
5	3,253	3,253	3,253
6	0	0	0
7	0	0	0
8	0	0	0
9	0	0	0
10	0	0	0
11	0	0	0
12	0	0	0
13	0	0	0
14	0	0	0
15	0	0	0
16	0	0	0
17	0	0	0
18	0	0	0
19	0	0	0
20	0	0	0
21	0	0	0
22	0	0	0
23	360	360	360
24	360	360	360
25	256	256	256
26	0	0	0
27	0	0	0
28	0	416	0
29	393	554	326
30	852	0	164
31	0	0	0
32	0	0	0
33	0	0	0
34	0	0	0
35	0	0	0
36	0	0	0
37	0	0	0
38	0	0	397
Total	9,632	9,357	9,274

^a See Figure 7 for center point of each 1-mi segment.

^b 200 East Area - Building 616 - South Gate.

^c 200 West Area - Building 616 - South Gate.

^d 100 North Area - Building 616 - South Gate.

5.5 CARGO-RELATED ACCIDENT TRANSPORTATION RISKS FOR THE GENERAL PUBLIC AND ON-SITE WORKERS

The potential risks associated with inhalation exposures to chemical releases under cargo-related transportation accidents were quantified. Human health risks to on-site workers and the general public for the HW four alternatives and the three health end points (potential life-threatening effects, increased carcinogenic risk, and any adverse effects) are evaluated and presented in Table 10. Also, relative risks compared with the no-action alternative and with the same alternative for off-site transportation were listed for comparison. The risks are expressed in terms of number of individuals potentially affected for the total shipment duration (20 years).

Volumes of HW transported on-site at Hanford would not increase under the no-action (baseline), decentralized (current program), or regionalized-2 alternatives, so health risks under these alternatives would be the same. Under the regionalized-1 alternative, about two-thirds of HW generated at Hanford and two-thirds of HW generated at LLNL would be transported to the incinerator at Hanford. Total quantities of HW generated at LLNL are larger than those at Hanford, so more shipments would pass the populated region near the 1100 Area at Hanford. As a result, health risks for the regionalized-1 alternative would be relatively higher than those for the no-action alternative, with respect to the end points of potential life-threatening effects, increased cancer risk, and any adverse health effects. When employees at the proposed incinerator facility area are included, health risks for the regionalized-1 alternative would be even higher.

Health risks from on-site transportation are generally much smaller (by 1 to 3 orders of magnitude) compared to those from off-site transportation, because fewer miles are involved and a rather sparse population is often near many of the on-site routes. HW from 10 DOE installations accounts for approximately 90% of the HW generation in the DOE Complex. In this analysis, Hanford, which was selected as representative of impacts for on-site transportation risks, is one of the largest DOE installations (i.e., longest on-site travel distances from the gate or boundary to the facility on-site). From Table 10, the ratios of off-site risks (all sites) to on-site risks (Hanford only) range from 87 to 2,900. If the on-site risk at Hanford is indeed representative of the other nine large DOE sites, then the ratio of off-site risks (all sites) to on-site risks (all sites) would probably range from about 9 to 290. Clearly, then on-site risks would be much smaller than off-site risks. In summary, potential health risks resulting from on-site transportation would be insignificant compared with those from off-site transportation.

5.6 CARGO-RELATED ACCIDENT TRANSPORTATION RISKS FOR THE MEI

The ALOHA™ model was used to estimate the hazard zones for PIH chemicals. A hazard zone is the maximum distance from the accident point within which life-threatening health effects might take place. Lethality is directly related to exposure to PIH chemicals.

TABLE 10 Comparison of Population Health Risks (Number of Individuals Potentially Affected) for Each HW Alternative for a 20-Year Period^a

Health Effect Alternative	Potential Life-Threatening Health Effects	Concerns for Potential Cancer Incidents	Potential Adverse Health Effects
No-action	1.1E-04 (1.0; 1,400) ^b	7.3E-03 (1.0; 300)	2.7E-02 (1.0; 2,900)
Decentralized	1.1E-04 (1.0; 540)	7.3E-03 (1.0; 160)	2.7E-02 (1.0; 1,800)
Regionalized-1	1.6E-04 (1.5; 350)	2.7E-02 (3.9; 87)	2.0E-01 (7.5; 430)
Regionalized-2	1.1E-04 (1.0; 710)	7.3E-03 (1.0; 290)	2.7E-02 (1.0; 2,200)

^a Risks are for the total shipment duration (20 years). To obtain the annual values, divide risks by 20.

^b The first value in parentheses is the relative risk compared with the no-action alternative for on-site transportation. The second value is the relative risk compared with the same alternative for off-site transportation (i.e., off-site risk divided by on-site risk at Hanford only).

Lethal PIH chemicals and their hazard zones are presented in Table 11. If an accidental release were to occur, most PIH chemicals could be lethal to on-site workers at facilities or guards at checkpoints who are located in close proximity to the release point. However, only nickel carbonyl and hydrogen fluoride could be lethal to the general public residing near the route running through the 1100 Area (Table 11). More than half of the PIH chemical shipments are made in and out of Hanford in small quantities, so the hazard zones are restricted to relatively small plumes located near the release points.

In this analysis, the MEI (on-site worker at facilities or guard at checkpoints) is assumed to be located 15 m (50 ft) away from the release point. An MEI among the general public off-site is not considered because of the longer travel distance of a plume than that for on-site receptors. An MEI was assumed to be an adult with body weight of 70 kg (155 lb) and inhalation rate of 0.014 m³/min (EPA 1989a). The analysis included all shipments to and from Hanford.

The potential for adverse health effects was evaluated by using the noncancer HQ, which is defined as an exposure level over a specified time period divided by a reference dose (RfD) derived for a similar exposure period (EPA 1989b). If an HQ exceeds unity, there may be concern for potential adverse effects. The HQ values do not represent statistical probabilities; a ratio of 0.001 does not mean that adverse effects would occur once in one thousand chances. Potential any adverse effect risks are shown in Table 12. Chemicals with HQ values less than or equal to unity are acetonitrile, aniline, dichlorodifluoromethane, ethylene glycol monobutyl ether, mercury, nitrobenzene, and trichlorofluoromethane. The HQs that have a potential to result in adverse effects for an MEI receptor range from 1.8 (methyl ethyl ketone) to 790 (chloroform). In general, uncertainties and conservatism exist in using EPA RfD values to evaluate single, short-term exposures. In addition, the ALOHA™

TABLE 11 Hazard Zones for Potential Life-Threatening Risks to an MEI

Chemical Name	Hazard Zone ^a (m)	Chemical Name	Hazard Zone (m)
Bromine	34	Phenyl isocyanate	10
Chlorine	235	Phosphorous trichloride	45
Dimethyl sulfate	10	Sulfur dioxide	12
Hydrogen fluoride	410	Sulfuric acid, fuming	10
Nickel carbonyl	594	Titanium tetrachloride	38
Nitric acid, fuming	40		

^a Defined as a maximum distance from the accident point within which life-threatening health effects might take place.

TABLE 12 Potential Any Adverse Health Effect Risks to an MEI

Chemical Name	Concentration (ppm)	Exposure Time (min)	Intake (mg/kg/d)	RfD (mg/kg/d)	Hazard Quotient
Acetonitrile	254	22	1.1E-01	1.4E-01	0.7
Ammonia	22,300	1	2.3E-01	2.9E-02	8.0
Aniline	0.9	60	2.8E-03	2.9E-03	1.0
Carbon disulfide	522	7	1.1E-01	2.9E-03	38
Carbon tetrachloride	141	14	1.5E-01	1.7E-02	8.5
Chloroform	12,900	14	9.0E+00	1.1E-02	790
Dichlorodifluoromethane	2,270	1	1.6E-01	5.7E-01	0.3
Epichlorohydrin	36	60	1.1E-01	2.9E-03	37
Ethylene glycol monobutyl ether	2.4	60	9.2E-03	5.7E-02	0.2
Hydrogen chloride	5,850	1	1.3E-01	2.0E-03	64
Mercury	0.009	60	6.0E-05	8.6E-05	0.7
Methyl ethyl ketone	785	21	5.3E-01	2.9E-01	1.8
Methyl isobutyl ketone	1,350	60	4.4E+00	2.3E-01	19
Methylene chloride	9,550	6	1.9E+00	8.6E-01	2.2
Nitrobenzene	1.0	60	4.2E-03	5.7E-03	0.7
Toluene	1,020	52	2.5E+00	1.1E-01	22
1,1,1-Trichloroethane	16,400	16	1.7E+01	2.9E-01	60
Trichlorofluoromethane	1,090	1	8.8E-02	2.0E+00	0.04
Triethylamine	81	14	5.7E-02	2.0E-03	29
Vinyl acetate	424	15	2.5E-01	5.7E-02	4.4

model does not accurately represent variations associated with near-field (close to the spill source) patchiness, which makes plume presentation unreliable and can potentially result in overestimation of short-distance effects. Considering these facts, the assumption can be made that the risk of adverse effects is minimal for substances with HQ values less than 10. Accordingly, the greatest potential for adverse effects to an MEI is associated with accidental release of the following substances: chloroform, hydrogen chloride, 1,1,1-trichloroethane, carbon disulfide, epichlorohydrin, triethylamine, toluene, and methyl isobutyl ketone. Once an accidental release is reported, evacuation would be made in a short time period for the area that is anticipated to be affected. Assuming evacuation would occur within 10 min of accidental release, chemicals with potentially adverse effects for an MEI are chloroform, hydrogen chloride, 1,1,1-trichloroethane, carbon disulfide, and triethylamine. In general, for the same shipment, risks for on-site transportation are higher than those for off-site transportation due to the shorter distances to a receptor.

Increased carcinogenic risk can be derived by using estimated daily intakes averaged over a lifetime of exposure and slope factor. A standard risk equation for inhalation of airborne chemicals was used (EPA 1989b). For the analysis, daily intakes were adjusted to short-term exposures. Lifetime cancer incidence risks for an MEI are given in Table 13.

Lifetime cancer risks range from 2.5×10^{-7} to 4.0×10^{-4} . Except for chloroform, risks for all carcinogens are considered to be insignificant and acceptable for HW sites. However, several of these carcinogens are severe irritants and would be expected to result in irritation to the MEI at high concentration levels. Lifetime cancer risk for chloroform was estimated to be 4.0×10^{-4} . Shipments by tankers for this chemical would originate from LLNL under the regionalized-1 alternative. Assuming evacuation would occur within 10 min of accidental release, shipment for chloroform still could result in some significant increased cancer risks under the accident conditions modeled.

TABLE 13 Lifetime Increased Carcinogenic Risks to an MEI

Chemical Name	Concentration (ppm)	Exposure Time (min)	Intake (mg/kg/d)	Slope Factor (mg/kg/d) ⁻¹	Cancer Incidence Risk
Benzene	511	18	1.9E-04	2.9E-02	5.5E-06
Carbon tetrachloride	141	14	8.0E-05	5.3E-02	4.2E-06
Chloroform	12,900	14	4.9E-03	8.1E-02	4.0E-04
1,2-Dichloroethane	120	25	7.9E-05	9.1E-02	7.2E-06
Dichloroethylene	599	1	1.9E-05	1.8E-01	3.3E-06
Epichlorohydrin	36	60	5.9E-05	4.2E-03	2.5E-07
Formaldehyde	9,970	1	9.8E-05	4.6E-02	4.5E-06
Methylene chloride	52,300	7	7.1E-04	1.7E-03	1.2E-06
Tetrachloroethane	79	60	2.5E-04	2.0E-01	5.1E-05
Tetrachloroethylene	107	60	3.2E-04	2.0E-03	6.5E-07
Trichloroethane	666	60	1.6E-03	5.6E-02	8.7E-05
Trichloroethylene	248	24	2.1E-04	6.0E-03	1.3E-06
Vinyl chloride	2,730	1	5.6E-05	2.9E-01	1.6E-05

6 REFERENCES

AIHA — See American Industrial Hygiene Association.

Alexeeff, G.V., et al., 1989, "Problems Associated with the Use of Immediately Dangerous to Life and Health (IDLH) Values for Estimating the Hazard of Accidental Chemical Releases," *American Industrial Hygiene Association Journal* 50(11):598-605.

American Industrial Hygiene Association, 1988-1992, *Emergency Response Planning Guidelines, Sets 1-7*, Akron, Ohio.

Beyer, W.H., 1991, *CRC Standard Mathematical Tables and Formulae*, 29th ed., CRC Press, Boca Raton, Fla.

Blowers, P., 1994, personal communication from Blowers (Westinghouse Hanford Company, Richland, Wash.) to J. Pffingston (Argonne National Laboratory, Argonne, Ill.), March 23.

Carson, B.L., et al., 1981, *Sulfuric Acid Health Effects*, EPA 460/3-81-025, prepared by Midwest Research Institute, Kansas City, Mo., for U.S. Environmental Protection Agency, Office of Mobile Source Air Pollution.

Daling, P.M., et al., 1991, *Transportation Plan: New Production Reactor at the Hanford Site*, WHC-EP-0340, Westinghouse Hanford Co., Richland, Wash.

DOE — See U.S. Department of Energy.

Dollarhide, J., 1992, personal communication from Dollarhide (Superfund Health Risk Technical Support Center, Cincinnati, Ohio) to H.M. Hartmann (Argonne National Laboratory, Argonne, Ill.), Oct. 27.

DOT — See U.S. Department of Transportation.

EPA — See U.S. Environmental Protection Agency.

Graf, V.D., and K. Archuleta, 1985, *Truck Accidents by Classification*, FHWA/CA/TE-85, California Department of Transportation, Jan.

Harwood, D.W., and E.R. Russell, 1990, *Present Practices of HIGHWAY Transportation of Hazardous Materials*, FHWA/RD-89/013, prepared by Midwest Research Institute, McLean, Va., for Federal Highway Administration, Office of Safety and Traffic Operations, May.

Klaassen, C.D., et al. (editors), 1986, *Casarett and Doull's Toxicology: The Basic Science of Poisons*, 3rd ed., MacMillan Publishing Company, New York, N.Y.

Maloney, D.M., 1990, personal communication from Maloney (Argonne National Laboratory, Argonne, Ill.) to J.C. Hess (U.S. Department of Transportation, Research and Special Programs Administration, Washington, D.C.).

Monette, F.A., et al., 1996, *Supplemental Information Related to Risk Assessment for the Off-site Transportation of Low-Level Mixed Waste for the U.S. Department of Energy Waste Management Programmatic Environmental Impact Statement*, ANL/EAD/TM-35, Argonne National Laboratory, Argonne, Ill., Dec.

National Institute of Occupational Safety and Health, 1992, *Registry of Toxic Effects of Chemical Substances (RTECS)*, Database, Cincinnati, Ohio.

National Resource Council, 1986, *Criteria and Methods for Preparing Emergency Exposure Guideline Level (EEGL), Short-Term Public Emergency Guidance Level (SPEGL), and Continuous Exposure Guidance Level (CEGL) Documents*, National Academy Press, Committee on Toxicology, Washington, D.C.

National Resource Council, 1993, *Guidelines for Developing Community Emergency Exposure Levels for Hazardous Substances*, National Academy Press, Committee on Toxicology, Washington, D.C.

Reynolds, R.M., 1992, *ALOHA™ (Areal Locations of Hazardous Atmospheres) 5.0: Theoretical Description*, NOAA-TM NOS ORCA-65, National Oceanic and Atmospheric Administration, Seattle, Wash., Aug.

Sax, N.I., and R.J. Lewis, 1992, *Dangerous Properties of Industrial Materials*, 8th ed., Van Nostrand Reinhold, New York, N.Y.

Sommer, M., 1994, personal communication from Sommer (Washington Public Power Supply System, Richland, Wash.) to J. Pflingston (Argonne National Laboratory, Argonne, Ill.), March 31.

U.S. Department of Energy, 1986, *Environmental Assessment, Deaf Smith County Site, Texas*, DOE/RW-0069, Office of Civilian Radioactive Waste Management, Washington, D.C., May.

U.S. Department of Energy, 1987, *Final Environmental Impact Statement, Disposal of Hanford Defense High-Level, Transuranic and Tank Wastes*, DOE/EIS-0013, Washington, D.C., Dec.

U.S. Department of Energy, 1990, *Environmental Impact Statement, Waste Isolation Pilot Plant, Final Supplement*, DOE/EIS-0026-FS, Office of Environmental Restoration and Waste Management, Washington, D.C., Jan.

U.S. Department of Energy, 1996, *Waste Management Programmatic Environmental Impact Statement for Managing Treatment, Storage, and Disposal of Radioactive and Hazardous Wastes*, DOE/EIS-0200-PF, Office of Environmental Management, Washington, D.C.

U.S. Department of Transportation, 1990, *The 1990 Emergency Response Guidebook*, DOT P 5800.5, Research and Special Programs Administration, Office of Hazardous Materials Transportation, Washington, D.C.

U.S. Department of Transportation, 1993a, *Hazardous Materials Information Reporting System Database, Research and Special Programs Administration — Hazardous Materials Safety*, Washington, D.C.

U.S. Department of Transportation, 1993b, *The 1993 Emergency Response Guidebook*, DOT P 5800.5, Research and Special Programs Administration, Office of Hazardous Materials Transportation, Washington, D.C.

U.S. Environmental Protection Agency, 1980, "Water Quality Criteria Document; Availability," *Federal Register* 45:79353, Nov. 28.

U.S. Environmental Protection Agency, 1986, "Guidelines for Carcinogenic Risk Assessment," *Federal Register* 51:33992-34003, Sept.

U.S. Environmental Protection Agency, 1989a, *Exposure Factors Handbook*, EPA/600/8-89/043, Office of Health and Environmental Assessment, Washington, D.C., May.

U.S. Environmental Protection Agency, 1989b, *Risk Assessment Guidance for Superfund, Volume I: Human Health Evaluation Manual, Part A*, (Interim Final), EPA/540/1-89/002, Office of Emergency and Remedial Response, Washington, D.C., Dec.

U.S. Environmental Protection Agency, 1991, *Risk Assessment Guidance for Superfund, Volume I: Human Health Evaluation Manual, Part B: Development of Risk Based Preliminary Remediation Goals, Interim*, EPA/540/R-92/003, Office of Emergency and Remedial Response, Washington, D.C., Dec.

U.S. Environmental Protection Agency, 1993a, *Health Effects Assessment Summary Tables (HEAST), Annual FY 1993*, OERR 9200.6-303 (92-1), Office of Emergency and Remedial Response, Washington, D.C., March.

U.S. Environmental Protection Agency, 1993b, *Integrated Risk Information System (IRIS), Database*, Office of Emergency and Remedial Response, Washington, D.C., accessed Oct.

U.S. Environmental Protection Agency, et al., 1987, *Technical Guidance for Hazardous Analysis — Emergency Planning for Extremely Hazardous Substances, Appendix D*, Office of Emergency and Remedial Response, Washington, D.C.

Westinghouse Hanford Co., 1993, *Hazardous Material Packaging and Shipping Manual*, WHC-CM-2-14, Westinghouse Hanford Co., Richland, Wash.

Wilson, D.J., 1991, "Accounting for Peak Concentrations in Atmospheric Dispersion for Worst Case Hazard Assessments," in the proceedings of the *International Conference and Workshop on Modeling and Mitigating the Consequences of Accidental Releases of Hazardous Materials*, May 20-24, 1991, New Orleans, La., American Institute of Chemical Engineers, New York, N.Y.

ADDENDUM I:

**TRANSPORTATION RISK ASSESSMENT FOR THE
HAZARDOUS COMPONENT OF LOW-LEVEL MIXED WASTE**

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ADDENDUM I:**TRANSPORTATION RISK ASSESSMENT FOR THE
HAZARDOUS COMPONENT OF LOW-LEVEL MIXED WASTE****1 INTRODUCTION**

This addendum summarizes the results of the hazardous waste (HW) transportation risk assessment for the Waste Management (WM) component of U.S. Department of Energy (DOE) Waste Management Environmental Impact Statement (WM PEIS) low-level mixed waste (LLMW). It includes a short summary of the risk assessment methodology, assumptions, models, and results. The results from this analysis compliment the similar analysis for the radiological risk (Argonne National Laboratory [ANL] 1994). A description of the LLMW characteristics and packaging can be found in ANL (1994).

The transportation risk analysis for LLMW is intended to provide input for decisions regarding alternatives for the treatment and disposal of the LLMW generated at installations within the DOE complex. The risks incurred during waste loading, unloading, and handling prior to and after shipment are not included because they are part of the facility accident analysis prepared in a separate document. The analysis in this data deliverable applies only to LLMW once it has left the DOE facilities and is on public roads.

The LLMW transportation risk assessment is based on HW shipments via trucks or railcars from generators to treatment, storage, and disposal (TSD) facilities. Cargo-related population risks are evaluated; the vehicle-related population risks are presented in ANL (1994). Potential cargo-related population risks associated with hypothetical transportation accidents are estimated for the following six cases, which are defined in Chapter 2 of the WM PEIS (DOE 1996).

- Decentralized — 49 sites treat contact-handled LLMW; 16 sites dispose
- Regionalized 1 — 11 sites treat contact-handled LLMW; 12 sites dispose
- Regionalized 2 — 7 sites treat contact-handled LLMW; 6 sites dispose
- Regionalized 3 — 7 sites treat contact-handled LLMW; 1 site disposes (Nevada Test Site)
- Regionalized 4 — 4 sites treat contact-handled LLMW; 6 sites dispose
- Centralized — 1 site treat contact-handled LLMW (Hanford); 1 site disposes (Hanford)

For each case, the population risks are evaluated under eight accident severity categories (I through VIII) established by the U.S. Nuclear Regulatory Commission (NRC 1977).

Because liquid and solid wastes are likely to be shipped in different containers and in separate shipments, the cargo-related population risks for these two types of wastes are also evaluated separately. Following a transportation accident, liquid wastes in the containers are assumed to be spilled onto the ground to form a vapor plume. Hazardous

chemicals in the plume are carried by the wind downward and dispersed in both horizontal and vertical directions, thereby affecting the nearby population. For solid wastes, two different approaches are used to assess the impact of transportation accident on population risks: (1) the evaporative gaseous emission approach and (2) the fugitive particulate emission approach. In the first approach, the entire content in a waste container is assumed to be dumped to form a waste pile on the ground. The amount of gaseous emissions of hazardous chemicals depends not only on the physical properties and volatilization rate of a specific chemical compound, but also on the size of the pile. The second approach treats atmospheric releases of hazardous chemicals as fugitive particulates and attempts to quantify their inhalation-related population risks under different accident severity categories.

2 RISK ASSESSMENT METHODOLOGY

The cargo-related risks from exposure to the HW component of LLMW resulting from a transportation accident can be either acute (result in immediate injury or fatality) or latent (result in cancer that would present itself after a latency period of several years). The primary exposure route of concern with respect to atmospheric HW releases is inhalation. Population risks are evaluated for (1) increased risk of cancer and (2) potential for any adverse effects. Increased carcinogenic risk is expressed as the number of individuals in the general population with an increased lifetime cancer risk of 10^{-6} (1 in 1 million) or greater. The risk from exposure to specific chemical carcinogens is calculated using increased carcinogenic risk concentration (ICRC) values. The potential for any adverse effects risk is expressed as the number of individuals in the general population exposed to specific chemicals at levels above the potential adverse effect concentration (PAEC) for that chemical. ICRC and PAEC values are benchmark levels derived specifically for the WM PEIS. Use of these types of population risk descriptors (that is, estimates of the number of persons exposed above specified benchmark levels) is recommended under U.S. Environmental Protection Agency (EPA) guidance.

Characterization of the LLMW hazardous chemical inventory is provided in Wilkins et al. (1996). Liquid and solid hazardous waste components with significant volatilization potential and inhalation toxicity values (i.e., slope factors or reference concentrations) available from the EPA were evaluated. Table 1 lists the identified carcinogenic and noncarcinogenic substances in the LLMW inventory and their respective ICRC and PAEC values. No substances are identified as an acute "poison inhalation hazard" by the U.S. Department of Transportation (DOT 1990). Thus, an evaluation of potential life-threatening acute effects is not necessary. In addition, no published data are presently available to determine the PAEC or ICRC values for insoluble hydrocarbons and some inorganic substances (e.g., lead, cyanide, silver, and selenium compounds). Although some

TABLE 1 Chemical-Specific Values of ICRC and PAEC for LLMW Carcinogenic and Any Adverse Affect Constituents

LLMW Codes	Substance	Health End Point Concentration Value		
<u>Carcinogenic Chemical Substances</u>		<u>ICRC Values (ppm)</u>		
75-09-2	Dichloromethane (methylene chloride)	380.0		
Cl-2-x	Dichloroethane	5.8		
Cl-4-x	Tetrachloroethene	160.0		
HC-soluble	Hydrocarbons-soluble (benzene, ^a xylene, toluene, etc.)	23.0		
		<u>PAEC Values (ppm)</u>		
<u>Any Adverse Affect Chemical Substances</u>		15 min	30 min	60 min
75-09-2	Dichloromethane (methylene chloride)	147.0	73.0	37.0
Cl-3-x	1,1,1-Trichloroethane	31.0	16.0	7.8
Cl-F-x	1,1,2-Trichloro-1,2,2-trifluoroethane (Freon 113)	670.0	330.0	170.0
HC-soluble	Hydrocarbons-soluble (benzene, xylene, toluene, ^b etc.)	18.0	9.0	4.5

^a The carcinogenic potential of soluble hydrocarbons was calculated using the ICRC value for benzene.

^b The potential adverse effects end point for soluble hydrocarbons was calculated using the PAEC value for toluene.

particulates are carcinogens (e.g., cadmium salts), low exposure dose and duration make risks low compared with risks from vapors and gases. Inorganic substances such as arsenic, barium, cadmium, chromium, lead, mercury, selenium, and silver compounds are considered to have either very low volatilization potentials or to be too heavy to remain suspended in air as respirable particulates. Based on these considerations, only those organic substances with identified PACE or ICRC values were selected in the risk assessment for HW transportation accidents.

The risk assessment considers historical hazardous-material traffic data for trucks and railcars, including accident probabilities, cargo release likelihood given an accident, and consequences of a range of possible transportation accidents. In the risk assessment, liquid LLMW is assumed to be shipped in Type A containers (55-gal drums) separately from solid LLMW, which may be shipped in various forms and sizes of containers. The probabilities of truck accidents, based on statistics compiled for the California Department of Transportation for the period 1979-1983, are presented in Section 2.1 of the main text. On the basis of data compiled by Saricks and Kvitck (1994) (see Section E.6.4 in WM PEIS, Appendix E), the national average railcar accident rate is 5.6×10^{-3} accidents/km (9.0×10^{-3} accidents/mi). To estimate the amount of atmospheric releases during a typical transportation accident, statistical data were compiled from the Hazardous Materials Incident Reporting System (HMIRS) database (DOT 1993) to arrive at the container breach rates and atmospheric release rates by truck and railcar shipments for different container sizes, as shown in Table 2. The statistical data on accidents presented in this table are used only for liquid LLMW shipments.

For cargo-related population risk assessment, the eight accident severity categories (I through VIII) defined in NUREG-0170 (NRC 1977) are designed to take into account all credible transportation-related accidents, including those with low probability but high consequences and vice versa. Category I accidents are the least severe but the most frequent, whereas Category VIII accidents are very severe but very infrequent. Each severity category represents a set of accident scenarios defined by a combination of mechanical (impact) and thermal (fire) forces and is assigned a conditional probability of occurrence. To determine the expected frequency of an accident of a given severity category, the conditional probability in the category is multiplied by the baseline accident rate. Each population density zone has a distinct baseline accident rate and distribution of accident severities related to differences in average vehicular velocity, traffic density, and other factors, including location (rural, suburban, or urban). Table 3 presents the fractional occurrences by population density zone, as well as release fractions, under the eight accident severity categories for both truck and railcar LLMW shipments. It should be noted that the value of the accident release fraction in this table is for the total mass release. For accidents involving shipments of liquid wastes, 100% of the total mass release is assumed to become aerosolized and respirable. For solid wastes, 10% of the total mass release is assumed to become aerosolized, of which only 5% will be respirable. A chemical spill dispersion model uses the respirable portion of aerosol releases into the atmosphere following a transportation accident to predict the plume footprint and estimate the chemical exposure area, as discussed in the next section. The assumed mass, aerosol, and respirable release fractions for LLMW shipment accidents are consistent with those used for radiological transportation risk assessment (refer to WM PEIS, Appendix E).

TABLE 2 Container Breach Rates and Atmospheric Releases Derived from HMIRS Statistical Data for Truck and Railcar Accidents

Transportation Mode	Container Contents	Container Size	Breach Rate (%)	Quantity Release (%)
Truck	Liquid/gas	Package freight containers		
		0-2 gal capacity	43.80	65.30
		2-10 gal capacity	45.10	36.80
		10-50 gal capacity	40.70	27.10
		>50 gal capacity	35.90 ^a	19.90 ^a
	Bulk containers		16.20	
	Solids	Package freight containers	30.60	23.50
Bulk containers			32.60	
Railcar	Liquids/gas	Package freight containers	25.00 ^a	38.00 ^a
		Bulk containers		6.60
	Solids	Package freight containers	40.90	44.15
		Bulk containers		1.26

^a Statistical data used in the HW transportation risk assessment.

TABLE 3 Fractional Occurrences by Population Density Zone and Estimated Release Fractions for LLMW Shipments under Various Accident Severity Categories^a

Severity Category	Fractional Occurrence	Fractional Occurrence by Population Density Zone			Estimated Release Fraction ^b
		Rural	Suburban	Urban	
Truck					
I	5.50E-01	1.00E-01	1.00E-01	8.00E-01	0.00E+00
II	3.60E-01	1.00E-01	1.00E-01	8.00E-01	1.00E-02
III	7.00E-02	3.00E-01	4.00E-01	3.00E-01	1.00E-01
IV	1.60E-02	3.00E-01	4.00E-01	3.00E-01	1.00E+00
V	2.80E-03	5.00E-01	3.00E-01	2.00E-01	1.00E+00
VI	1.10E-03	7.00E-01	2.00E-01	1.00E-01	1.00E+00
VII	8.50E-05	8.00E-01	1.00E-01	1.00E-01	1.00E+00
VIII	1.50E-05	9.00E-01	5.00E-02	5.00E-02	1.00E+00
Rail					
I	5.00E-01	1.00E-01	1.00E-01	8.00E-01	0.00E+00
II	3.00E-01	1.00E-01	1.00E-01	8.00E-01	1.00E-02
III	1.80E-01	3.00E-01	4.00E-01	3.00E-01	1.00E-01
IV	1.80E-02	3.00E-01	4.00E-01	3.00E-01	1.00E+00
V	1.80E-03	5.00E-01	3.00E-01	2.00E-01	1.00E+00
VI	1.30E-04	7.00E-01	2.00E-01	1.00E-01	1.00E+00
VII	6.00E-05	8.00E-01	1.00E-01	1.00E-01	1.00E+00
VIII	1.00E-05	9.00E-01	5.00E-02	5.00E-02	1.00E+00

^a Refer to Tables E-6 and E-7 in WM PEIS, Appendix E.

^b Values are for total material release fraction for Type A shipping containers.

3 MODELS AND ASSUMPTIONS

The Areal Locations of Hazardous Atmospheres (ALOHATM) model, jointly developed by the EPA and the National Oceanic and Atmospheric Administration (NOAA) (Reynolds 1992), was used to predict the plume footprints and their area coverage at or above the PAEC or ICRC values for hazardous chemicals released into the atmosphere following a hypothetical transportation accident. The various assumptions used in the modeling are summarized below.

3.1 MODE AND QUANTITY OF ATMOSPHERIC RELEASE

Container releases of volatile chemical vapors in LLMW accidents can enter the atmosphere in one or a combination of three modes: as a direct respirable aerosol (liquid

spill, no pool), as an evaporative gas from contaminated spoils pile (solid waste spill on ground), and as a respirable aerosol fraction (solid spill, direct to atmosphere).

Hazardous organic chemicals in LLMW are assumed to be released directly into the atmosphere following a transportation accident. The release duration is assumed to be one hour. For liquid wastes, the amount of liquid spilled is based on statistical data regarding container breach rates and atmospheric release rates for truck and railcar accidents presented in Table 2 and is computed from known shipping quantities for the eight accident severity categories given in Table 3. The spilled liquids are assumed to form a vapor plume immediately.

For transportation accidents involving solid wastes, the evaporative gaseous emission approach assumes that the entire cargo-load of the solid wastes would be dumped onto ground to form a cone-shape pile of no greater than 4 ft in height. Based on the average density of LLMW solid wastes of $1,250 \text{ kg/m}^3$ and known shipping quantity per truck or railcar, the following equation was used to estimate the rate of gaseous organic chemical emissions for each alternative route (EPA 1988):

$$E = D \times C_s \times A \times (P_t^{1.333333}) \times (M/d_{sc}) \quad , \quad (1)$$

where

E = emission rate of a specific chemical compound (g/s),

D = chemical diffusivity (cm^2/s),

C_s = saturation vapor concentration (g/cm^3),

M = chemical fraction in the waste,

P_t = total soil porosity (use default = 0.35),

A = exposure area (cm^2), and

d_{sc} = effective depth of solid LLMW pile (cm).

The fugitive particulate emission approach utilizes the same mass, aerosol, and respirable release fractions in the following eight accident severity categories, consistent with those used for radiological transportation risk assessment (see ANL 1994):

Severity Category	Release Fractions		
	Mass	Aerosol	Respirable
I	0.00	0.0	0.00
II	0.01	0.1	0.05
III	0.10	0.1	0.05
IV-VIII	1.00	0.1	0.05

For example, if a truck load of LLMW solid wastes contains 1,000 kg of benzene, the respirable particulate release of benzene under Severity Category III would be 0.5 kg [1,000 kg \times 0.1 \times 0.1 \times 0.05]. The mass, aerosol, and respirable release fractions are assumed to be zero in Severity Category I, indicating no atmospheric HW releases for a minor transportation accident. Thus the population risks to Severity Category I will always be zero.

3.2 HYPOTHETICAL METEOROLOGICAL CONDITIONS

The following hypothetical meteorological conditions were used to predict plume footprints and their areal extents in the ALOHA™ modeling:

Wind speed	4 m/s
Atmospheric stability	neutral (Pasquill Class D)
Ambient temperature	95°F
Relative humidity	50%

3.3 HEALTH RISK OF RELEASES OF MIXTURES OF CHEMICALS

In many of these shipment accidents, a number of chemicals are released to the environment. The issue is how to account for the inhalation of multiple chemicals for an individual downwind of the release. This additivity of human health impacts is addressed separately for increased cancer risk and the any-adverse-effects end points.

ALOHA™ was run first for each of the chemicals to determine its individual plume footprint at the specified ICRC or PAEC value (see Table 1). Using an iteration method, the "composite" plume footprint for all chemicals of concern is determined such that the following relationship can be reached:

$$\sum_1^n C_n/T_n \approx 1 \quad , \quad (2)$$

where

C_n = concentration at "composite" plume footprint for the n th chemical of concern, and

T_n = threshold limit value (level of concern) for n th chemical.

This method would yield a larger plume area of influence of the chemical mixture than any one of its components.

3.4 MAXIMALLY EXPOSED INDIVIDUAL RISK EVALUATION

The maximally exposed individual (MEI) was considered to be located at the point of highest chemical concentration accessible to the general public. This location is assumed to be 30 m (100 ft) from an accident resulting in the highest chemical concentration. To

evaluate the MEI for each health end point, the primary factors considered were a combination of chemical potency, quantity released, and vapor plume dispersion, as reflected by the chemical concentrations in air predicted by the ALOHA™ model.

The following formula was used to determine the lifetime MEI carcinogenic risk to adults over an exposure period of 70 years:

$$\text{MEI Carcinogenic Risk} = (CA \times IR \times ET \times ED \times SF)/(BW \times AT) \quad (3)$$

where

CA = chemical concentration in air (mg/m³);

IR = inhalation rate for adult (0.014 m³/min);

ET = exposure time, min/d (same as chemical release duration, assumed 60 min/d);

EF = exposure frequency (1 d/yr);

ED = exposure duration (1 yr);

BW = average body weight for an adult (70 kg);

AT = averaging time (70 yr × 365 d/yr); and

SF = inhalation slope factor (mg/kg-d)⁻¹.

The following formula was used to evaluate the MEI hazard quotient for noncarcinogenic substances, based on an average exposure period of 14 days for a 6-year-old child:

$$\text{Hazard Quotient} = [(CA \times IR \times ET \times EF \times ED)/(BW \times AT)]/RfD \quad (4)$$

where

CA = chemical concentration in air (mg/m³);

IR = inhalation rate for 6-year-old, moderate activity (0.033 m³/min);

ET = exposure time, min/d (same as chemical release duration, assumed 60 min/d);

EF = exposure frequency (1 d/yr);

ED = exposure duration (1 yr);

BW = average body weight for a 6-year-old child (21 kg);

AT = averaging time (14 d/yr × 1 yr); and

Rfd = reference dose (mg/kg/d).

A hazard quotient (HQ) greater than 1 indicates that an adverse effect for the MEI is likely. The level of concern associated with exposure to these compounds does not increase linearly at HQ values exceed 1. In other words, HQ values do not represent a probability or a percentage. One may conclude that, as the HQ value above 1 increases, greater concern exists about potential adverse effects; however, assuming that an HQ value of 10 indicates that adverse health effects are 10 times more likely to occur than for an HQ value of 1 is incorrect. Because of uncertainties and conservatism associated with the use of EPA RfD values to evaluate single, brief exposures, the assumption may be made that the risk of adverse effects is minimal for substances with HQ values between 1 and 10.

4 SUMMARY OF RESULTS

The collective cargo-related population risks to the general public for off-site LLMW transportation for a 10-year period, under the above six cases of treatment options, are summarized in Table 4 for highway shipments and in Table 5 for railway shipments.

With regard to concerns for potential cancer incidents, zero population risks were found involving solid waste shipments. For liquid waste shipments, the highest risk was found to occur under the Centralized Alternative: Severity Category IV for both highway and railway shipments.

Concerning potential health risk effects, zero population risks were found involving solid wastes shipped by truck. For liquid waste shipments, the highest risk was found to occur under the Centralized Alternative: Severity Category III for both highway and railway shipments.

The population risks involving solid waste shipments by trucks and railcars, based on the evaporative gaseous emission approach, were found to be zero. Using the fugitive particulate emission approach, the population risks were also found to be zero.

The HW component risks of the LLMW shipments are expected to be much lower than the transportation risk of the purely hazardous waste shipments (i.e., those with no radiological component).

With regard to MEI risk evaluation, the lifetime carcinogenic risks, the lifetime carcinogenic risks for potential cancer incident end points, and the HQs for adverse effects end points are summarized in Tables 6 and 7. The tables summarize the MEI risk results of both liquid and solid LLMW transportation accidents by trucks and railcars found by using the various atmospheric release approaches described in Section 2.1. The risk calculations were based on the maximum ambient concentrations at 100 ft from the release point for all shipments for a single truck or railcar accident predicted by the ALOHA™ model on a

chemical-specific basis. As indicated in Table 6, the carcinogenic risks for all chemicals are between 6.7×10^{-12} and 1.4×10^{-4} . For all cases except two (one liquid waste shipment by truck and railcar each), the estimated carcinogenic MEI risks are lower than the generally considered acceptable risk range of one in one million (10^{-6}). The carcinogenic risks of 5.6×10^{-5} for truck shipment and 1.4×10^{-4} for railcar shipment are for LLMW classified as soluble hydrocarbons. To yield a conservative assumption and facilitate calculations, soluble hydrocarbons were assumed to be the carcinogenic substance benzene. The risks presented for this waste category are probably overestimated, because it is highly unlikely that soluble hydrocarbons are actually composed of pure benzene. However, more data on the composition of the substance would be required to refine the risk estimates.

Adverse effects are considered possible for substances with associated hazard quotient (HQ) values greater than one. As shown in Table 7, HQs are greater than one for liquid waste shipments containing toluene and 1,1,1-trichloroethane and for solid waste shipments of toluene under Severity Categories IV-VIII. Thus, an accidental release involving any of these shipments would have the potential to result in adverse effects for receptors at the MEI locations.

TABLE 4 Summary of Cargo-Related Population Risks^a for LLMW Shipments by Highway for a 10-Year Period^b

Population Risk	LLMW Treatment Option					
	Decen- tralized	Region- alized 1	Region- alized 2	Region- alized 3	Region- alized 4	Central- ized
Shipment summary						
Number of shipments	5.00E+01	6.30E+02	1.23E+03	1.18E+03	2.49E+03	5.13E+03
Distance (km)	4.73E+04	3.23E+05	5.00E+05	4.44E+05	8.27E+05	2.33E+06
Liquid wastes per severity category^c						
Potential for increased cancer incidence						
I	0	0	0	0	0	0
II	0	0	0	0	0	0
III	0	5.98E-07	2.54E-04	2.54E-04	2.61E-04	3.08E-04
IV	2.49E-07	3.90E-06	3.42E-04	3.42E-04	3.53E-04	4.30E-04
V	3.42E-08	4.89E-07	4.39E-05	4.39E-05	4.54E-05	5.55E-05
VI	9.76E-09	1.16E-07	1.10E-05	1.10E-05	1.14E-05	1.41E-05
VII	4.99E-10	7.08E-09	6.44E-07	6.44E-07	6.67E-07	8.21E-07
VIII	6.30E-11	7.30E-10	7.09E-08	7.09E-08	7.38E-08	9.20E-08
Potential adverse health effects						
I	0	0	0	0	0	0
II	0	1.39E-06	8.01E-04	8.01E-04	8.09E-04	9.28E-04
III	0	8.28E-06	9.21E-04	9.21E-04	9.50E-04	1.22E-03
IV	1.53E-06	1.98E-05	1.33E-03	1.32E-03	1.37E-03	1.67E-03
V	2.10E-07	2.51E-06	1.70E-04	1.70E-04	1.76E-04	2.15E-04
VI	6.01E-08	6.07E-07	4.26E-05	4.25E-05	4.42E-05	5.45E-05
VII	3.07E-09	3.65E-08	2.50E-06	2.49E-06	2.59E-06	3.18E-06
VIII	3.88E-10	3.86E-09	2.75E-07	2.75E-07	2.87E-07	3.57E-07
Solid wastes (volatile-organic-contaminated soil/debris evaporative releases)						
Potential for increased cancer incidence	0	0	0	0	0	0
Potential adverse health effects	0	0	0	0	0	0
Solid wastes (respirable contaminated aerosol releases)						
Potential for increased cancer incidence	0	0	0	0	0	0
Potential adverse health effects	0	0	0	0	0	0

^a Cargo-related risks refer to the number of people affected and were computed from the product of the probability of accident release multiplied by the number of people exposed to the health criteria concentration.

^b Risks and travel distances are for the total shipment duration (10 yr). To obtain the annual values, the risks and distances must be divided by 10.

^c Value in bold italics represents the highest risk for a specific risk category.

TABLE 5 Summary of Cargo-Related Population Risks^a for LLMW Shipments by Railway for a 10-Year Period^b

Population Risk	LLMW Treatment Option					
	Decen- tralized	Region- alized 1	Region- alized 2	Region- alized 3	Region- alized 4	Central- ized
Shipment summary						
Number of shipments	5.00E+01	5.30E+02	8.10E+02	7.60E+02	1.32E+03	2.34E+03
Distance (km)	3.88E+04	3.65E+05	5.76E+05	5.17E+05	9.15E+05	2.46E+06
Liquid wastes per severity category^c						
Potential for increased cancer incidence						
I	0	0	0	0	0	0
II	0	0	2.42E-05	2.42E-05	2.42E-05	2.42E-05
III	0	1.84E-07	9.05E-05	9.05E-05	9.24E-05	1.12E-04
IV	9.84E-08	1.03E-06	7.42E-05	7.41E-05	7.60E-05	9.19E-05
V	7.56E-09	7.51E-08	5.36E-06	5.35E-06	5.50E-06	6.70E-06
VI	3.82E-10	3.41E-09	2.38E-07	2.38E-07	2.46E-07	3.04E-07
VII	8.53E-11	8.66E-10	7.22E-08	7.21E-08	7.42E-08	8.90E-08
VIII	1.57E-11	1.26E-10	9.62E-09	9.60E-09	9.98E-09	1.24E-08
Potential adverse health effects						
I	0	0	0	0	0	0
II	0	1.41E-07	1.38E-04	1.38E-04	1.38E-04	1.55E-04
III	0	3.13E-06	4.08E-04	4.08E-04	4.17E-04	4.92E-04
IV	4.41E-07	4.71E-06	2.92E-04	2.91E-04	2.99E-04	3.64E-04
V	3.39E-08	3.44E-07	2.11E-05	2.11E-05	2.17E-05	2.65E-05
VI	1.71E-09	1.57E-08	9.38E-07	9.37E-07	9.69E-07	1.20E-06
VII	3.82E-10	3.95E-09	2.84E-07	2.84E-07	2.92E-07	3.52E-07
VIII	7.04E-11	5.88E-10	3.79E-08	3.78E-08	3.93E-08	4.91E-08
Solid wastes (volatile-organic-contaminated soil/debris evaporative releases)						
Potential for increased cancer incidence	0	0	0	0	0	0
Potential adverse health effects	0	0	0	0	0	0
Solid wastes (respirable contaminated aerosol releases)						
Potential for increased cancer incidence	0	0	0	0	0	0
Potential adverse health effects	0	0	0	0	0	0

^a Cargo-related risks refer to the number of people affected and were computed from the product of the probability of accident release multiplied by the number of people exposed to the health criteria concentration.

^b Risks and travel distances are for the total shipping duration (10 yr). To obtain the annual values, the risks and distances must be divided by 10.

^c Value in bold italics represents the highest risk for a specific risk category.

TABLE 6 Lifetime MEI Carcinogenic Risk for LLMW Transportation

Transportation Mode	Release Mode	Chemical Name	Concentration at MEI Location (ppm)	Exposure Time (min/d)	Inhalation Air Intake (mg/kg/d) ^a	Slope Factor (mg/kg/d) ⁻¹	Carcinogenic MEI Risk
Highway	Liquid aerosol (direct)	Dichloromethane	1.22E+00	60	1.99E-06	1.65E-03	3.3E-09
		Dichloroethane	7.21E-01	60	1.37E-06	9.10E-02	1.2E-07
		Tetrachloroethene	1.15E+01	60	3.66E-05	5.95E-03	2.2E-07
		Benzene	1.28E+03	60	1.92E-03	2.91E-02	5.6E-05
	Vapor spoils pile (Superfund)	Dichloromethane	2.51E-03	60	4.09E-09	1.65E-03	6.7E-12
		Dichloroethane	1.69E-03	60	3.21E-09	9.10E-02	2.9E-10
		Tetrachloroethene	6.59E-04	60	2.10E-09	5.95E-03	1.2E-11
		Benzene	8.05E-03	60	1.21E-08	2.91E-02	3.5E-10
	Particulate (Severity Category II)	Dichloromethane	5.28E-03	60	8.60E-09	1.65E-03	1.4E-11
		Dichloroethane	2.31E-03	60	4.38E-09	9.10E-02	4.0E-10
		Tetrachloroethene	2.47E-02	60	7.86E-08	5.95E-03	4.7E-10
		Benzene	8.09E-02	60	1.21E-07	2.91E-02	3.5E-09
	Particulate (Severity Category III)	Dichloromethane	5.28E-02	60	8.60E-08	1.65E-03	1.4E-10
		Dichloroethane	2.31E-02	60	4.38E-08	9.10E-02	4.0E-09
		Tetrachloroethene	2.47E-01	60	7.86E-07	5.95E-03	4.7E-09
		Benzene	8.09E-01	60	1.21E-06	2.91E-02	3.5E-08
	Particulate (Severity Categories IV-VIII)	Dichloromethane	5.28E-01	60	8.60E-07	1.65E-03	1.4E-09
		Dichloroethane	2.31E-01	60	4.38E-07	9.10E-02	4.0E-08
		Tetrachloroethene	2.47E+00	60	7.86E-06	5.95E-03	4.7E-08
		Benzene	8.09E+00	60	1.21E-05	2.91E-02	3.5E-07
Railroad	Liquid aerosol (direct)	Dichloromethane	1.57E+01	60	2.56E-05	1.65E-03	4.2E-08
		Dichloroethane	7.27E+00	60	1.38E-05	9.10E-02	1.3E-06
		Tetrachloroethene	2.33E+01	60	7.41E-05	5.95E-03	4.4E-07
		Benzene	3.22E+03	60	4.82E-03	2.91E-02	1.4E-04
	Vapor spoils pile (Superfund)	Dichloromethane	2.51E-03	60	4.09E-09	1.65E-03	6.7E-12
		Dichloroethane	1.69E-03	60	3.21E-09	9.10E-02	2.9E-10
		Tetrachloroethene	6.59E-04	60	2.10E-09	5.95E-03	1.2E-11
		Benzene	8.05E-03	60	1.21E-08	2.91E-02	3.5E-10
	Particulate (Severity Category II)	Dichloromethane	5.28E-03	60	8.60E-09	1.65E-03	1.4E-11
		Dichloroethane	2.31E-03	60	4.38E-09	9.10E-02	4.0E-10
		Tetrachloroethene	2.47E-02	60	7.86E-08	5.95E-03	4.7E-10
		Benzene	8.09E-02	60	1.21E-07	2.91E-02	3.5E-09
	Particulate (Severity Category III)	Dichloromethane	5.28E-02	60	8.60E-08	1.65E-03	1.4E-10
		Dichloroethane	2.31E-02	60	4.38E-08	9.10E-02	4.0E-09
		Tetrachloroethene	2.47E-01	60	7.86E-07	5.95E-03	4.7E-09
		Benzene	8.09E-01	60	1.21E-06	2.91E-02	3.5E-08
	Particulate (Severity Categories IV-VIII)	Dichloromethane	5.28E-01	60	8.60E-07	1.65E-03	1.4E-09
		Dichloroethane	2.31E-01	60	4.38E-07	9.10E-02	4.0E-08
		Tetrachloroethene	2.47E+00	60	7.86E-06	5.95E-03	4.7E-08
		Benzene	8.09E+00	60	1.21E-05	2.91E-02	3.5E-07

^a Adjusted to short-term exposures.

TABLE 7 MEI Hazard Quotients for Adverse Effect End Points for LLMW Shipments

Transportation Mode	Release Mode	Chemical Name	Concentration at MEI Location (ppm)	Exposure Time (min/d)	Inhalation Air Intake (mg/kg/d) ^a	RfD (mg/kg/d) ^b	Hazard Quotient
Highway	Liquid aerosol (direct)	Dichloromethane	1.22E+00	60	2.9E-02	8.6E-01	3.33E-02
		1,1,1-Trichloroethane	7.21E-01	60	2.6E-02	2.9E-01	9.25E-02
		Freon 113	1.15E+01	60	5.9E-01	8.6E+00	6.90E-02
		Toluene	1.28E+03	60	3.2E+01	1.1E-01	2.84E+02
	Vapor spoils pile (Superfund)	Dichloromethane	2.51E-03	60	5.9E-05	8.6E-01	6.84E-05
		1,1,1-Trichloroethane	1.69E-03	60	6.2E-05	2.9E-01	2.17E-04
		Freon 113	6.59E-04	60	3.4E-05	8.6E+00	3.95E-06
		Toluene	8.05E-03	60	2.0E-04	1.1E-01	1.78E-03
	Particulate (Severity Category II)	Dichloromethane	5.28E-03	60	1.2E-04	8.6E-01	1.44E-04
		1,1,1-Trichloroethane	2.31E-03	60	8.5E-05	2.9E-01	2.96E-04
		Freon 113	2.47E-02	60	1.3E-03	8.6E+00	1.48E-04
		Toluene	8.09E-02	60	2.0E-03	1.1E-01	1.79E-02
	Particulate (Severity Category III)	Dichloromethane	5.28E-02	60	1.2E-03	8.6E-01	1.44E-03
		1,1,1-Trichloroethane	2.31E-02	60	8.5E-04	2.9E-01	2.96E-03
		Freon 113	2.47E-01	60	1.3E-02	8.6E+00	1.48E-03
		Toluene	8.09E-01	60	2.0E-02	1.1E-01	1.79E-01
	Particulate (Severity Categories IV-VIII)	Dichloromethane	5.28E-01	60	1.2E-02	8.6E-01	1.44E-02
		1,1,1-Trichloroethane	2.31E-01	60	8.5E-03	2.9E-01	2.96E-02
		Freon 113	2.47E+00	60	1.3E-01	8.6E+00	1.48E-02
		Toluene	8.09E+00	60	2.0E-01	1.1E-01	1.79E+00
Railroad	Liquid aerosol (direct)	Dichloromethane	1.57E+01	60	3.7E-01	8.6E-01	4.28E-01
		1,1,1-Trichloroethane	1.29E+02	60	4.7E+00	2.9E-01	1.66E+01
		Freon 113	7.65E-02	60	3.9E-03	8.6E+00	4.59E-04
		Toluene	2.68E+03	60	6.8E+01	1.1E-01	5.94E+02
	Vapor spoils pile (Superfund)	Dichloromethane	2.51E-03	60	5.9E-05	8.6E-01	6.84E-05
		1,1,1-Trichloroethane	2.87E-03	60	1.1E-04	2.9E-01	3.68E-04
		Freon 113	2.98E-05	60	1.5E-06	8.6E+00	1.79E-07
		Toluene	2.04E-03	60	5.2E-05	1.1E-01	4.52E-04
	Particulate (Severity Category II)	Dichloromethane	5.28E-03	60	1.2E-04	8.6E-01	1.44E-04
		1,1,1-Trichloroethane	3.85E-02	60	1.4E-03	2.9E-01	4.94E-03
		Freon 113	9.64E-04	60	5.0E-05	8.6E+00	5.78E-06
		Toluene	7.34E-02	60	1.9E-03	1.1E-01	1.63E-02
	Particulate (Severity Category III)	Dichloromethane	5.28E-02	60	1.2E-03	8.6E-01	1.44E-03
		1,1,1-Trichloroethane	3.85E-01	60	1.4E-02	2.9E-01	4.94E-02
		Freon 113	9.64E-03	60	5.0E-04	8.6E+00	5.78E-05
		Toluene	7.34E-01	60	1.9E-02	1.1E-01	1.63E-01
	Particulate (Severity Categories IV-VIII)	Dichloromethane	5.28E-01	60	1.2E-02	8.6E-01	1.44E-02
		1,1,1-Trichloroethane	3.85E+00	60	1.4E-01	2.9E-01	4.94E-01
		Freon 113	9.64E-02	60	5.0E-03	8.6E+00	5.78E-04
		Toluene	7.34E+00	60	1.9E-01	1.1E-01	1.63E+00

^a Adjusted to short-term exposures.^b RfD = inhalation reference dose.

5 REFERENCES

ANL — See Argonne National Laboratory.

Argonne National Laboratory, 1994, *Data Deliverable — LLMW Radiological Transportation Assessment, Summary of Collective Population Risks*, Argonne National Laboratory, Argonne, Ill., Sept. 6.

DOE — See U.S. Department of Energy.

DOT — See U.S. Department of Transportation.

NRC — U.S. Nuclear Regulatory Commission.

Reynolds, R.M., 1992, *ALOHA™ (Areal Locations of Hazardous Atmospheres) 5.0: Theoretical Description*, NOAA-TM NOS ORCA-65, National Oceanic and Atmospheric Administration, Seattle, Wash., Aug.

Saricks, C., and T. Kvittek, 1994, *Longitudinal Review of State-Level Accident Statistics for Carriers of Interstate Freight*, ANL/ESD/TM-68, Argonne National Laboratory, Argonne, Ill., July.

U.S. Department of Energy, 1996, *Waste Management Programmatic Environmental Impact Statement for Managing Treatment, Storage, and Disposal of Radioactive and Hazardous Waste*, DOE/EIS-0200-PF, U.S. Department of Energy, Office of Environmental Management, Washington, D.C.

U.S. Department of Transportation, 1990, *The 1990 Emergency Response Guidebook*, DOT P 5800.5, Research and Special Programs Administration, Office of Hazardous Materials Transportation, U.S. Department of Transportation, Washington, D.C.

U.S. Department of Transportation, 1993, *Hazardous Materials Information Reporting System Database, Research and Special Programs Administration — Hazardous Materials Safety*, U.S. Department of Transportation, Washington, D.C.

U.S. Environmental Protection Agency, 1988, *Superfund Exposure Assessment Manual*, EPA/540/1-68/1001, Washington, D.C.

U.S. Nuclear Regulatory Commission, 1977, *Final Environmental Statement on the Transportation of Radioactive Material by Air and Other Modes*, NUREG-0170, U.S. Nuclear Regulatory Commission, Washington, D.C.

Wilkins, B.D., et al., 1996, *Low-Level Mixed Waste Inventory, Characteristics, Generation, and Facility Assessment for Treatment, Storage, and Disposal Alternatives Considered in the U.S. Department of Energy Waste Management Programmatic Environmental Impact Statement*, ANL/EAD/TM-32, Argonne National Laboratory, Argonne, Ill.

ADDENDUM II:
TRANSPORTATION RISK ASSESSMENT FOR THE
HAZARDOUS COMPONENT OF TRANSURANIC WASTE

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ADDENDUM II:
TRANSPORTATION RISK ASSESSMENT FOR THE
HAZARDOUS COMPONENT OF TRANSURANIC WASTE

1 INTRODUCTION

This addendum evaluates the transportation risk due to the hazardous component of transuranic waste (TRUW) shipments among the various TRUW alternatives for the U.S. Department of Energy (DOE) Waste Management Programmatic Environmental Impact Statement (WM PEIS). In addition to the computed population risk discussion, impacts to the maximally exposed individual (MEI) are presented. All TRUW is assumed to be radioactive material mixed with other chemical substances and is divided into a number of waste stream categories (Table 1). The estimated concentrations of hazardous chemical constituents for the various categories of TRUW are given according to waste stream categories (aqueous liquids, organic liquids, organic sludge, cemented solids, inorganic sludge, solids, and debris — organic, heterogenous, inorganic, and inorganic nonmetal debris) in Table 2.

In the case of an accident during TRUW transportation, the impacts would be very low because of the use of TRUPACT-II containers, which lead to extremely low release rates compared to the rates from the usual 55-gal drums in which these wastes are stored at DOE facilities. The TRUPACT-IIs are external containers in which 55-gal drums are placed for transportation.

2 POPULATION RISKS OF ALTERNATIVES — TRUCK MODE

As can be seen from Table 2, organic liquids would present the greatest risk to the public in terms of hazardous waste impacts if a transportation accident occurred. This case was studied in detail, and the results revealed that the chemical plumes would be within 100 ft of the roadway where nonresidents are assumed to live. This was true for both the "carcinogenic" risk and "any adverse effects" health end points. No chemicals classified as "poison inhalation hazard" chemicals by the U.S. Department of Transportation (DOT 1990) were included in the TRUW inventory, so the potential for life-threatening effects end points was not evaluated. Assumptions for the worst case accident were as follows:

- Forty-two 55-gal drums are within a total of three TRUPACT-IIs that fill one truck;
- Each drum contains 0.21 m^3 of waste with a density of about $1,500 \text{ kg/m}^3$;

- The release fraction due to an accident encompasses all 42 drums and is at the rate of 0.0002 times the container contents; this release is consistent with the highest release fraction used for radiological risk computations;
- The release fraction for radioactive particulates (radiological impact) and chemical vapors (hazardous waste impact) is the same; volatile liquids are assumed to be 100% aerosolized and respirable, which is consistent with the radiological assumptions; and
- The concentrations of chemicals in the released waste are the same as in the drums (for this worst case truck shipment):

1,1,1-trichloroethane	15% by weight
carbon tetrachloride	5% by weight
Freon 113 (1,1,2-trichloro-1,2,2-trifluoroethane)	5% by weight

TABLE 1 Descriptions of Waste Streams within the TRUW Category

(1000) Aqueous Wastes

- ANL-1 *Waste Water* (Σ 1100s = 11XX)
Concentration of organic material ~1% in ANL-1.
- ANL-2 *Aqueous Slurry* (Σ 1200s = 12XX)
Dissolved and particulate material in ANL-2 is ~10%.

(2000) Organic Liquids

- ANL-3 *Aqueous Halogenated Organic Liquids* (Σ 2100s = 211X)
These liquids are approximately 50% water and contain a wide variety of chlorinated organics.
- ANL-4 *Aqueous Non-Halogenated Organic Liquids* (Σ 2120s = 212X)
These liquids are approximately 50% water and contain a wide variety of water soluble organic solvents (e.g., acetone, methanol, etc.)
- ANL-5 *Pure Halogenated Organic Liquids* (Σ 2210s = 221X)
These liquids typically have ~5% water and are dominated by a wide variety of chlorinated organic solvents.
- ANL-6 *Pure Non-Halogenated Organic Liquids* (Σ 2220s = 222X)
These liquids typically have less than 5% water and are dominated by organic solvents such as toluene, benzene, etc.

(3000) Process Wastes

- ANL-7 *Inorganic Particulates* (Σ 3110s+ 3130s = 311X)
Examples include fly ash, ion-exchange resins, inorganic absorbants, aluminum oxides, paint wastes, iron fines, etc.
- ANL-8 *Inorganic Sludges* (Σ 3120s = 312X)
Examples include pond sludge, uncemented inorganic sludges, plating sludges, filter sludge, laundry sludge, etc.
- ANL-9 *Salt Waste* (Σ 3140s = 314X)
Examples include evaporation bottoms, solid oxidizers, reactive salts, etc.

TABLE 1 (Cont.)

(3000) Process Wastes (cont.)

- ANL-10 *Solidified Inorganic Process Wastes* (Σ 3150s = 315X)
Examples include cemented pond sludge, cemented fly ash
- ANL-11 *Halogenated Organic Particulates and Sludges* (Σ 3210s + 3220s (nonhalogenated))
Examples include Freon sludge, grease cleaner sludges, solids with absorbed solvents, etc.
- ANL-12 *Non-Halogenated Organic Particulates and Sludges* [Σ 3210s+ 3220s (nonhalogenated)]
Examples include activated carbon, floor sweepings, oily sludges, etc.
- ANL-13 *Solid Organic Materials* (Σ 3230s)
- &14 Examples include plastic wastes, epoxy wastes, etc.

(4000) Contaminated Soils

- ANL-15 *Contaminated Soil without Debris* (Σ 4100s)

(5000) Debris

- ANL-17 *Metal Debris* (Σ 5100s)
Scrap metals, cadmium-coated high-efficiency particulate air (HEPA) filters, piping, contaminated machine tools, etc.
- ANL-18 *Inorganic Non-Metal Debris* (Σ 5200s)
Glass debris, concrete and brick debris, insulation, asbestos, etc.
- ANL-19 *Combustible Debris* (Σ 5300s)
Wood, rubber gloves, rags, plastic bags, Teflon, paper, etc.
- ANL-20 *Heterogeneous Debris* (Σ 5400s)
Mercury-contaminated debris, laboratory equipment, paper-metal mixtures, miscellaneous filters, etc.

(6000) Special Wastes

- ANL-21 *Organic Lab-packs* (Σ 6110s = 611X).
- ANL-22 *Aqueous Lab-packs* (Σ 6120s = 612X).
- ANL-23 *Solid Lab-packs* (Σ 6130s = 613X).

Note: Certain other wastes in the 7000 series are defined as hazardous and are radioactively contaminated. These wastes are generally homogeneous. Examples include activated lead shielding, beryllium initiators, contaminated liquid mercury, discarded activated batteries, etc. The waste stream concentrations used in this table can be found in Wilkins et al. (1996) and the Mixed Waste Inventory Report (MWIR) (DOE 1994).

Table 3 presents the results of the Areal Locations of Hazardous Atmospheres (ALOHA™) (Reynolds 1992) dispersion model runs for this truck accident scenario. Note that only carbon tetrachloride is considered carcinogenic, whereas all 3 chemicals are considered for the "any adverse effects" end point. A comparison of columns 4 and 5 in the table show that the ALOHA™-predicted concentrations are less than the health criteria for both the increased carcinogenic risk and the any adverse effects end points. Because this is the worst case shipment, all other shipments will be zero population risks as well. Consequently, the hazardous components for population risk under all alternatives are all zero, primarily due to very low release rates because of waste transportation in TRUPACT-IIIs.

TABLE 2 Estimated Concentration of Hazardous Constituents in Mixed TRUW by Waste Stream Category

Hazardous Constituent	Solid Process Residues (3000)														
	Aqueous Liquids (1000)			Organic Liquids (2000)			Organic Sludge (mg/kg)			Cemented Solids (mg/kg)			Inorganic Sludge (mg/kg)		
	Conc.	Mean		Conc.	Mean		Conc.	Mean		Conc.	Mean		Conc.	Mean	
1,1,1-Trichloroethane	20	20		150,000	150,000		150,000	150,000		20-200	63		20-200	63	
Carbon tetrachloride	15	15		50,000	50,000		50,000	50,000		15-25	19		15-25	19	
Freon 113 ^a	20	20		50,000	50,000		50,000	50,000		20-200	63		20-200	63	
Methylene chloride	5-700	59		0	0		0	0		5-700	59		5-700	59	
Methyl alcohol	5-25	11		0	0		0	0		5-25	11		5-25	11	
Butyl alcohol	5-10	7		0	0		0	0		5-10	7		5-10	7	
Xylene	10	10		0	0		0	0		10-50	22		10-50	22	
Toluene	10	10		0	0		0	0		10	10		10	10	
Ethyl benzene	10	10		0	0		0	0		10	10		10	10	
Cadmium	5-10	7		0	0		0	0		5-10	7		5-10	7	
Lead	10	10		0	0		0	0		0-400	63		10-400	63	
Mercury	0	0		0	0		0	0		0	0		0	0	
Debris (5000)															
Hazardous Constituent	Soils (4000)			Organic Debris (mg/kg)			Heterogenous Debris (mg/kg)			Inorganic Debris (mg/kg)			Inorganic Nonmetal Debris (mg/kg)		
	Conc.	Mean		Conc.	Mean		Conc.	Mean		Conc.	Mean		Conc.	Mean	
1,1,1-Trichloroethane	20-200	63		150-2,000	548		1-2,000	45		15	15		1-900	30	
Carbon tetrachloride	15-25	19		150-750	335		1-900	30		10	10		1-100	10	
Freon 113 ^a	20-200	63		100-2,500	500		1-8,000	89		75	75		1-8,000	89	
Methylene chloride	5-700	59		50-1,000	224		50-1,000	224		200	200		200	200	
Methyl alcohol	5-25	11		0	0		0	0		0	0		0	0	
Butyl alcohol	5-10	7		0	0		0	0		0	0		0	0	
Xylene	10-50	22		0	0		0	0		0	0		0	0	
Toluene	10	10		0	0		0	0		0	0		0	0	
Ethyl benzene	10	10		0	0		0	0		0	0		0	0	
Cadmium	5-10	7		0	0		0	0		0	0		0	0	
Lead	0-400	63		5-60,000	548		5-250,000	1,118		0	0		0	0	
Mercury	0	0		10->10	10		10->10	10		49,000-	110,688		49,000-	110,688	
										250,000	0		250,000	0	
										.0	0		10->10	0	

^a Freon 113 = 1,1,2-trichloro-1,2,2-trifluoroethane.

TABLE 3 Comparison of ALOHA™ Predictions at 100 ft from the Highway to Health Criteria Limits (ICRC for carcinogenic effects and PAEC for any effects impacts) — Truck Mode

Chemical Name	Molecular Weight	Emission Rate (kg/h)	ICRC/PAEC 1-Hours (ppm)	ALOHA™ Conc. at 100 ft (ppm)
Carcinogenic substances				
Carbon tetrachloride	153.82	0.13482	6.51	2.15E-01
Noncarcinogenic substances				
1,1,1-Trichloroethane	133.42	0.33894	7.79	5.86E-01
Carbon tetrachloride	153.82	0.13482	1.61	2.15E-01
Freon 113 ^a	187.38	0.11298	166.41	1.85E-01

^a Freon 113 = 1,1,2-trichloro-1,2,2-trifluoroethane.

3 MAXIMALLY EXPOSED INDIVIDUAL — TRUCK MODE

The impacts to the MEI are the same for all alternatives since (1) each alternative has organic liquids (the most risky shipment in relative terms) being transported on a road or highway in some direction, and (2) the MEI is always 100 ft from the highway road because residents are assumed not to live any closer to highways than that approximate distance.

The MEI risk calculations were performed using the assumptions and methods consistent with those presented in Section 3.3 of the Main Report. The results are summarized in Tables 4 and 5. The risks to the MEI listed in the tables are very small but are nonzero. The risks shown are consistent with the result of zero population risks because only carcinogenic risks of 10^{-6} or greater or hazard quotients of 1 or greater would result in a population risk that is reported in this assessment.

Vehicle-related risks are presented in Appendix E of WM PEIS along with the radiological impacts discussion.

4 POPULATION RISKS OF ALTERNATIVES — RAIL MODE

In the truck mode, there are 3 TRUPACT-IIs per truck ($14 \times 3 = 42$ 55-gal drums in all); in the rail mode, there are 6 TRUPACT-IIs per railcar (84 55-gal drums). The truck capacity is 8.4 m^3 , and the rail payload capacity is double (16.8 m^3).

The release rates of volatile chemicals from the railcar accident are computed the same way as for the truck accident (i.e., same release fraction = 2×10^{-4} for the greatest release accidents — severity categories VI-VIII; aerosolized fraction = 100%, and respirable fraction = 100%), and they become exactly twice the release rate for the truck accident.

TABLE 4 MEI Lifetime Increased Carcinogenic Risks for Mixed TRUW — Truck Mode

Chemical Name	Concentration at MEI location (ppm)	Exposure time (min/d)	Inhalation Air intake (mg/kg/d)	Slope Factor (mg/kg/d) ⁻¹	Carcinogenic MEI Risk
Carbon tetrachloride	2.15E-01	60	6.34E-07	5.25E-02	3.3E-08

TABLE 5 MEI Hazard Quotients for Adverse Effect End Point for Mixed TRUW — Truck Mode

Chemical Name	Molecular Weight	Concentration at MEI Location	Exposure time (min/d)	Inhalation Air intake (mg/kg/d)	Inhalation Rf (mg/kg/d) ⁻¹	Hazard Quotient
1,1,1-Trichloroethane	133.42	5.86E-01	60	2.1E-02	2.9E-01	7.52E-02
Carbon tetrachloride	153.82	2.15E-01	60	9.1E-03	1.7E-02	5.30E-01
Freon 113	187.38	1.85E-01	60	9.5E-03	8.6E+00	1.11E-03

Table 6 presents the results of the railcar accident. The ALOHA™ predicted that hazardous-chemical concentrations would be less than the health criteria, and, therefore, the population impacts would be zero for all alternatives.

5 MAXIMALLY EXPOSED INDIVIDUAL — RAIL MODE

The railcar accident release rates are twice the truck accident rates, because the railcars have a TRUPACT-II capacity of 6 (versus a truck capacity of three). Therefore, the carcinogenic risks and risks for any adverse effects presented in Tables E.17, E.18, and E.19 of Appendix E are twice the risks presented for truck mode. The hazard quotient (HQ) to the MEI from carbon tetrachloride is 1.06. This HQ indicates a very borderline potential for any adverse effects (potential for effects is considered unlikely for HQs less than 1). As a general guideline, the assumption can be made that the risk of adverse effects is minimal for substances with HQ values between 1 and 10 because of the uncertainties and conservatism associated with the use of EPA reference dose values to evaluate single, brief exposures. Therefore, adverse effects due to carbon tetrachloride exposure would be unlikely unless the MEI receptor was extremely sensitive with respect to chemical exposures. Tables 7 and 8 present the results of the railcar accident for carcinogenic and adverse effects to the MEI.

Accident and routine vehicle-related risks from transportation of TRUW are presented in Part I of Appendix E.

TABLE 6 Comparison of ALOHA™ Predictions at 100 ft from the Highway to Health Criteria Limits (ICRC for carcinogenic effects and PAEC for any effects impacts) — Rail Mode

Chemical Name	Molecular Weight	Emission Rate (kg/h)	ICRC/PAEC 1-Hours(ppm)	ALOHA™ Conc. at 100 ft (ppm)
Carcinogenic substances				
Carbon tetrachloride	153.82	0.26964	6.51	4.30E-01
Noncarcinogenic substances				
1,1,1-Trichloroethane	133.42	0.67788	7.79	1.17E+00
Carbon tetrachloride	153.82	0.26964	1.61	4.30E-01
Freon 113 ^a	187.38	0.22596	166.41	3.70E-01

^a Freon 113 = 1,1,2-trichloro-1,2,2-trifluoroethane.

TABLE 7 MEI Lifetime Increased Carcinogenic Risks for Mixed TRUW — Rail Mode

Chemical Name	Concentration at MEI Location	Exposure Time (min/d)	Inhalation Air Intake (mg/kg/d)	Slope Factor (mg/kg/d) ⁻¹	Carcinogenic MEI Risk
Carbon tetrachloride	4.30E-01	60	6.34E-07	5.25E-02	6.6E-08

TABLE 8 MEI Hazard Quotients for Adverse Effect End Points for Mixed TRUW — Rail Mode

Chemical Name	Concentration at MEI Location	Exposure Time (min/d)	Inhalation Air Intake (mg/kg/d)	Inhalation Rf (mg/kg/d) ⁻¹	Hazard Quotient
1,1,1-Trichloroethane	1.17E+00	60	2.1E-02	2.9E-01	1.50E-01
Carbon tetrachloride	4.30E-01	60	9.1E-03	1.7E-02	1.06E+00
Freon 113 ^a	3.70E-01	60	9.5E-03	8.6E+00	2.22E-03

^a Freon 113 = 1,1,2-trichloro-1,2,2-trifluoroethane.

6 SUMMARY AND CONCLUSIONS

The population risks from the hazardous components of TRUW during transportation are zero for all end points — potentially life-threatening health effects, additional cancers above 1 and 10^{-6} , and the any adverse effects end points. This conclusion holds true for both truck and rail options and is largely the result of the well-built TRUPACT-II containers transporting that waste.

Predictions of cancer and any adverse effects risk to the MEI (located 100 ft from the road) are very small. The increased carcinogenic risks and the HQs are twice as large for the worst case rail accident as for the worst case truck accident since release rates are twice as much for the railcar accident case.

7 REFERENCES

DOE, 1994, *Mixed Waste Inventory Report: Final Phase II Mixed Inventory Report Data*, EM-352, U.S. Department of Energy, Washington, D.C., May.

DOT, 1990, *The 1990 Emergency Response Guidebook*, DOT P 5800.5, Research and Special Programs Administration, Office of Hazardous Materials Transportation, U.S. Department of Transportation, Washington, D.C.

DOT, 1993, *Hazardous Materials Information Reporting System Database, Research and Special Programs Administration — Hazardous Materials Safety*, U.S. Department of Transportation, Washington, D.C.

Reynolds, R.M., 1992, *ALOHA™ (Areal Locations of Hazardous Atmospheres) 5.0: Theoretical Description*, NOAA-TM NOS ORCA-65, National Oceanic and Atmospheric Administration, Seattle, Wash., Aug.

Wilkins, B.D., et al., 1996, *Low-Level Mixed Waste Inventory, Characteristics, Generation, and Facility Assessment for Treatment, Storage, and Disposal Alternatives Considered in the U.S. Department of Energy Waste Management Programmatic Environmental Impact Statement*, ANL/EAD/TM-32, Argonne National Laboratory, Argonne, Ill.